innovative noise control

Canyon Springs Car Wash Noise Study

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1. Introduction

The following report provides a noise assessment of the proposed Canyon Springs car wash located at 6281 Canyon Springs Parkway, Riverside, California. Noise emissions from the blower equipment were assessed in relation to the noise requirements outlined in the City of Riverside Municipal Code. The project site is located on the northwestern corner of the intersection of Valley Springs Parkway and Corporate Centre Place in Riverside, California as shown in Figure 1–A.

The following is provided in this report:

- A brief introduction of the fundamentals of noise
- Review of the City of Riverside Municipal Codes and applicable noise limits
- A discussion of the noise modeling methodology and results
- An assessment of the blower equipment noise levels in relation to the City of Riverside Municipal Code.

Figure 1–A Location of the Canyon Springs Car Wash

2. Noise Fundamentals

Noise is defined as unwanted sound. Noise can be generated by man-made sources, for example traffic and construction, or natural sources such as thunder and wildlife calls. Excessive noise has the potential to cause negative effects on humans including speech interference, hearing damage, emotional and behavioral stress, sleep deprivation as well as increased blood pressure and heart rate. As well as humans, excess noise can negatively affect animals by potentially leading to habitat relocation or loss of habitat, behavioral stress, communication interference, hearing loss and lower reproduction rates. The following subsections present the fundamental concepts used commonly in noise analyses.

2.1 Sound Pressure Levels and the Decibel Scale

Sound is generated by pressure waves in air that are perceived by the human ear as our sense of hearing. Changes in air pressure can be used to measure sound, however these air pressure changes can vary, most commonly, in orders of magnitude from 20μPa to 200 Pa. As a more convenient method to measure sound pressure levels and reduce the need to analyze values in several orders of magnitude, these numbers are converted to a logarithmic scale known as the Decibel Scale (dB). Examples of common sound levels are shown in Figure 2–A.

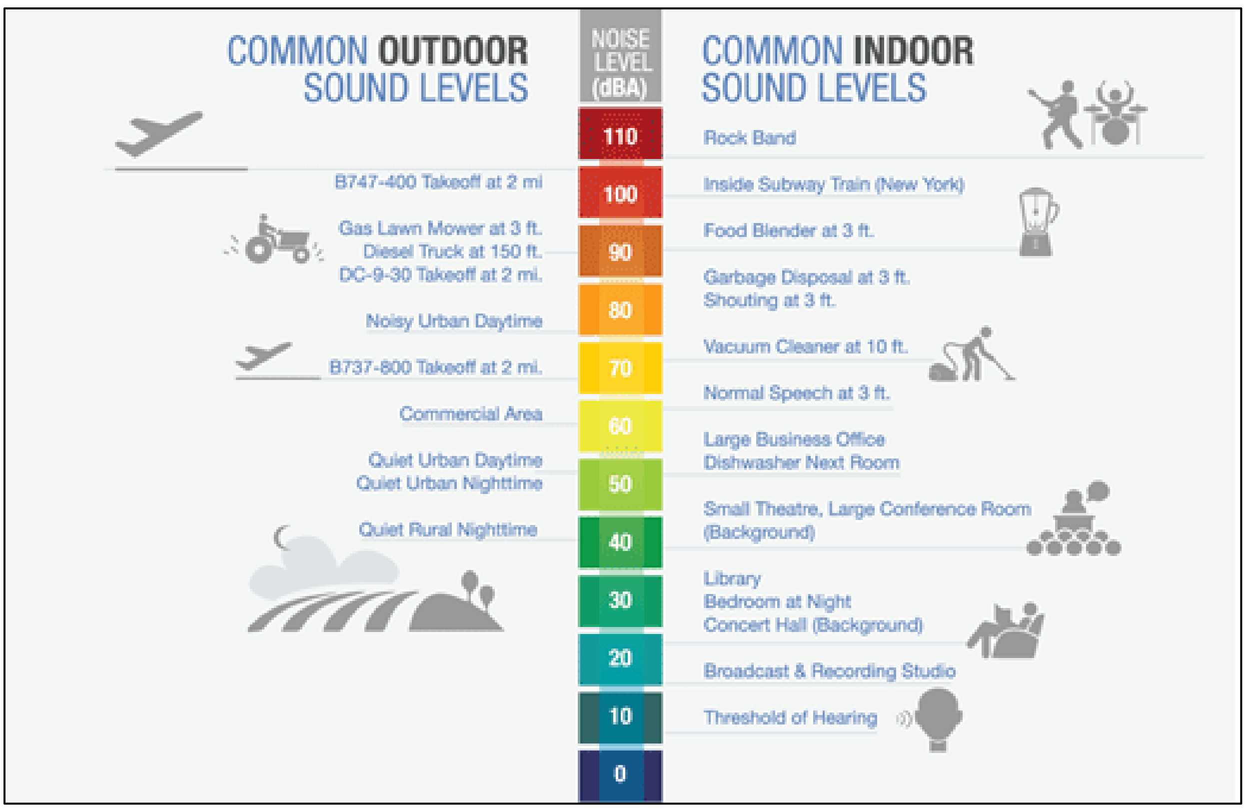

Figure 2–A Common Outdoor and Indoor Sound Pressure Levels

2.2 Frequency and the A-weighting Scale

The character of sound can often be described as low pitch such as a hum, high pitch such as a shriek or a mixture of low and high sounds. Scientifically, this perception can be described in terms of frequency. Frequency is measured in Hz and is defined as the number of wave cycles per second. A healthy, young human ear is capable of hearing frequencies between 20 Hz to 20,000 Hz. Low frequency sounds such as naturally occurring ocean waves or the sound output of subwoofers, propagate more efficiently though air than higher frequency sounds. This is why at distance, these sources of sound can be heard as a low rumble but up close, higher frequencies are audible.

As the human ear is not equally sensitive to sound levels within the audible frequency spectrum (20-20kHz), the A-weighting scale is often applied to measured sound levels. The A-weighting scale was developed to approximate the frequency sensitivity of the human ear. At frequencies up to approximately 1,000 Hz, the A-weighting scale reduces the sound levels in comparison to the unweighted equivalent. At frequencies between approximately 1,000 Hz and 5,000 Hz, where the human ear is more sensitive, the A-weighting scale increases the otherwise unweighted sound levels. At frequencies below 1,000 Hz, where the human ear is less sensitive, the A-weighting scale decreases the otherwise unweighted sound levels. When the A-weighting scale has been applied to a decibel level, the unit of measurement is often shown as dBA or dB(A). The graph in Figure 2–B shows the constants that can be applied to the unweighted scale to calculate a sound level in the A-weighting scale.

