



Policy Assessment for the Review of the Primary National Ambient Air Quality Standards for Nitrogen Dioxide

External Review Draft

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**Policy Assessment for the Review of the
Primary National Ambient Air Quality Standards
for Nitrogen Dioxide**

External Review Draft

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
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DISCLAIMER

This draft Policy Assessment has been prepared by staff in the U.S. Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards. Any findings and conclusions are those of the authors and do not necessarily reflect the views of the EPA. This draft document is being circulated to facilitate discussion with the Clean Air Scientific Advisory Committee CASAC and for public comment to inform the EPA's review of the Primary National Ambient Air Quality Standards for Nitrogen Dioxide. This information is distributed for the purposes of pre-dissemination peer review under applicable information quality guidelines. It does not represent, and should not be construed to represent, any Agency determination or policy. Questions or comments related to this draft document should be addressed to Dr. Jennifer Nichols, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, C539-06, Research Triangle Park, North Carolina 27711 (email: nichols.jennifer@epa.gov) and Dr. Stephen Graham, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, C539-06, Research Triangle Park, North Carolina 27711 (email: graham.stephen@epa.gov).

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LIST OF ACRONYMS AND ABBREVIATIONS

AADT	Annual Average Daily Traffic
Act	Clean Air Act
AQI	Air Quality Index
AQS	Air Quality System
AR	Airway responsiveness
ATS	American Thoracic Society
ATSDR	Agency for Toxic Substances and Disease Registry
BC	Black carbon
CAA	Clean Air Act
CASAC	Clean Air Scientific Advisory Committee
CBSA	Core-based statistical area
CDC	Centers for Disease Control
CFR	Code of Federal Regulations
CHS	Children's Health Study
CI	Confidence interval
CO	Carbon monoxide
COPD	Chronic obstructive pulmonary disease
DV	Design value
EC	Elemental carbon
ED	Emergency department
EGU	Electric power generating unit
eNO	Exhaled nitric oxide
EPA	Environmental Protection Agency
FEM	Federal Equivalent Method
FEV ₁	Forced Expiratory Volume for 1 second
FR	Federal Register
FRM	Federal Reference Method
HA	Hospital Admission
HNO ₃	Nitric acid
HNO ₄	Peroxynitric acid
HONO	Nitrous acid
HPMS	Highway Performance Monitoring System
IDW	Inverse distance weighted
IgE	Immunoglobulin E

IRP	Integrated Review Plan
ISA	Integrated Science Assessment
LUR	Land use regression
m	meter
Max	maximum
MSA	Metropolitan Statistical Area
NAAQS	National ambient air quality standards
NAB	North American background
NCEA	National Center for Environmental Assessment
NEI	National Emissions Inventory
NO	Nitric oxide
NO ₂	Nitrogen Dioxide
NO ₃ ⁻	Nitrate radicals
NO _x	Nitrogen Oxides
O ₃	Ozone
OAR	Office of Air and Radiation
OAQPS	Office of Air Quality Planning and Standards
OC	Organic carbon
OMB	Office of Management and Budget
ORD	Office of Research and Development
PA	Policy Assessment
PD	Provocative dose
PAMS	Photochemical Assessment Monitoring Stations
PANs	Peroxyacetyl nitrates
ppb	Parts per billion
PM	Particulate matter
PM _{2.5}	Particles generally less than or equal to 2.5 μm in diameter
PM ₁₀	Particles generally less than or equal to 10 micrometers (μm) in diameter
REA	Risk and Exposure Assessment
RTP	Research Triangle Park
SLAMS	State and Local Monitoring Stations
SO ₂	Sulfur Dioxide
sRAW	Specific airways resistance
Th2	Type 2 T helper cell
TBD	To be determined

U.S.
VOCs

United States
Volatile Organic Compounds

EXECUTIVE SUMMARY

This draft Policy Assessment (PA) has been prepared by staff in the Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards (OAQPS) as part of the Agency's ongoing review of the primary (health-based) national ambient air quality standards (NAAQS) for nitrogen dioxide (NO₂). It presents analyses and preliminary staff conclusions regarding the policy implications of the key scientific and technical information that informs this review. When final, the PA is intended to "bridge the gap" between the relevant scientific evidence and technical information and the judgments required of the EPA Administrator in determining whether to retain or revise the current standards. Development of the PA is also intended to facilitate advice and recommendations on the standards to the Administrator from an independent scientific review committee, the Clean Air Scientific Advisory Committee (CASAC), as provided for in the Clean Air Act (CAA).

Staff's preliminary conclusions in this draft PA are informed by consideration of the scientific evidence summarized and assessed in the Integrated Science Assessment for Oxides of Nitrogen – Health Criteria (ISA) and updated analyses comparing ambient NO₂ concentrations to health-based benchmarks, included herein. Emphasis is given to considering the extent to which the evidence newly available since the last review alters conclusions drawn in the last review with regard to health effects related to ambient exposure to NO₂, the exposure concentrations at which they occur, and populations that may be at increased risk for effects.

The overarching questions in this review, as in all NAAQS reviews, focus on the support provided by the available scientific and technical information for the adequacy of the current standards, and on the extent to which that scientific and technical information supports consideration of potential alternative standards. The analyses presented in this draft PA to address such questions lead to the preliminary staff conclusion that it is appropriate to consider retaining the current primary NO₂ standards, without revision, in this review. Accordingly, staff have not identified potential alternative standards for consideration in this review. Advice from CASAC and public comments, based on review of this draft PA, will inform staff's consideration of the scientific and technical information and staff's conclusions in the final PA.

History of Primary NO₂ NAAQS

The NAAQS for NO₂ was initially promulgated in 1971. At that time, the Administrator set a standard with an annual averaging time and a level of 53 ppb to protect against respiratory disease in children that had been reported in the available studies. In subsequent reviews of the

1 primary NO₂ NAAQS, completed in 1985 and 1996, the annual standard was retained without
2 revision.

3 The last review of the primary NO₂ NAAQS was completed in 2010. In that review, the
4 EPA supplemented the existing primary annual NO₂ standard by establishing a new 1-hour
5 standard. After considering an integrative synthesis of the body of evidence on human health
6 effects related to NO₂ exposures and the available information from quantitative assessments of
7 NO₂ exposures and health risks, the Administrator determined that the annual standard alone was
8 not sufficient to protect the public health from the array of effects that could occur following
9 short-term exposures to ambient NO₂. To increase protection against such exposures, the 1-hour
10 NO₂ standard was set with a level of 100 ppb, based on the 3-year average of the 98th percentile
11 of the annual distribution of daily maximum 1-hour concentrations. The EPA also retained the
12 existing annual NO₂ standard with its level of 53 ppb.

13 The Administrator particularly noted the potential for adverse health effects to occur
14 following exposures to elevated NO₂ concentrations that can occur around major roads.
15 Accordingly, the revisions to the primary NO₂ NAAQS in 2010 were accompanied by revisions
16 to the ambient air monitoring and reporting requirements. States were required to locate monitors
17 within 50 meters of heavily trafficked roadways in large urban areas and in other locations where
18 maximum NO₂ concentrations were expected occur. Near-road NO₂ monitors were initially
19 required to become operational between January 1, 2014 and January 1, 2017. Currently, there
20 are approximately 65 near-road monitors in operation in urban areas across the U.S., with
21 approximately one to two years of data available from most of these monitors.

22 Scope and Approach in the Current Review

23 Consistent with the review completed in 2010, this review focuses on health effects
24 associated with gaseous oxides of nitrogen and the protection afforded by the current primary
25 NO₂ standards. The gaseous oxides of nitrogen include NO₂ and nitric oxide (NO), together
26 referred to as NO_x, and their gaseous reaction products. Health effects associated with particulate
27 species (e.g., nitrates) are addressed in the review of the NAAQS for particulate matter (PM).
28 Additionally, the EPA is separately reviewing the welfare effects associated with oxides of
29 nitrogen and the protection provided by the secondary NO₂ standard in conjunction with a review
30 of the secondary SO₂ standard.

31 Staff's approach to reviewing the primary NO₂ standards in the current review is focused
32 on addressing a series of key policy-relevant questions. Consideration of these questions in the
33 final PA is intended to inform the Administrator's decisions as to whether, and if so, how, to
34 revise the current NO₂ standards. The Administrator's ultimate judgments on the primary

1 standards will most appropriately reflect an interpretation of the available scientific evidence and
2 information that neither overstates nor understates the strengths and limitations of that evidence
3 and information. This approach is consistent with the requirements of sections 108 and 109 of
4 the CAA, as well as with how the EPA and the courts have historically interpreted the CAA.

5 Characterization of NO_x Emissions Sources and Trends in Ambient NO₂ Concentrations

6 As was the case in previous reviews, the major sources of NO_x emissions include
7 highway vehicles, off-highway vehicles, and fuel combustion. Estimates indicate a 54%
8 reduction in NO_x emissions across all source categories since 1980, and emissions are expected
9 to decrease further as existing regulatory programs continue to be implemented. Reductions in
10 NO_x emissions over past decades have occurred largely as the result of substantial decreases in
11 emissions from mobile sources and from fuel combustion. Based on recent estimates, mobile
12 sources remain the largest source of NO_x emissions in the U.S., contributing approximately 40%
13 of the total.

14 Consistent with reductions in NO_x emissions, ambient NO₂ concentrations have declined
15 substantially since 1980 (i.e., by about 60% and 75% for annual and hourly concentrations,
16 respectively). Based on recent data, all NO₂ monitors measure ambient concentrations that meet
17 the existing NAAQS. Analyses of historical data indicate that monitoring sites meeting the
18 current 1-hour NO₂ standard have corresponding annual average NO₂ concentrations of about 35
19 ppb or below. Based on ongoing reductions in NO_x emissions, we anticipate that ambient NO₂
20 concentrations will continue to decline across most of the U.S.

21 Because mobile sources remain the largest contributors to NO_x emissions in the U.S., an
22 important part of the current review is the evaluation of monitoring data from recently deployed
23 near-road NO₂ monitors. Depending on local conditions, ambient NO₂ concentrations can be
24 higher near roadways than at sites in the same area but farther removed from the road (and from
25 other sources of NO_x emissions). Analyses included in this draft PA indicate that NO₂
26 concentrations are generally highest at sampling sites nearest to the road and decrease as distance
27 from the road increases. This pattern of decreasing concentrations with increasing distance from
28 the road has persisted over recent decades, though the absolute difference (in terms of ppb)
29 between NO₂ concentrations close to roads and those farther from roads has declined over time.

30 Consistent with this analysis of historical air quality information, the limited amount of
31 data available from recently deployed near-road monitors indicates that daily maximum 1-hour
32 NO₂ concentrations are generally higher at near-road monitors than at the non-near-road
33 monitors in the same area. This is the case in most of the CBSAs with near-road monitors,
34 though these relationships vary across CBSAs and over the years with available data, particularly

1 at the upper ends of the distributions of NO₂ concentrations (i.e., 98th, 99th percentiles). As more
2 years of data from near-road monitors become available, we expect to gain an improved
3 understanding of these relationships.

4 Health Effects Evidence and Review of the Primary NO₂ NAAQS

5 In this draft PA, we evaluate what the health effects evidence can tell us with regard to
6 the adequacy of the public health protection provided by the current NO₂ NAAQS. In doing so,
7 we consider the strength of the evidence for various effects and the extent to which that evidence
8 indicates adverse effects attributable to NO₂ exposures concentrations lower than previously
9 identified or below the current standards.

10 As in the last review, the strongest evidence continues to come from studies examining
11 respiratory effects following short-term NO₂ exposures (e.g., minutes up to one month). In
12 particular, the ISA concludes that “[a] causal relationship exists between short-term NO₂
13 exposure and respiratory effects based on evidence for asthma exacerbation.” The strongest
14 support for this conclusion comes from controlled human exposure studies examining the
15 potential for NO₂-induced increases in airway responsiveness (AR) (i.e., a hallmark of asthma) in
16 individuals with asthma. These studies, most of which were available in the last review, together
17 with an updated meta-analysis of their individual-level data, indicate increases in AR in some
18 people with asthma following resting exposures to NO₂ concentrations from 100 to 530 ppb.
19 Important limitations in this evidence include the lack of a dose-response relationship between
20 NO₂ and AR and uncertainty in the adversity of the reported increases in AR. In addition, within
21 the range of 100 to 530 ppb, the evidence for NO₂-induced increases in AR becomes less
22 consistent across studies that examined the lower exposure concentrations, particularly 100 ppb.

23 Evidence supporting the ISA conclusion also comes from epidemiologic studies reporting
24 associations between short-term NO₂ exposures and an array of respiratory outcomes related to
25 asthma exacerbation. Such studies consistently report associations with several asthma-related
26 outcomes, including asthma-related hospital admissions and emergency department visits in
27 children and adults. The epidemiologic evidence that is newly available in the current review is
28 consistent with evidence from the last review and does not fundamentally alter our understanding
29 of respiratory effects related to short-term NO₂ exposures. While our fundamental understanding
30 of such effects has not changed, recent epidemiologic studies do reduce some uncertainty from
31 the last review regarding the extent to which effects may be independently related to short-term
32 NO₂ exposures. This reduced uncertainty results from recent studies reporting health effect
33 associations with short-term NO₂ exposures in co-pollutant models and from recent studies using
34 improved exposure metrics.

1 In addition to the effects of short-term exposures, the ISA concludes that there is “likely
2 to be a causal relationship” between long-term NO₂ exposures and respiratory effects, based on
3 the evidence for asthma development in children. The strongest evidence supporting this
4 conclusion comes from recent epidemiologic studies demonstrating associations between long-
5 term NO₂ exposures and asthma incidence. Important uncertainties in these studies result from
6 the methods used to assign NO₂ exposures, the high correlations between NO₂ and other traffic-
7 related pollutants, and the lack of information regarding the extent to which reported effects are
8 independently associated with NO₂ rather than the overall mixture of traffic-related pollutants.
9 Additional support for the ISA conclusion comes from experimental studies supporting the
10 biological plausibility of a potential mode of action by which NO₂ exposures could cause asthma
11 development. These include studies that support a potential role for repeated short-term NO₂
12 exposures in the development of asthma.

13 While the overall evidence for NO₂-related respiratory effects supports a “causal”
14 relationship with short-term NO₂ exposures and a “likely to be causal” relationship with long-
15 term exposures, these studies do not provide evidence that calls into question the adequacy of the
16 public health protection provided by current primary NO₂ NAAQS. In particular, compared to
17 the last review when the 1-hour standard was set, evidence from controlled human exposure
18 studies has not altered our understanding of the NO₂ exposure concentrations that cause
19 increased AR. In addition, there remains uncertainty in this evidence due to the lack of a dose-
20 response relationship and uncertainty in the adversity of the response. These uncertainties are
21 increasingly important for the lower NO₂ exposure concentrations evaluated (i.e., at and near 100
22 ppb), where the evidence across studies is less consistent. In addition, while epidemiologic
23 studies report associations with asthma-related outcomes, these associations are generally in
24 locations that would likely have violated one or both of the existing standards over at least part
25 of the study periods. In the absence of studies reporting associations in locations meeting the
26 current NO₂ standards, there is greater uncertainty regarding the extent to which serious asthma
27 exacerbations (short-term exposures) or the development of asthma (long-term exposures) are
28 caused by the NO₂ exposures that occur with air quality meeting those standards.

29 Comparisons of Ambient NO₂ Concentrations with Health-Based Benchmarks

30 Beyond our consideration of the scientific evidence, we also consider the extent to which
31 quantitative analyses can inform conclusions on the adequacy of the public health protection
32 provided by the current primary NO₂ standards. In particular, we have conducted updated
33 analyses comparing NO₂ air quality with health-based benchmarks from 100 to 300 ppb to
34 estimate the potential for exposures of public health concern that could be allowed by the current
35 standards. Benchmarks are based on information from controlled human exposure studies

1 indicating NO₂-induced increases in AR and on the meta-analysis of individual-level data from
2 these studies.

3 Overall, these analyses indicate little potential for exposures to ambient NO₂
4 concentrations that would be of public health concern in locations meeting the current 1-hour
5 standard. In particular, based on recent ambient measurements, all of which meet the current
6 standards, analyses indicate almost no potential for 1-hour exposures to NO₂ concentrations at or
7 above any of the benchmarks examined, even the lowest benchmark (i.e., 100 ppb). When air
8 quality is adjusted upwards to simulate just meeting the current 1-hour NO₂ standard, there is
9 also virtually no potential for exposures to the NO₂ concentrations that have been shown most
10 consistently to increase AR in people with asthma (i.e., greater than 200 ppb), even under worst-
11 case conditions across a variety of study areas with among the highest NO_x emissions in the U.S.
12 Such NO₂ concentrations are not estimated to occur, even at monitoring sites adjacent to some of
13 the most heavily trafficked roadways in the country. In addition, the current standard limits NO₂
14 exposures that have the potential to exacerbate asthma symptoms, but for which the evidence is
15 less consistent (i.e., 100 ppb). Given the results of these analyses, and the uncertainties inherent
16 in their interpretation, there is little potential for exposures to ambient NO₂ concentrations that
17 would be of public health concern in locations meeting the current 1-hour standard.

18 Preliminary Conclusions

19 Staff has reached the preliminary conclusion that the available scientific evidence, in
20 combination with the available information from quantitative analyses, supports the adequacy of
21 the public health protection provided by the current primary NO₂. Staff further reaches the
22 preliminary conclusion that it is appropriate to consider retaining the current standards, without
23 revision, in this review.

24 Staff additionally notes that the final decision on the adequacy of the current standards is
25 largely a public health policy judgment to be made by the Administrator, drawing upon the
26 scientific information as well as judgments about how to consider the range and magnitude of
27 uncertainties that are inherent in the scientific evidence and technical analyses. In this context,
28 we recognize that the uncertainties and limitations associated with the many aspects of the
29 estimated relationships between NO₂ exposures and adverse respiratory effects are amplified
30 with consideration of increasingly lower NO₂ concentrations. In staff's view, there is appreciable
31 uncertainty in the extent to which reductions in asthma exacerbations or asthma development
32 would result from alternative NO₂ standards with levels lower than those of the current
33 standards. Thus, the basis for any consideration of alternative lower standard levels would reflect
34 different public health policy judgments as to the appropriate approach for weighing
35 uncertainties in the evidence.

1 Based on all of the above considerations, as noted above, we reach the preliminary
2 conclusion that consideration should be given to retaining the current standard, without revision,
3 in this review. In light of this conclusion, we have not identified any potential alternative
4 standards for consideration. Our final conclusions will additionally be informed by CASAC
5 advice and public input on this draft PA.

1 INTRODUCTION

1.1 PURPOSE

The U.S. Environmental Protection Agency (EPA) is conducting a review of the primary national ambient air quality standards (NAAQS) for Nitrogen Dioxide (NO₂). An overview of the approach to reviewing the primary NO₂ NAAQS is presented in the *Integrated Review Plan for the Primary NAAQS for Nitrogen Dioxide* (IRP, U.S. EPA, 2014). The IRP discusses the schedule for the review; the approaches to be taken in developing key scientific, technical, and policy documents; and the key policy-relevant issues that will frame EPA's consideration of whether the current NAAQS for NO₂ should be retained or revised.

As part of the review process, this draft Policy Assessment (PA) has been prepared by staff in the EPA's Office of Air Quality Planning and Standards (OAQPS). When final, the PA is intended to help bridge the gap between the relevant scientific information and assessments and the judgments required of the EPA Administrator in determining whether, and if so how, it is appropriate to revise the primary (health-based) NAAQS for NO₂. CASAC advice and public input on this draft PA will be considered in developing a final PA. The final PA will present the EPA's staff conclusions regarding the policy options that could be supported by the currently available scientific evidence and technical information for consideration by the Administrator. In so doing, we¹ recognize that the selection of a specific approach to reaching final decisions on the primary NO₂ standards will reflect the judgments of the Administrator.

The development of the PA is also intended to facilitate advice to the Agency and recommendations to the Administrator from an independent scientific review committee, the Clean Air Scientific Advisory Committee (CASAC), as provided for in the Clean Air Act. As discussed below in section 1.2.1, the CASAC is to advise not only on the Agency's assessment of the relevant scientific information, but also on the adequacy of the existing standards, and to make recommendations as to any revisions of the standards that may be appropriate. The EPA facilitates the CASAC's advice and recommendations, as well as public input and comment, by requesting CASAC review and public comment on one or more drafts of the PA.²

The decision whether to prepare one or more drafts of the PA is influenced by preliminary staff conclusions and associated CASAC advice and public comment, among other

¹ In this first draft PA, the terms "we" or "our" refer to staff in the EPA's Office of Air Quality Planning and Standards (OAQPS).

² Beyond informing the EPA Administrator and facilitating the advice and recommendations of CASAC and the public, the PA is also intended to be a useful reference to all parties interested in the review of the primary NO₂ NAAQS. It is intended to serve as a single source of the most policy-relevant information that informs the Agency's review of the primary NO₂ NAAQS, and it is written to be understandable to a broad audience.

1 factors. Typically, a second draft PA is prepared in cases where the available information calls
2 into question the adequacy of the current standard(s) and where staff analyses of potential
3 alternative standards are developed. In such cases, a second draft PA includes preliminary staff
4 conclusions regarding potential alternative standards and undergoes review the CASAC and
5 public comment prior to preparation of the final PA. When analyses of potential alternative
6 standards are not undertaken, a second draft PA may not be warranted.

7 In this draft PA, we take into account the available scientific and technical information as
8 assessed in the *Integrated Science Assessment for Oxides of Nitrogen – Health Criteria* (ISA,
9 U.S. EPA, 2016). In so doing, we focus on information that is most relevant to evaluating the
10 basic elements of NAAQS: indicator³, averaging time, form⁴, and level. These elements, which
11 together serve to define each standard, must be considered collectively in evaluating the health
12 protection afforded by the NO₂ standards. This draft PA also builds upon staff’s preliminary
13 conclusions regarding the potential support for updated quantitative analyses of NO₂ exposures
14 and/or health risks, as presented in the document titled *Review of the Primary National Ambient*
15 *Air Quality Standards for Nitrogen Dioxide: Risk and Exposure Assessment Planning Document*
16 (REA Planning Document, U.S. EPA, 2015), and advice from the CASAC on those preliminary
17 conclusions (Diez Roux and Frey, 2015).

18 The remainder of this chapter summarizes the NAAQS legislative requirements and
19 provides an overview of the history of the NO₂ NAAQS (Section 1.2), summarizes the approach
20 used to reaching decisions in the last review of the primary NO₂ standard (Section 1.4), and
21 provides an overview of our planned approach to reviewing the primary NO₂ standards in the
22 current review (Section 1.3). Following Chapter 1, this first draft PA presents an overview of the
23 NO₂ monitoring network and of the available information on ambient NO₂ concentrations and
24 trends (Chapter 2); staff’s consideration of the available evidence for NO₂-attributable health
25 effects and the NO₂ concentrations associated with those effects (Chapter 3); staff’s
26 consideration of quantitative analyses (Chapter 4); and staff’s preliminary conclusions regarding
27 the adequacy of the existing primary NO₂ standards (Chapter 5).

³The “indicator” of a standard defines the chemical species or mixture that is to be measured in determining whether an area attains the standard.

⁴The “form” of a standard defines the air quality statistic that is to be compared to the level of the standard in determining whether an area attains the standard.

1 **1.2 BACKGROUND**

2 **1.2.1 Legislative Requirements**

3 Two sections of the Clean Air Act (CAA) govern the establishment and revision of the NAAQS.
4 Section 108 (42 U.S.C. 7408) directs the Administrator to identify and list certain “air
5 pollutants” and then to issue air quality criteria for those pollutants that are listed. The
6 Administrator is to list those air pollutants that in her “judgment, cause or contribute to air
7 pollution which may reasonably be anticipated to endanger public health or welfare;” “the
8 presence of which in the ambient air results from numerous or diverse mobile or stationary
9 sources;” and “for which . . . [the Administrator] plans to issue air quality criteria. . . .” Air
10 quality criteria are intended to “accurately reflect the latest scientific knowledge useful in
11 indicating the kind and extent of all identifiable effects on public health or welfare which may be
12 expected from the presence of [a] pollutant in the ambient air” (42 U.S.C. 7408). Section
13 109 (42 U.S.C. 7409) directs the Administrator to propose and promulgate “primary” and
14 “secondary” NAAQS for pollutants for which air quality criteria are issued. Section 109(b)(1)
15 defines a primary standard as one “the attainment and maintenance of which in the judgment of
16 the Administrator, based on such criteria and allowing an adequate margin of safety, are requisite
17 to protect the public health.”⁵ A secondary standard, as defined in section 109(b)(2), must
18 “specify a level of air quality the attainment and maintenance of which, in the judgment of the
19 Administrator, based on such criteria, is requisite to protect the public welfare from any known
20 or anticipated adverse effects associated with the presence of such air pollutant in the ambient
21 air.”⁶ The secondary NO₂ standard will be reviewed separately in conjunction with the review of
22 the secondary sulfur dioxide (SO₂) standard.

23 The requirement that primary standards provide an adequate margin of safety was
24 intended to address uncertainties associated with inconclusive scientific and technical
25 information available at the time of standard setting. It was also intended to provide a reasonable
26 degree of protection against hazards that research has not yet identified. *See, e.g., State of*
27 *Mississippi v. EPA*, 744 F. 3d 1334, 1353 (D.C. Cir. 2012); *Lead Industries Association v. EPA*,

⁵The legislative history of section 109 indicates that a primary standard is to be set at “the maximum permissible ambient air level . . . which will protect the health of any [sensitive] group of the population,” and that for this purpose “reference should be made to a representative sample of persons comprising the sensitive group rather than to a single person in such a group” [S. Rep. No. 91-1196, 91st Cong., 2d Sess. 10 (1970)].

⁶Welfare effects as defined in section 302(h) (42 U.S.C. 7602(h)) include, but are not limited to, “effects on soils, water, crops, vegetation, man-made materials, animals, wildlife, weather, visibility, and climate, damage to and deterioration of property, and hazards to transportation, as well as effects on economic values and on personal comfort and well-being.”

1 647 F.2d 1130, 1154 (D.C. Cir 1980), *cert. denied*, 449 U.S. 1042 (1980); *American Petroleum*
2 *Institute v. Costle*, 665 F.2d 1176, 1186 (D.C. Cir. 1981), *cert. denied*, 455 U.S. 1034 (1982).
3 Both types of uncertainties are components of the risk associated with pollution at levels below
4 those at which human health effects can be said to occur with reasonable scientific certainty.
5 Thus, in selecting primary standards that provide an adequate margin of safety, the Administrator
6 is seeking not only to prevent pollution levels that have been demonstrated to be harmful but also
7 to prevent lower pollutant levels that may pose an unacceptable risk of harm, even if the risk is
8 not precisely identified as to nature or degree. The CAA does not require the Administrator to
9 establish a primary NAAQS at a zero-risk level or at background concentration levels, *see Lead*
10 *Industries Association v. EPA*, 647 F.2d at 1156 n. 51, but rather at a level that reduces risk
11 sufficiently so as to protect public health with an adequate margin of safety.

12 In addressing the requirement for an adequate margin of safety, the EPA considers such
13 factors as the nature and severity of the health effects involved, the size of the population(s) at
14 risk, and the kind and degree of the uncertainties that must be addressed. The selection of any
15 particular approach to providing an adequate margin of safety is a policy choice left specifically
16 to the Administrator’s judgment. *Lead Industries Association v. EPA*, 647 F.2d at 1161-62; *State*
17 *of Mississippi*, 744 F. 3d at 1353.

18 In setting primary and secondary standards that are “requisite” to protect public health
19 and welfare, respectively, as provided in section 109(b), the EPA’s task is to establish standards
20 that are neither more nor less stringent than necessary for these purposes. In so doing, the EPA
21 may not consider the costs of implementing the standards. See generally, *Whitman v. America*
22 *Trucking Associations*, 531 U.S. 457, 465-472, 475-76 (2001). Likewise, “[a]ttainability and
23 technological feasibility are not relevant considerations in the promulgation of national ambient
24 air quality standards.” *American Petroleum Institute v. Costle*, 665 F. 2d at 1185.

25 Section 109(d)(1) requires that “not later than December 31, 1980, and at 5-year intervals
26 thereafter, the Administrator shall complete a thorough review of the criteria published under
27 section 108 and the national ambient air quality standards . . . and shall make such revisions in
28 such criteria and standards and promulgate such new standards as may be appropriate”
29 Section 109(d)(2) requires that an independent scientific review committee “shall complete a
30 review of the criteria . . . and the national primary and secondary ambient air quality standards . .
31 . and shall recommend to the Administrator any new . . . standards and revisions of existing
32 criteria and standards as may be appropriate” This independent review function is now

1 performed by the Clean Air Scientific Advisory Committee (CASAC) of EPA’s Science
 2 Advisory Board.⁷

3 **1.2.2 Previous NO₂ NAAQS Reviews**

4 In 1971, the EPA added nitrogen oxides to the list of criteria pollutants under section
 5 108(a)(1) of the CAA and issued the initial air quality criteria (36 FR 1515, January 30, 1971;
 6 U.S. EPA, 1971). Based on these air quality criteria, the EPA promulgated NAAQS for nitrogen
 7 oxides using NO₂ as the indicator (36 FR 8186, April 30, 1971). Both primary and secondary
 8 standards were set at 100 micrograms per cubic meter (µg/m³) (equal to 53 parts per billion
 9 (ppb)), annual average. Since then, the Agency has completed multiple reviews of the air quality
 10 criteria and primary NO₂ standards, as summarized in Table 1-1.

11 **Table 1-1. Primary national ambient air quality standards for oxides of nitrogen since**
 12 **1971.**

Final Rule/Decision	Indicator	Averaging Time	Level	Form
1971 36 FR 8186 April 30, 1971	NO ₂	Annual	53 ppb ⁸	Annual arithmetic average
1985 50 FR 25532 June 19, 1985	Primary NO ₂ standards retained, without revision.			
1996 61 FR 52852 October 8, 1996	Primary NO ₂ standards retained, without revision.			
2010 75 FR 6474 February 9, 2010	NO ₂	1-hour	100 ppb	3-year average of the 98 th percentile of the annual distribution of daily maximum 1-hour concentrations
Primary annual NO ₂ standard retained, without revision.				

13

⁷ Lists of CASAC members and of members of the CASAC NO₂ Review Panel are available at:
<http://yosemite.epa.gov/sab/sabpeople.nsf/WebExternalCommitteeRosters?OpenView&committee=CASAC&secondname=Clean%20Air%20Scientific%20Advisory%20Committee> and
[http://yosemite.epa.gov/sab/sabpeople.nsf/WebCommitteesSubcommittees/CASAC%20Oxides%20of%20Nitrogen%20Primary%20NAAQS%20Review%20Panel%20\(2013-2016\)](http://yosemite.epa.gov/sab/sabpeople.nsf/WebCommitteesSubcommittees/CASAC%20Oxides%20of%20Nitrogen%20Primary%20NAAQS%20Review%20Panel%20(2013-2016)), respectively.

⁸ The official level of the annual NO₂ standard is 0.053 ppm, equal to 53 ppb, which is shown here for the purpose of clearer comparison to the 1-hour standard.

1 The EPA retained the primary NO₂ standard, without revision, in reviews completed in
2 1985 and 1996 (50 FR 25532, June 19, 1985; 61 FR 52852, October 8, 1996). In the latter of the
3 two decisions, the EPA concluded that “the existing annual primary standard appears to be both
4 adequate and necessary to protect human health against both long- and short-term NO₂
5 exposures” and that “retaining the existing annual standard is consistent with the scientific data
6 assessed in the Criteria Document (U.S. EPA, 1993), the Staff Paper (U.S. EPA, 1995), and the
7 advice and recommendations of [the] CASAC” (61 FR 52854, October 8, 1996).

8 The last review of the air quality criteria for oxides of nitrogen (health criteria) and the
9 primary NO₂ standard was initiated in December 2005 (70 FR 73236, December 9, 2005).^{9,10}
10 The EPA’s plans for conducting that review were presented in the *Integrated Review Plan for the*
11 *Primary National Ambient Air Quality Standard for Nitrogen Dioxide* (2007 IRP, U.S. EPA,
12 2007a), which included consideration of comments received during a CASAC consultation as
13 well as public comment on a draft IRP. The scientific assessment for the review was described in
14 the 2008 *Integrated Science Assessment for Oxides of Nitrogen – Health Criteria* (2008 ISA,
15 U.S. EPA, 2008a), multiple drafts of which received review by the CASAC and the public. The
16 EPA also conducted quantitative human risk and exposure assessments after consultation with
17 the CASAC and receiving public comment on an analysis plan (U.S. EPA, 2007b). These
18 technical analyses were presented in the *Risk and Exposure Assessment to Support the Review of*
19 *the NO₂ Primary National Ambient Air Quality Standard* (2008 REA, U.S. EPA, 2008b),
20 multiple drafts of which received CASAC and public review.

21 In the course of reviewing the second draft REA in the last review, the CASAC expressed
22 the view that the document would be incomplete without the addition of a policy assessment
23 chapter presenting an integration of evidence-based considerations and risk and exposure
24 assessment results. The CASAC stated that such a chapter would be “critical for considering
25 options for the NAAQS for NO₂” (Samet, 2008a, p.4). In addition, within the period of the
26 CASAC’s review of the second draft REA, the EPA’s Deputy Administrator indicated in a letter
27 to the CASAC chair, addressing earlier CASAC comments on the NAAQS review process, that
28 the risk and exposure assessment would include “a broader discussion of the science and how
29 uncertainties may affect decisions on the standard” and “all analyses and approaches for
30 considering the level of the standard under review, including risk assessment and weight of
31 evidence methodologies” (Peacock, 2008, p. 3). Accordingly, the final 2008 REA included a

⁹ Documents related to the current review as well as reviews complete in 2010 and 1996 are available at:
http://www.epa.gov/ttn/naaqs/standards/nox/s_nox_index.html.

¹⁰ The EPA conducted a separate review of the secondary NO₂ NAAQS jointly with a review of the secondary SO₂ NAAQS. The Agency retained those secondary standards, without revision, to address the direct effects on vegetation of exposure to gaseous oxides of nitrogen and sulfur (77 FR 20218, April 3, 2012).

1 policy assessment chapter that considered the scientific evidence in the 2008 ISA and the
2 exposure and risk results presented in other chapters of the 2008 REA as they related to the
3 adequacy of the then current primary annual NO₂ standard and potential alternative standards for
4 consideration (U.S EPA, 2008b, chapter 10).¹¹ The CASAC discussed the final version of the
5 2008 REA, with an emphasis on the policy assessment chapter, during a public teleconference on
6 December 5, 2008 (73 FR 66895, November 12, 2008). Following that teleconference, the
7 CASAC offered comments and advice on the primary NO₂ standard in a letter to the
8 Administrator (Samet, 2008b)

9 In a notice published in the Federal Register on July 15, 2009, the EPA proposed to
10 supplement the existing primary annual NO₂ standard by establishing a new short-term standard
11 (74 FR 34404, July 15, 2009). After considering an integrative synthesis of the body of evidence
12 on human health effects associated with the presence of NO₂ in the air and the exposure and risk
13 information, the Administrator determined that the existing primary NO₂ NAAQS, based on an
14 annual arithmetic average, was not sufficient to protect the public health from the array of effects
15 that could occur following short-term exposures to ambient NO₂. In so doing, the Administrator
16 particularly noted the potential for adverse health effects to occur following exposures to
17 elevated NO₂ concentrations that can occur around major roads (75 FR 6482, February 9, 2012).
18 In a notice published in the Federal Register on February 9, 2010, the EPA finalized a new short-
19 term NO₂ standard with a level of 100 ppb, based on the 3-year average of the 98th percentile of
20 the annual distribution of daily maximum 1-hour concentrations. The EPA also retained the
21 existing primary annual NO₂ standard with a level of 53 ppb, annual average (75 FR 6474,
22 February 9, 2010). The Agency's final decision included consideration of the CASAC's advice
23 (Samet, 2009) and public comments on the proposed rule. The EPA's final rule was upheld
24 against challenges in a decision issued by the U.S. Court of Appeals for the District of Columbia
25 Circuit on July 17, 2012. *API v. EPA*, 684 F.3d 1342 (D.C. Cir. 2012).

26 Revisions to the NAAQS were accompanied by revisions to the data handling
27 procedures, the ambient air monitoring and reporting requirements, and the Air Quality Index
28 (AQI).¹² As described in Chapter 2, one aspect of the new monitoring network requirements

¹¹ Subsequent to the completion of the 2008 REA, the EPA Administrator Jackson called for additional key changes to the NAAQS review process including reinstating a policy assessment document that contains staff analysis of the scientific bases for alternative policy options for consideration by senior EPA management prior to rulemaking (Jackson, 2009).

¹² The current federal regulatory measurement methods for NO₂ are specified in 40 CFR part 50, Appendix F and 40 CFR part 53. Consideration of ambient air measurements with regard to judging attainment of the standards is specified in 40 CFR part 50, Appendix S. The NO₂ monitoring network requirements are specified in 40 CFR part 58, Appendix D, section 4.3. The EPA revised the AQI for NO₂ to be consistent with the revised primary NO₂ NAAQS as specified in 40 CFR part 58, Appendix G. Certain topics related to implementation of the new standard were also discussed in the *Federal Register* notices for the proposed and final rules (74 FR 34404; 75 FR 6474).

1 included requirements for states to locate monitors near heavily trafficked roadways in large
2 urban areas and in other locations where maximum NO₂ concentrations can occur. Subsequent to
3 the 2010 rulemaking, the Agency revised the deadlines by which the near-road monitors were to
4 be operational in order to implement a phased deployment approach (78 FR 16184, March 14,
5 2013). The near-road NO₂ monitors were required to become operational between January 1,
6 2014 and January 1, 2017.

7 **1.2.3 Current Review of the Primary NO₂ NAAQS**

8 In February 2012, the EPA announced the initiation of the current periodic review of the
9 air quality criteria for oxides of nitrogen and of the Primary NO₂ NAAQS and issued a call for
10 information in the Federal Register (77 FR 7149, February 10, 2012). A wide range of external
11 experts as well as EPA staff representing a variety of areas of expertise (e.g., epidemiology,
12 human and animal toxicology, statistics, risk/exposure analysis, atmospheric science, and
13 biology) participated in a workshop held by the EPA on February 29 to March 1, 2012 in
14 Research Triangle Park, NC. The workshop provided an opportunity for a public discussion of
15 the key policy-relevant issues around which the Agency would structure this NO₂ primary
16 NAAQS review and the most meaningful new science that would be available to inform our
17 understanding of these issues.

18 Based in part on the workshop discussions, the EPA developed a draft plan for the
19 *Integrated Science Assessment for Nitrogen Oxides – Health Criteria* (ISA) and a draft plan for
20 the *Integrated Review Plan for the Primary National Ambient Air Quality Standards for*
21 *Nitrogen Dioxide* (IRP) outlining the schedule, process, and key policy-relevant questions that
22 would guide the evaluation of the air quality criteria for NO₂ and the review of the primary NO₂
23 NAAQS. The draft plan for the ISA was released in May of 2013 (78 FR 26026) and was the
24 subject of a consultation with the CASAC on June 5, 2013 (78 FR 27234). Comments received
25 from that consultation were considered in the preparation of first draft ISA, and preliminary
26 drafts of key ISA chapters were reviewed by subject matter experts at a public workshop hosted
27 by the EPA’s National Center for Environmental Assessment (NCEA) in May 2013 (78 FR
28 27374). The *First External Review Draft Integrated Science Assessment for Oxides of Nitrogen –*
29 *Health Criteria* was released in November 2013 (78 FR 70040). During this time, the draft IRP
30 was also in preparation and was released in February 2014 (79 FR 7184). Both the draft IRP and
31 first draft ISA were reviewed by the CASAC at a public meeting held in March 2014 (79 FR
32 8701), and the first draft ISA was further discussed at an additional teleconference held in May
33 2014 (79 FR 17538). The CASAC finalized its recommendations of the first draft ISA and the

1 draft IRP in letters dated June 10, 2014, and the final IRP was released in June 2014 (79 FR
2 36801).

