the science of insight

Meteorological Effects on Highway Noise - Update

ADC 40 Summer Meeting

July 28, 2017

Disclaimer

The materials presented here are in draft form and the process of being further analyzed. The results and conclusions may change in the final report.

The opinions and conclusions expressed or implied in this presentation of those of the research team. They are not necessarily those of the Transportation Research Board, the National Academies, or the program sponsors.

NCHRP 25-52 Project Objectives

Project Objectives

The objectives of this research are to:

1) **Measure and document the meteorological effects on roadway noise propagation under different atmospheric conditions, and**
2) **Develop best practices and provide guidance on how to**
   A. Quantify meteorological effects on roadway noise propagation, and
   B. How to explain those effects to the public.

Project Objectives

The guidance will, at a minimum:

- **Identify the most critical atmospheric parameters (e.g., atmospheric stability, wind, humidity, etc.) that affect roadway propagation, and the distances at which their respective influences may occur, and**
- **Aid in determining when meteorological effects should and should not be considered in noise analyses.**

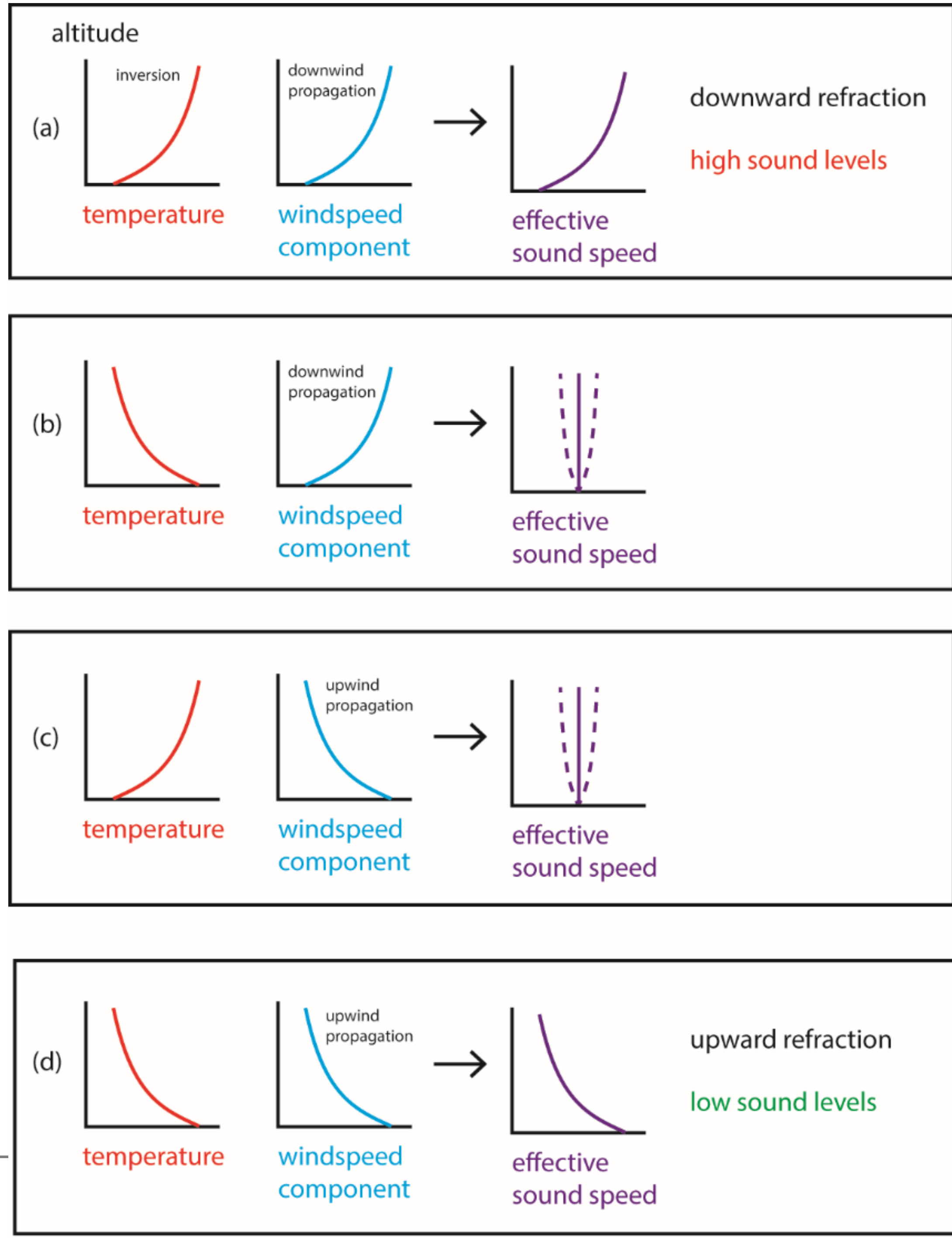
The research results should enable practitioners to understand and explain roadway noise levels under different atmospheric conditions in a roadway noise analysis.

Outline of Presentation

- Primer on meteorological effects
- Preliminary Data Analysis
  - Data processing
  - Data analysis
- Public outreach tool development