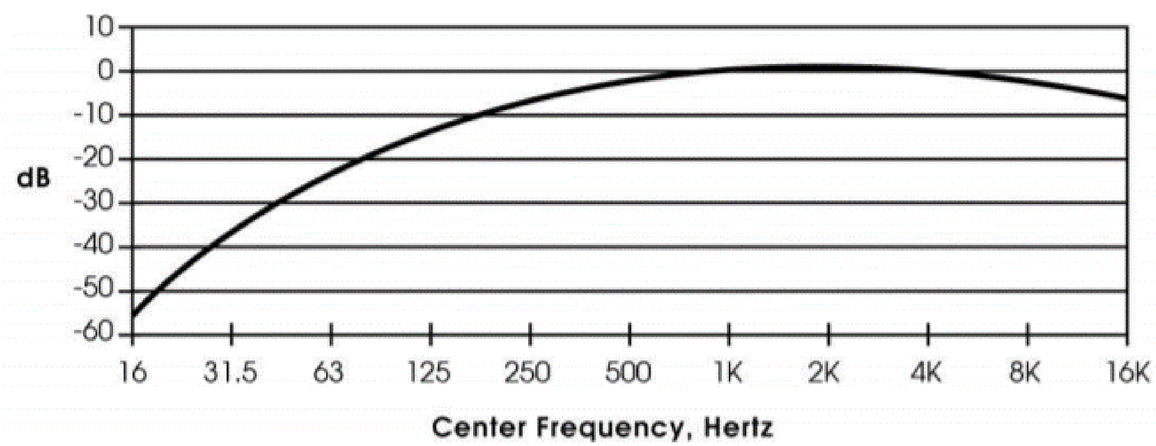

Figure 2–B The A-weighting Scale

3. City of Riverside Noise Standards

The car wash noise study was developed to evaluate operational noise levels at adjacent residential properties in terms of the City of Riverside Municipal Code. Chapter 7.25 Nuisance Exterior Sound Level Limits states:

> **7.15.010 Exterior sound level limits.**
>
> A. "Unless a variance has been granted as provided in this chapter, it shall be unlawful for any person to cause or allow the creation of any noise which exceeds the following:
>
> 1. The exterior noise standard of the applicable land use category, up to five decibels, for a cumulative period of more than 30 minutes in any hour; or
> 2. The exterior noise standard of the applicable land use category, plus five decibels, for a cumulative period of more than 15 minutes in any hour; or
> 3. The exterior noise standard of the applicable land use category, plus ten decibels, for a cumulative period of more than five minutes in any hour; or
> 4. The exterior noise standard of the applicable land use category, plus 15 decibels, for the cumulative period of more than one minute in any hour; or
> 5. The exterior noise standard for the applicable land use category, plus 20 decibels or the maximum measured ambient noise level, for any period of time.

Table 7.25.010A Exterior Noise Standards.

Land Use Category	Time Period	Noise Level
Residential	Night (10 p.m. to 7 a.m.) Day (7 a.m. to 10 p.m.)	45 dBA 55 dBA
Office/commercial	Any time	65 dBA
Industrial	Any time	70 dBA
Community Support	Any time	60 dBA
Public Recreation Facility	Any time	65 dBA
Nonurban	Any time	70 dBA

The car wash site is surrounded by a gas station to the northwest, a Sam's Club parking lot to the west, a vacant lot to the south and Valley Springs Parkway to the east. It is noted that the adjacent properties are not noise sensitive as there are no occupied areas that could be affected by noise from the car wash. The car wash blower equipment runs for 25 seconds in a two-minute car wash cycle. The blowers therefore run for a maximum of 12.5 minutes in any hour. Based on the exterior noise standards 7.15.010.A.3, the noise limit applicable to the adjacent property lines is the exterior noise standard plus 10 decibels. As the area is located in a commercial zone, the noise limit at the adjacent property lines is 75 dBA.

4. Canyon Springs Car Wash Noise Modeling

4.1 Noise Modeling Methodology

The noise modeling was completed using three-dimensional computer noise modeling software SoundPLAN version 8.0. The calculation method used was international standard ISO 9613-2 Attenuation of Sound During Propagation Outdoors. Using this standard, sound pressure levels are calculated based on distance, frequency spectra, topography, air absorption, reflectivity of the ground and shielding by barriers or buildings. The predicted noise levels represent only the contribution of the car wash blowers operating and do not include ambient noise or noise from other facilities. Actual field sound level measurements may vary from the modeled noise levels due to other noise sources such as traffic, other facilities, other human activity, or environmental factors.

4.2 Car Wash Operational Sound Levels

Sound level data utilized in the noise model were based on manufacturer sound data provided by Sandhu Enterprises. Using this data, a noise model was created to predict the constant, steady-state noise levels at the site and adjacent surroundings. The equipment sound power levels used in the modeling are shown in Table 4-A.

Table 4-A Equipment Quantity and Sound Power Level

Equipment	Quantity	Individual Component Sound Power Level (dBA)
Hanna Hess Blower	8	109.0

4.3 Car Wash Building Specifications

As the blowers are proposed to be enclosed in the car wash building, the sound transmission loss of the building components were included in the modeling. The transmission loss of the building components are shown in Table 4-B.

Table 4-B Building Component Sound Transmission Loss

Component	Specification	63 Hz	125 Hz	250 Hz	500 Hz	1 kHz	2 kHz	4 kHz
Wall (STC 46)	2x6 wood stud 16 inch O.C. with insulation in cavity and a plaster finish	15	20	36	45	50	51	55
Glass (STC 25)	Minimum thickness 3/32 inch	14	18	16	21	37	46	49

The car entry and exit were modeled as open areas because access doors would only be closed outside of operating hours.

4.4 Noise Sensitive Receptors

The noise sensitive receptors have been chosen to be consistent with the requirements of the City of Riverside Municipal Codes noise standards. Noise sensitive receptors were placed at the nearest property lines adjacent to the car wash facility. The modeled locations of the receptors can be seen in Figure 4–A.

