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FHWA HIGHWAY CONSTRUCTION NOISE HANDBOOK

Final Report
August 2006

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Washington, D.C. 20590

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13. ABSTRACT (Maximum 200 words)

The John A. Volpe National Transportation Systems Center Acoustics Facility (VCAF), in support of the Federal Highway Administration (FHWA) Office of Natural and Human Environment, has developed the Highway Construction Noise Handbook (the Handbook). The Handbook provides guidance to U.S. state transportation agencies in measuring, predicting, and mitigating highway construction noise and developing noise criteria. In order to help users predict construction noise, the Handbook includes the User's Guide for the FHWA Roadway Construction Noise Model (RCNM). This Handbook, which is accompanied by a CD-ROM, reflects substantial improvements and changes in the way highway construction noise has been addressed since the 1977 publishing of the FHWA Special Report, *Highway Construction Noise: Measurement, Prediction and Mitigation*. This updated Handbook, and the companion CD-ROM, address both acoustical and non-acoustical issues associated with highway construction noise. While it is understood that both similarities and differences exist between construction-related noise and construction-related vibration, the focus of the Handbook and CD-ROM is confined to noise-related issues.

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1 mile (mi)	= 1.6 kilometers (km)	1 meter (m)	= 1.1 yards (yd)
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1 square yard (sq yd, yd^2)	= 0.8 square meter (m^2)	1 square kilometer (km^2)	= 0.4 square mile (sq mi, mi^2)
1 square mile (sq mi, mi^2)	= 2.6 square kilometers (km^2)	10,000 square meters (m^2)	= 1 hectare (ha) = 2.5 acres
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1 short ton = 2,000 pounds (lb)	= 0.9 tonne (t)	1 tonne (t)	= 1,000 kilograms (kg)
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1 fluid ounce (fl oz)	= 30 milliliters (ml)	1 liter (l)	= 1.06 quarts (qt)
1 cup ©	= 0.24 liter (l)	1 liter (l)	= 0.26 gallon (gal)
1 pint (pt)	= 0.47 liter (l)		
1 quart (qt)	= 0.96 liter (l)		
1 gallon (gal)	= 3.8 liters (l)		
1 cubic foot (cu ft, ft^3)	= 0.03 cubic meter (m^3)	1 cubic meter (m^3)	= 36 cubic feet (cu ft, ft^3)
1 cubic yard (cu yd, yd^3)	= 0.76 cubic meter (m^3)	1 cubic meter (m^3)	= 1.3 cubic yards (cu yd, yd^3)
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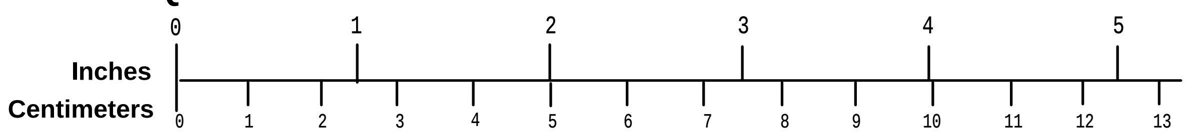

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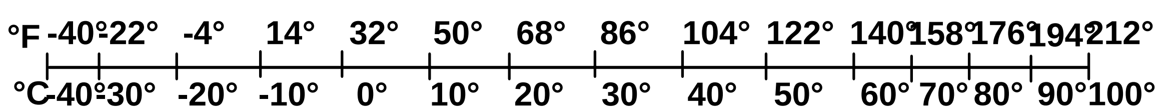

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PREFACE

The John A. Volpe National Transportation Systems Center Acoustics Facility (VCAF), in support of the Federal Highway Administration (FHWA) Office of Natural and Human Environment, has developed the Highway Construction Noise Handbook (the Handbook). The Handbook provides guidance to U.S. state transportation agencies in measuring, predicting, and mitigating highway construction noise and developing noise criteria. In order to help users predict construction noise, the Handbook includes the User's Guide for the FHWA Roadway Construction Noise Model (RCNM).

This Handbook, which is accompanied by a CD-ROM, reflects substantial improvements and changes in the way highway construction noise has been addressed since the 1977 publishing of the FHWA Special Report, *Highway Construction Noise: Measurement, Prediction and Mitigation*[ref001]. This updated Handbook, and the companion CD-ROM, address both acoustical and non-acoustical issues associated with highway construction noise. While it is understood that both similarities and differences exist between construction-related noise and construction-related vibration, the focus of the Handbook and CD-ROM is confined to noise-related issues.

TABLE OF CONTENTS

SECTION PAGE

TABLE OF CONTENTS (continued)

SECTION PAGE

TABLE OF CONTENTS (continued)

LIST OF FIGURES

LIST OF FIGURES (continued)

FIGURE PAGE

LIST OF FIGURES (continued)

FIGURE PAGE

LIST OF TABLES

1.0 INTRODUCTION

1.1 Background

The U.S. Department of Transportation, Research and Innovative Technology Administration, John A. Volpe National Transportation Systems Center (Volpe Center), Acoustics Facility, in support of the Federal Highway Administration (FHWA), Office of Natural and Human Environment, has developed the "FHWA Highway Construction Noise Handbook" (the Handbook). This document reflects substantial improvements and changes in addressing highway construction noise that have evolved since the publication in 1977 of the FHWA Special Report *Highway Construction Noise: Measurement, Prediction and Mitigation*[ref001] (1977 Handbook). The Handbook and its companion CD-ROM address both acoustical and non-acoustical issues associated with highway construction noise. While it is understood that both similarities and differences exist between construction-related noise and construction-related vibration, the focus of the Handbook and CD-ROM is confined to noise-related issues.

In 1977, the FHWA published the above-referenced guidance document plus a supplementary document, *1977 Symposium on Highway Construction Noise*[ref002], to aid State Highway Agencies in addressing the problem of highway construction noise. Over the last three decades, there have been substantial advancements in the methodology and technology of identifying impact and mitigating the effects of construction-related noise. Increased community, contractor, and government interest has fuelled the push to provide more effective, less expensive, and more environmentally friendly mitigation techniques. This increased interest has also fuelled a push to improve noise measurement and modeling technologies that aid State transportation agencies in determining the level of impact and the most suitable mitigation techniques.

Construction noise related to transportation projects is typically addressed in the project's noise analysis report and in the project environmental document. Most projects will not require modeling or any form of analysis associated with construction-related noise. In many cases, construction noise may be adequately addressed through a narrative discussion. Some projects may require application of a simplified manual calculation technique. For projects that require compliance with local ordinances, more detailed analysis techniques may be called for. Use of the most sophisticated and complex modeling techniques are typically required for the most complex projects such as the Big Dig[ref009] in Boston, MA, or the TREX[ref103] in Denver, CO. Such projects may require in-depth analysis including modeling, operation scheduling, continuous noise monitoring, and enforcement. Regardless of the type of project, it is important that any abatement techniques developed to address construction noise consider cost-effectiveness. Also essential is that construction noise criteria are attainable, easily understood, and well communicated to contractors and the public.

A recently developed analysis tool is the FHWA Roadway Construction Noise Model (RCNM)[ref083]. The RCNM is a new, state-of-the-art computer program[ref084] that enables the prediction of construction noise levels for a variety of construction operations based on a compilation of empirical data and the application of acoustical propagation formulas. The program enables the calculation of construction noise levels in more detail than manual methods while avoiding the need to collect extensive amounts of project-specific input data.

1.2 Objectives

The objectives of this document and companion CD-ROM are to identify factors that may be considered related to construction noise and provide information associated with reference sources related to the following issues and factors:

- Recognizing the potential for construction noise impact;
- Determining the extent and type of analysis appropriate to address the construction noise impact; and
- Evaluating and implementing techniques to effectively mitigate construction noise.

Every effort has been made to address and/or reference some common designs, materials, and techniques. However, it is impossible to encompass the proliferation of new concepts, equipment, construction techniques, and materials entering the market on a daily basis. Therefore, the specific discussions within this Handbook are not to be considered all-inclusive, and are not intended to limit the creativeness of the designer, manufacturer, and construction contractor. It is important that any new theory, design, material, or technique not addressed in this Handbook be evaluated with the general fundamentals of safety, functionality, and cost-effectiveness in mind.

1.3 Handbook and CD-ROM Use

The intent of this Handbook is not to recommend techniques to be used in identifying construction noise impacts or to recommend related mitigation techniques for specific projects or types of projects. Rather, it should be used in conjunction with the companion CD-ROM as a type of reference document containing a compendium of factors and issues that may be appropriate to consider in dealing with construction noise. While the Handbook itself provides a summary of the range of issues and factors associated with construction noise, the CD-ROM contains significantly more data associated with relative sources of information intended for use by those charged with addressing the objectives listed above.

While the focus of the discussion herein relates to the effects of construction noise associated with humans, references are also provided to material associated with the effects of construction noise on animals.

1.4 Handbook and CD-ROM Organization

Both the Handbook and the CD-ROM are divided into the following chapters:

- Chapter 1 - Introduction to Construction Noise;
- Chapter 2 - Terminology;
- Chapter 3 - Effects of Construction Noise;
- Chapter 4 - Construction Noise Criteria and Descriptors;
- Chapter 5 - Measurement of Construction Noise;
- Chapter 6 - Prediction of Construction Noise;
- Chapter 7 - Mitigation of Construction Noise;
- Chapter 8 - Public Involvement and Project Coordination;

- Chapter 9 - Construction Equipment Noise Levels and Ranges; and
- Chapter 10 - Construction Noise Contacts, Policies, and Reference Material.

2.0 TERMINOLOGY

This chapter presents pertinent terminology used throughout the Handbook and CD-ROM.

A

A-Weighting
The weighting network used to account for changes in level sensitivity as a function of frequency. The A-weighting network de-emphasizes the high (6.3 kHz and above) and low (below 1 kHz) frequencies, and emphasizes the frequencies between 1 kHz and 6.3 kHz, in an effort to simulate the relative response of the human ear. See also frequency weighting.

Acoustic Energy
Commonly referred to as the mean-square sound-pressure ratio, sound energy, or just plain energy, acoustic energy is the square of the ratio of the mean-square sound pressure (often referred to as frequency weighted), and the reference mean-square sound pressure of 20 μPa, the threshold of human hearing. It is arithmetically equivalent to 10(SPL/10), where SPL is the sound pressure level, expressed in decibels.

Ambient Noise
All-encompassing sound that is associated with a given environment, usually a composite of sounds from many sources near and far.

Amplitude
A non-negative scalar measure of a wave's magnitude of oscillation.

B

Background Noise
All-encompassing sound of a given environment without the sound source of interest.

Bridge
A structure which provides a roadway or walkway for the passage of vehicles and pedestrians across an obstruction, gap, water course, or facility and which is typically greater than 3 m (10') in span.

C

Community Noise Equivalent Level (CNEL, denoted by the symbol, L_{den})
A 24-hour time-averaged L_{AE} adjusted for average-day sound source operations. In the case of highway traffic noise, a single operation is equivalent to a single vehicle pass-by. The adjustment includes a 5-dB penalty for vehicle pass-bys occurring between 1900 and 2200 hours, local time, and a 10-dB penalty for those occurring between 2200 and 0700 hours, local time. The L_{den} noise descriptor is used primarily in the State of California. L_{den} is computed as follows:

$$L_{den} = L_{AE} + 10*\log_{10}(N_{day} + 3*N_{eve} + 10*N_{night}) - 49.4 \quad \text{(dB)}$$

where:

L_{AE} = Sound exposure level in dB;
N_{day} = Number of vehicle pass-bys between 0700 and 1900 hours, local time;
N_{eve} = Number of vehicle pass-bys between 1900 and 2200 hours, local time;
N_{night} = Number of vehicle pass-bys between 2200 and 0700 hours, local time; and
49.4 = A normalization constant which spreads the acoustic energy associated with highway vehicle pass-bys over a 24-hour period, i.e., $10*\log_{10}$(86,400 seconds per day) = 49.4 dB.

D

Day-Night Average Sound Level (DNL, denoted by the symbol, L_{dn})
A 24-hour time-averaged L_{AE}, adjusted for average-day sound source operations. In the case of highway traffic noise, a single operation is equivalent to a single vehicle pass-by. The adjustment includes a 10-dB penalty for vehicle pass-bys occurring between 2200 and 0700 hours, local time. L_{dn} is computed as follows:

$$L_{dn} = L_{AE} + 10*\log_{10}(N_{day} + 10*N_{night}) - 49.4 \quad \text{(dB)}$$

where:

L_{AE} = Sound exposure level in dB;
N_{day} = Number of vehicle pass-bys between 0700 and 1900 hours, local time;
N_{night} = Number of vehicle pass-bys between 1900 and 0700 hours, local time; and
49.4 = A normalization constant which spreads the acoustic energy associated with highway vehicle pass-bys over a 24-hour period, i.e., $10*\log_{10}$(86,400 seconds per day) = 49.4 dB.

Decibel (dB)
A unit of measure of sound level. The number of decibels is calculated as ten times the base-10 logarithm of the square of the ratio of the mean-square sound pressure (often referred to as frequency weighted), and the reference mean-square sound pressure of 20 μPa, the threshold of human hearing. A-weighted decibels are expressed as dBA or dB(A).

Diffracted Wave
A sound wave whose front has been changed in direction by an obstacle in the propagation medium, where the medium is air for the purposes of this document.

Degradation
The reduction of noise barrier effectiveness at receivers due to conditions such as multiple reflections of the noise between parallel barriers, noise leaks in a barrier, etc.

Divergence
The spreading of sound waves from a source in a free field environment. In the case of highway traffic noise, two types of divergence are common, spherical and cylindrical. Spherical divergence is that which would occur for sound emanating from a point source, e.g., a single vehicle pass-by. Cylindrical

divergence is that which would occur for sound emanating from a line source, or many point sources sufficiently close to behave as a line source, e.g., a continuous stream of roadway traffic.

E

Energy
See Acoustic energy.

Equivalent Sound Level (L_{eq}, denoted by the symbol, L_{AeqT})
Ten times the base-10 logarithm of the square of the ratio of time-mean-square, instantaneous A-weighted sound pressure, during a stated time interval, T (where $T=t_2-t_1$), divided by the squared reference sound pressure of 20 μPa, the threshold of human hearing, e.g., $L_{eq}(h)$, denoted by the symbol, L_{Aeq1H}, represents the hourly equivalent sound level. L_{AeqT} is related to L_{AE} by the following equation:

$$L_{AeqT} = L_{AE} - 10*\log_{10}(t_2-t_1) \quad \text{(dB)}$$

where L_{AE} = Sound exposure level in dB .

Existing Level
The measured or calculated existing noise level at a given location.

Exponential Time-Averaging
A method of stabilizing instrumentation response to signals with changing amplitude over time using a low-pass filter with a known, electrical time constant. The time constant is defined as the time required for the output level to reach 63.4 percent of the input, assuming a step-function input. Also, the output level will typically reach 100 percent of an input-step function after approximately five time constants.

F

Far-Field
That portion of a point source's sound field in which the sound pressure level (due to this sound source) decreases by 6 dB per doubling of distance from the source, i.e., spherical divergence. For a line source, the far-field is the portion of the sound field in which the sound pressure level decreases by 3 dB per doubling of distance.

Free-Field
A sound field whose boundaries exert a negligible influence on the sound waves. In a free-field environment, sound spreads spherically from a source and decreases in level at a rate of 6 dB per doubling of distance from a point source, and at a rate of 3 dB per doubling of distance from a line source.

Frequency
The number of cycles of repetition per second or the number of wavelengths that have passed by a stationary point in one second.

Frequency Weighting

A method used to account for changes in sensitivity as a function of frequency. Three standard weighting networks, A, B, and C, are used to account for different responses to sound pressure levels. Note: The absence of frequency weighting is referred to as "flat" response. See also A-weighting.

Fresnel Number
A dimensionless value used in predicting the attenuation provided by a noise barrier positioned between a source and a receiver.

G

Grade
The slope of the roadway, or roadway segment (expressed in percent). For example, a roadway that is 400 m in length and its end is 20 m higher in elevation relative to its start, has a 5-percent grade, i.e., 20/400 * 100 percent.

Ground Effect
The change in sound level, either positive or negative, due to intervening ground between source and receiver. Ground effect is a relatively complex acoustic phenomenon, which is a function of ground characteristics, source-to-receiver geometry, and the spectral characteristics of the source. A commonly used rule-of-thumb for propagation over soft ground (e.g., grass) is that ground effects will account for about 1.5 dB per doubling of distance. However, this relationship is quite empirical and tends to break down for distances greater than about 30.5 to 61 m (100 to 200 ft).

Ground Impedance
A complex function of frequency relating the sound transmission characteristics of a ground surface type. Measurements to determine ground impedance must be made in accordance with the ANSI Standard for measuring ground impedance.

H

Hard Ground
Any highly reflective surface in which the phase of the sound energy is essentially preserved upon reflection; examples include water, asphalt, and concrete.

I

Insertion Loss (IL)
The sound level at a given receiver before the construction of a barrier minus the sound level at the same receiver after the construction of the barrier. The construction of a noise barrier usually results in a partial loss of soft-ground attenuation. This is due to the barrier forcing the sound to take a higher path relative to the ground plane. Therefore, barrier IL is the net effect of barrier diffraction, combined with this partial loss of soft-ground attenuation.

J

K

L

L_{AE}
See Sound exposure level.

L_{AeqT}
See Equivalent sound level.

L_{den}
See Community noise equivalent level.

L_{dn}
See Day-night average sound level.

L_{10}
See Ten-percentile exceeded sound level.

Line-of-Sight
Refers to the direct path from the source to receiver without any intervening objects or topography.

Line Source
Multiple point sources moving in one direction, e.g., a continuous stream of roadway traffic, radiating sound cylindrically. Note: Sound levels measured from a line source decrease at a rate of 3 dB per doubling of distance.

M

Maximum Sound Level (MXFA or MXSA, denoted by the symbol, L_{AFmx} or L_{ASmx})
The maximum, A-weighted sound level associated with a given event (see Figure2.1). Fast-scale response (L_{AFmx}) and slow-scale response (L_{ASmx}) characteristics effectively damp a signal as if it were to pass through a low-pass filter with a time constant of 125 and 1000 milliseconds, respectively.
Note: Fast response is typically used for measuring individual highway vehicle pass-bys. Slow response is recommended for the measurement of long-term impact due to highway traffic noise, where impulsive noises are not dominant, and is also used for measurements of sound source levels which vary slowly as a function of time, such as aircraft.

N

Near-Field
The sound field between the source and the far-field. The near-field exists under optimal conditions at distances less than four times the largest sound source dimension.

Noise
Any unwanted sound. "Noise" and "sound" are used interchangeably in this document.

Noise Barrier

The structure, or structure together with other material, that potentially alters the noise at a site from a BEFORE condition to an AFTER condition.

Noise Reduction Coefficient (NRC)
A single-number rating of the sound absorption properties of a material; it is the arithmetic mean of the Sabine absorption coefficients at 250, 500, 1000, and 2000 Hz, rounded to the nearest multiple of 0.05.

Noise Reduction Goal
The amount of noise reduction that is desired. This value should be defined by a respective State Highway Agency and should typically be in the range of 5 to 10 dBA. Noise barriers must provide at least a 5 dBA reduction in highway traffic noise levels in order to provide noticeable and effective attenuation. A noise barrier should be designed to achieve the greatest reduction possible, but in no instance less than 5 dBA.

Normal Incidence (Sound)
(Also referred to as 0-degrees incidence) Occurs when sound waves impinge at an angle perpendicular, or normal, to the microphone diaphragm.

O

P

Panel
The panel component of a noise barrier is that portion which, when joined together, produces a solid wall. In most cases, the panels span the distance between supports, typically posts.

Parallel Barrier
The condition where two noise barriers flank a roadway, i.e., one on each side.

Parapet
Parapets are low walls, or railings or a combination of both which are located along the outside edges of bridge decks. They are designed to prevent vehicles from running off the sides of the bridge.

Point Source
Source that radiates sound spherically. Note: Sound levels measured from a point source decrease at a rate of 6 dB per doubling of distance.

Posts
Posts are typically considered as vertical supports for the noise barrier panels.

Prestressed Concrete
Reinforced concrete in which internal stresses and deformations are initially introduced, of such magnitude and distribution that the subsequent stresses and deformations resulting from dead and live loads are counteracted to a desired degree.

Q

R

Random Incidence (Sound)
Occurs when sound waves impinge at random angles to the microphone diaphragm. Such waves are common in a diffuse sound field.

Retaining Walls
A wall built to hold back earth or water.

Responsible Organization
Government transportation agency, emergency response unit, fire department, police department, etc.

Right-of-Way (ROW)
The entire strip or area of land adjacent to a highway used for highway purposes.

S

Sabine Absorption Coefficient (α_{sab})
Absorption coefficient obtained in a reverberation room by measuring the time rate of decay of the sound energy density with and without a patch of the sound-absorbing material under test laid on the floor. These measurements are performed in accordance with the American Society of Testing and Materials (ASTM) Standard C 423-90a.

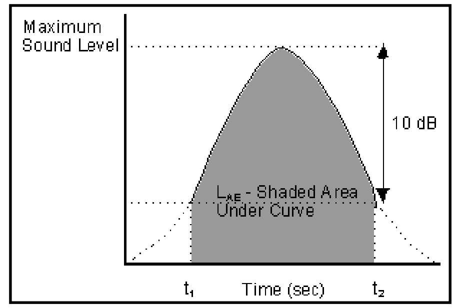
Shoulder
The part of a roadway contiguous to the traffic lanes for accommodating stopped vehicles, bikeways, and cleared snow.

Soft Ground
Any highly absorptive surface in which the phase of the sound energy is changed upon reflection; examples include terrain covered with dense vegetation or freshly fallen snow. (Note: at grazing angles greater than 20 degrees, which can commonly occur at short ranges, or in the case of elevated sources, soft ground becomes a good reflector and can be considered acoustically hard ground).

Sound Absorption Coefficient (SAC)
The ratio of the sound energy, as a function of frequency, absorbed by a surface, and the sound energy incident upon that surface.

Sound Energy
See Acoustic energy.

Figure 2.1 Graphical representation of L_{AE}



Sound Exposure Level (SEL, denoted by the symbol, L_{AE})
Over a stated time interval, T (where $T=t_2-t_1$), ten times the base-10 logarithm of the ratio of a given time integral of squared instantaneous A-weighted sound pressure, and the product of the reference sound pressure of 20 μPa, the threshold of human hearing, and the reference duration of 1 sec. The time interval, T, must be long enough to include a majority of the sound source's acoustic energy. As a minimum, this interval should encompass the 10 dB down points (see Figure 2.1).

In addition, L_{AE} is related to L_{AeqT} by the following equation:

$L_{AE} = L_{AeqT} + 10*\log_{10}(t_2-t_1)$ (dB)

where:

L_{AeqT} = Equivalent sound level in dB.

Sound Pressure
The root-mean-square of the instantaneous sound pressures during a specified time interval in a stated frequency band.

Sound Pressure Level (SPL)
Ten times the base-10 logarithm of the square of the ratio of the mean-square sound pressure, in a stated frequency band (often weighted), and the reference mean-square sound pressure of 20 μPa, the threshold of human hearing.

$SPL = 10*\log_{10}(p^2/p_{ref}^2)$ (dB)

where:

p = mean-square sound pressure; and
p_{ref} = reference mean-square sound pressure of 20 μPa.

Sound Transmission Class (STC)
A single-number rating used to compare the sound insulation properties of barriers. STC is derived by fitting a reference rating curve to the sound transmission loss (TL) values measured for the 16 contiguous one-third octave frequency bands with nominal mid-band frequencies of 125 Hz to 4000 Hz inclusive, by a standard method. The reference rating curve is fitted to the 16 measured TL values such that the sum of deficiencies (TL values less than the reference rating curve), does not exceed 32 dB, and no single deficiency is greater than 8 dB. The STC value is the numerical value of the reference contour at 500 Hz.

Spectrum
A signal's resolution expressed in component frequencies or fractional octave bands.

Structures
Includes retaining walls, bridges, culverts, and concrete drainage channels.

T

Ten-Percentile Exceeded Sound Level (L_{10})
The sound level exceeded 10 percent of a specific time period. For example, from a 50-sample measurement period, the fifth (10% of 50 samples) highest sound level is the 10-percentile exceeded sound level. Other similar descriptors include L_{50} (the sound level exceeded 50 percent of a specific time period), L_{90} (the sound level exceeded 90 percent of a specific time period), etc.

Transmission Loss (TL)
The loss in sound energy, expressed in decibels, as sound passes through a barrier or a wall. Measurements to determine a barrier's TL should be made in accordance with ASTM Recommended Practice E413-87.

U

Utilities
Transmission and distribution lines, pipes, cables and other associated equipment used for public services including, but not limited to, electric transmission and distribution, lighting, heating, gas, oil, water, sewage, cablevision, data communications, and telephone.

V

W

Wavelength
The perpendicular distance between two wave fronts in which the displacements have a difference in phase of one complete period.

X

Y

Z

3.0 EFFECTS OF CONSTRUCTION NOISE

3.1 Introduction

Construction noise in the community may not pose a health risk or damage peoples' sense of hearing, but it can adversely affect peoples' quality of life. To some degree, construction noise can be a contributing factor to the degradation of someone's health in that it can cause people to be irritated and stressed and can interrupt their ability to sleep – all of which may lead to higher blood pressure, anxiety, and feelings of animosity toward the people or agencies responsible for producing the noise.

In fact, several of the traditional definitions of "noise" (i.e. unwanted or undesirable sound) can be associated with construction noise. Construction noise can be perceived or considered to:

- be too loud;
- be impulsive;
- be uncontrollable;
- contain annoying pure tones;
- occur unexpectedly;
- occur at undesirable times of day; and/or
- interrupt people's activities.

Construction noise has the potential to disturb people at home in their residences, in office buildings or retail businesses, in public institutional buildings, at locations of religious services, while attending sporting events, or when on vacation.

Figure 3.1 Construction in residential area
(Photo #924)

Figure 3.2 Construction in business district
(Photo #714)

Figure 3.3 Construction in vicinity of sporting event venue
(Photo #718)

Figure 3.4 Construction in paradise
(Photo #1033)

While construction noise can be unwelcome during nighttime periods in residential areas when people are trying to sleep, it can be equally unwelcome during the daytime in commercial areas if it interferes with peoples' ability to conduct business. In short, construction noise has the potential to disturb people 24 hours a day, 7 days a week. If not properly addressed, specific public concerns related to a project could result in actions affecting the progress and/or cost of a project.

There is nothing particularly unique about construction noise – it's a fluctuation in air pressure oscillating above and below atmospheric pressure that is produced by construction equipment or activities with sufficient magnitude (loudness) and within a certain frequency range (audible spectrum) such that human beings can hear it – just like any other noise. Being a physical parameter, it can be measured, quantified, modeled, predicted, and in certain instances, abated to some degree.

Noise from construction-related activities can also affect non-human species such as aquatic life and land and airborne animals in a variety of ways. The non-human category includes domestic, farm-based, and creatures living in the wild. In assessing the effects of noise on non-humans, it is essential that noise analysts closely coordinate with qualified biologists in the assessment and mitigation of noise impacts.

Issues related to vibration may also be raised during project development. This is particularly true when blasting operations occur. There are no FHWA requirements directed specifically to traffic-induced or construction-related vibration. Most studies that State DOTs have done to assess the impact of operational traffic-induced vibrations have shown that both measured and predicted vibration levels are less than any known criteria for structural damage to buildings, although levels may be such as to cause various degrees of annoyance. Analysis of construction-related vibration effects is beyond the scope of this Handbook.

The intent of this Handbook is not to provide detailed discussion of the above-listed effects, but rather to summarize them and refer the reader to more detailed information regarding specific effects of construction-related noise.

3.2 Types of Effects

3.2.1 Physical Effects

Physical effects related to humans are probably most applicable to the operators of construction equipment as opposed to people residing adjacent to construction projects. An exception to this would be unique situations such as scuba diving or swimming activities occurring in the vicinity of a water-based pile driving or blasting operation. The potential for hearing loss or physical damage to the human hearing mechanism is protected by Occupational Safety and Health Administration (OSHA) criteria, and as such, is not discussed herein. While resulting in the potential to annoy or disturb humans, construction noise is typically not a danger to people's hearing.

Knowledge related to the physical effects of construction noise on non-human species such as land-based animals, birds, and owls is limited. It is recognized that aquatic mammals and fish can be physically damaged by water-born sound and vibration waves caused by construction activities such as underwater blasting and pile driving. In lieu of detailed discussions within this Handbook of the variety of specialized studies related to the physical effects of construction noise on such species, references to such studies are provided in a list at the end of this chapter.

3.2.2 Speech Interference

Loud noises from construction activities can create situations where people cannot effectively communicate, as documented in Tables 3.1 and 3.2. While such situations may be merely an annoyance or inconvenience in certain situations, they could be construed as a safety issue if such noises prevent people from hearing important local noises such as approaching traffic, emergency warning devices, alerts from other people, etc.

3.2.3 Activity Interference

Noise from construction activities can affect humans, land-based animals, aquatic wildlife, and airborne wildlife in a variety of ways. Humans are most affected in terms of sleep deprivation and the carrying on of normal daily activities such as watching television, listening to the radio, recreational activities, and activities requiring concentration, such as reading. Special activities such as those associated with churches, schools, and libraries can also be negatively affected by construction noise. Water-based activities such as scuba diving, swimming, and boating can also be affected.

3.2.4 Annoyance

While non-humans are most likely annoyed by construction noise, there is little known about the related effects. However, the annoyance of noise on humans has been studied for some time and is documented in a 1974 EPA report commonly referred to as the "Levels Document"[ref033]. It is complementary to the 1979 EPA document, "Protective Noise Levels"[ref052].

3.2.5 Examples of Data from Previous Studies (Effects on Humans)

A variety of studies have attempted to quantify the effects of noise on humans. An example is provided in the following table contained in the "Levels Document" referred to above. Note that all noise levels referred to in the "Levels Document" are A-weighted.

Table 3.1 Summary of Human Effects in Terms of Speech Communication, Community Reactions, Annoyance, and Attitude toward Area Associated with an Outdoor Day/Night Sound Level of 55 dB re 20 Micropascals.

Type of Effect	Magnitude of Effect
Speech - Indoors	100% sentence intelligibility (average) with a 5 dB margin of safety
Speech - Outdoors	100% sentence intelligibility (average) at 0.35 meters
	99% sentence intelligibility (average) at 1.0 meters
	95% sentence intelligibility (average) at 3.5 meters
Average Community Reaction	None evident; 7 dB below level of significant "complaints and threats of legal action" and at least 16 dB below "vigorous action" (attitudes and other non-level related factors may affect this result)
Complaints	1% dependent on attitude and other non-level related factors
Annoyance	1% dependent on attitude and other non-level related factors
Attitude Toward Area	Noise essentially the least important of various factors

Table 3.2. Steady A-weighted Sound Levels that Allow Communication with 95 Percent Sentence Intelligibility over Various Distances Outdoors for Different Voice Levels.