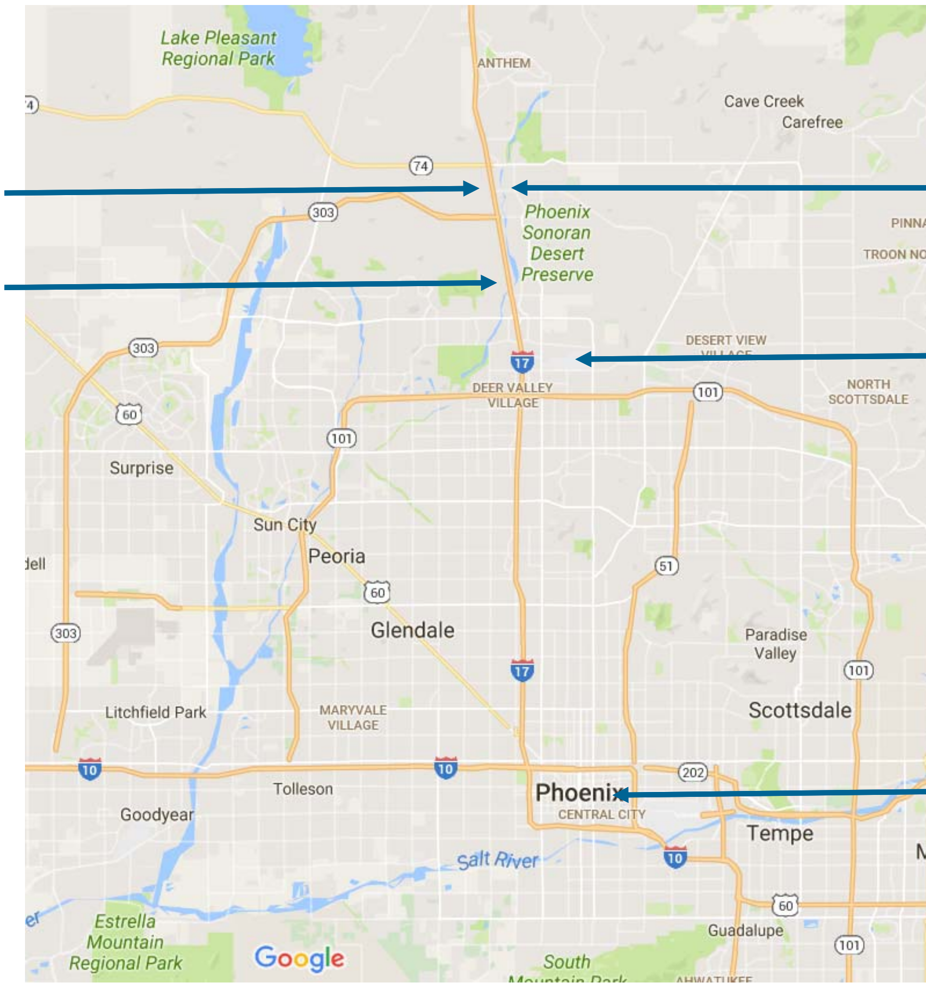
Primer on Met Effects

Effective sound speed is the combination of vector wind speed and sound speed



Data Collection

Data Collection was done along I-17 in Phoenix



No-Barrier Site

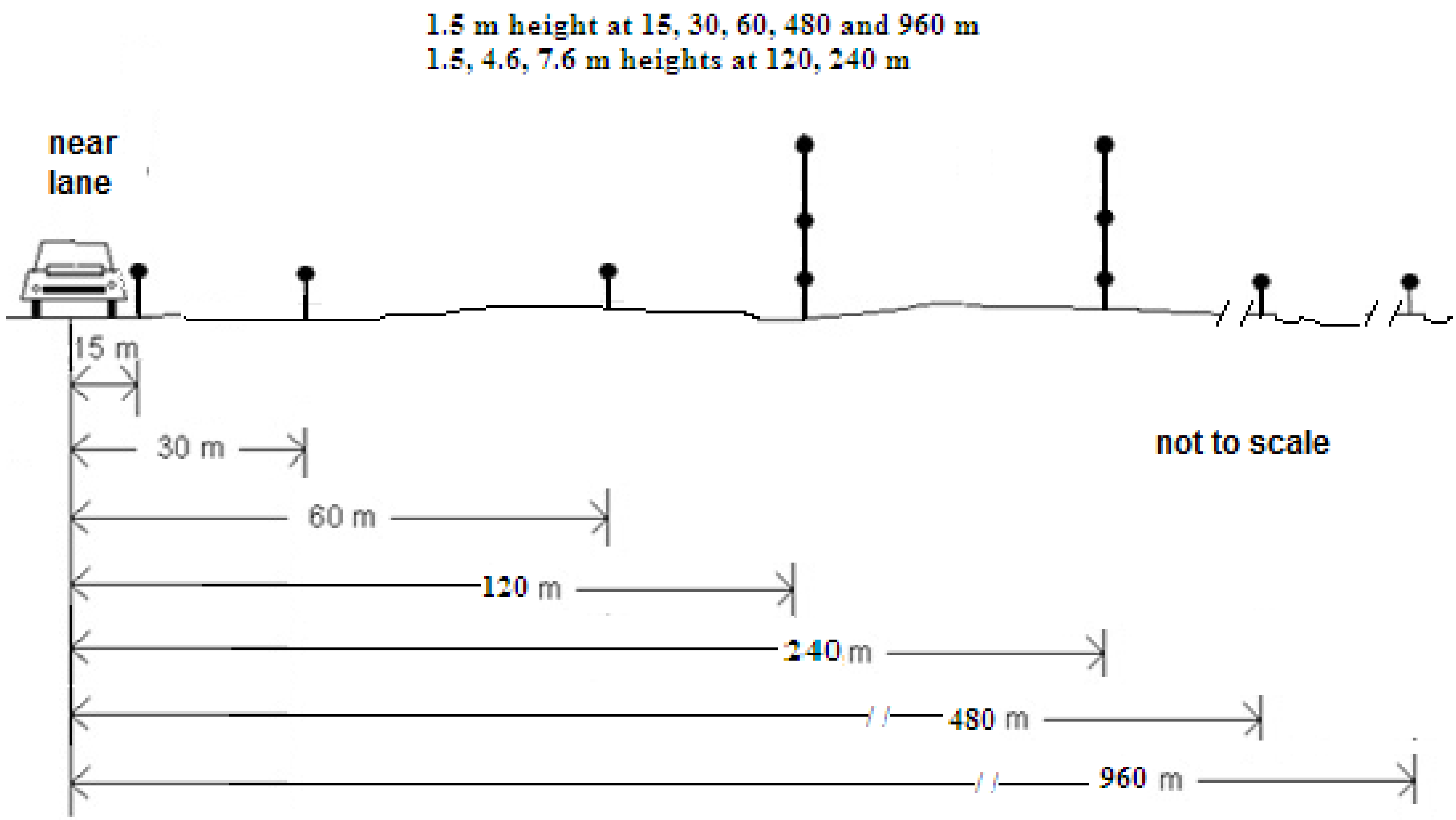
Barrier Site

Ridgeline Academy met data collection

Deer Valley Airport

PHX Airport

No-Barrier Location Microphones Located every doubling of distance from 15m to 960m



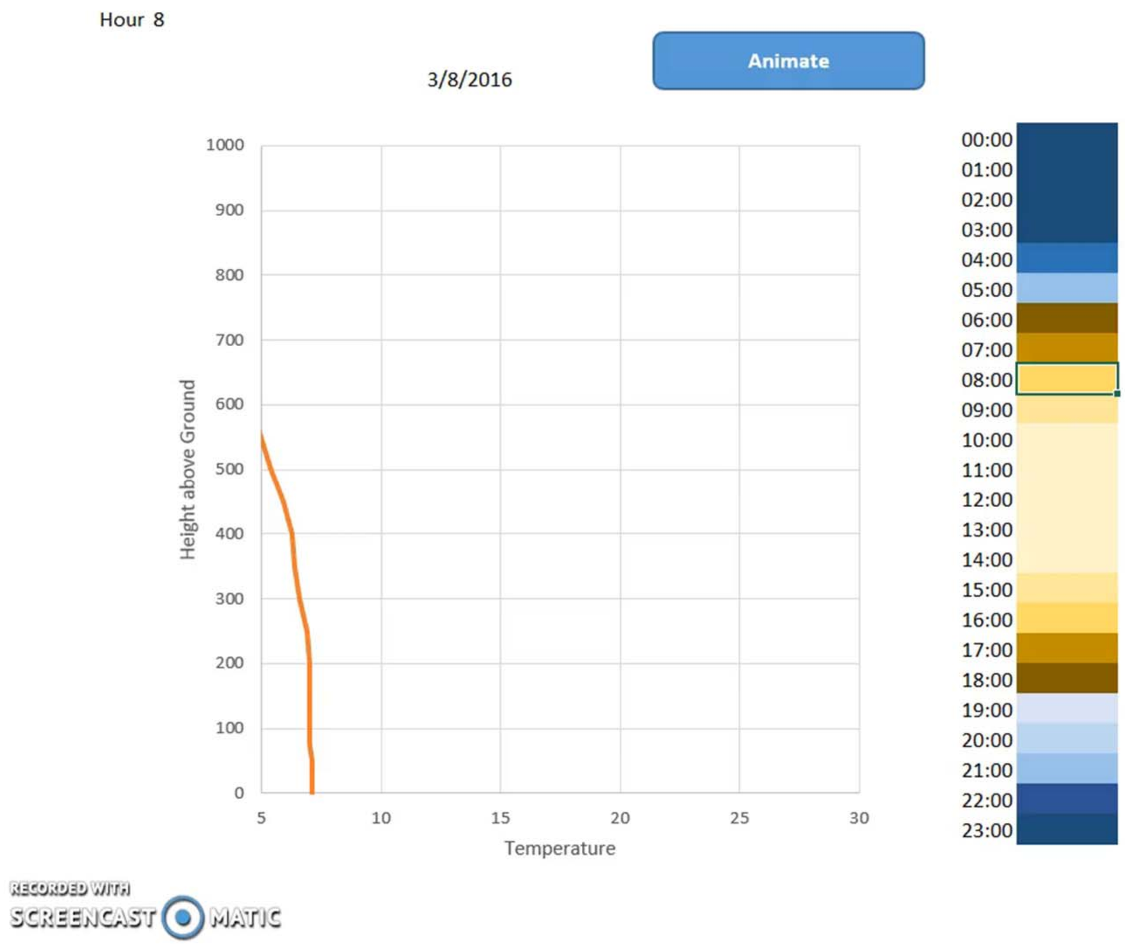
Video taken at the No-Barrier site – 120 meters

