BELLEVUE-AREA FREEWAY AIR DISPERSION MODELING REPORT

Bellevue, Washington

November 27, 2024

Prepared for

City of Bellevue
Bellevue, Washington

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EXECUTIVE SUMMARY

In an effort to better understand the nature and extent of air pollution attributable to freeway vehicles within its city limits, the City of Bellevue, Washington retained Landau Associates, Inc. (Landau) to prepare air dispersion modeling simulations. The simulations prepared by Landau used the American Meteorological Society (AMS)/US Environmental Protection Agency (EPA) regulatory model (AERMOD) air dispersion modeling system, which was developed by the EPA and is the most widely used tool for the regulatory analysis of the impacts of emissions associated with transportation. Inputs to the model include meteorological and terrain data, as well as detailed information about the locations and configuration of the freeways that pass through the city and air pollutant emissions information about the range of vehicle types that operate on the freeways.

The results of the modeling confirm the intuitive expectation that air pollutant concentrations diminish with distance from the freeways and with increasing height above ground. However, model results provide an understanding of the spatial distribution of the magnitudes of air pollutant concentrations, which can facilitate assessment of human health risk, evaluation of mitigation strategies, and land-use planning decisions. In general, the model results indicate that pollutant concentrations dissipate with increasing distance from the freeways in both the horizontal and vertical directions.

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LIST OF ABBREVIATIONS AND ACRONYMS

AERMOD	AMS/EPA regulatory mode
AMS	American Meteorological Society
APEZ	air pollution exposure zone
ASIL	acceptable source impact level
BKR	Bellevue-Kirkland-Redmond
CAA	Clean Air Act
City	City of Bellevue, Washington
DPM	diesel particulate matter
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
FHWA	Federal Highway Administration
g	grams
I-	Interstate
Landau	Landau Associates, Inc.
LiDAR	light detection and ranging
$\mu g/m^3$	micrograms per cubic meter
MMIF	Mesoscale Model InterFace
mph	miles per hour
MOVES4	EPA's Motor Vehicle Emission Simulator
NAAQS	National Ambient Air Quality Standards
NO_2	nitrogen dioxide
NO_X	oxides of nitrogen
OEHHA	California Office of Environmental Health Hazard Assessment
PAH	polycyclic aromatic hydrocarbon
$PM_{2.5}$	particulate matter with an aerodynamic diameter less than or equal to 2.5 microns
PM_{10}	particulate matter with an aerodynamic diameter less than or equal to 10 microns
PSCAA	Puget Sound Clean Air Agency
REL	reference exposure level
s	second
TAP	toxic air pollutant
URF	unit risk factor
USGS	US Geological Survey
VMT	vehicle miles traveled
WAC	Washington Administrative Code

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1.0 INTRODUCTION

In April 2023, the City of Bellevue (City) produced a report titled "Air Quality and Land Use Planning: A Review of the Literature of High-Volume Roadways, Health Effects, and Mitigation Strategies" (City of Bellevue 2023). The 2023 report provided a review of the literature on "environmental health information for the city to consider, along with other factors, when making long-range planning decisions to increase development capacity." Specifically, this report focused on research, studies, and planning guidance related to "air pollution that exists around high-volume roadways … which have shown that health impacts associated with traffic-related air pollution can be minimized by reducing exposure to high pollutant concentrations."

Three major freeways pass through the city of Bellevue (i.e., Interstate [I-] 405, I-90, and State Route 520), each of which carries more than 100,000 vehicles per day on average. To build on the information in the April 2023 report, the City retained Landau Associates, Inc. (Landau) to prepare and execute an air dispersion model developed by the US Environmental Protection Agency (EPA) to predict air pollutant concentrations in areas of the city that are potentially impacted by traffic on the freeways that traverse the city. This report provides a description of the air dispersion model, how the model was used, and the results of the modeling. The results of the modeling can be used to help inform land-use planning efforts in Bellevue.

2.0 MODEL SETUP, INPUTS, AND EXECUTION

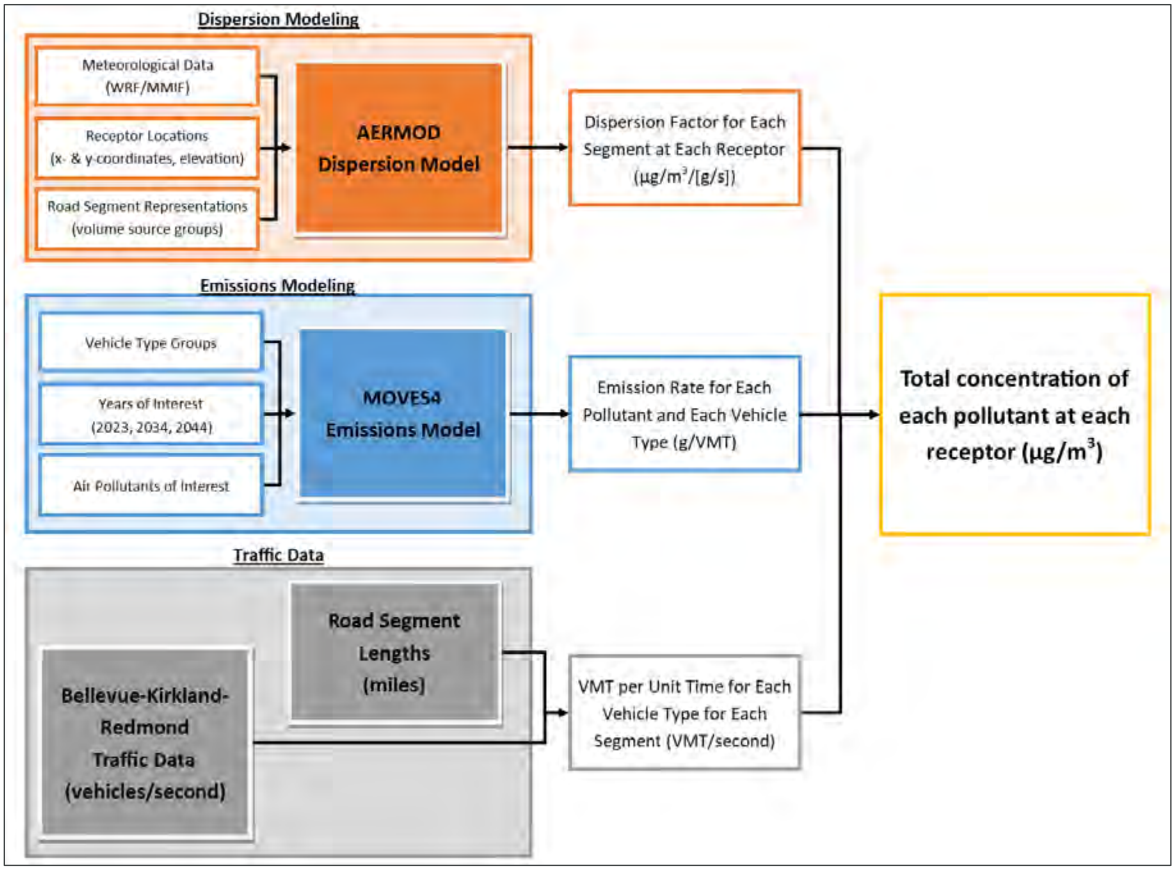
The EPA, in collaboration with the American Meteorological Society, has developed an air dispersion modeling system called AERMOD,[1] which is currently the EPA's preferred dispersion model recommended for, among other situations, complex air pollutant source configurations. In addition to being recommended by the EPA, the Washington State Department of Ecology (Ecology), and the Puget Sound Clean Air Agency, the AERMOD modeling system is the required dispersion model for transportation conformity analyses, and is therefore the most widely used tool for the regulatory analysis of the impacts of emissions associated with transportation.

AERMOD uses meteorological and terrain data specific to an area of interest (e.g., the area surrounding an industrial facility, a highway, an intermodal terminal, or a transit project) along with information about air pollutant emissions from a piece of equipment (e.g., a vehicle) to calculate the air concentration of that pollutant at a specific location defined by x and y coordinates and an elevation above ground, which is typically referred to as a "receptor location."

The AERMOD modeling system is composed of several computer programs. Two of these programs, AERMET and AERMAP, are used to process and format meteorological and terrain data, respectively. The AERMOD modeling system uses the prepared meteorological and terrain data along with exhaust characteristics and air pollutant emission rates to calculate air pollutant concentrations at receptor locations. The current regulatory versions of AERMOD and its preprocessor programs were used to simulate dispersion of air pollutants from vehicles operated on the freeways that pass through the city as influenced by meteorological and terrain data that are representative of conditions within and around the city.

[1] The air dispersion model developed by the American Meteorological Society (AMS)/ EPA Regulatory Model Improvements Committee (AERMIC) was called the "AERMIC Model," which was shortened to "AERMOD."

Figure 1: Model Inputs Flow Chart



Abbreviations and Acronyms:

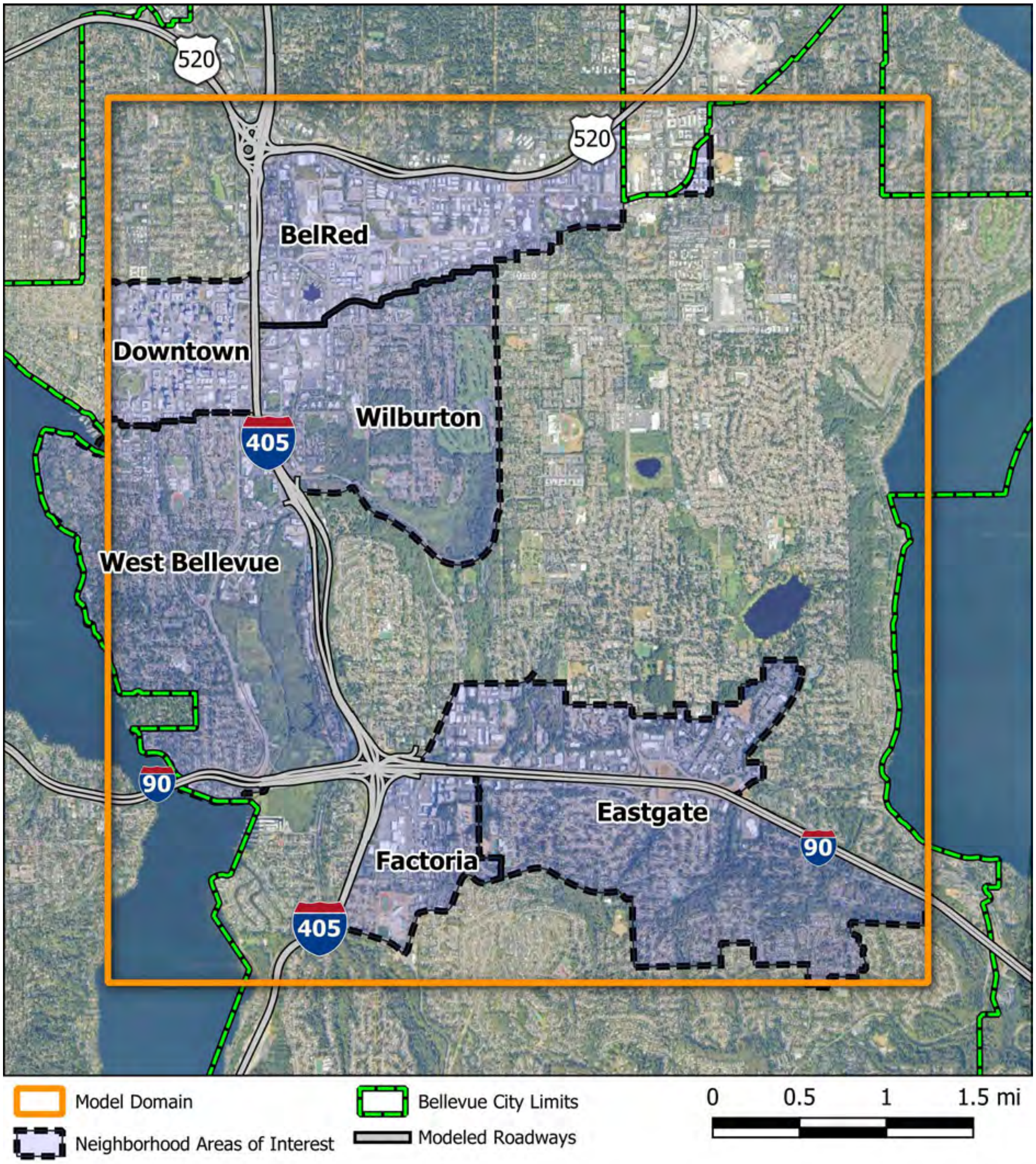
g = grams
µg/m³ = micrograms per cubic meter
MMIF = Mesoscale Model InterFace
s = second
VMT = vehicle miles traveled
WRF = Weather Research and Forecasting model

The subsections below describe the data and information provided to the model, and the options and settings used when the model was executed. Additional information about the algorithms and assumptions AERMOD uses to calculate air pollutant concentrations is provided in Appendix A. More detailed information about the specific inputs and assumptions used to model freeway vehicle emissions is provided in Appendix B.

2.1 Terrain Data and Receptor Locations

The City requested that the model be used to calculate air pollutant concentrations attributable to emissions from the three freeways as well as in the city's major growth areas, which include, but are not limited to: BelRed, Downtown, Eastgate, East Main, Factoria, and Wilburton. Landau designed the modeling domain shown on Figure 2 to encompass the neighborhood areas of interest, as well as enough of the three freeways to account for pollutant emissions moved by the wind from an upwind freeway to a downwind neighborhood area. Terrain data from the US Geological Survey (USGS) were used to determine the elevation of the ground above sea level, as well as the elevations of the freeways above the ground. These USGS data were also used to calculate the x and y coordinates and elevations of the receptor locations from which AERMOD would calculate the pollutant concentrations in air.

Figure 2: Model Domain with Neighborhood Areas of Interest and Modeled Freeways



The receptors were located throughout the domain at ground level as well as above ground. Because the areas near the freeways have the greatest potential for exposure to air pollutants from vehicles operated on the freeways, and are therefore of greatest interest, receptor locations nearest the freeways were spaced more closely. The horizontal spacing between receptor locations increased with increasing distance from the freeways. Pollutant emissions from vehicles were not expected to rise significantly,[2] so vertical spacing between receptor locations was decreased with increasing height above ground. Additional details about receptor locations are provided in Appendix B.

2.2 Meteorological Data

AERMOD requires meteorological data (i.e., wind speed, wind direction, air temperature, etc.) to calculate the degree to which emitted pollutants are dispersed (i.e., diluted in the air) and in which direction. Typically, one or more years of hourly average data gathered by a meteorological station are provided to AERMOD.[3] These stations are frequently located at airports and, typically, the greater the airport traffic, the more sophisticated and robust the associated meteorological station. While there are meteorological stations in King and Snohomish counties at Seattle-Tacoma International Airport, King County International Airport/Boeing Field, Paine Field, and Renton Municipal Airport, none is located within or in close proximity to the modeling domain.

Because significant terrain and water bodies are located between the modeling domain and the available meteorological stations, an alternative approach was used to obtain meteorological data representative of conditions within the modeling domain. Three years of AERMOD-ready hourly average meteorological data were prepared for a location in the modeling domain using 3 years of three-dimensional meteorological data generated by a “mesoscale”[4] numerical weather prediction computer model executed by the University of Washington. Additional details about the meteorological data are provided in Appendix B.

2.3 Emission Unit Representation in the Model

A combination of LiDAR[5] and geospatial data[6] were used to obtain the freeway coordinates to accurately locate them in the model with respect to the surrounding terrain. The LiDAR data provided the elevations of the freeways above the ground, and the geospatial data provided the locations of freeway centerlines and the width of each freeway, which varies with the number of lanes. These data were verified using aerial photographs to ensure that the modeling would be based on an accurate portrayal of the locations and configurations of the freeways.

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2 Aside from the effect of atmospheric conditions, air pollutant emissions rise in the atmosphere due to buoyancy (i.e., being warmer than the surrounding atmosphere) or momentum (i.e., exiting a stack or tailpipe with non-zero velocity).

3 Stationary source modeling analyses for regulatory purposes are typically required to use 1 year (i.e., 8,760 hours) of hourly average meteorological data if the data were gathered using an “onsite” meteorological station. If data from a meteorological station not located at or near the stationary source are used, 5 years of hourly average meteorological data are required.

4 “Mesoscale” meteorological models are those that cover areas with length scales between 1 and 1,000 miles. “Microscale” models cover areas with length scales of 1 mile or less, and “synoptic-scale” models cover areas with length scales greater than 1,000 miles.

5 2021 King County light detection and ranging (LiDAR) data provided by the USGS.

6 Provided by the Washington State Department of Transportation.

Once the coordinates used to define the locations of the freeways in three-dimensional space and the variable freeway widths were identified, the freeways were divided into segments. The length of each segment was determined by changes in the elevation and/or curvature of the roadway or the traffic volume. At the point where the elevation and/or curvature of the roadway changed significantly or if the traffic volume increased or decreased as a result of an on-ramp or off-ramp, that segment would end and a new segment that reflected the new elevation, new orientation, or traffic volume would begin. A group of three-dimensional "volume sources" were used to represent the emissions associated with each segment in the model. Use of this methodology to represent roadways in AERMOD was based on recommendations in an EPA report (EPA 2011).

A "volume source" is one of several emission source types available in AERMOD (e.g., point, area, line) and is a three-dimensional space defined in the model by its location (i.e., the x and y coordinates, ground elevation, and height above ground of the center of the defined space), its horizontal extent, its vertical extent, and the quantity of an air pollutant contained within the space. The shape of a volume source is perhaps best thought of as an oblate spheroid, which is something like an M&M® candy. The horizontal and vertical extents used to define the shape can be thought of as "stretching" the candy in the radial or vertical directions. The space defined by this shape is used by the model as the starting location and concentration of the pollutant emissions associated with that volume source during each hour of the model simulation. Over the course of a modeled hour of meteorological data, the atmospheric conditions described by those data move and disperse the emissions from that starting point. The greater the wind speed, the greater the distance the emissions will travel in that hour's predominant wind direction, and the more unstable the atmosphere, the more the pollutant in the volume source will be dispersed, which will decrease the concentration of the pollutant.

The modeled freeways were divided into 144 segments, and each segment was composed of between four and 137 individual volume sources, depending on the size of the segment. The horizontal extent of the volume sources within each segment depended on the width of the freeway and were the same for all volume sources within a given segment. The height of the center of each volume source above the roadway as well as the vertical extent of each volume source above and below the center of the volume source[7] were the same for all volume sources in all the segments.

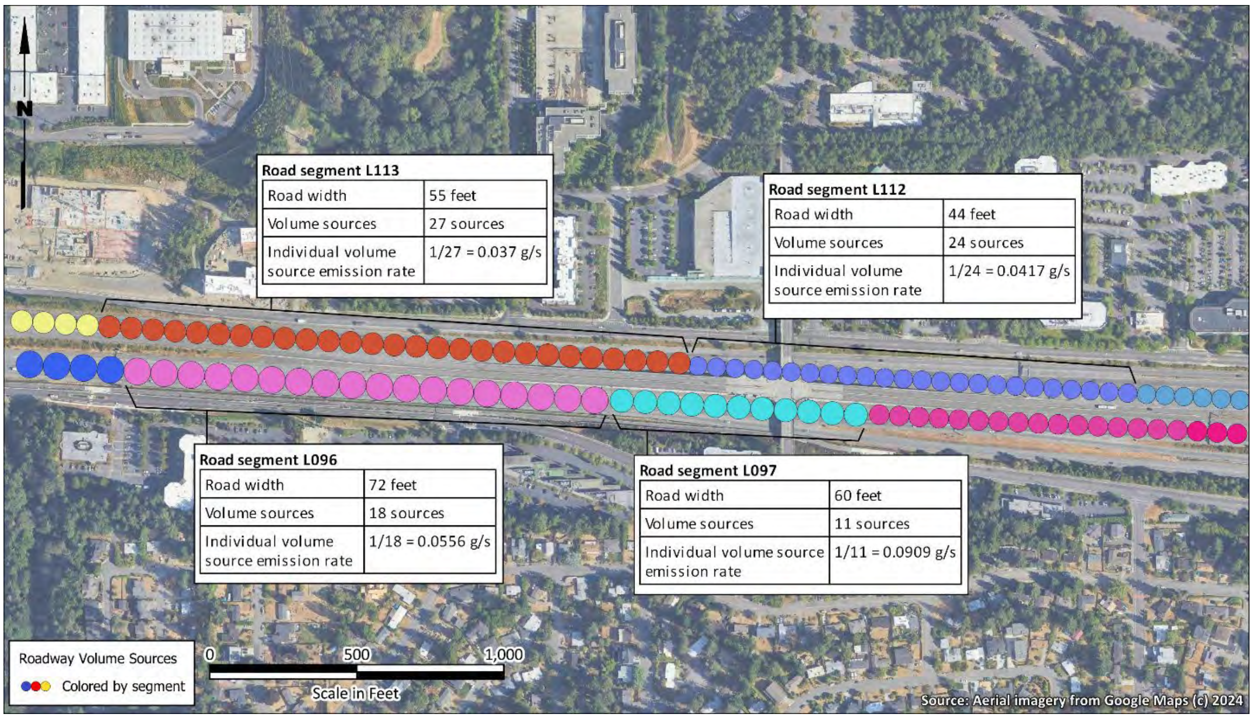
2.4 Modeled Emission Rates

If the model were executed to directly calculate the concentration of each air pollutant of interest at each receptor location for all vehicle types operated on each road segment, each of which has its own unique characteristics, the execution time would be unacceptably long. To obtain results within a more reasonable time, the model was executed using what is referred to as a "unit emission rate," which is typically 1 gram per second (1 g/s), and specific emission rate information was applied after model execution to calculate pollutant concentrations.

[7] The height of the center of the volume source is the location above the roadway, the extents of the volume source above that center is determined by the degree to which the oblate spheroid shape is "stretched" from that center up away from the roadway and down toward the freeway.

Each of the freeway segments described in the previous section are referred to within AERMOD as a "source group." These 144 source groups are composed of between four and 137 identically sized volume sources, as described in the previous section. The unit emission rate (i.e., 1 g/s) assigned to each road segment or "source group" was divided equally among the identically sized volume sources that comprise the source group. See Figure 3 for some examples of how the source group unit emission rate was divided among the individual volume sources that comprise the road segment source group. For a summary of source parameters, including range of elevations, roadway widths, and volume source counts by roadway segment, see Appendix B.

Figure 3: Example Model Setup and Individual Volume Source Unit Emission Rates



By using the unit emission rate approach described above for each road segment, the model does not calculate a concentration, in units of micrograms per cubic meter (µg/m^3), for each pollutant of interest at each receptor location attributable to that road segment. Instead, it calculates what is referred to as a "dispersion factor" for each averaging period with units of micrograms per cubic meter per gram per second (µg/m^3/[g/s]) at each receptor location associated with each road segment. The dispersion factor calculated by AERMOD for a given receptor location and road segment combination can then be combined with emission rates for multiple pollutants to obtain a concentration for each of those pollutants at that receptor location attributable to that road segment. This approach has the advantage of minimizing the number of times the model must be executed; instead of one execution of the model for each pollutant of interest, there is only one model execution followed by relatively simple multiplication to obtain concentrations for multiple pollutants at each receptor location attributable to each road segment. The pollutant concentration contributions from all road segments can be summed to obtain a total pollutant concentration at each receptor location.

2.5 Model Execution and Post-Processing

AERMOD used the inputs and options outlined above to calculate a dispersion factor for each road segment source group at each receptor location. The dispersion factor associated with a given segment was combined with a pollutant emission factor, in grams per vehicle miles traveled (g/VMT), for a given vehicle type and the vehicle-miles-traveled, in vehicle-miles-traveled per second (VMT/s), for that vehicle type and assumed travel speed within that segment to obtain the concentration of that pollutant attributable to that vehicle type at that receptor location.[8] By repeating this for each vehicle type and summing the concentrations, the total concentration of that pollutant at that receptor location is obtained. The process was repeated at each receptor location for all segments, vehicle types, and pollutants.

2.6 Vehicle Emission Factors

Vehicle type-specific pollutant emission factors were obtained using Version 4 of the EPA's MOtor Vehicle Emission Simulator (MOVES4). Emission factors were derived using the MOVES emission rates mode for light-duty, medium-duty and heavy-duty vehicles under two traffic conditions: free-flowing traffic, where vehicles were assumed to be traveling between 57.5 and 62.5 miles per hour (mph), and congested traffic, where vehicles were assumed to be traveling between 12.5 and 17.5 mph. The congested traffic emission factors were used to determine the ambient impacts for pollutants with short-term averaging period (e.g., 1-hour), while the free-flowing traffic emission factors were applied to pollutants with long-term averaging periods (e.g., 24-hour and annual).

Locale-specific information provided by the City was used in the modeling whenever available. Defaults were used only when city-specific data were not available. Landau executed MOVES using the on-road emissions module to generate exhaust, brake wear, and tire wear emission factors. The Puget Sound Regional Council provided vehicle weight class information for the city, which was used with default King County vehicle populations from MOVES for each modeled year to calculate weighted emission factors, which were applied to traffic model volumes per VMT provided by the City. Non-default data were used for traffic volumes, vehicle speeds, and vehicle-type distribution to better reflect local conditions in King County. Default data were used for other parameters such as meteorology, regional fuel usage, fuel properties, and vehicle age distribution where specific local information was unavailable.

The analysis accounted for vehicles in King County fueled by gasoline or diesel, as well as electric vehicles. While electric vehicles do not contribute tailpipe emissions, they do contribute brake and tire wear emissions. MOVES includes information such as future vehicle age distribution projections, fuel economy, and emission standards that enables it to forecast vehicle emission factors for future years (EPA 2023). The City requested emission scenarios for 2023, 2034, and 2044. To calculate emission factors for these years, default King County MOVES vehicle source type populations were mapped to vehicle weight classes and combined with projected traffic weight class traffic volumes provided by the

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8 Dispersion Factor (µg/m^3/[g/s]) * Emission Factor [g/mile] * VMT [mile/s] = Pollutant Concentration [µg/m^3])

City. The emission factors calculated for each pollutant are provided in Table 1 below. Additional details about the King County vehicle source type populations by year are provided in Appendix B.

Table 1: MOVES Emission Factors (g/VMT)

Pollutant	Period	2023			2034			2044		
		Heavy-Duty	Medium-Duty	Light-Duty	Heavy-Duty	Medium-Duty	Light-Duty	Heavy-Duty	Medium-Duty	Light-Duty
1,3-Butadiene	Daily/Annual	1.30E-04	2.27E-04	1.16E-04	1.10E-05	1.80E-05	1.19E-06	0	0	0
Acetaldehyde	Daily/Annual	2.96E-03	2.40E-03	4.25E-04	6.56E-04	4.26E-04	6.91E-05	3.98E-04	1.31E-04	3.99E-05
Acrolein	Daily/Annual	4.18E-04	3.93E-04	3.94E-05	7.09E-05	6.04E-05	7.89E-06	3.43E-05	1.16E-05	3.76E-06
Benzene	Daily/Annual	3.80E-04	1.65E-03	1.19E-03	3.29E-05	5.08E-04	3.13E-04	5.50E-08	2.25E-04	2.29E-04
DPM	Daily/Annual	4.23E-02	2.36E-02	8.40E-04	7.27E-03	4.43E-03	1.69E-04	3.35E-03	1.24E-03	1.95E-05
Ethyl Benzene	Daily/Annual	4.75E-04	7.05E-04	5.51E-04	1.47E-04	2.02E-04	1.06E-04	1.07E-04	1.01E-04	7.77E-05
Formaldehyde	Daily/Annual	4.66E-03	4.95E-03	6.63E-04	6.76E-04	7.88E-04	1.51E-04	2.54E-04	1.43E-04	8.62E-05
Naphthalene	Daily/Annual	4.46E-04	5.57E-04	8.71E-05	4.53E-05	8.13E-05	1.69E-05	5.58E-06	1.09E-05	9.67E-06
NO_X	Daily/Annual	2.59E+00	9.61E-01	2.04E-01	8.50E-01	2.34E-01	2.23E-02	6.07E-01	1.03E-01	6.79E-03
NO_X	1-Hour (AM Peak)	8.51E+00	2.67E+00	2.44E-01	3.93E+00	9.46E-01	3.20E-02	2.45E+00	5.14E-01	1.16E-02
NO_X	1-Hour (PM Peak)	8.36E+00	2.62E+00	2.43E-01	3.80E+00	9.21E-01	3.21E-02	2.28E+00	4.89E-01	1.16E-02
PAHs	Daily/Annual	1.85E-04	2.29E-04	3.63E-05	1.81E-05	3.79E-05	8.06E-06	1.75E-06	9.66E-06	4.53E-06
PM_{10} Brake wear	Daily/Annual	1.11E-02	1.18E-02	5.15E-03	1.10E-02	1.08E-02	5.20E-03	1.10E-02	1.00E-02	5.21E-03
PM_{10} Tire wear	Daily/Annual	2.40E-02	1.18E-02	7.15E-03	2.34E-02	1.15E-02	7.14E-03	2.31E-02	1.13E-02	7.13E-03
$PM_{2.5}$	Daily/Annual	4.73E-02	3.09E-02	4.46E-03	1.22E-02	9.52E-03	2.85E-03	8.20E-03	5.80E-03	2.43E-03
$PM_{2.5}$ Brake wear	Daily/Annual	1.39E-03	1.48E-03	6.44E-04	1.38E-03	1.35E-03	6.50E-04	1.37E-03	1.25E-03	6.52E-04
$PM_{2.5}$ Tire wear	Daily/Annual	3.60E-03	1.77E-03	1.07E-03	3.52E-03	1.72E-03	1.07E-03	3.47E-03	1.69E-03	1.07E-03
$PM_{2.5}$ Total Exh	Daily/Annual	4.23E-02	2.77E-02	2.74E-03	7.27E-03	6.45E-03	1.13E-03	3.35E-03	2.86E-03	7.08E-04

Notes:

1. Weighted emission rates in grams per vehicle miles traveled based on King County electric, gasoline, and diesel fueled vehicle populations for each vehicle weight class and year.
2. Vehicle weight class based on the following MOVES source types:
   a. Heavy-duty: Refuse trucks, combination short-haul trucks, and combination long-haul trucks
   b. Medium-Duty: Motor homes, single unit short-haul trucks, and single-unit long-haul trucks
   c. Light-Duty: Passenger car, passenger truck, and light commercial trucks
3. Daily/Annual emissions based on annual average hourly emission rates from MOVES for vehicles traveling between 57.5 and 62.5 mph.
4. AM Peak emissions based on annual average hourly emission rates between 6 a.m. and 9 a.m. for vehicles traveling between 12.5 and 17.5 mph.
5. PM Peak emissions based on annual average hourly emission rates between 4 p.m. and 7 p.m. for vehicles traveling between 12.5 and 17.5 mph.
6. DPM emissions from PM2.5 Total Exhaust for diesel-fueled vehicles.
7. Naphthalene based on sum of Naphthalene gas and particulate emissions.
8. PM2.5 based on sum of PM2.5 Total Exhaust, PM2.5 brakeware, and PM2.5 tireware emissions.
9. PAHs based on sum of gas and particulate emission for the following pollutants: Acenaphthene, acenaphthylene, anthracene, benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, dibenzo(a,h)anthracene, fluoranthene, fluorene, indeno(1,2,3,c,d)pyrene, phenanthrene, pyrene.

Abbreviations and Acronyms:

DPM = diesel particulate matter
PAHs = polycyclic aromatic hydrocarbons
PM_{10} = particulate matter with an aerodynamic diameter less than or equal to 2.5 microns
NO_X = oxides of nitrogen
$PM_{2.5}$ = particulate matter with an aerodynamic diameter less than or equal to 2.5 microns

2.7 Traffic Volumes

Regional traffic volume information is available from the Puget Sound Regional Council, the agency that develops the Regional Transportation Plan and the Regional Transportation Improvement Plan, and helps communities secure federal funding for transportation projects. Using this information as a base, transportation modelers with the City developed detailed traffic volume information for the Bellevue-Kirkland-Redmond (BKR) area in cooperation with the cities of Kirkland and Redmond with the BKRCast model. The model features more than 55,000 highway network links and 600 transit lines used to distribute trips by user class and time of day based on such inputs as land use and demographics.[9] In keeping with the preference for locale-specific data and information, the BKR traffic volume data were obtained from the City. Because traffic volume data were available only for 2019 and 2044, data for 2023 and 2034 were obtained by linear interpolation between the available years. Within the study area along the modeled roadway segments, total daily vehicle miles traveled for all vehicle weight classes increased by 6 percent between 2019 and 2044.

The BKR traffic volume data were applied to the appropriate freeway segments and multiplied by the length of each segment to obtain vehicle-miles-traveled (VMT) for each vehicle type. These vehicle miles traveled were used in the pollutant concentration calculations outlined above. Appendix B provides hourly AM and PM peak period VMT and total daily VMT for each modeled roadway segment.

[9] Additional information for the BKRCast traffic model is available on the team's GitHub Wiki pages: https://github.com/bellevuewa/BKRCast/wiki/Overview.

3.0 POLLUTANTS OF INTEREST

Pollutants of interest for the study were identified in consultation with the City. The EPA criteria air pollutants,[10] nitrogen dioxide (NO_2) and fine inhalable particulate matter[11] ($PM_{2.5}$), were chosen because they are those of greatest concern when considering emissions from vehicles operated on roadways. Nine "air toxics" that have been identified by the EPA as significant contributors from mobile sources[12] were also included in the study:

- Acetaldehyde
- Acrolein
- Benzene
- 1,3-Butadiene
- Diesel particulate matter (DPM)
- Ethylbenzene
- Formaldehyde
- Naphthalene
- Polycyclic aromatic hydrocarbons (PAHs)/polycyclic organic matter.

All of these compounds have been designated as "toxic air pollutants" (TAPs) in Washington state,[13] and all except acrolein are known, reasonably anticipated, or possible human carcinogens. In addition to being a criteria pollutant, NO_2 is considered a non-carcinogenic TAP in Washington state, so NO_2 impacts were evaluated as both a criteria pollutant and a TAP.

It should be noted that acrolein and NO_2 are highly reactive in most circumstances that are relevant for ambient air quality evaluation. Accurate prediction of NO_2 concentrations requires knowledge of how oxides of nitrogen (NO_X) are partitioned when emitted and the reactivity of the atmosphere into which the emissions are dispersed, and then execution of a complex, non-linear set of chemical reactions, all of

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10 "Criteria air pollutants" are the six common air pollutants identified in the Clean Air Act (CAA) for which the EPA is required to set National Ambient Air Quality Standards (NAAQS): carbon monoxide, lead, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. On-road vehicles are not meaningful sources of lead, ozone, or sulfur dioxide, and ambient carbon monoxide concentrations have been reduced to levels that, when compared with the applicable ambient standard, are generally not of interest and, therefore, not typically included in modeling studies, except for the most acute scenarios that involve particularly congested roadway intersections. In those cases, AERMOD is typically not the dispersion model employed.

11 "Fine inhalable particulate matter" is defined by the EPA as particulate matter with a diameter less than 2.5 microns.

12 A Federal Highway Administration (FHWA) guidance memorandum issued on January 18, 2023 concerning mobile source air toxics cited the EPA's 2011 National Air Toxics Assessment as having identified these nine compounds as having significant contributions from mobile sources. "Air toxics" is not a term with regulatory significance in the CAA or its amendments, but within the January 18, 2023 FHWA guidance memorandum, is equated with "hazardous air pollutant", which does have regulatory significance in the CAA and its amendments. https://www.fhwa.dot.gov/environMent/air_quality/air_toxics/policy_and_guidance/msat//fhwa_nepa_msat_memorandum_2023.pdf

13 Washington state regulations that address TAPs are in Chapter 173-460 of the Washington Administrative Code (WAC). Puget Sound Clean Agency (PSCAA) regulations that also address TAPs are in PSCAA Regulation III, Article 2.

which is beyond the scope of this study. Beyond a few minutes of transport or a few tens of meters of distance from the source, the modeled NO_2 values should, in most cases, be considered an upper bound. Algorithms that calculate the chemical reactions associated with acrolein reactivity have not been developed for use with AERMOD, so acrolein concentrations calculated by the model should similarly be considered conservative.

The model-calculated criteria air pollutant concentrations (i.e., NO_2, and $PM_{2.5}$) were compared with regulatory thresholds, while concentrations of non-carcinogenic TAPs (i.e., acrolein and NO_2) were compared with project screening thresholds provided in Washington regulations.[14] Carcinogenic TAP impacts were evaluated as incremental increases in cancer risk.

Cancer risk is the likelihood that a person will develop cancer, and an individual person's cancer risk may increase as the result of exposure to a carcinogenic air pollutant. In the context of this study, an increased cancer risk estimate describes the additional risk a person may experience because of exposure to a carcinogenic air pollutant. The cancer risk estimate does not include a person's background risk, which is the risk a person faces of developing cancer due to other causes. Increased cancer risk is expressed in terms of a person's increased chance of developing cancer over a lifetime of exposure (i.e., 70 years) to a given carcinogen at a given concentration for the entire exposure period.

According to California and federal guidance, a cancer risk that is at or less than 1 additional cancer in 1 million (i.e., $1e10^{-6}$) is not a public health concern. At this risk level or less, no more than 1 person in a population of 1 million people subject to the same exposure to a carcinogen would be expected to develop cancer over a lifetime. Based on this same guidance, a cancer risk greater than 1 additional cancer in 10,000 (i.e., $1e10^{-4}$) is generally unacceptable. At this risk level or greater, at least 1 person out of 10,000 people with the same exposure to a carcinogen would be expected to develop cancer over a lifetime of exposure at a given concentration (EPA 1999). These risk thresholds are considered in context with other factors when projects are reviewed and evaluated for approval by government agencies.

In Washington, TAPs emitted by stationary sources are regulated by Chapter 173-460 WAC, which provides human health risk-based screening thresholds called "Acceptable Source Impact Levels," or ASILs, for more than 400 TAPs that are applied on a per-project basis. This stationary source project-level screening threshold is based on an incremental cancer risk increase of 1 additional cancer per 1 million people, which, as discussed above, is an incremental exposure that is considered to not be a public health concern. Because vehicles operating on freeways evaluated together as a source of air pollutants is not a project-level source of emissions, the ASILs were not used as a sole basis for comparison. Instead, the impact of each TAP considered a known, reasonably anticipated, or probable carcinogen was considered in the context of the incremental cancer risk continuum described above. Cumulative cancer risk that considers the combined incremental cancer risk increases attributable to the modeled TAPs, as well as the cancer risk attributable to carcinogenic compounds emitted by other sources, was not estimated. To do so would involve evaluation of potential synergistic effects between

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[14] Washington State Ambient Air Quality Standards for criteria air pollutants are established in Chapter 173-476 WAC, and Acceptable Source Impact Levels (ASILs) for TAPs are in WAC 173-460-150.

compounds, in addition to estimation of the nature and concentration of compounds from other sources, all of which are beyond the scope of this study.

Table 2 provides the averaging period and regulatory threshold (i.e., National Ambient Air Quality Standards [NAAQS] or California Office of Environmental Health Hazard Assessment [OEHHA] Reference Exposure Level [REL]) associated with criteria pollutants and pollutants with acute (or short-term) exposure levels. Ecology adopted the OEHHA RELs as the ASILs for NO_2 and acrolein.

Table 2: Criteria Pollutant and Toxic Air Pollutant Thresholds

Criteria Pollutants		
Pollutant	**Averaging Period**	**NAAQS ($\mu g/m^3$)**
NO_2	1-hour	188
	Annual	100
$PM_{2.5}$	24-hour	35
	Annual	9
Toxic Air Pollutants		
Pollutant	**Averaging Period**	**OEHHA REL/Washington ASIL ($\mu g/m^3$)**
NO_2	1-hour	470
Acrolein	24-hour	0.35

Cancer risk was calculated for each carcinogenic TAP using the appropriate OEHHA cancer unit risk factor (URF), which is shown in Table 3. The URFs were developed based on analyses of epidemiological studies of humans and animals (EPA 1999; accessed August 19, 2024). URFs are expressed as the upper-bound probability of developing cancer, assuming continuous lifetime exposure to a substance at the maximum modeled concentration and are expressed in units of inverse concentration (i.e., $[\mu g/m^3]^{-1}$).

Table 3: Carcinogenic Pollutants and Risk Values

Pollutant	Averaging Period	OEHHA URF $(\mu g/m^3)^{-1}$	Concentration Associated with 100 Excess Cancer Risk per Million ($\mu g/m^3$)
1,3-Butadiene	Annual	1.7×10^{-4}	0.59
Acetaldehyde	Annual	2.7×10^{-6}	37.0
Benzene	Annual	2.9×10^{-5}	3.45
DPM	Annual	3.0×10^{-4}	0.33
Ethylbenzene	Annual	2.5×10^{-6}	40
Formaldehyde	Annual	6.0×10^{-6}	16.7
Naphthalene	Annual	3.4×10^{-5}	2.9
PAHs[(a)]	Annual	1.1×10^{-3}	0.091

Note:
(a) PAH potency factor is equivalent to the benzo[a]pyrene URF, determined using California AB2588 Program Guidance Manual (Appendix G).

4.0 RESULTS

The City Air Quality and Land Use report (City of Bellevue 2023) used information other than dispersion modeling to identify an "air pollution exposure zone" (APEZ), which is defined in that report as the area within 500 feet of a major freeway. The dispersion modeling study outlined in this report accounted for terrain, local meteorological parameters, and future vehicle fleet mix, to potentially enable the identification of three-dimensional areas (i.e., the horizontal distance from a major freeway, as well as the vertical distance above the ground) of particular concern for sensitive land uses (e.g., schools, childcare centers, and residential uses) that are likely to be impacted by air pollution emitted by vehicles operating on the three freeways that pass through Bellevue.

The maximum modeled concentrations across all receptor locations and modeled fleet mixes for each pollutant are provided in Table 4. Concentrations calculated by the model when using the 2023 emission factors were greater than those calculated for the other two modeled years (i.e., 2034 and 2044). Model-calculated combustion product concentrations (i.e., NO_2 and TAPs) for the 2034 scenario were, on average, 75 percent less than the model-calculated 2023 concentrations. Model-calculated combustion product concentrations for the 2044 scenario were, on average, 85 percent less than the model-calculated 2023 concentrations. Model-calculated concentrations of particulate matter, which consists of both combustion emissions and mechanically generated tire and brake dust emissions, are 44 percent less for the 2034 scenario and 52 percent less for the 2044 scenario when compared to the 2023 scenario. Information about the King County activity data and BKR VMT data that influence these future year changes are provided in Appendix B.

