Roadway Dispersion Modeling using AERMOD and R-LINE: an Investigation into Length, Width, and Dispersion Model Methodology for the Las Vegas Near-Road Field Study

Ryan Cleary[1], Michelle G. Snyder[1], and R. Chris Owen[2]
[1] Wood, RTP, NC [2] Environmental Protection Agency, RTP, NC

PURPOSE

Model selection and characteristics of a modeled roadway, such as length and width, impact estimates of near-road concentrations. As modelers seek to maximize simulation efficiency without sacrificing the quality of model results, we explore dispersion modeling methods using three AERMOD source types to estimate dispersion from a roadway:

- AERMOD version 18081 LINE
- AERMOD version D19XXX RLINE
- AERMOD version 18081 VOLUME

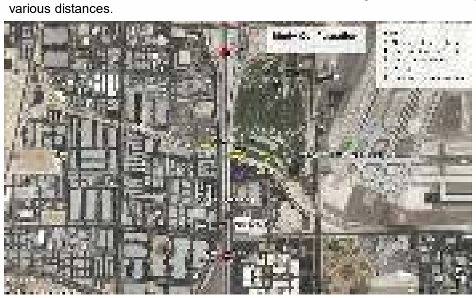
In this work, we determine if a reduction in the length of the modeled roadway sources results in a reasonable representation of the original sources. Additionally, we contrast model simulation time from shorter sources with model performance.

BACKGROUND/INTRODUCTION

- **The Research LINE source model for near-surface releases (R-LINE)** – R-LINE is a research dispersion modeling tool designed to characterize mobile sources along roadways, simulated as line source emissions. R-LINE was developed for near-surface releases in a flat-terrain environment and contains formulations for vertical and lateral dispersion, low wind meander, and Monin-Obukhov similarity profile of surface winds, and uses AERMET hourly surface meteorology (Snyder, M.G. and D.K. Heist., 2013).

- **R-LINE Integration into AERMOD** - The U.S. EPA Office of Air Quality Planning and Standards (OAQPS) is collaborating with the U.S. Department of Transportation's Federal Highway Association (FHWA) to evaluate impacts of traffic emissions on near-road air quality. As part of this effort, EPA has initiated the integration of the R-LINE version 1.2 model code and algorithms into the current version (18081) of the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) dispersion model. The integrated code, described here as "D19XXX", has not yet been released, but offers an opportunity to evaluate near-road surface releases using multiple AERMOD source types, including the new, developmental "RLINE" source type.

- **Las Vegas Field Study-** In a joint effort between the EPA and the FHWA, a long-term field study was conducted from December 2008 to December 2009 in Las Vegas to measure air pollutants, including CO, at various distances.



Study Characteristics (Kimbrough et al., 2012)

- Roadbed 5.4 meters below grade
- Road surface 60 meters wide
- Flat terrain at top of 20° sloping embankment
- Monitors/Receptors located 100m upwind and 20m, 100m, and 300m downwind
- Measured winds predominantly from southwest
- AADT volume of 206,000 vehicles/day

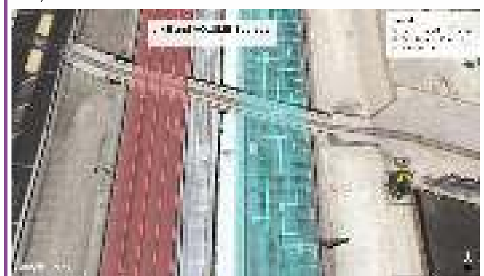
DISPERSION MODELING APPROACH

Modeling parameters and inputs used for all scenarios included:

- **Sources** - Defined to represent heavy duty (HD) and light duty (LD) vehicles for each of the 4 Northbound and 4 Southbound traffic lanes at the study site (16 total source combinations for the LINE and RLINE source types).
- **Parameters** - Source parameters for release height (1.3m for LD; 3.4m for HD) and initial vertical dimension (1.2m for LD; 3.2m for HD) in accordance with Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas Appendix J.
- **Emissions** - AERMOD was processed with hourly emissions (HOUREMIS) varying for each source. Emissions rates were generated for Clark County, NV with the EPA MOtor Vehicle Emission Simulator (MOVES), system for 13 vehicle types (4 LD and 9 HD).
- **Scenario** - March 10, 2009 Hour 06 through September 28, 2009 Hour 13.
- **Meteorology** - Las Vegas McCarran International Airport (KLAS) NWS surface and Mercury/Desert Rock, NV (KDRA) upper air meteorological data processed using AERMET version 18081.
- **Receptors** - 4 receptors based on the location of study monitor sites.
- **Model options** - Modeling was performed using the FLAT option, due to the R-LINE model formulation as a flat-terrain model, and the URBANOPT with a population of 1,000,000.

LENGTH ANALYSIS

Each of the selected source types can be used to model impacts from a roadway, with source type selection requiring various considerations. The LINE source type, currently recommended by EPA for modeling roadway sources, assumes emissions are uniformly distributed across the source, uses a version of the AERMOD AREA source numerical integration approach and is appropriate for low level releases. The recommended source length/width aspect ratio for LINE sources is less than 100 to 1, which was not maintained in this study (USEPA, 2018).