Data Processing

Very Large Data Set

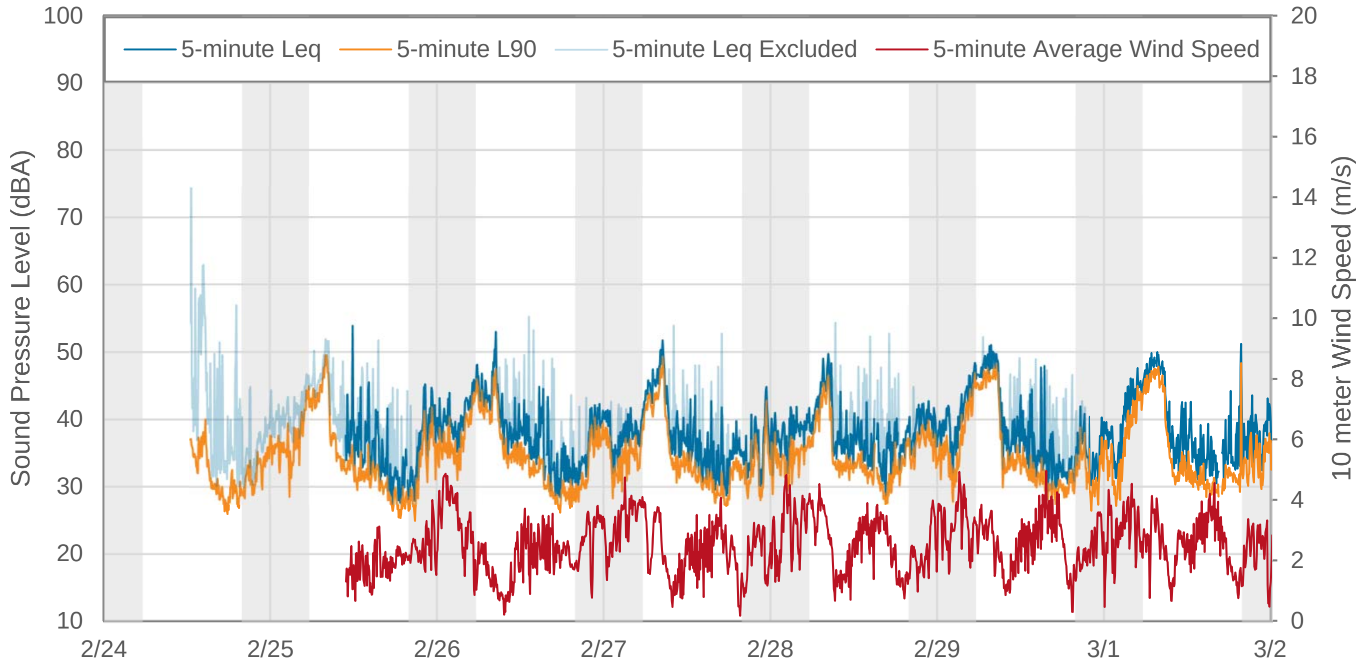
- Acoustic data from 16 positions (1-second logging)
- Two met towers with wind speed/direction, temperature, and relative humidity
- LIDAR (to 200m) and Temperature Profiler (to 1,000 m)
- Deer Valley and PHX airport met data
- Continuous ATR traffic counts, speed, and mix on I-75
- Continuous audio recordings at select microphones
- >35,000 good five-minute periods

Temperature profile was very consistent throughout, showing inversions every night



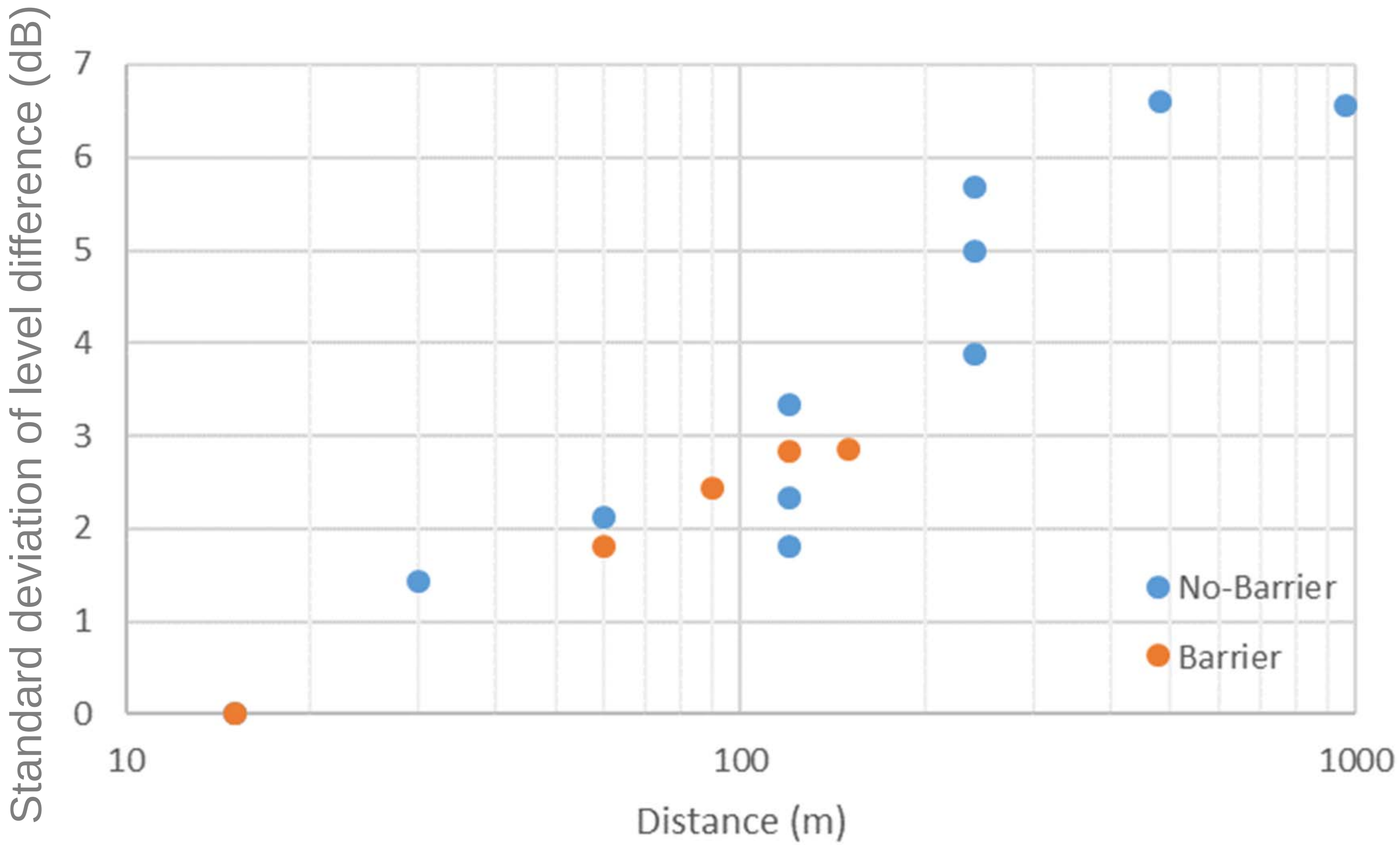
Sound Level Data included A, C, and Z weightings and 1/3 octave bands

- A, C, and Z weighting
- 1/3 octave bands, from 6.3 to 20,000 Hz
- 1-s data filtered for events and combined to 5-min