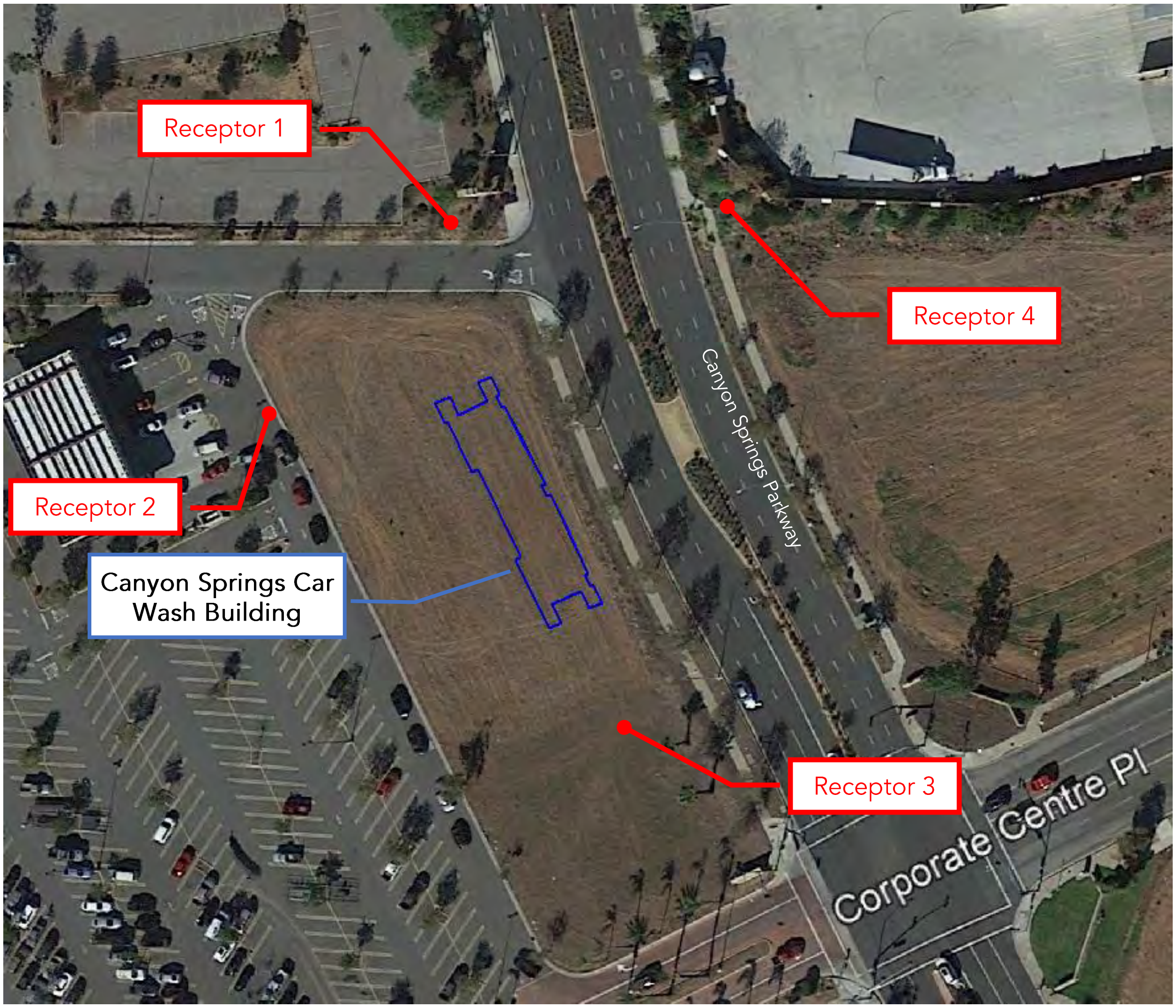

Figure 4–A Receptor Locations

4.5 Noise Modeling Results

The results of the noise modeling are presented in Table 4-C. The locations in the table correspond to the locations identified in Figure 4–A. The predicted noise levels represent only the contribution of the car wash blowers and do not include ambient noise or noise from other facilities. Actual field sound level measurements may vary from the modeled noise levels due to other noise sources such as traffic, other facilities, other human activity, or environmental factors.

Table 4-C Canyon Springs Car Wash Noise Modeling Results (dBA)

Location	Canyon Spring Car Wash Modeled Sound Pressure Levels
Receptor 1	74.0
Receptor 2	71.6
Receptor 3	73.3
Receptor 4	65.3

The results of the noise modeling indicate that the sound pressure levels at the receptors due to the car wash blowers operating are between 65.3 dBA and 74.0 dBA. The sound pressure levels at the property lines adjacent to the car wash are therefore below the City of Riverside noise limit of 75 dBA. The results of the noise modeling are also presented as a noise contour map in Figure 4–B. The noise contours are provided in 5 dB increments with the color scale indicating the sound level of each contour.