For comparison with the pollutant concentrations calculated for this study using AERMOD, pollutant concentrations calculated at locations in the study model domain are also provided in Table 4. Criteria pollutant Regional Background Design Values have been estimated by NW Airquest[15] using modeling and monitoring data from July 2014 through July 2017. The NW Airquest Regional Background Design Values project is a joint venture between Washington State University, Washington State Department of Ecology, Oregon Department of Environmental Quality, and Idaho Department of Environmental Quality. The Air Toxics Screening Assessment (AirToxScreen) is the EPA's ongoing review of air toxics concentrations in the US. AirToxScreen provides estimates of air toxics concentrations nationwide by census tract using a model methodology that is significantly different from that employed for this study (EPA; accessed August 2024). Both the NW Airquest Regional Background Design Values and AirToxScreen use hybrids of monitored data and modeled data to calculate ambient pollutant concentrations. Vehicle pollutant emissions that occurred during the modeled periods (i.e., 2014 to 2017 for NW Airquest and 2020 for AirToxScreen) are reflected in the ambient concentrations calculated by these models, and, because there are no significant industrial contributions to ambient concentrations in the Bellevue area, it is reasonable to assume that the vehicle traffic is the major contributor to pollutant concentrations predicted for the Bellevue area by these models. With the exceptions of NO_2 and 1,3-butadiene, the pollutant concentrations calculated by AERMOD for the 2023

[15] NW Airquest Background Concentrations for 47.62N, 122.16W extracted from: https://idahodeq.maps.arcgis.com/apps/MapSeries/index.html?appid=0c8a006e11fe4ec5939804b873098dfe.

scenario that are attributable to vehicles operated on the freeways are less than the concentrations calculated by either NW Airquest or AirToxScreen. However, these maximum concentrations are predicted to occur at a limited number of receptors located adjacent to the freeways.

Table 4: Model Results – 2023 Vehicle Emissions

Criteria Pollutants				
Pollutant	**Averaging Period**	**NAAQS ($\mu g/m^3$)**	**NW Airquest Background Concentration ($\mu g/m^3$)**	**Maximum Modeled Concentration ($\mu g/m^3$)**
NO_2	1-hour	188	94	358[a]
NO_2	Annual	100	26	40
$PM_{2.5}$	24-hour	35	17	2.3[a]
$PM_{2.5}$	Annual	9	6.1	0.80
Non-Carcinogenic TAPs				
Pollutant	**Averaging Period**	**REL Threshold ($\mu g/m^3$)**	**EPA AirToxScreen Background Concentration ($\mu g/m^3$)**	**Maximum Modeled Concentration ($\mu g/m^3$)**
NO_2	1-hour	470	94	358
Acrolein	24-hour	0.35	0.050	0.021
Carcinogenic TAPs				
Pollutant	**Averaging Period**	**100 in a Million Risk Threshold ($\mu g/m^3$)**	**EPA AirToxScreen Background Concentration ($\mu g/m^3$)**	**Maximum Modeled Concentration ($\mu g/m^3$)**
Acetaldehyde	Annual	37	1.4	0.073
Benzene	Annual	3.5	0.41	0.16
1,3-Butadiene	Annual	0.59	0.011	0.016
DPM	Annual	0.33	0.48	0.35
Ethylbenzene	Annual	40	0.21	0.074
Formaldehyde	Annual	17	1.4	0.12
Naphthalene	Annual	2.9	0.16	0.015
PAHs	Annual	0.091	0.056	0.0061

Note:

(a) Because the 1-hour average NO_2 and 24-hour average $PM_{2.5}$ ambient standards have statistical bases, as well as the assumption that 100 percent of NO_X is assumed to be converted to NO_2, comparisons with maximum predicted concentrations should be considered conservative.

Figures 4 through 13 show the spatial distribution of the concentrations calculated by the model at an elevation of approximately 5 feet (1.5 meters) above ground, which represents the breathing zone of an adult person, and 2023 vehicle fleet emission rates. The figures show contour lines that represent constant concentrations or constant increased cancer risk for each modeled pollutant. For reference, each figure includes the APEZ, which was identified in the 2023 Air Quality and Land Use report as the horizontal area within 500 feet of the freeways.

Figure 4: 1-Hour Average NO_2 Concentrations at 5 Feet Above Ground (2023 Vehicles – AM Scenario)

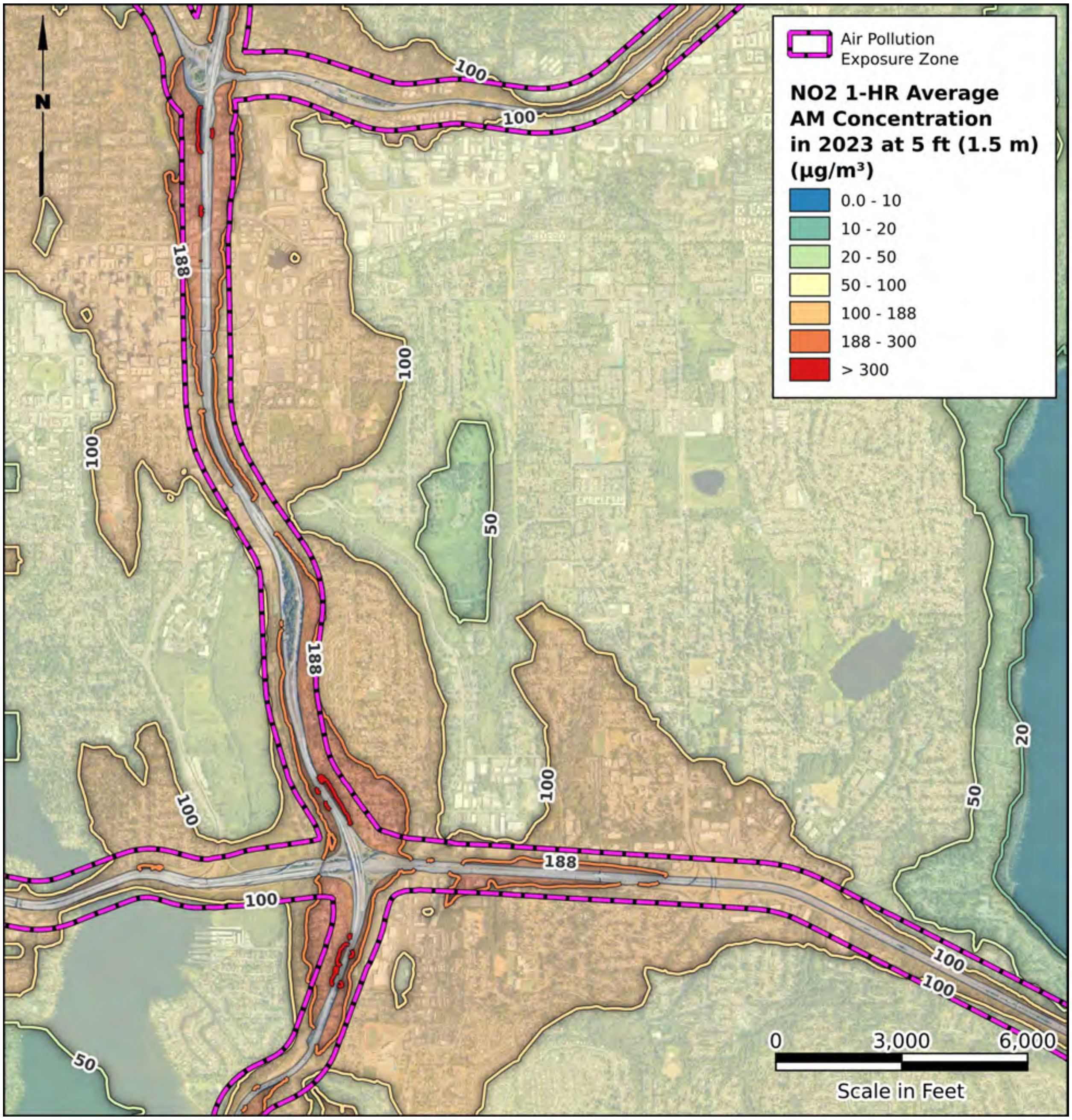
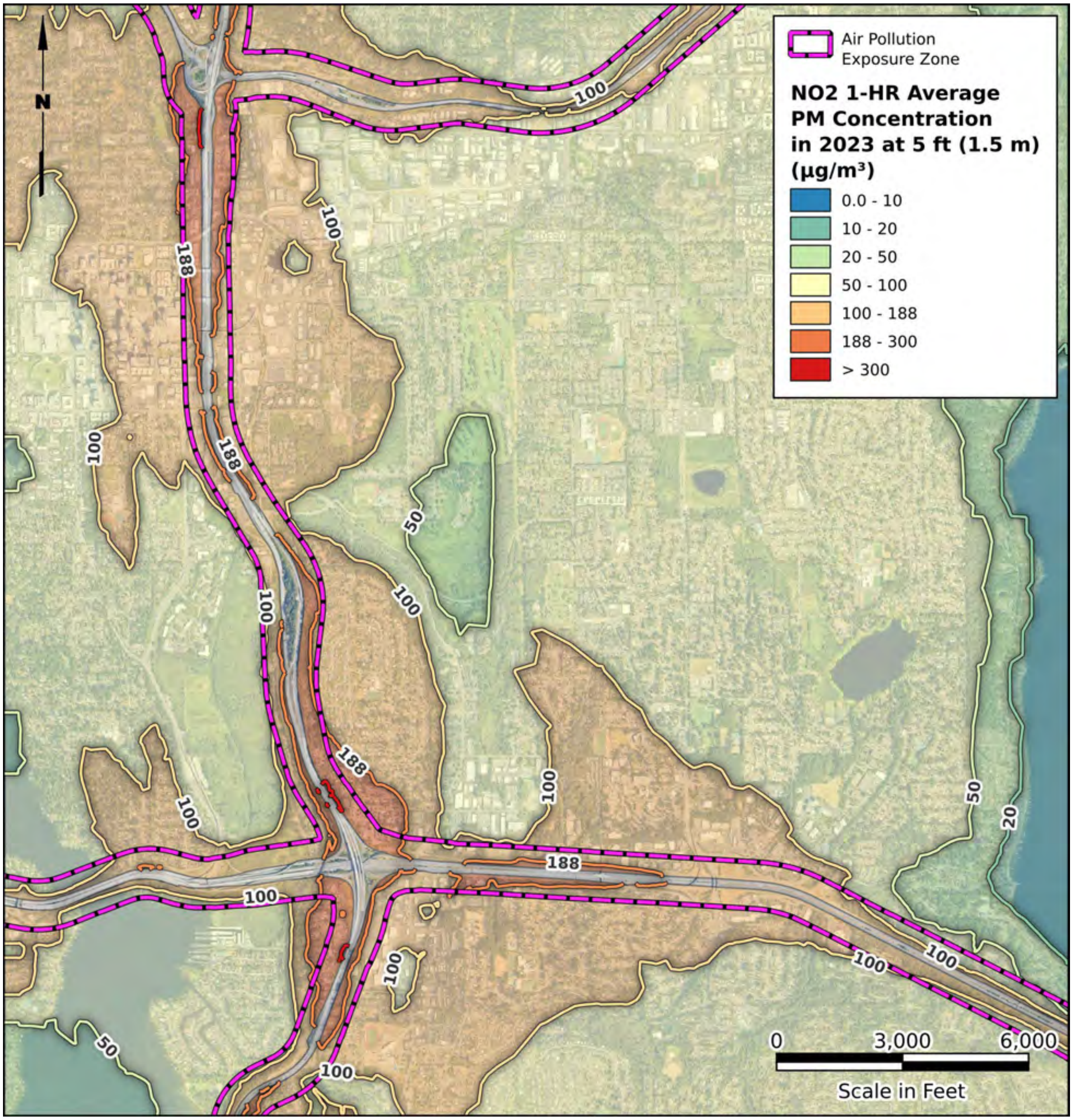


Figure 5: 1-Hour Average NO_2 Concentrations at 5 Feet Above Ground (2023 Vehicles – PM Scenario)



Figures 4 and 5 show 1-hour average NO_2 concentrations in the breathing zone for AM and PM traffic scenarios. Results for both scenarios indicate that concentrations throughout most of the model domain are less than the applicable ambient standard (i.e., 188 µg/m^3),[16] except for a few areas along I-405 and I-90, with a few receptors exceeding 300 µg/m³ south of the intersection of I-405 and SR 520 and near

[16] The modeled concentrations shown are the first highest high concentrations. The basis for the 1-hour average ambient NO_2 standard is statistically based, meaning the comparison shown is conservative; it is likely that modeled design concentrations with the same basis as the ambient standard would show no concentrations in excess of the standard.

the intersection of I-405 and I-90. All modeled concentrations are less than the acute REL threshold for NO_2 (i.e., 470 µg/m^3).

Figure 6: Annual Average NO_2 Concentrations at 5 Feet Above Ground (2023 Vehicles)

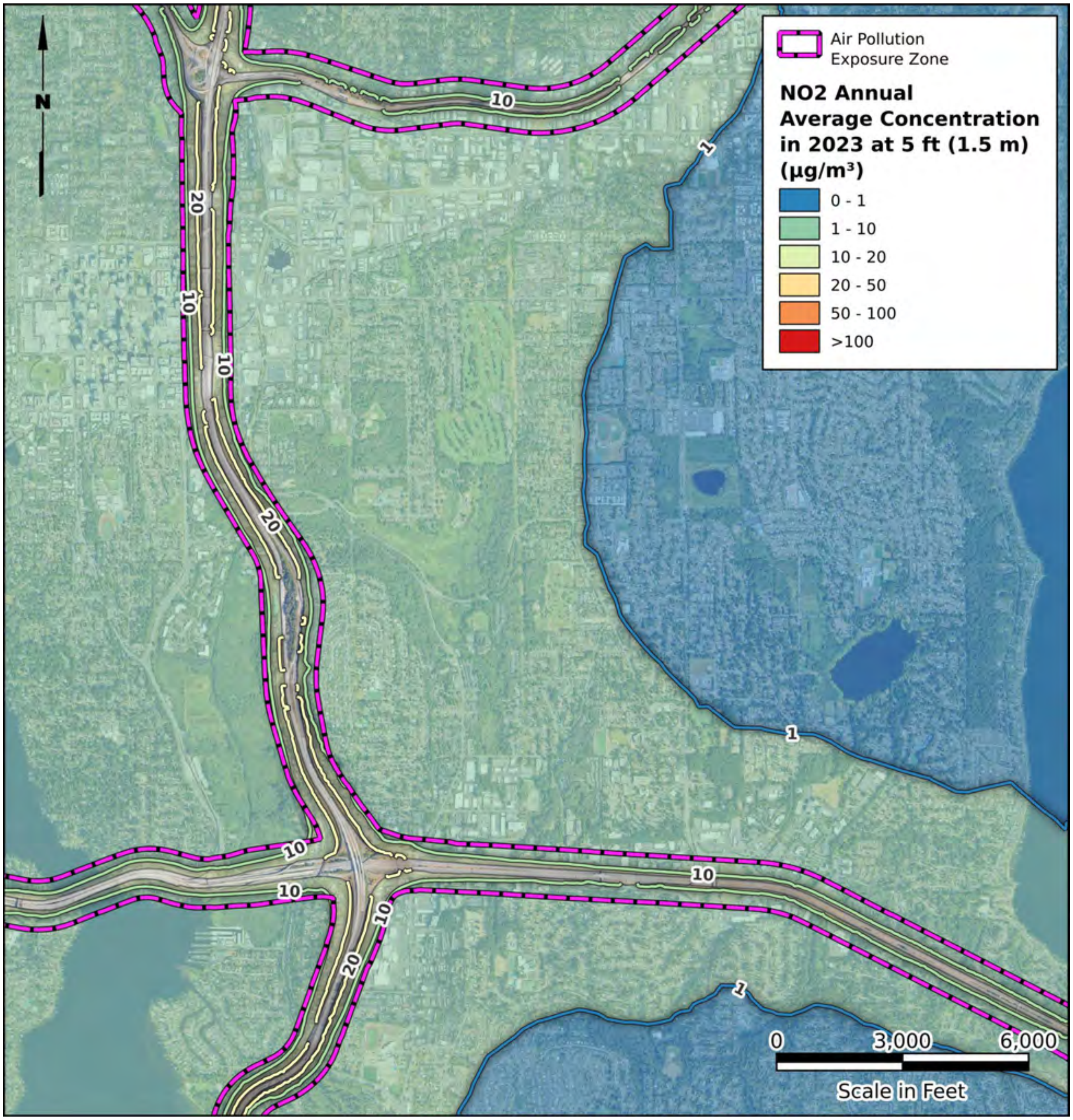


Figure 6 shows annual average NO_2 concentrations in the breathing zone, which indicate that concentrations throughout the model domain are considerably less than the applicable ambient standard (i.e., 100 µg/m^3).

Figure 7: 24-Hour Average $PM_{2.5}$ Concentrations at 5 Feet Above Ground (2023 Vehicles)

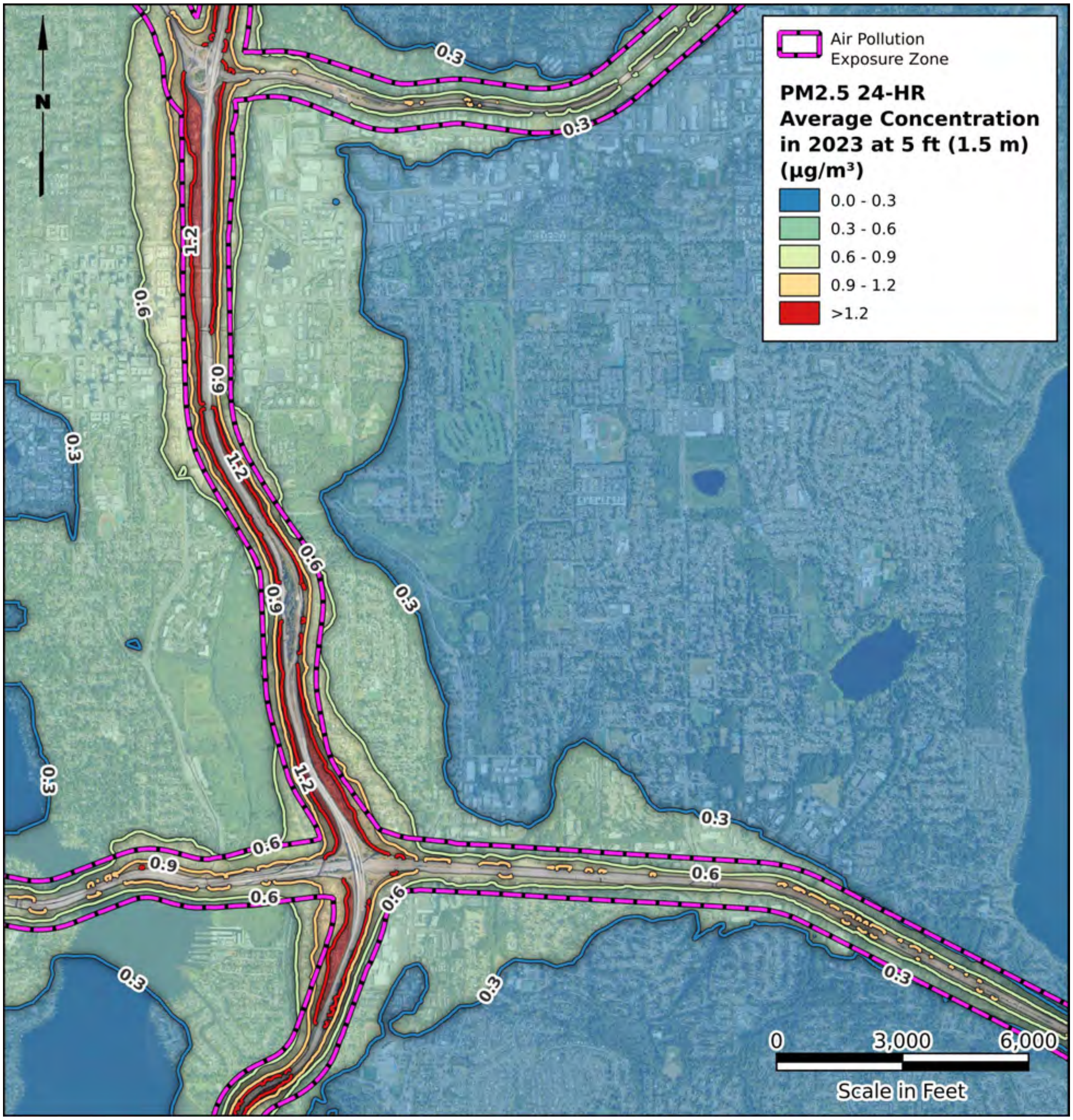


Figure 7 shows 24-hour average $PM_{2.5}$ concentrations in the breathing zone, which indicate that concentrations throughout the model domain are considerably less than the applicable ambient standard (i.e., 35 µg/m^3).

Figure 8: Annual Average $PM_{2.5}$ Concentrations at 5 Feet Above Ground (2023 Vehicles)

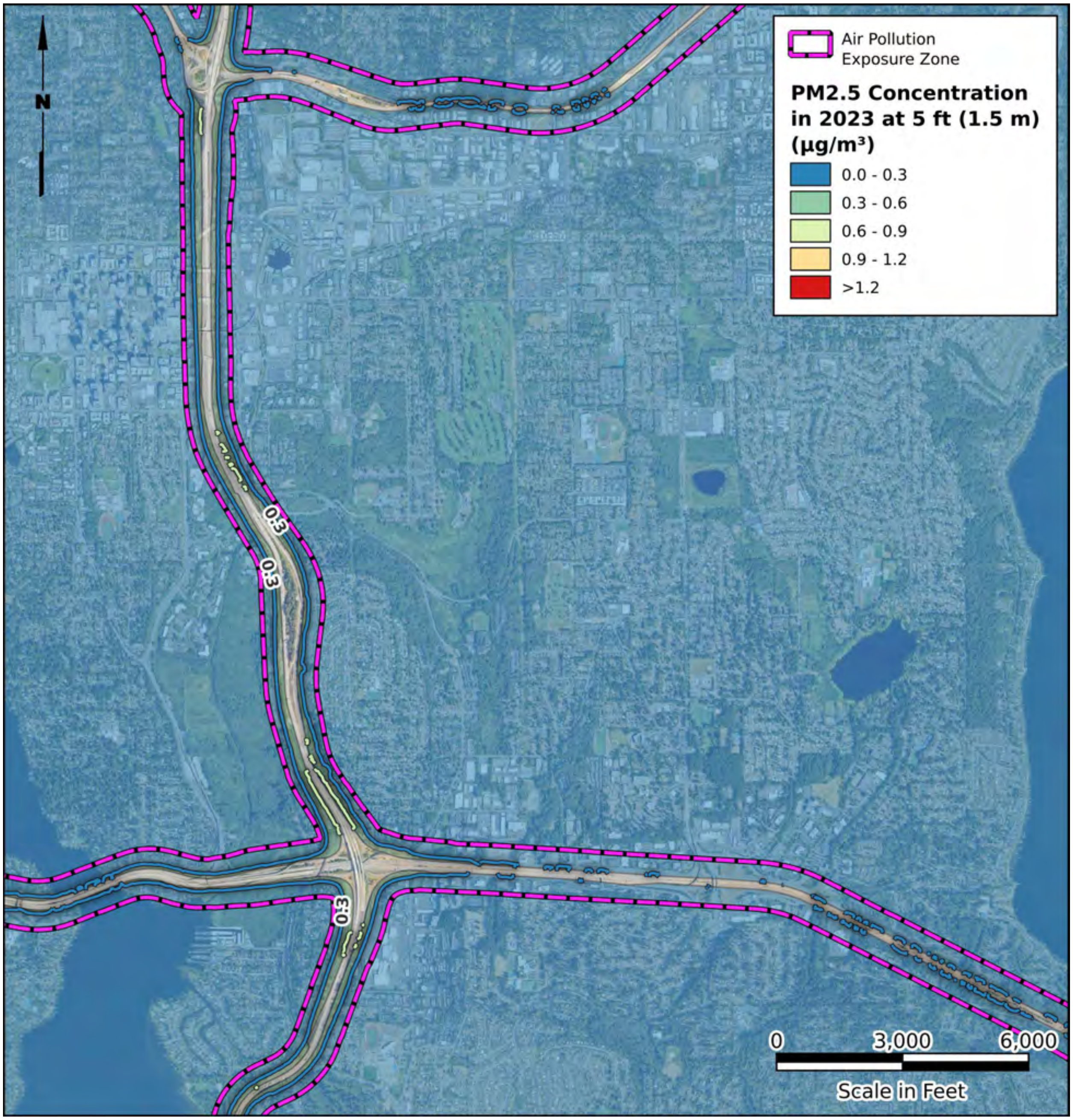


Figure 8 shows annual average $PM_{2.5}$ concentrations in the breathing zone, which indicate that concentrations throughout the model domain are considerably less than the applicable ambient standard (i.e., 9 µg/m^3).

Figure 9: 24-Hour Average Acrolein Concentrations at 5 Feet Above Ground (2023 Vehicles)

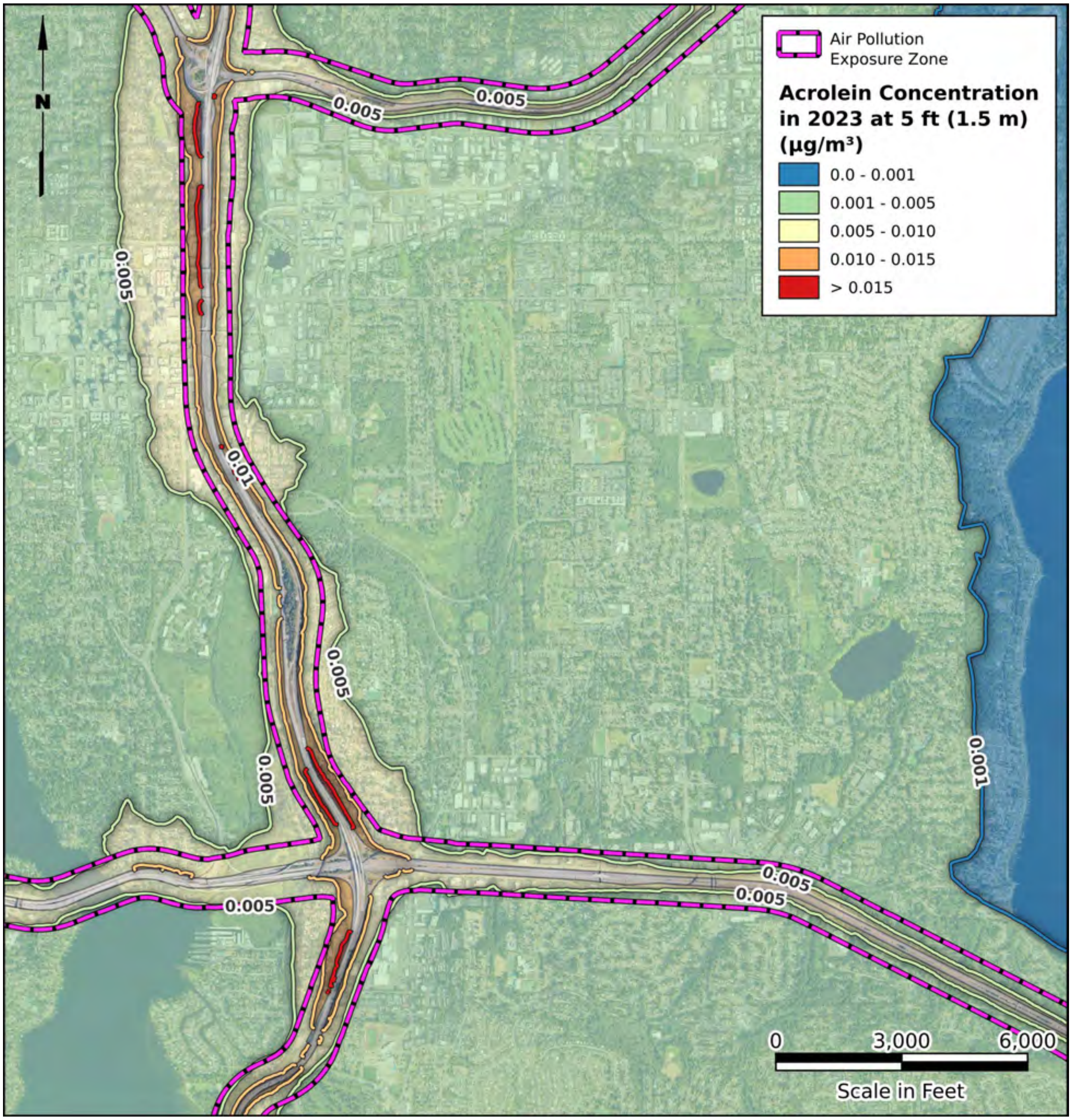


Figure 9 shows 24-hour average acrolein concentrations in the breathing zone, which indicate that concentrations throughout the model domain are considerably less than the acute REL threshold for acrolein (i.e., 0.35 µg/m^3).

Figure 10: Lifetime Increased Cancer Risk Attributable to Benzene at 5 Feet Above Ground (2023 Vehicles)

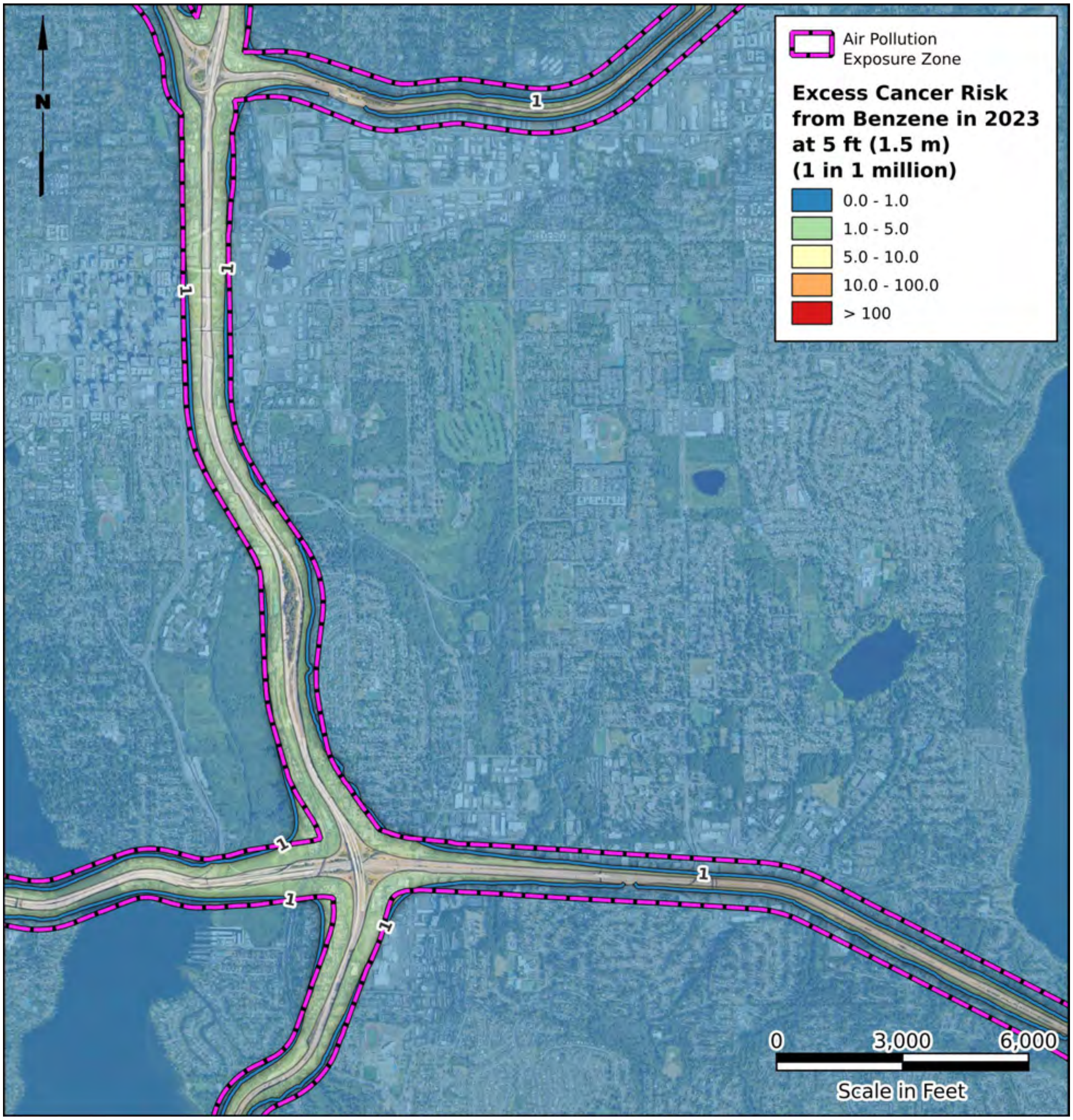


Figure 10 shows the lifetime increased cancer risk in the breathing zone attributable to benzene emissions. The calculated increased risk is less than 1 additional cancer in 1 million throughout the model domain, except for receptors located close to the freeways, where all increased risk is less than 5 additional cancers in 1 million.

Figure 11: Lifetime Increased Cancer Risk Attributable to 1,3-Butadiene at 5 Feet Above Ground (2023 Vehicles)

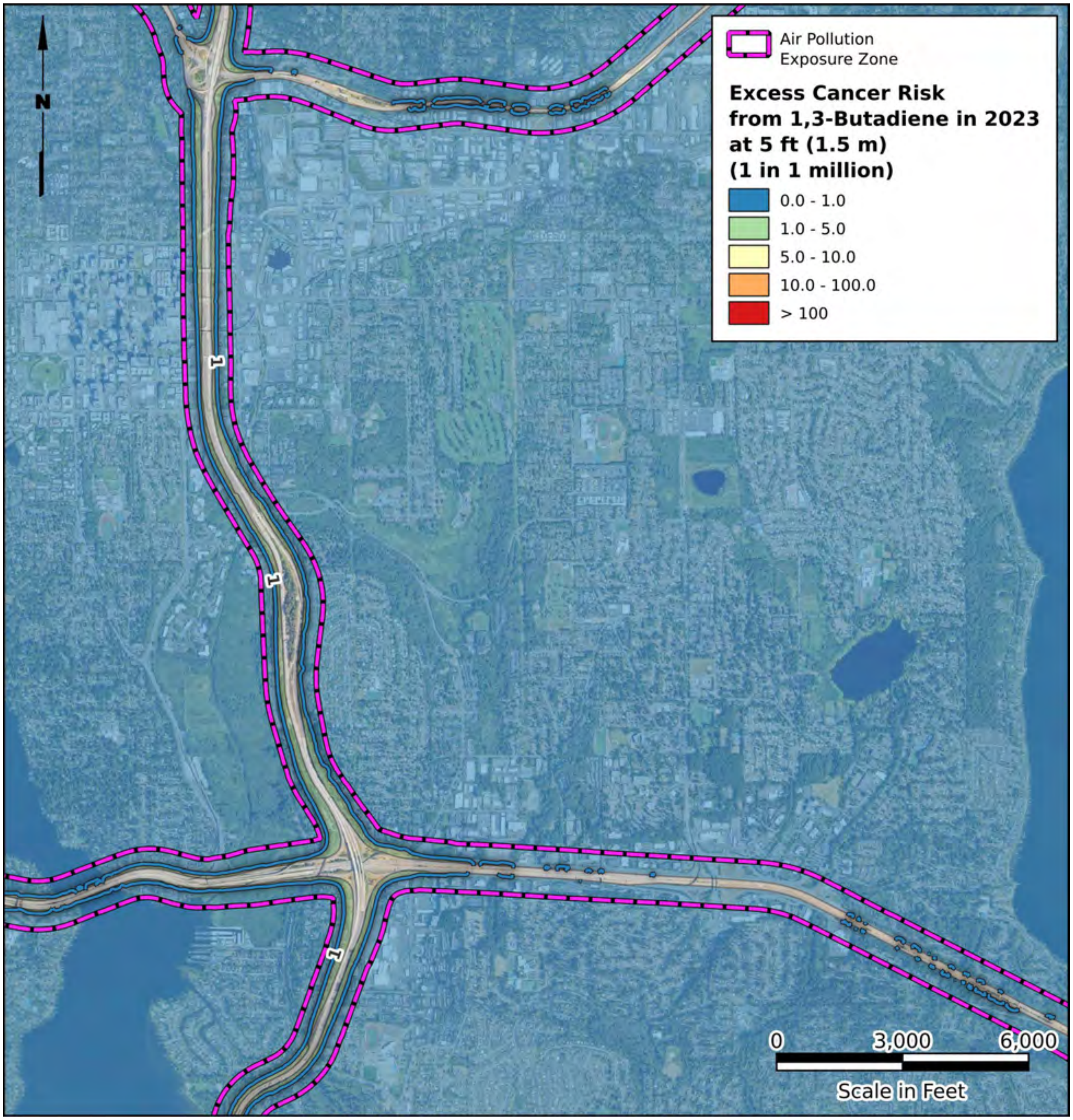


Figure 11 shows the lifetime increased cancer risk in the breathing zone attributable to 1,3-butadiene emissions. Except for receptors located close to the freeways, the calculated increased risk is less than 1 additional cancer in 1 million.

Figure 12: Lifetime Increased Cancer Risk Attributable to DPM at 5 Feet Above Ground (2023 Vehicles)

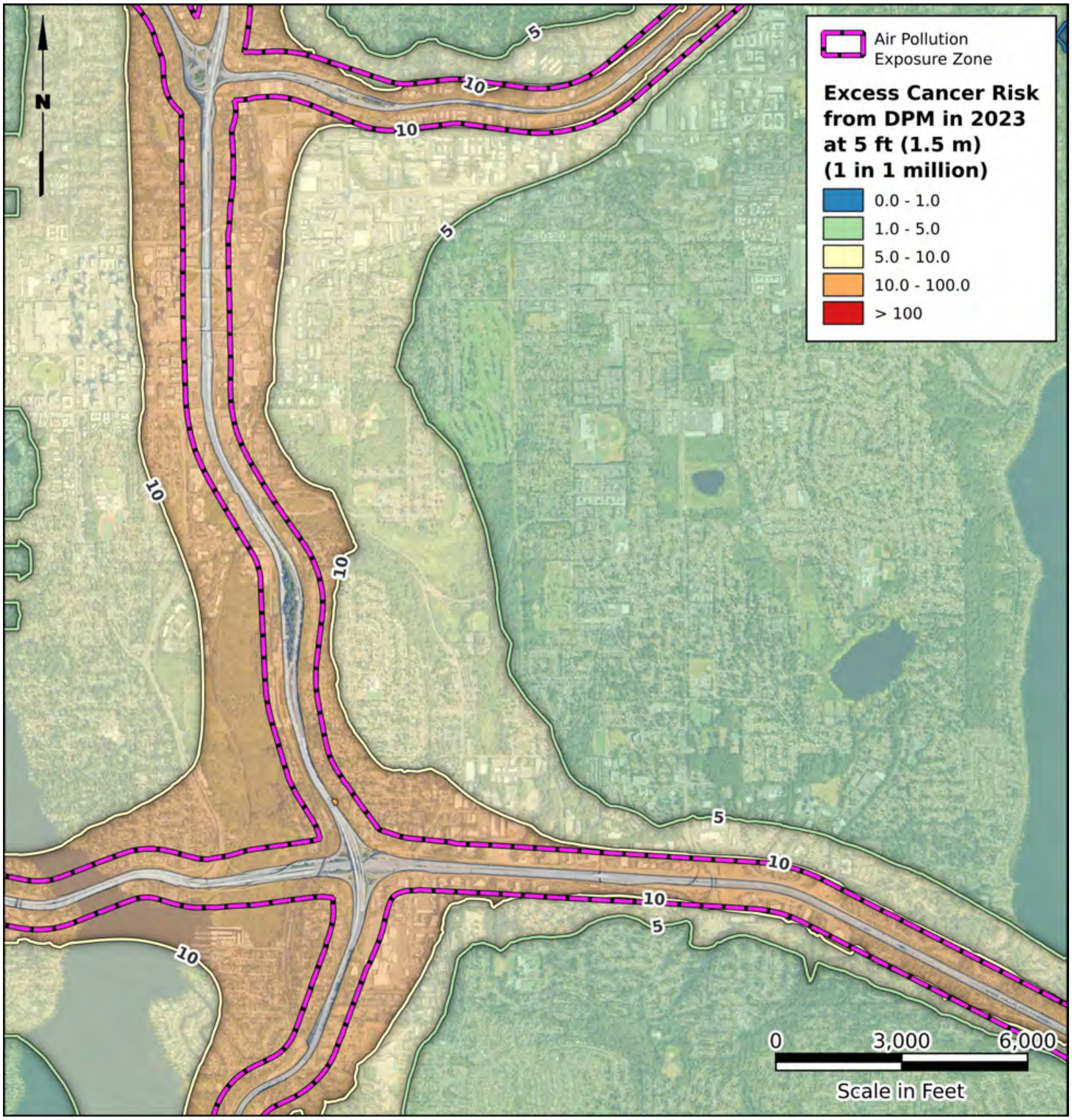


Figure 12 shows the lifetime increased cancer risk in the breathing zone attributable to DPM emissions. The increased cancer risk at all receptors in the model domain is greater than 1 additional cancer in 1 million. However, only a small number of receptors, located to the north of the intersection of I-405 and I-90, are calculated to exceed 100 additional cancers in 1 million.