Communication Distance (meters)	0.5	1	2	3	4	5
Normal Voice (dB)	72	66	60	56	54	52
Raised Voice (dB)	78	72	66	62	60	58

3.2.6 Effects on Non-Humans

The effects of construction-related noise on non-humans are less understood and probably most related to mating, nesting, migration, and feeding activities. While data on such effects is limited as compared with information on humans, some research is available[ref031 and ref032].

For a more detailed discussion of the general effects of noise on wildlife and other non-human species, the reader is directed to references dealing with the following:

- Effects on wildlife and other animals: ref031 and ref 032;
- Effects on marine mammals: ref 102;
- Effects on fish: ref030, ref036, ref046, ref054, ref060, and ref061; and
- Effects on owls: research underway as of the publication date of this Handbook by Washington State DOT (WSDOT); when available, any published reports will be available through the WSDOT webpage (see Table 10.1).

In determining noise impacts and possible mitigation measures for construction projects involving non-human species, noise analysts should closely coordinate with qualified biologists.

4.0 CONSTRUCTION NOISE CRITERIA AND DESCRIPTORS

4.1 Criteria

Construction noise levels may be evaluated in terms of human response and considered in the assessment of effects on wildlife and other non-human species. Noise levels and criteria are expressed in English, metric, or both conventions, depending upon the geographic area or the policies of the controlling agency. Typically, the English convention is used mostly in the United States, with the metric convention used in Canada and other countries.

While the issue of construction noise must be addressed as part of the planning of any transportation project, there are no standardized criteria on the federal level for assessing construction noise impacts related to transportation projects. Where project-specific construction noise criteria have been developed by individual agencies or municipalities, they typically consider the following factors which form the fundamentals for defining construction noise impact:

- Difference between existing noise levels prior to construction startup and expected noise levels during construction: This takes into account specific construction operations and/or individual pieces of equipment.

- Absolute level of expected construction noise: This may constitute the combined levels of all equipment and operations at a given time or be specifically related to the absolute noise level of a specific operation and/or piece of equipment.

- Adjacent land uses: Consideration of this factor provides an indicator of the degree of sensitivity that may be expected and will likely have a major effect on the operational time restraints and the noise level increases tolerated. For example, residential areas may typically have a restriction on night operations and possibly a noise level restriction during the day. Industrial areas may have no restrictions at all, and offices may or may not have a restriction on the noise levels during the day, with possibly no restriction for night operations. Examples of absolute and relative construction noise level criteria are provided in Table 7.1.

- Duration of construction/operation: The duration of high noise levels may play a significant role in how a noise impact is perceived and/or mitigated. If the levels are of a brief nature, possibly only occurring once or twice during the project, the perceived impact could be quite different than that associated with a constant noise source. Similarly, any related noise mitigation techniques employed could be substantially different in terms of type and/or duration of application.

4.1.1 History of Construction Noise Criteria

4.1.1.1 United States

While noise impact and abatement criteria have been established for the operation of transportation facilities in the United States, standardized criteria have not yet been established related to noise associated with the construction of such facilities. However, since the publication of the original 1977 Report[ref001], additional guidance has been disseminated (through agencies such as FHWA and FTA) and analysis tools developed to better address construction noise. For example, the FTA Transit Noise and Vibration Impact Assessment document[ref014] presents guidelines that "can be considered reasonable criteria for assessment" of construction noise impacts. In addition, a number of agencies, municipalities, and other entities have developed procedures for addressing construction noise impacts and implementing related noise mitigation for their areas of jurisdiction or on a project-specific basis.

In some instances, local entities may have developed noise ordinances that contain restrictions associated with construction noise levels. Noise practitioners and others involved in the project development process are encouraged to become familiar with such ordinances and their relationship to other State and/or municipal ordinances. In certain instances, the State jurisdiction may supersede any local noise ordinances.

Figure 4.1 Local noise ordinance
(Photo #314)

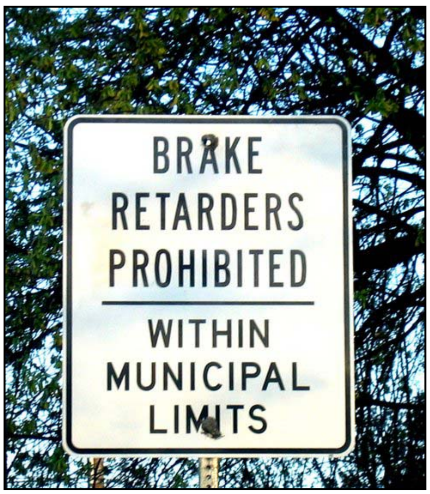


Figure 4.2 Local noise restrictions
(Photo #1206)

Noise restrictions may also be imposed by local and/or State authorities to deal with specific activities or operations. An example is the growing practice of restricting the use of engine compression brakes on heavy trucks in residential areas.

Noise restrictions may also be applied within the workplace associated with employee/worker exposure to noise levels over varying durations. These criteria have been established by OSHA. However, such criteria are typically not relevant or applicable to the transportation-related project construction noise levels experienced by people residing or working in areas adjacent to such projects. As such, they are not discussed within this Handbook.

Construction noise criteria within the United States vary considerably in terms of both scope and specificity and can be broadly categorized as follows, in order of complexity:

- No criteria specified;
- Qualitative criteria, e.g. "Noise levels shall not cause a disturbance";

- Relative criteria, e.g. "Noise levels shall not exceed existing (or ambient, or background) noise levels by more than x dB";
- Absolute criteria, e.g. "Maximum noise levels shall not exceed xx dB";
- Criteria containing a combination absolute and relative noise level limits; and
- Combinations of the above criteria elements with additional restrictions placed on time periods and types of land uses or activities.

An example of more complex criteria is that associated with the Central Artery/Tunnel Project in Boston, MA. Data related to these criteria are discussed in Reference 023 and illustrated in Table 7.1 of this Handbook. This project established criteria that include both L_{10} and L_{max} absolute noise level limits for defined noise sensitive locations (residences, institutions, hotels, etc.) for daytime, evening, and nighttime periods. In addition, the criteria established maximum noise level increases relative to established baseline noise levels. Relative and absolute noise level limits were also established for commercial and industrial areas.

From the standpoint of construction noise criteria, the intent of this Handbook is not to address all State and local noise ordinances and/or criteria, but rather, to address the approaches and techniques that may be contained in such criteria. As such, the discussions contained within this Handbook are meant to provide a summary of considerations related to all aspects of construction noise. The reader is encouraged to refer to specific references in Table 10.1 for more detailed information on noise criteria and other factors related to construction noise.

4.1.1.2 Canada

Similar to the United States, no standardized Canadian criteria exist related to transportation project construction noise. Where project-specific analysis techniques have been employed to address and/or mitigate construction-related noise and its impacts, such methods have been similar to those employed in the United States. Examples of such efforts may be found in References 010 and 019.

4.1.1.3 Other International

While an exhaustive survey of international criteria was not conducted, several criteria are discussed here for informational use only. More specifics may be found by accessing the relative links found in the Reference Database in Chapter 10.

- The Official Journal of the European Communities' Directive 2000/14/EC of the European Parliament and of the Council of 8 May 2000[ref017] establishes legislation dictating specific noise levels for individual pieces of construction equipment. It also contains specifics related to the measurement locations and equipment operating conditions relative to the testing of individual pieces of equipment.
- The Australian EPA's Environmental Noise Control Manual[ref015] establishes the following criteria which officers may specify related to construction noise:
    - For a construction period of four (4) weeks or less, the maximum L_{10} noise level measured over a period of not less than 15 minutes when the construction site is operating must not exceed the background noise level by more than 20 dBA;

- For a construction period greater than four (4) weeks, the maximum L_{10} noise level measured over a period of not less than 15 minutes when the construction site is operating must not exceed the background noise level by more than 10 dBA;
- Construction limited to 0700 to 1800 time period on Monday through Friday;
- Construction limited on Saturdays to 0700 to 1300 time period if inaudible on residential premises; otherwise, 0800 to 1300;
- No construction work may take place on Sundays or public holidays; and
- All possible steps should be taken to silence construction site equipment. It is particularly important that silenced equipment should be used on road or rail works where 24-hour operation is necessary.

4.2 Descriptors

While it is not the intent of this Handbook to establish criteria for evaluating construction noise impacts, it is important to stress that reasonable and defensible noise descriptors must be used to describe construction noise levels. The following are important elements related to selecting a workable noise descriptor for use in measuring and analyzing construction noise:

- Suitable for practical measuring methods;
- Accounts for temporal variations in equipment noise levels;
- Accounts for temporal variations in overall site noise level;
- Suitable for prediction modeling;
- Suitable for combining noise levels from various source types; and
- Relative to subjective responses.

The descriptor most commonly chosen for use is the A-weighted equivalent sound level (energy basis), L_{Aeq}. In many cases, the time average period applied to the L_{Aeq} value is one hour (designated L_{Aeq1h}). For certain projects and operations, the time period over which the L_{Aeq} is applied may need to be examined on a case-by-case basis. For several major construction projects in the United States and Canada, the L_{10} (applied generally during daytime periods) and L_{max} (applied for specific equipment and/or nighttime operations) descriptors have been used over varying time periods.

The L_{dn} descriptor has been used to assess annoyance and community reaction to construction noise. L_{dn} is an L_{Aeq}-based descriptor that applies a 10 dBA penalty to nighttime noise levels.

The L_{Aeq}-based and L_{10}-based descriptors satisfy the first four elements listed above. The L_{Aeq} satisfies the fifth element and may also satisfy the sixth element (relative to subjective responses). However, the L_{Aeq}, L_{10}, and L_{max} descriptors may not be suited for determining responses by some aquatic wildlife (where using an un-weighted sound pressure level may be more suitable) or for owls (where use of a different weighting category such as dBO or a descriptor such as SEL may be more suitable to account for effects such as air blasts associated with blasting). More detailed information related to these specific conditions might be found in documents listed in Section 3.2.6 of this document.

5.0 MEASUREMENT OF CONSTRUCTION NOISE

5.1 History

While the techniques for measuring noise described in the 1977 Handbook[ref001] remain valid, more sophisticated noise measurement equipment exists three decades later, allowing for more precise measurement of highway and construction-related noise with the likelihood of greater accuracy. For example, the "check-off" method for computing L_{10} or L_{Aeq} in the 1977 Handbook is documented in Chapter 3 of the 1973 textbook report titled *Fundamentals and Abatement of Highway Traffic Noise*[ref085] and was geared to use of the analog-type sound level meters typical of that time period. Current sound level meters are predominantly digital in nature, capable of internally integrating sound level information and providing direct readouts and/or printouts of L_{Aeq}, L_{10}, and other selected descriptors. Current FHWA guidance related to noise measurements can be found in the *FHWA Measurement of Highway Related Noise* document[ref006], with specific reference to construction equipment noise measurements found in Chapter 7[ref011] of that document.

No information related to the measurement of non-human noise impacts (effects on wildlife, fish, etc.) was presented in the 1977 Handbook. Since that time, additional research and studies[ref054 and ref060] have been conducted which have involved measurements of noise in a variety of habitats. Refer to documents listed in the Related Information column of Table 10.1 for the following States and agencies: EPA, Florida, U.S. Army Corps of Engineers, Washington, and West Virginia.

Evaluation of the effects of the operational and construction aspects of highways on non-humans is the responsibility of qualified biologists expert in specific fields of study associated with specific species. While noise analysts may provide acoustical information associated with highway operations and/or construction activities, any studies related to the effects of such operations or activities on non-humans are conducted by the appropriate qualified biologists. The overall results of such studies are typically reported in the sections of environmental documents dealing with biological resources and related environmental consequences.

5.2 Purpose of Noise Measurements

Excluding research projects and studies to address the requirements of OSHA, noise measurements related to highway construction are generally conducted to obtain information needed to identify and predict highway project construction noise impacts and then to evaluate mitigation strategies. While most projects will not require construction noise measurements, those cases where measurements may be required generally relate to the following purposes:

- Measurement of existing noise levels to determine baseline (background) conditions;

Figure 5.1 Measuring existing noise levels
(Photo #1301)

Figure 5.2 Measuring ambient noise levels in the absence of construction activity
(Photo #1291)

- Measurement of noise levels associated with individual pieces of construction equipment or construction operations for the purpose of establishing noise emission levels for inclusion in a reference database;

Figure 5.3 Measurement of an individual piece of equipment
(Photo #693)

- Measurement of noise levels associated with individual pieces of construction equipment to relate such levels to prescribed levels or limiting values;
- Measurement of the noise levels associated with a particular construction operation for comparison with background levels and/or established limiting values or criteria;

Figure 5.4 Measuring an individual construction operation (Photo #418)

- Measurement of noise levels associated with multiple construction operations for comparison with background levels and/or established limiting values or criteria; and

Figure 5.5 Several construction operations affecting noise levels at nearby residences (Photo #929)

- Measurement of noise levels of indirect activities (such as diverted traffic) associated with the construction of the project for comparison with pre-construction levels.

Figure 5.6 Undesignated routes may be used by construction-related traffic (Photos #1179 & #1399)

Figure 5.7 Routes may also be specifically designated for use by construction-related traffic (Photo #560)

In addition to measurements associated with the construction of a highway, certain types of highway project maintenance and/or rehabilitation operations may also require the measurement of construction noise levels. An example could be a bridge painting project where blasting is utilized in the paint removal process in the close proximity of sensitive receptors such as residences, churches, schools, etc. Under such circumstances, noise measurements could be performed at a property adjacent to the bridge, with simultaneous measurements taken close to the blasting zone. In combination, these measurements could then be used to determine source noise emissions and to estimate noise level drop-off rates.

For such a project, measurement of equipment other than the actual blasting nozzles would likely also be performed.

Figure 5.8 Compressors, vacuums, and paint chip collection equipment associated with paint removal operation
(Photo #398)

Monitoring may also be conducted of construction equipment and activities associated with other types of highway maintenance, bridge and pavement rehabilitation, etc.

Figure 5.9 Bridge rehabilitation activities
(Photo #1490)

Figure 5.10 Pavement rehabilitation project
(Photos #1407 & #1397)

5.3 Measuring Existing and Ambient Noise

5.3.1 Establishing Background Levels

Existing (or background) noise levels serve as a reference or benchmark level to which a comparison can be made with noise levels associated with construction operations. Background levels include noise contributions from all sources and may be the result of normal neighborhood activities plus noise generated by traffic on local transportation facilities. If the predominant noise source in an area is traffic on an existing transportation facility, existing noise levels can often be predicted using traffic noise prediction models such as the FHWA Traffic Noise Model® (FHWA TNM)[ref086] or the Federal Transit Administration (FTA) Transit Noise and Vibration Assessment procedure[ref014] (also refer to website links listed under FHWA and FTA in Table 10.1.). In such instances, little or no noise measurements may be required, with the only purpose of performing noise measurements being related to noise model verification or calibration.

Should the predominant existing noise sources be non-transportation related activities, noise measurements may be the only reliable means of establishing background noise levels. In either case, the information on existing noise levels is normally developed in the early stages of project planning, often years before the start of construction. Therefore, it may be necessary to re-evaluate the existing levels prior to the start of construction and/or at various intervals during the construction phase.

Measurement of background noise levels associated with the evaluation of construction noise on non-human species typically considers the habitat features, migration trends, spawning, and nesting characteristics of such species in establishing appropriate measurement periods. Regarding fish and other aquatic species, background noise levels often consider other activities occurring within the species' environment, including recreational activities, commercial fishing operations, boating patterns, etc. While providing links and references to selected material associated with non-human species, the authors of this Handbook suggest that any detailed evaluation of effects on non-humans be conducted by qualified experts in the appropriate field of study.

5.3.2 Selecting Measurement Sites and Periods

For the purposes of evaluating highway construction noise, noise measurement sites generally are selected for the following reasons:

- To determine existing noise levels in areas influenced predominantly by non-transportation noise generating sources; and
- For purposes of verifying or calibrating the noise model used to calculate existing noise levels generated by highway traffic on existing facilities.

In either of the above conditions, construction noise measurement sites are typically located as close as possible to the location at which noise impact evaluations are planned. It is important to recognize that sites selected for evaluation of potential construction noise impacts may or may not be the same as sites selected for evaluation of noise impacts resulting from the operation of vehicles on the proposed highway. In addition, the noise generated by highway vehicles is typically evaluated using future year traffic conditions that create the highest noise, while construction noise is normally evaluated for the year(s) in which construction is expected to occur and for the period(s) when construction noise is expected to be the highest. These peak construction periods may be in the middle of the night, on weekends, or during other periods that do not coincide with the peak traffic noise hour.

5.3.3 Determining Events/Activities to Include/Exclude

In determining the existing background noise levels for use in evaluating construction noise levels, it is important to consider the events and activities which will typically occur during the time period for which construction noise is planned to be evaluated. It is equally important to exclude infrequent noise events such as lawn mowing, neighborhood construction activities, shouting, loud radios, etc.

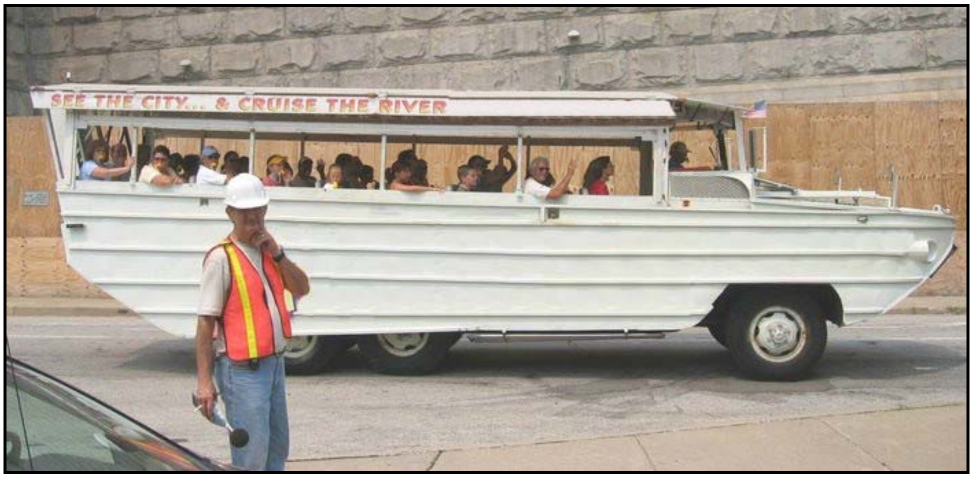


Figure 5.11 Excluded events could include vehicles with amplified sound systems (Photo #695)

Figure 5.12 Influences of neighborhood pets on measurements (Photo #1307)

In cases where a school or a church is to be evaluated, consideration of the following activities may be appropriate in determining the period(s) when noise measurements and analyses are performed:

- Periods of classes or services;
- Interior classroom activities;
- Exterior activities (recess, outdoor classes, after school activities, etc.); and
- Noise generated by church or school-related activities, including school bus entry and exit and parking lot noise events.

Figure 5.13 Measurements at church; consider also influences of air conditioning units (Photo #1302)

Figure 5.14 Measurements in vicinity of schools (Photo #1292)

Figure 5.15 Influence of train noise on measurement of background levels (Photo #1293)

If construction noise is to be evaluated in the vicinity of a noise-generating source such as an airport, rail line, factory, etc., the consideration of the operational characteristics of that noise source may be appropriate. If aircraft operations were continuous and likely to be occurring during the analyzed period of construction noise, such operations would most likely be included in any background measurements. Conversely, if aircraft operations are infrequent and/or minimal, it may be appropriate to exclude them from any background noise level measurements.

Once again, these considerations emphasize the importance of coordinating proposed measurement times with proposed periods of construction noise evaluation. As discussed above, such considerations also apply when obtaining and providing noise-related information to biologists involved in evaluating project effects on non-human species.

5.3.4 Determining the Appropriate Noise Descriptor

Noise descriptors are discussed in Chapter 3 in terms of their weighting characteristics. In certain instances, it may be necessary to perform frequency-based noise measurements, particularly if such measurements (and subsequent analyses) will be compared to an existing ordinance that contains criteria or noise limits that are expressed in terms of full or one-third octave band noise levels.

5.3.5 Consideration of Meteorological Factors

In most cases, noise measurements are conducted under controlled meteorological conditions based on accepted measurement protocols. Under unique circumstances, noise measurements may be appropriate under other conditions. For instance, if construction noise is being considered in a location which normally has strong winds, a predominant wind direction, snow cover over extended periods of time, etc., it may be appropriate to consider these conditions as the norm in measuring background noise levels and in measuring and analyzing construction noise levels.

Meteorological effects are more significant at larger distances from the noise source. As such, effects of wind speed (even within acceptable ranges), wind speed gradient, wind direction, and temperature lapse rates are factors appropriately considered in the measurement of background levels and construction noise events.

Figure 5.16 Wet roadways preclude valid noise measurements. Snow cover normally precludes valid measurements, except if a typical condition
(Photo #1299)

5.4 Measurement of Construction Operations

5.4.1 Establishing Measurement Locations and Periods

To the extent possible, measurement locations and time periods selected for the evaluation of noise generated by construction operations should be the same as those used to determine background or pre-construction noise levels. Such measurements are conducted in conformance with established measurement protocols, as previously discussed. Separate noise measurement protocols exist for measurement of individual pieces of construction equipment, and are discussed later in this section.

Most measurements of noise from construction activities are conducted in exterior locations. Depending upon how a particular controlling ordinance, regulation, or procedure is written, such measurements may be taken at different locations, including:

- At the property line closest to the construction activity;
- At a residence or other sensitive receptor; and
- At the point of closest frequent human activity.

Figure 5.17 Measurement near a residence
(Photo #1286)

Figure 5.18 Measurement on a raised deck
(Photo #1285)

Many local ordinances specifically require consideration of noise to be addressed at the property line location, while some regulations are less definitive in terms of precise locations. Measurements taken at or near the actual residence are more easily converted to interior levels through application of building reduction factors.

Figure 5.19 Property line noise measurement
(Photo #1290)

On occasion, it may be necessary to take interior noise measurements to establish interior levels. Building noise reduction factors can be obtained by simultaneous exterior and interior measurements.

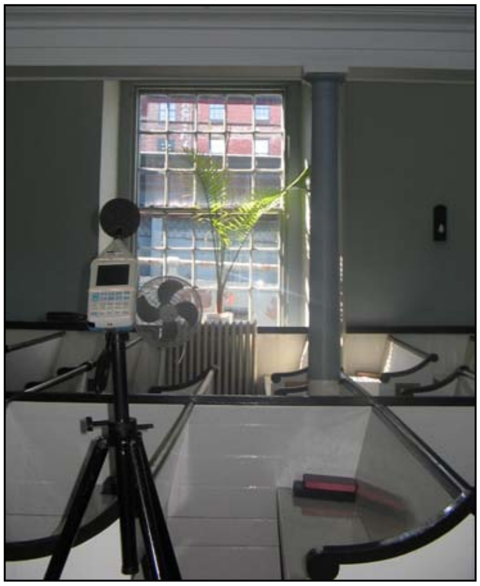


Figure 5.20 Noise measurement inside church sanctuary (Photo #1284)

Figure 5.21 Noise measurement in courtyard outside church sanctuary (Photo #1130)

5.4.2 Determining Events/Activities to Measure

When it has been determined that an analysis of construction noise is required, consideration of particular events or activities associated with the project's construction is appropriate. Each project is typically evaluated individually considering the relationship of both stationary and mobile construction activities to sensitive adjacent receptors and considering the timing of construction activities in relation to activities occurring within the community. Several options that exist in terms of the measurement of construction operations are discussed below.

5.4.2.1 Measuring Entire Project Construction Noise

Ideally, the most accurate representation of a project's construction noise level at any given location would be obtained by extensive and/or continuous monitoring of noise levels from all construction operations at that location. For the limited complex projects where such monitoring has been performed, complex noise monitoring systems and/or programs have been employed[ref009, ref082, and ref103]. Except for complex projects and projects where construction is of short duration and occurring within a limited project area, such monitoring is probably not practical based on timing, manpower, and equipment constraints.

5.4.2.2 Measuring an Entire Operation

Measuring an entire operation suggests that all activities associated with a particular construction operation are occurring in a relatively short timeframe. An example may be a paving operation that occurs in the vicinity of a particular home or neighborhood over a one-day period. In such a case, the collective noise generated from all components of the operation could be measured and compared to background levels and/or absolute noise level criteria. Evaluation and screening of the project's schedule of individual construction operations can be used to determine, in advance, which construction operations are likely to produce the greatest noise levels at a particular location. Emphasis can then be placed on monitoring the operations with the potential to create the highest noise levels at that location.

Figure 5.22 High concentration of activity, a good candidate for measuring an entire operation (Photo #462)

Since construction of a highway typically involves many different phases and operations, it is appropriate to consider the following operations and the sensitive receptors that could be potentially impacted by each operation:

- Mobilization;
- Demolition;
- Clearing and grubbing;
- Earthwork;
- Structures and foundations;
- Bridge Construction;
- Grading for pavement base construction;
- Paving; and
- Cleanup.

5.4.2.3 Measuring Partial Operations

The evaluation and screening process used to determine the activities with the highest potential for construction noise impacts may identify specific portions of an operation that could warrant noise monitoring. For instance, a bridge construction project, blasting for foundation construction, pile driving activities, or rock excavation operations may be identified as having significantly greater potential for noise impacts than other activities such as forming, concrete pours, rod setting, etc. Obviously, each activity may have its own established noise level limit that may need to be considered in this process.

Figure 5.23 Blasting operation
(Photo #1309)

Figure 5.24 Pile driving operation
(Photo #856)

Figure 5.25 Rock excavation operation
(Photo #981)

5.4.2.4 Measuring Indirect Noise Effects

Construction projects often create activities that extend beyond the project limits. It is essential to consider the potential for noise effects of such activities on adjacent sensitive receptors, particularly those located in communities particularly sensitive to noise. Examples of such activities include:

• Trucks supplying material (stone, concrete, steel, etc.) to the project;

Figure 5.26 Steel beam transported adjacent to residences
(Photo #1208)

• Trucks hauling excess material from the project;

Figure 5.27 Dump truck on local roadway
(Photo #1179)

• Activity associated with off-site operations such as concrete batch plants, waste areas, wetland creation sites, material storage areas, etc.; and

Figure 5.28 Concrete batch plant operation;
shown here with temporary noise barrier for community to the right
(Photo #322)

Figure 5.29 Stock pile operation in vicinity of residence
(Photo #1258)

• Effects of traffic detoured or rerouted due to construction activities.

Figure 5.30 Communities can be affected by traffic diverted by construction activities (Photo #1046)

5.5 Measurement of Equipment Noise

Compared to noise generated by construction operations, equipment noise levels can be measured under more controlled conditions. Standard measurement practices and techniques and acceptable limits (for certain projects) have been established for the measurement of noise from many specific types of construction equipment. Practices and techniques for the measurement of construction equipment noise levels on highway-related projects are described in Chapter 7 of Reference 006. Noise measurement procedures used in determining equipment noise levels that were ultimately incorporated into the RCNM program are described in Section 3.01 of Reference 023. In many cases, these protocols and limits account for the typical operational characteristics of the piece of equipment, such as stationary equipment (generators, pile drivers, jackhammers, compressors, etc.), mobile equipment (on-road trucks), and cyclical operating equipment (pans, graders, front end loaders, on-site truck operations, etc.).

Figure 5.31 Stationary construction operation
(Photo #123)

Figure 5.32 On-road construction vehicle
(Photo #1243)

Figure 5.33 Construction vehicle involved in cyclical operation
(Photo #1005)

5.6 Type of Noise Measurement Equipment and Systems

A wide variety of noise measurement equipment is currently available for use in the measurement of construction noise levels. Some examples of the range of such equipment include:

- Type I and Type II sound level meters with a variety of data output options and with the ability to report noise levels for a variety of noise level descriptors;

Figure 5.34 Type I sound level meters
(Photo #1296)

Figure 5.35 Type II sound level meter
(Photo #1297)

- Permanent, continuous noise monitoring systems, with and without integrated video systems; and
- Automated monitoring systems, with and without integrated video systems.

Figure 5.36 Permanent automated wireless noise monitoring system;
note solar cell, antenna, transmitter, and microphone
(Photo #48)

The need obviously exists to tailor the type of equipment utilized to the complexity of the project and its construction noise monitoring requirements.

In performing valid construction noise measurements, the following factors should generally be considered:

- Meeting ANSI S1.4 Standard for Type I or Type II accuracy;
- Using an "integrating" sound level meter;
- Ability to measure and display L_{eq}, L_{max}, and L_n;
- Ability to measure A-weighted decibels;
- Capable of measuring at slow and fast RMS response settings;
- Ability of monitor to be calibrated in the field;
- Use of a proper wind screen; and
- Proper measurement locations as related to adjacent buildings, structures, and activities.

References to documents containing specific information related to the following topics include:

- Types of measurement equipment[ref 006];
- History of measurement techniques[ref001, ref006, and ref007];
- Current construction noise monitoring state-of-the-art[ref006]; and
- Details related to complex noise monitoring systems and programs[ref009 and ref103].

5.7 Other Factors to Consider

In addition to the factors discussed above, other factors to consider in setting up a construction noise-monitoring program include:

- Loss prevention techniques – protection and security issues related to noise measurement equipment, particularly if left unmanned;
- Processing of measured data;
- Manpower requirements;
- Power requirements – electric, solar, etc.; and
- Need to identify unique and unusual noise generating events.

6.0 PREDICTION OF CONSTRUCTION NOISE

6.1 Historical Approaches to Predicting Construction Noise

The adverse effects of construction noise upon a community have historically been considered to be an inevitable, short-term, and necessary impact. Construction noise is evaluated in a quantitative manner on relatively few occasions and specific noise commitments are rarely included in a project's environmental documents. Typically, construction noise control commitments only include such common sense actions as ensuring that all vehicles have proper mufflers, trying to schedule work to be least disturbing, possibly erecting project noise barriers early in the construction process, and promising to comply with any and all local noise ordinances (which often exempt construction noise).

In the early 1970s, the EPA released several construction noise reports as well as the often-referenced EPA "Levels Document"[ref033]. These publications offered the nation's first suggested criteria limits for community noise, which were considered to apply to construction noise as well. The EPA's criteria limits were expressed in long-term noise units of both L_{eq}(24h) and L_{dn} for various degrees of potential hearing interference or annoyance.

In 1977, a landmark report prepared by Bolt Baranek & Newman, Inc. for the Empire State Electric Energy Research Corporation (ESEERCo) summarized the noise producing sources, phases of work, and potential mitigation options for construction noise. The ESEERCo guide also provided empirically based relationships of construction noise sources and associated noise levels, and contained fairly extensive noise emissions tables for specific pieces of equipment as a function of horsepower. The guide recommended that construction noise be assessed using the L_{eq}(h) and L_n percentile metrics.

