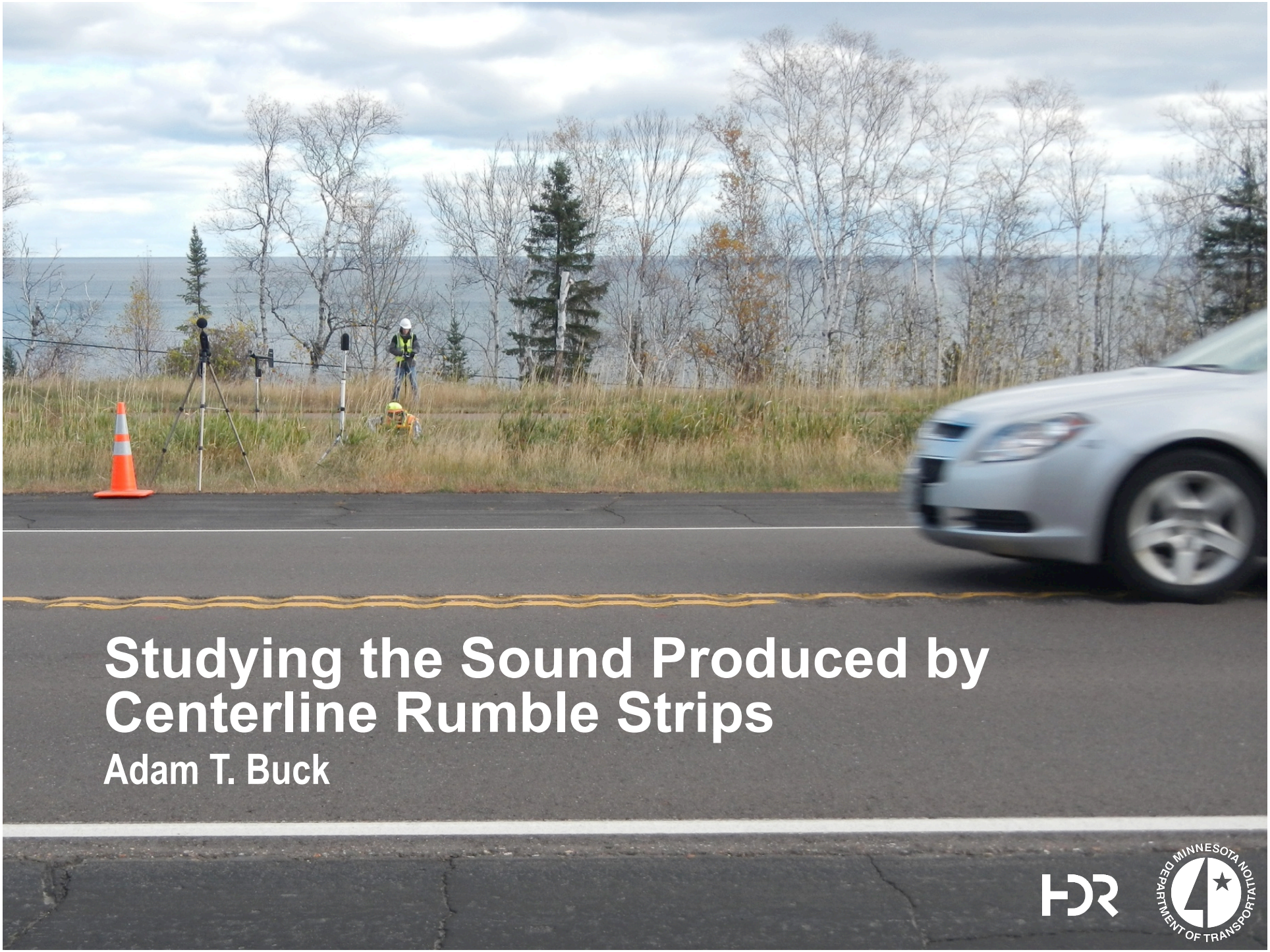
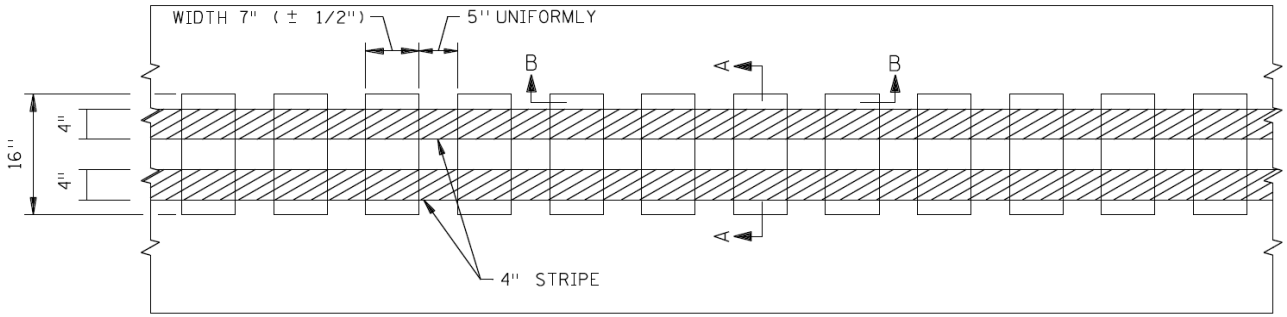


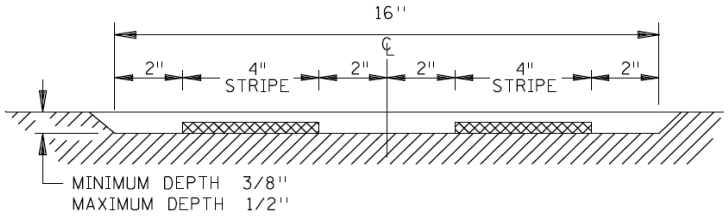
Studying the Sound Produced by Centerline Rumble Strips

Adam T. Buck

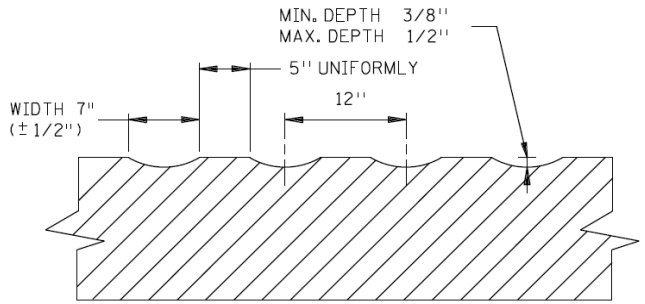
Project Background

- Centerline rumble strips
  - Part of MnDOT's "Toward Zero Deaths" initiative
  - Used on undivided rural highways with speeds of 55 mph