3 The EPA released the *Second External Review Draft Integrated Science Assessment for*
4 *Oxides of Nitrogen – Health Criteria* in January 2015 (80 FR 5110) and the *Review of the*
5 *Primary National Ambient Air Quality Standards for Nitrogen Dioxide Risk and Exposure*
6 *Assessment Planning Document* (REA Plan) in May 2015 (80 FR 27304), both of which were
7 review by the CASAC at a public meeting held in June 2015 (80 FR 22993). A follow-up
8 teleconference with the CASAC was held in August 2013 (80 FR 43085) to finalize
9 recommendations on the second draft ISA, and the final *Integrated Science Assessment for*
10 *Oxides of Nitrogen – Health Criteria* was released in January 2016 (81 FR 4910). The
11 CASAC’s recommendations on the draft REA Plan were provided to the EPA in a letter dated
12 September 9, 2015, and the EPA has prepared this draft PA after considering the CASAC’s
13 advice and public comments.

14 In addition, a complaint against the EPA has been filed for failure to complete its review
15 of the primary NAAQS for NO₂. Center for Biological Diversity et al. v. McCarthy, (No. 4:16-
16 cv-03796-VC, N.D. Cal., July 7, 2016). The EPA anticipates that this litigation will result in
17 court-ordered deadlines for completion of the review.

18 **1.3 SCOPE OF THE CURRENT REVIEW**

19 Consistent with the review completed in 2010, this review will focus on health effects
20 associated with gaseous oxides of nitrogen and the protection afforded by the primary NO₂
21 standards.¹³ The gaseous oxides of nitrogen include NO₂ and nitric oxide (NO) as well as their
22 gaseous reaction products. Total oxides of nitrogen include these gaseous species as well as
23 particulate species (e.g., nitrates). Collectively, we refer to the total set of species as NO_y (U.S.
24 EPA, 2013b, Section 2.2, Figure 2-1). Health effects associated with the particulate species are
25 addressed in the review of the NAAQS for particulate matter (PM) (78 FR 30866, January 15,

¹³Section 108(c) of the CAA specifies that the air quality criteria relating to NO₂ include consideration of nitric and nitrous acids, nitrites, nitrates, nitrosamines, and other carcinogenic and potentially carcinogenic derivatives of oxides of nitrogen.

1 2013; U.S. EPA, 2009).¹⁴ The EPA is separately reviewing the welfare effects associated with
2 oxides of nitrogen and the protection provided by the secondary NO₂ standard in conjunction
3 with a review of the secondary SO₂ standard (78 FR 53452, August 29, 2013).¹⁵

4 When referring to the group of gaseous oxidized nitrogen compounds as a whole, the ISA
5 and other assessment documents developed in this review use the term “oxides of nitrogen.” In
6 the last review, the EPA used “NO_x” as the abbreviation for oxides of nitrogen. However, based
7 on the definition commonly used in the scientific literature, in this review, the abbreviation NO_x
8 will refer specifically to the sum of NO₂ and NO concentrations, rather than all oxides of
9 nitrogen (U.S. EPA, 2016).¹⁶

10 **1.4 GENERAL APPROACH FOR REVIEW OF THE STANDARDS**

11 As described in Section 1.1 above, this draft PA presents a transparent evaluation and
12 staff’s preliminary conclusions regarding the adequacy of the current primary NO₂ standards.
13 Staff’s considerations and preliminary conclusions in this draft document are based on the
14 available body of scientific evidence assessed in the ISA (U.S. EPA, 2016) and on the results of
15 quantitative analyses comparing NO₂ air quality to NO₂ benchmarks based on the available
16 health evidence. In the final PA, staff’s considerations and conclusions on the adequacy of the
17 existing standards, and on the potential alternatives, if any, that are appropriate to consider, will
18 also be informed by the advice and recommendations received from CASAC during its review of
19 this draft of the PA and by public input received. Staff’s considerations and conclusions in the
20 final PA are intended to inform the Administrator’s decisions as to whether the existing primary
21 NO₂ standards should be retained or revised and, if revised, what revisions are appropriate.

22 Section 1.4.1 below summarizes the approach used by the Administrator in reaching
23 conclusions in the last review of the primary NO₂ NAAQS. Building on this approach from the
24 last review, Section 1.4.2 summarizes the planned approach to be taken by staff in this review to
25 inform the Administrator’s decisions on the primary NO₂ NAAQS.

¹⁴ Additional information on the PM NAAQS is available at:
http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_index.html.

¹⁵ Additional information on the ongoing and previous review of the secondary NO₂ and SO₂ NAAQS is available
at: <http://www.epa.gov/ttn/naaqs/standards/no2so2sec/index.html>.

¹⁶ “...the term “oxides of nitrogen” (NO_x) refers to all forms of oxidized nitrogen (N) compounds, including nitric
oxide (NO), nitrogen dioxide (NO₂), and all other oxidized N-containing compounds formed from NO and NO₂”
(U.S. EPA, 2016, p. 2-1). “A large number of oxidized nitrogen species in the atmosphere are formed from
the oxidation of NO and NO₂. These include nitrate radicals (NO₃), nitrous acid (HONO), nitric acid
(HNO₃), dinitrogen pentoxide (N₂O₅), nitryl chloride (ClNO₂), peroxyxynitric acid (HNO₄), PAN and its
homologues (PANs), other organic nitrates like alkyl nitrates [including isoprene nitrates(IN)], and pNO₃”
(U.S. EPA, 2016, p. 2-2).

1 1.4.1 Approach Used in the Last Review

2 As noted above (Section 1.2.2), the last review of the primary NO₂ NAAQS was
3 completed in 2010 (75 FR 6474, February 9, 2010). In that review, the EPA established a new 1-
4 hour standard to provide increased public health protection, including for people with asthma and
5 other at-risk populations,¹⁷ against an array of adverse respiratory health effects that had been
6 linked to short-term NO₂ exposures (75 FR 6498 to 6502; U.S. EPA, 2008a, Sections 3.1.7 and
7 5.3.2.1; Table 5.3-1). Specifically, the EPA established a short-term standard defined by the 3-
8 year average of the 98th percentile of the annual distribution of daily maximum 1-hour NO₂
9 concentrations, with a level of 100 ppb. In addition to setting the new 1-hour standard, the EPA
10 retained the existing annual standard with its level of 53 ppb (75 FR 6502, February 9, 2010).
11 Together, the two standards were concluded to provide protection against adverse respiratory
12 health effects associated with short-term exposures to NO₂ and effects potentially associated with
13 long-term exposures. As discussed further in Chapter 2 below, in conjunction with the revised
14 primary NO₂ NAAQS, the EPA also established a two-tiered monitoring network composed of
15 (1) near-road monitors which would be placed near heavily trafficked roads in urban areas and
16 (2) monitors located to characterize areas with the highest expected NO₂ concentrations at the
17 neighborhood and larger spatial scales (also referred to as “area-wide” monitors) (75 FR 6505 to
18 6506, February 9, 2010).

19 Key aspects of the Administrator’s approach to reaching these decisions are described
20 below. Section 1.4.1.1 summarizes her approach to reaching the conclusion that it was
21 appropriate to revise the primary NO₂ NAAQS. Section 1.4.1.2 summarizes her approach to
22 considering the elements of a revised standard. Section 1.4.1.3 discusses the key uncertainties in
23 the evidence and information identified in the last review.

24 1.4.1.1 Approach to Considering the Need for Revision

25 The 2010 decision to revise the existing primary NO₂ standard was based largely on the
26 body of scientific evidence published through early 2008 and assessed in the 2008 ISA (U.S.
27 EPA, 2008a); the quantitative exposure and risk analyses and the assessment of the policy-

¹⁷ As used here and similarly throughout this document, the term *population* refers to persons having a quality or characteristic in common, such as a specific pre-existing illness or a specific age or lifestage. Lifestage refers to a distinguishable time frame in an individual’s life characterized by unique and relatively stable behavioral and/or physiological characteristics that are associated with development and growth (i.e., children and older adults). Identifying at-risk populations includes consideration of intrinsic (e.g., genetic or developmental aspects) or acquired (e.g., disease or smoking status) factors that increase the risk of health effects due to exposure to oxides of nitrogen as well as extrinsic factors such as those related to socioeconomic status, reduced access to health care, or exposure. The ISA characterizes the strength of the evidence for various at-risk populations (U.S. EPA, 2016, Chapter 7).

1 relevant aspects of the evidence presented in the REA (U.S. EPA, 2008b);¹⁸ the advice and
2 recommendations of the CASAC (Samet, 2008); and public comments on the proposal.

3 As an initial consideration in reaching this decision, the Administrator noted that the
4 evidence relating short-term (minutes to hours) NO₂ exposures to respiratory morbidity was
5 judged in the ISA to be “sufficient to infer a likely causal relationship” (75 FR 6489, February 9,
6 2010; U.S. EPA, 2008a, Sections 3.1.7 and 5.3.2.1).¹⁹ The scientific evidence included
7 controlled human exposure studies providing evidence of increases in airway responsiveness in
8 people with asthma following short-term exposures to NO₂ concentrations as low as 100 ppb²⁰
9 and epidemiologic studies reporting associations between short-term NO₂ exposures and
10 respiratory effects in locations that would have met the annual standard.

11 The quantitative analyses presented in the 2008 REA included exposure and risk estimates
12 for air-quality adjusted to just meet the annual standard. The Administrator took note of the REA
13 conclusion that risks estimated for air quality adjusted upward to simulate just meeting the
14 current standard could reasonably be concluded to be important from a public health perspective,
15 while additionally recognizing the uncertainties associated with adjusting air quality in such
16 analyses (75 FR 6489, February 9, 2010). For air quality adjusted to just meet the existing annual
17 standard, the REA findings given particular attention by the Administrator included the
18 following: “a large percentage (8 to 9%) of respiratory-related emergency department visits in
19 Atlanta could be associated with short-term NO₂ exposures; most asthmatics in Atlanta could be
20 exposed on multiple days per year to NO₂ concentrations at or above 300 ppb; and most
21 locations evaluated could experience on-/near-road NO₂ concentrations above 100 ppb on more
22 than half of the days in a given year” (75 FR 6489, February 9, 2010; U.S. EPA, 2008b, Section
23 10.3.2).

24 In reaching the conclusion on adequacy of the then-existing standard, the Administrator
25 also considered advice received from the CASAC. In its advice, the CASAC agreed that the
26 primary concern in the review was to protect against health effects that have been associated
27 with short-term NO₂ exposures. The CASAC also agreed that the annual standard alone was not

¹⁸ As discussed in the IRP for NO₂ (U.S. EPA, 2014, section 1.3), due to changes in the NAAQS process, the last review of the NO₂ NAAQS did not include a separate Policy Assessment document. Rather, the REA for that review included a policy assessment chapter.

¹⁹ In contrast, the evidence relating long-term (weeks to years) NO₂ exposures to adverse health effects was judged to be either “suggestive but not sufficient to infer a causal relationship” (respiratory morbidity) or “inadequate to infer the presence or absence of a causal relationship” (mortality, cancer, cardiovascular effects, reproductive/developmental effects) (75 FR 6478, February 9, 2010). The causal framework used in the ISA for the current review is discussed below in Chapter 3.

²⁰ Transient increases in airway responsiveness have the potential to increase asthma symptoms and worsen asthma control (74 FR 34415, July 15, 2009; U.S. EPA, 2008a, sections 5.3.2.1 and 5.4).

1 sufficient to protect public health against the types of exposures that could lead to these health
2 effects. As noted in its letter to the EPA Administrator, “[The] CASAC concurs with EPA’s
3 judgment that the current NAAQS does not protect the public’s health and that it should be
4 revised” (Samet, 2008, p. 2).

5 Based on the considerations summarized above, the Administrator concluded that the
6 then-existing NO₂ primary NAAQS was not requisite to protect public health with an adequate
7 margin of safety and that the standard should be revised in order to provide increased public
8 health protection against respiratory effects associated with short-term exposures, particularly for
9 at-risk populations and lifestages such as asthmatics, children, and older adults (75 FR 6490,
10 February 9, 2010). Upon consideration of approaches to revising the standard, the Administrator
11 concluded that it was appropriate to set a new short-term standard, in addition to the existing
12 annual standard with its level of 53 ppb, as described below.

13 *1.4.1.2 Approach to Considering the Elements of a Revised Standard*

14 In considering appropriate revisions in the last review, each of the four basic elements of
15 the NAAQS (indicator, averaging time, level, and form) was evaluated. The sections below
16 summarize the approaches used by the Administrator, and her final decisions, on each of those
17 elements.

18 **Indicator**

19 In the review completed in 2010, as well as in previous reviews, the EPA focused on NO₂
20 as the most appropriate indicator for oxides of nitrogen because the available scientific
21 information regarding health effects was largely indexed by NO₂. Controlled human exposure
22 studies and animal toxicological studies provided specific evidence for health effects following
23 exposures to NO₂. In addition, epidemiologic studies typically reported effects associated with
24 NO₂ concentrations²¹ (75 FR 6490, February, 9, 2010; U.S. EPA 2008b, Section 2.2.3). Based on
25 the information available in the last review, and consistent with the views of the CASAC (Samet,
26 2008, p.2; Samet, 2009, p.2), the EPA concluded it was appropriate to continue to use NO₂ as the
27 indicator for a standard that was intended to address effects associated with exposure to NO₂,
28 alone or in combination with other gaseous oxides of nitrogen. In so doing, the EPA recognized
29 that measures leading to reductions in population exposures to NO₂ will also reduce exposures to
30 other oxides of nitrogen (75 FR 6490, February, 9, 2010).

31 **Averaging time**

²¹ The degree to which monitored NO₂ reflected actual NO₂ concentrations, as opposed to NO₂ plus other gaseous oxides of nitrogen, was recognized as an uncertainty (75 FR 6490, February, 9, 2010; U.S. EPA 2008b, section 2.2.3).

1 In considering the most appropriate averaging time(s) for the NO₂ primary NAAQS, the
2 Administrator noted the available scientific evidence as assessed in the ISA, the air quality
3 analyses presented in the REA, the conclusions of the policy assessment chapter of the REA, and
4 recommendations from the CASAC.²² Her key considerations are summarized below.

5 When considering averaging time, the Administrator first noted that the evidence relating
6 short-term (minutes to hours) NO₂ exposures to respiratory morbidity was judged in the ISA to
7 be “sufficient to infer a likely causal relationship” (U.S. EPA, 2008a, section 5.3.2.1) while the
8 evidence relating long-term (weeks to years) NO₂ exposures to adverse health effects was judged
9 to be either “suggestive but not sufficient to infer a causal relationship” (respiratory morbidity)
10 or “inadequate to infer the presence or absence of a causal relationship” (mortality, cancer,
11 cardiovascular effects, reproductive/developmental effects) (U.S. EPA, 2008a, Sections 5.3.2.4-
12 5.3.2.6). The Administrator concluded that these judgments most directly supported an averaging
13 time that focused protection on effects associated with short-term exposures to NO₂.

14 In considering the level of support available for specific short-term averaging times, the
15 Administrator noted that the policy assessment chapter of the REA considered evidence from
16 both experimental and epidemiologic studies. Controlled human exposure studies and animal
17 toxicological studies provided evidence that NO₂ exposures from less than 1 hour up to 3 hours
18 can result in respiratory effects such as increased airway responsiveness and inflammation (U.S.
19 EPA, 2008a, Section 5.3.2.7). She specifically noted the ISA conclusion that exposures of
20 asthmatic adults to 100 ppb NO₂ for 1-hour (or 200 to 300 ppb for 30 minutes) can result in
21 small but significant increases in nonspecific airway responsiveness (U.S. EPA, 2008a, Section
22 5.3.2.1). In addition, the epidemiologic evidence provided support for short-term averaging times
23 ranging from approximately 1 hour up to 24 hours (U.S. EPA, 2008a, Section 5.3.2.7). Based on
24 this, the Administrator concluded that a primary concern with regard to averaging time is the
25 degree of protection provided against effects associated with 1-hour NO₂ concentrations. Based
26 on REA analyses of ratios between 1-hour and 24-hour NO₂ concentrations (U.S. EPA, 2008b,
27 Section 10.4.2), she further concluded that a standard based on 1-hour daily maximum NO₂
28 concentrations could also be effective at protecting against effects associated with 24-hour NO₂
29 exposures.

30 Based on the above, the Administrator judged that it was appropriate to set a new NO₂
31 standard with a 1-hour averaging time. She concluded that such a standard would be expected to
32 effectively limit short-term (e.g., 1- to 24-hours) exposures that have been linked to adverse
33 respiratory effects. She also retained the existing annual standard to continue to provide
34 protection against effects potentially associated with long-term exposures to oxides of nitrogen

²² She also considered public comments received on the proposal (75 FR 6490, February, 9, 2010)

1 (75 FR 6502, February, 9, 2010). These decisions were consistent with CASAC advice to
2 establish a short-term primary standard for oxides of nitrogen based on using 1-hour maximum
3 NO₂ concentrations and to retain the current annual standard (Samet, 2008, p. 2; Samet, 2009, p.
4 2).

5 **Level**

6 With consideration of the available health effects evidence, exposure and risk analyses,
7 and air quality information, the Administrator set the level of the new 1-hour NO₂ standard at
8 100 ppb. This standard was focused on limiting the *maximum* 1-hour NO₂ concentrations in
9 ambient air (75 FR 6474, February, 9, 2010).²³ In establishing this new standard, the
10 Administrator emphasized the importance of protecting against exposures to peak concentrations
11 of NO₂, such as those that can occur around major roadways. Available evidence and
12 information suggested that roadways account for the majority of exposures to peak NO₂
13 concentrations and, therefore, are important contributors to NO₂-associated public health risks
14 (U.S. EPA, 2008b, Figures 8-17 and 8-18).

15 In setting the level of the new 1-hour standard at 100 ppb, the Administrator noted that
16 there is no bright line clearly directing the choice of level. Rather, the choice of what is
17 appropriate is a public health policy judgment entrusted to the Administrator. This judgment
18 must include consideration of the strengths and limitations of the evidence and the appropriate
19 inferences to be drawn from the evidence and the exposure and risk assessments.

20 The Administrator judged that the existing evidence from controlled human exposure
21 studies supported the conclusion that the NO₂-induced increase in airway responsiveness at or
22 above 100 ppb presented a risk of adverse effects for some asthmatics, especially those with
23 more serious (i.e., more than mild) asthma. The Administrator noted that the risks associated
24 with increased airway responsiveness could not be fully characterized based on available
25 controlled human exposure studies, and thus she was not able to determine whether the increased
26 airway responsiveness experienced by asthmatics in these studies was an adverse health effect.
27 However, the Administrator concluded that asthmatics, particularly those suffering from more
28 severe asthma, warrant protection from the risk of adverse effects associated with the NO₂-
29 induced increase in airway responsiveness. Therefore, the Administrator concluded that the
30 controlled human exposure evidence supported setting a standard level no higher than 100 ppb to
31 reflect a cautious approach to the uncertainty regarding the adversity of the effect. However,
32 those uncertainties led her to also conclude that this evidence did not support setting a standard
33 level lower than 100 ppb (75 FR 6500-6501, February, 9, 2010)..

²³ In conjunction with this new standard, the Administrator established a 2-tiered monitoring network that included monitors sited to measure the maximum NO₂ concentrations near major roadways, as well as monitors sited to measure maximum area-wide NO₂ concentrations.

1 The Administrator also considered the more serious health effects reported in NO₂
2 epidemiologic studies. She noted that a new standard focused on protecting against maximum 1-
3 hour NO₂ concentrations in ambient air anywhere in an area, with a level of 100 ppb and an
4 appropriate form (as discussed below), would be expected to limit area-wide²⁴ NO₂
5 concentrations to below those in locations where epidemiologic studies had reported associations
6 with respiratory-related hospital admissions or emergency department visits. The Administrator
7 also concluded that such a 1-hour standard would be consistent with the REA conclusions based
8 on the NO₂ exposure and risk information (75 FR 6501, February, 9, 2010).

9 Given the above considerations and the comments received on the proposal, and
10 considering the entire body of evidence and information before her, as well as the related
11 uncertainties, the Administrator judged it appropriate to set a 1-hour standard focused on limiting
12 the maximum allowable NO₂ concentrations that can occur anywhere in an area, with a level of
13 100 ppb. Specifically, she concluded that such a standard, with an appropriate form as discussed
14 below, would provide a significant increase in public health protection compared to that provided
15 by the annual standard alone and would be expected to protect against the respiratory effects that
16 have been linked with NO₂ exposures in both controlled human exposure and epidemiologic
17 studies. This includes limiting exposures at and above 100 ppb for the vast majority of people,
18 including those in at-risk groups, and maintaining area-wide NO₂ concentrations below those in
19 locations where key U.S. epidemiologic studies had reported that ambient NO₂ was associated
20 with clearly adverse respiratory health effects, as indicated by increased hospital admissions and
21 emergency department visits. The Administrator also noted that a standard level of 100 ppb was
22 consistent with the consensus recommendation of the CASAC. (75 FR 6501, February, 9, 2010).

23 In setting the standard level at 100 ppb rather than at a lower level, the Administrator also
24 acknowledged the uncertainties associated with the scientific evidence. She noted that a 1-hour
25 standard with a level lower than 100 ppb would only result in significant further public health
26 protection if, in fact, there is a continuum of serious, adverse health risks caused by exposure to
27 NO₂ concentrations below 100 ppb and/or associated with area-wide NO₂ concentrations well
28 below those in locations where key U.S. epidemiologic studies had reported associations with
29 respiratory-related emergency department visits and hospital admissions. Based on the available
30 evidence, the Administrator did not believe that such assumptions were warranted. Taking into
31 account the uncertainties that remained in interpreting the evidence from available controlled
32 human exposure and epidemiologic studies, the Administrator observed that the likelihood of
33 obtaining benefits to public health with a standard set below 100 ppb decreased, while the

²⁴As discussed below in Chapter 2, area-wide concentrations refer to those measured by monitors that have been sited to characterize ambient concentrations at the neighborhood and larger spatial scales.

1 likelihood of requiring reductions in ambient concentrations that go beyond those that are needed
2 to protect public health increased. (75 FR 6501-02, February, 9, 2010).

3 **Form**

4 The “form” of a standard defines the air quality statistic that is to be compared to the level of
5 the standard in determining whether an area attains the standard. The Administrator recognized that
6 for short-term standards, concentration-based forms which reflect consideration of a statistical
7 characterization of an entire distribution of air quality data with a focus on a single statistical metric,
8 such as the 98th or 99th percentile, can better reflect pollutant-associated health risks than forms based
9 on expected exceedances. This is the case because concentration-based forms give proportionally
10 greater weight to days when pollutant concentrations are well above the level of the standard than to
11 days when the concentrations are just above the level of the standard.²⁵ In addition, she concluded
12 that when averaged over three years, these concentration-based forms provide an appropriate balance
13 between limiting peak pollutant concentrations and providing a stable regulatory target, facilitating
14 the development of stable implementation programs (75 FR 6492, February, 9, 2010).

15 In the last review, the EPA considered two specific concentration-based forms (i.e., the 98th
16 and 99th percentile concentrations), averaged over 3 years, for the new 1-hour NO₂ standard. The
17 focus on the upper percentiles of the distribution was based, in part, on evidence of health effects
18 associated with short-term NO₂ exposures from experimental studies which provided information on
19 specific exposure concentrations that were linked to respiratory effects. In a letter to the
20 Administrator following issuance of the Agency’s proposed rule, the CASAC recommended a form
21 based on the 3-year average of the 98th percentile of the distribution of 1-hour daily maximum NO₂
22 concentrations (Samet, 2009, p. 2). In making this recommendation, the CASAC noted the potential
23 for instability in the higher percentile concentrations and the absence of data from the near-road
24 monitoring network.

25 Given the limited available information on the variability in peak NO₂ concentrations near
26 important sources of NO₂ such as near major roadways, and given the recommendation from the
27 CASAC regarding the potential for instability in the 99th percentile concentrations, the Administrator
28 judged it appropriate to set the form based on the 3-year average of the 98th percentile of the annual
29 distribution of daily maximum 1-hour NO₂ concentrations. In addition, consistent with the CASAC’s
30 advice (Samet, 2008, p. 2; Samet, 2009, p.2), the EPA retained the form of the annual standard (75
31 FR 6502, February, 9, 2010).

32 *1.4.1.3 Areas of Uncertainty in Last Review*

33 While the available scientific information informing the last review was stronger and
34 more consistent than in previous reviews and provided a strong basis for decision making in that

²⁵ Compared to an exceedance-based form, a concentration-based form reflects the magnitude of the exceedance of a standard level not just the fact that such an exceedance occurred.

1 review, the Agency recognized that areas of uncertainty remained. These were generally related
2 to the following: (1) understanding the role of NO₂ in the complex ambient mixture which
3 includes a range of co-occurring pollutants (e.g., PM_{2.5}, CO and other traffic-related pollutants;
4 ozone (O₃), SO₂,) (e.g., 75 FR 6485 February 9, 2010); (2) understanding the extent to which
5 monitored ambient NO₂ concentrations used in epidemiologic studies reflect exposures in study
6 populations and the range of ambient concentrations over which we continue to have confidence
7 in the health effects observed in the epidemiologic studies (e.g., 75 FR 6501, February 9, 2010);
8 (3) understanding the magnitude and potential adversity of NO₂-induced respiratory effects
9 reported in controlled human exposure studies (e.g., 75 FR 6500, February 9, 2010); and (4)
10 understanding the NO₂ concentration gradients around important sources, such as major roads,
11 and relating those gradients to broader ambient monitoring concentrations (e.g., 75 FR 6479,
12 February 9, 2010).

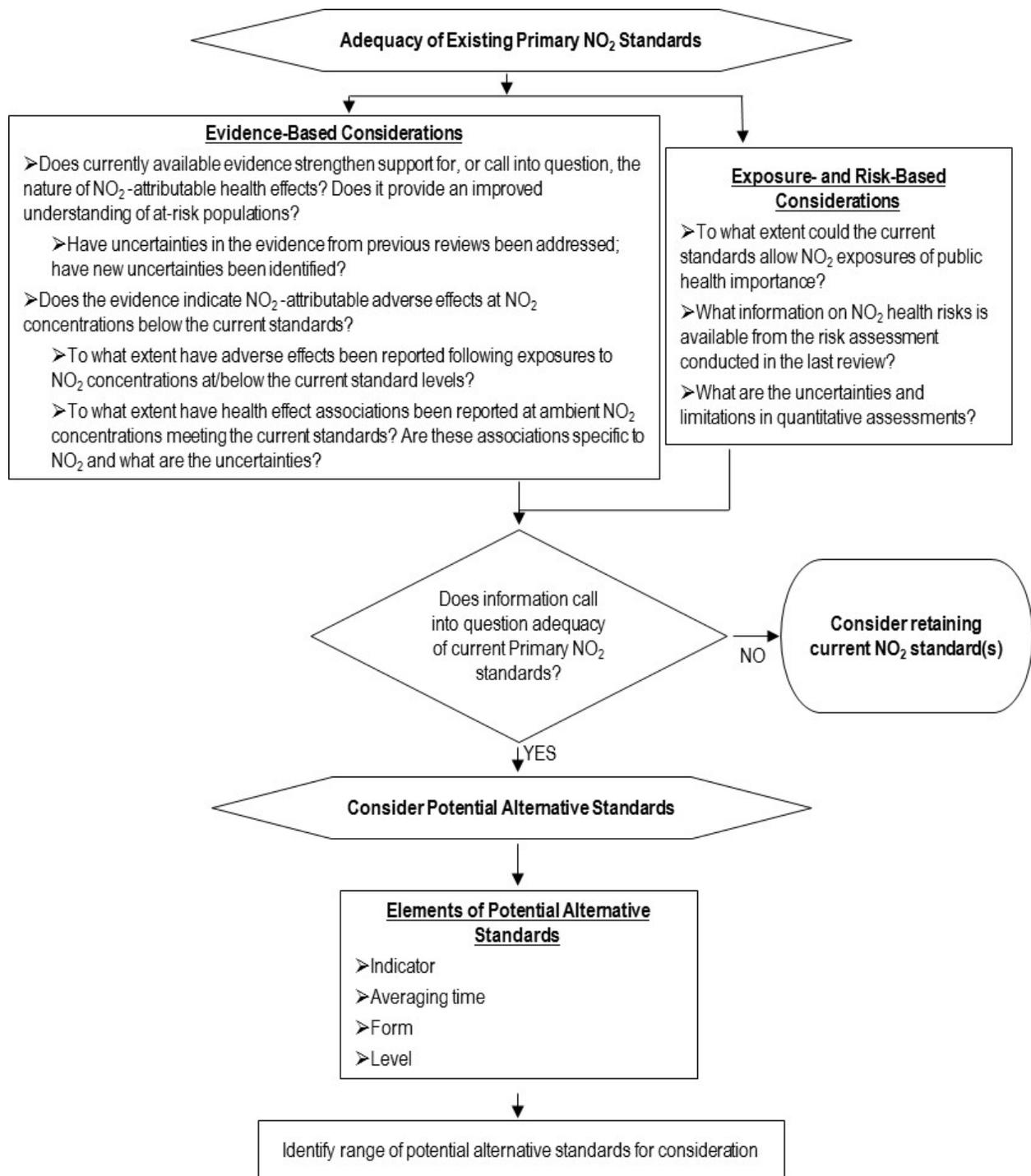
13 **1.4.2 General Approach for the Current Review**

14 Staff's approach to reviewing the primary NO₂ standards in the current review builds off
15 the approach taken in the last review and reflects the updated scientific and technical information
16 now available, as assessed in the 2016 ISA. Our considerations and conclusions related to the
17 primary NO₂ standards in the current review are framed by a series of key policy-relevant
18 questions, expanding upon those presented in the IRP at the outset of this review (U.S. EPA,
19 2014). Our consideration of these questions in the final PA is intended to inform the
20 Administrator's decisions as to whether, and if so how, to revise the current NO₂ standards.

21 In reaching conclusions on options for the Administrator's consideration, we note that the
22 final decision to retain or revise the current primary NO₂ standard is a public health policy
23 judgment to be made by the Administrator. This final decision by the Administrator will draw
24 upon the available scientific evidence for NO₂-attributable health effects and on information
25 from available quantitative analyses, including judgments about the appropriate weight to assign
26 the range of uncertainties inherent in the evidence and analyses. Our general approach in the
27 current review to informing these decisions recognizes that the available health effects evidence
28 reflects a continuum from relatively higher NO₂ concentrations, at which scientists generally
29 agree that health effects are likely to occur, through lower concentrations, at which the likelihood
30 and magnitude of a response become increasingly uncertain. In developing preliminary
31 conclusions in this draft PA, we are mindful that the Administrator's ultimate judgments on the
32 primary standard will most appropriately reflect an interpretation of the available scientific
33 evidence and information that neither overstates nor understates the strengths and limitations of
34 that evidence and information. This approach is consistent with the requirements of sections 108

1 and 109 of the CAA, as well as with how the EPA and the courts have historically interpreted the
2 CAA.

3 Figure 1-1 below provides an overview of our approach in this review. We believe that
4 the general approach outlined in Figure 1-1 provides a comprehensive basis to help inform the
5 judgments required of the Administrator in reaching decisions about the current and, if
6 appropriate, potential alternative primary NO₂ standards.



1 **Figure 1-1. Overview of the Approach to Reviewing the Primary NO₂ NAAQS.**

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24

2 NO₂ AIR QUALITY

This chapter presents information on NO₂ atmospheric chemistry, monitoring, and ambient concentrations, with a focus on information that is most relevant for our review of the primary NO₂ standards. It is intended as a prologue for detailed discussions on the evidence for health effects and ambient exposures to NO₂ that follow in the subsequent chapters, and as a source of information to help interpret those effects in the context of air quality. We generally focus on NO₂ in this chapter, as this is the indicator for oxides of nitrogen and most relevant to the evaluation of health evidence, however, a more thorough characterization of oxides of nitrogen is presented in the ISA (U.S. EPA, 2016, Chapter 2).

In this chapter, Section 2.1 provides an overview of the atmospheric chemistry of NO₂ formation and the NO_x emissions that contribute to ambient NO₂. Section 2.2 discusses NO₂ ambient monitoring methods and provides an overview of the U.S. ambient monitoring network for NO₂. Section 2.3 summarizes information on recent ambient concentrations of NO₂, including information from the near-road monitoring network, and on long-term temporal trends in NO₂ air quality.

2.1 NO₂ ATMOSPHERIC CHEMISTRY AND NO_x EMISSIONS

2.1.1 Atmospheric Chemistry

Ambient concentrations of NO₂ are influenced by both direct NO₂ emissions and by emissions of nitric oxide (NO), with the subsequent conversion of NO to NO₂ primarily through reaction with ozone (O₃). The initial reaction between NO and O₃ to form NO₂ occurs fairly quickly during the daytime, with reaction times on the order of minutes. However, NO₂ can also be photolyzed to reform NO, creating new O₃ in the process (U.S. EPA, 2016, Section 2.2).

Due to the close relationship between NO and NO₂, and their ready interconversion, these species are often grouped together and referred to as NO_x. The majority of NO_x emissions are in the form of NO. For example, 90% or more of tail-pipe NO_x emissions are in the form of NO, with only about 2 to 10% emitted as NO₂ (Itano et al., 2014; Kota et al., 2013; Jimenez et al., 2000; Richmond-Bryant et al., 2016). NO_x emissions from mobile sources require time and sufficient O₃ concentrations for the conversion of NO to NO₂ near roadways. As a result, while ambient NO₂ concentrations are often elevated near important sources of NO_x emissions, such as major roadways, the highest concentrations do not always occur immediately adjacent to those sources.

1 The near-road environment provides a clear example of the interplay between NO_x
2 emissions, meteorology, and the atmospheric chemistry that impacts ambient NO₂
3 concentrations. Vehicular emissions tend to peak during the morning and afternoon commutes,
4 while peak O₃ concentrations generally occur in the late morning to early evenings. In addition,
5 atmospheric mixing tends to be the strongest during the daytime, rapidly diluting roadway
6 emissions. Given the relative timing of O₃ availability and peak atmospheric mixing conditions,
7 the highest near-road NO₂ concentrations often occur during the early morning hours (i.e., before
8 atmospheric mixing can rapidly dilute emissions) (Kimbrough et al., 2016; Richmond-Bryant et
9 al., 2016).²⁶

10 **2.1.2 Emissions**

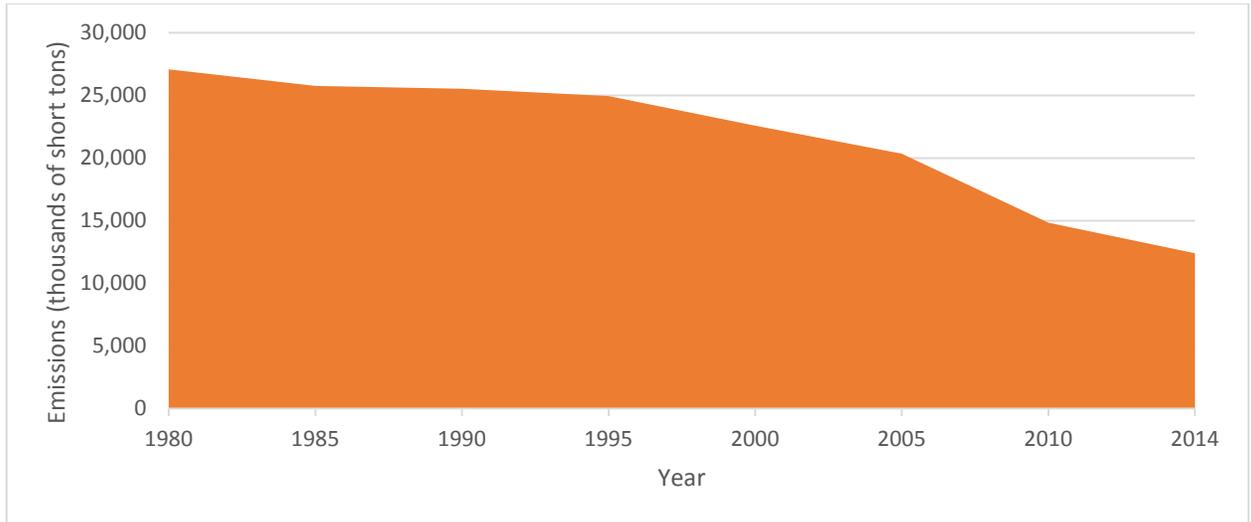
11 The National Emissions Inventory (NEI)²⁷ is a national compilation of emissions sources
12 collected from state, local, and tribal air agencies, as well as emission estimates developed by the
13 EPA from data on specific source sectors. Anthropogenic sources account for 97% of NO_x
14 emissions in the U.S., with highway vehicles, off-highway vehicles, and fuel combustion
15 identified in the NEI as the largest contributors. More specifically, highway vehicles include all
16 on-road vehicles, including light duty as well as heavy duty vehicles, both gasoline- and diesel-
17 powered. Off-highway vehicles and engines include aircraft, commercial marine vessels,
18 locomotives, and nonroad equipment. Fuel combustion-utilities includes electric power
19 generating units (EGUs), which derive their power generation from all types of fuels. EGU
20 emissions are dominated by coal combustion, which accounts for 86% of all NO_x emissions from
21 utilities in the 2011 NEI. The fuel combustion-other category includes commercial/institutional,
22 industrial, and residential combustion of biomass, coal, natural gas, oil, and other fuels. Other
23 anthropogenic sources include field burning, prescribed fires, and various industrial processes
24 (e.g., cement manufacturing, oil and gas production). On a national scale, agricultural field
25 burning and prescribed fires are the greatest contributors to the Other Anthropogenic sources
26 category. Biogenics and Wildfires include emissions estimates for plants and soil (i.e., biogenics)
27 and for wildfires.

28 Nationwide estimates indicate a 54% decrease in total NO_x emissions from 1980 to 2014
29 (Figure 2-1) as a result of multiple regulatory programs. These include the Acid Rain Program;

²⁶ Ambient NO₂ concentrations around stationary sources of NO_x emissions are similarly impacted by the availability of O₃ and by meteorological conditions, although surface-level NO₂ concentrations can be less impacted in cases where stationary source NO_x emissions are elevated substantially above ground level.

²⁷ <https://www.epa.gov/air-emissions-inventories>

1 NO_x Budget Trading Program; Clean Air Interstate Rule; Cross-State Air Pollution Rule; Tier 2
2 On-Road Light Duty Rule; Tier 3 Light-Duty Vehicle Emissions and Fuel Standards; Heavy
3 Duty Truck and Bus Rule; Clean Air Diesel Rule; Locomotive and Marine Diesel Rule; Non-
4 road Spark-Ignition Engine Rule; Ocean-Going Vessels Rule; and Voluntary Clean Diesel
5 Programs.²⁸



6 **Figure 2-1. U.S. national average NO_x emissions from 1980 to 2014.**²⁹

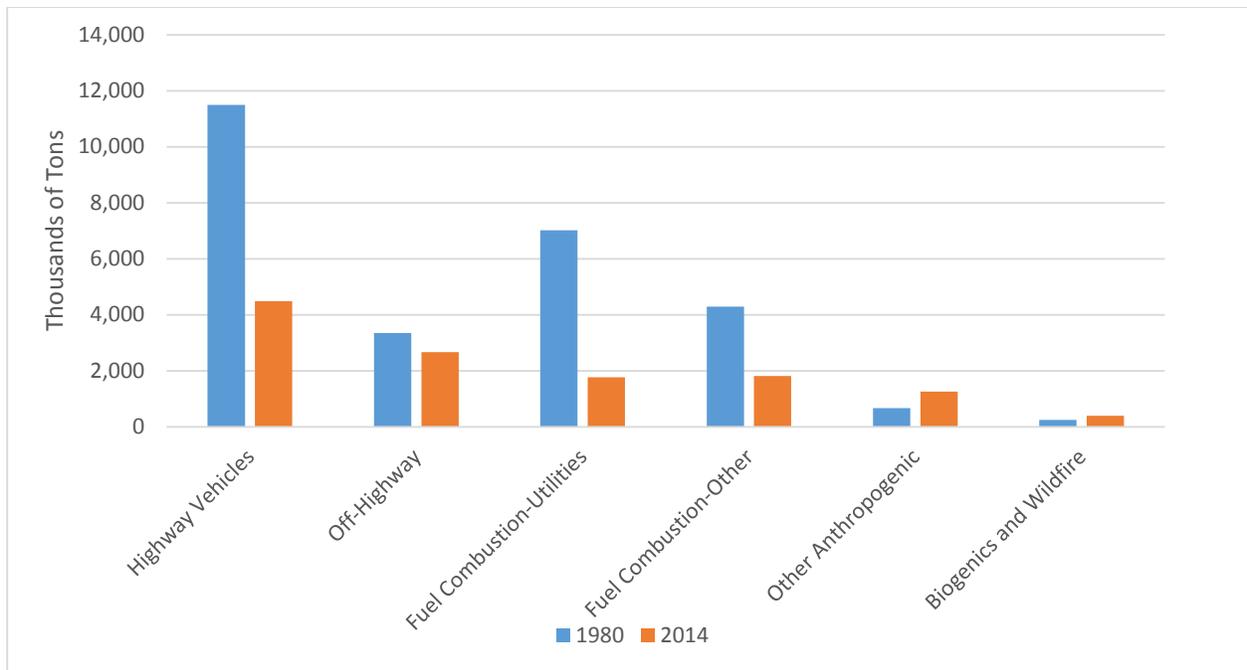
7 The overall decrease in NO_x emissions has been driven primarily by decreases from the
8 four largest emissions sources. Specifically, compared to the 1980 NEI, estimates for 2014³⁰
9 indicate a 61% reduction in NO_x emissions from Highway Vehicles, a 20% reduction from Off-
10 Highway vehicles and Engines, a 75% reduction from Fuel Combustion-Utilities, and a 58%
11 reduction from Fuel Combustion-Other (Figure 2-2, below).³¹

²⁸ See https://www.epa.gov/sites/production/files/2015-06/documents/cb_airwater_fact_sheet_jan2015.pdf;
[https://yosemite.epa.gov/sab/sabproduct.nsf/WebBOARD/INCFullReport/\\$File/Final%20INC%20Report%208%2019%2011%20without%20signatures.pdf](https://yosemite.epa.gov/sab/sabproduct.nsf/WebBOARD/INCFullReport/$File/Final%20INC%20Report%208%2019%2011%20without%20signatures.pdf)

²⁹ <http://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data>

³⁰ 2014 emissions estimates are based on projections from the 2011 NEI.