FHWA's first attempt to create and distribute a standardized construction noise model resulted in the early-1980s release of the Highway Construction Noise Model (HICNOM)[ref091]. It consisted of look-up charts, programmable calculator routines, and a computer model. The supporting noise studies were conducted in the late-1970s, concurrent with several of the aforementioned construction noise studies. At the time, FHWA recommended that construction noise should only be evaluated in a general manner for most projects, but that the HICNOM model could be used for any highly complex or controversial project. The model was originally written in FORTRAN and was later simplified to run as an executable file on IBM-compatible computers. The program required the generation of an "input file" in which assumptions, geometries, and equipment specifics were entered. The resulting "output file" provided the user with the overall L_{eq} level at a receptor position as well as the L_{eq} contribution for each piece of equipment.

From the early-1980's until the release of the FHWA Roadway Construction Noise Model (FHWA RCNM)[ref083] in 2006, there was very little, if any, substantive investigation of construction noise by the FHWA or any other federal agency. Today's modeling methods typically make use of algorithms promulgated by EPA in the early 1970's, in which the reference noise emission level of each piece of construction equipment is adjusted for distance and usage time and then summed at a discrete receptor location of interest. Modern-day, commercially available computer spreadsheet programs, such as MS Excel or Lotus123, provide users with relatively easy means of creating custom-made construction noise prediction models. However, these spreadsheet models have significant limitations in that they tend to only predict noise at a limited number of discrete receptor locations, and only for a fairly limited configuration of equipment. Also, the accuracy of these spreadsheet models can only be as good as the veracity of the input data used in the cell equations. In addition, these models do not readily allow for computation of noise mitigation effects associated with various ground effects or options such as noise barriers, enclosures, or acoustical window treatments. Consequently, these spreadsheet models can only provide an estimate of construction noise at various locations during snapshots in time.

More recently there have been very sophisticated noise prediction model programs commercially available such as SoundPLAN (by SoundPLAN LLC of Shelton, WA), Cadna/A (by DataKustik of Munich, Germany), and the Environmental Noise Model (ENM by RTA Technology of Australia). These programs are able to display the predicted noise levels in formats that provide much more information, when compared to spreadsheet models, by graphically displaying results as equivalent noise contour lines. In doing so, noise levels at any receptor location of interest can quickly be estimated by interpolating the results between adjacent noise contour lines. Moreover, the construction equipment types and working locations can be changed fairly easily in these models, and new noise results can be computed much more quickly than could be done with discrete receptor point models. These sophisticated models also allow for some evaluation of noise reduction effects from various mitigation measures and/or man-made or natural barriers.

However, these sophisticated models suffer from the same accuracy limitations as the spreadsheet versions. While these models can support input of equipment noise data in the form of sound power levels or sound pressure levels at a reference distance, they too rely on user-defined noise emission levels for each piece or generic type of construction equipment. Consequently, the resulting predicted noise levels and noise contour lines are again only as good as the veracity of the input assumptions.

6.2 Relevant Modeling Issues

In creating a construction noise model, there are many issues that must be considered and included in the model if the prediction results are to be meaningful. While some of these variables are more important than others, the overall accuracy of the model must be sufficient for general acceptance. This is particularly relevant when federal and/or State funds may be used to create and mitigate the construction noise.

In general, the larger the number of variables that can be integrated into a noise model, the higher the confidence in its noise level results. While noise levels within close proximity to a construction activity can be predicted sufficiently well by accounting for just a few variables, the accuracy of predicted noise levels at farther distances, or in complex building or terrain conditions, will require a greater number of variables to be taken into account in the model. The trade-off, of course, is one of accuracy versus complexity and cost. The more variables that are taken into account in the model, the more complex the algorithms. Likewise, the cost of the model is proportional to the degree of research and computer programming required in its development.

Nevertheless, there are some fundamental variables that are typically considered in the development of any construction noise model. Those variables include:

- the ability to model multiple pieces of construction equipment working either independently or simultaneously;

- the character of noise emission, be it impulsive noise or more steady noise;
- the ability to account for distances from each piece of equipment to each receptor location;
- the influence of time-of-day, be it daytime, evening, or nighttime;
- the expected duration of work;
- the propagation (ground) characteristics of the pathway between the equipment and the receptors;
- the attenuation effects of any man-made or natural barriers;
- the potential shielding or reflective effects of nearby buildings; and
- to a lesser degree, the meteorological effects on noise propagation.

A construction noise model should evaluate the severity or acceptability of the resulting predicted construction noise levels. Noise metrics such as L_{eq}, L_{dn}, or L_{90} are geared toward evaluating longer-term steady noise levels, while metrics such as L_{max}, L_{10}, and SEL are intended to evaluate shorter-term fluctuating noise conditions. While it is understood that no single noise metric or criteria limit will satisfy everyone exposed to the noise, the establishment of criteria limits should attempt to accommodate the vast majority of the affected public and consider both noise hardship and noise annoyance conditions. Additional discussion of noise metrics is contained in Chapter 4.

6.3 Types of Analysis Procedures

For those projects where some degree of highway construction noise level prediction is determined to be necessary, the following procedures (discussed in order of their complexity) are available:

6.3.1 Historical Data Related to Similar Conditions

Since the publication of the 1977 Handbook[ref001], substantial noise monitoring has been conducted as part of the transportation project development process. Sufficient noise measurement data associated with construction activities and/or equipment may be available to draw reasonable estimates of expected noise levels for a given construction operation, thus avoiding the need to conduct noise measurements or model noise levels. Such data may be useful in providing estimates of the range of construction noise levels for inclusion in environmental documents, planning reports, etc., during the earlier stages of project development.

6.3.2 Manual Calculations Using Historical Data

The 1977 Handbook contains manual methods for calculating construction noise levels. Similar methods are described in the FTA Transit Noise and Vibration Assessment document[ref014] and can be applied, as appropriate, to any type of construction project. While these methods still remain valid, it is recommended that the source input data be reviewed to assure the most current data is reflected. The reader is directed to the variety of source emission data contained and referenced in Chapter 9 of this Handbook.

6.3.3 Manual Calculations Using Measured Data

In lieu of using historical data, the analyst may deem it appropriate to use measured source data or to supplement historical data with measured data in one of the manual calculation processes[ref001].

6.3.4 The FHWA Roadway Construction Noise Model (RCNM)

This Windows-based noise prediction model has recently been developed in coordination with the preparation of this Handbook. It enables the prediction of construction noise levels for a variety of construction operations based on a compilation of empirical data and the application of acoustical propagation formulas. It enables the calculation of construction noise levels in more detail than the manual methods described above while avoiding the need to collect extensive amounts of project-specific input data. Appendix A of the hardcopy version of this Handbook contains the RCNM User's Guide. The RCNM User's Guide[ref083] and program[ref084] are directly accessible from the companion CD-ROM and web-based versions of this Handbook.

The RCNM is largely based on EPA methods from the 1970s in which equipment noise emissions, expressed as L_{max} levels at a reference distance of 50 feet, are then adjusted for the actual distance to the receptor as well as for the time (or usage factor) that the equipment is predicted to produce noise on the job site. The current version of the model includes an updated equipment noise emissions database as well as an empirical relationship between energy-averaged (L_{eq}) and percentile (L_{10}) noise levels.

The primary equation used in the RCNM for predicting construction-induced L_{10} noise levels at receptor locations, when summed over all operating equipment, is as follows:

$$L_{10} \text{ in dBA} = L_{max}@50ft - 20 \text{ LOG } (D/50) + 10 \text{ LOG } (U.F.\%/100) + 3 - IL_{bar}$$

where:

> $L_{max}@50ft$ is the emission level for the equipment at 50 feet, expressed in dBA "slow";
> D is the distance, in feet, between the equipment and the receptor;
> $U.F.\%$ is a time-averaging equipment usage factor, expressed in percent; and
> IL_{bar} is the insertion loss of any intervening barriers (computed separately) in dB.

The +3 dB adjustment factor was empirically determined by examining the average difference between L_{eq} and L_{10} noise levels during active construction.

Using RCNM, predicted noise levels can be evaluated at any distance from the construction activities. The selected location(s) analyzed will likely be dictated by the particular noise criteria in effect for the area and logistics in accessing measurement locations.

In addition to predicting the L_{10} noise level at a receptor location, the output of the model can also yield the predicted L_{max} level by eliminating the usage factor term and the +3 dB adjustment term from the algorithm. Similarly, the model can yield the L_{eq} level if just the +3 dB adjustment term is eliminated.

A comparison of the RCNM model and the manual calculation contained in the original 1977 Handbook can be found in Appendix B of this Handbook. Similar results are illustrated for Problem 5 (in the 1977 Handbook) using both analysis techniques.

6.3.5 The FHWA Highway Construction Noise Model (HICNOM)

Developed in 1982, this previously discussed model[ref091] enables the calculation of construction noise levels using a variety of methods, including manual (using charts and tables), programmable calculators, and a DOS-based computer program.

6.3.6 Other Models and Considerations

While the HICNOM is data intensive and more comprehensive, the RCNM[ref083 and ref084] is the most up-to-date model in terms of construction noise database information and is most easily applied to projects of varying complexities. In addition, other noise models such as the FHWA TNM, the FTA Transit Noise and Vibration Assessment procedure, and community noise models may be adapted for use in evaluating construction noise levels.

Either the computer version (see Table 10.1 for link to the FHWA TNM data) or the Look-Up version[ref090] of the FHWA TNM may be useful for the prediction of truck travel on haul roads, assessing impacts of diverted traffic, comparative modeling of line sources, barrier insertion loss calculations, etc. Either the manual[ref014] or one of the spreadsheet versions[ref073, ref074, or ref075] of the FTA procedure may be employed if construction operations involve rail routes for goods transportation, or if noise from other rail-related activities exists in the study area and needs to be addressed in the evaluation. The FTA model also provides a means of evaluating highway noise, as well as noise from other types of transportation facilities such as stations, maintenance yards, etc.

General environmental noise models and accepted acoustical algorithms may be employed in determining site-specific noise contributions from equipment such as pumps, compressors, demolition equipment, etc.

Table 6.1 below provides a list of the models discussed above plus a quick link to the models and/or their reference material:

Table 6.1 Noise Models and Links.

Model	Link
Federal Highway Administration (FHWA)	
1977 FHWA Manual Method	Reference 001
FHWA TNM	
Version 2.5 Users Guide Addendum	Reference 086
Model Info	http://trafficnoisemodel.org/
Look-Up Tables	Reference 090
FHWA HICNOM	Reference 091
RCNM	
Users' Guide	Reference 083
Model	Reference 084
Federal Transit Administration (FTA)	
1995 FTA Manual Method	Reference 014
FTA Spreadsheets	
Excel	Reference 073
Quattro Pro 6	Reference 074
Lotus	Reference 075
Federal Railroad Administration (FRA)	
2003 FRA Manual Method	Reference 092
Spreadsheet	Reference 093

6.4 Construction Noise Prediction Methodology

While the mechanisms associated with the various construction noise prediction techniques and models vary, the underlying prediction process methodologies are generally similar for all techniques, and include the following steps:

- Identify areas (including limits) with the potential to be impacted by construction noise;
  - Direct (from on-site activities)
  - Indirect (from activities such as detoured traffic, haul routes, off-site operations, etc.)
- Identify construction operations and their potential to create noise impacts;
- Determine time periods during which specific operations will occur;
  - Daytime
  - Nighttime
  - Weekends
  - Holidays
  - During special events
- Estimate duration and frequency of each significant noise-producing event;
  - Short term
  - Long term
  - Continuous
  - Intermittent
- Determine appropriate approach to addressing construction noise;

  - Qualitative discussion, no analysis
  - Qualitative discussion with screening type of analysis
  - Simple quantitative analysis using manual analysis techniques
  - More detailed quantitative analysis using model such as RCNM
  - More complex quantitative analysis using model similar to HICNOM
- Determine if measurements will be required and specifics related thereto;
- Select appropriate noise descriptor and time period for both measurements and analyses;
- Identify background existing noise levels;
- Determine component(s) of each construction operation in terms of equipment type and source noise level;
- Perform analyses;
- Define impacts, if any;
  - Based on absolute criteria/guidance
  - Based on relative noise levels – comparison with background
- Address mitigation; and
- Report results.

6.5 Qualifications of the Persons Performing Noise Evaluations

It is essential that those individuals performing measurements and analyses associated with the evaluation of construction noise possess the basic knowledge of the noise measurement techniques and prediction methodologies employed. Also essential is an understanding of the input data requirements and their sensitivities. A general knowledge of construction operations typical of the specific project being evaluated is also useful.

6.6 Factors Affecting Construction Noise Impact Evaluation

The range of items considered and the degree to which such items are addressed vary on a project-by-project basis. Things to consider include:

- Phase of project at which prediction/evaluation occurs;
  - Environmental document preparation
  - Preliminary engineering
  - Final design, including evaluations related to permit approvals
  - Construction
- Type and scope of analysis performed in previous phase(s); and
- Details, conclusions, and degree of information available from previous phase(s).

7.0 MITIGATION OF CONSTRUCTION NOISE

7.1 Introduction

This chapter provides more examples of typical mitigation techniques and options. Information provided is not to be considered all-inclusive, nor is it intended to limit the ingenuity or resourcefulness of designers, contractors, and inspectors, or create a strategy uniquely suited to the characteristics of a specific project.

Table 7.1 Overview of mitigation options.

Design Options
Design and Project Layout Sequence of Operations Alternative Construction Methods
Contract Specifications/Special Provisions
Operational Constraints Time Periods and Duration Specified Equipment Noise-Related Incentives/Disincentives Training Programs for Contractor
Mitigation at the Source
Stationary Equipment Mobile Equipment Selection of Equipment Inspection/Maintenance Programs Equipment Operation Training
Mitigation Along the Path
Natural Shielding Temporary Shielding Permanent Shielding
Mitigation at the Receiver
Building Envelope Improvements Masking Relocation of Residents
Public Involvement and Project Coordination
Critical components of the overall mitigation strategy. Should be considered during all phases of a project.

The level of detail in a contract required to address construction noise mitigation is dependant on the complexity of the project, the amount and type of work required, and the sensitivity of the area beyond the project boundary. Therefore, not all projects require the same amount of detail. Such detail could range anywhere from the inclusion of a standard specification requiring the contractor to be governed by local noise ordinances, to realigning the highway, providing for abatement structures, and/or relocation of residents.

The effective control of highway construction noise can be achieved in much the same manner as the control of operational traffic by considering the following techniques:

- Alternative design options;
- Mitigation at the source;
- Mitigation along the path; and
- Mitigation at the receiver.

Another effective technique is the inclusion of operational conditions via contract specifications and special provisions.

Public Involvement and project coordination are also essential components of the overall mitigation strategy worthy of consideration during all phases of a project. For a more detailed discussion of this topic, refer to Chapter 8.

Most of the options presented in this chapter can be employed independently or in combination, depending on the scope of the project and the resultant effects that are desired. While reductions in noise levels will vary with the method employed, consideration of all practical and feasible options is essential during all stages of the project development from planning through design and construction to final evaluation.

7.2 Design Options

Noise impacts can occur on any project involving the construction of a highway facility. While the magnitude of the impact construction noise may have on a community may not be known early in the project development stages, measures can be implemented during the design phase that can help to reduce the anticipated noise impacts at sensitive receptors. However, design changes and modification to project layout are not always practical or feasible. Also, the magnitude of the noise reduction attained from some of these techniques is usually difficult to determine prior to and possibly even during construction.

7.2.1 Design Phases

In addressing construction noise mitigation during the design phases of a project, abatement opportunities can be considered for a variety of areas and features including those listed below:

- **Storage Areas**: During the planning and design stages of a project, storage areas may be able to be designated in locations removed from sensitive receptors. Where this is not possible, the storage of waste materials, earth, and other supplies may be able to be positioned in a manner that will function as a noise barrier.

Figure 7.1 Storage area in highway right-of-way
(Photo #177)

Figure 7.2 Partial shielding of storage area in residential area
(Photo #247)

Figure 7.3 Storage area in remote location
(Photo #1257)

- **Haul Roads:** Haul roads can be designated in locations where the noise impacts caused by truck traffic will be reduced.

Figure 7.4 Designated haul routes
(Photo #560)

- **Detours:** Increased noise generated by temporarily rerouting traffic during construction is considered as part of construction noise. It is essential to consider efforts to reduce the impact from such changes during the design phases of the project.

Figure 7.5. Shifting of traffic to accommodate construction.
(Photo #1261)

Figure 7.6 Existing retaining wall acting as noise barrier during construction
(Photo #543)

- **Existing Barriers:** As early as possible in the design development process, natural and artificial barriers such as ground elevation changes, existing buildings, noise walls, and other structures can be considered for use as a noise shield during certain operations.

7.2.2 Sequence of Operation

The sequencing and scheduling of construction operations is equally important in addressing and mitigating construction-related noise:

- **Concurrent Operations:** It may be possible to schedule several noisy operations concurrently to take advantage of the fact that the combined noise levels produced may not be significantly greater than the level produced if the operations were performed separately.

Figure 7.7 Early construction of noise barriers
(Photo #447)

- **Early Construction of Noise Barriers:** Ultimately, noise barriers that are to be constructed as part of the project for traffic noise abatement can possibly be installed during the initial stages of construction to reduce the noise impacts of the construction.

7.2.3 Alternative Construction Methods

Alternatives to standard construction techniques may also be available and determined to be more practical and/or cost-effective in dealing with construction noise impacts and perceptions. Examples associated with several operations are discussed below.

- **Pile Driving:** Pile driving may produce noise levels in excess of acceptable limits, even when feasible noise reduction methods are used. Various dampening and shielding methods discussed later can attain some reduction. However, such methods rarely reduce the noise level to an acceptable level for the sensitive receptors close to the site. As an alternative to driving piles, it is possible to use vibration or hydraulic insertion techniques. Drilled or augured holes for cast-in-place piles are another alternative that may produce noise levels significantly lower than the traditional driving method.

Figure 7.8 Alternative to pile driving
(Photo #509)

- **Compressors:** While most compressors are powered by diesel or gasoline engines, many are contained or have baffles to help abate noise levels. Electric compressors are significantly quieter than diesel or gasoline engine powered compressors.

Figure 7.9 Diesel compressor with baffled housing (Photo #69)

7.3 Contract Specifications and Special Provisions

Contract specifications and special provisions are typically produced during the design stages of project development and may be included in the project plans and contract documents. Ideally, use of these documents is considered in conjunction with other control methods to achieve an overall construction noise strategy. Examples of such specifications[ref023, ref028, ref103, and ref053] are referenced in this Handbook.

7.3.1 Construction Noise Criteria Limits

When establishing suitable noise criteria limits for specifications and special provisions, they can be characterized as either being "relative" or "absolute" or a combination of both. These can be defined even further by dividing the set limits into specific time periods during the day, such as daytime, evening, and nighttime. Experience has shown that the "absolute" criteria combined with the "relative" criteria levels appears to be more realistic and tends to be self-adjusting to varying conditions, particularly when defined for the various periods of the day. An example of one such set of construction noise criteria is shown in Table 7.2.

Table 7.2 Example of Absolute and Relative Construction Noise Criteria Limits.

Lot-Line Construction Noise Criteria Limits A-weighted in dB, RMS slow						
Noise Receptor Locations and Land-Uses	**Daytime (7 AM - 6 PM)**		**Evening (6 PM - 10 PM)**		**Nighttime (10 PM - 7 AM)**	
	L_{10}	**L_{max}**	**L_{10}**	**L_{max}**	**L_{10}**	**L_{max}**
Noise-Sensitive Locations: (Residences, Institutions, Hotels, etc.)	75 or Baseline + 5 (whichever is louder)	85 90 (impact)	Baseline + 5	85	Baseline + 5 (if Baseline <70) Baseline + 3 (if Baseline 70)	80
Commercial Areas: (Businesses, Offices, Stores, etc.)	80 or Baseline + 5	None	None	None	None	None
Industrial Areas: (Factories, Plants, etc.)	85 or Baseline + 5	None	None	None	None	None

Notes: L_{10} noise compliance readings are averaged over 20 minute intervals. L_{max} noise compliance readings can occur instantaneously. Baseline noise conditions must be measured and established prior to construction work, commencing in accordance with the noise specification, which requires baseline noise readings over three 24-hour periods at each receptor lot-line location.
Source: Adapted from Central Artery/Tunnel Noise Specification and Table 2 in Appendix A.

As shown in Table 7.2, the noise specification's lot-line criterion is primarily a relative criterion in which construction noise levels, in general, can not exceed baseline (preconstruction) L_{10} noise levels by more than 5 dB at identified noise sensitive receptor locations. L_{max} noise limits also apply at the lot lines and are intended to address loud impact-type noise events. In the above criteria, the following three types of receptor land uses have been suggested:

- Noise Sensitive Areas consisting of sites with nighttime land use such as residences, hotels, and hospitals;
- Commercial Areas containing land uses such as businesses and office buildings; and
- Industrial Areas containing factories and large plants.

The lot-line criteria limits are more stringent for residential receptors than for commercial or industrial receptors in lieu of the more sensitive nature of residential land uses. In addition, there are different criteria limits depending on various times of day, with the most restrictive noise limits applied to the more sensitive nighttime period.

As shown in Table 7.3, contract specifications can also contain an absolute noise criterion which can be applied to generic classes of heavy equipment to limit their noise emissions. Equipment-specific A-weighted L_{max} noise limits, in dBA, evaluated at a reference distance of 50 feet, are defined in the noise specification. Thus, contract specifications could contain two types of noise criteria limits (relative lot-line limits and absolute equipment emissions limits), defining compliance requirements for the contractor. Consequently, if measured or anticipated construction noise levels exceed the allowable noise criteria limits, noise mitigation measures may be warranted during similar work activities.

Table 7.3 Example of Possible Construction Equipment Noise Emission Criteria Limits.

Equipment Description	L_{max} Noise Limit at 50 ft, dB, slow	Equipment Description	L_{max} Noise Limit at 50 ft, dB, slow
All other equipment > 5 HP	85	Gradall	85
Auger Drill Rig	85	Grader	85
Backhoe	80	Horizontal Boring Hydraulic Jack	80
Bar Bender	80	Hydra Break Ram	90
Blasting	94	Impact Pile Driver (diesel or drop)	95
Boring Jack Power Unit	80	Insitu Soil Sampling Rig	84
Chain Saw	85	Jackhammer	85
Clam Shovel	93	Mounted Impact Hammer (hoe ram)	90
Compactor (ground)	80	Paver	85
Compressor (air)	80	Pickup Truck	55
Concrete Batch Plant	83	Pneumatic Tools	85
Concrete Mixer Truck	85	Pumps	77
Concrete Pump	82	Rock Drill	85
Concrete Saw	90	Scraper	85
Crane (mobile or stationary)	85	Slurry Plant	78
Dozer	85	Slurry Trenching Machine	82
Dump Truck	84	Soil Mix Drill Rig	80
Excavator	85	Tractor	84
Flat Bed Truck	84	Vacuum Street Sweeper	80
Front End Loader	80	Vibratory Concrete Mixer	80
Generator (25 KVA or less)	70	Vibratory Pile Driver	95
Generator (more than 25 KVA)	82	Welder	73

Source: Adapted from Central Artery/Tunnel Noise Specification

7.3.2 Time Periods and Duration

Time constraints and use of equipment regulations can be effective in reducing the impacts caused during sensitive time periods. In addition, operating noisy equipment only when necessary and switching off such equipment when not in use can minimize noise impacts.

Figure 7.10 Nighttime bridge construction
(Photo #661)

Figure 7.11 Nighttime demolition operation
(Photo #1049)

7.3.3 Specified Equipment

Another effective noise mitigation technique involves use of the quietest practical type of equipment. To avoid confusion and misinterpretations, such types should be specified in the contract specifications and special provisions.

7.3.4 Noise Related Incentives/Disincentives

Another technique worthy of consideration involves the inclusion of incentives and/or disincentives in the contract specifications to encourage contractors to participate in the mitigation program and to make the contractors more accountable for impacts.

7.3.5 Training Programs for Contractors

It may be appropriate to require contractors to participate in training programs related to project-specific noise requirements, specifications, and/or equipment operations. Such training may be provided by agency or project management personnel, outside consultants, and/or equipment manufacturers or suppliers. For example, project personnel (or consultants assigned to the project) may train the contractor in the measurement of construction-related noise levels that may be required to meet the contract specifications.

The contractor may also receive onsite training related to noise-specific issues and noise-critical areas and sites adjacent to the project. Equipment manufacturers and/or suppliers may be available to provide training to the contractor on the proper use of the noise abatement features of specific pieces of construction equipment. Any training requirements that are envisioned to be required would typically be described or referenced within the contract's specifications and special provisions.

7.4 Mitigation at the Source

Source control is, in general, the most effective form of noise mitigation and involves controlling a noise source before it is able to emit potentially offensive noise levels. Construction noise (exclusive of blasting) is typically generated by two source types:

- Stationary equipment; and
- Mobile equipment.

Noise levels from both types of noise sources are dependent on equipment characteristics and their operation.

7.4.1 Equipment – All Types

The following discussions relate to both stationary and mobile construction equipment:

- **Use less noisy equipment:** One of the most effective methods of diminishing the noise impacts caused by individual equipment is to use less noisy machinery. By specifying and/or using less noisy equipment, the impacts produced can be reduced or, in some cases, eliminated. Source control requirements may have the added benefits of promoting technological advances in the development of quieter equipment.

Figure 7.12 In some instances, using a less noisy piece of equipment (right) may be possible, as opposed to using more conventional and sometimes noisier equipment (left) to perform the same operation
(Photos #505 & #506)

- **Mufflers:** Most construction noise originates from internal combustion engines. A large part of the noise emitted is due to the air intake and exhaust cycle. Specifying the use of adequate muffler systems can control much of this engine noise.

Figure 7.13 Muffler system on recycling equipment
(Photo #1287)

- **Shields:** Employing shields that are physically attached to the particular piece of equipment is effective, particularly for stationary equipment and where considerable noise reduction is required.

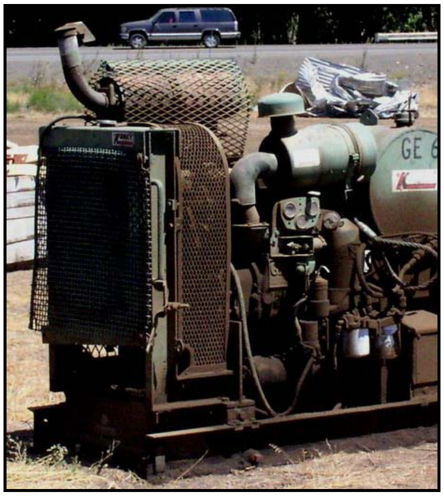


Figure 7.14 Unshielded, non-baffled equipment
(Photo #74)

Figure 7.15 Shielded compressor
(Photo #18)

- **Dampeners:** Equipment modifications, such as dampening of metal surfaces, is effective in reducing noise due to vibration. Another possibility is the redesign of a particular piece of equipment to achieve quieter noise levels.

Figure 7.16 Examples of pile driver shielding and dampening
(Photos #1277, #1281 & #1308)

- **Bubble Curtains:** Where piles are driven or drilled through water, bubble curtain technology may be employed. Bubble curtain techniques introduce specifically sized air bubbles into the water surrounding the pile in a controlled manner, thus dampening the shock waves and helping to minimize the effects on aquatic life. Air may be released in a variety of ways, including through a ring, as shown in Figure 7.18 below.

Figure 7.17 Bubble curtain
(Photo #57)

See References 030, 036, 046, 054, 060, 061, and 102 for information related to aquatic effects.

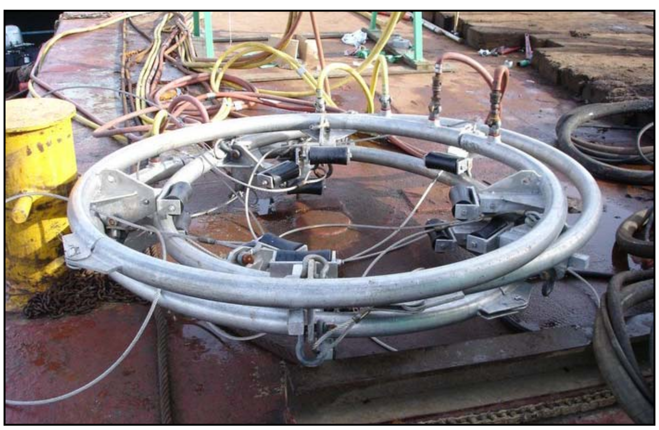


Figure 7.18 Bubble curtain air release ring
(Photo #51)

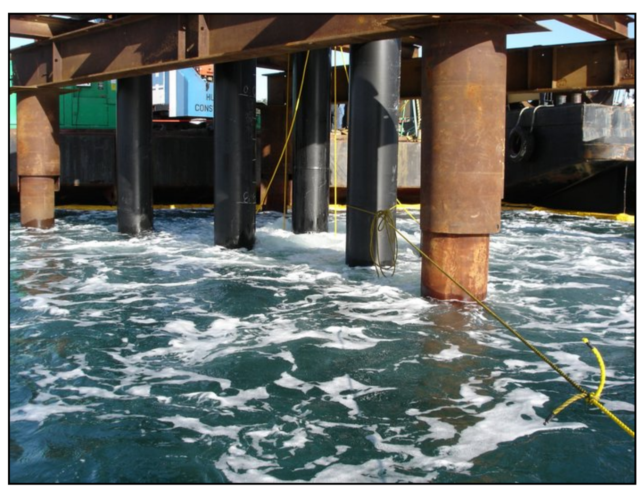


Figure 7.19 Bubble curtain
(Photo #52)

- **Aprons:** Sound aprons generally take the form of sound absorptive mats hung from the equipment or on frames attached to the equipment. The aprons can be constructed of rubber, lead-filled fabric, or PVC layers with possibly sound absorptive material covering the side facing the machine. Sound aprons are useful when the shielding must be frequently removed or if only partial covering is possible.

- **Enclosures:** Enclosures for stationary work may be constructed of wood or any other suitable material and typically surround the specific operation area and equipment. The walls could be lined with sound absorptive material to prevent an increase of sound levels within the structure. They should be designed for ease of erection and dismantling.

Figure 7.20 Straw bail enclosure for stationary equipment
(Photo #58)

- **Blasting Mats:** These mats are typically made with layers of used tires cabled together. They are commonly used as blankets for blasting operations to control and confine debris. These mats also provide a degree of noise attenuation from the blast. However, they do not mitigate vibration, which is usually more of a concern than noise.

Figure 7.21 Blasting mats constructed with black tires (in foreground of photo)
(Photo #261)

Figure 7.22 Blasting mats being placed into position
(Photo #1341)

- **Selection of Equipment:** Newer equipment is generally quieter than old equipment for many reasons, including technological advancements and the lack of worn, loose, or damaged components. Some equipment manufacturers have made their equipment quieter in recent years and have achieved significant reductions over older equipment. In some cases, the use of over- or under-powered equipment may be an unexpected source of excessive noise. The types of engines and power transfer methods also plays a significant roll in achieving lowered equipment noise. The use of electric powered equipment is typically quieter than diesel, and hydraulic powered equipment is quieter than pneumatic power.

