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Near-road NO_2 Monitoring Technical Assistance Document

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Near-road NO_2 Monitoring Technical Assistance Document

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Preface

This document is the June 2012 release of the Near-Road NO_2 Monitoring Technical Assistance Document (TAD). The TAD was developed to aid state and local air monitoring agencies in the implementation of required near-road NO_2 monitoring stations. The TAD reflects the collaboration between partner state and local air monitoring agencies and associations, partnering state departments of transportation, the Federal Highways Administration, and the EPA. This document also reflects feedback, concepts, and suggestions from two reviews conducted by the Clean Air Scientific Advisory Committee (CASAC) Ambient Monitoring and Methods Subcommittee (AMMS).

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Acknowledgments

This document reflects collaboration between multiple local, state, and federal entities who all have a stake in the implementation of required near-road NO_2 monitoring stations, along with contracted support. The EPA wishes to recognize these partners and thank them for their efforts in the conception, development, and review of this TAD, which covers a wide range of materials and concepts.

State and Local Air Agencies/Associations

Broward County (FL) Pollution Prevention Remediation and Air Quality Division
City of Albuquerque Environmental Health Department
Hillsborough County (FL) Environmental Protection Division
Idaho Department of Environmental Quality
Maryland Department of the Environment
National Association of Clean Air Agencies Monitoring Steering Committee

State and Federal Transportation Agencies/Associations

Florida Department of Transportation
Texas Department of Transportation
U.S. Department of Transportation Federal Highways Administration
American Association of State Highway and Transportation Officials

Contract Support

Sonoma Technology, Inc.

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Glossary

Term	Definition
AADT	Annual average daily traffic
AASHTO	American Association of State Highway and Transportation Officials
AERMOD	AMS/EPA Regulatory Model
AQS	Air Quality System
BAM	Beta attenuation monitor
BC	Black carbon
CAPS	Cavity Attenuated Phase Shift
CARB	California Air Resources Board
CASAC AMMS	Clear Air Scientific Advisory Committee Ambient Monitoring and Methods Subcommittee
CBSA	Core Based Statistical Areas
CFR	Code of Federal Regulations
CO	Carbon monoxide
CO_2	carbon dioxide
CRDS	Cavity Ring-Down Spectrometer
DNPH	dinitrophenyl hydrazine
DNSH	dansylhydrazine
DOT	department of transportation
DPM	diesel particulate matter
EC	elemental carbon
EMFAC	EMission FACtors
EPA	Environmental Protection Agency
FE-AADT	fleet equivalent annual average daily traffic
FEM	federal equivalent method
FHWA	Federal Highway Administration
FR	Federal Register
FRM	Federal reference method
GC	gas chromatograph
GC/MS	gas chromatograph/mass spectrometer
HC	hydrocarbons
HD	heavy duty
HDc	total number of heavy-duty vehicles for a particular road segment
HDm	a multiplier that represents the heavy-duty to light-duty NO_x emission ratio for a particular road segment
HNO_2	nitrous acid
HNO_3	nitric acid
HPMS	Highway Performance Monitoring System
HR-AMS	high-resolution aerosol mass spectrometer

IR	infrared
LD	light duty
LOS	level of service
MOVES	Motor Vehicle Emission Simulator
MPO	metropolitan planning organization
MSAT	mobile source air toxic
N_20	nitrous oxide
NAAQS	national ambient air quality standard
NFR	Notice of Final Rulemaking
NO	nitric oxide
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration's
NOx	oxides of nitrogen
NOy	total oxides of nitrogen
NPR	Notice of Proposed Rulemaking
NWS	National Weather Service
OC	organic carbon
OLM	Ozone Limiting Method
OMB	Office of Management and Budget
PAH	polycyclic aromatic hydrocarbon
PAN	peroxyacyl nitrates
PM	particulate matter
PM_{10}	particles less than or equal to 10 micrometers in aerodynamic diameter
$PM_{10-2.5}$	particles between 2.5 and 10 micrometers in diameter
$PM_{2.5}$	particles less than or equal to 2.5 micrometers in aerodynamic diameter
ppb	parts per billion
PSD	passive sampling devices
PUF	polyurethane foam
PVLMRM	Plume Volume Molar Ratio Method
REA	risk and exposure assessment
ROW	right of way
RWIS	Road Weather Information System
SLAMS	State and Local Air Monitoring Station
SO_2	sulfur dioxide
SVOC	semi-volatile organic compound
TAD	technical assistance document
TDM	travel demand model
TEOM	Tapered Element Oscillating Microbalance
V/C	volume to capacity ratio
VMT	vehicle miles traveled
VOC	volatile organic compound

Executive Summary

On February 9, 2010, the U.S. Environmental Protection Agency (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) and the retained annual 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 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, there are other factors that affect the selection and implementation of a near-road monitoring station, including satisfying siting criteria, favorable site logistics (e.g., gaining access to property and safety), and consideration of 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 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, is compatible with the EPA's multi-pollutant paradigm presented in the *Ambient Air Monitoring Strategy for State, Local, and Tribal Air Agencies* document published in 2008 (U.S. Environmental Protection Agency, 2008a), and has been noted within documents associated with the NO_2 NAAQS revision of 2010[1] and the Carbon Monoxide (CO) NAAQS review of 2011.[2] 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 monitoring stations, this TAD discusses other pollutants of interest that exist in the near-road environment, including definitions, basis of interest, and measurement methods.

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[1] These documents are available on the Internet at http://www.epa.gov/ttn/naaqs/standards/nox/s_nox_cr.html.

[2] These documents are available on the Internet at http://www.epa.gov/ttn/naaqs/standards/co/s_co_index.html.

Section 1. Background and Near-Road NO_2 Network Objectives

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 National Ambient Air Quality Standard (NAAQS) for NO_2. The NO_2 NAAQS was revised to include a 1-hour standard with a 98th percentile form and a maximum allowable NO_2 concentration of 100 ppb anywhere in an area, while retaining the annual standard of 53 ppb. In the 2009 NO_2 Risk and Exposure Assessment (found at http://www.epa.gov/ttn/naaqs/standards/nox/s_nox_cr_rea.html) created during the NAAQS revision process, and as reiterated in the preambles to the Notice of Proposed Rulemaking (NPR for NO_2) (74 FR 34404) and the Notice of Final Rulemaking (NFR for NO_2) (75 FR 6474) on the Primary NAAQS for NO_2, the U.S. Environmental Protection Agency (EPA) recognized that roadway-associated exposures account for a majority of ambient exposures to peak NO_2 concentrations.

In the rulemaking process leading to the recent NO_2 NAAQS revision, it was established that the combination of higher urban population densities with increased vehicle miles traveled (VMT), which correspond to on-road mobile source emissions, can result in an increased potential for exposure and associated risks to human health and welfare. In the NPR for NO_2, when proposing the level of the revised NO_2 NAAQS, the Administrator noted that "the available evidence and analyses support the importance of roadway-associated NO_2 exposures for public health. Specifically, the exposure assessment presented in the REA[3] estimated that roadway-associated exposures account for the great majority of exposures to peak NO_2 concentrations (REA, Figures 8-17 and 8-18)."

In the NPR for NO_2, the EPA clearly stated that the populations included in that assessment were people who live, work, play, or go to school near major roads, as well as those people who spend time commuting on major roads (74 FR 34419). Ultimately, the Administrator followed through on the proposed approach to setting the level of the NO_2 NAAQS, and promulgated a revised NO_2 NAAQS in the NFR for NO_2. This revised standard has a high degree of confidence in providing appropriate public health protection by limiting the higher short-term peak exposure concentrations expected to occur on and near major roadways, as well as the lower short-term exposure concentrations expected to occur away from those roadways.

As part of the NO_2 NAAQS revision, the EPA promulgated requirements for near-road NO_2 monitors in urban areas in conjunction. The primary objective of the required near-road NO_2 network is to support the Administrator's approach in revising the NO_2 NAAQS discussed above by focusing monitoring resources on near-road locations where peak, ambient NO_2 concentrations are expected to occur as a result of on-road mobile source emissions. Monitoring at such a location or locations within a particular urban area will provide data that can be

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[3] The REA is the EPA's *Risk and Exposure Assessment to Support the Review of the NO_2 Primary National Ambient Air Quality Standard* (U.S. Environmental Protection Agency, 2008b).

compared to the NAAQS and used to assess exposures for those who live, work, play, go to school, or commute within the near-roadway environment.

The near-road NO_2 data will provide a clear means to determine whether the NAAQS is being met within the near-road environment throughout a particular urban area. Near-road NO_2 monitoring sites are to be placed at locations with expected peak NO_2 concentrations in the near-road environment, although the target mobile sources and the roads they travel upon are ubiquitous throughout urban areas. Because of these two factors, these monitoring data may be said to represent the relative worst-case population exposures that may be occurring in the near-road environment throughout an urban area over the averaging times of interest.

Requirements for near-road monitors 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 Code of Federal Regulations [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. Further, 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 EPA believes that the site selection requirements and siting criteria for near-road NO_2 monitoring stations (presented in the CFR and reiterated in this Technical Assistance Document [TAD]) provide sufficient flexibility to state and local air agencies for near-road NO_2 monitoring 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. Because of this flexibility, the EPA strongly encourages states and local agencies to exercise due diligence in selecting and installing required near-road NO_2 monitoring stations and to provide sound rationale for their decisions consistent with their network design.

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

The primary objective of this TAD is to provide a set of options, including technical approaches and rationale, for the near-road NO_2 monitoring site selection process; these options are provided to assist state and local air monitoring agencies in implementing required near-road NO_2 monitoring stations in a manner that satisfies the requirements and intent of 40 CFR Part 58.

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 in 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 as required by the recent revisions to the NO_2 monitoring requirements in 40 CFR Part 58 Appendices D and E.

The material supporting this objective is primarily contained in Section 3 through Section 14 of this document. Section 4 provides a quick-start guide to the site selection process. Section 15 presents information on selecting a second near-road monitoring site. Section 16 presents information on other pollutants of interest in the near-road environment; these pollutants are not required to be measured unless noted otherwise, but monitoring these pollutants is recommended for the purpose of addressing issues relevant to science and policy.

The EPA has chosen to elaborate on multi-pollutant monitoring in this TAD because the characterization of 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 emission 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 for 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 (requirements are contained within 40 CFR Part 58), but rather as 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 any 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**.

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.[4] 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, 2005). 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” (Office of Management and Budget, 2000).

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 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.

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

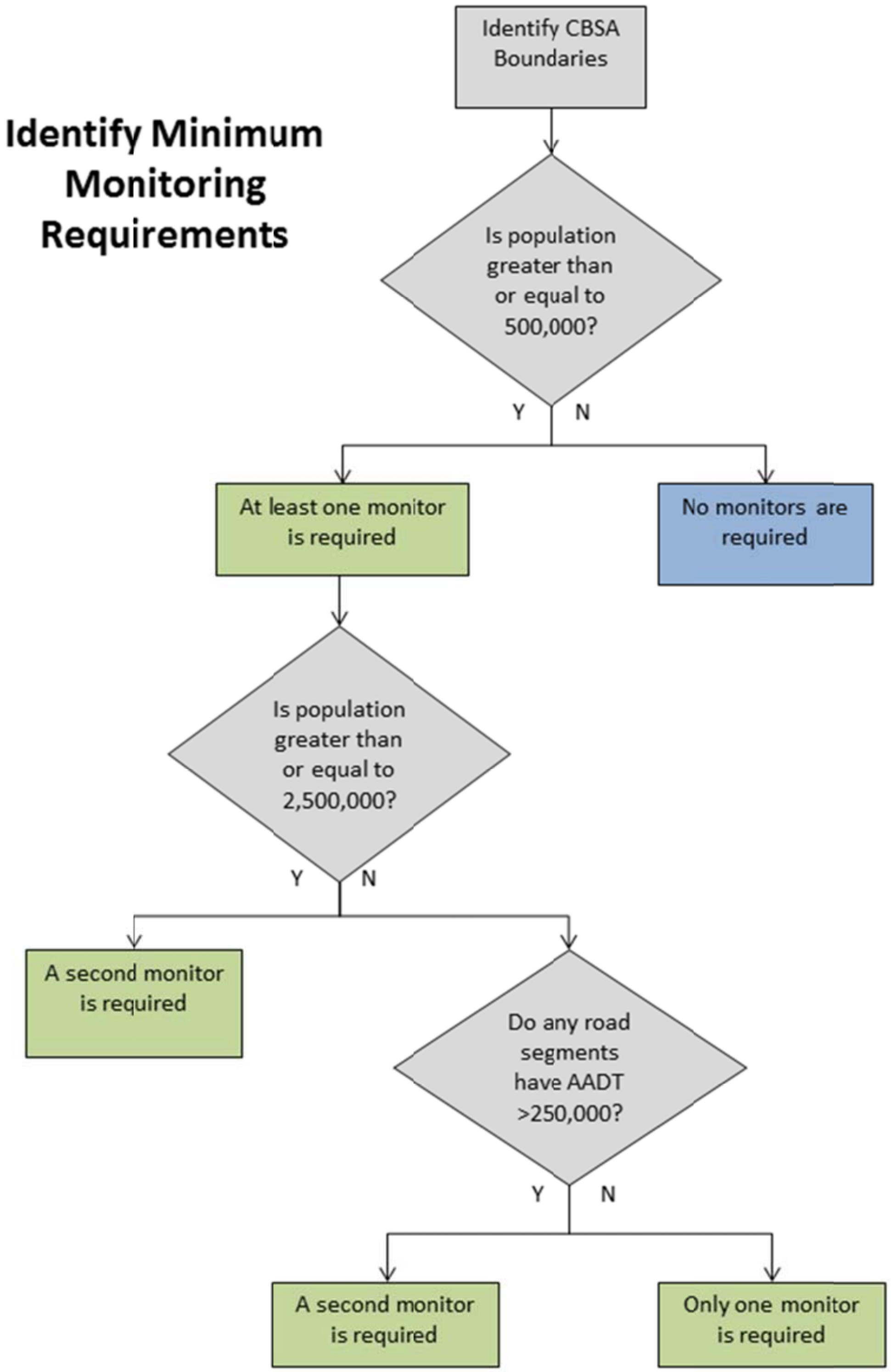

Figure 3-1. Flowchart illustrating the process of identifying whether minimum monitoring requirements for near-road NO_2 monitors apply to individual CBSAs.

The list of CBSAs, along with associated population data and estimate information, is available on the Internet from the U.S. Census Bureau (see Section 3.2).

3.2 Identifying Census Data

The EPA recommends 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/). However, the Census Bureau is now encouraging the public to use the American Fact Finder for population-related information; the American FactFinder is available at http://factfinder2.census.gov/. The American Fact Finder can be used to locate population counts and demographic information for a CBSA, including data collected during the 2010 census. In addition to entire 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

The EPA recommends 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 even if that CBSA has a population of fewer than 2,500,000 persons. Section 5.3 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, or may cover an area shared by more than one air monitoring agency, or both. 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. This process 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 ways in which 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 in each affected party's annual monitoring network plan of the location of all required near-road NO_2 monitors for a given CBSA, regardless of the operating air agency.

Section 4. Near-Road NO_2 TAD Quick-Start

This section is a quick-start guide to the TAD, providing a short, simplified summary of what is required by rule and the ideas and approaches state and local air agencies may take to implement required near-road NO_2 monitoring sites. This quick-start section highlights key points presented throughout this TAD; the rationale and supporting details for each key point are contained in subsequent sections of this document as noted in this quick-start section.

- 4.1 Obtain and Assess AADT, Fleet Mix, and Congestion Data
- 4.2 Consider Physical Site Characteristics
- 4.3 Review Siting Criteria
- 4.4 Prepare Candidate Site Comparison Matrix

4.1 Obtain and Assess AADT, Fleet Mix, and Congestion Data

Table 4-1 presents a summary of traffic information to be used in near-road NO_2 monitoring site consideration. **Figure 4-1** presents a flow chart outlining steps to develop a relatively prioritized list of potential candidate road segments based on available AADT, fleet mix, and congestion data for an entire CBSA.

Table 4-1. Summary of the traffic-related metrics for candidate site consideration.

Component	Rationale	Potential Data Sources
AADT	Focus on locations with high traffic volumes	State DOT, local/MPO, or U.S. Department of Transportation's (U.S. DOT's) Highway Performance Monitoring System (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 accounting for AADT and fleet mix; used to compare road segments	Use AADT and fleet mix in Equation 2 (Section 6.2)
Congestion	Frequent acceleration and stopping can lead to higher emissions per vehicle	State/local level of service (LOS); state DOT or HPMS (number of lanes); congestion maps

To start the site selection process, use the steps illustrated in Figure **4-1** to rank road segments from highest to lowest Fleet Equivalent AADT (FE-AADT) value. A complete introduction to the sources, interpretation, and use of these traffic data is presented and discussed in Section 5.

