B. Noise

B.1 NOISE FUNDAMENTALS

SOUND, NOISE, AND ACOUSTICS

Sound is a disturbance created by a moving or vibrating source in a gaseous or liquid medium or the elastic stage of a solid, and is capable of being detected by the hearing organs. Sound may be thought of as the mechanical energy of a vibrating object transmitted by pressure waves through a medium to a hearing organ, such as a human ear. For traffic sound, the medium is air.

Sound is actually a process that consists of three components: the sound source, the sound path, and the sound receiver. All three components must be present for sound to exist. Without a source to produce sound, there is no sound. Likewise, without a medium to transmit sound pressure waves, there is no sound. Finally, sound must be received; a hearing organ, sensor, or object must be present to perceive, register, or be affected by, sound or noise. In most situations, there are many different sound sources, paths, and receptors rather than just one of each. Acoustics is the field of science that deals with the production, propagation, reception, effects, and control of sound. Noise is defined as sound that is loud, unpleasant, unexpected, or undesired.

FREQUENCY AND HERTZ

A continuous sound can be described by its frequency (pitch) and its amplitude (loudness). Frequency relates to the number of pressure oscillations per second. Low-frequency sounds are low in pitch, like the low notes on a piano, whereas high-frequency sounds are high in pitch, like the high notes on a piano. Frequency is expressed in terms of oscillations, or cycles, per second. Cycles per second are commonly referred to as Hertz (Hz). A frequency of 250 cycles per second is referred to as *250* Hz. High frequencies are sometimes more conveniently expressed in units of kilo-Hertz (kHz), or thousands of Hertz. The extreme range of frequencies that can be heard by the healthiest human ear spans from 16–20 Hz on the low end to about 20,000 Hz (or 20 kHz) on the high end.

SOUND PRESSURE LEVELS AND DECIBELS

The amplitude of a sound determines its loudness. Loudness of sound increases and decreases with its amplitude. Sound pressure amplitude is measured in units of micro-Newton per square meter (N/rn^2), also called micro-Pascal (µPa). One µPa is approximately one-hundred billionth (0.00000000001) of normal atmospheric pressure. The pressure of a very loud sound may be 200 million µPa, or 10 million times the pressure of the weakest audible sound (20 µPa). Because expressing sound levels in terms of µPa would be very cumbersome, sound pressure level in logarithmic units is used instead to describe the ratio of actual sound pressures to a reference pressure squared. These units are called Bels, named after Alexander Graham Bell. To provide a finer resolution, a Bel is subdivided into 10 decibels, abbreviated dB.

A-WEIGHTED DECIBELS

Sound pressure level alone is not a reliable indicator of loudness. The frequency, or pitch, of a sound also has a substantial effect on how humans will respond. Although the intensity (energy

per unit area) of the sound is a purely physical quantity, the loudness or human response is determined by the characteristics of the human ear.

Human hearing is limited not only in the range of audible frequencies but also in the way it perceives the sound in that range. In general, the healthy human ear is most sensitive to sounds between 1,000 Hz and 5,000 Hz, and it perceives a sound within that range as more intense than a sound of higher or lower frequency with the same magnitude. To approximate the frequency response of the human ear, a series of sound level adjustments is usually applied to the sound measured by a sound level meter. The adjustments (referred to as a weighting network) are frequency-dependent.

The A-scale weighting network approximates the frequency response of the average healthy ear when listening to most ordinary sounds. When people make judgments of the relative loudness or annoyance of a sound, their judgments correlate well with the A-scale sound levels of those sounds. Other weighting networks have been devised to address high noise levels or other special situations (e.g., B-scale, C-scale, D-scale), but these scales are rarely, if ever, used in conjunction with highway traffic noise. Noise levels for traffic noise reports are typically reported in terms of A-weighted decibels (dBA). All sound levels discussed in this report are A-weighted. Examples of typical noise levels for common indoor and outdoor activities are depicted in Table B-1. The basic terminology and concepts of noise are described below, with technical terms defined in Table B-2 at the end of this section.