SECTION A-A

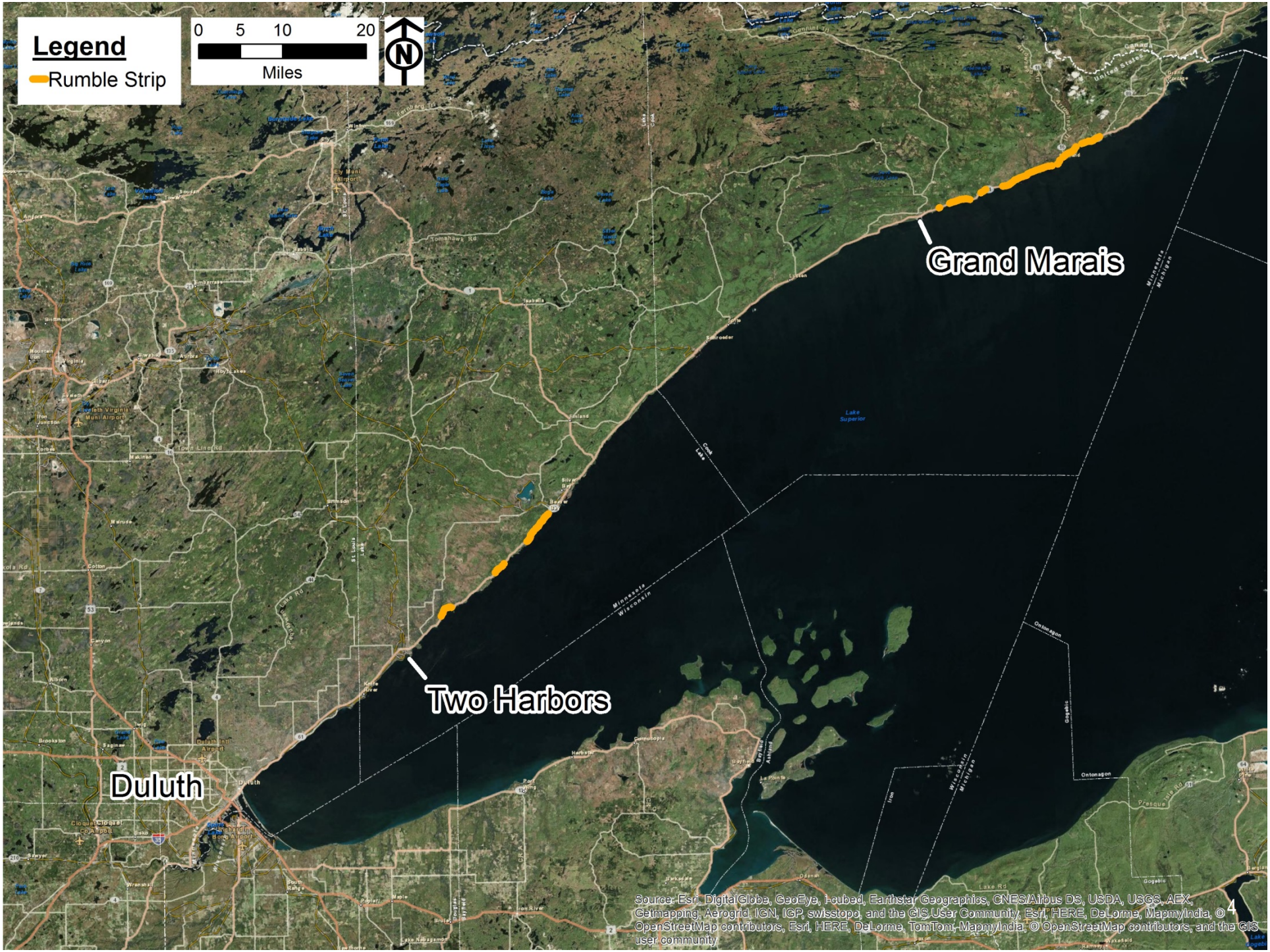


SECTION B-B

Source: MnDOT 2011

Project Background

- Minnesota Trunk Highway (TH) 61
  - Extends from Duluth, MN to the Canadian border
  - Annual Average Daily Traffic from 2,250 to 5,900 (MnDOT 2012)
  - Centerline rumble strips installed in Summer 2012 and 2013
  - Residents expressed concerns in Summer 2013


Legend
Rumble Strip
0 5 10 20
Miles
Grand Marais
Two Harbors
Duluth
Lake Superior
Minnesota
Wisconsin
Michigan
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