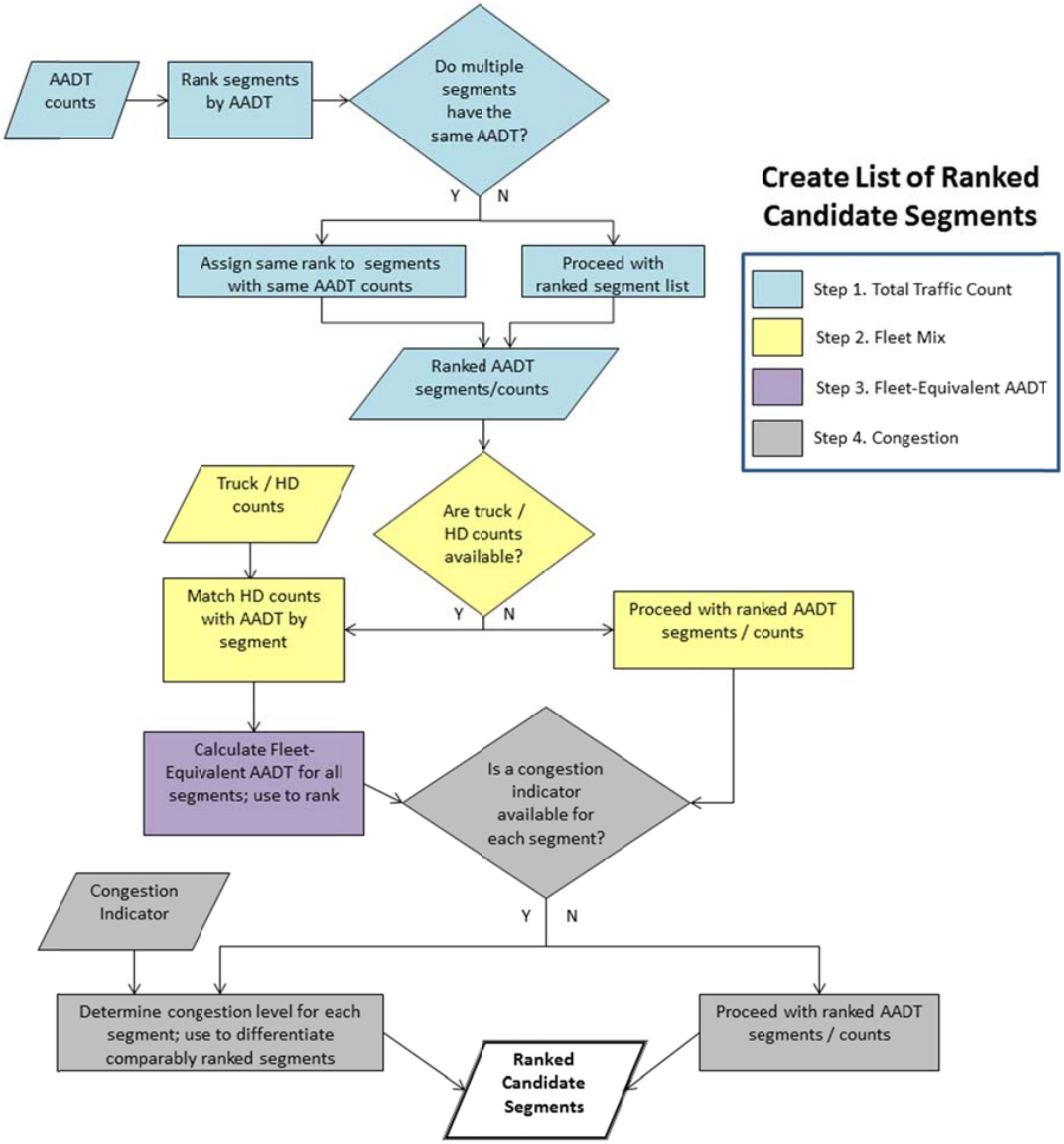

Figure 4-1. Candidate road segment ranking process. This flowchart presents the traffic data evaluation process of providing a prioritized list of candidate road segments (accounting for traffic volume [AADT], fleet mix, and congestion) for further evaluation as potential near-road NO_2 monitoring stations.

4.2 Consider Physical Site Characteristics

Table 4-2 provides a summary of physical site characteristics to be considered, and in some cases avoided, in the monitor site selection process. The physical considerations discussed include roadway design, roadside structures, terrain, and meteorology. A complete introduction to and discussion of the physical site considerations that need to be accounted for in near-road NO_2 monitoring site placement can be found in Section 7.

This TAD recommends that the target distance for near-road NO_2 monitor probes be within 20 meters of the target road whenever possible.

Table 4-2. Summary of physical considerations for candidate near-road sites.

Physical Site Component	Impact on Site Selection	Desirable Attributes	Least Desirable Attributes	Potential Information Sources
Roadway design or configuration	Feasibility of monitor placements; affects pollutant transport and dispersion.	At-grade or nearly at-grade with immediate surrounding terrain.	Deep cut-sections/significantly below grade; significantly above grade (fill or bridge); above grade (bridge).	Field reconnaissance; satellite imagery.
Roadside Structures	Feasibility of monitor placement; affects pollutant transport and dispersion.	No barriers present other than low (<2 m in height) vegetation or safety features such as guardrails.	Presence of sound walls, mature (high and thick) vegetation, obstructive buildings.	Field reconnaissance; satellite imagery.
Terrain	Affects pollutant dispersion, local atmospheric stability.	Flat or gentle terrain, within a valley, or along a 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; National Oceanic and Atmospheric Administration's (NOAA's) National Weather Service (NWS); EPA's Air Quality System (AQS).

4.3 Review Siting Criteria

Table 4-3 provides a summary of near-road NO_2 probe placement. For a complete discussion of siting requirements and associated recommendations, see Section 7.

Table 4-3. Key near-road siting criteria.

Near-Road NO_2 Siting Criteria (per 40 CFR Part 58, Appendix E)	
Horizontal spacing	According to 40 CFR Part 58 Appendix E: "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." **This TAD recommends that the target distance for near-road NO_2 monitor probes be within 20 meters of the target road 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, or between the monitor probe and the outside nearest edge of the traffic lanes of the target road segment.

Prepare Candidate Site Comparison Matrix

The candidate site comparison matrix presents and organizes all the data recommended to be collected to aid in identifying and prioritizing potential near-road monitoring sites. The individual pieces of information within the matrix are discussed throughout this TAD, from from Section 5 through Section 13. EPA believes state and local air agency decision-makers can use these data (suggested to be collected in the site comparison matrix) to adequately characterize selected near-road monitoring site(s) for public dissemination, such as annual monitoring network plans and in AQS, as discussed in Section 14.

Table 4-4. Suggested data for each candidate site entry in a site comparison matrix.

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Site/Segment Parameters	Description of Parameter
Location	Is the entry for a specific point along a road segment, or is it representative of a whole road segment? If the entry is for a point, provide a moniker and the latitude and longitude. If for a road segment, identify where the segment boundaries occur (such as an intersection, mile marker, or political boundary).
Road segment name	Given road name and common name (if applicable).
Road type	Type of road (controlled access highway, limited access freeway, arterial, etc.).
Road segment end points	Location of the road segment end points, including any given names, common names, and the latitude and longitude of each individual end point.
AADT	AADT, source of data, and vintage.

Table 4-4. Suggested data for each candidate site entry in a site comparison matrix.

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Site/Segment Parameters	Description of Parameter
FE-AADT	FE-AADT, noting HD_m value used. (HD_m is a multiplier; see Equation 2.) If not using the national default value, provide the source of data used to calculate the site-specific value.
Heavy-duty (HD) vehicle counts	HD counts, source of data, and vintage.
Congestion information	Value and type (e.g., LOS, volume-to-capacity ratio [$^V/_C$], or AADT by lane), data source, and vintage.
Roadway design	Design type or types present (flat, elevated-fill, cut, etc.). If not flat, identify whether the configuration is a vertical or sloped boundary. Include the height and degree of slope if applicable.
Terrain	Nature of the terrain immediately around the road; also, any larger-scale terrain features of note.
Meteorology	Predominant winds for a point, and whether the point is relatively upwind or downwind. For a whole segment, the orientation of the segment to the predominant winds.
Population exposure	Assessment of population exposure and/or likeness to other road segments throughout the CBSA.
Roadside structures	Presence of any roadside structures and the height, width, and length of those structures.
Safety features	Safety features present and the height, width, and length of those features.
Infrastructure	Existing infrastructure (light poles, billboards, etc.) and potential site proximity (distance).
Interchanges	Presence of any interchanges within or at the end points of the target road segment and potential site proximity (distance), including traffic information if available (AADT, HD counts, etc.).
Surrounding land use	Surrounding land use (residential, commercial, etc.); proximity to other large roads; areas of higher relative road density; and/or locations within or near central business districts or urban downtown areas.
Nearby sources	Nearby NO_X sources (type, tonnage, etc.) and potential site proximity (distance).
Current road construction	Visible or known road construction at the candidate site or along the target road segment.
Future road construction	Transportation agency plans for any future road construction (including time frame for completion).
Frontage roads	Presence of frontage roads; are those roads included as part of the target road segment?
Available space – site footprint	Limitations in the space available for a multipollutant monitoring station.
Property type	Is the property a right-of-way (ROW), or is it private property?
Property owner	Who manages or owns the property under evaluation?
Likelihood of access	Level of confidence and any uncertainties regarding the acquisition of access to a particular property.
Other details/local knowledge	Other pertinent details that may have bearing on why a particular candidate site may or may not be selected, such as information that reflects a state or local agencies' own knowledge of the area or roads under consideration.

Section 5. Recommended Traffic Data and Resources for Use in Identifying Candidate Road Segments for Near-Road NO_2 Monitoring

The key first step in identifying candidate NO_2 near-road monitoring sites is to collect and analyze traffic data. Traffic data indicate the 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.

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 aid in identifying 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.

5.1 Definitions of Terms

In traffic analysis, a number of terms are used, often interchangeably, to describe a road. The terms can vary by individual transportation agencies (e.g., DOTs and other transportation authorities); these terms are presented, defined, and discussed throughout this TAD as needed.

In general, a road can be defined as an open way for the passage of vehicles, persons, or animals on land. In this TAD, the term “road” or “roadway” includes 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 monitoring site selection process suggested in 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. In this TAD, the term “road segment” or “roadway segment” is defined as a length of road between two points along a road. Road segments are typically defined by transportation agencies as the sections between end points. 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.

5.2 AADT

AADT is a measure of the total volume of traffic on a roadway segment (typically in both directions unless specified otherwise) for one year divided by the number of days in the year. AADT 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. Because measurements are not made on every road segment in an urban area each year, AADT can vary from year to year, depending on actual changes in traffic volumes and when certain road segments are individually measured or estimated. However, for this TAD, data users may treat the measured and estimated data equally as long as they are using the latest available data (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.

5.3 Sources of AADT Data

State or local traffic volume data sets 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. 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 the HPMS is that the data may be one or more years older than data provided by state and local sources. This potential discrepancy in data source date is because the data in the HPMS originate from state DOTs and other local sources, and must be collected, reviewed, and otherwise processed by the U.S. DOT before being presented in the 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 the 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 Esri's 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 that is discussed in Section 6.

5.4 Fleet Mix

While AADT describes the total volume of traffic on a road, fleet mix data provide specific counts, or percentages of total traffic volume, of the different types of vehicles that comprise the total traffic volume. Most commonly, fleet mix data differentiate between light-duty (LD) vehicles (e.g., gasoline fueled) and HD vehicles (e.g., diesel fueled). 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 differentiate HD from LD vehicles.

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. On a per vehicle basis, HD vehicles typically emit much higher amounts of NO_x than LD vehicles. Since these NO_x emissions include both nitric oxide (NO) (which readily converts to NO_2 in the near-road environment in the presence of ozone and also can be oxidized to NO_2 through other photochemical processes) and directly-emitted $NO_{2,}$ 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. For more information on on-road mobile source NO_x emissions based upon EPA's Motor Vehicle Emission Simulator (MOVES), see **Appendix B**.

5.5 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 instead it may only be available for larger domains such as counties or urban areas. In cases where fleet mix data are available by segment, the data are often available with related total AADT count data and files, the sources of which are discussed in Section 5.3. Similar to the recommendations for AADT, state and local air agencies are encouraged to migrate the available fleet mix data into a spreadsheet or database (one that also contains AADT data) for use in the comparative process that is discussed in Section 6.

5.6 Congestion Patterns

Congestion patterns are an important factor in the near-road NO_2 monitoring site selection process because traffic congestion can lead to vehicle operating conditions, particularly stop-and-go traffic, where per-vehicle emissions may increase (as compared to vehicles operating at steady-state highway speeds). Congestion pattern data can be presented in multiple forms. Three example metrics of congestion data that can be used for consideration during the near-road NO_2 monitoring site selection process are discussed in Sections 5.6.1 through 5.6.3.

5.6.1 Level of Service

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. 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 or impeded flows, congestion, and frequent slowing and stopping during peak hours of use. As a result, when considering the candidacy of individual road segments as permanent near-road NO_2 monitoring sites, 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 have relatively higher NO_2 emissions per vehicle than road segments that are otherwise similar, but that have 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 a 1-hour standard, and the objective of the monitoring effort is to characterize the peak NO_2 concentrations that are occurring in the area. The greatest effects of traffic congestion on peak NO_2 concentrations, represented by LOS, are likely to occur during the worst indicated LOS conditions.

5.6.2 Volume-to-Capacity Ratio

A second metric that can be used as a congestion pattern indicator is the $^{V}/_{C}$ 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 takes into account the larger size of HD vehicles and focuses on traffic conditions during peak hours of operation.

5.6.3 AADT by Lane

If LOS or $^{V}/_{C}$ data are not available, a third metric for assessing 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. In the absence of LOS or $^{V}/_{C}$ information, AADT by lane can be used to aid in understanding the potential congestion of a road segment by accounting for how much traffic volume is using a given number of available driving lanes. A larger number of vehicles per lane indicates 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 for what those 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 of calculating AADT by lane is discussed in Section 5.7.

5.7 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 even 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**.

$$AADT\ by\ lane = \frac{AADT}{Number\ of\ Lanes} \tag{1}$$

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

Section 6. 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 7.

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 relative 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 6-1 presents a visualization of the traffic data evaluation process. The four steps presented in this section are illustrated as a flowchart, providing alternate evaluation paths that depend on what traffic data is available. After creating a prioritized list of road segments for further evaluation, and while working with partners and stakeholders (e.g., EPA Regions, transportation agencies), state and local air agencies will be in a position to consider the three remaining factors required of them in the CFR, which are roadway design, terrain, and meteorology, plus the additional case-by-case factors that will affect where near-road NO_2 monitoring sites might be placed.

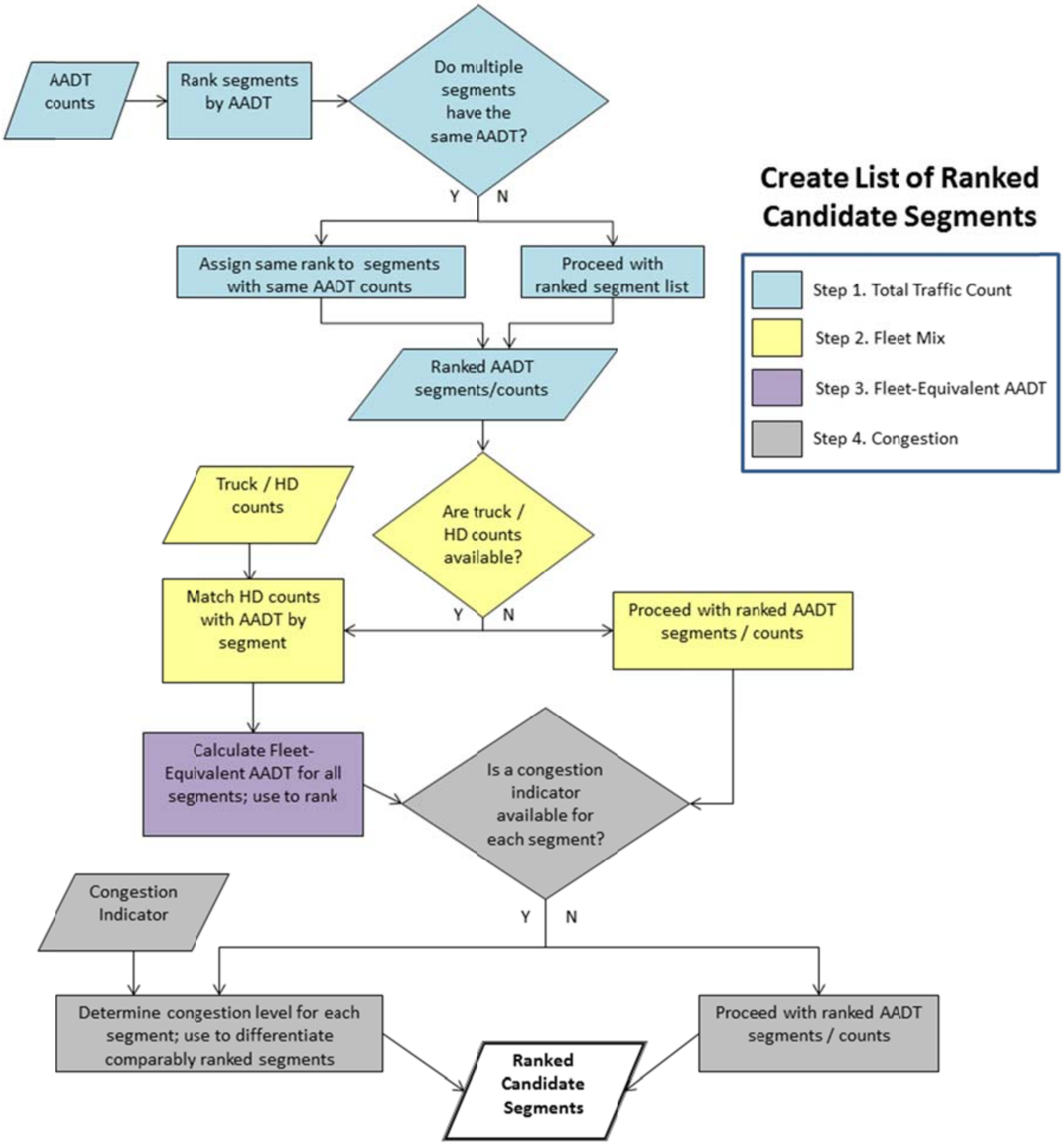

Figure 6-1. Candidate road segment ranking process. This flowchart presents the traffic data evaluation process for determining a prioritized list of candidate road segments (accounting for traffic volume [AADT], fleet mix, and congestion) for further evaluation as potential near-road NO_2 monitoring stations.

6.1 Use 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 at a minimum the road segment ID, location information, road information, and AADT value. In situations where two or more road segments have the same AADT value, those segments should be assigned the same numerical ranking.