Figure 13: Lifetime Increased Cancer Risk Attributable to PAHs at 5 Feet Above Ground (2023 Vehicles)

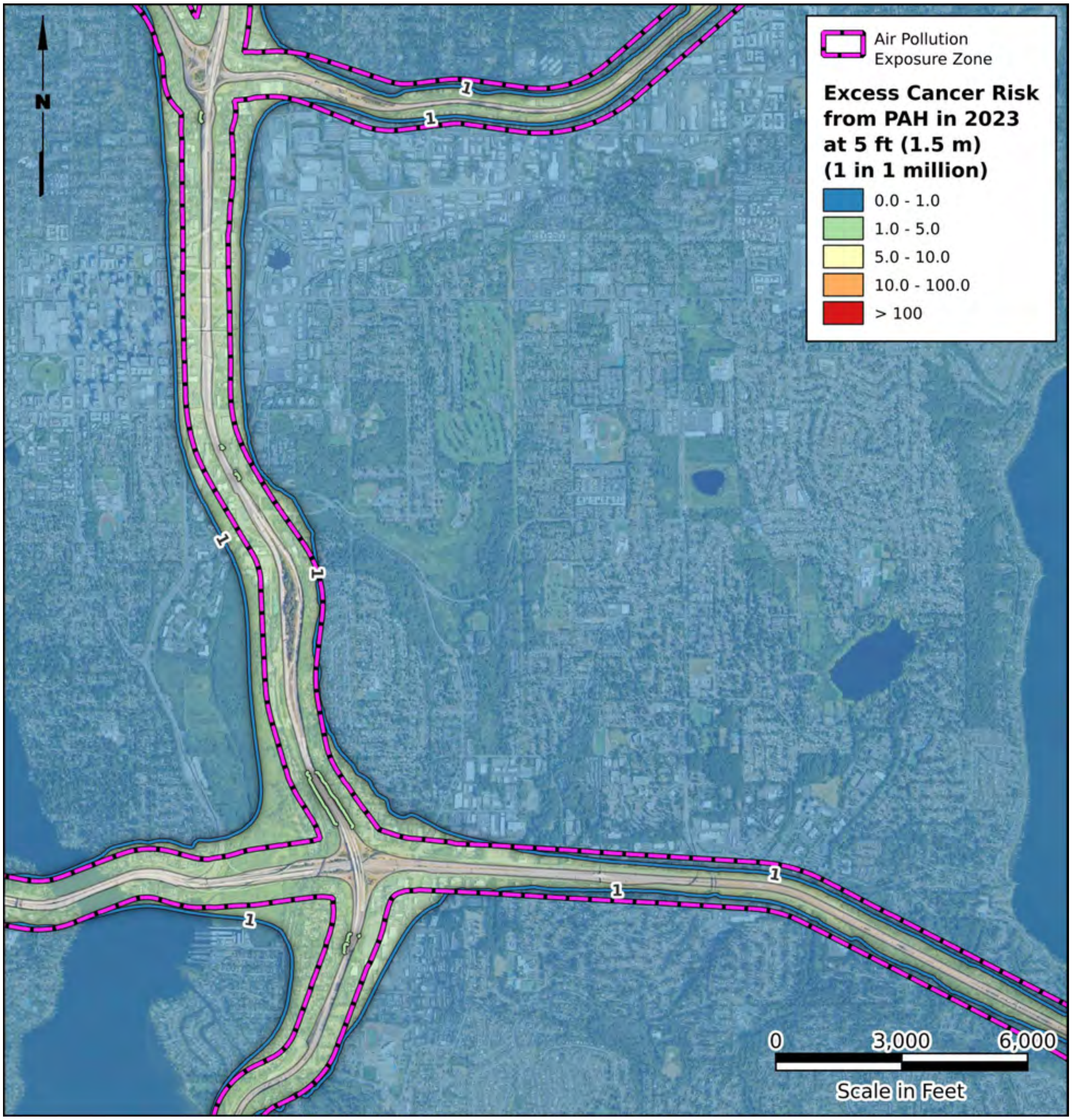


Figure 13 shows the lifetime increased cancer risk in the breathing zone attributable to PAH emissions. Except for receptors located close to the freeways, the calculated increased risk is less than 1 additional cancer in 1 million.

Modeled concentrations and increased cancer risk decrease with increasing height above ground. To demonstrate the magnitude of the decrease with height, Figures 14 and 15 show model-calculated pollutant concentrations at 98 feet (30 meters) above ground.

Figure 14: 1-Hour Average NO_2 Concentrations at 98 Feet Above Ground (2023 Vehicles – PM Scenario)

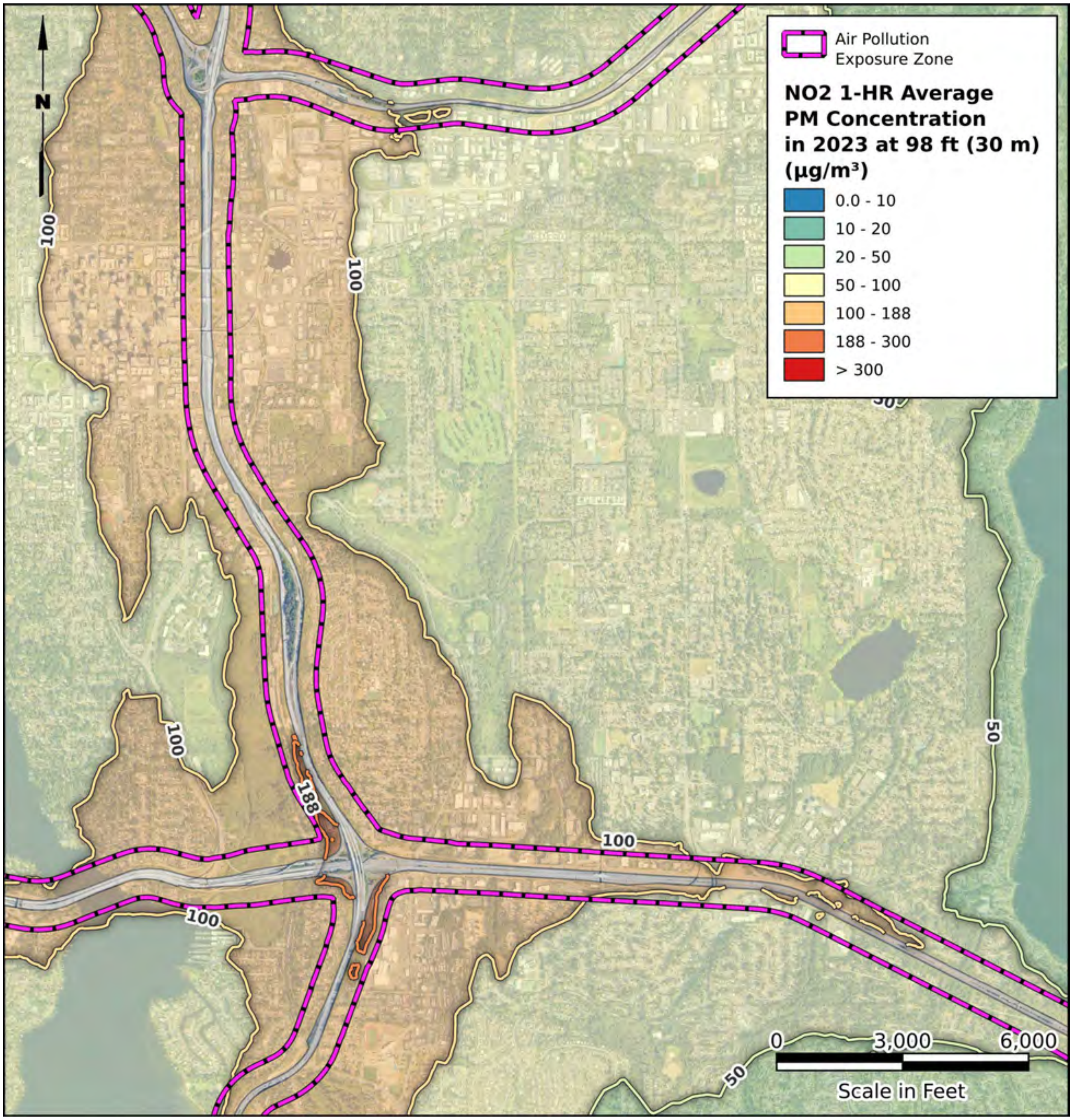


Figure 14 shows 1-hour average NO_2 concentrations at 98 feet above ground for the PM traffic scenario, and modeled concentrations throughout the model domain are less than 188 µg/m^3 except for a small number of receptors located near the intersection of I-405 and I-90. Similar to results shown on Figure 5, all modeled concentrations are less than the acute REL threshold for NO_2 (i.e., 470 µg/m^3).

Figure 15: Lifetime Increased Cancer Risk Attributable to DPM at 98 Feet Above Ground (2023 Vehicles)

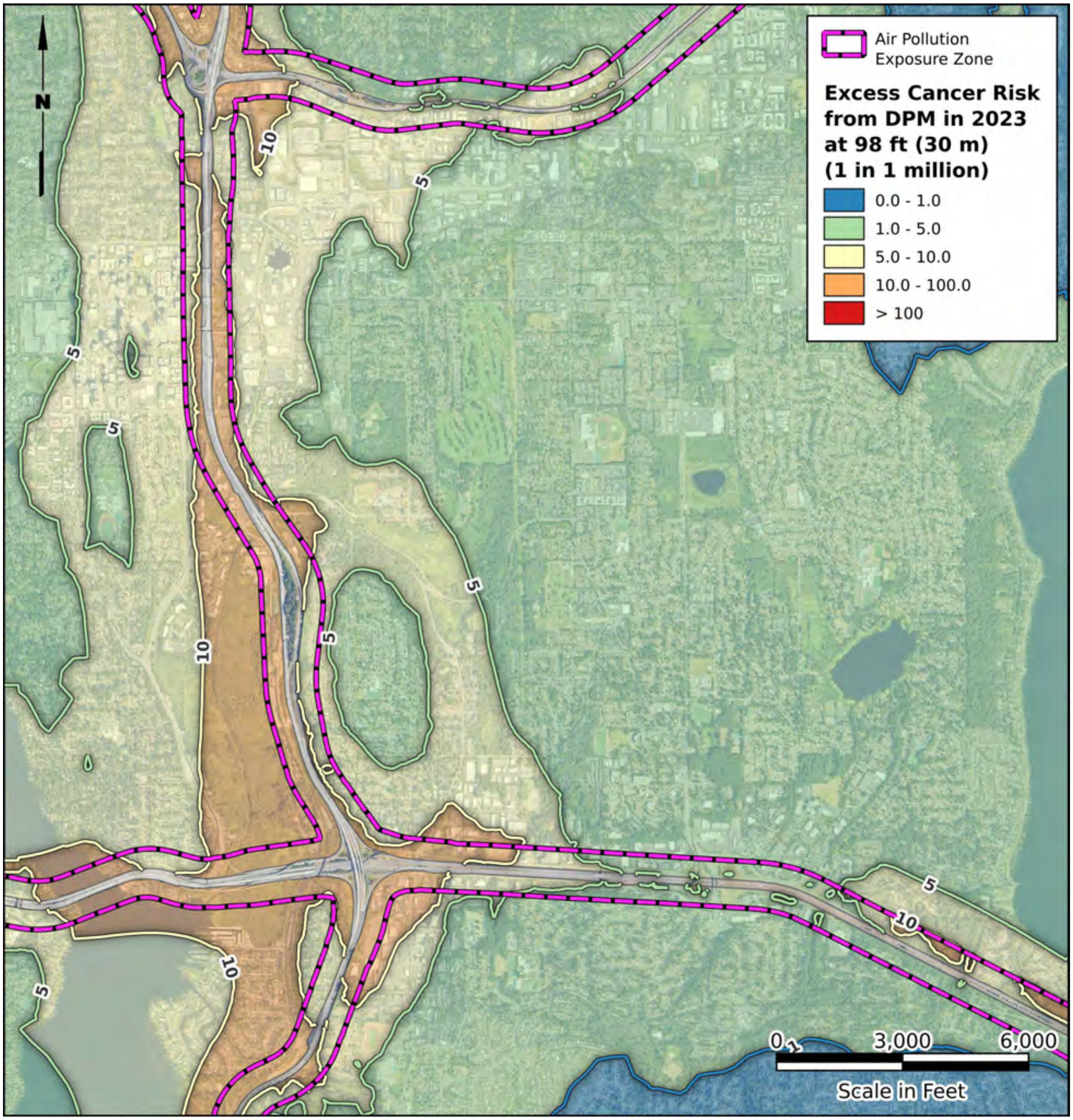


Figure 15 shows the lifetime increased cancer risk attributable to DPM emissions at 98 feet above ground. The increased cancer risk at all receptors in the model domain is greater than 1 additional cancer in 1 million. However, none of the receptor locations are calculated to exceed 100 additional cancers in 1 million.

4.1.1 Future Year Vehicle Emissions Scenarios

Table 5 and Figures 16 and 19 illustrate the impact on modeled concentrations of predicted changes to the vehicle fleet in future years. Table 5 shows the maximum concentration of each pollutant calculated by the model for each modeled year. Figures 16 and 17 show model results that reflect the 2034 vehicle fleet, and Figures 18 and 19 show those that reflect the 2044 vehicle fleet.

Table 5: Model Results – 2023, 2034, and 2044 Vehicle Emissions

Criteria Pollutants				
Pollutant	**Averaging Period**	**Maximum Modeled Concentration (µg/m^3)**		
		2023	**2034**	**2044**
NO_2[(a)]	1-hour	358	116	73
NO_2	Annual	40	7.9	4.6
$PM_{2.5}$	24-hour	2.3[(a)]	1.3	1.1
$PM_{2.5}$	Annual	0.80	0.44	0.39
Non-Carcinogenic TAPs				
NO_2	1-hour	358	116	73
Acrolein	24-hour	0.021	0.0042	0.0020
Carcinogenic TAPs				
1,3-Butadiene	Annual	0.016	0.00027	--
Acetaldehyde	Annual	0.073	0.014	0.0083
Benzene	Annual	0.16	0.044	0.034
DPM	Annual	0.35	0.072	0.025
Ethylbenzene	Annual	0.074	0.016	0.012
Formaldehyde	Annual	0.12	0.026	0.014
Naphthalene	Annual	0.015	0.0028	0.0015
PAHs	Annual	0.0061	0.0013	0.00069

Note:

(a) Because the 1-hour average NO_2 and 24-hour average $PM_{2.5}$ ambient standards have statistical bases, as well as the assumption that 100 percent of NO_X is assumed to be converted to NO_2, comparisons with maximum predicted concentrations should be considered conservative.

Figure 16: 1-Hour Average NO_2 Concentrations at 5 Feet Above Ground (2034 Vehicles – PM Scenario)

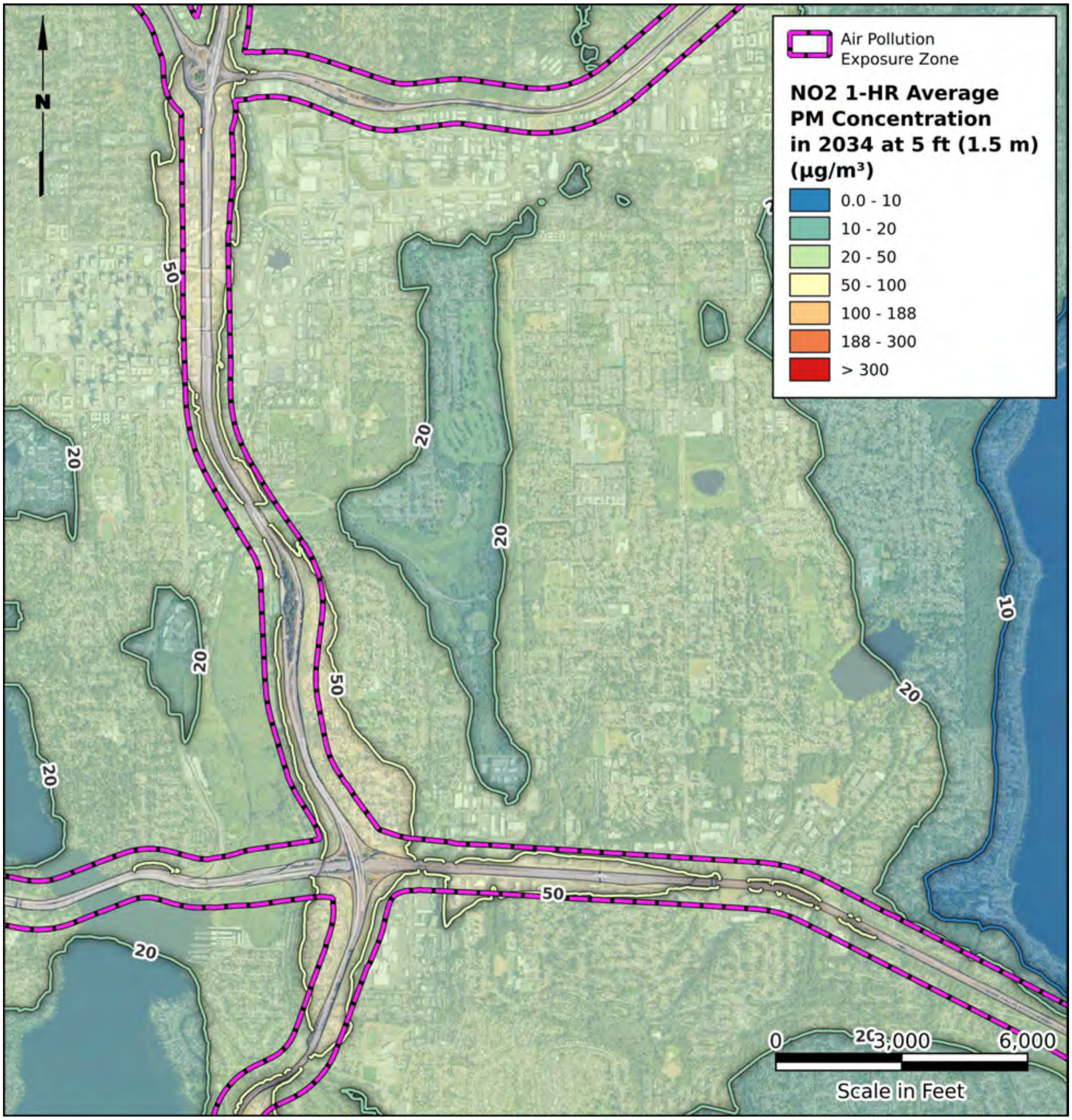


Figure 16 shows 1-hour average NO_2 concentrations in the breathing zone for the PM traffic scenario using predicted 2034 vehicle fleet emission rates. Except for a few areas near I-405 and I-90, modeled concentrations throughout the model domain are less than 50 µg/m^3. Similar to results shown on Figures 5 and 14, all modeled concentrations are less than the acute REL threshold for NO_2 (i.e., 470 µg/m^3).

Figure 17: Lifetime Increased Cancer Risk Attributable to DPM at 5 Feet Above Ground (2034 Vehicles)

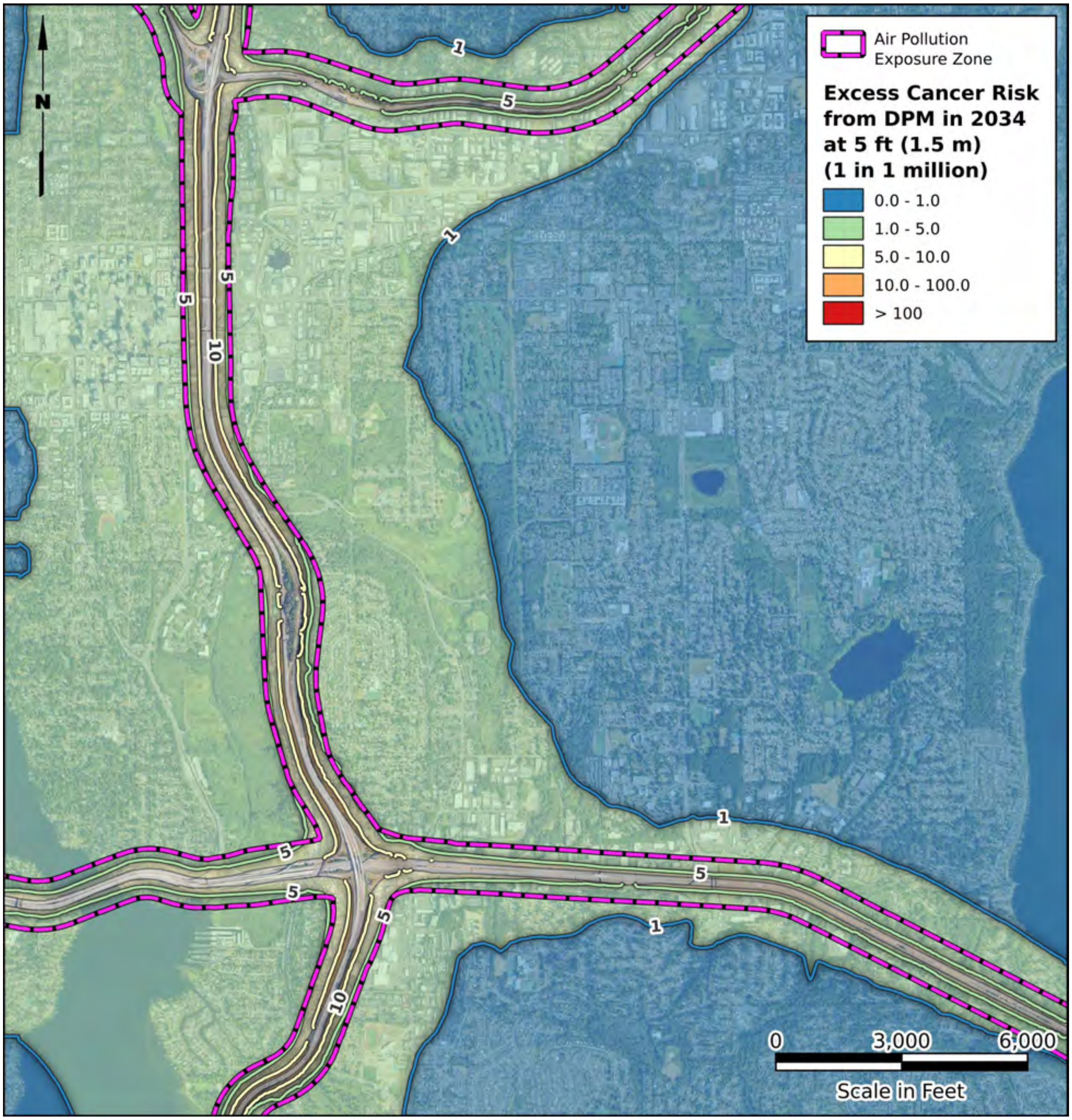


Figure 17 shows the lifetime increased cancer risk attributable to DPM emissions in the breathing zone using predicted 2034 vehicle fleet emission rates. Unlike Figures 12 and 15, not all receptor locations in the model domain have calculated increased cancer risk greater than 1 additional cancer in 1 million, and none of the receptors are calculated to exceed 100 additional cancers in 1 million.

Figure 18: 1-Hour Average NO_2 Concentrations at 5 Feet Above Ground (2044 Vehicles – PM Scenario)

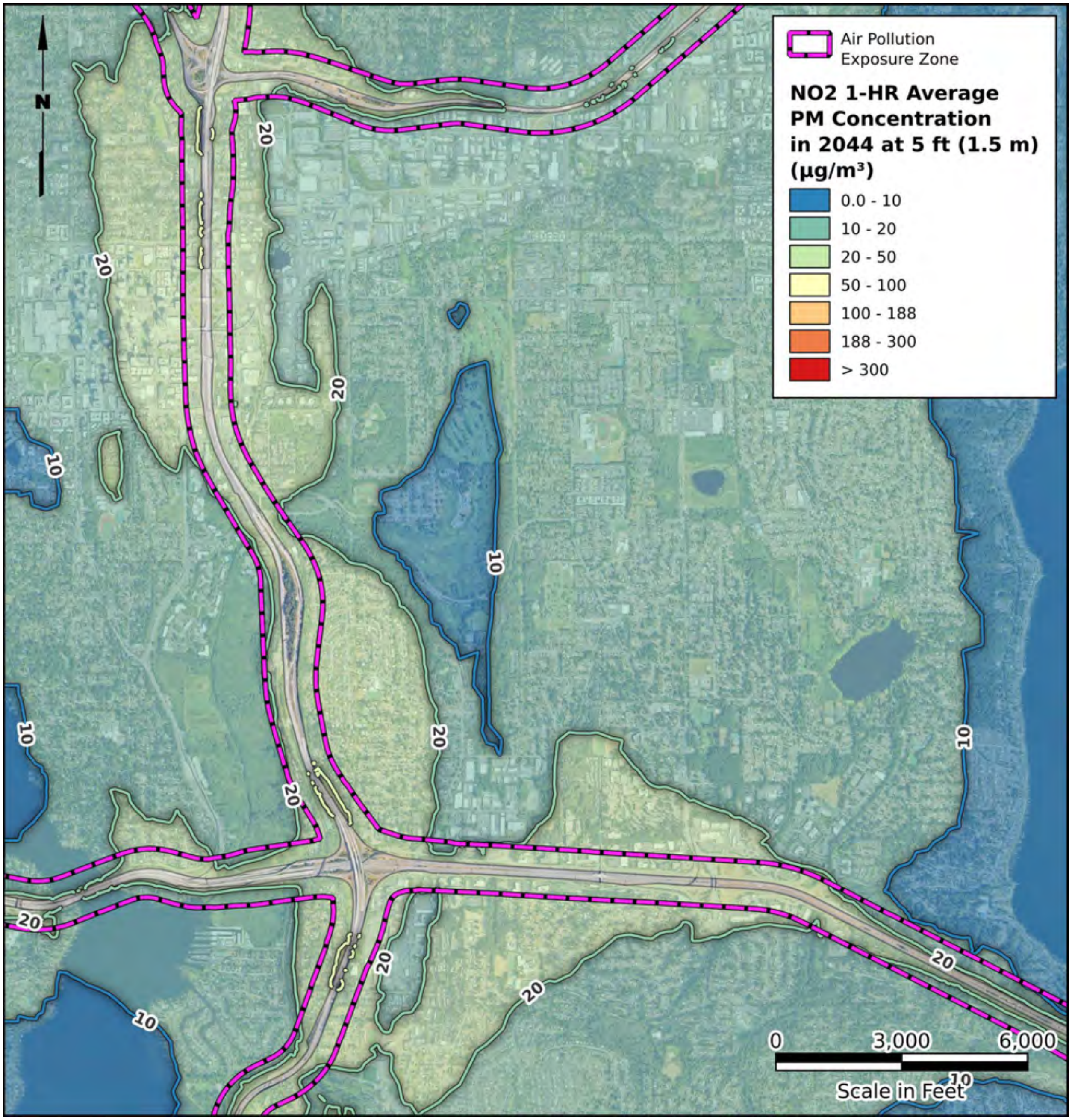


Figure 18 shows 1-hour average NO_2 concentrations in the breathing zone for the PM traffic scenario using predicted 2044 vehicle fleet emission rates. Except for a small number of receptor locations near I-405, modeled concentrations throughout the model domain are less than 50 µg/m^3. Similar to results shown on Figures 5, 14 and 16, all modeled concentrations are less than the acute REL threshold for NO_2 (i.e., 470 µg/m^3).

Figure 19: Lifetime Increased Cancer Risk Attributable to DPM at 5 Feet Above Ground (2044 Vehicles)

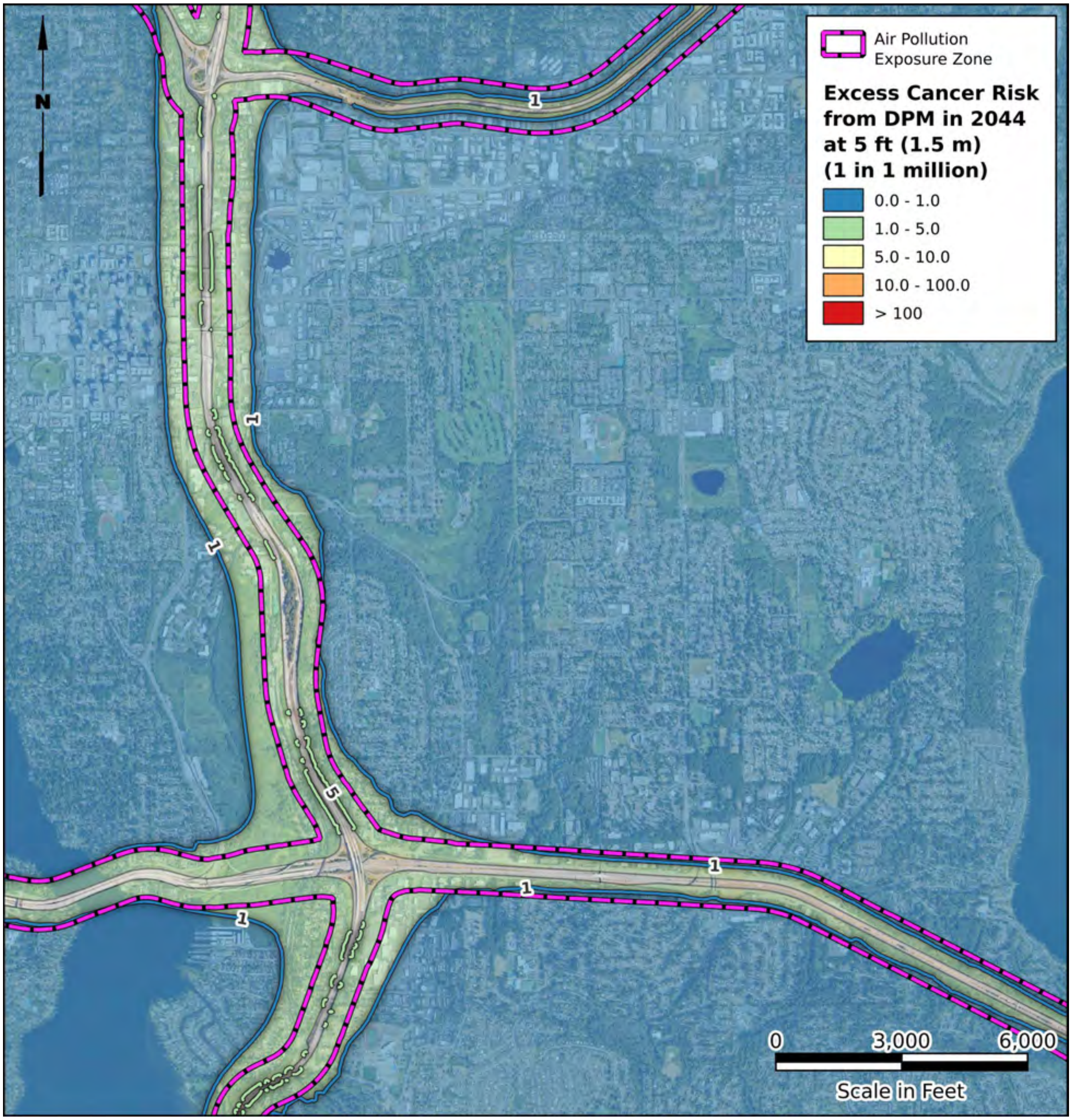


Figure 19 shows the lifetime increased cancer risk attributable to DPM emissions in the breathing zone using predicted 2044 vehicle fleet emission rates. Only receptor locations relatively near the freeways have calculated increased cancer risks greater than 1 additional cancer in 1 million, and none of the receptor locations are calculated to exceed 10 additional cancers in 1 million.

4.1.2 Brake and Tire Wear Emissions

The $PM_{2.5}$ concentrations shown in Table 3 and on Figures 7 and 8 are “total” $PM_{2.5}$, which includes vehicle exhaust emissions as well as particulate emissions from brake wear and tire wear. Figures 20 and 21 show $PM_{2.5}$ concentrations attributable solely to vehicle exhaust (i.e., without the contribution of brake wear and tire wear. All concentrations shown on Figures 20 and 21 are those calculated for receptor locations in the breathing zone (i.e., 5 feet above ground) using 2023 vehicle fleet emissions.

Figure 20: 24-Hour Average Vehicle Exhaust $PM_{2.5}$ Concentrations (i.e., Without Brake and Tire Wear) at 5 Feet Above Ground (2023 Vehicles)

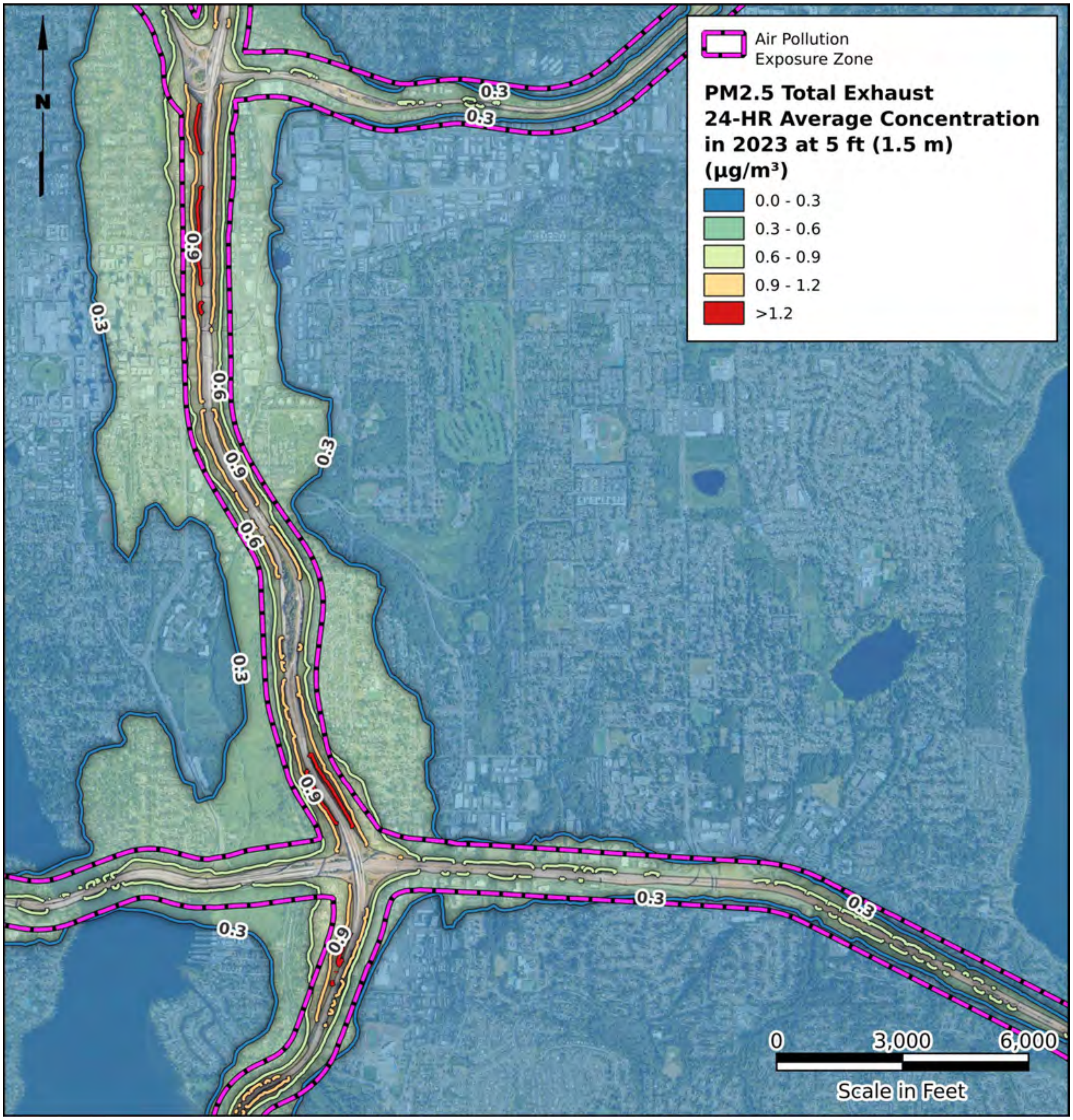
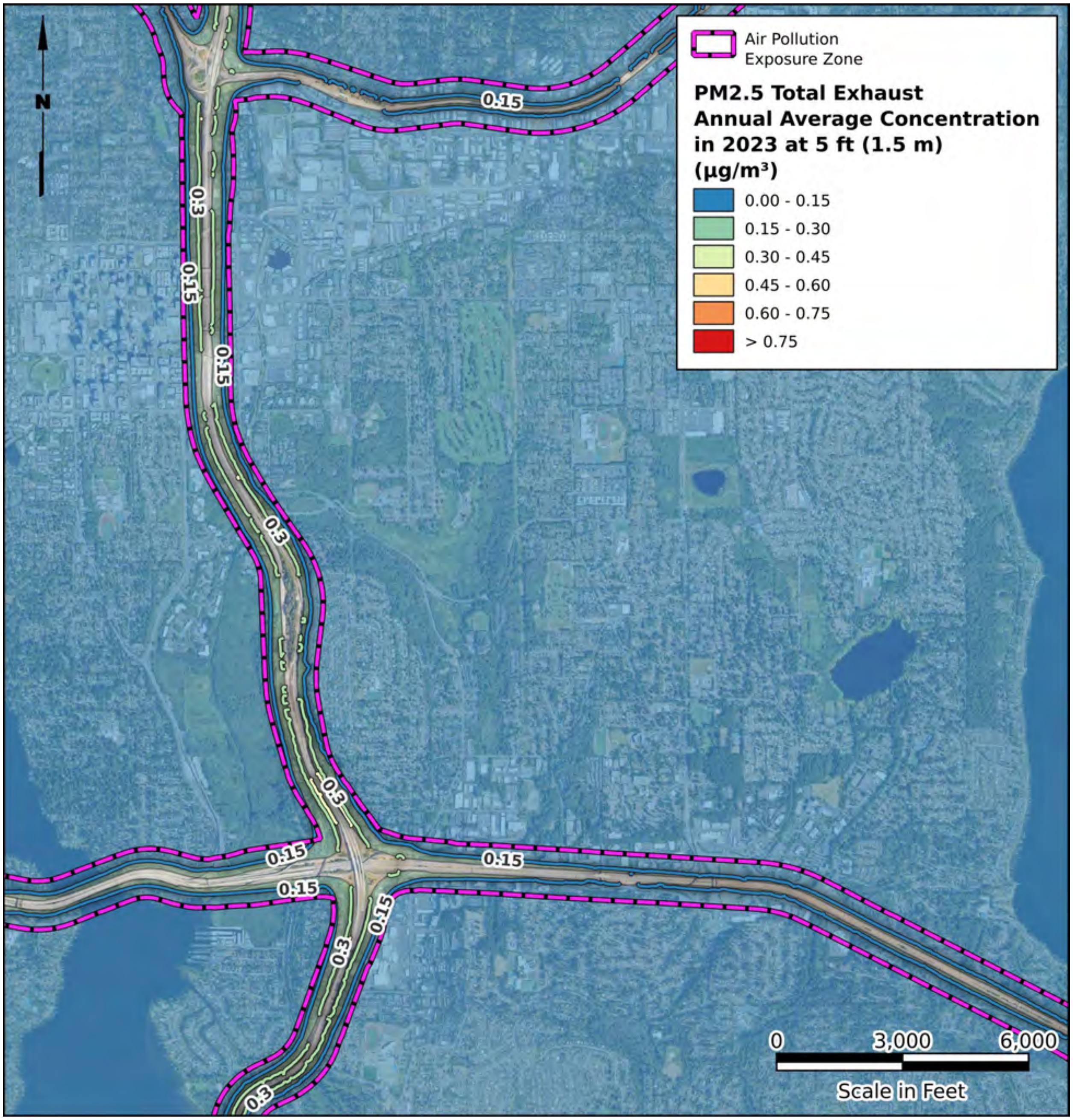


Figure 21: Annual Average Vehicle Exhaust $PM_{2.5}$ Concentrations (i.e., Without Brake and Tire Wear) at 5 Feet Above Ground (2023 Vehicles)



With brake and tire wear removed, the maximum 24-hour average $PM_{2.5}$ concentration calculated by the model decreases from 2.3 µg/m^3, as shown in Table 3, to 1.6 µg/m^3, a 29 percent decrease, and the maximum annual average $PM_{2.5}$ concentration calculated by the model decreases from 0.80 µg/m^3 to 0.61 µg/m^3, also a 29 percent decrease. These decreases and comparisons of Figures 20 and 21 with Figures 7 and 8 indicate that brake and tire wear are significant contributors to $PM_{2.5}$ concentrations, and, as vehicle tailpipe emissions decrease in the future, brake and tire wear will comprise a greater proportion of total $PM_{2.5}$ emissions and concentrations, which will increase the significance of the contribution.

4.1.3 Vertical Variability of Pollutant Concentrations

Figures 4 through 13 show modeled concentrations in the horizontal plane at approximately 5 feet above ground (i.e., the breathing zone), and those on Figures 14 and 15 show modeled concentrations in the horizontal plane at 98 feet above ground to demonstrate changes in calculated concentrations with increasing height above ground. To further describe the vertical spatial variation of concentrations, air pollutant concentration figures referred to as “curtain plots” have been prepared. These plots show modeled concentrations in a vertical plane along a given horizontal “path” or “slice.” The path/slice locations of the prepared curtain plots are shown on Figure 22, and the curtain plots are shown on Figures 23 through 26.