³¹ Highway Vehicles include all on-road vehicles, including light duty as well as heavy duty vehicles, both gasoline- and diesel-powered. Off-Highway Vehicles and Engines include aircraft, commercial marine vessels, locomotives, and nonroad equipment. Fuel Combustion-Utilities includes electric power generating units (EGUs), which derive their power generation from all types of fuels. EGU emissions are dominated by coal combustion, which accounts for 86% of all NO_x emissions from utilities in the 2011 NEI. The Fuel Combustion-Other category includes commercial/institutional, industrial, and residential combustion of biomass, coal, natural gas, oil, and other fuels. Other Anthropogenic sources include field burning, prescribed fires, and various industrial processes (e.g., cement manufacturing, oil and gas production). On a national scale, agricultural field burning and prescribed fires are the greatest contributors to the Other Anthropogenic sources category. Biogenics and Wildfires include emissions estimates for plants and soil (i.e., biogenics) and for wildfires.



1

2 **Figure 2-2. Major sources of NO_x emissions in the U.S. from the 1980 and 2014 National**
 3 **Emissions Inventories.**

4 Despite substantial reductions, mobile source-related emissions still dominate the NO_x emissions
 5 inventory. Highway vehicles are the largest source NO_x emissions in the U.S., contributing 40%
 6 of the total NO_x emissions. Off-highway vehicles and engines account for 21% of emissions,
 7 EGUs for 14%, fuel combustion-other for 12%, other anthropogenic sources for 9%, and
 8 biogenics and wildfires for 3%.³²

9 In contrast to the reductions estimated across the largest categories of NO_x emitters,
 10 estimated NO_x emissions were 60% higher for the other anthropogenic category (Figure 2-2,
 11 above), with the greatest increases observed for oil and gas production, agricultural field burning,
 12 prescribed fires, and mining. While the fraction of total NO_x emissions that comes from oil/gas
 13 production is only about 5% nationwide, regional and local contributions from this industry can
 14 be much higher. For example, estimates in New Mexico, Oklahoma, and Texas indicate that up
 15 to about 14 to 17% of state NO_x emissions come from oil and gas operations.

³² <http://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data>

1 **2.2 AMBIENT NO₂ MONITORING**

2 **2.2.1 NO₂ Methods**

3 Ambient NO₂ concentrations are measured by monitoring networks operated by state,
4 local, and tribal air agencies, which are typically funded in part by the EPA. The main network
5 of monitors providing ambient data for use in implementation activities related to the NAAQS is
6 the State and Local Air Monitoring Stations (SLAMS) network. This network relies on a
7 chemiluminescent Federal Reference Method (FRM) and on Federal Equivalent Methods (FEM)
8 that use either chemiluminescence or direct measurement of NO₂. Chemiluminescent-based
9 FRMs only detect NO in the sample stream. Therefore, a two-step process is employed to
10 measure NO₂, based on the subtraction of NO from oxidized nitrogen.³³ Data produced by
11 chemiluminescent analyzers include NO, NO₂, and NO_x measurements, which are all routinely
12 logged by state and local agencies. Hourly average values are typically reported to the EPA’s Air
13 Quality System (AQS). There have been recent advances in methods that provide direct
14 measurements of NO₂, including cavity attenuated phase shift [CAPS] spectrometry and cavity
15 ring-down spectroscopy, but these methods do not provide NO or NO_x data (U.S. EPA, 2016,
16 Section 2.4).

17 **2.2.2 Ambient Monitoring Network**

18 Ambient NO₂ monitors in the SLAMS network began operating in the late 1970s and
19 have been used to make measurements supporting NAAQS compliance, the Photochemical
20 Assessment Monitoring Station (PAMS) program, and other objectives at the national, state, and
21 local levels. As of 2015, approximately 462 NO₂ monitors were in operation across the nation
22 and reporting to AQS. The network is currently growing with the addition of near-road monitors
23 (discussed below) and as part of the revisions to the PAMS requirements (80 FR 65291,
24 December 28, 2015).

³³ First, the analyzer determines the amount of NO in the sample air. Second, the analyzer re-routes air flow so that the sample air stream passes over a heated molybdenum oxide catalytic converter reducing a large majority (if not all) of the oxidized nitrogen species present in the sample stream to NO, before again measuring the amount of NO in the sample. The analyzer then subtracts the measured, actual ambient NO, determined in the first step, from the amount measured in the second step, allowing for the determination of NO, NO₂, and NO_x (where NO_x = NO + NO₂). The catalytic converter can convert nitric acid (HNO₃) and peroxyacetyl nitrate to NO, which would subsequently be counted as NO₂. Photolytic-chemiluminescence FEM carries out the reduction of NO₂ to NO in a photolytic converter with a known converter efficiency rate, which is specific to NO₂ and, thus, is not subject to the same positive bias potential as the chemiluminescent FRM.

1 In consideration of the location and measurement taken, each monitor is assigned a
2 spatial scale associated with the size of the area that it represents. The monitor spatial scales are
3 defined in 40 CFR 58 appendix D as:

- 4 1. *Microscale*: area dimensions ranging from several meters up to about 100 meters.
- 5 2. *Middle scale*: areas up to several city blocks in size with dimensions ranging from
6 about 100 meters to 0.5 kilometer.
- 7 3. *Neighborhood scale*: extended city area with relatively uniform land use and
8 dimensions in the 0.5 to 4.0 kilometers range.
- 9 4. *Urban scale*: area of city-like dimensions, on the order of 4 to 50 kilometers. Within
10 a city, the geographic placement of sources may result in there being no single site
11 that can be said to represent air quality on an urban scale.
- 12 5. *Regional scale*: rural area of reasonably homogeneous geography without large
13 sources, and extends from tens to hundreds of kilometers.
- 14 6. *National and global scales*: concentrations characterizing the nation and the globe as
15 a whole.

16 At the time of the last review of the primary NO₂ NAAQS, the majority of NO₂ monitors were
17 sited to represent the neighborhood scale. We used the term “area-wide” to refer to monitors
18 sited at neighborhood, urban, and regional scales, as well as those monitors sited at either micro-
19 or middle-scale that are representative of many such locations in the same core-based statistical
20 area (CBSA)³⁴ (75 FR 6474, February 9, 2010).

21 In the 2010 review of the primary NO₂ NAAQS, consideration of population exposures
22 was focused on major roadways. Due to the lack of monitors specifically sited near major
23 roadways, new near-road monitoring requirements were promulgated (75 FR 6474, February 9,
24 2010). Specifically, one near-road monitor was required in any CBSA with a population of
25 500,000 or more. An additional near-road monitor was required in CBSAs with populations of at
26 least 2,500,000 and in CBSAs with populations of at least 500,000 with roadway segments
27 carrying traffic volumes of at least 250,000 vehicles per day.

28 The near-road network was ultimately planned to be implemented in three phases. The
29 first phase included CBSAs with populations greater than 1,000,000 and was required to be
30 operational as of January 2014. The second phase included CBSAs with populations greater than
31 2,500,000 or with a road segment with an AADT of at least 250,000, and was required to be in
32 operation starting in January 2015. The third phase of monitors for CBSAs having a population

³⁴ A CBSA is a geographic area defined by the Office of Management and Budget (OMB) that consists of one or more counties anchored by an urban core with a population $\geq 10,000$. CBSAs have replaced metropolitan statistical areas (MSAs) that were previously used by OMB.

1 of 500,000 up to 1,000,000 were required to be in operation by January 2017.³⁵ As of the
 2 summer of 2016 the EPA estimates that 65 near-road monitors are in operation and reporting
 3 data to AQS.³⁶ Characteristics of near-road monitors are presented below in Table 2-1.

4
 5

Table 2-1. Characteristics of Newly Deployed Near-Road NO₂ Monitors.

CBSA Full Name	CBSA Population in 2015	Target Road	AADT of Target Road	Distance to Target Road (m)	NO ₂ Start Date
Atlanta-Sandy Springs-Roswell, GA	5,710,795	I-85	284,920	2.0	6/15/14
		I-285	146,000	30.0	12/31/14
Austin-Round Rock, TX	2,000,860	I-35	188,150	27.0	4/16/14
Bakersfield, CA	882,176	CA 99	132,000	20.0	8/1/16
Baltimore-Columbia-Towson, MD	2,797,407	I-95	186,750	16.2	4/1/14
		I-695/I-795	187,617	30.0	1/1/16
Birmingham-Hoover, AL	1,145,647	I-20	141,190	23.2	1/1/14
Boise, ID	676,909	I-84	103,000	32.0	4/1/12
Boston-Cambridge-Newton, MA-NH	4,774,321	I-93	198,239	10.0	6/1/13
		I-495	130,000	-	6/1/16
Buffalo-Cheektowaga-Niagara Falls, NY	1,135,230	I-90	131,019	20.0	3/24/14
Charlotte-Concord-Gastonia, NC-SC	2,426,363	I-77	153,000	30.0	7/17/14
Chicago-Naperville-Elgin, IL-IN-WI	9,551,031	I-90	330,000	25.0	TBD
		I-80/I-94	116,400	27.0	TBD
Cincinnati, OH-KY-IN	2,157,719	I-75	163,000	8.0	1/1/14
Cleveland-Elyria, OH	2,060,810	I-271	153,660	20.0	8/1/14
Columbus, OH	2,021,632	I-270	142,361	32.0	1/1/14
Dallas-Fort Worth-Arlington, TX	7,102,796	I-635	235,790	24.0	4/2/14
		I-20	184,680	15.0	3/12/15
Denver-Aurora-Lakewood, CO	2,814,330	I-25	249,000	8.7	6/1/13
		I-25	192,000	6.0	10/13/15
Des Moines-West Des Moines, IA	622,899	I-235	110,000	13.0	1/1/13
Detroit-Warren-Dearborn, MI	4,302,043	I-96	140,500	8.5	9/1/11
		I-275	172,600	49.0	1/1/15
Fresno, CA	974,861	CA 99	93,000	20.0	1/1/16
Hartford-West Hartford-East Hartford, CT	1,211,324	I-84	159,900	17.7	4/1/13
Houston-The Woodlands-Sugar Land, TX	6,656,947	I-69/US 59	324,119	24.0	1/22/14
		I-610	202,120	15.0	4/15/15
Indianapolis-Carmel-Anderson, IN	1,988,817	I-70	189,760	24.5	2/7/14
Jacksonville, FL	1,449,481	I-95	139,000	20.0	1/1/14
Kansas City, MO-KS	2,087,471	I-70	114,495	20.0	7/1/13
Las Vegas-Henderson-Paradise, NV	2,114,801	I-15	260,000	15.0	8/1/15
		US 95	177,000	15.0	9/1/15
Los Angeles-Long Beach-Anaheim, CA	13,340,068	I-5	272,000	9.0	1/1/14
		I-710	192,000	9.0	4/1/15
Louisville/Jefferson County, KY-IN	1,278,413	I-264	163,000	32.0	2/19/14
Memphis, TN-MS-AR	1,344,127	I-40	140,850	23.8	7/1/14
Miami-Fort Lauderdale-West Palm Beach, FL	6,012,331	I-95	306,000	30.0	4/20/15
		FL-836	197,000	-	6/1/16
Milwaukee-Waukesha-West Allis, WI	1,575,747	I-94	133,000	14.0	1/1/14
Minneapolis-St. Paul-Bloomington, MN-WI	3,524,583	I-94/I-35W	277,000	32.5	4/1/13
		I-35	87,000	30.0	1/1/15

³⁵ The EPA has proposed to remove the third phase of the near-road network (81 FR 30224, May 16, 2016).

³⁶ The meta-data collected about these sites are available at <http://www3.epa.gov/ttn/amtic/nearroad.html>.

Nashville-Davidson--Murfreeseboro--Franklin, TN	1,830,345	I-40/I-24	144,204	30.0	7/1/14
New Orleans-Metairie, LA	1,262,888	I-610	68,015	28.5	3/18/14
New York-Newark-Jersey City, NY-NJ-PA	20,182,305	I-95/US 1	311,234	20.0	6/26/14
		I-495	166,339	28.0	9/1/16
Oklahoma City, OK	1,358,452	I-44	155,300	13.6	4/1/15
Orlando-Kissimmee-Sanford, FL	2,387,138	I-4	195,773	49.5	12/1/16
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	6,069,875	I-95	124,610	12.0	1/1/14
		I-76	154,955	18.0	7/1/15
Phoenix-Mesa-Scottsdale, AZ	4,574,531	I-10	320,138	12.0	2/13/14
		I-10	260,136	20.0	9/1/15
Pittsburgh, PA	2,353,045	I-376	87,534	18.0	9/1/14
Portland-Vancouver-Hillsboro, OR-WA	2,389,228	I-5	156,000	27.0	4/21/14
Providence-Warwick, RI-MA	1,613,070	I-95	186,300	5.0	4/1/14
Raleigh, NC	1,273,568	I-40	141,000	20.0	1/8/14
Richmond, VA	1,271,334	I-95	151,000	21.0	10/17/13
Riverside-San Bernardino-Ontario, CA	4,489,159	I-10	245,300	50.0	7/1/14
		SR-60	215,000	9.0	1/1/15
Rochester, NY	1,081,954	I-490	110,990	20.0	12/18/14
Sacramento--Roseville--Arden-Arcade, CA	2,274,194	I-5	186,000	20.0	10/13/15
Salt Lake City, UT	1,170,266	-	-	-	TBD
San Antonio-New Braunfels, TX	2,384,075	I-35	201,840	20.0	1/8/14
San Diego-Carlsbad, CA	3,299,521	I-5	160,000	-	6/1/16
		I-15	223,000	37.0	3/27/15
San Francisco-Oakland-Hayward, CA	4,656,132	I-880	216,000	20.0	2/1/14
		I-80	265,000	25.0	8/1/16
San Jose-Sunnyvale-Santa Clara, CA	1,976,836	US 101	191,000	32.0	9/21/14
San Juan, Puerto Rico	2,196,538	De Diego	127,300	12.0	7/8/14
		-	-	-	TBD
Seattle-Tacoma-Bellevue, WA	3,733,580	I-5	237,000	8.0	3/31/14
		I-5	208,000	30.0	12/23/15
St. Louis, MO-IL	2,811,588	I-64	159,326	25.0	1/1/13
		I-70	161,338	27.0	1/10/15
Tampa-St. Petersburg-Clearwater, FL	2,975,225	I-275	190,500	20.0	2/5/14
		I-275	141,000	25.0	6/1/16
Virginia Beach-Norfolk-Newport News, VA-NC	1,724,876	I-264	199,000	10.0	12/1/16
Washington-Arlington-Alexandria, DC-VA-MD-WV	6,097,684	I-95	297,000	16.0	4/5/16
		DC-295	115,480	15.0	6/1/15

Italicized dates reflect anticipated start dates; a '-' indicates that information is not available

1

2 2.3 NO₂ MONITORING DATA TRENDS AND AIR QUALITY RELATIONSHIPS

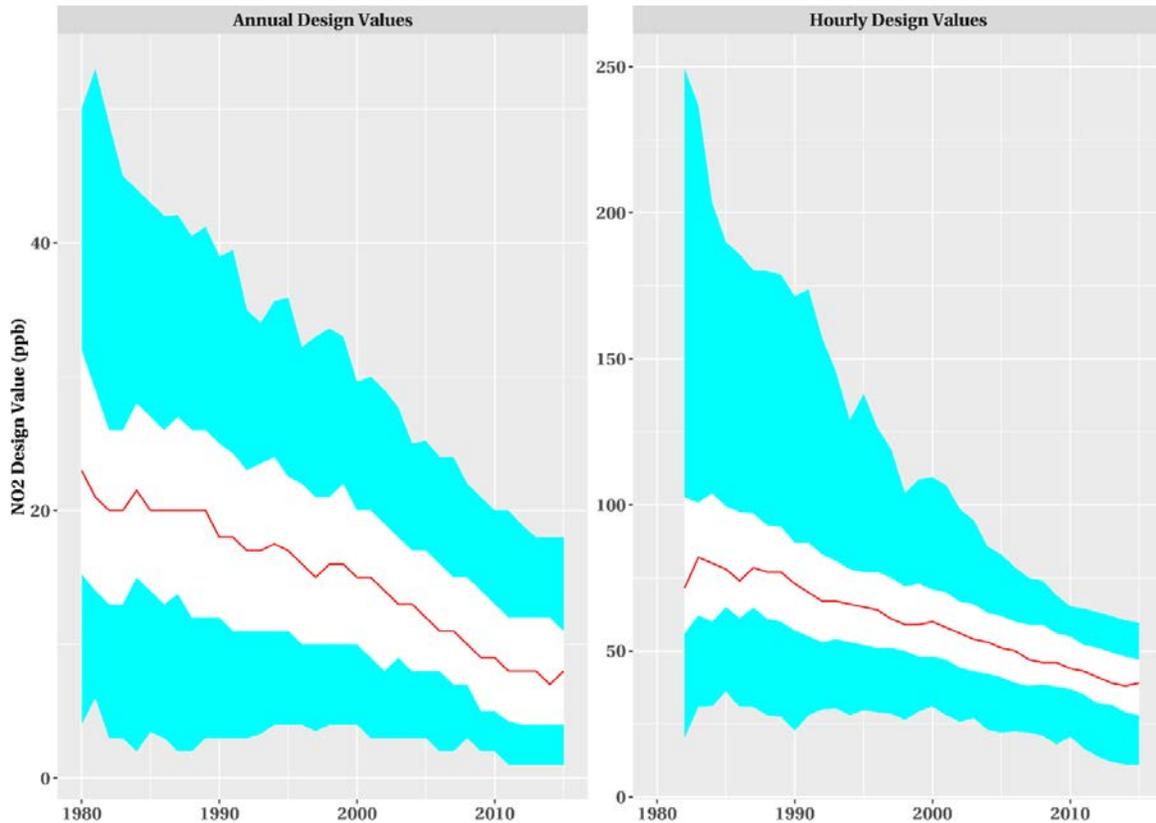
3 This section presents information on ambient NO₂ concentrations. Section 2.3.1 presents
4 data on national trends in ambient NO₂ concentrations, Section 2.3.2 presents data on the NO₂
5 concentrations measured by recently deployed near-road monitors, Section 2.3.3 presents data on
6 the relationships between 1-hour and annual NO₂ concentrations, and Section 2.3.4 discusses
7 background NO₂ concentrations.

8 2.3.1 National Trends in Ambient NO₂ Concentrations

9 The metric used to determine whether areas meet or violate the NAAQS is called a
10 design value (DV). In the case of NO₂, there are 2 types of DVs: the annual DV and the hourly

1 DV. The annual DV for a particular year is the average of all hourly values within that calendar
2 year. The hourly DV is the three-year average of the 98th percentiles of the annual distributions
3 of daily maximum 1-hour NO₂ concentrations. DVs are considered to be valid if the monitoring
4 data used to calculate them meet completeness criteria described in the CFR.³⁷

5 The long-term trends in DVs across the U.S. are displayed in Figures 2-3 and 2-4. The
6 distributions of valid³⁸ DVs across the country as a function of time are shown in Figure 2-3.
7 Figure 2-3 shows that DVs across the country have been, on average, declining since 1980.



8

9 **Figure 2-3. Distributions of NO₂ design values across the U.S. from 1980- 2015.** The middle
10 lines represent the median, the middle white band extends from the 25th to the 75th percentile,
11 and the outer colored band extends from the 5th to the 95th percentile.

³⁷ See http://www.ecfr.gov/cgi-bin/text-idx?SID=86b930e674d72c8e0e14bb65c51a0047&mc=true&node=se40.2.50_111&rgn=div8 for more information on the calculation of DVs.

³⁸ As indicated previously, 40 CFR part 50 appendix S states that a year is considered complete when all 4 quarters have at least 75 percent of the sampling days, with a sampling day requiring coverage of 75 percent of the hours in the day. The 1-hour DV requires 3 years of complete data.

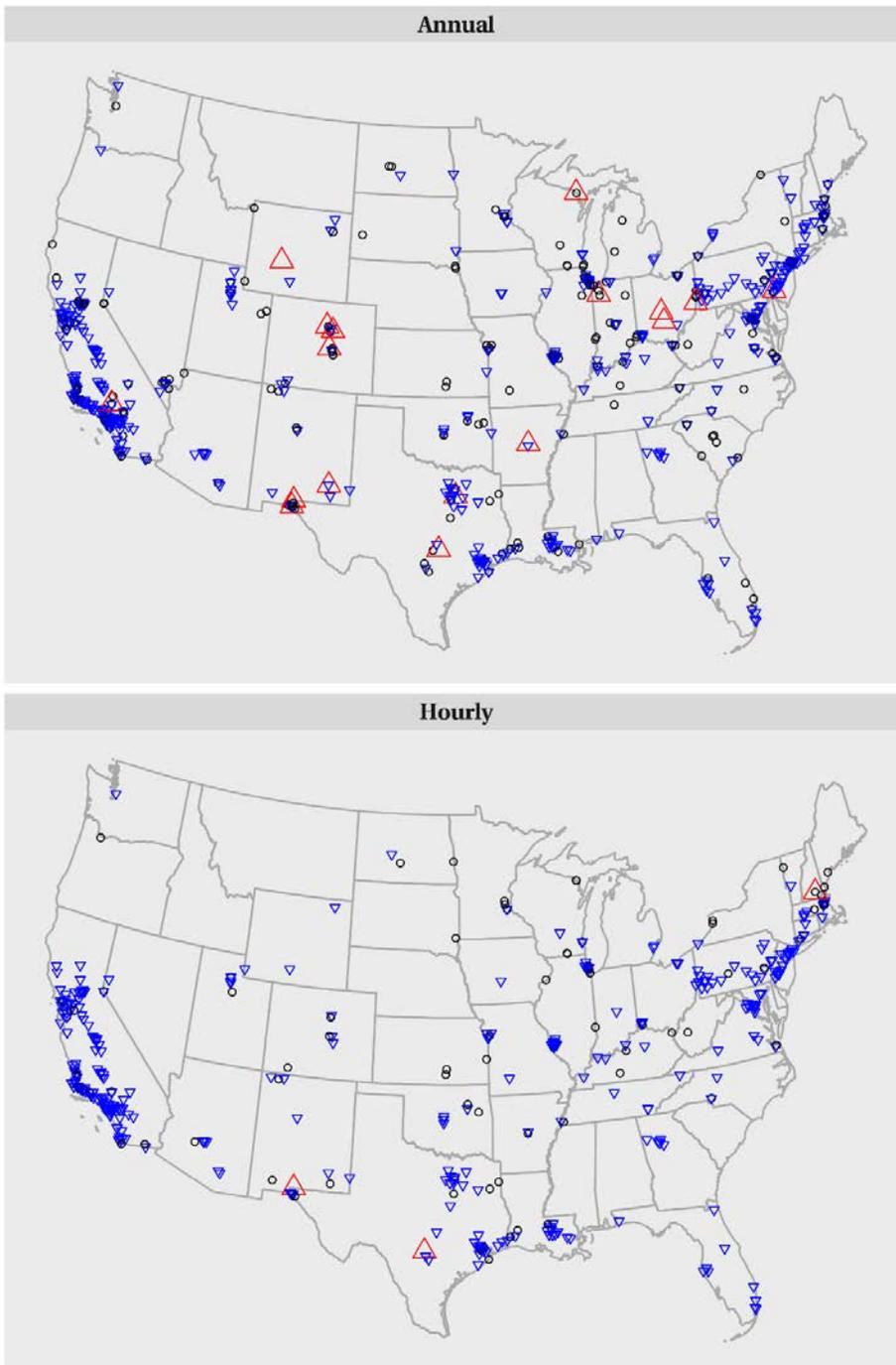
1 Figure 2-4 shows maps of the NO₂ monitoring network, with the direction of the symbol and
2 color of each point indicating the long term (1980-2015) trend direction.³⁹ Since 1980, NO₂
3 sampling has been performed at 2099 sites across the continental U.S. However, only sampling
4 sites with data sufficient to produce at least 5 valid DVs were considered in this analysis. After
5 this screen, 647 and 433 monitors were used to determine trends of annual and hourly DVs,
6 respectively.

7 Figure 2-4 shows that the majority of sampling sites have observed statistically
8 significant downward trends in ambient NO₂ concentrations, with the annual and hourly DVs
9 showing downward trends at 61.5% and 74.8% of monitoring sites, respectively.⁴⁰ At 3.9% and
10 1.8% of sites the annual and hourly DVs trended upward, and at the remaining 34.6% and 23.3%
11 sites no significant trend was found.

12

³⁹ These directions were determined using the sign of spearman correlation coefficient between DV and year. Only DVs determined to be valid by the completeness criteria in CFR 40 Appendix S were included in the calculation. Trend directions were determined to be insignificant if the associated p-values were greater than 0.05 (95% confidence level).

⁴⁰ Since this analysis required 5 valid DVs, these trends do not reflect the near-road monitoring network.



Direction of DV Trend: ▽ Decreasing ▲ Increasing ○ Insignificant

1

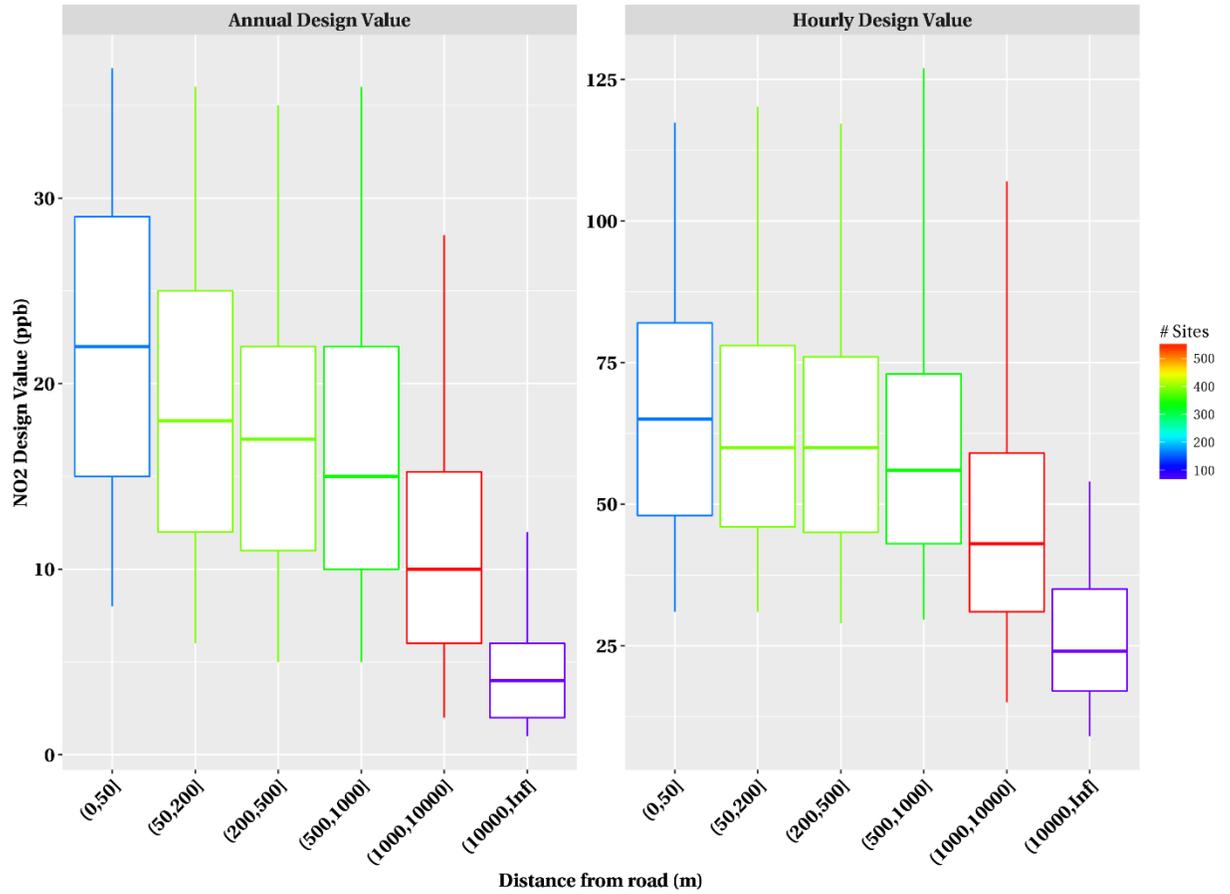
2 **Figure 2-4. Trend directions of NO₂ design values for 1980-2015 at U.S. sampling sites.**

2.3.2 Near-Road NO₂ Air Quality

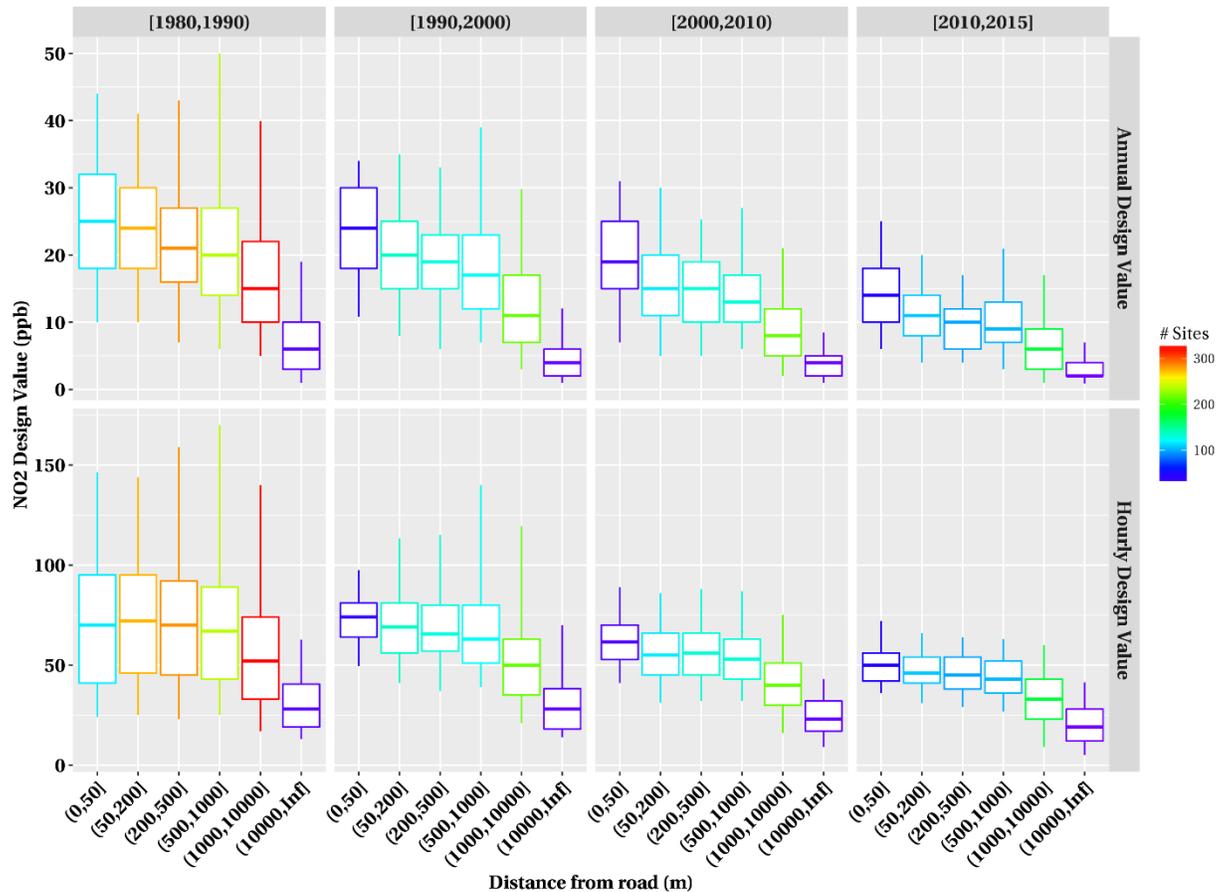
As discussed above, the largest single source of NO_x emissions is on-road vehicles, and emissions are primarily in the form of NO, with NO₂ formation requiring both time and sufficient O₃ concentrations. Depending on local meteorological conditions and O₃ concentrations, ambient NO₂ concentrations can be higher near roadways than at sites in the same area but farther removed from the road (and from other sources of NO_x emissions). To better understand the historical relationships between distributions of NO₂ concentrations at monitors near roadways and monitors further away from roads,⁴¹ the annual and hourly DVs from 1980 to 2015 are plotted as a function of distance from road in Figures 2-5 and 2-6.⁴² This analysis focused on monitors located inside the boundary of CBSAs. Figure 2-5 pools data from all years, and Figure 2-6 presents distributions of DVs for each decade from 1980 to 2015, which includes monitors from the EPA near-road network. In all graphs, the color is mapped to the number of sites included in each boxplot.

⁴¹ As defined by the 2012 HPMS shapefile used to determine road locations, located at <http://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm>. This file contains main roads that are part of the National Highway System. See Appendix A for more details.

⁴² NO₂ monitors meeting the near-road siting requirements set forth in the 2010 NO₂ NAAQS were not available in most CBSAs prior to 2014. In particular, monitors were not sited within 50 m of the most heavily trafficked roads in an area. Thus, the historical relationships reflected in Figures 2-5 and 2-6 do not reflect the relationships that existed between NO₂ concentrations and distance from the most heavily trafficked roads.



1
 2 **Figure 2-5. Distributions of NO₂ design values as a function of the distances from roads in**
 3 **CBSAs from 1980-2015.** The middle lines represent the median, box edges represent the 25th
 4 and 75th percentiles, and whisker ends represent the 5th and 95th percentiles.



1
 2 **Figure 2-6. Distributions by decade of NO₂ design values for six different bins of distances**
 3 **from major roads in CBSAs.** The middle lines represent the median, box edges represent the
 4 25th and 75th percentiles, and whisker ends represent the 5th and 95th percentiles.

5
 6 Figures 2-5 and 2-6 indicate that NO₂ DVs are generally highest at sampling sites nearest
 7 to the road (less than 50 meters) and decrease as distance from the road increases. This
 8 relationship is more pronounced for annual DVs than for hourly DVs (Figure 2-5). The general
 9 pattern of decreasing DVs with increasing distance from the road has persisted over time (Figure
 10 2-6), though the absolute difference (in terms of ppb) between NO₂ concentrations close to roads
 11 and those farther from roads has decreased over time (i.e., Figure 2-6, compare 1980-1990 DVs
 12 with 2010-2015 DVs⁴³). This decrease is likely due to the concurrent decrease in mobile source
 13 NO_x emissions discussed above (Figure 2-2).

⁴³ In Figure 2-6, data from recently deployed near-road monitors are included for the 2010 to 2015 time frame. However, because three years of data are not yet available from most near-road monitors, the 1-hour “near-road” concentrations plotted in Figure 2-6 generally do not reflect actual hourly DVs.

1 Figures 2-7, 2-8 and 2-9 further explore the relationships between NO₂ concentrations
2 measured by newly deployed near-road monitors and those measured by non-near-road monitors
3 (generally area-wide⁴⁴) in the same CBSA. For the years 2013, 2014 and 2015, we identified
4 CBSAs with complete NO₂ data from at least one near-road and one non-near-road monitor.⁴⁵
5 Each near-road monitor was paired with the non-near-road monitor in the same CBSA that
6 measured the highest 98th percentile NO₂ concentrations.⁴⁶ Distributions of daily maximum 1-
7 hour NO₂ concentrations from these monitor pairs are presented for 2013 (Figure 2-7), 2014
8 (Figure 2-8) and 2015 (Figure 2-9).⁴⁷

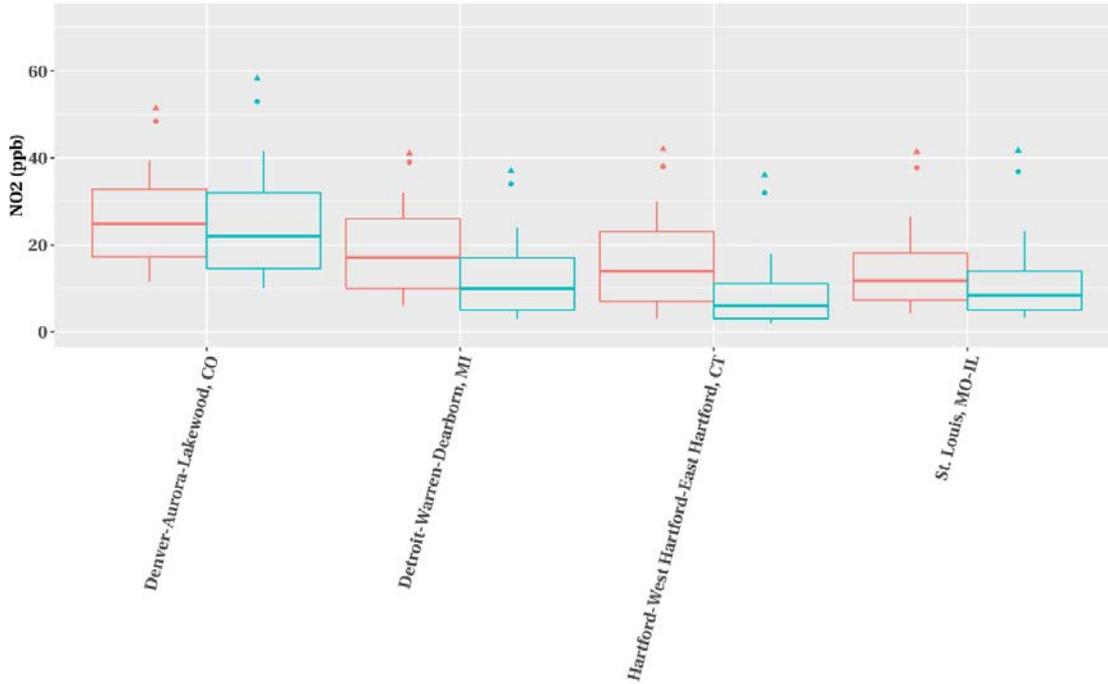
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⁴⁴ Non-near-road monitors can generally be considered area-wide, but in some cases, non-near-road monitors can be located close to stationary sources of NO_x emissions.