Figure 7.23 Older equipment may be as efficient as new, but may not meet noise emission requirements
(Photo #809)

Figure 7.24 Newer paving equipment
(Photo #813)

• **Maintenance Programs:** Poor maintenance of equipment typically causes excessive noise levels. Faulty or damaged mufflers and loose engine parts such as screws, bolts, or metal plates contribute to increased noise levels. Removal of noise-reducing attachments and devices such as mufflers, silencers, covers, guards, vibration isolators, etc., will, to varying degrees, increase noise emission levels. Old equipment may be made quieter by simple modifications, such as adding new mufflers or sound absorbing materials. Loose and worn parts should be fixed as soon as possible.

• **Equipment Operation Training:** Careless or improper operation or inappropriate use of equipment can increase noise levels. Poor loading, unloading, excavation, and hauling techniques are examples of how lack of adequate guidance and training may lead to increased noise levels.

Figure 7.25 Regular service of equipment is an essential component to quietest operation possible. Equipment suppliers may also be valuable sources of training related to proper use of equipment. (Photo #827)

7.4.2 Stationary Equipment

Whenever possible, positioning stationary noise sources such as generators and compressors as far away as possible from noise sensitive areas should be considered. Temporary barriers can be employed and/or enclosures can be built around noisy equipment. These techniques can significantly reduce noise levels and, in many cases, are relatively inexpensive. These barriers can typically be constructed on the work site from common construction building material (plywood, block, stacks, or spoils). Enclosures are often constructed from commercial panels lined with sound absorbing material to achieve the maximum possible shielding effect.

Figure 7.26 Temporary shielding of stationary equipment (Photo #1340)

To be effective, the length of a barrier should be greater than its height, the noise source should not be visible, and any barrier should be located as close as possible to either the noise source or the receiver. In addition, providing increased distance between a noise source and a noise receiver can also be considered a form of abatement.

Figure 7.27 Temporary barrier around stationary activity (Photo #1339)

7.4.3 Mobile Equipment

Many construction operations are mobile and tend to progress along the length of a project at varying rates. Noise levels at the receiver tend to vary considerably, not only as the speed and power of the equipment varies, but also as the equipment is constantly changing in terms of its distance from the receivers and its relative location. To address this, all the equipment noise mitigation techniques listed in Section 7.4.1 are worthy of consideration with the exception of the enclosures. Enclosing mobile equipment is usually not possible, unless the operation is slow moving and the enclosures can be easily moved.

7.5 Mitigation along the Path

In some situations, such as in urban areas or on isolated sections of a project, it may be beneficial and necessary to construct barriers adjacent to the work area or at the right-of-way. These can take the form of natural shielding, temporary shielding, and/or permanent shielding.

7.5.1 Existing Features

Utilizing existing shielding such as berms, existing noise barriers, or structures for relatively static equipment such as pumps, generators, compressors, air ventilation, batch plants, and storage areas may be appropriate.

Figure 7.28 Existing noise barrier left in place until replacement noise barrier is constructed (Photo #483)

Figure 7.29 Equipment and storage area shielded by existing structures (Photo #558)

7.5.2 Temporary Abatement

Advantage may also be taken of the screening effect of any nearby object such as parapet walls, buildings, trailers, or temporary site offices.

Figure 7.30 Use of existing structure and temporary plywood on chain link fence plus absorptive mats to shield recycling equipment
(Photos #690, #390, #395 & #679)

Figure 7.31 Temporary barrier of plastic material
(Photo #194)

Other temporary abatement techniques include the use of temporary and/or movable shielding for both specific and nonspecific operations. Some mobile shielding is capable of being moved intact or being repeatedly erected and dismantled to shield a moving operation. An example of such a barrier utilizes noise curtains in conjunction with trailers to create an easily movable, temporary noise barrier system.

Figure 7.32 Storage trailers modified to act as temporary noise barrier (Photos #1030 & #1029)

7.5.3 Early Construction of Permanent Noise Barriers

As mentioned in Section 7.2.2, shielding of certain construction activities may be accomplished by specifying that the construction of permanent noise barriers be implemented as early as possible during the project's construction phase. Obviously, some noise-producing activities will likely be required before such barriers can be constructed. In addition, the actual erection of the noise barriers is a noise generating activity.

Figure 7.33 Early construction of permanent noise barriers
(Photo #472)

7.6 Mitigation at the Receiver

Mitigation at a receiver can vary in its complexity, ranging anywhere from relocating residents for a day to insulation of a building. Even after mitigation measures have been applied, the outcome may still be unpredictable with no guarantees that the implemented methods achieve expected results. Therefore, mitigation at the receiver should only be considered as a last alternative. However, there are cases where creative techniques have been successfully implemented.

7.6.1 Building Envelope Improvements

Building envelope mitigation to reduce construction noise can include techniques such as sealing existing building elements, providing new sealed windows and doors, adding building insulation, etc. Such techniques, while effective, may also require modification of the building's heating, ventilation, and air conditioning system. Prior to proposing such treatments, thorough consideration of the costs and implications of such modifications is suggested.

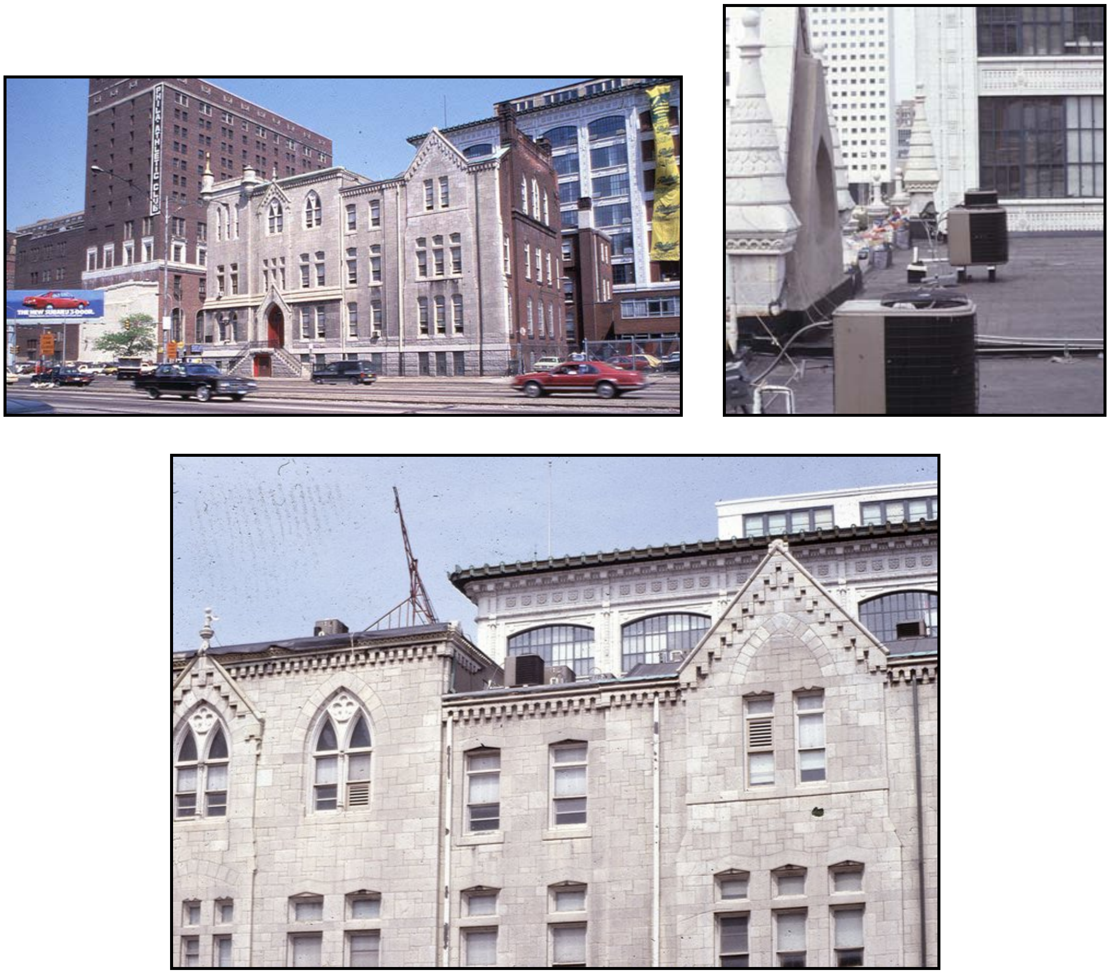


Figure 7.34 Installation of a complete air handling system and window treatments at urban school solely to abate construction noise due to future conversion of arterial to depressed expressway (Photos #1300, #1303 & #1304)

The following discussion of window treatments is based on information provided in Reference 009. The reader is directed to this reference document for more information.

Acoustical window treatments to improve the noise reduction qualities of residential window openings represents a proven successful means to implement receptor noise control. In general, window openings are the weak link in a structure's external façade, allowing noise infiltration into the building. When properly specified and installed, window treatments can provide for a significantly quieter interior noise environment, particularly in multi-story buildings with upper floors that may not benefit from typical noise barriers. In general, window treatments are most cost-effective when a relatively few or widely scattered number of receptors require noise mitigation. Window treatments have the added attraction of reducing noise from all noise sources, such as traffic noise, aircraft noise, and general community noise, in addition to reducing construction noise.

Several forms of acoustical window treatments are available. Each has its pros and cons:

- Interior glass sash – simple to install, least costly, good noise reduction, no historic restrictions, but limits sill space;
- Temporary interior clear vinyl curtains – simple and quick, inexpensive, but somewhat unattractive;
- Full replacement acoustical windows – double or triple pane glass, excellent noise reduction, but expensive; and
- Exterior storm sash – inexpensive, marginal additional noise reduction, subject to historic preservation limitations.

The recommended type of window treatment for a given receptor should be evaluated on an individual basis. If the existing windows and frames are in decent physical condition and if the window frame depth will allow the necessary air space (~ 3 inches), then the most cost-effective treatment may involve insertion of interior storm sashes. If, however, an existing window or frame is in disrepair, then a full replacement acoustic window may be more appropriate.

Timing and logistic issues that may challenge any window treatment program could include:

- Legal concerns;
- Labor agreements;
- Historic preservation issues;
- Procurement schedules;
- Staffing requirements;
- Cost implications;
- Contractor scheduling; and
- Correspondence with eligible recipients.

In light of these issues, a project should consider evaluating any window treatment options based on some eligibility criterion that evaluates the need and justifies window treatments on a case-by-case basis.

It is recommended that any type of noise abatement treatment applied to a building be verified as to its proper installation and performance. Providing funding for such treatments directly to a property owner without such a performance and verification program is not recommended and, in fact, would be against federal regulations.

7.6.2 Noise Masking

Noise masking is a technique that is still in the developmental stage but may have potential in isolated cases. Masking considerations could include techniques such as constructing water falls or other cascading water designs, employment of noise cancellation technologies, changing "background" noise levels, etc. Such techniques require a consideration of the type of noise generator (stationary, mobile, etc.), the source's noise frequency content, variability of the noise source in terms of its magnitude and duration, and the noise environment of the receptor being protected.

Figure 7.35 Experimental sound system used to mask nighttime construction noise in the community (Photos #42 & #38)

7.6.3 Relocation of Residents

In certain instances it may be appropriate, and possibly more cost-effective, to temporarily relocate a resident or residents from the construction area. By temporarily eliminating the noise receptor, noisy construction activities may be able to be undertaken unimpeded and completed in far less time than would be required under a noise-restrictive procedure. Such a technique was employed when several spans of a damaged interstate highway structure required demolition in close proximity to a row of residences. The residents were relocated to a hotel for a weekend while the damaged bridge structure was completely demolished. Another project which included relocation of residents as a mitigation measure is discussed in Reference 103.

7.7 Selection of Mitigation Measures

After the potential impacts resulting from the construction activities have been established, the next step in the process is the selection of appropriate control measures to be implemented on the project. This can typically be accomplished by identifying all feasible measures that could be used, selecting the most suitable techniques, and assembling them into a final mitigation strategy.

7.7.1 Identification of Feasible and Reasonable Measures

This stage involves identification of control strategies that could be implemented to bring about the desired reductions in noise impacts. Some of the factors that influence this identification process are:

- Amount of reduction needed;
- Local sentiment toward the proposed project;

- Local noise ordinances;
- Length of the construction period;
- Effectiveness of control strategies; and
- Cost of control strategies.

Based on these and other factors, various noise mitigation strategies can be examined to determine what measures are best suited for implementation on a specific project. Factors influencing this selection include:

- Cost;
- Practicality;
- Achievable noise reduction; and
- Effect on overall project operation.

7.7.2 Selection of Mitigation Strategies

This stage involves the selection of a reasonable control strategy from the methods examined in the identification stage. The measure or measures chosen should be weighed as to their benefits compared to their adverse effects. This weighting should take into consideration:

- Monetary costs involved;
- Feasibility of carrying out the mitigation techniques;
- Problems with implementation of the method;
- Ability to enforce any requirements of the strategy;
- Degree of noise reduction achievable;
- Gauging the sensitivity of the receptors in the area; and
- Evaluation of the strategy with regard to any adverse impact on the overall operation of the project caused by delays or disruption of critical construction scheduling.

7.8 Monitoring Noise Levels During Construction

Regardless of the types of noise abatement strategies and techniques employed on any particular project, successes or failures are ultimately determined by resultant effects on noise levels at sensitive sites and the adherence of the resultant noise levels to the stated construction noise level criteria.

Evaluation of such success or failure is typically addressed by a program, the requirements of which are usually detailed in the contract specifications and special provisions. An adequate program requires:

- Properly trained staff for the task of monitoring noise;
- Equipment sufficient to properly monitor noise levels and operations;
- Well-written specifications to avoid misinterpretations;
- Well-defined goals that can be achieved and measured;
- Knowledgeable and properly trained operators and contractors who have an understanding of what has to be achieved, why it has to be achieved, and how to achieve it; and
- Clearly defined chain of responsibility to ensure compliance in a timely and proper manner.

On those projects where construction noise impacts require a significant level of physical and operational mitigation, the ability to successfully monitor construction noise is closely tied to the commitment to meet the requirements detailed in the contract specifications and special provisions.

To be able to successfully enforce any project's construction noise requirements, it is essential that the project's specifications and special provisions embody the following:

- Empowerment of staff;
- Clearly defined consequences; and
- Dispute resolution mechanism.

7.9 Examples of Construction Noise Regulations

While 23 CFR 772 requires the evaluation of construction noise and the consideration of mitigation for identified construction noise impacts, it does not include specifications or specific language related to construction noise mitigation techniques, criteria, or restrictions. Such detail is included in various State and local documents, some of which are included as References 001, 009, 053, 077, and 103 and/or referred to in Table 10.1 of this Handbook.

8.0 PUBLIC INVOLVEMENT AND PROJECT COORDINATION

8.1 Public Involvement

An effective public involvement program provides a mechanism to keep the stakeholders informed throughout the project development process, to obtain valuable data related to the project, and to become aware of any project-related issues in a timelier manner. An ongoing public involvement program can also help to establish a degree of trust and credibility between the stakeholders and the project team members and foster public acceptance of the project. Regulation 23 CFR 771.111(h)(2) requires that State public involvement/public hearing procedures provide for:

- Coordination of public involvement activities and public hearings with the entire NEPA process and
- Early and continuing opportunities during project development for the public to be involved in the identification of social, economic, and environmental impacts, as well as impacts associated with relocation of individuals, groups, or institutions.

The regulation emphasizes the need for early and continuing opportunities for public involvement. While much of this interaction may occur during the design process, the continuation of such public involvement activities may be necessary during the construction phase of the project, dependent upon the specifics of the project.

Five basic components of a public involvement program include:

- Goals and objectives;
- Identification of stakeholders;
- Outreach techniques;
- Evaluation and revision; and
- Budget and schedule.

Each of these components builds on the previous one. For example, the goals and objectives may help identify which stakeholders are contacted. The stakeholders may help determine what techniques are used, etc.

8.1.1 Goals and Objectives

The goals and objectives of a successful public involvement program should be considered throughout all phases of the project.

8.1.1.1 Early Phases

The noise-related aspects of a public involvement program are aimed at presenting project-related information to the public and obtaining public views and input. During the earlier phases of project development, the project's purpose and need is presented to regulatory agencies and the public. Both have opportunities to comment and provide input related to purpose and need. Presentations are made of the range of alternatives under consideration. Broad-scale corridor-type alternatives are usually presented in the earlier stages of project development when no or limited data is available related to noise effects. As such, any discussions related to project-related and construction-related noise are typically qualitative in nature at this stage.

8.1.1.2 Preliminary Engineering / Environmental Analysis Phase

As a wider and more detailed range of alternatives is developed, horizontal and vertical alignments options are usually evaluated along with options such as traffic management measures. Existing and planned land uses are usually considered during this stage in identifying noise sensitive or noise study areas (NSAs), noise measurement plans, and noise analysis sites. Public involvement activities can provide a means of conveying information on study plans plus provide a means of identifying (through public input) areas of concern or importance that might otherwise have been overlooked. The public involvement process also provides the opportunity of stakeholders to review and comment on existing noise levels (both measured and modeled), future predicted noise levels, and preliminary noise abatement considerations. At this stage, the discussion of construction noise is typically still conceptual in nature. The development of the RCNM[ref083 and ref 084] now provides a tool for evaluating construction noise in more detail than a qualitative analysis, but without the necessity of an extensive analysis. As such, some quantitative evaluation may be appropriate at this stage using general project information.

8.1.1.3 Final Design Phase

Details related to final determinations associated with noise abatement measures (items such as barrier types, colors, textures, etc.) are typically presented during the final design phase. During this period, the public often provides input regarding barrier details and may vote on noise abatement options. For the majority of highway improvement projects, construction noise may be discussed in qualitative terms, except on major and controversial projects where detailed information of construction noise may be presented. The RCNM may be a useful tool at this stage, when more detailed project-related information is available. Such information may be presented in a table similar to Table 8.1 below.

Table 8.1 Summary of Estimated Construction Noise Levels Based on RCNM.

Site	Existing Noise Levels in dBA		Assumed Construction Operation	Equipment Assumed to Be Operating	Assumed Distance (in feet) from Equipment to Site	Estimated Noise from Construction Activity in dBA		Estimated Increase in Noise Due To Construction Operation in dBA	
	L_{eq}	L_{max}				L_{eq}	L_{max}	L_{eq}	L_{max}
A	62.7	76.8	Demolition	Backhoe	175	62.7	66.7		
				Compressor	175	62.8	66.8		
				Dump Truck	175	61.6	65.6		
				Front End Loader	175	64.2	68.2		
				Mounted Impact Hammer (hoe ram)	175	72.4	79.4		
				All Equipment		74.0	79.4*	11.3	2.6
B	75.7	86.3	Wall Construction	Auger Drill Rig	30	81.8	88.8		
				Compressor	100	67.7	71.6		
				Crane	200	60.6	68.5		
				Concrete Mixer Truck	100	68.8	72.8		
				Welder/Torch	100	64.0	68.0		
				Flat Bed Truck	200	58.2	62.2		
				All Equipment		82.3	88.8*	6.6	2.5
C	74.6	88.5	Excavation, Including Some Rock Removal	Backhoe	200	61.5	65.5		
				Blasting	200	62.0	82.0		
				Excavator	200	64.7	68.7		
				Dump Truck	200	60.4	64.4		
				Dump Truck	200	60.4	64.4		
				Rock Drill	200	62.0	69.0		
				All Equipment		69.9	82.0*	-4.7	-6.5

* = L_{max} of noisiest piece of equipment

8.1.1.4 Construction Phase

During the construction of most projects, noise-related public involvement activities are most often related to responses to specific concerns from adjacent property owners. However, major or more sensitive projects may have a construction noise control/mitigation program that includes a public involvement element. In such instances, there could be ongoing noise monitoring during construction, established construction noise criteria, and a related reporting process to the public.

Figure 8.1 Construction in the community
(Photo #925)

8.1.2 Stakeholders

Depending upon the makeup of the project study area, the project stakeholders will likely be comprised of a mixture of elements such as:

- Citizens;
- Elected and non-elected officials;
- Community organizations;
- Businesses;
- Institutions (schools, churches, etc.);
- Regulatory agencies; and
- Special interest groups.

Figure 8.2 Multiple land uses in a project area
(Photo #1305)

While all of these stakeholders may be involved at some point within the project development process and may have specific interests related to noise issues, it is most likely that construction-related noise issues will be of concern primarily to citizens, institutions, and businesses. Each area is likely represented by one or more elected or appointed officials that represent the residents, institutions, and business interests in that area.

8.1.3 Outreach Techniques

A wide variety of techniques are available for informing the public of the noise-related aspects of the project and receiving public input, including:

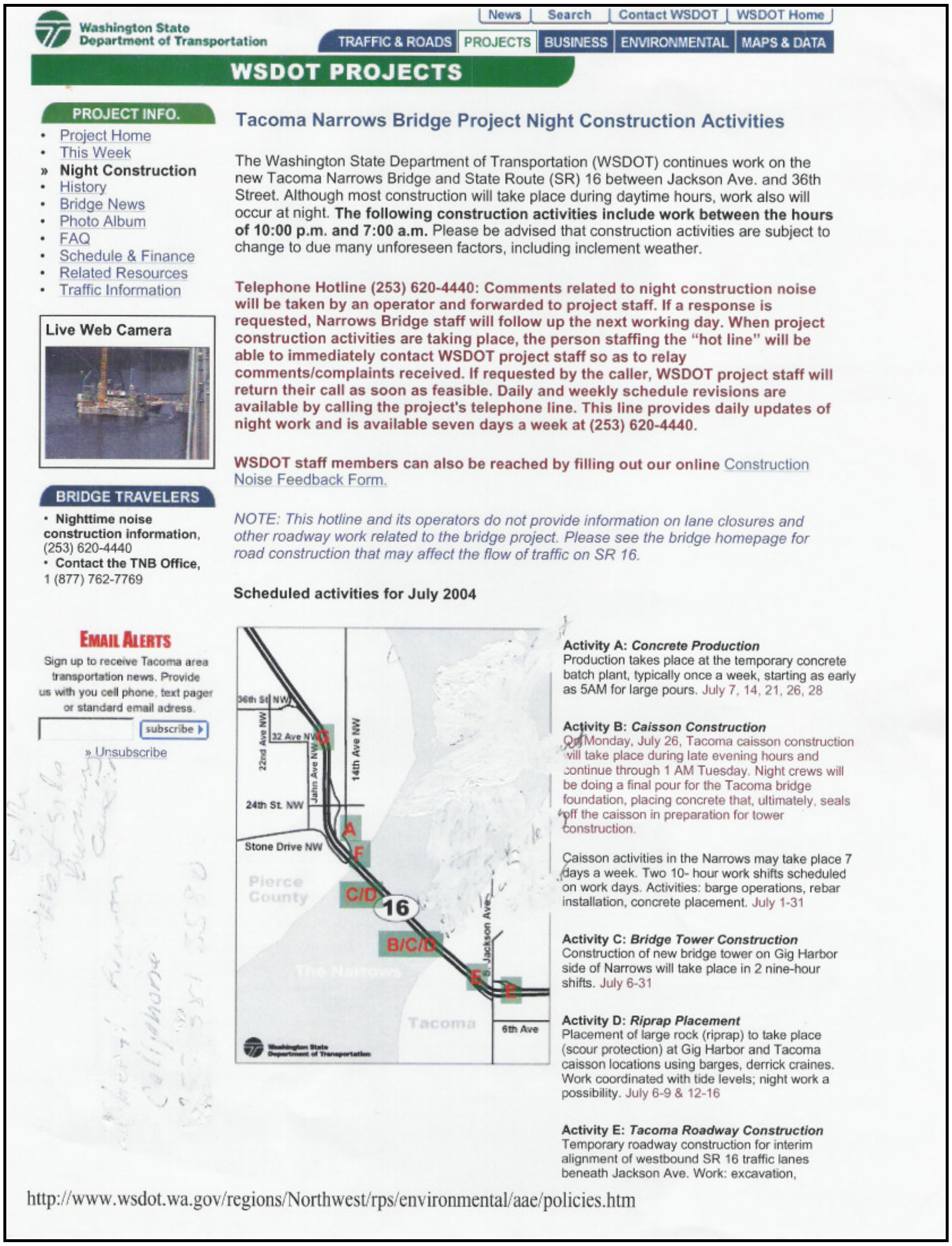
- Meetings, hearings, and workshops;

Figure 8.3 Public meeting presentation
(Photo #485)

- Field reviews and site visits;

Figure 8.4 Field walks to project area with public
(Photo #625)

- Newsletters and handouts[ref098, ref099, and ref100];
- Websites and phone hotlines;



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Tacoma Narrows Bridge Project Night Construction Activities

The Washington State Department of Transportation (WSDOT) continues work on the new Tacoma Narrows Bridge and State Route (SR) 16 between Jackson Ave. and 36th Street. Although most construction will take place during daytime hours, work also will occur at night. **The following construction activities include work between the hours of 10:00 p.m. and 7:00 a.m.** Please be advised that construction activities are subject to change to due many unforeseen factors, including inclement weather.

Telephone Hotline (253) 620-4440: Comments related to night construction noise will be taken by an operator and forwarded to project staff. If a response is requested, Narrows Bridge staff will follow up the next working day. When project construction activities are taking place, the person staffing the "hot line" will be able to immediately contact WSDOT project staff so as to relay comments/complaints received. If requested by the caller, WSDOT project staff will return their call as soon as feasible. Daily and weekly schedule revisions are available by calling the project's telephone line. This line provides daily updates of night work and is available seven days a week at (253) 620-4440.

WSDOT staff members can also be reached by filling out our online Construction Noise Feedback Form.

NOTE: This hotline and its operators do not provide information on lane closures and other roadway work related to the bridge project. Please see the bridge homepage for road construction that may affect the flow of traffic on SR 16.

Scheduled activities for July 2004

Activity A: ***Concrete Production***
Production takes place at the temporary concrete batch plant, typically once a week, starting as early as 5AM for large pours. July 7, 14, 21, 26, 28

Activity B: ***Caisson Construction***
On Monday, July 26, Tacoma caisson construction will take place during late evening hours and continue through 1 AM Tuesday. Night crews will be doing a final pour for the Tacoma bridge foundation, placing concrete that, ultimately, seals off the caisson in preparation for tower construction.

Caisson activities in the Narrows may take place 7 days a week. Two 10- hour work shifts scheduled on work days. Activities: barge operations, rebar installation, concrete placement. July 1-31

Activity C: ***Bridge Tower Construction***
Construction of new bridge tower on Gig Harbor side of Narrows will take place in 2 nine-hour shifts. July 6-31

Activity D: ***Riprap Placement***
Placement of large rock (riprap) to take place (scour protection) at Gig Harbor and Tacoma caisson locations using barges, derrick craines. Work coordinated with tide levels; night work a possibility. July 6-9 & 12-16

Activity E: ***Tacoma Roadway Construction***
Temporary roadway construction for interim alignment of westbound SR 16 traffic lanes beneath Jackson Ave. Work: excavation,

http://www.wsdot.wa.gov/regions/Northwest/rps/environmental/aae/policies.htm

Figure 8.5 Project construction information provided via updates on website

- E-mail;
- TV and radio;
- Public displays and kiosks;

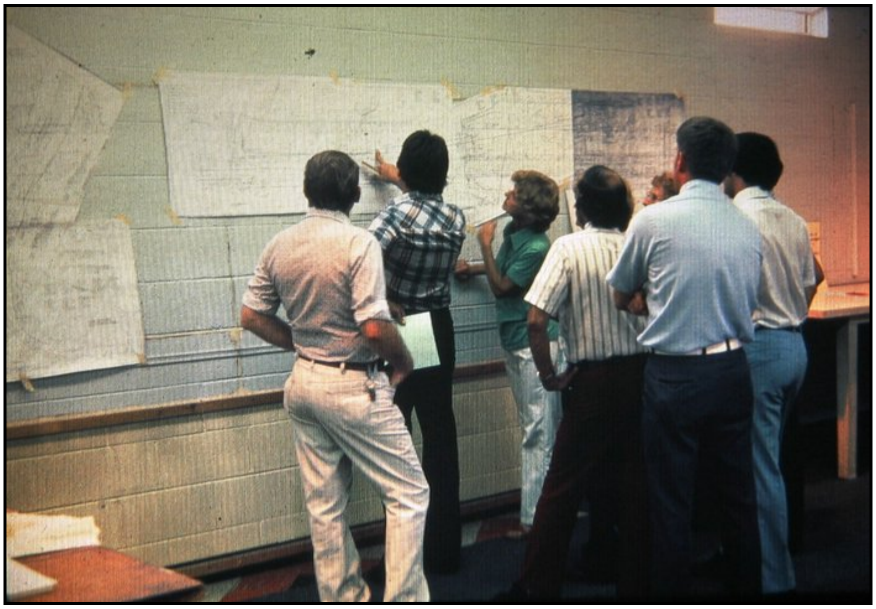

Figure 8.6 Public plans display
(Photo #753)

- Dedicated project office;
- Surveys and interviews;
- Notifications in the project area; and

Figure 8.7 Signs in the neighborhood
(Photo #561)

- Other means.

Figure 8.8 Other ways the public provides its input
(Photo #1298)

It is important to remember that no one technique or method is best for all projects. What works well for one project may be a failure on another. For this reason, it is essential that the methods selected be tailored to the particular project, the project area, and the stage of the project. A public involvement activity used to discuss noise barriers in the design process may not be the best technique to use in addressing a construction noise related issue during the project's construction phase.

Regardless of the public involvement technique(s) utilized, it is useful to have a specific program or process by which to deal with any complaints received from the community or the public at large. This could include having a specific communications strategy[ref057] (including an advertised phone number or website address dedicated to the reporting of complaints) or personnel assigned to the project for the specific purpose of dealing with noise-related complaints. States may also choose to include noise-related incentives and/or disincentives in construction contracts and/or include language in such contracts enabling the State to shut down a project if noise-related criteria are not met or if prescribed abatement programs are not adequately implemented.

The listed techniques are best evaluated on a project-by-project, stage-by-stage basis, with the timing of public involvement meetings, newsletters, and other information-disseminating events dictated by when pertinent noise-related information is available as opposed to some arbitrary schedule, such as a meeting every 3 months.

8.1.4 Evaluating Comments and Response Process

It is important that the results of public involvement activities are adequately documented and that all construction noise related issues are addressed in a timely manner. It is equally important that the responses to comments are disseminated in a manner that enables the public to recognize how their comments were addressed. Conveying the results of the analyses or actions performed to address a construction noise related issue could occur in several ways. Response to a comment dealing with a broad issue may best be disseminated via a newsletter or published meeting minutes. If the comment pertains to an issue related to just one or two individuals, then it may be more appropriate to respond to each individual with a letter or phone call. It may also be useful to begin the next public meeting with a summary of changes made as the result of previous comments or to point out any changes or additional data that was generated as the result of previous comments.

Figure 8.9 General and specific noise concerns
(Photos #1206 & #1207)

8.1.5 Effects on Project Budget and Schedule

Many factors can affect the budget and schedule of a public involvement program and the project as a whole. The budget and schedule of a public involvement program obviously affects the overall project budget and schedule, and vice-versa. While it may be worthwhile to incorporate a substantial amount of time and resources into a noise-related public involvement program, the project's overall budget and schedule might accommodate a less ambitious program.