Figure 22: Curtain Plot Locations

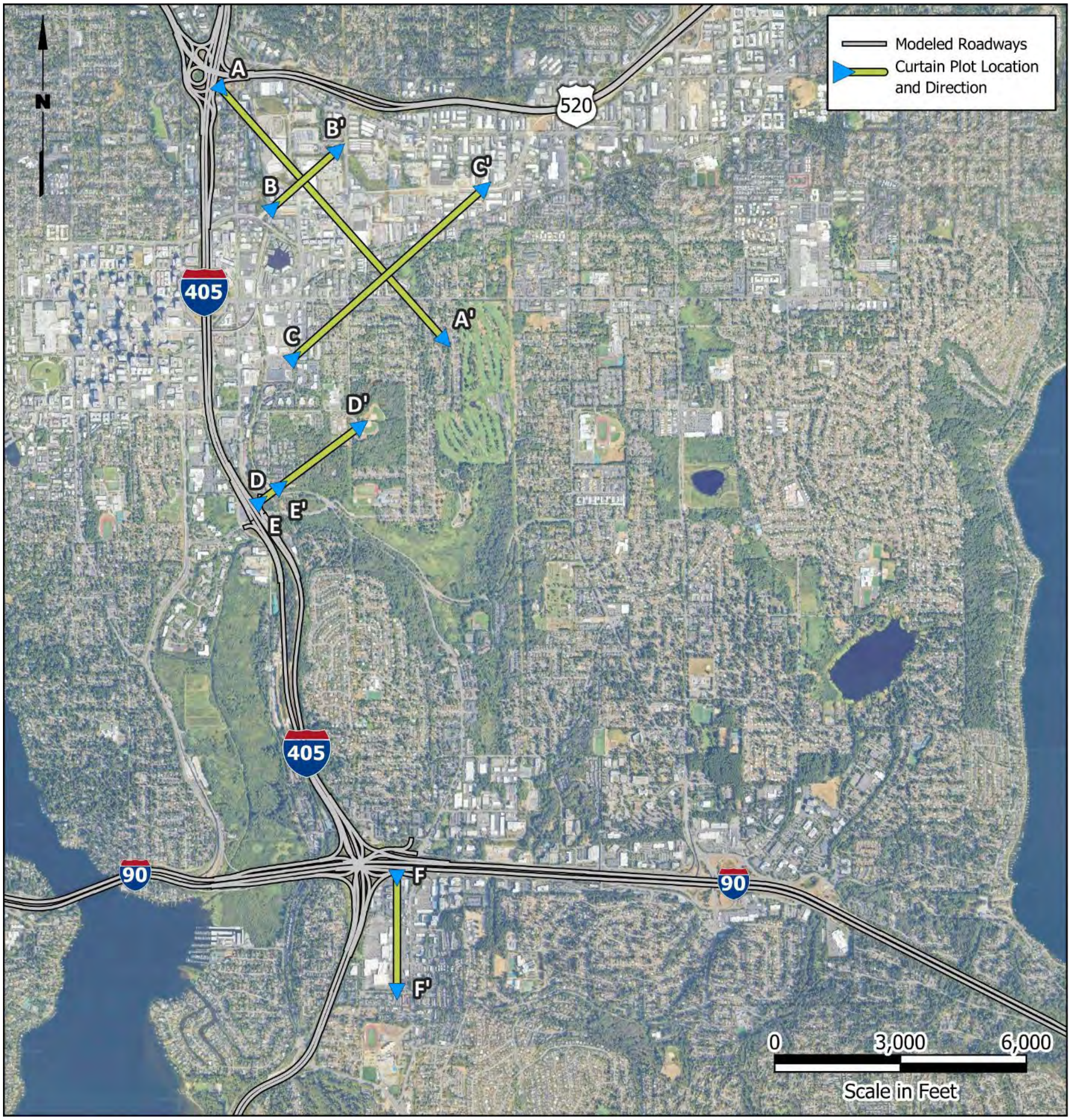


Figure 23: Curtain Plot of 1-Hour Average NO_2 Concentrations from I-405/SR 520 Interchange to Southeast (2023 Vehicles – PM Scenario)

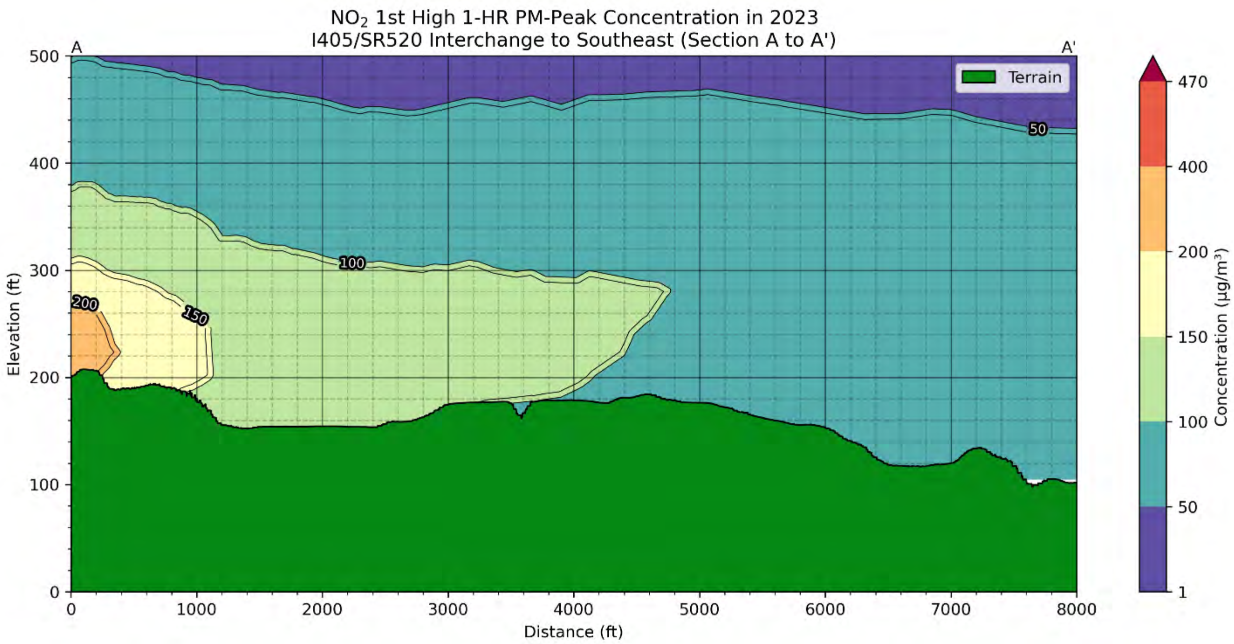


Figure 24: Curtain Plot of 1-Hour Average NO_2 Concentrations from I-405 to Wilburton Hill Park (2023 Vehicles – PM Scenario)

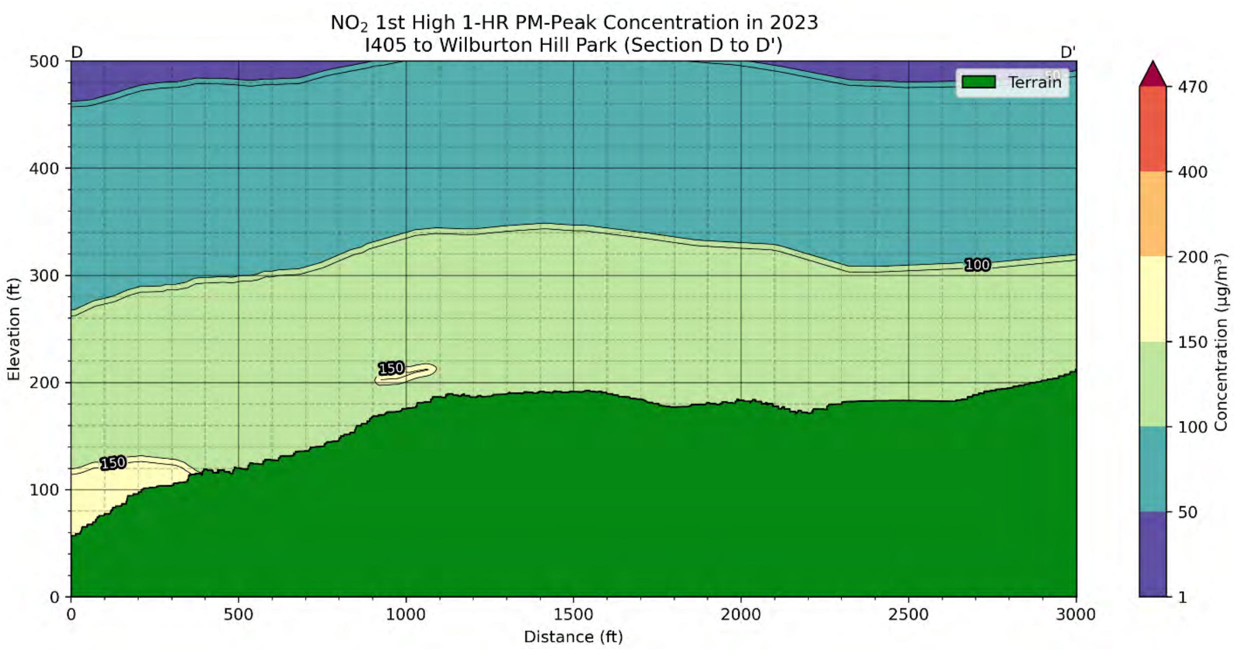


Figure 25: Curtain Plot of 1-Hour Average NO_2 Concentrations from I-405/SR 520 Interchange Through BelRed and Wilburton Neighborhoods (2023 Vehicles – PM Scenario)

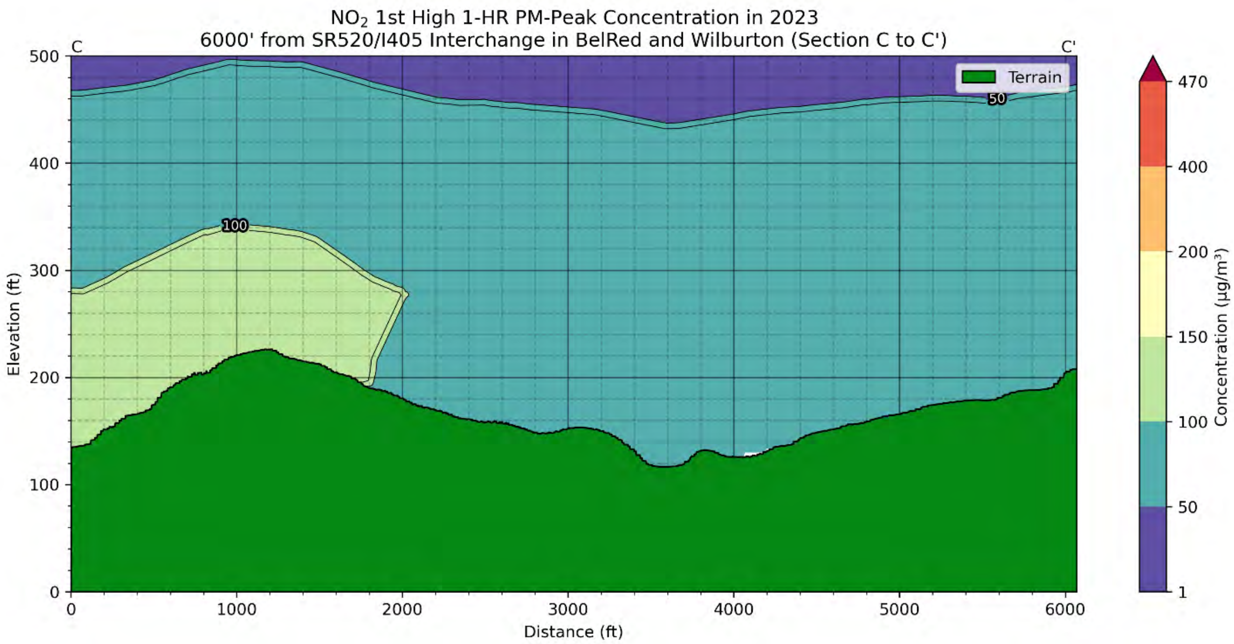


Figure 26: Curtain Plot of 1-Hour Average NO_2 Concentrations from I-405/SR 520 Interchange Through BelRed Neighborhood (2023 Vehicles – PM Scenario)

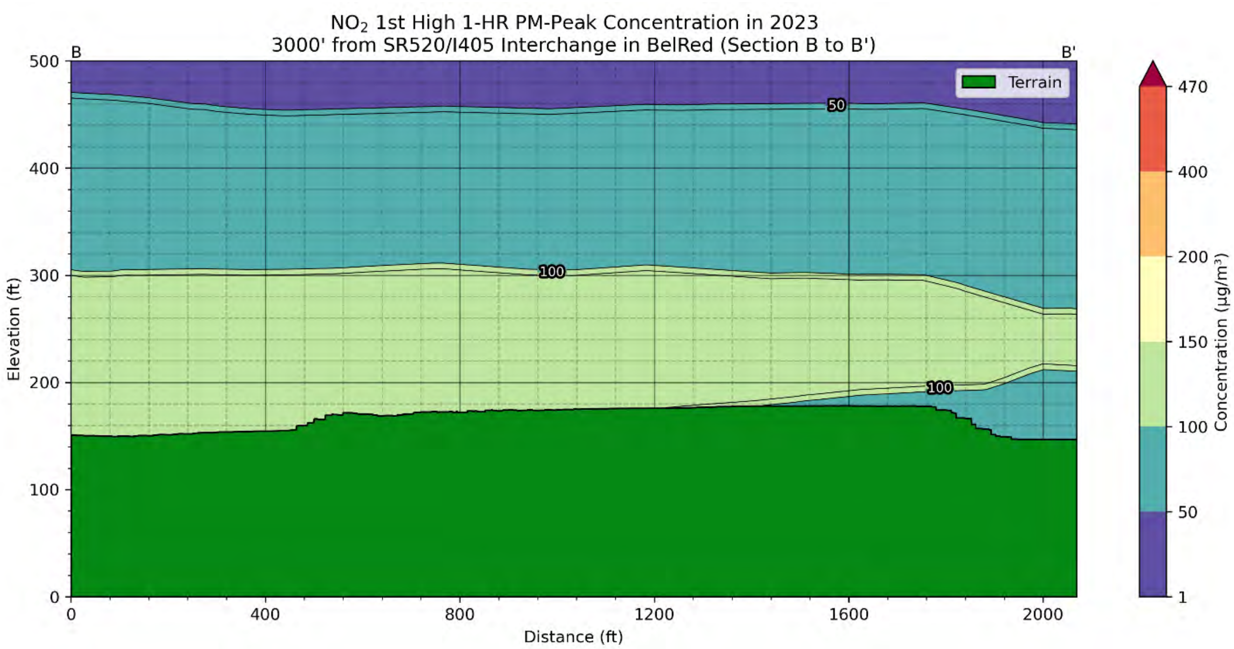


Figure 27: Curtain Plot of Increased Cancer Risk Attributable to DPM from I-405/SR 520 Interchange to Southeast (2023 Vehicles)

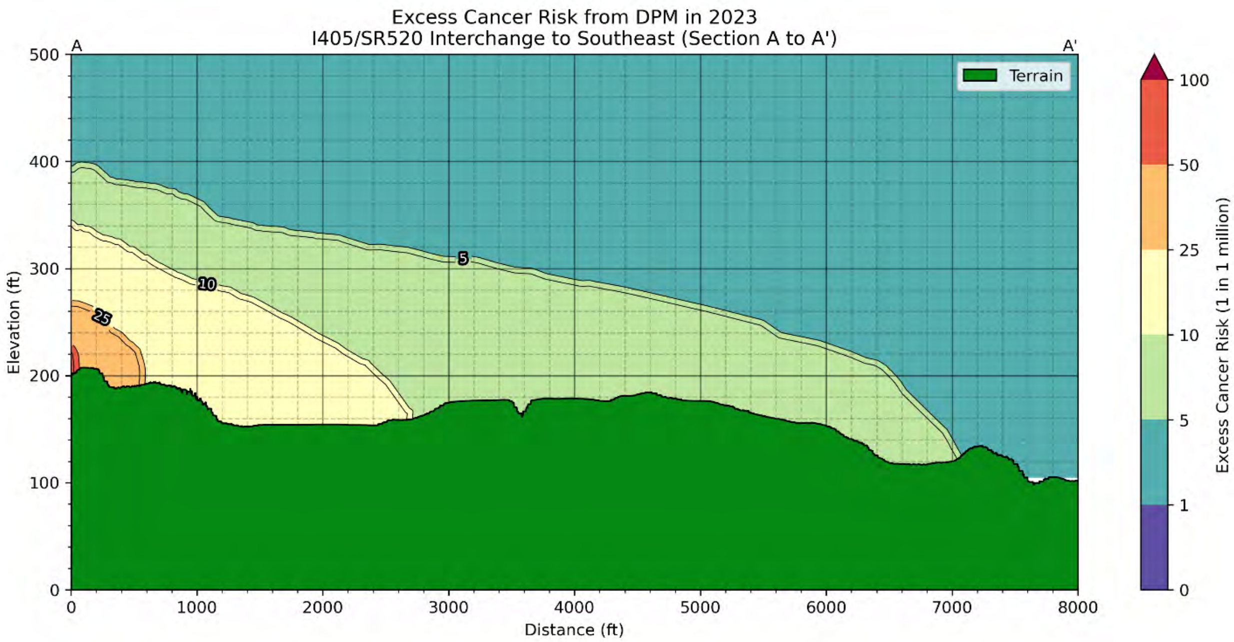


Figure 28: Curtain Plot of Increased Cancer Risk Attributable to DPM from I-405 to Wilburton Hill Park (2023 Vehicles)

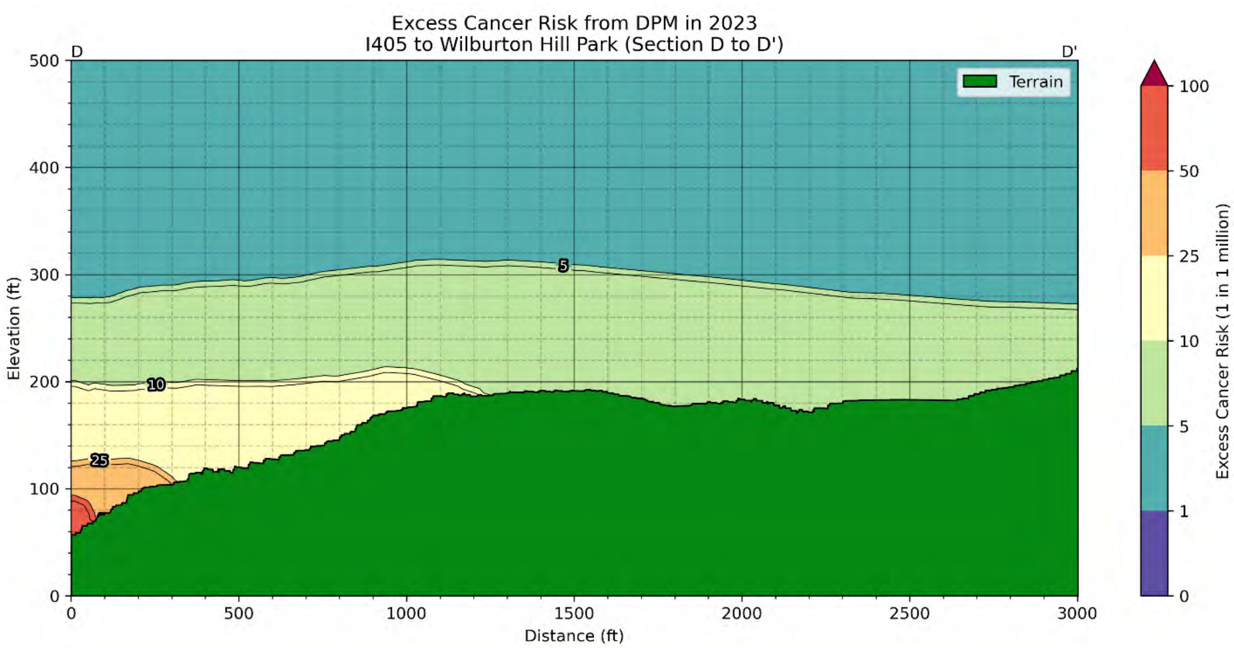


Figure 29: Curtain Plot of Increased Cancer Risk Attributable to DPM from I-405/SR 520 Interchange Through BelRed and Wilburton Neighborhoods (2023 Vehicles)

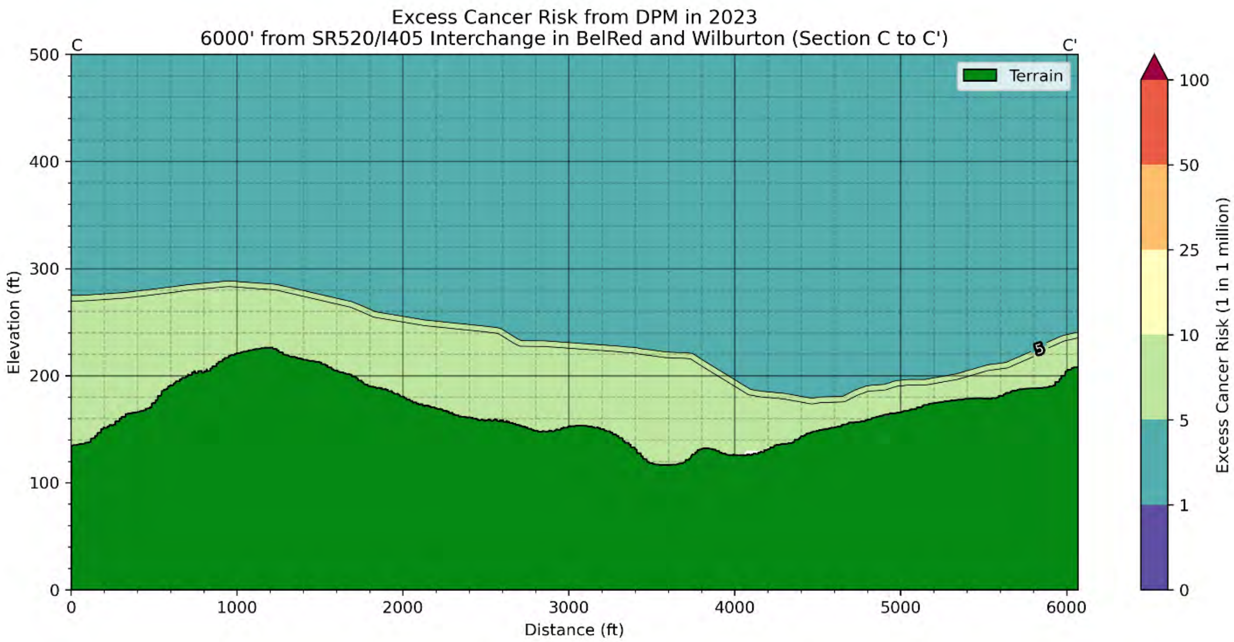
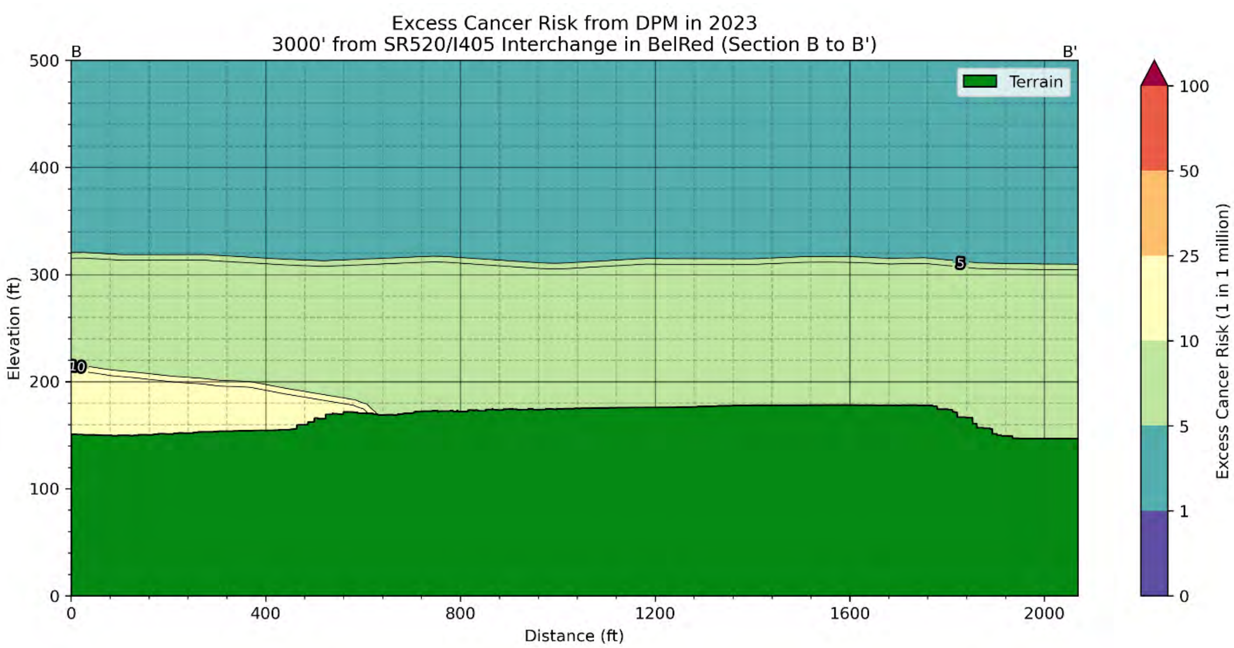


Figure 30: Curtain Plot of Increased Cancer Risk Attributable to DPM from I-405/SR 520 Interchange Through BelRed Neighborhood (2023 Vehicles)



4.1.4 On- and Off-Ramp Sensitivity Analysis

The scope of the modeling includes emissions from vehicles operated on all freeways but excludes emissions associated with vehicles operated on- and off-ramps that provide access to and from the freeways and nearby surface streets. To investigate the contribution of on- and off-ramps, two areas were selected and modeled for a sensitivity analysis.

The two on- and off-ramp areas selected were those that provide access to/from I-405 and SE 8th Street and those that provide access to/from I-405 and I-90 in the Factoria area. Figures 31 through 46 show 1-hour average NO_2 concentrations and increased cancer risk attributable to DPM calculated for the two chosen on- and off- ramp areas with and without the emissions contribution from vehicles operated on the on- and off-ramps. All concentrations shown on these figures reflect receptors located in the breathing zone and 2023 vehicle fleet emissions.

Figure 31: 1-Hour Average NO_2 Concentrations in the I-405 & SE 8th Street Area with On- and Off-Ramp Emissions at 5 Feet Above Ground (2023 Vehicles – PM Scenario)

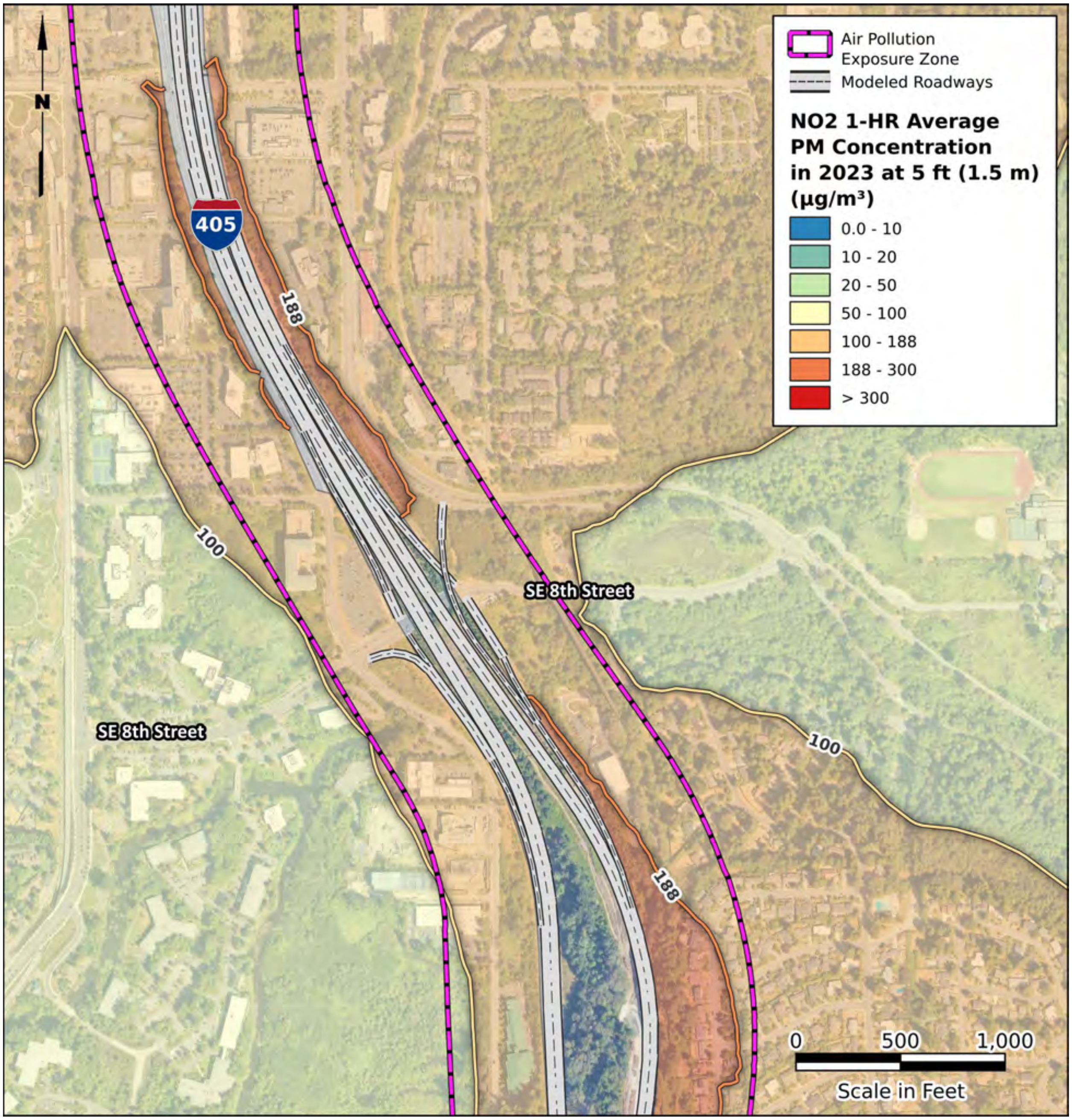


Figure 32: 1-Hour Average NO_2 Concentrations in the I-405 & SE 8th Street Area without On- and Off-Ramp Emissions at 5 Feet Above Ground (2023 Vehicles – PM Scenario)

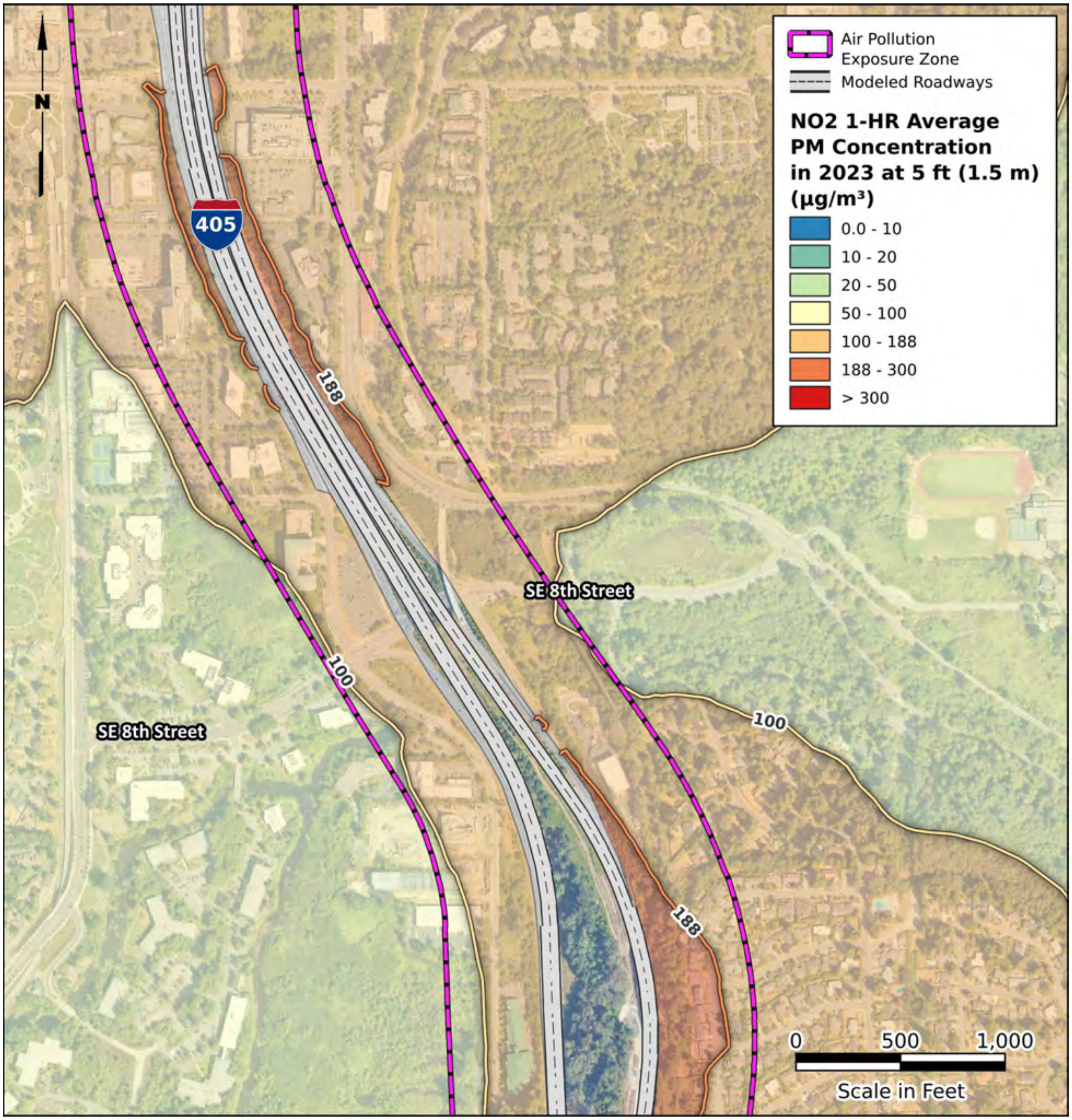


Figure 33: Curtain Plot of 1-Hour Average NO_2 Concentrations in the I-405 & SE 8th Street Area with On- and Off-Ramp Emissions (2023 Vehicles – PM Scenario)

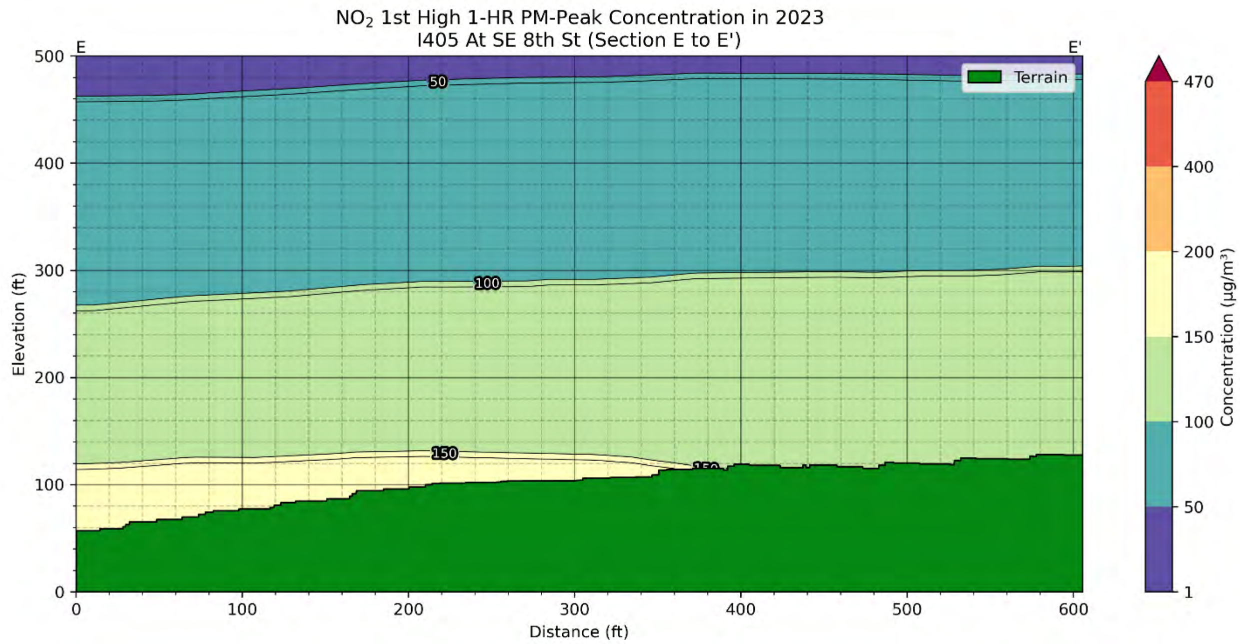


Figure 34: Curtain Plot of 1-Hour Average NO_2 Concentrations in the I-405 & SE 8th Street Area without On- and Off-Ramp Emissions (2023 Vehicles – PM Scenario)

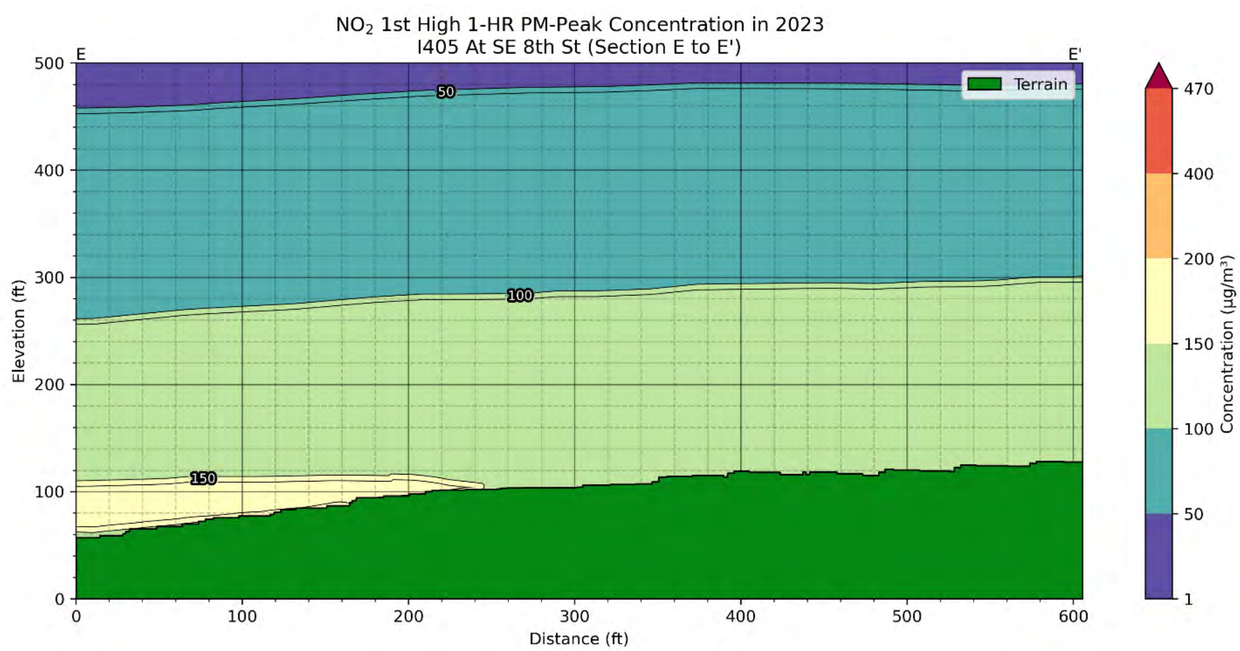


Figure 35: Lifetime Increased Cancer Risk Attributable to DPM in the I-405 & SE 8th Street Area with On- and Off-Ramp Emissions at 5 Feet Above Ground (2023 Vehicles)

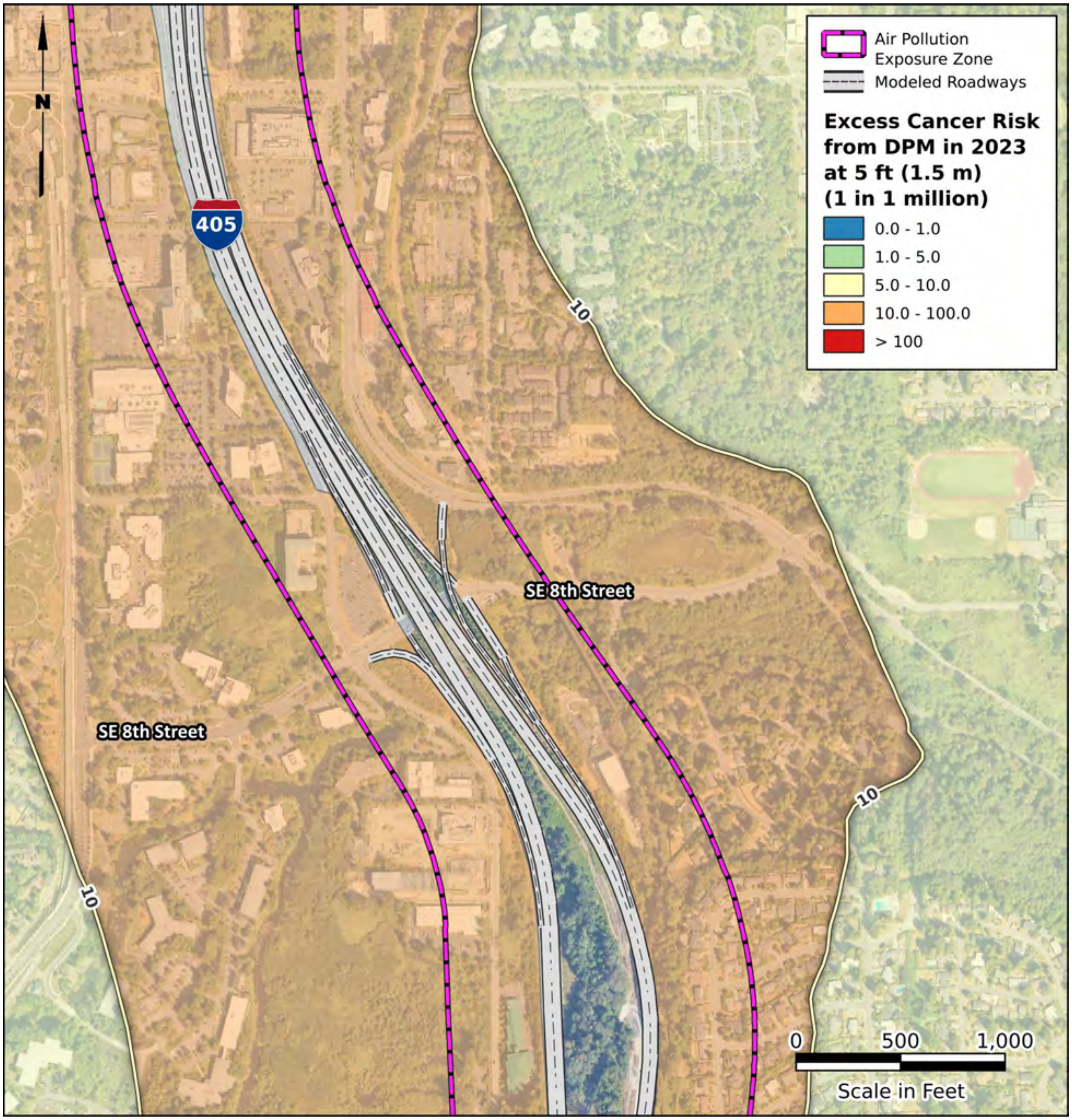


Figure 36: Lifetime Increased Cancer Risk Attributable to DPM in the I-405 & SE 8th Street Area without On- and Off-Ramp Emissions at 5 Feet Above Ground (2023 Vehicles)