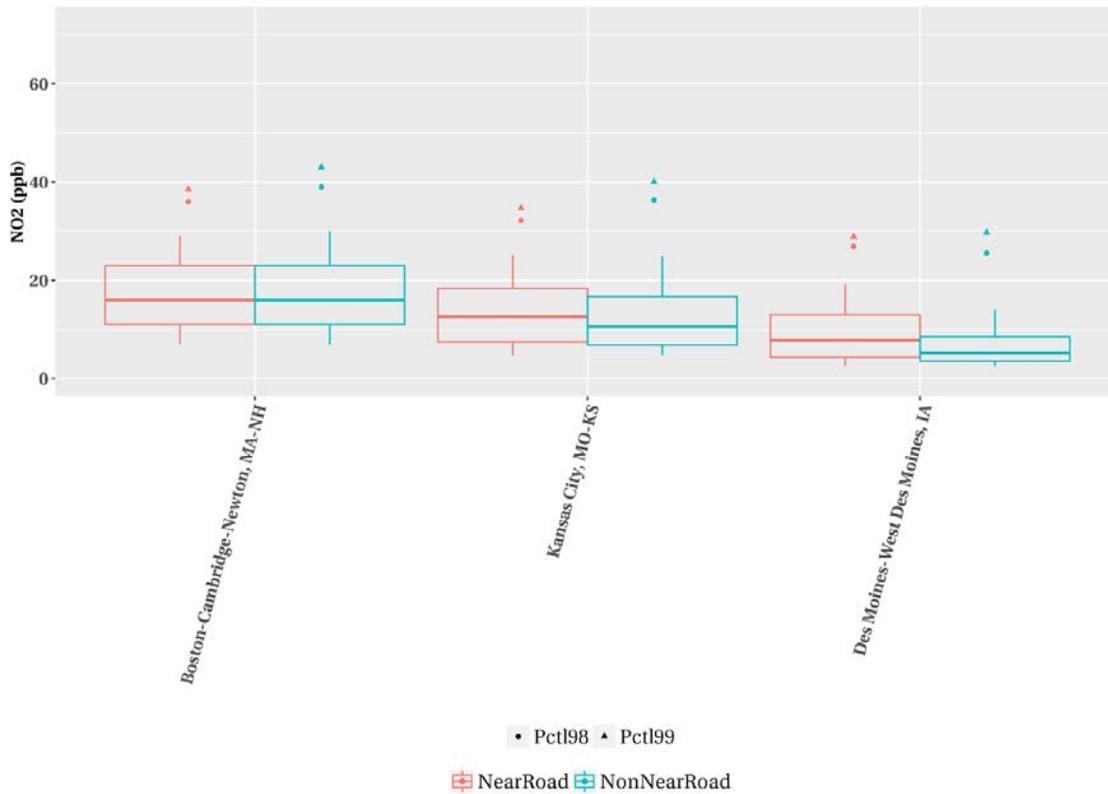
⁴⁵ As indicated, 40 CFR part 50 appendix S states that a year is considered complete when all 4 quarters have at least 75 percent of the sampling days, with a sampling day requiring coverage of 75 percent of the hours in the day.

⁴⁶ 98th percentiles from non-near-road monitors were based on the same years that the near-road monitor was in operation.

⁴⁷ Because three years of data are not available from most near-road monitors, true DVs could not be calculated from measurements at these monitors.

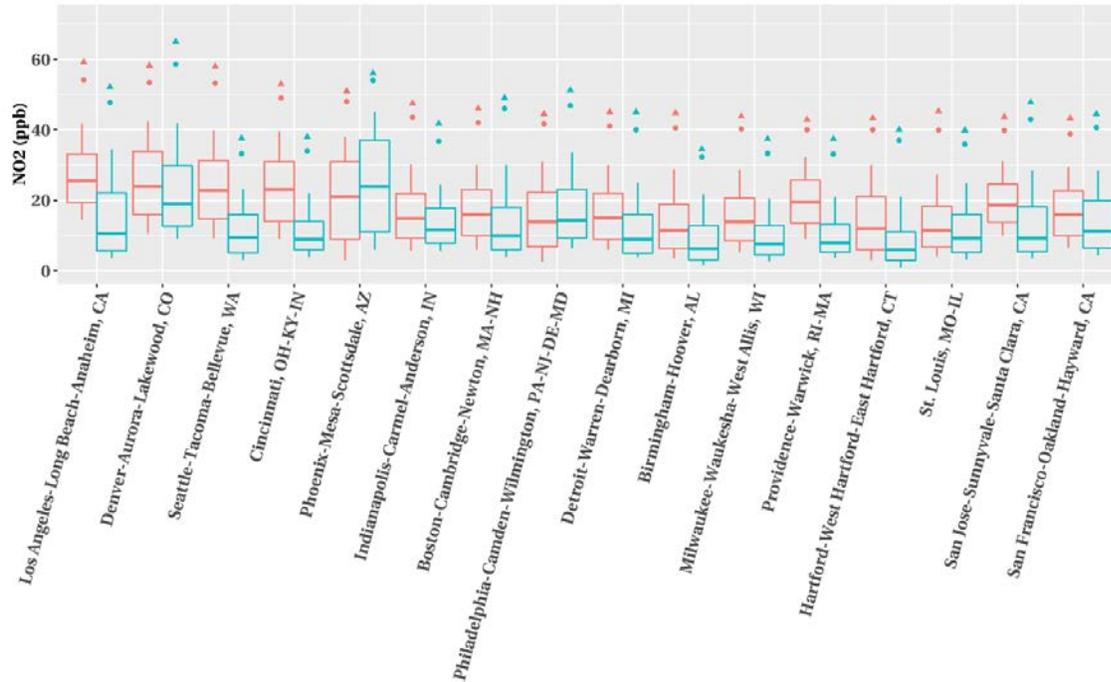


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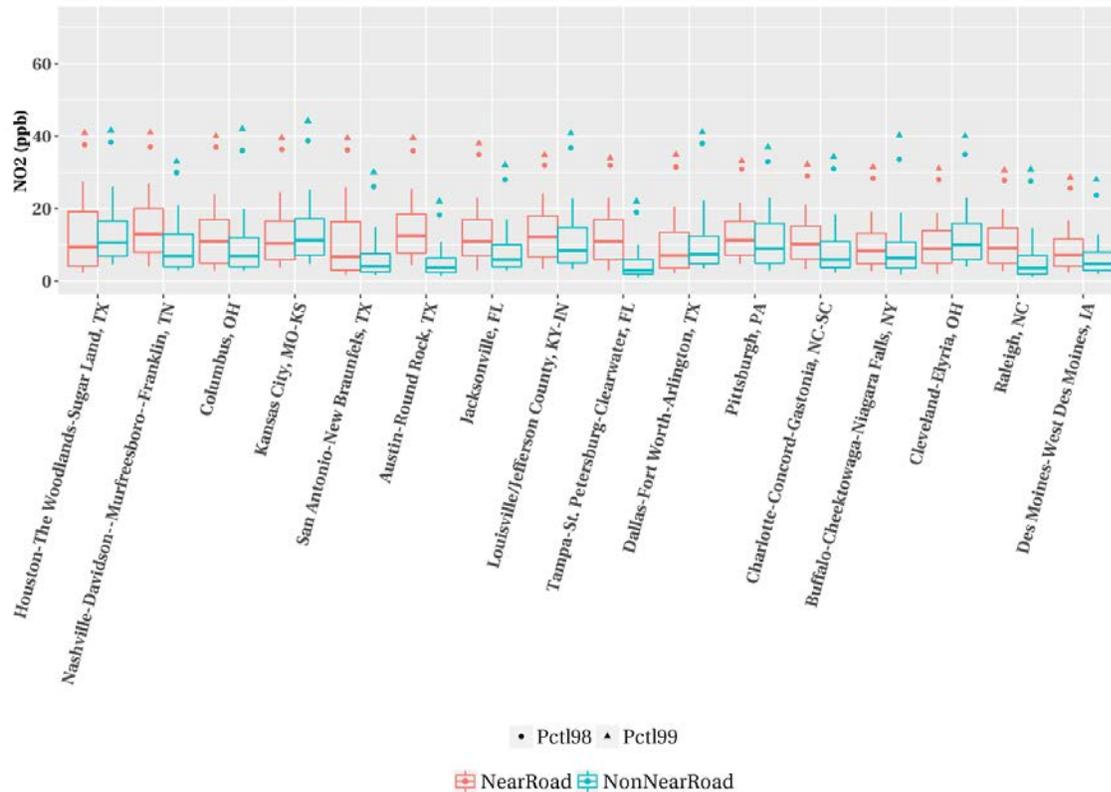


2

Figure 2-7. Distributions of the near-road and non-near-road maximum 1-hr daily NO₂ concentrations from 2013. The middle lines represent the median, box edges represent the 25th and 75th percentiles, and whisker ends represent the 5th and 95th percentiles. Circles represent 98th percentiles and triangles represent 99th percentiles.

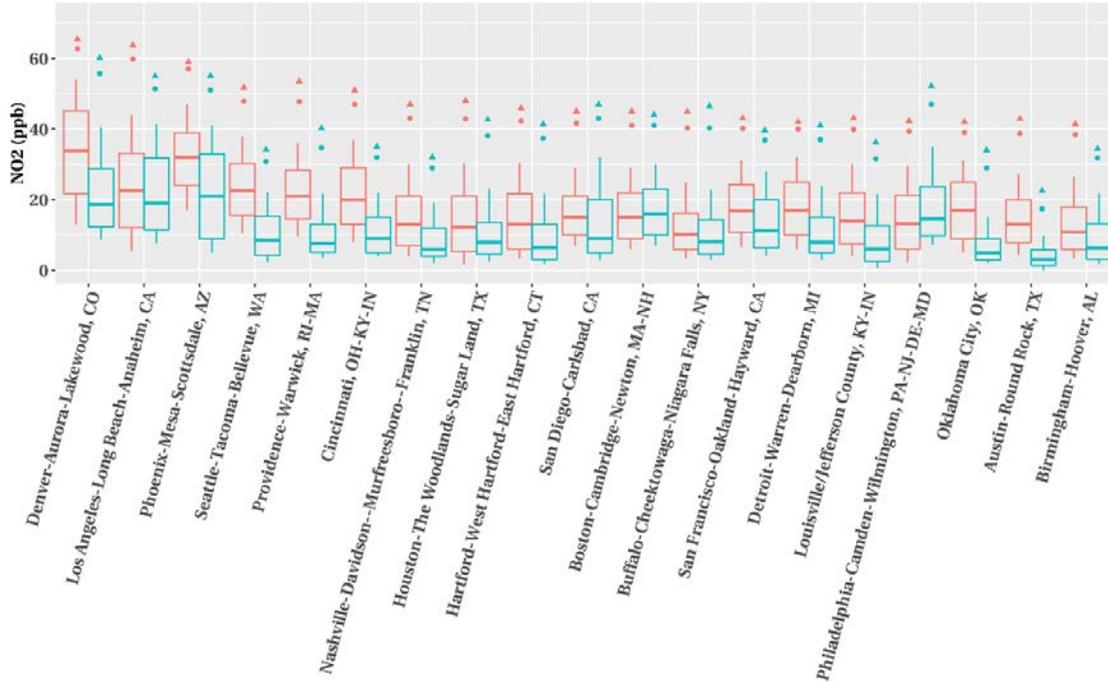


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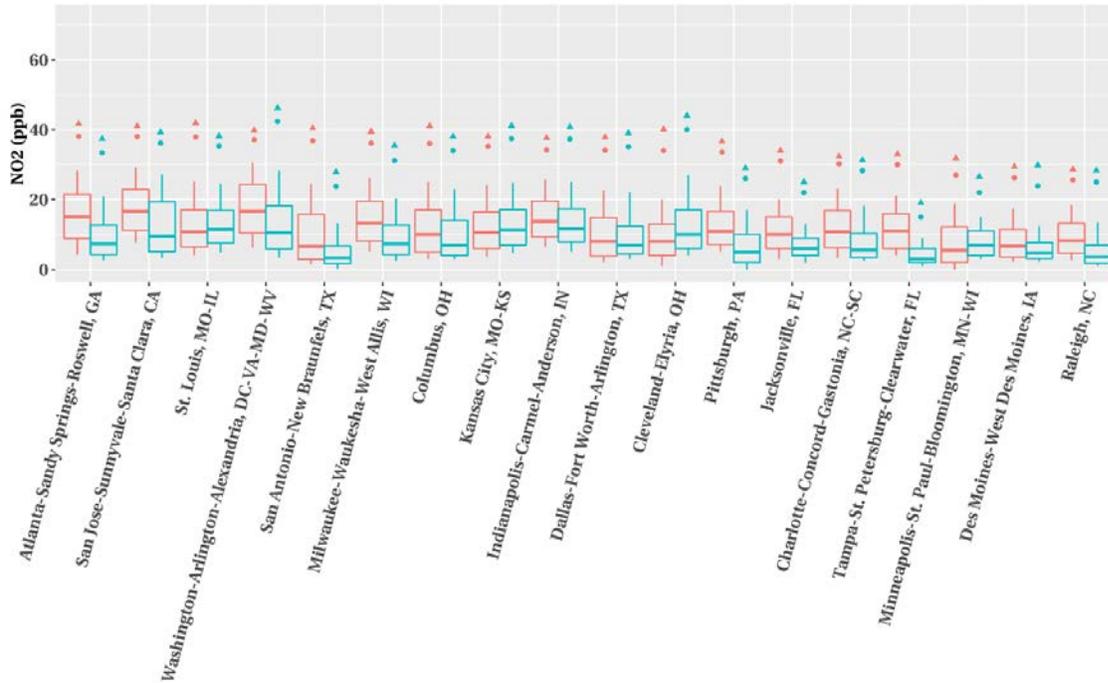


2

3 **Figure 2-8. Distributions of the near-road and non-near-road maximum 1-hr daily NO₂**
 4 **concentrations from 2014.** The middle lines represent the median, box edges represent the 25th
 5 and 75th percentiles, and whisker ends represent the 5th and 95th percentiles. Circles represent
 6 98th percentiles and triangles represent 99th percentiles.



1



• Pctl98 ▲ Pctl99

■ NearRoad ■ NonNearRoad

2

3 **Figure 2-9. Distributions of the near-road and non-near-road maximum 1-hr daily NO₂**
 4 **concentrations from 2015.** The middle lines represent the median, box edges represent the 25th
 5 and 75th percentiles, and whisker ends represent the 5th and 95th percentiles. Circles represent
 6 98th percentiles and triangles represent 99th percentiles.

1 For the 3 years of available data, Figures 2-7 to 2-9 indicate that daily maximum 1-hour
2 NO₂ concentrations are generally higher at near-road monitors than at the non-near-road
3 monitors in the same CBSA. The 98th percentile of 1-hour daily maximum concentrations (the
4 statistic most relevant to the current standard) were higher at near-road monitors in 58-73% of
5 the CBSAs evaluated, depending on the year.⁴⁸

6 **2.3.3 Relationships between Hourly and Annual NO₂ Concentrations**

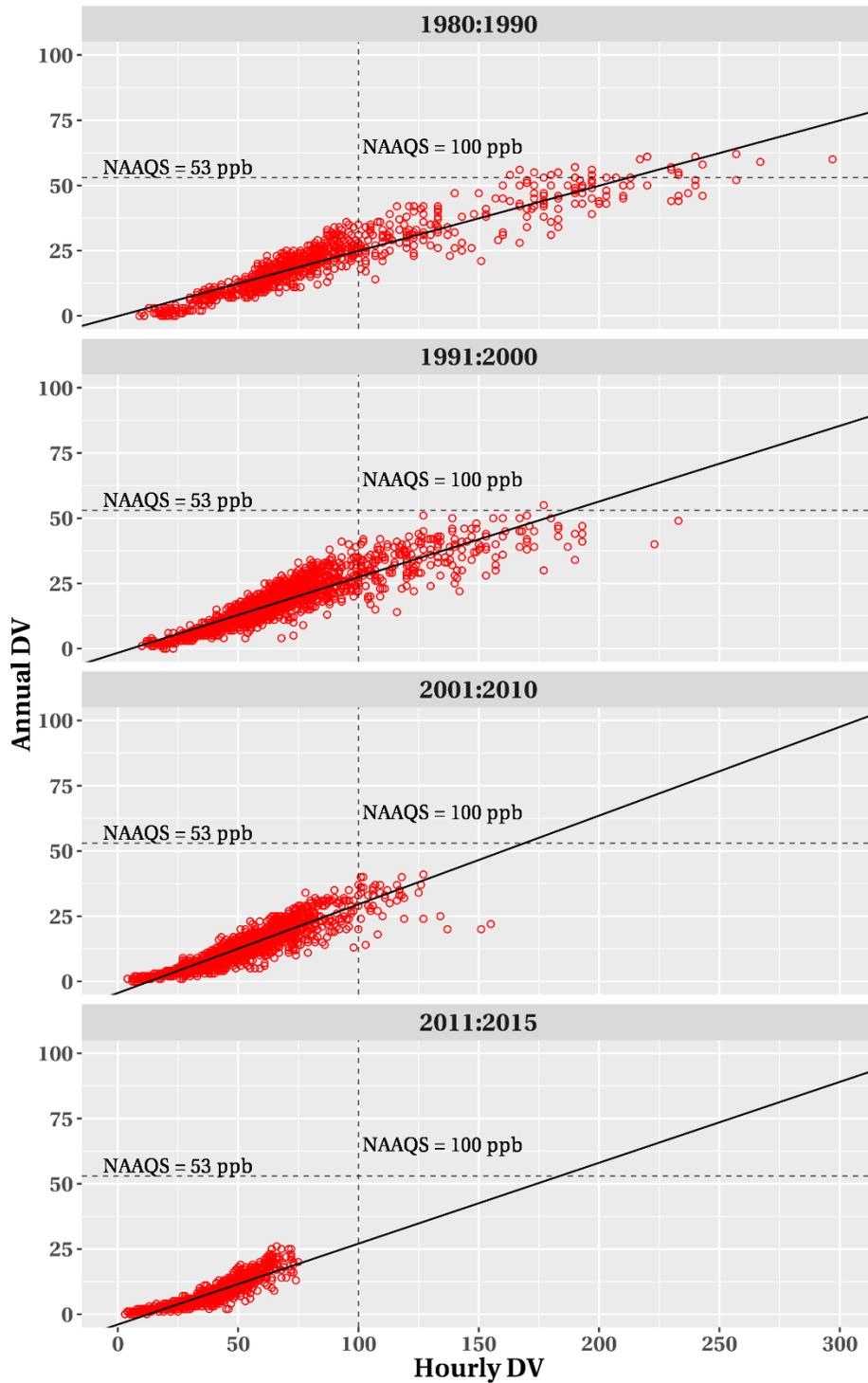
7 As discussed above, control programs have resulted in substantial reductions in NO_x
8 emissions since the 1980s. These reductions in NO_x emissions have decreased both short-term
9 peak NO₂ concentrations and annual average concentrations. In Figure 2-10, we examine how
10 the relationship between hourly and annual NO₂ concentrations, based on 1-hour and annual NO₂
11 DVs, has changed since 1980. Figure 2-10 illustrates the relationship between 1-hour and annual
12 DVs at individual monitors across the U.S., with data segregated by decade.⁴⁹

13 When considering the change from the 1980-1990 bin to the 2010-2015 bin, the median
14 annual DV has decreased by about 65% (i.e., from ~23 ppb to ~8 ppb) and the median 1-hour
15 DV has decreased by about 50% (i.e., from ~74 ppb to ~37 ppb) (Figure 2-10). At various times
16 in the past, a number of sites would have violated the 1-hour standard without violating the
17 annual standard; however, no sites would have violated the annual standard without also
18 violating the 1-hour standard. Furthermore, these data indicate that 1-hour DVs correspond to
19 annual DVs of about 35 ppb or below. Thus, meeting the 1-hour standard with its level of 100
20 ppb would be expected to maintain annual NO₂ concentrations well-below the 53 ppb level of
21 the annual standard.⁵⁰

⁴⁸ This is the case for 4 of 7 CBSAs in 2013, 18 of 32 CBSAs in 2014, and 29 of 37 CBSAs in 2015.

⁴⁹ Because the annual DV is based on a single year of data, while the 1-hour DV is based on three years of data, the pairing is based on the last year of data included as part of each DV (i.e., the 2012 annual DV at a particular monitor is paired with the hourly DV based on data from 2010-2012 from the same monitor).

⁵⁰ Near-road monitors are not included in this analysis due to the limited amount of data available.



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 2 **Figure 2-10. Relationships between annual and hour DVs from 1980 to 2015.** Hourly and
 3 annual DVs are plotted for various decades. Linear regression lines are shown.

1 **2.3.4 Background NO₂ Concentrations**

2 In the context of the review of a NAAQS, the EPA generally defines background
3 concentrations in a way that distinguishes among concentrations that result from precursor
4 emissions that are relatively less controllable from those that are relatively more controllable
5 through U.S. policies or through international agreements. One approach to considering
6 background concentrations is to estimate the pollutant concentrations that would exist in the
7 absence of anthropogenic emissions from the U.S., Canada, and Mexico. Such background
8 concentrations are referred to as North American Background (NAB). NAB includes
9 contributions resulting from emissions by natural sources (e.g., soils, wildfires, and lightning
10 around the world and by anthropogenic sources outside of the U.S., Canada, and Mexico.⁵¹

11 NO₂ background concentrations are much lower than the NO₂ concentrations currently
12 measured in the ambient air (and much lower than current standard levels). In particular, as
13 discussed in the 2008 ISA, NAB is less than 300 ppt over most of the continental U.S. and less
14 than 100 ppt in the eastern U.S. (U.S. EPA, 2008, Figure 2.4-18). The distribution of background
15 concentrations in the 2008 ISA was shown to reflect the distribution of soil NO emissions and
16 lightning, with some local increases due to biomass burning, mainly in the western U.S. In the
17 northeastern U.S., where present-day NO₂ concentrations are highest, NAB contributes <1% to
18 the total NO₂ concentration (U.S. EPA, 2016, Section 2.5.6).

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⁵¹ Other approaches to defining background include U.S. background (USB), which includes contributions from emissions from natural sources and from anthropogenic sources outside the U.S., and natural background, which includes only contributions from emissions from natural sources.

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3 CONSIDERATION OF EVIDENCE FOR NO₂-RELATED HEALTH EFFECTS

In this chapter, the scientific evidence on health effects attributable to short or long-term NO₂ exposure is discussed, with a focus on the most policy relevant information. Staff has drawn from the EPA's synthesis and assessment of the scientific evidence presented in the *Integrated Science Assessment for Oxides of Nitrogen – Health Criteria (ISA)* (U.S. EPA, 2016). In this chapter, Section 3.1 summarizes the weight of evidence approach used in evaluating and integrating scientific evidence in the ISA. Section 3.2 characterizes the evidence for health effects attributable to short-term NO₂ exposures, and Section 3.3 characterizes the evidence for health effects attributable to long-term NO₂ exposures. Section 3.4 discusses the potential public health implications of NO₂-attributable effects.

3.1 WEIGHT OF EVIDENCE IN THE ISA

In the current review of the primary NO₂ NAAQS, the Agency has used two frameworks: one for characterizing the strength of the available scientific evidence for health effects attributable to NO₂ exposures and the other a recently developed framework to classify evidence for factors that may increase risk in some populations or lifestages (U.S. EPA, 2015, Preamble, Section 6). These frameworks provide the basis for robust, consistent, and transparent evaluation of the scientific evidence, including uncertainties in the evidence, and for drawing conclusions on air pollution-related health effects and at-risk populations.

With regard to characterization of the health effects, the ISA uses a five-level hierarchy to classify the overall weight-of-evidence into one of the following categories: causal relationship; likely to be a causal relationship; suggestive of, but not sufficient to infer, a causal relationship; inadequate to infer a causal relationship; and not likely to be a causal relationship (U.S. EPA, 2015, Preamble Table II). In using the weight of evidence approach to inform judgments about the likelihood that various health effects are caused by exposure to NO₂, the ISA notes that confidence in the relationship increases when the evidence base is large and consistently supports a relationship with a particular health endpoint. In addition, biological plausibility, strength, and coherence in the evidence are important aspects considered in making judgments regarding causal relationships. Conclusions about biological plausibility, consistency, and coherence of NO₂-related health effects are drawn from the integration of multiple lines of evidence including epidemiologic, controlled human exposure, and animal toxicological studies as discussed in the ISA (U.S. EPA, 2015, Section 5.c.) and further described below. In this draft PA, we consider the full body of health evidence, placing the greatest emphasis on the effects for

1 which the evidence has been judged in the ISA to demonstrate a “causal” or a “likely to be a
2 causal” relationship with NO₂ exposures.

3 Controlled human exposure studies can provide direct evidence of relationships between
4 pollutant exposures and human health effects (U.S. EPA, 2015, Preamble section 4.c). Because
5 data on health effects in these studies are collected under closely monitored conditions, this type
6 of evidence can provide information on exposure concentrations, durations, and ventilation rates
7 under which effects can occur, as well as information on exposure-response relationships.
8 Further, as discussed in the ISA, controlled human exposure studies can provide clear and
9 compelling evidence for an array of human health effects that are directly attributable to acute
10 exposures to NO₂ *per se* (i.e., as opposed to other oxides of nitrogen species, for which NO₂ is an
11 indicator, or other co-occurring pollutants) (U.S. EPA, 2016, Preamble Section 4.c). In addition,
12 exposure concentrations used in some controlled human exposure studies are near those found in
13 the ambient air and results are not subject to uncertainties related to inter-species variation.

14 Toxicological studies in animals provide another line of experimental evidence that can
15 inform understanding of effects related to NO₂ exposures, particularly the biological action of a
16 pollutant under controlled and monitored exposure circumstances. Compared to controlled
17 human exposure studies, animal toxicological studies can examine more severe outcomes,
18 invasive endpoints (i.e., pathology), and effects of long-term exposures. However, results from
19 animal studies are subject to uncertainty due to inter-species variation.⁵² Also, animal studies are
20 often conducted with NO₂ concentrations well above those in ambient air. Although some of
21 these high concentrations are considered to be ambient-relevant because of dosimetric
22 considerations (U.S. EPA, 2016, Section 1.2), results from animal studies are subject to
23 uncertainties regarding the likelihood that such effects could occur with ambient exposures in
24 humans. Nonetheless, evidence from animal studies can provide support for effects observed in
25 human studies. Together, evidence from human and animal studies can provide information on
26 and confidence regarding key events in the proposed mode(s) of action, which informs biological
27 plausibility for health effects observed in epidemiologic studies.

28 Epidemiologic studies provide information on associations between variability in short-
29 term and long-term average ambient NO₂ concentrations and various health outcomes, including
30 those related to asthma exacerbation and incidence (i.e., airway responsiveness, lung function

⁵² “The differences between humans and other species have to be considered, including metabolism, hormonal regulation, breathing pattern, and differences in lung structure and anatomy. Given these differences, uncertainties are associated with quantitative extrapolations of observed pollutant-induced pathophysiological alterations between laboratory animals and humans, as those alterations are under the control of widely varying biochemical, endocrine, and neuronal factors.” (U.S. EPA, 2016, pp. liii).

1 decrements, respiratory symptoms, pulmonary inflammation, hospital admissions, emergency
2 department visits, and asthma incidence) (U.S. EPA, 2016, Chapters 5 and 6). Epidemiologic
3 studies can inform our understanding of the effects in the study population of real-world
4 exposures to the range of NO₂ concentrations in ambient air, and can provide evidence of
5 associations between exposures to ambient NO₂ and serious acute and chronic health effects that
6 cannot be assessed in controlled human exposure studies. Moreover, epidemiologic studies often
7 include populations or lifestages that may have increased risk for pollutant-related health effects
8 (e.g., individuals with pre-existing disease, children, and older adults). In evaluating
9 epidemiologic studies, it is important to consider the degree of uncertainty introduced by
10 potential confounding variables (e.g., other pollutants, temperature) and other factors (e.g., study
11 design exposure assessment, statistical methods) affecting the level of confidence that the
12 observed health effects are independently related to ambient exposure to NO₂.

13 The ISA also includes an evaluation and synthesis of evidence across scientific
14 disciplines to inform whether specific populations or lifestages may be at increased risk of a
15 health effect related to NO₂ exposures. The ISA characterizes the evidence for a number of
16 “factors”, including both intrinsic (i.e., biologic, such as pre-existing disease or lifestage) and
17 extrinsic (i.e., non-biologic, such as diet or socioeconomic status) factors. The categories
18 considered in classifying the evidence for these potential at-risk factors are “adequate evidence,”
19 “suggestive evidence,” “inadequate evidence,” and “evidence of no effect.” These categories are
20 discussed in more detail in the ISA (U.S. EPA, 201, Section 5.c, Table II). In this PA, we focus
21 our consideration of potential at-risk populations and lifestages on those factors for which the
22 ISA judges there is “adequate” evidence (U.S. EPA, 2016, Table 7-27). The primary NAAQS are
23 set to protect the public health with an adequate margin of safety, including the health of
24 populations⁵³ at increased risk for pollutant-related health effects, and thus, identifying at-risk
25 populations and lifestages is a critical part of this review. At-risk populations and potential
26 public health implications are discussed in more detail in Section 3.4.

27 **3.2 EFFECTS OF SHORT-TERM NO₂ EXPOSURES**

28 This section discusses the nature of the health effects that have been shown to occur following
29 short-term NO₂ exposures (Section 3.2.1) and the NO₂ concentrations at which those effects have
30 been demonstrated to occur (Section 3.2.2).

⁵³ As defined in Chapter 1, the term “population” refers to people having a quality or characteristic in common, including a specific pre-existing illness or a specific age or lifestage.

1 **3.2.1 Nature of Effects**

2 Across previous reviews of the primary NO₂ NAAQS (U.S. EPA, 1993; U.S. EPA,
3 2008), evidence has consistently demonstrated respiratory effects attributable to short-term NO₂
4 exposures. In the last review, the 2008 ISA concluded that evidence was “sufficient to infer a
5 likely causal relationship between short-term NO₂ exposure and adverse effects on the
6 respiratory system” based on the large body of epidemiologic evidence demonstrating positive
7 associations with respiratory symptoms and hospitalization or ED visits as well as supporting
8 evidence from controlled human exposure and animal studies (U.S. EPA, 2008, p. 5-6). Evidence
9 for cardiovascular effects and mortality evaluated in the 2008 ISA was weaker and was judged
10 “inadequate to infer the presence or absence of a causal relationship” or “suggestive of, but not
11 sufficient to infer, a causal relationship,” respectively. In particular, the 2008 ISA noted an
12 overarching uncertainty in determining the extent to which NO₂ is independently associated with
13 effects or if NO₂ is a marker for the effects of another traffic-related pollutant or mix of
14 pollutants (U.S. EPA, 2008, Section 5.3.2.2 to 5.3.2.6).

15 For the current review, there is newly available evidence for both respiratory effects and
16 other health effects critically evaluated in the ISA as part of the full body of evidence informing
17 the nature of the relationship between health effects and short-term exposures to NO₂ (U.S. EPA,
18 2016). In characterizing the available evidence and the causal determinations presented in the
19 ISA, this section poses the following policy-relevant questions:

- 20 • **To what extent does the currently available scientific evidence strengthen, or otherwise**
21 **alter, our conclusions from the last review regarding health effects attributable to**
22 **short-term NO₂ exposure? Have previously identified uncertainties been reduced?**
23 **What important uncertainties remain and have new uncertainties been identified?**

24 As discussed above, causal determinations for health effects related to short-term NO₂
25 exposures are presented in the ISA, which classifies short-term exposures as those that are one
26 month or less (U.S. EPA, 2016). Table 3-1, below, lists the causal determinations from the ISA
27 for the current review as well as those from the previous review for respiratory and
28 cardiovascular health effects, and mortality.⁵⁴ It is noteworthy that the causal determinations for
29 respiratory and cardiovascular health effects have been strengthened in the current review due, in
30 part, to more explicit consideration of the evidence integrated for specific outcomes (e.g., asthma
31 exacerbation for respiratory) rather than broad outcome categories (e.g., all respiratory effects).

⁵⁴ Short-term exposure studies on reproductive and birth health effects and cancer are considered in the context of long-term exposures for cohesive discussion.

1 The evidence informing these determinations, including uncertainties in that evidence, is
2 summarized below.

Table 3-1. Causal determinations for short-term nitrogen dioxide (NO₂) exposure and health effects evaluated in the ISA for Oxides of Nitrogen in the previous and current reviews

Health effect	Review completed 2010	Current Review
Respiratory	Sufficient to infer a likely causal relationship	Causal relationship
Cardiovascular	Inadequate to infer the presence or absence of a causal relationship	Suggestive of, but not sufficient to infer, a causal relationship
Total Mortality	Suggestive of, but not sufficient to infer, a causal relationship	Suggestive of, but not sufficient to infer, a causal relationship

3

4 Respiratory

5 The ISA concludes that evidence for respiratory effects related to short-term NO₂
6 exposures indicates that there is a causal relationship, primarily based on evidence for asthma
7 exacerbation. This conclusion is strengthened from the last review “because epidemiologic,
8 controlled human exposure, and animal toxicological evidence together can be linked in a
9 coherent and biologically plausible pathway to explain how NO₂ exposure can trigger an asthma
10 exacerbation” (U.S. EPA, 2016, p. 1-17). The 2008 ISA described much of the same evidence
11 and determined it was “sufficient to infer a likely causal relationship”, citing uncertainty as to
12 whether the epidemiologic results for NO₂ primarily reflected the effects of other traffic-related
13 pollutants. The 2008 ISA did not explicitly evaluate the extent to which various lines of evidence
14 supported effects on asthma attacks. In contrast, in the current review the ISA states that “the
15 determination of a causal relationship is not based on new evidence as much as it is on the
16 integrated findings for asthma attacks with due weight given to experimental studies” (U.S. EPA,
17 2016, p. 1xxxiii). When taken together, the epidemiologic evidence for asthma attacks and
18 controlled human exposure study findings for increased airway responsiveness (AR)⁵⁵ and
19 allergic inflammation demonstrate that short-term NO₂ exposure has an independent relationship
20 with respiratory effects, specifically with asthma exacerbation, and is not just an indicator for
21 other traffic-related pollutants.

⁵⁵ The ISA states that airway responsiveness is “inherent responsiveness of the airways to challenge by bronchoconstricting agents” (U.S. EPA, 2016, p. 5-9). More specifically, airway responsiveness refers to increased sensitivity of the airways to an inhaled bronchoconstricting agent. This is most often quantified as the dose of challenge agent that results in a 20% reduction in FEV₁, but some studies report the change in FEV₁ for a specified dose of challenge agent. The change in specific airways resistance (sRaw) is also used to quantify AR.

1 The evaluation of controlled human exposure studies in the ISA focuses on results from a
2 recently published meta-analysis of NO₂-induced increases in AR by Brown (2015). AR has
3 been the key respiratory outcome from controlled human exposures in the previous and current
4 reviews of the primary NO₂ NAAQS, and the ISA specifically notes that “airway
5 hyperresponsiveness can lead to poorer control of symptoms and is a hallmark of asthma” (U.S.
6 EPA, 2016, p. 1-18). Brown (2015) examined the relationship between AR and NO₂ exposures in
7 subjects with asthma across the large body of controlled human exposure studies, most of which
8 were available in the last review (Tables 3-2 and 3-3). More specifically, the meta-analysis
9 identified the fraction of individuals having an increase in AR following NO₂ exposure,
10 compared to the fraction having a decrease, across studies. The meta-analysis also stratified
11 results to consider the influence of factors that may affect results including exercise/rest and non-
12 specific/specific challenge agents.⁵⁶

13 The results from the meta-analysis demonstrate that the majority of study volunteers with
14 asthma experienced increased AR following resting exposure to NO₂ concentrations ranging
15 from 100 to 530 ppb, relative to filtered air. While results from individual studies did not always
16 demonstrate NO₂-induced increases in AR, particularly for exposure concentrations between 100
17 and 200 ppb (U.S. EPA, 2016, Table 5-1), the meta-analysis indicates that when data are pooled,
18 a statistically significant majority of study volunteers experienced an increase in nonspecific
19 airway responsiveness following (1) 20 to 60-minute exposures to 400-530 ppb NO₂, (2)
20 30-minute exposures to 250 to 300 ppb NO₂, and (3) 60-minute exposures to 100 to 200 ppb
21 NO₂. When comparing results across the three exposure categories, not including study
22 volunteers that experienced no change in AR, the fractions of individuals with increased AR are
23 73%, 78%, and 67%, respectively, and all were statistically significant with *p*-values < 0.05
24 (U.S. EPA, 2016, Table 5-3). In addition, the meta-analysis shows that, for some study
25 volunteers, NO₂ exposures reduced by one-half the dose of a challenge agent required to increase
26 airway responsiveness, indicating the potential for NO₂-induced increases in AR to be clinically
27 relevant in about a quarter of the volunteers with asthma exposed to NO₂ at rest.⁵⁷

⁵⁶ "Bronchial challenge agents can be classified as nonspecific (e.g., histamine; SO₂; cold air) or specific (i.e., an allergen). Nonspecific agents can be differentiated between “direct” stimuli (e.g., histamine, carbachol, and methacholine) which act on airway smooth muscle receptors and “indirect” stimuli (e.g., exercise, cold air) which act on smooth muscle through intermediate pathways, especially via inflammatory mediators. Specific allergen challenges (e.g., house dust mite, cat allergen) also act “indirectly” via inflammatory mediators to initiate smooth muscle contraction and bronchoconstriction.” (U.S. EPA, 2016, p. 5-8)

⁵⁷ With regard to this, the ISA notes that “In a joint statement of the American Thoracic Society (ATS) and European Respiratory Society, one doubling dose change in PD is recognized as a potential indicator, although not a validated estimate, of clinically relevant changes in airway responsiveness (Reddel et al., 2009).”

1 Controlled human exposure studies also evaluated a range of other respiratory effects,
2 including lung function decrements, respiratory symptoms, and pulmonary inflammation. The
3 evidence does not consistently demonstrate these effects following exposures to NO₂
4 concentrations at or near those found in the ambient air in the U.S. However, a subset of studies
5 using exposures to 260 ppb for 15-30 min or 400 ppb for up to 6 hours provide evidence that
6 study volunteers with asthma and allergy can experience increased inflammatory responses
7 following allergen challenge. Evidence for pulmonary inflammation was more mixed across
8 studies that did not use an allergen challenge following NO₂ exposures ranging from 300-1,000
9 ppb (U.S. EPA, 2016, Section 5.2.2.5).

10 In addition to this evidence for NO₂-induced increases in AR and allergic inflammation
11 in controlled human exposure studies, the ISA also describes consistent evidence from
12 epidemiologic studies for positive associations between short-term NO₂ exposures and an array
13 of respiratory outcomes related to asthma. Thus, coherence and biological plausibility is
14 demonstrated in the evidence integrated between controlled human exposure studies and the
15 various asthma-related outcomes examined in epidemiologic studies. The ISA indicates that
16 epidemiologic studies consistently demonstrate NO₂-health effect associations with asthma
17 hospital admissions and ED visits among subjects of all ages and children, and with asthma
18 symptoms in children (U.S. EPA, 2016, Sections 5.2.2.4 and 5.2.2.3). The robustness of the
19 evidence is demonstrated by associations found in studies conducted in diverse locations in the
20 U.S., Canada, and Asia, including several multicity studies. The evidence for asthma
21 exacerbation is substantiated by several recent studies with strong exposure assessment
22 characterized by measuring NO₂ concentrations in subjects' location(s). Epidemiologic studies
23 also demonstrated associations between short-term NO₂ exposures and respiratory symptoms,
24 lung function decrements, and pulmonary inflammation, particularly for measures of personal
25 total and ambient NO₂ exposures and NO₂ measured outside schools. This is important because
26 there is considerable spatial variability in NO₂ concentrations, and measurements in subjects'
27 locations may better represent this variability in ambient NO₂ exposures, compared to
28 measurements at central site monitors (U.S. EPA, 2016, Sections 2.5.3 and 3.4.4). Epidemiologic
29 studies generally did not find NO₂-associated changes in inflammatory cell counts in populations
30 with asthma; however, they did consistently indicate ambient or personal NO₂-associated
31 increases in exhaled nitric oxide (eNO, a marker of airway inflammation), which is coherent with
32 experimental findings for allergic inflammation (U.S. EPA, 2016, Section 5.2.2.6).

