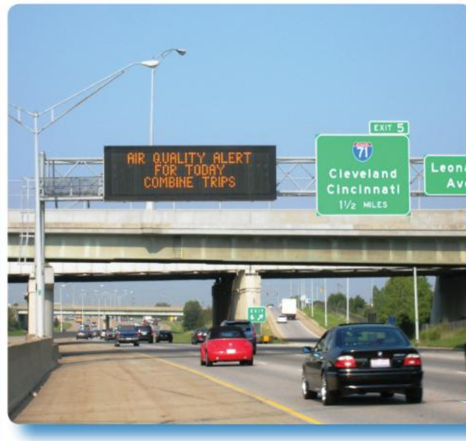
United States
Environmental Protection
Agency



Near-Road NO_2 Monitoring

Technical Assistance Document

DRAFT

August 11, 2011

Preface

This document (released August 11, 2011) is a draft of the Near-Road NO_2 Monitoring Technical Assistance Document (TAD). The TAD is being developed to aid state and local air monitoring agencies in the implementation of required near-road NO_2 stations. Note that this version of the TAD is a draft document and will be subjected to further revision. The EPA has released this draft version of the TAD for review by the Clean Air Scientific Advisory Committee (CASAC) Ambient Monitoring and Methods Subcommittee (AMMS), along with the ambient air monitoring and transportation agency communities.

The EPA will entertain comment on this version of the draft document from federal, state, and local air monitoring stakeholders and federal, state, and local transportation stakeholders during the period of the CASAC AMMS review. Upon conclusion of the CASAC AMMS review, the EPA will then revise the TAD, accounting for comments received, with the intent to release an updated version as soon as practicable.

Acknowledgments

Table of Contents

List of Figures

List of Tables

Executive Summary

In February of 2010, EPA promulgated new minimum monitoring requirements for the nitrogen dioxide (NO_2) monitoring network in support of a newly revised 1-hour NO_2 National Ambient Air Quality Standards (NAAQS). In the new monitoring requirements, state and local air monitoring agencies are required to install near-road NO_2 monitoring stations at locations where peak hourly NO_2 concentrations are expected to occur within the near-road environment in our larger urban areas. State and local air agencies are required to consider traffic volumes, fleet mix, roadway design, traffic congestion patterns, local terrain or topography, and meteorology in determining where a required near-road NO_2 monitor should be placed. In addition to those required considerations listed above, there are other factors that impact the selection and implementation of a near-road monitoring station including satisfying siting criteria, site logistics (e.g., gaining access to property and safety) and population exposure. The purpose of this Near-Road NO_2 Monitoring Technical Assistance Document (TAD) is to provide state and local air monitoring agencies with recommendations and ideas on how to successfully implement near-road NO_2 monitors required by the new (2010) revisions to the NO_2 minimum monitoring requirements.

This document also provides information on optional or discretionary multi-pollutant monitoring in the near-road environment. The establishment of near-road NO_2 monitoring stations will create an infrastructure that will likely be capable of housing other ambient air monitoring equipment. Considering the near-road NO_2 monitoring stations for multi-pollutant monitoring, even though it may not be required, matches with the Agency's multi-pollutant paradigm, presented in the *Ambient Air Monitoring Strategy for State, Local, and Tribal Air Agencies* document published in 2008, and has been noted within documents associated with the

NO_2 NAAQS revision of 2010 and the proposed Carbon Monoxide (CO) NAAQS revision of 2011. The intent of the multi-pollutant paradigm is to encourage the integration of multiple individual pollutant monitoring networks to broaden the understanding of air quality conditions and pollutant interactions, furthering the ability to evaluate air quality models, develop emissions control strategies, and support long-term scientific studies (including health studies). In light of this potential for multi-pollutant monitoring at near-road NO_2 sites, this TAD discusses other pollutants of interest that exist in the near-road environment, including definitions, basis of interest, and measurement methods.

Section 1. Background

On February 9, 2010, new minimum monitoring requirements for the nitrogen dioxide (NO_2) monitoring network were promulgated (75 FR 6474) in support of a revised Oxides of Nitrogen National Ambient Air Quality Standard (NAAQS). The NO_2 NAAQS was revised to include a 1-hour standard with a 98th percentile form and a level of 100 ppb, intending to protect against peak 1-hour exposures that may occur anywhere in an area, while retaining the annual standard of 53 ppb.

In the latest NO_2 Risk and Exposure Assessment (found at http://www.epa.gov/ttn/naaqs/standards/nox/s_nox_cr_rea.html) and reiterated in the preamble to the final NO_2 rulemaking, the EPA recognized that roadway-associated exposures account for a majority of ambient exposures to peak NO_2 concentrations. In particular, the EPA recognized that the combination of increased vehicle-miles-traveled (VMT), which correspond to on-road mobile source emissions, with higher urban population densities can result in an increased potential for exposure and associated risks to human health and welfare. As a result, the EPA promulgated requirements for near-road NO_2 monitors in urban areas where peak, ambient 1-hour NO_2 concentrations can be expected to occur that are particularly attributable to on-road mobile sources. Monitoring requirements are based upon population levels and a specific traffic metric within Core Based Statistical Areas (CBSAs). State and local ambient air monitoring agencies are required (per 40 CFR Part 58 Appendix D, Section 4.3.2.a) to use the latest available census figures (e.g., census counts and/or estimates) and available traffic data in assessing what may be required of them under this new rule. The required near-road NO_2 monitoring network is to be implemented and operational by January 1, 2013. State and local ambient air monitoring agencies are required to submit their plans for any required near-road NO_2 stations in their annual monitoring network plans due July 1, 2012.

The EPA believes that the site selection requirements and siting criteria for near-road NO_2 monitoring stations (presented in the Code of Federal Regulations and reiterated in this Technical Assistance Document [TAD]), provide sufficient flexibility to state and local air agencies for near-road NO_2 site implementation. This flexibility should allow state and local air agencies to balance the over-arching objective of placing monitor probes “as near as practicable” to highly trafficked roads where peak NO_2 concentrations are expected to occur with the variety of site implementation issues that exist in the real world. As such, the EPA strongly encourages states and local agencies to exercise due diligence in selecting and installing required near-road NO_2 stations, providing sound rationale of their decisions in light of the intention of the network design.

Section 2. Near-Road NO_2 Monitoring Technical Assistance Document Objectives

During the public comment period on the proposed NO_2 rulemaking, and upon the promulgation of the final NO_2 rulemaking that requires the near-road NO_2 monitoring network (75 FR 6474), the EPA received feedback from the air monitoring community requesting further clarification and/or assistance on how the required near-road NO_2 network might best be implemented. The EPA responded with a commitment to provide assistance through the form of this Near-Road NO_2 Monitoring TAD. The purpose of this TAD is to provide recommendations and ideas on how to successfully install near-road NO_2 monitors required by the recent revisions to the NO_2 monitoring requirements in 40 CFR Part 58 Appendices D and E.

The primary objective of this TAD is to provide a set of suggested technical approaches on the near-road NO_2 site selection process, including supplemental/optional methods, by which state and local air monitoring agencies might implement near-road NO_2 monitoring stations in a manner that satisfies 40 CFR Part 58 requirements. The material supporting this objective is primarily contained in Sections 3 through 13 of this document. Section 14 of this TAD presents information on other pollutants of interest in the near-road environment, which are not required to be measured unless noted otherwise. The characterization of these other pollutants and metrics can broaden the understanding of air quality conditions and pollutant interactions (particularly in the near-road environment), furthering the ability to evaluate air quality models, develop emissions control strategies, and support long-term scientific studies (including health studies). The information provided about these other pollutants or metrics of interest includes definitions, reason of interest, and measurement methods. In addition to the body of this TAD, the appendices provide a variety of supporting information and data. Finally, the EPA notes that the recommendations in this TAD should not be construed as requirements, but rather technically-appropriate approaches to implement required near-road NO_2 monitoring stations.

Section 3. Identifying Core Based Statistical Areas with Required Near-Road Monitoring

The first step in implementing required monitoring is for state and local ambient air monitoring agencies to identify the extent to which the monitoring requirements apply to their respective territories. Specifically, in 40 CFR Part 58 Appendix D, the EPA requires state and local air agencies to operate one near-road NO_2 monitor in each Core Based Statistical Area (CBSA) with a population of 500,000 or more persons. Further, those CBSAs with 2,500,000 or more persons, or those CBSAs with one or more roadway segments carrying traffic volumes of 250,000 or more vehicles (as measured by annual average daily traffic [AADT] counts), shall have two near-road NO_2 monitors. State and local ambient air monitoring agencies are required to use the most up-to-date census information and traffic data in assessing what may be required of them under this rule, per 40 CFR Part 58 Appendix D, Section 4.3.2.a. The process of identifying minimum monitoring requirements is shown in **Figure 3-1**.

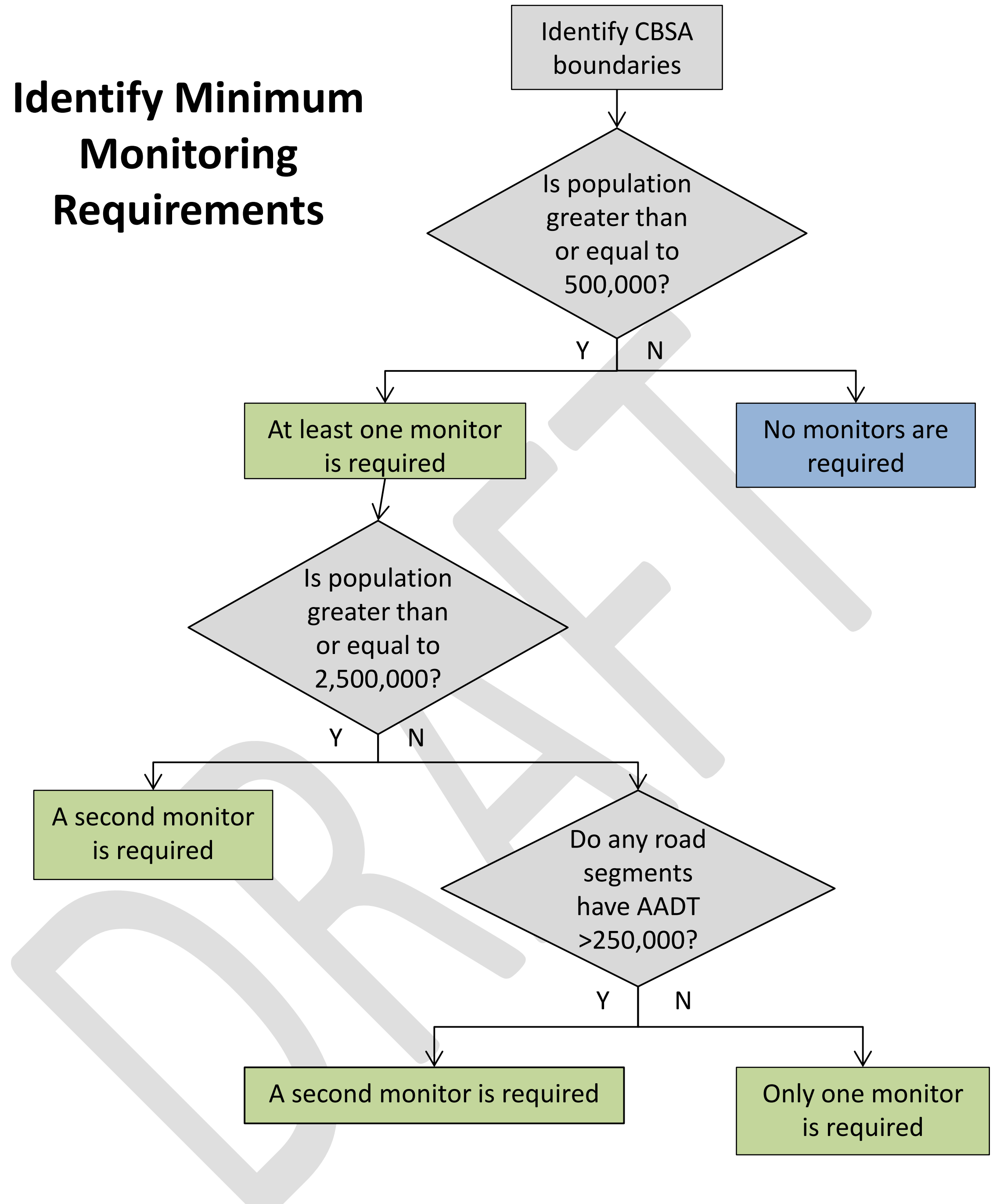


Figure 3-1. Flowchart illustrating the process of identifying whether minimum monitoring requirements for near-road NO2 monitors apply to individual core based statistical areas (CBSAs).

3.1 Identifying CBSA Boundaries

CBSAs are made up of whole counties, which may or may not all be within the same state. CBSA is a collective term for both micropolitan and metropolitan statistical areas[1]. Micropolitan (micro) and metropolitan (metro) statistical areas, and thus CBSAs, are geographic entities defined by the U.S. Office of Management and Budget (OMB) for use by Federal agencies in collecting, tabulating, and publishing Federal statistics, such as population.

A micro area contains an urban core in a county or counties of at least 10,000 people, but fewer than 50,000, while a metro area has one or more counties containing a core urban area of 50,000 people or more. Each micro or metro area consists of one or more counties and includes the counties containing the core urban area, as well as any adjacent counties that have a high degree of social and economic integration (as measured by commuting to work) with the urban core (U.S. Census Bureau, www.census.gov/population/www/metroareas/metroarea.html). A full explanation of the development and application can be found in the *Federal Register*, specifically, "Standards for Defining Metropolitan and Micropolitan Statistical areas; Notice" *Federal Register*, 56 (Wednesday December 27, 2000): 82228-82238.

The list of CBSAs, along with associated population data and estimate information, is conveniently available on the web from the U.S. Census Bureau (see Section 3.2 below). The use of CBSAs to define areas where near-road monitoring is to occur is appropriate because they account for populations within core urban areas and their surrounding communities. These areas are affiliated socially and economically as measured by commuting patterns that offer a direct relation between traffic and population. Further, because CBSAs include more than just the core

[1] Typically, in the ambient air monitoring culture, metropolitan statistical areas are synonymous with the acronym MSA.

urban areas, it is highly unlikely that roads with high total traffic volumes or high truck (or heavy-duty vehicle) traffic counts that are not located in the immediate vicinity of a core urban area would be overlooked and/or excluded in the consideration process for near-road monitoring.

3.2 Identifying Census Data

It is recommended that states and local air agencies use the U.S. Census Bureau as the source of their population estimates. A convenient list of CBSAs and their estimated populations have historically been available on the Census Bureau's website in the population estimate section (http://www.census.gov/popest/metro/metro.html). However, the Census Bureau is now encouraging the public to use the American Fact Finder for population-related information at http://factfinder.census.gov. The American Fact Finder can be used to locate population counts and demographic information for a CBSA, including data collected during the recent 2010 census. In addition to whole CBSA populations, information is also available at different geographic levels, such as block, block group, and census tract. The geographic boundaries of these levels can be found within reference maps on the American Fact Finder website.

3.3 Identifying Roadway Traffic Volumes in Excess of 250,000 AADT

It is recommended that state and local air agencies obtain traffic volume data from a state or local Department of Transportation (DOT), other local entities such as metropolitan planning organizations (MPOs), or from the U.S. DOT for the most up-to-date traffic information available, including AADT data. These data can then be analyzed to ascertain whether one or more road segments in a CBSA have an AADT count of 250,000 or greater, which would warrant a second near-road monitor if that CBSA has a population less than 2,500,000 persons.

Section 4.2 of this TAD provides a list of recommended sources for traffic volume data in the form of AADT.

3.4 Meeting Requirements in CBSAs Covering Multiple Geo-Political Boundaries (Multi-Agency/Multi-State)

In a number of cases, a CBSA may cover more than one state and/or cover an area shared by more than one air monitoring agency. In such cases, state and local air agencies are encouraged to engage each other, including all of the affected parties, in determining where any near-road monitoring may be conducted. These discussions are most helpful if conducted before and during the traffic data analysis process and while determining an initial list of candidate road segments (discussion starting in Section 5). This will ensure that all parties are aware of the most appropriate road segments to focus upon for identifying candidate near-road monitoring sites. Further, it is strongly advised that state and local agencies engage associated EPA Regional staff in identifying how multiple air monitoring agencies can collaborate to satisfy minimum monitoring requirements for individual CBSAs.

While EPA Regional staff should be readily available for consultation and participation in this process, the state and local air agencies are expected to take the lead on the decision making. One suggested result of this collaboration should be the inclusion of where all required near-road NO_2 monitors will be placed for a given CBSA in each affected party's annual monitoring network plan, regardless of whether a particular air agency will be operating a monitor.

Section 4. Recommended Traffic Data and Resources for Use in Identifying Candidate Road Segments for Near-Road NO_2 Monitoring

The key first steps in identifying candidate NO_2 near-road monitoring sites will be collecting and analyzing traffic data. Traffic data indicate the anticipated level and type of activity on a given road that can be used to compare anticipated pollutant emissions among multiple road segments in a CBSA. In order to begin traffic analysis, we must first define the target: a road. There are a number of terms that can be interchangeably used by the public to describe a road, but can have different meanings to individual transportation agencies (e.g., DOTs and other transportation authorities). These varied terms will be presented, defined, and discussed throughout the TAD as needed.

In general, a road can be defined as an open way for the passage of vehicles, persons, or animals on land. For the purposes of this TAD, the use of the term "road" or "roadway" shall be interpreted to include the entire cross-section or travel corridor (i.e., both directions of the primary travel lanes, plus any ramps, special use lanes, and included frontage roads) of any open ways for passage (over land and water) that may otherwise be labeled as a road, street, collector, arterial, highway, expressway, toll-way, parkway, freeway, or other such commonly used terms. Further, the near-road NO_2 site selection process suggested within this TAD calls for the evaluation of individual sections or lengths of a road where information about the traffic on the road is known and characterized.

For the purposes of this TAD, the term "road segment" or "roadway segment" is used to define a length of road between two points along a road. Road segments are typically defined by transportation agencies where road segment end-points are located at intersections, highway exits, highway mile markers, geo-political boundaries, or other features where traffic volumes or patterns are likely to change.

This section summarizes the data and sources that are recommended for use in generating a list of candidate road segments for evaluation as potential near-road NO_2 monitoring sites. The purpose of using these recommended data is ultimately to identify locations where the highest motor vehicle emissions leading to peak near-road NO_2 concentrations are likely to occur. In addition to the descriptions in this section, Appendix A provides more detailed information on the variability and some of the uncertainties of these parameters.

4.1 Annual Average Daily Traffic

AADT is a measure of the total volume of traffic on a roadway segment (in both directions) for one year divided by the number of days in the year. This parameter can be used to identify the relative traffic activity and corresponding potential for pollutant emissions experienced along roads. Generally, AADT is representative of the traffic volume along a given length of road or individual road segment. Some traffic data sources may present traffic counts at point locations instead of specifically representing a defined length of road. In these cases, the length and nature of individual road segments and their boundaries may need to be clarified for use in the recommended near-road NO_2 monitoring site selection process as presented in this TAD.

Traffic volume data are typically collected by state DOTs and other local sources, such as MPOs. AADT data sets generally comprise two types of data, recorded and estimated, which are merged to create a full data set. These data can vary from year to year, depending on actual changes in traffic volumes and based on the timing of when certain road segments are individually measured or estimated, since measurements are not made on every road segment in an urban area each year. However, for this TAD, data users may treat the measured and estimated data equally as long as they are using the latest available data, which is typically provided annually. In addition to traditional AADT data, metropolitan area urban travel demand models (TDMs) can also be consulted to estimate future traffic volumes on these segments if needed.

4.2 Sources of AADT Data

State or local traffic volume datasets are created by state DOTs and sometimes MPOs. Often, these data are available on DOT or MPO websites, and likely represent the most up-to-date traffic counts available. In addition to state or local sources, a national source for traffic data is the Highway Performance Monitoring System (HPMS), managed by the U.S. Department of Transportation (U.S. DOT). HPMS (http://www.fhwa.dot.gov/policy/ohpi/hpms/index.cfm) AADT data can be downloaded in shapefile format, either as one national file or by region, from the Bureau of Transportation Statistics' National Transportation Atlas Database (http://www.bts.gov/publications/national_transportation_atlas_database/). (Shapefiles contain data within a geospatial format, and thus are displayed as map features.)

One key issue regarding the use of data from HPMS is that the data may be one or more years older than data provided by state and local sources. This is because the data in HPMS originates from state DOTs and other local sources, and must be collected, reviewed, and otherwise processed by U.S. DOT before being presented in HPMS. It is thus recommended that state and local air agencies first attempt to obtain and use the most recent data set available from their state DOT or other local sources. In the event that sufficient traffic data are not available from state or local sources, it is then recommended that state and local air agencies use the most recent data available in HPMS for use in the near-road NO_2 monitoring site selection process.

Traffic volume data varies by location, but is most often provided as “counts” for particular road segments. The format of these count data may be available within an interactive interface or may come as downloadable tables, images, or shapefiles. To use shapefiles, state and local air agencies will need to use a mapping software program such as ArcGIS. Regardless of the formatting, state and local air agencies are encouraged to migrate the available data into a spreadsheet or database for use in a comparative process discussed in Section 5 of this TAD.

4.3 Fleet Mix Data

While AADT describes the total volume of traffic on a road, fleet mix data provides specific counts, or percentages of total traffic volume, of different types of vehicles that comprise the total traffic volume. Most commonly, fleet mix data differentiate between light-duty (LD) passenger vehicles and heavy-duty (HD) trucks. The manner in which fleet data are defined depends on the monitoring methods employed by the state or local transportation agency. In most cases, LD and HD vehicles are differentiated by either weight or length of vehicles on the road. The number of axles can also be used to identify HD from LD vehicles. In the U.S., LD vehicles typically burn gasoline, while HD trucks operate on diesel fuel. Understanding the number or percentage of HD vehicles within the total traffic volume is important because the difference in the amount of nitrogen oxides (NO_x) emitted on a per vehicle basis between the two vehicle types varies greatly. HD vehicles typically emit much higher amounts of NO_x than LD vehicles. Since these NO_x emissions include NO_2 (as well as nitrogen oxide [NO], which readily converts to NO_2 in the near-road environment in the presence of ozone, and which also can be oxidized to NO_2 through other photochemical processes), these emission differences are important in identifying locations where peak NO_2 concentrations may occur. For all vehicles, NO_x emissions vary by vehicle type, load, speed, and highway grade. More information on on-road mobile source NO_x emissions, based upon EPA's Motor Vehicle Emission Simulator (MOVES), can be found in Appendix B.

4.4 Sources of Fleet Mix Data

Similar to AADT data, fleet mix data are typically collected by state DOTs or possibly by MPOs. However, fleet mix data are not measured and disseminated as routinely as AADT data. Thus, fleet mix data availability is much more variable from state to state or between individual CBSAs. Further, fleet mix data may not be available for individual road segments, but for larger domains such as counties or urban areas. In cases where fleet mix data are available on a segment by segment basis, it is often available with related total AADT count data and files, the sources of which are discussed in Section 4.2. Similarly to AADT, state and local air agencies are encouraged to migrate the available fleet mix data into a spreadsheet or database, with AADT data, for use in a comparative process discussed in Section 5 of this TAD.

4.5 Congestion Patterns

Congestion patterns are an important factor in the near-road NO_2 site selection process because traffic congestion can lead to vehicle operating conditions, particularly stop-and-go traffic, that may increase emissions per vehicle (as compared to vehicles operating at steady-state highway speeds). Congestion pattern data can be presented in multiple forms. This TAD will discuss three metrics as examples of congestion data that can be used for consideration during the near-road NO_2 site selection process.

The first example of congestion pattern data is the level of service (LOS) metric. The LOS system describes the effectiveness of a transportation facility, such as a road segment. LOS is determined for individual road segments by the evaluation of multiple pieces of traffic information, including time-resolved traffic counts, traffic speeds, and the relative frequency of occurrence of congested conditions. The LOS is presented as a qualitative measure, using a letter grading system.