Table 6-1 is an example of road segments ranked by AADT for the Tampa, Florida, CBSA using 2009 data from the Florida DOT. The roadway name is listed in the first column, the physical end points of the road segment are listed in columns two and three, AADT for the road segment is listed in the fourth, and the segment's rank is listed in the final column. Although all road segments were ranked in the development of this example, for illustrative purposes, only the top segments are listed here. State and local agencies should rank those segments for which data are available for each CBSA in this initial step.

Table 6-1. Ranking of road segments by AADT, 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 segments are shown.

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

6.2 Combine Fleet Mix Data and AADT Data to Rank Road Segments

As discussed in Section 5.4, 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 HD vehicles emit higher amounts of NO_x on a per vehicle basis than LD vehicles. 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 6.4.

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 6-2 has been updated from Table 6-1 and contains a new column for HD vehicles for each of the initial road segments found in Step 1 and presented in Table 6-1. For illustration purposes, the rows were re-ranked based on HD vehicle counts. In this example, the twenty-eighth–ranked AADT road segment had the highest HD counts. The top-ranked total AADT road segment from Step 1 has the twenty-seventh–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.

Table 6-2. Ranking of road segments using fleet mix data as described in Step 2. This modified version of Table 6-1 illustrates the ranking of road segments based on fleet mix for the Tampa, Florida, CBSA, using 2009 traffic data available from Florida DOT. For illustrative purposes, this table was re-ranked by heavy duty vehicle AADT.

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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

Table 6-2. Ranking of road segments using fleet mix data as described in Step 2. This modified version of Table 6-1 illustrates the ranking of road segments based on fleet mix for the Tampa, Florida, CBSA, using 2009 traffic data available from Florida DOT. For illustrative purposes, this table was re-ranked by heavy duty vehicle AADT.

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Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank
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
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

6.3 Calculate FE-AADT for All Segments

Although comparing Table 6-1 to Table 6-2 is informative, it is not easy to simultaneously compare the ranked lists between both AADT and fleet mix. 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 HD vehicle volume, the EPA recommends the use of FE-AADT, a unique metric that accounts for both total traffic volume and fleet mix for comparison purposes .

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 Equation 3 (if using the national default HD to LD ratio of 10). 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.

With FE-AADT, 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 factors:

1. total traffic volume, presented as AADT counts,
2. fleet mix, presented as HD vehicle counts, and
3. the heavy-duty to light-duty vehicle NO_x emission ratio.

Equation 2 can be used to calculate an FE-AADT value for each road segment.

$$Fleet\ Equivalent\ AADT = (AADT - HD_c) + (HD_m * HD_c) \qquad \mathbf{(2)}$$

where AADT is the total traffic volume count for a particular road segment, HD_c is the total number of heavy-duty vehicles for a particular road segment, and HD_m 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 as described below. Using this option results in a value for HD_m, which should be suitable for most situations. Alternatively, the HD_m value can be derived from local vehicle speed and/or emissions estimates for a given CBSA that can provide a specific HD_m value across the CBSA, or provide HD_m values for individual road segments.

For this TAD, we have used the national default approach. Based on information derived from EPA's MOVES, the EPA suggests that the national default for HD_m be 10. This HD_m value is used in all examples where FE-AADT is calculated in this TAD. In using a national default where HD_m equals 10, the NO_x emissions from one HD vehicle are assumed to be equivalent to the NO_x emissions from 10 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**.

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

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. If air agencies have appropriate on-road vehicle fleet mix and speed characterizations for roads in their jurisdictions, they may choose to calculate their own ratio, which may be more accurate for their particular road segment(s) of interest. For example, state and local agencies may choose to calculate a local HD_m value or values based on information for a specific road segment (e.g., a given segment experiences higher congestion with lower average vehicle speeds or may have a higher percentage of older diesel trucks or buses). Agencies may also consider calculating a local HD_m value for a particular season, such as when air quality violations occur in only one season at an existing area-wide NO_2 monitor.

Table 6-3 has been updated from Table 6-2 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 sixth-ranked AADT (tenth-ranked HD) segment has moved to the first-ranked position. Two notable changes are that the first-ranked AADT (twenty-seventh–ranked HD) segment is only moved down to second, and that the first-ranked HD segment (twenty-eighth–ranked AADT) is now ranked eighth. 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, with the magnitude of this effect dependent on the HD_m value(s) chosen.

Table 6-3. Ranking of road segments based on FE-AADT as described in Step 3. The listed road segments from the Tampa CBSA are ranked by FE-AADT, which was calculated using 2009 traffic data available from Florida DOT.

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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

Table 6-3. Ranking of road segments based on FE-AADT as described in Step 3. The listed road segments from the Tampa CBSA are ranked by FE-AADT, which was calculated using 2009 traffic data available from Florida DOT.

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Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank	FE-AADT	FE-AADT Rank
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
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

6.4 Use 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). This recommendation is made because of the relatively higher potential for incomplete data and overall uncertainties in congestion pattern indicators. 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 $^{V}/_{C}$ ratios or "AADT by lane" is available for use, a higher priority should be placed on road segments with higher $^{V}/_{C}$ 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 6-4 has been updated from Table 6-3 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 6-4 shows that a majority of the higher ranked FE-AADT segments have an LOS value of F, 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.

Table 6-4. Ranking of road segments including congestion pattern information per segment. The last column here was added to Table 6-3 from the Tampa, Florida, CBSA. 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.

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Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank	FE-AADT	FE-AADT Rank	LOS (Year)
I-4	10320000/10320001	Bridge No-100658	164,000	6	12,251	10	274,259	1	F (2005)
I-275	Bridge No-100128	Bridge No-100110	192,000	1	8,467	27	268,203	2	F (2005)
I-4	US 301 / SR 43	I-75/SR 93A	136,500	15	14,073	5	263,157	3	F (2008)
I-4	Bridge No-100658	US 41/SR 599/50TH ST	151,000	13	12,050	11	259,450	4	F (2005)
I-4	I-75/SR 93A	Mango Rd	136,500	15	13,172	6	255,048	5	F (2008)
I-275	S600/U92/DALE MABRY	Bridge No-100128	170,500	3	8,713	25	248,917	6	F (2005)
I-4	Bridge No-100599	S566/THONOTOSASSA RD	110,000	25	15,279	3	247,511	7	F (2008)
I-4	Bridge No-100607	HILLS/POLK CO LINE	105,000	28	15,719	1	246,471	8	F (2008)
I-275	SLIGH AVE	Bridge No-100219	167,000	5	8,684	26	245,156	9	F (2005)
I-275	Bridge No-100138	10320000/10320001	169,000	4	8,298	29	243,682	10	F (2005)
I-275	Bridge No-100110	Bridge No-100138	169,000	4	8,298	29	243,682	10	D (2005)
I-275	FLORIBRASKA AVE	Bridge No-100203	160,500	8	9,229	21	243,561	11	F (2005)
I-275	CR587/WESTSHORE BLVD	Bridge No-100120	176,500	2	7,413	36	243,217	12	F (2005)
I-4	Bridge No-100605	Bridge No-100607	103,000	29	15,388	2	241,492	13	F (2008)
I-275	Bridge No-100120	S600/U92/DALE MABRY	163,000	7	7,824	32	233,416	14	F (2005)
I-4	MCINTOSH RD	Bridge No-100599	117,932	22	12,595	8	231,287	15	F (2008)
I-275	EAST END BR 150107	Bridge No-100115	147,000	14	9,026	22	228,234	16	E (2005)
I-275	4TH ST N	END BRIDGE 150107	147,000	14	9,026	22	228,234	16	D (2008)
I-4	S566/THONOTOSASSA RD	Bridge No-100605	98,000	30	14,396	4	227,564	17	F (2008)
I-275	SR 600 / HILLS AVE	SLIGH AVE	156,500	10	7,669	34	225,521	18	F (2005)
I-75	GIBSONTON DR	SR 43 / US 301	111,500	24	12,577	9	224,693	19	C (2008)
I-4	SR 574/ML KING BLVD	ORIENT RD	122,000	20	11,236	13	223,124	20	E (2008)
I-275	Bridge No-100203	SR 600 / HILLS AVE	153,500	11	7,736	33	223,124	20	F (2005)

Table 6-4. Ranking of road segments including congestion pattern information per segment; the last column here was added to Table 6-3 from the Tampa, Florida, CBSA. 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.

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Roadway	From	To	AADT	AADT Rank	Heavy Duty Vehicle AADT	Heavy Duty Vehicle AADT Rank	FE-AADT	FE-AADT Rank	LOS (Year)
I-4	Mango Rd	MCINTOSH RD	127,000	18	10,465	16	221,185	21	F (2008)
I-275	SR 580 / BUSCH BLVD	Bridge No-100231	151,500	12	7,105	39	215,445	22	E (2005)
I-275	Bridge No-100219	SR 580 / BUSCH BLVD	151,500	12	7,105	39	215,445	22	F (2005)
SR-60	SR 616	SR 93 / I-275	158,000	9	5,941	42	211,469	23	C (2005)
I-275	Columbus Dr	FLORIBRASKA AVE	147,000	14	7,159	38	211,431	24	F (2005)
I-275	SR 688/Ulmerton Rd	4TH ST N	130,000	17	8,281	30	204,529	25	D (2007)
I-75	SR 582 / FOWLER AVE	CR 582A/FLETCHER AVE	108,500	26	10,579	14	203,711	26	F (2008)
I-75	SR 400 / I-4	SR 582 / FOWLER AVE	108,500	26	10,579	14	203,711	26	F (2008)
I-75	SR 574/M L KING BLVD	SR 400 / I-4	108,500	26	10,579	14	203,711	26	F (2008)
I-4	US 41/SR 599/50TH ST	SR 574/ML KING BLVD	121,000	21	9,014	23	202,126	27	F (2008)
I-275	Bridge No-100115	CR587/WESTSHORE BLVD	135,500	16	7,371	37	201,839	28	F (2005)
I-4	ORIENT RD	US 301 / SR 43	113,000	23	8,215	31	186,935	29	E (2008)
I-75	CR 582A/FLETCHER AVE	C581/BRUCE B.DOWNS B	90,500	34	10,498	15	184,982	30	F (2008)
I-275	GANDY BLVD/SR 694	ROOSEVELT BL/SR 686	123,000	19	6,876	41	184,884	31	A, B, or C (2007)

6.5 Rank the Road Segments

Completion of as many of the steps in Sections 6.1 through 6.4 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.

The parameters described in this section, along with their recommended sources and/or methods of calculation, are needed to produce the list of prioritized candidate road segments. **Table 6-5** summarizes these parameters. This list is recommended as a guide to 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 6-5. 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
FE-AADT	Single metric to compare road segments, accounting for AADT and fleet mix	Use AADT and fleet mix in Equation 2 (Section 6.2)
Congestion	Frequent acceleration and stopping can lead to higher per-vehicle emissions	State/local LOS; state DOT or HPMS (number of lanes); congestion maps

Section 7. 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 6, through use of methods such as monitoring or modeling as described in Sections 9 and 10, or via other approaches, select segments must 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 review of the three, non-traffic related data considerations listed in the CFR: roadway design (including related roadside structures), terrain, and meteorology.

Table 7-1 provides an overview of the physical characteristics that need to be considered in evaluating candidate sites, including positive and negative attributes. Additional details on these characteristics are included in the sections that follow.

Table 7-1. Summary of physical considerations for candidate near-road sites.

Physical Site Component	Impact on Site Selection	Desirable Attributes	Least Desirable Attributes	Potential Information Sources
Roadway design or configuration	Feasibility of monitor placements; affects pollutant transport and dispersion.	At-grade or nearly at-grade with immediate surrounding terrain.	Deep cut-sections/significantly below grade; significantly above grade (fill or bridge); above grade (bridge).	Field reconnaissance; satellite imagery.
Roadside Structures	Feasibility of monitor placement; affects pollutant transport and dispersion.	No barriers present other than low (<2 m in height) vegetation or safety features such as guardrails.	Presence of sound walls, mature (high and thick) 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.

7.1 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 the potential for stop-and-go vehicle operations resulting from traffic congestion.

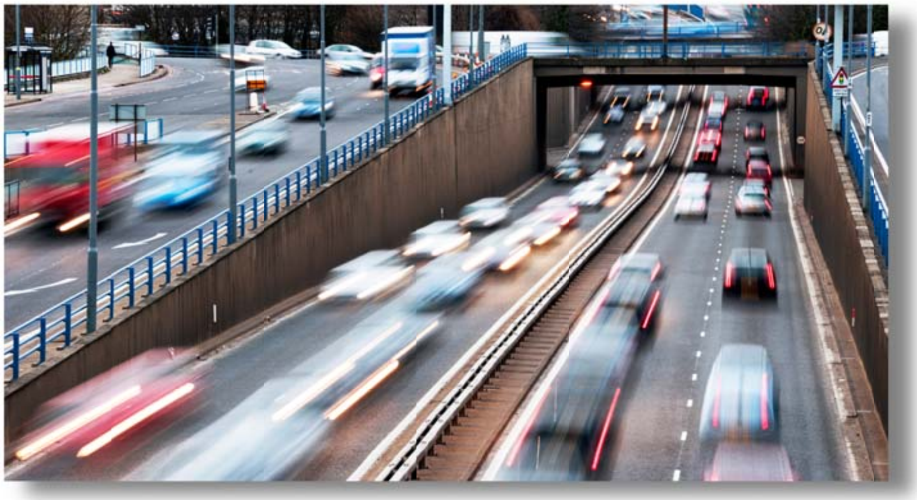
The relative position of a road to the immediate terrain around the roadway can have a significant influence on pollutant transport and dispersion along and/or away from the source road. The three general types of roadway design discussed here are at-grade, below-grade or cut-sections, and above-grade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

7.1.1 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 immediate 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 7.2) that can exist in the near-road environment.

Photo courtesy of Eric Stuve, OKRoads.com.

7.1.2 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; 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 in the road canyon, 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.

7.1.3 Above-Grade or Elevated Roads

Elevated roadways are those where the roadway surface is higher 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.

7.1.3.2 Elevated Roads Over Solid Fill Material

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 – shown below) can cause the traffic plume to loft above the ground immediately adjacent to the vertical or sharply sloped wall (where eddy formation immediately downwind of the roadbed is occurring), with the core of the emission plume impacting the ground further downwind from the vertical or sharply sloped wall.

Imagery © 2012 Google Maps.

7.1.3.3 Elevated Roads Which Are Open Underneath

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 near at-grade roadside locations or near similar roads which are elevated on fill.

7.1.4 Relative Desirability in Roadway Designs

The general understanding of the effect of roadway design on emissions dispersion has been derived through review of near-road field studies and the use of wind tunnel facilities. For example, **Figure 7-1** shows results 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 show that some roadway designs are more desirable than others, considering the goal of monitoring peak NO_2 concentrations.

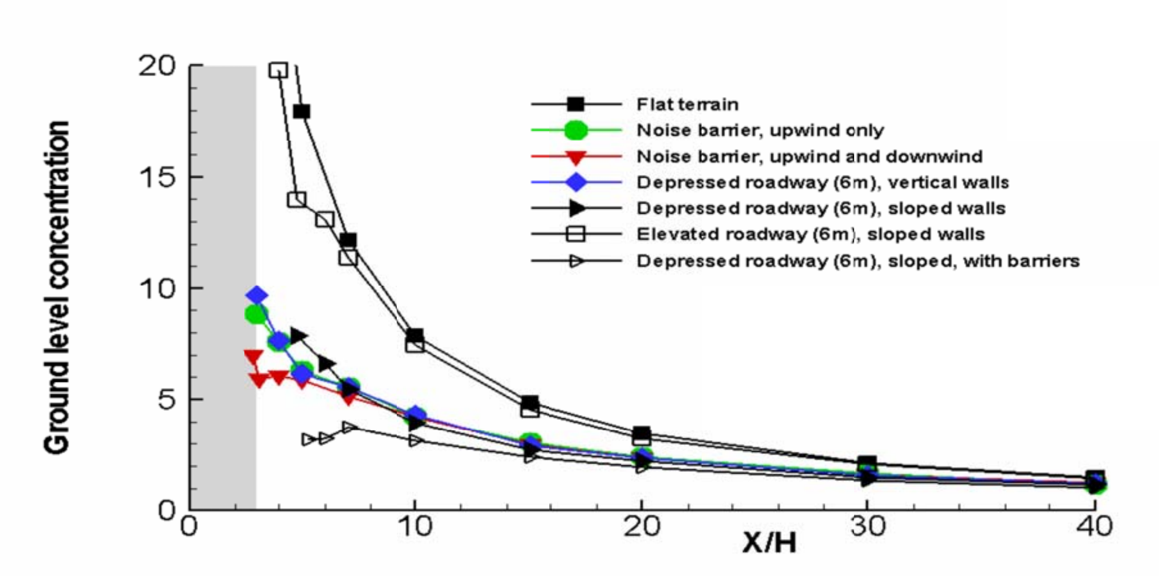


Figure 7-1. Wind tunnel study results comparing downwind air pollutant concentrations from a road with varying topography and roadside structures. The distance downwind (x-axis; X) is expressed in multiples of the height of the noise barrier studied (H; 6 m). Multiplying the x-axis values by 6 provides 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 was obtained from Baldauf et al. (2009), with Heist et al. (2009) providing additional details on the wind tunnel studies conducted.

Figure 7-1 highlights how roadside features can affect downwind pollutant concentrations under wind conditions normal to the source road. Notably, flat terrain, which is 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), and 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 with gently sloped walls, where maximum concentrations are very close to concentrations found with at-grade locations.