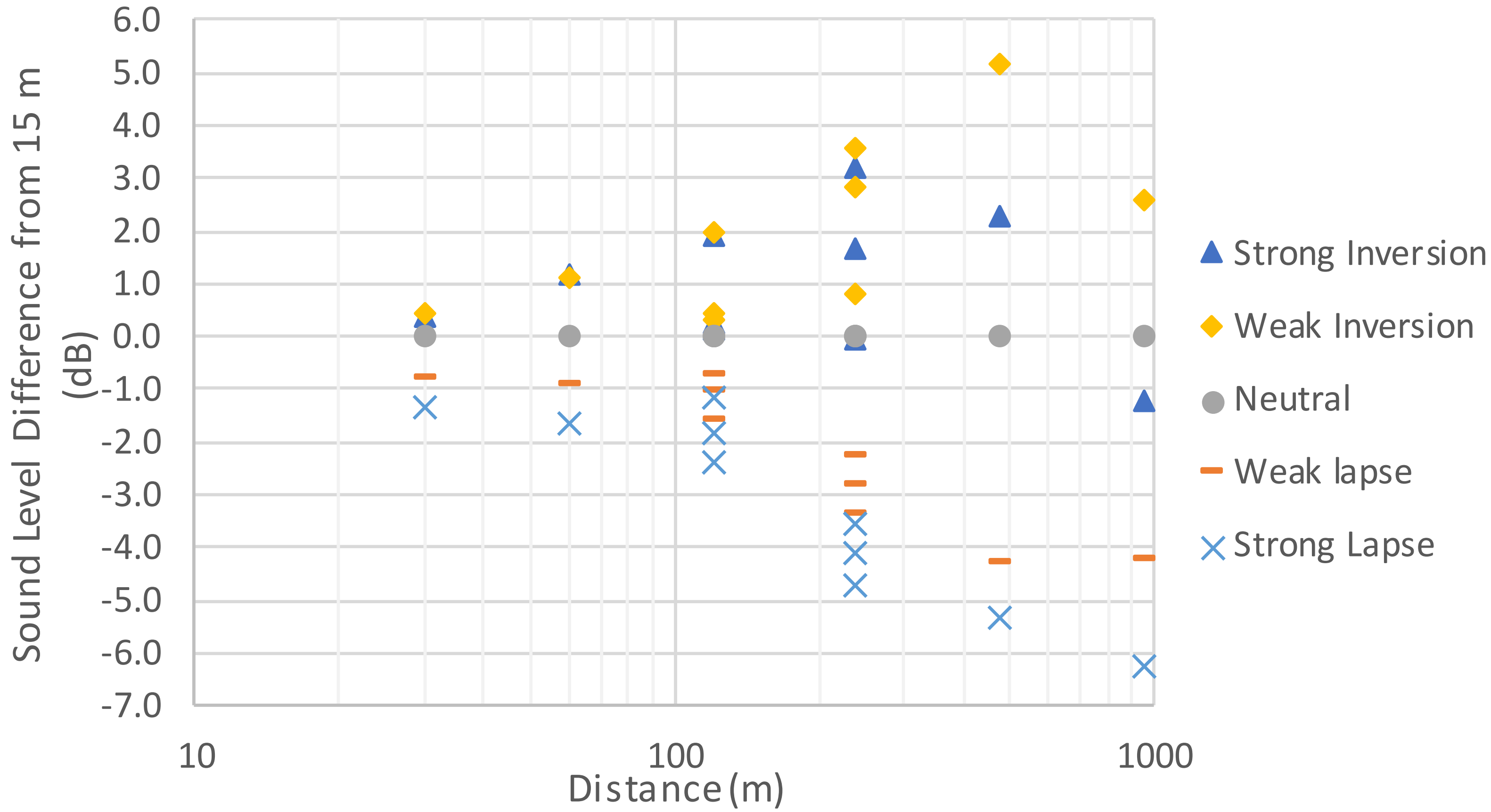


Comparisons and Statistics

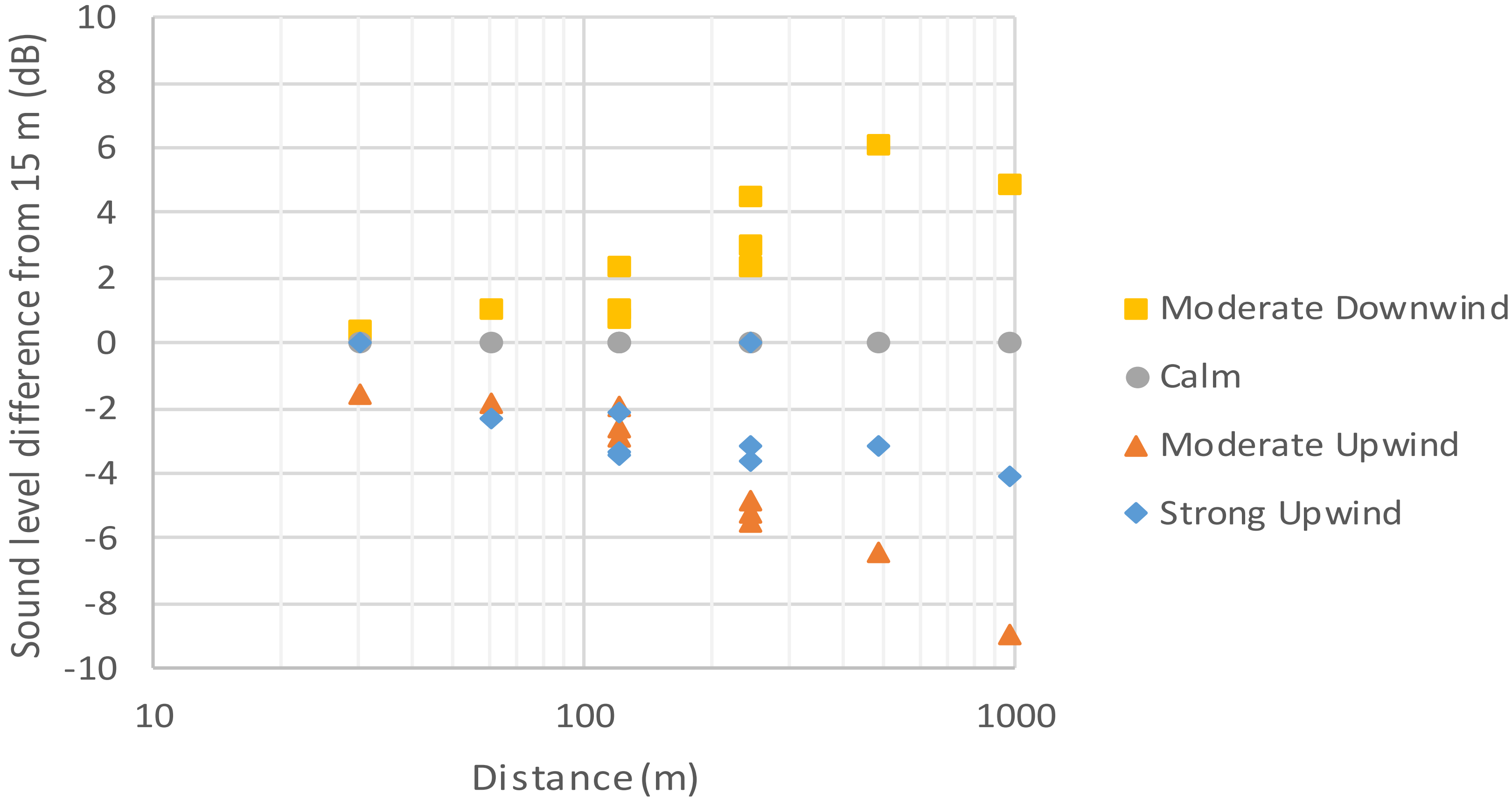
Standard deviation of level difference shows greater variance at larger distances



Sound level difference is a function of temperature profile…



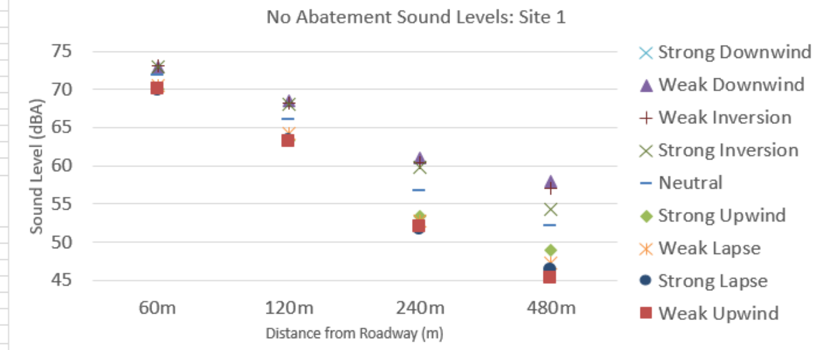
…and wind profile



Implications for Noise Impact and Noise Abatement Conclusions

Sites

- Two neighborhoods
  - Site #1: Medium density
  - Site #2: High density
- TNM modeling
- Spreadsheet tool
  - Applies adjustments based on measured data
    - Seven conditions
      - No strong downwind data
  - Assesses impacts
  - Evaluates feasibility and reasonableness