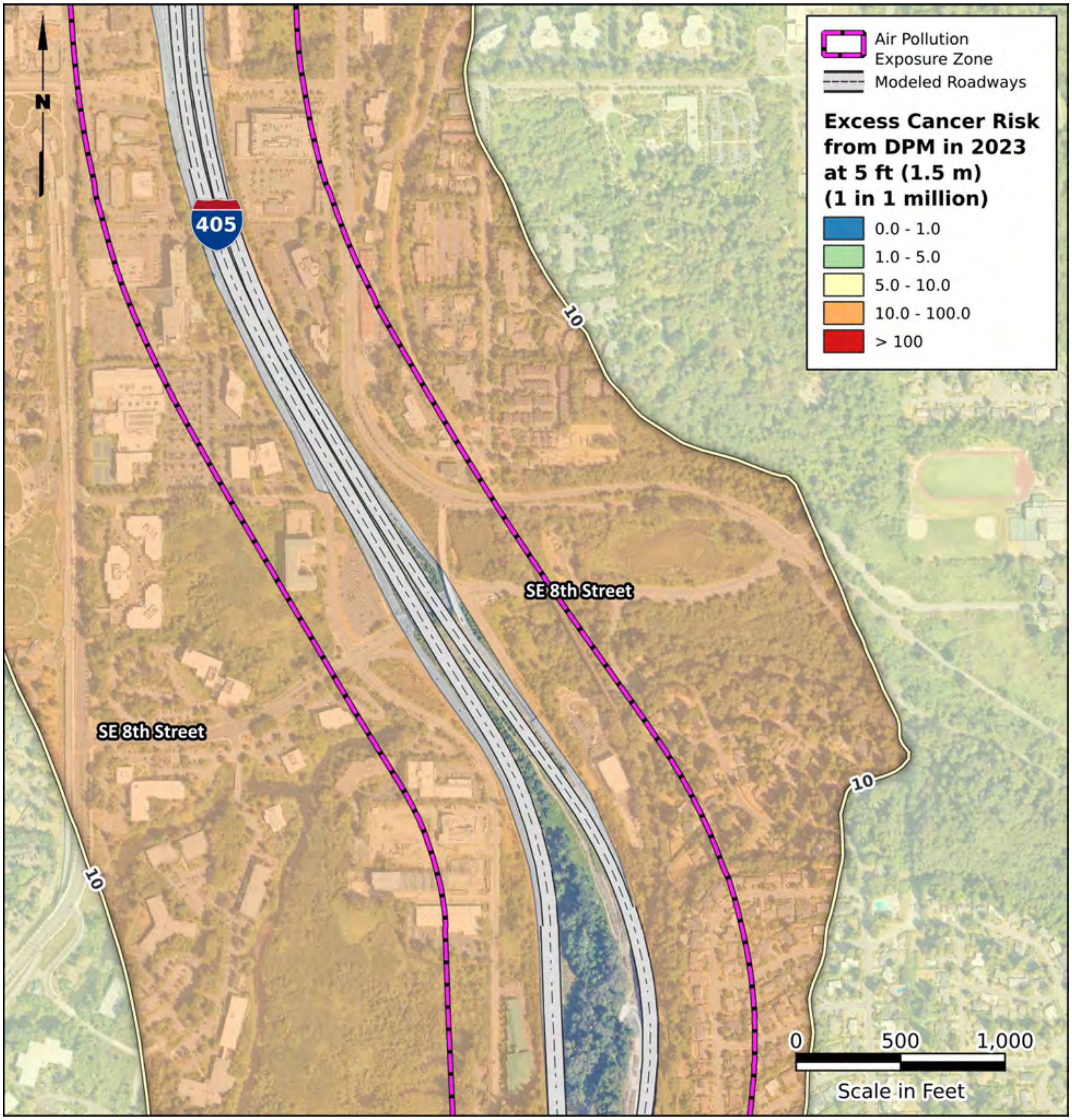


Figure 37: Curtain Plot of Increased Cancer Risk Attributable to DPM in the I-405 & SE 8th Street Area with On- and Off-Ramp Emissions (2023 Vehicles)

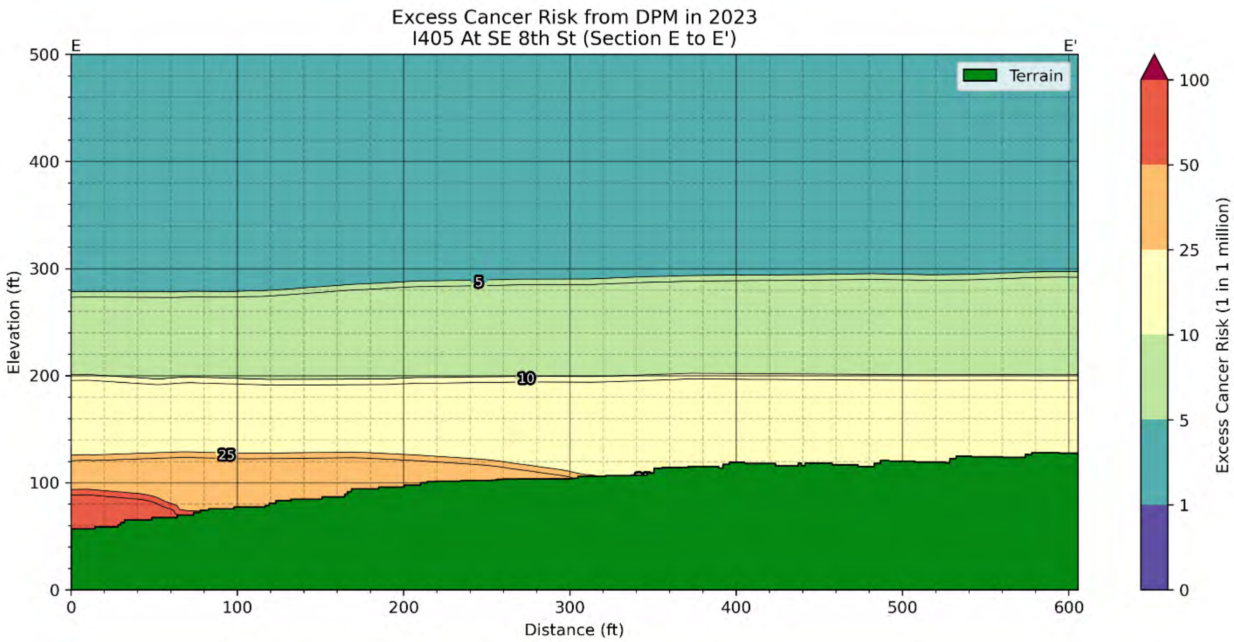


Figure 38: Curtain Plot of Increased Cancer Risk Attributable to DPM in the I-405 & SE 8th Street Area without On- and Off-Ramp Emissions (2023 Vehicles)

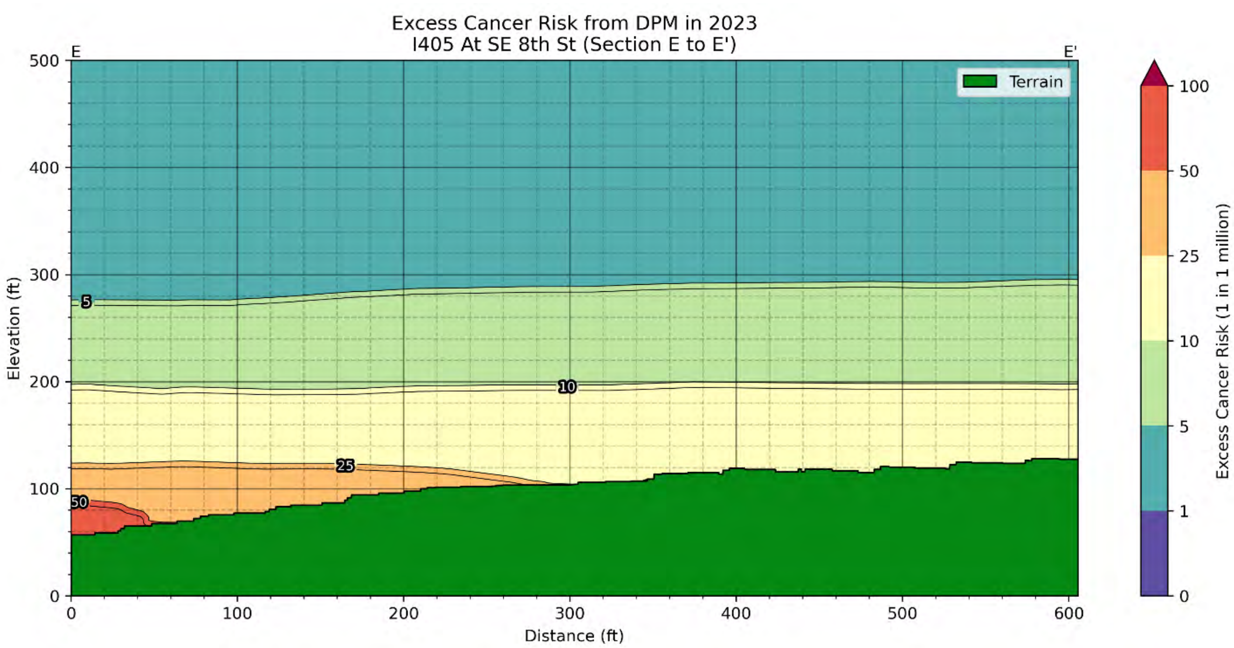


Figure 39: 1-Hour Average NO_2 Concentrations in the Factoria Area with On- and Off-Ramp Emissions at 5 Feet Above Ground (2023 Vehicles – PM Scenario)

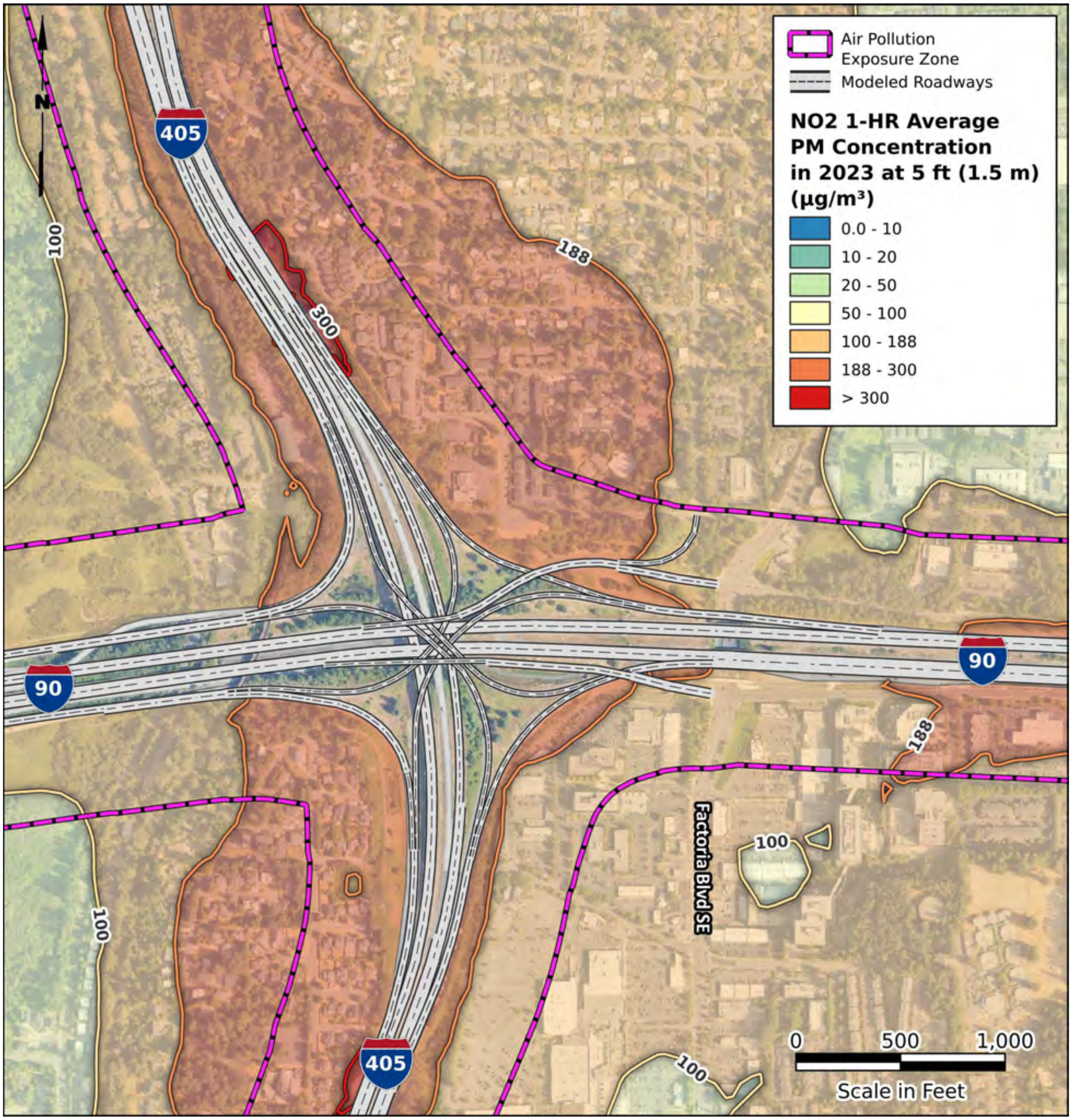


Figure 40: 1-Hour Average NO_2 Concentrations in the Factoria Area without On- and Off-Ramp Emissions at 5 Feet Above Ground (2023 Vehicles – PM Scenario)

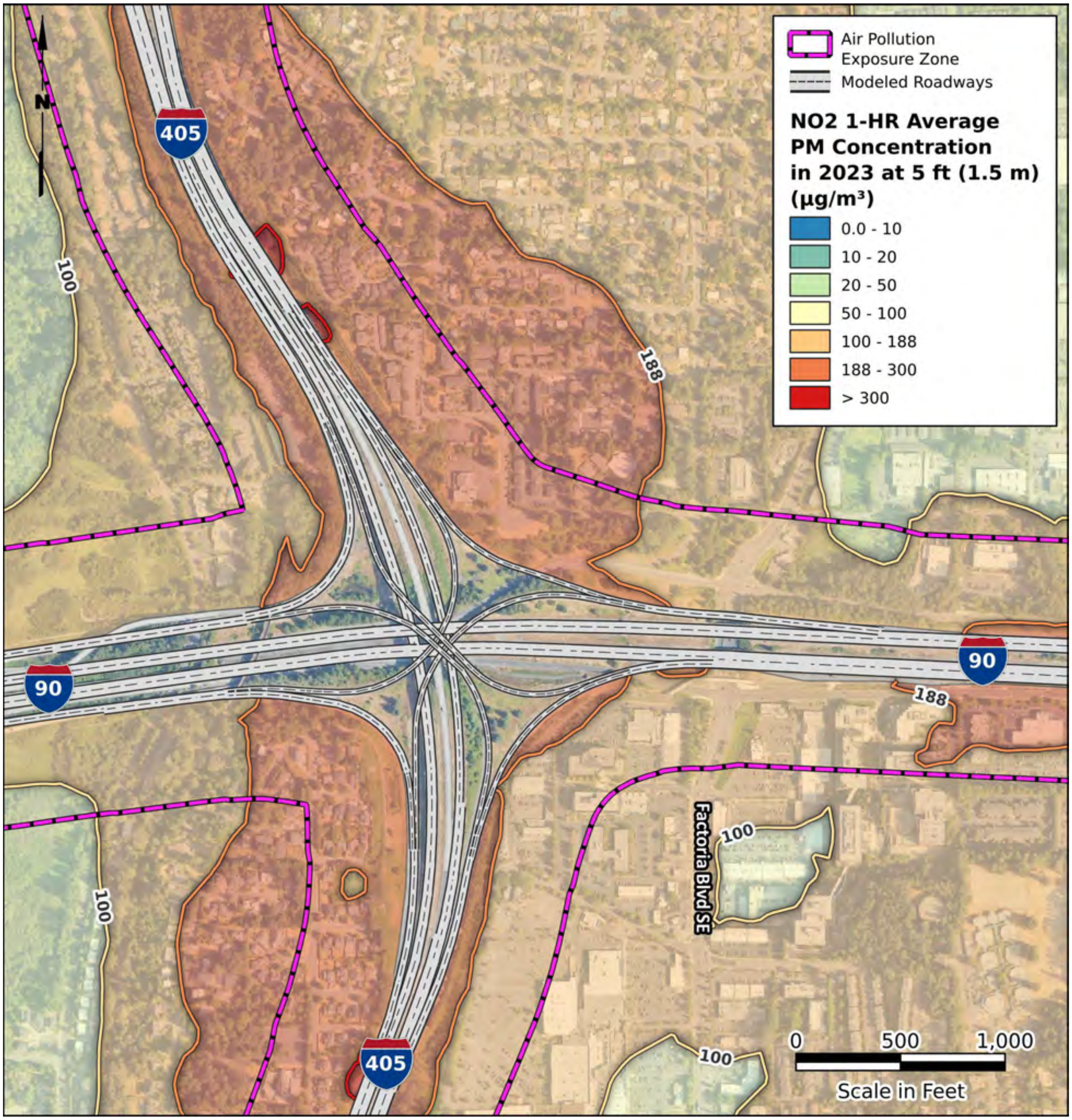


Figure 41: Curtain Plot of 1-Hour Average NO_2 Concentrations in the Factoria Area with On- and Off-Ramp Emissions (2023 Vehicles – PM Scenario)

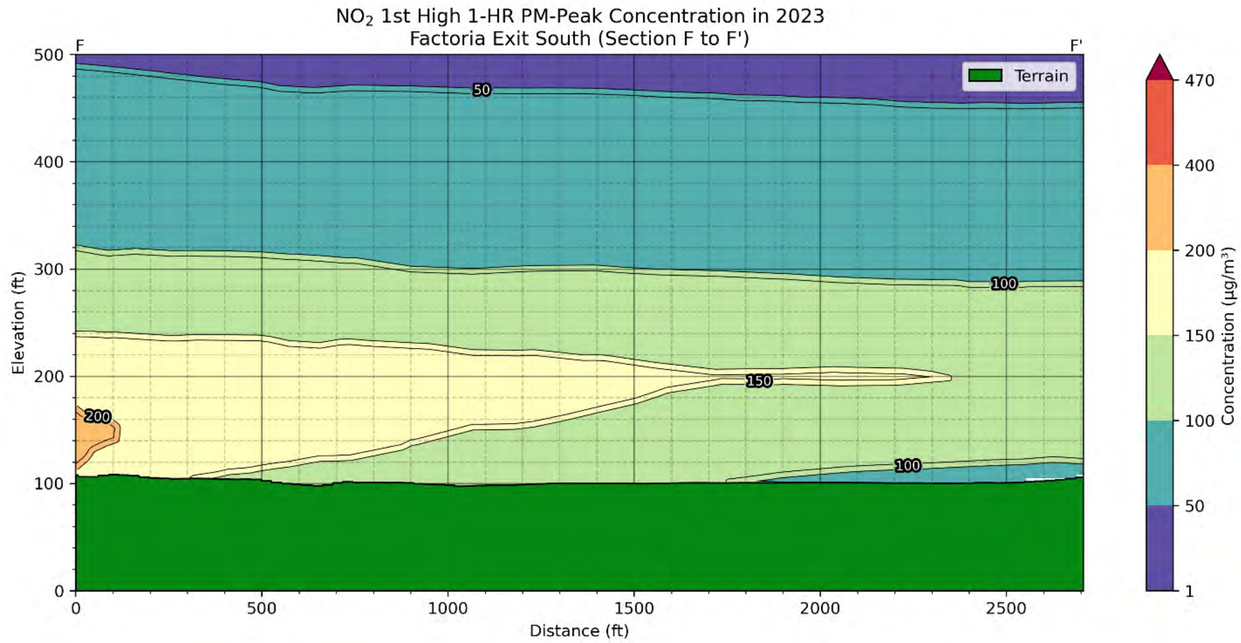


Figure 42: Curtain Plot of 1-Hour Average NO_2 Concentrations in the Factoria Area without On- and Off-Ramp Emissions (2023 Vehicles – PM Scenario)

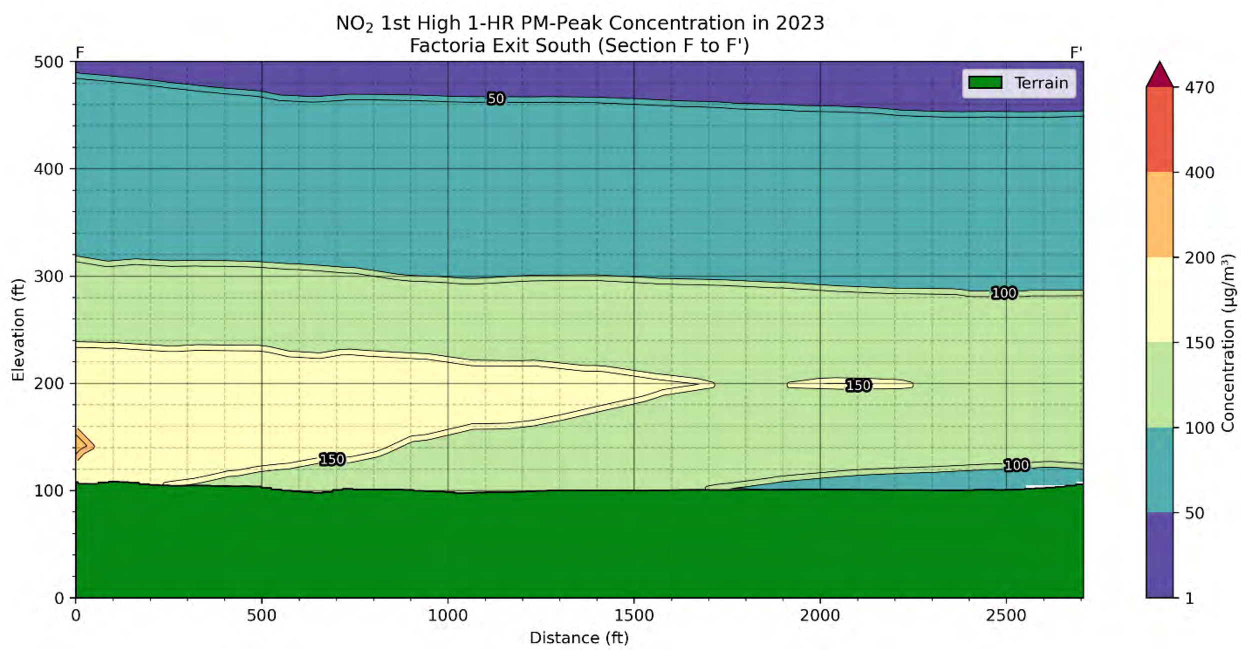


Figure 43: Lifetime Increased Cancer Risk Attributable to DPM in the Factoria Area with On- and Off-Ramp Emissions (2023 Vehicles)

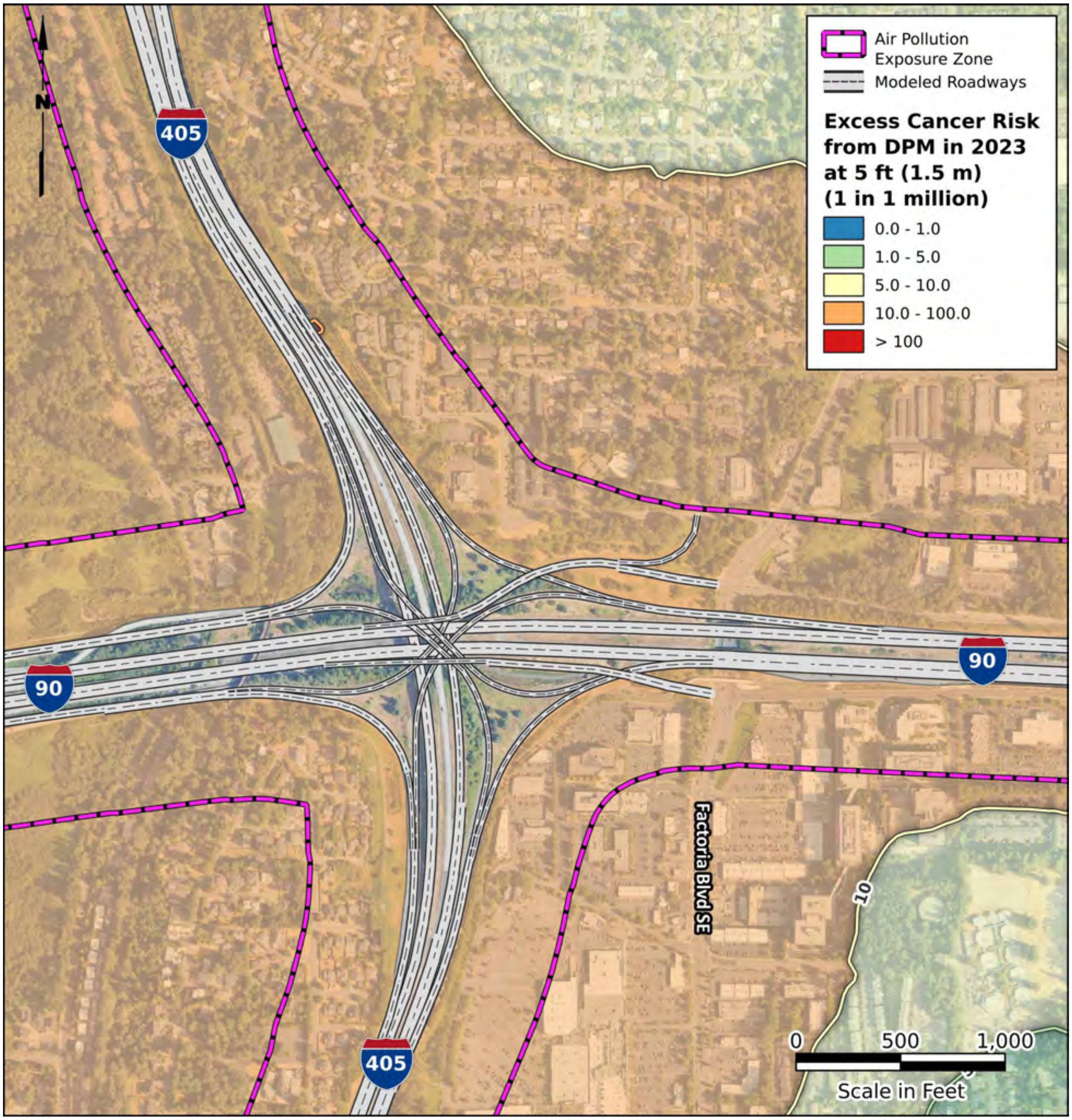


Figure 44: Lifetime Increased Cancer Risk Attributable to DPM in the Factoria Area without On- and Off-Ramp Emissions (2023 Vehicles)

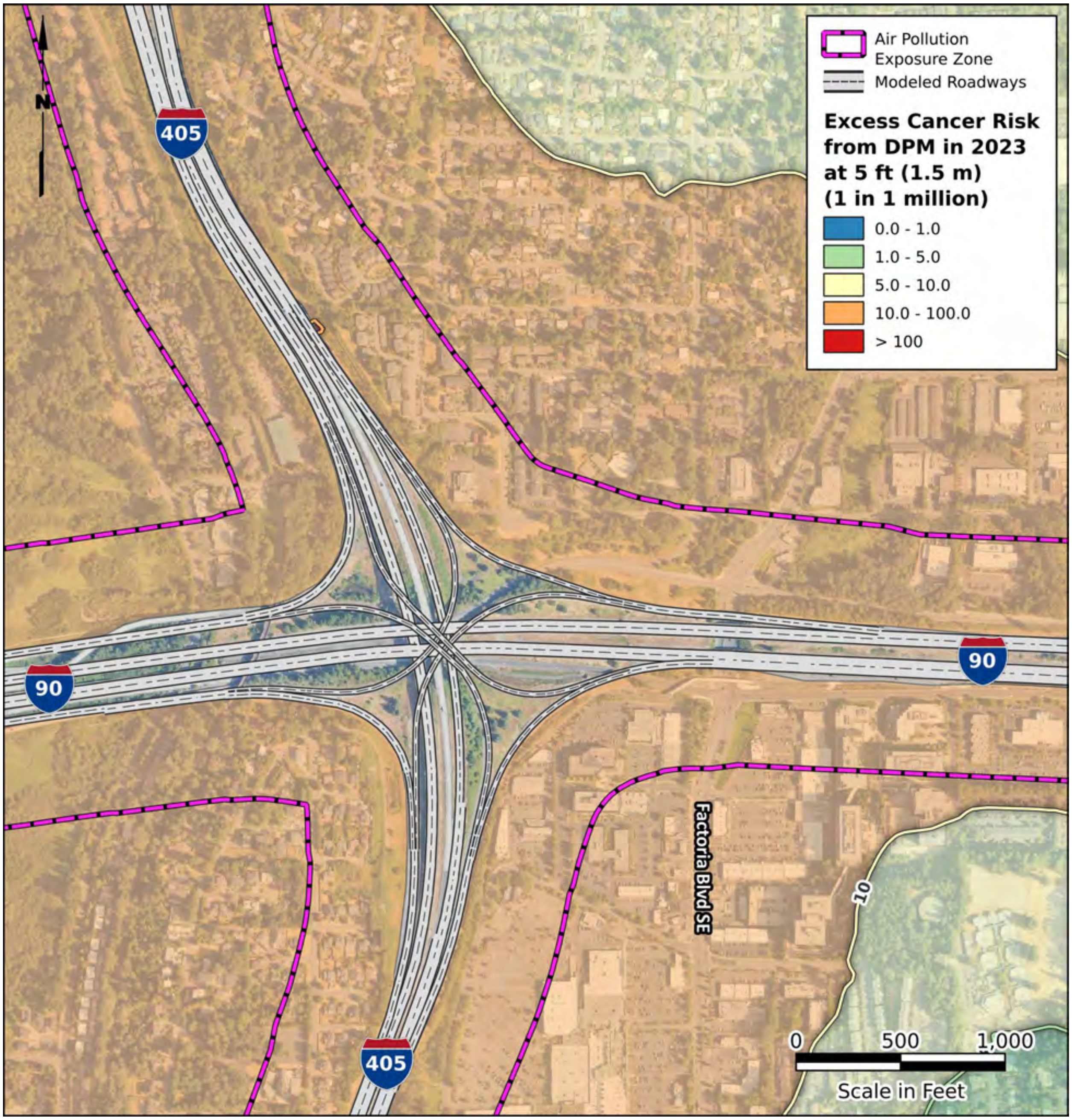


Figure 45: Curtain Plot of Lifetime Increased Cancer Risk Attributable to DPM in the Factoria Area with On- and Off-Ramp Emissions (2023 Vehicles)

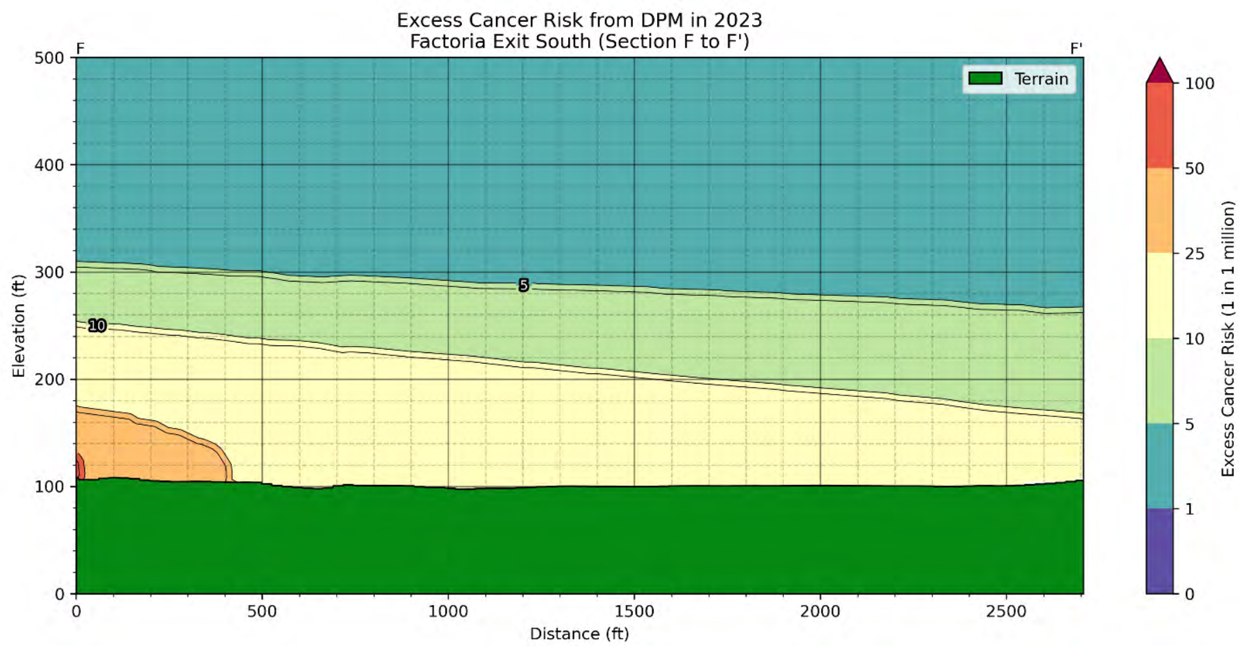
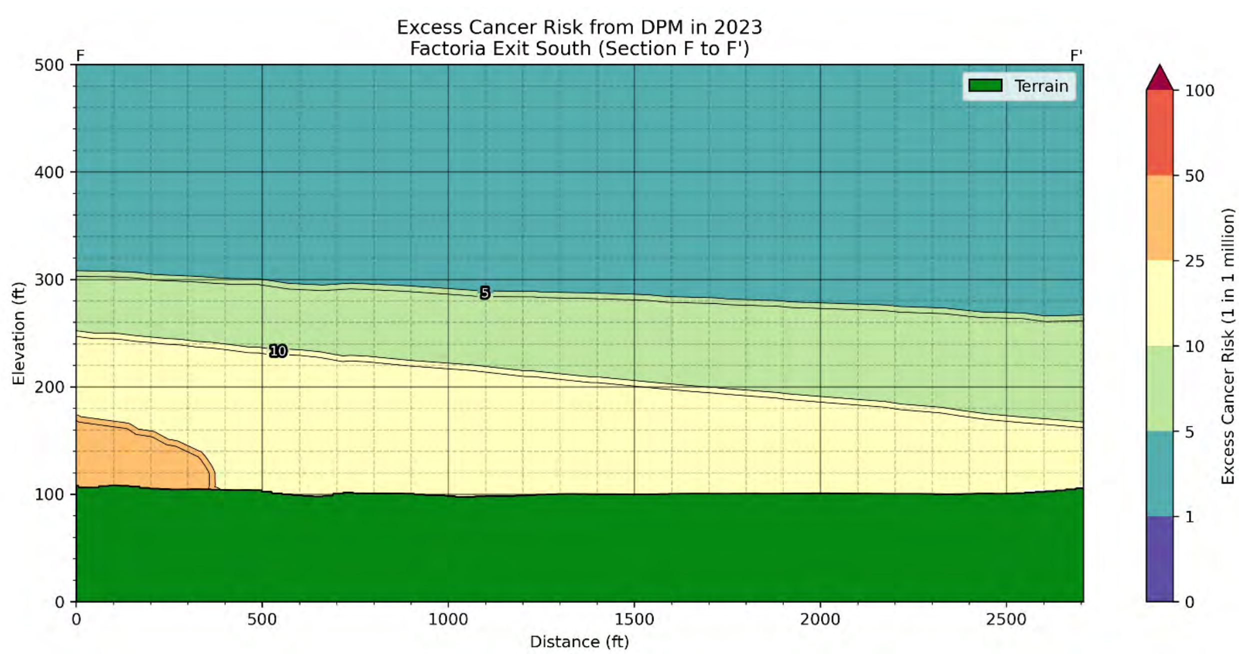


Figure 46: Curtain Plot of Lifetime Increased Cancer Risk Attributable to DPM in the Factoria Area without On- and Off-Ramp Emissions (2023 Vehicles)



Concentrations calculated by the model are greater with the on- and off-ramps included. However, the increase as a result of their inclusion is not significant and decreases with increasing distance from the freeways. Based on these results, the additional effort required to include on- and off-ramps in the modeling may not be warranted, unless the area of particular interest is proximate to a significant number of on- and off-ramps.

5.0 MITIGATION STRATEGIES

The City's April 2023 report includes a review of approaches that have the potential to avoid or minimize exposure to air pollution generated by vehicles operated on the freeways that pass through the city. There are many mitigation strategies potentially under consideration, and dispersion modeling results may have a role in the evaluation of certain alternatives.

Primary mitigation strategies are interventions that seek to prevent pollution from being emitted. These include programs that seek to reduce the number of vehicle trips or improve fuel efficiency. Secondary mitigation strategies are interventions that seek to reduce the effects of emitted pollution. These include roadside barriers such as walls or vegetation, land-use buffers, and improved urban design. The results of the dispersion modeling prepared for the City can potentially assist with the assessment of the effectiveness of suitable mitigation strategies by quantifying concentration reductions as well as identifying locations/areas where concentration reductions may be achieved. Mitigation strategies that are suitable for evaluation using dispersion modeling results fall into two categories: land-use and property development policies, and transportation/vehicle policies.

The potential effectiveness of land-use and property development policies could be developed and/or evaluated by examining the spatial variation of pollutant concentrations and/or increased risk associated with those concentrations to craft policies that would promote or restrict certain development associated with sensitive populations. In addition, pollutant concentration changes attributable to land-use and property development policies that influence the mix of vehicle types, traffic volumes, and vehicle speeds could be quantified. Land-use and property development mitigation strategies identified in the City's April 2023 report that are potentially suitable for evaluation using dispersion modeling results include the following:

- Building design standards/guidelines, e.g., centralized heating, ventilation, and air-conditioning, air intake location, other filtration strategies
- Sensitive use siting, e.g., residential units only above certain floors or beyond a certain distance
- Open space/building placement
- Land-use buffers
- Transit-oriented development.

Transportation/vehicle strategies suitable for evaluation using modeling results are those for which changes attributable to a given strategy affect, for example, pollutant emission rates, traffic volumes, vehicle speeds (i.e., increase or decrease), etc. These changes to emission rates, volumes, speeds, etc. would have to be quantified, the affected vehicle types identified, and, as applicable, the locations where the changes would be realized. Transportation/vehicle mitigation strategies identified in the City's April 2023 report that are potentially suitable for evaluation using dispersion modeling results include the following:

- Diesel vehicle retrofits
- Fleet electrification
- Walking, biking, rideshare, public transit, first-/last-mile programs
- Congestion or time-of-day tolling/pricing.

6.0 UNCERTAINTY AND CONCLUSIONS

6.1 Uncertainty Characterization

This modeling study involves several assumptions, each with an associated uncertainty. In particular, there are uncertainties associated with the information used to locate the roadways and vehicles, the meteorological data, the estimated vehicle emissions, the toxicity of the TAPs considered, and the air dispersion model itself.

6.1.1 Location Information

The LiDAR data provided the elevations of the freeways above the ground, and the geospatial data provided the locations of freeway centerlines and the width of each freeway, which varies with the number of lanes. There are uncertainties associated with the LiDAR data obtained from the USGS and the geospatial data obtained from the Washington State Department of Transportation used to determine the locations of the freeways and, therefore, the vehicle emissions for the model.

LiDAR datasets can be affected by a variety of factors, including the type of surface being scanned, weather conditions, and sensor calibration. These factors can introduce errors or inconsistencies that make the data difficult to work with or interpret. Geospatial data errors can originate from various sources, such as measurement errors, sampling errors, classification errors, digitizing errors, geometric errors, projection errors, and attribution errors. These errors can affect the accuracy, precision, completeness, consistency, and currency of the spatial data.

These data were verified using available aerial photographs to ensure that the modeling would be based on an accurate portrayal of the locations and configurations of the freeways. The location information used in the model is representative of actual current conditions, with a high degree of confidence. No attempt was made to adjust the locations or configurations of the freeways to simulate future conditions.

6.1.2 Meteorological Data

The selection of meteorological data for air dispersion modeling using AERMOD is an important part of the model setup. Ideally, the meteorological data are representative of conditions throughout the model domain, which is a challenge for large domains as well as those that include variable terrain and water bodies. For domains that do not include a meteorological station that can provide representative data, the EPA has provided the Mesoscale Model InterFace (MMIF) program to extract meteorological data at locations modeled by the three-dimensional weather model WRF. Numerous evaluations that compare measured meteorological data with MMIF-extracted data have indicated that, while there are differences between the observations and the extracted data, the differences are not unreasonable. While small differences in meteorological variables, such as temperature, wind speed, or direction, can lead to significant differences in air dispersion modeling results, the use of meteorological data from a single location within the model domain, whether measured or extracted, is an uncertainty inherent in AERMOD's design, and not the result of the decision to use extracted meteorological data.

6.1.3 Vehicle Emissions

An emission rate, which is a quantity of pollutant per unit time (e.g., pounds per hour or grams per second), is calculated from an emission factor, which is a quantity of pollutant per unit of an activity (e.g., pounds per vehicle miles traveled), and an activity rate, which is a measure of an activity per unit of time (e.g., vehicle miles traveled per hour). Emission factors from the EPA's MOVES model represent the EPA's most up-to-date assessment of current and future vehicle emissions. The BKR traffic information provided by the City is based on a state-of-the-science travel demand model and includes local information specific to the BKR region as well as alignment with assumptions and methodology used by the Puget Sound Regional Council. As such, the vehicle emissions included in the model are most likely representative of current conditions and are as accurate a reflection of future conditions as is currently possible.

6.1.4 Toxicity Values

Critical studies that show effects from exposure to chemicals of interest are chosen by agencies such as the EPA, California Office of Environmental Health Hazard Assessment (OEHHA), and Agency for Toxic Substances and Disease Registry (ATSDR) to derive toxicity or risk values. Agencies do not always choose the same studies, which may result in variation between the animal species or chemical formulation tested, the exposure duration, and the exposure concentrations, which can result in different toxicity values for the same chemical. Even if agencies choose the same critical study, methodological differences between agencies can result in different toxicity values. Once a benchmark concentration is chosen, the agency then extrapolates to a value relevant to humans for a particular exposure duration. This requires the use of uncertainty factors that attempt to account for, among other things, the use of experimental animal data for human effects, variable susceptibility in the human population (e.g., genetic, nutritional, age), extrapolation of a selected benchmark dosage, prediction of chronic exposure effects using sub-chronic exposure studies, the use of an inadequate dataset, and for unaddressed uncertainties. The magnitude of the uncertainty factors is often based on professional judgment, which may differ between agencies.