Table B-1: Typical Sound Levels in the Environment and Industry

Common Outdoor Activities	*Noise Level (dBA)*	*Common Indoor Activities*
—	110	Rock Band
Jet Fly over at 300 m (1000 feet)	100	—
Gas Lawn Mower at 1 m (3 feet)	90	—
Diesel Truck at 15 m (50 feet), at 80 km/hr (50 mph)	80	Food Blender at 1 m (3 feet) Garbage Disposal at 1 m (3 feet)
Noisy Urban Area, Daytime Gas Lawn Mower at 30 m (100 feet)	70	Vacuum Cleaner at 3 m (10 feet)
Commercial Area Heavy Traffic at 90 m (300 feet)	60	Normal Speech at 1 m (3 feet)
Quite Urban Daytime	50	Large Business Office Dishwasher Next Room
Quite Urban Nighttime	40	Theater, Large Conference Room (Back-ground)
Quite Suburban Nighttime	30	Library
Quite Rural Nighttime	20	Bedroom at Night, Concert Hall (Back-ground)

Table B-1: Typical Sound Levels in the Environment and Industry

Common Outdoor Activities	*Noise Level (dBA)*	*Common Indoor Activities*
—	10	Broadcast/Recording Studio
Lowest Threshold of Human Hearing	0	Lowest Threshold of Human Hearing

Source: Caltrans 1998

Addition of Decibels

Because decibels are logarithmic units, sound pressure levels cannot be added or subtracted by ordinary arithmetic means. For example, if one automobile produces a sound level of 70 dBA when it passes an observer, two cars passing simultaneously would not produce 140 dBA; they would, in fact, combine to produce 73 dBA. When two sounds of equal sound level are combined, they will produce a combined sound level three dBA greater than the original individual sound level. In other words, sound energy must be doubled to produce a three dBA increase. If two sound levels differ by 10 dBA or more, the combined sound level is equal to the higher sound level; in other words, the lower sound level does not increase the higher sound level.

Human Response to Changes in Noise Levels

Under controlled conditions in an acoustics laboratory, the trained, healthy human ear is able to discern changes in sound levels of one dBA when exposed to steady, single-frequency signals in the mid-frequency range. Outside such controlled conditions, the trained ear can detect changes of two dBA in normal environmental noise. It is widely accepted that the average healthy ear, however, can barely perceive noise level changes of three dBA. A change of five dBA is readily perceptible, and a change of 10 dBA is perceived as twice or half as loud. As discussed above, a doubling of sound energy results in a three dBA increase in sound, which means that a doubling of sound energy (e.g., doubling the volume of traffic on a highway) would result in a barely perceptible change in sound level.

Noise Descriptors

Leq: Additional units of measure have also been developed to evaluate the long-term characteristics of sound. The equivalent sound level (L_{eq}), is also referred to as the time-average sound level. It is the equivalent steady state sound level which in a stated period of time would contain the same acoustical energy as the time-varying sound level during the same time period. The one-hour A-weighted equivalent sound level, $L_{eq}(h)$, is the energy average of the A-weighted sound levels occurring during a one-hour period.

CNEL: People are generally more sensitive and annoyed by noise occurring during the evening and nighttime hours. Thus, another noise descriptor used in community noise assessments termed the Community Noise Equivalent Level (CNEL) was introduced. The CNEL scale represents a time-weighted 24-hour average noise level based on the A-weighted sound level. CNEL accounts for the increased noise sensitivity during the evening (7:00 p.m.–10:00 p.m.) and nighttime hours (10:00 p.m.–7:00 a.m.) by adding five and ten decibels, respectively, to the average sound levels occurring during these hours.

Sound Propagation

Sound propagation (i.e., the passage of sound from a noise source to a receiver) is influenced by several factors. These factors include geometric spreading, ground absorption and atmospheric effects, as well as shielding by natural and/or manmade features, as described below.

Geometric spreading: Sound from a small, localized source (i.e., a point source) radiates uniformly outward as it travels away from the source in a spherical pattern. The sound level attenuates (or drops off) at a rate of six dBA for each doubling of distance. Highway noise is not a single, stationary point source of sound. The movement of the vehicles on a highway makes the source of the sound appear to emanate from a line (i.e., a line source) rather than a point. This line source results in cylindrical spreading rather than the spherical spreading that occurs from a point source. The change in sound level from a line source is three dBA per doubling of distance.

Ground absorption: Most often the noise path between the highway and the observer is very close to the ground. Noise attenuation from ground absorption and reflective wave canceling adds to the attenuation associated with geometric spreading. Traditionally, the excess attenuation has also been expressed in terms of attenuation per doubling of distance. This approximation is done for simplification only; for distances of less than 60 meters (200 feet) prediction results based on this scheme are sufficiently accurate. For acoustically hard sites (i.e., those sites with a reflective surface, such as a parking lot or a smooth body of water, between the source and the receiver), no excess ground attenuation is assumed. For acoustically absorptive or soft sites (i.e., those sites with an absorptive ground surface, such as soft dirt, grass, or scattered bushes and trees, between the source and the receiver), an excess ground attenuation value of 1.5 dBA per doubling of distance is normally assumed. When added to the geometric spreading, the excess ground attenuation results in an overall drop-off rate of 4.5 dBA per doubling of distance for a line source.

