SECTION 3 STUDY APPROACH

This section defines sound and noise, and discusses sound level descriptors and what affects sound levels. It also describes project coordination and how the traffic noise study was performed.

What are sound and noise?

Sound is created when objects vibrate, resulting in a minute variation in surrounding atmospheric pressure called *sound pressure*. The human response to sound depends on the magnitude of a sound as a function of its frequency and time pattern.[1] *Magnitude* is a measure of sound energy in the air. Noise is unwanted sound.

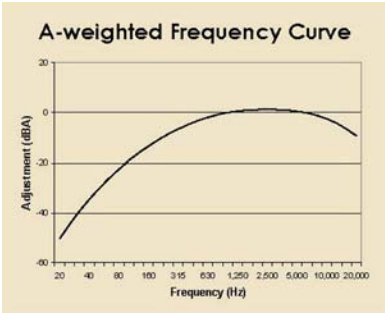
The range of magnitude, from the faintest to the loudest sound the ear can hear, is very large. The sound pressure near an airport runway is approximately one million times greater than a soft whisper. To accommodate this range, sound levels are expressed on a logarithmic scale in units called *decibels* (dB).

What is the logarithm scale?

Logarithm is the exponent that indicates the power to which a number must be raised to produce a given number.

For example: if $B^2 = N$, 2 is the logarithm of N (to the base B), or $10^2 = 100$ and the logarithm of 100 (to the base 10) = 2.

Humans respond to a sound's frequency or pitch. The human ear can very effectively perceive sounds with a frequency between approximately 500 and 5,000 Hertz (Hz). Humans' ability to perceive sounds decreases outside this range. Environmental sounds are composed of many frequencies, each occurring simultaneously at its own sound pressure level. Frequency weighting, which is applied electronically by a sound level meter, combines the overall sound frequency into one sound level that simulates how a typical person hears sounds. The commonly used frequency weighting for environmental sounds is A-weighting (dBA), which is the most similar to how humans perceive sounds of low to moderate magnitude.



Loudness, in contrast to sound level, refers to how people subjectively perceive a sound. This varies from person to person, but most people judge the relative loudness between sound levels similarly. The human ear can barely perceive a

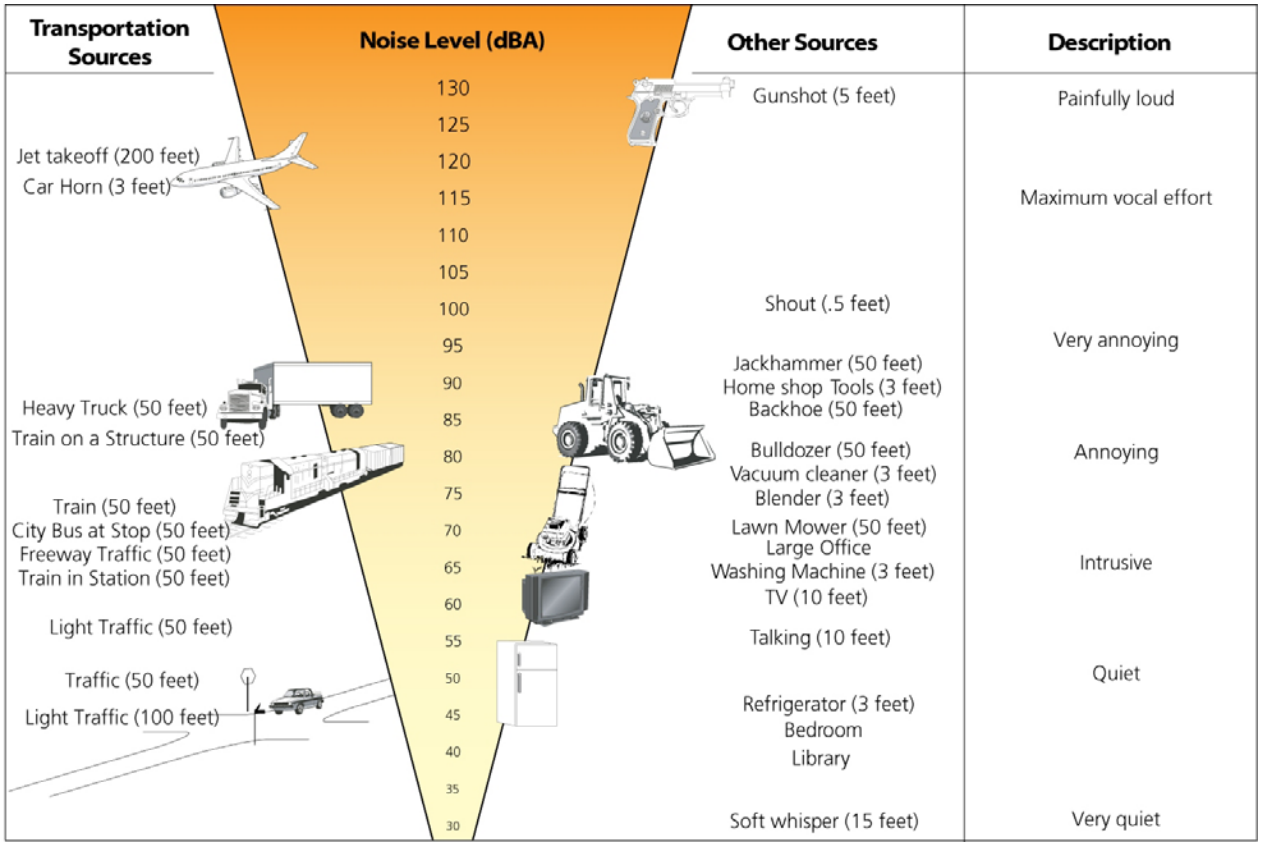
[1] *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety.* Report Number 550/9-74-004. EPA, 1974.