1 In assessing the evidence from epidemiologic studies, the ISA not only considers the
2 consistency of effects across studies, but also evaluates other study attributes that affect study
3 quality, including potential confounding and exposure assignment. Regarding potential
4 confounding, the ISA notes that NO₂ associations with asthma-related effects persist with
5 adjustment for temperature; humidity; season; long-term time trends; and PM₁₀, SO₂, or O₃.
6 Recent studies also add findings for NO₂ associations that generally persist with adjustment for
7 key copollutants, including PM_{2.5} and traffic-related copollutants such as elemental carbon (EC)
8 or black carbon (BC), ultra-fine particles (UFPs), or carbon monoxide (CO) (examined in few
9 studies). Confounding by organic carbon (OC), PM metal species, or volatile organic compounds
10 (VOCs) is poorly studied, but NO₂ associations with asthma exacerbation tend to persist in the
11 few available copollutant models. We recognize, however, that copollutant models have inherent
12 limitations and cannot conclusively rule out confounding (U.S. EPA, 2015, Section 4.b). Recent
13 epidemiologic results also suggest asthma exacerbation in relation to indices that combine NO₂
14 with EC, PM_{2.5}, O₃, and/or SO₂ concentrations, but neither epidemiologic nor experimental
15 studies strongly indicate synergistic effects between NO₂ and copollutants (U.S. EPA, 2016,
16 Section 5.2.9).

17 Finally, the ISA also notes that results based on personal exposures or pollutants
18 measured at people's locations also provide support for NO₂ associations that are independent of
19 PM_{2.5}, EC/BC, OC, or UFPs. Compared to ambient NO₂ concentrations measured at central-site
20 monitors, personal NO₂ exposure concentrations and indoor NO₂ concentrations exhibit lower
21 correlations with many traffic-related copollutants (e.g., $r = -0.37$ to 0.31). Thus, these health
22 effect associations with personal and indoor NO₂ may be less prone to confounding by these
23 traffic-related copollutants (U.S. EPA, 2016, Section 1.4.3).

24 Overall, in consideration of this evidence in answering the question posed above, we note
25 that for respiratory effects, the strongest evidence supporting the conclusion of the causal
26 relationship determined in the ISA comes from controlled human exposure studies demonstrating
27 NO₂-induced increases in AR in individuals with asthma, with supporting evidence for a range of
28 respiratory effects from epidemiologic studies. The conclusion of a causal relationship in the ISA
29 is based on this evidence, and its explicit integration within the context of effects related to
30 asthma exacerbation. Most of the controlled human exposure studies assessed in the ISA were
31 available in the last review, particularly studies of non-specific AR, and thus, do not themselves
32 provide substantively new information. However, the newly available meta-analysis by Brown
33 (2015) has partially addressed an uncertainty from the last review by demonstrating the potential
34 for clinically relevant NO₂-induced increases in AR pooling data from a limited number of
35 studies. Similarly, the epidemiologic evidence that is newly available in the current review is

1 consistent with evidence from the last review and does not alter our understanding of respiratory
2 effects related to ambient NO₂ exposures. New epidemiologic evidence does, however, reduce
3 some uncertainty from the last review regarding the extent to which effects may be
4 independently related to NO₂ as there is more evidence from studies using measures that better
5 capture personal exposure as well as a more robust evidence base examining copollutant
6 confounding. Some uncertainty remains in the epidemiologic evidence regarding confounding by
7 the most relevant copollutants (i.e., those from traffic).

8 Cardiovascular

9 The evidence for cardiovascular health effects and short-term NO₂ exposures in the ISA
10 was judged “suggestive of, but not sufficient to infer, a causal relationship” (U.S. EPA, 2016,
11 Section 5.3.11), which is stronger than the conclusion in the last review that the evidence was
12 “inadequate to infer the presence or absence of a causal relationship.” The recent causal
13 determination was primarily supported by consistent epidemiologic evidence from multiple new
14 studies indicating associations for triggering of a myocardial infarction. However, further
15 evaluation and integration of evidence points to uncertainty related to exposure measurement
16 error and potential confounding by traffic-related pollutants. There is consistent evidence
17 demonstrating NO₂-associated hospital admissions and ED visits for ischemic heart disease,
18 myocardial infarction, and angina as well as all cardiovascular diseases, which is coherent with
19 evidence from other studies indicating NO₂-associated repolarization abnormalities and
20 cardiovascular mortality. There are experimental studies that provide some evidence for effects
21 on key events in the proposed mode of action (e.g., systemic inflammation) but do not provide
22 evidence that is coherent with the epidemiologic studies to help rule out chance, confounding,
23 and other biases. Beyond evidence for myocardial infarction, there were studies examining other
24 cardiovascular health effects, but results across these outcomes are inconsistent. While the
25 evidence is stronger in the current review than in the last review, it does not substantially alter
26 our understanding of cardiovascular effects related to short-term NO₂ exposures, and important
27 uncertainties remain regarding the independent effects of NO₂.

28

29 Mortality

30 The ISA concludes that the evidence for short-term NO₂ exposures and total mortality is
31 “suggestive of, but not sufficient to infer, a causal relationship” (U.S. EPA, 2016, Section 5.4.8),
32 which is the same conclusion reached in the last review (U.S. EPA, 2008). Several recent
33 multicity studies add to the evidence base for the current review and demonstrate associations
34 that are robust in copollutant models with PM₁₀, O₃, or SO₂. However, confounding by traffic-

1 related copollutants is of greatest concern, which is not examined in the available copollutant
2 models for NO₂-associated mortality. Overall, the recent evidence assessed in the ISA builds
3 upon and supports conclusions in the last review, but key limitations across the evidence include
4 a lack of biological plausibility as experimental studies and epidemiologic studies on
5 cardiovascular morbidity, a major cause of mortality, do not clearly provide a mechanism by
6 which NO₂-related effects could lead to mortality as well as uncertainties regarding the
7 independent effect of NO₂.

8 **3.2.2 Consideration of NO₂ Concentrations: Health Effects of Short-Term NO₂ Exposures**

9 In evaluating the NO₂ exposure concentrations associated with health effects within the
10 context of the adequacy of the current standard, we consider the following specific question:

- 11 • **To what extent does the evidence indicate adverse respiratory effects attributable to**
12 **short-term exposures to NO₂ concentrations lower than previously identified or that**
13 **would be allowed by the current standards?**

14 In addressing this question, we evaluate the extent to which NO₂-induced adverse effects have
15 been reported over the ranges of NO₂ exposure concentrations evaluated in controlled human
16 exposure studies and the extent to which NO₂-associated effects have been reported for
17 distributions of ambient NO₂ concentrations in epidemiologic study locations meeting existing
18 standards. Each of these is discussed below.

19 *3.2.2.1 NO₂ Concentrations in Controlled Human Exposure Studies*

20 Controlled human exposure studies, most of which were available and considered in the
21 last review, have evaluated various respiratory effects following short-term NO₂ exposures.
22 These include AR, inflammation and oxidative stress, respiratory symptoms, and lung function
23 decrements, as discussed in detail in the ISA (U.S. EPA, 2016) and summarized above in Section
24 3.2.1. Generally, when considering respiratory effects from controlled human exposure studies in
25 healthy adults without asthma, evidence does not indicate respiratory symptoms or lung function
26 decrements following NO₂ exposures below 4,000 ppb and limited evidence indicates airway
27 inflammation following exposures below 1,500 ppb (U.S. EPA, 2016, Section 5.3.7). There is a
28 substantial body of evidence demonstrating increased AR in healthy adults with exposures in the
29 range of 1,500-3,000 ppb.

30 Evidence for respiratory effects following exposures to NO₂ concentrations at or near
31 those found in the ambient air is strongest for AR in individuals with asthma (U.S. EPA, 2016,
32 Section 5.2.2 p. 5-7). In contrast, controlled human exposure studies evaluated in the ISA do not
33 provide consistent evidence for respiratory symptoms, lung function decrements, or pulmonary
34 inflammation in adults with asthma following exposures to NO₂ concentrations at or near those

1 in ambient air (i.e., <1,000 ppb; U.S. EPA, 2016, Section 5.2.2). There is some indication of
 2 allergic inflammation in adults with allergy and asthma following exposures to 260-1,000 ppb.
 3 However, evidence across studies is inconsistent, making it difficult to interpret the likelihood
 4 that these effects could potentially occur following NO₂ exposures at or below the level of the
 5 current standard.

6 Thus, in considering evidence from controlled human exposure studies to address the
 7 above question, we focus on the body of evidence for NO₂-induced increases AR in adults with
 8 asthma. In evaluating the NO₂ exposure concentrations at which increased AR is observed, we
 9 consider both the group mean results reported in individual studies and the results evaluated
 10 across studies in a recent meta-analysis (Brown, 2015; U.S. EPA, 2016, Section 5.2.2.1). Group
 11 mean responses in individual studies, and the variability in those responses, can provide insight
 12 into the extent to which observed changes in AR are due to NO₂ exposures, rather than to chance
 13 alone, and have the advantage of being based on the same exposure conditions. The meta-
 14 analysis by Brown (2015) can aid in identifying trends in individual-level responses across
 15 studies and can have the advantage of increased power to detect effects, even in the absence of
 16 statistically significant effects in individual studies.

17 Tables 3-2 and 3-3 (adapted from the ISA; U.S. EPA, 2016, Tables 5-1 and 5-2) provide
 18 details for the studies examining AR in individuals with asthma at rest and with exercise,
 19 respectively. These tables note various study details including the exposure concentration,
 20 duration of exposure, type of challenge (nonspecific or specific⁵⁸), number of study subjects,
 21 number of subjects having an increase or decrease in AR following NO₂ exposure, average
 22 provocative dose (PD; dose of challenge agent required to elicit a particular magnitude of change
 23 in FEV₁ or other measure of respiratory function) across subjects, and the statistical significance
 24 of the change in AR following NO₂ exposures.

Table 3-2. Resting exposures to nitrogen dioxide and airway responsiveness in individuals with asthma.^a

Reference	NO ₂ ppb	Exp. (min)	Challenge Type	N	Change in AR ^b		Average PD ± SE ^c		p-value ^d
					+	-	Air	NO ₂	
Ahmed et al., 1983a	100	60	Non-specific, CARB	20	13	7	6.0 ± 2.4	2.7 ± 0.8	NA

⁵⁸ As previously described, bronchial challenge agents can be classified as nonspecific (e.g., histamine; sulfur dioxide, SO₂; cold air) or specific (i.e., an allergen). Nonspecific agents can be differentiated between “direct” stimuli (e.g., histamine, carbachol, and methacholine) and “indirect” stimuli (e.g., exercise, cold air) (U.S. EPA, 2016)

Table 3-2. Resting exposures to nitrogen dioxide and airway responsiveness in individuals with asthma.^a

Reference	NO ₂ ppb	Exp. (min)	Challenge Type	N	Change in AR ^b		Average PD ± SE ^c		p-value ^d
					+	-	Air	NO ₂	
Orehek et al., 1976	100	60	Non-specific, CARB	20	14	3	0.56 ± 0.08	0.36 ± 0.05	<0.01 ^e
Hazucha et al., 1983	100	60	Non-specific, METH	15	6	7	1.9 ± 0.4	2.0 ± 1.0	n.s.
Ahmed et al., 1983b	100	60	Specific, RAG	20	10	8	9.0 ± 5.7	11.7 ± 7.6	n.s.
Tunncliffe et al., 1994	100	60	Specific, HDM	8	3	5	-14.62 ΔFEV ₁	-14.41 ΔFEV ₁	n.s.
Bylin et al., 1988	140	30	Non-specific, HIST	20	14	6	0.39 ± 0.07	0.28 ± 0.05	0.052 ^f
Orehek et al., 1976	200	60	Non-specific, CARB	4	3	0	0.60 ± 0.10	0.32 ± 0.02	n.s.
Jörres et al., 1990	250	30	Non-specific, SO ₂	14	11	2	46.5 ± 5.1	37.7 ± 3.5	<0.01
Barck et al., 2002	260	30	Specific, BIR, TIM	13	5	7	-5 ± 2 ΔFEV ₁	-4 ± 2 ΔFEV ₁	n.s.
Strand et al., 1997	260	30	Specific, BIR, TIM	18	9	9	860 ± 450	970 ± 450	n.s.
Strand et al, 1998	260	30	Specific, BIR	16	11	4	-0.1 ± 0.8 ΔFEV ₁	-2.5 ± 1.0 ΔFEV ₁	0.03
Bylin et al., 1988	270	30	Non-specific, HIST	20	14	6	0.39 ± 0.07	0.24 ± 0.04	<0.01
Tunncliffe et al., 1994	400	60	Specific, HDM	8	8	0	-14.62 ΔFEV ₁	-18.64 ΔFEV ₁	0.009
Bylin et al, 1985	480	20	Non-specific, HIST	8	5	0	>30	>20	0.04
Mohsenin et al., 1987	500	60	Non-specific, METH	10	7	2	9.2 ± 4.7	4.6 ± 2.6	0.042
Bylin et al., 1988	530	30	Non, specific, HIST	20	12	7	0.39 ± 0.07	0.34 ± 0.08	n.s.

AR = airway responsiveness; BIR = birch; CARB = carbachol; Exp. = exposure; HDM = house dust mite allergen; HIST = histamine; METH = methacholine; NA = not available; NO₂ = nitrogen dioxide; n.s. = less than marginal statistical significance, *p* > 0.10; RAG = ragweed; SO₂ = sulfur dioxide; TIM = timothy

^a Adapted from Table 5-1 in Integrated Science Assessment for Oxides of Nitrogen (Health) – Final (U.S. EPA, 2016, Section 5.2.2.1)

^bChange in AR: number of individuals showing increased (+) or decreased (-) airway responsiveness after NO₂ exposure compared to air.

^cPD ± SE: arithmetic or geometric mean provocative dose (PD) ± standard error (SE). See individual papers for PD calculation and dosage units. ΔFEV₁ indicates the change in FEV₁ response at a constant challenge dose.

^dStatistical significance of increase in AR to bronchial challenge following NO₂ exposure compared to filtered air as reported in the original study unless otherwise specified. Statistical tests varied between studies, e.g., sign test, t-test, and analysis of variance.

^eStatistical significance for all individuals with asthma from analysis by Dawson et al. (1979). Orehek et al. (1976) only tested for differences in sub-sets of individuals classified as “responders” and “non-responders.”

^fThis p-value from p. 609 of Bylin et al. (1988) corrects the “n.s.” indicated in the 2016 ISA and Brown (2015)

Table 3-3. Exercising exposures to nitrogen dioxide and airway responsiveness in individuals with asthma.^a

Reference	NO ₂ ppb	Exp. (min)	Challenge Type	N	Change in AR ^b		Average PD ± SE ^c		p-value ^d
					+	-	Air	NO ₂	
Roger et al., 1990	150	80	Non-specific, METH	19	10 ^d	7 ^d	3.3 ± 0.7	3.1 ± 0.7	n.s.
Kleinman et al., 1983	200	120	Non-specific, METH	31	20	7	8.6 ± 2.9	3.0 ± 1.1	<0.05
Jenkins et al., 1999	200	360	Specific, HDM	11	6	5	2.94	2.77	n.s.
Jörres et al., 1991	250	30	Non-specific, METH	11	6	5	0.41 ± 1.6	0.41 ± 1.6	n.s.
Strand et al., 1996	260	30	Non-specific, HIST	19	13	5	296 ± 76	229 ± 56	0.08
Avol et al., 1988	300	120	Non-specific, COLD	37	11 ^d	16 ^d	-8.4 ± 1.8 ΔFEV ₁	-10.7 ± 2.0 ΔFEV ₁	n.s.
Avol et al., 1989	300	180	Non-specific, COLD	34	12 ^d	21 ^d	-5 ± 2 ΔFEV ₁	-4 ± 2 ΔFEV ₁	n.s.
Bauer et al., 1986	300	30	Non-specific, COLD	15	9	3	0.83 ± 0.12	0.54 ± 0.10	<0.05
Morrow et al., 1989	300	240	Non-specific, CARB	20	7 ^e	2 ^e	3.31 ± 8.64 ^e ΔFEV ₁	-6.98 ± 3.35 ^e ΔFEV ₁	n.s.
Roger et al., 1990	300	80	Non-specific, METH	19	8 ^d	9 ^d	3.3 ± 0.7	3.3 ± 0.8	n.s.
Rubinstein et al., 1990	300	30	Non-specific, SO ₂	9	4	5	1.25 ± 0.23	1.31 ± 0.25	n.s.
Riedl et al., 2012	350	120	Non-specific, METH	15	6	7	7.5 ± 2.6	7.0 ± 3.8	n.s.
Riedl et al., 2012	350	120	Specific, CA	15	4	11	-6.9 ± 1.7 ΔFEV ₁	-0.5 ± 1.7 ΔFEV ₁	<0.05 ^f
Jenkins et al., 1999	400	180	Specific, HDM	10	7	3	3.0	2.78	0.018
Witten et al., 2005	400	180	Specific, HDM	15	8	7	550 ± 240	160 ± 60	n.s.
Avol et al., 1988	600	120	Non-specific, COLD	37	13 ^e	16 ^e	-8.4 ± 1.8 ΔFEV ₁	-10.4 ± 2.2 ΔFEV ₁	n.s.
Roger et al., 1990	600	80	Non-specific, METH	19	11 ^d	8 ^d	3.3 ± 0.7	3.7 ± 1.1	n.s.

AR = airway responsiveness; BIR = birch; CARB = carbachol; Exp. = exposure; HDM = house dust mite allergen; HIST = histamine; METH = methacholine; NA = not available; NO₂ = nitrogen dioxide; n.s. = less than marginal statistical significance, $p > 0.10$; RAG = ragweed; SO₂ = sulfur dioxide; TIM = timothy
^a Adapted from Table 5-2 in Integrated Science Assessment for Oxides of Nitrogen (Health) – Final (U.S. EPA, 2016, Section 5.2.2.1)

^bChange in AR: number of individuals showing increased (+) or decreased (-) airway responsiveness after NO₂ exposure compared to air.

^cPD ± SE: arithmetic or geometric mean provocative dose (PD) ± standard error (SE). See individual papers for PD calculation and dosage units. ΔFEV₁ indicates the change in FEV₁ response at a constant challenge dose.

^dStatistical significance of increase in AR to bronchial challenge following NO₂ exposure compared to filtered air as reported in the original study unless otherwise specified. Statistical tests varied between studies, e.g., sign test, t-test, analysis of variance.

^eStatistical significance for all individuals with asthma from analysis by Dawson et al. (1979). Orehek et al. (1976) only tested for differences in sub-sets of individuals classified as “responders” and “non-responders.”

1

2 *Consideration of group mean results from individual studies*

3 In first considering studies conducted at rest, we note that the lowest NO₂ concentration
4 to which individuals with asthma have been exposed is 100 ppb, with an exposure duration of 60
5 minutes in all studies. Of the five studies conducted at 100 ppb, a statistically significant increase
6 in AR following exposure to NO₂ was only observed in the study by Orehek et al. (1976) (N =
7 20). Of the four studies that did not report statistically significant increases in AR following
8 exposures to 100 ppb NO₂, three reported weak trends towards decreased AR (n = 20, Ahmed et
9 al., 1983b; n = 15, Hazucha et al., 1983; n = 8, Tunnicliffe et al., 1994), and one reported a trend
10 towards increased AR (n = 20, Ahmed et al., 1983a). Resting exposures to 140 ppb NO₂ resulted
11 in increases in AR that reached marginal statistical significance (n = 20; Bylin et al., 1988). In
12 addition, the one study conducted at 200 ppb demonstrated a trend towards increased AR, but
13 this study was small and results were not statistically significant (n = 4; Orehek et al., 1976).
14 Thus, individual controlled human exposure studies have generally not reported statistically
15 significant increases in AR following resting exposures to NO₂ concentrations from 100 to 200
16 ppb. Group mean responses in these studies suggest a trend towards increased AR following
17 exposures to 140 and 200 ppb NO₂, while trends in the direction of group mean responses were
18 inconsistent following exposures to 100 ppb NO₂.

19 In next considering studies in individuals with asthma conducted with exercise, we note
20 that three studies evaluated NO₂ exposure concentrations between 150 and 200 ppb (n = 19,
21 Roger et al., 1990; n = 31, Kleinman et al., 1983; n = 11, Jenkins et al., 1999). Of these studies,
22 only Kleinman et al. (1983) reported a statistically significant increase in AR following NO₂
23 exposure (i.e., at 200 ppb). Roger et al. (1990) and Jenkins et al. (1999) did not report
24 statistically significant increases, but showed weak trends for increases in AR following
25 exposures to 150 ppb and 200 ppb NO₂, respectively. Thus, as with studies of resting exposures,

1 studies that evaluated exposures to 150 to 200 ppb NO₂ with exercise report trends toward
2 increased AR, though results are generally not statistically significant.

3 Several studies evaluated exposures of individuals with asthma to NO₂ concentrations
4 above 200 ppb. Of the five studies that evaluated 30 minute resting exposures to NO₂
5 concentrations from 250 to 270 ppb, NO₂-induced increases in AR were statistically significant
6 in three (n = 14, Jörres et al., 1990; n = 18, Strand et al., 1988; n = 20, Bylin et al., 1988).
7 Significant increases in airway responsiveness are also more consistently reported across studies
8 that evaluated resting exposures to 400-530 ppb NO₂, with three of four studies reporting a
9 significant increase in airway responsiveness following such exposures. However, studies
10 conducted with exercise do not indicate consistent increases in AR following exposures to NO₂
11 concentrations from 300 to 600 ppb (Table 3-3).⁵⁹

12 *Consideration of results from the meta-analysis*

13 As discussed above in Section 3.2.1, the ISA assessment of the evidence for AR in
14 individuals with asthma also focuses on a recently published meta-analysis (Brown, 2015)
15 investigating individual-level data from the studies included in Tables 3-2 and 3-3. While
16 individual controlled human exposure studies can lack statistical power to identify effects, the
17 meta-analysis of individual-level data combined from multiple studies (Brown, 2015) has greater
18 statistical power due to increased sample size. The meta-analysis considered individual-level
19 responses, specifically whether individual study subjects experienced an increase or decrease in
20 AR following NO₂ exposure compared to air exposure, combining information from the studies
21 presented in Tables 3-2 and 3-3. Evidence was evaluated together across all studies and also
22 stratified for exposures conducted with exercise and at rest, and for measures of specific and
23 non-specific AR. The ISA notes that these methodological differences may have important
24 implications with regard to results (U.S. EPA, 2016; Brown, 2015; Goodman et al., 2009).
25 Overall, the meta-analysis presents the fraction of individuals having an increase in AR
26 following exposure to various NO₂ concentrations (i.e., 100 ppb, 100 ppb up to 200 ppb, 200 ppb
27 up to and including 300 ppb, and above 300 ppb) (U.S. EPA, 2016, Section 5.2.2.1).⁶⁰ The

⁵⁹ There are eight additional studies with exercising exposures to 300-350 ppb NO₂ as presented in Table 3-3, with exposure durations ranging from 30-240 minutes. Results across these studies are less consistent, with only two of eight reporting significant results. Only one of four studies with exercising exposures of 400 or 600 ppb reported statistically significant increases in airway responsiveness.

⁶⁰ Brown et al. (2015) compared the number of study participants who experienced an increase in AR following NO₂ exposures to the number who experienced a decrease in AR. Study participants who experienced no change in AR were not included in comparisons. *P*-value refers to the significance level of a two-tailed sign test.

1 number of participants in each study and the number having an increase or decrease in AR is
2 indicated in Tables 3-2 and 3-3.

3 We first consider the meta-analysis results across all exposure conditions (i.e., resting,
4 exercising, non-specific challenge, and specific challenge). For 100 ppb NO₂ exposures, Brown
5 (2015) reported that, of the study participants who experienced either an increase or decrease in
6 AR following NO₂ exposures, 61% experienced an increase ($p = 0.08$). For 100 to 200 ppb NO₂
7 exposures, 62% of study subjects experienced an increase in AR following NO₂ exposures ($p =$
8 0.014). For 200 to 300 ppb NO₂ exposures, 58% of study subjects experienced an increase in AR
9 following NO₂ exposures ($p = 0.008$). For exposures above 300 ppb NO₂, 57% of study subjects
10 experienced an increase in AR following NO₂ exposures, though this fraction was not
11 statistically different than the fraction experiencing a decrease.

12 We also consider the results of Brown (2015) for various subsets of the available studies,
13 based on the exposure conditions evaluated (i.e., resting, exercising) and the type of challenge
14 agent used (specific, non-specific). For exposures conducted at rest, across all exposure
15 concentrations (i.e., 100-530 ppb NO₂, $n = 139$; Table 3-2), Brown (2015) reported that a highly
16 significant fraction of study participants (71%, $p < 0.001$) experienced an increase in AR
17 following NO₂ exposures, compared to the fraction that experienced a decrease in AR. The meta-
18 analysis also presented results for various concentrations or ranges of concentrations. Following
19 resting exposure to 100 ppb NO₂, 66% of study participants experienced increased non-specific
20 AR. For exposures to concentrations of 100 ppb up to 200 ppb, 200 ppb up to and including 300
21 ppb, and above 300 ppb, increased non-specific AR was reported in 67%, 78%, and 73% of
22 study participants, respectively.⁶¹ For non-specific challenge agents, the differences between the
23 fractions of individuals who experienced increased AR following resting NO₂ exposures and the
24 fraction who experienced decreased AR reached statistical significance for all of the ranges of
25 exposures concentrations evaluated ($p < 0.05$).

26 In contrast to the results from studies conducted at rest, the fraction of individuals having
27 an increase in AR following NO₂ exposures with exercise was not consistently greater than 50%,
28 and none of the results were statistically significant (Brown, 2015). Across all NO₂ exposures
29 with exercise, measures of non-specific AR were available for 241 individuals, 54% of whom
30 experienced an increase in AR following NO₂ exposures relative to air controls. There were no
31 studies in this group conducted at 100 ppb, and for exercising exposures to 150-200 ppb, 250-

⁶¹ For the exposure category of “above 300 ppb”, exposures included 400, 480, 500, and 530 ppb. No studies used concentrations between 300 and 400 ppb.

1 300 ppb, and 350-600 ppb, the fraction of individuals with increased AR was 59%, 55%, and
2 49%, respectively.

3 In addition to examining results from studies of non-specific AR, the meta-analysis also
4 considered results from studies that evaluated changes in specific AR (i.e., AR following an
5 allergen challenge; n=130; Table 3-3) following NO₂ exposures. The results do not indicate
6 statistically significant fractions of individuals having an increase in specific AR following
7 exposure to NO₂ at concentrations below 400 ppb, even when considering resting and exercising
8 exposures separately (Brown, 2015). Of the three studies evaluating specific AR at
9 concentrations of 400 ppb, one was conducted at rest (Tunnicliffe et al., 1994) and reported a
10 significant fraction of individuals with increased in AR following NO₂ exposure (Brown, 2015).
11 The other two studies were conducted with exercising exposures (Jenkins et al., 1999; Witten et
12 al., 2005), and the meta-analysis reported that 48% of study subjects experienced NO₂-induced
13 increases AR. Overall, results across studies are less consistent for increases in specific AR
14 following NO₂ exposures.

15 *Uncertainties in evidence for airway responsiveness*

16 When considering the evidence for NO₂-induced increases in AR in individuals with
17 asthma, there are important uncertainties that should be considered. Both the meta-analysis by
18 Brown (2015) and an additional meta-analysis and meta-regression by Goodman et al. (2009)
19 conclude that there is no indication of a dose-response relationship for exposures between 100
20 and 500 ppb NO₂ and increased AR in individuals with asthma. A dose-response relationship
21 generally increases confidence that observed effects are due to pollutant exposures rather than to
22 chance; however, a lack of a dose-response relationship does not necessarily indicate that there is
23 no relationship between the exposure and effect, particularly in these analyses based on between-
24 subject comparisons. For example, as discussed in the ISA, there are a number of methodological
25 differences across studies that could contribute to between-subject differences and obscure a
26 dose-response relationship between NO₂ and AR. These include subject activity level (rest vs.
27 exercise) during NO₂ exposure, asthma medication usage, choice of airway challenge agent (e.g.,
28 direct and indirect non-specific stimuli), method of administering the bronchoconstricting agents,
29 and physiological endpoint used to assess airway responsiveness. Such methodological
30 differences across studies likely contribute to the variability and uncertainty in results across
31 studies and complicate interpretation of the overall body of evidence for NO₂-induced AR. Thus,
32 while the lack of an apparent dose-response relationship adds uncertainty to our interpretation of
33 controlled human exposure studies of AR, it does not necessarily indicate the lack of an NO₂
34 effect.

1 An additional uncertainty in interpreting these studies within the context of the adequacy
2 of the protection provided by the NO₂ NAAQS is the clinical relevance of the reported NO₂-
3 induced increases in AR. Clear guidelines on the clinical relevance of AR have not been
4 established. The meta-analysis by Brown (2015) used an approach that is consistent with
5 guidelines from the American Thoracic Society (ATS) and the European Respiratory Society for
6 the assessment of therapeutic agents (Reddel et al., 2009) to assess the potential for clinical
7 relevance. Specifically, based on individual-level responses reported in a subset of studies,
8 Brown (2015) considered a halving of the provocative dose to indicate responses that may be
9 clinically relevant.⁶² Only five studies provided data for each individual's provocative dose.
10 These five studies provided individual-level data for a total of 72 study participants (116 AR
11 measurements) and eight NO₂ exposure concentrations, for resting exposures and non-specific
12 bronchial challenge agents. Across exposures to 100, 140, 200, 250, 270, 480, 500, and 530 ppb
13 NO₂, 24% of study participants experienced a halving of the provocative dose while 8% showed
14 a doubling of the provocative dose. The relative distributions of the provocative doses at
15 different concentrations were similar, with no dose-response relationship indicated. Although
16 this analysis is limited to a small subset of studies and study participants, these results support
17 the potential for clinically relevant increases in AR in some individuals with asthma following
18 NO₂ exposures between 100 and 530 ppb.

19 *Preliminary Conclusion*

20 As in the last review, a meta-analysis of individual-level data supports the potential for
21 increased AR in individuals with asthma following 30 minute to 1 hour exposures to NO₂
22 concentrations from 100 to 600 ppb, particularly for resting exposures and measures of non-
23 specific AR (N = 33 to 70 for various ranges of NO₂ exposure concentrations). Individual studies
24 most consistently report statistically significant NO₂-induced increases in AR following
25 exposures to NO₂ concentrations at or above 250 ppb. Individual studies (N = 4 to 20) generally
26 do not report statistically significant increases in AR following exposures to NO₂ concentrations
27 at or below 200 ppb, though the evidence suggests a trend toward increased AR following NO₂
28 exposures from 140 to 200 ppb. In contrast, individual studies do not indicate a consistent trend
29 towards increased AR following 1-hour exposures to 100 ppb NO₂. Important limitations in this
30 evidence include the lack of a dose-response relationship between NO₂ and AR and uncertainty

⁶² More specifically, clinical relevance in the ISA is based on evidence from clinical studies evaluating efficacy of inhaled corticosteroids that are used to prevent bronchoconstriction and airway responsiveness as described by Reddel et al. (2009). Generally, a change of at least one doubling dose is considered to be an indication of clinical relevance (this represents a decline in AR as the dose to induce AR is doubled). Based on this, a halving of the provocative dose is taken in the ISA to represent an increase in AR that is an indication of clinical relevance.

1 in the adversity of the reported increases in AR. These limitations become increasingly important
2 to consider at the lower NO₂ exposure concentrations (i.e., at or near 100 ppb), where the
3 evidence for NO₂-induced increases in AR is not consistent across studies.

4 3.2.2.2 *Concentrations in Locations of Epidemiologic Studies*

5 We next consider distributions of ambient NO₂ concentrations in locations where
6 epidemiologic studies have examined NO₂ associations with asthma-related hospital admissions
7 or emergency department visits. These outcomes are clearly adverse and study results comprise a
8 key line of epidemiologic evidence in the determination of a causal relationship in the ISA (U.S.
9 EPA, 2016, Section 5.2.9). As in other NAAQS reviews (U.S. EPA, 2014; U.S. EPA, 2011),
10 when considering epidemiologic studies within the context of the adequacy of the current
11 standard, we emphasize those studies conducted in the U.S. and Canada.⁶³ For short-term
12 exposures to NO₂, we emphasize studies reporting associations with effects judged in the ISA to
13 be robust to confounding by other factors, including co-occurring air pollutants. In addition, we
14 consider the statistical significance and precision of study results, and the inclusion of at-risk
15 populations for which the NO₂-health effect associations may be larger. These considerations
16 help inform the range of ambient NO₂ concentrations over which we have the most confidence in
17 NO₂-associated health effects and the range of concentrations over which our confidence in
18 such effects is appreciably lower. In our consideration of these issues, we specifically focus on
19 the following question:

- 20 • **To what extent have U.S. and Canadian epidemiologic studies reported associations**
21 **between asthma-related hospital admissions or emergency department visits and short-**
22 **term NO₂ concentrations in study areas that would have met the current 1-hour NO₂**
23 **standard during the study period?**

24 Addressing this question can provide important insights into the extent to which NO₂-
25 health effect associations are present for distributions of ambient NO₂ concentrations that would
26 be allowed by the current standards. The presence of such associations would support the
27 potential for the current standards to allow the NO₂-associated effects indicated by epidemiologic
28 studies. To the degree studies have not reported associations in locations meeting the current
29 NO₂ standards, there is greater uncertainty regarding the potential for the reported effects to
30 occur following NO₂ exposures associated with air quality meeting those standards.

31

⁶³ Such studies are likely to reflect air quality and exposure patterns that are generally applicable to the U.S. In addition, air quality data corresponding to study locations and study time periods is often readily available for studies conducted in the U.S. and Canada. Nonetheless, we recognize the importance of all studies, including other international studies, in the ISA's assessment of the weight of the evidence that informs causal determinations.

1 In addressing the question above and considering the available evidence, we place the
2 greatest emphasis on studies reporting positive, and relatively precise, health effect associations.
3 In evaluating whether such associations are likely to reflect NO₂ concentrations meeting the
4 existing 1-hour standard, we consider the 1-hour ambient NO₂ concentrations measured at
5 monitors in study locations during study periods. We also consider what additional information
6 is available to inform our understanding of the ambient NO₂ concentrations that could have been
7 present in the study locations during the study periods (e.g., around major roads). When
8 considered together, this information can provide important insights into the extent to which NO₂
9 health effect associations have been reported for NO₂ air quality concentrations that likely would
10 have met the current 1-hour NO₂ standard.

11 We have identified U.S. and Canadian studies of respiratory-related hospital admissions
12 and emergency department (ED) visits, with a focus on studies of asthma-related effects (studies
13 identified from ISA Table 5-10).⁶⁴ For each NO₂ monitor in the locations evaluated by these
14 studies and the ranges of years encompassed by studies, we have identified the 3-year averages
15 of the 98th percentiles of the annual distributions of daily maximum 1-hour NO₂ concentrations.⁶⁵
16 These concentrations are approximations of the DVs that are used when determining whether an
17 area meets the primary NO₂ NAAQS.⁶⁶ Thus, these DVs can provide perspective on whether
18 study areas would likely have met or violated the primary 1-hour NO₂ NAAQS during the study
19 periods. Based on this approach, study locations could have met the current 1-hour standard over
20 the entire study period if all of the hourly DVs were at or below 100 ppb.

21 A key limitation in these analyses of NO₂ DVs is that currently required near-road NO₂
22 monitors were not in place during study periods. The studies evaluated (see Figure 3-1 below)
23 were based on air quality from 1980-2006, with most studies spanning the 1990s to early 2000s.
24 As discussed above in Chapter 2, there were no specific near-road monitoring network
25 requirements during these years, and most areas did not have monitors sited to measure NO₂

⁶⁴ These studies were identified in the ISA as comprising an important line of epidemiologic evidence to support the conclusion that there is a “causal” relationship between short-term NO₂ exposures and respiratory effects (U.S. EPA, 2016). Strong support was also provided by epidemiologic studies for respiratory symptoms, but the majority of studies on respiratory symptoms were only conducted over part of a year, complicating the evaluation of a DV based on data from 3 years of monitoring data relative to the respective health effect estimates. For more information on these studies and the DVs in the study locations, see Appendix A.

⁶⁵ All study locations had maximum annual design values below 53 ppb (Appendix A).

⁶⁶ As described in Chapter 2, a design value is a metric used to determine whether areas meet or violate the NAAQS. For the 1-hour NO₂ standard, the DV is calculated at individual monitors and based on 3 consecutive years of data collected from that site. In the case of the 1-hour NO₂ standard, the design value for a monitor is based on the 3-year average of the 98th percentile of the annual distribution of daily maximum 1-hour NO₂ concentrations. For more information on these studies and DVs, see Appendix A

1 concentrations near the most heavily-trafficked roadways. In addition, mobile source NO_x
2 emissions were considerably higher during the time periods of available epidemiologic studies
3 than in more recent years, suggesting that the NO₂ concentration gradients around major roads
4 were likely more pronounced than indicated by data from recently deployed near-road monitors
5 (Figure 2-6).⁶⁷ This information suggests that if the current near-road monitoring network had
6 been in operation during study periods, NO₂ DVs measured at near-road monitors would likely
7 have been higher than the DVs reflected in Figure 3-1 below. This uncertainty particularly limits
8 the degree to which we can draw strong conclusions based on study areas with DVs that are at or
9 just below 100 ppb.

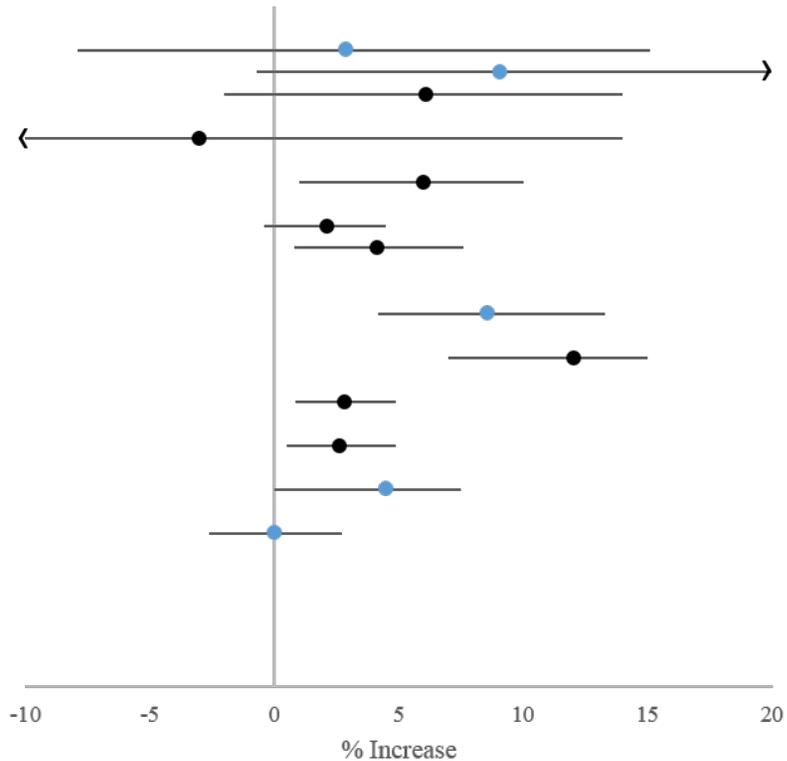
10 With this key limitation in mind, we consider what the available epidemiologic evidence
11 can tell us with regard to the adequacy of the public health protection provided by the current 1-
12 hour standard against short-term NO₂ exposures. Figure 3-1, below, highlights the epidemiologic
13 studies examining associations between asthma hospitalizations or ED visits and short-term
14 exposures to ambient NO₂ that were conducted in the U.S. and Canada. These studies were
15 identified and evaluated in the ISA and include both the few recently published studies and the
16 studies that were available in the previous review. Figure 3-1 depicts the range of associations
17 across U.S. and Canadian studies and also indicates maximum and mean hourly DVs for the
18 study locations and years.⁶⁸

⁶⁷ Recent data indicate that, for most near-road monitors, measured 1-hour NO₂ concentrations are higher than those measured at all of the non-near-road monitors in the same CBSA (Section 2.3.2).

⁶⁸ Similar analyses of study area air quality were presented in the 2008 REA. However, because the 1-hour standard was set in the 2010 final decision, the methods for calculating 1-hour NO₂ DVs had not been established at the time of the development of the 2008 REA. Therefore, the study area NO₂ concentrations identified in the 2008 REA did not correspond to 1-hour DVs for the current 1-hour NO₂ standard. As a result, even when the same study is evaluated, study area NO₂ concentrations are not identical in the 2008 REA and in Figure 3-1 of this draft PA.

