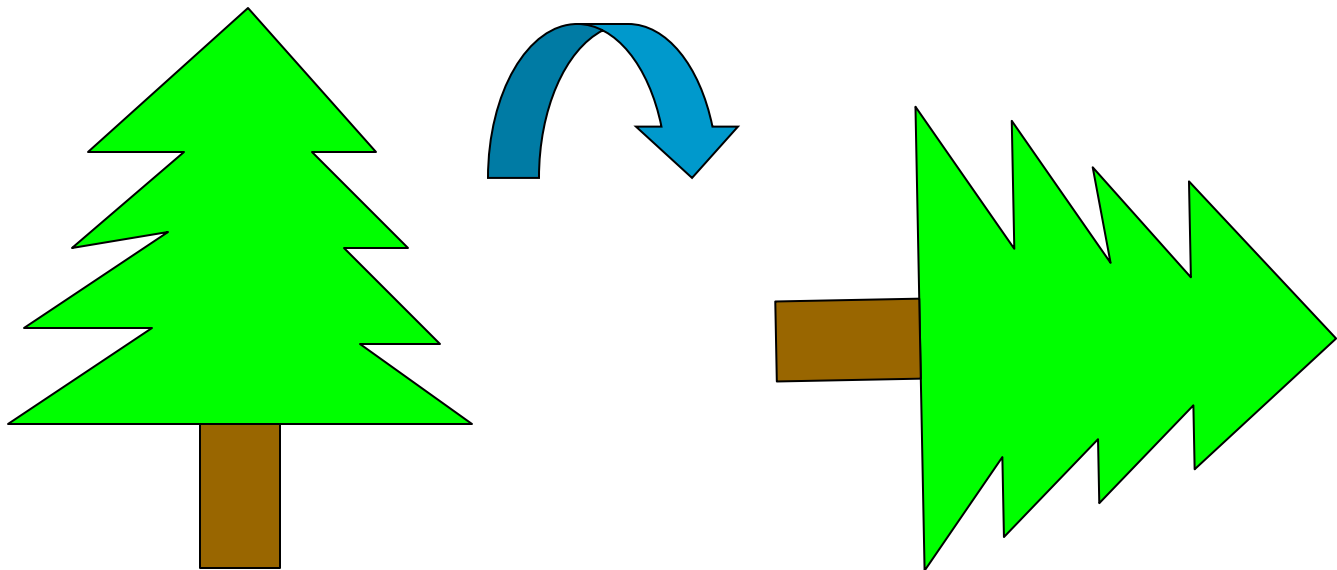




BASICS OF ACOUSTICS

PRESENTED BY: JAY WALDSCHMIDT, P.E.
WisDOT Noise & Air Quality Engineer

If a tree falls in the forest
and nobody is there to hear
it, does it make a sound???



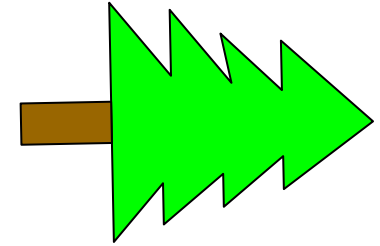


NO!

To have SOUND you need:

■ SOURCE

(Sound Pressure)



■ PATH

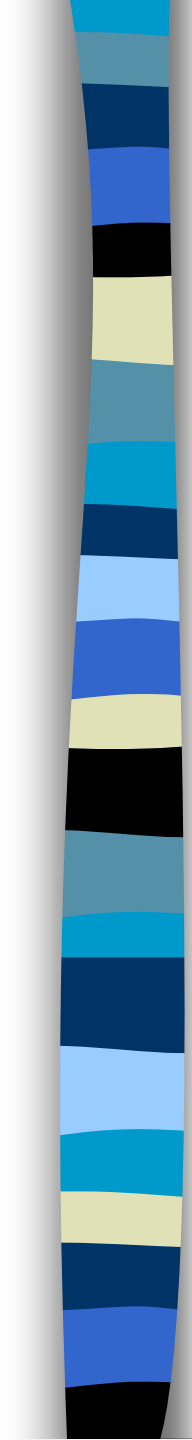
(Air, Water, Solid, Etc.)