3-dBA increase, but a 5- or 6-dBA increase is readily noticeable and appears as if the sound is about one and one-half times as loud. A 10-dBA increase appears to be a doubling in sound level to most listeners.

What are typical sound levels and what affects them?

Exhibit 3-1 presents typical A-weighted sound levels from various sources. The sound environments described, from a quiet whisper or light wind at 30 dBA to a jet takeoff at 120 dBA, demonstrate the human ear's great range. A typical conversation ranges from 60 to 70 dBA.

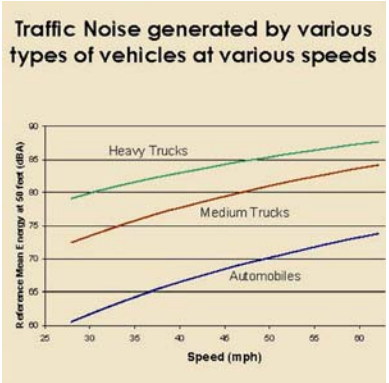
Exhibit 3-1: Typical Noise Levels



Sources of Sound

Because of the logarithmic decibel scale, a doubling of the number of sound sources (e.g., the number of cars operating on a roadway) increases sound levels by 3 dBA. A ten-fold increase in the number of sound sources adds 10 dBA. As a

result, a sound source emitting a sound level of 60 dBA combined with another sound source of 60 dBA yields a combined sound level of 63 dBA (not 120 dBA).



Noise levels from traffic sources depend on volume, speed, and vehicle type. An increase in volume, speed, or vehicle size generally increases traffic noise levels. Vehicular noise is a combination of noises from engines, exhaust, and tires. Defective mufflers, steep grades, and roadway surface materials and conditions also affect the generation of traffic noise.

The Effect of Distance

Sound levels decrease with distance from the source. For a line source such as a roadway, sound levels decrease 3 dBA over hard ground (concrete or asphalt, pavement) or 4.5 dBA over soft ground (grass) for every doubling of distance between the source and the receptor. For point sources such as construction sources, sound levels decrease between 6 and 7.5 dBA for every doubling of distance from the source.

The Effect of Terrain and Shielding

The propagation of sound can be greatly affected by terrain and the elevation of the receiver relative to the sound source, as shown in Exhibit 3-2. Depressed terrain dominates the study area.

What is a receiver?

A *receiver* is the location at which noise is measured (e.g., a residence, school, park, or church).