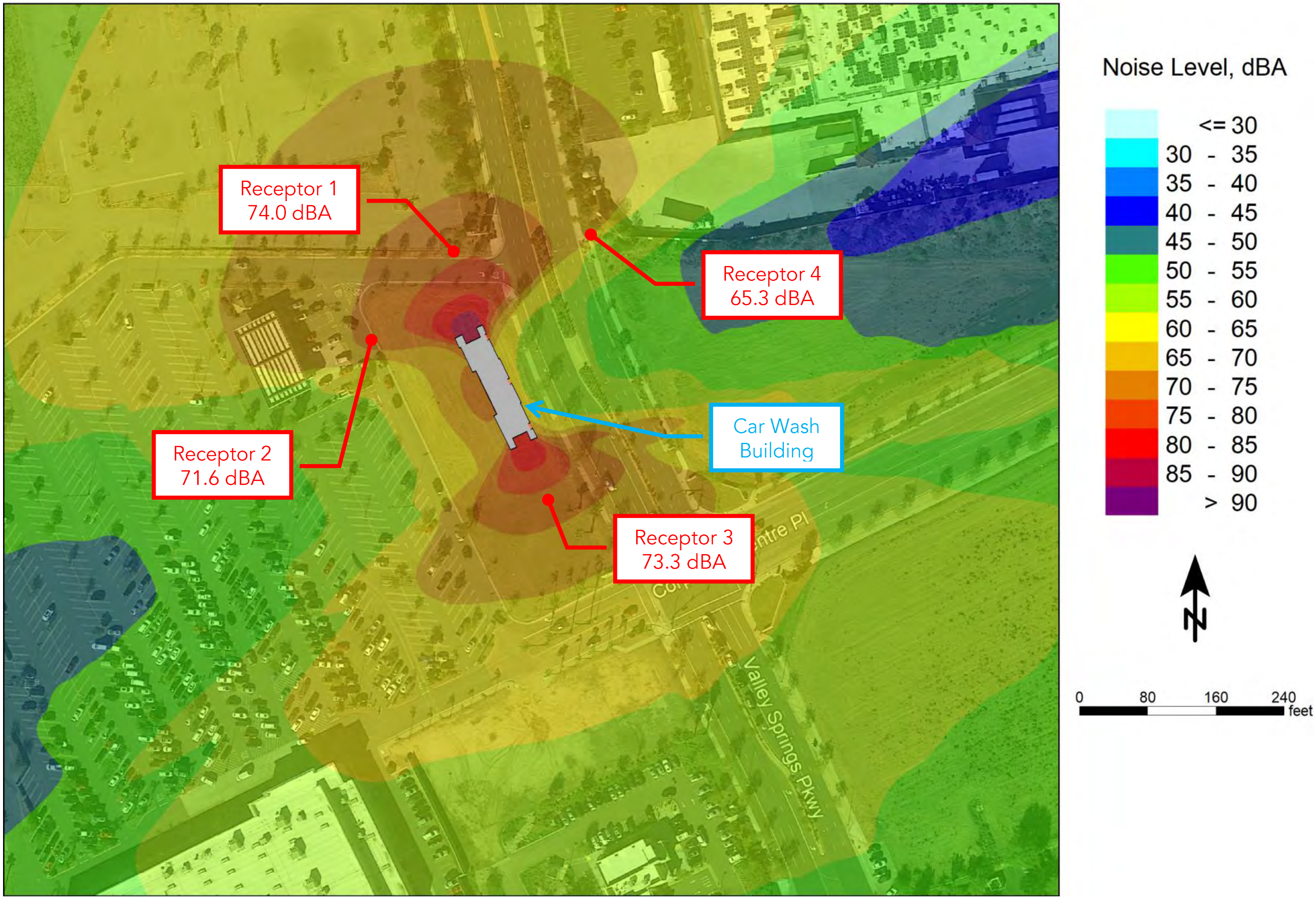

Figure 4–B Unmitigated Canyon Springs Car Wash Operational Noise Contour Map (dBA)

5. Conclusion

A noise assessment of the proposed Canyon Springs car wash located at 6281 Canyon Springs Parkway, Riverside, California. Noise levels due to the blower equipment were assessed in terms of the City of Riverside Municipal Code Chapter 7.25 Nuisance Exterior Sound Level Limits.

Using manufacturer data, a noise model was used to predict noise levels from the car wash operation. The results of the noise modeling are presented in Table 5-A.

Table 5-A Canyon Springs Car Wash Noise Modeling Results (dBA)

Location	Canyon Spring Car Wash Modeled Sound Pressure Levels
Receptor 1	74.0
Receptor 2	71.6
Receptor 3	73.3
Receptor 4	65.3

The results of the noise modeling indicate that the sound pressure levels at the receptors due to the car wash blowers operating are between 65.3 dBA and 74.0 dBA. The sound pressure levels at the property lines adjacent to the car wash are therefore below the City of Riverside noise limit of 75 dBA.

Appendix I

Glossary of Acoustical Terms

Absorption: The attenuation of sound caused by conversion of sound energy into other forms of energy, usually heat, within a medium. Absorption is a property of the medium. In noise barrier material, absorption can be considered the complement of reflection. A perfectly absorptive material does not reflect any sound energy, and a nonabsorptive (i.e., reflective) material reflects almost all sound energy. In either case, a small portion of sound energy is transmitted through the barrier and continues in roughly the same direction as the incident noise propagation. In typical highway traffic noise barriers, the sound energy passing through is less than 1% of the incident noise energy. See also "Transmission Loss."

Absorption Coefficient: A term that approximately equals the ratio of sound energy absorbed by a material to the energy incident on the material. Absorption coefficients range from 0 (no absorption) to 1 (perfect absorption). In highway noise barriers, material with an absorption coefficient of 0 will reflect back almost all incident noise energy, and material with a coefficient of 1 will not reflect back any sound energy. The absorption coefficient depends on material, sound frequency, and angle of incidence.

Absorptive Grounds: Types of ground, such as normal earth and most grounds with vegetation, that are absorptive to sound energy and that reverse the phase of reflected energy at grazing angles of incidence. See also "Soft Sites" and "Ground Effects."

Acoustics: The broad field of science that deals with the production, propagation, reception, effects, and control of sound, both audible and inaudible to the human ear, and occurring in all media.

Airborne Sound: Sound that reaches the point of interest primarily by propagation through the air. Ambient Noise: All-encompassing noise at a given place and time. This is usually a composite of sounds from all sources near and far, including any specific sources of interest.

Amplitude: The strength or magnitude of the pressure of a sound wave.

Anechoic Chamber: A room that has boundaries designed to absorb nearly all of the sound incident on them, producing a test room that is essentially free from reflected sound, and simulates free field conditions for the limited space defined by the room's boundaries.

Angle of Diffraction: The angle through which sound energy is diffracted as it passes over the top of a noise barrier and proceeds toward the receiver. Receivers deeper into the shadow zone have larger angles of diffraction and therefore higher barrier attenuation. See also "Diffraction" and "Shadow Zone." Angle of Incidence: The angle formed by the radial line of sound waves striking a surface at a specific location and the plane of that surface. See also "Angle of Reflection."

Angle of Reflection: The angle formed by the radial line of sound waves reflecting off a surface at a specific location and the plane of that surface. See also "Angle of Incidence."

Atmospheric Effects: Sound absorption by air molecules and water vapor, sound refraction caused by temperature and near-ground wind gradients, and air turbulence are collectively called atmospheric effects. Although atmospheric effects are mostly responsible for substantial noise fluctuations at distant receivers, they also can have a significant effect at distances within 330 feet.