In the LOS grading framework, the grading ranges from A to F, where A describes a road segment with free flowing traffic conditions with speeds at or above the posted limit. Meanwhile, on the other end of the spectrum, the letter grade F represents the lowest measure of efficiency for a road segment, which has traffic subjected to forced flows, congestion, and frequent slowing and stopping during peak hours of use. As a result, when considering the candidacy of individual road segments for being a permanent near-road NO_2 site, congestion patterns can be considered in a qualitative manner. In the case of using LOS data to consider congestion patterns, those road segments with higher relative congestion (e.g., a worse letter grade) may be more likely to have relatively higher NO_2 emissions potential per vehicle than otherwise similar road segments with less congestion.

In some cases, LOS may be available for both directions of a particular road segment, and/or may be presented with multiple classifications based on season or time of day. In such cases, the EPA suggests that the worst letter grade LOS be used to represent that particular segment when making comparisons with other road segments. We believe this is an appropriate approach considering that the NO_2 NAAQS is an hourly standard, and the objective of the monitoring effort is to characterize the peak NO_2 concentrations that are occurring in the area. As such, the greatest impacts from traffic congestion on peak NO_2 concentrations, represented by LOS, are likely to occur during the worst indicated LOS conditions.

A second metric that can be used as a congestion pattern indicator is the volume-to-capacity ($^{V}/_{c}$) ratio. The $^{V}/_{c}$ ratio compares peak traffic volumes on a road segment with the capacity of the road based on the number of lanes. This calculation typically accounts for the larger size of HD vehicles and focuses on traffic conditions during peak hours of operation.

If LOS or $^{V}/_{c}$ data are not available, a third metric to assess possible congestion is a simple calculation to determine the "AADT by lane" for individual road segments. This indicator can be determined by dividing the total AADT by the number of lanes on a road segment. AADT by lane can be used to aid in understanding the potential congestion of a road segment in the absence of LOS or $^{V}/_{c}$ information by accounting for how much traffic volume is using a given number of available driving lanes. As such, a larger number of vehicles per lane indicate a greater potential for traffic congestion. However, AADT by lane is not based on the multiple metrics that LOS and $^{V}/_{c}$ are based upon, and should be viewed only as a rough surrogate to what these data might represent for a given road segment. Thus, AADT by lane is suggested for use only if LOS or $^{V}/_{c}$ data are not available. The method to calculate AADT by lane is discussed in section 4.6.

4.6 Sources of Congestion Pattern Data

LOS and $^{V}/_{c}$ data, if available, are determined and disseminated by state DOTs or MPOs. However, these metrics are not as common as AADT or fleet mix data and thus may not be available for all CBSAs where near-road NO_2 monitoring is required. If these data are not available from state DOTs or MPOs, the use of AADT by lane or some other similar congestion pattern metric is recommended as a surrogate. To determine AADT by lane, knowledge of the number of lanes on a road segment, along with the total number of vehicles on that segment is required. If those data are known, the AADT by lane can be estimated by using **Equation 1**.

$$\text{AADT by lane} = \text{AADT/Number of Lanes} \quad \textbf{(1)}$$

where AADT is the actual total traffic volume on the road segment, and the number of lanes is the total number of lanes, in both directions, on that road segment.

Section 5. Creating an Initial List of Candidate Road Segments Using Traffic Data

The site selection process for required near-road NO_2 monitors, per 40 CFR Part 58 Appendix D, includes the ranking of road segments in a CBSA by AADT, followed by the consideration of five other factors, which include fleet mix and congestion patterns, in the site selection process. The other three factors (roadway design, terrain, and meteorology) are discussed in Section 6 of this TAD.

This section presents a process by which state and local air agencies may use available traffic data to create an initial list of candidate road segments for further evaluation as potential near-road monitoring sites. In this process, the EPA believes that a state or local agency will be satisfying a portion of the minimum monitoring requirements by ranking road segments using AADT, and by considering both fleet mix and congestion patterns as factors in the ranking process. The purpose of this process is to identify road segments, ranked by priority, where peak NO_2 concentrations attributable to on-road mobile sources are most likely to occur in a CBSA on a routine basis. **Figure 5-1** presents a visualization of the traffic data evaluation process, reflecting the four steps presented in this section as a flowchart, providing alternate evaluation paths dependent on what traffic data may or may not be available. Subsequent to creating a prioritized list of road segments for further evaluation, state and local air agencies will be in a position to consider the three remaining factors required of them in CFR, which are roadway design, terrain, and meteorology, plus the additional case-by-case factors that will impact where near-road NO_2 sites might go, while working with partners and stakeholders (e.g., EPA Regions, transportation agencies).

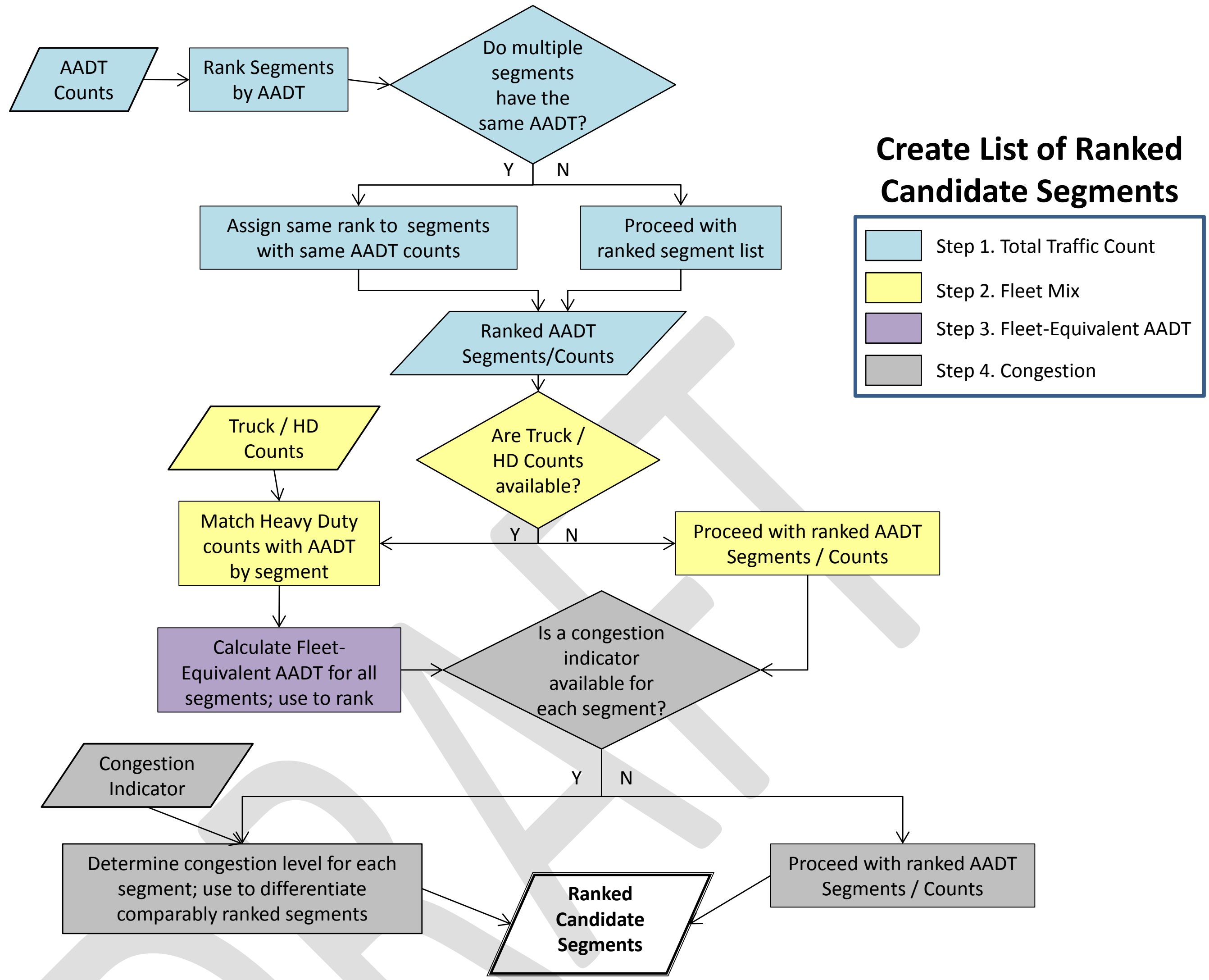


Figure 5-1. Candidate Road Segment Ranking Process. This flowchart presents the traffic data evaluation process to provide a prioritized list of candidate road segments (accounting for traffic volume [AADT], fleet mix, and congestion) for further evaluation as potential near-road NO2 monitoring stations.

5.1 Using AADT to Initially Rank Road Segments

The first step in the traffic data evaluation process is to satisfy the requirement in 40 CFR Part 58, Appendix D, section 4.3, to rank road segments in a CBSA based on the total traffic volume, represented by AADT. The intent of this first step is to begin to focus the evaluation process on road segments that are more likely to have higher potential for NO_x emissions due to their higher volumes of traffic.

STEP 1 – Generate a list of road segments in the CBSA in descending order, where the segment with the highest AADT is ranked first. This list should include the road segment ID, location information, road information, and AADT value at a minimum. In situations where two or more road segments have the same AADT value, those segments should be assigned the same numerical ranking.

Table 1 is an example of road segments ranked by AADT for the Tampa, Florida CBSA using 2009 data from the Florida DOT. It lists the roadway name in the first column, the physical end points of the road segment in columns two and three, AADT in the fourth, and the segment rank in the final column. Although all road segments were ranked in the development of this example, only the top thirty segments are listed here for illustrative purposes. State and local agencies should rank all segments for which data are available for each CBSA in this initial step.

Roadway	From	To	AADT	AADT Rank
I-275	Bridge No-100128	Bridge No-100110	192,000	1
I-275	CR587/WESTSHORE BLVD	Bridge No-100120	176,500	2
I-275	S600/U92/DALE MABRY	Bridge No-100128	170,500	3
I-275	Bridge No-100138	10320000/10320001	169,000	4
I-275	Bridge No-100110	Bridge No-100138	169,000	4
I-275	SLIGH AVE	Bridge No-100219	167,000	5
I-4	10320000/10320001	Bridge No-100658	164,000	6
I-275	Bridge No-100120	S600/U92/DALE MABRY	163,000	7
I-275	FLORIBRASKA AVE	Bridge No-100203	160,500	8
SR-60	SR 616	SR 93 / I-275	158,000	9
I-275	SR 600 / HILLS AVE	SLIGH AVE	156,500	10
I-275	Bridge No-100203	SR 600 / HILLS AVE	153,500	11
I-275	SR 580 / BUSCH BLVD	Bridge No-100231	151,500	12
I-275	Bridge No-100219	SR 580 / BUSCH BLVD	151,500	12
I-4	Bridge No-100658	US 41/SR 599/50TH ST	151,000	13
I-275	EAST END BR 150107	Bridge No-100115	147,000	14
I-275	4TH ST N	END BRIDGE 150107	147,000	14
I-275	Columbus Dr	FLORIBRASKA AVE	147,000	14
I-4	US 301 / SR 43	I-75/SR 93A	136,500	15
I-4	I-75/SR 93A	Mango Rd	136,500	15
I-4	Bridge No-100115	CR587/WESTSHORE BLVD	135,500	16
I-275	SR 688/Ulmerton Rd	4TH ST N	130,000	17
I-4	Mango Rd	MCINTOSH RD	127,000	18
I-275	GANDY BLVD/SR 694	ROOSEVELT BL/SR 686	123,000	19
I-275	38TH AVE N	54TH AVE N	123,000	19
I-275	ROOSEVELT BL/SR 686	N/A	123,000	19
I-275	54TH AVE N	GANDY BLVD/SR 694	123,000	19
I-275	22ND AVE N	38TH AVE N	123,000	19
I-4	SR 574/ML KING BLVD	ORIENT RD	122,000	20
I-4	US 41/SR 599/50TH ST	SR 574/ML KING BLVD	121,000	21
I-4	MCINTOSH RD	Bridge No-100599	117,932	22
I-4	ORIENT RD	US 301 / SR 43	113,000	23
I-75	GIBSONTON DR	SR 43 / US 301	111,500	24
I-4	Bridge No-100599	S566/THONOTOSASSA RD	110,000	25
I-75	SR 582 / FOWLER AVE	CR 582A/FLETCHER AVE	108,500	26
I-75	SR 400 / I-4	SR 582 / FOWLER AVE	108,500	26
I-75	SR 574/M L KING BLVD	SR 400 / I-4	108,500	26
RTE-41	OLD COLUMBUS DR(UNS)	N 48TH ST	107,500	27
I-4	Bridge No-100607	HILLS/POLK CO LINE	105,000	28

Roadway	From	To	AADT	AADT Rank
I-4	Bridge No-100605	Bridge No-100607	103,000	29
I-4	S566/THONOTOSASSA RD	Bridge No-100605	98,000	30

Table 1. Table 1 illustrates the ranking of road segments, as described in Step 1, for the Tampa, Florida, CBSA, using 2009 traffic data available from Florida DOT. Note that all available road segments within the CBSA were ranked; however, to conserve space within this document only the top 30 segments are shown in Table 1.

5.2 Combining Fleet Mix Data and AADT Data to Rank Road Segments

As discussed in Section 4.3, the fleet mix metric accounts for the amount of HD vehicles on a roadway, or the ratio of HD vehicles to LD vehicles on a road. Fleet mix is an important factor because of the higher amount of NO_x emitted by HD vehicles per vehicle. Therefore, accounting for fleet mix in the near-road NO_2 monitoring site selection process more accurately focuses the search on road segments where potential on-road emissions may more consistently lead to peak NO_2 concentrations in the near-road environment.

If fleet mix data are available on a segment by segment basis, or some other categorization up to a county by county characterization, proceed with Step 2. If you do not have fleet mix data that is differentiated within a CBSA, skip ahead to Step 4 in Section 5.3 below.

STEP 2 – Link the total volume of heavy-duty vehicles to the AADT list generated in Step 1, matching the two data sets by segment. If another form of fleet mix distribution is available (such as county level data), assign the available values or percentages to all the corresponding road segments.

Table 2 is updated from Table 1 and contains a new column for heavy-duty (HD) vehicles for each of the initial road segments found in Step 1 and presented in Table 1. For illustration purposes, the rows were re-ranked based on HD vehicle counts. In this example, the 28^{th} ranked AADT road segment had the highest HD counts. The top-ranked total AADT road segment from

Step 1 has the 27th highest rank based solely on HD counts. Again, this list is arbitrarily cut off to conserve space in this document; all segments with available data should be included in this step.

Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank
I-4	Bridge No-100607	HILLS/POLK CO LINE	105,000	28	15,719	1
I-4	Bridge No-100605	Bridge No-100607	103,000	29	15,388	2
I-4	Bridge No-100599	S566/THONOTOSASSA RD	110,000	25	15,279	3
I-4	S566/THONOTOSASSA RD	Bridge No-100605	98,000	30	14,396	4
I-4	US 301 / SR 43	I-75/SR 93A	136,500	15	14,073	5
I-4	I-75/SR 93A	Mango Rd	136,500	15	13,172	6
I-75	PASCO CO LINE	US 98 / CORTEZ BLVD	40,500	102	12,859	7
I-75	N/A	HERNANDO CO LINE	40,500	102	12,859	7
I-4	MCINTOSH RD	Bridge No-100599	117,932	22	12,595	8
I-75	GIBSONTON DR	SR 43 / US 301	111,500	24	12,577	9
I-4	10320000/10320001	Bridge No-100658	164,000	6	12,251	10
I-4	Bridge No-100658	US 41/SR 599/50TH ST	151,000	13	12,050	11
I-75	HILLSBOROUGH CO LINE	CR 54	68,500	49	11,542	12
I-4	SR 574/ML KING BLVD	ORIENT RD	122,000	20	11,236	13
I-75	SR 582 / FOWLER AVE	CR 582A/FLETCHER AVE	108,500	26	10,579	14
I-75	SR 400 / I-4	SR 582 / FOWLER AVE	108,500	26	10,579	14
I-75	SR 574/M L KING BLVD	SR 400 / I-4	108,500	26	10,579	14
I-75	CR 582A/FLETCHER AVE	C581/BRUCE B.DOWNS B	90,500	34	10,498	15
I-4	Mango Rd	MCINTOSH RD	127,000	18	10,465	16
I-75	SR 674/E COLLEGE AVE	Bridge No-100363	67,000	51	10,285	17
I-75	Bridge No-100363	GIBSONTON DR	89,000	35	10,217	18
I-75	SB I-275	NB I-275	60,500	60	9,462	19
I-75	HILLSBOROUGH COUNTY	SB I-275	60,500	60	9,462	19
I-75	C581/BRUCE B.DOWNS B	PASCO CO LINE	60,500	60	9,462	19
I-75	SR 52	N/A	40,000	103	9,304	20
I-275	FLORIBRASKA AVE	Bridge No-100203	160,500	8	9,229	21
I-275	EAST END BR 150107	Bridge No-100115	147,000	14	9,026	22
I-275	4TH ST N	END BRIDGE 150107	147,000	14	9,026	22
I-4	US 41/SR 599/50TH ST	SR 574/ML KING BLVD	121,000	21	9,014	23
I-75	MANATEE CO LINE	SR 674/E COLLEGE AVE	55,500	68	8,919	24
I-275	S600/U92/DALE MABRY	Bridge No-100128	170,500	3	8,713	25

Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank
I-275	SLIGH AVE	Bridge No-100219	167,000	5	8,684	26
I-275	Bridge No-100128	Bridge No-100110	192,000	1	8,467	27
RTE-41	OLD COLUMBUS DR(UNS)	N 48TH ST	107,500	27	8,342	28
I-275	Bridge No-100138	10320000/10320001	169,000	4	8,298	29
I-275	Bridge No-100110	Bridge No-100138	169,000	4	8,298	29
I-275	SR 688/Ulmerton Rd	4TH ST N	130,000	17	8,281	30
I-4	ORIENT RD	US 301 / SR 43	113,000	23	8,215	31
I-275	Bridge No-100120	S600/U92/DALE MABRY	163,000	7	7,824	32
I-275	Bridge No-100203	SR 600 / HILLS AVE	153,500	11	7,736	33
I-275	SR 600 / HILLS AVE	SLIGH AVE	156,500	10	7,669	34
I-75	N/A	SR 60/ADAMO DR	92,500	33	7,530	35
I-75	SR 43 / US 301	N/A	92,500	33	7,530	35
I-75	SR 60/ADAMO DR	SR 574/M L KING BLVD	92,500	33	7,530	35
I-275	CR587/WESTSHORE BLVD	Bridge No-100120	176,500	2	7,413	36

Table 2. Table 2 is updated from Table 1 to include fleet mix data as described in Step 2. It illustrates the ranking of road segments based on fleet mix for the Tampa, Florida, CBSA, using 2009 traffic data available from Florida DOT. The table was re-ranked by heavy duty vehicle AADT for illustrative purposes.

Comparing Table 1 to Table 2 is informative, but does not easily allow the ranked lists between both AADT and fleet mix to be simultaneously compared. In order to more easily compare one road segment to another, particularly when those road segments have a varied amount of both total traffic volume and heavy-duty vehicle volume, the EPA recommends the use of a unique metric that accounts for both total traffic volume and fleet mix for comparison purposes, called Fleet Equivalent (FE) AADT. With the FE AADT metric, roads can be re-ranked in an order that reflects both AADT and fleet mix (if information on the amount of heavy-duty vehicles that are present on each individual road segment are available) within one numerical value. Re-ranking by FE AADT presents a prioritized list of road segments that are more likely representative of estimated or potential NO_X emissions than either AADT or fleet mix alone. The determination of FE AADT per segment depends on three variables: (1) total traffic volume, presented as AADT counts, (2) fleet mix, presented as HD vehicle number counts, and (3) the heavy-duty to light-duty vehicle NO_X emission ratio. **Equation 2** can be used to determine a Fleet-Equivalent AADT value for each road segment:

$$\text{Fleet-Equivalent (FE) AADT} = (\text{AADT} - \text{HD}_c) + (\text{HD}_m * \text{HD}_c) \qquad \textbf{(2)}$$

where AADT is the total traffic volume count for a particular road segment, the HD_c variable is the total number of heavy-duty vehicles for a particular road segment, and the HD_m variable is a multiplier that represents the heavy-duty to light-duty NO_x emission ratio for a particular road segment.

The HD_m multiplier can be obtained several ways. One option is to determine HD_m from national average motor vehicle emission factors, resulting in the same HD_m value being used for all road segments being characterized in a CBSA. Alternatively, the HD_m value can be derived from local emissions estimates obtained in a given CBSA that can provide a specific HD_m value across the CBSA or for each individual road segment.

For this TAD, we have used the national default approach. In this approach, the national default value of 10 can be used for the HD_m variable and is applied and used in all examples where FE AADT is calculated. In using a national default where HD_m equals 10, the assumption is made that the NO_x emissions from one HD vehicle are equivalent to the NO_x emissions from ten LD vehicles operating on the same road segment and under the same environmental and relative operating conditions. When using the national default HD_m of 10, Equation 2 can be simplified to **Equation 3**.

$$\text{FE-AADT} = (\text{AADT} - \text{HD}_c) + (10 * \text{HD}_c) \qquad \textbf{(3)}$$

The details on the rationale for the national default HD_m value of 10, as well as guidance for local municipalities to calculate their own HD_m value, are included in Appendix B. The EPA notes that state and local air agencies do not have to use the national default ratio. If air agencies so desire, and have appropriate on-road vehicle fleet mix and speed characterizations for roads in their jurisdictions, they may calculate their own ratio, which may be more accurate for their particular road segment(s) of interest.

STEP 3 - Calculate the Fleet-Equivalent AADT values for each road segment using Equation 2 (if using locally derived HD to LD NO_X emission ratios) or 3 (using the national default HD to LD ratio of 10) of this TAD. Re-prioritize the candidate site list based upon FE AADT, where the road segment with the highest FE AADT value is ranked first and subsequent road segments are presented in descending order.

Table 3 is updated from Table 2 with an additional column to reflect FE AADT. The road segments have been re-ranked based on the FE AADT value. In this example, the 6^{th}-ranked

AADT (10^{th}-ranked HD) segment has moved to the 1^{st}-ranked position. Two notable changes are that the 1^{st} -ranked AADT (27^{th}-ranked HD) segment is only moved down to 2^{nd}, and that the 1^{st}-ranked HD segment (28^{th}-ranked AADT) is now ranked 8^{th}. This table illustrates that accounting for higher per-vehicle NO_X emission rates for HD vehicles using the heavy-duty to light-duty NO_X emissions ratio (described in Equations 2 and 3) has a significant effect on the ranking of the road segments for further consideration as candidate near-road NO_2 monitoring sites.

Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank	FE AADT	FE AADT Rank
I-4	10320000/10320001	Bridge No-100658	164,000	6	12,251	10	274,259	1
I-275	Bridge No-100128	Bridge No-100110	192,000	1	8,467	27	268,203	2
I-4	US 301 / SR 43	I-75/SR 93A	136,500	15	14,073	5	263,157	3
I-4	Bridge No-100658	US 41/SR 599/50TH ST	151,000	13	12,050	11	259,450	4
I-4	I-75/SR 93A	Mango Rd	136,500	15	13,172	6	255,048	5
I-275	S600/U92/DALE MABRY	Bridge No-100128	170,500	3	8,713	25	248,917	6
I-4	Bridge No-100599	S566/THONOTOSASSA RD	110,000	25	15,279	3	247,511	7
I-4	Bridge No-100607	HILLS/POLK CO LINE	105,000	28	15,719	1	246,471	8
I-275	SLIGH AVE	Bridge No-100219	167,000	5	8,684	26	245,156	9
I-275	Bridge No-100138	10320000/10320001	169,000	4	8,298	29	243,682	10
I-275	Bridge No-100110	Bridge No-100138	169,000	4	8,298	29	243,682	10
I-275	FLORIBRASKA AVE	Bridge No-100203	160,500	8	9,229	21	243,561	11
I-275	CR587/WESTSHORE BLVD	Bridge No-100120	176,500	2	7,413	36	243,217	12
I-4	Bridge No-100605	Bridge No-100607	103,000	29	15,388	2	241,492	13
I-275	Bridge No-100120	S600/U92/DALE MABRY	163,000	7	7,824	32	233,416	14
I-4	MCINTOSH RD	Bridge No-100599	117,932	22	12,595	8	231,287	15
I-275	EAST END BR 150107	Bridge No-100115	147,000	14	9,026	22	228,234	16
I-275	4TH ST N	END BRIDGE 150107	147,000	14	9,026	22	228,234	16
I-4	S566/THONOTOSASSA RD	Bridge No-100605	98,000	30	14,396	4	227,564	17
I-275	SR 600 / HILLS AVE	SLIGH AVE	156,500	10	7,669	34	225,521	18
I-75	GIBSONTON DR	SR 43 / US 301	111,500	24	12,577	9	224,693	19
I-4	SR 574/ML KING BLVD	ORIENT RD	122,000	20	11,236	13	223,124	20
I-275	Bridge No-100203	SR 600 / HILLS AVE	153,500	11	7,736	33	223,124	20
I-4	Mango Rd	MCINTOSH RD	127,000	18	10,465	16	221,185	21
I-275	SR 580 / BUSCH BLVD	Bridge No-100231	151,500	12	7,105	39	215,445	22
I-275	Bridge No-100219	SR 580 / BUSCH BLVD	151,500	12	7,105	39	215,445	22
SR-60	SR 616	SR 93 / I-275	158,000	9	5,941	42	211,469	23
I-275	Columbus Dr	FLORIBRASKA AVE	147,000	14	7,159	38	211,431	24
I-275	SR 688/Ulmerton Rd	4TH ST N	130,000	17	8,281	30	204,529	25
I-75	SR 582 / FOWLER AVE	CR 582A/FLETCHER AVE	108,500	26	10,579	14	203,711	26
I-75	SR 400 / I-4	SR 582 / FOWLER AVE	108,500	26	10,579	14	203,711	26

Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank	FE AADT	FE AADT Rank
I-75	SR 574/M L KING BLVD	SR 400 / I-4	108,500	26	10,579	14	203,711	26
I-4	US 41/SR 599/50TH ST	SR 574/ML KING BLVD	121,000	21	9,014	23	202,126	27
I-4	Bridge No-100115	CR587/WESTSHORE BLVD	135,500	16	7,371	37	201,839	28
I-4	ORIENT RD	US 301 / SR 43	113,000	23	8,215	31	186,935	29
I-75	CR 582A/FLETCHER AVE	C581/BRUCE B.DOWNS B	90,500	34	10,498	15	184,982	30
I-275	GANDY BLVD/SR 694	ROOSEVELT BL/SR 686	123,000	19	6,876	41	184,884	31
I-275	38TH AVE N	54TH AVE N	123,000	19	6,876	41	184,884	31
I-275	ROOSEVELT BL/SR 686	N/A	123,000	19	6,876	41	184,884	31
I-275	54TH AVE N	GANDY BLVD/SR 694	123,000	19	6,876	41	184,884	31
I-275	22ND AVE N	38TH AVE N	123,000	19	6,876	41	184,884	31
RTE-41	OLD COLUMBUS DR(UNS)	N 48TH ST	107,500	27	8,342	28	182,578	32
I-75	Bridge No-100363	GIBSONTON DR	89,000	35	10,217	18	180,953	33
I-75	HILLSBOROUGH CO LINE	CR 54	68,500	49	11,542	12	172,378	34
I-75	N/A	SR 60/ADAMO DR	92,500	33	7,530	35	160,270	35
I-75	SR 43 / US 301	N/A	92,500	33	7,530	35	160,270	35
I-75	SR 60/ADAMO DR	SR 574/M L KING BLVD	92,500	33	7,530	35	160,270	35
I-75	SR 674/E COLLEGE AVE	Bridge No-100363	67,000	51	10,285	17	159,565	36

Table 3. Table 3 is updated from Table 2 to reflect the calculation of Fleet Equivalent (FE) AADT as described in Step 3. As such, the listed road segments from the Tampa CBSA are ranked by FE AADT, which was calculated by using 2009 traffic data available from Florida DOT.

5.3 Using Congestion Pattern Indicators to Supplement Road Segment Rankings

The EPA does not recommend that any of the congestion indicators be used in a quantitative manner to further re-rank or re-prioritize the whole list of candidate road segments resulting from Step 3 (or Step 1 if fleet mix data are not available). Instead, such data are believed to be more useful as a qualitative measure by which one road segment might be selected over other relatively similar candidate road segments in the overall selection process. In such a situation, it is recommended that when using LOS data, a higher priority should be placed on road segments with a lower or worse LOS, where A is the highest or best LOS grade and F is the lowest or worst LOS grade. If LOS is not available, but either $^{\mathrm{V}}/_{\mathrm{C}}$ ratios or "AADT by lane" is available for use, a higher priority should be placed on road segments with higher $^{\mathrm{V}}/_{\mathrm{C}}$ or AADT per lane values.

> STEP 4 – Add the congestion indicator (LOS, $^{v}/_{c}$, or AADT by lane value from Equation 2, if available) to the candidate site list. These data will be used in the overall evaluation process, and can be used as a qualitative metric to aid in selecting one candidate road segment over other similarly ranked candidates.

Table 4 is updated from Table 3 with a column displaying congestion information in the form of LOS letter grades. The LOS for the example was gathered from five different data sources. Table 4 shows that a majority of the higher ranged FE AADT segments have a value of F for LOS, which indicates that these segments are also some of the most congested. As a result, there is little discernible difference among the higher FE-AADT ranked candidate sites for the Tampa CBSA example based on the congestion indicators.

Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank	FE AADT	FE AADT Rank	(1999 LOS) (2005 LOS) 2007 LOS *2007 LOS* 2010 LOS
I-4	10320000/10320001	Bridge No-100658	164,000	6	12,251	10	274,259	1	(F)
I-275	Bridge No-100128	Bridge No-100110	192,000	1	8,467	27	268,203	2	(F)
I-4	US 301 / SR 43	I-75/SR 93A	136,500	15	14,073	5	263,157	3	F
I-4	Bridge No-100658	US 41/SR 599/50TH ST	151,000	13	12,050	11	259,450	4	(F)
I-4	I-75/SR 93A	Mango Rd	136,500	15	13,172	6	255,048	5	F
I-275	S600/U92/DALE MABRY	Bridge No-100128	170,500	3	8,713	25	248,917	6	(F)
I-4	Bridge No-100599	S566/THONOTOSASSA RD	110,000	25	15,279	3	247,511	7	F
I-4	Bridge No-100607	HILLS/POLK CO LINE	105,000	28	15,719	1	246,471	8	F
I-275	SLIGH AVE	Bridge No-100219	167,000	5	8,684	26	245,156	9	(F)
I-275	Bridge No-100138	10320000/10320001	169,000	4	8,298	29	243,682	10	(F)
I-275	Bridge No-100110	Bridge No-100138	169,000	4	8,298	29	243,682	10	(D)
I-275	FLORIBRASKA AVE	Bridge No-100203	160,500	8	9,229	21	243,561	11	(F)
I-275	CR587/WESTSHORE BLVD	Bridge No-100120	176,500	2	7,413	36	243,217	12	(F)
I-4	Bridge No-100605	Bridge No-100607	103,000	29	15,388	2	241,492	13	F
I-275	Bridge No-100120	S600/U92/DALE MABRY	163,000	7	7,824	32	233,416	14	(F)
I-4	MCINTOSH RD	Bridge No-100599	117,932	22	12,595	8	231,287	15	F
I-275	EAST END BR 150107	Bridge No-100115	147,000	14	9,026	22	228,234	16	(E)
I-275	4TH ST N	END BRIDGE 150107	147,000	14	9,026	22	228,234	16	D
I-4	S566/THONOTOSASSA RD	Bridge No-100605	98,000	30	14,396	4	227,564	17	F
I-275	SR 600 / HILLS AVE	SLIGH AVE	156,500	10	7,669	34	225,521	18	(F)
I-75	GIBSONTON DR	SR 43 / US 301	111,500	24	12,577	9	224,693	19	C
I-4	SR 574/ML KING BLVD	ORIENT RD	122,000	20	11,236	13	223,124	20	E
I-275	Bridge No-100203	SR 600 / HILLS AVE	153,500	11	7,736	33	223,124	20	(F)
I-4	Mango Rd	MCINTOSH RD	127,000	18	10,465	16	221,185	21	F
I-275	SR 580 / BUSCH BLVD	Bridge No-100231	151,500	12	7,105	39	215,445	22	(E)
I-275	Bridge No-100219	SR 580 / BUSCH BLVD	151,500	12	7,105	39	215,445	22	(F)
SR-60	SR 616	SR 93 / I-275	158,000	9	5,941	42	211,469	23	(C)
I-275	Columbus Dr	FLORIBRASKA AVE	147,000	14	7,159	38	211,431	24	(F)
I-275	SR 688/Ulmerton Rd	4TH ST N	130,000	17	8,281	30	204,529	25	*D*

Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank	FE AADT	FE AADT Rank	(1999 LOS) (2005 LOS) 2007 LOS *2007 LOS* 2010 LOS
I-75	SR 582 / FOWLER AVE	CR 582A/FLETCHER AVE	108,500	26	10,579	14	203,711	26	F
I-75	SR 400 / I-4	SR 582 / FOWLER AVE	108,500	26	10,579	14	203,711	26	F
I-75	SR 574/M L KING BLVD	SR 400 / I-4	108,500	26	10,579	14	203,711	26	F
I-4	US 41/SR 599/50TH ST	SR 574/ML KING BLVD	121,000	21	9,014	23	202,126	27	F
I-275	Bridge No-100115	CR587/WESTSHORE BLVD	135,500	16	7,371	37	201,839	28	(F)
I-4	ORIENT RD	US 301 / SR 43	113,000	23	8,215	31	186,935	29	E
I-75	CR 582A/FLETCHER AVE	C581/BRUCE B.DOWNS B	90,500	34	10,498	15	184,982	30	F
I-275	GANDY BLVD/SR 694	ROOSEVELT BL/SR 686	123,000	19	6,876	41	184,884	31	*A, B, or C*
I-275	38TH AVE N	54TH AVE N	123,000	19	6,876	41	184,884	31	*E*
I-275	ROOSEVELT BL/SR 686	N/A	123,000	19	6,876	41	184,884	31	*D*
I-275	54TH AVE N	GANDY BLVD/SR 694	123,000	19	6,876	41	184,884	31	*F*
I-275	22ND AVE N	38TH AVE N	123,000	19	6,876	41	184,884	31	*F*
RTE-41	OLD COLUMBUS DR(UNS)	N 48TH ST	107,500	27	8,342	28	182,578	32	-
I-75	Bridge No-100363	GIBSONTON DR	89,000	35	10,217	18	180,953	33	D
I-75	HILLSBOROUGH CO LINE	CR 54	68,500	49	11,542	12	172,378	34	**(E)**
I-75	N/A	SR 60/ADAMO DR	92,500	33	7,530	35	160,270	35	D
I-75	SR 43 / US 301	N/A	92,500	33	7,530	35	160,270	35	B
I-75	SR 60/ADAMO DR	SR 574/M L KING BLVD	92,500	33	7,530	35	160,270	35	F
I-75	SR 674/E COLLEGE AVE	Bridge No-100363	67,000	51	10,285	17	159,565	36	C
I-75	PASCO CO LINE	US 98 / CORTEZ BLVD	40,500	102	12,859	7	156,231	37	**C**

Table 4. Table 4 is updated from Table 3, and now has congestion pattern information per segment from the Tampa, Florida, CBSA added in the last column. In this example, LOS data were available from Florida DOT. The segments are still ranked by FE AADT. Note that LOS data that were made available span several years; however, we have treated the data equally in this example.

5.4 Road Segment Ranking Process

Completion of as many of the steps in Sections 5.1 through 5.3 as possible (based on available traffic data) results in a prioritized list of candidate road segments in which the highest-ranked road segments are expected to be the locations where traffic volume, fleet mix, and congestion patterns combine to contribute to a greater potential for and/or more frequent occurrences of peak NO_2 concentrations in the near-road environment. **Table 5** summarizes the parameters described in this section, along with their recommended sources and/or methods of calculation, needed to produce the list of prioritized candidate road segments. This list is recommended to guide subsequent evaluation processes (described in the following sections of this document) to determine where permanent near-road NO_2 monitoring stations will be installed.

Table 5. Summary of the traffic-related metrics for candidate site consideration.

Component	Rationale	Potential Sources
AADT	Focus on locations with high traffic volumes	State DOT, local/MPO, or US DOT's HPMS
Fleet mix	Trucks emit greater amounts of NO_x on an average, per-vehicle basis	State DOT, local/MPO
Fleet equivalent (FE) AADT	Single metric to compare road segments, accounting for AADT and fleet mix	Use AADT and fleet mix in Equation 2 (Section 5.2)
Congestion	Frequent acceleration and idling can lead to higher per-vehicle emissions	State/local LOS; state DOT or HPMS (number of lanes); congestion maps

Section 6. Physical Considerations for Candidate Near-Road Monitoring Sites

Once an initial list of candidate sites is created, whether through a process such as that described in Section 5, through use of methods such as monitoring or modeling as described in Sections 8 and 9, or via other approaches, select segments should be further evaluated to determine adequacy for a near-road monitoring station. Specifically, candidate road segments need to be inspected to account for roadway design, terrain, and meteorological factors (covered in this section), and also for safety and logistical considerations, and possibly for population exposure potential (covered in subsequent sections). This section provides a brief review of the three, non-traffic related data considerations listed in the CFR: roadway design (including related roadside structures), terrain, and meteorology.

Table 6 provides an overview of the physical characteristics that need to be considered in evaluating candidate sites, including positive and negative attributes to consider. Additional details on these characteristics are included in the sections that follow.

Table 6. Summary of physical considerations for near-road candidate sites.

Physical Site Component	Impact on Site Selection	Desirable Attributes	Less Desirable Attributes	Potential Information Sources
Roadway design or configuration	Feasibility of monitor placements; affects pollutant transport and dispersion	Near ramps, intersections, lane merge locations/ interchanges; at grade with surrounding terrain	Cut-section/below grade; above grade (bridge)	Field reconnaissance; satellite imagery
Roadside Structures	Feasibility of monitor placement; affects pollutant transport and dispersion	No barriers present besides low (<2 m in height) safety features such as guardrails	Presence of sound walls, high vegetation, obstructive buildings	Field reconnaissance; satellite imagery
Terrain	Affects pollutant dispersion, local atmospheric stability	Flat or gentle terrain, within a valley, or along road grade	Along mountain ridges or peaks, hillsides, or other naturally windswept areas	Field reconnaissance; digital elevation models and vegetation files; satellite imagery
Meteorology	Affects pollutant transport and dispersion	Relative downwind locations – winds from road to monitor	Strongly predominant upwind positions	Local data; NOAA/NWS; AQS

6.1 Roadway Design

The design (or configuration) of a roadway can influence the amount of emissions generated from motor vehicles and the transport and dispersion of those emissions along and/or away from the road. Roadway design includes features of the road itself, such as the slope or grade of a roadbed (which is often a reflection of local terrain or topography), the presence of access ramps, intersections, interchanges, or other such locations where traffic may merge or disperse, and a roadbed's position relative to the immediate surrounding terrain. In particular, road grades create an increased load on vehicles ascending a grade, leading to increased exhaust emissions as the vehicle does more work to continue its forward motion. In addition, the presence of ramps, intersections, and lane merge locations can lead to increased but localized emissions due to the propensity for acceleration and potential for stop-and-go vehicle operations resulting from traffic congestion.

The relative position of a road to the immediate terrain around the roadway can have a significant influence on pollutant transport and dispersion along and/or away from the source road. The three general types of roadway design discussed here are at-grade, cut-section, and elevated roads.

6.1.1 At-Grade Roads

At-grade roads are those where the roadway surface (on which the vehicles are travelling) is generally at the same elevation as the surrounding terrain. In any particular wind condition (e.g., winds parallel or normal to the road) at-grade roads will experience the least amount of influence on pollutant dispersion among all roadway design types, not accounting for other structures or obstacles (discussed in Section 6.2) that can exist in the near-road environment.

6.1.2 Below-Grade or Cut-Section Roads

Cut-section roads are those where the roadway surface elevation is below the surrounding terrain. A cut-section road can have vertical or sloped walls, of which the walls can be natural or man-made. Under perpendicular wind conditions (normal to the road), cut-section roads tend to cause lofting of the traffic plume as wind flows through, up, and out of the depressed road canyon. With wind conditions parallel or near-parallel to the source road, on-road emissions may be funneled downwind for some distance with emissions contained, akin to what happens in an urban street canyon. Channeling of winds may also occur within the cut section as a result of turbulence and wind flow generated from the vehicles operating on the road.

6.1.3 Above-Grade or Elevated Roads

Elevated roadways are those where the roadway surface is higher, in the vertical, than the surrounding topography. Elevated roads can be elevated primarily in two ways: (1) roads built on an earthen berm or other solid material, where such earth or material may be referred to as "fill," with no open space underneath the road surface for airflow, and (2) roads built on pilings or supports with open space underneath, where air may flow both above and beneath the road surface, such as a bridge.

- Elevated roads over solid fill material can have similar dispersion patterns as at-grade roads with winds normal to the road, since shear forces can draw the traffic plume back to the surface, downwind of a sloped fill section. However, some fill configurations (e.g., those with vertical or sharply sloped walls) can cause the traffic plume to loft above the ground immediately adjacent to the vertical or sharply sloped wall (due to eddy formation immediately downwind of the roadbed), with the core of the emission plume impacting the ground further downwind from the vertical or sharply sloped wall.
- Elevated roads which are open underneath can have enhanced dispersion of on-road emissions with all wind directions. In these cases, emissions are more readily dispersed due to the increased dilution air (moving above and below the roadbed) and from the turbulence caused by the elevated road structure itself. Because of this, ground-level concentrations downwind of the elevated roadbed may not be as high as concentrations found at at-grade roads or similar roads which are elevated on fill.

6.1.4 Relative Desirability in Roadway Designs

The general understanding of the effect of roadway design on emissions dispersion as described above has been derived through review of near-road field studies and the use of wind tunnel facilities. For example, **Figure 6-1** shows an example from a wind tunnel study comparing roadway configurations and changes in near-road air pollutant concentrations (along a path normal to the source roadway) that illustrates these effects. These results can be translated to a qualitative hierarchy of relative desirability in roadway deigns for consideration in the near-road site selection process.

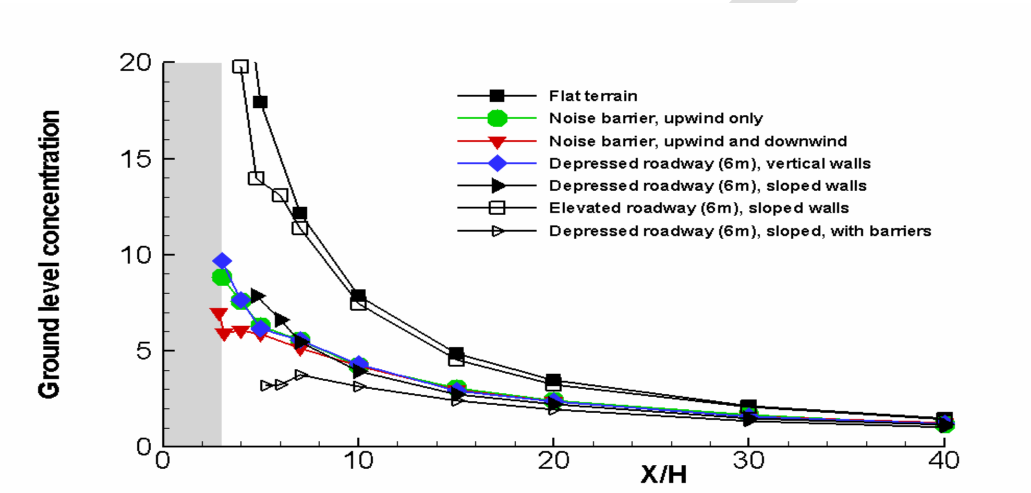


Figure 6-1. Wind tunnel study results comparing downwind air pollutant concentrations from a road with varying topography and roadside structures. The distance downwind (x-axis) is expressed in multiples of the height of the noise barrier studied (6 m for this figure). Multiplying the x-axis values by 6 provides an estimate of downwind concentrations at distances in units of meters. The ground-level concentrations have been non-dimensionalized to represent inert pollutant dispersion. This figure (from Baldauf et al., 2009; Heist et al., 2009) contains details on the wind tunnel studies.

Figure 6-1 highlights how roadside features can impact downwind pollutant concentrations under wind conditions normal to the source road. Notably, flat terrain, which would be representative of at-grade roads, shows the least disruption in dispersion, where relative ground-level concentrations are highest as on-road emissions are dispersed, with a Gaussian-type gradient, where concentrations decrease with increasing distance from the source roadway. At-grade road configurations would have the least complicated dispersion scenarios to consider while targeting maximum NO_2 concentrations, and thus be the most desirable setting for near-road NO_2 monitoring stations. The second most desirable near-road monitoring location is adjacent to elevated roads on fill material, where maximum concentrations are found that are very close in value to concentrations found at at-grade locations. Based on the data in Figure 6-1, those roadway designs that may be less preferable when considering near-road NO_2 monitor locations would be adjacent to elevated road that are open underneath, or cut (or depressed) road beds (where deeper cuts or depressions likely present increasingly more significant impacts or complications on pollutant dispersion). Recommendations on siting a monitor probe near above and below grade roads are discussed in Section 7.

6.2 Roadside Structures

In addition to the manner in which roadway design affects pollutant transport and dispersion, roadside structures may be present that also affect near-road pollutant concentrations. These structures include sound walls or noise barriers, vegetation, and buildings.

Physical barriers affect pollutant concentrations around the structure by blocking initial dispersion and increasing turbulence and initial mixing of the emitted pollutants. Figure 6-1 illustrates the potential effects of roadside barriers, as part of certain roadway designs, on the pollutant dispersion of on-road emissions. In Figure 6-1, those sample road configurations with noise barriers are shown to have the largest impacts on pollutant dispersion, relative to flat, at-grade roadway designs.

Additionally, Figure 6-1 specifically focuses on the impacts of roadside barriers on pollutant dispersion, based upon field measurements taken from three locations: (1) an open field, (2) behind a noise barrier, and (3) behind a noise barrier and mature vegetation stands. **Figure 6-2** illustrates how these roadside features can reduce downwind pollutant concentrations. In the figure, the pollutant is ultrafine particulate matter, which is a strong traffic emissions marker; however, the impacts on NO_2 concentrations would be similar. While these roadside structures can trap pollutants upwind of the structure, the effects are very localized and likely do not contribute to peak NO_2 exposures for the nearby, adjacent population.

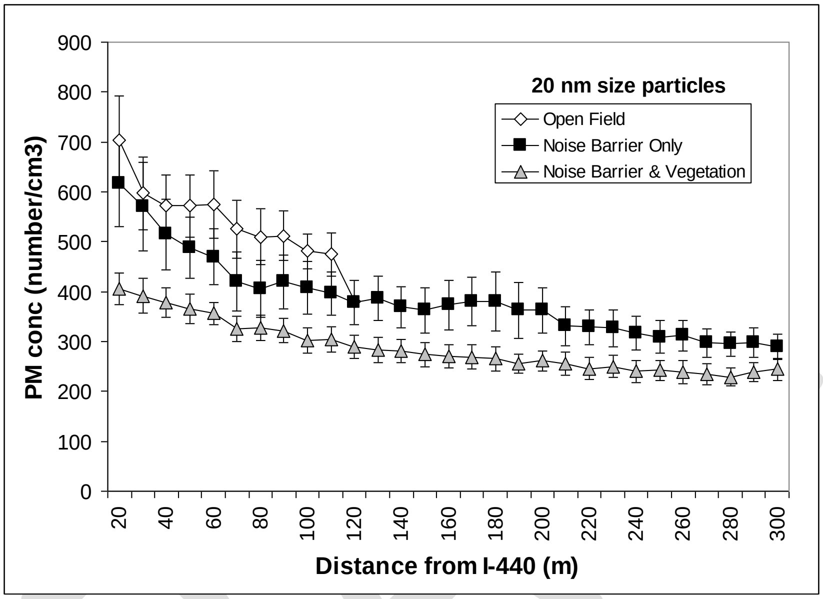


Figure 6-2. Measurements of 20 nm size particle number counts at varying distances from a 125,000 AADT highway for an at-grade road with no obstructions (Open Field), behind only a noise barrier (Noise Barrier Only), and behind a noise barrier with mature vegetation stands (Noise Barrier & Vegetation). Bars represent 95% confidence intervals for each distance (Baldauf et al., 2008b).