Input received during the public involvement program could affect (positively or negatively) both the project timetable and budget. Examples related to construction noise issues could include stakeholders' views (spurred by noise concerns) on specific construction events, timing, schedule of operations, and detour routes.

8.1.6 Other Factors

In addition to the main components of a public involvement program just presented, several other factors are worth considering.

8.1.6.1 Types and Locations of Public Outreach Venues

It is important for the location of public participation event to be consistent with the intent of the event and the type of information to be presented. Some State DOT facilities have varying sizes of meeting rooms, while others are more limited. Unless the State DOT facility is in proximity to the project area, it is probably more convenient to hold any meeting within the project area.

If the intent is to strictly present generalized construction noise data during the project design phases and solicit general comments from the public, an auditorium setting may be appropriate. However, if the intent is to discuss specifics with the public on a one-on-one basis or to conduct a workshop, then a gymnasium setting may be better. One-on-one interaction and face-to-face presentations with stakeholders may be essential in order to get the message/options across.

In addition, the means of presenting data should be considered. If data are presented on paper plans, then a gymnasium setting usually works better than an auditorium. If data are presented via projection methods using a tool such as PowerPoint, either type facility may work well, assuming an adequate size of screen is used. Larger type meeting rooms are usually best for public hearings and meetings required as part of the NEPA environmental process. During this process, noise will be just one of a variety of topics presented and discussed, and construction-related noise issues may or may not be an issue. Smaller meeting rooms usually work better for meetings with individual community groups, assuming all plans can be adequately displayed or presented and the room size comfortably accommodates the expected audience. For smaller groups, a residence within the community often provides a relaxed location for more informal types of meetings. Similarly, meetings in the field can provide important information that cannot be depicted as well in a meeting room. Such field visits are often particularly useful in giving residents an understanding of a particular construction noise issue. Such field views are usually limited to relatively small groups.

Combinations of the above venues may be appropriate. For instance, a large auditorium may be used for a general presentation of the project and construction noise related policies and procedures, followed by one-on-one question and answer sessions in a gymnasium or smaller breakout room to discuss site-specific construction noise levels and issues. A meeting may be held in a resident's home to discuss construction noise issues of specific interest to only a small group of individuals, possibly followed by a field trip to the project site.

8.1.6.2 Content and Detail of Presented Information

It is important that the content and detail of presented information be consistent with the ability of the public to understand and comprehend such information and that the information is relevant to the specific interests of the particular public to which it is disseminated. Information that is too detailed can tend to confuse and frustrate the public. Conversely, generalized information presented to people interested in receiving specific information can be perceived as an attempt to hide information or avoid an issue. In summary, know the audience. This will dictate and define many of the issues of content and detail.

8.2 Project Coordination

It is essential that consideration of construction-related noise issues occur as early as possible within the project development process. For certain projects, such considerations may not be possible until late in the final design phase. However, under certain conditions, the potential for construction-related noise effects may be recognizable earlier in the project design development. The lack of information sharing at all levels and directions can be costly and cause frustration, delays, and loss of public confidence. It is therefore critical that the project team share information among themselves, with the rest of the department, with other government agencies (federal, State, and local), with the contractors and subcontractors, with the community, and with any other stakeholders. A sense of involvement and knowledge by the interested parties tends to reduce conflict during the crucial stages of any project.

Construction-related noise coordination can occur at any stage and at the intra-agency, inter-agency, and/or public involvement level. Consideration of potential construction-related issues by project planners or metropolitan planning agencies during early project planning stages may help shape the alternatives evaluated by agency engineers or their consultants during subsequent design phases and may have a bearing on the ultimate selection of a recommended alternative. For instance, an alternative could appear very favorable from an operation and environmental standpoint but could be ruled out or substantially modified early in the project planning stages based on information related to potential construction noise issues.

Early construction-related coordination may also affect how a project is ultimately constructed. For instance, if a project is planned in the area of a facility such as an outdoor amphitheatre, park, or fairground, which has numerous summertime outdoor events, the construction staging may be modified accordingly to avoid operations during these periods or events. For projects in the vicinity of schools, it may be more appropriate to schedule project construction (or at least the noisiest activities) during the season when classes are not in session.

Construction noise-related conditions and decisions can affect not only the project schedule, but also the project costs. This can result in a project's timeframe being extended into additional construction years and have an effect on maintenance operations, particularly if such decisions affect scheduled maintenance projects in the area or normal maintenance operations such as snow removal. As such, for budgetary, operational, and scheduling reasons, it is best to identify such contributing factors as early as possible in the project development process.

As decisions related to construction-related noise issues are identified and addressed during the various project development phases, it is essential that they be documented and relayed to individuals responsible for project development activities during subsequent phases. Table 8.2 provides an example of how such considerations and decisions could be "passed on" through the project development process.

As each project will likely have its own unique coordination issues and opportunities, Table 8.2 provides merely a sample of some possible coordination interactions and supplements the material presented earlier in this chapter related to the various means of and venues for obtaining input and disseminating information related to construction noise issues.

Table 8.2 Coordination Throughout Project Development.

Project Phase	Information Obtained and/or Developed/Supplied By:							Information Passed on To:						Possible Means of Information Exchange
	Planners	Designers and/or Consultants	Construction Personnel	Maintenance Personnel	Equipment Suppliers	Local Officials	The Public	Planners	Designers and/or Consultants	Construction Personnel	Maintenance Personnel	Local Officials	The Public	
Planning	X											X	X	Planning process documents and hearings
						X	X	X					X	Public hearing and public involvement process
Preliminary Engineering and Environmental	X								X					Planning process documents
		X										X	X	Environmental documents and associated public involvement process
						X	X		X					Public meetings and/or hearings
Final Design		X											X	Public meetings
							X		X					
					X				X					Information requests for equipment noise levels
			X	X					X					Response for plan/specification review
			X	X					X					Requested review of proposed construction schedule and operations
Construction			X						X					Coordination related to design-related plans and specifications, design changes, etc.
						X	X			X				Construction-related noise complaints/issues
		X	X									X	X	Response to construction-related noise issues

9.0 CONSTRUCTION EQUIPMENT NOISE LEVELS AND RANGES

9.1 Equipment Type Inventory and Related Emission Levels

Noise levels generated by individual pieces of construction equipment and specific construction operations form the basis for the prediction of construction-related noise levels. A variety of information exists related to sound emissions related to such equipment and operations. This data transcends the period beginning in the 1970s thru 2006. This information exists for both stationary and mobile sources and for steady, intermittent, and impulse type generators of noise.

9.1.1 Stationary Equipment

Stationary equipment consists of equipment that generates noise from one general area and includes items such as pumps, generators, compressors, etc. These types of equipment operate at a constant noise level under normal operation and are classified as non-impact equipment. Other types of stationary equipment such as pile drivers, jackhammers, pavement breakers, blasting operations, etc., produce variable and sporadic noise levels and often produce impact-type noises. Impact equipment is equipment that generates impulsive noise, where impulsive noise is defined as noise of short duration (generally less than one second), high intensity, abrupt onset, rapid decay, and often rapidly changing spectral composition. For impact equipment, the noise is produced by the impact of a mass on a surface, typically repeating over time.

9.1.2 Mobile Equipment

Mobile equipment such as dozers, scrapers, graders, etc., may operate in a cyclic fashion in which a period of full power is followed by a period of reduced power. Other equipment such as compressors, although generally considered to be stationary when operating, can be readily relocated to another location for the next operation.

9.2 Sources of Information

Construction-related equipment and operation noise level data may be provided by numerous sources, including suppliers, manufacturers, agencies, organizations, etc. Some information is included in this document, and many web-based links are given for equipment manufacturers.

9.3 Specifics of Construction Equipment and Operation Noise Inventories

Details included in each specific inventory of construction equipment and operation noise emission levels are often variable in terms of how data is represented. Some inventories include ranges of noise levels while others present single numbers for each equipment type. Others provide levels for specific models of each type of construction equipment. Often, different noise descriptors are used, such as L_{Aeq}, L_{max}, L_{10}, sound power level, etc. As such, the array of data does not readily lend itself to being combined into a single table or easily compared. As such, this Handbook attempts to summarize a variety of such inventories and provide links to each, thereby providing the reader with a variety of sources from which to choose the appropriate levels for use in his or her respective analysis.

9.4 Summaries of Referenced Inventories

Included below are examples of several inventories of construction-related noise emission values. These and additional inventories are included on the companion CD-ROM.

9.4.1 RCNM Inventory

Equipment and operation noise levels in this inventory are expressed in terms of L_{max} noise levels and are accompanied by a usage factor value. They have been recently updated and are based on extensive measurements taken in conjunction with the Central Artery/Tunnel (CA/T) Project. Table 9.1 summarizes the equipment noise emissions database used by the CA/T Project. While these values represent the "default" values for use in the RCNM, user-defined equipment and corresponding noise levels can be added.

Table 9.1 RCNM Default Noise Emission Reference Levels and Usage Factors.

Equipment Description	Impact Device?	Acoustical Usage Factor (%)	Spec. 721.560 L_{max} @ 50 feet (dBA, slow)	Actual Measured L_{max} @ 50 feet (dBA, slow) (Samples Averaged)	Number of Actual Data Samples (Count)
All Other Equipment > 5 HP	No	50	85	N/A	0
Auger Drill Rig	No	20	85	84	36
Backhoe	No	40	80	78	372
Bar Bender	No	20	80	N/A	0
Blasting	Yes	N/A	94	N/A	0
Boring Jack Power Unit	No	50	80	83	1
Chain Saw	No	20	85	84	46
Clam Shovel (dropping)	Yes	20	93	87	4
Compactor (ground)	No	20	80	83	57
Compressor (air)	No	40	80	78	18
Concrete Batch Plant	No	15	83	N/A	0
Concrete Mixer Truck	No	40	85	79	40
Concrete Pump Truck	No	20	82	81	30
Concrete Saw	No	20	90	90	55
Crane	No	16	85	81	405
Dozer	No	40	85	82	55
Drill Rig Truck	No	20	84	79	22
Drum Mixer	No	50	80	80	1
Dump Truck	No	40	84	76	31
Excavator	No	40	85	81	170
Flat Bed Truck	No	40	84	74	4
Front End Loader	No	40	80	79	96
Generator	No	50	82	81	19
Generator (<25KVA, VMS Signs)	No	50	70	73	74
Gradall	No	40	85	83	70
Grader	No	40	85	N/A	0
Grapple (on backhoe)	No	40	85	87	1

Equipment Description	**Impact Device?**	**Acoustical Usage Factor (%)**	**Spec. 721.560 L_{max} @ 50 feet (dBA, slow)**	**Actual Measured L_{max} @ 50 feet (dBA, slow) (Samples Averaged)**	**Number of Actual Data Samples (Count)**
Horizontal Boring Hydraulic Jack	No	25	80	82	6
Hydra Break Ram	Yes	10	90	N/A	0
Impact Pile Driver	Yes	20	95	101	11
Jackhammer	Yes	20	85	89	133
Man Lift	No	20	85	75	23
Mounted Impact Hammer (hoe ram)	Yes	20	90	90	212
Pavement Scarifier	No	20	85	90	2
Paver	No	50	85	77	9
Pickup Truck	No	40	55	75	1
Pneumatic Tools	No	50	85	85	90
Pumps	No	50	77	81	17
Refrigerator Unit	No	100	82	73	3
Rivit Buster/Chipping Gun	Yes	20	85	79	19
Rock Drill	No	20	85	81	3
Roller	No	20	85	80	16
Sand Blasting (single nozzle)	No	20	85	96	9
Scraper	No	40	85	84	12
Sheers (on backhoe)	No	40	85	96	5
Slurry Plant	No	100	78	78	1
Slurry Trenching Machine	No	50	82	80	75
Soil Mix Drill Rig	No	50	80	N/A	0
Tractor	No	40	84	N/A	0
Vacuum Excavator (Vac-Truck)	No	40	85	85	149
Vacuum Street Sweeper	No	10	80	82	19
Ventilation Fan	No	100	85	79	13
Vibrating Hopper	No	50	85	87	1
Vibratory Concrete Mixer	No	20	80	80	1
Vibratory Pile Driver	No	20	95	101	44
Warning Horn	No	5	85	83	12
Welder/Torch	No	40	73	74	5

For each generic type of equipment listed in Table 9.1, the following information is provided:

- an indication as to whether or not the equipment is an impact device;
- the acoustical usage factor to assume for modeling purposes;
- the specification "Spec" limit for each piece of equipment expressed as an L_{max} level in dBA "slow" at a reference distance of 50 foot from the loudest side of the equipment;
- the measured "Actual" emission level at 50 feet for each piece of equipment based on hundreds of emission measurements performed on CA/T work sites; and
- the number of samples that were averaged together to compute the "Actual" emission level.

A comparison of the "Spec" emission limits against the "Actual" emission levels reveals that the Spec limits were set, in general, to realistically obtainable noise levels based on the equipment used by contractors on the CA/T Project. When measured in the field, some equipment such as pile drivers, sand blasting, demolition shears, and pumps tended to exceed their applicable emission limit. As such, these noisy devices needed to have some form of noise mitigation in place in order to comply with the Spec emission limits. Other equipment, such as clamshell shovels, concrete mixer trucks, truck-mounted drill rigs, man-lifts, chipping guns, ventilation fans, pavers, dump trucks, and flatbed trucks, easily complied. Therefore, the Spec emission limits for these devices could have been reduced somewhat further. It is recommended that the user review the RCNM User's Guide contained in Appendix A for detailed guidance regarding application of values contained in Table 9.1.

9.4.2 FHWA Special Report Inventories

Appendix A of the 1977 Handbook provides tables of construction equipment noise levels and ranges. The majority of the data were provided by the American Road Builders Association. These data were taken during a 1973 survey in which member contractors were asked to secure readings of noise exposure to operators of various types of equipment. Additionally, the contractors were asked to take readings at 50 feet from the machinery. These 50-foot peak readings are provided in Tables 9.2 through 9.8. Though the data were produced under varying conditions and degrees of expertise, the values are relatively consistent.

Table 9.2 Construction Equipment Noise Levels Based on Limited Data Samples - Cranes.

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Northwestern	80D	77	Within 15m 1958 mod
Northwestern	8	84	Within 15m 1940 mod
Northwestern	6	72	Within 15m 1965 mod
American	7260	82	Within 15m 1967 mod
American	599	76	Within 15m 1969 mod
American	5299	70	Within 15m 1972 mod
American	4210	82	Within 15m 1968 mod
Buck Eye	45C	79	Within 15m 1972 mod
Buck Eye	308	74	Within 15m 1968 mod
Buck Eye	30B	73	Within 15m 1965 mod
Buck Eye	30B	70	Within 15m 1959 mod
Link Belt	LS98	76	Within 15m 1956 mod
Manitowoc	4000	94	Within 15m 1956 mod
Grove	RF59	82	Within 15m 1973 mod
Koehr	605	76	Within 15m 1967 mod
Koehr	435	86	Within 15m 1969 mod
Koehr	405	84	Within 15m 1969 mod

Table 9.3 Construction Equipment Noise Levels Based on Limited Data Samples - Backhoes.

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Link Belt	4000	92	Within 15m 1971 mod
John Deere	609A	85	Within 15m 1971 mod
Case	680C	74	Within 15m 1973 mod
Drott	40 yr.	82	Within 15m 1971 mod
Koehr	1066	81 & 84	Within 15m 2 tested

Table 9.4 Construction Equipment Noise Levels Based on Limited Data Samples - Front Loaders.

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Caterpillar	980	84	Within 15m 1972 mod
Caterpillar	977K	79	Within 15m 1969 mod
Caterpillar	977	87	Within 15m 1971 mod
Caterpillar	977	94	Within 15m 1967 mod
Caterpillar	966C	84	Within 15m 1973 mod
Caterpillar	966C	85	Within 15m 1972 mod
Caterpillar	966	81	Within 15m 1972 mod
Caterpillar	966	77	Within 15m 1972 mod
Caterpillar	966	85	Within 15m 1966 mod
Caterpillar	955L	90	Within 15m ;1973 mod
Caterpillar	955K	79	Within 15m 1969 mod
Caterpillar	955H	94	Within 15m 1963 mod
Caterpillar	950	78 & 80	Within 15m 1972 mod
Caterpillar	950	75	Within 15m 1968 mod
Caterpillar	950	88	Within 15m 1967 mod
Caterpillar	950	86	Within 15m 1965 mod
Caterpillar	944A	80	Within 15m 1965 mod
Caterpillar	850	82	Within 15m 1968 mod
Michigan	75B	90	Within 15m 1969 mod
Michigan	475A	96	Within 15m 1967 mod
Michigan	275	85	Within 15m 1971 mod

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Michigan	125	87	Within 15m 1967 mod
Hough	65	82	Within 15m 1971 mod
Hough	60	91	Within 15m 1961 mod
Hough	400B	94	Within 15m 1961 mod
Hough	H90	86	Within 15m 1961 mod
Trojan	3000	85	Within 15m 1956 mod
Trojan	RT	82	Within 15m 1965 mod
Payloader	H50	85	Within 15m 1963 mod

Table 9.5 Construction Equipment Noise Levels Based on Limited Data Samples - Dozers.

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Caterpillar	D5	83	Within 15m 1967 mod
Caterpillar	D6	85	Within 15m 1967 mod
Caterpillar	D6	86	Within 15m 1964 mod
Caterpillar	D6	81	Within 15m 1967 mod
Caterpillar	D6B	83	Within 15m 1967 mod
Caterpillar	D6C	82	Within 15m 1962 mod
Caterpillar	D7	85	Within 15m 1956 mod
Caterpillar	D7	86	Within 15m 1969 mod
Caterpillar	D7	84	Within 15m 1969 mod
Caterpillar	D7	78	Within 15m 1970 mod
Caterpillar	D7	78	Within 15m 1972 mod
Caterpillar	D7E	86	Within 15m 1965 mod
Caterpillar	D7E	78	Within 15m 1970 mod
Caterpillar	D7E	84	Within 15m 1973 mod
Caterpillar	D7F	80	Within 15m 1972 mod
Caterpillar	D8	92	Within 15m 1954 mod
Caterpillar	D8	95	Within 15m 1968 mod
Caterpillar	D8	86	Within 15m 1972 mod
Caterpillar	D8H	88	Within 15m 1966 mod
Caterpillar	D8H	82	Within 15m 1972 mod

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Caterpillar	D9	85	Within 15m 1972 mod
Caterpillar	D9	94	Within 15m 1972 mod
Caterpillar	D9	90	Within 15m 1963 mod
Caterpillar	D9	87	Within 15m 1965 mod
Caterpillar	D9	90	Within 15m 1965 mod
Caterpillar	D9	88	Within 15m 1968 mod
Caterpillar	D9	92	Within 15m 1972 mod
Caterpillar	D9G	85	Within 15m 1965 mod
Allis Chambers	HD41	93	Within 15m 1970 mod
International	TD15	79	Within 15m 1970 mod
International	TD20	87	Within 15m 1970 mod
International	TD25	90	Within 15m 1972 mod
International	TD8	83	Within 15m 1970 mod
Case	1150	82	Within 15m 1972 mod
John Deer	350B	77	Within 15m 1971 mod
John Deer	450B	65	Within 15m 1972 mod
Terex	8230	70	Within 15m 1972 mod
Terex	8240	93	Within 15m 1969 mod
Michigan	280	85	Within 15m 1961 mod
Michigan	280	90	Within 15m 1962 mod
Caterpillar	824	90	Within 15m 1968 mod

Table 9.6 Construction Equipment Noise Levels Based on Limited Data Samples - Graders.

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Caterpillar	16	91	Within 15m 1969 mod
Caterpillar	16	86	Within 15m 1968 mod
Caterpillar	140	83	Within 15m 1970 mod
Caterpillar	14E	84	Within 15m 1972 mod
Caterpillar	14E	85	Within 15m 1971 mod
Caterpillar	14C	85	Within 15m 1971 mod
Caterpillar	14B	84	Within 15m 1967 mod

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Caterpillar	12F	82	Within 15m 1961-72 mod
Caterpillar	12F	72-92	Within 15m 1961-72 mod
Caterpillar	12E	81.3	Within 15m 1959-67 mod
Caterpillar	12E	80-83	Within 15m 1959-67 mod
Caterpillar	12	84.7	Within 15m 1960-67 mod
Caterpillar	12	82-88	Within 15m 1960-67 mod
Gallon	T500	84	Within 15m 1964 mod
Allis Chambers		87	Within 15m 1964 mod

Table 9.7 Construction Equipment Noise Levels Based on Limited Data Samples - Scrapers.

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Caterpillar	660	92	Within 15m
Caterpillar	641B	85	Within 15m 1972 mod
Caterpillar	641B	86	Within 15m 1972 mod
Caterpillar	641	80 & 84	Within 15m 1972 mod
Caterpillar	641	83 & 89	Within 15m 1965 mod
Caterpillar	637	87	Within 15m 1971 mod
Caterpillar	633	87	Within 15m 1972 mod
Caterpillar	631C	89	Within 15m 1973 mod
Caterpillar	631C	83	Within 15m 1972 mod
Caterpillar	631B	94	Within 15m 1969 mod
Caterpillar	631B	84-87	Within 15m 1968 mod
Caterpillar		85 avg.	Within 15m 1968 mod
Caterpillar	621	90	Within 15m 1970 mod
Caterpillar	621	86	Within 15m 1967 mod
Caterpillar	613	76	Within 15m 1972 mod
Terex	TS24	87	Within 15m 1972 mod
Terex	TS24	84-91	
Terex	TS24	82	Within 15m 1971 mod
Terex	TS24	81-83	Within 15m 1971 mod
Terex	TS24	94	Within 15m 1966 mod

Manufacturer	Type or Model	Peak Noise Level (dBA)	Remarks
Terex	TS24	92-98	Within 15m 1966 mod
Terex	TS24	94.7	Within 15m 1963 mod
Terex	TS24	94-95	Within 15m 1963 mod
Terex	TS14	82	Within 15m 1969 mod
Terex	S35E	84	Within 15m 1971 mod

Table 9.8 Noise Levels of Standard Compressors.

Manufacturer	Model	Silenced or Standard	Type Eng.	Type Comp.	Test Avg. Cond. (cfm.psi)	Avg. Cond. Noise Lev. (cfm.psi) (dBA) at 7m*
Atlas	ST-48	Standard	Diesel	Reciprocal	160,100	83.6
Atlas	ST-95	Standard	Diesel	Reciprocal	330,105	80.2
Atlas	VSS-170Dd	Silenced	Diesel	Reciprocal	170,850	70.2
Atlas	VT-85M	Standard	Gas	Reciprocal	85,100	81.4
Atlas	VS-85Dd	Silenced	Gas	Reciprocal	85,100	75.5
Atlas	VSS-125Dd	Silenced	Diesel	Reciprocal	125,100	70.1
Atlas	STS-35Dd	Silenced	Diesel	Reciprocal	125,100	73.5
Atlas	VSS-170Dd	Silenced	Diesel	Reciprocal	170,100	
Gardner-Denver	SPWDA/2	Silenced	Diesel	Rotary-Screw	1200,000	73.3
Gardner-Denver	SPQDA/2	Silenced	Diesel	Rotary-Screw	750,000	78.2
Gardner-Denver	SPHGC	Silenced	Gas	Rotary-Screw	185,000	77.1
Ingersoll-Rand	DXL 1200	Standard	Diesel	Rotary-Screw	1200,125	92.6
Ingersoll-Rand	DXL 1200 (doors open)	Standard	Diesel	Rotary-Screw	1200,125	
Ingersoll-Rand	DXL 900S	Silenced	Diesel	Rotary-Screw	900,125	76.0
Ingersoll-Rand	DXL 900S	Silenced	Diesel	Rotary-Screw	900,125	75.1
Ingersoll-Rand	DXLCU1050	Standard	Diesel	Rotary-Screw	1050,125	90.2
Ingersoll-Rand	DXL 900S	Silenced	Diesel	Rotary-Screw	900,125	75.3
Ingersoll-Rand	DXL 900S	Silenced	Diesel	Rotary-Screw	900,125	75.0
Ingersoll-Rand	DXL 900	Standard	Diesel	Rotary-Screw	900,125	89.9
Ingersoll-Rand	DXL 750	Standard	Diesel	Rotary-Screw	750,125	87.7
Jaeger	A	Standard	Gas	Rotary-Screw	175,100	88.2
Jaeger	A(doors	Standard	Gas	Rotary-	175,100	

Manufacturer	Model	Silenced or Standard	Type Eng.	Type Comp.	Test Avg. Cond. (cfm.psi)	Avg. Cond. Noise Lev. (cfm.psi) (dBA) at 7m*
	open)			Screw		
Jaeger	E	Standard	Gas	Vane	85,100	81.5
Jaeger	E(doors open)	Standard	Gas	Vane	85,100	
Worthington	60 G/2Qt	Silenced	Gas	Vane	160,100	74.2
Worthington	750-QTEX	Silenced	Diesel	Rotary-Screw	750,100	74.7

*Data taken from EPA Report - EPA 550/9-76-004.

9.4.3 FTA Noise and Vibration Assessment Procedure

Chapter 12 of the FTA Transit Noise and Vibration Guidance Handbook discusses construction noise evaluation methodology and contains the noise emission levels for construction equipment displayed in Table 9.9.

Table 9.9 FTA Construction Equipment Noise Emission Levels.

Equipment	Typical Noise Level (dBA) 50 ft from Source*
Air Compressor	81
Backhoe	80
Ballast Equalizer	82
Ballast Tamper	83
Compactor	82
Concrete Mixer	85
Concrete Pump	82
Concrete Vibrator	76
Crane Derrick	88
Crane Mobile	83
Dozer	85
Generator	81
Grader	85
Impact Wrench	85
Jack Hammer	88
Loader	85
Paver	89
Pile Driver (Impact)	101
Pile Driver (Sonic)	96
Pneumatic Tool	85
Pump	76
Rail Saw	90
Rock Drill	98
Roller	74
Saw	76
Scarifier	83
Scraper	89
Shovel	82
Spike Driver	77
Tie Cutter	84

Equipment	Typical Noise Level (dBA) 50 ft from Source*
Tie Handler	80
Tie Inserter	85
Truck	88

*Table based on EPA Report, measured data from railroad construction equipment taken during Northeast Corridor improvement project and other measured data.

9.5 Links to Equipment Manufacturers

Table 9.10 contains web-based links to manufacturers of construction equipment. While few of these links contain noise-related data associated with the equipment, they provide descriptions and/or specifications related to the equipment, as well as sources for possibly obtaining additional information related to the equipment. Information in this table is by no means all-inclusive and does not represent any type of endorsement of the manufacturers, suppliers, or equipment. Users are hereby advised that the referenced websites may have certain restrictions, copyrights, etc., associated with any use of data contained therein.

Table 9.10 Equipment Manufacturers and Websites.