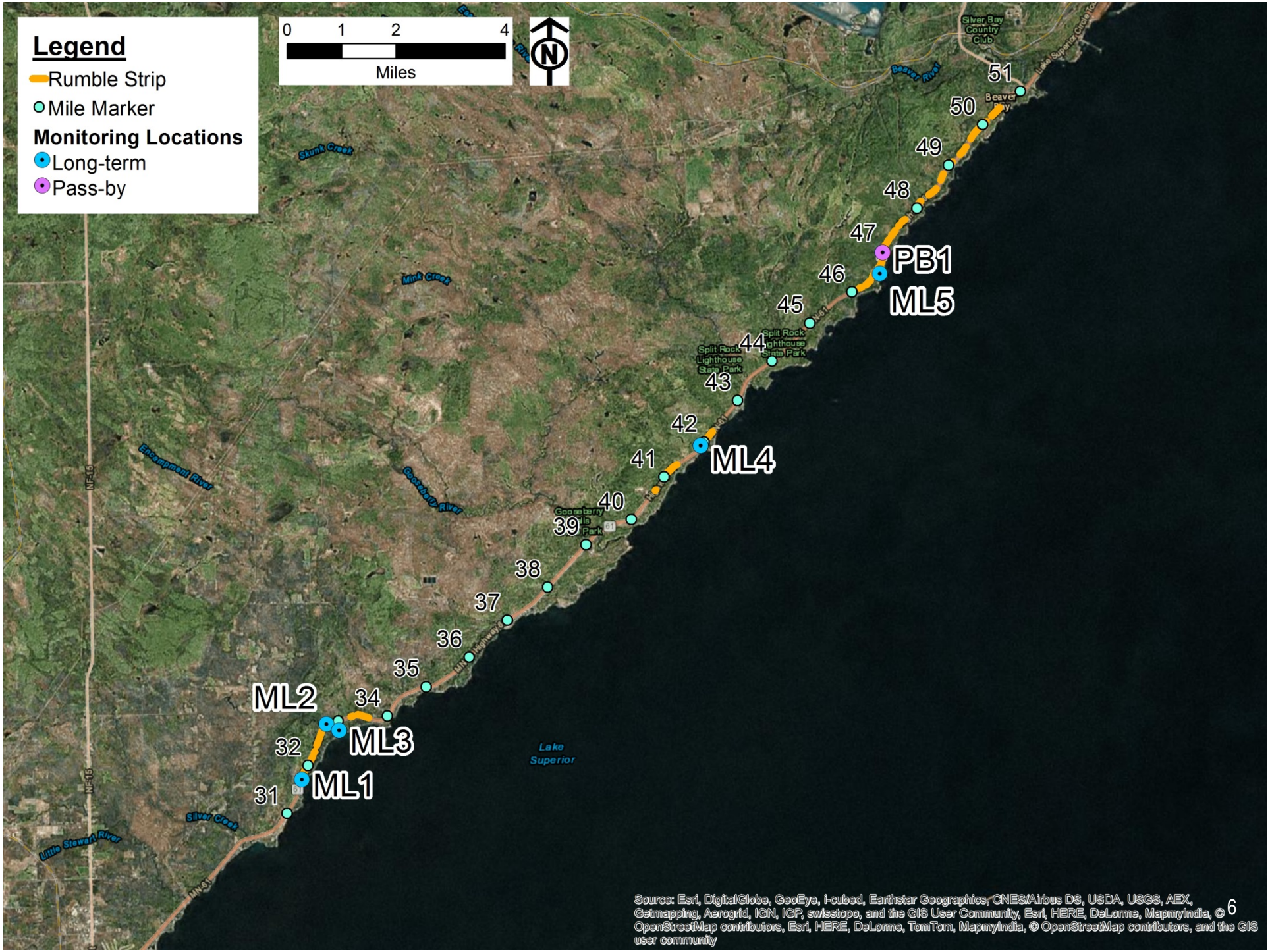
Project Background

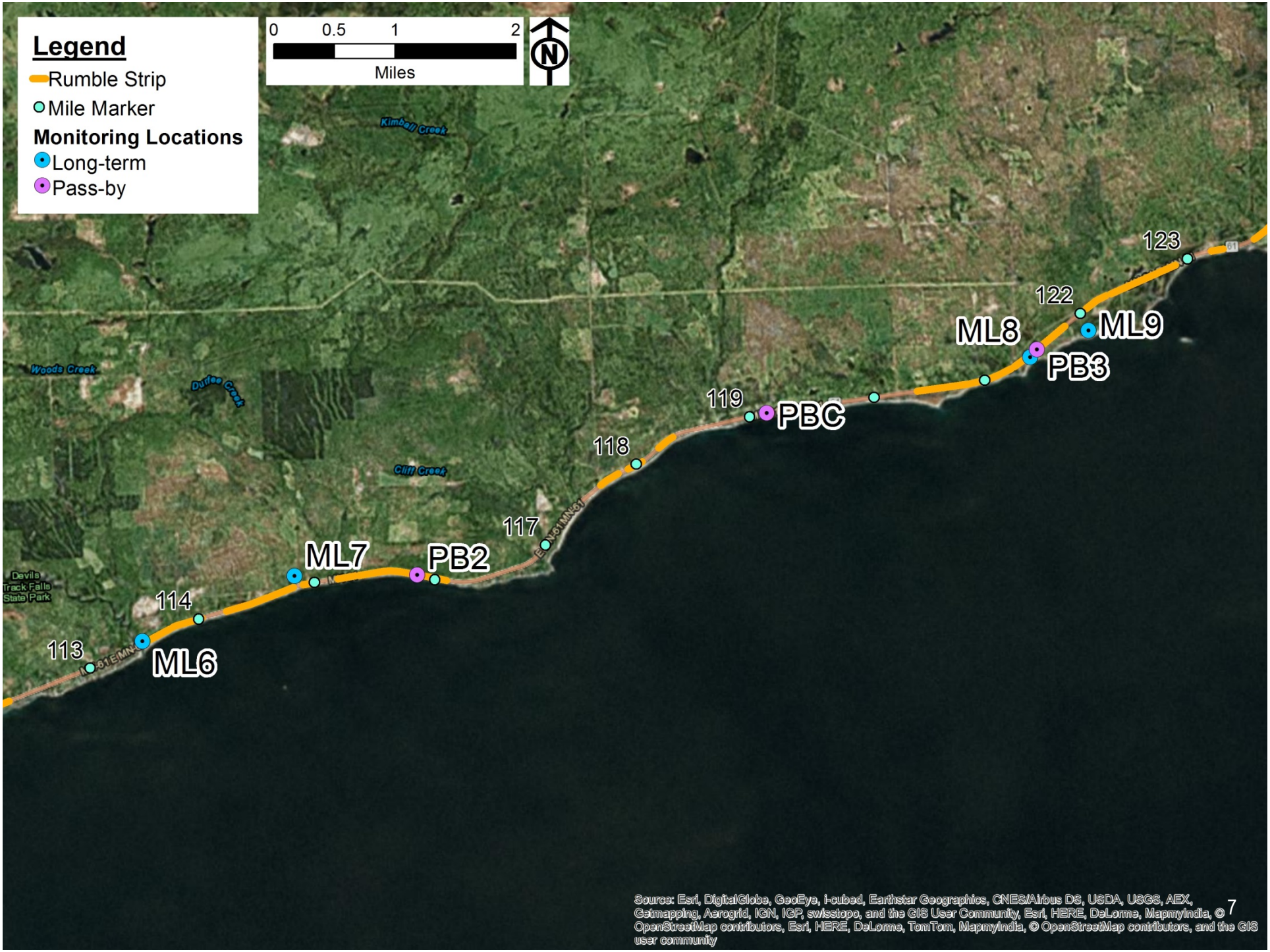
- Goals
  - Evaluate compliance with Minnesota Pollution Control Agency (MPCA) noise standard
    - Long-term monitoring in October and November 2013

Time of Day	L10, dBA	L50, dBA
Daytime (7 AM – 10 PM)	65	60
Nighttime (10 PM – 7 AM)	55	50

Source: MPCA 2008

  - Document sound levels produced by centerline rumble strips
    - Controlled vehicle pass-by monitoring in October 2013
      - » AASHTO TP 98-12


Legend
Rumble Strip
Mile Marker
Monitoring Locations
Long-term
Pass-by
0 1 2 4
Miles
N
Silver Bay Country Club
Beaver River
Beaver Bay
Skunk Creek
Mink Creek
Split Rock Lighthouse State Park
Encampment River
Gooseberry River
Gooseberry Falls State Park
Lake Superior
Silver Creek
Little Stewart River
NF-15
MN-61
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
35
34
32
31
PB1
ML5
ML4
ML2
ML3
ML1
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS user community


Legend
Rumble Strip
Mile Marker
Monitoring Locations
Long-term
Pass-by
0 0.5 1 2
Miles
N
Kimball Creek
Woods Creek
Dutee Creek
Cliff Creek
Devils Track Falls State Park
113
114
117
118
119
122
123
ML6
ML7
PB2
PBC
ML8
PB3
ML9
Source: Esri, DigitalGlobe, GeoEye, i-cubed, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, Esri, HERE, DeLorme, TomTom, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

Measurements

- Long-term data collection
  - 7 residences, 1 lodge, and 1 clearing
  - Varying landscapes 30 to 900 feet from TH 61
  - 7-day monitoring periods
  - Sound levels in 1-hour and 1-second intervals
  - Continuous audio recordings
  - Wind speeds (excluded if ≥ 11 mph) and precipitation events

Measurements

- Controlled pass-by data collection
  - 4 grassy clearings
  - Sound level meters at 25, 50, and 100 feet
  - Microphones approximately same height above pavement
  - Sound levels in 100-ms and 125-ms intervals
  - Continuous audio recordings
  - Wind speeds

Measurements

- Controlled pass-by data collection
  - Vehicle speeds using handheld radar gun
  - 27 total pass-by events per location
    - 3 passes
    - 3 vehicle speeds: 45, 55, and 65 mph
    - 3 vehicle maneuvers
      - » Control pass-by
      - » Drift onto rumble strip
      - » Merge across rumble strip