■ RECEPTOR

(Person, Animal, Etc.)





What does
70 dBA L_{eq}
mean?



SOUND CRITERIA

■ LOUDNESS	→	dB
■ FREQUENCY	→	A
■ DURATION	→	L_{eq}
■ SUBJECTIVITY	→	Noise



Criteria 1: LOUDNESS

Sound Pressure is expressed in

Micropascals (μPa)

$20 \mu\text{Pa}$ \rightarrow $200,000,000 \mu\text{Pa}$

(Threshold of Hearing)

(Threshold of Pain)



Sound Pressure Level is expressed in

Decibels (dB)

$$\text{dB} = 10 \log_{10} [(P/P_0)^2]$$

P_0 = Reference Pressure (20 μPa)

P = Sound Pressure

$$10 \log_{10} [(63,246 \mu\text{Pa}/20 \mu\text{Pa})^2] = \underline{70 \text{ dB}}$$

DECIBEL ADDITION

How much is
70 dB + 70 dB?



140 dB?

WRONG!!!



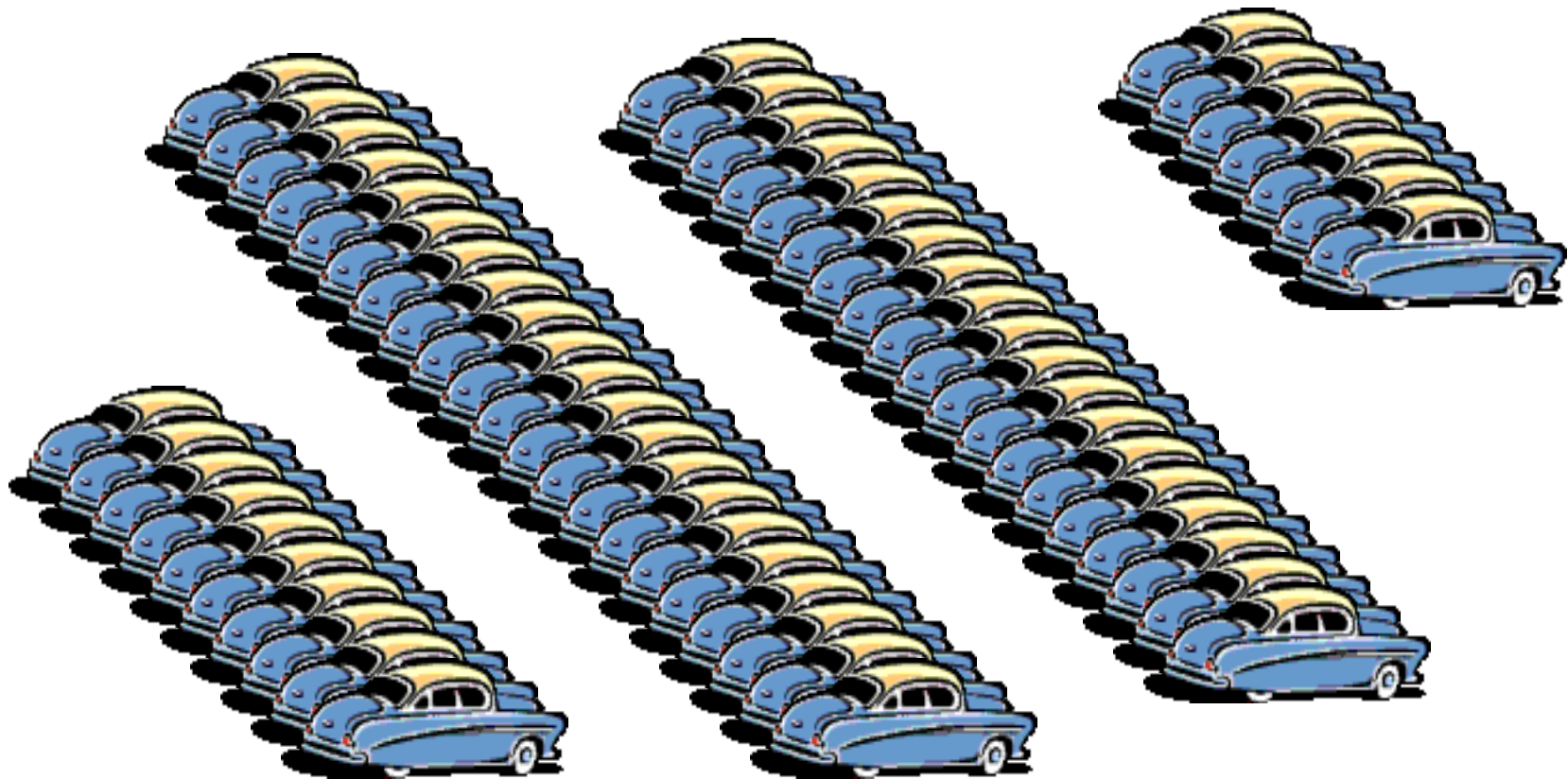
$$10 \log_{10} [(63,246 \mu\text{Pa}/20 \mu\text{Pa})^2 + (63,246 \mu\text{Pa}/20 \mu\text{Pa})^2] = \underline{73.1 \text{ dB}}$$