1

Study	Location	Hourly DV (Max, Mean)	Study Years
Li (2011), 2-18 yrs	Detroit	55, 55	2004-2006
Jaffe (2003), 5-34 yrs	Clev/Cinc	92, 83	1991-1996
ATSDR (2006)	Manhattan	86, 86	1999-2000
ATSDR (2006)	Bronx	94, 94	1999-2000
Peel (2005)	Atlanta	100, 90	1993-2000
Peel (2005), 2-18yrs	Atlanta	100, 90	1993-2000
Strickland (2010), 5-17 yrs	Atlanta	100, 87	1993-2004
Ito (2007)	New York City	102, 102	1999-2002
Linn (2000)	Los Angeles	171, 170	1992-1995
Burnett (1999)	Toronto	227, 142	1980-1994
Villeneuve (2007), >2 yrs	Edmonton	242, 103	1999-2002
Stieb (2009)	Montreal	85, 81	1997-2002
	Ottawa	198, 94	1992-2000
	Edmonton	242, 103	1992-2002
	St. John	96, 65	1992-1996
	Halifax	67, 64	1999-2002
	Toronto	98, 92	1999-2003
	Vancouver	86, 66	1999-2003



2

3 **Figure 3-1. U.S. and Canadian epidemiologic studies of short-term NO₂ exposures and asthma hospital admissions and**
 4 **emergency department visits.** Study locations and years are reported with hourly DVs for studies asthma hospital admissions and ED
 5 visits with effect estimates and 95% confidence intervals, standardized as described in the ISA (U.S. EPA, 2016) Effect estimates in
 6 blue represent studies that are new in the current review. Clev = Cleveland; Cinc = Cincinnati. If ages are not specified after the study,
 7 then hospital admissions and ED visits for all ages were included. Li et al. reports an effect estimate from a time-series analysis and
 8 case-crossover analysis. Because hourly DVs are based on 3 years of data, DVs for the first 2 years of a study period were not considered.
 9 The ATSDR study did not include 3 years, thus DVs reported for these locations include data from a year preceding the study (1998).

10

1 Figure 3-1 includes both multi-city and single city studies. In considering the information
2 in Figure 3-1, we note that multi-city studies tend to have greater power to detect associations.
3 The one multi-city study that has become available since the last review (Stieb et al., 2009)
4 reported a null association with asthma ED visits, based on study locations with maximum DVs
5 ranging from 67-242 ppb (six of seven study cities had maximum DVs at or above 85 ppb). Of
6 the single city studies in Figure 3-1, those reporting positive and relatively precise (i.e., relatively
7 narrow 95% CIs) associations were conducted in locations with maximum, and often mean, DVs
8 at or above 100 ppb (i.e., Linn et al., 2000; Peel et al., 2005; Ito et al., 2007; Villeneuve et al.,
9 2007; Burnett et al., 2009; Strickland et al., 2010). For the other single city studies in Figure 3-1,
10 two reported more mixed results in locations with maximum DVs around 90 ppb (Jaffe et al.,
11 2003; ATSDR, 2006).⁶⁹ Associations in these studies were generally not statistically significant,
12 were less precise (i.e., wider 95% CIs), and included a negative association (Manhattan, NY).
13 One single city study was conducted in a location with 1-hour DVs well-below 100 ppb (Li et al.,
14 2011), though the reported associations were not statistically significant and were relatively
15 imprecise. Thus, of the U.S. and Canadian studies that can most clearly inform our consideration
16 of the adequacy of the current NO₂ standards, the lone multicity study did not report a positive
17 health effect association and the single-city studies reporting positive, and relatively precise,
18 associations were generally conducted in locations with maximum 1-hour DVs at or above 100
19 ppb. The evidence for associations in locations with maximum DVs below 100 ppb is more
20 mixed, and reported associations are generally less precise.

21 An uncertainty in this body of evidence is the potential for copollutant confounding.
22 When pollutants are highly correlated, it can be difficult to determine the independent effects of
23 single pollutants from other pollutants in the mixture. Copollutant (two-pollutant) models can be
24 used in epidemiologic studies in an effort to disentangle independent effects, particularly for
25 pollutants emitted from the same sources. For NO₂, the copollutants that are most relevant to
26 consider are those from traffic sources such as CO, EC/BC, UFP, and benzene as well as PM_{2.5}
27 and PM₁₀, whose concentrations are more spatially homogenous (ISA, Section 3.5). Of the
28 studies examining asthma-related hospital admissions and ED visits in the U.S. and Canada in
29 Figure 3-1, three examined effect estimates from copollutant models (Ito et al., 2007; Villeneuve
30 et al., 2007; Strickland et al., 2010)). Ito et al. (2007) found that in copollutant models with
31 PM_{2.5}, SO₂, CO, or O₃, NO₂ consistently had the strongest effect estimates that were robust to the

⁶⁹ The study by the U.S. Agency for Toxic Substances and Disease Registry (ATSDR) was not published in a peer-review journal. Rather, it was a report prepared by New York State Department of Health's Center for Environmental Health, the New York State Department of Environmental Conservation and Columbia University in the course of performing work contracted for and sponsored by the New York State Energy Research and Development Authority and the ATSDR.

1 other copollutant. Villeneuve et al. (2007) utilized a model including NO₂ and CO (r = 0.74) for
2 ED visits in the warm season and reported that associations for NO₂ were robust to CO.
3 Strickland et al. (2010) found that the relationship between ambient NO₂ and asthma ED visits in
4 Atlanta, GA was robust in models including O₃, but copollutant models were not analyzed for
5 other pollutants and the correlations between NO₂ and other pollutants were not reported. Taken
6 together, these studies provide some evidence for independent effects of NO₂ for asthma ED
7 visits, but some important traffic-related copollutants (e.g. EC/BC, VOCs) have not been
8 examined in this body of evidence and the limitations of copollutant models in demonstrating an
9 independent association are well recognized (U.S. EPA, 2015, Section 4.b).

10 Preliminary Conclusions

11 Considering this evidence together, we note the following observations. First, the only
12 recent multicity study evaluated, which had maximum DVs ranging from 67 to 242 ppb, did not
13 report a positive association between NO₂ and ED visits (Stieb et al., 2009). In addition, of the
14 single-city studies in Figure 3-1 reporting positive and relatively precise associations between
15 NO₂ and asthma hospital admissions and ED visits, most locations likely had NO₂ concentrations
16 above the current 1-hour NO₂ standard over at least part of the study period. Although maximum
17 DVs for the studies conducted in Atlanta were 100 ppb, it is likely that those DVs would have
18 been higher than 100 ppb had currently required near-road monitors been in place. For the study
19 locations with maximum DVs below 100 ppb, mixed results are reported with associations that
20 are generally statistically non-significant and imprecise, indicating the asthma-related ED visits
21 are not consistently or strongly associated with NO₂ concentrations in locations that could have
22 met the current standards. Given that near-road monitors were not in operation during study
23 periods, it is not clear that even these DVs below 100 ppb indicate study areas that would have
24 met the current 1-hour standard. Thus, when considering our analyses of study area NO₂
25 concentrations in light of uncertainties related to roadway NO₂ concentrations and copollutant
26 confounding, we reach the preliminary conclusion that available U.S. and Canadian
27 epidemiologic studies do not indicate NO₂-associated hospital admissions or emergency
28 department visits in locations with NO₂ concentrations that would likely have met the current 1-
29 hour NO₂ standard.

30 **3.3 EFFECTS OF LONG-TERM NO₂ EXPOSURES**

31 **3.3.1 Nature of Effects**

32 In the last review of the primary NO₂ NAAQS, evidence for health effects related to long-
33 term ambient NO₂ exposure was judged “suggestive of, but not sufficient to infer” or
34 “inadequate to infer the presence or absence of” a causal relationship across health effect

1 categories. These included respiratory, cardiovascular, and reproductive and developmental
 2 effects as well as cancer and total mortality. In the current review, new epidemiologic evidence,
 3 in conjunction with explicit integration of evidence across related outcomes, has resulted in
 4 strengthening of some of the causal determinations. However, there are still a number of
 5 uncertainties limiting our understanding of the role of long-term NO₂ exposures in causing health
 6 effects. We focus our discussion of evidence available in the current review for health effects
 7 related to long-term NO₂ exposures, including strengths and limitations, on the following
 8 overarching questions:

- 9 • **To what extent does the currently available scientific evidence alter or strengthen our**
 10 **conclusions from the last review regarding health effects attributable to long-term NO₂**
 11 **exposures? Have previously identified uncertainties been reduced? What important**
 12 **uncertainties remain and have new uncertainties been identified?**

13 Table 3-4 provides an overview of the causal determinations for the previous and current
 14 reviews for long-term NO₂ exposures and various health effect categories including respiratory,
 15 cardiovascular, and reproductive and developmental effects, as well as mortality and cancer. In
 16 particular, the causal determination between long-term NO₂ exposures and respiratory effects
 17 was strengthened to “likely to be a causal relationship.” The evidence on which these causal
 18 judgments are based is summarized below.

Table 3-4. Causal determinations for long-term nitrogen dioxide (NO₂) exposure and health effects evaluated in the ISA for Oxides of Nitrogen in the previous and current review

Health effect	Review completed 2010	Current Review
Respiratory	Suggestive of, but not sufficient to infer, a causal relationship	Likely to be a causal relationship
Cardiovascular and Diabetes	Inadequate to infer the presence or absence of a causal relationship	Suggestive of, but not sufficient to infer, a causal relationship
Total Mortality	Inadequate to infer the presence or absence of a causal relationship	Suggestive of, but not sufficient to infer, a causal relationship
Reproductive and Developmental– Fertility, Reproduction, Pregnancy		Inadequate to infer a causal relationship
Reproductive and Developmental – Birth Outcomes	Inadequate to infer the presence or absence of a causal relationship ^a	Suggestive of, but not sufficient to infer, a causal relationship
Reproductive and Developmental– Postnatal Development		Inadequate to infer a causal relationship
Cancer	Inadequate to infer the presence or absence of a causal relationship	Suggestive of, but not sufficient to infer, a causal relationship

^a Previous review combined evidence for reproductive and developmental effects and made one causal determination.

1 Respiratory

2 The 2016 ISA concluded that there is “likely to be a causal relationship” between long-
3 term NO₂ exposure and respiratory effects, based primarily on evidence integrated across
4 disciplines for a relationship with asthma development in children. Evidence for other outcomes
5 integrated across epidemiologic and experimental studies, including decrements in lung function
6 and partially irreversible decrements in lung development, respiratory disease severity, chronic
7 bronchitis/asthma incidence in adults, COPD hospital admissions, and respiratory infections, is
8 less consistent and has larger uncertainty in whether there is an independent effect of long-term NO₂
9 exposure (U.S. EPA, 2016, Section 6.2.9).

10 The conclusion of a “likely to be a causal relationship” in the current review represents a
11 change from 2008 ISA conclusion that the evidence was “suggestive of, but not sufficient to
12 infer, a causal relationship” (U.S. EPA, 2008, Section 5.3.2.4). The epidemiologic evidence base
13 has expanded since the last review. This expanded evidence includes several recently published
14 longitudinal studies that indicate positive associations between asthma incidence in children and
15 long-term NO₂ exposures, with improved exposure assessment in some studies based on NO₂
16 modeled estimates for children’s homes or NO₂ measured near children’s homes or schools.
17 Associations were observed across various periods of exposure, including first year of life, year
18 prior to asthma diagnosis, and cumulative exposure. In addition, the ISA notes several other
19 strengths of the evidence base including the general timing of asthma diagnosis and relative
20 confidence that the NO₂ exposure preceded asthma development in longitudinal studies, more
21 reliable estimates of asthma incidence based on physician-diagnosis in children older than 5
22 years of age from parental report or clinical assessment, as well as residential NO₂
23 concentrations estimated from land use regression (LUR) models with good NO₂ prediction in
24 some studies.

25 While the causal determination has been strengthened in this review, the ISA notes that
26 key uncertainties remain. For example, the ISA notes that as in the last review, a “key
27 uncertainty that remains when examining the epidemiologic evidence alone is the inability to
28 determine whether NO₂ exposure has an independent effect from that of other pollutants in the
29 ambient mixture” (U.S. EPA, 2016, Section 6.2.2.1, p. 6-21). The ISA further indicates that:
30 “Epidemiologic studies of asthma development in children have not clearly characterized
31 potential confounding by PM_{2.5} or traffic-related pollutants [e.g., CO, BC/EC, volatile organic
32 compounds (VOCs)]. In the longitudinal studies, correlations with PM_{2.5} and BC were often high
33 (e.g., $r = 0.7-0.96$), and no studies of asthma incidence evaluated models to address copollutant
34 confounding, making it difficult to evaluate the independent effect of NO₂” (U.S. EPA, 2016, p.

1 6-64). This is important to consider when interpreting the epidemiologic evidence regarding the
2 extent to which NO₂ is independently related to asthma development.

3 For additional context, the ISA also evaluated copollutant confounding in long-term
4 studies beyond asthma incidence to examine whether studies of other respiratory effects could
5 provide information on the potential for confounding by traffic-related copollutants. Several
6 studies examined correlations between NO₂ and traffic-related copollutants and found them to be
7 relatively high in many cases, ranging from 0.54-0.95 for PM_{2.5}, 0.54-0.93 for BC/EC, 0.2-0.95
8 for PM₁₀, and 0.64-0.86 for OC (U.S. EPA, 2016, Tables 3-10 and 6-1). Additionally, three
9 studies (McConnell et al., 2003; MacIntyre et al., 2014; Gehring et al., 2013) evaluated co-
10 pollutant models with NO₂ and PM_{2.5}, and some findings suggest that associations for NO₂ with
11 bronchitic symptoms, lung function, and respiratory infection are not robust because effect
12 estimates decreased in magnitude and became imprecise when other pollutants were added in the
13 model. Overall, examination of evidence from studies of other respiratory effects indicates
14 moderate to high correlations between long-term NO₂ concentrations and traffic-related
15 copollutants, with very limited evaluation of the potential for confounding. Thus, when
16 considering the collective evidence, it is difficult to disentangle the independent effect of NO₂
17 from other traffic-related pollutants or mixtures in epidemiologic studies (U.S. EPA, 2016,
18 Sections 3.4.4 and 6.2.9.5).

19 While this uncertainty continues to apply to the epidemiologic evidence for asthma
20 incidence in children, the ISA describes that the uncertainty is partly reduced by the coherence of
21 findings from experimental studies and epidemiologic studies. Experimental studies demonstrate
22 effects on key events in the mode of action proposed for the development of asthma and provide
23 biological plausibility for the epidemiologic evidence. For example, one study demonstrated that
24 airway hyperresponsiveness was induced in guinea pigs after long-term exposure to NO₂
25 [1,000–4,000 ppb; (Kobayashi and Miura, 1995)]. Other experimental studies examining
26 oxidative stress report mixed results, but some evidence from short-term studies supports a
27 relationship between NO₂ exposure and increased pulmonary inflammation in healthy humans.
28 The ISA also points to supporting evidence from studies demonstrating that short-term exposure
29 repeated over several days (260-1,000 ppb) and long-term NO₂ exposure (2,000-4,000 ppb) can
30 induce Th2 skewing/allergic sensitization in healthy humans and animal models by showing
31 increased Th2 cytokines, airway eosinophils, and IgE-mediated responses (U.S. EPA, 2016,
32 Sections 4.3.5 and 6.2.2.3). Epidemiologic studies also provide some supporting evidence for
33 these key events in the mode of action. Evidence from epidemiologic studies also demonstrates
34 associations between short-term ambient NO₂ concentrations and increases in pulmonary
35 inflammation in healthy children and adults (U.S. EPA, 2016, Section 5.2.2.5). Overall, evidence

1 from experimental and epidemiologic studies provide support for a role of NO₂ in asthma
2 development by describing a potential role for repeated exposures to lead to recurrent
3 inflammation and allergic responses.

4 In considering the evidence and conclusions presented in the ISA for addressing the
5 overarching questions posed above, there is new evidence available that strengthens conclusions
6 from the last review regarding respiratory health effects attributable to long-term ambient NO₂-
7 exposure. The majority of new evidence is from epidemiologic studies of asthma incidence in
8 children with improved exposure assessment (i.e., measured or modeled at or near children's
9 homes or schools), which builds upon previous evidence for associations of long-term NO₂ and
10 asthma incidence and also partly reduces uncertainties related to measurement error. Explicit
11 integration of evidence for individual outcome categories (e.g. asthma incidence, respiratory
12 infection) provides improved characterization of biological plausibility and mode of action,
13 including some new evidence from studies of short-term exposure supporting an effect on
14 asthma development. Although this partly reduces the uncertainty regarding independent effects
15 of NO₂, because of the high correlation with other traffic-related copollutants and the lack of
16 copollutant model results in epidemiologic studies, the potential for confounding remains a
17 concern when interpreting epidemiologic studies of NO₂ and asthma development. In particular,
18 it remains unclear the degree to which NO₂ may be serving primarily as a surrogate for the
19 broader traffic-pollutant mix.

20 Cardiovascular and Diabetes

21 In the previous review, the 2008 ISA stated that the evidence for cardiovascular effects
22 attributable to long-term ambient NO₂ exposure was “inadequate to infer the presence or absence
23 of a causal relationship.” The epidemiologic and experimental evidence was limited with
24 uncertainties related to traffic-related copollutant confounding (U.S. EPA, 2008). For the current
25 review, the body of epidemiologic evidence available is substantially larger than that in the last
26 review and includes evidence for diabetes. The conclusion on causality is stronger in the current
27 review with regard to the relationship between long-term exposure to NO₂ and cardiovascular
28 effects and diabetes as the ISA judged the evidence to be “suggestive, but not sufficient to infer”
29 a causal relationship (U.S. EPA, 2016, Section 6.3). The strongest evidence comes from recent
30 epidemiologic studies reporting positive associations of NO₂ with heart disease and diabetes with
31 improved exposure assessment (i.e., residential estimates from models that well predict NO₂
32 concentrations in the study areas), but the evidence across experimental studies remains limited
33 and inconsistent and does not provide sufficient biological plausibility for effects observed in
34 epidemiologic studies. Thus, substantial uncertainty exists regarding the independent effect of
35 NO₂ and the total evidence is “suggestive of, but not sufficient to infer, a causal relationship”

1 between long-term NO₂ exposure and cardiovascular effects and diabetes (U.S. EPA, 2016,
2 Section 6.3.9).

3 Reproductive and Developmental Effects

4 In the previous review, a limited number of epidemiologic and toxicological studies had
5 assessed the relationship between long-term NO₂ exposure and reproductive and developmental
6 effects. The 2008 ISA concluded that there was not consistent evidence for an association
7 between NO₂ and birth outcomes and that evidence was “inadequate to infer the presence or
8 absence of a causal relationship” with reproductive and developmental effects overall (U.S. EPA,
9 2008). In the ISA for the current review, a number of recent studies added to the evidence base,
10 and reproductive effects were considered as three separate categories: birth outcomes; fertility,
11 reproduction, and pregnancy; and postnatal development (U.S. EPA, 2016, Section 6.4). Overall,
12 the evidence is “suggestive of, but not sufficient to infer, a causal relationship” between long-
13 term exposure to NO₂ and birth outcomes and is “inadequate to infer the presence or absence of a
14 causal relationship” between exposure to NO₂ and fertility, reproduction and pregnancy as well
15 as postnatal development. Evidence for effects on fertility, reproduction, and pregnancy and for
16 effect on postnatal development is inconsistent across both epidemiologic and toxicological
17 studies. Additionally, there are few toxicological studies available. The ISA concludes the
18 change in the causal determination for birth outcomes reflects the large number of studies that
19 generally observed associations with fetal growth restriction and the improved outcome
20 assessment (e.g., measurements throughout pregnancy via ultrasound) and exposure assessment
21 (e.g., well-validated LUR models) employed by many of these studies (U.S. EPA, 2016, Section
22 6.4.5). For birth outcomes, there is uncertainty in whether the epidemiologic findings reflect an
23 independent effect of NO₂ exposure.

24 Total Mortality

25 In the 2008 ISA, a limited number of epidemiologic studies assessed the relationship
26 between long-term exposure to NO₂ and mortality in adults. The 2008 ISA concluded that the
27 scarce amount of evidence was “inadequate to infer the presence or absence of a causal
28 relationship” (U.S. EPA, 2008c). The ISA for the current review concludes that evidence is
29 “suggestive of, but not sufficient to infer, a causal relationship” between long-term exposure to
30 NO₂ and mortality among adults (U.S. EPA, 2016, Section 6.5.3). This causal determination is
31 based on evidence from recent studies demonstrating generally positive associations between
32 long-term exposure to NO₂ and total mortality from extended analyses of existing cohorts as well
33 as original results from new cohorts. In addition, there is evidence for associations between long-
34 term NO₂ exposures and mortality due to respiratory and cardiovascular causes. However, there

1 were several studies that did not observe an association between long-term exposure to NO₂ and
2 mortality.

3 Some recent studies examined the potential for copollutant confounding by PM_{2.5}, BC, or
4 measures of traffic proximity or density in copollutant models with results from these models
5 generally showing attenuation of the NO₂ effect with the adjustment for PM_{2.5} or BC. It remains
6 difficult to disentangle the independent effect of NO₂ from the potential effect of the traffic-
7 related pollution mixture or other components of that mixture. Further, as described above, there
8 is large uncertainty whether long-term NO₂ exposure has an independent effect on the
9 cardiovascular and respiratory morbidity outcomes that are major underlying causes of mortality.
10 Thus, it is not clear by what biological pathways NO₂ exposure could lead to mortality. In
11 conclusion, the generally positive epidemiologic evidence with uncertainty regarding an
12 independent NO₂ effect is “suggestive of, but not sufficient to infer, a causal relationship”
13 between long-term exposure to NO₂ and total mortality (U.S. EPA, 2016, 6.5.3).

14 Cancer

15 The evidence evaluated in the 2008 ISA was judged “inadequate to infer the presence or
16 absence of a causal relationship” (U.S. EPA, 2008c) based on a few epidemiologic studies
17 indicating associations between long-term NO₂ exposure and lung cancer incidence but lack of
18 toxicological evidence demonstrating that NO₂ induces tumors. In the current review, the
19 integration of recent and older studies on long-term NO₂ exposure and cancer yielded an
20 evidence base judged “suggestive of, but not sufficient to infer, a causal relationship” (U.S. EPA,
21 2016, Section 6.6.9). This conclusion is based primarily on recent epidemiologic evidence, some
22 of which shows NO₂-associated lung cancer incidence and mortality but does not address
23 confounding by traffic-related copollutants, and is also based on previous toxicological evidence
24 that implicates NO₂ in tumor promotion (U.S. EPA, 2016, Section 6.6.9).

25 **3.3.2 Consideration of NO₂ Concentrations: Health Effects of Long-Term NO₂ Exposures**

26 In evaluating the adequacy of the current NO₂ standards to protect against long-term NO₂
27 exposures, we consider the following question:

- 28 • **To what extent does the evidence support the occurrence of NO₂-attributable asthma**
29 **development in children at NO₂ concentrations below the existing standards?**

30 To address this question, we consider (1) the extent to which epidemiologic studies
31 indicate associations between long-term NO₂ exposures and asthma development for
32 distributions of ambient NO₂ concentrations that would likely have met the existing standards
33 and (2) the extent to which effects related to asthma development have been reported following

1 the range of NO₂ exposure concentrations examined in experimental studies. Each of these is
2 discussed below.

3 3.3.2.1 *Ambient NO₂ Concentrations in Locations of Epidemiologic Studies*

4 As discussed above for short-term exposures (Section 3.2.2.2), when considering
5 epidemiologic studies within the context of the adequacy of the current NO₂ standards, we
6 emphasize studies conducted in the U.S. and Canada.⁷⁰ We consider the extent to which these
7 studies report positive and relatively precise associations with long-term NO₂ exposures, and the
8 extent to which important uncertainties could impact our emphasis on particular studies. For the
9 studies with potential to inform our conclusions on adequacy, we also evaluate available air
10 quality information in study locations, focusing on DVs over the course of study periods.

11 In first considering the availability of studies that could inform our conclusions on
12 adequacy, we focus the following specific questions:

- 13 • **To what extent do U.S. and Canadian epidemiologic studies report positive, and**
14 **relatively precise, associations between long-term NO₂ exposures and asthma**
15 **development? What are the important uncertainties in these studies?**

16 The epidemiologic studies available in the current review that evaluate associations
17 between long-term NO₂ exposures and asthma incidence are summarized in Table 6-1 of the ISA
18 (U.S. EPA, 2016, pp. 6-7). There are six longitudinal epidemiologic studies conducted in the
19 U.S. and Canada that vary in terms of the populations examined and methods used. Of the six
20 studies, the ISA identifies three as key studies supporting the causal determination (Carlsten et
21 al., 2011; Clougherty et al., 2007; Jerrett et al., 2008). The other three studies, not identified as
22 key studies in the ISA causality determination, had a greater degree of uncertainty inherent in
23 their characterizations of NO₂ exposures (Clark et al., 2010; McConnell et al., 2010, Nishimura
24 et al., 2013). In evaluating the adequacy of the current NO₂ standards, we place the greatest
25 emphasis on the three U.S. and Canadian studies identified in the ISA as providing key
26 supporting evidence for the causal determination. However, we also consider what the additional
27 three U.S. and Canadian studies can tell us about the adequacy of the current standards, while
28 noting the increased uncertainty in these studies.

29 Effect estimates in U.S. and Canadian studies are generally positive and, in some cases,
30 statistically significant and relatively precise (U.S. EPA, 2016, Table 6-1; Figure 3-2). However,

⁷⁰ As indicated in Section 3.2.2.2, studies from the U.S. and Canada are likely to reflect air quality and exposure patterns that are generally applicable to the U.S. In addition, air quality data corresponding to study locations and study time periods is often readily available for studies conducted in the U.S. and Canada. Nonetheless, we recognize the importance of all studies, including other international studies, in the ISA's assessment of the weight of the evidence that informs causal determinations.

1 there are important uncertainties in this body of evidence for asthma incidence, limiting the
2 extent to which these studies can inform our consideration of the adequacy of the current NO₂
3 standards to protect against long-term NO₂ exposures. Most notable is uncertainty in the degree
4 to which reported associations are specific to NO₂, rather than reflecting associations with
5 another traffic-related copollutant or the broader mix of pollutants. Overall, the potential for
6 copollutant confounding has not been well studied in this body of evidence. As described above
7 (Section 3.3.1), the ISA concludes that “[e]pidemiologic studies of asthma development in
8 children have not clearly characterized potential confounding by PM_{2.5} or traffic-related
9 pollutants [e.g., CO, BC/EC, volatile organic compounds (VOCs)]” (U.S. EPA, 2016, p. 6-64).
10 The ISA further notes that “[i]n the longitudinal studies, correlations with PM_{2.5} and BC were
11 often high (e.g., $r = 0.7-0.96$), and no studies of asthma incidence evaluated copollutant models
12 to address copollutant confounding, making it difficult to evaluate the independent effect of
13 NO₂” (U.S. EPA, 2016, p. 6-64).⁷¹ In addition, given the relatively high correlations for NO₂
14 with co-occurring pollutants, study authors often interpreted associations with NO₂ as reflecting
15 associations with traffic-related pollution more broadly (e.g., Jerrett et al., 2008; McConnell et
16 al., 2010).⁷²

17 Another important uncertainty is the potential for exposure measurement error in these
18 epidemiologic studies. The ISA states that “a key issue in evaluating the strength of inference
19 about NO₂-related asthma development from epidemiologic studies is the extent to which the
20 NO₂ exposure assessment method used in a study captured the variability in exposure among
21 study subjects” (U.S. EPA, 2016, pp. 6-16). We note that the ISA conclusion of a “likely to be a
22 causal relationship” is based on the total body of evidence, with the strongest basis for inferring
23 associations of NO₂ with asthma incidence coming from studies that “estimated residential NO₂
24 from LUR models that were demonstrated to predict well the variability in NO₂ in study
25 locations or examined NO₂ measured at locations 1-2 km of subjects’ school or home” (U.S.
26 EPA, 2016, pp. 6-21). The studies that meet this criteria were mostly conducted outside of the
27 U.S. or Canada, with the exception of Carlsten et al. (2011), which used a LUR model with good
28 predictive capacity. The other U.S. and Canadian studies employed LUR models with unknown
29 validation or central-site measurements that have well-recognized limitations in reflecting
30 variability in ambient NO₂ concentrations in a community and may not well represent variability

⁷¹Of the U.S. and Canadian studies, only two reported copollutant correlations (Carlsten et al., 2011; Clark et al., 2010), which ranged from 0.4-0.7 for NO₂ with BC or PM_{2.5}.

⁷²For example, McConnell et al. (2010) reported that “modeled exposures reflect the mixture of multiple pollutants from nearby traffic, and the high correlation of pollutants in the mixture precludes identifying the effect of any specific pollutant in the mixture” (p. 1023 in published article).

1 in NO₂ exposure among subjects. Thus, the extent to which these U.S. and Canadian studies
2 provide reliable estimates of asthma incidence for particular NO₂ concentrations is unclear.

3 Overall, in revisiting the question posed above, we note that U.S. and Canadian
4 epidemiologic studies report positive, and in some cases relatively precise, associations between
5 long-term NO₂ exposure and asthma incidence in children. While it is appropriate to consider
6 what these studies can tell us with regard to the adequacy of the existing NO₂ standards (see
7 below), the emphasis that we place on these considerations will reflect important uncertainties
8 related to the potential for confounding by traffic-related copollutants and for exposure
9 measurement error.

10 While keeping in mind these uncertainties, we next consider the ambient NO₂
11 concentrations present at monitoring sites in locations and time periods of key U.S. and Canadian
12 epidemiologic studies. We specifically consider the following question:

- 13 • **To what extent do U.S. and Canadian epidemiologic studies report associations with**
14 **long-term NO₂ in locations likely to have met the current NO₂ standards?**

15 As discussed above (section 3.2.2), addressing this question can provide important
16 insights into the extent to which NO₂-health effect associations are present for distributions of
17 ambient NO₂ concentrations that would be allowed by the current standards. The presence of
18 such associations would support the potential for the current standards to allow the NO₂-
19 associated asthma development indicated by epidemiologic studies. To the degree studies have
20 not reported associations in locations meeting the current NO₂ standards, there is greater
21 uncertainty regarding the potential for the development of asthma to result from the NO₂
22 exposures associated with air quality meeting those standards.

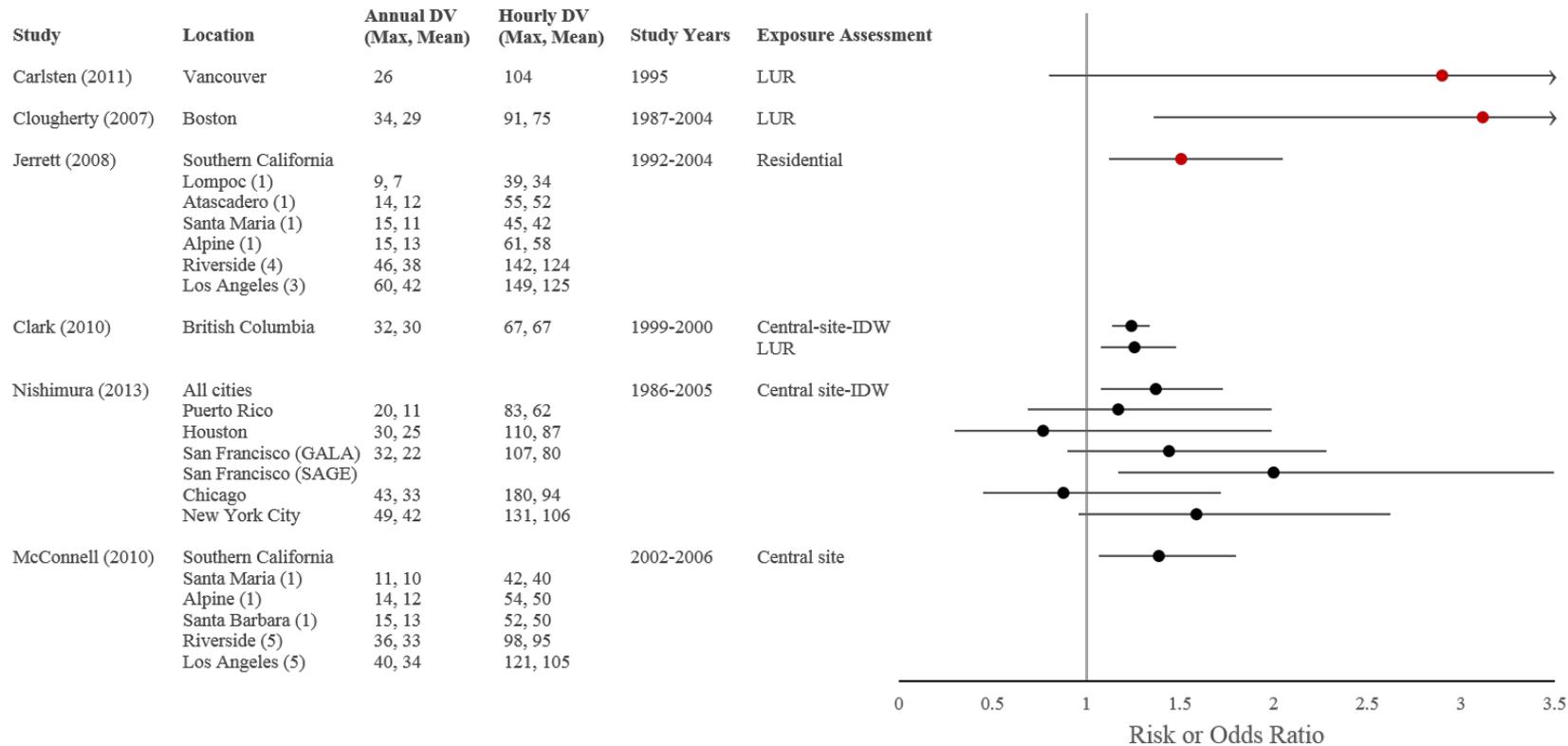
23 To evaluate this issue, we compare NO₂ DVs in study areas to the levels of the current
24 NO₂ standards. In addition to comparing annual DVs to the level of the annual standard,
25 support for consideration of 1-hour DVs comes from the ISA's integrated mode of action
26 information from short- and long-term experimental and epidemiologic evidence to describe the
27 biological plausibility for development of asthma (Section 3.1). In particular, studies demonstrate
28 the potential for repeated short-term NO₂ exposure to induce pulmonary inflammation and
29 development of allergic responses. The ISA states that “findings for short-term NO₂ exposure
30 support an effect on asthma development by describing a potential role for repeated exposures to
31 lead to recurrent inflammation and allergic responses,” which are “identified as key early events
32 in the proposed mode of action for asthma development” (U.S. EPA, 2016, p. 6-66 and p. 6-64).

1 Thus, when considering the protection provided by the current standards against long-term NO₂
2 exposures, we consider the combined protection afforded by the 1-hour and annual standards.⁷³

3 To inform our consideration of whether study areas could have met the current NO₂
4 standards during study periods, we have calculated DVs based on the NO₂ concentrations
5 measured at existing monitors during the years over which the epidemiologic studies of long-
6 term NO₂ exposures were conducted. The DVs for the epidemiologic studies of asthma incidence
7 conducted in the U.S. and Canada, discussed above, are presented below in Figure 3-2. Mean
8 DVs represent the average DVs across study periods and maximum DVs represent the year
9 (annual standard) or 3-year period (1-hour standard) with the highest DV during the study
10 period. Study locations could have met the current standards for the respective study periods if
11 all of the annual averages were at or below 53 ppb and all of the 3-year averages of the 98th
12 percentiles of daily maximum 1-hour NO₂ concentrations were at or below 100 ppb.

13 In interpreting these comparisons of DVs with the NO₂ standards, we also consider
14 uncertainty in the extent to which identified DVs represent the higher NO₂ concentrations likely
15 to have been present near major roads during study periods (see Section 3.2.2). In particular, as
16 discussed above for short-term exposures, study area DVs are based on NO₂ concentrations from
17 the generally area-wide NO₂ monitors that were present during study periods. Calculated DVs
18 could have been higher if the near-road monitors that are now required in major U.S. urban areas
19 had been in place. On this issue, we note that the published scientific literature supports the
20 occurrence of higher NO₂ concentrations near roadways and that recent air quality information
21 from the new near-road NO₂ monitoring network generally indicates higher NO₂ concentrations
22 at near-road monitoring sites (Section 2.3.2) than at non-near road monitors in the same CBSA.
23 In addition, mobile source NO_x emissions were substantially higher during the majority of study
24 periods (1986-2006) than they are today (Section 2.1.2), and NO₂ concentration gradients around
25 roadways were generally more pronounced during study periods than indicated by recent air
26 quality information. Thus, even in cases where DVs during study periods are at or somewhat
27 below the levels of current standards, it is not clear that study areas would have met the standards
28 if the currently required near-road monitors had been in place.

⁷³ It is also the case that broad changes in NO₂ concentrations will affect both hourly and annual metrics. Thus, as in the recent review of the O₃ NAAQS (80 FR 65292, October 26, 2015), it is appropriate to consider the extent to which a short-term standard could provide protection against longer-term pollutant exposures.



1
2 **Figure 3-2. U.S. and Canadian epidemiologic studies of long-term NO₂ exposures and asthma incidence.** Study locations and
3 years are reported with annual and hourly DVs for studies of asthma incidence with risk/odds ratios and 95% confidence intervals
4 standardized to 10 ppb increment in NO₂, as presented in the ISA (U.S. EPA, 2016). Effect estimates in red are for studies identified
5 as key evidence in the ISA (U.S. EPA, 2016). IDW = inverse distance weighted; LUR = land use regression; GALA and SAGE are
6 different study cohorts. For Jerrett et al. (2008) and McConnell et al. (2010), parentheses indicate the number of communities
7 represented by the DVs. For the Riverside and Los Angeles CBSAs, all monitors within the CBSAs were considered given the
8 likelihood that they represent study communities within those CBSAs given their close proximity, and DVs for the highest monitor are
9 reported. Community-specific monitors were selected for the other communities as CBSA-wide monitors had wide spatial distribution
10 and were not likely to represent the respective study locations (Lompoc, Atascadero, Santa Maria, Alpine, and Santa Barbara). For
11 more details on DV calculation and study communities, see Appendix A.

1 In considering the studies in Figure 3-2, we first note the information from the key
2 studies as identified in the ISA (Jerrett et al., 2008; Carlsten et al., 2011, Clougherty et al., 2007).
3 Jerrett et al. (2008) reported positive and relatively precise associations with asthma incidence,
4 based on analyses across several communities in Southern California.⁷⁴ Of the 11 study
5 communities evaluated by Jerrett et al. (2008), most (i.e., seven) had maximum annual DVs that
6 were near (i.e., 46 ppb for the four communities represented by the Riverside DVs) or above
7 (i.e., 60 ppb for the three communities represented by the Los Angeles DVs) 53 ppb.⁷⁵ These
8 seven communities also had 1-hour DVs (max and mean) that were well-above 100 ppb. The
9 other key studies, conducted in single cities, reported positive but statistically imprecise
10 associations. The annual DVs in locations of these studies during study years were below 53 ppb,
11 but 1-hour DVs were near or above 100 ppb.

12 We also consider the information from the other U.S. and Canadian studies available that,
13 due to additional uncertainties, were not identified as key studies in the ISA (Clark et al., 2010;
14 McConnell et al., 2010; Nishimura et al., 2013). The multi-city study by Nishimura et al. (2013)
15 reports a positive and relatively precise association with asthma incidence, based on five U.S.
16 cities and Puerto Rico (see “combined” estimate in Figure 3-2). Annual DVs in all study cities
17 were below 53 ppb, while maximum 1-hour DVs were above 100 ppb in four of the five study
18 cities (mean 1-hour DVs were also near or above 100 ppb in most study cities). Nishimura et al.
19 (2013) also reported mixed results in city-specific effects estimates. McConnell et al. (2010) also
20 conducted a multi-community study in Southern California and reported a positive and relatively
21 precise association between asthma incidence and long-term NO₂ exposures based on central-site
22 measurements. This study encompasses some of the same communities as Jerrett et al. (2008),
23 and while the annual DVs for these study years are more mixed, the 1-hour DVs representing 10
24 of 13 communities are near or above 100 ppb. Finally, Clark et al. (2010) reported a relatively
25 precise and statistically significant association in a study conducted over a two-year period in
26 British Columbia, with annual and hourly DVs of 32 ppb and 67 ppb, respectively. However, this
27 study, as noted previously, was based on central-site NO₂ measurements that have well-
28 recognized limitations in reflecting variability in ambient NO₂ concentrations in a community
29 and variability in NO₂ exposure among subjects.