NO PASSING ZONE

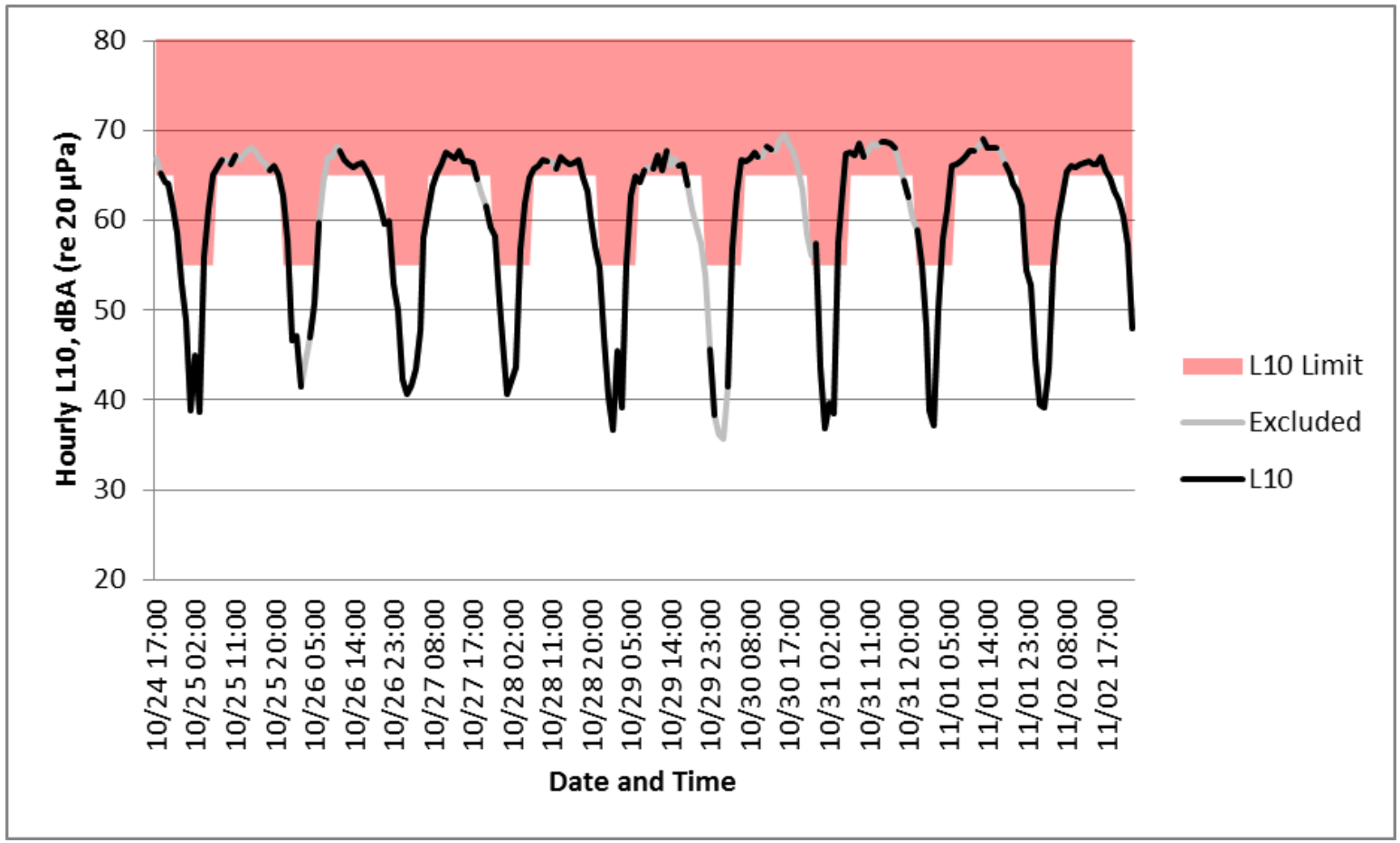
Results

- Summary of long-term measurements

Monitoring Location	Distance to TH 61, feet	Lday, dBA	Lnight, dBA	Ldn, dBA
ML4	30	69	62	70
ML2	60	62	56	64
ML8	60	59	52	60
ML6	80	61	54	62
ML1	130	52	47	54
ML5	430	46	43	50
ML7	450	49	45	52
ML9	800	44	44	50
ML3	900	42	39	46

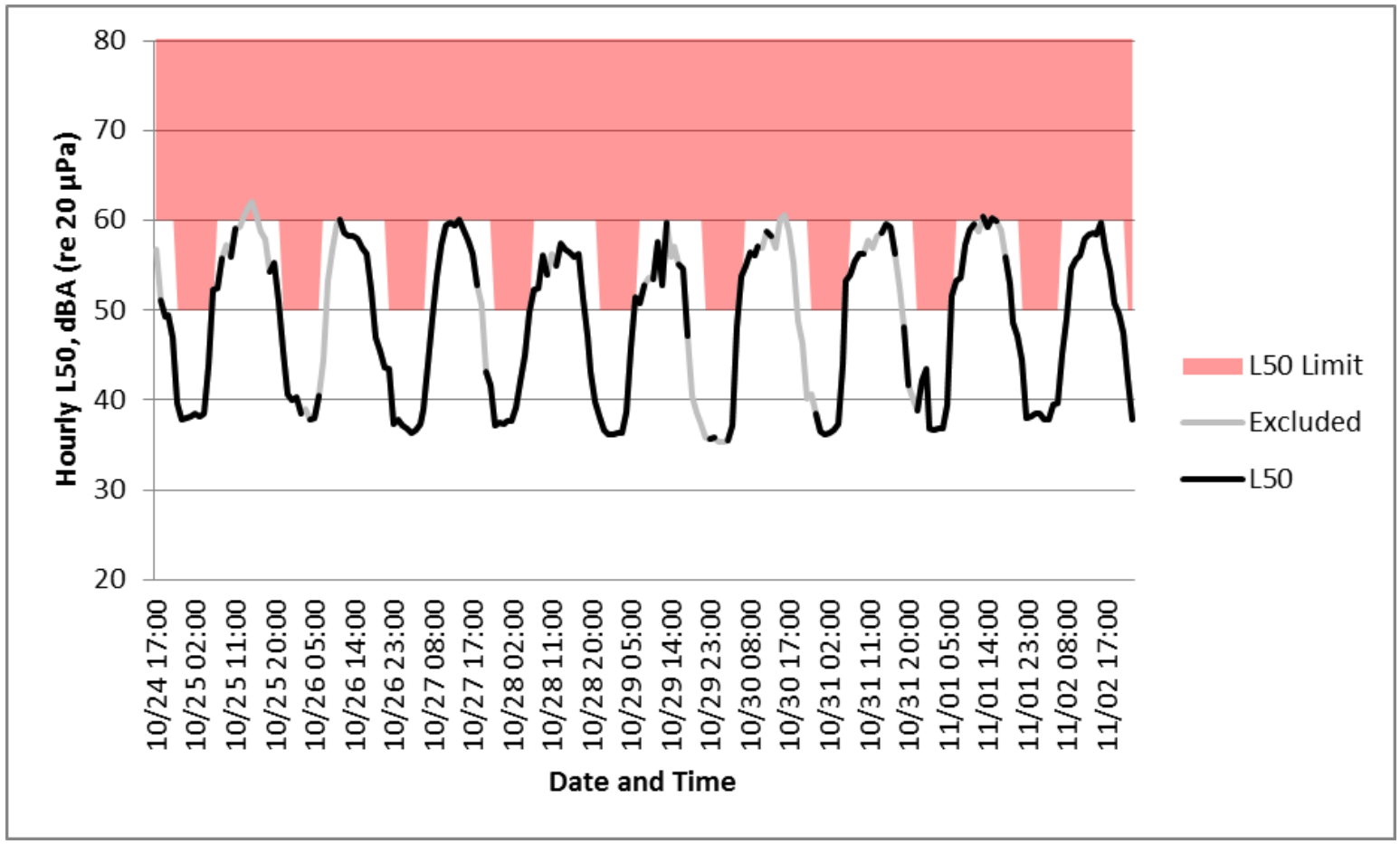
Results

- Hourly L10 at ML2 (60 feet from TH 61)