In other situations, such as when winds blow along the roadway, the barriers may channel emissions downwind, without much dispersion occurring normal to the road. As such, even if siting criteria can be met at a site, the EPA suggests that monitor placement adjacent to these structures be avoided when possible, particularly if other, similar candidate near-road locations are available that do not have such roadside structures.

6.3 Terrain

As mentioned in Section 6.1 (on roadway design), local topography is often a part of roadway design and can greatly influence pollutant transport and dispersion. However, large-scale terrain features, beyond the local roadway configuration, may also impact where peak NO_2 concentrations from on-road mobile sources can occur. The consideration of large-scale terrain in the siting process is more of a case-by-case issue for individual sites. In these cases, the EPA believes that state and local air agencies likely have a good understanding of large-scale terrain impacts on pollution dispersion in or within a CBSA, as these impacts would not be unique to near-road emissions, but also have effects on wider scale ambient monitoring.

In terms of making sure that larger scale terrain is considered in the near-road NO_2 site selection process, one example could be identifying multiple air basins within a single CBSA, and considering how individual basins may affect pollutant build-up and dispersion. Another example might be considering roads through valleys, where, due to the increased potential for inversion conditions within the valley, higher near-road NO_2 concentrations may be found than what is found along alignments on the tops of hills, along hillsides, or in open terrain.

6.4 Meteorology

Evaluating historical meteorological data could be useful in determining whether certain candidate locations may experience a higher proportion of direct traffic emission impacts from a given target road segment due to the local winds. More specifically, an evaluation of local meteorology may also provide some indication on which side of an individual road segment under consideration, might experience a higher proportion of direct traffic emission impacts from a given target road segment. Most studies showing elevated pollutant concentrations near roads have focused on measurements when winds were from the road to the downwind monitor or receptor (typically along a line normal to the roadbed). In addition to relatively small scale impacts on a candidate road segment, state and local air agencies may also consider other meteorological impacts, such as the frequency of inversions, which can lead to increased potential for pollutant build-up due to limited atmospheric mixing.

In the preamble to the final NO_2 rulemaking, it is noted that downwind monitoring is not required, but the EPA strongly encouraged it. Some evidence suggests that wind direction may not always be a major factor in leading to peak concentrations in close proximity to a major roadway. Often, peak NO_2 concentrations may occur during stable, low wind speed conditions. In addition, the turbulence created by vehicles on the road can lead to “upwind meandering” of pollutants, where a monitor upwind of the target road would still be characterizing on-road emissions. However, there are situations where meteorological patterns may warrant strong consideration for the relative downwind side of a target road segment. One example might be a road that runs relatively parallel to a coastline, where diurnal wind patterns, such as a sea breeze, may significantly impact pollutant build up and dispersion along that roadway. Another example might be roads in valley areas which are subject to air flows driven by diurnal mountain air flow patterns. Thus, historical wind directions should be considered in establishing NO_2 monitoring sites. In most cases, monitor placement on the climatologically down-wind side of a road segment is preferred; however, the EPA stresses that this should not preclude consideration of sites located in the predominant climatologically upwind direction in light of applicable site access, safety, and other logistical issues.

Section 7. Siting Criteria

The primary requirements related to horizontal and vertical probe placement for near-road NO_2 monitors are specified by the EPA in 40 CFR Part 58, Appendix E. Horizontal placement of near-road NO_2 monitor probes, with respect to the target roadway, are required to be installed so "…the monitor probe shall be as near as practicable to the outside nearest edge of the traffic lanes of the target road segment; but shall not be located at a distance greater than 50 meters, in the horizontal, from the outside nearest edge of the traffic lanes of the target road segment." The key component of this passage is that the monitoring probes are to be placed "as near as practicable" to the target road segment. Baldauf et al. (2009) note that a distance of 10 to 20 meters should be considered for near-roadway monitoring, and as such, the EPA strongly encourages state and local agencies to try to place near-road NO_2 monitor probes within 20 meters from target road segments when possible. Key requirements from 40 CFR Part 58, Appendix E are shown in **Table 7**.

Table 7. Key Near-Road Siting Criteria.

Near-Road NO2 Siting Criteria (per 40 CFR Part 58, Appendix E)	
Horizontal spacing	As near as practicable to the outside nearest edge of the traffic lanes of the target road segment; but shall not be located at a distance greater than 50 meters, in the horizontal, from the outside nearest edge of the traffic lanes of the target road segment. **The recommended target distance for near-road NO_2 monitor probes from the target road is within 20 meters whenever possible.**
Vertical spacing	Microscale near-road NO_2 monitoring sites are required to have sampler inlets between 2 and 7 meters above ground level.
Spacing from supporting structures	The probe must be at least 1 meter vertically or horizontally away from any supporting structure, walls, parapets, penthouses, etc., and away from dusty or dirty areas.
Spacing from obstructions	For near-road NO_2 monitoring stations, the monitor probe shall have an unobstructed air flow, where no obstacles exist at or above the height of the monitor probe, between the monitor probe and the outside nearest edge of the traffic lanes of the target road segment.

Vertical placement requirements of near-road NO_2 monitoring probes are "… to have the sampler inlet between 2 and 7 meters above ground level." There are several situations where the limits of the allowable vertical range for inlet probe heights may be appropriate. For example, if a candidate monitoring site is nearly at-grade with the target road, or if the target road is a cut-section road, the state and local air agency should consider placing the inlet probe closer to the 2 meter height limit above ground level. This recommendation is based on the information presented in Section 6.1, where the impact of the roadway designs will likely lead to peak concentrations more frequently occurring closer to ground level. Further, monitor probe placement at or near a 2 meter height above ground level is generally considered to be at or near "breathing height," which is a human exposure consideration.

Alternatively, if a near-road monitoring station is being considered for placement adjacent to an elevated fill section of road, particularly where the elevated roadbed has vertical or sharply sloped walls, the state or local air agency should consider placing the inlet probe higher in the 2 to 7 meter range above the ground level so that the sampler inlet might be closer to the elevation of the target road surface, if they are immediately adjacent to the target road. This follows the rationale, as discussed in Section 6.1, where emission plumes from elevated roads may be aloft in winds normal to the roadway (due to eddy formation immediately downwind of the roadbed) with the core of the emission plume impacting the ground further downwind from the vertical or sharply sloped wall. In this situation, depending on the relative difference in height between the target road surface and ground-level at the monitor probe location, and the steepness of the grade between the two locations, the state or local air agency could also consider placing the monitor probe slightly further away from the target road to avoid situations where the inlet probe may be in the eddy cavity downwind of the elevated road structure, causing the emission plume to potentially pass over the inlet probe.

Finally, per 40 CFR Part 58 Appendix E, near-road NO_2 monitor probes need to be spaced away from certain supporting structures and have an open, unobstructed fetch to the target road segment. In a majority of monitoring sites, gas analyzer inlet probes such as those used for NO_2, are placed on a monitoring shelter or on a tower on or adjacent to a monitoring shelter. However, for some monitoring site configurations, inlet probes may be placed upon walls, parapets, or other existing infrastructure, which could include a noise barrier in the near-road environment. In these cases, the probe must be at least 1 meter vertically and/or horizontally away from any supporting structure, and away from dusty or dirty areas. Further, for near-road NO_2 monitors, there will likely be some distance between the target road segment and the NO_2 inlet probe. It is required that there be an unobstructed air flow, or open fetch, where no obstacles exist at or above the height of the monitor probe and the outside nearest edge of the traffic lanes of the target road segment. Technically speaking, open fetch would be observed along a path directly between the road and the NO_2 inlet, normal to the roadbed. However, as the EPA noted in the preamble to the final NO_2 NAAQS rule, the NO_2 inlet will likely be influenced by various parts of the target road segment that are at a relative angle compared to the normal transect between the road and the NO_2 inlet.

When considering site locations, the recommended approach is for state and local air agencies to consider more than one linear pathway between the target road segment and the monitor probe, and to choose sites where the monitor probe will be clear of obstructions.

Section 8. Using Exploratory Air Quality Monitoring to Identify Roadway Segments for Near-Road Site Selection Evaluation

To provide increased confidence of the likelihood for measuring peak NO_2 concentrations at a particular location, agencies may elect to conduct air quality monitoring to either identify candidate near-road monitoring sites or evaluate candidate monitoring sites identified through the process described in Sections 5 to 7 of this TAD. A variety of fixed and/or mobile monitoring techniques can be used to accomplish this task, and they can be used in a variety of applications including a saturation study, a more limited and focused monitoring campaign (as was conducted as part of the near-road NO_2 pilot study), or through mobile monitoring. The methods that could be used in such exploratory monitoring campaigns include passive and active devices that provide integrated or continuous measurements. Saturation studies typically use a large number of low cost, portable samplers to “saturate” an area with sampling devices in order to identify the spatial variability of pollutant concentrations. In this case, the application could be to deploy many samplers or devices among a number of roadside locations to estimate which roadways might have relatively higher pollutant levels. Other exploratory monitoring studies might use a more focused approach to create data for comparison or evaluation at a smaller number of sites, such as those derived from the process in Section 5 using traffic data, and considering any subsequent physical reconnaissance. Mobile monitoring uses instrumented vehicles or moveable platforms to measure pollutant concentrations at multiple locations. In this case, such mobile monitoring could potentially be used to determine spatial variability of pollutant concentrations amongst a number of road segments. These methods may be used exclusively or in combination to aid in the site selection process.

8.1 Passive Monitoring

Passive Sampling Devices (PSDs) for the measurement of NO_2 have been used widely in saturation sampling applications, and in more focused applications, including near-road monitoring studies. PSDs are a relatively inexpensive method, requiring only modest hardware and infrastructure to utilize in the field, with the largest expense being laboratory analysis of the exposed sampling media. PSDs are small, lightweight, and do not require power to operate. These characteristics allow PSDs to be more easily deployed in saturation monitoring campaigns, where a relatively large number can be deployed near numerous road segments at almost any location for comparison. The primary limitation to these devices for near-road applications is the long exposure times needed to collect a sufficient sample for analysis. In typical urban areas, these samplers must be exposed to ambient air for three or more days, and traditionally are exposed for week-long or multi-week periods. As a result, PSDs are not able to directly reveal those locations experiencing short-term, one-hour average NO_2 concentration peaks (which are part of the NO_2 NAAQS, along with the annual standard). However, generally speaking, using PSDs to differentiate long-term concentration variability among candidate near-road monitoring locations as part of the near-road site selection process can be useful. Several studies have compared PSDs with a Federal Reference Method (FRM) and other real-time monitors, with the accuracy and precision of these devices varying by application and the time averaging periods evaluated.

A number of references (such as those listed below) can be consulted for more information on how to conduct passive sampling for a near-road evaluation, advantages and disadvantages of this approach, and the precision and accuracy that can be anticipated when conducting this type of project. Some of these references focus on NO_2 applications; however, passive samplers can also be used for other contaminants if multi-pollutant monitoring is desired.

8.1.1 References

Quality Assurance Project Plan: Use of Passive Sampling Devices (PSDs) in a Near-Road Monitoring Environment, http://www.epa.gov/ttn/amtic.nearroad.html

New York City Community Air Survey, http://www.nyc.gov/html/doh/html/eode/nyccas.shtml

Mukerjee et al., 2009, "Field comparison of passive air samplers with reference monitors for ambient volatile organic compounds and nitrogen dioxide under week-long integrals" J. Environ. Monit., 2009, 11, 220–227

8.2 Stationary Continuous or Integrated Monitoring

Several small, lightweight, and portable NO_2 analyzers are commercially available that which may be useful for conducting a saturation study, or a more focused study on a handful of road segments, to further evaluate potential near-road monitoring sites. Many of these samplers are battery-operated, so they have much of the same advantages of PSDs in the flexibility of monitoring at almost any location. These samplers cost more than PSDs; however, most are significantly lower than the cost of an FRM sampler. These samplers may also collect real-time, or near real-time, or otherwise integrated NO_2 data; so the data collected from these samplers can be more comparable to the 1-hour time average of the NO_2 NAAQS than data provided by PSDs. However, these sampling techniques are relatively new compared to FRM and PSD samplers, so the precision and accuracy of these devices is often uncertain and not well characterized, especially for near-road applications. Thus, if these samplers are chosen for the purpose of establishing a near-road NO_2 monitoring site, care must be taken to ensure that the precision and accuracy of these devices is well characterized, which would include collocated sampling with an FRM or FEM sampler, collocation of the portable devices, and rotation of the portable samplers to evaluate potential individual sampler bias.

8.3 Mobile Monitoring

The use of mobile monitoring platforms for research and exploratory monitoring has increased in recent years. Mobile monitoring entails the placement of air quality sampling systems on-board a moveable platform (e.g., car/truck, bicycle, cart). This technique allows for a greater spatial coverage of monitoring over fairly short time periods. For some applications, the mobile platform is continuously moving, with short-term air quality measurements collected during this movement. This provides a broad spatial coverage of an area of interest over a short time period. In other applications, the moveable platform is rotated from location to location, collecting short or longer term measurements at each spot, where the time averaged measurements are typically on the order of minutes to hours at each location. Limitations of mobile monitoring often are identified to be the lack of simultaneous monitoring at multiple sites; as there is potential to miss maximum concentrations over the entire area of interest if changes occur in the strength or location of emissions over short time periods. In addition, these measurements may not be easily correlated to the maximum one-hour average concentrations of interest for the NO_2 NAAQS if collected over short-term durations (one to five-second average concentrations). To address these limitations, some studies have incorporated the use of multiple mobile monitoring platforms, or integrated mobile and stationary monitoring.

In general, mobile monitoring studies tend to be much more expensive than PSD or other saturation studies using portable equipment. While few NO_2 mobile monitoring studies have been conducted due to the lack of continuous instrumentation, these studies will likely increase with the availability of new real-time NO_2 monitors. Mobile monitoring may also be useful for conducting multi-pollutant assessments since a number of air quality samplers can be placed on a mobile platform for simultaneous use. If state or local agencies consider the use of mobile monitoring as a tool to assist in the determination of where a near-road NO_2 station might best be located, a number of key concepts and measurement routines should be considered. These concepts and routines include ideas like repeating travel loops over the course of hours and or days, and the determination of how much data collection will provide a sufficient amount for comparison purposes, among others. These are described in peer reviewed literature, such as Hagler et al., 2010 article (and references within), and such literature should be considered as a template for how a mobile monitoring study might be conducted.

8.3.1 References

Hagler et al., 2010, "High-Resolution Mobile Monitoring of Carbon Monoxide and Ultrafine Particle Concentrations in a Near-Road Environment" J. Air & Waste Manage Assoc., Vol. 60 (3), pp. 328-336

Westerdahl et al., 2005, "Mobile platform measurements of ultrafine particles and associated pollutant concentrations on freeways and residential streets in Los Angeles" Atmos. Environ., Vol. 39 (20), pp. 3597-3610

Westerdahl et al., 2009, "Characterization of on-road vehicle emission factors and microenvironmental air quality in Beijing, China" Atmos. Environ., Vol. 43 (3), pp. 697-705

Section 9. Using Air Quality Modeling to Identify Roadway Segments for Near-Road Site Selection Evaluation

Air quality modeling can be used in several different ways to aid in the near-road site selection process. One use could be to conduct dispersion modeling of several candidate near-road sites, such as those derived from traffic data evaluation and subsequent physical reconnaissance. The model output could be used to provide further confidence of the likelihood for measuring peak NO_2 concentrations, by comparing the relative concentrations amongst the modeled road segments. Another use of modeling could be to further refine locations for near-road stations along individual road segments, as necessary. A third application of modeling, although potentially laborious, could be to model a larger number of road segments to identify those segments where peak NO_2 concentrations might be expected. This third application could possibly be performed in lieu of the traffic analysis suggested in Section 5 in order to generate a prioritized list of road segments for further evaluation. All three of these air quality modeling applications require the use of both a vehicle emissions model and an air quality dispersion model. This TAD will use EPA regulatory models (e.g., MOVES for vehicle emissions and the AMS/EPA Regulatory Model [AERMOD] for dispersion) as the example for this type of assessment. We note that the state of California maintains the Emission Factors (EMFAC) model for predicting vehicle emissions in that state, and the California Air Resources Board (CARB) guidance should be consulted for using that model.

9.1 Motor Vehicle Emissions Simulator (MOVES) Model

EPA's MOtor Vehicle Emission Simulator (MOVES) is a computer model that estimates emissions from cars, trucks, buses, and motorcycles.[2] MOVES replaced MOBILE6.2, EPA's previous emissions model. MOVES is based on an extensive review of in-use vehicle emissions data collected and analyzed since the release of MOBILE6.2. MOVES estimates emissions of NOx and other pollutants, accounting for variations in speed, temperature, and other factors, and can do so at a high level of geographic resolution. Accordingly, MOVES can incorporate a wide array of vehicle activity for each road segment.

MOVES includes various emission processes (running, start, brake wear, tire wear, extended idle, and crankcase) that are applicable in different contexts. Because the emphasis in this TAD is high-traffic road segments, the emphasis of emissions modeling should focus on the NOx emission processes prevalent on roadways: running exhaust and crankcase. For other pollutants, such as PM, HC, and CO, other emission processes are important.

9.2 AERMOD Air Quality Dispersion Model

The purpose of this section is to provide guidance to those state and local agencies choosing to use modeling to further inform the implementation of NO_2 near-road monitors. The information provided here, along with more the more detailed information in Appendix C of this document covers the selection of an air quality model, modeling domain (including receptor placement), characterization of emission sources, meteorological inputs, and inclusion of

[2] See EPA's website for these guidance documents at: www.epa.gov/otaq/stateresources/transconf/policy.htm#project

background concentrations. For the purposes of this TAD we have selected AERMOD as the regulatory model as the example dispersion model.

9.2.1 NO_2 Chemistry Using OLM PVMRM

NO to NO_2 conversion can be modeled explicitly in AERMOD using one of two methods, the Plume Volume Molar Ratio Method [PVMRM (Hanrahan, 1999a; 199b; Cimorelli et al., 2004))] or the Ozone Limiting Method (OLM)[3]. These methods use NO_2/NO_x in-stack ratios and background ozone concentrations to convert NO to NO2 within AERMOD. For more information regarding the use of PVMRM and OLM, the user should consult the AERMOD User's Guide and addendum, the material in Appendix C in this document, and the March, 2011 EPA memorandum "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard" (http://www.epa.gov/ttn/scram/Additional_Clarifications_AppendixW_Hourly-NO2-NAAQS_FINAL_03-01-2011.pdf), which offers more guidance and background information on these two algorithms.

9.2.2 AERMOD and NO_2

On March 1, 2011, EPA issued the memorandum "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard" to provide clarification and guidance on the use of Appendix W guidance for the 1-hour NO_2 standard, including guidance for the implementation of OLM and PVMRM in AERMOD, inclusion of background concentrations, and other modeling guidance. Much of the information noted in the memo is presented in Appendix C of this document.

[3] Appendix D also discusses two conservative methods of calculating NO_2 concentrations based on information in Appendix W.

9.2.3 Including Background and Nearby Sources in Analyses

As noted at the beginning of this section, there are three possible applications of dispersion modeling for informing implementation of a near-road monitoring site. While the emphasis is on mobile source emissions, two other components usually considered in a modeling exercise are the inclusion of background concentrations and the modeling of nearby sources. More information on how to handle background and nearby source in a near-road centric modeling effort is presented in Appendix C.

9.3 References

Cimorelli, A. J., S. G. Perry, A. Venkatram, J. C. Weil, R. J. Paine, R. B. Wilson, R. F. Lee, W. D. Peters, R. W. Brode, and J. O. Paumier, 2004. AERMOD: Description of Model Formulation, EPA-454/R-03-004. U.S. Environmental Protection Agency, Research Triangle Park, NC. http://www.epa.gov/ttn/scram/7thconf/aermod/aermod_mfd.pdfU.S. EPA, 1985: Guideline for Determination of Good Engineering Practice Stack Height (Technical Support Document for the Stack Height Regulations), Revised. EPA-450/4-80-023R. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. http://www.epa.gov/ttn/scram/guidance/guide/gep.pdf

Hanrahan, P.L., 1999a. "The plume volume molar ratio method for determining NO2/NOx ratios in modeling. Part I: Methodology," J. Air & Waste Manage. Assoc., **49**, 1324-1331.

Hanrahan, P.L., 1999b. "The plume volume molar ratio method for determining NO2/NOx ratios in modeling. Part II: Evaluation Studies," J. Air & Waste Manage. Assoc., **49**, 1332-1338.

Section 10. Field Reconnaissance: Physical Characteristics of Candidate Near-Road Sites

Using the list of prioritized candidate near-road segments produced in the process discussed in Section 5 of this TAD, and also under consideration of any supplemental exploratory monitoring and/or modeling that also might have been conducted, state and local air agencies should be in a position to perform a more detailed evaluation of potential near-road sites to further characterize and prioritize the list of candidate near-road site locations. Such characterizations and evaluations can be carried out through the use of electronic data resources including satellite imagery (e.g., Google Earth), mapping resources (e.g., Bing Maps or Google Maps), and/or ArcGIS, for example. In addition to these resources, the EPA also advises that state and local air agencies take efforts to conduct reconnaissance in the field to characterize candidate sites. This section provides a suggested checklist for state and local air agencies to use in their reconnaissance. The EPA notes that some information suggested to be gathered to characterize any given road segment may already be reflected in any traffic data analysis that has been conducted.

10.1 Road Segment Identification

The road segment identifier is most likely part of the traffic analysis data. However, in some cases the identifying terms in the traffic analysis may not be the most commonly used or known terms. For practical means of understanding and communicating information about candidate near-road sites, it may be necessary to correlate the assigned roadway identifiers with any other useful identifying information and/or commonly used names for these traffic facilities. For example, using our Tampa, Florida example from Section 5 (Table 4, row 2), it is rather common knowledge that I-275 indicates “Interstate 275”. However, it might be useful during the evaluation process if the I-275 road segment was listed as "I-275/US 93" since US Highway 93 also utilizes the same corridor for the road segment used in this particular example, but is not listed in the traffic data table. Another example might be for situations where a road is 'named' and commonly referenced by that name, such as the Kennedy Expressway in the Chicago, Illinois area. In this example, while the road identifier may be "I-90/I-94" for a road segment on that stretch of expressway, it may more commonly be known as the Kennedy Expressway. As such, it is recommended that when applicable, state and local air agencies use combinations of given road identifiers along with more useful identification and/or commonly used labeling to aid in the site identification process. This should allow interested parties to more easily identify and understand which road segments are being described or characterized.

10.2 Road Segment Type

During reconnaissance it should be noted whether the road is a controlled access roadway, limited access expressway, limited or full access arterial, or other type of road. Controlled access roads (also referred to as freeways or sometimes expressways) are divided highways with full control of access. The control of access is established two ways: 1) by a lack of access to the roadway by any adjoining property (e.g., no driveways), and 2) the traffic on the road is free-flowing, where traffic flow is unhindered because there are no traffic signals or intersections that might cause traffic to stop. Access to these roads is typically provided by on and off ramps at interchanges with other roads. Limited access roads may have traffic signals, intersections, and access to adjoining properties; however, these access points are limited in number and location. Understanding the type of road for a candidate road segment can help determine the likelihood of safe, feasible monitoring shelter access. Controlled and limited access segments should not be avoided for monitoring site consideration; however, the evaluation of these segments should consider how potential monitoring sites will be accessed and maintained.