⁷⁴ The multi-community studies by Jerrett et al. (2008) and McConnell et al. (2010) did not include community-specific analyses.

⁷⁵ For the studies by Jerrett et al. (2008) and McConnell et al. (2010), the majority of communities were located within the Los Angeles and Riverside CBSAs. Because of this, and because community-specific NO₂ monitoring data were often not available in these areas (Appendix A), DVs for the Los Angeles and Riverside CBSAs were used to represent multiple study communities.

1 Preliminary conclusions

2 Based on the information discussed above, we reach the preliminary conclusion that the
3 available evidence from epidemiologic studies does not provide strong support for NO₂-
4 associated asthma development in locations that would have met the existing annual and 1-hour
5 NO₂ standards. This preliminary conclusion stems from our consideration of the available
6 evidence from U.S. and Canadian studies for NO₂-associated asthma incidence, our
7 consideration of the ambient NO₂ concentrations present in study locations during study periods,
8 and the uncertainties and limitations inherent in the evidence and in our analysis of study area
9 DVs.

10 With regard to uncertainties in the evidence, we particularly note the potential for
11 confounding by co-occurring pollutants, as described above, given the following: (1) the
12 relatively high correlations observed between long-term concentrations of NO₂ and long-term
13 concentrations of other roadway-associated pollutants; (2) the general lack of information from
14 copollutant models on the potential for NO₂ associations that are independent of another traffic-
15 related pollutant or mix of pollutants. This uncertainty limits what these studies can tell us with
16 regard to the adequacy of the public health protection provided by the current NO₂ standards.

17 Even if we were to dismiss this fundamental uncertainty in the epidemiologic evidence,
18 our analysis of study area DVs does not support the occurrence of NO₂-associated asthma
19 incidence in locations with ambient NO₂ concentrations meeting the current NAAQS. In
20 particular, for most of the study locations evaluated in the lone key U.S. multi-community study
21 (Jerrett et al., 2008), 1-hour DVs were above 100 ppb and annual DVs were near or above 53
22 ppb. In addition, the two key single-city studies evaluated reported positive, but relatively
23 imprecise, associations in locations with 1-hour DVs near (Clougherty et al., 2007 in Boston) or
24 above (Carlston et al., 2011 in Vancouver) 100 ppb. Had currently required near-road monitors
25 been in operation during study periods, DVs in U.S. study locations would likely have been
26 higher. Other U.S. and Canadian studies evaluated were subject to greater uncertainties in the
27 characterization of NO₂ exposures. Given these additional uncertainties, the degree to which
28 these studies can inform our consideration of the adequacy of the current NO₂ NAAQS is
29 limited.

30 *3.3.2.2 NO₂ Concentrations in Long-Term Experimental Studies*

31 In addition to the evidence from epidemiologic studies, we also consider evidence from
32 experimental studies in animals and humans.⁷⁶ In assessing the evidence for respiratory

⁷⁶ While there are not controlled human exposure studies for long-term exposures, we consider the extent to which evidence from short-term studies can provide support for effects observed in long-term studies.

1 morbidity related to long-term NO₂ exposures, we consider the following specific question
2 regarding exposure concentrations in experimental studies:

- 3 • **To what extent do experimental studies demonstrate effects plausibly related to the**
4 **development of asthma following exposures to NO₂ lower than previously observed**
5 **and/or at concentrations below the levels of the existing standards?**

6 Experimental studies examining asthma-related effects attributable to long-term NO₂
7 exposures are largely limited to animal exposures to NO₂ concentrations well-above those found
8 in the ambient air (i.e. $\geq 1,000$ ppb). As discussed above, the ISA indicates evidence from these
9 animal studies supports the causal determination by characterizing “a potential mode of action
10 linking NO₂ exposure with asthma development” (U.S. EPA, 2016, p. 1-20). In particular, there
11 is limited evidence for airway responsiveness in guinea pigs with exposures to 1,000-4,000 ppb
12 for 6-12 weeks. There is inconsistent evidence for pulmonary inflammation across all studies,
13 though effects were reported following NO₂ exposures of 500-2,000 ppb for 12 weeks. Despite
14 providing support for the “likely to be a causal” relationship, evidence from these experimental
15 studies, by themselves, does not provide insight into the occurrence of adverse health effects
16 following exposures below the levels of the existing NO₂ standards.⁷⁷

17 Overall Preliminary Conclusions

18 Taking all of the evidence and information together, including important uncertainties,
19 we revisit the question posed at the beginning of this section:

- 20 • **To what extent does the evidence support the occurrence of NO₂-attributable asthma**
21 **development in children at NO₂ concentrations below the existing standards?**

22 Based on the considerations discussed above, we reach the preliminary conclusion that
23 the available evidence does not provide support for asthma development attributable to long-term
24 exposures to NO₂ concentrations that would meet the existing annual and 1-hour NO₂ standards.
25 In particular, epidemiologic studies of long-term NO₂ exposures and asthma development do not
26 provide a clear basis for concluding that ambient NO₂ concentrations allowed by the current
27 standards are independently (i.e., independent of co-occurring roadway pollutants) associated
28 with the development of asthma. In addition, while experimental studies provide support for
29 NO₂-attributable effects that are plausibly related to asthma development, the relatively high
30 NO₂ exposure concentrations used in these studies do not provide insight into whether such

⁷⁷ In addition, the ISA draws from short-term experimental evidence to support the biological plausibility of asthma development. Consideration of the NO₂ exposure concentrations evaluated in these studies is discussed in Section 3.3.2.

1 effects would occur at NO₂ exposure concentrations that would be allowed by the current
2 standards.

3 **3.4 POTENTIAL PUBLIC HEALTH IMPLICATIONS**

4 Evaluation of the public health protection provided against ambient NO₂ exposures
5 requires consideration of populations and lifestages that may be at greater risk of experiencing
6 NO₂-attributable health effects. In the last review, the 2008 ISA for Oxides of Nitrogen noted
7 that a considerable fraction of the U.S. population lives, works, or attends school near major
8 roadways, where ambient NO₂ concentrations are often elevated (U.S. EPA, 2008a, section 4.3).
9 Of this population, the 2008 ISA concluded that “those with physiological susceptibility will
10 have even greater risks of health effects related to NO₂” (U.S. EPA, 2008, p. 4-12). With regard
11 to susceptibility, the 2008 ISA concluded that “[p]ersons with preexisting respiratory disease,
12 children, and older adults may be more susceptible to the effects of NO₂ exposure” (U.S. EPA,
13 2008, p. 4-12).

14 In the current review, the ISA again notes because of the large populations attending
15 school, living, working, and commuting on or near roads, where ambient NO₂ concentrations can
16 be higher than in many other locations (Section 2.5.3),⁷⁸ there is widespread potential for
17 elevated ambient NO₂ exposures. For example, Rowangould et al. (2013) found that over 19% of
18 the U.S. population lives within 100 m of roads with an annual average daily traffic (AADT) of
19 25,000 vehicles, and 1.3% lives near roads with AADT greater than 200,000. The proportion is
20 much larger in certain parts of the country, mostly coinciding with urban areas. Among
21 California residents, 40% live within 100 m of roads with AADT of 25,000 (Rowangould, 2013).
22 In addition, 7% of U.S. schools serving a total of 3,152,000 school children are located within
23 100 m of a major roadway, and 15% of U.S. schools serving a total of 6,357,000 school children
24 are located within 250 m of a major roadway (Kingsley et al., 2014). Thus, as in the last review,
25 the available information indicates that large proportions of the U.S. population potentially have
26 elevated NO₂ exposures as a result of living, working, attending school, or commuting on or near
27 roadways.

28 The impacts of exposures to elevated NO₂ concentrations, such as those that can occur
29 around roadways, are of particular concern for populations at increased risk of experiencing
30 adverse effects. In the current review, our consideration of potential at-risk populations draws
31 from the 2016 ISA’s assessment of the evidence (U.S. EPA, 2016, Chapter 7). The ISA uses a
32 systematic approach to evaluate factors that may increase risks in a particular population or

⁷⁸ The ISA specifically notes that a zone of elevated NO₂ concentrations typically extends 200 to 500 m from roads with heavy traffic (U.S. EPA, 2016, Section 2.5.3).

1 during a particular lifestage, noting that increased risk could be due to “intrinsic or extrinsic
2 factors, differences in internal dose, or differences in exposure” (U.S. EPA, 2016, p. 7-1).

3 The ISA evaluates the evidence for a number of potential at-risk factors, including pre-
4 existing diseases like asthma (U.S. EPA, 2016, section 7.3), genetic factors (U.S. EPA, 2016,
5 Section 7.4), sociodemographic factors (U.S. EPA, 2016, Section 7.5), and behavioral and other
6 factors (U.S. EPA, 2016, section 7.6). The ISA then uses a systematic approach for classifying
7 the evidence for each potential at-risk factor (U.S. EPA, 2015, Section 6.a, Table III). The
8 categories considered are “adequate evidence,” “suggestive evidence,” “inadequate evidence,”
9 and “evidence of no effect” (U.S. EPA, 2016, Table 7-1). Consistent with other recent NAAQS
10 reviews (e.g., 80 FR 65292, October 26, 2015), we focus our consideration of potential at-risk
11 populations on those factors for which the ISA determines there is “adequate” evidence (U.S.
12 EPA, 2016, Table 7-27). In the case of NO₂, this includes people with asthma, children and older
13 adults (U.S. EPA, 2016, Table 7-27), based primarily on evidence for asthma exacerbation or
14 asthma development as evidence for other health effects is more uncertain.

15 Our consideration of the evidence supporting these at-risk populations specifically
16 focuses on the following question:

- 17 • **To what extent does the currently available scientific evidence expand our**
18 **understanding of populations and/or lifestages that may be at greater risk for NO₂-**
19 **related health effects?**

20 In addressing this question, we consider the evidence for effects in people with asthma (section
21 3.4.1), children (Section 3.4.2), and older adults (Section 3.4.3) (U.S. EPA, 2016, Chapter 7,
22 Table 7-27). Section 3.4.4 presents our overall conclusions regarding the populations at
23 increased risk of NO₂-related effects.

24 **3.4.1 People with Asthma**

25 Approximately 8.0% of adults and 9.3% of children (age <18 years) in the U.S. currently
26 have asthma (Blackwell et al., 2014; Bloom et al., 2013), and it is the leading chronic illness
27 affecting children (U.S. EPA, 2016, Section 7.3.1). Individuals with pre-existing diseases like
28 asthma may be at greater risk for some air pollution-related health effects if they are in a
29 compromised biological state. The 2008 ISA for Oxides of Nitrogen (U.S. EPA, 2008)
30 concluded that those with pre-existing pulmonary conditions, especially asthma, were likely to
31 be at greater risk for NO₂-related respiratory effects.

32 As in the last review, controlled human exposure studies demonstrating NO₂-induced
33 increases in AR provide key evidence that people with asthma are more sensitive than people
34 without asthma to the effects of short-term NO₂ exposures. In particular, a meta-analysis
35 conducted by Folinsbee et al. (1992) demonstrates that NO₂ exposures from 100 to 300 ppb

1 increased AR in the majority of adults with asthma, while AR in adults without asthma was
2 increased only for NO₂ exposure concentrations greater than 1,000 ppb (U.S. EPA, 2016, Section
3 7.3.1). Brown (2015) showed that following resting exposures to NO₂, about a quarter of
4 individuals with asthma experience clinically relevant increases in AR to non-specific bronchial
5 challenge. Results of epidemiologic studies are less clear regarding potential differences between
6 populations with and without asthma (U.S. EPA, 2016, Section 7.3.1). Additionally, studies of
7 activity patterns do not clearly indicate difference in time spent outdoors to suggest differences
8 in NO₂ exposure. However, the meta-analysis of information from controlled human exposure
9 studies clearly demonstrates increased sensitivity of adults with asthma compared to healthy
10 adults.⁷⁹ Thus, consistent with observations made in the 2008 ISA (U.S. EPA, 2008a), in the
11 current review the ISA determines that the “evidence is adequate to conclude that people with
12 asthma are at increased risk for NO₂-related health effects” (U.S. EPA, 2016, p. 7-7).

13 **3.4.2 Children**

14 According to the 2010 census, 24% of the U.S. population is less than 18 years of age,
15 with 6.5% less than age 6 years (Howden and Meyer, 2011). The National Human Activity
16 Pattern Survey shows that children spend more time than adults outdoors (Klepeis et al., 1996),
17 and a longitudinal study in California showed a larger proportion of children reported spending
18 time engaged in moderate or vigorous outdoor physical activity (Wu et al., 2011b). In addition,
19 children have a higher propensity than adults for oronasal breathing (U.S. EPA, 2016, Section
20 4.2.2.3) and the human respiratory system is not fully developed until 18–20 years of age (U.S.
21 EPA, 2016, Section 7.5.1). All of these factors could contribute to children being at higher risk
22 than adults for effects attributable to ambient NO₂ exposures (U.S. EPA, 2016, Section 7.5.1.1).

23 Epidemiologic evidence across diverse locations (U.S., Canada, Europe, Asia, Australia)
24 consistently demonstrates adverse effects of both short- and long-term NO₂ exposures in
25 children. In particular, short-term increases in ambient NO₂ concentrations are consistently
26 associated with larger increases in asthma-related hospital admissions, emergency department
27 visits or outpatient visits in children than in adults (U.S. EPA, 2016, Section 7.5.1.1, Table 7-13).
28 In general, these results indicate NO₂-associated impacts that are 1.8 to 3.4-fold larger in
29 children (Son et al., 2013; Ko et al., 2007; Atkinson et al., 1999; Anderson et al., 1998). In
30 addition, asthma development in children has been reported to be associated with long-term NO₂
31 exposures, based on exposure periods spanning infancy to adolescence (U.S. EPA, 2016, Section
32 6.2.2.1). Given the consistent epidemiologic evidence for associations between ambient NO₂ and

⁷⁹ Though, as discussed above (section 3.2), there is uncertainty in the extent to which increases in AR following exposures to NO₂ concentrations near those found in the ambient air (i.e., around 100 ppb) would be adverse.

1 asthma-related outcomes, including the larger associations with short-term exposures observed in
2 children, the ISA concludes the evidence “is adequate to conclude that children are at increased
3 risk for NO₂-related health effects” (U.S. EPA, 2016, p. 7-32).

4 **3.4.3 Older adults**

5 According to the 2012 National Population Projections issued by the U.S. Census
6 Bureau, 13% of the U.S. population was age 65 years or older in 2010, and by 2030, this fraction
7 is estimated to grow to 20% (Ortman et al., 2014). The 2008 ISA (U.S. EPA, 2008) indicated
8 that older adults may be at increased risk for NO₂-related respiratory effects and mortality, and
9 recent epidemiologic findings add to this body of evidence (Table 7-15). While it is not clear that
10 older adults experience greater NO₂ exposures or doses, epidemiologic evidence generally
11 indicates greater risk of NO₂-related health effects in older adults compared with younger adults.
12 For example, comparisons of older and younger adults with respect to NO₂-related asthma
13 exacerbation generally show larger (one to threefold) effects in adults ages 65 years or older than
14 among individuals ages 15–64 years or 15–65 years (Ko et al., 2007; Villeneuve et al., 2007;
15 Migliaretti et al., 2005; Anderson et al., 1998). Results for all respiratory hospital admissions
16 combined also tend to show larger associations with NO₂ among older adults ages 65 years or
17 older (Arbex et al., 2009; Wong et al., 2009; Hinwood et al., 2006; Atkinson et al., 1999). The
18 ISA determined that, overall, the consistent epidemiologic evidence for asthma-related hospital
19 admissions and ED visits “is adequate to conclude that older adults are at increased risk for NO₂-
20 related health effects” (U.S. EPA, 2016, p. 7-37).

21 **3.4.4 Conclusions**

22 Consistent with the last review, the ISA determined that the available evidence is
23 adequate to conclude that people with asthma, children, and older adults are at increased risk for
24 NO₂-related health effects. The large proportions of the U.S. population that encompass each of
25 these groups and lifestages (i.e., 8% adults and 9.3% children with asthma, 24% children, 13%
26 older adults) underscores the potential for important public health impacts attributable to NO₂
27 exposures. These impacts are of particular concern for members of these populations and
28 lifestages who live, work, attend school or otherwise spend a large amount of time in locations of
29 elevated ambient NO₂, including near heavily trafficked roadways.

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15

4.1 APPROACH TO CONSIDERING POTENTIAL SUPPORT FOR UPDATED QUANTITATIVE ANALYSES

In each NAAQS review, selection of the appropriate model(s) for the characterization of exposures and/or risks is influenced by the nature and strength of the evidence for the subject pollutant. Depending on the type of evidence available, analyses may include quantitative risk assessments based on dose-response, exposure-response, or ambient concentration-response relationships. Analyses may also include comparisons of health-based benchmark concentrations, drawn from controlled human exposure studies, with modeled exposure estimates or with ambient air quality concentrations (i.e., as surrogates for potential ambient exposures). The variety of approaches that have been employed in NAAQS reviews is summarized in Figure 4-1.

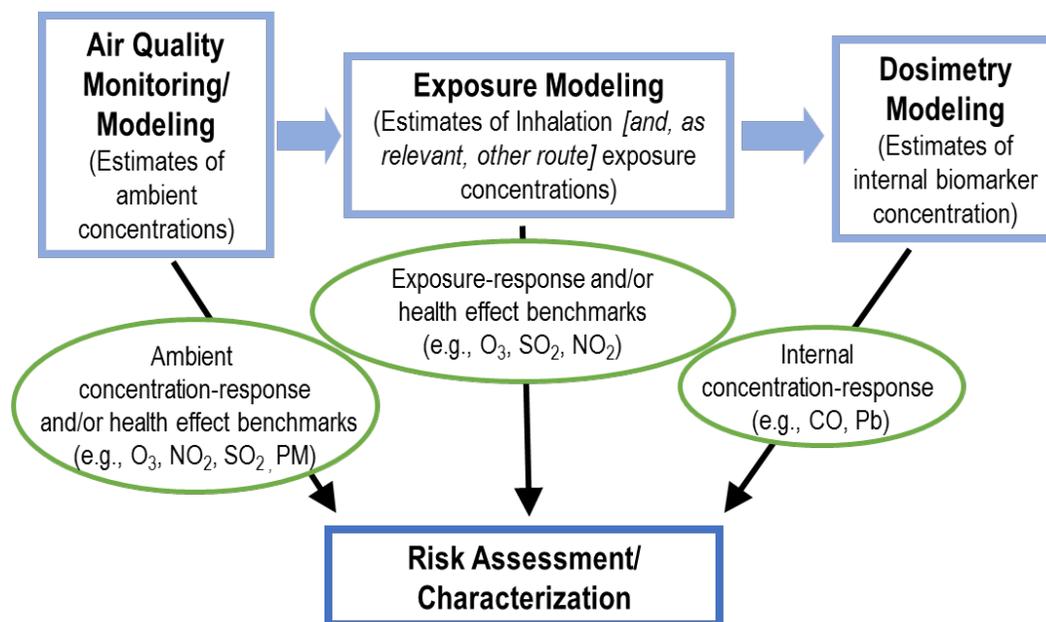


Figure 4-1. Risk characterization models employed in NAAQS Reviews.

In the last review of the primary NO₂ NAAQS, the 2008 ISA concluded that the strongest evidence supported the occurrence of respiratory effects following short-term NO₂ exposures (U.S. EPA, 2008b). Based on that evidence, the REA employed three approaches to quantify NO₂ exposures and health risks (U.S. EPA, 2008a):

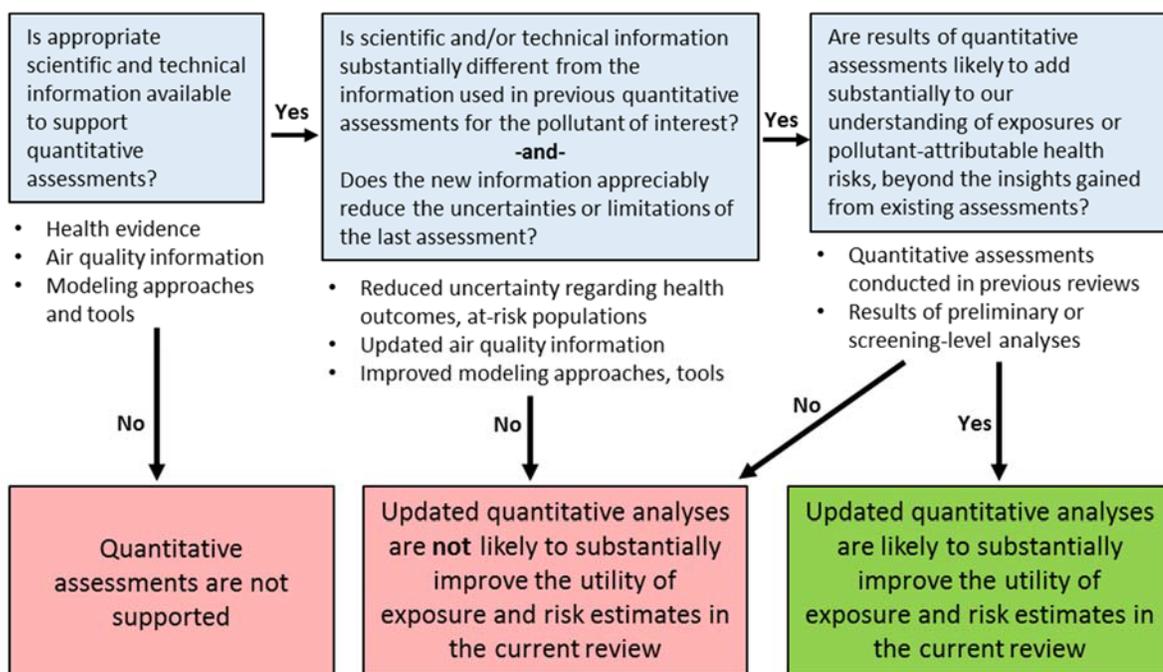
- 1) Benchmarks were identified based on information from controlled human exposure studies of NO₂-induced increases in AR. Ambient NO₂ concentrations were compared to these benchmarks. In urban areas across the U.S., such comparisons were made for

- 1 ambient NO₂ concentrations at locations of NO₂ monitoring sites and simulated
2 concentrations on/near roadways⁸⁰ (U.S. EPA, 2008a, Chapter 7).
- 3 2) Modeled estimates of personal NO₂ exposures were compared to benchmarks in a single
4 urban area (Atlanta, GA), with a focus on children with asthma and people of all ages
5 with asthma (U.S. EPA, 2008a, Chapter 8).
- 6 3) Concentration-response relationships from an epidemiologic study (Tolbert et al., 2007)
7 were used to estimate NO₂-associated emergency department visits for respiratory causes
8 in Atlanta, GA (U.S. EPA, 2008a, Chapter 9).

9 For this review, conclusions regarding the extent to which the newly available evidence
10 and information support updated quantitative analyses are based on our consideration of a variety
11 of factors. As noted above, these include consideration of the available health evidence and the
12 available technical information, tools and methods. Our consideration of these factors inform
13 judgments as to the likelihood that particular quantitative analyses will add substantially to our
14 understanding of NO₂ exposures or health risks, beyond the insights gained from the analyses
15 conducted in the last review. These key considerations and judgments are discussed in the REA
16 Planning document (U.S. EPA, 2015a) and are summarized in Figure 4-2.

⁸⁰ Based on the available evidence, there was uncertainty regarding the locations of maximum NO₂ concentrations with respect to roadway emissions and transformation of NO to NO₂. Therefore, in the last review the EPA characterized these simulated concentrations as on- or near-road (75 FR 6474, February 9, 2010).

1



2

3 **Figure 4-2. Key considerations for updated quantitative analyses.**

4 As indicated in Figure 4-2, an initial consideration is the available health effects evidence
 5 and the foundation it may provide for updated quantitative analyses. As discussed in Chapter 3 of
 6 this draft PA, our evaluation of the scientific evidence is based on the assessment of the full body
 7 of evidence in the 2016 ISA (U.S. EPA, 2016). Consistent with prior reviews, in considering the
 8 evidence with regard to support for quantitative analyses, we give foremost consideration to
 9 health endpoints for which the ISA concludes the evidence supports a “causal” relationship or
 10 indicates that there is “likely to be a causal” relationship. As discussed in more detail in Chapter
 11 3 of this draft PA, in the current review, the ISA reaches the following conclusions in this regard:

- 12 • “A causal relationship exists between short-term NO₂ exposure and respiratory effects based
 13 on evidence for asthma exacerbation” (U.S. EPA, 2016, p. 1-17).
- 14 • “There is likely to be a causal relationship between long-term NO₂ exposure and respiratory
 15 effects based on evidence for the development of asthma” (U.S. EPA, 2016, p. 1-20).

16 For all other health endpoints evaluated, the evidence was determined to be either “suggestive of,
 17 but not sufficient to infer, a causal relationship” or “inadequate to infer a causal relationship”
 18 (U.S. EPA, 2016, Table ES-1).

19 Given these ISA conclusions, our consideration of potential support for updated
 20 quantitative analyses in this review focuses on evidence for health outcomes related to asthma
 21 exacerbation (short-term NO₂ exposures) and the development of asthma (long-term NO₂

1 exposures). Our consideration of this evidence is discussed further below as it relates to the
2 identification of NO₂ benchmarks (Sections 4.2, 4.3) and as to whether updated risk assessments
3 are supported in the current review (Section 4.4).

4 **4.2 COMPARISON OF NO₂ AIR QUALITY TO HEALTH-BASED BENCHMARKS**

5 As discussed in Chapter 3, controlled human exposure studies of AR provide the
6 strongest evidence supporting a causal relationship between short-term NO₂ exposures and
7 respiratory effects.⁸¹ A meta-analysis of individual-level data from these studies (Brown, 2015)
8 supports the occurrence of increased AR in individuals with asthma following resting NO₂
9 exposures from 100 to 530 ppb (U.S. EPA, 2016, Section 5.2.2.1). In the last review, the 2008
10 REA compared NO₂ benchmarks based on information from such controlled human exposure
11 studies with estimates of ambient NO₂ concentrations. These comparisons provided perspective
12 on the potential for populations to experience NO₂ exposures that may be of public health
13 concern (U.S. EPA, 2008a).

14 Given that mobile sources were identified in the last review as the largest contributors to
15 U.S. NO_x emissions, and that NO₂ monitors were generally not located near heavily trafficked
16 roads, an important uncertainty identified in the 2008 REA was the characterization of 1-hour
17 NO₂ concentrations around major roadways. Based largely on the fact that information is newly
18 available in this review from near-road NO₂ monitors (Chapter 2), the REA Planning document
19 reached the preliminary conclusion that updated analyses comparing ambient NO₂ concentrations
20 (i.e., as surrogates for potential exposure concentrations) to health-based benchmarks are
21 supported (U.S. EPA, 2015a). In particular, the REA Planning document noted that new
22 information from near-road monitors would be expected to provide important perspective,
23 beyond what was available in the last review, on the extent to which NO₂ exposures around
24 roads could have potentially important implications for public health (U.S. EPA, 2015a, Section
25 2.2.1). We have since conducted updated analyses comparing ambient NO₂ concentrations to
26 benchmarks, the details of which are described in Section 4.2.1 and in Appendix B to this draft
27 PA. Section 4.2.2 presents our overall conclusions based on these updated analyses.

28 **4.2.1 Updated Analyses Comparing NO₂ Air Quality with Health-Based Benchmarks**

29 In this draft PA, we have conducted updated analyses comparing NO₂ air quality to
30 benchmarks in 23 study areas (Table 4-1). Our selection of study areas focused on CBSAs with

⁸¹ Increased AR in people with asthma is the only health endpoint that has been shown to occur in controlled human exposure studies following exposures to NO₂ concentrations near those typically found in the ambient air in the U.S. (Section 3.2).

1 near-road monitors in operation,⁸² CBSAs with the highest NO₂ design values and CBSAs with a
2 relatively large number of NO₂ monitors overall (i.e., providing improved spatial
3 characterization). Based on these criteria, a total of 23 CBSAs from across the U.S. were selected
4 as study areas (See Appendix B, Figure B2-1).⁸³ Further evaluation indicates that these 23 study
5 areas are among the most populated CBSAs in the U.S.; they have among the highest total NO_x
6 emissions and mobile source NO_x emissions in the U.S.; and they include a wide range of
7 stationary source NO_x emissions (Appendix B, Figures B2-2 to B2-8).

8 Air quality-benchmark comparisons were conducted in study areas with unadjusted air
9 quality and with air quality adjusted upward to just meet the existing 1-hour standard.⁸⁴ Upward
10 adjustment was required because all locations in the U.S. meet the current NO₂ NAAQS. These
11 comparisons inform our consideration of the following questions:

- 12 • **To what extent are the current NO₂ standards estimated to allow ambient NO₂**
13 **concentrations that may be of public health concern? What are the important**
14 **uncertainties associated with those estimates?**

15 In addressing these questions, an important focus is on the extent to which ambient NO₂
16 concentrations at or above health-based benchmarks could occur near major roadways. While
17 data from the recently deployed near-road monitors will inform our consideration of this issue,
18 the data available from these monitors are limited. Most near-road monitors have been in
19 operation for only one to two years (Section 2.2.2), and true NO₂ DVs could not be calculated at

⁸² As discussed above (Section 2.2.2), in the last review near-road monitors were required within 50 m of major roads in large urban areas that met certain criteria for population size or traffic volume. Most near-road monitors are sited within about 30 m of the road, and in some cases they are sited almost at the roadside (i.e., as close as 2 m from the road; Table 2-1).

⁸³ Study area CBSAs are Atlanta-Sandy Springs-Roswell, GA; Baltimore-Columbia-Towson, MD; Boston-Cambridge-Newton, MA-NH; Chicago-Naperville-Elgin, IL-IN-WI; Dallas-Fort Worth-Arlington, TX; Denver-Aurora-Lakewood, CO; Detroit-Warren-Dearborn, MI; Houston-The Woodlands-Sugar Land, TX; Kansas City, MO-KS; Los Angeles-Long Beach-Anaheim, CA; Miami-Fort Lauderdale-West Palm Beach, FL; Minneapolis-St. Paul-Bloomington, MN-WI; New York-Newark-Jersey City, NY-NJ-PA; Philadelphia-Camden-Wilmington, PA-NJ-DE-MD; Phoenix-Mesa-Scottsdale, AZ; Pittsburgh, PA; Richmond, VA; Riverside-San Bernardino-Ontario, CA; Sacramento--Roseville--Arden-Arcade, CA; San Diego-Carlsbad, CA; San Francisco-Oakland-Hayward, CA; St. Louis, MO-IL; Washington-Arlington-Alexandria, DC-VA-MD-WV.

⁸⁴ In all study areas, ambient NO₂ concentrations required smaller upward adjustments to just meet the 1-hour standard than to just meet the annual standard. Therefore, when adjusting air quality to just meet the current NO₂ NAAQS, we applied the adjustment needed to just meet the 1-hour standard. Air quality was adjusted such that the three-year average of the 98th percentiles of the annual distributions of daily maximum 1-hour NO₂ concentrations equals 100 ppb. Information on the air quality adjustment approach can be found in Appendix B, Section B2.4.1.

1 these monitors for the one-hour standard (i.e., because 1-hour DVs are based on three years of
2 data).⁸⁵

3 In this section, we discuss our approach to identifying and interpreting the NO₂ health-
4 based benchmarks (Section 4.2.1.1), summarize the results of the air quality-benchmark
5 comparisons (Section 4.2.1.2) and discuss uncertainties in these analyses (Section 4.2.1.3). More
6 detailed descriptions of the approaches used to conduct analyses, and the results of those
7 analyses, are provided in Appendix B.

8 *4.2.1.1 Health-Based Benchmarks*

9 Based on the evidence from controlled human exposure studies of NO₂-induced increases
10 in AR, the 2008 REA identified NO₂ benchmarks from 100 to 300 ppb (U.S. EPA, 2008a). As
11 discussed further below, in the current review we have again identified benchmarks from 100 to
12 300 ppb for comparison to ambient NO₂ concentrations, based largely on information from the
13 same controlled human exposure studies of AR that were available in the last review (U.S. EPA,
14 2016, Tables 5-1 and 5-2). This evidence indicates the potential for increased AR in some people
15 with asthma following resting exposures to NO₂ concentrations from 100 to 530 ppb, though
16 important uncertainties remain.

17 In identifying the range of NO₂ health-based benchmarks to evaluate, and the weight to
18 place on specific benchmarks within this range, we consider both the group mean responses
19 reported in individual studies of AR and the results of a meta-analysis that combined individual-
20 level data from multiple studies (Brown, 2015; U.S. EPA, 2016, Section 5.2.2.1). Group mean
21 responses in individual studies, and the variability in those responses, can provide insight into the
22 extent to which observed changes in AR are due to NO₂ exposures, rather than to chance alone,
23 and have the advantage of being based on the same exposure conditions. With regard to
24 individual studies, we consider both the direction and the statistical significance of group mean
25 responses in AR following exposures to various NO₂ concentrations. Beyond what we can learn
26 from individual studies, the meta-analysis by Brown (2015) can aid in identifying trends in
27 individual-level responses across studies and can have the advantage of increased power to
28 detect effects, even in the absence of statistically significant effects in individual studies. With
29 regard to the meta-analysis, we consider the fraction of people with asthma who experienced
30 increased AR following exposures to various NO₂ concentrations, and the extent to which those
31 fractions reflect statistically significant majorities of study volunteers.

⁸⁵ One implication of this is that near-road monitors were generally not used as the basis for adjusting air quality to just meet the current standard. As discussed below (Section 4.2.1.4), this introduces uncertainty into our air quality adjustments.

1 In first considering studies conducted in resting individuals, where the data are most
2 consistent (U.S. EPA, 2016, Section 5.2.2.1), we note that the lowest NO₂ concentration to which
3 individuals with asthma have been exposed is 100 ppb. Of the five controlled human exposure
4 studies conducted in resting asthmatics at 100 ppb, a statistically significant increase in AR
5 following exposure to NO₂ was only observed in the study by Orehek et al. (1976) (N = 20;
6 Table 3-2). Of the four studies that did not report statistically significant increases in airway
7 responsiveness following resting exposures to 100 ppb NO₂, three reported non-significant trends
8 toward decreased airway responsiveness (Ahmed et al., 1983b (N = 20); Hazucha et al., 1983 (N
9 = 15); Tunnicliffe et al., 1994 (N = 8)), and one reported a trend towards increased AR (Ahmed
10 et al., 1983a (N = 20)) (Table 3-2). When individual-level data from these five studies were
11 combined in a meta-analysis, Brown (2015) reported that a marginally significant majority of
12 study participants experienced an increase in AR following exposure to 100 ppb NO₂ (i.e., 61%,
13 $p = 0.08$; N = 76).⁸⁶ When the analysis was restricted to non-specific AR, the percentage who
14 experienced increased AR was larger and statistically significant (i.e., 66%, $p = 0.033$; N = 50).
15 In contrast, when the analysis was restricted to specific AR, study participants exposed to 100
16 ppb NO₂ were evenly divided between experiencing increases and decreases in AR (i.e., 50%
17 increased and 50% decreased; N = 26) (Brown, 2015, Table 4).

18 Compared to 100 ppb, increased AR has been reported more consistently following
19 exposures to higher NO₂ concentrations. In particular, most studies conducted in resting
20 individuals report statistically significant increases in AR following exposures at or above 250
21 ppb NO₂ (Section 3.2.2). In addition, when resting NO₂ exposure concentrations above 100 ppb
22 are examined in the meta-analysis, results indicate that statistically significant majorities of study
23 participants experienced increased AR (Brown, 2015, Tables 3 to 5).⁸⁷ These results are largely
24 due to non-specific AR. In contrast, specific AR was not increased in the majority of study
25 volunteers following exposures to NO₂ concentrations at or below 300 ppb. In addition, neither
26 specific nor non-specific AR was affected following exposures to any of the NO₂ concentrations

⁸⁶ Brown et al. (2015) compared the number of study participants who experienced an increase in AR following NO₂ exposures to the number who experienced a decrease in AR. Study participants who experienced no change in AR were not included in comparisons. Thus, of the study participants who experienced either an increase or decrease in AR following exposure to 100 ppb NO₂, 61% experienced an increase and 39% experienced a decrease. The percentage of total study participants who experienced an increase in AR was slightly smaller than the percentage reported here and in Brown (2015) (i.e., 55% rather than 61% for 100 ppb NO₂ exposure, based on information in Table 1 of Brown (2015)).

⁸⁷ Specifically, for resting exposures to concentrations of 100 ppb up to 200 ppb, 200 ppb up to and including 300 ppb, and above 300 ppb, increased AR was reported in 63%, 65%, and 78% of study participants, respectively. The fractions of individuals who experienced increased AR following resting exposures, compared to the fraction who experienced decreased AR, reached statistical significance for all of the ranges of exposure concentrations evaluated ($p < 0.05$) (Brown, 2015, Table 5).

1 evaluated during exercise (i.e., including exposure concentrations up to 600 ppb) (Brown, 2015,
2 Tables 3 to 5).

3 In further considering these studies within the context of identifying appropriate
4 benchmarks, we note the discussion of uncertainties in Section 3.2.2.1 above. As discussed in
5 more detail in that section, there is no indication of a dose-response relationship between NO₂
6 and AR (Goodman, 2009; Brown, 2015). Though the lack of an apparent dose-response
7 relationship does not necessarily indicate the lack of an NO₂ effect, it adds uncertainty to our
8 interpretation of the controlled human exposure studies of AR. An additional uncertainty is the
9 clinical relevance of the reported NO₂-induced increases in AR. While the meta-analysis by
10 Brown (2015) has partially addressed this uncertainty by evaluating the magnitudes of responses
11 in a subset of study participants, clear guidelines on the clinical relevance of AR have not been
12 established.

13 When taken together, the results of controlled human exposure studies and of the meta-
14 analysis by Brown (2015) support consideration of NO₂ benchmarks from 100 to 300 ppb, based
15 largely on studies of non-specific AR in study participants exposed at rest. Benchmarks from the
16 upper end of this range are supported by the results of individual studies, the majority of which
17 reported statistically significant increases in AR following NO₂ exposures at or above 250 ppb,
18 and by the results of the meta-analysis by Brown (2015). Benchmarks from the lower end of this
19 range are supported by the results of the meta-analysis, even though individual studies do not
20 consistently report statistically significant NO₂-induced increases in AR following exposures
21 below 250 ppb. Given uncertainties in the evidence, including the lack of an apparent dose-
22 response relationship and uncertainty in the potential adversity of reported increases in AR,
23 caution is appropriate when interpreting the potential public health implications of 1-hour NO₂
24 concentrations at or above these benchmarks. This is particularly the case for the 100 ppb
25 benchmark, given the less consistent results at this exposure concentration.

26 4.2.1.2 *Summary of Results*

27 We have evaluated the occurrence of 1-hour ambient NO₂ concentrations at or above the
28 various benchmarks for as-is (i.e., unadjusted) air quality from 2010 to 2015 and for NO₂ air
29 quality adjusted to just meet the existing 1-hour standard.⁸⁸ In considering these results, our
30 focus is on the number of days per year that such 1-hour NO₂ concentrations could occur at each
31 monitoring site in each study area. Detailed results of these analyses can be found in Appendix B

⁸⁸ As noted above, in all study areas, ambient NO₂ concentrations required smaller upward adjustments to just meet the 1-hour standard than to just meet the annual standard. Therefore, when adjusting air quality to just meet the current NO₂ NAAQS, we applied the adjustment needed to just meet the 1-hour standard.

1 (Section B3). In Tables 4-1 and 4-2 below, we present the number of days per year with daily
2 maximum 1-hour NO₂ concentrations calculated to be at or above benchmarks of 100, 150,⁸⁹ and
3 200 ppb,⁹⁰ based on non-near-road monitors (Table 4-1)⁹¹ and near-road monitors (Table 4-2).
4

⁸⁹ Though no studies specifically evaluated the potential for increased AR following exposures to 150 ppb NO₂, results for the 150 ppb benchmark can provide information on the degree to which exceedances of the 100 ppb benchmark are due to ambient NO₂ concentrations closer to 100 ppb or 200 ppb.