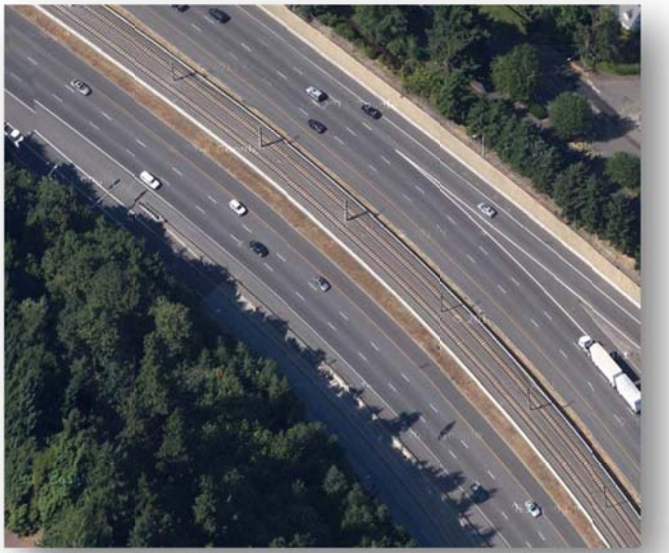
Those roadway designs that may be less preferable when considering near-road NO_2 monitor locations would be those where a site would be adjacent to elevated roads that are open underneath, or cut (or depressed) road beds (where deeper cuts or depressions likely present increasingly more significant impacts or complications on pollutant dispersion). Recommendations on siting a monitor probe near above- and below-grade roads are discussed in Section 8.

7.2 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. In wind tunnel studies such as that reported by Baldauf et al. (2009), sample road configurations with noise barriers are shown to have the largest impacts on pollutant dispersion, relative to flat, at-grade roadway designs. In other situations, such as when winds blow along the roadway, roadside structures may channel emissions downwind, without much dispersion occurring normal to the road. Therefore, 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 without roadside structures are available.

7.3 Vegetation

Vegetation along a road segment can affect on-road pollutant transport and dispersion. Winds flowing through vegetative structures can experience increased mixing and dilution due to the complex system of branches and leaves, while also leading to calmer winds behind the vegetation compared with similar winds in an open field situation. In addition, the branches and leaves can provide surfaces for particle deposition through impaction or diffusion as pollutants are transported through the vegetation.



Imagery © 2012 Google Maps.

7.4 Terrain

As mentioned in Section 7.1 (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 affect 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 consideration of this issue, 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, because these impacts would not be unique to near-road emissions, but would also affect wider-scale ambient monitoring.

Larger scale terrain needs to be considered in the near-road NO_2 monitoring site selection process, as appropriate. One example could be to identify multiple air basins within a single CBSA (if present), and consider how those individual basins may affect pollutant build-up and dispersion. Another example might be to consider 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 concentrations measured at sites on the tops of hills, along hillsides, or in open terrain.

7.5 Meteorology

Evaluating historical meteorological data should be useful in determining whether certain candidate locations might experience a higher proportion of direct traffic emissions impacts from a given road segment due to the local winds. More specifically, an evaluation of local meteorology may provide some indication of which side of a candidate segment might experience a higher proportion of direct traffic emission impacts. In the process of identifying near-road gradients, most research studies showing elevated pollutant concentrations near roads have focused on measurements in situations where winds were from the road to the downwind monitor or receptor (typically along a line normal to the roadbed). These studies indicate that monitor placement very near the road, on the relative downwind side of the target road, is typically appropriate when attempting to measure peak concentrations.

In addition to considering relatively small-scale impacts on a candidate road segment (upwind/downwind), 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 NFR for NO_2, it is discussed that downwind monitoring is not required, but the EPA strongly encourages it. There were several reasons for the decision not to make downwind monitoring a requirement. Some evidence suggests that wind direction may not always be a major factor in peak concentrations close to a major roadway. Often, peak NO_2 concentrations may occur during stable, low-wind-speed conditions when wind direction is less influential. Further, in some situations the turbulence created by vehicles on the road can lead to “upwind meandering” of pollutants, so that a monitor upwind of the target road would still be characterizing a portion of the on-road emission plume. Finally, the EPA did not want such a restrictive siting criterion in place which may not always be applicable.

There are situations where meteorological patterns may warrant very 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/land breeze set-up, may significantly affect pollutant buildup 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 and local knowledge of wind patterns should be considered in establishing NO_2 monitoring sites.

In most cases, monitor placement on the climatologically downwind side of a road segment is preferred; however, the EPA stresses that meteorology should not preclude consideration of sites located in the predominant climatologically upwind direction if applicable site access, safety, and other logistical issues are still favorable when considering a relatively high ranked candidate road segment.

Section 8. 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. For horizontal placement (with respect to the target roadway), near-road NO_2 monitor probes 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."

This TAD recommends that the target distance for near-road NO_2 monitor probes be within 20 meters of the target road whenever possible.

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) notes that a distance of 10 to 20 meters should be considered for near-roadway monitoring; the EPA strongly encourages state and local agencies 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 8-1**.

Table 8-1. Key near-road siting criteria.

Near-Road NO_2 Siting Criteria (per 40 CFR Part 58, Appendix E)	
Horizontal spacing	According to 40 CFR Part 58 Appendix E: "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." **This TAD recommends that the target distance for near-road NO_2 monitor probes be within 20 meters of the target road 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 between the monitor probe and the outside nearest edge of the traffic lanes of the target road segment, where no obstacles exist at or above the height of the monitor probe.

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 7.1, 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 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 and out of a possible eddy cavity. This follows the rationale, as discussed in Section 7.1, that emissions plumes from elevated roads may have peak concentrations aloft when winds are normal to the roadway (due to eddy formation immediately downwind of the roadbed) with the core of the emission plume impacting the ground relatively further downwind from the edge of the road. In this situation, depending on the relative difference in height between the target road surface, ground-level at the monitor probe location, and the steepness of the grade between the two locations, the state or local air agency should consider placing the monitor probe slightly higher and further away from the target road. This placement avoids situations in which 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.

According to 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 of the NFR for NO_2, the NO_2 inlet will likely be influenced by various parts of the target road segment that are at a relative angles compared to the normal transect between the road and the NO_2 inlet. Because of this, a desirable characteristic is to have increasingly open areas without obstructions along the length of the road segment on either side of the monitoring station. Therefore, 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 to have open fetch characteristics, and to choose sites where the monitor probe will be increasingly clear of obstructions.

Section 9. 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 earlier in 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, or through mobile monitoring. The methods that could be used in such exploratory monitoring campaigns include passive devices or active devices that provide integrated or continuous measurements.

- Saturation studies typically involve the use of 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 at a number of roadside locations to estimate which roadways might have relatively higher pollutant levels.
- Focused exploratory monitoring studies might use a an approach to create data for comparison or evaluation at a smaller number of sites, such as those derived from the process in Section 6 using traffic data, and subsequently considering the results of physical reconnaissance.
- Mobile exploratory monitoring utlizes instrumented vehicles or moveable platforms to measure pollutant concentrations at multiple locations. In this case, mobile monitoring could potentially be used to determine spatial variability of pollutant concentrations among a number of road segments.

These methods may be used exclusively or in combination to aid in the site selection process.

Passive Monitoring for Saturation Studies

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. Using PSDs is a relatively inexpensive method, requiring only modest hardware and infrastructure to use in the field, with the greatest 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.

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 typically are exposed to ambient air for at least three or more days, and traditionally are exposed for week-long or multi-week periods. Because of this, PSDs are not able to directly reveal those locations experiencing short-term, 1-hour average NO_2 concentration peaks. However, it can be useful to use PSDs to differentiate the variability in long-term concentrations among candidate near-road monitoring locations as part of the near-road site selection process. Several studies have compared PSDs with 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.

The EPA believes that even though sample data are collected over longer time periods, PSDs can still be used in a comparative manner to help identify those road segments which may have a relatively higher probability of experiencing peak NO_2 concentrations on shorter time intervals. 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. Resources include the following materials:

- Quality Assurance Project Plan: Use of Passive Sampling Devices (PSDs) in a Near-Road Monitoring Environment, http://www.epa.gov/ttnamti1/files/nearroad/20110428qapp.pdf
- New York City Community Air Survey, http://www.nyc.gov/html/doh/html/eode/nyccas.shtml
- Mukerjee S., Oliver K.D., Seila R.L., Jacumin H.H. Jr, Croghan C., Daughtrey E.H. Jr, Neas L.M., Smith L.A. (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(1), 220–227

9.2 Stationary Continuous or Integrated Monitoring

Several small, lightweight, and portable NO_2 analyzers are commercially available that may be useful for conducting a saturation study, or a more focused study on a small set of road segments, to further evaluate potential near-road monitoring sites. Many of these samplers are battery-operated, with many of the same advantages of PSDs, including the flexibility of making monitoring possible at almost any location. These samplers cost more than PSDs; however, most cost significantly less than an FRM sampler. These samplers can also collect real-time, near-real-time, or otherwise integrated NO_2 data, so the data collected from these samplers may 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 are well characterized, which would include collocated sampling with an FRM or Federal equivalent method (FEM) sampler, collocation of two or more of the portable devices, and rotation of the portable samplers to evaluate potential individual sampler bias.

9.3 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, or 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 mobility provides a broad spatial coverage of an area of interest over a short time. 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.

One limitation of mobile monitoring is the lack of simultaneous monitoring at multiple sites; with mobile monitoring, there is the potential of missing maximum concentrations over the entire area of interest if changes occur in the strength or location of emissions over short time periods. Another limitation is that mobile measurements may not be easily correlated to the maximum 1-hour average concentrations of interest for the NO_2 NAAQS if collected over short time periods(1- to 5-second average concentrations). To address these limitations, some studies have incorporated the use of multiple mobile monitoring platforms, or have employed integrated mobile and stationary monitoring for reference.

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 determining 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 repeating travel loops over the course of hours and/or days, and determining how much data collection will be sufficient for comparison purposes. These concepts are described in peer-reviewed literature, such as the Hagler et al. (2010) article (and references within); such literature should be considered as a template for how a mobile monitoring study might be conducted.

Resources include the following materials:

- Hagler G.S.W., Thoma E.D., and Baldauf R.W. (2010) High-resolution mobile monitoring of carbon monoxide and ultrafine particle concentrations in a near-road environment. *J. Air & Waste Manage* **60**(3), 328–336.

- Westerdahl D., Fruin S., Sax T., Fine P.M., and Sioutas C. (2005) Mobile platform measurements of ultrafine particles and associated pollutant concentrations on freeways and residential streets in Los Angeles. *Atmos. Environ.* **39**(20), 3597–3610. Available on the Internet at http://www.sciencedirect.com/science/article/B6VH3-4G4N0HK-1/2/2f105ea20bb843af35c9586c0f810cac.
- Westerdahl D., Wang X., Pan X., and Zhang K.M. (2009) Characterization of on-road vehicle emission factors and microenvironmental air quality in Beijing, China. *Atmos. Environ.* **43**(3), 697–705. Available on the Internet at http://www.sciencedirect.com/science/article/pii/S1352231008009011.

Section 10. 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 the near-road site selection process. One use is to conduct dispersion modeling of several candidate near-road sites, such as those identified through traffic data evaluation and subsequent physical reconnaissance. The model output could be used to provide further confidence of the likelihood of measuring peak NO_2 concentrations by comparing the relative concentrations among 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 time intensive, 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 6 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 section describes these applications in terms of EPA regulatory models (e.g., MOVES for vehicle emissions and the AMS/EPA Regulatory Model [AERMOD] for dispersion). We note that 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.

10.1 The MOVES Model

EPA's MOVES is a computer model that estimates emissions from on-road motor vehicles, including cars, trucks, buses, and motorcycles.[5] MOVES was released in December 2009 and replaces MOBILE6.2, EPA's previous emissions model.[6] 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 NO_x and other pollutants based on vehicle type, age, and activity. MOVES accounts 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 on high-traffic road segments, the emphasis of emissions modeling should focus on the NO_x

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[5] See EPA's MOVES website for further information on downloading MOVES, the MOVES User Guide, and other technical documentation: http://www.epa.gov/otaq/models/moves/index.htm. For guidance documents, see http://www.epa.gov/otaq/stateresources/transconf/policy.htm#project.

[6] This document uses "MOVES" to refer generically to any approved version of the MOVES model. Unless EPA notes otherwise, this guidance is applicable to current and future versions of the MOVES model.

emission processes prevalent on roadway segments: running exhaust and crankcase.[7] For other pollutants, such as particulate matter (PM), hydrocarbons (HC), and CO, other emission processes are important. See **Appendix C** for further information on using MOVES for project-level analyses.

10.2 AERMOD Air Quality Dispersion Model

This section provides guidance to state and local agencies that choose to use air quality modeling to further inform the implementation of near-road NO_2 monitors. The information provided here, along with the more detailed information in Appendix C, covers the selection of an air quality model, modeling domain (including receptor placement), characterization of emission sources, meteorological inputs, and inclusion of background concentrations.

For this TAD, AERMOD was selected as the regulatory dispersion model. Promulgated in 2005, AERMOD is EPA's preferred near-field dispersion model for a wide range of regulatory applications in all types of terrain based on extensive development and performance evaluation. AERMOD is the recommended model for most mobile source modeling scenarios.[8] In regard to NO_2 mobile sources, AERMOD was used for the NO_2 Risk and Exposure Assessment (U.S. EPA, 2008) and performed generally well.

10.2.1 NO_2 Chemistry Using PVMRM or OLM Algorithms

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, b); (Cimorelli et al., 2004)] or the Ozone Limiting Method (OLM).[9] These methods use NO_2/NO_x emitted ratios and background ozone concentrations to convert NO to NO_2 within AERMOD.

On March 1, 2011, EPA issued "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard" (U.S. Environmental Protection Agency, 2011) 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 PVMRM and OLM in AERMOD, inclusion of background concentrations, and other modeling guidance. Much of the information noted in the memorandum is presented in Appendix C.

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[7] If other transportation facilities are evaluated (e.g., diesel truck or bus activity at terminals), then additional emission processes would be considered in MOVES.

[8] For example, EPA cites AERMOD as a recommended model when completing PM hot-spot analyses for transportation conformity analyses of highway and transit projects. See EPA's *Transportation Conformity Guidance for Quantitative Hot-spot Analyses in* $PM_{2.5}$ *and* PM_{10} *Nonattainment and Maintenance Areas* (U.S. Environmental Protection Agency, 2010a, b).

[9] Appendix C of this TAD also discusses two conservative methods of calculating NO_2 concentrations based on information in Appendix W, Modeling Guidance.

For more information regarding the use of PVMRM and OLM, consult the following resources:

- the AERMOD User's Guide and addendum (Cimorelli et al., 2004),
- the material in Appendix C in this document, and
- the March 1, 2011 EPA memorandum, "Additional Clarification Regarding Application of Appendix W Modeling Guidance for the 1-hour NO_2 National Ambient Air Quality Standard," which offers more guidance and background information on these two algorithms (U.S. Environmental Protection Agency, 2011).

10.2.2 Including Background and Nearby Sources in Analyses

While this section of the TAD has emphasized mobile source emissions, two other components usually considered in a modeling exercise are the inclusion of background concentrations and the modeling of nearby sources, including stationary sources and other mobile sources. The inclusion of background concentrations will affect the magnitude of cumulative (all sources) concentrations. Inclusion of nearby sources will also affect the magnitude of cumulative concentrations, and may also change the location of maximum modeled concentrations or design values. Also, as described in Appendix C, the inclusion of additional sources can also affect the competition among sources for ozone when using the PVMRM or OLM algorithms in AERMOD. More information on how to handle background and nearby source in a near-road centric modeling effort is presented in Appendix C.

10.3 Resource

U.S. Environmental Protection Agency (1985) Guideline for determination of good engineering practice stack height (technical support document for the stack height regulations, revised). Technical memorandum by the Office of Air and Radiation, Office of Air Quality Planning and Standards, Research Triangle Park, NC, EPA-450/4-80-023R, June. Available on the Internet at http://www.epa.gov/ttn/scram/guidance/guide/gep.pdf.

Section 11. Physical Characteristics of Candidate Near-Road Sites

Using the list of prioritized candidate near-road segments produced in the process discussed in Section 6, and any supplemental exploratory monitoring and/or modeling that may have been conducted, state and local air agencies can perform a more detailed evaluation of potential near-road sites to further characterize and prioritize candidate segments. 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, the EPA also advises that state and local air agencies conduct physical reconnaissance 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 prior traffic data analysis.

11.1 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. To better understand and communicate information about candidate near-road sites, it may be necessary to correlate the assigned roadway identifiers with other useful identifying information and/or commonly used names for these traffic facilities. For example, using the Tampa, Florida, example from Section 6 (Table 6-4, 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 uses the same corridor for the road segment used in this particular example (but is not listed in the traffic data table).

Another example of additional useful road segment identification is adding a commonly referenced road 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, the segment may be more commonly known as the Kennedy Expressway.

When applicable, EPA recommends that state and local air agencies use the combination of the given road identifiers along with more useful identification and/or commonly used labeling to aid in the site identification process. More detailed names make it easier for interested parties to identify and understand which road segments are being described or characterized.

11.2 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. by free-flowing traffic (i.e., 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.

11.3 Road Segment End Points

Similar to the suggestion to use additional information and 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 the Tampa, Florida, example from Section 6, the highest-ranked FE-AADT road segment on I-275 (Table 6-4, row 2) has 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 of the road segment. To improve understanding and communication of 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 can aid in the site identification process, making it easier for interested parties to identify and understand the location of a candidate road segment.

11.4 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. A robust but unofficial resource on the types of interchanges transportation agencies use in building transportation facilities can be found at http://en.wikipedia.org/wiki/Interchange_(road).

11.5 Roadway Design

As discussed in Section 7.1, 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 monitoring 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 the type of walls (i.e., sloped or vertical). For elevated roads, note whether the road 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.

11.6 Terrain

Akin to roadway design, state and local air agencies should note the following about terrain relative to their candidate sites:

- the type of terrain on which the candidate road lies
- the terrain immediately adjacent to the candidate road segment
- any larger-scale terrain features within which the candidate road may lie
- any larger-scale terrain features that may potentially influence the candidate road

One example of a terrain feature to note is whether the road segment is along a grade for its entire length, or a portion of its length. Another example might be noting a road segment's proximity to hills, bluffs, canyons, ridges, bodies of water, or other topographical features that can influence local meteorology.