10.3 Road Segment End Points

Similar to the suggestion to use additional information and increasingly common names or labels for road segment identification, it may also be helpful to use more descriptive language to describe, in name and location, those transportation facilities or boundaries that denote the end points to any given road segment (e.g., intersections, highway exits, highway mile markers, geo-political boundaries). For example, using our Tampa, Florida example from Section 5, the highest ranked FE AADT road segment on I-275 (Table 4, row 2), is indicated to have end points at Bridge No – 100128 and Bridge No – 100110. Such traffic facility infrastructure identifications may not be commonly known or easily translated into physical and geographical locations to aid in understanding the extent to which the road segment extends. For practical means of understanding and communicating information about candidate near-road sites, it may be necessary to combine the DOT assigned traffic facility identifiers with any other commonly used names for these traffic facilities. In this example, it may be more useful to label Bridge 100128 as the "interchange of I-275/US 93 with Business 41/SR 685" and Bridge 100110 as the location where "Armenia Avenue crosses I-275." The use of more commonly used or readily understood labeling will likely aid in the site identification process; allowing interested parties to more easily identify and understand where a candidate road segment site location might be located.

10.4 Interchanges

State and local air agencies should note the presence of interchanges or road junctions within or at the ends of a particular road segment. Information could include the identification of the intersecting or connecting road(s) and the type of interchange. There are multiple types of interchanges including four-way (i.e., cloverleaf, stack, and diamonds) and three-way interchanges, among others. A robust but unofficial resource on the types of interchanges transportation agencies use in building transportation facilities can be found on the web at: http://en.wikipedia.org/wiki/Interchange_(road).

10.5 Roadway Design

As discussed above in Section 6.1, the roadway design can have a significant impact on pollutant transport and dispersion. During the reconnaissance of a road segment, state and local air agencies should note the design of the candidate road segment (e.g., at-grade, above-grade - on fill or open underneath, below-grade, or even a mix) including the notation of changes in design and the related local terrain along the length of the segment if present. In those cases where the road is above or below grade, air agencies should attempt to characterize the nature of the cut road or elevated road. For example, if a road is below grade, estimate the depth of the cut below the surrounding terrain and note what type walls – sloped or vertical. For elevated roads, note whether the road bed is on a bridge or fill section, the height of the roadbed above the surrounding land, and for a fill section, whether the road is supported by vertical or sloped walls.

10.6 Terrain

Akin to roadway design, state and local air agencies should note the type of terrain on which a candidate road lays, the terrain immediately adjacent to the candidate road segment, and any larger scale terrain features within which the road may lie, or is potentially influenced by. Examples of terrain features that might be noted include whether the road segment is along a grade, along its length or for a portion of its length. Another example might be noting a road segment's proximity to hills, bluffs, canyons, ridges or other topographical features that can influence local meteorology.

10.7 Roadside Structures

As discussed above in Section 6.2, roadside structures can have a significant impact on pollutant transport and dispersion. Further, roadside structures can seriously impact the candidacy of a road segment to host a near-road monitoring station. During the reconnaissance of a road segment, state and local agencies should note all roadside structures throughout the length of the candidate road segment. Notation on the existence, type, location, length, and approximate height of any structures should be captured for any sound walls, vegetation, earthen berms, buildings, or other structure along each side of the segment.

10.8 Existing Safety Features

Safety in the near-road environment is a very important consideration in the installation of a near-road monitoring station (a more detailed discussion on safety issues is presented below in Section 11.3). Safety of the travelling public on the road, the air monitoring staff members who services a near-road monitoring station and the monitoring station itself should be a top priority. During the reconnaissance of a candidate road segment, state and local air agencies should take note of existing safety features along parts or all of the road segment, on each side of the road, including ditches, berms, guard rails, cable barriers, jersey barriers, or other features. Placement of a monitoring station behind such safety features would be preferable when possible.

10.9 Existing Infrastructure

Existing structures, traffic related monitoring systems, and other highway maintenance facilities may already exist in the near-road environment along some candidate road segments. These pieces of infrastructure may provide a leveraging opportunity for a near-road monitoring site at a location that may already be accessible, have safety features, have power, and/or have other utilities, which might ease the installation of a possible near-road NO_2 station. Such infrastructure can include sign supports (traffic or billboard), light poles, automatic traffic counters, traffic camera installations, dynamic message signs, Road Weather Information System (RWIS) installations, truck weigh stations, and weigh-in-motion locations. Additionally, state and local air agencies may be able to identify the location and nature of some RWIS infrastructure through U.S. DOT's Clarus System website (http://www.clarus-system.com/), depending upon individual state participation.

10.10 Surrounding Land Use

State and local air agencies should note the general or mixed use of land (e.g., urban or suburban residential, commercial, industrial, agricultural, forested) around candidate road segments during the reconnaissance process. Specific information (e.g., presence of schools, hospitals, low-rise or high-rise buildings) is also useful to note. In addition to the traditional land use categories noted above, state and local air agencies should also determine and note (through field reconnaissance and possibly emissions inventory review) if any significant sources (off-road mobile or otherwise stationary in nature) are nearby.

10.11 Current Road Construction

The potential for future road construction on candidate road segments is discussed in Section 11. However, during candidate road segment reconnaissance, state and local air agencies should note any ongoing road construction along with any immediately apparent preparations for road construction.

10.12 Frontage Roads

Also called service roads or access roads, frontage roads typically run parallel to major highways, and may or may not be considered part of the major highway, thus they may or may not be controlled access or limited access roads. They are often one-way roads with traffic flowing in the same direction of the adjacent lanes of the partnering major roadway. They can provide access to property adjacent to major roads and connect these properties with roads which have direct access to the main roadway. Frontage roads can also provide a means for traffic in and around the properties adjacent to a major road to access that road, most often at interchanges. During candidate road segment analysis, the presence of frontage roads should be noted.

10.13 Meteorology

State and local agencies should attempt to understand the general climatological wind rose for candidate road segments, which can be used to aid in the determination of what might be dominant upwind and downwind locations along a particular segment. This can likely be determined by reviewing local and regional weather and climatological data collected by NOAA and any data collected by air agencies themselves at existing air monitoring stations in the area.

Section 11. Monitoring Site Logistics in the Near-Road Environment

A key component in the determination of whether a candidate near-road monitoring site is truly feasible is determining if an air monitoring agency will be able to access the desired location, whether the site would be safe for site operators and the public during routine operations, and whether there is sufficient availability of power and telecommunications services, or the ability to procure and install those services. Per 40 CFR Part 58, Appendix E, section 6.4(a), "…the monitor probe shall be as near as practicable to the outside nearest edge of the traffic lanes of the target road segment; but shall not be located at a distance greater than 50 meters, in the horizontal, from the outside nearest edge of the traffic lanes of the target road segment." With emphasis on being "as near as practicable" to the target road segment, a number of candidate near-road sites are expected to fall within right-of-way properties under the jurisdiction and maintenance of state or local DOTs or other transportation authorities, collectively referred to as transportation agencies. This section provides background information regarding the access of right-of-ways, including associated terminology, safety guidelines, procedures, and expectations regarding the access to such properties. This section also includes suggestions on engaging and collaborating with transportation agencies to access highway property for installation of a near-road monitoring station in a right-of-way.

If a candidate near-road site is accessible without the state having to use the right-of-way (i.e., on property not otherwise managed or governed by a transportation agency), states will more than likely be able to treat the site access investigation as they would for any other traditional ambient air monitoring site. In these cases, the EPA still encourages states to make special accommodations and considerations for safety such as those presented within this section.

11.1 Terminology

Air rights - The term "air rights" is a legal term used to describe that area above (e.g., air space) or below the plane of the transportation facility and located within the right-of-way boundaries under authority of the appropriate highway agency.

Air space lease – The agreement between the managing transportation authority and another entity dictating the length and terms by which the requesting entity may have access to highway air rights.

Easement – An easement is a right to use property belonging to someone else, for a stated purpose, without owning that property.

Federal-aid Highway – Per 23 CFR 470.103, federal-aid highways are those that are part of the federal-aid highway system and all other public roads not classified as local roads or rural minor collectors.

Federal-aid Highway System – Per 23 CFR 470.103, the federal-aid highway system means the National Highway System and the Dwight D. Eisenhower National System of Interstate and Defense Highways (the "Interstate System"). Specific information on the National Highway System and the Interstate System can be found at http://www.fhwa.dot.gov/planning/nhs/.

Right-of-way – The right-of-way (ROW) is a type of easement that gives someone the right to travel across property owned by someone else. In situations dealing with ROWs along major highways, the use of ROW space is typically governed or managed by state or local DOTs or other transportation authorities.

11.2 Accessing the Right-of-Way

The feasibility of a potential near-road NO_2 site requires the determination of whether a given location can be accessed. If the prospective location is located within the right-of-way (ROW) of an existing road, state and local air agencies will need to engage their respective transportation agencies to gain access to the air rights of that property. This would be most likely accomplished through a permitting process that would ultimately lead to the development and establishment of an air space lease. The right to use space within the ROW by public entities or private parties for interim non-highway uses may be granted in airspace leases, as long as such uses will not interfere with the construction, operation or maintenance of the transportation facility; anticipated future transportation needs; or the safety and security of the facility for both highway and non-highway users. This means that state and local air agencies considering potential near-road sites within the ROW would need to work with their companion transportation agencies to consider near and long-term construction plans, potential interference with routine highway operations and maintenance due to the presence of a monitoring station, safety, and security of the highway ROW during the development of the lease agreement. The permitting and lease agreement process is likely different from state to state, or from one urban area to another; however, this process will likely consider similar factors and take some amount of time to complete, before physical access is granted to the state or local air agency. The U.S. Federal Highway Administration (FHWA) maintains information on airspace access on the web at http://www.fhwa.dot.gov/realestate/airguide.htm.

When considering a site within the ROW, state and local air agencies should consider several different factors that may impact the ease of negotiating an air space lease. The first factor is physical access. It is anticipated that transportation agencies will prefer that any potential near-road NO_2 site in the ROW be planned in a manner that the site be made accessible from outside the ROW, or have accommodations that preclude the need to access the site from the primary travel lanes of the target highway.

If it is determined during the evaluation of a candidate site that the installation of a locked access point (such as a gate) is required to access the ROW, the state or local transportation agency must submit justifications and obtain approval from FHWA, which is a formal federal action, if the facility is an interstate facility. FHWA's policies on changes in access to the interstate highway ROW are maintained on the web at http://www.fhwa.dot.gov/programadmin/fraccess.cfm. It is noted that this requirement does not preclude the establishment of a monitoring station where access is only feasible from the target highway; however, an approach requiring the use of a new locked access point may be more preferable to a transportation agency in an air space lease negotiating process than a plan relying upon access solely from the target road.

A second factor to be considered for site feasibility and the impact on negotiating an air space lease is the availability of utilities. State and local air agencies need to determine whether utilities are already present, need to be relocated, or need to be installed to support the air monitoring station. Any activity to change or install utilities will require approval from the managing transportation agency. If the road segment in question is part of a federal-aid highway, the state or local transportation agency must ensure that any permits to install necessary utilities must comply with the appropriate federal regulation and FHWA policies. However, identifying potential site locations adjacent to, or otherwise near, existing infrastructure within the ROW with existing power may avoid some permitting procedures and possibly reduce utility related installation costs. More information on utility considerations, particularly with respect to bringing utilities into the ROW, can be found at http://www.fhwa.dot.gov/programadmin/utility.cfm

11.3 Safety in the Near-Road Environment

Near-road NO_2 monitoring sites must be safely sited for both the traveling public on the roadway and the personnel operating the monitoring site. Near-road monitoring sites must be accessible to station operators in a safe and legal manner, and not pose safety hazards to drivers, pedestrians, or nearby residents. Safety hazards to drivers can include obstructions to sight lines and distractions, which can lead to accidents. Safety hazards to pedestrians include obstructions that block safe movement along the road or walkways. Safety hazards to monitoring site operators include factors which inhibit the safe entrance to or egress from a site and factors that could allow vehicles to encroach upon and damage the site infrastructure. Since near-road NO_2 sites may be located on transportation agency maintained ROW, as discussed above, it is anticipated that state and local air agencies will engage their respective transportation agency regarding access to such locations. During discussions on the potential access and use of locations within the ROW, safety should be a primary concern.

Transportation agencies deal with multiple roadway safety issues when building and maintaining traffic facilities. FHWA maintains a safety program addressing safety issues, on which information can be found at http://safety.fhwa.dot.gov. However, of the multiple safety categories that are dealt with, the one category that may be most relevant with regard to the near-road NO_2 monitoring network is ‘roadway departure’ safety. FHWA defines a roadway departure accident as a non-intersection crash which occurs after a vehicle crosses an edge line or a center line, or otherwise leaves the traveled way. Since near-road NO_2 monitoring stations are not on the road, but relatively near the outside edge of travel lanes, the roadway departure of vehicles likely poses the biggest safety risk to the travelling public, the air monitoring staff working at a near-road site, and the monitoring site infrastructure. Depending upon roadway design and terrain, there are multiple means by which transportation agencies can improve or increase safety within the ROW or at the edge of ROW space. Examples include roadway paving techniques (e.g., rumble strips or safety edging), increasing pavement friction, the use of retaining barriers, and maintaining open areas within the ROW which are called "clear zones." With respect to near-road NO_2 monitoring stations, existing safety features provided by the local terrain, man-made barriers, or clear zones should be considered as positive attributes to a potential site in the site selection process.

The terrain of a road segment can, in some cases, increase safety by reducing roadway departures that impact a near-road monitoring site. Such examples are ditches or berms made of earthen fill, which might exist between the roadway and the monitoring station. So long as these terrain features do not obstruct the fetch between the monitor probe and the target road, they may be viewed as positive attributes for a given candidate road site.

Man-made barriers or retainers in the ROW come in many forms, most of which can generically be referred to as longitudinal barriers. FHWA maintains a list of crash-worthy longitudinal barriers on the web at http://safety.fhwa.dot.gov/roadway_dept/policy_guide/road_hardware/barriers/. Some examples of the many individual types of longitudinal barriers available include temporary and permanent concrete barriers (sometimes referred to as 'Jersey barriers'), multiple configurations of steel and/or wood guardrails, water-filled barriers, and cable barriers. The presence of any type of longitudinal barrier, so long as it does not obstruct the fetch between the monitor probe and the target road, may be viewed as a positive attribute for a given candidate near-road site.

Clear zones are defined by FHWA to be an unobstructed, traversable roadside area that allows a driver to stop safely, or regain control of a vehicle that has left the roadway. The width of the clear zone (e.g., the distance between the outside edge of the road to an obstacle) is based on risk, which is derived from a roadway's traffic volume, vehicle speeds, and the slope of the underlying and adjacent terrain. In practice, a clear zone is free of obstructions (including safety barriers) and would denote an area or distance from the road that a near-road monitoring station would be placed outside of, measured from the outside edge of the travel lanes. As a rule of thumb, highways with no natural or man-made obstructions alongside the travel lanes typically might be prescribed to have a clear zone on the order of 10 meters. Although FHWA provides a summarization of clear zones on the web (http://safety.fhwa.dot.gov/roadway_dept/clear_zones/#zones), clear zone guidance is created by the American Association of State Highway and Transportation Officials (AASHTO). The guidance material is not free to the public.

[THE EPA IS AWAITING PERMISSION TO REPRODUCE AASHTO CLEAR ZONE AND SAFETY BARRIER GUIDANCE IN THIS TAD. IF APPROVED, THIS TAD WILL REPRINT THAT GUIDANCE HERE.]

In addition, a state and local air agency may benefit from inquiring with their respective state or local transportation agency about approved design manuals they might have that contain specific safety criteria and/or guidance that could be applied to any particular candidate road segment under evaluation.

The EPA stresses that safety is a top priority in all field operations. Ambient air monitoring operations in the near-road environment present additional safety issues that must be addressed in the site selection process. As such, the Agency recommends that state and local air agencies fully evaluate the presence of existing protection or safety features along candidate road segments. If appropriate safety features are not present, the state or local air agency will need to consult with their DOT to determine whether there is a need, and if so what the design and installation process might be for infrastructure additions or enhancement to ensure safety for all highway and monitoring station users. Further, given the importance of protecting the public, air monitoring staff persons, and the site infrastructure, air agencies can also consider allowable safety measures beyond standard practice to further reduce safety related risk.

11.4 Engaging a Transportation Agency

State and local air agencies will need to obtain permission from the appropriate transportation agency if a monitoring site is to be located within a ROW. Most often, this permission will come in the form of an airspace lease negotiated with the managing transportation agency. The following sets of questions and issues are intended to prepare state and local air agencies to engage transportation agencies, including those that will need to be answered amongst the state or local air agency, the state or local transportation agency, and potentially FHWA.

- Who is the public authority responsible for the ROW?
- What are the transportation agency requirements for considering and approving leases (or permits) to allow for the subject installation?

- Is the near-road site within interstate highway ROW? If so, the request for a lease or permit to the responsible state or local transportation agency responsible for the ROW must include information FHWA requires to be addressed in the review and approval of such an action. These issues will likely include the air rights agreement, locked-gate access (as necessary), and compliance with applicable utilities accommodation and relocation policy.
- What other policies, procedures, standards, leases/permits required or desired by the managing transportation agency will need to be addressed?

In addition to the overarching questions listed above, there are some anticipated questions that transportation agencies may have about a potential ambient air monitoring station, and some suggested questions that air agencies should consider asking their transportation agency counterparts regarding individual candidate road segments.

11.4.1 Information to Provide a Transportation Authority

There are a number of questions that state or local transportation agencies may have when first approached by a state or local air agency regarding the placement of an ambient air monitoring station in the near-road environment. Some anticipated questions might include, but are not limited to the following:

- Who will own the monitoring equipment?
- How long would the air monitoring site be used/needed?
- What are the physical dimensions of the monitoring site and shelter?

  (State and local air agencies need to consider the potential for multi-pollutant monitoring when preparing this information. Multipollutant monitoring in near-road NO_2 sites is discussed in Sections 12.2 and 14 of this TAD.)

- What type of structure (shelter) will be installed at the site? (Pictures are useful here.)
- How often would air monitoring staff need to access the site?
- If there are no existing utilities at the candidate site location, who will prepare the request for permit, and subsequently pay for the installation of required utilities?
- Who will be financially responsible for the upkeep of the monitoring station? This includes routine operations, and the inspection, maintenance, and security of the site.
- Who would be responsible for any closure, removal, and relocation of the station, if necessary?

11.4.2 Questions to Ask Your State or Local Transportation Agency

There are a variety of questions that state and local air agencies may want to ask their partner transportation agencies about the long-term feasibility and access of a site within the highway ROW. Some general questions an air agency might want to ask include:

- What, if any, construction is planned along the candidate road segment that might impact traffic operations on the road, the safety of the monitoring site, or safe and efficient access to the monitoring site?
- What, if any, construction is planned on nearby road segments or to the CBSA transportation network that might impact traffic operations along the candidate site road segment?
- In the future, if access to the monitoring site is either temporarily or permanently affected by a highway project, what contingencies might be available for alternative access to the site or alternative sites along the same road segment?

- Will an air space lease, if awarded, be a one-time process, or will that lease need to be renewed on some interval? If it would require renewal, are there any particular criteria that might cause the renewal to be disapproved in the future?
- Under what conditions should or could safety features be added to a road segment if a near-road station is to be installed in the ROW? If a clear zone is currently in use, is that sufficient, or would additional safety features be allowed to be installed?
- If safety feature installation or improvements are desired, what types of features are available to be considered for installation (such as guardrails, barriers, etc.)?
- Are there any other safety provisions that an air agency would need to conform to if they routinely access and work on and within a monitoring station in the ROW?

Section 12. Prioritizing Candidate Near-Road Locations for Monitoring Site Selection

The EPA expects that by: 1) following the traffic analysis procedures to aid development of a prioritized list of candidate road segments (described in Section 5 of this TAD), and 2) evaluating select candidate road segments through reconnaissance, possible use of optional evaluation tools (e.g., exploratory monitoring or modeling), and possible discussions with respective transportation agencies (discussed in Sections 6 through 11 of this TAD); state and local air agencies will be in possession of sufficient information to begin to making informed decisions regarding the selection of near-road NO_2 sites.

The EPA expects that state and local air agencies will have a variety of option sets once they compile candidate site information. It is important to recall that the objective is to monitor as near as practicable to roads where peak, ground-level NO_2 concentrations are expected to occur. However, even with all the factors that can impact whether candidate near-road locations are feasible, undoubtedly some air agencies will have a relative wide array of candidate sites to choose from, and will have to begin narrowing their options by placing weight on one or more road segment characteristics over others. It is at this point in the site selection process that two other considerations come into play, population exposure and the potential for multi-pollutant monitoring. The EPA suggests using a site comparison matrix to aid in the site selection decision process. A matrix will help ensure that all available information is presented in a format easy for decision makers to review.

12.1 Considering Population Exposure as a Selection Criterion

Per 40 CFR Part 58, Appendix D, section 4.3.2(a)(1), "where a state or local air monitoring agency identifies multiple acceptable candidate sites where maximum hourly NO_2 concentrations are expected to occur, the monitoring agency shall consider the potential for population exposure in the criteria utilized to select the final site location." Therefore, when considering all the available information (particularly AADT, fleet mix, congestion patterns, roadway design, terrain, meteorology, and siting criteria) for which candidate locations are suitable for a required near-road NO_2 station, population exposure should be given subsequent consideration. Specifically, amongst a pool of otherwise similar candidate near-road sites, the site that may represent a higher population exposure should be given increased consideration.

Population exposure can be considered in a number of ways, all of which cannot be listed here. In some cases, the consideration of population exposure may be relatively straight-forward. A hypothetical example might involve two segments, one in a rural or less populated area of the CBSA and one located in a more urbanized or more densely population area. In this example, the higher population exposure would lead a state or local air agency to give greater weight to the more urbanized sites.

However, the EPA anticipates that in more cases than not, such a simple example will not be the reality for state and local air agencies. In more complicated situations, the use of publicly available demographic and socioeconomic data for the populations living along and near candidate road segments can be used to aid in considering population exposure as an additional selection criterion. One example might be to use census block information, particularly focusing on those census blocks that contain, or are adjacent to, candidate road segments, or are otherwise able to be spatially connected to one or more candidate road segments. The official source for census block data is the U.S. Census Bureau's American Fact Finder website (http://factfinder.census.gov). Data can be downloaded in batch format from the following URL: (http://factfinder.census.gov/servlet/DownloadDatasetServlet?_lang=en). These data can then be associated with spatial files located at http://www.census.gov/geo/www/tiger/, and then displayed within GIS software. The instructions for downloading and spatially associating census data for use in GIS are maintained at http://www.census.gov/geo/www/tiger/wwtl/wwtl.html. An alternative data source and analysis tool for spatially utilizing census data in the near-road site selection process is gCensus, located at http://gecensus.stanford.edu/gcensus/. While not officially endorsed, gCensus provides census-level demographic information that can be downloaded and visualized in Google Earth. Further, if socioeconomic data are available to state and local air agencies, the EPA further encourages states and local air agencies to consider sites that are located in areas with susceptible and vulnerable populations.

12.2 Potential for Multi-pollutant Monitoring

A number of pollutants and measureable metrics of interest that exist in the near-road environment, other than NO_2, are discussed in some detail in Section 14 of this TAD. Although this document specifically provides suggestions on siting required near-road NO_2 monitors, the EPA also encourages state and local air agencies to consider the potential of a site to house other pollutant monitors and measurement devices. This would specifically be accomplished in the site selection process by considering the footprint and layout of the infrastructure of a near-road monitoring station. The EPA believes that the footprint of a typical NCore station (which houses analyzers for carbon monoxide, ozone, sulfur dioxide, total oxides of nitrogen (NO_Y), a variety of PM instruments [including $PM_{2.5}$ and lead samplers], and meteorological gear, along with all the associated support equipment) may be a conservative approximation of a multipollutants site footprint. Although this NCore type footprint can be bigger than a single pollutant shelter, the EPA believes, based on research experiences, that this should not typically create additional burden or restrictions for site installation versus a single gas pollutant monitoring shelter.