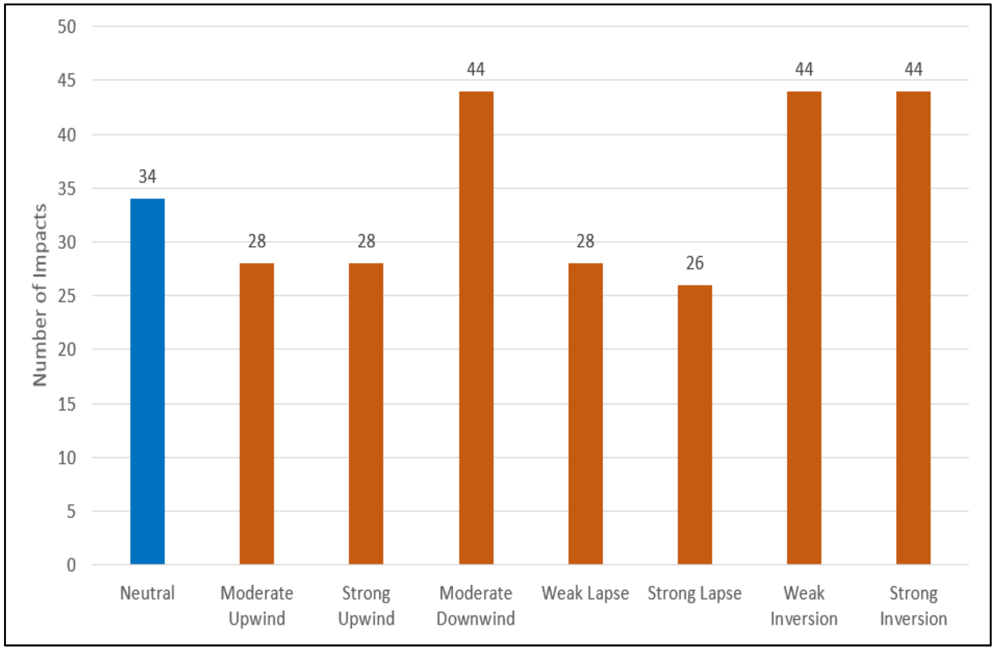
	No Met Effects	Weak Upwind	Strong Upwind	Weak Downwind	Strong Downwind	Weak Lapse	Strong Lapse	Weak Inversion	Strong Inversion
Total Impacts	20	10	10	20	n/a	10	10	20	20

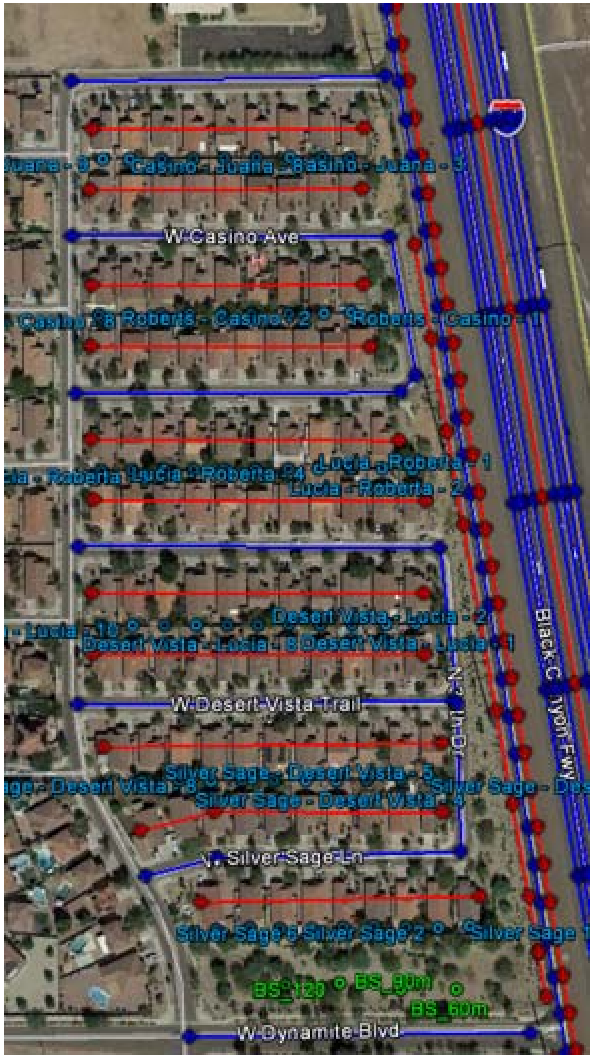
Rec Name	No Abatement Sound Levels, dBA								
	Neutral	Weak Upwind	Strong Upwind	Weak Downwind	Strong Downwind	Weak Lapse	Strong Lapse	Weak Inversion	Strong Inversion
Rec 1-1	73.7	72.2	72.8	74.5	n/a	72.5	71.9	74.7	74.5
Rec 1-2	73.6	72.1	72.7	74.4	n/a	72.4	71.8	74.6	74.4
Rec 1-3	74.0	72.5	73.1	74.8	n/a	72.8	72.2	75.0	74.8
Rec 1-4	74.2	72.7	73.3	75.0	n/a	73.0	72.4	75.2	75.0
Rec 1-5	74.3	72.8	73.4	75.1	n/a	73.1	72.5	75.3	75.1
Rec 1-6	74.3	72.8	73.4	75.1	n/a	73.1	72.5	75.3	75.1
Rec 1-7	74.3	72.8	73.4	75.1	n/a	73.1	72.5	75.3	75.1
Rec 1-8	74.5	73.0	73.6	75.3	n/a	73.3	72.7	75.5	75.3
Rec 1-9	74.3	72.8	73.4	75.1	n/a	73.1	72.5	75.3	75.1
Rec 1-10	74.3	72.8	73.4	75.1	n/a	73.1	72.5	75.3	75.1
Rec 2-1	66.2	63.7	63.7	68.2	n/a	64.5	63.7	68.1	67.8
Rec 2-2	66.1	63.6	63.6	68.1	n/a	64.4	63.6	68.0	67.7
Rec 2-3	66.2	63.7	63.7	68.2	n/a	64.5	63.7	68.1	67.8
Rec 2-4	66.2	63.7	63.7	68.2	n/a	64.5	63.7	68.1	67.8
Rec 2-5	66.3	63.8	63.8	68.3	n/a	64.6	63.8	68.2	67.9
Rec 2-6	66.3	63.8	63.8	68.3	n/a	64.6	63.8	68.2	67.9
Rec 2-7	66.2	63.7	63.7	68.2	n/a	64.5	63.7	68.1	67.8
Rec 2-8	66.0	63.5	63.5	68.0	n/a	64.3	63.5	67.9	67.6
Rec 2-9	66.2	63.7	63.7	68.2	n/a	64.5	63.7	68.1	67.8
Rec 2-10	66.6	64.1	64.1	68.6	n/a	64.9	64.1	68.5	68.2
Rec 3-1	62.3	59.2	59.5	64.9	n/a	60.1	59.3	64.7	64.4
Rec 3-2	61.6	58.5	58.8	64.2	n/a	59.4	58.6	64.0	63.7
Rec 3-3	61.3	58.2	58.5	63.9	n/a	59.1	58.3	63.7	63.4
Rec 3-4	61.4	58.3	58.6	64.0	n/a	59.2	58.4	63.8	63.5