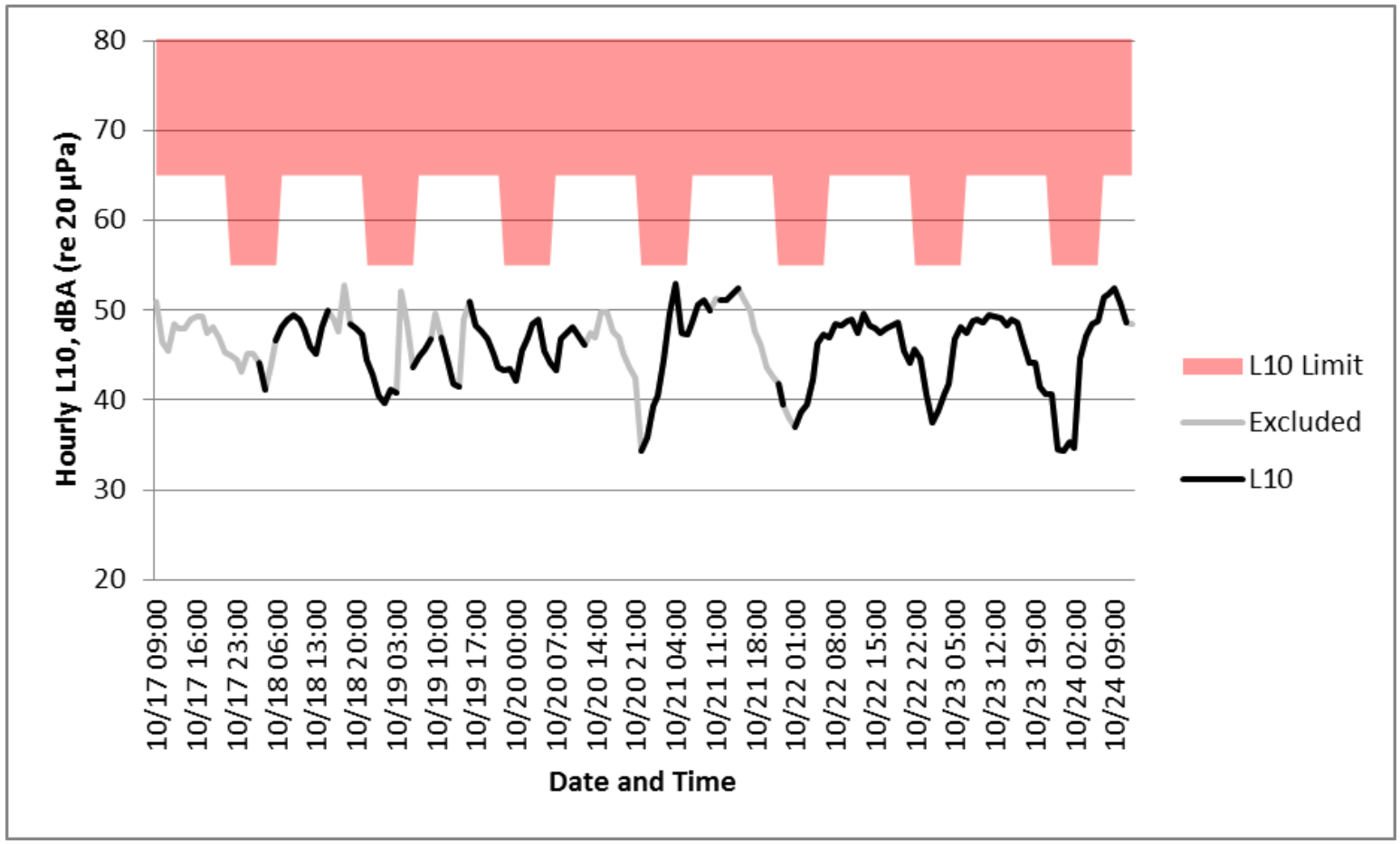
Results

- Hourly L50 at ML2 (60 feet from TH 61)



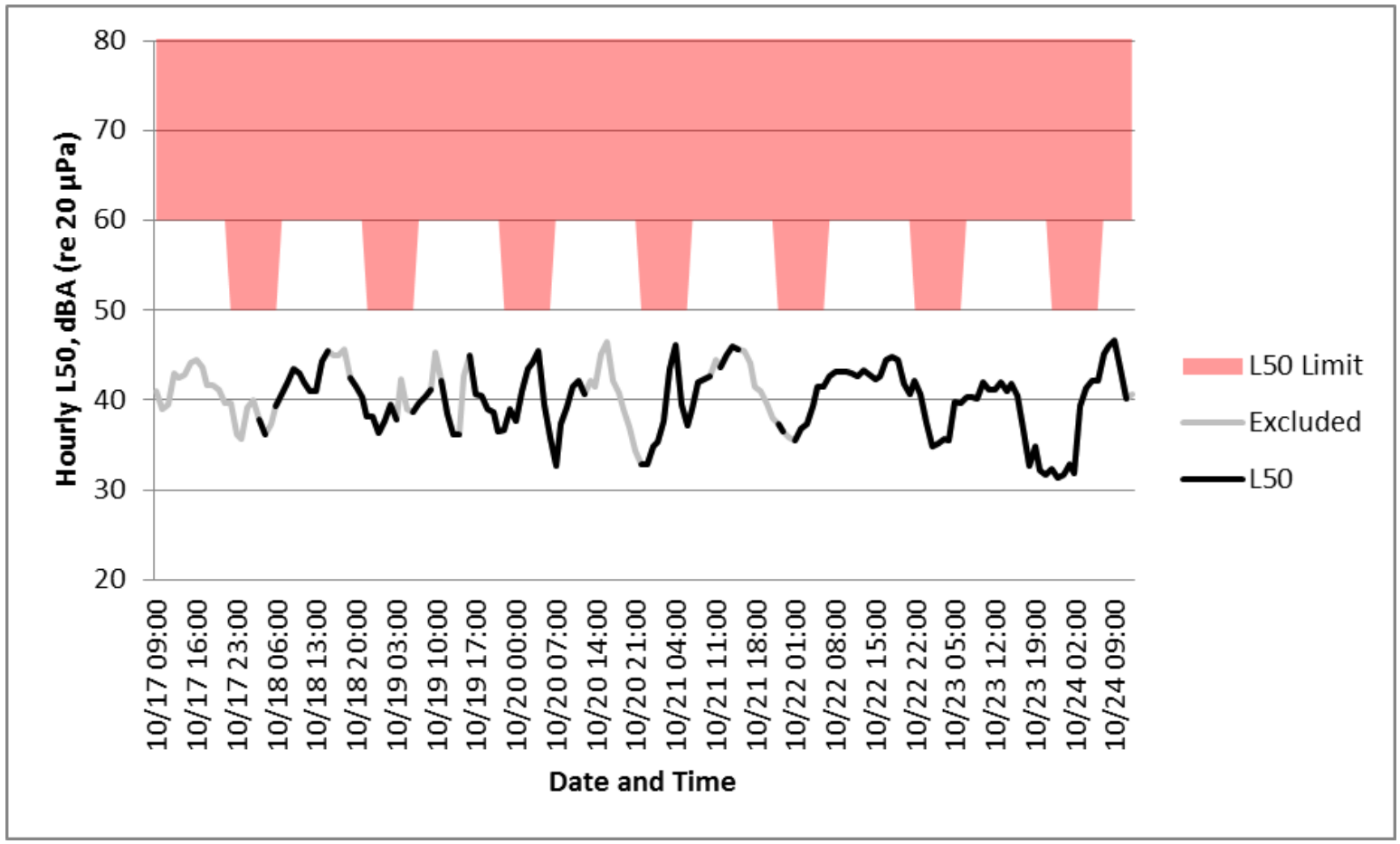
Results

- Hourly L10 at ML5 (430 feet from TH 61)



Results

- Hourly L50 at ML5 (430 feet from TH 61)