6.1.5 Air Dispersion Modeling

Any attempt to mathematically model a physical process will involve uncertainties. In this case, potential exposures were based on short-term and annual average concentrations calculated using AERMOD, a regulatory model designed and demonstrated to over-predict ambient concentrations. In addition, the concentrations used to calculate exposure are outdoor concentrations, which do not account for effects that tend to diminish concentrations as air migrates indoors (e.g., absorption by building materials, deterioration, chemical reactions, or filtration by ventilation systems). Uncertainty associated with the design of the dispersion model is most likely characterized as the degree to which the predicted concentrations overestimate the actual concentrations.

As discussed above, the meteorological data provided to the model can be a source of uncertainty, related to the quality of the data, and whether the selected data are representative of conditions in the area of interest. In this case, there are no meteorological stations located in the model domain, so data extracted from a modeled three-dimensional dataset were used. Based on qualitative comparisons with data extracted at locations near meteorological stations, the meteorological data used in the model are not considered a significant source of uncertainty.

While there are uncertainties associated with estimating ambient concentrations using an air dispersion model, Landau believes that reasonable care has been taken to consistently not underestimate potential exposures.

6.2 Conclusions and Recommendations

Concentrations of air pollutants emitted by vehicles that commonly operate on freeways were estimated using AERMOD, an air dispersion model, which was executed using input data that are representative of current conditions in the city of Bellevue, as well as for expected future conditions. Air pollutant concentrations were calculated by the model throughout the city at ground level, as well as at elevations above ground.

7.0 USE OF THIS REPORT

This report has been prepared for the exclusive use of the City of Bellevue for specific application to the Bellevue-area freeway air dispersion modeling project. No other party is entitled to rely on the information, conclusions, and recommendations included in this document without the express written consent of Landau. Further, the reuse of information, conclusions, and recommendations provided herein for extensions of the project or for any other project, without review and authorization by Landau, shall be at the user's sole risk. Landau warrants that within the limitations of scope, schedule, and budget, our services have been provided in a manner consistent with that level of care and skill ordinarily exercised by members of the profession currently practicing in the same locality under similar conditions as this project. Landau makes no other warranty, either express or implied.

8.0 REFERENCES

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APPENDIX A

AERMOD Model Description

Appendix A
AERMOD Model Description

The Clean Air Act (CAA), which was initially enacted in 1963 and has been amended several times, requires the US Environmental Protection Agency (EPA) to establish ambient concentration standards for six air pollutants: carbon monoxide (CO), lead (Pb), oxides of nitrogen (NO_X), ozone (O_3), particulate matter (PM), and sulfur dioxide (SO_2); these pollutants are typically referred to as “criteria pollutants.” In the late 1960s, the EPA began to develop air dispersion models for use by urban and transportation planners as well as by government agencies tasked with the management and protection of air quality. Air quality agencies needed a tool to assess whether new or existing sources of air pollution would cause or contribute toward exceedances of ambient air quality standards.

By the mid- to late 1980s, it became clear that the dispersion models developed for regulatory use by the air quality agencies produced results that did not agree with observations. In response, the EPA and the American Meteorological Society (AMS) formed a working group of scientists in the early 1990s, called the AMS/EPA Regulatory Model Improvements Committee (AERMIC), to develop a state-of-the-art air dispersion model for regulatory applications. The model, called the “AERMIC Model,” universally shortened to “AERMOD,” was fully adopted by the EPA in December 2006 as the preferred dispersion model for near-field applications (i.e., within 50 kilometers [approximately 31 miles] of the source). Since that adoption, the model has been revised and updated several times to incorporate new and/or improved algorithms or to fix identified software errors (i.e., “bugs”).

For most regulatory applications, AERMOD is employed to estimate concentrations of air pollutants in the planetary boundary layer (PBL), which is the layer of the atmosphere just above the earth’s surface where conditions are dependent on the degree to which the sun is heating the earth’s surface and the amount of friction caused by the wind moving over the earth’s surface. The thickness of the PBL typically ranges from a few hundred meters (approximately 1,000 feet) at night when conditions are stable, to between 1 and 2 kilometers (approximately 0.5 to 1 mile) during the day when there is vertical mixing.

The AERMOD modeling system is designed to calculate air pollutant concentrations for rural and urban areas, flat and complex terrain, surface and elevated emission releases, and multiple types of emission sources, including, point, area, and volume sources. The modeling system consists of the dispersion model (i.e., AERMOD) and two pre-processors. The meteorological pre-processor (AERMET) provides AERMOD with information necessary to characterize meteorological conditions in the PBL. The terrain pre-processor (AERMAP) characterizes the terrain in the modeling domain and can be used to generate receptor grids.

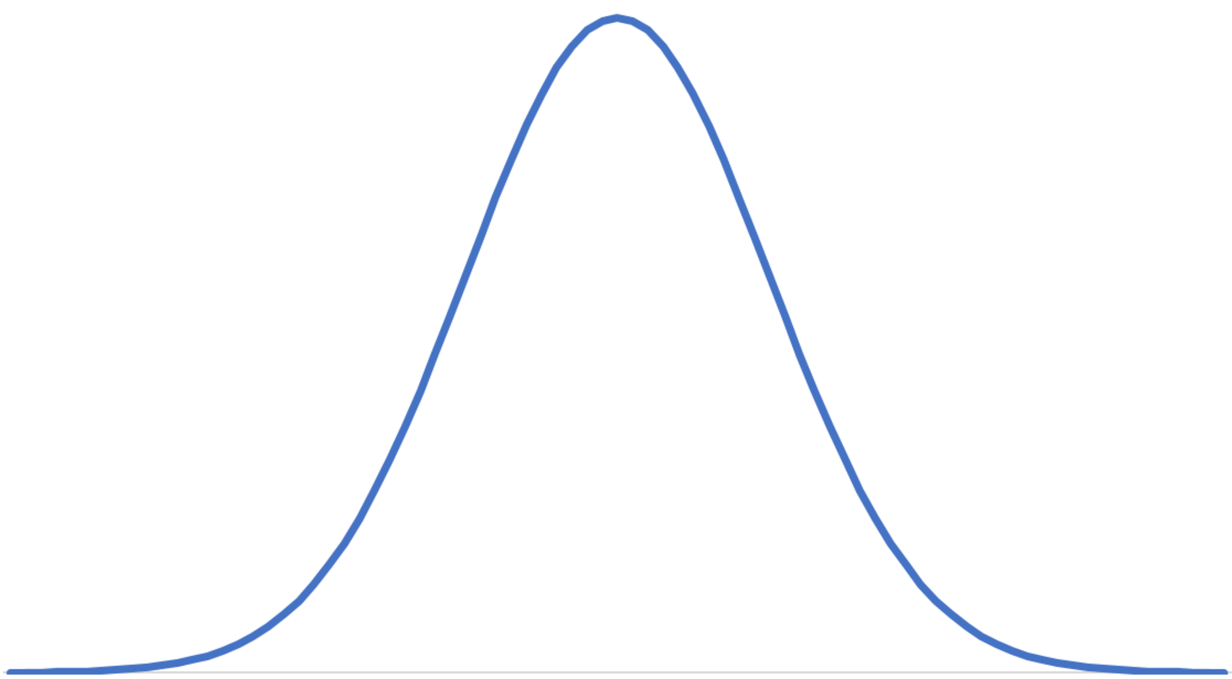
Inputs to AERMET include hourly-average meteorological data (e.g., wind speed, wind direction, temperature, etc.) collected near the earth’s surface, which are referred to as “surface data,” and vertical measurements of pressure, temperature, and relative humidity collected twice daily using weather balloons, which are referred to as “upper air data,” and are used to identify the height of the PBL. AERMET is also supplied with data about the terrain around the location where the surface data were collected. These data include information about the reflectivity of the earth, the roughness of the earth, and how heat is transferred between the surface and the air. AERMET processes these data and calculates parameters that AERMOD uses to calculate the movements of air pollutant emissions. The hourly-average parameters calculated by AERMET for each hour of the model simulation are assumed to be representative of the meteorology throughout the modeling domain for that hour and are applied by AERMOD at all receptor locations within the modeling domain during that hour of the simulation.

AERMAP uses gridded terrain data (i.e., elevation of the earth's surface above sea level) gathered by the US Geological Survey to calculate the elevations above sea level of receptor locations throughout the modeling domain as well as information about the potential for elevated terrain to influence an exhaust plume at each receptor location, which is referred to as the "hill height scale."

AERMOD is a steady-state plume model, meaning it uses hourly-average meteorological information that is assumed to apply throughout the modeling domain during each hour of the model simulation to calculate how plumes of emitted air pollutants are influenced during that entire hour. The model calculates concentrations based on a vertical profile of the structure of the PBL and algorithms developed over several decades that characterize how plumes are dispersed in the atmosphere under various conditions.

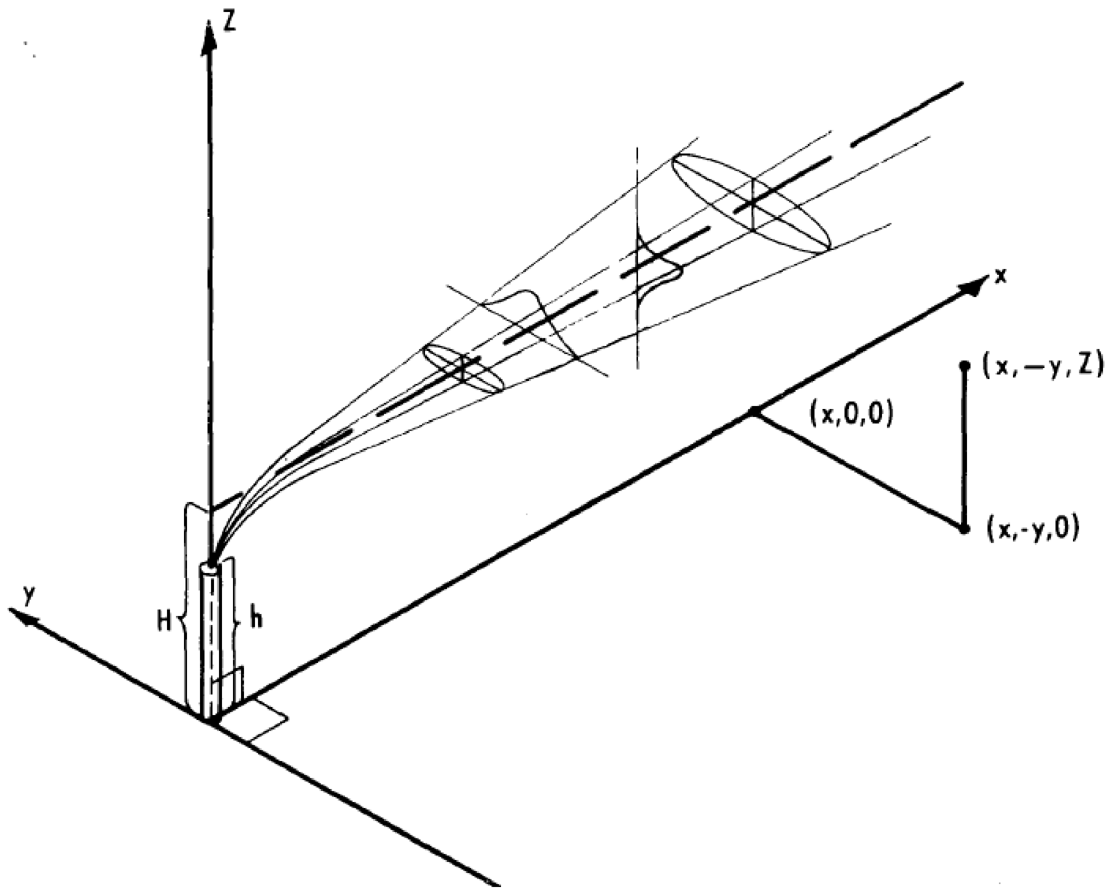
When the boundary layer is said to be "stable," it means that air at the earth's surface is cooler than the air above it, which means it tends to stay where it is and not rise. This is typical of conditions at night and/or in the winter, when there is no, or little, sunlight on the ground to warm the air close the ground. For a stable boundary layer (SBL), the model assumes that the concentration distribution within the exhaust plume is Gaussian (i.e., a "normal" distribution, see the figure below for a general example) in both the vertical and horizontal directions.

Figure A-1: An example of a "normal" or "Gaussian" distribution



The figure below shows an exhaust stack of height, h, with an exhaust plume that rises to a height, H above ground. The final height of the plume is determined by the temperature difference between the gases in the plume and the surrounding air. The greater the temperature difference, the greater the buoyancy of the plume, and the greater the plume rise. Plume rise is also influenced by the vertical velocity at which the exhaust plume exits the stack, but the buoyancy effect is more significant. As the plume spreads out (i.e., disperses) in the horizontal (i.e., y axis) and vertical (i.e., z axis) directions, the concentration of pollutants within the plume is assumed to follow a Gaussian distribution, where the concentration is greatest at the center, and diminishes with distance from the center, at some point becoming zero.

Figure A-2: Coordinate system showing Gaussian distributions in the horizontal and vertical [1]

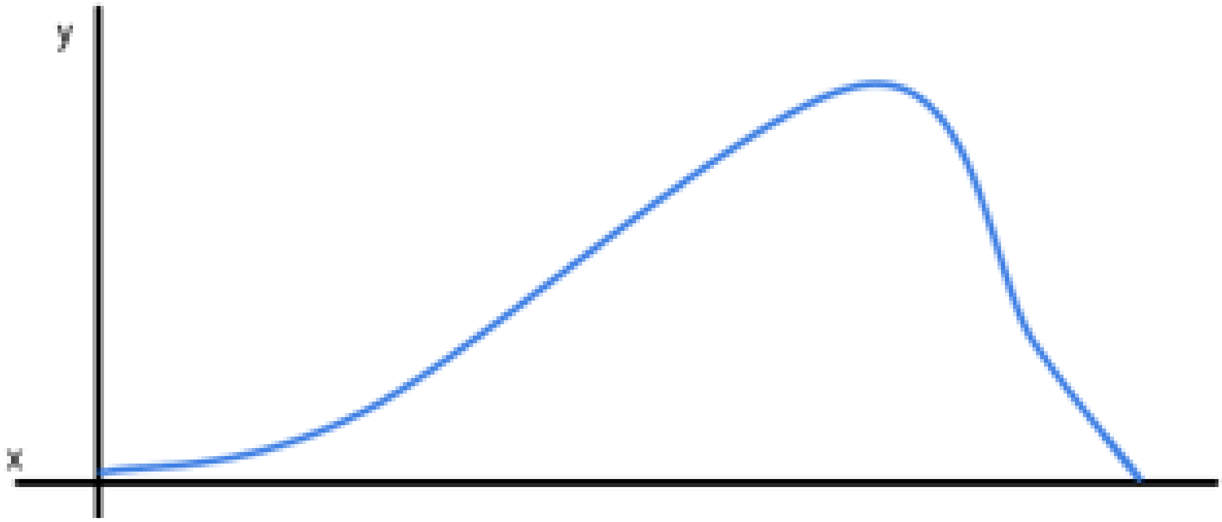


The boundary layer is described as "convective," or "unstable," when the sun is heating the earth's surface, which causes air near the surface to rise, cool as it rises, and then fall again, where it is reheated by the surface and rises again. These conditions typically occur during the day when cloud cover does not prevent sunlight from warming the surface of the Earth. For a convective boundary layer (CBL), the horizontal distribution of pollutant concentrations within the plume is also assumed to be Gaussian, but the vertical distribution is described with a "bi-Gaussian probability density function" (PDF). A PDF is

[1] Turner, D. Bruce. 1970. "Workbook of Atmospheric Dispersion Estimates." Air Resources Field Research Office, Environmental Science Services Administration, US Environmental Protection Agency.

Gaussian distribution that can be "skewed" (see general example below) to reflect the influence of observed phenomena such as updrafts or downdrafts on a vertical concentration distribution.

Figure A-3: An example of a "skewed" distribution



Additionally, in a CBL, AERMOD treats "plume lofting," whereby a portion of plume mass, released from a buoyant source, rises to and remains near the top of the boundary layer before becoming mixed into the CBL. AERMOD also tracks any plume mass that penetrates the elevated stable layer, and then allows it to re-enter the boundary layer when and if appropriate. For sources in both a CBL and an SBL, AERMOD treats the enhancement of lateral dispersion resulting from plume meander. In complex terrain, plumes are modeled as either impacting and/or following the terrain.

AERMOD constructs vertical profiles of required meteorological variables based on measurements and extrapolations of those measurements. Vertical profiles of wind speed, wind direction, turbulence, temperature, and temperature gradient are estimated using all available meteorological observations. AERMOD is designed to run with a minimum of observed meteorological parameters using data of a type that is readily available from National Weather Service stations. AERMOD requires only a single surface measurement of wind speed, wind direction, ambient temperature, and observed cloud cover. However, if cloud cover is not available (e.g., from an onsite monitoring program) two vertical measurements of temperature (typically at 2 and 10 meters), and a measurement of solar radiation can be substituted. A full morning upper air sounding[2] is also required to calculate the convective mixing height throughout the day. Surface characteristics[3] are also needed to construct profiles of the relevant PBL parameters.

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[2] Upper air observations, or "soundings," are accomplished using a small, expendable telemetry instrument and a weather balloon. The weather balloon is released, and the telemetry unit transmits data (i.e., temperature, pressure, relative humidity, location) as it rises through the atmosphere. The data obtained are used to create a profile of the structure of the upper atmosphere (i.e., above approximately 7 km or 23,000 feet above sea level) at that time.

[3] The necessary surface characteristics are: albedo, Bowen ratio, and surface roughness length. Surface roughness length is a measure of the height of obstacles on the ground to the wind, and is the height above ground at which the mean horizontal wind speed is zero. The Bowen ratio, an indicator of surface moisture, is the ratio of sensible heat flux to latent heat flux at the surface. Albedo is the fraction of total incident solar radiation reflected by the surface back to space without absorption.

APPENDIX B

Documentation of Model Inputs, Setup, and Execution

Appendix B
Documentation of Model Inputs, Setup, and Execution

Introduction

The American Meteorological Society (AMS)/US Environmental Protection Agency (EPA) regulatory model (AERMOD) modeling system was used to calculate air pollutant concentrations attributable to vehicles operated on the freeways that pass through Bellevue, Washington. This appendix provides additional technical details of the model inputs and the modeling methodology.

Terrain Data and Receptor Locations

The elevations above sea level of receptor locations as well as of the terrain beneath all receptors and emission sources (i.e., the freeways upon which the vehicles that emit the air pollutants travel) were obtained using the AERMOD terrain pre-processor AERMAP (version 18081) and digital topographical data from the National Elevation Dataset (NED), which was obtained from the National Map Access API website (https://apps.nationalmap.gov/tnmaccess/).

The horizontal and vertical positioning and spacing of the receptors used in the modeling are summarized in Tables B-1 and B-2, respectively, and shown graphically on Figures B-1 and B-2, respectively.

Table B-1: Horizontal Receptor Spacing

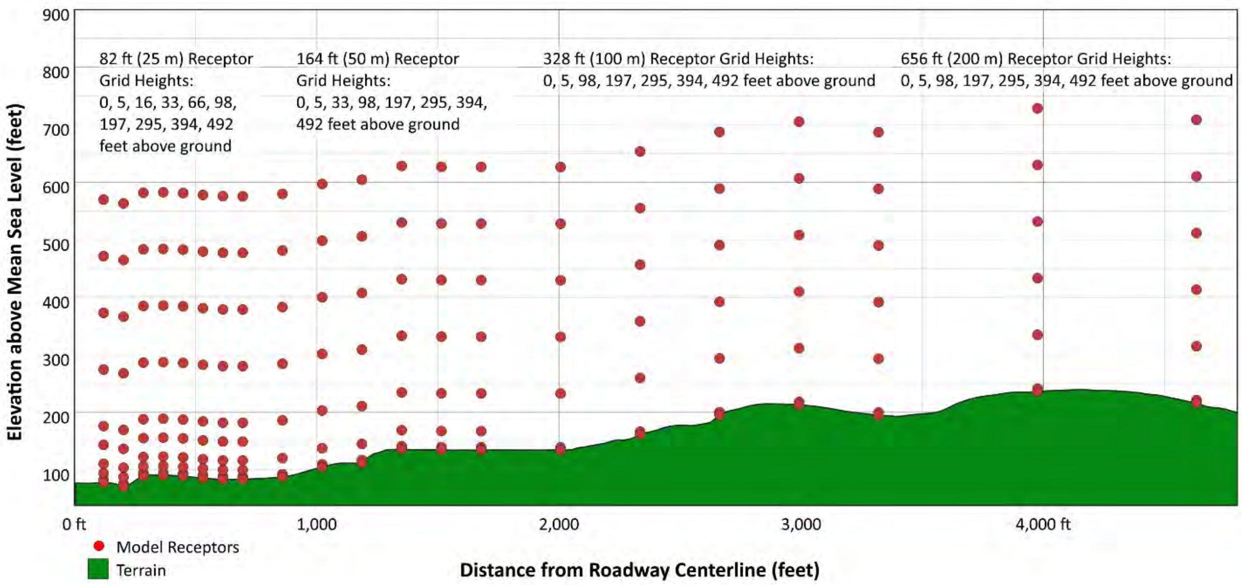
Distance from Freeway Centerline		Receptor Spacing	
(meters)	(feet)	(meters)	(feet)
Up to 200	Up to 656	25	82
200 to 500	656 to 1,640	50	164
500 to 1,000	1,640 to 3,280	100	328
1,000 to domain extents	3,280 to domain extents	200	656

Table B-2: Vertical Receptor Spacing

Distance from Freeway Centerline (meters)	Distance from Freeway Centerline (feet)	Distances Above Ground	
25	82	(meters)	0, 1.5, 5, 10, 20, 30, 60, 90, 120, 150
		(feet)	0, 5, 16, 33, 66, 98, 197, 295, 394, 492
50	164	(meters)	0, 1.5, 10, 30, 60, 90, 120, 150
		(feet)	0, 5, 33, 98, 197, 295, 394, 492
100	328	(meters)	0, 1.5, 30, 60, 90, 120, 150
		(feet)	0, 5, 98, 197, 295, 394, 492
200	656	(meters)	0, 1.5, 30, 60, 90, 120, 150
		(feet)	0, 5, 98, 197, 295, 394, 492

Figure B-1: Horizontal Receptor Placement

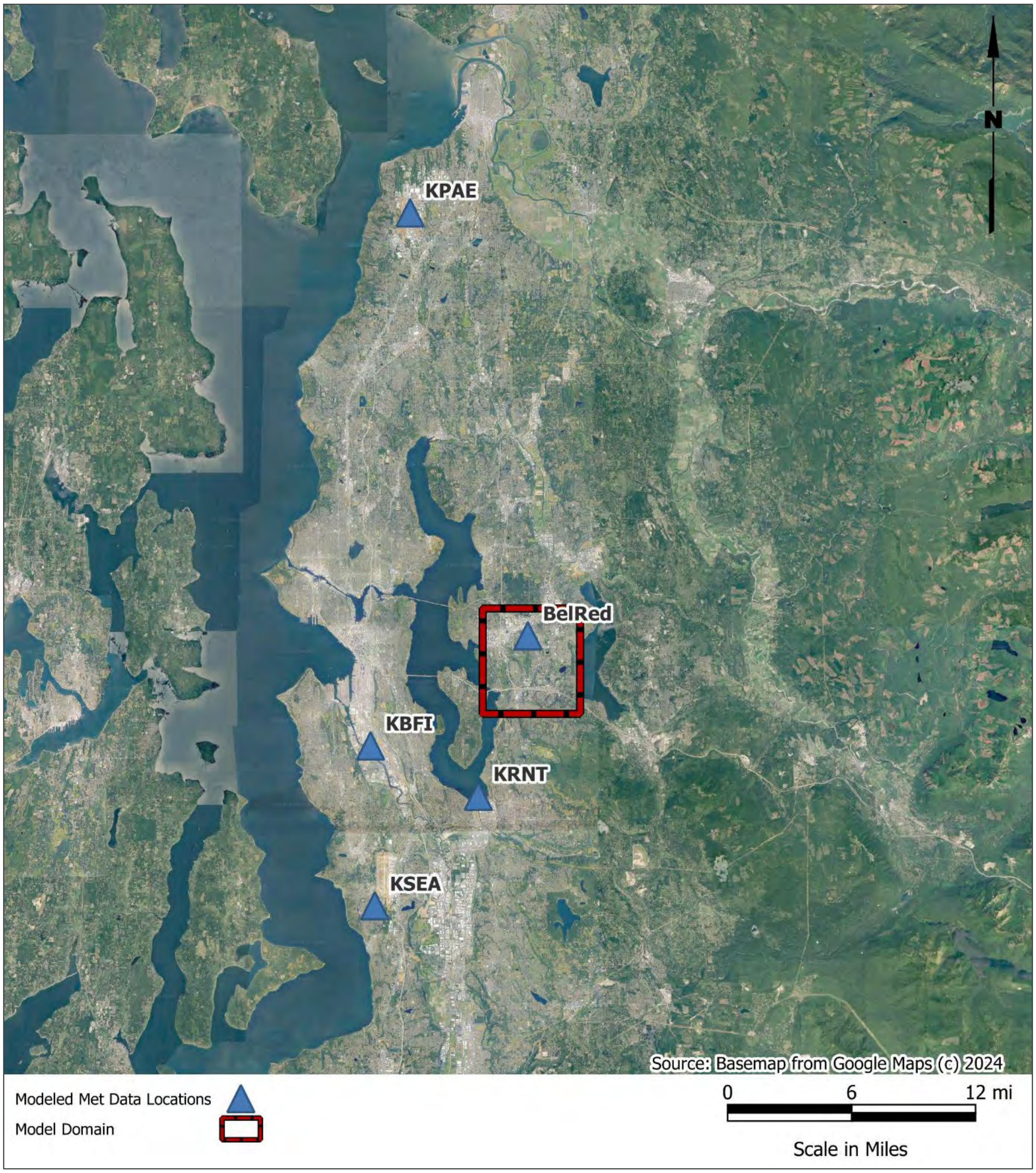
Figure B-2: Vertical Receptor Placement



Meteorological Data

Hourly meteorological data are one of the necessary inputs AERMOD requires to calculate pollutant concentrations. While there are meteorological stations in King and Snohomish Counties (e.g., Sea-Tac International Airport, Boeing Field, Paine Field, Renton Airport, etc.), none of them are located within or near the modeling domain. Because significant terrain and water bodies are located between the modeling domain and these meteorological stations, an alternative approach was used to obtain meteorological data representative of conditions within the modeling domain. The locations of the meteorological stations and the BelRed location are identified on Figure B-3.

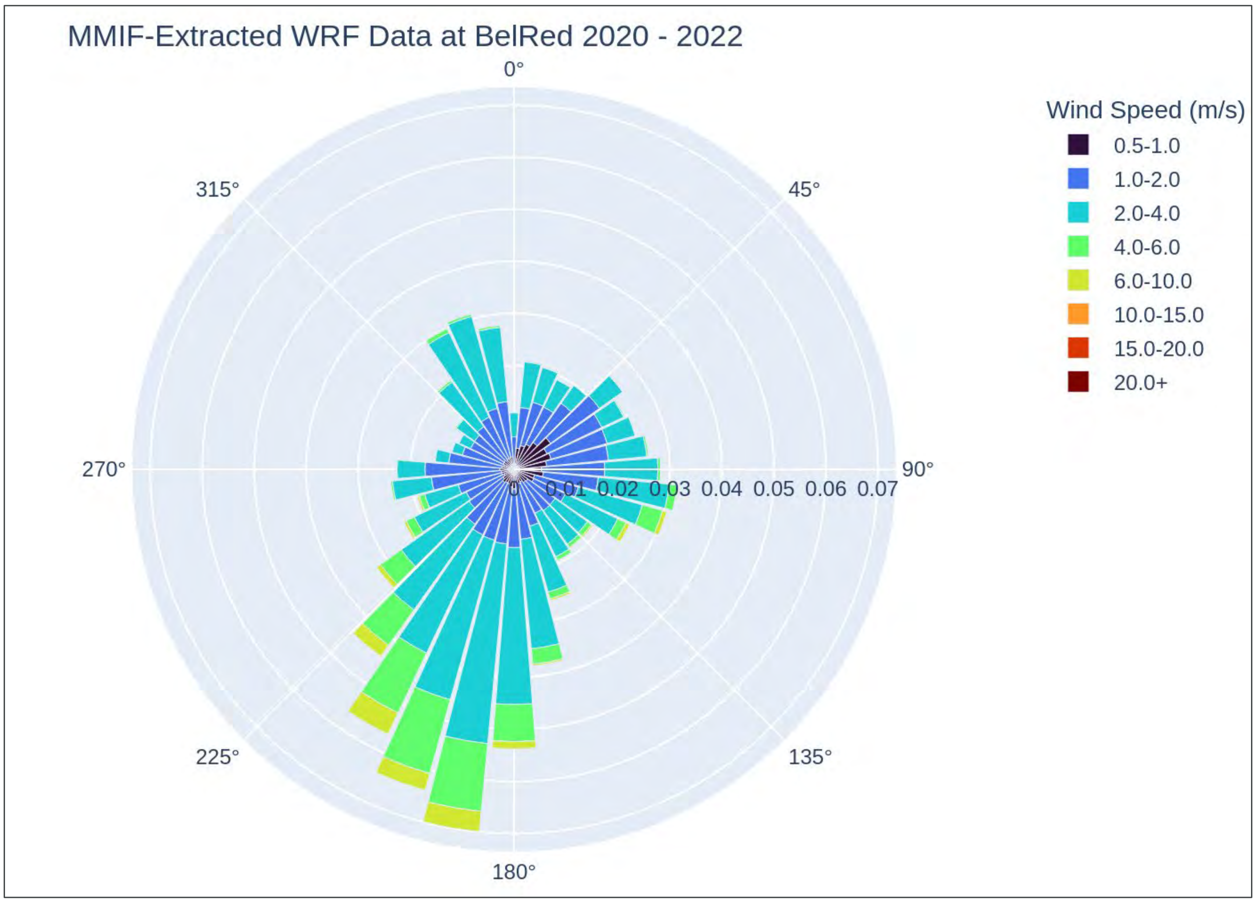
Figure B-3: King and Snohomish County Airport Meteorology Stations



In cases where representative meteorological data are not available for use with AERMOD, such data can be generated using meteorological data from a three-dimensional mesoscale computer model. The current state-of-the-science model used to generate these data is the Weather Research and Forecasting (WRF) model, version 4.1.3. The Northwest Regional Modeling Consortium (NRMC) provided Landau Associates, Inc. (Landau) with three-dimensional meteorological data produced by the University of Washington using WRF. These data are based on a horizontal grid with 4-kilometer (km) spacing and a modeling domain that covers Washington, Oregon, and Idaho, as well as parts of neighboring states and provinces. NRMC provided 3 years of data (i.e., 2020, 2021, and 2022).

The WRF data and the US Environmental Protection Agency's (EPA's) Mesoscale Model InterFace program (MMIF), version 4.1, were used to generate an AERMOD-ready meteorological dataset at a selected coordinate within the AERMOD modeling domain. MMIF was employed in accordance with the EPA's Guidance on the Use of MMIF for AERMOD applications. The two files produced by MMIF are the "surface file," which provides hourly-boundary-layer parameters, and the "profile file," which provides multi-level observations of wind speed, wind direction, temperature, and standard deviation of fluctuating wind components. A summary of the 3 years of meteorological data calculated and processed by MMIF is shown on Figure B-4 below in a windrose format. As shown on the figure, the winds are predominantly from the south-southwest.

Figure B-4: Windrose for MMIF-Extracted WRF Data Based in Bellevue, Washington



When using MMIF to process prognostic meteorological data to comply with regulatory requirements (e.g., an air permit application), the prognostic data should be compared to National Weather Service (NWS) observational data to assess whether the data are a reasonable replication of observed meteorological conditions during the time periods modeled. Because the modeling for this study was not prepared in support of compliance with a regulatory requirement, a qualitative model performance evaluation of the MMIF-processed WRF data was conducted to compare observations and prognostic data. Phil Swartzendruber of Puget Sound Clean Air Agency and Chair of the NRMC recommended that MMIF-processed WRF data be used for the study modeling and facilitated Landau's receipt of the WRF data from NRMC.[1]

To qualitatively evaluate the performance of the MMIF-processed WRF data, Landau compared the outputs of the MMIF-processed WRF data at a simulated meteorological tower collocated at each of the four area airport meteorological towers (i.e., Seattle-Tacoma International Airport [KSEA], Seattle Paine Field International Airport [KPAE], Boeing Field International Airport [KBFI], and Renton Municipal Airport [KRNT]). By collocating the simulated tower at the same latitude and longitude as the NWS meteorological tower, the measured data can be compared directly with the prognostic data.

AERMET (Version 23132), the AERMOD modeling system's meteorological data pre-processor, was used to process four types of meteorological input data in two stages to generate two input files. The four types of meteorological input data processed by AERMET for each airport location are:

- Hourly surface-layer observations collected at each meteorological station over the 3-year period (i.e., January 1, 2020 through December 31, 2022).
- One-minute wind speed and wind direction data to reduce the number of low-wind speed (i.e., "calms") and highly variable (i.e., "missing") wind conditions.
- Twice-daily upper air soundings collected at the meteorological station in Quillayute, Washington, which is operated by the NWS. Data collected over the same 3-year period of upper air data was processed in AERMET.
- Surface characteristic parameters (i.e., albedo, Bowen ratio, and surface roughness) for the areas surrounding each meteorological station were calculated using the AERSURFACE program (version 20060) and land-use data. These parameters were calculated within 12 equal sectors of a circle centered on the surface station tower. A default study radius of 1 km was used for surface roughness and a 10-km radius for the Bowen ratio and albedo. US Geological Survey National Land Cover Data 2016 archives (MRLC; accessed September 20, 2022) were used as the land-use data source. The following four default seasonal categories were used: 1) mid-summer with lush vegetation; 2) autumn with unharvested cropland; 3) winter without continuous snow; and 4) transitional spring with partial green coverage or short annuals. The AERSURFACE designation for an airport location, with the assumed surface roughness calculated based on 95 percent transportation land use and 5 percent commercial and industrial land use, was used for each airport. Average surface moisture was used for the 3-year period.

Windrose diagrams were created for each airport location using the AERMET-generated and MMIF-processed WRF data. Windroses graphically present the wind direction and windspeed using surface file inputs. Figures B-5, B-6, B-7, and B-8 show the NWS surface data (observed) in comparison with the MMIF-processed WRF data (modeled) for KSEA, KPAE, KBFI, and KRNT, respectively. The windroses for KSEA, KPAE, and KRNT show similar wind direction patterns. The wind direction at KBFI is less consistent between the two data sets.

[1] A January 18, 2024 letter from the NMRC outlines the terms under which Landau and the City of Bellevue could use the WRF data.

Figure B-5: KSEA Windrose Comparison – Observation Data (left) and MMIF-extracted WRF Data (right)

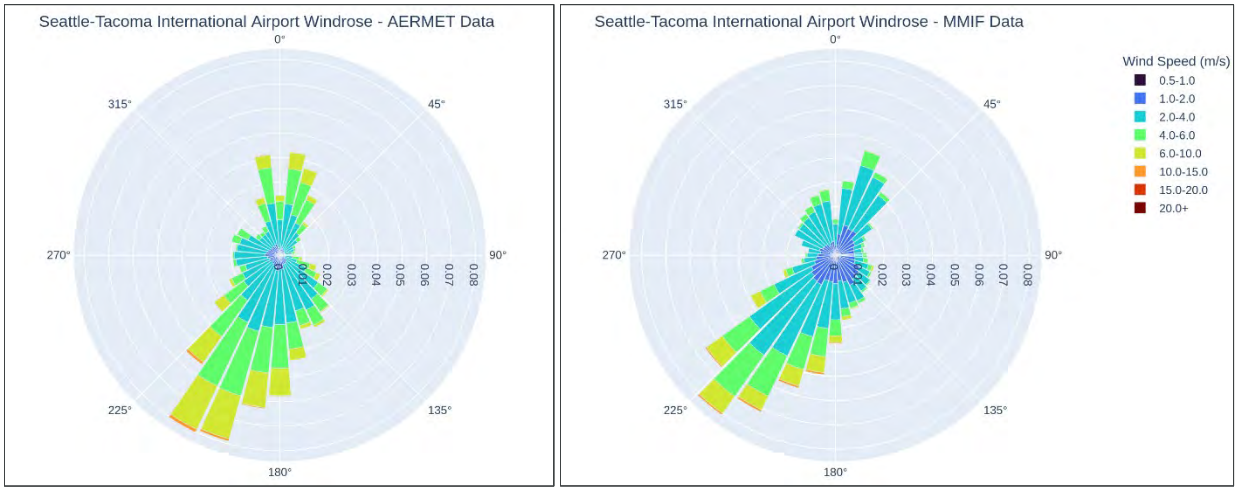


Figure B-6: KPAE Windrose Comparison – Observation Data (left) and MMIF-extracted WRF Data (right)

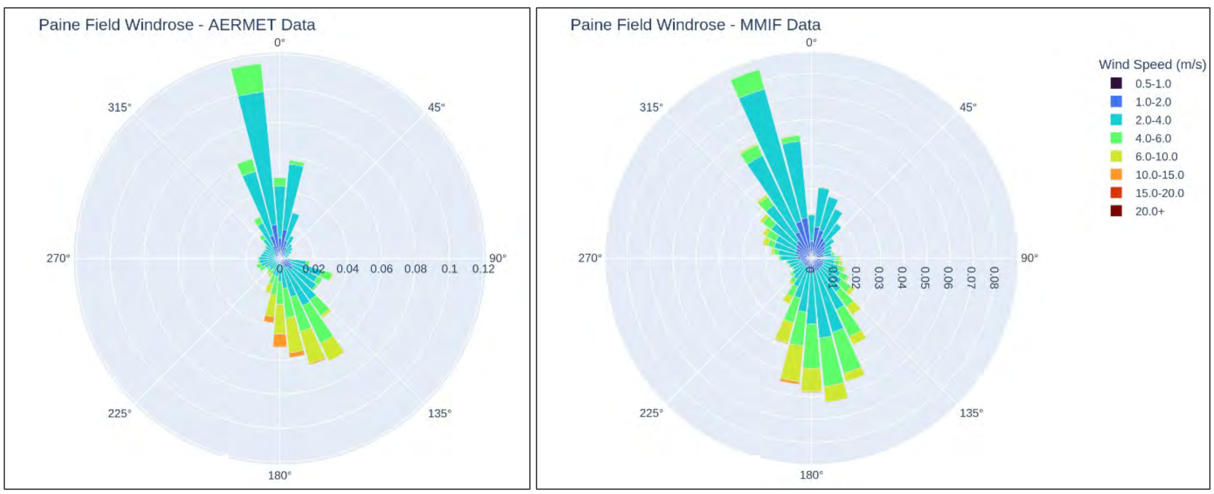


Figure B-7: KBFI Windrose Comparison – Observation Data (left) and MMIF-extracted WRF Data (right)

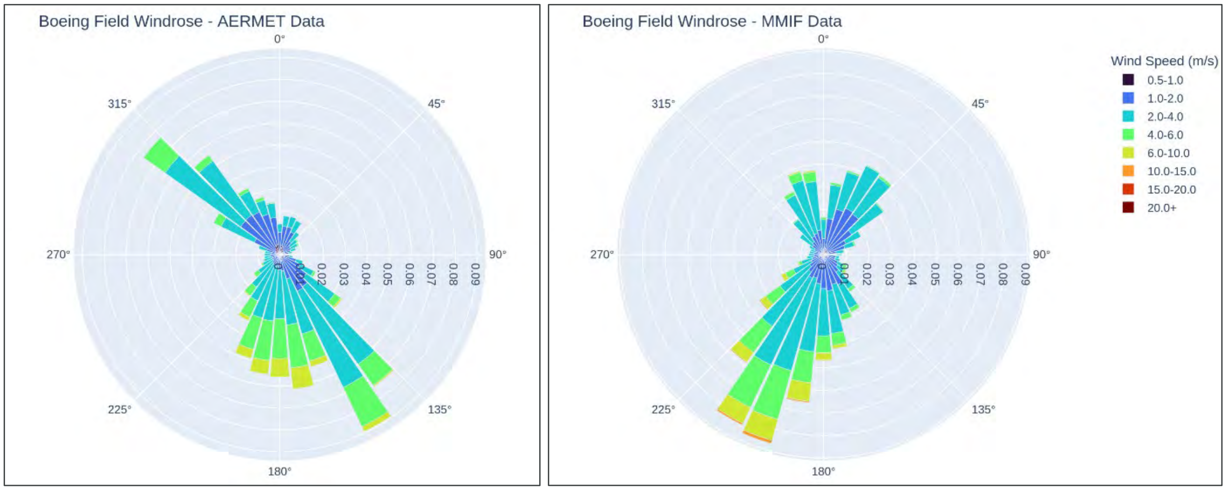
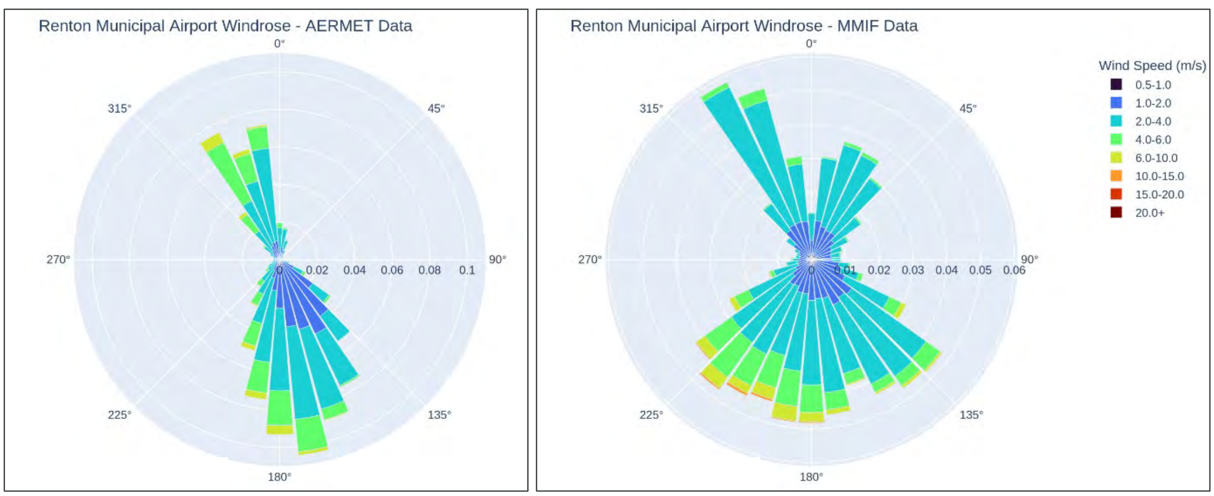


Figure B-8: KRNT Windrose Comparison – Observation Data (left) and MMIF-extracted WRF Data (right)



Low-wind speed values, or calms, in NWS observations are a function of the instrumentation that measures the wind speed. The number of calms and missing values from the KBFI and KRNT NWS observational data is greater than 10 percent for at least one quarter out of the 5-year data set. In a regulatory application, these data would likely be considered insufficient for permitting projects. MMIF-extracted WRF data do not have the same data collection limitations; therefore, there are no hours with missing or calm data across the 3-year data set. Generally, the MMIF-extracted WRF data sets have a higher proportion of low-wind speed values. Calm hours are generally the least favorable for dispersion, and result in higher model-predicted concentrations than hours with higher wind speeds. AERMOD will skip calculating concentrations for hours with missing or calm data, so the MMIF-extracted WRF data are likely to result in higher concentrations during those periods.