11.7 Roadside Structures

As discussed in Section 7.2, roadside structures can have a significant effect on pollutant transport and dispersion. Further, roadside structures can seriously impact the candidacy of a road segment for near-road monitoring. 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 structures along each side of the segment.

11.8 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 in Section 12.2). Safety of the travelling public on the road, the air monitoring staff members who service 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 on each side of the road along the road segment, including ditches, berms, guard rails, cable barriers, jersey barriers (temporary and permanent concrete barriers), or other features. Placement of a monitoring station behind such safety features would be preferable when possible.

11.9 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, rest stops, or other such locations. Additionally, depending upon individual state participation, state and local air agencies may be able to identify the location and nature of some RWIS infrastructures through U.S. DOT's Clarus System website (http://www.clarus-system.com/).

11.10 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 (such as the presence of schools, hospitals, and 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) whether any significant emissions sources (off-road mobile or stationary sources) are nearby. Beyond traditional land use characterization, the EPA also suggests that state and local air agencies identify the proximity of a candidate road segment to other heavily trafficked roads, areas of higher relative road density, and/or locations within or near central business districts or urban downtown areas.

11.11 Current Road Construction

The potential for future road construction on candidate road segments is discussed in Section 12. However, during reconnaissance of candidate road segments, state and local air agencies should note any ongoing road construction along with any immediately apparent preparations for road construction.

11.12 Frontage Roads

During candidate road segment analysis, the presence of frontage roads should be noted. Frontage roads, also called service roads or access roads, typically run parallel to major highways, and may or may not be considered part of the major highway. Frontage roads can be (but aren't necessarily) controlled access or limited access roads, and are often one-way roads with traffic flowing in the same direction of the adjacent lanes of the partnering main-line travel lanes. 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.

11.13 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. Local data, such as that collected by the air agency themselves, is preferable, along with any other local and such collected by the air agencies themselves regional weather and climatological data collected by NOAA.

Section 12. Monitoring Site Logistics in the Near-Road Environment

Key components in determining whether a candidate near-road monitoring site is truly feasible include determining whether

- an air monitoring agency will be able to access the desired location
- the site will be safe for site operators and the public during routine operations
- there is sufficient availability of power and telecommunications services (or the ability to procure and install those services)

According to 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. Terminology specific to this section is provided in **Table 12-1**.

Table 12-1. Terminology used by transportation agencies that is relevant to this section.

Term	Definition
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 rights typically include access to a parcel of ground within the right-of-way.
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	According to 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	According to 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 (ROW)	The right-of-way 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.

12.1 Accessing the Right-of-Way

The feasibility of a potential near-road NO_2 monitoring site depends upon the determination of whether a given location can be accessed. If the prospective location is within the 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 access would most likely be accomplished through a permitting process that would ultimately lead to the development and establishment of an air space lease (or permit).

The right to use space within the ROW by public entities or private parties for interim non-highway uses may be granted in air space 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.

State and local air agencies considering potential near-road sites within the ROW 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 involve similar factors and take 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 air space access on the Internet at http://www.fhwa.dot.gov/realestate/airguide.htm.

When considering a site within the ROW, state and local air agencies should consider several factors that may affect 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 monitoring site in the ROW be planned so that the site is or will 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 road.

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, if the candidate site is an interstate facility, the state or local transportation agency must submit justifications and obtain approval from FHWA, which is a formal federal action. FHWA's policies on changes in access to the interstate highway ROW are maintained on the Internet at http://www.fhwa.dot.gov/programadmin/fraccess.cfm. 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 make it possible to 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

12.2 Safety in the Near-Road Environment

The EPA stresses that safety is a top priority in all field operations.

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 safely and legally accessible to station operators, 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 monitoring sites may be located on ROWs maintained by a transportation agency, 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; more 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), increased pavement friction, the use of retaining barriers, and maintenance of open areas within the ROW 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.

12.2.1 Terrain

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) that 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.

12.2.2 Man-Made Barriers

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 internet 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, 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.

12.2.3 Clear Zones

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, design speeds, and the slope of the underlying and adjacent terrain. In practice, a clear zone is free of obstructions (including safety barriers) and denotes 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 have a prescribed clear zone on the order of about 9 to 10 meters (30 feet), with maximum clear zone recommendations of approximately 13 meters (46 feet) for elevated fill roads.

Although FHWA provides a summarization of clear zones on the Internet (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). AASHTO's *Roadside Design Guide* [also known as the "green book"; (American Association of State Highway and Transportation Officials, 2011)] contains more specific information on clear zones, providing variable clear zone distances based on traffic volume, speeds, and roadside geometry. **Table 12-2** and **Figure 12-1**, which are reprinted here with permission of AASHTO, show information on clear zones. As stated in the *Roadside Design Guide,* the table and curves depicted were based on limited empirical data; the clear zone distances suggest only an approximate center of a range of distances to be considered and not a precise or absolute distance. In addition, clear zone distance recommendations do not preclude the establishment of monitoring stations at closer distances to the road; however, stations located within the clear zone will likely require the installation of safety devices (as previously discussed).

Table 12-2. Clear zone information in U.S. customary units (reprinted with permission from AASHTO).

Design Speed (mph)	Design ADT[a]	Foreslopes[b]			Backslopes[b]		
		1V:6H or Flatter	**1V:5H to 1V:4H**	**1V:3H[c]**	**1V:3H**	**1V:5H to 1V:4H**	**1V:6H or Flatter**
40 or less	Under 750	7–10	7–10		7–10	7–10	7–10
	750–1,500	10–12	12–14		10–12	10–12	10–12
	1,500–6,000	12–14	14–16		12–14	12–14	12–14
	Over 6,000	14–16	16–18		14–16	14–16	14–16
45–50	Under 750	10–12	12–14		8–10	8–10	10–12
	750–1,500	14–16	16–20		10–12	12–14	14–16
	1,500–6,000	16–18	20–26		12–14	14–16	16–18
	Over 6,000	20–22	24–28		14–16	18–20	20–22
55	Under 750	12–14	14–18		8–10	10–12	10–12
	750–1,500	16–18	20–24		10–12	14–16	16–18
	1,500–6,000	20–22	24–30		14–16	16–18	20–22
	Over 6,000	22–24	26–32[d]		16–18	20–22	22–24
60	Under 750	16–18	20–24		10–12	12–14	14–16
	750–1,500	20–24	26–32[d]		12–14	16–18	20–22
	1,500–6,000	26–30	32–40[d]		14–18	18–22	24–26
	Over 6,000	30–32[d]	36–44[d]		20–22	24–26	26–28
65–70	Under 750	18–20	20–26		10–12	14–16	14–16
	750–1,500	24–26	28–36[d]		12–16	18–20	20–22
	1,500–6,000	28–32[d]	34–42[d]		16–20	22–24	26–28
	Over 6,000	30–34[d]	38–46[d]		22–24	26–30	28–30

[a] ADT = average daily traffic.

[b] The two most common slopes used in road construction are foreslopes and backslopes. The foreslope extends from the outside of the shoulder to the bottom of the ditch. The backslope extends from the top of the cut at the existing grade to the bottom of the ditch. The amount of slope in either the foreslope or backslope is the ratio of the horizontal distance (H) to the vertical distance (V).

[c] Since recovery is less likely on the unshielded, traversable 1V:3H slopes, fixed objects should not be present in the vicinity of the toe of these slopes. Recovery of high-speed vehicles that encroach beyond the edge of the shoulder may be expected to occur beyond the toe of the slope. Determination of the width of the recovery area at the toe of the slope should take into consideration right-of-way availability, environmental concerns, economic factors, safety needs, and crash histories. Also, the distance between the edge of the through-traveled lane and the beginning of the 1V:3H slope should influence the recovery area provided at the toe of the slope. While the application may be limited by several factors, the foreslope parameters which may enter into determining a maximum desirable recovery area are illustrated in AASHTO's *Roadside Design Guide*.

[d] Where site-specific investigation indicates a high probability of continuing crashes, or such occurrences are indicated by crash history, the designer may provide clear-zone distances greater than the clear zone shown in this table. Clear zones may be limited to 30 feet for practicality and to provide a consistent roadway template if previous experience with similar projects or designs indicates satisfactory performance.

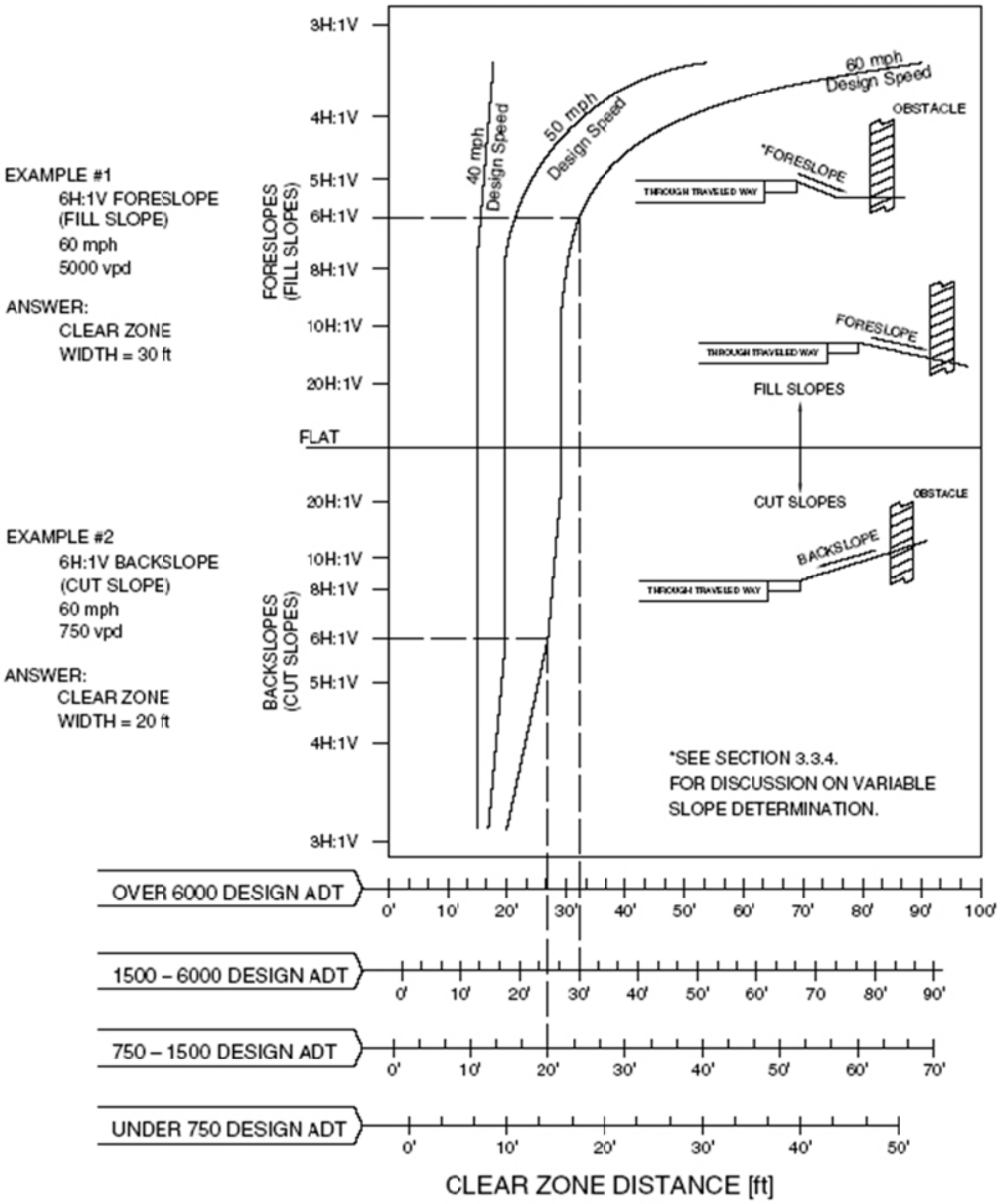

Figure 12-1. Clear zone distance curves (reprinted with permission from AASHTO). For definitions, see the footnotes for Table 12-2.

State or local transportation agency might have approved design manuals that contain specific safety criteria and/or guidance that could be applied to any particular candidate road segment under evaluation. In addition to using the preceding material from FHWA and AASHTO, a state and local air agency may also benefit from asking their respective state or local transportation agency about such manuals.

12.2.4 Other Safety Considerations

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. Because of this priority, the EPA 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 for safety features, 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.

For example, if a longitudinal barrier does not exist along a candidate site, state and local air agencies should bear in mind that, with permission from and in coordination with their companion transportation agency, they can procure and install longitudinal barriers specifically to protect the near-road monitoring site. The EPA has learned that these barriers are relatively inexpensive compared to other typical site installations.

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.

12.3 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 an ROW. Most often, this permission will come in the form of an air space lease (or permit) 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 among 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 an 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 that the 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 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 regarding individual candidate road segments, as discussed next.

12.3.1 Questions a Transportation Agency May Have

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 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 monitoring sites is discussed in Section 13.4 and Section 16.)
- What type of structure (shelter) will be installed at the site? (Pictures showing the structure are useful.)
- 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?

12.3.2 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 affect 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 what alternative sites could be used 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 regularly? If the lease requires renewal, are there any particular criteria that might cause the renewal to be disapproved in the future?
- If a near-road station is to be installed in the ROW, under what conditions should or could safety features be added to a road segment? If a clear zone is currently in use, is that sufficient, or do additional safety features need to be installed? If additional safety features need to be installed, will that be allowed?
- If safety feature installation or improvements are desired, what types of features are available to be considered for installation (such as guardrails or barriers)?
- 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 13. Prioritizing Candidate Near-Road Locations for Monitoring Site Selection

The EPA expects that state and local air agencies will be in possession of sufficient information to begin making informed decisions regarding the selection of near-road NO_2 monitoring sites by

1. following the traffic analysis procedures to aid development of a prioritized list of candidate road segments (described in Section 6), 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 in Section 7 through Section 12).

The EPA expects that state and local air agencies will have a variety of options once they compile candidate site information. It is important to recall that the objective is to monitor in locations that are 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 affect whether candidate near-road locations are feasible accounted for, undoubtedly some air agencies will have multiple candidate sites to choose from. These air agencies 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 a number of other factors should be considered: population exposure, unique and background source influences, confounding data, and the potential for multi-pollutant monitoring. To assist with this, 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.

13.1 Considering Population Exposure as a Selection Criterion

According to 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) to determine which candidate locations are suitable for a required near-road NO_2 station, population exposure should subsequently be considered. Specifically, among a pool of otherwise similar candidate near-road sites, the site that may represent a higher population exposure, or exposures to susceptible or vulnerable populations, should be given increased consideration.

Population exposure can be considered in a number of ways, not all of which can 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 populated area. In this example, the higher population exposure would lead a state or local air agency to give greater weight to the more urbanized site(s).

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://factfinder2.census.gov/). Data can be downloaded from the FactFinder site and these data can then be associated with spatial files located at http://www.census.gov/geo/www/tiger/ and finally 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, since available socioeconomic data can be used by state and local air agencies, the EPA encourages state and local air agencies to determine sites that are located in areas with susceptible and vulnerable populations.

13.2 Unique Locations and Background Source Influences

In the evaluation process, state and local air agencies may encounter situations where certain road segments of interest have characteristics that make the location a unique near-road location that has elevated pollutant concentrations. In such cases, the pollutant concentrations are not representative of other near-road locations across the CBSA. The unique characteristics of these locations could be due to the close proximity of a substantial stationary source, non-road mobile sources, or roadway design features (such as tunnel entrances and exits or toll plazas). In situations where a state or local air agency has a choice between road segments that otherwise have similar potential for peak NO_2 concentrations, the air agencies should place a higher weight on sites that are most influenced by typical roadway activity rather than those that are heavily influenced by unique sources or features. This approach increases the probability that the chosen site can represent a larger population exposure within and across CBSAs.

The EPA recognizes that state and local air agencies will likely have a good understanding of whether candidate near-road NO_2 monitoring sites have unique characteristics that do or do not represent the CBSA that those sites are within. The EPA encourages state and local air agencies to use their local knowledge in site selection and to engage the EPA Regional staff for assistance in evaluating such a situation as necessary.

13.3 Confounding Information

There may be instances where state and local air agencies have data or insights that indicate that certain candidate near-road sites may be preferable to those identified through other technical analyses, including those suggested in this TAD. Such data may be from one or more sources, including, but not necessarily limited to, traffic data analysis and projections, exploratory monitoring, modeling, or local knowledge. In cases where measured data (of sufficient amount, quality, and confidence) are available as compared to estimated, modeled, or otherwise approximated information, measured data may be more reliable, unless those data are suspect due to poor quality assurance or other reasons. An example of such a situation might be a comparison between exploratory monitored data and modeled data, where the exploratory monitoring would provide measured data that may differ and have higher confidence that the modeled results. Ultimately, the EPA expects air agencies to use their best judgment when presented with confounding information to make the best decision for their individual case. The EPA also encourages state and local air agencies to engage the EPA Regional staff for assistance in evaluating any such situation.

13.4 Potential for Multi-Pollutant Monitoring

Other than NO_2, a number of pollutants and measureable metrics of interest that exist in the near-road environment are discussed in some detail in Section 16. Although this document specifically provides suggestions on siting required near-road NO_2 monitors, the EPA strongly 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 may be a conservative approximation of a multipollutant site footprint. A typical NCore station houses analyzers for CO, ozone, sulfur dioxide (SO_2), total oxides of nitrogen (NO_Y), a variety of PM instruments (including PM with an aerodynamic diameter of 2.5 µm and less [$PM_{2.5}$] and lead samplers), and meteorological gear, along with all the associated support equipment. Although this NCore-type footprint can be bigger than a single pollutant shelter, the EPA believes, based on research experiences, that installing a site with room for multi-pollutant monitoring efforts should not typically create additional burden or restrictions for site installation versus a single gas pollutant monitoring shelter.