12.3 Candidate Site Comparison Matrix

Upon the completion of traffic data analysis, field reconnaissance, and the conclusion of any other evaluation efforts, the EPA recommends that state and local air agencies consider compiling their research for use in the final stages of the site selection process. A suggested approach is to create a candidate site comparison matrix. Such a matrix would consolidate the data collected in the evaluation process and present that information in a comparable format, creating a foundation for the rationale of why one site might be selected over other candidate sites. The matrix would likely aid state air staff and other decision makers, and will also be a useful source of data supporting the discussion with the EPA, other stakeholders, and possibly the public, on site selection. Further, the Agency anticipates that the matrix will be a useful reference for users of the data, who may want to further investigate what the data represent.

The candidate site comparison matrix is recommended to include at a minimum, traffic data, surveilled field information, site feasibility information such as permission of, or lack of, access for individual candidate sites, safety issues (if applicable), probable distance between the inlet probe and the outside edge of the target road, and any other collected ambient data and/or modeled data. The matrix can be used to represent individual points along a road segment or for whole road segments under consideration. As such, a detailed matrix could have several candidate locations that are available along the same target road segment. **Table 8** includes a list of variables that could be included in the matrix.

Table 8. Suggested data for each candidate site entry in a site comparison matrix.

Site/Segment Parameters	Description of Parameter
Location	Describe if the entry is for a specific point along a road segment or if the entry is representative of a whole road segment. If the entry is for a point, provide a moniker and the latitude and longitude.
Road segment name	Provide given road name and common name if applicable
Road type	Type of road (controlled access freeway, limited access arterial, etc.)
AADT	Provide AADT, source of data, and vintage
HD counts	As available, provide HD counts, source of data, and vintage
FE AADT	As available, provide FE AADT, noting HD_m value used
Congestion information	Denote value and type (e.g., LOS, $^V/_C$, or AADT by lane) and vintage
Terrain	Denote the nature of the terrain immediately around the road and also any larger scale terrain features of note
Meteorology	If the entry is for a point, denote the predominate winds and whether the point is relatively upwind or downwind. If the entry is for a whole segment, denote the orientation of the segment to the predominant winds.
Road segment end points	Denote the location of the road segment end points, including any given names, common names, and the latitude and longitude of each individual end point.
Population exposure	Denote any assessment of potential for population exposure
Roadway design	Denote design type or types present (flat, elevated-fill, cut, etc.)
Roadside structures	Denote the presence of any roadside structures
Safety features	Denote any safety features present
Infrastructure	Denote any existing infrastructure (light poles, billboards, etc.)
Interchanges	Denote the presence of any interchanges within or at the end points of the target road segment
Surrounding land use	Denote surrounding land use (residential, commercial, etc.)
Nearby sources	If applicable, note nearby NO_X sources (type, tonnage, and distance)
Current road construction	Denote any visible or known road construction at the candidate site location or along the target road segment
Future road construction	If known, denote transportation agency plans for any future road construction (including time frame for completion)
Frontage roads	Denote the presence of frontage roads, and whether those roads are included as part of the target road segment.
Available space – site footprint	Denote any limitations in the space available for a multipollutant monitoring station
Property type	Is it ROW or private property?
Property owner	Who manages or owns the property under evaluation?
Likelihood of access	Note the level of confidence and any uncertainties regarding the acquisition of access to a particular property
Other details	List any other pertinent details that may have bearing on why a particular candidate site may or may not be selected

Section 13. Final Near-Road Site Selection

The EPA expects that state and local air agencies will engage the EPA Regional staff as necessary during the site selection process and certainly when a choice is made that is intended to be reflected in annual monitoring plans. At a minimum, the EPA Regions will provide feedback on any near-road site selection listed in the annual monitoring plan before issuing a network plan approval letter, as is typically done. The availability of data supporting the rationale behind a site selection, such as that within the candidate site comparison matrix, will facilitate the review process.

Once a location has been selected for the installation, the EPA suggests that state and local air agencies prepare and include site record metadata about the near-road location (along with monitor record data) which would eventually be input into AQS for inclusion in annual monitoring plans. AQS manuals and guidelines, including information on required and optional metadata fields associated with monitoring sites and monitor records, are maintained by EPA at http://www.epa.gov/ttn/airs/airsaqs/manuals/. For new near-road NO_2 sites, the EPA requires that certain metadata are entered into AQS, as is the case for any new State and Local Air Monitoring Station (SLAMS) site. The new site information should be added to AQS online or via the AA Basic Site Information transaction with an action indicator of “I” for “insert.” If using a batch transaction, refer to the AA Basic Site Information for formatting; the required fields are presented in **Table 9**.

Table 9. Near-road site information required in AQS – metadata (AA – basic site information).

AQS Metadata (AA – Basic Site Information)	
Transaction Type	Horizontal Datum
Action Indicator	Source Scale
State Code or Tribal Indicator	Horizontal Accuracy
County Code or Tribal Code	Vertical Measure
Site ID	Time Zone
Latitude	Agency Code
Longitude	Street Address
UTM Zone	Land Use Type
UTM Easting	Location Setting
UTM Northing	Date Site Established
Horizontal Collection Method	

In addition to the Basic Site information required for every new SLAMS site in AQS, the EPA strongly suggests that air agencies also populate the AB Site Street Information metadata fields for near-road NO_2 sites. This can be done online in AQS via the Maintain Site → Tangent Roads tab or via the AB Site Street Information transaction with an action indicator of "I" for "insert." If using a batch transaction, refer to the AB Site Street Information for formatting; the required fields are presented in **Table 10**. (Note that Tangent Street Number [also called Tangent Road Number] is merely used as a unique identifier supplied by the user [i.e., "1", "2", ..., "99"]; it does not refer to a physical street number.)

Table 10. Additional near-road site information in AQS – metadata (AB site street information).

AQS Metadata (AB Site Street Information)	
Transaction Type	Street Name
Action Indicator	Road Type
State Code or Tribal Indicator	Traffic Count
County Code or Tribal Code	Year of Traffic Count
Site ID	Direction from Site to Street
Tangent Street Number	Source of Traffic Count

For traffic-related data fields, state and local air agencies should utilize the data gathered as part of the site selection process. For location-oriented data fields (e.g., Street/Road Name) the EPA suggests that these fields reflect the target road segment. The Agency recognizes that a site may not have a traditional street number if it is within the ROW of a major interstate or freeway.

Before a site can go into "production" status on AQS, (meaning it can be seen by public users, it MUST have at least one monitor associated with it. This is accomplished by populating monitor record fields, as it done for any SLAMS monitor. Within the multiple data input formats that exist for monitor record fields, the EPA suggests that state and local air agencies ensure that the following fields for near-road NO_2 monitors be populated as noted:

- Monitor Objective – At least reflect that it is a “source oriented”
- CBSA Represented – Reflect the CBSA that the monitor is within
- Distance from Monitor to Tangent Road – As accurately as possible, reflect the distance, in the horizontal, between the inlet probe and the outside nearest edge of the target road segment
- Dominant Source – Reflect that the “mobile source” category is the dominant source

The EPA believes that full and accurate characterization of the monitoring site and the monitor itself will greatly improve the ability to use and analyze data at near-road NO_2 stations.

Section 14. Multipollutant Monitoring at Near-Road Monitoring Stations

The EPA has expressed the intent to pursue the integration of monitoring networks and programs through the encouragement of multipollutant monitoring wherever possible. This is evidenced by actions taken in the 2006 monitoring rule that created the NCore network, the expression of the multipollutant paradigm in the 2008 Ambient Air Monitoring Strategy for State, Local, and Tribal Air Agencies, and through recent rulemakings where minimum monitoring requirements have been proposed in a manner that would either require or strongly encourage multipollutants monitoring within SLAMS. Multipollutant monitoring is viewed by the EPA as a means to broaden the understanding of air quality conditions and pollutant interactions, furthering our capability to evaluate air quality models, develop emission control strategies, and support research, including health studies.

This section of the TAD discusses a number of pollutants of interest in the near-road environment; they are of interest due to their direct emission by on-road mobile sources, or the formation from or interaction with on-road mobile source emissions. The CASAC AAMMS, in their review of the EPA's "Near-road Guidance Document – Outline" and "Near-road Monitoring Pilot Study Objectives and Approach" (CASAC AAMMS review) dated November 24, 2010, located at http://yosemite.epa.gov/sab/sabproduct.nsf/ACD1BD26412312DC852577E500591B37/$File/EPA-CASAC-11-001-unsigned.pdf, stated that "CASAC recognizes the importance for public health of better characterizing near-road pollutant concentrations." This section of the TAD is intended to discuss a number of pollutants of interest in the near-road environment due to their direct emission by on-road mobile sources, or the formation from, or interaction with on-road mobile source emissions. The pollutants discussed in this section are presented in the relative order of priority the CASAC AAMMS suggested to EPA in their near-road review, beginning with Section 14.4 (on black carbon).

14.1 Nitrogen Dioxide (NO_2)

NO_2 is an important target of ambient air monitoring because of its adverse impact on human health. Scientific evidence links short-term NO_2 exposures with adverse respiratory effects including airway inflammation in healthy people and increased respiratory symptoms in people with asthma. Further, some health studies have linked NO_2 exposure to increased visits to emergency departments and hospital admissions for respiratory issues.

NO_2 is one of a number of oxidized nitrogen species. Scientifically, nitrous oxide (NO) and NO_2 are collectively referred to as NO_X, where $NO + NO_2 = NO_X$. However, there are other oxidized nitrogen species in the ambient air including nitric acid (HNO_3), nitrous acid (HNO_2), nitrous oxide N_2O, peroxyacyl nitrates (PANs), and organic nitrates among others. These "other" oxidized nitrogen species are collectively known as NO_Z. The entire family of oxidized nitrogen species is known as NO_Y, which may operationally include some particulate nitrate species with respect to measurements of NO_Y; where $NO_Y = NO_X + NO_Z$.

NO_2 is the key focus of this document because of its role as the indicator of the oxides of nitrogen NAAQS, and the requirement to measure NO_2 in the near-road environment where, as noted in Section 1, the EPA recognized that roadway-associated exposures account for a majority of ambient exposures to peak NO_2 concentrations. The near-road environment is of interest because motor vehicles are significant contributors to the total NO_X and NO_2 inventory in the US. In tailpipe emissions, which are primary emissions, the majority of NO_X exhaust is in the form of NO. NO_2 quickly forms by photochemical reaction in the ambient air from the reaction of NO and ozone (O_3), and also through other photochemical processes. Although all motor vehicles emit NO_X, heavy-duty (diesel) vehicles emit more NO_X on a per vehicle basis than gasoline powered vehicles. Further, primary NO_X emissions from newer technology heavy-duty diesel engines with after-treatment devices may contain a much greater percentage of NO_2 in the exhaust (although the total amount of NO_X is reduced) than older diesel engines. Thus, NO and NO_2 will be present in varying concentrations in the near-road microenvironment.

In the current SLAMS network, NO_2 is almost exclusively measured using the chemiluminescent NO_X analyzer, which is a FRM. In the chemiluminescent FRM, NO_2 is measured by difference, as the NO_2 analyzer is only capable of measuring NO directly. The analyzer directly measures NO by introducing ozone to the sample stream, where the reactions between the two compounds releases energy in the form of light (chemiluminescence). In order to determine the amount of NO_2 in the ambient air, the analyzer will first detect the amount of NO in the ambient air.

Next, the analyzer re-routes the incoming ambient air stream through a heated converter (usually containing molybdenum) which reduces the NO_2 in the air stream to NO. The analyzer then detects all NO in that air stream that has passed through the converter. The ambient NO_2 concentration is determined by subtracting the original amount of NO measured in the un-converted air from the amount measured in the air that was passed through the heated converter, where the available ambient NO_2 was reduced to NO. A known drawback to the traditional chemiluminescent measurement technique is that other NO_Z species, if present in the heated converter, will also be reduced to NO; meaning reduction by the heated converter is not specific to just NO_2. Thus, if a significant amount of NO_Z species are present in the ambient air, some of those species may make it to the heated converted and erroneously be counted as NO_2 when the analyzer determines the NO_2 concentration by difference. The EPA does not believe this measurement bias is a significant concern in the near-road environment (and typically in many urban sites) because the gaseous NO_Y species present in are dominated by NO and NO_2, due to the proximity to the emission source (e.g., vehicles on the road). This measurement bias is of greater concern when measuring so-called "aged" air masses, where there has been time for NO_X emissions to be further oxidized into other NO_Z species.

There are other techniques that are commercially available to measure NO_2, however, as of the production of this document (circa August 2011) there are no other approved methods for NO_2 measurement with which the data could be used to determine compliance with the NAAQS. One of the available methods is a photolytic-chemiluminescent analyzer. This method, like the traditional chemiluminescent analyzer, can only directly measure NO. However, the photolytic-chemiluminescent analyzer uses a photolytic converter (instead of a heated metal converter) to reduce NO_2 to NO for measurement.

The advantage that this method has over the traditional chemiluminescent analyzer is that the photolytic converter is specific to NO_2, and does not reduce other NO_Z species to NO, removing the potential for bias if NO_Z species are present. Another commercially available method to measure NO_2 is the Cavity Ring-Down Spectrometer (CRDS). The CRDS uses the measured decay of laser light at a specific wavelength due to NO_2 absorption to determine the NO_2 concentration in the sampled air. Beyond these two examples, there are other laser based techniques that are available to measure NO_2, although they largely are still considered to be research-grade instruments. The EPA plans to continue to work with academia and measurement technology vendors to improve measurement techniques, increasing the accuracy, precision, and speed of these next generation measurement technologies. Eventually, the EPA hopes that the advancement of such measurement technologies will lead to their consideration as reference or equivalent methods as they are ready.

14.2 Meteorological Measurements

Meteorological data measured on-site at a near-road monitoring station can provide important information that can be used to characterize the pollutant data being measured at the station. As part of the CASAC AAMMS review, the panel stated that "the AAMMS believes meteorological parameters (wind speed and direction) should be one of the highest tier measurements considered as part of [the near-road NO_2] network." A key advantage to having meteorological data collected on site would be the ability to correlate the occurrence of peak NO_2 concentrations to wind conditions. Data analysis of the collected data will be greatly enhanced by knowing if winds are calm, parallel to the road, or at any other angle making the monitoring site relatively upwind or downwind when peak NO_2 concentrations are measured. Although meteorological measurements were proposed to be required at near-road NO_2 sites, the EPA did not require them. However, the EPA strongly encourages states to measure meteorological parameters at near-road sites whenever possible. The EPA suggests that state and local air agencies try to measure wind speed, wind direction, temperature, and relative humidity, at a minimum (which matches those parameters required at NCore stations). If possible, other measurements such as precipitation, solar radiation, and barometric pressure, among others should be considered as well. More information on meteorological parameters, measurement techniques, and related quality assurance can be found in EPA's Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements, located at: http://www.epa.gov/ttn/amtic/met.html.

14.3 Traffic Counters and/or Cameras

Traffic counting devices and/or traffic cameras are another non-pollutant measurement that could be useful to an air agency to aid in characterizing measured pollutants at a near-road monitoring site. Understanding the traffic behavior can allow for correlation to measured pollutant concentrations, such as the correlation of peak NO_2 readings to time periods when traffic is heaviest and/or experiencing increased congestion, for example. There are a number direct-measure methods used to characterize traffic including over the road tube counters, imbedded devices such as contact closure loops for counts or piezo-electric sensors used for weigh-in-motion, speed and red light cameras, and vehicle classification and counts. These methods are used by placing the sensors on or within the road surface of active travel lanes. Unless a transportation agency has installed (or plans to install) such devices on a target road segment, the EPA does not encourage air agencies to pursue the use of such methods to gather traffic count information. However, there are remote sensing methods available to characterize traffic that use radar or camera based technology. These methods are able to be installed along-side of roads (such as on a meteorological tower or monitoring shelter) and can look down on the target road segment to characterize the traffic. The sophistication of remotely sensing instruments is variable, but the EPA suggest that if such a device is investigated for use, it should be capable of making total traffic counts for at least an hourly interval. Other data metrics that would also be useful include the ability to segregate HD from LD vehicle counts and those methods with sub-hourly time resolution capability.

The EPA envisions any air agency collecting such data should do so only for the internal use of analyzing air quality data, and not to broadcast traffic data publicly independent of their local transportation agency. In some cases, the local transportation agency might be in a position to collaborate with an air agency that is looking to collect traffic data for a particular road segment where no traffic data is currently being collected. In such a case, there may be a synergistic advantage for both the air agency and the transportation agency; allowing the air agency to gather traffic data for air quality analysis with the support of a transportation agency, while the transportation agency may gain another source of traffic data for their use as well, at no cost to them. The EPA encourages state and local air agencies to pursue such collaboration if traffic data collection is pursued at near-road monitoring sites.

14.4 Black (or Elemental) Carbon

The graphitic-containing portion of PM, represented by black carbon (BC) or elemental carbon (EC), also referred to as "soot," is emitted in motor vehicle exhaust. BC and EC are operationally-defined. BC and EC are of interest because they serve as a measure of diesel particulate matter (DPM). Long-term (i.e., chronic) inhalation exposure to diesel exhaust (combination of gases and particles) is likely to pose a lung cancer hazard to humans, as well as damage the lung in other ways depending on exposure. Short-term (i.e., acute) exposures can cause irritation and inflammatory symptoms of a transient nature, these being highly variable across the population (http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=29060). Although BC and EC are primarily associated with emissions from heavy-duty diesel engines, a portion of all motor vehicle combustion emissions contains these constituents. BC is measured through light absorption while EC is measured thermally. BC measurements can be made sub-hourly to hourly while EC measurements are typically hourly to daily. Other sources of BC or EC exist in urban areas (such as wood smoke), but emissions from motor vehicles usually dominate these sources in near-road air quality, thus making BC or EC measurements a useful parameter for identifying impacts from motor vehicle emissions.

14.5 Carbon Monoxide (CO)

CO is a colorless, odorless gas emitted from combustion processes. CO can cause harmful health effects by reducing oxygen delivery to the body's organs (like the heart and brain) and tissues. In addition, CO is a useful indicator of the transport and dispersion of inert, primary combustion emissions from on-road mobile sources, as CO does not react in the near-road environment. The majority of CO emissions come from mobile sources, where approximately 60% of the national inventory is attributable to on-road mobile sources (per the 2008 National Emissions Inventory). Although ambient CO levels have seen significant reduction over the past several decades, motor vehicles remain the primary source of this pollutant in most locations. Although all motor vehicles emit CO, the majority of mobile source CO is from light-duty, gasoline-powered vehicles.

Ambient CO measurements are routinely on an hourly interval using analyzers based upon gas filter correlation methodology, which relies on infrared (IR) absorption of CO at a specific radiation wavelength. This method has been in use since the 1970s and the current ambient CO compliance monitoring network is comprised of wholly of analyzers based on this infrared absorption method. Of these analyzers, there currently two types of IR absorption sub-species in use, the standard analyzer and a more recently commercialized 'trace-level' line of analyzers. Standard analyzers have levels of detection on the order of 0.5 to 1 ppm, while the trace-level analyzers have levels of detection down to approximately 0.04 ppm. While trace-level analyzers are strongly encouraged for use in the CO monitoring network when possible, standard CO analyzers are expected to be sufficient for use in the near-road environment, where ambient levels are expected to be relatively higher than at other locations more representative of area-wide spatial scales.

[THE EPA WILL INSERT ANY RELATED NEAR-ROAD CO REQUIREMENTS RESULTING FROM AUGUST 12th, 2011, RULEMAKING HERE, WHEN PUBLICLY AVAILABLE.]

14.6 Particulate Matter (PM) - Number Concentration

PM emitted through the combustion process occurs initially in the ultrafine size range (i.e., less than 0.1 µm in diameter) and a very large number of these small particles are emitted. Despite the large number of ultrafine particles emitted, the impact on PM mass is negligible. Research has shown that PM number concentration measurements often provide a good indication of primary PM exhaust emissions from motor vehicles. Several health studies suggest that ultrafine particles may lead to adverse health effects. A number of devices exist to measure PM number concentrations, ranging from inexpensive industrial hygiene monitors to research-grade ambient air monitors (e.g., condensation particle counter, differential mobility analyzer). Most of these devices can provide number concentration measurements in near real-time, although the range of particle sizes and concentrations detected vary. When comparing measurements from different devices, any differences in particle size ranges detected must be noted. Measurements show that as the distance or transit time from emission to sampling increases, the size distribution shifts to larger particle diameters.

14.7 Particulate Matter (PM) – Mass

PM is a complex mixture of small particles and liquid droplets comprised of sulfates, nitrates, acids, ammonium, elemental carbon, organic carbon compounds, trace elements such as metals, and water. The size of particles is directly linked to their potential for causing health problems. Particles that are 10 micrometers in diameter or smaller (PM_{10}) are of concern because those are the particles that generally pass through the throat and nose and enter the lungs. Once inhaled, these particles can affect the heart and lungs and cause serious health effects. Motor vehicles emit significant amounts of PM through combustion, brake wear, and tire wear. Motor vehicles may also contribute to elevated near-road PM concentrations by re-suspending dust present on the road surface.

In the United States, the NAAQS regulates ambient concentrations of PM_{10} and PM less than 2.5 μm in diameter ($PM_{2.5}$). Both of these PM size fractions are emitted by motor vehicles. In general, PM from combustion is in the $PM_{2.5}$ size fraction, with combustion-emitted particles typically being ultrafine particles (those PM having a diameter less than 0.1 μm). These ultrafine particles contribute little to ambient $PM_{2.5}$ mass concentrations, contribute significantly to PM number concentrations, and can impact the chemical composition of the $PM_{2.5}$ mass collected near the road relative to urban background conditions. Ultrafine particles tend to exist as disaggregated particles for very short periods of time (minutes) and rapidly coagulate into accumulation mode particles. Accumulation mode PM that is secondarily formed from motor vehicle combustion emissions may have a greater impact on $PM_{2.5}$ mass concentrations further downwind from the source road. PM emitted through mechanical processes of vehicle operation (e.g., brake wear, tire wear, re-suspended road dust) will tend to be in the PM_{10} size fraction and can lead to elevated mass concentrations. As a result, both PM_{10} and $PM_{2.5}$ mass measurements and any speciation of PM mass at near-road sties can be very informative in furthering the understanding of the concentrations, properties, and behavior of PM in the near-road environment.

Currently, a majority of PM_{10} mass measurements and a slight majority of $PM_{2.5}$ mass measurements use filter-based, gravimetric analyses over a 24-hour sample collection period.

Diurnal variations in traffic and meteorology can have a tremendous impact on near-road air quality that is not identifiable in 24-hour average measurements. Thus, continuous (i.e., hourly or sub hourly) PM measurements provide useful information for near-road applications. Continuous particle measurement methods include the use of Beta attenuation, Tapered Element Oscillating Microbalances (TEOMs), and optical (light scattering) measurements (e.g., nephelometry). However, care must be taken in choosing a sampling method. Optical PM mass samplers, for example, typically cannot detect particles less than approximately 0.2-0.5 μm in diameter. These measurement devices may not capture a significant amount of the PM mass related to motor vehicle combustion emissions. In addition, some continuous PM samplers heat the inlet air prior to analysis. Since motor vehicle PM emissions contain a significant amount of semi-volatile organic compounds, these samplers may have the potential to underestimate the PM mass in the near-road environment by volatilizing the organic PM prior to detection.