Chemical Transformations

AERMOD includes several optional algorithms that calculate the conversion of nitric oxide (NO) to nitrogen dioxide (NO_2). For this study, emissions of oxides of nitrogen (NO_X), which is composed of both NO and NO_2, were conservatively assumed to be 100 percent converted to NO_2, meaning calculated NO_X concentrations are assumed to be equivalent to NO_2 concentrations. The fraction of each species (i.e., NO and NO_2) prior to being discharged to the atmosphere from a stack or tailpipe is typically determined empirically for each emission unit type. The degree to which the NO portion of the emitted NO_X is converted to NO_2 after being discharged to the atmosphere is a function of the amount of ozone (O_3) available in the atmosphere to convert NO to NO_2. The assumption that all NO is converted to NO_2 is a conservative assumption and means that NO_2 concentrations calculated for this study by the model should be understood to be at the conservative end of the range of possible estimates.

Urban Option

Urban areas are known to experience a "convective-like" boundary layer at night as a result of heat absorbed during the day being re-radiated at night,[2] in contrast with rural areas, which typically have a stable boundary layer at night. AERMOD includes an "urban option," which enhances turbulence[3] in the boundary layer to account for this condition. Because more than 50 percent of the modeling domain is considered urban,[4] the AERMOD option for urban dispersion was used. The AERMOD urban option includes an input for a population of the metropolitan area. This population is used to calculate the urban boundary layer height, based on a reference height and reference population. Based on the guidance in the AERMOD Implementation Guide (EPA 2024), the population of the Seattle Metropolitan Statistical Area as of the 2020 census (i.e., 4,018,762 people) was input as the population (US Census Bureau; accessed June 27, 2024).

Volume Source Parameters

AERMOD determines dispersion of volume sources using three parameters:

- The center of the volume source (release height) above ground
- The initial lateral dimension (sigma-y) of the volume source

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[2] The boundary layer is described as "convective," or "unstable," when the sun is heating the earth's surface, which causes air near the surface to rise, cool as it rises, and then fall again, where it is reheated by the surface and rises again. These conditions typically occur during the day when cloud cover does not prevent sunlight from warming the surface of the Earth. In an urban area, the "heat island" effect, where buildings, roads, and other structures absorb energy from the sun during the day and re-radiate it at night, which causes air near the surface of those structures to be heated and to rise, causing unstable or "convective-like" conditions at night.

[3] Turbulence in the boundary layer enhances dispersion. The greater the turbulence, the more effective the dispersion.

[4] Appendix W to 40 CFR Part 51 (Revisions to the Guideline on Air Quality Models, or the "Guideline") defines an urban area using land-use classification procedure. If 50 percent of the area within a 3-km radius of the source is classified as Auer Classifications I1 (Heavy Industrial), I2 (Light-Moderate Industrial), C1 (Commercial Office and Apartment Buildings), R2 (Compact Residential – single and multifamily), and R3 (Compact Residential - multifamily), the area is considered "urban" and the urban dispersion coefficients can be used. Most of the modeling domain would be considered C1, R2, and R3 under the Auer classification system. Therefore, the urban dispersion coefficients were used in the model setup.

- The initial vertical dimension (sigma-z) of the volume source.

The initial lateral and vertical dimensions are derived from an emission source's width and height, respectively. When representing surface-based line sources by adjacent volumes, such as highways, AERMOD's user guide suggests dividing the center-to-center distance and vertical dimension of a source by 2.15. Release height, center-to-center distance, or width, and vertical dimensions for all roadways were based on recommendations from the Haul Roads Workgroup guidance (EPA 2011). To simplify the model assessment, all emissions were assumed to be well mixed along the highway corridors and affected by haul trucks 9.84 feet (three meters) tall. The Haul Roads Workgroup guidance for modeling roadways as volume sources recommends calculating the top of plume height as 1.7 times vehicle height and release height as half the plume height. Therefore, all emissions were released at a height of 8.37 feet (2.55 meters) above the road with a vertical dimension of 7.78 feet (2.37 meters).

For multi-lane roadways, the Haul Roads Workgroup guidance recommends calculating the plume width, or center-to-center distance, as the roadway width plus 19.68 feet (six meters). 144 highway segments were developed to represent changes in traffic volumes and roadway width. Each segment was further divided to more accurately represent changes in roadway elevation and travel directions (i.e., curves). As discussed in Section 2.4 of the Air Dispersion Modeling Report text, roadway width determined the number of volume sources distributed along each segment and, therefore, the individual volume source emission rate within each segment. Table B-3 summarizes the number of volume sources, range in elevation, and other source parameters for all 144 roadway segments.

Table B-3:Roadway Source Parameter Summary by Segment ID

Segment ID	Description	Length (miles)	Road Width (feet | meters)	Initial Lateral Dimension (feet | meters)	Elevations (feet range | meter range)	Volume Source Count	Individual Source Emission Rate (g/s)
L001	520EB EO MP5	0.35	36 | 11.0	25.9 | 7.9	10.4 - 14.3 | 34 - 47	33	3.03E-02
L002	520EB EO MP5	0.32	60 | 18.3	37.1 | 11.3	8.2 - 13.4 | 27 - 44	21	4.76E-02
L003	520EB WO MP6	0.09	36 | 11.0	25.9 | 7.9	7.6 - 7.9 | 25 - 26	9	1.11E-01
L004	520EB Thru MP6	0.44	36 | 11.0	25.9 | 7.9	5.5 - 7.3 | 18 - 24	42	2.38E-02
L005	520EB EO MP6	0.44	48 | 14.6	31.5 | 9.6	7.8 - 14.5 | 26 - 48	34	2.94E-02
L006	520EB WO MP7	0.23	36 | 11.0	25.9 | 7.9	14.0 - 16.6 | 46 - 55	22	4.55E-02
L007	520EB Thru MP7	0.16	36 | 11.0	25.9 | 7.9	17.1 - 18.3 | 56 - 60	15	6.67E-02
L008	520EB EO MP7	0.27	36 | 11.0	25.9 | 7.9	17.7 - 19.5 | 58 - 64	26	3.85E-02
L009	520EB WO MP8	0.34	36 | 11.0	25.9 | 7.9	20.1 - 25.3 | 66 - 83	32	3.13E-02
L010	520EB Thru MP8	1.09	36 | 11.0	25.9 | 7.9	21.3 - 27.7 | 70 - 91	103	9.71E-03
L011	520EB Thru MP9	0.31	36 | 11.0	25.9 | 7.9	25.3 - 28.7 | 83 - 94	30	3.33E-02
L012	520EB EO MP9	0.35	36 | 11.0	25.9 | 7.9	29.3 - 31.9 | 96 - 105	33	3.03E-02
L013	520EB WO MP10	0.36	36 | 11.0	25.9 | 7.9	32.0 - 33.2 | 105 - 109	33	3.03E-02
L014	520EB Thru MP10	0.27	36 | 11.0	25.9 | 7.9	33.2 - 33.5 | 109 - 110	26	3.85E-02
L015	520WB Thru MP10	0.29	36 | 11.0	25.9 | 7.9	33.2 - 33.5 | 109 - 110	28	3.57E-02
L016	520WB WO MP10	0.28	48 | 14.6	31.5 | 9.6	32.3 - 32.9 | 106 - 108	21	4.76E-02
L017	520WB Thru MP9	0.69	36 | 11.0	25.9 | 7.9	25.1 - 32.3 | 83 - 106	66	1.52E-02
L018	520WB Thru MP8	1.45	36 | 11.0	25.9 | 7.9	20.4 - 27.7 | 67 - 91	137	7.30E-03
L019	520WB EO MP7	0.22	48 | 14.6	31.5 | 9.6	18.0 - 19.5 | 59 - 64	17	5.88E-02
L020	520WB Thru MP7	0.25	36 | 11.0	25.9 | 7.9	16.2 - 18.3 | 53 - 60	24	4.17E-02
L021	520WB WO MP7	0.20	36 | 11.0	25.9 | 7.9	14.5 - 16.2 | 48 - 53	18	5.56E-02
L022	520WB EO MP6	0.23	48 | 14.6	31.5 | 9.6	11.0 - 14.0 | 36 - 46	19	5.26E-02
L023	520WB Thru MP6	0.50	36 | 11.0	25.9 | 7.9	5.5 - 10.4 | 18 - 34	47	2.13E-02
L024	520WB WO MP6	0.16	36 | 11.0	25.9 | 7.9	6.1 - 7.0 | 20 - 23	15	6.67E-02
L025	520WB EO MP5	0.39	36 | 11.0	25.9 | 7.9	7.9 - 14.3 | 26 - 47	37	2.70E-02
L026	520WB EO MP5	0.33	36 | 11.0	25.9 | 7.9	11.3 - 14.6 | 37 - 48	32	3.13E-02

Segment ID	Description	Length (miles)	Road Width (feet | meters)	Initial Lateral Dimension (feet | meters)	Elevations (feet range | meter range)	Volume Source Count	Individual Source Emission Rate (g/s)
L027	520EB to 405	0.16	24 | 7.3	20.3 | 6.2	14.9 - 18.3 | 49 - 60	19	5.26E-02
L028	520EB to 405NB	0.49	12 | 3.7	14.7 | 4.5	18.9 - 23.5 | 62 - 77	82	1.22E-02
L029	520 to 405NB	0.16	22 | 6.7	19.4 | 5.9	19.2 - 21.6 | 63 - 71	20	5.00E-02
L030	520 to 405NB	0.16	12 | 3.7	14.7 | 4.5	21.6 - 23.8 | 71 - 78	27	3.70E-02
L031	520EB to 405SB	0.32	12 | 3.7	14.7 | 4.5	18.9 - 21.9 | 62 - 72	54	1.85E-02
L032	520WB to 405NB	0.33	12 | 3.7	14.7 | 4.5	17.7 - 19.2 | 58 - 63	55	1.82E-02
L033	520WB to 405SB	0.18	12 | 3.7	14.7 | 4.5	15.8 - 18.0 | 52 - 59	30	3.33E-02
L034	405SB to 8th	0.16	12 | 3.7	14.7 | 4.5	5.2 - 6.2 | 17 - 21	28	3.57E-02
L035	405SB SO MP16	0.62	60 | 18.3	37.1 | 11.3	20.4 - 30.8 | 67 - 101	42	2.38E-02
L036	405SB Thru MP15	0.24	60 | 18.3	37.1 | 11.3	18.0 - 20.0 | 59 - 66	16	6.25E-02
L037	405SB SO MP15	0.33	60 | 18.3	37.1 | 11.3	18.4 - 21.9 | 61 - 72	21	4.76E-02
L038	405SB SO MP15	0.35	66 | 20.1	39.9 | 12.1	18.3 - 21.9 | 60 - 72	22	4.55E-02
L039	405SB NO MP14	0.23	60 | 18.3	37.1 | 11.3	15.2 - 17.4 | 50 - 57	15	6.67E-02
L040	405SB Thru MP14	0.21	60 | 18.3	37.1 | 11.3	11.9 - 14.3 | 39 - 47	14	7.14E-02
L041	405SB SO MP14	0.22	48 | 14.6	31.5 | 9.6	9.4 - 11.0 | 31 - 36	17	5.88E-02
L042	405SB NO MP13	0.16	60 | 18.3	37.1 | 11.3	6.7 - 7.6 | 22 - 25	11	9.09E-02
L043	405SB NO MP13	0.16	48 | 14.6	31.5 | 9.6	4.9 - 6.1 | 16 - 20	12	8.33E-02
L044	405SB Thru MP13	0.25	60 | 18.3	37.1 | 11.3	4.6 - 5.5 | 15 - 18	17	5.88E-02
L045	405SB SO MP13	0.51	60 | 18.3	37.1 | 11.3	5.5 - 6.7 | 18 - 22	34	2.94E-02
L046	405SB Thru MP12	0.86	72 | 21.9	42.6 | 13.0	5.8 - 14.0 | 19 - 46	50	2.00E-02
L047	405SB Thru MP11	0.88	36 | 11.0	25.9 | 7.9	13.7 - 15.5 | 45 - 51	82	1.22E-02
L048	405SB SO MP11	0.21	60 | 18.3	37.1 | 11.3	15.8 - 15.8 | 52 - 52	14	7.14E-02
L049	405SB NO MP10	0.52	36 | 11.0	25.9 | 7.9	9.1 - 15.2 | 30 - 50	49	2.04E-02
L050	405SB SO MP10	0.59	36 | 11.0	25.9 | 7.9	10.4 - 11.9 | 34 - 39	56	1.79E-02
L051	405SB NO MP9	0.36	36 | 11.0	25.9 | 7.9	11.9 - 13.1 | 39 - 43	34	2.94E-02
L052	405SB Thru MP9	0.04	36 | 11.0	25.9 | 7.9	13.4 - 13.4 | 44 - 44	4	2.50E-01
L053	405NB Thru MP9	0.05	36 | 11.0	25.9 | 7.9	13.4 - 13.4 | 44 - 44	5	2.00E-01

Segment ID	Description	Length (miles)	Road Width (feet | meters)	Initial Lateral Dimension (feet | meters)	Elevations (feet range | meter range)	Volume Source Count	Individual Source Emission Rate (g/s)
L054	405NB NO MP9	0.54	36 | 11.0	25.9 | 7.9	12.2 - 13.1 | 40 - 43	51	1.96E-02
L055	405NB SO MP10	0.42	48 | 14.6	31.5 | 9.6	10.4 - 12.8 | 34 - 42	33	3.03E-02
L056	405NB NO MP10	0.33	48 | 14.6	31.5 | 9.6	9.8 - 12.8 | 32 - 42	26	3.85E-02
L057	405NB NO MP10	0.36	60 | 18.3	37.1 | 11.3	13.1 - 15.8 | 43 - 52	24	4.17E-02
L058	405NB SO MP11	0.14	48 | 14.6	31.5 | 9.6	13.7 - 14.8 | 45 - 49	11	9.09E-02
L059	405NB SO MP11	0.12	36 | 11.0	25.9 | 7.9	13.7 - 14.6 | 45 - 48	11	9.09E-02
L060	405NB Thru MP11	0.49	24 | 7.3	20.3 | 6.2	14.3 - 15.5 | 47 - 51	60	1.67E-02
L061	405NB Thru MP12	1.03	60 | 18.3	37.1 | 11.3	13.7 - 17.4 | 45 - 57	68	1.47E-02
L062	405NB Thru MP13	0.60	48 | 14.6	31.5 | 9.6	5.2 - 13.7 | 17 - 45	47	2.13E-02
L063	405NB NO MP13	0.12	60 | 18.3	37.1 | 11.3	4.6 - 4.9 | 15 - 16	8	1.25E-01
L064	405NB NO MP13	0.57	48 | 14.6	31.5 | 9.6	4.6 - 10.7 | 15 - 35	44	2.27E-02
L065	405NB SO MP14	0.16	60 | 18.3	37.1 | 11.3	11.6 - 13.3 | 38 - 44	11	9.09E-02
L066	405NB Thru MP14	0.22	66 | 20.1	39.9 | 12.1	13.3 - 16.0 | 44 - 53	13	7.69E-02
L067	405NB NO MP14	0.46	60 | 18.3	37.1 | 11.3	17.5 - 21.9 | 58 - 72	31	3.23E-02
L068	405NB Thru MP15	0.78	60 | 18.3	37.1 | 11.3	18.3 - 24.1 | 60 - 79	52	1.92E-02
L069	405NB NO MP15	0.38	72 | 21.9	42.6 | 13.0	25.0 - 30.8 | 82 - 101	22	4.55E-02
L070	405SB to 520WB	0.28	12 | 3.7	14.7 | 4.5	15.5 - 19.2 | 51 - 63	47	2.13E-02
L071	405 to 520WB	0.07	24 | 7.3	20.3 | 6.2	14.6 - 15.2 | 48 - 50	9	1.11E-01
L072	405SB to 520EB	0.55	12 | 3.7	14.7 | 4.5	16.8 - 20.1 | 55 - 66	92	1.09E-02
L073	405SB to 90	0.27	33 | 10.1	24.5 | 7.5	13.1 - 14.0 | 43 - 46	27	3.70E-02
L074	405SB to 90WB	0.24	24 | 7.3	20.3 | 6.2	7.3 - 12.8 | 24 - 42	29	3.45E-02
L075	405 to 90WB	0.17	33 | 10.1	24.5 | 7.5	4.0 - 7.0 | 13 - 23	18	5.56E-02
L076	405 to 90WB	0.31	22 | 6.7	19.4 | 5.9	3.7 - 4.6 | 12 - 15	39	2.56E-02
L077	405SB to 90EB	0.42	12 | 3.7	14.7 | 4.5	8.5 - 13.1 | 28 - 43	60	1.67E-02
L078	405NB to 90	0.22	24 | 7.3	20.3 | 6.2	13.7 - 14.3 | 45 - 47	27	3.70E-02
L079	405NB to 90WB	0.39	12 | 3.7	14.7 | 4.5	7.3 - 13.4 | 24 - 44	52	1.92E-02
L080	405NB to 90EB	0.24	12 | 3.7	14.7 | 4.5	11.0 - 13.4 | 36 - 44	40	2.50E-02

Segment ID	Description	Length (miles)	Road Width (feet | meters)	Initial Lateral Dimension (feet | meters)	Elevations (feet range | meter range)	Volume Source Count	Individual Source Emission Rate (g/s)
L081	405NB to 520	0.19	24 | 7.3	20.3 | 6.2	18.9 - 19.5 | 62 - 64	24	4.17E-02
L082	405NB to 520	0.19	24 | 7.3	20.3 | 6.2	19.8 - 22.3 | 65 - 73	23	4.35E-02
L083	405NB to 520	0.11	36 | 11.0	25.9 | 7.9	21.3 - 22.3 | 70 - 73	10	1.00E-01
L084	405NB to 520WB	0.41	12 | 3.7	14.7 | 4.5	15.5 - 20.7 | 51 - 68	69	1.45E-02
L085	405NB to 520EB	0.11	24 | 7.3	20.3 | 6.2	20.4 - 20.7 | 67 - 68	14	7.14E-02
L086	405NB to 520EB	0.19	12 | 3.7	14.7 | 4.5	18.3 - 20.7 | 60 - 68	31	3.23E-02
L087	90EB Thru MP8	0.49	48 | 14.6	31.5 | 9.6	7.6 - 12.5 | 25 - 41	39	2.56E-02
L088	90EB EO MP8	0.59	48 | 14.6	31.5 | 9.6	7.3 - 11.0 | 24 - 36	46	2.17E-02
L089	90EB WO MP9	0.20	60 | 18.3	37.1 | 11.3	8.5 - 10.7 | 28 - 35	13	7.69E-02
L090	90EB Thru MP9	0.36	60 | 18.3	37.1 | 11.3	5.5 - 8.2 | 18 - 27	23	4.35E-02
L091	90EB EO MP9	0.33	48 | 14.6	31.5 | 9.6	4.6 - 4.6 | 15 - 15	26	3.85E-02
L092	90EB WO MP10	0.24	48 | 14.6	31.5 | 9.6	5.2 - 8.4 | 17 - 28	19	5.26E-02
L093	90EB Thru MP10	0.34	48 | 14.6	31.5 | 9.6	9.1 - 12.3 | 30 - 41	27	3.70E-02
L094	405 to 90EB	0.08	24 | 7.3	20.3 | 6.2	11.9 - 12.2 | 39 - 40	10	1.00E-01
L095	90EB EO MP10	0.42	72 | 21.9	42.6 | 13.0	13.0 - 20.3 | 43 - 67	24	4.17E-02
L096	90EB WO MP11	0.32	72 | 21.9	42.6 | 13.0	21.6 - 26.4 | 71 - 87	18	5.56E-02
L097	90EB Thru MP11	0.16	60 | 18.3	37.1 | 11.3	27.3 - 29.6 | 90 - 97	11	9.09E-02
L098	90EB EO MP11	0.21	48 | 14.6	31.5 | 9.6	28.8 - 30.3 | 95 - 100	16	6.25E-02
L099	90EB WO MP12	0.65	48 | 14.6	31.5 | 9.6	30.5 - 31.7 | 100 - 104	51	1.96E-02
L100	90EB Thru MP13	1.37	55 | 16.8	34.7 | 10.6	23.8 - 31.7 | 78 - 104	97	1.03E-02
L101	90EB Thru MP14	0.75	44 | 13.4	29.6 | 9.0	14.8 - 23.5 | 49 - 77	62	1.61E-02
L102	90EB to 405	0.36	24 | 7.3	20.3 | 6.2	3.4 - 4.9 | 11 - 16	44	2.27E-02
L103	90EB to 405	0.11	33 | 10.1	24.5 | 7.5	5.2 - 7.0 | 17 - 23	11	9.09E-02
L104	90EB to 405NB	0.43	12 | 3.7	14.7 | 4.5	7.3 - 14.6 | 24 - 48	71	1.41E-02
L105	90 to 405NB	0.14	24 | 7.3	20.3 | 6.2	14.3 - 14.3 | 47 - 47	17	5.88E-02
L106	90EB to 405SB	0.19	22 | 6.7	19.4 | 5.9	7.3 - 11.9 | 24 - 39	25	4.00E-02
L107	90EB to 405SB	0.07	12 | 3.7	14.7 | 4.5	11.9 - 12.8 | 39 - 42	12	8.33E-02

Segment ID	Description	Length (miles)	Road Width (feet | meters)	Initial Lateral Dimension (feet | meters)	Elevations (feet range | meter range)	Volume Source Count	Individual Source Emission Rate (g/s)
L108	90 to 405SB	0.20	22 | 6.7	19.4 | 5.9	12.8 - 14.6 | 42 - 48	25	4.00E-02
L109	90WB Thru MP14	0.74	44 | 13.4	29.6 | 9.0	14.0 - 22.1 | 46 - 73	62	1.61E-02
L110	90WB Thru MP13	0.97	55 | 16.8	34.7 | 10.6	22.8 - 29.9 | 75 - 98	69	1.45E-02
L111	90WB Thru MP12	1.08	44 | 13.4	29.6 | 9.0	29.7 - 32.0 | 98 - 105	90	1.11E-02
L112	90WB EO MP11	0.29	44 | 13.4	29.6 | 9.0	28.3 - 29.7 | 93 - 98	24	4.17E-02
L113	90WB WO MP11	0.38	55 | 16.8	34.7 | 10.6	21.5 - 27.7 | 71 - 91	27	3.70E-02
L114	90WB EO MP10	0.26	55 | 16.8	34.7 | 10.6	14.3 - 19.7 | 47 - 65	18	5.56E-02
L115	90WB Thru MP10	0.45	44 | 13.4	29.6 | 9.0	10.1 - 13.4 | 33 - 44	38	2.63E-02
L116	405S to 8th	0.03	33 | 10.1	24.5 | 7.5	4.9 - 4.9 | 16 - 16	3	3.33E-01
L117	90WB WO MP10	0.29	44 | 13.4	29.6 | 9.0	4.0 - 9.1 | 13 - 30	24	4.17E-02
L118	90WB EO MP9	0.30	33 | 10.1	24.5 | 7.5	3.7 - 4.6 | 12 - 15	30	3.33E-02
L119	90WB EO MP9	0.14	55 | 16.8	34.7 | 10.6	5.6 - 6.7 | 19 - 22	10	1.00E-01
L120	90WB Thru MP9	0.21	55 | 16.8	34.7 | 10.6	7.0 - 9.1 | 23 - 30	15	6.67E-02
L121	90WB WO MP9	0.34	66 | 20.1	39.9 | 12.1	9.4 - 10.7 | 31 - 35	21	4.76E-02
L122	90WB EO MP8	0.47	44 | 13.4	29.6 | 9.0	6.7 - 9.8 | 22 - 32	39	2.56E-02
L123	90WB Thru MP8	0.47	44 | 13.4	29.6 | 9.0	7.0 - 11.9 | 23 - 39	39	2.56E-02
L124	90WB to 405	0.21	24 | 7.3	20.3 | 6.2	12.2 - 13.4 | 40 - 44	26	3.85E-02
L125	90WB to 405SB	0.39	12 | 3.7	14.7 | 4.5	12.2 - 13.7 | 40 - 45	65	1.54E-02
L126	90WB to 205NB	0.31	12 | 3.7	14.7 | 4.5	12.5 - 14.6 | 41 - 48	52	1.92E-02
L127	8th to 405SB	0.04	12 | 3.7	14.7 | 4.5	4.9 - 4.9 | 16 - 16	6	1.67E-01
L128	8th to 405SB	0.06	24 | 7.3	20.3 | 6.2	4.3 - 4.6 | 14 - 15	7	1.43E-01
L129	8th to 405SB	0.10	33 | 10.1	24.5 | 7.5	5.2 - 5.6 | 17 - 19	10	1.00E-01
L130	8th to 405SB	0.16	12 | 3.7	14.7 | 4.5	5.5 - 5.6 | 18 - 19	27	3.70E-02
L131	405NB to 8th/LkHills	0.19	12 | 3.7	14.7 | 4.5	9.4 - 13.7 | 31 - 45	32	3.13E-02
L132	405NB to 8th	0.07	12 | 3.7	14.7 | 4.5	7.3 - 8.2 | 24 - 27	11	9.09E-02
L133	405NB to 8th	0.06	33 | 10.1	24.5 | 7.5	5.2 - 6.4 | 17 - 21	7	1.43E-01
L134	405NB to LkHills	0.19	12 | 3.7	14.7 | 4.5	6.9 - 9.3 | 23 - 31	32	3.13E-02

Segment ID	Description	Length (miles)	Road Width (feet | meters)	Initial Lateral Dimension (feet | meters)	Elevations (feet range | meter range)	Volume Source Count	Individual Source Emission Rate (g/s)
L135	405NB to LkHills	0.03	24 | 7.3	20.3 | 6.2	10.1 - 10.5 | 33 - 35	4	2.50E-01
L136	8th to 405NB	0.12	22 | 6.7	19.4 | 5.9	5.5 - 6.4 | 18 - 21	16	6.25E-02
L137	8th to 405NB	0.14	12 | 3.7	14.7 | 4.5	5.5 - 6.1 | 18 - 20	24	4.17E-02
L138	128th to 90WB	0.09	12 | 3.7	14.7 | 4.5	11.7 - 12.6 | 39 - 42	16	6.25E-02
L139	Eastgate to 90WB	0.09	24 | 7.3	20.3 | 6.2	10.0 - 11.4 | 33 - 38	11	9.09E-02
L140	128th/Eastgate to 90WB	0.15	24 | 7.3	20.3 | 6.2	11.1 - 11.9 | 37 - 39	19	5.26E-02
L141	128th/Eastgate to 90WB	0.09	12 | 3.7	14.7 | 4.5	9.8 - 10.7 | 32 - 35	15	6.67E-02
L142	90EB to 36th	0.15	12 | 3.7	14.7 | 4.5	9.1 - 10.8 | 30 - 36	25	4.00E-02
L143	90EB to 36th	0.13	24 | 7.3	20.3 | 6.2	9.8 - 11.0 | 32 - 36	16	6.25E-02
L144	90EB to 36th	0.07	33 | 10.1	24.5 | 7.5	9.4 - 9.4 | 31 - 31	7	1.43E-01

Abbreviations and Acronyms:

Eastgate = SE Eastgate Way
EB = eastbound direction
EO = east of
ft = feet
g/s = grams per second
LkHills = Lake Hills Connector
m = meters
MP = milepost number
NB = northbound direction
NO = north of
SB = southbound direction
SO = south of
WB = westbound direction
WO = west of

8^{th} = SE 8^{th} Street
36^{th} = SE 36^{th} Street
90 = Interstate 90
128^{th} = 128^{th} Avenue SE
405 = Interstate 405
520 = State Route 520

MOVES - Vehicle Emission Factors

The EPA developed its MOtor Vehicle Emission Simulator (MOVES) to estimate the effect of regulations and policies on air pollutant emissions from mobile sources (i.e., cars, trucks, and other on-road sources of air pollutants) and to generate emissions information that could be used to generate emission inventories of mobile sources. The EPA intends for MOVES to be used by state and local governments and agencies to develop emission inventories for a variety of purposes, including the development of state implementation plans, transportation conformity determinations, general conformity determinations, and other required regulatory analyses.

MOVES is designed to account for an extensive suite of emission factor types associated with various classes of mobile sources, vehicle activities, and fuel types, not all of which are pertinent to vehicles when operated on a freeway, so not all emission factors calculated by MOVES were used to produce the model results. Landau included running exhaust emissions, tire wear emissions, and brake wear emissions. Other emissions, such as startup emissions, evaporative emissions, "hoteling" or extended idle emissions, or refueling emissions, were not included.

Based on the Washington State Department of Transportation (WSDOT) quarterly vehicle speed reports for 2019 (WSDOT; accessed July 10, 2024), on average, vehicles travel more than 57 mph on the highways near Bellevue. Therefore, emissions were developed using the 57.5 - 62.5 mph MOVES speed bin. Congested traffic conditions were assumed to occur during the AM and PM peak hour NO_X modeling assessments. Congested traffic condition vehicle speeds are assumed to be 15 mph, and emission factors were obtained using the 12.5 - 17.5 mph MOVES speed bin.

Landau grouped the emission factors (per VMT) by source types from MOVES into emission factors for the different vehicle weight classes: light-duty vehicles (LDV, 10,000 lbs or less), medium-duty vehicles (MDV, 10,000-25,000 lbs), and heavy-duty vehicles (HDV, greater than 26,000 lbs) to align with traffic volume data provided by the City. This grouping was based on the vehicle classification provided in Table B-4, which Landau developed using information from Appendix A, Table A-1 of the MOVES technical guidance (EPA 2023).

Table B-4: Vehicle Weight Class Classification

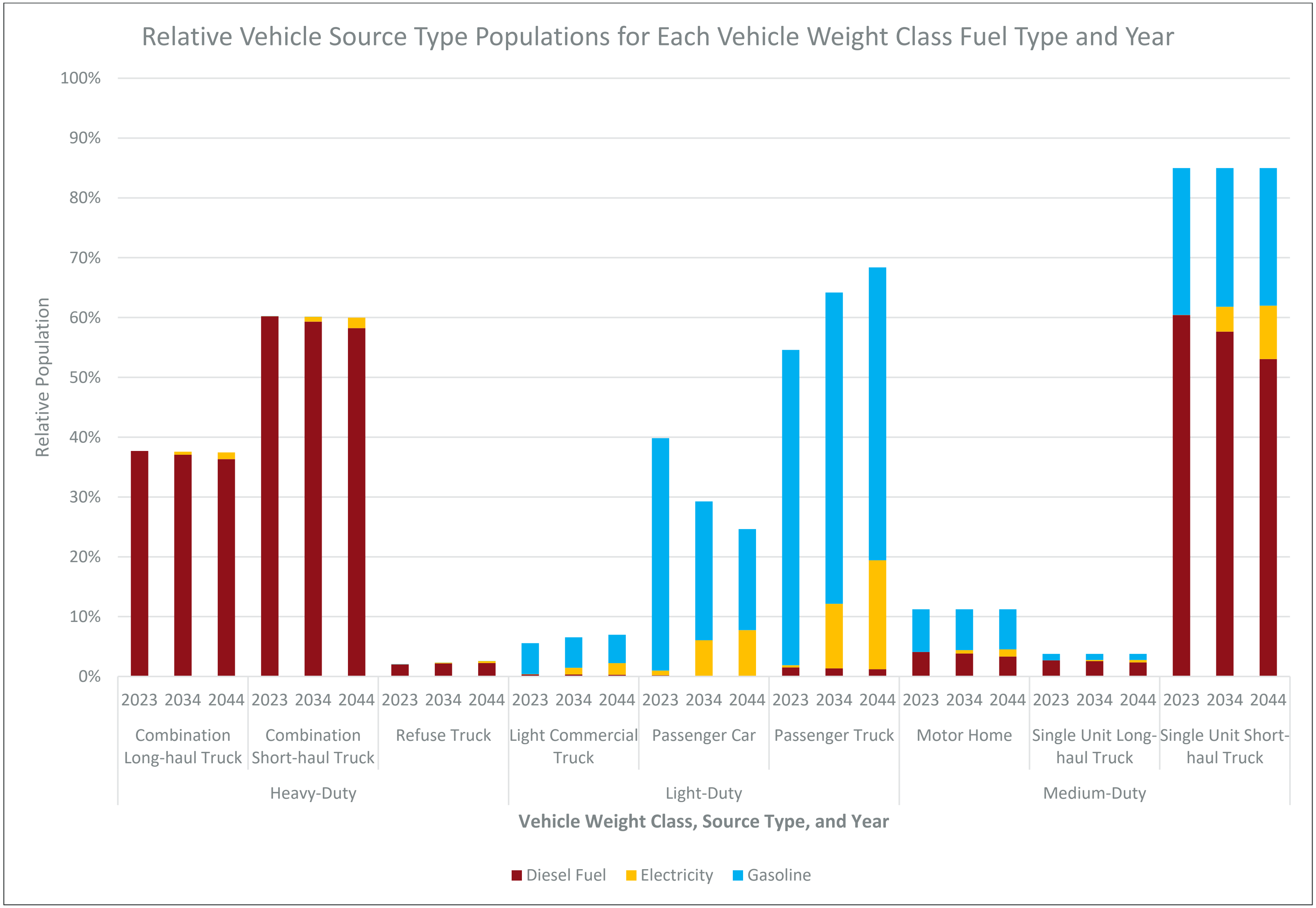
Source Type	Vehicle Weight Class
Passenger Car	Light-Duty
Passenger Truck	Light-Duty
Light Commercial Truck	Light-Duty
Refuse Truck	Heavy-Duty
Single Unit Short- haul Truck	Medium-Duty
Single Unit Long- haul Truck	Medium-Duty
Motor Home	Medium-Duty
Combination Short-haul Truck	Heavy-Duty
Combination Long-haul Truck	Heavy-Duty

King County vehicle source type population data for electric, diesel, and gasoline fueled vehicles were used to weight emission rates for each vehicle weight class. The MOVES population data are shown in Table B-5 for each year of analysis. Figure B-9 shows the relative change in populations for each vehicle weight class.

Table B-5: MOVES King County Vehicle Populations by Year

Vehicle Weight Class	Vehicle Source Type	Fuel Type	Model Year 2023	2034	2044
Heavy-Duty	Combination Long-haul Truck	Diesel Fuel	4,983	5,594	5,745
		Electricity	-	76	175
	Combination Short-haul Truck	Diesel Fuel	7,958	8,950	9,206
		Electricity	1	122	275
		Gasoline	2	-	-
	Refuse Truck	Diesel Fuel	268	330	356
		Electricity	-	17	50
		Gasoline	4	-	-
Medium-Duty	Motor Home	Diesel Fuel	2,040	2,504	2,570
		Electricity	-	363	942
		Gasoline	3,555	4,448	5,192
	Single Unit Long-haul Truck	Diesel Fuel	1,338	1,669	1,827
		Electricity	-	120	307
		Gasoline	544	671	792
	Single Unit Short-haul Truck	Diesel Fuel	30,094	37,540	41,097
		Electricity	5	2,707	6,915
		Gasoline	12,238	15,107	17,826
Light-Duty	Light Commercial Truck	Diesel Fuel	4,462	4,492	4,281
		Electricity	473	15,300	27,508
		Gasoline	66,304	68,950	67,813
	Passenger Car	Diesel Fuel	2,536	636	251
		Electricity	10,086	81,512	110,333
		Gasoline	497,415	314,856	241,600
	Passenger Truck	Diesel Fuel	19,476	18,360	17,209
		Electricity	4,516	146,439	260,406
		Gasoline	674,895	705,854	699,634

Figure B-9: MOVES Relative King County Vehicle Populations



Traffic Volumes

The weighted MOVES emission factors used in the model are provided in Section 2.6 of the Air Dispersion Modeling Report text as grams per vehicle-mile-traveled (g/VMT). These emission factors were applied to traffic volume information for the Bellevue-Kirkland-Redmond (BKR) area. The BKR traffic data provided by the City were compiled by vehicle weight class and distributed along a network of links throughout the BKR area for the following periods in 2019 and 2044:

- AM Peak Period: 3 hours from 6:00 a.m. to 9:00 a.m.
- Midday Period: 6.5 hours from 9:00 a.m. to 3:30 p.m.
- PM Peak Period: 3 hours from 3:30 p.m. to 6:30 p.m.
- Nighttime Period: 11.5 hours from 6:30 p.m. to 6 a.m.

The BKR volumes were assigned to each of the 144 modeled roadway segments and total vehicle-miles-traveled (VMT) per vehicle weight class were calculated by multiplying the volumes by each roadway segment length. VMT were linearly interpolated between 2019 and 2044 to determine VMT for 2023 and 2034. Hourly AM and PM peak period VMT for each modeled roadway segment are provided in Table B-6 and Table B-7, respectively. Daily VMT are provided in Table B-8. See Table B-3 for roadway segment descriptions and lengths.