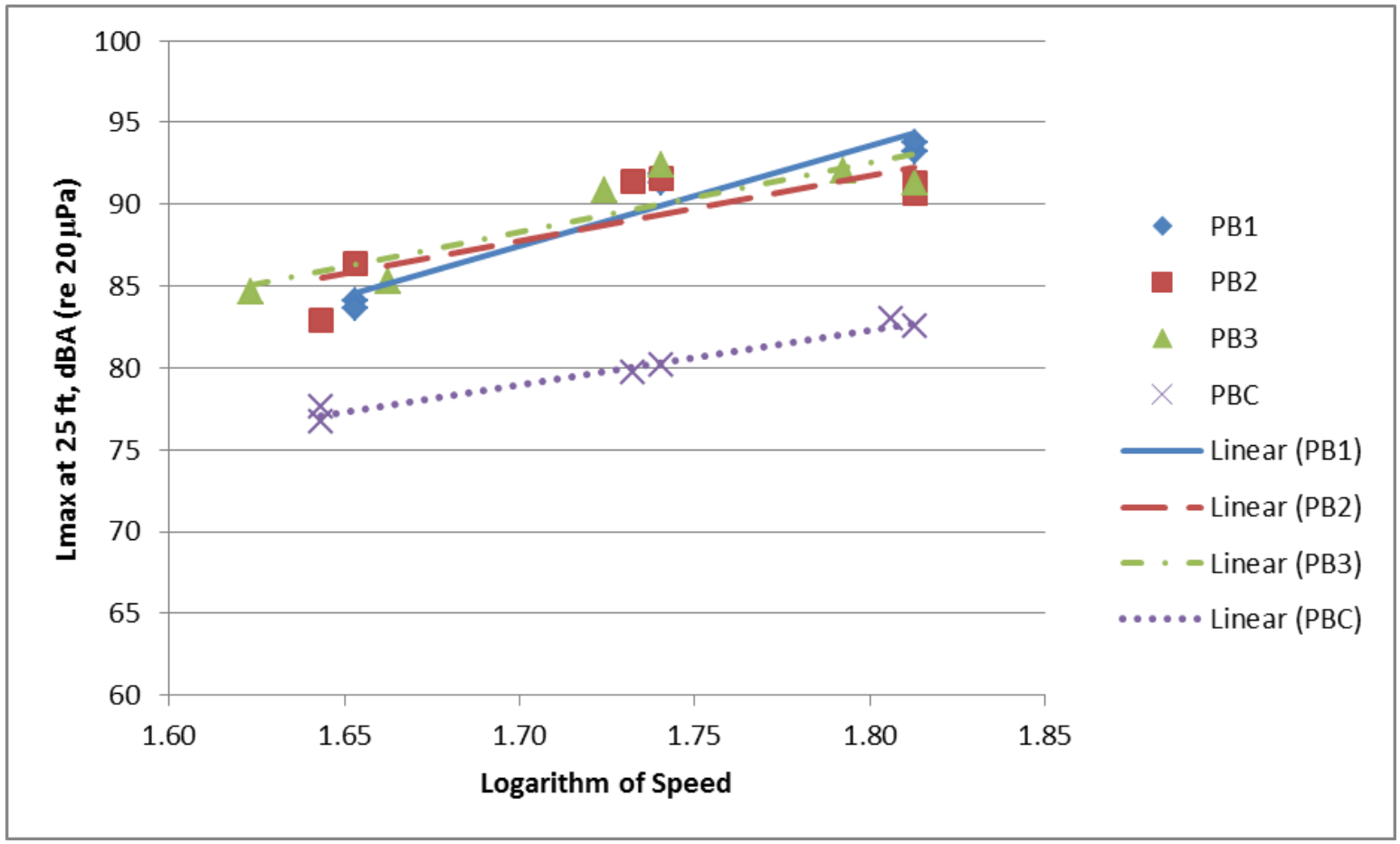


Results

- Controlled pass-by data analysis
  - Linear regression analysis (AASHTO TP 98-12)
  - Evaluate independent variables
    - Monitoring location
    - Vehicle maneuver
    - Lane of travel
    - Vehicle speed
    - Distance