	No Met Effects	Weak Upwind	Strong Upwind	Weak Downwind	Strong Downwind	Weak Lapse	Strong Lapse	Weak Inversion	Strong Inversion
Number of Impacted Receptors Receiving 5 dB reduction	10	10	10	19	n/a	10	10	16	10
Feasible?	Yes	Yes	Yes	Yes	n/a	Yes	Yes	Yes	Yes
Number of Benefited Residences (≥ 5 dB)	10	10	10	36	n/a	10	10	16	10
First Row Benefits	10	10	10	10	n/a	10	10	10	10
1st row Benefits Receiving 7 dB	10	0	0	10	n/a	0	0	10	10
NRDG	100%	0%	0%	100%	n/a	0%	0%	100%	100%
Allowable Area per Benefited Residence (ft^2)	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400	1,400
Area (ft^2)	7,319	7,319	7,319	7,319	n/a	7,319	7,319	7,319	7,319
Area Per Benefited Residence (ft^2)	732	n/a	n/a	203	n/a	n/a	n/a	457	732
Reasonable?	Yes	No	No	Yes	n/a	No	No	Yes	Yes

Implications for Noise Impacts (Site #2)

- Upwind and lapse reduce sound levels at impacted residences by 2-3 dB reducing the number of impacts by 6 to 8.
- Downwind and inversion increase sound levels for some 3rd and 4th row residences increasing the number of impacts by 10.





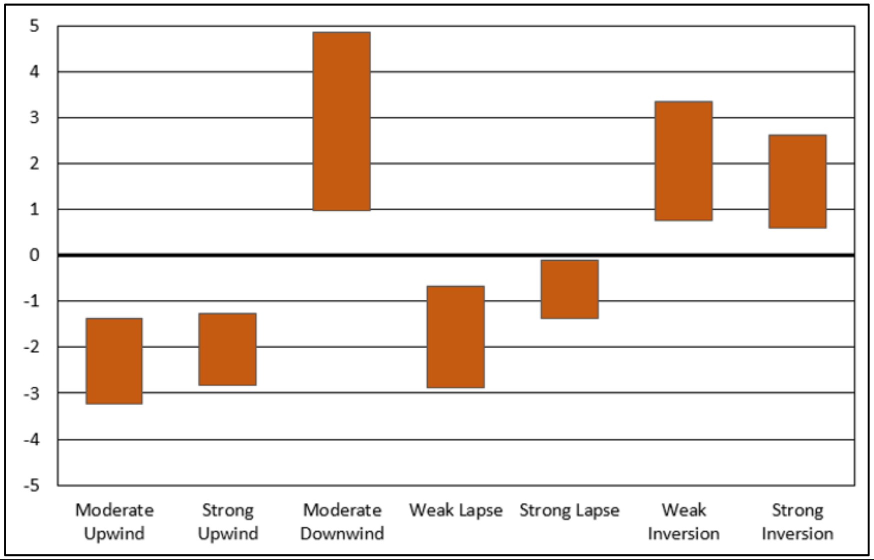
Implications for Noise Barrier Evaluation (Site #2)

Design philosophy

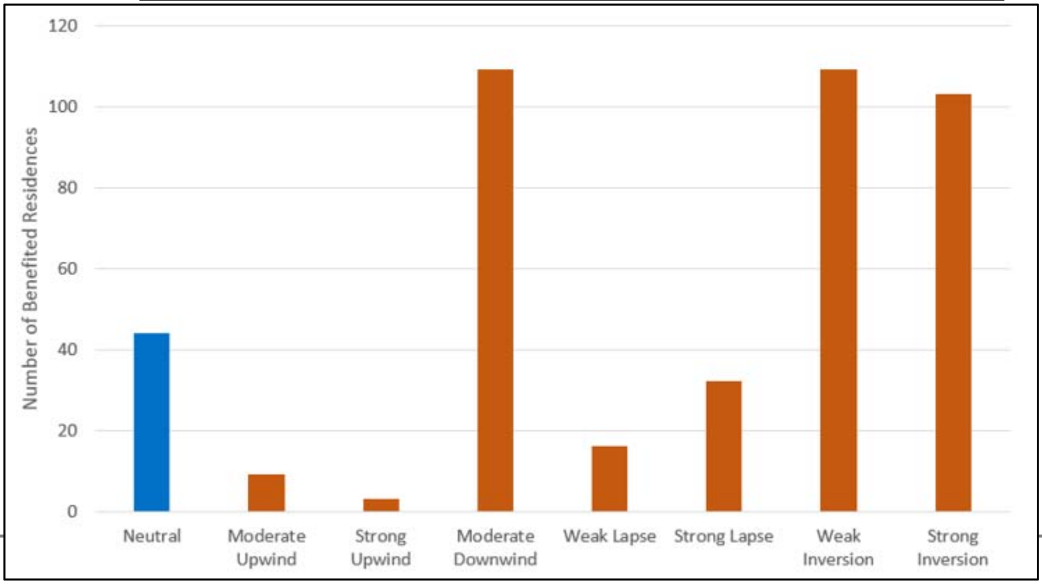
- 7 dB for impacted first-row residences

Results

- upwind and lapse reduce ILs and benefits
- downwind and inversion increase ILs and benefits



Change in Insertion Loss



Change in Benefited Residences

Implications for Noise Barrier Evaluation (Site #2)

– Feasibility
  - met under all conditions

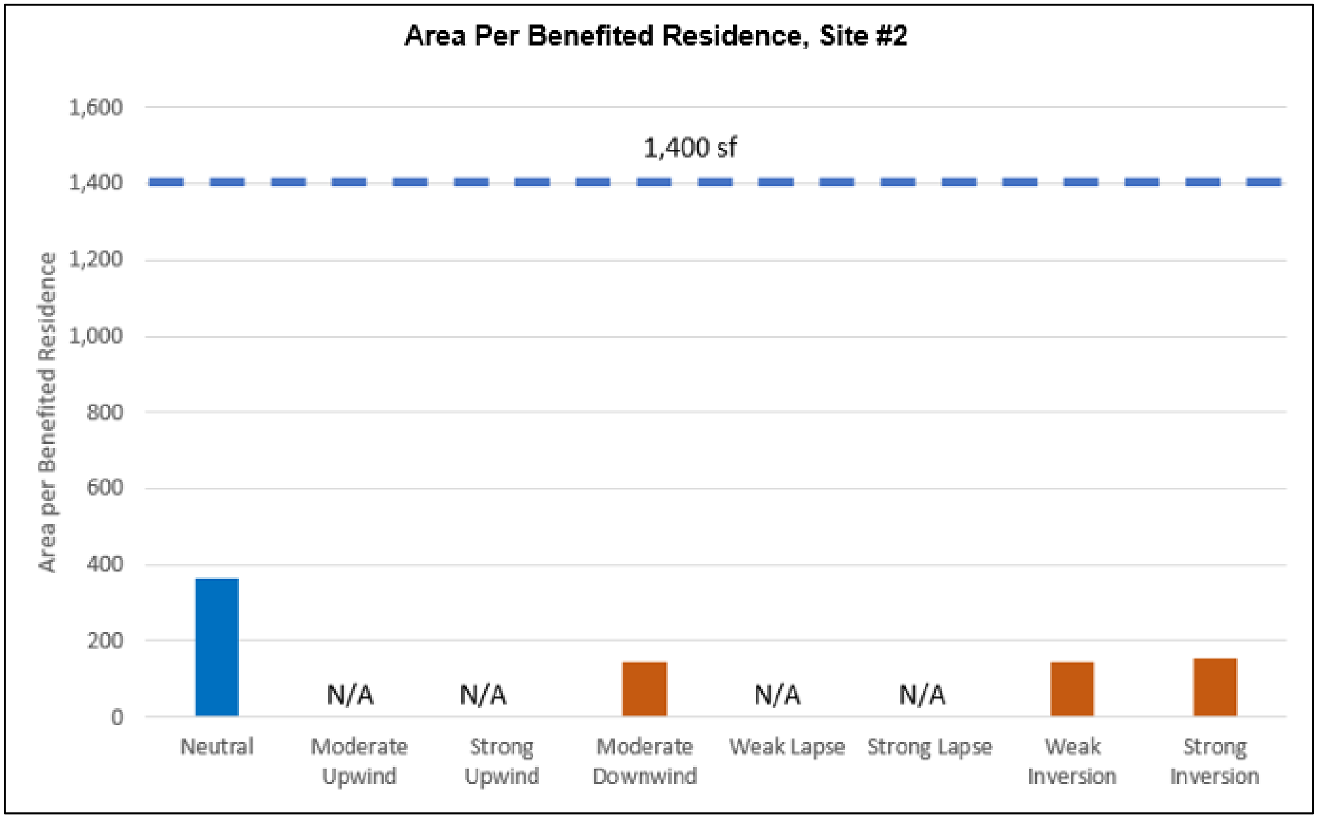
– Noise Reduction Design Goal
  - 7 dB for 50% of first-row benefited
    – Met for downwind and inversion
      » ILs increased for first-row residences
    – Not met for upwind and lapse
      » First-row residences receive than 5 dB (upwind and weak lapse)
      » First-row residences receive than 7 dB (strong lapse)