13.5 Candidate Site Comparison Matrix

The EPA recommends that, upon the completion of traffic data analysis, field reconnaissance, and other evaluation efforts, 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 another. The matrix would likely aid state air staff and other decision makers, and will also be a useful source of data supporting site selection discussion with the EPA, other stakeholders, and possibly the public. Further, the EPA anticipates that the matrix will be a useful reference for users of the data, who may want to analyze the data for applications beyond NAAQS compliance.

The candidate site comparison matrix is recommended to include, at a minimum,

- traffic data
- field information (e.g., type of road);
- site feasibility information, such as permission for, or lack of, access to individual candidate sites;
- probable distance between the inlet probe and the outside edge of the target road;
- safety issues (if applicable); and
- any other collected ambient data and/or modeled data for the site.

The matrix can be used to represent individual points along a road segment or for whole road segments under consideration. Such a detailed matrix could have several candidate locations that are available along the same target road segment. **Table 13-1** includes a list of variables that could be included in the matrix.

Table 13-1. Suggested data for each candidate site entry in a site comparison matrix.

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Site/Segment Parameters	Description of Parameter
Location	Is the entry for a specific point along a road segment, or is it representative of an entire road segment? For a point, provide a moniker and the latitude and longitude. For a road segment, identify where the segment boundaries occur (e.g., intersection, mile marker, political boundary).
Road segment name	Given road name and common name (if applicable).
Road type	Type of road (controlled access highway, limited access freeway, arterial, etc.).
Road segment end points	Location of the road segment end points, including any given names, common names, and the latitude and longitude of each individual end point.
AADT	AADT, source of data, and vintage.
HD counts	Provide HD counts (if available), source of data, and vintage.
FE-AADT	Provide FE-AADT (if available), noting HD_m value used. If not using the national default value for HD_m, provide the source of data used to calculate the site-specific value.
Congestion information	Value and type (e.g., LOS, $^V/_C$, or AADT by lane), data source, and vintage.
Roadway design	Design type or types present (flat, elevated-fill, cut, etc.). If not flat, identify whether the configuration is a vertical or sloped boundary. Include the height (and degree of slope if applicable).

Table 13-1. Suggested data for each candidate site entry in a site comparison matrix.

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Site/Segment Parameters	Description of Parameter
Terrain	Nature of the terrain immediately around the road; also, any larger-scale terrain features of note.
Meteorology	For a point, the predominant winds and whether the point is relatively upwind or downwind. For a whole segment, the orientation of the segment to the predominant winds.
Population exposure	Assessment of population exposure and/or likeness to other road segments throughout the CBSA.
Roadside structures	Presence of any roadside structures and their height, width, and length.
Safety features	Safety features present and their height, width, and length.
Infrastructure	Existing infrastructure (light poles, billboards, etc.) and potential site proximity (distance).
Interchanges	Presence of any interchanges within or at the end points of the target road segment and potential site proximity (distance), including traffic information if available (AADT, HD counts, etc.).
Surrounding land use	Surrounding land use (residential, commercial, etc.). Also, proximity to other large roads, areas of higher relative road density, and/or locations within or near central business districts or urban downtown areas.
Nearby sources	Nearby NO_X sources if applicable (type, tonnage, etc.) and potential site proximity (distance).
Current road construction	Visible or known road construction at the candidate site location or along the target road segment.
Future road construction	Transportation agency plans (if known) for any future road construction (including time frame for completion).
Frontage roads	Presence of frontage roads, and whether those roads are included as part of the target road segment.
Available space–site footprint	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	Level of confidence and any uncertainties regarding the acquisition of access to a particular property.
Other details/local knowledge	Any other pertinent details that may have bearing on why a particular candidate site may or may not be selected. This can include information that reflects a state or local agency's own knowledge of the area or roads under consideration.

Section 14. Final Near-Road Site Selection

The EPA expects that state and local air agencies will engage the EPA Regional staff during the site selection process (as needed) and when a site has been selected it will 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 selection of a site, 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 monitoring 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 AQS metadata form (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 14-1**.

Table 14-1. Near-road site information metadata required in AQS (AA – Basic Site Information transaction).

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 monitoring 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 14-2**.

Table 14-2. Additional near-road site information metadata in AQS (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[a]	Source of Traffic Count

[a] Tangent Street Number (also called Tangent Road Number) is merely a unique identifier supplied by the user (i.e., “1”, “2”, ..., “99”); it does not refer to a physical street number.

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 EPA recognizes that a site may not have a traditional street number if it is within the ROW of a major interstate or freeway. In such cases, try to use an appropriate descriptor as allowable.

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 is 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 “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. This will be a highly visible and often used piece of metadata.
- Dominant Source – reflect that the “mobile source” category is the dominant source.

The EPA believes that a full and accurate characterization of the monitoring site and the monitor itself will greatly improve the usefulness of data at near-road NO_2 monitoring stations for subsequent analyses.

Section 15. Selecting a Second Near-Road Site

According to 40 CFR Part 58 Appendix D, CBSAs meeting one of the following criteria are required to have a second near-road NO_2 monitoring site:

- the CBSA has a population of 2.5 million or more persons
- the CBSA has a population of 500,000 or more persons and has one or more road segments of 250,000 AADT or greater

The EPA prescribes that these second near-road NO_2 monitoring sites be selected so that sites are differentiated from the first near-road NO_2 monitoring site by one or more factors affecting traffic emissions and/or pollutant transport (such as fleet mix, congestion patterns, terrain, geographic area within the CBSA), or by different route, interstate, or freeway designation.

The data gathered to select the initial near-road NO_2 monitoring site will be very useful in determining where to place a second site. The EPA's primary recommendation for a second site is to attempt to have the second site represent as many of the characteristics listed above differently from the first site, without sacrificing the objective of measuring relative peak NO_2 concentrations in the near-road environment. In some cases, this could allow for the consideration of sites that may have characteristics that make the location more unique. Examples include, but are not limited to, a site with potentially higher population exposure (including vulnerable and susceptible populations); a site with a different fleet mix (e.g., high LD component); a site closer to an area-wide monitoring location, as applicable (for relative gradient assessment); or a site with relatively unique features.

Section 16. Multipollutant Monitoring at Near-Road Monitoring Stations

The EPA has expressed the intention of pursuing the integration of monitoring networks and programs by encouraging multipollutant monitoring wherever possible. This intention 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 that are of interest in the near-road environment due to their direct emission by on-road mobile sources, or due to their formation from or interaction with on-road mobile source emissions. The Clear Air Scientific Advisory Committee (CASAC) Ambient Monitoring and Methods Subcommittee (AMMS), in their review of the EPA's "Near-road Guidance Document – Outline" and "Near-road Monitoring Pilot Study Objectives and Approach" (CASAC AMMS review dated November 24, 2010[10]), stated that "CASAC recognizes the importance for public health of better characterizing near-road pollutant concentrations." Subsequently, the CASAC AMMS held public teleconferences (September 29th, 2011, and November 17th, 2011) to discuss their review of the August 11th, 2011, draft version of this TAD.[11] In response to a question regarding the relative priority for measuring other pollutants or other metrics of interest in the near-road environment, should state and local air monitoring agencies choose to invest in additional measurements, the CASAC AMMS suggested three pollutant groups, with relative priority (i.e., primary, secondary, and tertiary), to provide some guidance to air agencies choosing to conduct monitoring (**Table 16-1**). These pollutants or metrics are discussed in this section, including definitions, basis of interest, and measurement methods.

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[10] Located on the Internet at http://yosemite.epa.gov/sab/sabproduct.nsf/ACD1BD26412312DC852577E500591B37/$File/EPA-CASAC-11-001-unsigned.pdf.

[11] Located on the Internet at http://yosemite.epa.gov/sab/SABPRODUCT.NSF/81e39f4c09954fcb85256ead006be86e/bea1681f1769e6f185257781005fcf8d!OpenDocument&TableRow=2.0#2.

Table 16-1. CASAC AAMMS's recommended priorities for multipollutant monitoring at a near-road site.

Priority	Pollutants
Primary	NO and NO_2 (where NO_2 is required), CO (required in a subset of near-road NO_2 monitoring sites), ozone, and meteorology (wind speed, wind direction).
Secondary	Air toxics (at least benzene, toluene, ethyl benzene, and xylenes), black carbon, ultrafine particle size distribution (preferred) or ultrafine particle number concentration, and traffic counters (if the site is not already in proximity of a fixed transportation agency traffic counting device).
Tertiary	$PM_{2.5}$, $PM_{10-2.5}$, CO_2, and organic and elemental carbon (OC and EC, respectively).[a]

[a] PM_{10} is particulate matter with an aerodynamic diameter of 10 µm or less. $PM_{10-2.5}$ is particulate matter with an aerodynamic diameter less than 10 µm and more than 2.5 µm; it is also called coarse particulate matter

16.1 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 increased hospital admissions for respiratory issues.

NO_2 is one of a number of oxidized nitrogen species. Scientifically, 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. 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 NAAQS for the oxides of nitrogen, and the requirement to measure NO_2 in the near-road environment where, as noted in Section 1, the EPA recognizes 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 United States. 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, and also through other photochemical processes. Although all motor vehicles emit NO_X, heavy-duty (diesel) vehicles emit more NO_X per vehicle 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 an 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 release 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; this means that 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 converter 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 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 two type of chemiluminescent analyzers in the market today: the standard analyzer, and a more recently commercialized “trace-level” line of analyzers. Standard analyzers have levels of detection on the order of 0.4 ppb, while the trace-level analyzers have levels of detection down to approximately 0.05 ppb. While trace-level analyzers are strongly encouraged for use in the NO_2 monitoring network when possible, standard NO_2 analyzers are expected to be sufficient for use in the near-road environment, where ambient NO_2 levels are expected to be relatively higher than at other locations more representative of area-wide spatial scales.

There are other techniques that are commercially available to measure NO_2; however, as of the production of this document, there are no other approved methods for NO_2 measurement by 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 much more 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.

Other commercially available methods to measure NO_2 include the Cavity Ring-Down Spectrometer (CRDS) and the Cavity Attenuated Phase Shift (CAPS) technology. These devices are laser light (at a specific wavelength) based devices that utilize NO_2 absorption to determine the NO_2 concentration in the sampled air. The EPA plans to continue to work with academia and measurement technology vendors to improve measurement techniques, and increase the accuracy, precision, specificity, 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.

16.2 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).

While all motor vehicles emit CO, the majority of mobile source CO is from light-duty, gasoline-powered vehicles, where LD vehicles produce more CO per vehicle than HD vehicles. Ambient CO measurements are routinely taken by analyzers using 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; the current ambient CO compliance monitoring network wholly comprises analyzers based on this infrared absorption method. Of these analyzers, there are currently two types of IR absorption analyzers 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 CO levels are expected to be relatively higher than at other locations more representative of area-wide spatial scales.

On August 12, 2011, the EPA promulgated minimum monitoring requirements for CO in the near-road environment. According to 40 CFR Part 58 Appendix D, one CO monitor is required to be co-located with a near-road NO_2 monitor in CBSAs having populations of 1 million or more persons. State and local air agencies can make a request to the EPA Regional Administrator for permission to place a required CO monitor at another near-road location in that CBSA if they can provide quantitative evidence in support of that request. However, the EPA expects that in most cases, state and local agencies will find it advantageous to leverage the near-road NO_2 infrastructure and also conduct multipollutant monitoring at their near-road NO_2 monitoring site.

16.3 Ozone

Ozone is not usually emitted directly into the air, but created at ground-level by a chemical reaction between NO_x and volatile organic compounds (VOCs) in the presence of sunlight. NO_x and VOCs are emitted by mobile sources, among others. Ozone can trigger a variety of respiratory health problems; worsen bronchitis, emphysema, and asthma; reduce lung function; and inflame the linings of the lungs. Ozone is routinely measured *in situ* using photometry or chemiluminescence on a sub-hourly to hourly sampling frequency. To date, ozone measurements have not typically been collected for near-road applications. The presence of elevated NO concentrations in the near-road microenvironment typically leads to lower ozone concentrations due to "ozone scavenging" as part of the formation of NO_2 from NO and ozone. However, ozone measurements may be useful in the near-road environment for increasing the understanding of NO_2 concentrations, NO_2 formation behavior, and broader photochemistry processes in the near-road environment. Further, ozone monitoring in the near-road environment may 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.

The EPA notes that while the measurement of ozone in the near-road environment would provide data that could be useful for furthering the understanding of photochemistry in the near-road environment, and would also provide data that could be compared with the NAAQS, the monitor would not meet minimum monitoring requirements for ozone (which calls for area-wide monitors) as prescribed in 40 CFR Part 58 Appendix D.

16.4 Meteorological Measurements

Meteorological data measured onsite 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 AMMS review, the panel stated that "the AMMS 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 onsite would be the ability to correlate the occurrence of peak NO_2 concentrations (and other pollutant peaks) to wind conditions. Data analysis of the collected pollutant data will be greatly enhanced by knowing whether 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 originally proposed in the NPR for NO_2 to be required at near-road NO_2 monitoring sites, the EPA did not ultimately require them within 40 CFR Part 58. However, the EPA strongly encourages states to measure meteorological parameters at near-road sites whenever possible. The EPA suggests that if meteorological measurements are made, state and local air agencies at a minimum measure wind speed, wind direction, temperature, and relative humidity (which match 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* (U.S. Environmental Protection Agency, 2008c).

16.5 Air Toxics

In addition to some criteria pollutants, motor vehicles emit a large number of other compounds which can cause adverse health effects, such as air toxics (hazardous air pollutants). A discussion and listing of potential air toxics of concern for near-road monitoring can be found in the EPA's Mobile Source Air Toxics (MSAT) Rule (U.S. Environmental Protection Agency, 2007). These pollutants include VOCs, semi-volatile organic compounds (SVOCs), and organic and inorganic PM constituents. Reasons for monitoring these pollutants for a near-road program include concerns about adverse human health effects and ecological effects, and the need to provide data for evaluating 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, ethyl benzene, 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 collecting ambient air using evacuated canister sampling and subsequently analyzing the samples using a gas chromatograph (GC). For evacuated canister sampling, depending on the collection equipment used, the sample collection time can vary from an instantaneous grab sample to averaging times of more than 24 hours. Auto-GCs can be used to measure specific 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 that concentrations are elevated near heavily trafficked roads.

SVOCs present in near-road emissions are naphthalene and other polycyclic aromatic hydrocarbons (PAHs). SVOC sampling is done using XAD/polyurethane foam (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, along with other elements (such as soil components), are present in $PM_{2.5}$ and PM_{10} samples. 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 are not widely used. Concentration gradients of these toxic metals near roads 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.

16.6 Black Carbon and Elemental Carbon

The graphitic-containing portion of PM, represented by black carbon (BC) or EC, also referred to as “soot,” is emitted in motor vehicle exhaust. BC and EC are of interest because they serve as a measure of diesel particulate matter (DPM). 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. Long-term (i.e., chronic) inhalation of diesel exhaust (a 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 the nature of the 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).

BC and EC are operationally defined. 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, such as wood smoke, exist in urban areas, but emissions from motor vehicles usually dominate these sources in near-road air quality.

16.7 Ultrafine Particulate Matter

PM emitted through the combustion process occurs initially in the ultrafine size range (i.e., less than 0.1 μm in diameter); 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 particle 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 particle 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, while some devices are capable of providing particle number concentrations within specific size bins. 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.

16.8 Traffic Counters and/or Cameras

Traffic counting devices and/or traffic cameras provide other non-pollutant measurements that could be useful to an air agency to aid in characterizing measured pollutants at a near-road monitoring site. Understanding traffic behavior can help analysts better understand measured pollutant concentrations, such as the correlation of peak NO_2 readings to time periods when traffic is heaviest and/or experiencing increased congestion. There are a number of direct-measure methods used to characterize traffic, including over-the-road tube counters, embedded devices such as contact closure loops for counts or piezoelectric sensors used for weigh-in-motion, speed cameras and red-light cameras, and vehicle classification and count devices. These methods are applied by placing the sensors on or within the road surface of active travel lanes.

Unless a transportation agency has installed (or plans to install) on-road or embedded 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 can be installed alongside roads (such as on a meteorological tower or monitoring shelter), and can focus on the target road segment. The sophistication of remotely sensing instruments is variable, but the EPA suggest that if such a device is investigated for use, a minimum requirement should be 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 purpose of analyzing air quality data, and not to broadcast traffic data publicly in a manner that is 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 are currently being collected. In such a case, there may be a synergistic advantage to the agencies; the air agency can 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 conducted at near-road monitoring sites.

16.9 PM Mass

PM is a complex mixture of small particles and liquid droplets comprised of sulfates, nitrates, acids, ammonium, EC, OC 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 µm 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 $PM_{2.5}$. Both 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. These ultrafine particles contribute little to ambient $PM_{2.5}$ mass concentrations, contribute significantly to particle number concentrations, and can affect 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 (i.e., minutes) and rapidly coagulate into accumulation-mode particles (0.3 to 0.7 µm). Accumulation-mode PM that is secondarily formed from motor vehicle combustion emissions may have a greater effect on $PM_{2.5}$ mass concentrations in or near the near-road environment.

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 (and also the coarse fraction, $PM_{10\text{-}2.5}$) measurements and any speciation of PM mass at near-road sites can further the understanding of concentrations, properties, and behavior of PM in the near-road environment.

Currently, a large 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 effect on near-road air quality, an effect that is not identifiable in 24-hour average measurements. Thus, continuous or semi-continuous (i.e., hourly or sub-hourly) PM measurements may be considered to provide useful time-resolved information. 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 smaller than approximately 0.2–0.5 µm in diameter. Because of this, these measurement devices may not detect or characterize 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 organic PM prior to detection.