Atmospheric effects: Research by Caltrans and others has shown that atmospheric conditions can have a significant effect on noise levels. The most significant meteorological parameters are wind speed and direction, and temperature gradients. Humidity and air turbulence also can have significant effects. Receptors located downwind from a source can be exposed to increased noise levels relative to calm conditions, whereas locations upwind can have lower noise levels. Increased sound levels can also occur as a result of temperature inversion conditions (i.e., increasing temperature with elevation).

Shielding by natural or human-made features: A large object or barrier in the path between a noise source and a receiver can substantially attenuate noise levels at the receiver. The amount of attenuation provided by this shielding depends on the size of the object and the frequency content of the noise source. Natural terrain features (e.g., hills and dense woods) and human-made features (e.g., buildings and walls) can substantially reduce noise levels. Walls are often constructed between a source and a receiver specifically to reduce noise. A barrier that breaks the line of sight between a source and a receiver will typically result in at least five dBA of noise reduction. A taller barrier may provide as much as 20 dBA of noise reduction.

Table B-2: Acoustical Terms and Definitions

Term	*Definition*
Ambient Noise Level	The composite of noise from all sources near and far. The normal or existing level of environmental noise at a given location.
A-Weighted Sound Level, dBA	The sound pressure level in decibels as measured on a sound level meter using the A-weighted filter network. The A-weighting filter de-emphasizes the very low and very high frequency components of the sound in a manner similar to the frequency response of the human ear and correlates well with subjective reactions to noise.
Background Noise	The total of all noise in a system or situation, independent of the presence of the noise source of interest (i.e., without the noise of interest).
Community Noise Equivalent Level, CNEL	CNEL is the average equivalent A-weighted sound level during a 24-hour day. CNEL accounts for the increased noise sensitivity during the nighttime (10 PM to 7 AM) and evening (7 PM to 10 PM) by adding ten dB to the sound levels at night and five dB to the sound levels during the evening.
Decibel, dB	A unit for measuring sound pressure level and is equal to 10 times the logarithm to the base 10 of the ratio of the measured sound pressure squared to a reference pressure, which is 20 micropascals.
Equivalent Continuous Sound Level, L_{eq}	The sound level corresponding to a steady state sound level containing the same total energy as a time varying signal over a given sample period. Leq is designed to average all of the loud and quiet sound levels occurring over a time period.
L_x Statistical Descriptors (x= 1-99; e.g., L_1, L_{10}, L_{50})	The sound level exceeded x percent of a specific time period. L_{10} is the level exceeded 10% of the time; L_{50} is the level exceeded 50% of the time.
Maximum A-weighted Sound Level, L_{max}	The greatest sound level measured on a sound level meter during a designated time interval or event.

B.2 APPLICABLE NOISE REGULATIONS AND STANDARDS

Various regulations and plans have been adopted by the City and State. These documents and standards are listed in Table B-3.

Table B-3: Existing Regulations, Plans and Standards

Regulation	*Description*
California Environmental Quality Act (CEQA)	CEQA considers exposure to excessive noise an environmental impact. Implementation of CEQA ensures that during the decision-making stage of development, City officials and the public will be informed of

Table B-3: Existing Regulations, Plans and Standards

Regulation	*Description*
	any potentially excessive noise levels and available mitigation measures to reduce them to acceptable levels.
California Noise Insulation Standards (California Code of Regulations, Title 24)	Title 24 establishes an interior noise standard of 45 dBA for multiple unit and hotel/motel structures. Acoustical studies must be prepared for proposed multiple unit residential and hotel/motel structures within the Community Noise Equivalent Level (CNEL) noise contours of 60 dBA or greater. The studies must demonstrate that the design of the building will reduce interior noise to 45 dBA CNEL or lower.
City of San Diego General Plan (Noise Element)	The purpose of the Noise Element is to protect people living and working in the City of San Diego from excessive noise. The Noise Element provides background information regarding noise, identifies noise planning goals and policies, establishes desired noise level criteria, and other related regulations and plans to implement the noise element.
The City of San Diego Noise Abatement and Control Ordinance (Municipal Code Section 59.5.0101 et seq.)	Provides controls for excessive and annoying noise from sources such as refuse vehicles, parking lot sweepers, watercraft, animals, leaf blowers, alarms, loud music, and construction activities.