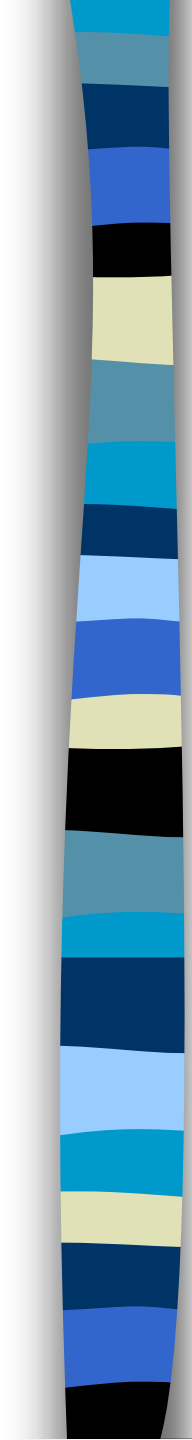


JAY'S FIRST LAW
OF THE BASICS OF ACOUSTICS

WHEN YOU ADD
TWO SIMILAR SOURCES
YOU INCREASE BY 3 dB

At what point does adding one more similar source not make a difference to the Loudness?




$$60 \text{ dB} + 60 \text{ dB} = 63 \text{ dB}$$

$$+ 60 \text{ dB} = 65 \text{ dB}$$

$$+ 60 \text{ dB} = 66 \text{ dB}$$

$$+ 60 \text{ dB} = 67 \text{ dB}$$

$$= 68 \text{ dB} \leftarrow + 60 \text{ dB} = 68 \text{ dB} \rightarrow$$
$$+ 60 \text{ dB} = 69 \text{ dB}$$

$$+ 60 \text{ dB} = 70 \text{ dB}$$

$$+ 60 \text{ dB} = 70 \text{ dB}$$

70 dB



60 dB



$$10 \log_{10} [(63,246 \mu\text{Pa}/20 \mu\text{Pa})^2 + (20,000 \mu\text{Pa}/20 \mu\text{Pa})^2] = \underline{\underline{70.4 \text{ dB}}}$$