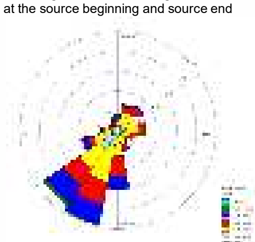
Use of the VOLUME source type addresses horizontal meander algorithms, unlike the LINE source type, but requires longer simulation times. Scripts were developed to convert LINE source locations and dispersion parameters to VOLUME sources, based on AERMOD model guidance. Modeling the roadway by lane provides consideration for the "receptor exclusion zone", where VOLUME sources should be defined to ensure receptors are not located within 1 meter of the source (USEPA, 2015).

The RLINE source type simulates near-surface releases by numerically integrating point source emissions. RLINE does not account for terrain elevation variations, but includes vertical and lateral dispersion rates, based on field and wind tunnel studies, and horizontal meander.

The base-case sources were processed for an approximately 1-mile length of roadway along the I-15 Las Vegas Freeway. The test-case sources had lengths of 0.25, 0.50, and 0.75 of the original. Reduced-length sources maintained the center point of the full length sources, with reductions at the source beginning and source end points.

Concentrations were evaluated based on the wind direction observed for that hour in the AERMET surface meteorology file. Wind directions were allocated using the following meteorological wind direction angles:

- Parallel: wind direction < 30°; or ≥ 150° and ≤ 210 °; or > 330°
- Easterly: wind direction > 30° and < 150 °
- Westerly: wind direction > 210° and < 330°



Simulation time was recorded for each of the individual length scenarios for each AERMOD source type to evaluate the impact of the reduction in number of sources.

RESULTS

AERMOD LINE Source

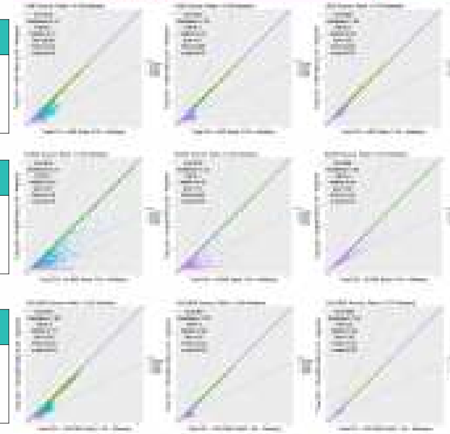
Length Ratio	No. Sources	Simulation Time
1.00	16	1 min
0.75	16	1 min
0.50	16	1 min
0.25	16	1 min

AERMOD RLINE Source

Length Ratio	No. Sources	Simulation Time
1.00	16	5 min
0.75	16	4 min
0.50	16	3 min
0.25	16	2 min

AERMOD VOLUME Source

Length Ratio	No. Sources	Simulation Time
1.00	436	1 hr 46 min
0.75	327	1 hr 15 min
0.50	218	50 min
0.25	109	25 min



Length Ratio	Receptor	Source Length/ Receptor Distance	LINE r^2	LINE Geom Mean	RLINE r^2	RLINE Geom Mean	VOLUME r^2	VOLUME Geom Mean
0.75	X20	60.4	0.996	0.99	0.999	1.00	0.999	1.00
0.75	X100	12.1	0.997	1.00	0.999	1.00	0.998	1.01
0.75	X300	4.0	0.996	1.01	0.998	1.01	0.968	1.10
0.50	X20	40.3	0.999	1.00	0.999	1.00	0.998	1.01
0.50	X100	8.1	0.996	1.02	0.998	1.02	0.995	1.05
0.50	X300	2.7	0.725	1.36	0.817	1.34	0.640	1.66
0.25	X20	20.2	0.956	1.09	0.972	1.08	0.994	1.05
0.25	X100	4.0	0.557	1.79	0.616	1.90	0.798	1.39
0.25	X300	1.3	0.152	28.21	0.233	11.81	0.246	5.93

CONCLUSIONS

- Shorter source lengths result in a reduction in modeled concentrations for each of the modeled source types and wind directions.
- A source length of 8x the receptor distance is sufficient (based on the 100-m downwind receptor for the 0.50 test-case) for modeling concentrations from a roadway, while a source length of 4x the receptor distance is insufficient (300-m downwind receptor for the 0.25 test-case). Inclusion of additional receptors at intermediate distances is required for refinement of a recommended source length.
- Simulation time decreases proportionately with decreases in the number of VOLUME sources modeled, with model results comparable for the base-case and 0.75 test-case.
- The VOLUME source type requires significantly longer computational time compared to the LINE or RLINE source types. Additional investigation is required to determine if the increased simulation time results in better model performance.

REFERENCES/ACKNOWLEDGEMENTS

- Snyder, M. G. and D. K. Heist, 2013: User's Guide for R-Line Model Version 1.2: A Research Line Source Model for Near-Surface Releases, U.S. EPA/ORD/NERL, RTP, NC, MD-81.
- Kimbrough, S., R. Baldauf, G. S. W. Hagler, R. C. Shores, W.A. Mitchell, D. A. Whitaker, C. W. Croghan, and D. A/ Vallero, 2012. Long-Term Continuous Measurement of Near-Road Air Pollution in Las Vegas: Seasonal Variability in Traffic Emissions Impact on Local Air Quality. Air Quality Atmosphere & Health. 10.1007/s11869-012-0171-x.
- USEPA, 2015: Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas, U.S. EPA, OTAQ, RTP, NC, EPA-420/B-15-084.
- USEPA, 2018: User's Guide for the AMS/EPA Regulatory Model (AERMOD), U.S. EPA, OAQPS, RTP, NC, EPA-454/B-18-001.