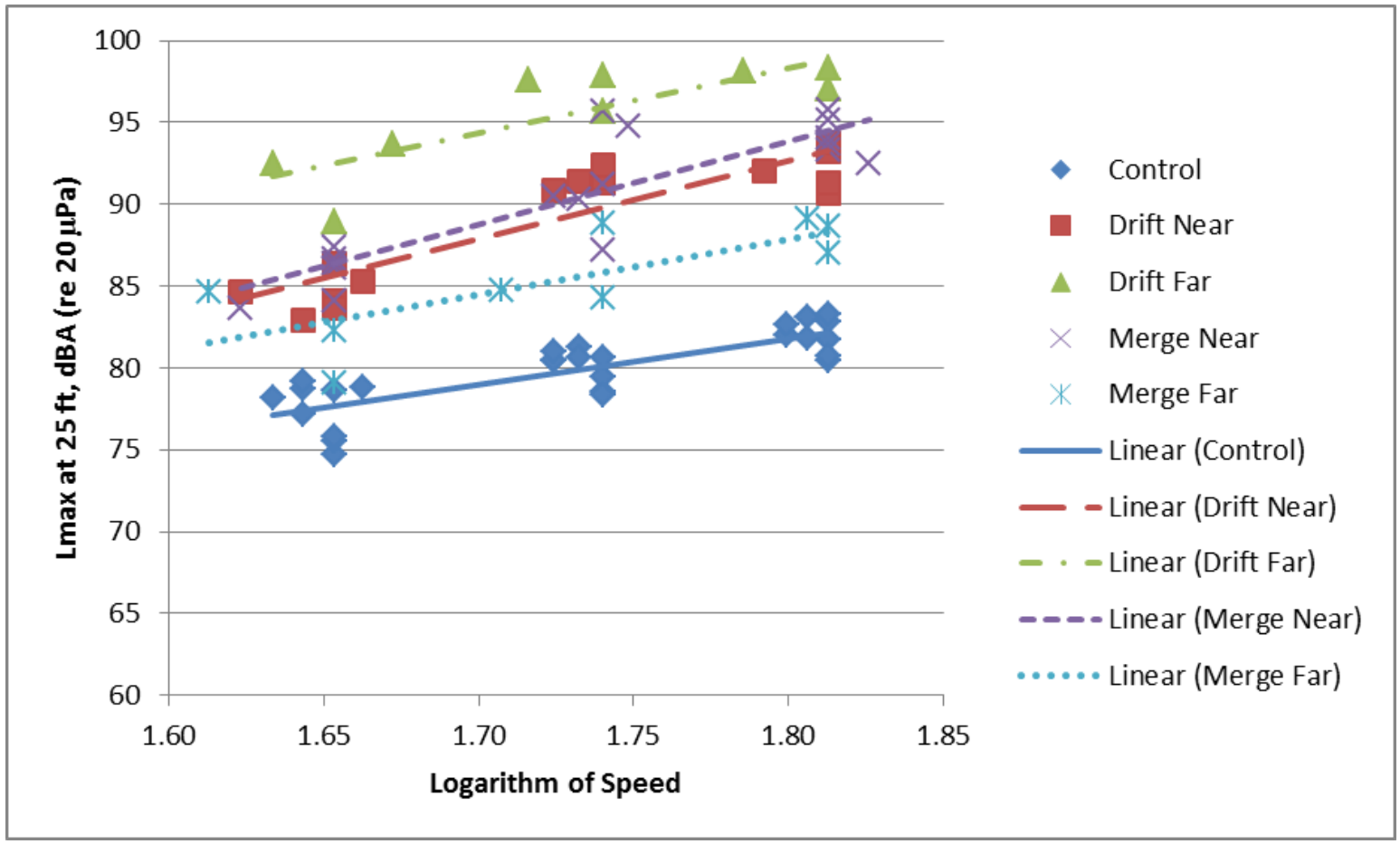
Results

- Location analysis – Drift maneuver in near lane



Results

- Maneuver and lane analysis

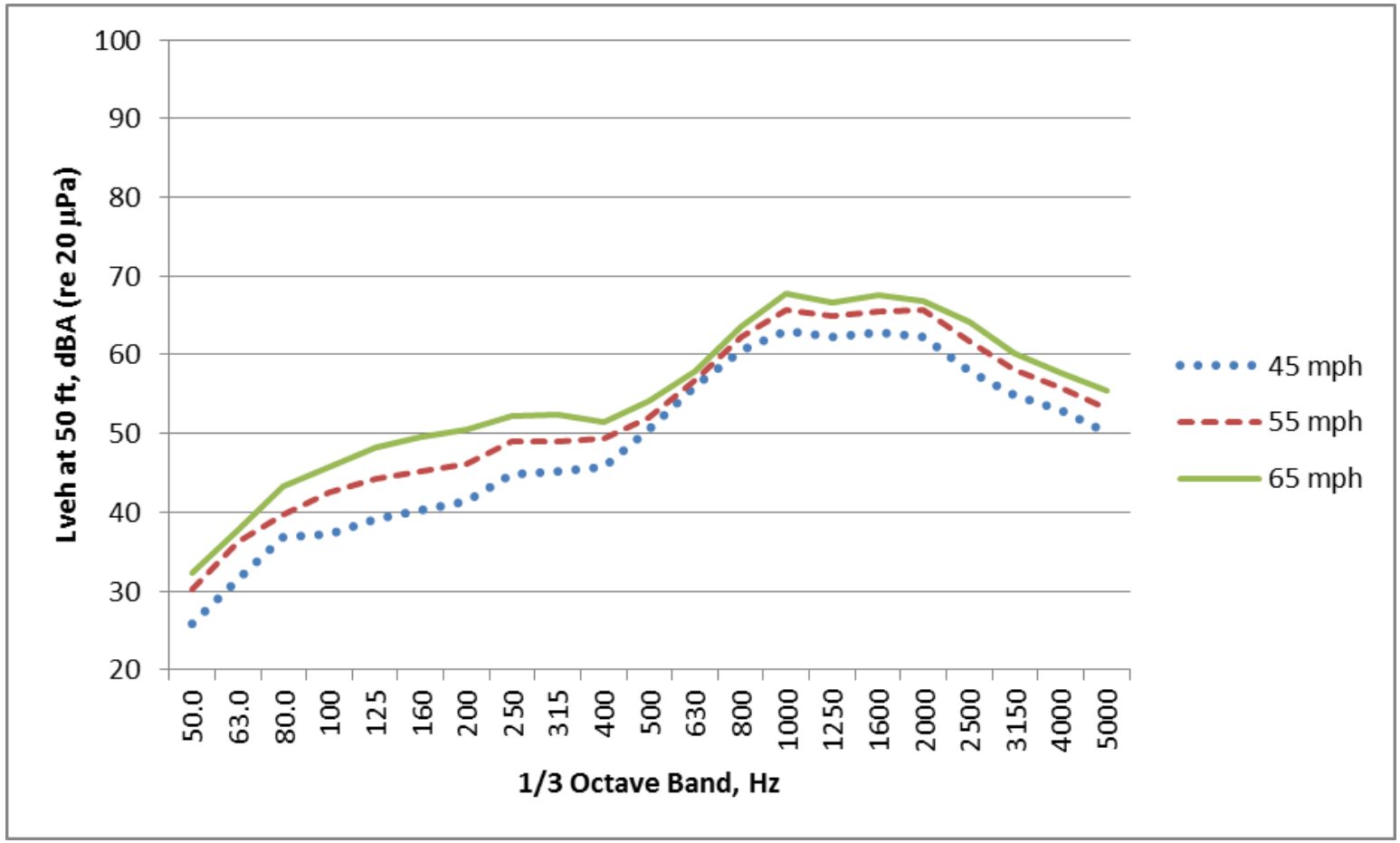


Results

- Vehicle can shield the tire-rumble strip interaction
  - Far lane louder for drift maneuver
  - “Near lane” louder for merge maneuver