Audible Spectrum: The frequency range normally associated with human hearing, usually considered between 16 and 20,000 Hz. For noise control purposes, the audible spectrum of interest usually lies between 20 and 10,000 Hz.

Average Level: Typically the energy-averaged noise level in decibels, wherein the contributing levels are first converted to relative energies or energy ratios, and added and divided by the number of contributing levels. The result is then converted back to decibels.

A-Weighted Sound Level: Expressed in dBA or dB(A). Frequency weighted sound pressure level approximating the frequency response of the human ear. It is defined as the sound level in decibels measured with a sound level meter having the metering characteristics and a frequency weighting specified in the American National Standards Institute Specification for Sound Level Meters, ANSI S 1.4–1983. The A-weighting de-emphasizes lower frequency sound sounds below 1,000 Hz (1 kHz) and higher frequency sounds above 4 kHz. It emphasizes sounds between 1 and 4 kHz. A-weighting is the most commonly used measure for traffic and environmental noise throughout the world.

Background Noise: The total noise in a system or situation independent of the presence of (i.e., without) the noise source of interest.

Baffle: A shielding structure or series of partitions used to increase the effective external transmission path length between two points in an acoustic system.

Band: See "Frequency Band."

Band Center Frequency: The designated geometric mean frequency of a band of noise.

Band Pressure Level: The SPL contained within a specified band.

Barrier Attenuation: The noise reduction from barrier diffraction only.

Broadband Noise: Noise with components over a wide range of frequencies.

Calibrator: A device used to calibrate or properly adjust for valid measurement results a sound level meter and microphone system. Calibration must be performed before and after the sound level measurement sequence.

Community Noise Equivalent Level: A noise level that accounts for all the A-weighted noise energy from a source during 24 hours, and weights the evening (7 p.m. to 10 p.m.) and night (10 p.m. to 7 a.m.) noise by adding 5 and 10 dBA, respectively, during these periods.

Compression: The portion of a sound wave in which the air molecules are slightly compressed with respect to the barometric air pressure. The opposite of rarefaction.

Cylindrical Divergence: Sound waves generated by a line source, such as approximated by a highway, tend to form cylindrical wavefronts that propagate by radiating outward from their original line source in cylindrical pressure waves of ever-increasing areas. This process is referred to as cylindrical divergence or spreading. The same sound energy distributed over an ever-increasing cylindrical area is responsible for reducing the sound's energy per unit area (i.e., intensity) by half for each doubling of distance. This corresponds with a noise level decrease of 3 dB per doubling of distance.

Cycles per Second: See "Hertz."

Day-Night Level: See "Ldn."

Decibel: A decibel is one-tenth of a bel. It is a measure on a logarithmic scale that indicates the squared ratio of sound pressure to a reference sound pressure (unit for sound pressure level) or the ratio of sound power to a reference sound power (unit for sound power level). See also "Sound Pressure Level" and "Sound Power Level."

Descriptor: A generic term for a noise indicator such as Leq, Lmax, or Ldn.

Diffuse Sound Field: A sound field in which the time average of the mean square sound pressure is the same everywhere and the flow of acoustic energy in all directions is equally probable. For example, a sound source in a reverberation room, where many reflected sound waves are present and the sound level is equal at any location in the room.

Diffraction: The bending of sound pressure waves around an obstacle. The ease with which the pressure waves diffract around an obstacle depends on the ratio of wavelength to the size of the obstacle. Pressure waves with a given wavelength diffract more readily around a small object than a large one. Pressure waves with longer wavelengths diffract more easily around an object of a given size than pressure waves with a shorter wavelength. Because of the above principles, highway traffic noise barriers provide a more defined noise "shadow" behind the barrier and more noise attenuation for higher-frequency noise than lower-frequency noise. See also "Angle of Diffraction" and "Shadow Zone."

Doppler Effect: The change in observed frequency of a sound wave caused by a time rate of change in the effective path length between the sound source and receiver. If the path length rate of change causes the source and receiver to approach each other, the observed frequency shifts upward. If the source and receiver recede relative to each other, the frequency shifts downward. The frequency shift is called the Doppler shift, and the unit is hertz.

Dosimeter: An instrument measuring noise exposure for compliance with OSHA standards.

Dynamic Range: The range in sound levels, in decibels, through which a source or receiver can emit or receive sound. For example, the dynamic range of a sound level meter typically ranges from 20 to 140 dB.

Energy Average: The result of energy averaging or a method of averaging various SPLs based on their squared pressures. This method involves the conversion of decibels to equivalent relative energy or energy ratios, averaging the values, and changing the values back to decibels.

Energy Ratio: See "Relative Energy."

Equivalent Level: See "Leq."

Excess Attenuation: Sound attenuation in addition to that caused by geometric spreading. It is usually meant to be the attenuation from ground effects and sometimes atmospheric effects. See also "Geometric Spreading," "Ground Effects," and "Atmospheric Effects."

Existing Noise Levels: The noise resulting from the natural and mechanical sources and human activity considered to be usually present in a particular area.

Far Field: The region beyond the near field, where the effects of source dimensions are less important and noise propagates with a simple relationship between sound level and distance.

Filter: A device for separating components of a signal based on their frequency. It allows components in one or more frequency bands to pass relatively unattenuated and attenuates components in other frequency bands.

Flanking Noise: Refers to noise energy that arrives at an observer by an unexpected or unexamined pathway.

Flow Resistivity: A measure of the acoustical absorption of the ground located between a sound source and receiver.

Free Field: A sound field that is free from enclosures or boundaries, and in which there are no reflections and accompanying interference and reverberation effects such as found in auditoriums.

Frequency: The number of oscillations per second of a periodic wave sound and of a vibrating solid, expressed in units of hertz, formerly cycles per second (cps). 1 Hz = 1 cps = 1 oscillation per second. The value is the reciprocal (1/x) of the period of oscillations in seconds. The symbol for frequency is f.

Frequency Band: An interval of the frequency spectrum defined between an upper and lower cutoff frequency. The band may be described in terms of these two frequencies or (preferably) by the width of the band and the geometric mean frequency of the upper and lower cutoff frequencies (e.g., an octave band "centered" at 500 Hz).