14.8 Organic Carbon (OC)

OC is a complicated mixture of thousands of individual molecules and is a combination of both primary particulate emissions and gaseous precursors that can form secondary aerosol. Some of the OC compounds, such as polycyclic aromatic hydrocarbons (PAHs), are known or suspected carcinogens. OC is often the largest component of PM in urban areas in the Western U.S. and especially in near-roadway environments. Motor vehicle fuel combustion is an important contributor of OC. OC is typically measured by collected PM on filters and then thermally quantifying the OC portion of the PM. These measurements are most commonly performed daily but continuous instruments that allow for 1-hr time resolution are in use. Other sources of OC exist in urban areas (such as wood smoke, industrial processes, biogenic emissions). Little is known about OC concentration gradients from roadways; however emissions from motor vehicles usually dominate these sources in near-road air quality.

To further investigate the OC mass, samples can be collected and analyzed for a wide range of organic species. These organic PM samples are most often collected on filters backed by a cartridge to collect gas-phase constituents. Sample collection typically uses high-volume samplers to maximize the amount of PM mass obtained for detailed chemical and physical analysis; thus, collection times can be from 24-hours to over a week, or samples are consolidated, to collect an ample amount of mass. Detailed speciation of organic PM compounds present in near-road samples can be useful in conducting or evaluating source apportionment studies to estimate the impacts of traffic emissions on near-road PM concentrations, although the long sample averaging times required for this analysis may limit the ability to discern differences in vehicle activity on organic PM air quality impacts. Alternatively, higher time resolution measurements can be made with instruments such as the high resolution aerosol mass spectrometer (HR-AMS), where e.g., 2-minute resolved data can be gathered. While specific molecules are not quantified, the amount of primary versus secondary OC can be quantified, and as well as local versus regional influences.

14.9 CO_2

Fossil fuel combustion is the primary source of CO_2 emissions, with the transportation sector contributing about 33% of U.S. CO_2 emissions. CO_2 is of concern as the most important greenhouse gas contributing to climate change. Continuous CO_2 measurements are typically made using a non-dispersive infrared system with which sub hourly sampling duration can be achieved. CO_2 concentrations can be elevated near roads, so high resolution measurement methods with good precision (high signal to noise ratios) would be needed to quantify near road impacts to relative background concentrations.

14.10 Ozone (O_3)

O_3 is not usually emitted directly into the air, but at ground-level is created by a chemical reaction between oxides of nitrogen (NO_x) and volatile organic compounds (VOCs) in the presence of sunlight. NO_x and VOCs are emitted by mobile sources. O_3 can trigger a variety of respiratory health problems; worsen bronchitis, emphysema, and asthma; reduce lung function; and inflame the linings of the lungs. O_3 is routinely measured in situ using photometry or chemiluminescence on a sub hourly to hourly sampling frequency. O_3 measurements are not typically collected for near-road applications. However, the presence of elevated NO concentrations in the near-road microenvironment may lead to lower O_3 concentrations due to "ozone scavenging" as part of the formation of NO_2 from NO and O_3. O_3 measurements may be useful in select circumstances to support health studies investigating the role of ozone and other co-pollutants on adverse health effects given the potentially lower concentrations of this pollutant relative to other pollutants in this microenvironment. O_3 measurements may also aid in understanding NO_2 concentrations in the near road environment.

14.11 Sulfur Dioxide (SO_2)

Sulfur dioxide emissions from the transportation sector include the burning of high sulfur containing fuels by locomotives, large ships, and non-road equipment. On road diesel fueled vehicles emit little SO_2 because of limits to the amount of sulfur that can be present in the fuel. SO_2 is linked with a number of adverse effects on the respiratory system. SO_2 is usually measured using ultraviolet fluorescence techniques. Similar to ozone, SO_2 measurements are not typically collected for near-road applications. SO_2 measurements may be useful in select circumstances to support health studies investigating the role of SO_2 and other co-pollutants on adverse health effects given the potentially lower concentrations of this pollutant relative to other pollutants in this microenvironment.

14.12 Air Toxics

In addition to criteria pollutants, motor vehicles emit a large number of other compounds which can cause adverse health effects such as air toxics (or hazardous air pollutants). A discussion and listing of potential air toxics of concern for near-road monitoring can be found in the U.S. EPA's Mobile Source Air Toxics (MSAT) Rule (U.S. EPA, 2007). These pollutants include volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and organic and inorganic PM constituents. Reasons for monitoring these pollutants for a near-road program include concerns over adverse human health effects, ecological effects, and the evaluation of the effectiveness of mobile source control programs. Air toxics span the entire range of pollutants present in the atmosphere; they are present as particles, gases, and in semi-volatile form. No one measurement method captures all air toxics of interest in a near road environment. This section discusses potential monitoring activities for a number of classes of air toxics, but a discussion of all potential air toxic compounds identified in the MSAT rule is beyond the scope of this document.

Typical VOCs of concern for near-road monitoring include, but are not limited to, benzene, toluene, ethylbenzene, xylenes, styrene, 1,3-butadiene and various aldehydes. These air toxics can contribute to long term health issues (e.g., cancer) and are also ozone precursors. A more detailed listing of potential VOCs of health concern is included in the MSAT Rule. VOCs are typically measured by the collection of ambient air using evacuated canister sampling and subsequent analysis on a gas chromatograph (GC). Sampling frequency can range from 1 hour, for automated systems, up to 24 hours. For evacuated canister sampling, the sample collection time can vary from an instantaneous grab sample to averaging times of more than 24-hours depending on the collection equipment used. Auto-GCs can be used to measure select VOC pollutant concentrations semi-continuously at a monitoring site. A number of manufacturers also advertise semi-continuous analyzers for one or more VOCs of interest using various GC technologies.

Aldehydes emitted from motor vehicles include, but are not limited to, formaldehyde, acetaldehyde, and acrolein. A more detailed listing of aldehydes with potential health concerns is included in the MSAT Rule. These pollutants are also formed through secondary production in the atmosphere. Aldehydes are typically measured using cartridges containing dinitrophenyl hydrazine (DNPH). In addition, other methods, including evacuated canisters and cartridges with dansylhydrazine (DNSH), have been used to measure ambient concentrations of some of these compounds. Sample collection periods of 24-hours or more are typically required for assessing ambient aldehyde concentrations although a few manufacturers advertise semi-continuous analyzers for select compounds. Accurate acrolein measurements remain a challenge. Measurements of these pollutants have indicated concentrations are elevated near heavily trafficked roads.

SVOCs present in near-road emissions are naphthalene and other polycyclic aromatic hydrocarbons (PAH). SVOC sampling is done using XAD/PUF cartridges within high volume samplers over 24 hour sampling periods. The XAD/PUF cartridges are extracted and analyzed using a gas chromatograph with a mass spectrometer, GC/MS.

Toxic metals are present in $PM_{2.5}$ and PM_{10} samples, along with other elements (such as soil components). These toxic metals can be emitted from brake wear, tire wear, engine wear, and oil and lubricant combustion. Inorganic PM samples are usually collected on filters using high-volume samplers and longer sampling times to collect sufficient mass for elemental analyses. Higher frequency monitoring methods, sub hourly to multiple hours, are developed, but not in wide use. Concentration gradients near roads of these toxic metals have not been widely studied in real-time. Metal deposition has been shown to have a similar gradient to other motor vehicle related pollutants near roads.

14.13 Lead (Pb)

Before the introduction of unleaded gasoline throughout much of the world, motor vehicle lead emissions were a major public health concern. While lead is no longer added to gasoline in many countries, motor vehicle fuels still contain trace amounts of Pb from crude oil. Lead is also present in trace amounts in lubricating oil. Other sources that may contribute to ambient Pb concentrations in the near-road environment include brake wear, tire wear, and the degradation of wheel weights used for aftermarket tire balancing. Re-suspended road dust may also contain Pb from historically deposited industrial or mobile source emissions. Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems and the cardiovascular system. Lead exposure also affects the oxygen carrying capacity of the blood. Lead is typically measured through total suspended particulate (TSP) sampling with filter collection and subsequent chemical analysis. Sampling times are typically 24-hr.

Appendix A Supporting Information on Uncertainties in Traffic Data and Rationale for Roadway Design Considerations

A.1 Uncertainties in Traffic Data

Uncertainties exist in the data collected for the HPMS and Traffic Demand Modeling applications that should be recognized when interpreting this data to identify suitable road segments for NO_2 near road NAAQS monitoring. These uncertainties relate to the type and frequency of traffic data collected, location of sampling, and the characterization of vehicle type with these systems.

A.1.1 Measurement and Frequency Uncertainties

Measurement types include fixed, automated sensors and temporary devices that can be deployed for short periods of time on a given road section.

A.1.2 Fixed Measurement Systems

Automated traffic recorders and weigh-in-motion devices comprise the options available for fixed, long-term measurements of traffic volume. These sampling devices typically operate for over a year, so these measurements can be directly related to an AADT value.

A.1.3 Temporary Measurement Systems

Pneumatic tubes can be used for short-term measurements of traffic volumes. When these devices are used for traffic measurements, expansion factors must be used to estimate AADT volumes on that road segment. These expansion factors can be related to maximum hourly traffic volumes or the overall number of days of sampling conducted with the temporary devices.

A.1.4 Sampling Location Uncertainties

Since resource restrictions do not allow for the siting of traffic counting devices at all locations, there are uncertainties associated with the estimation of traffic volumes along roadway segments not monitored.

A.1.5 Vehicle Characterization Uncertainties

The measurement devices described above have limitations in differentiating the mix of vehicles present on the roadway. Many devices separate light-duty from heavy-duty vehicles using length factors as described above. These lengths can be misclassified due to a number of factors including tailgating and multiple truck axles, although misclassification depends on the measurement device. In addition, these devices cannot differentiate between vehicles operating on gasoline versus diesel fuels. While this differentiation is not critical for highway planning, understanding the distribution of gasoline versus diesel vehicles can be very important for emissions and air quality characterization. In the United States, the vast majority of light-duty vehicles (less than 20 feet in length) operate on gasoline, while the vast majority of heavy-duty vehicles (greater than 40 feet in length) operate on diesel fuel. Medium-duty vehicles (between 20 and 40 feet in length) can operate on either gasoline or diesel fuels, and present the highest uncertainties related to air pollutant emissions and fuel use.

Appendix B Using MOVES to Create a Heavy-Duty to Light-Duty NO_x Emission Ratio for Use in this TAD

As described in Section 5 of the TAD, the HD_m ratio provides a means to weight the contribution of heavy-duty vehicle emissions compared with emission rates from light-duty vehicles for use in creating FE-AADT values. Since the FE-AADT process is used to only compare the potential for maximum NO_2 concentrations among road segments within a CBSA, a ratio was chosen using national default emission values for both heavy and light-duty vehicles. Actual emission rates can vary based on a number of factors including the vehicle technology, fuel burned, vehicle speed, vehicle load, and ambient temperature. Thus, a single HD_m value cannot capture all of the variability that can be experienced among differing vehicle types. The default HD_m value represents a ratio of average heavy-duty to light-duty vehicle emissions experienced across the U.S. for typical highway driving conditions. State/local air agencies may also want to develop their own HD_m value based on data specific to their CBSA. To assist with this process, the AMTIC Near-road Monitoring webpage is planned to (http://www.epa.gov/ttn/amtic/nearroad.html) contains the 2010 MOVES data for NO_X emissions across multiple vehicle types, speed ranges, and ambient temperatures, as well as default assumptions used when applicable

Appendix C MODELING

C.1 Purpose

The purpose of this section is to offer specific guidance to those state and local agencies choosing to use modeling to further inform the implementation of NO_2 near-road monitors. This modeling guidance will offer guidance on the selection of an air quality model, modeling domain (including receptor placement), characterization of emission sources, meteorological inputs, and inclusion of background concentrations.

C.2 Guidance on Air Emissions Models

This guidance is based on the MOVES user guide and Section 4 of EPA's *Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas* and EPA's *Using MOVES in Project-Level Carbon Monoxide Analyses.* The following sections provide guidance on running the MOVES model to meet the objectives of this TAD.[to be inserted in future draft]

C.3 Guidance on Air Quality Models

This guidance is based on and is consistent with EPA's *Guideline on Air Quality Models,* also published as Appendix W of 40 CFR Part 51. Appendix W is the primary source of information on the regulatory application of air quality models for State Implementation Plan (SIP) revisions for existing sources and for New Source Review (NSR) and Prevention of Significant Deterioration (PSD) programs. Air quality modeling to inform the implementation of

NO2 near-road monitors would need to employ air quality dispersion models[4] that properly address NO_2 emissions and, thus, should rely upon the principles and techniques in Appendix W.

Appendix W was originally published in April 1978 and was incorporated by reference in the regulations for the Prevention of Significant Deterioration of Air Quality, Title 40, Code of Federal Regulations (CFR) sections 51.166 and 52.21 in June 1978 [43 FR 26382-26388]. The purpose of Appendix W guidelines is to promote consistency in the use of modeling within the air quality management process. These guidelines are periodically revised to ensure that new model developments or expanded regulatory requirements are incorporated.

Clarifications and interpretations of modeling procedures become official EPA guidance through several courses of action: 1) the procedures are published as regulations or guidelines; 2) the procedures are formally transmitted as guidance to Regional Office managers; 3) the procedures are formally transmitted as guidance to Regional Modeling Contacts as a result of a Regional consensus on technical issues; or 4) the procedures are a result of decisions by the EPA's Model Clearinghouse that effectively establish national precedent. Formally located in the Air Quality Modeling Group (AQMG) of EPA's Office of Air Quality Planning and Standards (OAQPS), the Model Clearinghouse is the single EPA focal point for the review of criteria pollutant modeling techniques for specific regulatory applications. Model Clearinghouse and related Clarification memoranda involving decisions with respect to interpretation of

[4] Dispersion modeling uses mathematical formulations to characterize the atmospheric processes that disperse a pollutant emitted by a source. Based on emissions and meteorological inputs, a dispersion model can be used to predict concentrations at selected downwind receptor locations.

modeling guidance are available at the Support Center for Regulatory Atmospheric Modeling (SCRAM) website.[5]

Recently issued EPA guidance of relevance for consideration in modeling for attainment and maintenance demonstrations includes:

- "Applicability of Appendix W Modeling Guidance for the 1-hour NO_2 NAAQS" June 28, 2010—confirming that Appendix W guidance is applicable for NSR/PSD permit modeling for the new NO_2 NAAQS (U.S EPA, 2010a).
- "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard" March 1, 2011– provides additional guidance regarding NO_2 permit modeling and also relevant to modeling for implementation of NO_2 near-road monitors (U.S. EPA, 2011a).
- "Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas" – provides guidance on hot-spot analyses for $PM_{2.5}$ and PM_{10} and has applicable guidance relevant to NO_2. (U.S. EPA, 2010b, 2010c)[6].

The following sections will refer to the relevant sections of Appendix W and other existing guidance with summaries as necessary. Please refer to those original guidance documents for full discussion and consult with the appropriate EPA Regional Modeling Contact if questions arise about interpretation on modeling techniques and procedures[7].

C.4 Model Selection

Preferred air quality models for use in regulatory applications are addressed in Appendix A of EPA's *Guideline on Air Quality Models*. If a model is to be used for a particular application,

---

[5] The Support Center for Regulatory Atmospheric Modeling (SCRAM) website is available at: http://www.epa.gov/ttn/scram/.

[6] Hereafter referred to as "PM hot-spot guidance."

[7] List of Regional Modeling Contacts by EPA Regional Office is available from SCRAM website at: http://www.epa.gov/ttn/scram/guidance_cont_regions.htm

the user should follow the guidance on the preferred model for that application. These models may be used without an area specific formal demonstration of applicability as long as they are used as indicated in each model summary of Appendix A. Further recommendations for the application of these models to specific source problems are found in subsequent sections of Appendix W. In 2005, EPA promulgated the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) as the Agency's preferred near-field dispersion modeling for a wide range of regulatory applications in all types of terrain based on extensive developmental and performance evaluation.

As described in the PM hot-spot guidance (U.S. EPA, 2010b, 2010c), two dispersion models have been recommended for use in the PM hot-spot analyses and are applicable as well to NO_2 modeling: EPA's preferred near-field dispersion model, AERMOD (U.S. EPA, 2004a; U.S. EPA, 2011b) or CAL3QHCR (U.S. EPA, 1995).

For most scenarios to be considered as part of this TAD, AERMOD should be used. AERMOD was used in the NO2 Risk and Exposure Assessment (U.S. EPA, 2008b) and performed generally well and is the recommended model for most mobile source modeling scenarios (See Exhibit 7-2 of the PM hot-spot guidance). The guidance discussed here will focus on the use of AERMOD for mobile source modeling. For more information about the use of CAL3QHCR in mobile source modeling see the PM hot-spot guidance (U.S. EPA, 2010b, 2010c) and the CAL3QHCR User's Guide addendum (U.S. EPA, 1995).

The AERMOD modeling system includes several components, which fall into one of two categories: regulatory and non-regulatory. The regulatory components are:

- AERMOD: the dispersion model (U.S. EPA, 2004a; U.S. EPA, 2011b)
- AERMAP: the terrain processor for AERMOD (U.S. EPA, 2004b, U.S. EPA, 2011c)

- AERMET: the meteorological data processor for AERMOD (U.S. EPA, 2004c; U.S. EPA, 2011d)
- BPIPPRIME: the building input processor (U.S. EPA, 2004d)

The non-regulatory components are:

- AERSURFACE: the surface characteristics processor for AERMET (U.S. EPA, 2008a)
- AERSCREEN: a recently released screening version of AERMOD (U.S. EPA, 2011e)

Before running AERMOD, the user should become familiar with the user's guides associated with the modeling components listed above and the AERMOD Implementation Guide (AIG) (U.S. EPA, 2009). The AIG lists several recommendations for applications of AERMOD which would be applicable for NO_2 roadway modeling.

C.5 Receptor Placement

The receptor grid is unique to the particular situation and depends on the size of the modeling domain, number of modeled sources, and complexity of terrain. Receptors should be placed in areas that are considered ambient air. Receptor placement should be of sufficient density to provide resolution needed to detect significant gradients in the concentrations with receptors placed closer together near the source to detect local gradients and placed farther apart away from the source. In addition, the user should place receptors at key locations such as around facility fence lines (which define the ambient air boundary for a particular source) or monitor locations (for comparison to monitored concentrations for model evaluation purposes). The receptor network should cover the modeling domain. Refer to Section 7.6 of the PM hot-spot guidance for general guidance on placing receptors near roadways and the AERMOD User's Guide and Addendum for receptor inputs into AERMOD. Receptors may also be placed in locations that may represent potential monitoring sites as outlined in Section 6 of this document.

C.6 OLM and PVMRM

As outlined in Section 5.2.4 of Appendix W, there is a three-tiered approach to estimating NO_2 concentrations from AERMOD. The first tier, the most conservative, is to assume total conversion of NO to NO_2. The second, less conservative tier is to apply a representative equilibrium NO_2/NO_x Ratio to modeled concentrations to yield NO_2 concentrations. The third tier is to use a detailed analysis on a case-by-case basis, using PVMRM (Hanrahan, 1999a, 1999b; Cimorelli et al., 2004) or OLM. In the March 1, 2011, memorandum "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard," clarification was provided for tiers 2 and 3. A summary is provided here but users are strongly encouraged to read the memorandum for details.

For the tier 2 option of applying an ambient ratio, Appendix W listed a default ratio of 0.75 to apply to annual NO concentrations to yield annual NO_2. The June 29, 2010 memorandum, "Applicability of Appendix W Modeling Guidance for the 1-hour NO_2 NAAQS" cautioned against the use of the 0.75 ratio for hourly NO2 concentrations. The March 1, 2011 memorandum further clarified this position and recommended a value of 0.80 for 1-hour concentrations.

For the tier 3 approach, either PVMRM or OLM, the March 1, 2011 memorandum gave clarification about their use. The clarifications are summarized here, but again the user is strongly encouraged to read the March 1, 2011 memorandum in full as well as consult the AERMOD User's Guide (U.S. EPA, 2004a) and addendum (U.S. EPA, 2011b) for details about the implementation of PVMRM and OLM in AERMOD. The key points of the March 1 memorandum are:

- Two inputs needed for the PVMRM or OLM options in AERMOD are: 1) in-stack ratio of NO_2 to NO_x (AERMOD keyword NO2STACK, or for source specific ratios AERMOD keyword NO2RATIO) and background ozone concentration
- The memorandum recommended an acceptance of 0.5 for the NO_2/NO_x ratio in the absence of more appropriate source-specific ratios.
- Limited evaluations of PVMRM show encouraging results and there appears to be generally good performance and PVMRM and OLM (with OLMGROUP ALL)
- PVMRM is not inherently superior to OLM for cumulative analyses.
- PVMRM as currently implemented may also have a tendency to overestimate conversion of NO to NO_2 for low-level plumes by overstating the amount of ozone available for conversion due to the manner in which the plume volume is calculated.
- PVMRM has further limitations for area source applications, especially for elongated area sources that may be used to simulate road segments. A series of volume sources is recommended for simulating NO_2 impacts from roadway emissions if PVMRM is used.
- OLM with OLMGROUP ALL was used in the NO_2 Risk and Exposure Assessment (U.S. EPA, 2008b) and generally showed good results, suggesting that OLM with OLMGROUP ALL is appropriate for modeling such emissions[8].

[8] The June 29, 2010 memorandum recommends that for all applications involving the use of OLM (subject to approval under Section 3.2.2.e of Appendix W) should routinely utilize the "OLMGROUP ALL" option for combining plumes.

C.6.1 Source Characterization

As described in the PM hot-spot guidance Appendix J (U.S. EPA, 2010b, 2010c), road segments can be characterized as either elongated area sources (AERMOD source type AREA) or a series of volume sources (AERMOD source type VOLUME). For more information about these source characterizations and their use in near-roadway modeling refer to Appendix J of the PM hot-spot guidance (U.S. EPA, 2010). For general information about these source types, refer to the AERMOD User's Guide and addendum (U.S. EPA, 2004a; U.S. EPA, 2011b). As noted in Section D.6.4, if modeling roadway segments with PVMRM, it is recommended to represent the roadway as a series of volume sources.

C.6.2 Inclusion of Nearby Sources

The inclusion of stationary sources in modeling of NO_x mobile emissions should be considered carefully and is complicated given the nature of the pollutant, the form of the NO_2 NAAQS standard, and the purpose of the modeling. Sometimes, moderate or large stationary sources may be located within a few kilometers of a major roadway. Inclusion of stationary sources in mobile source modeling may heavily influence the near-road environment and change the spatial distribution and magnitude of modeled concentrations and are discussed below.

If road segments are modeled without any consideration of nearby stationary sources, the modeled peak concentrations will usually be near the road segments. If road segments are modeled as elongated areas sources, the maximum concentration will often occur near the ends of segments as the wind blows along the source. However, if stationary sources are included in the modeling results, and the sources are sufficiently large enough, the peak concentrations' locations may shift toward those sources away from the roads, thus impacting the decision on near-road monitor sites. Also, those sources could influence the near-road environment and any monitor placed near the road may measure influences from those sources.

Another implication of inclusion or non-inclusion of stationary sources in the modeling is in the application of PVMRM or OLM to model NO to NO2 conversion in AERMOD. If the stationary sources are included in the same model run with the road segment sources, there are more sources to compete for the input ozone to convert NO to NO2. The additional sources can lead to a different final result than if they were not included in the model run.

One recommendation is to model the road segment or segments of interest along with any nearby stationary sources that may influence the near-road environment and model with the OLM option with OLMGROUP ALL. For model output, create multiple source groups with the SRCGROUP keyword and output design values for each source group to analyze the effects of the stationary sources. Note, that the grouping of sources for SRCGROUP is independent of the grouping for OLM (see Section 2.5.5 of the AERMOD User's Guide Addendum (U.S. EPA, 2011b).

For example, if an area contains a road segment of interest and three stationary sources are nearby, then all sources can be modeled with OLM and using the OLMGROUP ALL option. Two source groups can be created: 1) a source group for the road segment only, and 2) a source group representing contributions from all sources (SRCGROUP ALL). The user can then output concentrations for design values for the road only source group and values for the total source group (See Section D.9 for output options for design value calculations).