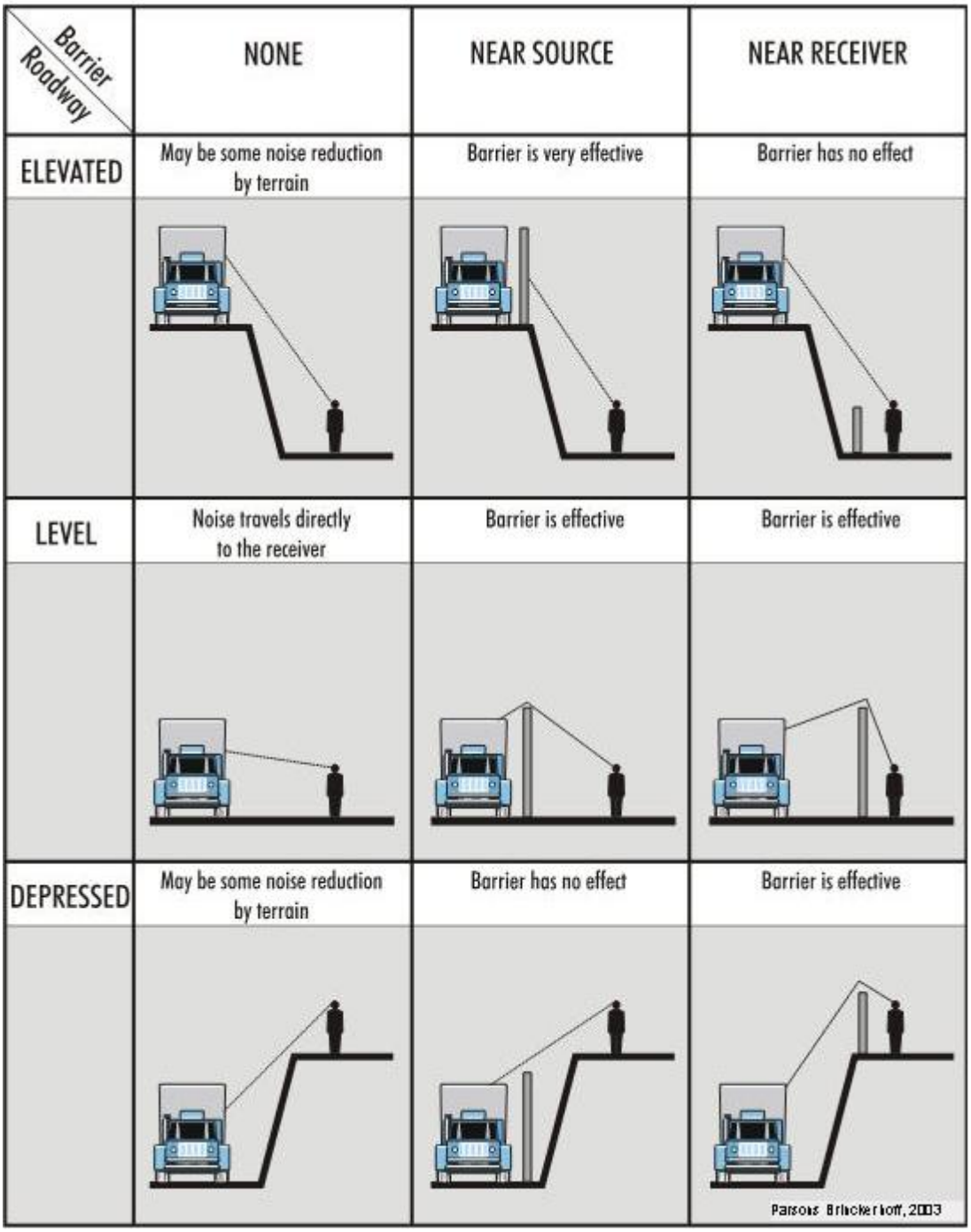
Level ground is the simplest scenario: sound travels in a straight line-of-sight path between the source and receiver. As shown in the bottom row of Exhibit 3-2, if the sound source is depressed or the receiver is elevated, sound will generally travel directly to the receiver. However, sound levels may be reduced if the terrain crests between the source and receiver and creates a partial sound wall near the receiver.

What is terrain?

Terrain is a term used to describe land features.