16.10 Carbon Dioxide (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.

16.11 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 PAHs, are known or suspected carcinogens. OC is often the largest component of PM in urban areas in the western United States, and especially in near-roadway environments. Motor vehicle fuel combustion is an important contributor of OC.

OC is typically measured by collecting 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-hour 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 are expected to have a significant contribution to PM 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 speciated 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 source apportionment studies to estimate the effects 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, for example, 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.

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U.S. Environmental Protection Agency (2010b) Transportation conformity guidance for quantitative hot-spot analyses in $PM_{2.5}$ and PM_{10} nonattainment and maintenance areas: Appendices. Guidance document prepared by the Transportation and Regional Programs Division, Office of Transportation and Air Quality, EPA-420-B-10-040, December. Available on the Internet at http://www.epa.gov/otaq/stateresources/transconf/policy/420b10040-appx.pdf.

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

The HPMS and Traffic Demand Modeling applications contain uncertainties that need to be understood to properly interpret these data when they are used 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 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. Data collected during relatively short duration campaigns can sometimes be used to represent longer periods of time, such as annual averages.

A.2 Fixed Measurement Systems

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

A.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 over longer time periods (i.e., “expand” a short-term traffic volume into a long-term value). These expansion factors can be related to maximum hourly traffic volumes or the overall number of days of sampling conducted with the temporary devices. If these devices are used, the state DOT or local planning organization should be consulted to determine the most appropriate expansion factors to use for their given location and time period of sampling.

A.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 unmonitored roadway segments.

A.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. These lengths can be misclassified due to a number of factors, including tailgating vehicles and trucks with multiple axles, although misclassification depends on the measurement device.

In addition, these devices cannot differentiate between vehicles operating on gasoline and vehicles operating on diesel. 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, most light-duty vehicles (less than 20 feet in length) operate on gasoline, while most 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 when looking at traffic counts 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 6 of the TAD, the HD_m ratio of 10 was chosen as the national default value to weight the contribution of heavy-duty vehicle emissions compared with emission rates from light-duty vehicles for use in creating FE-AADT values. This ratio was chosen using national default emission values for both heavy- and light-duty vehicles, and represents a realistic ratio of average heavy-duty to light-duty vehicle emissions nationally for typical highway driving conditions. 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. There may be situations under which a state may choose to calculate a local HD_m value or local values based on information for a specific road segment or for a particular season, for use in calculating FE AADT as discussed in Section 6 of the TAD.

Table B-1 lists average motor vehicle emission rates using national default values of fleet distribution and speed for the year 2010 as provided by EPA's Office of Transportation and Air Quality (OTAQ); these data are from running the MOVES emissions model. The year 2010 was chosen based on the likely year of traffic data available to state and local air agencies during the initial process of identifying candidate sites. Note that these emission factors represent hot, stabilized running conditions only; cold starts are not included, since these events are unlikely to occur during highway or other high-volume roadway driving activities. In addition, the default temperature and humidity used to calculate this ratio for January and July represented national averages. As shown in this table, an HD_m value of 10 provides a representative approximation of the heavy-duty to light-duty vehicle emissions ratio using national default values. A simplified HD_m factor of 10 signifies a ratio of a combination of heavy-duty and light-duty vehicles commonly found on U.S. highways at typical highway operating speeds.

Table B-1. Average motor vehicle emissions rates within two seasonally representative months using national default values of fleet distribution and speed for 2010.

Month	Vehicle Type	NO_x Emission Rate (g/mile)	HD_m Ratio
January	Heavy Duty	10.09	10.96
	Light Duty	0.92	
July	Heavy Duty	8.47	9.33
	Light Duty	0.91	

For areas that have data on road segment congestion or fleet mix, a more detailed assessment can be made using MOVES emissions results. **Figure B-1** and **Figure B-2** provide examples of how emission rates vary by vehicle speed and type. These graphs compare emission rates for vehicles commonly using U.S. highways, with separate graphs provided for January and July of

2010 (to highlight emission differences between colder and warmer ambient temperatures). As shown, the ratio of emissions can vary widely among vehicle types and speeds.

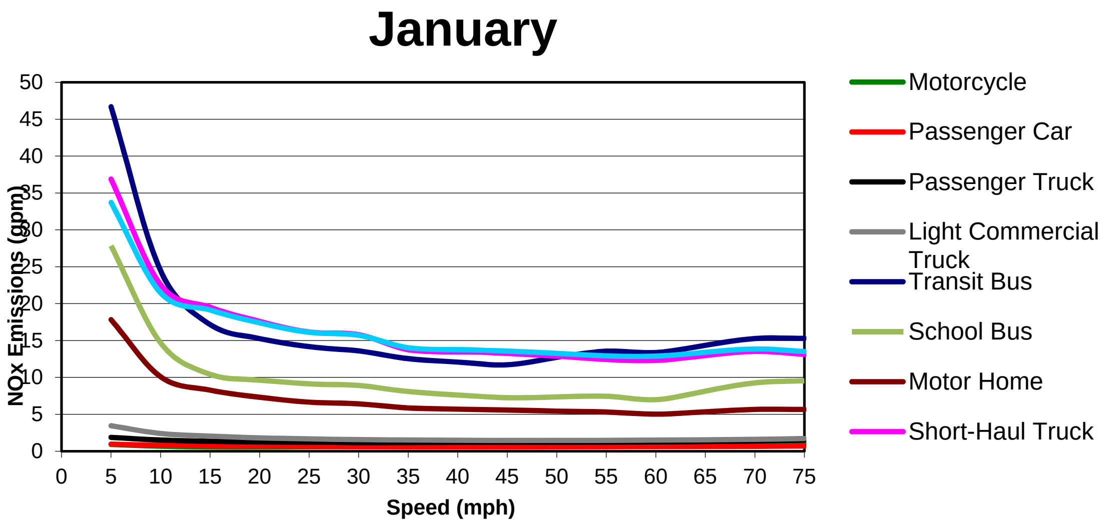

Figure B-1. Average NO_x emission rates by vehicle type and speed for January 2010 (from MOVES).

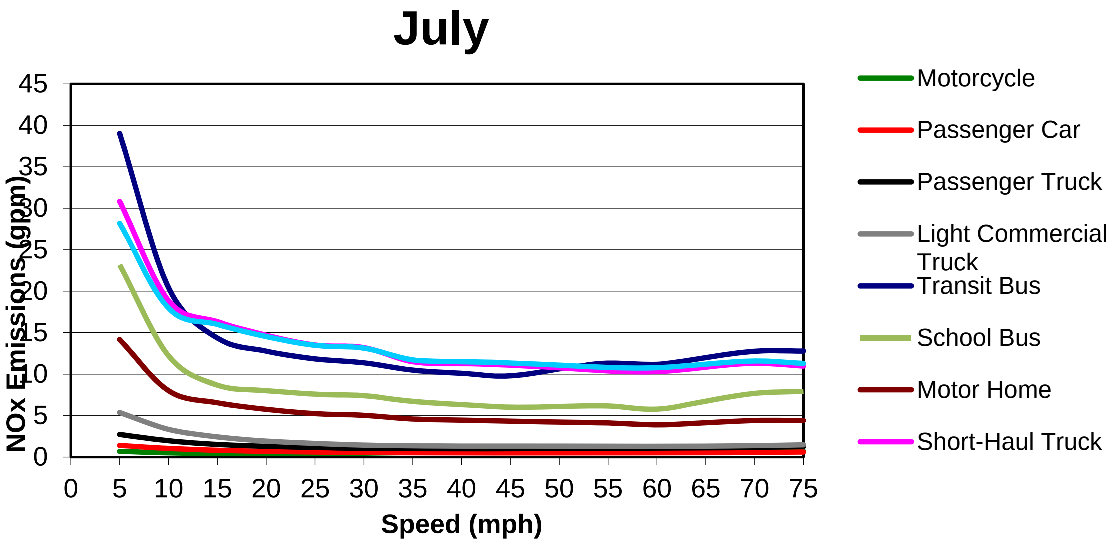

Figure B-2. Average NO_x emission rates by vehicle type and speed for July 2010 (from MOVES).

Appendix C. Modeling

This appendix offers specific guidance to those state and local agencies choosing to use modeling to further inform the implementation of near-road NO_2 monitors. This appendix offers guidance on the selection of an air quality model, modeling domain (including receptor placement), characterization of emissions sources, meteorological inputs, and inclusion of background concentrations.

C.1 Guidance on Air Emissions Models

The following sections provide an overview of using MOVES for project-level analyses.[12] This guidance is based on

1. the MOVES User Guide (U.S. Environmental Protection Agency, 2010a),
2. Section 4 of EPA's *Transportation Conformity Guidance for Quantitative Hot-spot Analyses in* $PM_{2.5}$ *and* PM_{10} *Nonattainment and Maintenance Areas* (U.S. Environmental Protection Agency, 2010b), and
3. EPA's "Using MOVES in Project-Level Carbon Monoxide Analyses"[13] (U.S. Environmental Protection Agency, 2010c).

Interested agencies should consult these documents for further details when performing MOVES project-level analyses.[14] For guidance documents, see http://www.epa.gov/otaq/stateresources/transconf/policy.htm#project.

C.1.1 Geographic Scale of Analysis

MOVES can be used to model emissions for different geographic scales. For analyzing individual road segments, the "Project" scale of MOVES should be employed. The "County" and "National" scales are not suitable for analyzing individual road segments. See Section C.1.3 for further information on specifying the Project scale in a MOVES "Run Specification."

At the Project scale, MOVES represents emissions of a particular roadway as a series of "links." The purpose of defining a roadway as one or more MOVES links is to accurately capture emissions where they occur. Generally, links specified for a roadway should include segments with similar traffic characteristics and vehicle activity. Using link-specific vehicle activity and other inputs, MOVES calculates emissions from every link of a project for a given hour. There are no limits to the number of links that can be defined in MOVES.

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[12] This appendix uses "MOVES" to refer generically to any approved version of the MOVES model. This guidance is applicable to current and future versions of the MOVES model, unless EPA notes otherwise.

[13] For the user guide, see http://www.epa.gov/otaq/models/moves/index.htm#user; other guidance documents are available at http://www.epa.gov/otaq/models/moves/index.htm. For guidance documents, see http://www.epa.gov/otaq/stateresources/transconf/policy.htm#project.

[14] Note that these technical guidance documents were developed to address other requirements. However, certain sections of the guidance may be applicable when completing analyses of transportation projects for other purposes, such as when completing NO_2 modeling as described in this appendix.

Using the Project scale and the Project Data Manager, users can enter data that applies to the project being analyzed. Modeling to support siting of near-road NO_2 monitors should incorporate the most recently available data. MOVES also includes a default database of meteorology, fleet, activity, fuel, and control program data for the entire United States. The information in the default database comes from a variety of sources; these data may not necessarily be the most accurate or up-to-date information available. For some needed inputs, such as fuel information, it may be appropriate to use the national defaults.

C.1.2 Time Period of Analysis

When MOVES is run at the Project scale, it estimates emissions for only the hour specified by the user. State and local agencies may have activity data collected over a range of possible temporal resolutions. Multiple MOVES runs can be completed to represent emissions during different time periods. In most cases, traffic data will represent weekdays, which should be so indicated in MOVES. The year, month, and hour should be defined for each MOVES run. Since modeling will be used to compare potential impacts at multiple sites, it is important that the same modeling years are evaluated for each road segment.

C.1.3 Developing a MOVES Run Specification (RunSpec)

A MOVES RunSpec is a computer file in XML format that can be edited and executed directly or with the MOVES Graphical User Interface (GUI). MOVES needs the user to set up a RunSpec to define the place and time of the analysis, as well as the vehicle types, road types, fuel types, and the emissions-producing processes and pollutants that will be included in the analysis.

A RunSpec is entered through the Navigation Panel of the MOVES GUI (shown in **Figure C-1**).

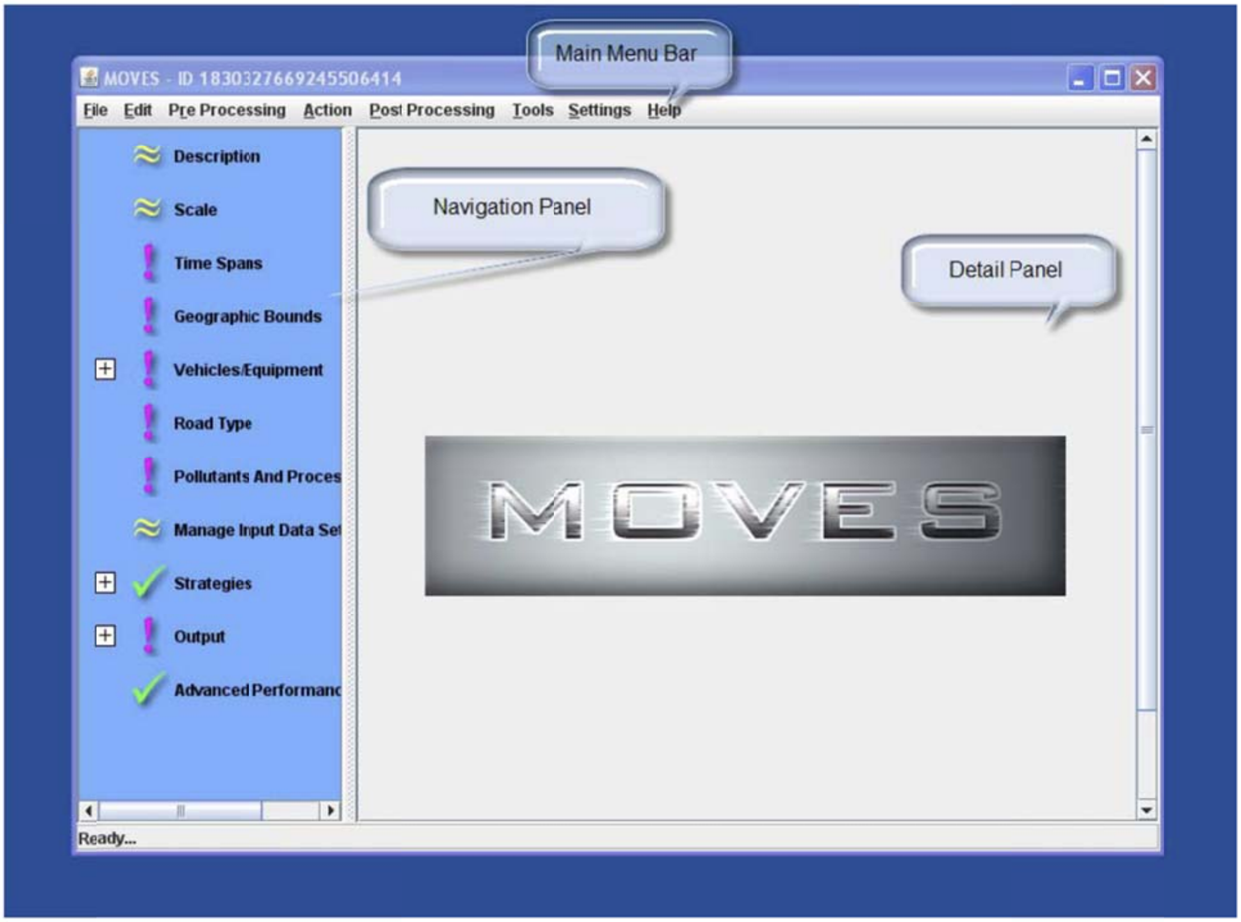

Figure C-1. The MOVES opening screen; the Navigation Panel is on the left. Image from the MOVES2010a user guide (U.S. Environmental Protection Agency, 2010a).

To create a project-level RunSpec, a user moves through the relevant tabs and fills in data appropriate for each item.

- *Description* – Users may enter up to 5,000 characters of text.
- *Scale* – Users must specify the “Project” scale. In this panel, the user also should select output as “Inventory” (grams per hour per link) if using American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) to complete the air quality modeling.
- *Time Spans* – Here, users specify the hour, day, month, and year. Also, users specify time aggregation (select “hour” for analysis of individual road links).
- *Geographic Bounds* – Users define the county being modeled. County information in MOVES determines some default information in the analysis.
- *Vehicles/Equipment* – Users specify the vehicle and fuel types to be included. MOVES includes 13 “source use types,” such as “passenger car” and “long-haul combination truck.”

- *Road Type* – Users define the types of roads included in the run. Road types determine which default vehicle driving cycles MOVES assigns to vehicles. In most scenarios evaluated for NO_2 near-road monitoring, the urban restricted access road type will be used, although a state or local agency may be interested in comparing impacts from other road types and segments.
- *Pollutants and Processes* – Users identify the pollutants and emission processes to be calculated by MOVES. For NO_2 modeling, the user should identify "Oxides of Nitrogen," "Nitrogen Oxide," and "Nitrogen Dioxide." "Running Exhaust" and "Crankcase Running" emission processes should be selected for modeling individual road links.[15]
- *Manage Input Data Sets* – This panel is not used in most project-level analyses. The Project Data Manager is used for creating input databases. (For more information, see Section C.1.4.)
- *Strategies* – Users can model alternative control strategies that affect the composition of the vehicle fleet. In most situations, the state or local agency should use the same strategies for all road segments analyzed unless existing information is known regarding a difference in applicable strategies among different road segments.
- *Output* – Users specify output formats. Under "General Output," users should select "grams," "miles," and "joules" for output units, and "Distance Traveled" and "Population" to obtain vehicle volume information for each link modeled and to provide details for evaluating MOVES results. Under "Output Emissions Detail," emissions by hour and link are required for use in AERMOD (discussed in Section C.3).
- *Advanced Performance Features* – This panel is not used in most project-level analyses.