JAY'S SECOND LAW
OF THE BASICS OF ACOUSTICS

**WHEN THE SOURCES
DIFFER BY 10 dB,
THE LOUDEST SOURCE IS
DOMINANT**

JAY'S THIRD LAW OF THE BASICS OF ACOUSTICS

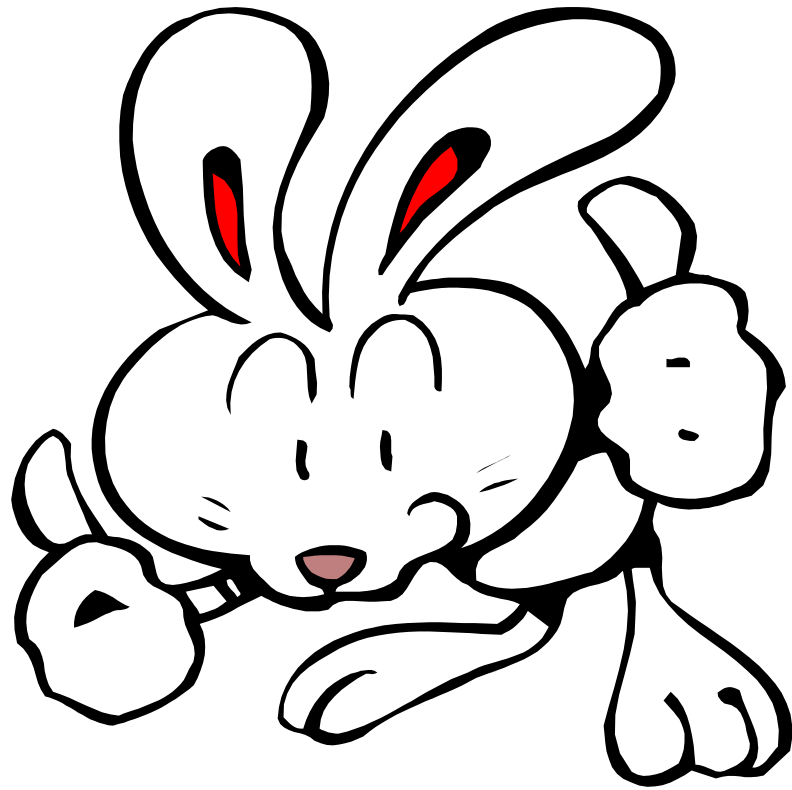
A 3 dB CHANGE IS BARELY
NOTICEABLE TO THE
HEALTHY HUMAN EAR



JAY'S FOURTH LAW OF THE BASICS OF ACOUSTICS

A 10 dB CHANGE IS
PERCEIVED AS A HALVING
OR A DOUBLING OF THE
SOUND LEVEL





Now you know what 70 dB means!

Criteria 2: FREQUENCY

Sound is separated into
8 – 10 octave bands

<u>HERTZ</u>	<u>MEAN</u>
22-44	31.5
44-88	63
88-177	125
177-355	250
355-710	500
710-1420	1000
1420-2840	2000
2840-5860	4000
5680-11360	8000
11360-22720	16000

500 Hz

10000 Hz

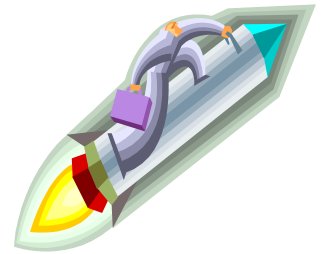
**RANGE
MOST
NOTICEABLE
TO
HUMANS**

WEIGHTING

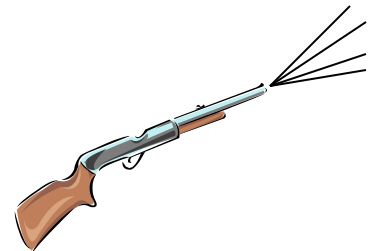
A – Weighted: How the human ear typically responds