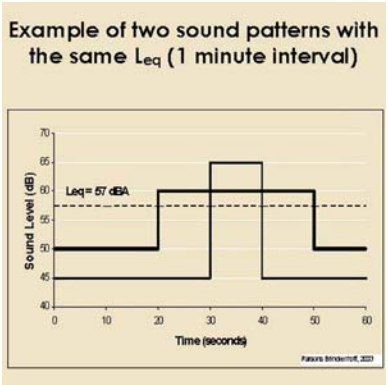
If the sound source is elevated or the receiver is depressed, sound may be reduced at the receiver by the edge of the roadway. Even a short wall such as a solid concrete safety barrier can effectively block sound transmission between the source and receiver (see the top row of Exhibit 3-2). If the line of sight between the receiver and the highest elevation of the sound source is broken, a noise reduction of approximately 5 dBA results.

Exhibit 3-2: Noise Barrier Effectiveness



How are sound levels described?

The equivalent sound level (L_{eq}) is widely used to describe noise in human environments. L_{eq} is a measure of average sound energy during a specified period of time. It is defined as the constant level that, over a given period of time, transmits to the receiver the same amount of acoustical energy as the actual time-varying sound. For example, two sounds, one containing twice as much energy but lasting half as long as the other, can have the same L_{eq} sound levels. L_{eq} measured over a 1-hour period is the hourly L_{eq} [L_{eq}(h)], which is used for highway noise impact and abatement analyses.



What are the effects of loud noises?

Prolonged exposure to high-intensity environmental noise directly affects human health by causing hearing loss. The U.S. Environmental Protection Agency (EPA) has established a protective level of 70 dBA L_{eq}(24). This protective sound level is set to conserve hearing for 40 years of exposure.[2]

What does L_{eq} (24) refer to?

L_{eq} (24) is the equivalent sound level measured over a period of 24 hours.

Although scientific evidence is not currently conclusive, noise is suspected of causing or aggravating other diseases. Environmental noise indirectly affects human welfare by interfering with sleep, thought, and conversation. The Federal Highway Administration (FHWA) noise abatement criteria (NAC) are based on speech interference, which is a well-documented effect that is relatively reproducible in human response studies. Noise can also disturb wildlife by disrupting communication, interfering with mating, and reducing the ability to obtain sufficient food, water, and cover.

What project coordination was performed?

The I-405 Team coordinated with federal, state, and local agencies and community members. Scoping meetings were held specifically for the Tukwila to Renton Project and general neighborhood meetings were held for the I-405 corridor program. This included consulting with FHWA, the City of Tukwila, and the City of Renton, and participation in community meetings with local residents. Residents received project information and provided input on the project and potential noise monitoring locations.

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[2] *Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety.* Report Number 550/9-74-004. EPA 1974.

What criteria are used to evaluate the project's potential effects on the acoustical environment?

Operational Noise Standards

Noise regulations and guidelines are the basis for evaluating potential noise effects. For state and federally funded highway projects, traffic noise effects occur when predicted L_{eq}(h) noise levels approach, meet, or exceed the FHWA NAC or substantially exceed existing noise levels.[3] Although the FHWA does not define "substantially exceed", WSDOT considers an increase of 10 to 14 dBA to be a Tier 1 substantial increase and an increase of 15 to 29 dBA to be a Tier 2 substantial increase.[4]

The FHWA NAC specify exterior and interior L_{eq} (h) noise levels for various land activity categories, as shown in Exhibit 3-3. All exterior noise-sensitive uses within the study area are Category B uses. WSDOT considers a noise impact to occur if predicted L_{eq} (h) noise levels approach within 1 dBA of the NAC listed in Exhibit 3-3. Therefore, if a noise level is 66 dBA or higher it approaches the FHWA NAC of 67 dBA for residences.

WSDOT defines severe traffic noise impacts as 80 dBA or more for Category B areas, or 30 dBA or more over existing traffic noise levels. Substantial noise levels are classified as Tier 1 (10 to 14 dBA over existing traffic noise levels) and Tier 2 (15 to 29 dBA over existing traffic noise levels), or as total highway noise levels between 76 and 79 dBA.

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[3] *Procedures for Abatement of Highway Traffic Noise and Construction Noise. Federal-Aid Highway Program Manual.* Volume 7, Chapter 7, Section 3. Washington, D.C. U.S. Department of Transportation, 1982, Noise Abatement Council.