C.1.4 Entering Project Details Using the Project Data Manager

Once the choices for establishing a RunSpec have been set, the user should create appropriate input databases using the Project Data Manager, which can be accessed from the Pre-Processing menu item on the menu bar on top of the GUI. The Project Data Manager has a series of tabs through which site-specific data are entered:

- *Links* – MOVES represents individual road segments as "links." Use this importer to define individual road links, which must be assigned a unique identification (ID). This importer requires information on the link's length, traffic volume, average speed, and road grade.
- *Link Source Type* – Users enter the fraction of link's traffic volume represented by each vehicle type (source type).

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[15] If other transportation facilities are evaluated (e.g., diesel truck or bus activity at terminals), then additional emission processes would be considered in MOVES.

- *Link Drive Schedule* – An optional importer that imports a 1-second time series driving trace (speed and road grade) intended to represent vehicle driving behavior on the road link modeled.
- *Operating Mode Distribution* – Users specify the distribution of operating modes for source types, hour/day combinations, roadway links, and pollutant/process combinations that are included in the run specification. This importer is considered an advanced option that requires detailed vehicle activity data, and is typically not used.
- *Off-Network* – Users specify vehicle populations and activity for locations where vehicles park, start, and/or idle for extended periods of time, such as parking lots or truck stops.
- *Age Distribution* – Used to enter information on the distribution of vehicle ages (ageID) within the calendar year and vehicle type.
- *Fuel Supply and Fuel Formulation* – Used to provide fuels and fuel mix in the area modeled. These inputs should generally be the same for all road segments in an area.
- *Meteorology* – Used to specify temperature and humidity data for the month and hour modeled in the MOVES RunSpec.
- *Inspection and Maintenance* – In general, inspection and maintenance (I/M) programs apply to vehicle fleets throughout certain nonattainment and maintenance areas.

C.1.5 MOVES Output Format

MOVES produces an output database that contains a line for each year, hour, link, pollutant, process, fuel, and model year (if selected). MOVES produces either "inventories" (mass emissions per hour) or emission rates. Inventory output can be used in AERMOD directly (with additional source characterization as described next). MOVES emission rates must be post-processed to obtain emission rates suitable for use in AERMOD.

C.2 Guidance on Air Quality Models

The guidance in this section is based on and is consistent with EPA's *Guideline on Air Quality Models*, also published as Appendix W of Title 40 CFR Part 51 (U.S. Environmental Protection Agency, 1993, 2005). 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 and Prevention of Significant Deterioration programs. Because air quality modeling to inform the implementation of NO_2 near-road monitors needs to employ air quality dispersion models[16] that properly address NO_2 emissions, such modeling 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, CFR Sections

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[16] 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.

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 modeling guidance are available at the Support Center for Regulatory Atmospheric Modeling (SCRAM) website.[17]

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 New Source Review/Prevention of Significant Deterioration permit modeling for the new NO_2 NAAQS (U.S. Environmental Protection Agency, 2010d).
- "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. Environmental Protection Agency, 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[18] (U.S. Environmental Protection Agency, 2010b, e).

The following sections refer to the relevant sections of Appendix W and other existing guidance, with summaries as necessary. Please refer to those original guidance documents for

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[17] The SCRAM website is available at http://www.epa.gov/ttn/scram/

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

full discussion, and consult with the appropriate EPA Regional Modeling Contact if questions arise about interpreting modeling techniques and procedures.[19]

C.3 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, the user should follow the guidance on the preferred model for that application. As long as they are used as indicated in each model summary of Appendix A, these models may be used without an area-specific formal demonstration of applicability. Further recommendations for the application of these models to specific source problems are found in subsequent sections of Appendix W.

As described in the PM hot-spot guidance (U.S. Environmental Protection Agency, 2010b, e) EPA's preferred near-field dispersion model, AERMOD (U.S. Environmental Protection Agency, 2004a, 2011b) has been recommended for use in PM hot-spot analyses and is applicable as well to NO_2 modeling.

For most scenarios to be considered as part of this TAD, AERMOD should be used. In 2005, after extensive development and performance evaluation, EPA promulgated AERMOD as the Agency's preferred near-field dispersion modeling for a wide range of regulatory applications in all types of terrain.

AERMOD performed generally well in the NO_2 Risk and Exposure Assessment (U.S. Environmental Protection Agency, 2008a) and is the recommended model for most mobile source modeling scenarios.[20] The guidance discussed here focuses on the use of AERMOD for mobile source modeling.

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. Environmental Protection Agency, 2004a, 2011b)
- AERMAP: the terrain processor for AERMOD (U.S. Environmental Protection Agency, 2011c, 2004b)
- AERMET: the meteorological data processor for AERMOD (U.S. Environmental Protection Agency, 2004c, 2011d)

The non-regulatory components are

- AERSURFACE: the surface characteristics processor for AERMET (U.S. Environmental Protection Agency, 2008b)

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[19] For a list of regional modeling contacts by EPA Regional Office, see the SCRAM website: http://www.epa.gov/ttn/scram/guidance_cont_regions.htm.

[20] For example, EPA cites AERMOD as a recommended model when completing PM hot-spot analyses for transportation conformity purposes. See Section 7.3 of EPA's PM hot-spot guidance (U.S. Environmental Protection Agency, 2010e).

- AERSCREEN: a recently released screening version of AERMOD (U.S. Environmental Protection Agency, 2011e)
- BPIPPRIME: the building input processor (U.S. Environmental Protection Agency, 2004d)

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

C.4 Receptor Placement

The receptor grid is unique to each particular situation. It depends on the size of the modeling domain, number of modeled sources, and complexity of terrain. Receptors should be placed in areas that have representative ambient air. Receptor placement should be of sufficient density to provide the resolution needed to detect significant gradients in concentrations of the pollutants of concern, 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 at monitor locations for comparison to monitored concentrations for model evaluation purposes.

Generally, the receptor network should cover the modeling domain. However, for the purpose of the modeling discussed in this TAD, receptors may not have to be placed throughout the domain, but only near the roadways; i.e., receptors may not have to be placed out to one or five kilometers from the roadways for road comparison purposes in an effort to identify or aid in the identification of candidate near-road monitoring sites. Refer to Section 7.6 of the PM hot-spot guidance for additional guidance on placing receptors near roadways, and to 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 TAD.

C.5 PVMRM and OLM

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, b; 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 modeling of mobile NO_x emissions, it is expected that the tier 3 approach would be implemented to account for the chemical transformations from NO_x to NO_2, and that NO_x will not be treated as an inert pollutant.

For the tier 3 approach, the March 1, 2011, memorandum gave clarification about the use of PVMRM and OLM. The clarifications are summarized in Section 10.2.1 of this TAD, but again the user is strongly encouraged to read the March 1, 2011, memorandum in full, and to consult the AERMOD User's Guide (U.S. Environmental Protection Agency, 2004a) and addendum (U.S. Environmental Protection Agency, 2011b) for details about the implementation of PVMRM and OLM in AERMOD.

C.5.1 Source Characterization

As described in the Appendix J of the PM hot-spot guidance (U.S. Environmental Protection Agency, 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). Refer to that appendix for more information about these source characterizations and their use in near-roadway modeling. For general information about these source types, refer to the AERMOD User's Guide and addendum (U.S. Environmental Protection Agency, 2004a, 2011b). As noted in Section 10.2.1 of this TAD, if modeling roadway segments with PVMRM, it is recommended that the user represent the roadway as a series of volume sources.

C.5.2 Inclusion of Nearby Sources

The inclusion of stationary sources or other nearby mobile sources in modeling of NO_x mobile emissions should be considered carefully. Such inclusion 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 or other major roadways may be located within a few kilometers of a targeted major roadway. Inclusion of other sources in mobile source modeling may heavily influence the characterization of the near-road environment and change the spatial distribution and magnitude of modeled concentrations; the inclusion of these other sources is discussed in this section.

If road segments are modeled without any consideration of nearby sources, the modeled peak concentrations of NO_x 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 other sources are included in the modeling results, and the sources produce sufficiently large enough concentrations, the peak concentrations' locations may shift toward those sources away from the roads of interest, thus affecting the decision on where to place near-road monitors. Also, those sources could influence the near-road environment; the measurements from any monitor placed near the road may be influenced by those sources.

Another implication of inclusion or non-inclusion of other sources in the modeling is in the use of PVMRM or OLM in modeling NO-to-NO_2 conversion in AERMOD. If the other sources are included in the same model run with the road segment sources of interest, there are more sources competing for the input ozone to convert NO to NO_2. The additional sources can lead to a different final result than if they were not included in the model run.

A recommendation is to model the road segment or segments of interest along with any nearby sources that may influence the near-road environment around the road segment(s) of interest, and to model with the OLM option with OLMGROUP ALL selected. 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 other sources. Note that the grouping of sources for SRCGROUP is independent of the grouping for OLM; for more information, see Section 2.5.5 of the AERMOD User's Guide Addendum (U.S. Environmental Protection Agency, 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 C.8 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.5.3 Urban/Rural Classification

For any dispersion modeling exercise, the urban or rural classification of a source is important in determining the boundary layer characteristics that affect the model's prediction of downwind concentrations. **Figure C-2** gives examples of maximum 1-hour concentration profiles within 100 meters for a road segment represented by an area source (Figure C-2a) and a volume source (Figure C-2b) based on urban versus rural designation. The urban population used for the examples is 100,000. For both cases, the urban concentrations are much lower than the rural concentrations. These profiles show that the urban or rural designation of a source can be quite important.

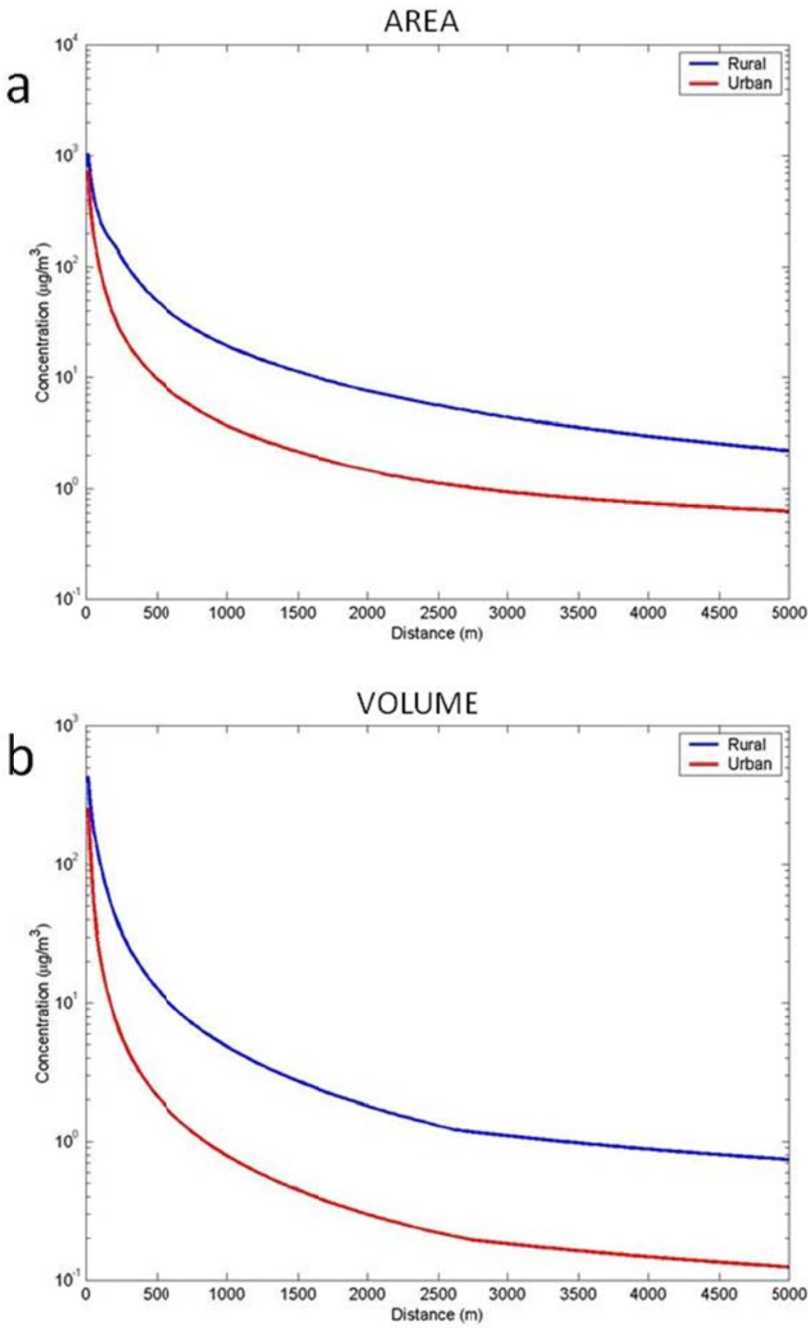

Figure C-2. Urban (red) and rural (blue) concentration profiles for (a) area source release, and (b) volume source release.

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. Environmental Protection Agency, 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. Environmental Protection Agency, 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. In Section 5.1, the AIG cautions users against using the land use scheme on a source-by-source basis, and instead 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.

Another consideration that may need attention is when the user is 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. AERMOD calculates boundary layer heights that are due to thermal and mechanical turbulence forcing separately. In urban areas, there is constant thermal forcing at night, whereas in rural areas, nocturnal mixing is purely mechanical in nature. The use of the urban option may not be appropriate for buoyant 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 whether 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 as follows:

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

where z_{iuc} is the height of the nocturnal boundary layer due to convection effects alone, P is population, and 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 type, the plume may extend above the urban boundary layer and may be best characterized as a rural source, even if it is near an urban complex. Exclusion of these elevated sources from application of the urban option would need to be justified for each case in consultation with the appropriate reviewing authority.

AERMOD requires the input of urban population when using 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. Environmental Protection Agency, 2004a, 2011b). If multiple urban areas are entered, AERMOD requires that each urban source be associated with a particular urban area; otherwise, AERMOD model calculations will abort. Urban populations can be determined by using a method described in Section 5.2 of the AIG (U.S. Environmental Protection Agency, 2009).

C.6 Meteorological Inputs

This section 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 C.6.2.2, the use of a new tool, AERMINUTE (U.S. Environmental Protection Agency, 2011f), is introduced. AERMINUTE is an AERMET pre-processor that calculates hourly averaged winds from ASOS (Automated Surface Observing System) 1-minute winds.

C.6.1 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 the following:

- proximity of the meteorological monitoring site to the area under consideration,
- complexity of terrain,

- exposure of the meteorological site, and
- period of time over which data are collected.

Sources of meteorological data are NWS stations; site-specific or onsite data; and other sources, such as universities, Federal Aviation Administration (FAA), and military stations. 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 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 geographically close, if there is complex terrain between them, 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 offsite 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. Environmental Protection Agency, 2004c, 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. Environmental Protection Agency, 2008b)]. 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. Environmental Protection Agency, 2009). EPA has developed a tool, AERSURFACE (U.S. Environmental Protection Agency, 2008b), to aid in determining surface characteristics. The current version of AERSURFACE uses 1992 National Land Cover Data. Note that the use of AERSURFACE is not a regulatory requirement; however, the methodology outlined in Section 3.1.2 of the AIG should be followed unless an alternative method can be justified.

C.6.2 Meteorological Data

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 five years of NWS meteorological data or at least one year of site-specific data should be used (Section 8.3.1.2, Appendix W); the data used should adequately represent 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 uses three years of monitoring data, this does not preempt the use of five years of NWS data or at least one year of site-specific data in the modeling. The five-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 three-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. Environmental Protection Agency, 2010d)]. See the memorandum for more details on the use of five years of NWS data or at least one year of site-specific data and applicability to the NAAQS.

C.6.2.1 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 C.6.1, when using data from an NWS station alone or 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. Environmental Protection Agency, 2011d) and/or the appropriate EPA Regional Modeling Contact.

C.6.2.2 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 1-hour standard, these light wind conditions may be the controlling meteorological circumstances 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 when calculating 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. Environmental Protection Agency, 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 obtained from the archive of meteorological data. This approach 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; for more information about the processing of NWS data in AERMET and AERMINUTE, see the AERMET (U.S. Environmental Protection Agency, 2004c, 2011d) and AERMINUTE User's Guides (U.S. Environmental Protection Agency, 2011f).

C.6.2.3 Site-Specific Data

The use of site-specific meteorological data is the best way to achieve spatial representativeness in the modeling. 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. Environmental Protection Agency, 2004c, 2011d), and Meteorological Monitoring Guidance for Regulatory Modeling Applications (U.S. Environmental Protection Agency, 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, in order to avoid double-counting the effects of enhanced turbulence due to the urban heat island, the guide recommends that site-specific turbulence measurements should not be used when applying AERMOD's urban option.

C.6.2.4 Upper-Air Data

AERMET requires full upper air soundings to calculate the convective mixing height. For AERMOD applications in the United States, 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 as free downloads from the Radiosonde Database Access website. Users should choose all levels or mandatory and significant pressure levels[21] 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.7 Background Concentrations

Background concentrations are often included in a modeling analysis to account for natural sources or sources not explicitly modeled. Given the nature of the modeling described in this TAD, 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

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[21] 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.

of Appendix W gives more detailed general guidance regarding background concentrations. The March 1, 2011, memorandum also gives guidance specific to NO_2 and is summarized here:

- The June 28, 2010, memorandum initially discussed a “first tier” option of adding the maximum 1-hour background NO_2 concentration from a representative monitor to the modeled design value. 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.
- 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 three years of monitor data.
- Also discussed in the March 1, 2011, memorandum is the use of temporally varying background concentrations; i.e., using the 98th 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 TAD, 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 to inform monitor siting or to identify peaks, then background concentrations, as well as emissions from stationary sources, should be included (see Section C.6) in order to fully characterize the air quality situation).

C.8 Running AERMOD and Implications for Design Value Calculations

Recent enhancements to AERMOD include options that aid in calculating 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., 8th 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). For more details about the enhancements, see the AERMOD User's guide Addendum (U.S. Environmental Protection Agency, 2011c).

C.9 References

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