Noise Barrier Evaluation Results, Site #2

	Neutral	Moderate Upwind	Strong Upwind	Moderate Downwind	Strong Downwind	Weak Lapse	Strong Lapse	Weak Inversion	Strong Inversion
NOISE REDUCTION DESIGN GOAL									
Number of Benefited Residences	44	9	3	109	---	16	32	109	103
First Row Benefited Residences	13	0	0	13	---	0	13	13	13
First Row Benefited Residences Receiving 7 dB Reduction	13	0	0	13	---	0	0	13	13
Noise Reduction Design Goal	100%	0%	0%	100%	---	0%	0%	100%	100%
Noise Reduction Design Goal Met?	Yes	No	No	Yes	---	No	No	Yes	Yes

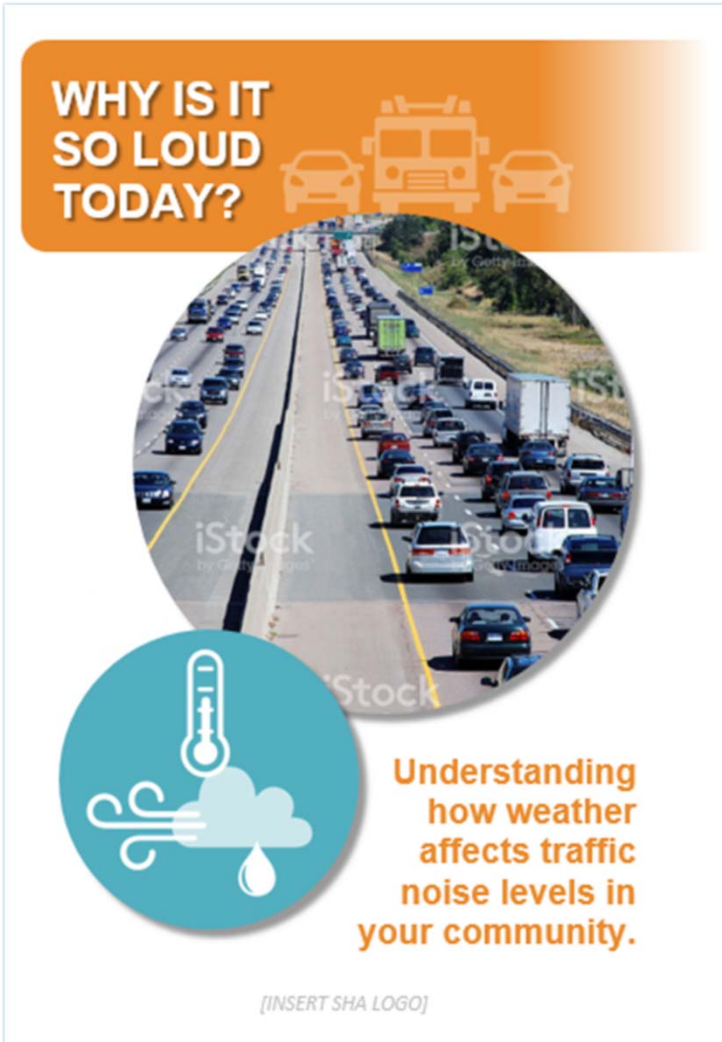
Implications for Noise Barrier Evaluation (Site #2)

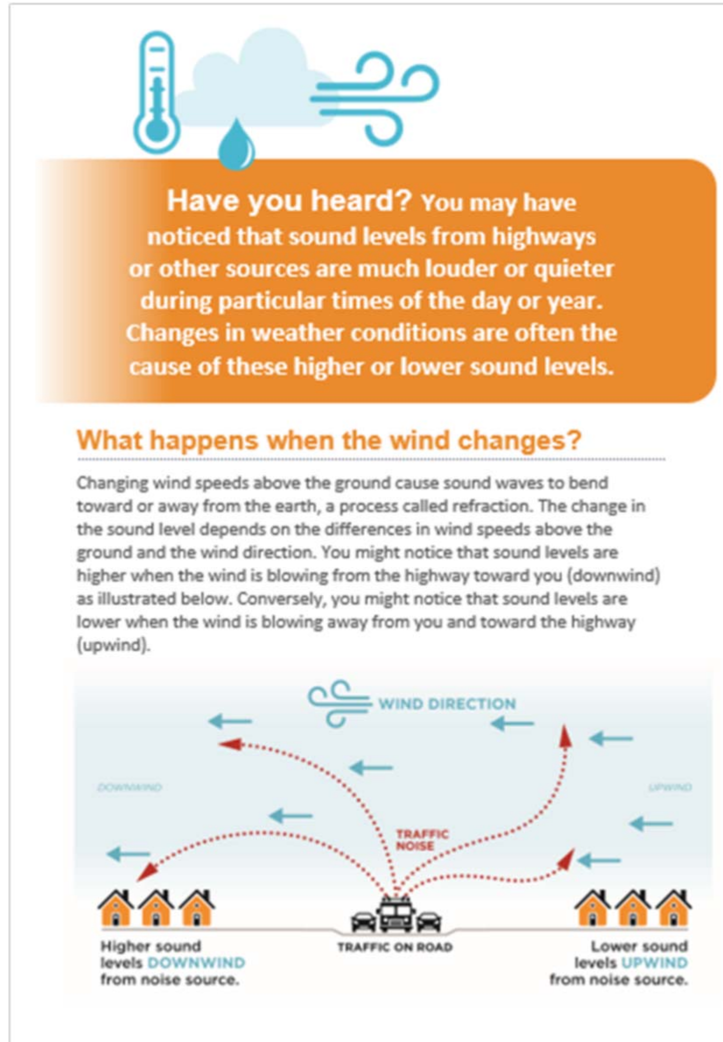
- Cost Effectiveness
  - 1,400 sf per benefited residence
  - Downwind and weak inversion increased benefits and reduced the APBR



Public Outreach Tools

Public Outreach Materials - Brochure

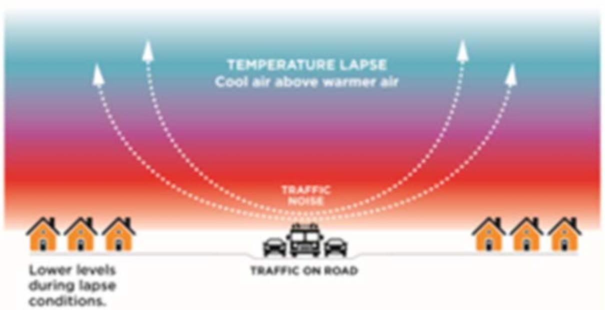




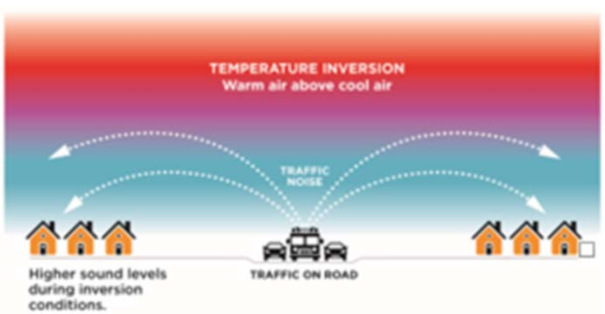
Public Outreach Materials - Brochure

What happens when the temperature changes?