[4] *Traffic Noise Analysis and Abatement Policy and Procedures.* Olympia, Washington. WSDOT, 2006.

Exhibit 3-3: FHWA Noise Abatement Criteria

Activity Category	L_{eq}(h) (dBA)	Description of Activity Category
A	57 (exterior)	Lands on which serenity and quiet are of extraordinary significance and serve an important public need, and where the preservation of those qualities is essential if the area is to continue to serve its intended purpose.
B	67 (exterior)	Picnic areas, recreation areas, playgrounds, active sports areas, parks, residences, motels, hotels, schools, churches, libraries, and hospitals.
C	72 (exterior)	Developed lands, properties, or activities not included in Categories A or B.
D	–	Undeveloped lands.

Source: USDOT, 1982.

The Washington State Department of Ecology (Ecology) regulates noise levels at property lines of neighboring properties (WAC Chapter 173-60-040). Traffic noise is exempt from property line noise limits, but these limits apply to construction noise during certain hours. The maximum permissible noise levels depend on the land uses of both the source noise and receiving property, as shown in Exhibit 3-4. King County, the City of Renton, and the City of Tukwila have adopted the State of Washington's property line standards with King County Code 12.88.020; Renton Municipal Code, Title 8, Chapter 7, Section 8-7-2; and Tukwila Municipal Code, Chapter 8.22.

Exhibit 3-4: Maximum Permissible Environmental Noise Levels

EDNA[1] of Noise Source	EDNA of Receiving Property		
	Residential	Commercial	Industrial
Residential	55	57	60
Commercial	57	60	65
Industrial	60	65	70

1. Environmental designation for noise abatement

Source: WAC 173-60-040.

The maximum permissible environmental noise level at residential receiving properties is reduced by 10 dBA between 10 p.m. and 7 a.m. Short-term exceedences above the permissible sound level are allowed. The maximum level may be exceeded by 5 dBA for a total of 15 minutes, by 10 dBA for a total of 5 minutes, or by 15 dBA for a total of 1.5 minutes during any 1-hour period, as shown in Exhibit 3-5.

Exhibit 3-5: Allowed Exceedences of the Maximum Permissible Noise

Duration of Exceedence	Allowed Exceedence	Statistical Descriptor	Equivalent L_{eq}(h) Increase
15 minutes	5 dBA	L_{25}	2 dBA
5 minutes	10 dBA	L_8	2 dBA
1.5 minutes	15 dBA	$L_{2.5}$	2 dBA

Source: WAC 173-60-040.

Considering the allowed short-term exceedences in Exhibit 3-5, the permissible hourly L_{eq} is approximately 2 dBA higher than the values in Exhibit 3-4. For example, a noise level of 57 dBA for 45 minutes and 62 dBA for 15 minutes (57 dBA + a 5-dBA exceedence) is permissible for noise from a commercial activity received by a residential property. This sound pattern has a L_{eq} (h) of 59 dBA.

Construction Noise Standards

Construction noise from projects within the state of Washington is exempt from Ecology property line regulations during daytime hours, but regulations apply to construction noise during nighttime hours (10 p.m. to 7 a.m. weekdays and 10 p.m. to 8 a.m. weekends). Performance of construction activities during nighttime hours will require noise variances from the City of Renton and the City of Tukwila.

How was the noise study performed?

Ambient noise levels were measured for 15-minute periods at 15 locations near the study area. These measurements help describe the existing noise environment, identify major noise sources in the study area, validate the noise model, and characterize the weekday background environmental noise levels. Appendix A describes the results of these measurements.

Measurement locations characterize the variety of noise conditions and represent other sensitive receptors near the proposed project. Baseline (year 2014) and future noise levels for the No Build (year 2030) and Build (design year 2030) alternatives were modeled at all of the 15-minute noise measurement locations. These noise levels were also modeled at 46 additional locations that may potentially be affected by the project. 2005 was evaluated as the existing year to be consistent with this project's transportation analysis. 2014 was evaluated as the baseline year to correspond with a completed Renton Nickel Improvement Project.