Frequency Response: The response to an oscillating phenomenon (e.g., sound pressure) by an object (e.g., microphone or ear) measured in decibels as a function of frequency. For example, the A-weighting curve corresponds closely to the frequency response of human hearing at a certain constant level of sound energy. See also "A-Weighted Sound Level."

Frequency Spectrum: The description of a sound wave's resolution into components of different frequency and usually different amplitude and phase.

Fundamental Frequency: The frequency with which a periodic function (e.g., sound wave) reproduces itself, sometimes called the first harmonic. See also "Harmonic."

Geometric Divergence: Refers to the shape of sound pressure wavefronts and the manner in which they propagate. Geometric divergence or spreading is a generic term used for specific types of divergence, such as cylindrical or spherical divergence. See also "Cylindrical Divergence" and "Spherical Divergence."

Gradient: Variation of speed of sound, temperature, and wind velocity with height above the ground surface. A gradient in speed of sound can be caused by differences in temperature with height above the ground or differences in wind velocities with height above the ground. The speed of sound gradient in turn causes atmospheric refraction of sound which can create noise "shadows" (i.e., decreases) in certain areas and noise concentrations (i.e., increases) in others. See also "(Atmospheric) Refraction."

Ground Effects: The effects of sound grazing absorptive ground. See also "Absorptive Grounds."

Hard Site: Term used for reflective characteristics of the ground surface between a noise source and receiver. The term is most often used in traffic noise prediction models, where it is associated with a 3 dB per doubling of distance line source attenuation (because of geometric spreading only, without excess attenuation).

Harmonic: A sinusoidal (i.e., pure-tone) component whose frequency is a whole-number multiple of the fundamental frequency of the wave. If a component has a frequency twice that of the fundamental frequency, it is called the second harmonic.

Hertz: Unit of frequency, formerly called cycles per second. 1 Hz = 1 cps. See also "Frequency."

Hourly Equivalent Sound Level: See "Leq(h)."

Incident Sound: Direct sound striking a surface. See also "Angle of Incidence."

Infrasound: A sound with a frequency less than the audible sound spectrum (i.e., generally lower than 16 to 20 Hz).

Insertion Loss: The actual noise level reduction at a specific receiver from construction of a noise barrier between the noise source (e.g., traffic) and the receiver. Generally, it is the net effect of the barrier attenuation and loss of ground effects.

Inverse Square: The increasing of sound amplitude from the process of spherical divergence from a point source. See also "Spherical Divergence." For a point source, the sound pressure level SPL1 at distance D1 is related to the sound pressure level SPL2 at a distance of D2 as follows: SPL1 – SPL2 = 10log(D1 / D2) 2 kHz: Abbreviation for kilohertz, or 1,000 Hz. See also "Hertz."

Ldn: Abbreviation for the day-night level noise descriptor. It is the energy average of the A-weighted sound levels occurring during a 24-hour period, with 10 dB added to the A-weighted sound levels occurring from 10 p.m. to 7 a.m.

Leq: The equivalent steady-state sound level that in a stated period of time would contain the same acoustical energy as the time-varying sound level during the same period.

Leq(h): The energy-average of the A-weighted sound levels occurring during a 1-hour period in decibels (i.e., a 1-hour Leq). See also "Leq."

Level: In acoustics, the value of a logarithm of the ratio or ratio squared of that quantity t a reference quantity of the same kind in decibels. The base of the logarithm is commonly 10. The reference quantity and kind of level must be specified (e.g., sound pressure level of 60 dB RE: 20 μPa, sound power level RE: 10-12 W).

Line of Sight: A straight line between the observer's location and a specific noise source.

Line Source: A source of noise spread out into a line, such as approximated by the combined traffic on a roadway.

Lmax: The highest SPL in a specific time period.

Logarithm: A mathematical operation that, for values more than 1, condenses these values into smaller values through the reverse of yx , where x is the number being operated on. Normally, the base, or value of y, is taken as 10 (common log). If the base is not specified, its value is usually considered 10.

Loudness: The judgment of intensity of a sound in terms of which sounds may be ranked on a scale from soft to loud. On this scale, a doubling of a reference sound energy is barely perceptible to the human ear, a tripling of the sound energy is readily perceptible, and 10 times the sound energy is about twice as loud. Decreasing the sound by the same factors has a reciprocal effect—reducing the reference sound energy to one-tenth of the original energy the sound is perceived as half as loud. Although loudness depends primarily on the intensity of the sound, it also depends on the sound's frequency and wave form.

Loudness Level: Defined as the median SPL in a specified number of trials of a 1,000-Hz tone that is judged equally loud to the listener as the sound in question. Described in units of phons.

Lx: The sound pressure level exceeded x percent of a specific time period. For example, L10 is the level exceeded 10% of the time, and L50 is the level exceeded 50% of the time.

Masking: The action of bringing one sound, audible when heard by itself, to inaudibility or unintelligibility by the introduction of another sound.

Medium: A substance carrying a sound wave, such as air, water, or steel.

Meter Response: Measure of the quickness with which the needle of an analog sound level meter or the display of a digital sound level meter follows changes in the actual sound level.

Microphone: An electroacoustic transducer that transforms sound waves into equivalent electric waves.

Natural Frequency: Frequency of free oscillation of a system (i.e., the frequency at which a system vibrates when given an initial excitation and allowed to vibrate freely without constraints).

Near Field: The part of a sound field, usually within about two wavelengths of the lowest sound frequency from a sound source, in which the dimensions of the sound source have an important effect and where there is no simple relationship between sound level and distance. For traffic noise, the near field usually exists within 25 feet of the nearest traffic. Noise measurements or predictions should be avoided in the near field.

Noise: Sound that is loud, unpleasant, unexpected, or otherwise undesirable.

Noise Barrier: A generic term for any feature that blocks or diminishes sound in its path from the source to receiver. Although the term can technically refer to any feature, manmade or natural, the two most common features included in noise barriers are soundwalls and earth berms. Almost all noise barriers in California are soundwalls; therefore, the terms "noise barrier" and "soundwall" are frequently interchanged, although soundwalls are a subset of noise barriers. See also "Soundwalls" and "Earth Berms."