Table B-6: Hourly AM Peak Period Vehicle Miles Traveled (VMT) by Vehicle Weight Class and Model Year

	2023			2034			2044		
Segment ID	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L001	679.4	37.3	2.2	809.7	43.0	2.7	928.2	48.1	3.0
L002	731.5	35.9	2.0	850.4	41.2	2.4	958.4	46.0	2.8
L003	205.9	10.1	0.6	239.3	11.6	0.7	269.8	13.0	0.8
L004	718.9	36.6	2.8	832.0	41.6	3.4	934.8	46.1	3.9
L005	907.8	43.9	3.0	1,009.3	50.0	3.5	1,101.6	55.6	4.0
L006	289.4	15.9	1.3	319.8	17.5	1.6	347.4	19.0	1.8
L007	365.7	14.0	1.9	382.1	15.0	2.1	396.9	15.9	2.4
L008	726.5	24.1	3.5	762.0	25.5	4.0	794.2	26.7	4.5
L009	619.5	22.9	1.5	648.3	24.3	1.7	674.4	25.5	1.8
L010	3,365.0	140.3	29.7	3,628.7	166.8	33.8	3,868.3	190.8	37.6
L011	741.1	32.6	8.4	777.7	38.2	9.6	811.0	43.2	10.6
L012	741.4	33.1	8.7	774.1	38.1	9.9	803.8	42.5	11.0
L013	991.2	43.0	9.6	1,027.3	48.9	11.1	1,060.0	54.2	12.5
L014	500.9	23.9	7.2	520.4	26.6	8.3	538.2	29.0	9.3
L015	1,157.9	26.2	8.0	1,131.1	30.2	11.2	1,106.7	33.7	14.0
L016	1,224.8	30.8	7.8	1,204.5	36.3	10.8	1,186.1	41.4	13.6
L017	2,172.2	61.3	19.1	2,220.7	73.9	26.7	2,264.7	85.3	33.7
L018	5,086.3	157.4	43.7	4,379.0	152.3	60.0	3,736.0	147.8	74.8
L019	888.5	28.9	8.5	800.2	29.1	11.2	720.0	29.2	13.6
L020	940.2	29.1	8.0	823.7	28.9	10.9	717.8	28.7	13.5
L021	463.8	16.2	1.2	395.6	16.0	1.4	333.5	15.9	1.5
L022	889.8	25.8	1.7	773.7	25.9	1.9	668.1	26.1	2.0

Segment ID	2023			2034			2044		
	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L023	1,284.6	44.1	3.7	1,113.5	45.3	4.0	957.9	46.3	4.4
L024	474.5	16.3	1.3	412.2	16.6	1.4	355.7	16.9	1.4
L025	1,326.0	48.4	3.0	1,155.2	50.5	3.2	999.9	52.5	3.4
L026	1,059.1	39.8	2.6	913.8	41.5	2.8	781.7	43.1	2.9
L027	125.5	4.8	0.2	140.8	5.8	0.2	154.8	6.8	0.2
L028	88.2	5.5	0.2	101.5	6.6	0.3	113.7	7.6	0.3
L029	84.6	4.5	1.2	97.5	5.1	1.4	109.2	5.7	1.6
L030	86.7	4.6	1.2	100.0	5.3	1.4	112.0	5.8	1.6
L031	198.1	6.1	0.2	220.7	7.6	0.2	241.3	8.9	0.2
L032	119.9	5.9	2.4	138.4	6.4	2.7	155.1	6.9	3.1
L033	243.8	5.9	4.5	223.3	5.9	6.4	204.6	5.8	8.1
L034	84.8	0.9	0.0	84.6	1.3	0.0	84.4	1.6	0.0
L035	5,147.3	71.6	96.3	4,977.2	75.4	112.7	4,822.6	78.9	127.7
L036	1,549.0	20.0	36.0	1,520.7	21.7	42.3	1,495.0	23.1	48.0
L037	2,556.4	38.2	57.3	2,479.6	40.4	69.3	2,409.8	42.3	80.3
L038	2,747.4	40.9	61.3	2,700.1	43.3	74.2	2,657.0	45.4	85.9
L039	1,897.8	30.6	39.5	1,861.0	33.1	47.8	1,827.6	35.4	55.4
L040	1,336.4	23.9	37.3	1,337.1	24.9	45.2	1,337.8	25.7	52.3
L041	1,213.5	19.6	38.9	1,222.7	20.4	47.1	1,231.1	21.1	54.6
L042	872.2	14.1	28.0	878.8	14.7	33.9	884.8	15.1	39.2
L043	860.7	13.7	27.2	901.1	14.3	33.0	937.9	14.7	38.2
L044	1,665.0	37.9	50.8	1,710.7	42.1	61.0	1,752.2	45.9	70.3
L045	3,082.4	73.3	102.1	3,175.0	80.7	122.6	3,259.2	87.3	141.2
L046	5,476.0	135.3	174.9	5,727.9	150.6	209.8	5,956.9	164.4	241.6
L047	5,134.8	88.0	142.4	5,957.3	94.0	173.9	6,705.0	99.4	202.5
L048	1,084.3	28.9	35.1	1,169.7	31.1	44.1	1,247.3	33.2	52.3
L049	2,380.6	57.8	85.1	2,583.2	61.7	107.7	2,767.4	65.1	128.2
L050	2,965.3	74.8	97.9	3,220.9	79.9	123.9	3,453.3	84.5	147.5
L051	1,658.0	39.9	44.1	1,753.1	45.0	67.7	1,839.5	49.7	89.1
L052	213.5	5.4	7.2	231.9	5.8	9.1	248.6	6.1	10.9
L053	265.5	3.3	5.6	290.6	4.2	7.4	313.4	5.1	9.1
L054	3,013.4	39.3	63.0	3,096.4	50.2	86.2	3,171.9	60.0	107.3
L055	2,911.1	48.3	62.8	3,131.9	51.1	74.4	3,332.7	53.8	85.1
L056	2,124.9	34.4	50.0	2,287.3	36.4	59.3	2,434.9	38.2	67.8
L057	2,725.6	42.3	54.8	2,894.1	45.0	64.9	3,047.4	47.4	74.2
L058	755.0	11.7	21.1	827.9	12.5	24.9	894.1	13.3	28.4
L059	661.7	10.2	18.5	725.6	11.0	21.9	783.7	11.7	24.9
L060	2,636.9	40.8	73.8	2,891.6	43.8	87.1	3,123.1	46.5	99.2
L061	8,560.0	163.8	222.8	9,130.7	172.6	258.4	9,649.6	180.7	290.7
L062	4,276.9	83.9	127.9	4,605.3	86.3	147.7	4,903.9	88.4	165.7
L063	912.7	18.4	25.4	982.0	19.0	29.3	1,045.0	19.6	32.9
L064	3,017.8	61.0	104.4	3,209.7	60.1	122.3	3,384.2	59.3	138.6
L065	911.2	21.9	30.1	972.2	22.1	35.3	1,027.7	22.4	40.0
L066	1,292.1	30.2	41.5	1,372.1	30.5	48.7	1,444.7	30.8	55.1
L067	1,863.4	45.8	74.8	2,020.0	46.0	87.9	2,162.4	46.1	99.8
L068	3,408.9	91.4	126.1	3,705.6	95.0	148.1	3,975.2	98.3	168.1
L069	1,881.0	56.0	64.8	2,058.3	59.2	76.1	2,219.6	62.2	86.3
L070	260.0	4.7	0.2	225.9	4.8	0.2	194.9	4.9	0.3

Segment ID	2023			2034			2044		
	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L071	102.0	2.0	0.1	91.4	2.1	0.1	81.8	2.2	0.1
L072	524.9	8.6	3.1	506.3	8.0	3.4	489.3	7.5	3.6
L073	659.8	15.3	11.0	646.7	18.3	12.3	634.9	20.9	13.5
L074	347.0	6.0	3.4	331.6	7.5	4.8	317.5	8.9	6.0
L075	385.0	7.4	2.6	367.6	8.7	3.7	351.8	9.9	4.6
L076	579.2	11.1	4.6	544.2	13.5	6.4	512.4	15.6	8.0
L077	419.3	13.5	11.2	426.2	15.4	10.8	432.6	17.1	10.5
L078	475.6	7.4	0.3	464.0	7.7	0.5	453.5	8.0	0.7
L079	440.5	6.8	0.3	421.6	7.3	0.4	404.3	7.6	0.5
L080	248.1	3.9	0.1	247.0	4.0	0.3	246.0	4.0	0.4
L081	337.6	7.0	4.6	341.2	7.2	5.3	344.5	7.4	5.9
L082	396.8	13.1	4.5	396.3	14.9	5.2	395.9	16.5	5.8
L083	237.7	7.8	2.7	237.4	8.9	3.1	237.1	9.9	3.5
L084	218.1	4.8	0.1	206.2	5.2	0.1	195.4	5.5	0.1
L085	173.1	6.3	2.6	175.9	7.3	3.0	178.5	8.1	3.3
L086	78.4	0.4	0.2	83.9	0.2	0.3	88.9	0.1	0.4
L087	2,367.7	80.8	52.7	2,442.5	83.2	59.6	2,510.6	85.5	65.9
L088	2,816.4	96.1	62.6	2,905.5	99.0	70.9	2,986.4	101.7	78.3
L089	1,168.5	38.3	21.6	1,197.8	39.5	24.3	1,224.5	40.5	26.8
L090	1,607.9	58.6	39.0	1,616.1	60.4	44.0	1,623.5	62.1	48.5
L091	904.8	32.3	26.1	913.1	33.3	29.7	920.7	34.3	32.9
L092	684.5	23.6	18.8	691.0	24.6	21.3	697.0	25.4	23.7
L093	647.5	23.3	26.6	658.2	23.6	30.1	668.0	24.0	33.2
L094	155.0	3.7	2.1	155.9	4.0	2.0	156.7	4.4	2.0
L095	1,640.6	48.6	43.8	1,658.7	51.0	47.9	1,675.2	53.2	51.7
L096	1,083.3	37.0	33.3	1,094.5	38.8	36.5	1,104.7	40.5	39.4
L097	437.6	15.4	17.2	447.9	16.2	18.8	457.2	17.0	20.3
L098	377.3	14.8	21.8	391.7	15.7	23.8	404.8	16.6	25.7
L099	1,218.0	46.5	68.3	1,265.2	49.4	74.7	1,308.0	52.0	80.6
L100	3,197.1	128.3	143.4	3,233.1	135.3	157.2	3,265.8	141.7	169.7
L101	1,662.9	66.2	79.2	1,699.9	71.1	86.8	1,733.5	75.6	93.7
L102	678.9	24.4	11.3	705.5	25.1	12.5	729.7	25.7	13.6
L103	219.8	7.7	3.5	227.6	7.9	3.9	234.6	8.1	4.2
L104	634.7	21.4	12.2	667.7	21.7	13.7	697.6	22.1	15.1
L105	403.4	10.4	9.1	408.5	10.7	10.1	413.0	11.1	11.0
L106	98.5	3.8	0.6	97.2	4.0	0.6	96.0	4.2	0.5
L107	36.8	1.4	0.2	36.3	1.5	0.2	35.9	1.6	0.2
L108	253.3	7.6	1.2	266.6	8.3	2.6	278.7	9.0	3.9
L109	4,123.5	56.3	82.6	4,161.2	62.0	101.4	4,195.5	67.1	118.5
L110	6,243.7	81.6	108.2	5,857.6	84.5	132.3	5,506.7	87.1	154.2
L111	5,230.5	71.4	116.7	5,216.1	77.8	142.7	5,203.0	83.5	166.4
L112	1,425.5	23.9	31.1	1,402.6	25.1	38.0	1,381.8	26.2	44.3
L113	2,206.0	40.5	41.1	2,158.6	43.4	50.1	2,115.6	46.0	58.4
L114	1,570.9	28.1	28.5	1,536.8	30.1	34.8	1,505.7	32.0	40.6
L115	1,675.3	27.9	30.4	1,601.3	29.3	36.1	1,534.1	30.7	41.2
L116	13.2	0.1	0.0	13.1	0.2	0.0	13.1	0.2	0.0
L117	1,323.7	25.3	19.5	1,269.2	27.3	23.1	1,219.6	29.2	26.4
L118	1,207.6	25.2	20.5	1,141.5	27.0	24.3	1,081.4	28.7	27.8

Segment ID	2023			2034			2044		
	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L119	843.9	17.1	11.9	796.1	19.1	14.5	752.7	20.9	16.9
L120	1,275.1	24.3	16.9	1,204.4	27.2	20.6	1,140.2	29.7	24.1
L121	2,389.6	53.1	29.8	2,264.6	60.7	36.3	2,150.9	67.6	42.3
L122	2,892.5	61.4	40.9	2,753.1	70.9	49.8	2,626.3	79.6	58.0
L123	2,897.6	61.5	41.0	2,757.9	71.0	49.9	2,630.9	79.7	58.1
L124	472.2	9.4	8.6	479.3	10.4	11.0	485.8	11.2	13.2
L125	303.3	7.3	1.2	332.3	8.4	4.1	358.6	9.3	6.7
L126	455.1	8.1	11.7	442.6	8.6	13.0	431.2	9.1	14.1
L127	4.0	0.2	0.1	4.1	0.2	0.1	4.1	0.2	0.2
L128	10.3	0.5	0.0	9.4	0.7	0.0	8.6	0.8	0.0
L129	28.7	1.4	0.4	27.3	1.7	0.4	26.1	2.0	0.5
L130	47.5	2.2	0.6	45.2	2.8	0.7	43.2	3.3	0.8
L131	233.2	3.8	0.8	235.1	4.7	1.1	236.8	5.5	1.4
L132	34.9	0.6	0.0	33.6	0.7	0.0	32.5	0.8	0.0
L133	32.3	0.6	0.0	31.1	0.7	0.0	30.0	0.8	0.0
L134	132.4	2.0	0.8	137.8	2.6	1.1	142.8	3.1	1.4
L135	22.3	0.3	0.1	23.3	0.4	0.2	24.1	0.5	0.2
L136	67.7	1.9	0.0	72.1	2.0	0.0	76.0	2.1	0.0
L137	78.7	2.2	0.0	83.8	2.3	0.0	88.4	2.5	0.0
L138	28.6	0.8	0.0	26.1	0.9	0.0	23.9	1.0	0.0
L139	51.0	1.5	0.0	51.1	1.8	0.0	51.2	2.0	0.0
L140	134.3	4.0	0.0	130.5	4.6	0.0	127.0	5.1	0.0
L141	78.5	2.3	0.0	76.3	2.7	0.0	74.2	3.0	0.0
L142	140.7	4.5	0.0	140.1	4.9	0.1	139.5	5.2	0.1
L143	126.0	4.0	0.0	125.4	4.4	0.1	124.9	4.7	0.1
L144	66.7	2.1	0.0	66.4	2.3	0.0	66.1	2.5	0.1

Abbreviations and Acronyms:

VMT = vehicle-miles-traveled
LDV = light-duty vehicles
MDV = medium duty vehicles
HDV = heavy duty vehicles

Table B-7: Hourly PM Peak Period Vehicle Miles Traveled (VMT) by Vehicle Weight Class and Model Year

Segment ID	2023			2034			2044		
	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L001	877.7	39.5	2.1	767.3	40.4	2.2	666.9	41.3	2.3
L002	928.9	38.1	1.9	826.0	39.1	2.0	732.4	40.0	2.1
L003	261.4	10.7	0.5	232.5	11.0	0.6	206.2	11.3	0.6
L004	989.8	41.1	2.6	878.7	41.5	2.7	777.6	41.9	2.9
L005	1,420.3	48.1	2.6	1,312.4	50.1	2.7	1,214.3	51.9	2.9
L006	431.6	16.7	1.2	397.1	17.6	1.3	365.7	18.4	1.3
L007	414.8	15.4	1.9	400.7	16.6	2.1	387.9	17.7	2.3
L008	875.7	28.0	4.8	856.7	30.5	5.7	839.4	32.7	6.5
L009	801.6	26.5	3.0	769.8	29.2	3.8	741.0	31.6	4.6
L010	4,127.1	149.3	27.2	4,388.2	183.2	33.0	4,625.6	214.1	38.3
L011	953.1	34.9	7.7	971.4	41.7	9.3	988.0	47.9	10.8

Segment ID	2023			2034			2044		
	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L012	1,014.1	36.2	7.7	1,035.2	43.6	9.4	1,054.4	50.4	11.0
L013	1,466.8	43.3	8.1	1,463.3	51.6	9.9	1,460.2	59.2	11.4
L014	891.1	20.9	6.1	883.5	24.1	7.3	876.5	27.0	8.5
L015	708.0	25.6	6.9	742.1	29.1	7.9	773.1	32.3	8.8
L016	948.7	32.7	6.7	1,002.0	37.1	7.7	1,050.5	41.1	8.6
L017	1,730.3	66.0	15.8	1,903.5	76.6	18.7	2,060.9	86.2	21.3
L018	4,671.1	165.6	36.8	4,462.8	161.3	43.0	4,273.4	157.3	48.6
L019	866.2	28.7	7.3	873.4	29.0	9.1	879.9	29.3	10.7
L020	808.6	29.9	7.3	819.6	30.1	9.0	829.6	30.3	10.6
L021	279.9	12.9	0.9	305.3	14.3	1.0	328.4	15.5	1.2
L022	486.6	20.4	1.1	526.1	22.8	1.4	562.0	25.0	1.7
L023	610.5	34.7	2.4	714.4	38.8	3.0	808.8	42.6	3.6
L024	251.2	12.7	0.8	294.6	14.2	1.0	334.1	15.6	1.2
L025	774.9	38.4	1.9	901.3	43.8	2.3	1,016.2	48.6	2.8
L026	546.5	31.4	1.6	651.8	35.8	2.0	747.5	39.7	2.4
L027	210.9	5.7	0.1	196.0	5.8	0.1	182.6	5.9	0.1
L028	202.6	5.2	0.2	186.9	5.3	0.2	172.6	5.4	0.2
L029	186.5	3.7	0.8	179.8	3.9	1.0	173.8	4.0	1.2
L030	191.2	3.8	0.8	184.4	4.0	1.0	178.3	4.1	1.2
L031	297.5	8.3	0.1	277.5	8.4	0.1	259.4	8.5	0.1
L032	259.1	4.5	1.5	255.6	4.6	1.9	252.4	4.8	2.3
L033	316.3	9.4	4.4	301.2	8.3	5.4	287.5	7.4	6.3
L034	76.1	2.2	0.0	90.0	2.4	0.0	102.7	2.5	0.0
L035	3,605.3	94.1	87.3	3,854.1	100.5	101.2	4,080.4	106.3	113.9
L036	1,156.3	28.1	32.4	1,230.8	29.3	37.6	1,298.4	30.3	42.3
L037	2,159.6	55.7	52.1	2,232.3	55.3	61.0	2,298.4	55.0	69.2
L038	2,356.1	61.1	55.7	2,559.7	64.8	65.3	2,744.8	68.1	74.1
L039	1,695.5	44.1	35.9	1,731.3	44.0	42.0	1,763.9	43.8	47.6
L040	1,315.2	29.9	33.8	1,354.7	28.9	39.6	1,390.6	28.0	44.9
L041	1,292.7	27.0	35.2	1,351.3	26.5	41.4	1,404.5	26.1	46.9
L042	929.1	19.4	25.3	971.2	19.1	29.7	1,009.5	18.7	33.7
L043	984.1	18.9	24.6	1,074.7	18.5	28.9	1,157.1	18.2	32.8
L044	2,012.7	36.7	43.5	2,132.5	38.3	50.9	2,241.4	39.6	57.6
L045	3,809.1	67.0	87.4	4,006.3	69.5	102.2	4,185.6	71.7	115.7
L046	7,727.7	132.3	154.5	8,284.4	140.1	180.1	8,790.4	147.2	203.4
L047	6,097.9	73.2	102.7	7,010.6	75.9	119.3	7,840.3	78.4	134.5
L048	1,464.6	23.3	24.6	1,629.0	25.3	28.7	1,778.4	27.1	32.5
L049	3,059.2	51.2	60.4	3,410.2	55.1	70.6	3,729.2	58.6	79.8
L050	3,845.3	64.5	69.5	4,330.6	70.3	81.2	4,771.7	75.5	91.9
L051	1,969.7	32.4	34.2	2,121.8	38.6	45.5	2,260.0	44.2	55.7
L052	249.6	4.0	5.0	278.0	4.7	5.9	303.8	5.4	6.8
L053	235.1	5.7	6.5	255.8	6.0	7.7	274.6	6.2	8.7
L054	2,591.9	52.4	54.8	2,771.5	63.5	80.2	2,934.7	73.5	103.4
L055	2,317.5	54.4	59.3	2,509.4	57.2	70.1	2,683.9	59.6	79.8
L056	1,673.0	38.4	47.3	1,826.2	40.3	55.9	1,965.4	42.1	63.7
L057	2,184.4	50.6	51.9	2,352.3	53.0	61.3	2,505.0	55.3	69.8
L058	644.4	14.9	19.5	695.5	15.7	22.5	742.0	16.4	25.2
L059	564.9	13.1	17.1	609.6	13.8	19.7	650.3	14.4	22.1

Segment ID	2023			2034			2044		
	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L060	2,250.9	52.1	68.2	2,429.3	54.8	78.7	2,591.5	57.3	88.2
L061	7,431.3	174.4	184.7	7,757.2	190.5	210.5	8,053.4	205.2	233.9
L062	3,801.5	89.3	98.1	3,981.5	97.1	116.7	4,145.2	104.2	133.6
L063	846.4	19.0	19.5	882.9	20.8	23.2	916.0	22.5	26.5
L064	2,894.2	54.1	84.4	2,962.3	57.2	96.3	3,024.2	60.0	107.1
L065	993.8	18.4	24.3	1,007.6	19.9	27.7	1,020.1	21.4	30.8
L066	1,484.1	25.3	33.5	1,465.4	27.5	38.2	1,448.3	29.5	42.5
L067	2,427.3	33.9	59.2	2,382.4	35.5	66.7	2,341.6	36.9	73.5
L068	5,224.2	78.6	100.4	5,082.7	82.1	113.0	4,954.1	85.2	124.4
L069	3,022.6	47.8	51.3	2,936.9	49.8	57.9	2,859.0	51.6	63.9
L070	111.4	4.1	0.1	119.1	4.7	0.1	126.1	5.2	0.2
L071	46.4	1.5	0.0	49.3	1.8	0.0	51.8	2.0	0.1
L072	346.2	11.3	3.6	382.3	13.2	4.1	415.1	15.0	4.5
L073	1,014.6	18.9	16.8	1,022.3	20.5	19.7	1,029.3	22.0	22.4
L074	484.6	11.3	6.0	432.4	10.8	6.9	384.9	10.5	7.7
L075	343.5	11.5	4.7	345.4	11.2	5.4	347.1	11.0	6.0
L076	568.5	19.6	8.3	571.6	19.2	9.5	574.4	18.8	10.6
L077	731.6	9.7	15.8	836.2	13.0	18.8	931.2	16.0	21.5
L078	319.5	7.4	1.0	341.7	7.7	2.0	361.9	7.9	3.0
L079	218.3	7.3	0.8	226.1	7.4	0.8	233.2	7.5	0.9
L080	213.6	3.6	0.6	232.9	3.8	1.7	250.5	4.0	2.6
L081	267.9	7.7	4.2	270.4	8.9	5.1	272.7	10.0	6.0
L082	407.9	12.9	4.1	406.1	16.1	5.0	404.4	19.0	5.8
L083	244.3	7.7	2.4	243.2	9.6	3.0	242.2	11.4	3.5
L084	109.8	2.9	0.1	115.0	3.5	0.1	119.8	4.0	0.1
L085	207.9	6.7	2.3	205.5	8.4	2.9	203.3	10.0	3.3
L086	124.4	1.4	1.1	127.6	1.8	1.5	130.5	2.1	1.8
L087	2,937.3	64.7	39.1	2,822.2	74.8	46.5	2,717.6	84.1	53.1
L088	3,494.0	76.9	46.6	3,357.1	89.0	55.3	3,232.7	100.0	63.2
L089	1,411.4	31.0	15.8	1,362.1	35.3	18.8	1,317.2	39.3	21.5
L090	2,008.1	44.3	28.6	1,948.5	48.2	33.9	1,894.3	51.8	38.8
L091	1,332.2	28.1	21.1	1,264.2	29.2	25.1	1,202.4	30.1	28.7
L092	1,164.9	24.0	15.5	1,103.8	24.4	18.2	1,048.3	24.7	20.6
L093	1,321.6	25.6	21.9	1,237.2	25.1	25.7	1,160.5	24.7	29.2
L094	200.4	2.9	3.1	225.4	3.6	3.9	248.2	4.2	4.7
L095	2,713.3	47.2	43.5	2,747.5	50.3	53.0	2,778.6	53.0	61.6
L096	1,934.2	35.9	33.1	1,965.3	38.2	40.3	1,993.5	40.4	46.9
L097	860.1	15.3	17.1	880.5	16.5	20.8	899.1	17.6	24.2
L098	932.5	16.3	21.7	966.9	17.7	26.4	998.1	19.0	30.7
L099	3,230.4	51.2	68.0	3,321.0	55.5	82.9	3,403.3	59.5	96.4
L100	8,483.5	128.6	144.3	8,098.1	134.6	173.8	7,747.7	140.0	200.7
L101	4,094.6	66.4	79.5	4,094.7	70.7	95.9	4,094.7	74.7	110.8
L102	725.4	14.4	6.1	720.4	17.3	7.3	715.9	19.9	8.3
L103	242.8	4.7	1.9	252.4	5.9	2.3	261.2	6.9	2.6
L104	607.5	13.6	7.2	593.2	16.1	8.5	580.2	18.4	9.6
L105	360.9	8.7	5.6	354.6	10.0	6.1	348.9	11.3	6.5
L106	151.4	2.2	0.1	174.9	3.0	0.1	196.3	3.8	0.1
L107	56.6	0.8	0.0	65.4	1.1	0.0	73.4	1.4	0.1

Segment ID	2023			2034			2044		
	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L108	356.7	5.5	0.2	390.0	6.8	0.3	420.3	8.0	0.5
L109	2,076.6	61.3	70.5	2,127.3	66.1	78.3	2,173.5	70.5	85.4
L110	3,309.8	88.7	92.3	3,132.5	86.7	101.9	2,971.2	84.8	110.6
L111	2,456.4	74.4	101.8	2,546.4	79.1	113.0	2,628.2	83.4	123.3
L112	932.3	26.2	27.1	951.2	28.0	30.1	968.4	29.6	32.8
L113	1,616.2	44.0	35.8	1,640.6	47.2	39.7	1,662.8	50.0	43.4
L114	1,167.0	30.6	24.8	1,188.7	32.8	27.6	1,208.3	34.7	30.1
L115	980.4	30.4	31.6	1,001.3	31.3	35.7	1,020.4	32.0	39.4
L116	11.8	0.3	0.0	14.0	0.4	0.0	15.9	0.4	0.0
L117	990.0	29.3	20.3	1,001.1	30.8	23.1	1,011.2	32.1	25.6
L118	890.3	29.3	21.4	901.9	30.5	24.3	912.4	31.6	27.0
L119	688.6	23.1	14.0	695.5	23.5	16.0	701.8	23.8	17.7
L120	1,106.2	32.8	19.9	1,072.7	33.3	22.7	1,042.3	33.8	25.2
L121	2,272.5	69.7	34.9	2,302.2	72.2	39.4	2,329.2	74.4	43.4
L122	2,719.8	82.9	47.6	2,757.0	86.1	53.7	2,790.8	89.1	59.3
L123	2,724.6	83.0	47.7	2,761.8	86.3	53.8	2,795.7	89.3	59.4
L124	473.2	10.2	5.1	480.6	11.5	5.4	487.5	12.8	5.7
L125	401.9	6.6	0.2	420.7	7.4	0.4	437.8	8.2	0.7
L126	378.2	9.8	7.4	374.3	11.1	7.6	370.8	12.3	7.9
L127	11.7	0.3	0.3	10.3	0.3	0.3	9.0	0.3	0.4
L128	60.6	0.8	0.1	56.8	1.0	0.0	53.3	1.2	0.0
L129	136.6	2.2	0.9	126.2	2.6	0.9	116.7	3.0	1.0
L130	226.1	3.7	1.4	208.9	4.4	1.5	193.2	5.0	1.6
L131	174.4	4.1	3.2	177.8	4.6	2.1	180.9	5.0	1.1
L132	19.3	0.4	0.0	19.4	0.5	0.0	19.6	0.6	0.0
L133	17.8	0.3	0.0	18.0	0.5	0.0	18.1	0.6	0.0
L134	118.5	3.0	3.1	121.5	3.2	2.0	124.1	3.3	1.0
L135	20.0	0.5	0.5	20.5	0.5	0.3	21.0	0.6	0.2
L136	96.7	1.3	0.0	97.5	1.6	0.0	98.2	1.9	0.0
L137	112.4	1.6	0.0	113.3	1.9	0.0	114.2	2.2	0.1
L138	35.5	1.3	0.0	36.1	1.5	0.1	36.7	1.7	0.1
L139	78.8	1.9	0.0	77.5	1.9	0.0	76.3	2.0	0.0
L140	193.4	5.3	0.1	192.2	5.7	0.1	191.1	6.2	0.2
L141	113.0	3.1	0.0	112.3	3.4	0.1	111.7	3.6	0.1
L142	143.7	3.7	0.0	142.7	4.1	0.0	141.9	4.5	0.0
L143	128.7	3.3	0.0	127.8	3.7	0.0	127.1	4.0	0.0
L144	68.1	1.7	0.0	67.7	1.9	0.0	67.3	2.1	0.0

Abbreviations and Acronyms:

VMT = vehicle-miles-traveled
LDV = light-duty vehicles
MDV = medium duty vehicles
HDV = heavy duty vehicles

Table B-8: Daily Vehicle Miles Traveled (VMT) by Vehicle Weight Class and Model Year

	2023			2034			2044		
Segment ID	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L001	9,851.7	514.4	30.1	9,898.1	556.9	34.0	9,940.4	595.5	37.5
L002	10,623.5	497.8	27.6	10,669.3	538.8	31.1	10,710.9	576.0	34.4
L003	2,990.1	140.1	7.8	3,003.0	151.6	8.8	3,014.7	162.1	9.7
L004	11,130.7	534.4	38.0	11,168.9	571.2	43.0	11,203.6	604.6	47.5
L005	15,320.6	635.0	38.4	15,299.6	691.6	43.4	15,280.6	743.1	48.0
L006	4,693.4	219.4	17.0	4,660.5	234.8	19.2	4,630.6	248.8	21.3
L007	5,317.6	209.7	28.4	5,388.4	225.7	32.0	5,452.8	240.3	35.3
L008	10,871.2	418.9	97.0	10,991.8	477.5	114.9	11,101.4	530.9	131.2
L009	9,515.3	408.6	59.0	9,421.9	471.6	69.7	9,336.9	528.9	79.4
L010	57,079.7	2,268.4	496.3	60,505.9	2,703.8	571.4	63,620.6	3,099.6	639.7
L011	12,394.8	501.7	140.4	12,848.0	594.1	161.7	13,260.1	678.1	181.1
L012	12,869.4	514.5	142.8	13,400.5	612.4	164.6	13,883.3	701.4	184.4
L013	18,835.6	650.2	152.5	19,161.7	760.9	175.6	19,458.2	861.5	196.6
L014	10,640.5	332.2	113.6	10,675.6	374.9	130.9	10,707.6	413.7	146.6
L015	12,013.9	376.9	124.2	12,039.0	424.0	147.3	12,061.8	466.7	168.3
L016	14,913.7	504.0	120.6	15,137.7	582.4	143.1	15,341.4	653.7	163.5
L017	27,673.9	1,060.0	295.2	28,989.2	1,246.9	353.4	30,184.9	1,416.8	406.4
L018	72,359.4	2,750.1	676.2	67,249.2	2,834.9	802.1	62,603.6	2,912.1	916.6
L019	12,872.5	466.0	130.1	12,560.7	494.4	162.4	12,277.2	520.2	191.7
L020	11,999.5	462.2	129.3	11,530.3	486.4	161.2	11,103.6	508.4	190.3
L021	4,221.1	181.8	12.4	4,123.4	194.9	15.0	4,034.6	206.9	17.4
L022	8,493.7	314.3	18.0	8,246.8	337.7	21.6	8,022.4	359.1	24.9
L023	11,324.7	536.8	38.1	11,164.3	573.4	46.0	11,018.6	606.6	53.2
L024	4,351.6	190.6	12.7	4,336.2	204.6	15.1	4,322.3	217.5	17.3
L025	13,059.7	581.5	33.1	12,924.3	628.7	37.5	12,801.2	671.6	41.5
L026	9,801.3	474.8	28.4	9,659.2	513.1	32.2	9,530.1	547.8	35.7
L027	2,248.6	76.1	2.0	2,263.8	85.7	2.3	2,277.5	94.5	2.5
L028	2,124.9	73.6	4.0	2,064.9	78.5	4.5	2,010.4	82.9	4.9
L029	2,501.1	72.2	14.7	2,548.7	79.2	18.3	2,592.0	85.5	21.6
L030	2,565.2	74.1	15.1	2,614.0	81.2	18.8	2,658.4	87.7	22.2
L031	3,195.5	106.9	1.6	3,265.3	123.5	1.8	3,328.7	138.5	2.0
L032	3,873.2	103.6	28.5	4,014.5	115.1	35.8	4,142.9	125.5	42.5
L033	4,633.3	161.2	79.6	4,391.7	166.4	99.6	4,172.1	171.2	117.8
L034	1,024.3	19.2	0.4	1,062.3	23.5	0.5	1,096.9	27.5	0.6
L035	59,247.4	1,349.8	2,005.8	60,706.4	1,440.0	2,362.7	62,032.8	1,522.0	2,687.2
L036	18,281.4	395.5	756.3	18,784.0	420.2	892.2	19,240.9	442.6	1,015.7
L037	33,455.9	837.9	1,174.3	33,685.1	881.1	1,396.0	33,893.6	920.4	1,597.5
L038	36,287.7	916.2	1,256.5	37,901.2	1,016.8	1,494.3	39,368.0	1,108.2	1,710.4
L039	25,264.3	651.8	808.4	25,471.4	693.2	961.0	25,659.6	730.9	1,099.6
L040	18,837.3	467.2	763.3	19,196.5	481.6	907.5	19,523.1	494.7	1,038.5
L041	17,568.6	395.0	797.4	18,162.9	402.4	948.2	18,703.1	409.0	1,085.3
L042	12,627.1	283.9	573.1	13,054.2	289.2	681.5	13,442.5	294.0	780.0
L043	12,854.1	276.2	557.5	13,948.5	281.3	662.9	14,943.5	285.9	758.7
L044	27,835.8	645.3	987.0	29,195.2	704.3	1,165.3	30,431.1	758.0	1,327.4
L045	52,769.2	1,237.7	1,983.6	55,383.8	1,342.8	2,342.0	57,760.8	1,438.3	2,667.9
L046	98,898.9	2,286.0	3,396.6	105,954.2	2,499.8	4,006.4	112,368.1	2,694.1	4,560.8

Segment ID	2023			2034			2044		
	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L047	83,725.8	1,277.1	2,632.7	96,072.3	1,375.2	3,139.1	107,296.4	1,464.3	3,599.5
L048	20,060.7	429.2	669.9	21,964.8	467.1	803.3	23,695.8	501.5	924.6
L049	43,630.5	929.2	1,647.5	46,662.2	979.1	1,975.6	49,418.3	1,024.5	2,274.0
L050	53,828.7	1,161.2	1,895.0	58,156.4	1,243.3	2,272.5	62,090.7	1,317.9	2,615.6
L051	29,650.9	654.5	991.2	31,440.0	718.5	1,285.4	33,066.4	776.7	1,552.9
L052	3,727.5	82.6	139.6	4,029.3	89.7	167.7	4,303.8	96.3	193.2
L053	3,801.7	83.8	153.6	4,117.9	89.8	181.6	4,405.3	95.2	207.0
L054	43,410.3	942.6	1,581.7	45,809.6	1,036.9	2,036.9	47,990.8	1,122.7	2,450.7
L055	37,791.6	835.8	1,438.2	40,580.5	876.4	1,679.3	43,115.8	913.2	1,898.4
L056	27,408.4	595.7	1,148.4	29,646.5	624.7	1,340.9	31,681.2	651.1	1,515.9
L057	35,924.7	767.5	1,252.1	38,231.2	808.8	1,461.6	40,328.1	846.4	1,652.0
L058	10,242.2	215.5	454.7	11,052.6	228.4	528.4	11,789.2	240.1	595.4
L059	8,977.2	188.9	398.5	9,687.5	200.2	463.1	10,333.1	210.4	521.9
L060	35,774.1	752.8	1,588.0	38,604.4	797.7	1,845.5	41,177.5	838.5	2,079.6
L061	116,495.9	2,838.3	4,299.2	122,234.5	3,048.3	4,945.2	127,451.4	3,239.2	5,532.5
L062	60,007.6	1,488.5	2,449.9	63,352.1	1,579.6	2,821.5	66,392.5	1,662.4	3,159.4
L063	13,027.0	318.4	485.8	13,707.3	340.1	559.5	14,325.8	359.8	626.6
L064	42,943.4	995.1	2,122.4	44,711.5	1,017.1	2,452.9	46,319.0	1,037.2	2,753.5
L065	14,315.1	353.9	611.1	14,820.8	372.2	706.2	15,280.6	388.8	792.7
L066	21,008.3	488.3	843.1	21,340.4	513.5	974.4	21,642.4	536.4	1,093.7
L067	30,956.9	661.2	1,530.1	31,685.5	679.1	1,765.6	32,347.8	695.4	1,979.7
L068	59,889.5	1,348.7	2,579.8	61,236.9	1,413.3	2,974.7	62,461.7	1,472.1	3,333.6
L069	35,546.2	839.6	1,302.1	36,324.5	888.5	1,504.8	37,032.2	932.9	1,689.0
L070	2,264.9	63.1	2.8	2,181.6	66.8	3.3	2,105.9	70.1	3.8
L071	1,046.8	29.6	1.0	1,007.5	32.0	1.1	971.7	34.1	1.3
L072	6,461.7	171.9	53.9	6,777.7	188.5	60.6	7,064.9	203.6	66.7
L073	12,015.2	323.1	255.1	12,195.5	359.8	290.6	12,359.4	393.3	322.9
L074	5,373.9	166.4	84.1	5,262.5	179.6	100.1	5,161.3	191.6	114.6
L075	4,724.9	167.2	66.2	4,647.6	180.0	78.5	4,577.4	191.7	89.7
L076	7,580.3	280.3	115.8	7,407.3	303.0	137.5	7,250.1	323.7	157.2
L077	9,310.5	211.7	250.9	9,790.2	245.8	278.2	10,226.2	276.9	302.9
L078	5,813.1	129.3	49.8	5,947.3	134.3	61.7	6,069.3	138.9	72.6
L079	4,215.3	102.0	10.2	4,163.3	109.0	11.6	4,116.0	115.4	12.8
L080	3,739.0	78.2	47.7	3,915.7	79.4	59.8	4,076.4	80.5	70.9
L081	5,213.5	145.5	89.0	5,196.1	159.8	104.0	5,180.2	172.8	117.7
L082	6,856.9	235.4	86.5	6,769.9	276.4	101.0	6,690.8	313.6	114.2
L083	4,107.0	141.0	51.8	4,054.9	165.5	60.5	4,007.6	187.9	68.4
L084	2,842.8	81.9	1.7	2,733.4	90.6	1.8	2,634.0	98.4	1.9
L085	3,233.7	115.1	49.8	3,212.0	136.7	58.2	3,192.2	156.2	65.8
L086	1,350.8	46.5	34.0	1,352.2	68.4	42.2	1,353.4	88.2	49.7
L087	35,181.5	1,160.0	724.7	34,401.7	1,248.6	828.0	33,692.7	1,329.1	921.9
L088	41,849.4	1,379.9	862.1	40,921.8	1,485.2	985.0	40,078.5	1,581.0	1,096.7
L089	17,602.3	545.8	295.2	17,231.7	584.6	337.1	16,894.9	619.9	375.1
L090	25,740.6	806.9	533.4	25,048.0	847.2	609.0	24,418.3	883.9	677.7
L091	15,182.2	447.4	365.6	14,301.9	450.6	416.8	13,501.5	453.6	463.3
L092	12,237.1	342.3	263.9	11,550.1	344.8	300.2	10,925.6	347.1	333.2
L093	11,990.0	328.3	371.4	11,399.0	323.2	423.5	10,861.8	318.7	470.9
L094	2,876.2	63.2	60.6	3,019.3	69.8	69.4	3,149.4	75.7	77.4

	2023			2034			2044		
Segment ID	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L095	30,415.7	747.6	785.8	30,477.9	777.4	897.6	30,534.4	804.5	999.3
L096	21,437.6	568.9	598.0	21,513.9	591.6	683.2	21,583.2	612.2	760.6
L097	9,091.2	242.3	309.0	9,206.4	253.9	353.0	9,311.1	264.5	393.0
L098	9,443.0	255.9	392.6	9,676.7	269.9	448.5	9,889.2	282.6	499.3
L099	31,711.2	802.6	1,231.4	32,386.0	846.6	1,406.7	32,999.5	886.6	1,566.1
L100	89,559.1	2,127.9	2,591.4	85,916.7	2,212.8	2,953.8	82,605.5	2,290.0	3,283.3
L101	43,247.3	1,094.5	1,430.4	43,327.5	1,161.1	1,630.7	43,400.5	1,221.7	1,812.9
L102	10,120.8	332.5	144.9	10,395.9	369.6	166.1	10,646.0	403.4	185.4
L103	3,371.1	107.6	44.8	3,461.6	118.5	51.4	3,543.8	128.3	57.3
L104	8,985.5	317.6	162.4	8,944.4	344.3	185.0	8,907.1	368.6	205.6
L105	5,521.9	167.5	129.5	5,497.5	182.9	143.7	5,475.3	196.9	156.6
L106	1,852.5	45.2	5.1	2,030.7	52.1	6.3	2,192.7	58.4	7.5
L107	692.6	16.9	1.9	759.2	19.5	2.4	819.7	21.8	2.8
L108	5,096.4	118.5	41.7	5,410.2	132.2	54.0	5,695.5	144.7	65.2
L109	38,770.5	983.4	1,365.1	39,238.3	1,071.4	1,562.0	39,663.5	1,151.3	1,741.0
L110	62,214.1	1,430.9	1,787.7	58,443.3	1,424.4	2,035.1	55,015.3	1,418.5	2,260.1
L111	48,553.1	1,217.2	1,964.7	49,134.3	1,307.7	2,245.6	49,662.8	1,390.1	2,500.9
L112	16,305.4	425.9	523.1	16,257.5	450.9	597.9	16,214.0	473.7	665.9
L113	26,384.8	688.2	689.7	26,221.2	729.7	788.1	26,072.4	767.5	877.6
L114	18,858.7	478.1	479.2	18,765.2	506.9	547.5	18,680.2	533.2	609.7
L115	16,139.4	433.5	480.1	15,710.0	444.7	548.9	15,319.6	455.0	611.5
L116	158.8	3.0	0.1	164.7	3.6	0.1	170.1	4.3	0.1
L117	14,899.7	419.6	309.1	14,361.3	433.2	353.8	13,871.8	445.5	394.4
L118	13,186.7	407.9	326.0	12,730.0	419.2	373.1	12,314.9	429.5	416.0
L119	9,804.5	324.8	208.8	9,507.0	340.8	241.3	9,236.6	355.4	270.8
L120	15,204.8	461.3	296.5	14,749.9	484.1	342.7	14,336.4	504.8	384.7
L121	30,471.1	973.6	518.0	29,846.5	1,041.8	594.8	29,278.6	1,103.8	664.7
L122	35,306.7	1,155.1	706.8	34,543.8	1,242.2	811.6	33,850.2	1,321.4	906.9
L123	35,368.6	1,157.1	708.0	34,604.4	1,244.4	813.0	33,909.6	1,323.7	908.5
L124	7,508.6	179.1	158.3	7,633.2	196.8	180.8	7,746.5	212.9	201.2
L125	6,364.3	143.8	72.3	6,627.8	157.0	94.1	6,867.3	169.1	113.8
L126	6,012.5	149.8	175.9	5,986.9	165.3	191.8	5,963.6	179.5	206.2
L127	91.5	3.1	2.3	84.4	3.3	2.7	78.0	3.6	3.0
L128	442.2	8.6	0.3	410.0	10.6	0.2	380.6	12.4	0.1
L129	1,013.8	23.2	6.9	938.7	27.4	7.7	870.4	31.2	8.4
L130	1,677.7	38.4	11.4	1,553.5	45.3	12.8	1,440.5	51.6	14.0
L131	2,602.7	55.0	21.4	2,607.6	65.1	23.5	2,612.1	74.3	25.4
L132	353.1	7.3	0.3	342.6	8.4	0.3	333.1	9.5	0.3
L133	326.7	6.7	0.2	317.0	7.8	0.3	308.2	8.8	0.3
L134	1,580.1	34.0	20.5	1,615.1	40.7	22.5	1,646.9	46.9	24.3
L135	266.8	5.7	3.5	272.7	6.9	3.8	278.1	7.9	4.1
L136	1,179.4	24.3	0.4	1,197.7	28.1	0.5	1,214.3	31.5	0.6
L137	1,371.1	28.3	0.5	1,392.4	32.7	0.6	1,411.7	36.6	0.7
L138	407.2	16.7	0.2	371.2	17.2	0.4	338.5	17.6	0.5
L139	1,032.2	28.3	0.4	984.6	29.8	0.5	941.3	31.2	0.5
L140	2,438.3	75.8	1.0	2,297.8	79.2	1.4	2,170.0	82.3	1.7
L141	1,425.0	44.3	0.6	1,342.9	46.3	0.8	1,268.2	48.1	1.0
L142	2,334.4	68.4	1.2	2,167.6	72.1	0.9	2,015.9	75.5	0.6

Segment ID	2023			2034			2044		
	LDV	MDV	HDV	LDV	MDV	HDV	LDV	MDV	HDV
L143	2,090.8	61.3	1.0	1,941.4	64.6	0.8	1,805.5	67.7	0.6
L144	1,106.5	32.4	0.5	1,027.4	34.2	0.4	955.5	35.8	0.3

Abbreviations and Acronyms:

VMT = vehicle-miles-traveled
LDV = light-duty vehicles
MDV = medium duty vehicles
HDV = heavy duty vehicles

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