The temperature of the air above the ground changes with height. When the air above the ground is cooler than the air near the ground, a temperature lapse occurs. Temperature lapses are common during the day. Lapses cause sound waves to bend away from the earth and reduce sound levels in nearby communities as illustrated below. You might notice that sound levels are lower during the day than at night even though there may be more traffic on the road.



Conversely, when the air above the ground is warmer than the air near the ground, a temperature inversion occurs. Temperature inversions are common at night when the weather is clear and winds are calm. Inversions cause sound waves to bend back toward the earth and increase sound levels as illustrated below. You might notice that sound levels are higher at night or in the early morning than during the day.



What are the effects my on community?

The effects on a particular community depend on the distance to highways and the frequency and duration of particular weather conditions. Weather patterns that change sound levels may be more common in certain areas.. Higher sound levels will be more common in areas where the wind typically blows from a highway toward a community (downwind) than in locations where the wind typically blows from a highway toward a community (downwind) from the community toward the highway (upwind). Higher sound levels will also be more common in areas where temperature inversions are common.

[Note: A SHA could customize this section to describe the types of weather conditions that are typical for the state.]

What if my neighborhood has a noise barrier?

Changes in weather conditions also affect how well a noise barrier performs. Temperature inversions and downwind conditions can increase sound levels in neighborhoods protected by a noise barrier. Temperature lapses and upwind conditions can further reduce sound levels in neighborhoods protected by a noise barrier. The changes in sound levels will depend on the specific wind and temperature conditions.

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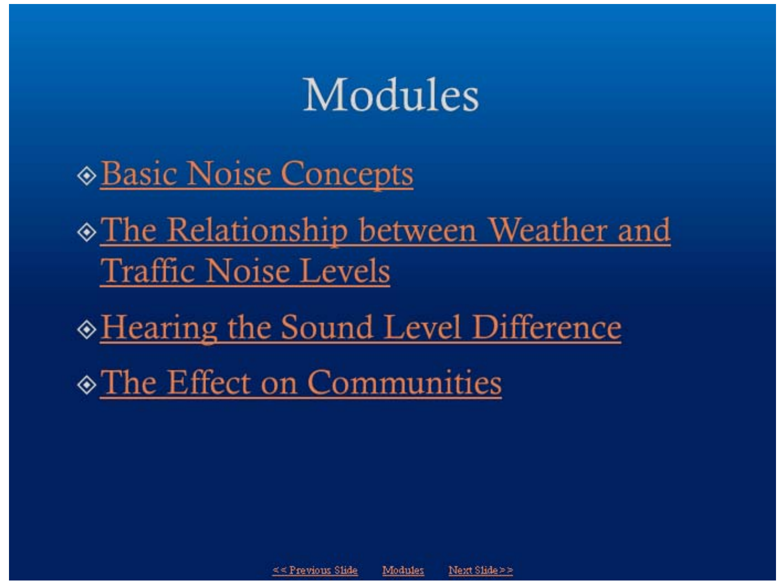
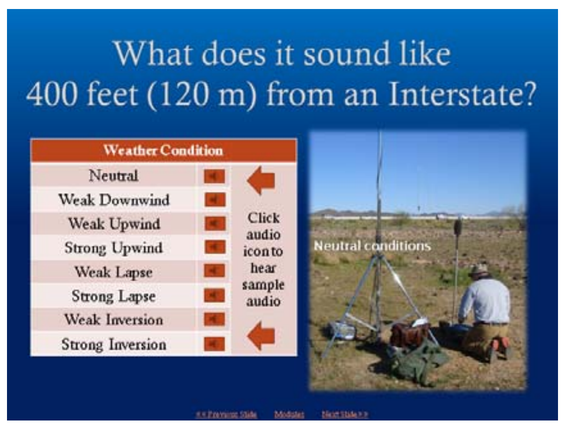
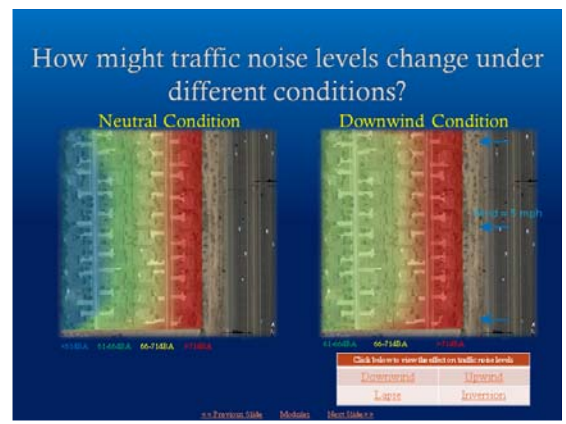
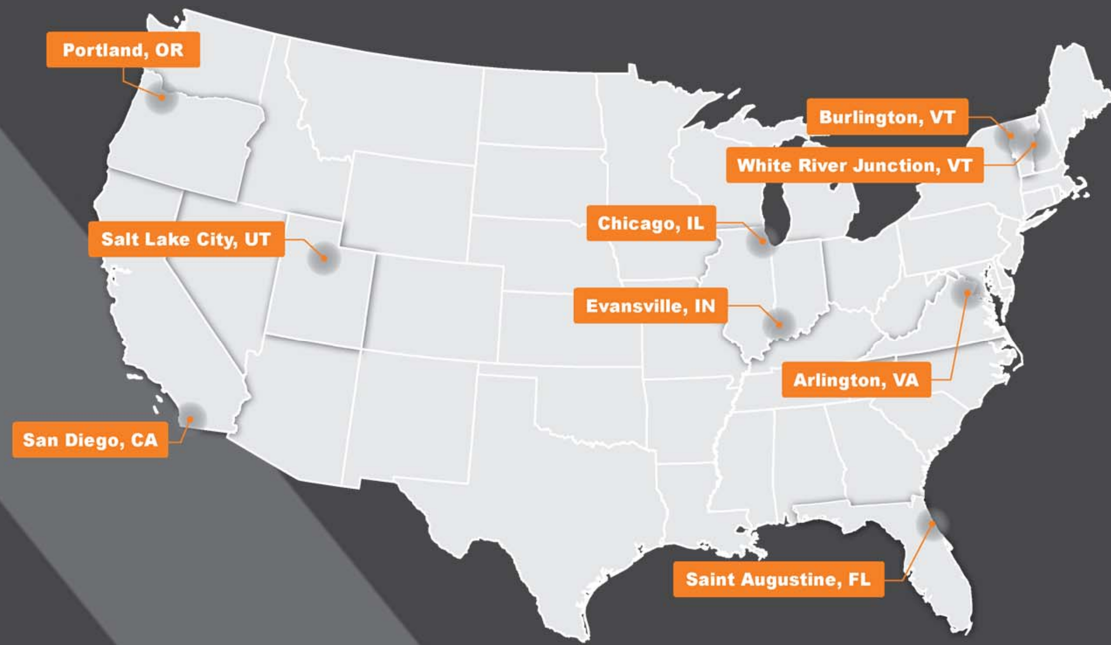
Public Outreach Materials – Interactive Tool









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NCHRP 25-52 Panel

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- Timothy Casey, HDR Engineering, Inc.
- Ahmed El-Aassar, PhD, Environmental Acoustics
- Cora Helm, Montana DOT
- Paul Kohler, Virginia DOT
- Carole Newvine, Oregon DOT
- Bruce Rymer, P.E., California DOT
- Ray Umscheid, Texas DOT

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