Noise Contour: An imaginary line shown on a plan along which all sound levels are equal.

Noise Floor: The level of noise, in decibels, that represents the threshold of sensitivity for a sound level meter and below which the inherent (i.e., device's own) noise limits its detectability of low-level signals.

Noise Reduction Coefficient: A value representing the arithmetic average of the absorption coefficients in four octave bands with respective center frequencies of 250, 500, 1,000, and 2,000 Hz.

Octave: The interval between two sounds having a frequency ratio of 1:2; (e.g., 500 to 1,000 Hz; 440 to 880 Hz).

Octave Band: A frequency band in which the interval between the upper and lower cutoff frequency is one octave. As with all frequency bands, the octave band is usually described by its center frequency. Octave bands are centered by preferred frequencies described by ISO R 266. An example is the 500-Hz octave band. See also "Frequency Band."

One-Third Octave: The interval between two sounds having a frequency ratio of the cube root of 2 (approximately 1.26). Three contiguous onethird octaves cover the same frequency range as an octave.

One-Third Octave Band: A frequency band in which the interval between the upper and lower cutoff frequency is one-third of an octave. As with all frequency bands, the one-third octave band is usually described by its center frequency. Three contiguous octave bands make up one octave band. As with octave bands, one-third octave bands are centered by preferred frequencies described by ISO R 266. For example, three one-third octave bands centered at 400, 500, and 630 Hz make up the 500-Hz octave band. See also "Frequency Band."

Overall Level: The SPL that includes all the energy in all frequency bands of interest.

Pascal: A unit of pressure (in acoustics, normally rms sound pressure) equal to 1 Newton per square meter (N/m2). The pascal is abbreviated Pa. A reference pressure for a sound pressure level of 0 dB is 20 μPa.

Peak Sound Level: See "Peak Sound Pressure Level."

Peak Sound Pressure: The maximum instantaneous (i.e., non-rms) sound pressure for a transient or impulsive sound of short duration or in a specified time interval for a sound of long duration. The unit is pascals.

Peak Sound Pressure Level: Level of peak sound pressure. The unit is decibels with stated frequency weighting, if any. See also "Peak Sound Pressure" and "Sound Pressure Level."

Permanent Threshold Shift: Permanent hearing loss from frequent exposures to noise of high intensities. See also "Temporary Threshold Shift."

Phon: Unit of loudness judged or calculated in definition of loudness level. See also "Loudness Level."

Pink Noise: Broadband noise that yields the same energy for each octave band over its entire range of frequencies. Because, going from low to high frequencies, each subsequent octave band contains twice the frequency range as the previous band, the energy decreases with increasing frequency to maintain equal energy per octave band. Compare with white noise.

Point Source: A noise source essentially concentrated at a single point from which noise propagates outward in all directions. A single vehicle observed from some distance can be approximated as a point source. See also "Spherical Divergence" and "Spreading."

Propagation: The passage of sound energy from a noise source to receiver through a medium (e.g., air).

Pure Tone: A sound wave whose waveform is a sine wave (single frequency).

Random Incidence: Refers to sound waves that strike the receiver randomly from all angles of incidence. Such waves are common in a diffuse sound field.

Random Noise: Noise that has random characteristics in both time and amplitude (i.e., any occurrence of any amplitude is as likely to occur at any one moment as any other).

Rarefaction: The portion of a sound wave in which the air molecules are rarefied or in a slight vacuum with respect to the barometric air pressure. The opposite of compression.

Rate of Decay: The time rate at which SPL decreases at a given receiver after the sound source is turned off. The commonly used unit is decibels per second (dB/s). It is used in measuring reverberation time of a room. See also "Reverberation" and "Reverberation Time."

Receiver: Most basically defined as any natural or artificial sensor that can perceive, register, or be affected by sound (e.g., human ear, microphone). When modeling noise, a receiver is a point in the model that represents a single receptor or multiple receptors (defined below). For example if three single-family residences are in an area where acoustic conditions are the same, each residence is a receptor. For more modeling purposes the three residences can be represented by a single receiver in the model.

Receptor: Most basically defined as any natural or artificial sensor that can perceive, register, or be affected by sound (e.g., human ear, microphone).

Reference Pressure: Any sound pressure to which a test pressure is being compared on a decibel scale. Also, the sound pressure at 1,000 Hz that normal young adults can just detect, taken as 20 μPa.

Reflection: Bouncing back of sound waves away from an object that is larger in exposed section than the wavelengths and of sufficient surface weight, density, and stiffness to present a very large increase in impedance compared to the surrounding air.

Reflective Ground: Grounds that do not absorb sound energy and reflect back most of the energy. Examples are paved surfaces (e.g., asphalt, concrete) and hard-packed soils. The opposite of absorptive ground.

Refraction: The bending of sound waves in arcing curves either downward or upward because of different velocities of sound with respect to height above the ground. The sound velocity differences are caused either by differences in near-ground wind velocity from wind shear, or vertical changes in temperature (sound velocity increases with air temperature). Downward refraction occurs for downwind sound propagation and during near-ground temperature inversions (temperature increases with height), and is responsible for noise increases. Upward refraction occurs for upwind sound propagation and during near-ground temperature lapses (temperature decreases with height), and is responsible for noise decreases.

Relative Energy: The energy ratio between a sound level and reference level. For example, the sound energy of 60 dB is 106 , or 1,000,000 times larger than that of 0 dB. The sound energy of 67 dB is 106.7, or 5,011,872 times larger than that of 0 dB.

Resonance: The relatively large amplitude of sound or vibration produced when the frequency of the source of the sound or vibration "matches" (i.e., synchronizes) with the natural frequency of vibration of an object. See also "Natural Frequency."

Resonator: A device that resounds or vibrates in sympathy with a source of sound and vibration (i.e., the source frequency matches the natural frequency of the resonator).

Reverberant Field: The region in a room where the reflected sound dominates, as opposed to the noise source where the direct sound dominates.

Reverberation: The persistence of sound in an enclosed space, because of multiple reflections, after the sound source has stopped.

Reverberation Room: A room having a long reverberation time, especially designed to make a sound field inside it as diffuse as possible. Also called a live room. The opposite of an anechoic chamber. See also "Anechoic Chamber."