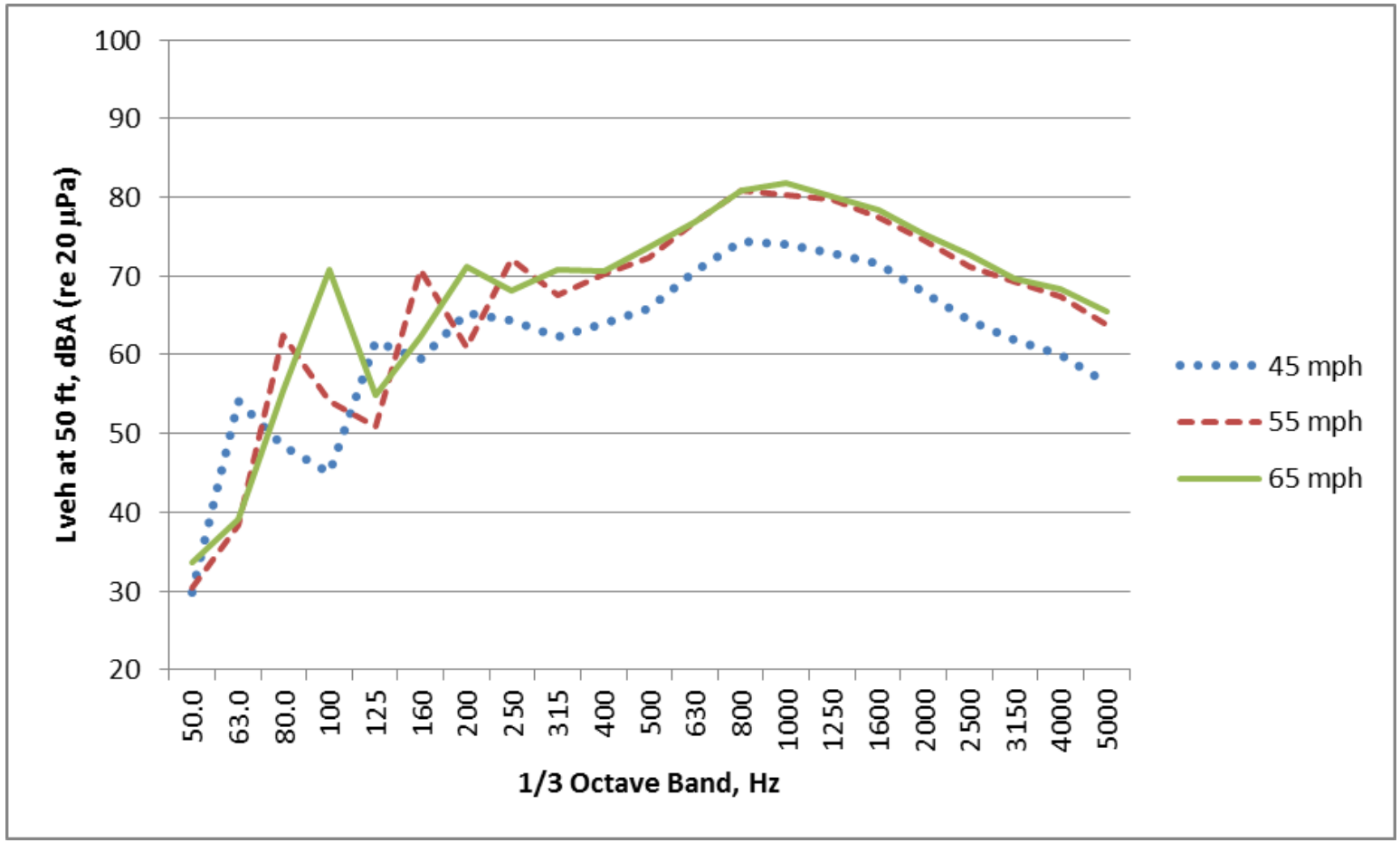
Results

- Spectral analysis – Control maneuver



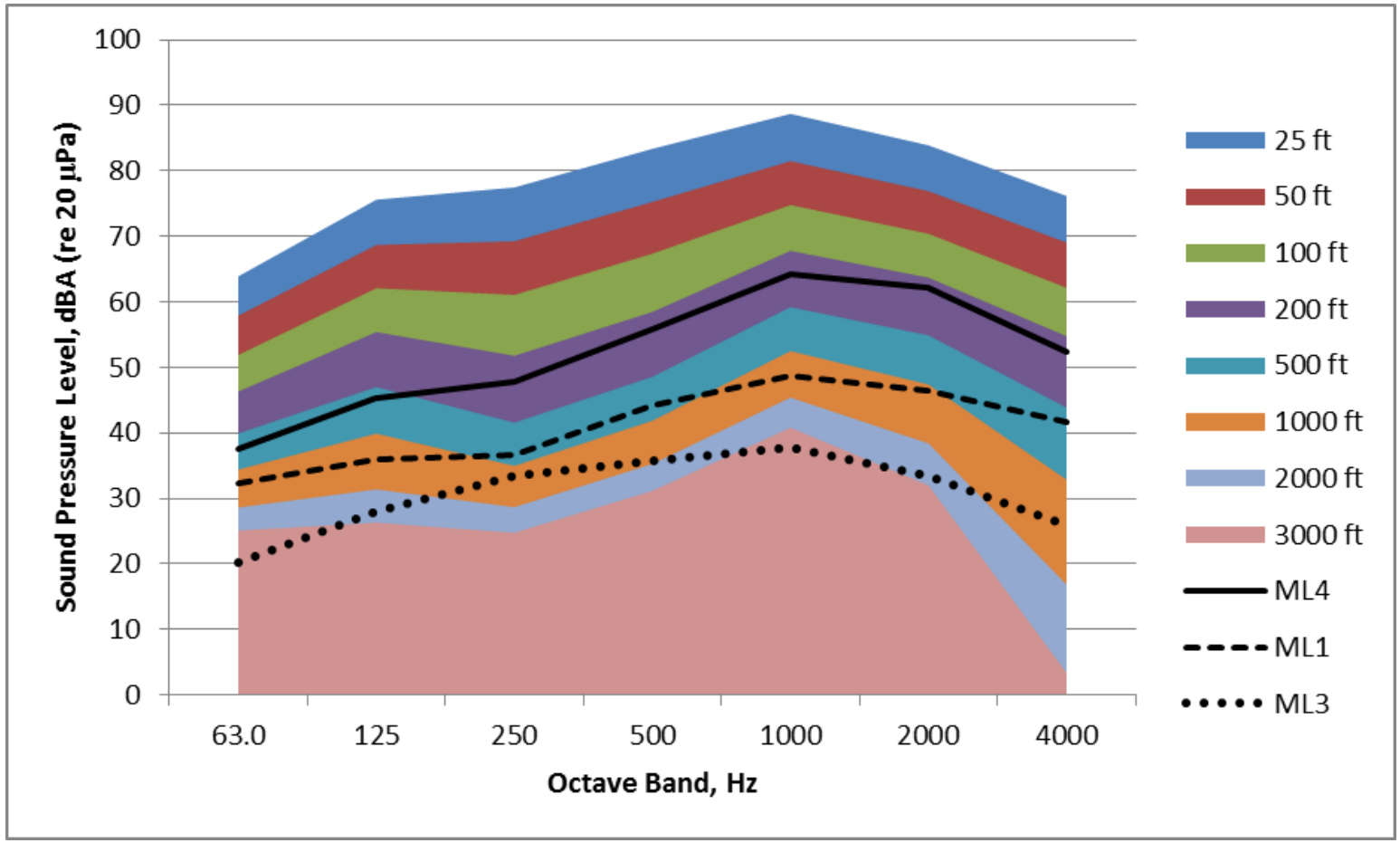
Results

- Spectral analysis – Drift maneuver



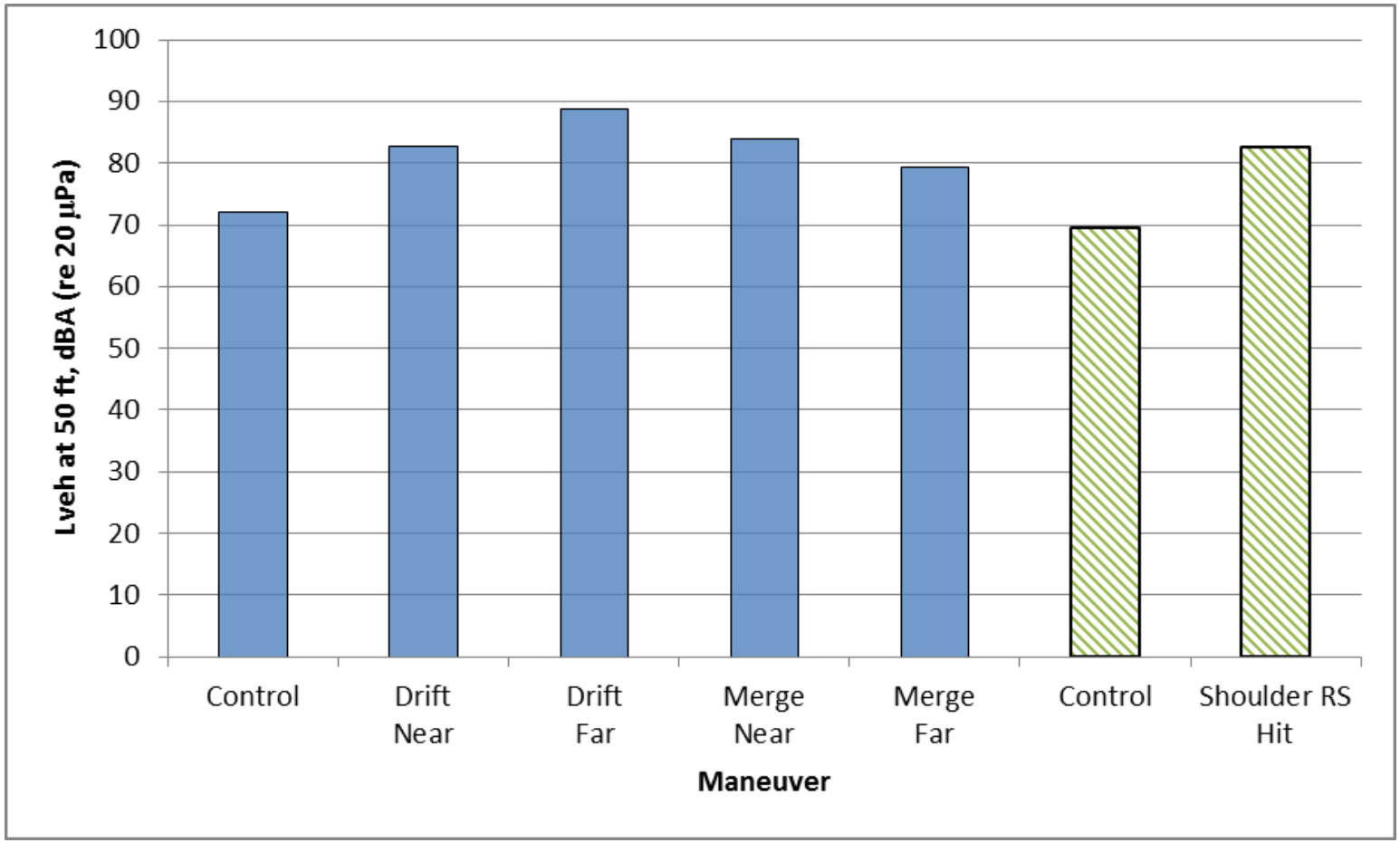
Results

- Distance analysis using Cadna-A



Results

- Comparison with previous MnDOT study (MnDOT 2009)



Conclusions

- Documented the sound environment
- Evaluated MPCA compliance
- Documented rumble strip sound levels
- Analyzed characteristics of rumble strip hits

Thank you!

adam.buck@hdrinc.com

Full report: http://www.dot.state.mn.us/trafficeng/safety/rumble/techreportfinal.pdf

References

- American Association of State Highway and Transportation Officials (AASHTO). 2012. "Determining the Influence of Road Surfaces on Vehicle Noise Using the Statistical Isolated Pass-By (SIP) Method." AASHTO TP 98-12.

- Minnesota Department of Transportation (MnDOT). 2012. "County Maps." *Traffic Forecasting & Analysis*. Available: http://www.dot.state.mn.us/traffic/data/maps-county-alpha.html.

- Minnesota Department of Transportation (MnDOT). 2011. "Rumble Strips and StripEs on Rural Trunk Highways." Technical Memorandum Number 11-02-T-02. Engineering Services Division. Available: http://dotapp7.dot.state.mn.us/edms/download?docId=1055001.

- Minnesota Department of Transportation (MnDOT). 2009. "Rumble Stripe Noise Study." Office of Traffic, Safety, and Technology. Available: http://www.dot.state.mn.us/trafficeng/safety/rumble/powerpoints/Mndot%20Rumble%20Stripe%20Noise%20Study.pdf.

- Minnesota Pollution Control Agency (MPCA). 2008. "A Guide to Noise Control in Minnesota: Acoustical Properties, Measurement, Analysis, and Regulation." Available: http://www.pca.state.mn.us/index.php/view-document.html?gid=5355.