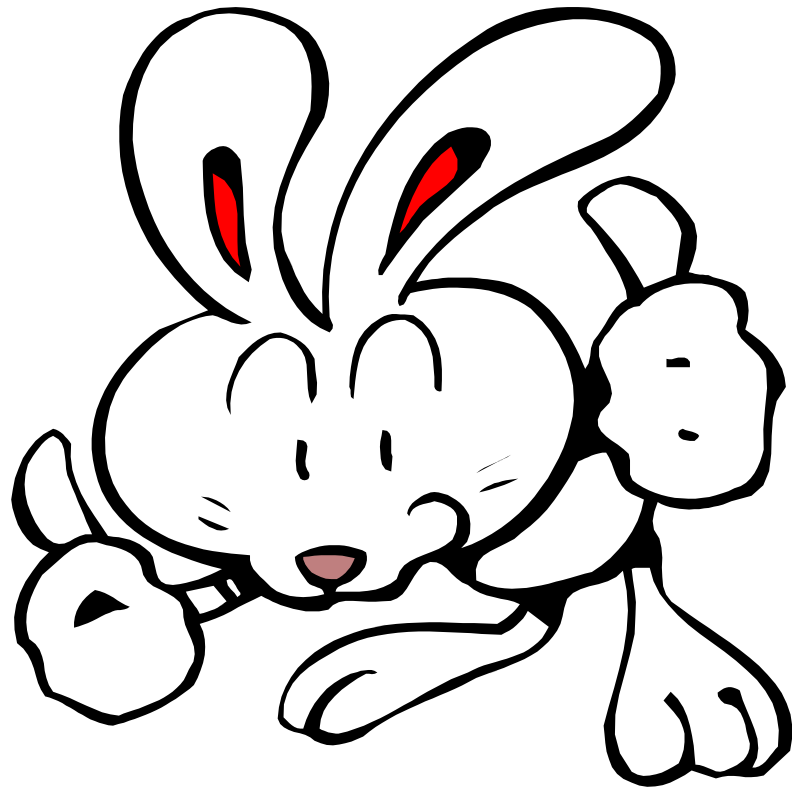


B – Weighted: The way the human ear responds to more intense sounds



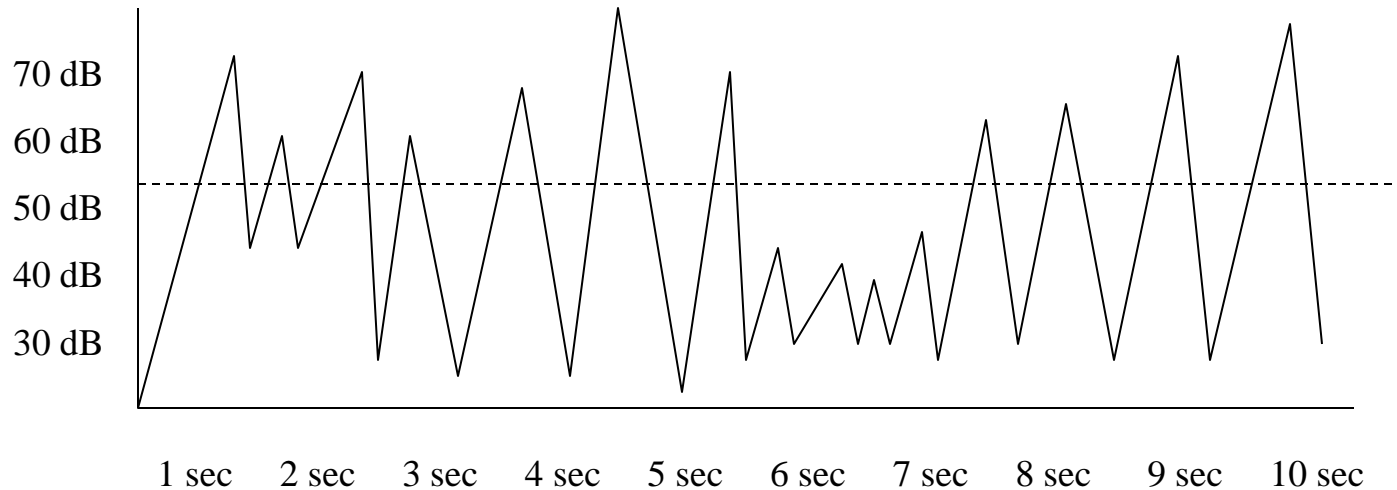
C – Weighted: The way the human ear responds to very loud sounds





Now you know what 70 dBA means!

Criteria 3: DURATION



L_{eq} – Equivalent sound level averaged over a given time period.
Often expressed as $L_{eq}(24 \text{ hr})$.