Equipment	Manufacturer	Website Address
Arrow Boards		
	North Star	http://northstar-traffic.com/index.cfm?SC=14&PT=1
	Trafcom	http://www.trafcon.com
	Allmand	http://www.allmand.com/MB%20AB%20page.htm
Articulated Trucks		
	Case	http://www.casece.com/products/products.asp?RL=NAE&id=196
	Hitachi	http://www.hitachi-c-m.com/global/products/articulate/index.html
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=182b2104d7a1ce2c68b57b49f8c1436c&nav=prod#nb_0fb692066603522ee229a7ff28293d18
	Caterpillar	http://www.cat.com/cda/layout?m=37840&x=7
	Volvo	http://www.volvo.com/constructionequipment/na/en-us/products/articulatedhaulers/
Asphalt Saws		
	Allied	http://www.alliedcp.com/products/rotocut.asp
Augers – See Drills / Augers		
Backhoes – See Loaders/Backhoes		
Boring Equipment – See Pile Drivers/Boring Equipment		
Compaction Equipment		
	Allied	http://www.alliedcp.com/products/compactor.asp
Compressors		

Equipment	Manufacturer	Website Address
	Sullair	http://www.sullair.com/corp/details/0,10294,CLI1_DIV61_ETI5714,00.html
	Compair	http://www.compair.com/Products/Portable_Compressors.aspx
Concrete and Asphalt Batch/Mixing Plants and Equipment		
	Con-E-Co	http://www.con-e-co.com/products.cfm
	Terex	http://www.terex.com/main.php?obj=prod&action=VIEW&id=a253f234f9c3bd69195320d1fe6e1cd9&nav=prod&cid=7713bf85ccb5a97458457e944ca4ed76
	Gunter &	http://www.guntert.com/concrete_mobilebatching.asp
	Rex Con	http://www.rexcon.com/products.html
Concrete Breakers/ Hydraulic Hammers/Hydraulic Breakers		
	Drillman	http://www.drillmanindia.com/concrete-breaker.html
	Hydro Khan	http:/www.sangi.co.kr/english/e_product1_2.php
	Stanley	http://www.stanley-hydraulic-tools.com/Hand%20Held/NoAmbreakers.htm
	Lynx	http://www.stanley-hydraulic-tools.com/Lynx/breakers.htm
Concrete Chain Saws		
	Lynx	http://www.stanley-hydraulic-tools.com/Lynx/concrete-saws.htm
Concrete Core Drilling Machines		
	Multiquip	http://www.multiquip.com/multiquip/318_ENU_HTML.htm
Concrete Cutters		
	Vermeer	http://www.vermeermfg.com/vcom/TrenchingEquipment/Line.jsp?PrdlnID=3618
Concrete/Material Pumps		
	Multiquip	http://www.multiquip.com/multiquip/309_ENU_HTML.htm
	Reed	http://www.reedpumps.com/
Concrete Mixer Trucks		
	Oshkosh	http://www.oshkoshtruck.com/concrete/products~overview~home.cfm
	London	http://www.lmi.ca/mixers.cfm
	Terex/Advance	http://www.advancemixer.com/trucks.asp
Concrete Saws		
	Multiquip	http://www.multiquip.com/multiquip/315_ENU_HTML.htm
	Diamond Core Cut	http://www.diamondproducts.com/dp_home.htm
Concrete Screeds		
	Multiquip	http://www.multiquip.com/multiquip/317_ENU_HTML.htm

Equipment	Manufacturer	Website Address
Concrete Vibrators		
	Multiquip	http://www.multiquip.com/multiquip/313_ENU_HTML.htm
	Sullair	http://www.sullair.com/corp/details/0,10294,CLI1_DIV61_ETI5722,00.html
Cranes		
	Malcolm Drilling	www.malcolmdrilling.com
	Link-Belt	http://www.linkbelt.com/lit/products/frameproducthome.htm
	Casagrande	http://www.casagrandegroup.com/home_fond.php
	Liebherr	http://www.liebherr.com/em/en/35381.asp
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=487c16c8ff145d0843f57512eafb8592&nav=prod
Crawler Tractors – See Dozers/Crawler Tractors		
Crushing and Screening Equipment		
	Cedarapids	http://www.cedarapids.com/crushscr.htm
	Hitachi	http://www.hitachi-c-m.com/global/products/crusher/index.html
	Komatsu	http://www.komatsu.com/ce/products/mobile_crushers.html
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=e75ed9c85681b27ffcfe5cadbd68c04e&nav=prod
Crushers/Pulverizers		
	Hydro Khan	http://www.sangi.co.kr/english/e_product3.php
Cutoff Saws		
	Multiquip	http://www.multiquip.com/multiquip/309_ENU_HTML.htm
	Lynx	http://www.stanley-hydraulic-tools.com/Lynx/cutoff%20saw.htm
Dozers/CrawlerTractors		
	John Deere	http://www.deere.com/en_US/cfd/construction/deere_const/crawlers/deere_dozer_selection.html
	Caterpillar	http://www.cat.com/cda/layout?m=37840&x=7
	Case	http://www.casece.com/products/products.asp?RL=NAE&id=2
	Komatsu	http://www.komatsu.com/ce/products/crawler_dozers.html
Dewatering Pumps		
	Multiquip	http://www.multiquip.com/multiquip/371_ENU_HTML.htm
Drills / Augers		
	Malcolm Drilling	www.malcolmdrilling.com
	Casagrande	www.casagrandegroup.com/home_fond.php
	Soilmec	http://www.soilmec.com/_vti_g1_techno.aspx?rpstry=4_

Equipment	Manufacturer	Website Address
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=702f2c2ab1d75e021729f249258879f4&nav=prod#nb_cd8eeb0c300ecd6c7df8a7462718172d
Excavators		
	Hitachi	http://www.hitachi-c-m.com/global/products/excavator/index.html
	Caterpiller	http://www.cat.com/cda/layout?m=37840&x=7
	Volvo	http://www.volvo.com/constructionequipment/na/en-us/products/compactexcavators/
		http://www.volvo.com/constructionequipment/na/en-us/products/wheeledexcavators/
		http://www.volvo.com/constructionequipment/na/en-us/products/crawlerexcavators/
	John Deere	http://www.deere.com/en_US/cfd/construction/deere_const/excavators/deere_excavator_selection.html
	Liebherr	http://www.liebherr.com/em/en/18891.asp
	Soilmec	http://www.soilmec.com/_vti_g1_t02.aspx?rpstry=29_
	Gehl	http://www.gehl.com/const/prod_sl.html
	Case	http://www.casece.com/products/products.asp?RL=NAE&id=216
	Komatsu	http://www.komatsu.com/ce/products/crawler_excavators.html
		http://www.komatsu.com/ce/products/wheel_excavators.html
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=477c69a0ac11ed40efe034eb1420b8c6&nav=prod
	Link-Belt	http://www.lbxco.com/lx_series.asp
	Gradall	http://www.gradall.com/
	Badger Daylighting	http://www.badgerinc.com/
Fork Lifts – See Lifts / Variable Reach Fork Lifts/ Material Handlers		
Generators		
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=6cde2dee72c250aafbd68c5b8c8d028b&nav=prod
	Multiquip	http://www.multiquip.com/multiquip/212_ENU_HTML.htm
	Sullair	http://www.sullair.com/corp/details/0,10294,CLI1_DIV61_ETI5714,00.html
	Baldor	http://www.baldor.com/products/generators/ts.asp
Graders		
	Case	http://www.casece.com/products/products.asp?RL=NAE&id=190
	Volvo	http://www.volvo.com/constructionequipment/na/en-us/products/MotorGraders/

Equipment	Manufacturer	Website Address
	Komatsu	http://www.komatsu.com/ce/products/motor_graders.html
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=b71fa964f478a2243ebbbbafa04bf814&nav=prod
Hand Compaction Equipment		
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=4c93fdc86b1c7733c1564fc8c41ee691&nav=prod#nb_cbcf35494fa399b7350f8edf5bc27373
	Multiquip	http://www.multiquip.com/multiquip/56_ENU_HTML.htm
Hydraulic Hammers/Hydraulic Breakers – See Concrete Breakers/ Hydraulic Hammers/Hydraulic Breakers		
Jackhammers – See Rock Drilling Equipment/Jackhammers		
Lifts / Variable Reach Fork Lifts/ Material Handlers		
	Genie Lift	www.genielift.com
	Sky Track	www.kirby-smith.com/
	Ingersol-Rand	www.ingersollrand.com
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=6d18d9a15fdb6da73f44a893c21c0fb4&nav=prod
	Roadtec	http://www.roadtec.com/products/mtv/default.htm
Light Towers		
	Baldor	http://www.baldor.com/products/generators/mlt.asp
	Multiquip	http://www.multiquip.com/multiquip/293_ENU_HTML.htm
	Allmand	http://www.allmand.com/Night%20Lite%20Pro%20page.htm
Loaders/Backhoes		
	Case	http://www.casece.com/products/products.asp?RL=NAE&id=54
	Caterpillar	http://www.cat.com/cda/layout?m=37840&x=7
	Volvo	http://www.volvo.com/constructionequipment/na/en-us/products/backhoeloaders/
	John Deere	http://www.deere.com/en_US/cfd/construction/deere_const/backhoes/deere_backhoe_selection.html
	Komatsu	http://www.komatsu.com/ce/products/backhoe_loaders.html
Material Handlers – See Lifts / Variable Reach Fork Lifts/ Material Handlers		
Milling Machines		
	Wirtgen	https://www.wirtgenamerica.com/noflash.html
Mining Trucks – See Rigid Dump Trucks/Mining Trucks		
Pans – See Scrapers/Pans		
Pavers/Paving Equipment		

Equipment	Manufacturer	Website Address
	Caterpillar/ Barber Greene	http://www.cat.com/cda/layout?m=37840&x=7
	Rosco	http://www.leeboy.com/rosco/
	Bomag	http://www.bomag.com/americas/index.aspx?&Lang=478
	Gehl	http://www.gehl.com/const/prodpg_ap.html
	Leeboy	http://www.leeboy.com/leeboy/
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=7713bf85ccb5a97458457e944ca4ed76&nav=prod#nb_70af03a93dfc933f83a7e6afdc2dc833
	Ingersoll-Rand	http://www.road-development.irco.com/Default.aspx?MenuItemID=12
	Vogele	http://www.vogeleamerica.com/noflash.html
	GOMACO	http://www.gomaco.com/index.html
	Roadtec	http://www.roadtec.com/products/asphalt_pavers/default.htm
Pile Drivers/Boring Equipment		
	Soilmec	http://www.soilmec.com/_vti_g1_t09.aspx?rpstry=29_
	Leffer	http://www.leffer.com/hme.html
	Bauer	http://www.bauer.de/en/maschinenbau/produkte/drehbohrgeraete/bg_reihe/usbg15h.htm
Pipelayers/Trenchers		
	Liebherr	http://www.liebherr.com/em/en/18908.asp
	Caterpillar	http://www.cat.com/cda/layout?m=37840&x=7
	Case	http://www.casece.com/products/products.asp?RL=NAE&id=28&archived=1
	Vermeer	http://www.vermeermfg.com/vcom/TrenchingEquipment/trenching-equipment.htm
	Ditchwitch	http://www.ditchwitch.com/dwcom/Product/ProductView/115
	Eagle	http://www.guntert.com/trenchers_home.asp
Profilers – See Roadway Planers/Profilers		
Rammers		
	Multiquip	http://www.multiquip.com/multiquip/56_ENU_HTML.htm
Rebar Benders/Cutters		
	Multiquip	http://www.multiquip.com/multiquip/1316_ENU_HTML.htm
Recyclers – See Stabilizers/Recyclers		
Rigid Dump Trucks/Mining Trucks		
	Hitachi	http://www.hitachi-c-m.com/global/products/rigid/index.html
	Caterpillar	http://www.cat.com/cda/layout?m=37840&x=7
	Liebherr	http://www.liebherr.com/em/en/18898.asp
	Komatsu	http://www.komatsu.com/ce/products/dump_trucks.html

Equipment	Manufacturer	Website Address
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=182b2104d7a1ce2c68b57b49f8c1436c&nav=prod#nb_d97e204d5e73962e595735d68fad8ae3
Roadway Planers/Profilers		
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=7713bf85ccb5a97458457e944ca4ed76&nav=prod#nb_c9b8a083c7d9ebb936cd1e4f642eba59
	Roadtec	http://www.roadtec.com/products/cold_planers/default.htm
Rock Drilling Equipment/Jackhammers		
	Drillman	http://www.drillmanindia.com/rock-drilling-machine.html
	Whaker	http://www.wackergroup.com/webapp/wcs/stores/servlet/ViewAllModels?storeId=10051&prodgrpId=10070&langId=-1
	Sullair	http://www.sullair.com/corp/details/0,10294,CLI1_DIV61_ETI5721,00.html
	Allied	http://www.alliedcp.com/products/hammers.asp
Rollers – See Tampers/Rollers		
Scrapers/Pans		
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=e3959eefdc65adcc4e0e616b833694b1&nav=prod
Screening Equipment – See Crushing and Screening Equipment		
Slabbuster		
	Allied	http://www.alliedcp.com/products/slabbuster.asp
Slip Form Pavers		
	Huron	http://www.huronmanufacturing.com/
	Guntert & Zimmerman	http://www.guntert.com/concreteSlipformPavers.asp
Stabilizers/Recyclers		
	Bomag	http://www.bomag.com/americas/index.aspx?&Lang=478
	Komatsu	http://www.komatsu.com/ce/products/mobile_crushers.html
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=7713bf85ccb5a97458457e944ca4ed76&nav=prod#nb_d920dd8094cc1af5cb5d82359f8f227b
	Wirtgen	https://www.wirtgenamerica.com/noflash.html
	Roadtec	http://www.roadtec.com/products/cir/default.htm
Sweepers		
	Elgin	http://www.elginsweeper.com/index.asp
	Johnston	http://www.johnstonsweepers.com/
Tampers/ Rollers		

Equipment	Manufacturer	Website Address
	Bomag	http://www.bomag.com/americas/index.aspx?&Lang=478
	Komatsu	http://www.komatsu.com/ce/products/vibratory_rollers.html
	Whaker	http://www.wackergroup.com/webapp/wcs/stores/servlet/ViewAllModels?storeId=10051&prodgrpId=10070&langId=-1
	Lynx	http://www.stanley-hydraulic-tools.com/Lynx/tamper.htm
	Multiquip	http://www.multiquip.com/multiquip/181_ENU_HTML.htm
	Ingersoll-Rand	http://www.road-development.irco.com/Default.aspx?MenuItemID=15
Trenchers – See Pipelayers/Trenchers		
Trucks – See Articulated Trucks, Concrete Mixer Trucks, Rigid Dump Trucks/Mining Trucks		
Vacuum Units		
	Advanced Recycling Systems	www.arsrecycling.com/
	Vacmasters	http://www.vacmasters.com/airsystm.htm
	Vector	http://www.vector-vacuums.com/
Variable Message Signs		
	Allmand	http://www.allmand.com/MB%20only%20page.htm
	North Star	http://northstar-traffic.com/index.cfm?SC=13&PT=1
	Trafcom	http://www.trafcon.com
	Daktronics	http://www.daktronics.com/vms_prod/dak_vms_products.cfm
Vibratory Rammers		
	Whaker	http://www.wackergroup.com/webapp/wcs/stores/servlet/ViewAllModels?storeId=10051&prodgrpId=10070&langId=-1
Welders/Welding Equipment		
	Airgas	www.airgas.com
	Multiquip	http://www.multiquip.com/multiquip/408_ENU_HTML.htm
	Miller	http://www.millerwelds.com/products/
	Lincoln	http://www.mylincolnelectric.com/Catalog/equipmentseries.asp?browse=101|400|
Wheel Loaders		
	Hitachi	http://www.hitachi-c-m.com/global/products/loader/index.html
	Case	http://www.casece.com/products/products.asp?RL=NAE&id=30
	Caterpillar	http://www.cat.com/cda/layout?m=37840&x=7
	Volvo	http://www.volvo.com/constructionequipment/na/en-us/products/wheelloaders/
	Terex	http://www.terex.com/main.php?obj=category&action=BROWSE&cid=ad8a2ae2f52f113b6d143bfd7765b165&nav=prod

Equipment	Manufacturer	Website Address
	Komatsu	http://www.komatsu.com/ce/products/wheel_loaders.html
	TCM	http://www.tcmglobal.net/products/main02.html

10.0 CONSTRUCTION NOISE CONTACTS, POLICIES, AND REFERENCE MATERIAL

10.1 Introduction

This chapter is comprised of an Excel-based construction noise contact and policy database containing the following information:

- US State, Canadian Province, or other government agency;
- Primary contact person;
- The latest State, Province, or agency policy related to noise;
- Information related to where construction noise is addressed within the policy;
- Any appropriate website address related to the policy and/or its construction noise content; and
- Related information associated with noise available within or through the State, Province, or agency.

All policies and documents are available for download from the companion CD-ROM version of this Handbook. Websites may be directly reached via clicking on the appropriate link within the database.

10.2 Database

The database is contained in Table 10.1 below. The companion CD-ROM version of this table has been developed in Microsoft Excel format so as to be a self-contained unit: As such, all linked .pdf files are contained within the CD-ROM itself. Thus, the database can be extracted from the CD-ROM and used and updated based on the user's needs, with all existing links remaining intact.

Be aware that contact information listed for individuals is current for the release date of this document (August 2006). For updated information, contact the specific agency or access the Transportation Research Board (TRB) Committee ADC40 membership list for U.S. States (www.adc40.org, listed under Highway Noise Subcommittee – State Transportation Agency Members).

Table 10.1 Contacts, Policies, and Reference Material.

State / Province / Agency	Contact	Noise Policy pdf - Policy Date	Construction Noise Discussed in:	Noise Policy Web Site Link	Related Information
Alabama	Daniel Turman Environmental Technical Section Alabama Department of Transportation 1409 Coliseum Blvd. Montgomery, Alabama 36130-3050 Phone 334-242-6828 FAX 334-269-0826 Email turmand@dot.state.al.us	Alabama.pdf N/A	Section IV.B.8	N/A	
Alaska	Bill Ballard State Environmental Coordinator Alaska Department of Transportation 3132 Channel Drive Juneau, Alaska 99801-7898 Phone 907-465-6954 FAX 907-465-5240 Email bill_ballard@dot.state.ak.us	Alaska.pdf March 1996	Page 5	www.dot.state.ak.us/stwddes/dcsenviron/assets/pdf/procedures/noiseabate0396.pdf	Environmental Reevaluation Checklist
Arizona	Fred Garcia Environmental Planning Section Arizona Department of Transportation 205 South 17th Avenue Room 213 Mail Drop 619E Phoenix, Arizona 85007-3212 Phone 602-712-8635 FAX 602-712-3352 Email fgarcia@azdot.gov	Arizona.pdf December 2005	N/A	www.azdot.gov/Highways/EEG/documents/noise_guidance.asp	
Arkansas	Mike Webb Environmental Division Arkansas Department of Transportation Post Office Box 2261 Little Rock, Arkansas 72203 Phone 501-569-2281 FAX 501-569-2009 Email mike.webb@arkansashighways.com	Arkansas.pdf	N/A	N/A	
Australia	Roads and Traffic Authority	Australia.pdf	Section 9	http://www.rta.nsw.gov.au/environment/noise/index.html	Australia EPA Construction Noise Manual

Table 10.1 (cont.) Contacts, Policies, and Reference Material

State / Province / Agency	Contact	Noise Policy pdf - Policy Date	Construction Noise Discussed in:	Noise Policy Web Site Link	Related Information
British Cloumbia	Chris Zacharias British Columbia Ministry of Transportation and Highways Engineering Branch, Environmental Management Section PO Box 9850 Stn Prov Gov't Victoria, British Columbia V8W 9T5 Phone 250-387-1264 FAX 250-387-3756 Email Chris.Zacharias@gems4.gov.bc.ca	British Columbia.pdf November 1993	N/A	http://www.gov.bc.ca/bvprd/bc/search.do?action=searchresult&nh=10&navId=NAV_ID_-8394&rq=0&qp=&qt=noise+policy&inthe=86400&amo=1&ady=1&ayr=2001&bmo=1&bdy=1&byr=2002&lk=1&rf=0&st=1	Workers' Compensation Board of BC - Construction Noise Report Sea to Sky Highway Project
California	Bruce Rymer CALTRANS Division of Environmental Analysis P.O. Box 942874 1120 N Street, M.S. 27 Sacramento, California 94274-0001 Phone 916-653-6073 FAX 916-653-5927 Email bruce_rymer@dot.ca.gov	California.pdf July 1999	N/A	http://www.dot.ca.gov/hq/oppd/pdpm/chap_htm/chapt30/chapt30.htm	Highway Design Manual - Highway Traffic Noise Abatement Draft PWRP 2025 Plan and EIR - Construction Noise Chapter Santa Rosa Transit Oriented Project - Construction Noise Analysis Ventura Construction Noise Threshold Criteria and Control Measures
Colorado	Bob Mero Colorado Department of Transportation Office of Environmental Services 4201 East Arkansas Avenue, EPB-400 Denver, Colorado 80222-3400 Phone 303-757-9016 FAX 303-757-9445 Email bob.mero@dot.state.co.us	Colorado.pdf December 2002	Section 6	http://www.dot.state.co.us/environmental/CulturalResources/Noise.asp	
Connecticut	Desmond P. Dickey Office of Environmental Planning Connecticut Department of Transportation Post Office Box 317546 2800 Berlin Turnpike Newington, Connecticut 06131-7546 Phone 860-594-2945 FAX 860-594-3028 Email d.paul.dickey@po.state.ct.us	Connecticut.pdf July 1998	Page 15	N/A	Guide to Understanding Traffic Noise General Conditions - Environmental Compliance
Delaware	Edwin Kuipers Delaware Department of Transportation Post Office Box 778 Dover, Delaware 19903 Phone 302-760-2515 FAX 302-739-8282 Email ekuipers@mail.dot.state.de.us	Delaware.pdf N/A	Section X	N/A	

Table 10.1 (cont.) Contacts, Policies, and Reference Material

State / Province / Agency	Contact	Noise Policy pdf - Policy Date	Construction Noise Discussed in:	Noise Policy Web Site Link	Related Information
District of Columbia	Maurice Keys District of Columbia Dept. of Public Works 2000 14th Street, NW Washington, DC 20009 Phone 202-671-2740 FAX 202-671-0617 Email maurice.keys@dc.gov	DC.pdf DC Table 1.pdf N/A	Page 4	N/A	
Environmental Protection Agency	Environmental Protection Agency Ariel Rios Building 1200 Pennsylvania Avenue, N.W. Washington, DC 20460 Phone 202-272-0167				Construction Noise Control Technology Initiatives Effects of Noise on Wildlife and Other Animals 1 Effects of Noise on Wildlife and Other Animals 2 EPA Levels Document Condensed Version of Levels Document Noise Guide for Local Government Noise Emission Standards for Construction Equipment
Europe	Various European States	Europe.pdf May 2000			
Federal Highway Administration	Mark Ferroni Chris Corbisier Federal Highway Administration 400 7th Street, SW Washington, DC Phones 202-366-3233 202-366-1473 FAX Emails mark.ferroni@dot.gov chris.corbisier@dot.gov			Download information on the FHWA TNM Model at the below website: http://www.trafficnoisemodel.org	Original 1977 Construction Noise Handbook 1977 Symposium on Highway Construction Noise 1984 Technical Advisory on Highway Construction Noise 1995 Noise Policy and Guidance Measurement of Highway Related Noise FHWA TNM Look-Up Tables
Federal Railroad Administration	James Pegues 1120 Vermont Ave Washington, DC 20005 Phone 202-493-6245 FAX 202-493-6230 Email james.pegues@fra.dot.gov	FRA.pdf October 2005	Chapter 10	Download the entire guidance manual at: http://www.fra.dot.gov/us/content/253	High Speed Rail Prediction Excel Spreadsheet
Federal Transit Administration	Joseph Ossi, Jr., Office of Planning and Environment, TPL-30 400 Seventh St., SW, Room 9413 Washington, DC 20590 Phone 202-366-1612 FAX 202-366-2478 Email joseph.ossi@fta.dot.gov	FTA.pdf April 1995	FTA Guidance Manual - Chapter 12	Download the entire Guidance Manual for the FTA Transit Noise and Vibration Assessment procedure plus other FTA http://www.fta.dot.gov/transit_data_info/reports_publications/publications/environment/4805_5144_ENG_HTM	Description of the FTA Spreadsheet FTA Spreadsheet - Excel Version FTA Spreadsheet - Quattro Pro 6 Version FTA Spreadsheet - Lotus 123 Version OR Download Speadsheets from the below link: http://www.fta.dot.gov/transit_data_info/reports_publications/publications/environment/1165_5953_ENG_HTML.htm

Table 10.1 (cont.) Contacts, Policies, and Reference Material

State / Province / Agency	Contact	Noise Policy pdf - Policy Date	Construction Noise Discussed in:	Noise Policy Web Site Link	Related Information
Florida	Mariano Berrios Florida Department of Transportation 605 Suwannee Street, MS-37 Tallahassee, Florida 32399-0450 Phone 850-414-5250 FAX 850-414-4443 Email mariano.berrios@dot.state.fl.us	Florida.pdf October 2003	Section 17-4.7.5	http://www.dot.state.fl.us/emo/pubs/pdeman/pdeman.htm FDOT Noise Abatement Policy Letter: See also this link for FDOT guidance for construction project personnel in dealing with construction noise issues	Pile Driver Acoustical Blanket Evaluatiuon (Bernard Kinney)
Georgia	Greg Hood Georgia Department of Transportation 3993 Aviation Circle Atlanta, GA 30336 Phone 404-699-4404 FAX 404-699-4440 Email greg.hood@dot.state.ga.us	Georgia.pdf April 2005	N/A	http://www.dot.state.ga.us/topps/pre/env/4415-11.htm	
Hawaii	Steve Ege Hawaii Department of Transportation Highway Division Materials, Testing & Research Branch 2530 Likelike Highway Honolulu, Hawaii 96819 Phone 808-832-3405x230 FAX 808-832-3407 Email steve.ege@hawaii.gov Leslie Imada Hawaii Department of Transportation Highway Division Materials, Testing & Research Branch 2530 Likelike Highway Honolulu, Hawaii 96819 Phone 808-832-3405x228 FAX 808-832-3407 Email leslie.imada@hawaii.gov	Hawaii.pdf N/A	N/A	N/A	
Hong Kong	The Government of the Hong Kong Environmental Protection Department Hong Kong, China	Hong Kong 1.pdf Hong Kong 2.pdf Hong Kong 3.pdf Hong Kong 4.pdf July 2001/Feb 1998	Legislation Example of actual construction noise permit Code of Practice for Construction Noise Guidelines for Construction Sites Quality Powered Mechanical Equipment	Noise Control Ordinance Guide at: http://www.epd.gov.hk/epd/english/environmentinhk/noise/guide_ref/guide_nco.html Quality Powered Mechanical Equipment at: http://www.epd.gov.hk/cgi-bin/npg/qpme/background.pl?lang=eng	For Noise Overview see link below: http://www.epd.gov.hk/epd/english/environmentinhk/noise/noise_maincontent.html For numerous noise guidelines go to: http://www.epd.gov.hk/epd/english/environmentinhk/noise/guide_ref/noise_guidelines.html To see actual construction noise contracts currently in place go to: http://www.epd.gov.hk/cgi-bin/npg/search.pl?lang=eng&par=Yes&page=1&st=sim&type=gw&district=0 Legislation for the Management of Noise can be found at: http://www.epd.gov.hk/epd/misc/ehk05/english/noise/07.html

Table 10.1 (cont.) Contacts, Policies, and Reference Material

State / Province / Agency	Contact	Noise Policy pdf - Policy Date	Construction Noise Discussed in:	Noise Policy Web Site Link	Related Information
Idaho	Roy Jost Idaho Department of Transportation Environmental Section 3311 West State Street Boise, Idaho 83707-1129 Phone 208-334-8477 FAX 208-334-8025 Email rjost@itd.state.id.us	Idaho.pdf	Exhibit 1300-7	http://itd.idaho.gov/manuals/Online_Manuals/Environmental/HTML%20Files/1300.htm	
Illinois	Kathy Ames Noise Specialist Illinois Department of Transportation 2300 South Dirksen Parkway, Room 330 Springfield, Illinois 62764 Phone 217-785-0203 FAX 217-524-9356 Email amesks@nt.dot.state.il.us	Illinois.pdf March 2000	Pages 7 and 8	See also: http://www.dot.il.gov/desenv/noise/part1.html	
Indiana	Janice Osadczuk, Chief Division of Environment, Planning and Engineering Indiana Department of Transportation 100 N. Senate Avenue, Room N848 Indianapolis, Indiana 46204-2249 Phone 317-232-5468 FAX 317-232-5478 Email josadczuk@indot.state.in.us	Indiana.pdf October 1997	Paragraph F	http://www.in.gov/dot/programs/environment/noise.html	
Iowa	Ron Ridnour Office of Location and Environment Iowa Department of Transportation 800 Lincoln Way Ames, Iowa 50010 Phone 515-239-1613 FAX 515-239-1726 Email ronald.ridnour@dot.state.ia.us	Iowa.pdf	Paragraph III.C	N/A	
Japan	Ministry of the Environment Government Godochosha No. 5, Kasumigaseki 1-2-2, Chiyoda-ku, Tokyo 100-8975, Japan. Tel: +81-(0)3-3581-3351 Email MOE@env.go.jp			http://www.env.go.jp/en/air/noise/noise.html	

Table 10.1 (cont.) Contacts, Policies, and Reference Material					
State / Province / Agency	**Contact**	**Noise Policy pdf - Policy Date**	**Construction Noise Discussed in:**	**Noise Policy Web Site Link**	**Related Information**
Kansas	Joan E. Myer Bureau of Design Kansas Department of Transportation 700 SW Harrison Street Topeka, KS 66603-3754 Phone 785-296-0853 FAX 785-296-8399 Email joanm@ksdot.org	Kansas.pdf August 1996	N/A	N/A	
Kentucky	Tom Koos Kentucky Transportation Cabinet Division of Environmental Analysis 200 Mero Street Frankfort, Kentucky 40622-1994 Phone 502-564-7250 FAX 502-564-5655 Email Tom.Koos@ky.gov	Kentucky.pdf February 2000	N/A	N/A	
Louisiana	Noel Ardoin Louisiana Department of Transportation and Development Post Office Box 94245 Baton Rouge, Louisiana 70804-9245 Phone 225-242-4504 FAX 225-242-4500 Email noelardoin@dotd.louisiana.gov	Louisiana.pdf October 1997	Paragraph 13	N/A	
Maine	Duane Scott Maine Department of Transportation Bureau of Planning 16 State House Station Augusta, Maine 04333-0016 Phone 207-624-3309 FAX 207-624-3301 Email duane.scott@maine.gov	Maine.pdf November 2001	Paragraph 9	www.maine.gov/mdot/planning-process-programs/pdf/noisepolicy.pdf	
Maryland	Ken Polcak Maryland State Highway Administration Office of Environmental Design 707 N. Calvert Street C-305 Baltimore, Maryland 21202 Phone 410-545-8601 FAX 410-209-5003 Email kpolcak@sha.state.md.us	Maryland.pdf May 1998	N/A	N/A	General Provisions

Table 10.1 (cont.) Contacts, Policies, and Reference Material

State / Province / Agency	Contact	Noise Policy pdf - Policy Date	Construction Noise Discussed in:	Noise Policy Web Site Link	Related Information
Massachusetts	John Fallon Massachusetts Highway Department 10 Park Plaza Boston, Massachusetts 02116-3973 Phone 617-973-7408 FAX 617-973-8879 Email john.fallon@state.ma.us	Massachusetts.pdf April 1996	N/A	N/A	Central Artery Noise Control Program (Erich Thalheimer) Central Artery Construction Noise Specification Under water noise measurements
Michigan	Tom Hanf Michigan Department of Transportation Environmental Analysis Unit Post Office Box 30050 Lansing, Michigan 48909 Phone 517-241-2445 FAX 517-373-9255 Email hanft@michigan.gov	Michigan.pdf July 2002	N/A	http://www.michigan.gov/mdot/0,1607,7-151-9621_11041_25846---,00.html	
Minnesota	Melvin Roseen Minnesota Department of Transportation Noise Analysis Unit 6000 South Minnehaha Avenue Saint Paul, Minnesota 55111 Phone 612-725-2373 FAX 612-725-2385 Email melvin.roseen@dot.state.mn.us	Minnesota.pdf July 2005	N/A	http://www.dot.state.mn.us/environment/noise_analysis/policy.html See also Section IV, Sections B and C of this link.	
Mississippi	Elton D. Holloway Planning Division Mississippi Department of Transportation Post Office Box 1850 Jackson, Mississippi 39215-1850 Phone 601-359-7685 FAX 601-359-7652 Email eholloway@mdot.state.ms.us	Mississippi.pdf June 1996	Chapter III	N/A	
Missouri	Macey Jett Missouri Department of Transportation 105 West Capitol Post Office Box 270 Jefferson City, Missouri 65102 Phone 573-526-5648 FAX 573-522-1973 Email macey.jett@modot.mo.gov	Missouri.pdf September 1997	Page 7	N/A	

Table 10.1 (cont.) Contacts, Policies, and Reference Material

State / Province / Agency	Contact	Noise Policy pdf - Policy Date	Construction Noise Discussed in:	Noise Policy Web Site Link	Related Information
Montana	Cora G. Helm Montana Department of Transportation Environmental Services Post Office Box 201001 Helena, Montana 59620-1001 Phone 406-444-7659 FAX 406-444-7245 Email cohelm@mt.gov	Montana.pdf June 2001	N/A	N/A	Traffic Noise in Montana
Nebraska	Mark Otteman Project Development Division Nebraska Department of Roads Post Office Box 94759 Lincoln, Nebraska 68509-4759 Phone 402-479-4684 FAX 402-479-3629 Email motteman@dor.state.ne.us	Nebraska.pdf May 1998	N/A	N/A	
Nevada	Daniel Harms Environmental Services Division Nevada Department of Transportation 1263 S. Stewart Street Carson City, Nevada 89712 Phone 775-888-7685 FAX 775-888-7104 Email dharms@dot.state.nv.us	Nevada.pdf September 1996	Paragraph 5	N/A	
New Hampshire	Charles Hood Project Development Section Bureau of Environment Room 109 New Hampshire Department of Transportation Post Office Box 483 Concord, New Hampshire 03302-0483 Phone 603-271-3226 FAX 603-271-7199 Email chood@dot.state.nh.us	New Hampshire.pdf July 1996	Section VI	N/A	
New Jersey	Edward Tomaszewski New Jersey Department of Transportation P.O. Box 600 Trenton, New Jersey 08625 Phone 609-530-2835 FAX 609-530-3767 Email edward.tomaszewski@dot.state.nj.us	New Jersey.pdf July 2003	N/A	http://www.state.nj.us/transportation/eng/documents/BDC/doc/bdc03t05.doc http://www.state.nj.us/transportation/eng/documents/miscref/noisestudy.shtm See also: http://www.state.nj.us/dep/enforcement/	New Jersey Model Noise Ordinance