Reverberation Time: The time taken for the sound energy to decrease to one millionth, corresponding to a drop of 60 dB in SPL, of its steady-state value when the sound source is suddenly stopped. It is a measure of the persistence of an impulsive sound in a room and of acoustical absorption present inside the room.

Root Mean Square Pressure: The square root of the mean of the squares of a set of instantaneous positive, negative, or zero pressure amplitudes. The rms value is calculated by squaring the pressure values at each instant, adding them, dividing the total by the number of values, and taking the square root of the result. The squaring of both the positive and negative values ensures a positive result. An rms sound pressure is directly correlated with sound energy.

Shadow Zone: The area behind a noise barrier that is blocked from direct view of the source of noise.

Shielding: A noise reduction at the receiver because of the placement or existence of natural or artificial barriers (e.g., walls, berms, rows of buildings, or trees, if thick and dense enough).

Sine Wave: A sound wave, audible as a pure tone, in which the sound pressure is a sinusoidal function of time.

Soft Site: See "Absorptive Ground."

Sound: A vibratory disturbance created by a moving or vibrating source in the pressure and density of a gaseous, liquid medium or in the elastic strain of a solid that is capable of being detected by hearing organs. Sound may be thought of as mechanical energy of a vibrating object transmitted by pressure waves through a medium to the ears. The medium of main concern is air. Unless otherwise specified, sound will be considered airborne, not structureborne, earthborne, etc.

Sound Energy: See "Relative Energy."

Sound Insulation: The use of structures and materials designed to reduce the transmission of sound from one room or area to another, or from the exterior to interior of a building. Also, the degree by which sound transmission is reduced by means of sound-insulating structures and materials.

Sound Intensity: The average rate of sound energy transmitted in a specified direction through a unit area normal to this direction at a point considered.

Sound Level: Frequency-weighted SPL measured using metering characteristics and frequency weighting, such as A, B, or C, specified in the ANSI Specification for Sound Level Meters.

Sound Level Meter: An instrument used for measuring sound levels in a specified manner. It generally consists of a microphone, amplifier, output display, and frequency weighting networks.

Sound Power: The total amount of energy radiated into the atmosphere per unit time by a source of sound.

Sound Power Level: The level of sound power, averaged over a period of time, the reference being 10-12 watts.

Sound Pressure Level: Ten times the logarithm to the base 10 of the ratio of the time mean-square pressure of a sound, in a stated frequency band to the square of the reference sound pressure in gasses, of 20 μPa. SPL represents only unweighted rms levels. The unit is decibels. See also "Root Mean Square."

Source: A general term designating the sound energy generator. In transportation, noise sources are classified as point and line sources, which have different propagation characteristics. See also "Point Source" and "Line Source."

Source Heights: The effective acoustic height of noise sources. The heights represent the energy average of all subsources and are most important in evaluating noise barrier attenuation.

Sound Transmission Class: A single figure rating system designed to estimate sound insulation properties of a partition or a rank ordering of a series of partitions. It is intended for use primarily when speech and office noise constitutes the principal problem.

Spectrum: See "Frequency Spectrum."

Speed of Sound: The speed of sound for standard temperature of dry air at 32°F and standard air pressure of 29.29 inches Hg standard is 1,087.3 feet per second.

Spherical Divergence: Sound waves generated by a point source, such as approximated by a single vehicle, tend to form spherical wavefronts that propagate by radiating outward from their original point source in spherical pressure waves of ever-increasing areas. This process is referred to as "spherical divergence" or "spreading." The same sound energy distributed over an ever-increasing spherical area is responsible for reducing the sound's energy per unit area (intensity) by one-quarter for each doubling of distance. This corresponds with a noise level decrease of 6 dB per doubling of distance. See also "Cylindrical Divergence."

Spherical Wave: A sound wave in which the surfaces of constant phase are concentric spheres. A small (point) source radiating into an open space produces a free sound field of spherical waves.

Steady-State Sound: Sounds for which average characteristics remain constant in time (e.g., sound of an air conditioner, fan, or pump).

Structureborne Sound: Sound that reaches the receiver over at least part of its path by vibration of a solid structure.

Temporary Threshold Shift: A temporary hearing loss, evidenced by an increase in the threshold of audibility (see "Threshold of Audibility") occurring after exposure to noise of high intensity. After a given time, usually up to several hours, the ear recovers to almost normal, but not quite so. After an excessive number of exposures of high intensity a hearing loss, or permanent threshold shift develops gradually.

Threshold of Audibility: The minimum SPL at which a person can hear a specific sound for a specified fraction of trials.

Transducer: A device capable of being actuated by waves from one or more transmission systems or media, and supplying related waves to one or more other transmission systems or media (e.g., microphones, loud speakers, accelerometers, seismometers).

Transient Sound: Transient sounds are those whose average properties do not remain constant over time (e.g., aircraft flyover, passing train, sonic boom, gunshot).

Transmission Loss: The loss in sound energy at a specific frequency, expressed in decibels, as sound passes through a barrier or a wall. Transmission loss is not a reduction in total energy, only a transformation from sound energy into heat. Almost all highway noise barriers provide a loss of at least 25 dBA, which means that less than 1/3 of a percent of the sound energy travels through the wall.

Wave: In acoustics, a propagation wave is a cyclic pressure variation in air. The waves move at a characteristic speed (e.g., the speed of sound) through the medium (e.g., air) as an elastic response to a pressure perturbation at a source.

Wave Front: A portion of any wave, whether in compression or rarefaction state, that can be followed as it propagates throughout the medium, analogous to the crest of a tidal wave as it crosses the ocean. At all points on the wave front, the wave has equal amplitude and phase.

Wavelength: For a non-periodic wave, such as sound in air, the normal distance between analogous points of any two successive waves. The wavelength of sound in air or water is inversely proportional to the frequency of the sound. Therefore, the lower the frequency, the longer the wavelength.

White Noise: Broadband noise, the energy of which is constant over a wide range of frequencies (i.e., energy/Hz = constant). Because each octave band range increases by a factor of two, from low to high frequencies, each subsequent octave band contains twice the acoustical energy as the previous one. This corresponds to an increase of 3 dB in energy for each subsequent octave band. Compare with "Pink Noise."

Ultrasonic: Pertaining to sound frequencies above the audible sound spectrum (in general, more than 20,000 Hz).