OTHER DURATION DESCRIPTORS

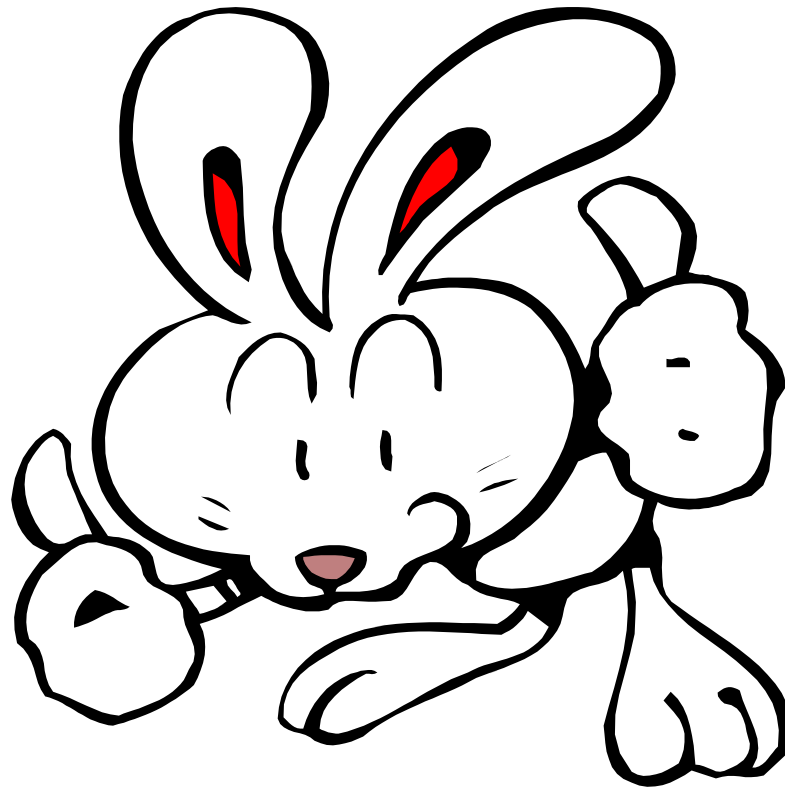
L_{xx} – Equivalent SPL that is exceeded over a given period of time a certain percentage of that time period. For example;

60 dBA L_{10} (1 hr) means: A SPL of 60 dB was exceeded 10 % of the time in a 1 hour period.

L_{\max} = Maximum SPL during a given period

L_{\min} = Minimum SPL during a given period

DNL = Day/Night Sound Level - Airports
(10 dB less during sleeping hours)



Now you know what 70 dBA \underline{L}_{eq} means!



Criteria 4: SUBJECTIVITY

Noise is defined as unwanted sound

Many have tried to find an absolute definition of when sound becomes noise

All have failed!!!

SOUND PATH

SOFT SITE: Grass, Woods, Farm Fields, etc.



HARD SITE: Asphalt, PCC, Air, Ice, Water, etc.

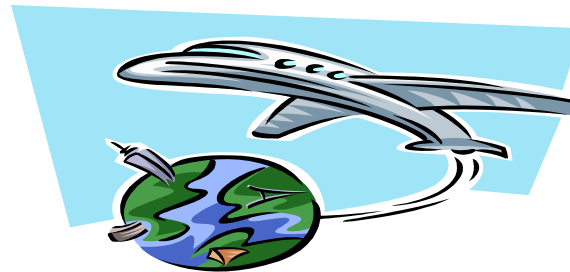


SOURCE TYPES

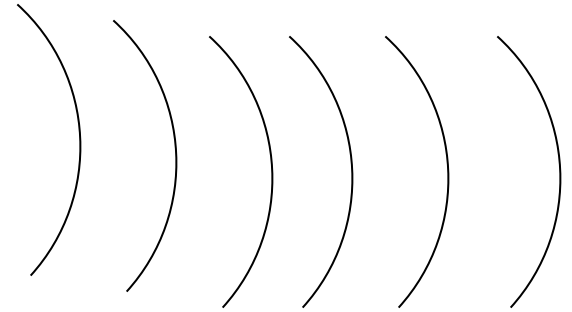
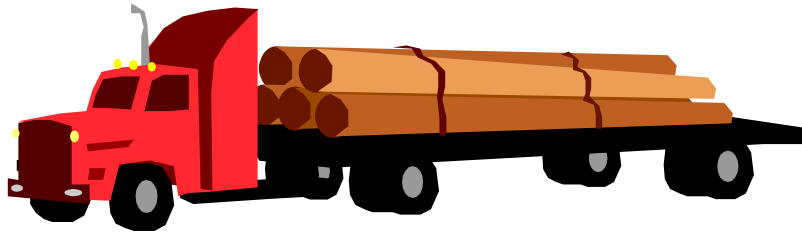
POINT SOURCE: Crushers, Milling, Factories, etc.