Table 10.1 (cont.) Contacts, Policies, and Reference Material					
State / Province / Agency	**Contact**	**Noise Policy pdf - Policy Date**	**Construction Noise Discussed in:**	**Noise Policy Web Site Link**	**Related Information**
New Mexico	Colleen Vaughn or Steve Reed Environmental Section, Room 213 New Mexico State Highway & Transportation Department Post Office Box 1149 Santa Fe, New Mexico 87504-1149 Phone 505-827-3234 FAX 505-827-6862 Email colleen.vaughn@nmshtd.state.nm.us	New Mexico.pdf December 1992	N/A	N/A	
New South Wales, Australia	Noise Policy Section Environmental Policy Branch Environmental Protection Auyhority 59-61 Goulburn Street, P.O. Box A290 Sydney South 1232 Australia Phone: (02) 9733 5000 FAX: (02) 9733 5002	Anew South Wales, Australia.pdf May-99	N/A	www.epa.nsw.gov.au/noise	
New York	William McColl Environmental Analysis Bureau New York State Department of Transportation State Campus, 5-303 Albany, New York 12232 Phone 518-457-2385 FAX 518-457-6887 Email wmccoll@dot.state.ny.us	New York.pdf August 1998	Chapter VI	See also Chapter 3 of the below link: http://www.dot.state.ny.us/eab/epm.html	
North Carolina	Stephen Walker North Carolina Department of Transportation Office of Human Environment 1583 Mail Service Center Raleigh, North Carolina 27699-1583 Phone 919-715-1614 FAX 919-715-1522 Email swalker@dot.state.nc.us	North Carolina.pdf	N/A	See also following links: http://www.ncdot.org/doh/preconstruct/pe/ohe/NoiseAir/ http://www.ncdot.org/doh/preconstruct/pe/ohe/NoiseAir/abatement.html	
North Dakota	Mark Gaydos Design Engineer North Dakota Department of Transportation 608 E. Boulevard Avenue Bismark, North Dakota 58505-0700 Phone 701-328-2555 FAX 701-328-0103 Email mgaydos@state.nd.us	North Dakota.pdf May 1997	N/A	N/A	
Ohio	Elvin W. Pinckney Ohio Department of Transportation Office of Environmental Services 1980 West Broad Street Columbus, Ohio 43223 Phone 614-466-5154 FAX 614-728-7368 Email elvin.pinckney@dot.state.oh.us	Ohio.pdf July 2005	N/A	http://www.dot.state.oh.us/oes/noise.htm	

Table 10.1 (cont.) Contacts, Policies, and Reference Material					
State / Province / Agency	**Contact**	**Noise Policy pdf - Policy Date**	**Construction Noise Discussed in:**	**Noise Policy Web Site Link**	**Related Information**
Ontario	Chris T. Blaney Ontario Ministry of Transportation Planning and Environmental Office 3rd Floor, Building 'D' 1201 Wilson Avenue Downsview, Ontario M3M 1J8 Canada Phone 416-235-5561 Email 416-235-3446 Email chris.blaney@mto.gov.on.ca	Ontario.pdf October 1987			
Oklahoma	Staci Beasley Noise Specialist Oklahoma Department of Transportation 200 Northeast 18th Street Oklahoma City, Oklahoma 73105 Phone 405-521-2515 FAX 405-521-6948 Email sbeasley@odot.org	Oklahoma.pdf 1999	N/A	N/A	
Oregon	David Goodwin Environmental Services Oregon Department of Transportation 355 Capitol Street, NE Room 301 Salem, Oregon 97301 Phone 503-986-3488 FAX 503-986-3407 Email david.a.goodwin@odot.state.or.us	Oregon.pdf June 1996	Section 6.000; Appendix I	http://egov.oregon.gov/ODOT/HWY/GEOENVIRONMENTAL/docs/Noise_Manual/NoiseMan_Revised_061704.pdf	
Pennsylvania	Danielle Shellenberger Pennsylvania Department of Transportation Bureau of Design P.O. Box 3790 Harrisburg, Pennsylvania 17120 Phone 717-783-6503 FAX 717-772-0834. Email dashellenb@state.pa.us	Pennsylvania.pdf February 2002	Section II, Step 6	ftp://ftp.dot.state.pa.us/public/pdf/pennDOTpub24.pdf	Example special provision
Puerto Rico	Luis Rodriquez Puerto Rico Highway and Transportation Authority Post Office Box 42007 San Juan, Puerto Rico 00940 Phone 787-721-8787 Ext. 11529 FAX 787-727-5503 Email	Puerto Rico. pdf	Section XIV	N/A	

Table 10.1 (cont.) Contacts, Policies, and Reference Material					
State / Province / Agency	**Contact**	**Noise Policy pdf - Policy Date**	**Construction Noise Discussed in:**	**Noise Policy Web Site Link**	**Related Information**
Rhode Island	Bob Smith Rhode Island Department of Transportation Highway Engineering Division 2 Capitol Hill Providence, Rhode Island 02903 Phone 401-222-2023 Ext. 4023 FAX 401-222-3006 Email rasmith@dot.state.ri.us	Rhode Island.pdf	N/A	N/A	
South Carolina	Wayne Hall Environmental Management Office South Carolina Department of Transportation Post Office Box 191 Columbia, South Carolina 29201 Phone 803-737-1872 FAX 803-737-1394 Email halljw@scdot.org	South Carolina.pdf	N/A	N/A	
South Dakota	Alice Whitebird South Dakota Department of Transportation 700 E. Broadway Avenue Pierre, South Dakota 57501-2586 Phone 605-773-3309 FAX 605-773-6608 Email Alice.Whitebird@state.sd.us	South Dakota.pdf April 1996	N/A		
Tennessee	Jim Ozment Tennessee Department of Transportation Office of Environmental Planning and Permits Suite 900, James K. Polk Building 505 Deaderick Street Nashville, Tennessee 37243-0334 Phone 615-741-5373 FAX 615-741-1098 Email jim.ozment@state.tn.us	Tennessee.pdf	N/A	See also link below: http://www.tdot.state.tn.us/news/2005/030405.htm	
Texas	Michael Shearer Texas Department of Transportation Environmental Affairs Division 125 E. 11th Street Austin, Texas 78701-2409 Phone 512-416-2622 FAX 512-416-2319 Email mshearer@dot.state.tx.us	Texas.pdf June 1996 (Change 1, July 1997)	Section IV, J.1.	http://www.dot.state.tx.us/env/pdf/resources/TxDOTnoise96.pdf	

Table 10.1 (cont.) Contacts, Policies, and Reference Material					
State / Province / Agency	**Contact**	**Noise Policy pdf - Policy Date**	**Construction Noise Discussed in:**	**Noise Policy Web Site Link**	**Related Information**
United Kingdom		United Kingdom.pdf 2003			
Utah	Jerry Chaney Utah Department of Transportation Environmental Division Box 148450 Salt Lake City, Utah 84114-8450 Phone 801-965-4317 Cell 801-633-6218 FAX 801-965-4564 Email jchaney@utah.gov	Utah.pdf March 2004	N/A	N/A	Roadway Pavement Grinding Noise Study
U.S. Army Corps of Engineers	Headquarters, USACE 441 G Street Washington, DC 20314-1000 Phone 202-761-0010 & 202-761-0011 FAX 202-761-1803			http://www.usace.army.mil/inet/functions/cw/cecwp/envdref2/pages/ncao1972.htm	Environmental Effects of Underwater Explosions on plants, anphibians, reptiles,fish,and marine mammals, with mitigation methods
Vermont	Dennis Benjamin Program Development Division Vermont Agency of Transportation National Life Building, Drawer 33 Montpelier, Vermont 05633-5001 Phone 802-828-3978 FAX 802-828-2334 Email dennis.benjamin@state.vt.us	Vermont.pdf		Noise policy is contained in Appendix C of below link to August 2001 Environmental Operations Manual - Noise Policy is dated July 1997 http://www.aot.state.vt.us/TechServices/Documents/EnvirOpsManual/FullEnviroOpsManual.pdf	
Virginia	Amy Costello Air, Noise & Energy Section Manager Virginia Department of Transportation 1401 East Broad Street Richmond, Virginia 23219 Phone 804-371-6773 FAX 804-786-7401 Email amy.costello@vdot.virginia.gov	Virginia.pdf January 1997	N/A	http://www.virginiadot.org/projects/pr-noise-policy.asp	Woodrow Wilson Bridge Construction Noise Special Provision

Table 10.1 (cont.) Contacts, Policies, and Reference Material

State / Province / Agency	Contact	Noise Policy pdf - Policy Date	Construction Noise Discussed in:	Noise Policy Web Site Link	Related Information
Washington	Mia Waters Washington State Department of Transportation P.O. Box 330310, NB82-138 Seattle, Washington 98133-9710 Phone 206-440-4541 FAX 206-440-4805 Email watersy@wsdot.wa.gov	Washington.pdf March 17, 2006	Chapter 15	Noise policy can be found at the following link: http://www.wsdot.wa.gov/regions/Northwest/rp&s/environmental/aae/policies.htm View WSDOT projects at below site: http://www.wsdot.wa.gov/projects WSDOT Environmental Procedures Manual See vaious topics under Acoustics heading on the web site below: http://www.wsdot.wa.gov/regions/Northwest/rp&s/environmental/aae/default.htm	Bubble Curtain Application to mitigate noise impacts on fish Tacoma Narrows Bridge - Nighttime Construction (Communications Strategy) Tacoma Narrows Bridge - Nighttime Construction (Operations Plan) Tacoma Narrows Bridge Nighttime Construction Activities - Newsletter
West Virginia	James Colby West Virginia Department of Transportation State Capitol Complex Building 5, Room A-450 1900 Kanawha Boulevard, East Charleston, West Virginia 25305-0430 Phone 304-558-2885 FAX 304-558-7296 Email jcolby@dot.state.wv.us	West Virginia.pdf February 1998	Mitigation Directive October 2003	Noise Guidelines are contained on the below listed web site under Coordination/Environment (DD 207); Mitigation Directive is DD 206 http://www.wvdot.com/engineering/dds.htm	Fish Passage Studies
Wisconsin	Jay Waldschmidt Wisconsin Department of Transportation Bureau of Equity and Environmental Services Room 451 4802 Sheboygan Avenue Post Office Box 7965 Madison, Wisconsin 53707-7965 Phone 608-267-9806 FAX 608-266-7818 Email jay.waldschmidt@dot.state.wi.us	Wisconsin.pdf	Construction Stage Impact Evaluation December 2005	Construction stage noise discussion can be found at: http://www.dot.wisconsin.gov/forms/docs/dt2074.doc	
Wyoming	Timothy M. Carroll, P.E. Environmental Project Engineer Wyoming Department of Transportation 5300 Bishop Boulevard Cheyenne, Wyoming 82009-3340 Phone 307-777-4378 FAX 307-777-4193 Email timothy.carroll@dot.state.wy.us	Wyoming.pdf June 1996	N/A	N/A	

N/A = Not available or not applicable

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APPENDIX A: FHWA ROADWAY CONSTRUCTION NOISE MODEL USER'S GUIDE

An executable version of the FHWA Roadway Construction Noise Model (RCNM) is available in electronic form on the companion CD-ROM. The User's Guide below offers instructions on how to use the RCNM.

U.S. Department of Transportation

Federal Highway Administration

FHWA Roadway Construction Noise Model User's Guide

FHWA-HEP-05-054
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January 2006

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13. ABSTRACT (Maximum 200 words)

The Roadway Construction Noise Model (RCNM) is the Federal Highway Administration's (FHWA) national model for the prediction of construction noise. Due to the fact that construction is often conducted in close proximity to residences and businesses, construction noise must be controlled and monitored to avoid impacts on surrounding communities. In addition to community issues, excessive noise can threaten a construction projects' progress. Each project needs to balance the community's need for peace and quiet with the contractor's need to progress the work.

During the Central Artery/Tunnel (CA/T) project in Boston, Massachusetts, the project's noise control program developed the Construction Noise Control Specification 721.560, the most comprehensive noise specification ever developed in the United States. As part of the CA/T project noise control program, a construction noise prediction spreadsheet was developed. Because the CA/T prediction tool can benefit other state and local governments, the FHWA developed the RCNM, which is based on the noise prediction calculations and equipment database used in the CA/T prediction spreadsheet. The RCNM provides a construction noise screening tool to easily predict construction noise levels and determine compliance with noise limits for a variety of construction noise projects of varying complexity.

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Table of Contents

Section Page

List of Figures

List of Tables

1 Introduction

The Roadway Construction Noise Model (RCNM) is the Federal Highway Administration's (FHWA) national model for the prediction of construction noise. Due to the fact that construction is often conducted in close proximity to residences and businesses, construction noise must be controlled and monitored to avoid impacts on surrounding communities. In addition to community issues, excessive noise can threaten a construction project's progress. Each project needs to balance the community's need for peace and quiet with the contractor's need to progress the work.

The Central Artery/Tunnel (CA/T) project in Boston, Massachusetts, which began in the early 1990s, is the largest urban construction project ever conducted in the United States. Its noise control program developed the Construction Noise Control Specification 721.560, the most comprehensive noise specification ever developed in the United States [1]. As part of the CA/T project noise control program, a construction noise prediction spreadsheet was developed [2]. Because the CA/T prediction tool can benefit other state and local governments, the FHWA developed the RCNM, which is based on the noise prediction calculations and the equipment database used in the CA/T prediction spreadsheet. The RCNM provides a construction noise screening tool to easily predict construction noise levels and to determine compliance with noise limits for a variety of construction noise projects of varying complexity.

2 Background

The RCNM is a national model based on the noise calculations and extensive construction noise data compiled for the CA/T Project. The basis for the national model is a spreadsheet tool developed in support of the CA/T project [2]. The CA/T predictions originated from Environmental Protection Agency (EPA) noise level work [3] and an Empire State Electric Energy Research Corp. Guide [4] which utilizes an "acoustical usage factor" to estimate the fraction of time each piece of construction equipment is operating at full power (i.e., its loudest condition) during a construction operation. Table 1 presents a construction equipment noise database compiled through the CA/T project [2]. This database is used to predict construction noise within the RCNM. The noise levels listed represent the A-weighted maximum sound level (Lmax), measured at a distance of 50 feet from the construction equipment.

Table 1. CA/T equipment noise emissions and acoustical usage factors database.

CA/T Noise Emission Reference Levels and Usage Factors					
filename: EQUIPLST.xls					
revised: 7/26/05		Acoustical	Spec 721.560	Actual Measured	No. of Actual
	Impact	Use Factor	Lmax @ 50ft	Lmax @ 50ft	Data Samples
Equipment Description	Device ?	(%)	(dBA, slow)	(dBA, slow)	(Count)
				(samples averaged)	
All Other Equipment > 5 HP	No	50	85	-- N/A --	0
Auger Drill Rig	No	20	85	84	36
Backhoe	No	40	80	78	372
Bar Bender	No	20	80	-- N/A --	0
Blasting	Yes	-- N/A --	94	-- N/A --	0
Boring Jack Power Unit	No	50	80	83	1
Chain Saw	No	20	85	84	46
Clam Shovel (dropping)	Yes	20	93	87	4
Compactor (ground)	No	20	80	83	57
Compressor (air)	No	40	80	78	18
Concrete Batch Plant	No	15	83	-- N/A --	0
Concrete Mixer Truck	No	40	85	79	40
Concrete Pump Truck	No	20	82	81	30
Concrete Saw	No	20	90	90	55
Crane	No	16	85	81	405
Dozer	No	40	85	82	55
Drill Rig Truck	No	20	84	79	22
Drum Mixer	No	50	80	80	1
Dump Truck	No	40	84	76	31
Excavator	No	40	85	81	170
Flat Bed Truck	No	40	84	74	4
Front End Loader	No	40	80	79	96
Generator	No	50	82	81	19
Generator (<25KVA, VMS signs)	No	50	70	73	74
Gradall	No	40	85	83	70
Grader	No	40	85	-- N/A --	0
Grapple (on backhoe)	No	40	85	87	1
Horizontal Boring Hydr. Jack	No	25	80	82	6
Hydra Break Ram	Yes	10	90	-- N/A --	0
Impact Pile Driver	Yes	20	95	101	11
Jackhammer	Yes	20	85	89	133
Man Lift	No	20	85	75	23
Mounted Impact Hammer (hoe ram)	Yes	20	90	90	212
Pavement Scarafier	No	20	85	90	2
Paver	No	50	85	77	9
Pickup Truck	No	40	55	75	1
Pneumatic Tools	No	50	85	85	90
Pumps	No	50	77	81	17
Refrigerator Unit	No	100	82	73	3
Rivit Buster/chipping gun	Yes	20	85	79	19
Rock Drill	No	20	85	81	3
Roller	No	20	85	80	16
Sand Blasting (Single Nozzle)	No	20	85	96	9
Scraper	No	40	85	84	12
Shears (on backhoe)	No	40	85	96	5
Slurry Plant	No	100	78	78	1
Slurry Trenching Machine	No	50	82	80	75
Soil Mix Drill Rig	No	50	80	-- N/A --	0
Tractor	No	40	84	-- N/A --	0
Vacuum Excavator (Vac-truck)	No	40	85	85	149
Vacuum Street Sweeper	No	10	80	82	19
Ventilation Fan	No	100	85	79	13
Vibrating Hopper	No	50	85	87	1
Vibratory Concrete Mixer	No	20	80	80	1
Vibratory Pile Driver	No	20	95	101	44
Warning Horn	No	5	85	83	12
Welder / Torch	No	40	73	74	5

3 The RCNM

The RCNM is a computer program used to assess construction noise impacts. The computer on which it is installed should be equipped with the Microsoft Windows 98 or newer operating system (OS) and 192 MB or more of random access memory (RAM). The display should be set to 1024 x 768 pixels or greater, and the computer should carry the Adobe Acrobat 4.0 or newer software.

The RCNM allows the estimation of three key metrics of interest: Lmax, Leq, and L10 at receptor locations for a construction operation that can include up to 20 pieces of equipment. RCNM allows for user-defined construction equipment and user-defined noise limit criteria. The two main uses of the RCNM are to allow typical computer users to: 1. easily predict noise emissions from construction equipment, and 2. determine a construction work plan's compliance with noise criteria limits. A variety of construction work scenarios can be created quickly, allowing the user to determine the impact of changing construction equipment and adding/removing the effects of shielding due to noise mitigation devices such as barriers.

3.1 RCNM Main Page

The RCNM consists of one main display page with Input Data and Results sections, shown in Figure 1.

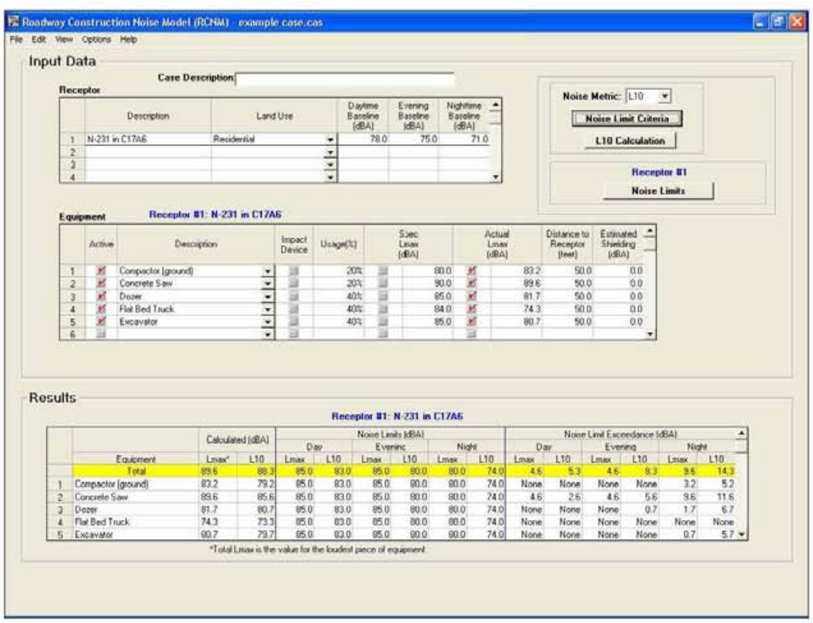

Figure 1. The RCNM main page

Several command buttons and pull-down menus allow the user to modify the input data before results are calculated by the model.

3.1.1 File Menu

The <File> menu, shown in Figure 2, contains items that allow the user to create, open, and save a case, export the results of a case, and exit the program.

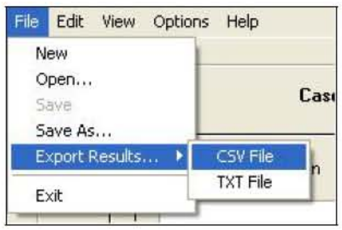

Figure 2. <File> Menu

- <New> creates a new case. If a case is currently open, the user is prompted to save it before closing.
- <Open…> allows the user to open an existing case file ([name].cas).
- <Save> saves the case with the current filename. If this is a new case, the user is asked for a new filename ([name].cas).
- <Save As…> The user is asked for a filename for a new case ([name].cas) and saves the case with that filename.
- <Export Results> prompts the user to save the case results for the current or all receptors to a comma separated value (CSV) file with the following naming convention: [name].csv. This type of file is easily read into a spreadsheet program. The user can also save the case results to a text file (TXT), which saves the results to a space-separated text format with the following naming convention: [name].txt.
- <Exit> closes the application. If changes have been made to the open case, the user is asked if he/she would like to save the case.

3.1.2 Edit Menu

The <Edit> menu, shown in Figure 3, allows the user to copy and paste data, delete data, and undo changes.

Figure 3. <Edit> Menu

- <Copy> lets the user copy into a clipboard the contents of a single cell or an entire line from an RCNM dialogue box.
- <Paste> lets the user copy the contents of the clipboard into a single cell or an entire line of an RCNM dialogue box.
- <Delete> lets the user delete from the case a receptor or piece of equipment selected in the receptor or equipment dialogue box.
- <Undo> lets the user revert the RCNM one step to where it was before the latest change was made.

3.1.3 View Menu

The <View> menu, shown in Figure 4, allows the user to focus in <Zoom +> on either the Input Data or Results section of the RCNM's main page. To activate Zoom +, click on Zoom + and guide the spyglass + icon to either Input Data or Results and single-click.

Figure 4. <View> Menu

To deactivate Zoom + and go back to the full RCNM screen, click on Zoom – and guide the spyglass – icon to the Input Data or Results section that has been maximized on the screen.

3.1.4 Options Menu

The <Options> menu, shown in Figure 5, allows the user to modify the equipment list and change the case's units of measure from feet to meters.

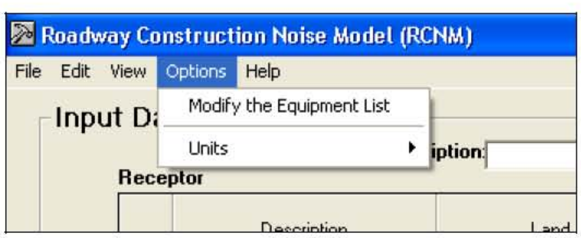

Figure 5. <Options> menu

The <Options> menu allows the user to add new types of equipment to the equipment list. The equipment list modification dialogue box, shown in Figure 6, allows the user to specify a user-defined piece of equipment and add it. The user can specify the following data: whether the equipment is an impact device, the equipment's usage factor[1], and the equipment's Lmax level (spec and/or actual[2]). The user can also delete equipment that's been added by selecting it and clicking the delete button. The default equipment cannot be modified, but it may be deleted entirely from the case by selecting it and clicking the delete button. Selecting the default button restores the default equipment list (from the CA/T Project) and eliminates any user-defined equipment.

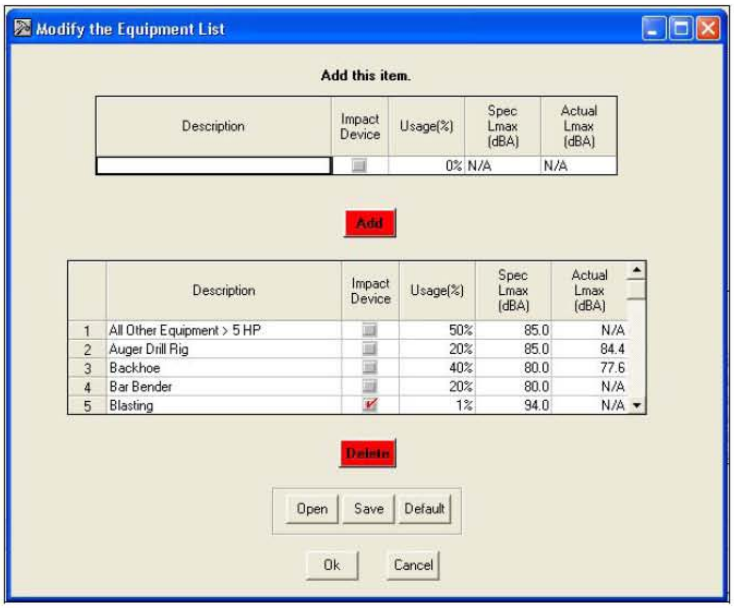

Figure 6. Equipment list modification dialogue box

Data for user-defined pieces of equipment may be saved to an equipment file ([name].equ), along with all other equipment in the current list, including default equipment. This file may be opened in other cases to incorporate these pieces of equipment.

The <Options> menu, as shown in Figure 7, also allows the user to change the case's units of measure from feet to meters or from meters to feet. The only input data affected by this tool are the Distance to Receptor values.

[1] Usage factor is the percentage of time during a construction noise operation that a piece of construction equipment is operating at full power. In the case of construction blasting, the equipment gives a very short duration blast, and can be quantified by using a 1% usage factor in the RCNM to allow for some prediction. Never use a usage factor of zero because the log of zero causes a mathematical impossibility. The usage factor term only affects the computation of Leq and L10. The usage factor does not enter into the equation when calculating the more important term for blasting, that being the Lmax.

[2] "Spec" refers to noise levels stated in noise specifications, and "Actual" refers to Lmax values measured at 50 ft from the equipment.

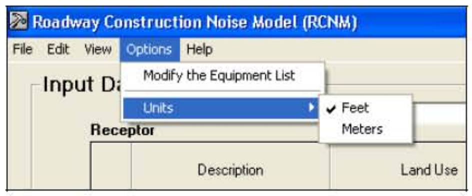

Figure 7. Units modification pull-down menu

3.1.5 Help Menu

The <Help> Menu loads for the user the RCNM User's Guide in Portable Document Format (PDF). This PDF is searchable by key word using the Adobe Acrobat Edit / Find search tool.

3.2 Input Data

The user is required to input receptor data and equipment data before a case can be processed. The user is advised to type in some summary comments about the case in the Case Description dialogue box before inputting data. Also, in order to determine noise limit exceedance values, the user can input noise limit criteria.

3.2.1 Receptors

Multiple receptors may be input for a case, but only one receptor may be processed at a time. The name of the highlighted receptor chosen for processing appears in blue type above the Equipment input dialogue box and the Noise Limits command button (see Figure 1). The user specifies the receptors for a study by entering information into the Receptors input box in the main window of the RCNM. The user is required to enter the receptor name, land use, daytime baseline L10 or Leq, evening baseline L10 or Leq, and nighttime baseline L10 or Leq. The baseline levels indicate the sound level at a receptor before any construction noise contributions. Baseline levels are only necessary if the desired noise criteria limits are based on *relative* increases in noise level. If the desired noise criteria limits are *absolute* noise levels, then the user should insert a placeholder number other than zero.

When entering information for more than one receptor, it may be desirable to copy information already entered. An entire receptor row may be highlighted and copied to another row, where copying multiple rows requires the selection of the same number of rows when pasting (this same functionality also applies to editable cells). Note: Entire rows may be selected by clicking on the row number.

Again, the RCNM will only calculate results for the receptor displayed in blue type in the Input Data portion of the main page. The results for other receptors may be displayed by selecting the desired receptor in the Receptor window; to select a receptor, click in any cell in the row. Up to 100 receptors may be included in any case. Information for receptors is saved in the case file ([name].cas).

3.2.2 Equipment

Core equipment noise data are stored in the RCNM and are accessible by a pull-down menu in the main page, as in Figure 8.

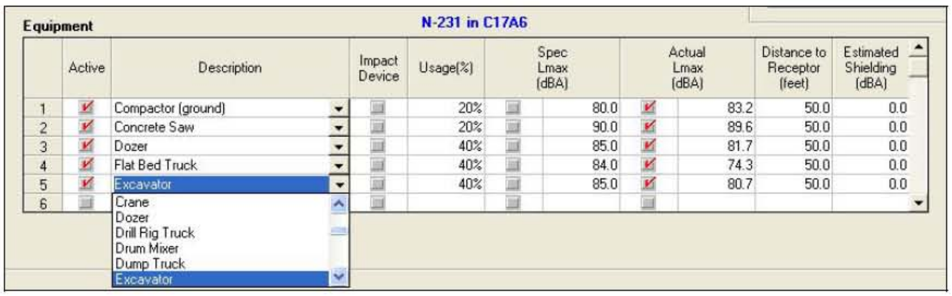

Figure 8. Equipment dialogue box, with pull-down menu shown

As discussed in Section 3.1.4, new pieces of equipment may be added to a case and saved in an equipment file ([name].equ). When the user-defined equipment file is opened through the <Options> / <Modify the Equipment List> menu, user-defined equipment will appear in the equipment pull-down menu. The user activates and inactivates chosen equipment types by ticking and unticking the "Active" checkbox. The user is required to specify:

1. The type of reference emission levels to use ("Spec", if applicable, or "Actual", [the default is "Actual"]);
2. Distance to Receptor – that is, the distance between each type of equipment and the receptor being analyzed (the default distance is 50 feet); and
3. Estimated Shielding (in dBA) associated with each type of equipment (can leave the default value of 0.0 when not considering shielding). **NOTE: A Best Practices document is presented in Appendix A showing how to determine Estimated Shielding using several Rules of Thumb developed from experience at the CA/T project.**

When entering information for more than one piece of equipment, it may be desirable to copy information already entered. An entire equipment row may be highlighted and copied to another row, where copying multiple rows requires the selection of the same number of rows when pasting (this same functionality also applies to editable cells). Note: Entire rows may be selected by clicking on the row number.

The user may analyze up to 20 pieces of equipment at one time, and they may be included in any combination of different or identical equipment types.

3.2.3 Noise Metric and Noise Limit Criteria

While a case is open, the user can choose a noise metric (for baseline levels, noise limits, and calculated results) and enter the noise limit criteria for a local area. The user may edit the Lmax and L10 or Leq day, evening, and night noise limit criteria for a residential, commercial, or industrial area. Daytime, evening, and nighttime may represent any time periods the user wishes, but they are typically defined as 7 AM to 6 PM, 6 PM to 10 PM, and 10 PM to 7 AM, respectively. The criteria, used together with the baseline sound levels, define the noise limits for each receptor. CA/T Noise Limit Criteria are used as a default [1], but users may input their own criteria. The RCNM offers a metric pull-down menu and two or three command buttons to the right of the Receptor input dialogue box.

- Metric Pull-Down Menu

A pull-down menu allows the user to choose between the L10 or Leq metric, as in Figure 9. The chosen metric represents that used for the baseline levels, noise limits, and calculated results. For the noise limits and calculated results, Lmax values are also included.