The City's noise compatibility guidelines are shown on Table B-4 for evaluating land use noise compatibility when reviewing proposed land use development projects. A compatible land use indicates that standard construction methods will attenuate exterior noise to an acceptable indoor noise level and people can carry out outdoor activities with minimal noise interference. For land uses indicated as conditionally compatible, structures must be capable of attenuating exterior noise to the indoor noise level as shown on Table B-4. For land uses indicated as incompatible, new construction should generally not be undertaken. Due to severe noise interference, outdoor activities are unacceptable and for structures, extensive mitigation techniques are required to make the indoor environment acceptable.

Within the Proposed project, the most frequently encountered regulations are from the CEQA, California Noise Insulation Standards, City of San Diego General Plan Noise Element and City of San Diego Noise Ordinance.

Table B-4: Land Use – Noise Compatibility Guidelines Land Use Category

Land Use Category	**Exterior Noise Exposure (dBA CNEL)**				
	60	*65*	*70*	*75*	
Open Space and Parks and Recreational					
Community & Neighborhood Parks; Passive Recreation					
Regional Parks; Outdoor Spectator Sports, Golf Courses; Athletic Fields; Outdoor Spectator Sports, Water Recreational Facilities; Horse Stables; Park Maint. Facilities					
Agricultural					
Crop Raising & Farming; Aquaculture, Dairies; Horticulture Nurseries & Greenhouses; Animal Raising, Maintenance & Keeping; Commercial Stables					
Residential					
Single Units; Mobile Homes; Senior Housing		**45**			
Multiple Units; Mixed-Use Commercial/Residential; Live Work; Group Living Accommodations **For uses affected by aircraft noise, refer to Policies NE-D.2. & NE-D.3.*		**45**	**45***		
Institutional					
Hospitals; Nursing Facilities; Intermediate Care Facilities; Kindergarten through Grade 12 Educational Facilities; Libraries; Museums; Places of Worship; Child Care Facilities		**45**			
Vocational or Professional Educational Facilities; Higher Education Institution Facilities (Community or Junior Colleges, Colleges, or Universities)		**45**	**45**		
Cemeteries					
Sales					
Building Supplies/Equipment; Food, Beverages & Groceries; Pets & Pet Supplies; Sundries, Pharmaceutical, & Convenience Sales; Wearing Apparel & Accessories			**50**	**50**	
Commercial Services					
Building Services; Business Support; Eating & Drinking; Financial Institutions; Assembly & Entertainment; Radio & Television Studios; Golf Course Support			**50**	**50**	
Visitor Accommodations		**45**	**45**	**45**	
Offices					
Business & Professional; Government; Medical, Dental & Health Practitioner; Regional & Corporate Headquarters			**50**	**50**	
Vehicle and Vehicular Equipment Sales and Services Use					
Commercial or Personal Vehicle Repair & Maintenance; Commercial or Personal Vehicle Sales & Rentals; Vehicle Equipment & Supplies Sales & Rentals; Vehicle Parking					
Wholesale, Distribution, Storage Use Category					

Table B-4: Land Use – Noise Compatibility Guidelines Land Use Category

Land Use Category	**Exterior Noise Exposure (dBA CNEL)**				
	60	*65*	*70*	*75*	
Equipment & Materials Storage Yards; Moving & Storage Facilities; Warehouse; Wholesale Distribution					
Industrial					
Heavy Manufacturing; Light Manufacturing; Marine Industry; Trucking & Transportation Terminals; Mining & Extractive Industries					
Research & Development				**50**	

	Compatible	Indoor Uses	Standard construction methods should attenuate exterior noise to an acceptable indoor noise level. Refer to Section I.
		Outdoor Uses	Activities associated with the land use may be carried out.
	Conditionally Compatible	Indoor Uses	Building structure must attenuate exterior noise to the indoor noise level indicated by the number for occupied areas. Refer to Section I.
		Outdoor Uses	Feasible noise mitigation techniques should be analyzed and incorporated to make the outdoor activities acceptable. Refer to Section I.
	Incompatible	Indoor Uses	New construction should not be undertaken.
		Outdoor Uses	Severe noise interference makes outdoor activities unacceptable.

Source: City of San Diego General Plan – March 2008