LINE SOURCE: Traffic, Planes, Trains, etc.



Decibel Reduction



$$\text{dB Reduction} = 10 \log_{10} (D/D_0)$$

D_0 = Original distance between source and receptor

D = New distance between source and receptor

$$10 \log_{10} (100'/50') = \underline{\underline{3.01 \text{ dB}}}$$



JAY'S FIFTH LAW
OF THE BASICS OF ACOUSTICS

DOUBLING THE DISTANCE
BETWEEN A LINE SOURCE
AND RECEPTOR REDUCES
THE SOUND LEVEL BY 3 dB
OR 4.5 dB DEPENDING ON
THE SITE CONDITIONS



JAY'S SIXTH LAW
OF THE BASICS OF ACOUSTICS

DOUBLING THE DISTANCE
BETWEEN A POINT SOURCE
AND RECEPTOR REDUCES
THE SOUND LEVEL BY 6 dB
OR 7.5 dB DEPENDING ON
THE SITE CONDITIONS



State and Federal Policy

1. National Environmental Policy Act of 1969
2. U.S. DOT Order 5610.1C
3. 23 CFR 771 – All
4. 23 CFR 772 – Noise
5. FHWA Technical Advisory 6640.8A
6. **WisDOT Facilities Development Manual – Chapter 23**
7. Wisconsin Administrative Code – Chapter Trans 405



TYPE I PROJECTS

1. The construction of a highway on new location; or,
2. The physical alteration of an existing highway where there is either:
 - a. Substantial horizontal alteration – The project halves the distance between the traffic noise source and the closest receptor between the existing condition to the future build condition; or,
 - b. Substantial vertical alteration – The project removes shielding therefore exposing the line-of-sight between the receptor and the traffic noise source. This is done by either altering the vertical alignment of the highway or by altering the topography between the highway traffic noise source and the receptor; or,
3. The addition of a through-traffic lane(s). This includes the addition of a through-traffic lane that functions as a High-Occupancy Vehicle (HOV) lane, High-Occupancy Toll (HOT) lane, bus lane, or truck climbing lane; or,
4. The addition of an auxiliary lane, except for when the auxiliary lane is a turn lane; or,
5. The addition or relocation of an interchange lane(s) or ramp(s) added to a quadrant to complete an existing partial interchange; or,
6. Restriping existing pavement for the purpose of adding a through-traffic lane or an auxiliary lane; or,
7. The addition of a new or substantial alteration of a weigh station, rest stop, ride-share lot or toll plaza.

Analysis is required!!!

ANALYSIS METHODS

1. Field Measurements

2. Traffic Noise Model (TNM)





IMPACT DETERMINATION

Evaluate Existing and Design Year (const.+20)

An Impact Occurs if;

1. Design year sound levels approach or exceed the Noise Level Criteria in FDM Chapter 23,
 - Residential NLC = 67 dBA
 - Commercial NLC = 72 dBA
 - Approach = 1 dB less than the NLC

OR,

2. Design year sound levels increase by 15 dB or more over existing levels

DOCUMENTATION

1. Screening Worksheets for CECs, PCEs, ERs and EAs
2. Standard Verbiage for Environmental Impact Statements (EISs)





IMPACT MITIGATION

Buzzword Bingo!

1. Feasible
2. Reasonable
3. Likely to be Incorporated

FEASIBLE

We are Engineers!

Anything is Feasible!!!