Figure 9. Noise Metric pull-down menu

- Noise Limit Criteria Pop-up Dialogue Box

A pop-up dialogue box allows the user to specify Noise Limit Criteria information for an area being studied in a case, as in Figure 10. The flexibility of the Noise Limit Criteria allows RCNM users to incorporate criteria based on local noise ordinances and baseline levels measured for each receptor.

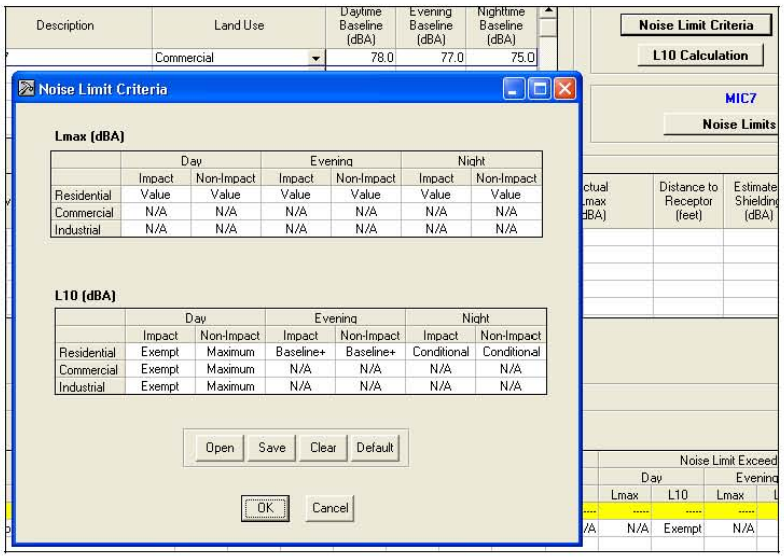

Figure 10. Noise Limit Criteria pop-up dialogue box

The user may populate this dialogue box with Noise Limit Criteria information derived from CA/T Construction Noise Control Spec. 721.560 [1] by clicking on the "Default" command button and clicking "Yes" when asked to load information from the default file, which is stored in the RCNM (see Table 2).

Table 2. Default Noise Limit Criteria

	Daytime (7 AM to 6 PM)		**Evening (6 PM to 10 PM)**		**Nighttime (10 PM to 7 AM)**	
Land Use	**L10 Limit (dBA)**	**Lmax Limit (dBA)**	**L10 Limit (dBA)**	**Lmax Limit (dBA)**	**L10 Limit (dBA)**	**Lmax Limit (dBA)**
Residential	maximum of 75 and baseline + 5 for non-impact* and exempt for impact**	85 for non-impact and 90 for impact	baseline + 5	85	if baseline <70 then baseline +5; if baseline ≥70 then baseline + 3	80
Commercial	maximum of 80 and baseline + 5 for non-impact and exempt for impact	N/A	N/A	N/A	N/A	N/A
Industrial	maximum of 85 and baseline+5 for non-impact and exempt for impact	N/A	N/A	N/A	N/A	N/A

* Non-impact equipment is equipment that generates a constant noise level while in operation.

** Impact Equipment is equipment that generates impulsive noise. Impulse Noise is defined as noise produced by the periodic impact of a mass on a surface, of short duration (generally less than one second), high intensity, abrupt onset and rapid decay, and often rapidly changing spectral composition.

Otherwise, the user may clear any information present in the dialogue box and specify new data in each cell. Clicking on the "Clear" command button will prompt the user to set all the cells in the dialogue box to Not Applicable (N/A), as in Figure 11. By clicking "Yes," the user will populate all cells with N/A; by clicking "No," the dialogue box will return to the data present before the user clicked "Clear."

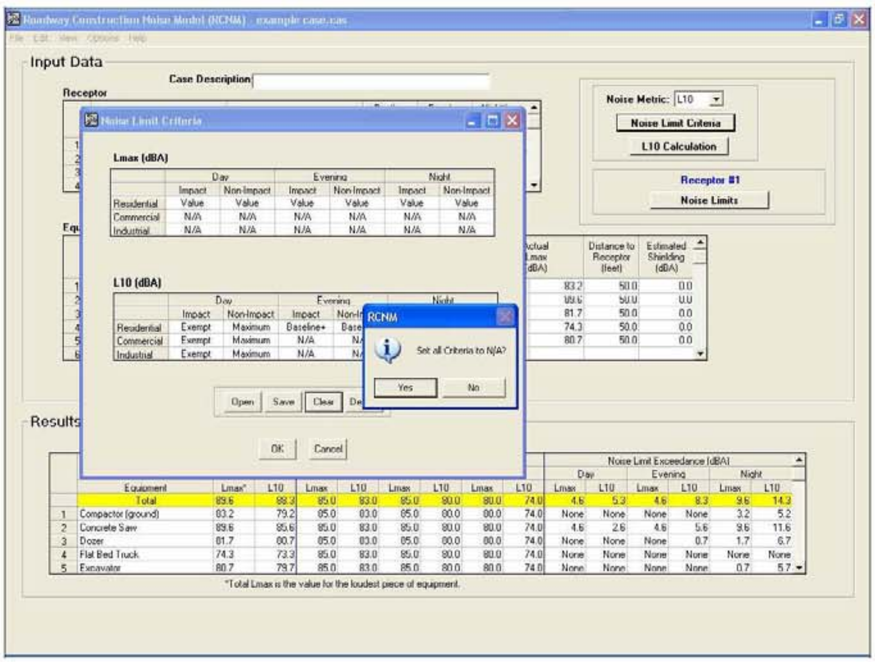

Figure 11. The Noise Limit Criteria "Clear" command button

Clicking on any cell in the Noise Limit Criteria dialogue box reveals a Noise Limit Criteria pull-down menu. Click on this pull-down menu to access the six options, as in Figure 12.

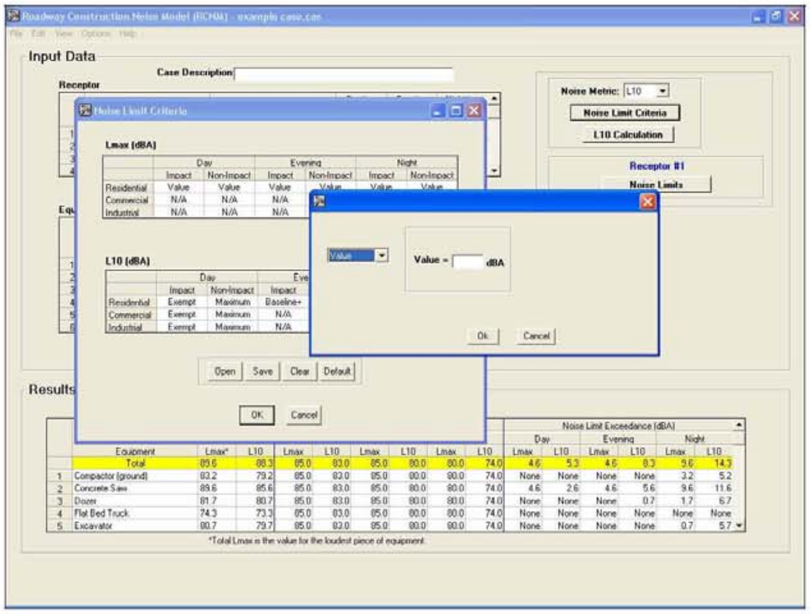

Figure 12. Noise Limit Criteria pull-down menu

Through these six options, the user specifies what Noise Limit Criteria changes, if any, are desirable in each cell. The six cell options are:

i. Exempt (for the specified metric and land use, the equipment is exempt from noise limits)
ii. N/A (for the specified metric and land use, the equipment does not have applicable noise limits)
iii. Value (user is prompted to enter a value for which the noise level should not exceed), as in Figure 13:

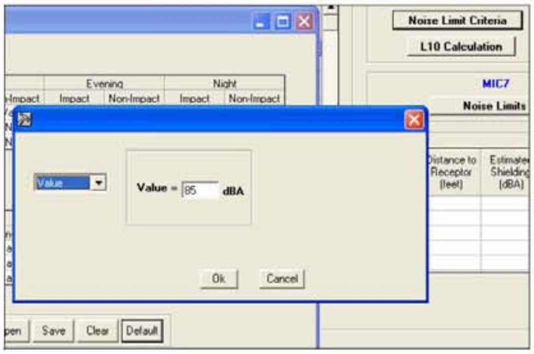

Figure 13. Noise Limit Criteria "Value" dialogue box

iv. Maximum (set value for which a noise level should not exceed to the maximum of two possible levels: A user-defined level or the Baseline level plus some user-defined increment), as in Figure 14:

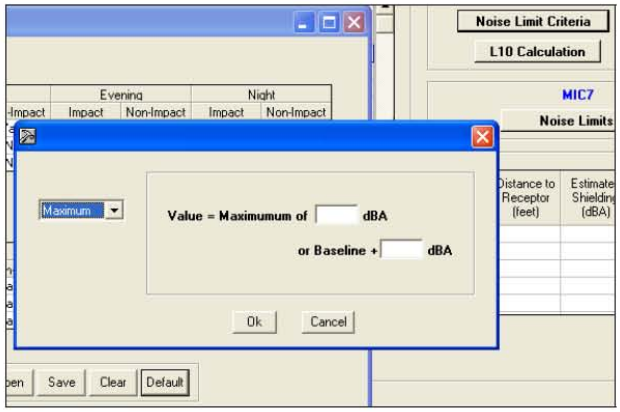

Figure 14. Noise Limit Criteria "Maximum" dialogue box

v. Baseline + (set value for which a noise level should not exceed to the Baseline level plus some user-defined increment), as in Figure 15:

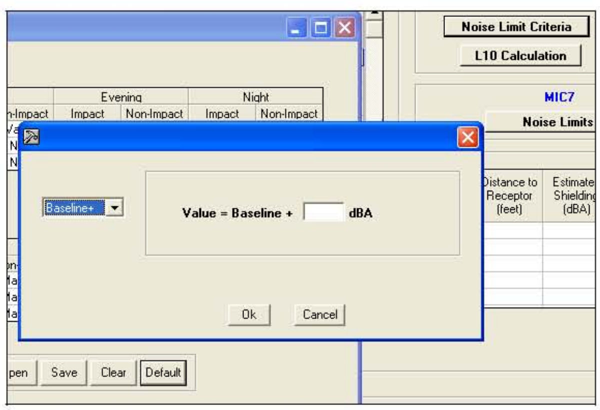

Figure 15. Noise Limit Criteria "Baseline +" dialogue box

vi. Conditional (set conditional value for which a noise level should not exceed; the user is prompted to enter the following information: 1. a comparison value, i.e., "If Baseline < [value], then …"; 2. an increment value to add to the baseline level if the baseline level is *less than* the comparison value; 3. an increment value to add to the baseline level if the baseline level is *greater than or equal to* the comparison value), as in Figure 16:

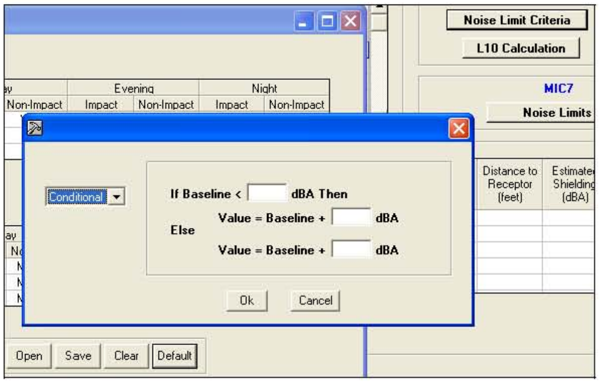

Figure 16. Noise Limit Criteria "Conditional" dialogue box

To see the current value of a cell, simply hold the mouse pointer over the cell. Once the user has specified values for all the cells in the Noise Limit Criteria dialogue box, these criteria can be saved in a criteria file ([name].cri) by clicking on the "Save" command button. The user will be prompted to give the criteria file a name. These criteria can thereafter be loaded into any case by clicking on the "Open" command button.

The user returns to the Noise Limit Criteria dialogue box by clicking "Ok", and returns to the case by clicking "Ok" again.

- L10 Calculation (this button is present if the L10 metric is chosen)

By clicking on the "L10 Calculation" command button, the user can specify the adjustment factor used to calculate L10, as in Figure 17. By clicking the "Default" command button, the user automatically calls for an adjustment factor of 3 dBA, a value empirically derived from extensive CA/T Project data [2].

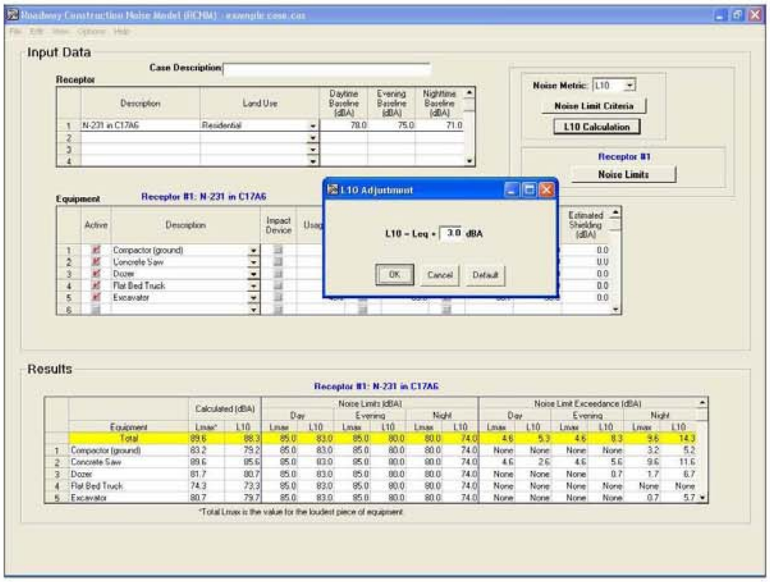

Figure 17. L10 Adjustment dialogue box

- Noise Limits

The "Noise Limits" command button opens a display window that looks exactly like the "Noise Limit Criteria" dialogue box, except that it is not editable, and the only button in the opened window is "Ok". The values in the cells are based on the criteria set in the Noise Limit Criteria window and the baseline levels for the selected receiver, as in Figure 18. (If a receiver is not selected, the dialogue box is unavailable for viewing.)

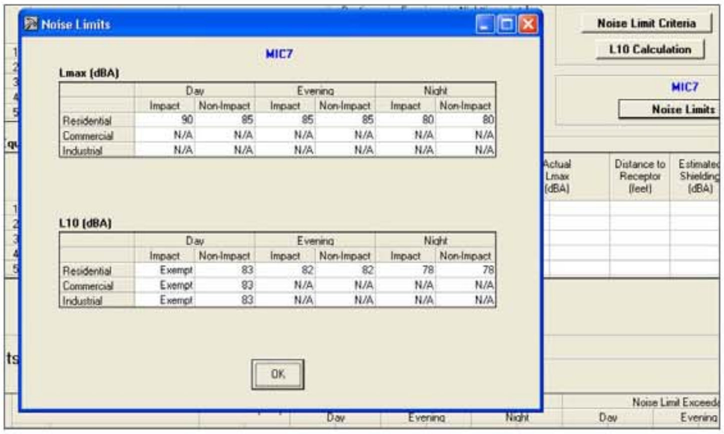

Figure 18. Noise Limits display window

Again, these limits may be changed by the user through the Noise Limit Criteria data entry window.

4 Results

Once the data for one receptor and up to 20 pieces of equipment have been specified in the Input Data portion of the main screen, the RCNM will automatically calculate the Results readout displayed in the bottom portion of the main screen, as in Figure 19. Any changes to the Input Data will automatically cause the RCNM to update the Results. The results for only one receptor will be displayed at a time; results for other receptors can be displayed by selecting the desired receptor in the Receptor window (click in any cell in the desired receptor row). Results for up to 100 receptors can be saved in a case. If Noise Limit Criteria information has been specified, the corresponding results (limits and exceedance values) will be updated as well.

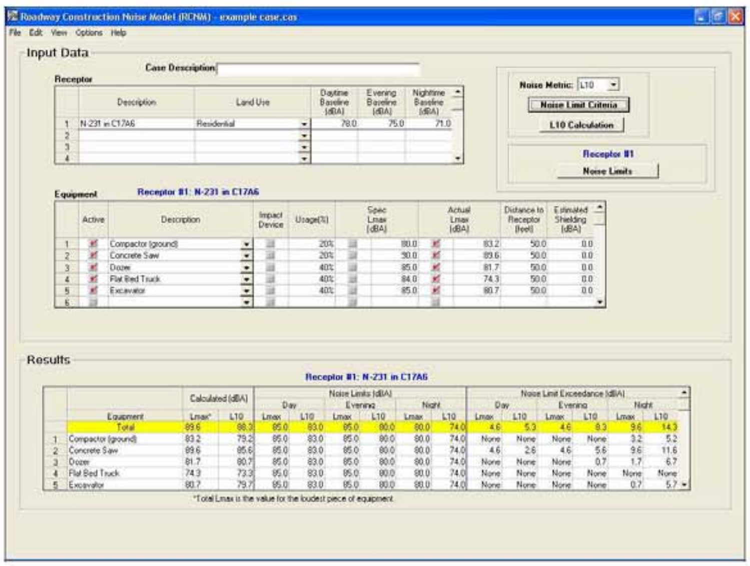

Figure 19. The RCNM main-page Results display

If there is insufficient input data for RCNM to compute a result, then a "Check Input Data" button will appear in the middle of the screen. Clicking on this button will provide the user with an indication of what additional input data are required.

The Results are presented in a read-only spreadsheet that contains the following fields, all applicable to the selected receptor:

- Equipment – the name/description of the equipment type
- Calculated Lmax – the calculated Lmax value for the equipment type. This is calculated from the "Spec" or "Actual" equipment Lmax, distance, and estimated shielding.

- Calculated Leq or L10 – the calculated Leq or L10 value (depending on what is selected in the Noise Metric pull-down menu) for the equipment type. This is calculated from the Calculated Lmax values, equipment usage factors, and selected adjustment factor.
- Day Lmax Noise Limit – the daytime Lmax noise limit for the equipment type.
- Day Leq or L10 Noise Limit – the daytime Leq or L10 noise limit for the equipment type.
- Evening Lmax Noise Limit – the evening Lmax noise limit for the equipment type.
- Evening Leq or L10 Noise Limit – the evening Leq or L10 noise limit for the equipment type.
- Night Lmax Noise Limit – the nighttime Lmax noise limit for the equipment type.
- Night Leq or L10 Noise Limit – the nighttime Leq or L10 noise limit for the equipment type.
- Day Lmax Noise Limit Exceedance – the daytime Lmax noise limit exceedance for the equipment type. If the criteria limit was not exceeded, the value is "None".
- Day Leq or L10 Noise Limit Exceedance – the daytime Leq or L10 noise limit exceedance for the equipment type. If the criteria limit was not exceeded, the value is "None".
- Evening Lmax Noise Limit Exceedance – the evening Lmax noise limit exceedance for the equipment type. If the criteria limit was not exceeded, the value is "None".
- Evening Leq or L10 Noise Limit Exceedance – the evening Leq or L10 noise limit exceedance for the equipment type. If the criteria limit was not exceeded, the value is "None".
- Night Lmax Noise Limit Exceedance – the nighttime Lmax noise limit exceedance for the equipment type. If the criteria limit was not exceeded, the value is "None".
- Night Leq or L10 Noise Limit Exceedance – the nighttime Leq or L10 noise limit exceedance for the equipment type. If the criteria limit was not exceeded, the value is "None".

The user may scroll down to view equipment results that are not visible, or the <View> / <Zoom +> menu may be used to zoom in on the Results display only (see Section 3.1.3). There is a row at the top of the Results display, highlighted in yellow, that calculates the total for all equipment combined. This row is always visible during scrolling of the Results spreadsheet. (Calculations for totals are explained in Section 5.3.)

Again, users may export a case's input information and results to a comma separated value (CSV) report file ([name].csv) by choosing the <Export Results> option from the <File> menu. The user can also save the case results to a text file (TXT), which saves the results to a space-separated text format ([name].txt). Results may be saved for a single receptor or all receptors in the case.

5 Calculations in the RCNM

The RCNM uses the primary equation described in the CA/T Construction Noise Control Specification 721.560 [1] for the construction noise calculations.

5.1 Metric Calculation

LmaxCalc = selected_Lmax – 20log(D/50) - shielding (1)

where

selected_Lmax is the "Spec" or "Actual" maximum A-weighted sound level at 50 ft., listed in Table 1 for all pieces of equipment, in dBA,
D is the distance between the equipment and the receptor, in feet,
shielding is the insertion loss of any barriers or mitigation, in dBA (see Appendix A).

Leq = LmaxCalc + 10log(U.F.%/100) (2)

where

U.F.% is the time-averaging equipment usage factor, in percent (see footnote 1 on p 7).

L10 = Leq + 3 dBA adjustment factor (3)

The RCNM calculates L10 by adding 3 dBA to the Leq, where the 3 dBA default L10 adjustment factor was empirically derived by comparing extensive CA/T construction noise data. This adjustment factor may be changed in the RCNM at the user's discretion.

5.2 Exceedance Calculation

Daytime Lmax Exceedance = LmaxCalc – Daytime Lmax Limit (4)

Daytime Leq or L10 Exceedance = Leq or L10 – Daytime Leq or L10 Limit (5)

Evening Lmax Exceedance = LmaxCalc – Evening Lmax Limit (6)

Evening Leq or L10 Exceedance = Leq or L10 – Evening Leq or L10 Limit (7)

Nighttime Lmax Exceedance = LmaxCalc – Nighttime Lmax Limit (8)

Nighttime Leq or L10 Exceedance = Leq or L10 – Nighttime Leq or L10 Limit (9)

5.3 Totals Calculation

The Total values in the Results section are determined in the following manner:

1) Total Leq = 10*log(Σ (individual equipment Leq values[3]))
2) Total L10 = 10*log(Σ (individual equipment L10 values[3]))
3) Total Lmax = Maximum among individual equipment Lmax values
4) Total noise limits and limit exceedances:
    a. Determine whether or not total is impact or non-impact
        i. If all the equipment is non-impact, label the total as non-impact.
        ii. If all the equipment is impact, label the total as impact.
        iii. If the equipment is mixed non-impact and impact, label the total as non-impact.
    b. Determine total noise limits and limit exceedances the same way as with individual pieces of equipment (see Section 5.2), only use the calculated total sound levels (Total Leq or Total L10) and the impact or non-impact label according to the criteria specified in i through iii.

[3] The Leq and L10 levels are energy averages.

6 References

[1] Construction Noise Control Specification 721.560, Central Artery/Tunnel Project, Massachusetts Turnpike Authority, Boston, MA, 2002.

[2] Thalheimer, Erich. "Construction Noise Control Program and Mitigation Strategy at the Central Artery/Tunnel Project". Noise Control Engineering Journal, Vol. 48, No. 5, pp 157-165, September - October 2000.

[3] "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety", Environmental Protection Agency, ONAC 550/9-74-004. Washington, DC, March 1974.

[4] "Power Plant Construction Noise Guide". Bolt, Beranek, and Newman Inc. and Empire State Electric Energy Research Corp., Report No. 3321. New York, NY May 1977.

Appendix A: Best Practices for Calculating Estimated Shielding for Use in the RCNM

This Appendix presents some simplified shielding factors for use in the RCNM. These suggestions are "rules of thumb" based on experience gathered by CA/T construction noise experts working in the field [2].

1) If a noise barrier or other obstruction (like a dirt mound) just barely breaks the line-of-sight between the noise source and the receptor, use 3 dBA.

2) If the noise source is completely enclosed OR completely shielded with a solid barrier located close to the source, use 8 dBA. If the enclosure and/or barrier has some gaps in it, reduce the effectiveness to 5 dBA.

3) If the noise source is completely enclosed AND completely shielded with a solid barrier located close to the source, use 10 dBA.

4) If a building stands between the noise source and receptor and completely shields the noise source, use 15 dBA.

5) If a noise source is enclosed or shielded with heavy vinyl noise curtain material (e.g., SoundSeal BBC-13-2" or equivalent), use 5 dBA.

6) If dilapidated windows are replaced with new acoustical windows, or quality internal or exterior storm sashes, use an incremental improvement of 10 dBA for an overall Outside-to-Inside Noise Reduction (OINR) of 35 dBA.

7) If work is occurring deep inside a tunnel using the "top-down" construction method (i.e. cover the tunnel work with concrete roadway decks to allow surface traffic and then excavate underneath the roof deck), use 12 dBA.

APPENDIX B: COMPARISON OF RCNM MODEL AND 1977 FHWA SPECIAL REPORT MANUAL CALCULATION METHOD

Problem 5 from Reference 001: 1977 FHWA Special Report - Highway Construction Noise: Measurement, Prediction and Mitigation, Pages 25 and 26

Problem:

The project has now progressed to the point where contractors are bidding on the project. The special provisions require that the exterior L_{eq}(h) on school grounds be less than 75 dBA during school hours. A long fill is to be constructed adjacent to a school. One prospective contractor would like to use two dozers and three scrapers to construct this fill. The contractor has collected the data presented in Table B.1 on equipment used in previous projects.

Table B.1 Contractor equipment data.

EQUIPMENT	L_j	L_m-L_b	T_a/T
Dozer 1	86	10	.5
Dozer 2	88	12	.5
Scraper 1	86	12	.3
Scraper 2	84	12	.3
Scraper 3	82	12	.3

Where:

L_j = Sound level measured using the SAE J88a test procedure.
L_m = Maximum sound level.
L_b = Reduced sound level of the work cycle.
T_a = Time spent at the maximum level (L_m) during the work cycle.
T = Work cycle time.

Compute the noise emission level of the equipment and estimate the L_{eq}(h) at the school.

Solution:

Step 1: The noise emission levels (E.L). in L_{eq}(h) at 15.2 m of the equipment is calculated by:

E.L. = L_j + E.F.

Where:

E.F. = Equivalency Factor derived from Table 2 of the 1977 Handbook

The noise emission levels (E.L.) are shown in Table B.2.

Table B.2 Equipment noise emission levels.

Equipment	L_j (dBA)	E.F. (From Table 2 in 1977 Handbook)	E.L. (dBA)
Dozer	86	-3	83
Dozer 2	88	-3	85
Scraper 1	86	-5	81
Scraper 2	84	-5	79
Scraper 3	82	-5	77

Step 2: Assign an average location to each piece of equipment. This is shown in Figure B.1.

Step 3: Compute the $L_{eq}(h)$ for each piece of equipment using Equation 3-1 (Page 19 of Reference 001) and the overall construction noise level using Equation 3-2 (Page 19 of Reference 001).

Equation 3.1: L_{eq} equipment = E.L. + 10 log U.F. – k log D/D_0

Where:

L_{eq} equipment = A-weighted, equivalent sound level at a receptor resulting from the operation of a single piece of equipment over some time period.
E.L. = Noise emission level of the particular piece of equipment based on its work cycle.
K = Constant that accounts for topography and geometric spreading.
D = Distance from the receptor to the piece of equipment.
D_0 = Reference distance at which the noise level was measured for the piece of equipment = 15.2 meters.
U.F. = Usage factor that accounts for the percent time that the equipment is in use over the time period.

Equation 3.2: $$L_{eq}(h)\ \text{site} = 10 \log \sum_{i=1}^{n} 10^{\text{Leq (equipment)}/10}$$

Where:

L_{eq} (equipment) = (E.L. – 20 log D/D_0) equipment.
Leq(h) site = One-hour, A-weighted, overall equivalent construction noise sound level obtained by summing the individual equipment noise levels on an energy basis.
N= Number of pieces of equipment included in the summation..

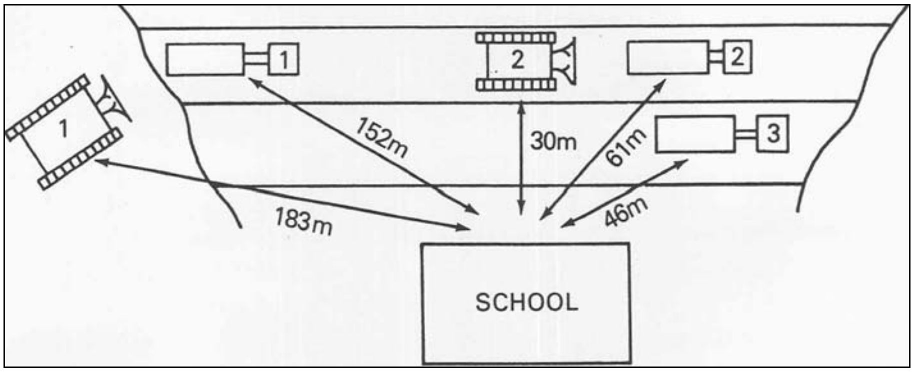

Figure B.1 Construction Site

The results are shown in Table B.3. The construction L_{eq}(h) of 80 dBA exceeds the specified goal by 5 dBA.

Table B.3 Results from Manual Calculation Method.

Phase	Equipment	NoiseEmission Level (dBA)	Distance from Equipment to Observer (meters)	Equipment L_{eq}(h) at Receptor (dBA)	Overall L_{eq}(h) at Receptor (dBA)
Earthwork	Dozer No.1	83	183	61	
	Dozer No.2	85	30	79	
	Scraper No.1	81	152	61	
	Scraper No.2	79	61	67	
	Scraper No.3	77	46	67	
					80 dBA

The 80 dBA value in the sixth column was obtained by dB addition. The value could also have been determined by:

$$
\begin{aligned}
L_{eq}(h)\text{ site} &= \text{SUM } L_{eq}(h)\text{ equipment} \\
&= 10 \log (10^{6.1} + 10^{7.9} + 10^{6.1} + 10^{6.7} + 10^{6.7}) \\
&= 80 \text{ dBA}
\end{aligned}
$$

RCNM Results

Roadway Construction Noise Model (RCNM), Version 1.0

Report Date: 01/19/2006
Case Description: 1977 Handbook Problem Number 5 (from page 26)

Table B.4 Receptor #1 data.

			Baselines (dBA)			
Description	**Land use**		**Daytime**	**Evening**	**Night**	
School	Residential		75.0	65.0	55.0	
Equipment						
Description	**Impact Device**	**Usage (%)**	**Spec L_{max} (dBA)**	**Actual L_{max} (dBA)**	**Receptor Distance (meters)**	**Estimated Shielding (dBA)**
Dozer #1	No	50		86.0	183.0	0.
Dozer #2	No	50		88.0	30.0	0.
Scraper #1	No	30		86.0	152.0	0.
Scraper #2	No	30		84.0	61.0	0.
Scraper #3	No	30		82.0	46.0	0.

Table B.5 Results from RCNM Run (Daytime).

Equipment	L_{max} in dBA	L_{eq} in dBA
Dozer #1	64.4	61.4
Dozer #2	82.1	79.1
Scraper #1	66.0	60.8
Scraper #2	72.0	66.7
Scraper #3	72.4	67.2
All Equipment	82.1	79.7

APPENDIX C: PHOTO DATABASE

The FHWA Highway Construction Noise Handbook photo database is available on the Handbook's companion CD-ROM.