The user can then analyze those results to see the effects of the stationary sources near the roadway and use that information to inform the monitor siting decision or inform the peak concentration analysis. The user can use design values based on the road segment to refine the monitor siting location.

C.6.3 Urban/Rural Classification

For any dispersion modeling exercise, the urban or rural determination of a source is important in determining the boundary layer characteristics that affect the model's prediction of downwind concentrations. Figure 6-1 gives example maximum 1-hour concentration profiles for a road segment represented by an area source (Figure 6-2a) and a volume source (Figure 6-2b) based on urban vs. rural designation. The urban population used for the examples is 100,000. For both cases, the urban and rural concentrations are nearly equal at short distances but as distance from the source increases, the urban concentrations become much less than the rural concentrations. These profiles show that the urban or rural designation of a source can be quite important.

Determining whether a source is urban or rural can be done using the methodology outlined in Section 7.2.3 of Appendix W and recommendations outlined in Sections 5.1 through 5.3 in the AIG (U.S. EPA, 2009). In summary, there are two methods of urban/rural classification described in Section 7.2.3 of Appendix W.

The first method of urban determination is a land use method (Appendix W, Section 7.2.3c). In the land use method, the user analyzes the land use within a 3 km radius of the source using the meteorological land use scheme described by Auer (1978). Using this methodology, a source is considered urban if the land use types, I1 (heavy industrial), I2 (light-moderate industrial), C1 (commercial), R2 (common residential), and R3 (compact residential) are 50% or more of the area within the 3 km radius circle. Otherwise, the source is considered a rural source. The second method uses population density and is described in Section 7.2.3d of Appendix W. As with the land use method, a circle of 3 km radius is used. If the population density within the circle is greater than 750 people/km^2, then the source is considered urban. Otherwise, the source is modeled as a rural source. Of the two methods, the land use method is considered more definitive (Section 7.2.3e, Appendix W).

Caution should be exercised with either classification method. As stated in Section 5.1 of the AIG (U.S. EPA, 2009), when using the land use method, a source may be in an urban area but located close enough to a body of water or other non-urban land use category to result in an erroneous rural classification for the source. The AIG in Section 5.1 cautions users against using the land use scheme on a source by source basis, but advises considering the potential for urban heat island influences across the full modeling domain. When using the population density method, Section 7.2.3e of Appendix W states, "Population density should be used with caution and should not be applied to highly industrialized areas where the population density may be low and thus a rural classification would be indicated, but the area is sufficiently built-up so that the urban land use criteria would be satisfied..." With either method, Section 7.2.3(f) of Appendix W recommends modeling all sources within an urban complex as urban, even if some sources within the complex would be considered rural using either the land use or population density method.

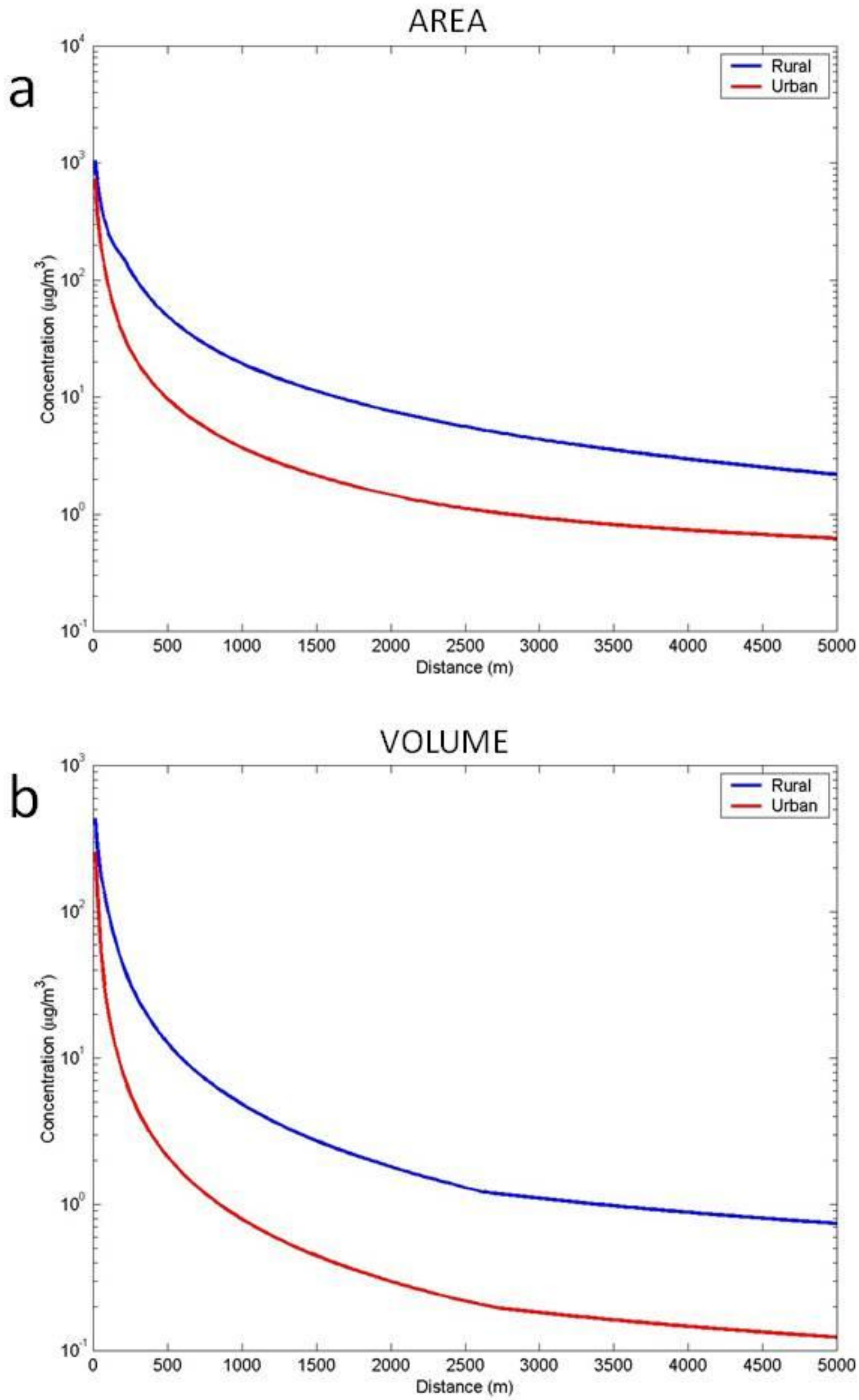


Figure C-1. Urban (red) and rural (blue) concentration profiles for (a) area source release, and (b) volume source release.

Another consideration that may need attention by the user, if including stationary sources in the modeling exercise, which is discussed in Section 5.1 of the AIG, regarding tall stacks located within or adjacent to small to moderate size urban areas. In such cases, the stack height or effective plume height for very buoyant sources may extend above the urban boundary layer height. The application of the urban option in AERMOD for these types of sources may artificially limit the plume height. The use of the urban option may not be appropriate for these sources, since the actual plume is likely to be transported over the urban boundary layer. Section 5.1 of the AIG gives details on determining if a tall stack should be modeled as urban or rural, based on comparing the stack or effective plume height to the urban boundary layer height and equation 104 of the AERMOD formulation document (Cimorelli, et al., 2004). This equation is:

$$z_{iuc} = z_{iuo}\left(\frac{P}{P_o}\right)^{1/4} \quad \textbf{(D-1)}$$

where z_{iuo} is a reference height of 400 m corresponding to a reference population P_o of 2,000,000 people.

If a stack is a buoyant release, the plume may extend above the urban boundary layer and may be best characterized as a rural source, even if it were near an urban complex. Exclusion of these elevated sources from application of the urban option would need to be justified on a case-by-case basis in consultation with the appropriate reviewing authority.

AERMOD requires the input of urban population when utilizing the urban option. Population can be entered to one or two significant digits (i.e., an urban population of 1,674,365 can be entered as 1,700,000). Users can enter multiple urban areas and populations using the URBANOPT keyword in the runstream file (U.S. EPA, 2004a; U.S. EPA, 2011b). If multiple urban areas are entered, AERMOD requires that each urban source be associated with a particular urban area or AERMOD model calculations will abort. Urban populations can be determined by using a method described in Section 5.2 of the AIG (U.S. EPA, 2009).

C.7 Meteorological Inputs

Section B.7 gives guidance on the selection of meteorological data for input into AERMOD. Much of the guidance from Section 8.3 of Appendix W is applicable to NO_2 near-road modeling and is summarized here. In Section B.7.2.1, the use of a new tool, AERMINUTE (U.S. EPA, 2011f), is introduced. AERMINUTE is an AERMET pre-processor that calculates hourly averaged winds from ASOS (Automated Surface Observing System) 1-minute winds.

C.7.1 Surface Characteristics and Representativeness

The selection of meteorological data that are input into a dispersion model should be considered carefully. The selection of data should be based on spatial and climatological (temporal) representativeness (Appendix W, Section 8.3). The representativeness of the data is based on: 1) the proximity of the meteorological monitoring site to the area under consideration, 2) the complexity of terrain, 3) the exposure of the meteorological site, and 4) the period of time during which data are collected. Sources of meteorological data are: National Weather Service (NWS) stations, site-specific or onsite data, and other sources such as universities, Federal Aviation Administration (FAA), military stations, and others. Appendix W addresses spatial representativeness issues in Sections 8.3.a and 8.3.c.

Spatial representativeness of the meteorological data can be adversely affected by large distances between the source and receptors of interest and the complex topographic characteristics of the area (Appendix W, Section 8.3.a and 8.3.c). If the modeling domain is large enough such that conditions vary drastically across the domain then the selection of a single station to represent the domain should be carefully considered. Also, care should be taken when selecting a station if the area has complex terrain. While a source and meteorological station may be in close proximity, there may be complex terrain between them such that conditions at the meteorological station may not be representative of the source. An example would be a source located on the windward side of a mountain chain with a meteorological station a few kilometers away on the leeward side of the mountain. Spatial representativeness for off-site data should also be assessed by comparing the surface characteristics (albedo, Bowen ratio, and surface roughness) of the meteorological monitoring site and the analysis area. When processing meteorological data in AERMET (U.S. EPA, 2004c; U.S. EPA, 2011d), the surface characteristics of the meteorological site should be used [Section 8.3.c of Appendix W and the AERSURFACE User's Guide (U.S. EPA 2008a)]. Spatial representativeness should also be addressed for each meteorological variable separately. For example, temperature data from a meteorological station several kilometers from the analysis area may be considered adequately representative, while it may be necessary to collect wind data near the plume height (Section 8.3.c of Appendix W).

Surface characteristics can be calculated in several ways. For details see Section 3.1.2 of the AIG (U.S. EPA, 2009). EPA has developed a tool, AERSURFACE (U.S. EPA, 2008a) to aid in the determination of surface characteristics. The current version of AERSURFACE uses 1992 National Land Cover Data. Note that the use of AERSURFACE is not a regulatory requirement but the methodology outlined in Section 3.1.2 of the AIG should be followed unless an alternative method can be justified.

C.7.2 Meteorological Inputs

Appendix W states in Section 8.3.1.1 that the user should acquire enough meteorological data to ensure that worst-case conditions are adequately represented in the model results. Appendix W states that 5 years of NWS meteorological data or at least one year of site-specific data should be used(Section 8.3.1.2, Appendix W) and should be adequately representative of the study area. If one or more years (including partial years) of site-specific data are available, those data are preferred. While the form of the NO_2 NAAQS contemplates obtaining three years of monitoring data, this does not preempt the use of 5 years of NWS data or at least one year of site-specific data in the modeling. The 5-year average based on the use of NWS data, or an average across one or more years of available site specific data, serves as an unbiased estimate of the 3-year average for purposes of modeling demonstrations of compliance with the NAAQS (See the June 28, 2010, Clarification Memorandum on "Applicability of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard" (U.S. EPA, 2010a). See the memorandum for more details on the use of 5 years of NWS data or at least one year of site-specific data and applicability to the NAAQS.

C.7.2.1 NWS Data

NWS data are available from the National Climatic Data Center (NCDC) in many formats, with the most common one in recent years being the Integrated Surface Hourly data (ISH). Most available formats can be processed by AERMET. As stated in Section B.7.1, when using data from an NWS station alone or in conjunction with site-specific data, the data should be spatially and temporally representative of conditions at the modeled sources.

A recently discovered issue with ASOS is that 5-second wind data that are used to calculate the 2-minute average winds are truncated rather than rounded to whole knots. For example, a wind of 2.9 knots is reported as 2 knots, not 3 knots. To account for this truncation of NWS winds (either standard observation or AERMINUTE output), an adjustment of ½ knot or 0.26 m/s is added to the winds in stage 3 AERMET processing. For more details refer to the AERMET User's Guide Addendum (U.S. EPA, 2011d) and/or the appropriate EPA Regional Modeling Contact.

C.7.2.2 AERMINUTE

In AERMOD, concentrations are not calculated for variable wind (i.e., missing wind direction) and calm conditions, resulting in zero concentrations for those hours. Since the NO_2 NAAQS is a one hour standard, these light wind conditions may be the controlling meteorological circumstances in some cases because of the limited dilution that occurs under low wind speeds which can lead to higher concentrations. The exclusion of a greater number of instances of near-calm conditions from the modeled concentration distribution may therefore lead to underestimation of daily maximum 1-hour concentrations for calculation of the design value.

To address the issues of calm and variable winds associated with the use of NWS meteorological data, EPA has developed a preprocessor to AERMET, called AERMINUTE (U.S. EPA, 2011f) that can read 2-minute ASOS winds and calculate an hourly average. Beginning with year 2000 data, NCDC has made the 1-minute wind data, reported every minute from the ASOS network freely available. The AERMINUTE program reads these 2-minute winds and calculates an hourly average wind. In AERMET, these hourly averaged winds replace the standard observation time winds read from the archive of meteorological data. This results in a lower number of calms and missing winds and an increase in the number of hours used in averaging concentrations. For more details regarding the use of NWS data in regulatory applications see Section 8.3.2 of Appendix W and for more information about the processing of NWS data in AERMET and AERMINUTE, see the AERMET (U.S. EPA, 2004c; U. S. EPA, 2011d) and AERMINUTE User's guides (U.S. EPA, 2011f).

C.7.2.3 Site-Specific Data

The use of site-specific meteorological data is the best way to achieve spatial representativeness. AERMET can process a variety of formats and variables for site-specific data. The use of site-specific data for regulatory applications is discussed in detail in Section 8.3.3 of Appendix W. Due to the range of data that can be collected onsite and the range of formats of data input to AERMET, the user should consult Appendix W, the AERMET User's Guide (U.S. EPA, 2004c; U. S. EPA, 2011d), and Meteorological Monitoring Guidance for Regulatory Modeling Applications (U.S. EPA, 2000). Also, when processing site-specific data for an urban application, Section 3.3 of the AERMOD Implementation Guide offers recommendations for data processing. In summary, the guide recommends that site-specific turbulence measurements should not be used when applying AERMOD's urban option, in order to avoid double counting the effects of enhanced turbulence due to the urban heat island.

C.7.2.4 Upper-Air Data

AERMET requires full upper air soundings to calculate the convective mixing height. For AERMOD applications in the U.S., the early morning sounding, usually the 1200 UTC (Universal Time Coordinate) sounding, is typically used for this purpose. Upper air soundings can be obtained from the Radiosonde Data of North America CD for the period 1946-1997. Upper air soundings for 1994 through the present are also available for free download from the Radiosonde Database Access website. Users should choose all levels or mandatory and significant pressure levels[9] when selecting upper air data. Selecting mandatory levels only would not be adequate for input into AERMET as the use of just mandatory levels would not provide an adequate characterization of the potential temperature profile.

C.8 Background Concentrations

Background concentrations are often included in a modeling analysis to account for sources not explicitly modeled or natural sources. Given the nature of the modeling described in this document, either for comparing road segments or refining monitor locations, inclusion of background concentrations may not be necessary, but best professional judgment should be used. Section 8.2 of Appendix W gives more detailed general guidance regarding background concentrations. The March 1, 2011 memorandum also gives guidance specific to NO2 and is summarized here:

- The June 28, 2010 memorandum initially discussed a "first tier" option of including the maximum 1-hour NO_2 concentration from a representative with the modeled design values. This option may be applied without further justification.
- The March 1, 2011 memorandum recognized that the above approach may be overly conservative and may be prone to reflecting source oriented impacts from nearby sources, thus increasing chances of double counting.

[9] By international convention, mandatory levels are in millibars: 1,000, 850, 700, 500, 400, 300, 200, 150, 100, 50, 30, 20, 10,7 5, 3, 2, and 1. Significant levels may vary depending on the meteorological conditions at the upper-air station.

- The March 1, 2011 memorandum discussed a second less conservative form of application of a uniform background by using monitored design values from the most recent 3-years of monitor data.
- Also discussed in the March 1, 2011 memorandum is the use of temporally varying background concentrations, i.e. using the 98^{th} percentile of concentrations by season and hour-of-day. The memorandum also discussed including a day of week component to background concentrations for mobile sources.

The user is strongly encouraged to read the March 1, 2011 memorandum for full details about background concentrations.

For the purposes of the modeling discussed in this technical document, inclusion of background concentrations may not be necessary. If the purpose of the modeling is to compare relative impacts of road segments, including background concentrations may not be necessary, since the purpose of the modeling is not a cumulative impact analysis. However, if the purpose of the modeling is for informing monitor siting or identifying peaks, background concentrations should be included, as well as stationary sources (See Section D.6.4) in order to fully characterize the air quality situation.

C.9 Running AERMOD and Implications for Design Value Calculations

Recent enhancements to AERMOD include options to aid in the calculation of design values for comparison with the NO_2 NAAQS. These enhancements include:

- The output of daily maximum 1-hour concentrations by receptor for each day in the modeled period for a specified source group. This is the MAXDAILY output option in AERMOD.

- The output, for each rank specified on the RECTABLE output keyword, of daily maximum 1-hour concentrations by receptor for each year for a specified source group. This is the MXDYBYYR output option.
- The MAXDCONT option, which shows the contribution of each source group to the high ranked values for a specified target source group, paired in time and space. The user can specify a range of ranks to analyze, or specify an upper bound rank, i.e. 8^{th} highest, and a lower threshold value, such as the NAAQS for the target source group. The model will process each rank within the range specified, but will stop after the first rank (in descending order of concentration) that is below the threshold, specified by the user. A warning message will be generated if the threshold is not reached within the range of ranks analyzed (based on the range of ranks specified on the RECTABLE keyword). This option may be needed to aid in determining which sources should be considered for controls.

For more details about the enhancements see the AERMOD User's guide Addendum (U. S. EPA, 2011b).

C.10 References

Auer, Jr., A.H., 1978: Correlation of Land Use and Cover with Meteorological Anomalies. Journal of Applied Meteorology, 17(5), 636-643.

Cimorelli, A. J., S. G. Perry, A. Venkatram, J. C. Weil, R. J. Paine, R. B. Wilson, R. F. Lee, W. D. Peters, R. W. Brode, and J. O. Paumier, 2004. AERMOD: Description of Model Formulation, EPA-454/R-03-004. U.S. Environmental Protection Agency, Research Triangle Park, NC. http://www.epa.gov/ttn/scram/7thconf/aermod/aermod_mfd.pdfU.S. EPA, 1985: Guideline for Determination of Good Engineering Practice Stack Height

(Technical Support Document for the Stack Height Regulations), Revised. EPA-450/4-80-023R. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. http://www.epa.gov/ttn/scram/guidance/guide/gep.pdf

Hanrahan, P.L., 1999a. "The plume volume molar ratio method for determining NO_2/NO_x ratios in modeling. Part I: Methodology," *J. Air & Waste Manage. Assoc.*, **49**, 1324-1331.

Hanrahan, P.L., 1999b. "The plume volume molar ratio method for determining NO_2/NO_x ratios in modeling. Part II: Evaluation Studies," *J. Air & Waste Manage. Assoc.*, **49**, 1332-1338.

U.S. EPA., 1995: Addendum to the User's Guide to CAL3QHC Version 2.0. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711

U.S. EPA, 2000: Meteorological Monitoring Guidance for Regulatory Modeling Applications. EPA-454/R-99-005. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. http://www.epa.gov/ttn/scram/guidance/met/mmgrma.pdf

U.S. EPA, 2004a: User's Guide for the AMS/EPA Regulatory Model – AERMOD. EPA-454/B-03-001. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. http://www.epa.gov/ttn/scram/models/aermod/aermod_userguide.zip

U.S. EPA, 2004b: User's Guide for the AERMOD Terrain Preprocessor (AERMAP). EPA-454/B-03-003. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.
http://www.epa.gov/ttn/scram/models/aermod/aermap/aermap_userguide.zip

U.S. EPA, 2004c: User's Guide for the AERMOD Meteorological Preprocessor (AERMET). EPA-454/B-03-002. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. http://www.epa.gov/ttn/scram/7thconf/aermod/aermet_userguide.zip

U.S. EPA, 2004d: User's Guide to the Building Profile Input Program. EPA-454/R-93-038. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711.

U.S. EPA, 2005. *Guideline on Air Quality Models*. 40 CFR Part 51 Appendix W. http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf

U.S. EPA, 2008a: AERSURFACE User's Guide. EPA-454/B-08-001. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711. http://www.epa.gov/ttn/scram/7thconf/aermod/aersurface_userguide.pdf

U.S. EPA, 2008b: Risk and Exposure Assessment to Support the Review of the NO_2 Primary National Ambient Air Quality Standard. EPA-452/r-08-008a. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, 27711. http://www.epa.gov/ttnnaaqs/standards/nox/data/20081121_NO2_REA_final.pdf

U.S. EPA, 2009: AERMOD Implementation Guide. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711. http://www.epa.gov/ttn/scram/7thconf/aermod/aermod_implmtn_guide_19March2009.pdf

U.S. EPA, 2010a: Applicability of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard. Tyler Fox Memorandum dated June 28, 2010, Research Triangle Park, North Carolina 27711. http://www.epa.gov/ttn/scram/ClarificationMemo_AppendixW_Hourly-NO2-NAAQS_FINAL_06-28-2010.pdf

U.S. EPA, 2010b: Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas. EPA-420/B-10-040. U.S. Environmental Protection Agency, Ann Arbor, Michigan 48105. http://www.epa.gov/otaq/stateresources/transconf/policy/420b10040.pdf

U.S. EPA, 2010c: Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas: Appendices. EPA-420/B-10-040. U.S. Environmental Protection Agency, Ann Arbor, Michigan 48105. http://www.epa.gov/otaq/stateresources/transconf/policy/420b10040-appx.pdf

U.S. EPA, 2011a: Additional Clarification Regarding the Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard. Tyler Fox Memorandum dated March 1, 2011, Research Triangle Park, North Carolina 27711. http://www.epa.gov/ttn/scram/Additional_Clarifications_AppendixW_Hourly-NO2-NAAQS_FINAL_03-01-2011.pdf

U.S. EPA, 2011b: Addendum – User's Guide for the AMS/EPA Regulatory Model – AERMOD. EPA-454/B-03-001, Research Triangle Park, North Carolina 27711. http://www.epa.gov/ttn/scram/models/aermod/aermod_userguide.zip

U.S. EPA, 2011c: Addendum - User's Guide for the AERMOD Terrain Preprocessor (AERMAP). EPA-454/B-03-003. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711. http://www.epa.gov/ttn/scram/models/aermod/aermap/aermap_userguide.zip

U.S. EPA, 2011d: Addendum - User's Guide for the AERMOD Meteorological Preprocessor (AERMET). EPA-454/B-03-002. U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. http://www.epa.gov/ttn/scram/7thconf/aermod/aermet_userguide.zip

U.S. EPA, 2011e: AERSCREEN User's Guide. EPA-454-/B-11-001. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711. http://www.epa.gov/ttn/scram/models/screen/aerscreen_userguide.pdf

U.S. EPA, 2011f: AERMINUTE User's Guide. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711. http://www.epa.gov/ttn/scram/7thconf/aermod/aerminute_v11059.zip