REASONABLE

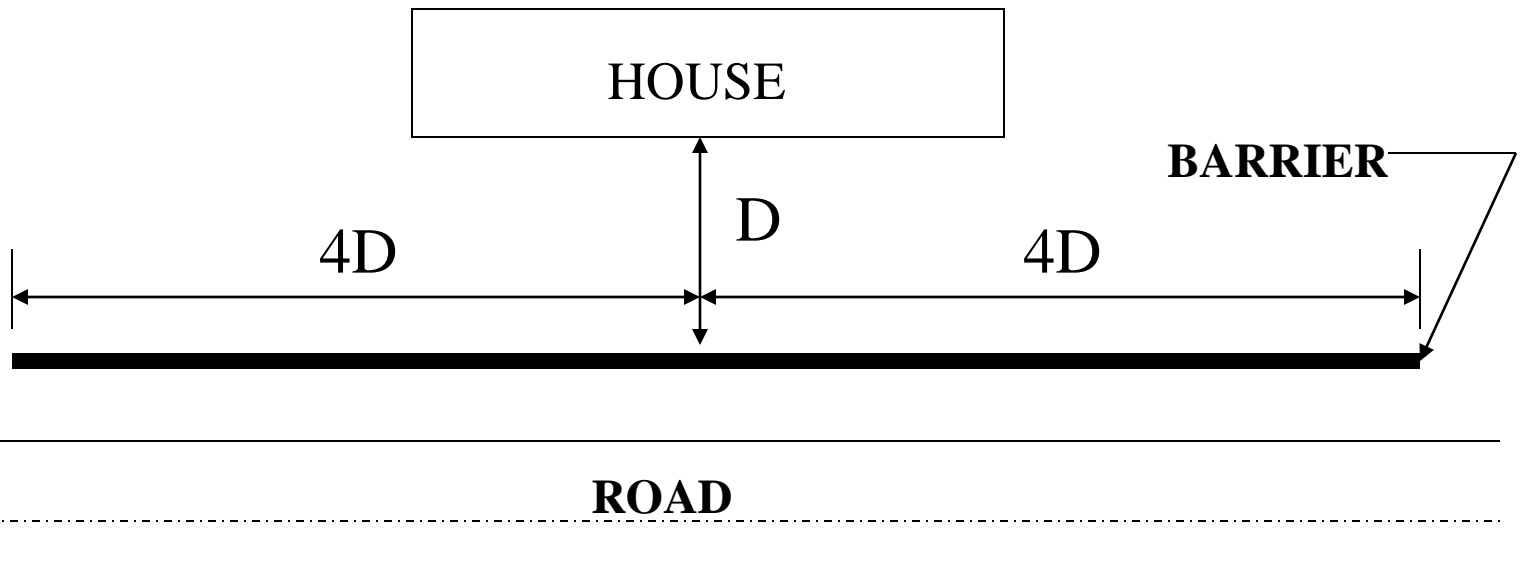
1. Alignment Shifts
2. Truck Prohibitions
3. Berms, Barriers, Soundproofing
 - a. 8 dB reduction
 - b. <\$48,000/benefited receptor*

***Benefited receptor means a receptor or common use area receiving a minimum eight (8) decibel reduction in sound level as a result of the proposed abatement measure. WisDOT also has a design goal which requires one receptor to receive at least a minimum nine (9) decibel reduction.**

BARRIER COST ESTIMATE

If the road and receptor are at the same elevation,
assume the barrier will be 16' high

Length must be 8 times the distance from the barrier
to the receptor





BARRIER COST ESTIMATE

(Cont.)

WisDOT barriers typically cost \$27.00/sq. ft.*

- a) Wood/Cement Composite (Absorptive)
- b) Metal
- c) Wood

If the estimate is in the area of \$48,000/benefited receptor, then TNM is used to refine the estimate

*About \$2,000,000/mile



LIKELY TO BE INCORPORATED

If Reasonable and Feasible, then;

1. Hold a Public Informational Meeting (PIM)
2. Benefited receptors are given a vote
3. For each benefited receptor that is an owner-occupied residence, the owner shall have one vote
4. For each benefitted receptor that is not an owner-occupied residence, the owner shall have one vote and one resident shall have one vote
5. A simple majority of “Yes” votes means the barrier will be built



OTHER ISSUES

1. Construction Noise
2. Pavement Surface Texture
3. Meteorological Effects on Noise

QUESTIONS

?