Traffic Noise Prediction

The FHWA Traffic Noise Model (TNM) Version 2.5 computer model[5] was used to predict L_{eq}(h) traffic noise levels. TNM provides precise estimates of noise levels at discrete points, by considering interactions between different noise sources and topographical features. This model estimates acoustic intensity at receiver locations, calculated from a series of straight-line roadway sections. Noise emissions from each roadway are calculated based on the number of automobiles, medium trucks, and heavy trucks per hour; vehicular speed; and the reference noise emission levels of an individual vehicle. TNM also considers the effects of intervening walls, topography, trees, and atmospheric absorption.

Why don't the highest noise levels occur during rush hour?

Small changes in vehicle speed have a greater effect on noise than small changes in traffic volume. Therefore, the loudest traffic noise levels are often not experienced during rush hour. During rush-hour traffic, vehicle speeds decrease and traffic volumes increase, resulting in lower traffic noise levels.

Noise from sources other than traffic is not included. When non-traffic noise such as aircraft noise is considerable in an area, TNM under-predicts the actual noise level. Because the project effects only depend on traffic noise levels, under-predicting the total environmental noise level does not affect the study's findings.

The I-405 Team's noise specialists imported base maps and design files into the TNM package. Major roadways, topographical features, buildings, and sensitive receptors were digitized into the model. Elevations for the area surrounding the project were added from the 2-foot contour data. Elevations for planned improvements were taken from design profiles, proposed cross-sections, and proposed cut-and-fill limits.

[5] FHWA, 2005.

Analysis of Project Effects

Predicted noise levels were based on the loudest traffic hour of the day (when volumes are high but not congested) to estimate worst-case noise levels.

Traffic analysis for the year 2005 shows that existing traffic volumes on this portion of I-405 are at capacity for part of the day. I-405 traffic volumes in 2030 are expected to increase over existing volumes and will be at or near the roadway's capacity for the Build and No Build alternatives.

For use in TNM, the No Build Alternative assumed the same traffic volume on I-405 as the Baseline Conditions model during the loudest hour. The Build Alternative added 1,750 vehicles to baseline conditions loudest-hour traffic volumes on I-405 in areas where an extra lane will be built. For other roadways in the study area, predicted future traffic volumes were used. This approach ensures that the loudest traffic hour is represented in the model, because small changes in vehicle speed have a greater effect on noise than small changes in traffic volume. The Build Alternative noise model included all project elements including: bridge replacements and additions; improvements to the SR 181, SR 167, and SR 169 interchanges; construction of a split diamond interchange at Lind Avenue and Talbot Road; general-purpose direct access between southbound I-405 and southbound SR 167; HOV direct access between SR 167 and I-405; and the replacement of Cedar and Renton Avenues on Renton Hill.

The traffic volumes and vehicle mix were based on the *Tukwila to Renton Project Transportation Discipline Report*.[6] The modeled sites represented similar receptors in the area, although noise levels at adjacent receptors may be different because of terrain or distance.

What is WSDOT's Noise Abatement Criteria (NAC) level?

Noise levels approach, meet, or exceed the noise abatement criteria (NAC) at 66 dBA. Noise mitigation must be evaluated when noise levels reach 66 dBA.

Noise Mitigation Analysis

The I-405 Team's noise specialists compared predicted noise levels to the FHWA NAC and counted the receptors affected by the Build Alternative. At receptors where noise levels were modeled to approach, meet, or exceed the NAC, noise specialists evaluated whether mitigation measures could reduce traffic noise substantially enough to warrant the cost of barrier construction. This evaluation was based on WSDOT

[6] *I-405, Tukwila to Renton Project Transportation Discipline Report*, WSDOT, 2007.

feasibility and reasonableness criteria (a detailed discussion of WSDOT feasibility and reasonableness criteria is provided in the *Measures to Avoid or Minimize Effects* section of this report). Noise barriers were evaluated using TNM in all areas where noise effects predicted to result from this project could be mitigated by a noise barrier.

The I-405 Team's noise specialists evaluated the effectiveness of noise barriers at the outermost boundary of the right-of-way.

How was construction noise analyzed?

Construction noise was assessed using EPA reference levels. The analysis was based on noise levels from construction equipment typically used on this type of project. Noise levels were assessed at various distances from the construction site. Potential measures to reduce disturbance caused by construction noise were evaluated and are described in the *Measures to Avoid or Minimize Effects* section of this report.

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