⁹⁰ Because ambient NO₂ concentrations never reached or exceeded even the 200 ppb benchmark under the air quality scenarios that we have evaluated in this draft PA, we do not present results for the 300 ppb benchmark.

⁹¹ Most, though not all, of these NO₂ monitors are classified as “area-wide.” We use the term “area-wide” to refer to monitors sited at neighborhood, urban, and regional scales, as well as those monitors sited at either micro- or middle-scale that are representative of many such locations in the same CBSA (Section 2.2.2, above).

Table 4-1. Average and maximum number of days per year with non-near road NO₂ concentrations at or above benchmarks.

Study Area ⁹²	100 ppb benchmark ^{a,b}					150 ppb benchmark ^{a,b}					200 ppb benchmark ^{a,b}				
	As Is Air Quality	Air Quality Adjusted to Just meet the Existing 1-hr Standard ^c				As Is Air Quality	Air Quality Adjusted to Just meet the Existing 1-hr Standard				As Is Air Quality	Air Quality Adjusted to Just meet the Existing 1-hr Standard			
	2010-2015	2010-2012	2011-2013	2012-2014	2013-2015	2010-2015	2010-2012	2011-2013	2012-2014	2013-2015	2010-2014	2010-2012	2011-2013	2012-2014	2013-2015
Atlanta, GA	0 (0)	3 (15)	5 (30)	4 (16)	2 (16)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Baltimore, MD	0 (0)	4 (12)	5 (12)	4 (12)	4 (11)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Boston, MA	0 (0)	5 (15)	5 (15)	6 (18)	3 (12)	0 (0)	0.5 (1)	0.5 (1)	1 (1)	0.5 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Chicago, IL	0.5 (1)	7 (24)	-	-	4 (12)	0 (0)	0 (0)	-	-	0 (0)	0 (0)	0 (0)	-	-	0 (0)
Dallas, TX	0 (0)	1 (9)	2 (11)	2 (16)	2 (12)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Denver, CO	0.5 (1)	-	14 (29)	5 (10)	4 (10)	0 (0)	-	0.5 (1)	1 (1)	0.5 (1)	0 (0)	-	0 (0)	0 (0)	0 (0)
Detroit, MI	0 (0)	6 (12)	9 (23)	8 (18)	4 (9)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Houston, TX	0.5 (3)	2 (12)	2 (8)	2 (15)	2 (14)	0 (0)	0.5 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Kansas City, MO-KS	0 (0)	5 (9)	5 (9)	7 (11)	7 (10)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Los Angeles, CA	0.5 (1)	5 (19)	5 (22)	5 (23)	4 (27)	0 (0)	0.5 (1)	0.5 (1)	0.5 (1)	0.5 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Miami, FL	0 (0)	5 (15)	4 (12)	5 (12)	6 (17)	0 (0)	0.5 (1)	0.5 (1)	1 (1)	0.5 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Minneapolis, MN	0 (0)	6 (22)	4 (11)	4 (14)	2 (10)	0 (0)	0.5 (2)	0.5 (3)	0.5 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
New York, NY	0.5 (1)	3 (9)	3 (12)	3 (12)	4 (12)	0.5 (1)	0.5 (1)	0.5 (1)	0.5 (1)	0.5 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Philadelphia, PA	0.5 (1)	3 (18)	3 (23)	-	2 (13)	0 (0)	0.5 (1)	0.5 (1)	-	0.5 (1)	0 (0)	0 (0)	0 (0)	-	0 (0)
Phoenix, AZ	0.5 (1)	2 (9)	4 (13)	3 (12)	3 (9)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Pittsburgh, PA	0 (0)	2 (9)	3 (22)	-	3 (14)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)
Richmond, VA	0 (0)	6 (17)	5 (17)	7 (15)	2 (6)	0 (0)	0 (0)	0.5 (1)	0.5 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Riverside, CA	0.5 (7)	1 (14)	4 (25)	-	1 (5)	0 (0)	0.5 (1)	0.5 (8)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)

⁹²Tables 4-1 and 4-2 identify study areas as individual cities. However, actual study areas include the entire CBSAs within which the identified cities are located. Complete study areas are defined above and in Appendix B.

Sacramento, CA	0 (0)	2 (10)	3 (14)	4 (21)	3 (17)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
San Diego, CA	0.5 (1)	1 (9)	1 (12)	1 (12)	0.5 (4)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
San Francisco, CA	0.5 (1)	1 (13)	1 (23)	1 (11)	2 (14)	0 (0)	0 (0)	0.5 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
St. Louis, MO	0 (0)	-	2 (8)	4 (14)	1 (5)	0 (0)	-	0 (0)	0 (0)	0 (0)	0 (0)	-	0 (0)	0 (0)	0 (0)
Washington, DC	0 (0)	4 (14)	4 (20)	5 (24)	6 (24)	0 (0)	0.5 (1)	0.5 (1)	0.5 (1)	0.5 (1)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)

^aAll calculated means were rounded to the nearest integer, though for mean values <0.50, rather than round downward to zero, a value of 0.5 was designated to distinguish it from instances where there were absolutely no (i.e., 0) days at or above benchmark levels during the collective years of interest.

^bIn parentheses are the maximum number of days in single year during the collective years of interest.

^dBlank cells (indicated by “-”) indicate time periods for which sufficient monitoring data were not available to generate estimates

Table 4-2. Number of days in 2014 and 2015 with near-road NO₂ concentrations at or above benchmarks.⁹³

Study Area	Site ID	Annual Average Daily Traffic (AADT)	Distance from Road (m)	100 ppb Benchmark				150 ppb Benchmark				200 ppb Benchmark			
				As-Is Air Quality		Adjusted Air Quality		As-Is Air Quality		Adjusted Air Quality		As-Is Air Quality		Adjusted Air Quality	
				2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Atlanta, GA	130890003	146,000	30	-	0	-	7	-	0	-	0	-	0	-	0
	131210056	284,920	2	-	0	-	3	-	0	-	0	-	0	-	0
Baltimore, MD	240270006	186,750	16	-	0	-	7	-	0	-	0	-	0	-	0
Boston, MA	250250044	198,239	10	0	0	11	6	0	0	0	0	0	0	0	0
Chicago, IL	170313103			1	0	4	4	0	0	0	0	0	0	0	0
Dallas, TX	481131067	235,790	24	-	0	-	5	-	0	-	0	-	0	-	0
Denver, CO	080310027	249,000	9	0	0	5	3	0	0	0	0	0	0	0	0
Detroit, MI	261630093	140,500	9	0	0	9	9	0	0	0	0	0	0	0	0
	261630095	172,600	49	-	0	-	5	-	0	-	0	-	0	-	0
Houston, TX	482011066	324,119	24	0	0	4	3	0	0	0	0	0	0	0	0
Kansas City, MO-KS	290950042	114,495	20	0	0	4	3	0	0	0	0	0	0	0	0
Los Angeles, CA	060590008	272,000	9	0	0	21	1	0	0	0	0	0	0	0	0
Minneapolis, MN	270370480	87,000	30	-	0	-	3	-	0	-	0	-	0	-	0
	270530962	277,000	33	0	0	11	10	0	0	0	0	0	0	0	0
New York, NY	340030010	311,234	20		1	-	8	-	1	-	0	-	0	-	0
Philadelphia, PA	421010075	124,610	12	0	0	3	2	0	0	0	0	0	0	0	0
Phoenix, AZ	040134019	320,138	12	0	0	3	2	0	0	0	0	0	0	0	0
Pittsburgh, PA	420031376	87,534	18	-	0	-	11	-	0	-	0	-	0	-	0
Richmond, VA	517600025	151,000	21	-	0	-	9	-	0	-	0	-	0	-	0
Riverside, CA	060710026	245,300	50	-	0	-	8	-	0	-	0	-	0	-	0
San Francisco, CA	060010012	216,000	20	0	0	2	1	0	0	0	0	0	0	0	0
St. Louis, MO	291890016	161,338	27	-	0	-	1	-	0	-	0	-	0	-	0
	295100094	159,326	25	0	0	10	2	0	0	0	0	0	0	0	0

⁹³ Where monitor was in operation for 300 or more days in the year. Blank cells (indicated by “-”) indicate time periods for which sufficient monitoring data were not available.

1 Based on the results presented in Tables 4-1 and 4-2 above, we make the following key
2 observations for study areas when air quality was unadjusted (“as-is”) and when air quality was
3 adjusted to just meet the current 1-hour NO₂ standard:

4 1. For unadjusted air quality

- 5 a. One-hour ambient NO₂ concentrations in study areas, including those near major
6 roadways, were always below 200 ppb, and were virtually always below 150 ppb.
 - 7 i. Even in the worst-case years (i.e., the years with the largest number of
8 days at or above benchmarks), no study areas had any days with 1-hour
9 NO₂ concentrations at or above 200 ppb, and only one area had any days
10 (i.e., one day) with 1-hour concentrations at or above 150 ppb.
- 11 b. One-hour ambient NO₂ concentrations in study areas, including those near major
12 roadways, only rarely reached or exceeded 100 ppb. On average in all study areas,
13 1-hour NO₂ concentrations at or above 100 ppb occurred on less than one day per
14 year.
 - 15 i. Even in the worst-case years, most study areas had either zero or one day
16 with 1-hour NO₂ concentrations at or above 100 ppb (7 days in the single
17 worst-case location and worst-case year).

18 2. For air quality adjusted to just meet the current primary 1-hour NO₂ standard

- 19 a. The current standard is estimated to allow no days in study areas with 1-hour
20 ambient NO₂ concentrations at or above 200 ppb. This is true for both area-wide
21 and near-road monitoring sites, even in the worst-case years.
- 22 b. The current standard is estimated to allow almost no days with 1-hour ambient
23 NO₂ concentrations at or above 150 ppb, based on both area-wide and near-road
24 monitoring sites (i.e., zero to one day per year, on average).
 - 25 i. In the worst-case years in most study areas, the current standard is
26 estimated to allow either zero or one day with 1-hour ambient NO₂
27 concentrations at or above 150 ppb. In the single worst-case year and
28 location, the current standard is estimated to allow eight such days.
- 29 c. At area-wide monitoring sites in most of the study areas, the current standard is
30 estimated to allow from one to seven days per year, on average, with 1-hour
31 ambient NO₂ concentrations at or above 100 ppb. At near-road monitoring sites in
32 most of the study areas, the current standard is estimated to allow from about one
33 to 10 days per year with such 1-hour concentrations.
 - 34 i. In the worst-case years in most of the study areas, the current standard is
35 estimated to allow from about 5 to 20 days with 1-hour NO₂
36 concentrations at or above 100 ppb (30 days in the single worst-case
37 location and year).

38 *4.2.1.3 Limitations and uncertainties*

39 There are a variety of limitations and uncertainties in these comparisons of NO₂ air
40 quality with health-based benchmarks. In particular, we note uncertainties in the evidence

1 underlying the benchmarks themselves, as discussed in Section 4.2.1.1, uncertainties in the
2 upward adjustment of NO₂ air quality concentrations, and uncertainty in the degree to which
3 monitored NO₂ concentrations reflect the highest potential NO₂ exposures. Each of these is
4 discussed below.

5 Health-Based benchmarks

6 The primary goal of this analysis is to inform conclusions regarding the potential for the
7 existing primary NO₂ standards to allow exposures to ambient NO₂ concentrations that may be of
8 concern for public health. As discussed in detail above (Sections 3.2.2, 4.2.1.1), while the meta-
9 analysis by Brown (2015) indicates the potential for increased AR in some people with asthma
10 following NO₂ exposures from 100 to 600 ppb, there is uncertainty in the degree to which these
11 effects would be of public health concern. In particular, the lack of an apparent dose-response
12 relationship between NO₂ and AR and uncertainties in the magnitude and clinical significance of
13 the increase in AR following NO₂ exposures complicate our interpretation of comparisons
14 between ambient NO₂ concentrations and health-based benchmarks. When considered in the
15 context of the less consistent results observed following exposures to 100 ppb NO₂, compared to
16 higher exposure concentrations,⁹⁴ these uncertainties have the potential to be of particular
17 importance for interpreting the public health implications of ambient NO₂ concentrations at or
18 above the 100 ppb benchmark.

19 With regard to the magnitude and clinical relevance of the NO₂-induced increase in AR
20 in particular, we note that the meta-analysis by Brown (2015) attempts to address this
21 uncertainty. Specifically, as discussed above (section 3.2.2), the meta-analysis evaluates the
22 available individual-level data on the magnitude of the change in AR following resting NO₂
23 exposures. Brown (2015) reports that the magnitude of the increases in AR observed following
24 resting NO₂ exposures from 100 to 530 ppb were large enough to be of potential clinical
25 relevance in about a quarter of the 72 study volunteers with available data. This is based on the
26 fraction of exposed individuals who experienced a halving of the provocative dose of challenge
27 agent following NO₂ exposures. This magnitude of change has been recognized by the American
28 Thoracic Society (ATS) and the European Respiratory Society as a “potential indicator, although
29 not a validated estimate, of clinically relevant changes in airway responsiveness” (Reddel et al.,
30 2009) (U.S. EPA, 2016, p. 5-12). While this analysis by Brown (2015) indicates the potential for

⁹⁴ As discussed previously, while the meta-analysis indicates that the majority of study volunteers experienced increased non-specific AR following exposures to 100 ppb NO₂, results were marginally significant when specific AR was also included in the analysis. In addition, individual studies have generally not indicated statistically significant increases in AR following exposures to 100 ppb NO₂.

1 some people with asthma to experience effects of clinical relevance following resting NO₂
2 exposures from 100 to 530 ppb, it is based on a relatively small subset of volunteers and the
3 interpretation of these results for any specific exposure concentration within the range of 100 to
4 530 ppb is uncertain.

5 Approach to adjusting ambient NO₂ concentrations

6 These analyses use historical air quality relationships as the basis for adjusting ambient
7 NO₂ concentrations to just meet the current 1-hour standard (Appendix B). The adjusted air
8 quality is meant to illustrate a hypothetical scenario, and does not represent expectations
9 regarding future air quality trends. If ambient NO₂ concentrations were to increase in some
10 locations to the point of just meeting the current standards, it is not clear that the spatial and
11 temporal relationships reflected in the historical data would persist. In particular, as discussed in
12 Section 2.1.2 of this draft PA, we expect that ongoing implementation of existing regulations and
13 the implementation of the recently revised O₃ NAAQS⁹⁵ will result in continued reductions in
14 ambient NO₂ concentrations over much of the U.S. (i.e., reductions beyond the “unadjusted” air
15 quality used in these analyses). Thus, if ambient NO₂ concentrations were to increase to the point
16 of just meeting the existing 1-hour NO₂ standard in some areas, the resulting air quality patterns
17 may not be similar to those estimated in our air quality adjustments.

18 There is also uncertainty in the upward adjustment of NO₂ air quality because three years
19 of data are not yet available from most near-road monitors. In most study areas, true DVs were
20 not calculated at near-road monitors and, therefore, near-road monitors were generally not used
21 as the basis for identifying adjustment factors for just meeting the existing standard.⁹⁶ In
22 locations where near-road monitors measure the highest NO₂ DVs, reliance on those near-road
23 monitors to identify air quality adjustment factors would result in smaller adjustments being
24 applied to monitors in the study area. Thus, monitors in such study areas would be adjusted
25 upward by smaller increments, potentially reducing the number of days on which the current
26 standard is estimated to allow 1-hour NO₂ concentrations at or above benchmarks. Given that
27 near-road monitors in most areas measure higher 1-hour NO₂ concentrations than the area-wide
28 monitors in the same CBSA (Figures 2-7 to 2-9), this uncertainty has the potential to impact
29 results in many of our study areas. While the magnitude of the impact is unknown at present, the
30 inclusion of additional years of near-road monitoring information in the determination of updated

⁹⁵ Based on analyses conducted as part of the 2015 Regulatory Impact Analysis for the O₃ NAAQS, available at https://www3.epa.gov/ttnecas1/docs/ria/naaqs-o3_ria_final_2015-09.pdf.

⁹⁶ Though in a few study locations, near-road monitors did contribute to the calculation of air quality adjustments, as described in Appendix B (Table B2-7).

1 air quality adjustments could result in fewer estimated 1-hour NO₂ concentrations at or above
2 benchmarks in some study areas.

3 *Degree to which monitored NO₂ concentrations reflect the highest potential NO₂ exposures*

4 To the extent there are unmonitored locations where ambient NO₂ concentrations exceed
5 those measured by monitors in the current network, the potential for NO₂ exposures at or above
6 benchmarks could be underestimated. In the last review, this uncertainty was determined to be
7 particularly important for potential exposures around roads. The 2008 REA estimated that the
8 large majority of modeled exposures to ambient NO₂ concentrations at or above benchmarks
9 occurred on or near roads (U.S. EPA, 2008a, Figures 8-17 and 8-18). When characterizing
10 ambient NO₂ concentrations, the 2008 REA attempted to address this uncertainty by estimating
11 the elevated NO₂ concentrations that can occur on or near the road. These estimates were
12 generated by applying literature-derived adjustment factors to NO₂ concentrations at monitoring
13 sites located away from the road.⁹⁷

14 In the current review, given that the 23 selected study areas have among the highest NO_x
15 emissions in the U.S., and given the siting characteristics of existing NO₂ monitors, this
16 uncertainty likely has only a limited impact on the results of the air quality-benchmark
17 comparisons. In particular, as described above, mobile sources tend to dominate NO_x emissions
18 within most CBSAs, and the 23 study areas evaluated have among the highest mobile source
19 NO_x emissions in the U.S. (Appendix B, Section B2.3.2). Most study areas have near-road NO₂
20 monitors in operation, which are required within 50 m of the most heavily trafficked roadways in
21 large urban areas. The majority of these near-road monitors are sited within 30 m of the road,
22 and several are sited within 10 m (see Atlanta, Cincinnati, Denver, Detroit, Los Angeles in Table
23 2-1). Thus, even though the location of highest NO₂ concentrations around roads can vary
24 (Section 2.1), we anticipate that the near-road NO₂ monitoring network, with monitors sited from
25 2 to 50 m away from heavily trafficked roads, effectively captures the types of locations around
26 roads where the highest NO₂ concentrations can occur.

27 This conclusion is consistent with the ISA's analysis of available data from near-road
28 NO₂ monitors, which indicates that near-road monitors with target roads having the highest
29 traffic counts also had among the highest 98th percentiles of 1-hour daily maximum NO₂

⁹⁷ Sensitivity analyses included in Appendix B use updated data from the scientific literature (Richmond-Bryant et al., 2016) to estimate "on-road" NO₂ concentrations, based on monitored concentrations around a roadway in Las Vegas (Appendix B, Section B2.4.2). However, as noted above, there remains considerable uncertainty in the relationship between on-road and near-road NO₂ concentrations, and in the degree to which they may differ. Therefore, in evaluating the potential for roadway-associated NO₂ exposures, we focus on the concentrations at locations of near-road monitors.

1 concentrations (U.S. EPA, 2016, Section 2.5.3.2). The ISA concludes that “[o]verall, the very
2 highest 98th percentile 1-hour maximum concentrations were generally observed at the monitors
3 adjacent to roads with the highest traffic counts” (U.S. EPA, p. 2-66).

4 In addition to major roads, study areas also include non-near-road NO₂ monitors sited to
5 determine the highest ambient NO₂ concentration expected to occur, or to determine the impacts
6 of other significant sources. Overall, the 23 selected study areas include CBSAs with large non-
7 roadway sources of NO_x emissions as discussed in the ISA (U.S. EPA, 2016, Section 2.5.3.3).
8 This includes study areas with among the highest NO_x emissions from electric power generation
9 facilities (EGUs) and airports, the two types of non-roadway sources that emit the most NO_x in
10 the U.S. (Appendix B, Section B2.3.2).

11 Table 2-12 in the ISA (U.S. EPA, 2016) summarizes NO₂ concentrations at selected
12 monitoring sites that are likely to be influenced by non-road sources, including nearby ports,
13 airports, border crossings, petroleum refining, or oil and gas drilling. For example, the Los
14 Angeles, CA CBSA includes one of the busiest ports and one of the busiest airports in the U.S.
15 Out of 18 monitors in the Los Angeles CBSA, three of the five highest 98th percentile 1-hour
16 maximum concentrations were observed at the near-road site, the site nearest the port, and the
17 site adjacent to the airport. In the Chicago, IL CBSA, the highest hourly NO₂ concentration
18 measured in 2014 (105 ppb) occurred at the Schiller Park, IL monitoring site, located adjacent to
19 O’Hare International airport and very close to a major rail yard (i.e., Bedford Park Rail Yard)
20 (U.S. EPA, 2016, section 2.5.3.2).⁹⁸ In addition, one of the highest 1-hour daily maximum NO₂
21 concentrations recorded in recent years (136 ppb) was observed at a Denver, CO non-near-road
22 site. This concentration was observed at a monitor located one block from high-rise buildings
23 that form the edge of the high-density central business district. This monitor is likely influenced
24 by local traffic, as well as by commercial heating and other activities (U.S. EPA, 2016, section
25 2.5.3.2).⁹⁹ Thus, beyond the NO₂ near-road monitors, we anticipate that some non-near-road NO₂
26 monitors are also sited to capture high ambient NO₂ concentrations around important sources of
27 NO_x emissions.

⁹⁸ Sections B5.1 and B5.2 of Appendix B provides data on the large sources of NO_x emissions in areas where NO₂ monitors are located.

⁹⁹ Recent traffic counts on the nearest streets were 44,850 (in 2014) and 23,389 (in 2013) vehicles per day, respectively. Traffic counts on other streets within one block of this monitor were 22,000, 13,000, 5,000, and 2,490 vehicles per day. Together, this adds up to more than 100,000 vehicles per day on streets within one block of this non-near-road monitor (U.S. EPA, 2016, section 2.5.3.2).

1 4.2.2 Conclusions Based on Air Quality-Benchmark Comparisons

2 As discussed above and in the REA Planning document (U.S. EPA, 2015, Section 2.1.1),
3 an important uncertainty identified in the 2008 REA was the characterization of 1-hour NO₂
4 concentrations around major roadways. In the current review, data from recently deployed near-
5 road NO₂ monitors improves our understanding of such ambient NO₂ concentrations. In this draft
6 PA we have conducted updated analyses comparing ambient NO₂ concentrations (i.e., as
7 surrogates of potential exposures) to health-based benchmarks, with a particular focus on study
8 areas where near-road monitors have been deployed.

9 As discussed in Chapter 2, recent NO₂ concentrations measured in all U.S. locations meet
10 the existing primary NO₂ NAAQS. Based on these recent (i.e., unadjusted) ambient
11 measurements, analyses estimate almost no potential for 1-hour exposures to NO₂ concentrations
12 at or above benchmarks, even at the lowest benchmark examined (i.e., 100 ppb).

13 Analyses of air quality adjusted upwards to just meet the current 1-hour standard also
14 indicate no potential for 1-hour exposures to NO₂ concentrations at or above the 200 ppb
15 benchmark, and almost no potential for exposures at or above 150 ppb. This is the case for both
16 average and worst-case years, including in study areas with near-road monitors sited within a
17 few meters of heavily trafficked roads. With respect to the lowest benchmark evaluated, analyses
18 estimate that the current 1-hour standard allows the potential for exposures to 1-hour NO₂
19 concentrations at or above 100 ppb on some days (i.e., about one to 10 days per year, on
20 average).¹⁰⁰

21 These results are consistent with our expectations, given that the current 1-hour standard,
22 with its 98th percentile form, is anticipated to limit, but not eliminate, exposures to 1-hour NO₂
23 concentrations at or above 100 ppb.¹⁰¹ These results are similar to the results presented in the
24 REA from the last review, based on NO₂ concentrations at the locations of area-wide ambient
25 monitors (Appendix B, Section B5.9, Table B5-66). In contrast, compared to the on/near road
26 simulations in the last review, these results indicate substantially less potential for 1-hour

¹⁰⁰ Results for the 100 ppb benchmark are due primarily to 1-hour NO₂ concentrations that are closer to 100 ppb than 200 ppb, based on the results for the 150 ppb benchmark.

¹⁰¹ The 98th percentile generally corresponds to the 7th or 8th highest 1-hour concentration in a year.

1 exposures to near-road NO₂ concentrations at or above benchmarks (Appendix B, Section B5.9,
2 Table B5-66).¹⁰²

3 When these results and associated uncertainties are taken together, we note that the
4 current 1-hour NO₂ standard is expected to allow virtually no potential for exposures to the NO₂
5 concentrations that have been shown most consistently to increase AR in people with asthma
6 (i.e., above 200 ppb), even under worst-case conditions across a variety of study areas with
7 among the highest NO_x emissions in the U.S. Such NO₂ concentrations were not estimated to
8 occur, even at monitoring sites adjacent to some of the most heavily trafficked roadways.

9 In addition, the current standard is expected to limit, though not eliminate, exposures to
10 1-hour concentrations at or above 100 ppb. Though the current standard is estimated to allow 1-
11 hour NO₂ concentrations at or above 100 ppb on some days, the potential public health
12 implications of exposures to these concentrations are unclear. In particular, individual studies
13 generally do not indicate statistically significant NO₂-induced increases in AR following
14 exposures to 100 ppb NO₂ and meta-analysis results based on all available data at 100 ppb (i.e.,
15 resting exposures, specific and non-specific AR) were marginally significant. When combined
16 with uncertainty due to the lack of an overall dose-response relationship and uncertainty in the
17 degree to which effects would be adverse should they occur, there is considerable uncertainty
18 regarding the potential public health implications of exposures to 100 ppb NO₂. In limiting
19 exposures to NO₂ concentrations at or above 100 ppb, the current standard provides protection
20 against exposures for which the evidence of adverse NO₂-attributable effects is less certain.

21 In reaching an overall conclusion based on the results of analyses comparing NO₂ air
22 quality with health-based benchmarks, we consider all of the information discussed above. Given
23 the results of these analyses, and the uncertainties inherent in their interpretation, we conclude
24 that there is little potential for exposures to ambient NO₂ concentrations that would be of public
25 health concern in locations meeting the current 1-hour standard. Additionally, while a lower
26 standard level (i.e., lower than 100 ppb) would be expected to further limit the potential for
27 exposures to 100 ppb NO₂, the public health implications of such reductions are unclear,
28 particularly given that no additional protection would be expected against exposures to NO₂
29 concentrations at or above the higher benchmarks (i.e., 200 ppb and above). Thus, we conclude
30 that these analyses comparing ambient NO₂ concentrations to health-based benchmarks do not

¹⁰² On-/near-road simulations in the last review estimated that a 1-hour NO₂ standard with a 98th percentile form and a 100 ppb level could allow about 20 to 70 days per year with 1-hour NO₂ concentrations at or above the 200 ppb benchmark and about 50 to 150 days per year with 1-hour concentrations at or above the 100 ppb benchmark (Appendix B, Table B5-56).

1 provide support for considering potential alternative standards to increase public health
2 protection, beyond the protection provided by the current standards.

3 **4.3 MODEL-BASED EXPOSURE ASSESSMENT**

4 In the last review, in addition to analyses comparing NO₂ air quality to benchmarks, the
5 REA used an exposure model to generate estimates of 1-hour personal NO₂ exposures in a single
6 urban study area (i.e., Atlanta, GA). These modeled 1-hour personal exposures were compared to
7 1-hour benchmarks ranging from 100 to 300 ppb. The exposure assessment in the last review
8 served to complement the results of the broader, less resource-intensive, analyses comparing NO₂
9 air quality to benchmarks (described above).

10 In the current review, the REA Planning document (U.S. EPA, 2015, Chapter 3) indicated
11 that the potential utility of an updated model-based assessment of personal NO₂ exposures would
12 depend on the results of the updated comparison of NO₂ air quality with health effect
13 benchmarks (Section 4.2). To the extent air quality-benchmark comparisons indicate little
14 potential for exposures to ambient NO₂ concentrations that would be of public health concern,
15 the REA Planning document concluded that the added value of more refined estimates of
16 personal NO₂ exposures would be limited.

17 As discussed in Section 4.2 above, analyses comparing NO₂ air quality with health-based
18 benchmarks indicate little potential for exposures to ambient NO₂ concentrations that would be
19 of public health concern in locations meeting the current 1-hour standard. Given the results of
20 these analyses, more refined estimates of personal NO₂ exposures would be of limited additional
21 value. Based on these conclusions, we have not conducted an updated assessment of modeled
22 NO₂ exposures in this review.

23 **4.4 EPIDEMIOLOGY-BASED RISK ASSESSMENT**

24 Risk estimates based on epidemiologic studies have the potential to provide perspective on
25 the most serious pollutant-associated public health risks (e.g., hospital admissions, emergency
26 department (ED) visits, premature mortality) in populations that often include at-risk groups.
27 However, the emphasis given to such quantitative risk estimates depends on the extent to which
28 the underlying epidemiologic studies address key uncertainties related to NO₂ associations with
29 health effects, including the potential for confounding by co-occurring pollutants. This section
30 provides an overview of staff's considerations and conclusions regarding potential support for
31 risk assessment based on information from epidemiology studies of short short-term (Section
32 4.3.1) and a long-term (Section 4.3.2) NO₂ concentrations.

4.4.1 Short-Term Epidemiologic-Based Risk Assessment

In the last review of the primary NO₂ NAAQS, NO₂-associated respiratory-related ED visits in the Atlanta Metropolitan Statistical Area (MSA) were estimated for short-term ambient NO₂ concentrations, based on concentration-response functions from an epidemiologic study by Tolbert et al. (2007) (U.S. EPA, 2008a, Chapter 9). Specifically, the 2008 REA modeled respiratory-related ED visits (including asthma, chronic obstructive pulmonary disease (COPD), upper respiratory illness, pneumonia and bronchiolitis) for individuals of all ages based on a 3-day moving average of the daily maximum 1-hour NO₂ concentrations measured at a single central-site monitor. The REA reported several main findings, including the following:

1. When air quality was adjusted to simulate just meeting the existing annual standard, about 8 to 9% of respiratory-related ED visits in the Atlanta MSA were estimated to be attributable to short-term NO₂ exposures, based on a single-pollutant model. Risk estimates were reduced by as much as about 60% when based on co-pollutant models.¹⁰³ Ninety-five percent confidence intervals, reflecting statistical uncertainty in the NO₂ coefficient, included negative risk estimates when based on co-pollutant models that included O₃ or PM₁₀ (U.S. EPA, 2008a, Section 9.7).
2. When air quality was adjusted to simulate just meeting potential alternative standards with 1-hour averaging times, standards with levels of 50, 100, and 150 ppb reduced estimated NO₂-associated risks compared to the annual standard alone (U.S. EPA, 2008a, Tables 9-3 and 9-4).
3. When air quality was adjusted to simulate just meeting a potential alternative standard with a 1-hour averaging time and a level of 200 ppb, estimated risks were similar to those estimated for the annual standard alone (U.S. EPA, 2008a, Tables 9-3 and 9-4).

The 2008 REA noted that a number of key uncertainties should be considered when interpreting these results with regard to decisions on the standard. These included the following (U.S. EPA, 2008a, Section 9.6):

1. Uncertainties in the estimates of NO₂ coefficients in concentration-response functions used in the assessment.
2. Uncertainties concerning the specification of the concentration-response model (including the shape of the relationships) and whether or not a population threshold exists within the range of concentrations examined in the studies.
3. Uncertainty concerning potential confounding by co-occurring pollutants.

¹⁰³ Risk estimates were reduced to about 3% of respiratory-related ED visits based on a co-pollutant model that included PM₁₀, and to about 4-5% of such visits based on a model that included O₃ (U.S. EPA, 2008a, Tables 9-3 and 9-4).

1 4. Uncertainty in the adjustment of air quality distributions to simulate just meeting various
2 standards.

3 Overall, the 2008 REA concluded that the risks estimated to be associated with just
4 meeting the annual NO₂ standard (i.e., the existing standard at the time of the last review) can be
5 judged important from a public health perspective (U.S. EPA, 2008a). In the 2010 final decision,
6 the Agency further noted that a 1-hour standard with a level at or below 100 ppb "could
7 substantially reduce exposures to ambient NO₂ and associated health risks (compared to just
8 meeting the current standard)" (75 FR 6483, February 9, 2010). Upon further consideration of
9 these results, and their associated uncertainties, the risk assessment was not used to distinguish
10 between the support for particular standard levels at or below 100 ppb.

11 In considering whether to conduct an updated epidemiology-based risk assessment in the
12 current review, in the REA Planning document we evaluated the newly available information in
13 the context of that which was previously available. We specifically considered the extent to
14 which the new information would be likely to reduce uncertainties and/or substantially improve
15 our understanding of NO₂-attributable health risks, beyond the insights gained from the risk
16 assessment conducted in the last review.

17 As discussed in more detail in the REA Planning document (U.S. EPA, 2015, Section
18 4.2.2), the evidence that has become available since the last review has not substantially changed
19 our understanding of health effects attributable to short-term NO₂ exposures or of the
20 populations potentially at increased risk of such effects. Updated risk estimates based on
21 information from epidemiology studies in the current review would be subject to the same
22 uncertainties identified in the 2008 REA.

23 In particular, recent studies do not provide an improved basis, compared to the last review,
24 for quantifying NO₂-attributable risks independent of important traffic-related pollutants (e.g.,
25 CO, EC, UFP, benzene, PM_{2.5}, and PM₁₀) (U.S. EPA, 2016, Section 3.5). The ISA concludes
26 that an important uncertainty in the current review continues to be the "[s]trength of inference
27 from copollutant models about independent associations of NO₂, especially with pollutants
28 measured at central site monitors" (U.S. EPA, 2016, Table 1-1). In particular, of the key studies
29 supporting the determination of a causal relationship with respiratory effects (U.S. EPA, 2016,
30 Table 5-39), two U.S. studies evaluating asthma-related hospital admissions or emergency
31 department visits have become available since the last review (Strickland et al., 2010; Li et al.,
32 2012). Neither of these studies reported NO₂ health effect associations in co-pollutant models
33 that included other roadway-related pollutants.

34 Based on the above considerations, in the REA Planning document we concluded that an
35 updated epidemiology-based risk assessment estimating respiratory-related endpoints attributable

1 to short-term NO₂ exposures would be subject to uncertainties that are essentially the same as
2 those identified in the 2008 REA (U.S. EPA, 2008a). We reached the preliminary conclusion that
3 such an updated epidemiology-based risk assessment in the current review would not appreciably
4 reduce uncertainties and limitations from the assessment conducted in the last review and would
5 be unlikely to substantially improve our understanding of NO₂-attributable health risks or
6 increase our confidence in risk estimates beyond the assessment from the last review. The
7 CASAC agreed with this conclusion in its review of the REA Planning document, stating that
8 “the CASAC concurs that an updated epidemiology-based risk assessment in the current review
9 would be unlikely to substantially improve our understanding of NO₂-attributable health risks, or
10 to increase our confidence in risk estimates, beyond the assessment from the last review” (Diez
11 Roux and Frey, 2015, p. 5). Based on our consideration of the evidence, as summarized above,
12 and CASAC advice, we have not conducted an updated quantitative risk assessment of short-
13 term NO₂ exposures based on information from epidemiology studies.

14 **4.4.2 Long-Term Epidemiologic-Based Risk Assessment**

15 This section discusses our consideration of potential support for a quantitative risk
16 assessment based on information from epidemiology studies of long-term NO₂ concentrations,
17 and presents our conclusion that such an assessment is not supported by the available evidence
18 and information. Section 4.4.2.1 summarizes our preliminary considerations and conclusions
19 presented in the REA Planning document (U.S. EPA, 2015). Section 4.4.2.2 summarizes the
20 CASAC’s advice on those preliminary considerations and conclusions, based on its review of the
21 NO₂ REA Planning document (Diez Roux and Frey, 2015). Section 4.4.2.3 presents our
22 additional considerations and our conclusion that a quantitative risk assessment is not supported
23 in the current review.

24 *4.4.2.1 Preliminary Considerations and Conclusions from the REA Planning Document*

25 The REA Planning Document presented our preliminary considerations and conclusions
26 regarding support for a quantitative risk assessment based on information from epidemiology
27 studies of long-term NO₂ concentrations. In reaching preliminary conclusions, we considered the
28 evidence assessed in the second draft ISA (U.S. EPA, 2015b), noting the draft ISA determination
29 that the evidence “indicates there is likely to be a causal relationship between long-term NO₂
30 exposure and respiratory effects” (U.S. EPA, 2015b, section 1.5.1, pp. 1-19 and 1-21) and that
31 the “strongest evidence is for effects on asthma development” (U.S. EPA, 2015b, Table 1-1). As
32 discussed above (Section 3.3), key evidence supporting this causal determination comes from
33 recent epidemiologic cohort studies reporting associations between long-term ambient NO₂
34 exposures (i.e., averaged over 1–10 years) and development of asthma in children, and from

1 experimental studies for airway responsiveness and allergic responses. The REA Planning
2 document considered the extent to which epidemiologic studies of long-term NO₂ exposures
3 could support a quantitative risk assessment in the current review.

4 In reaching preliminary conclusions, the REA Planning document noted that, as for short-
5 term NO₂ exposures, an important uncertainty in the epidemiologic studies of long-term NO₂
6 exposures and health effect associations is the extent to which effects are independently related
7 primarily to NO₂ rather than another pollutant. Compared to studies of short-term NO₂
8 exposures, this is an even more important issue for long-term exposures, given the higher
9 correlations between long-term NO₂ concentrations and other pollutants reported in many
10 epidemiologic studies (U.S. EPA, 2016, Table 6-1).¹⁰⁴

11 The REA Planning document further noted that, of the key studies evaluating
12 associations between long-term NO₂ exposures and the development of asthma (U.S. EPA, 2016,
13 Table 6-5), none evaluated associations in co-pollutant models for traffic-related pollutants.
14 Speaking to this issue, the 2016 ISA notes uncertainty “in identifying an independent effect of
15 NO₂ exposure from traffic-related copollutants because evidence from experimental studies for
16 effects related to asthma development is limited, and epidemiologic analysis of confounding is
17 lacking” (U.S. EPA, 2016, Table 1-1). In particular, the ISA states that “correlations with PM_{2.5}
18 and BC were often high (e.g., $r = 0.7-0.96$), and no studies of asthma incidence evaluated
19 copollutant models to address copollutant confounding, making it difficult to evaluate the
20 independent effect of NO₂” (U.S. EPA, 2016, p. 6-64). The REA Planning Document concluded
21 that a quantitative risk assessment based on information from studies of NO₂-associated asthma
22 development in children would be subject to considerable uncertainty due to the inability to
23 distinguish the contributions of NO₂ from the contributions of other highly correlated pollutants
24 (U.S. EPA, 2015a). Given this uncertainty, the REA Planning document reached the preliminary
25 conclusion that such a risk assessment would not substantially add to our understanding of NO₂-
26 attributable health risks and would therefore be of limited value in informing decisions in the
27 current review.

28 4.4.2.2 CASAC Advice on the REA Planning Document

29 In its review of the REA Planning document, the CASAC generally agreed with staff’s
30 concerns regarding the potential for confounding by co-occurring pollutants, and the potential
31 implications of such confounding for risk estimates. However, given the stronger evidence for

¹⁰⁴ In studies of NO₂-associated asthma development, correlations with co-occurring pollutants were most often reported for PM. NO₂ and PM were often highly correlated in these studies, particularly in studies that used land use regression or dispersion modeling to estimate long-term NO₂ exposures (e.g., r values were greater than 0.9 in several studies) (U.S. EPA, 2016, Table 6-1).

1 NO₂-associated asthma incidence in the current review, the CASAC encouraged EPA staff to
2 further consider the feasibility of a risk assessment based on information from epidemiology
3 studies of long-term NO₂ exposures. Specifically, the CASAC provided the following advice
4 (Diez Roux and Frey, 2015, pp. 5-6):

5 The CASAC concurs with the assessment that a quantitative risk
6 assessment based on the epidemiologic evidence [of long-term
7 NO₂ exposures] would be challenged by “considerable uncertainty
8 due to the inability to distinguish the contributions of NO₂ from the
9 contributions of other highly correlated pollutants.” Nevertheless
10 the finding that the evidence for these relationships is likely to be
11 causal dictates a thoughtful consideration of an updated risk
12 assessment, even in the face of these uncertainties. The CASAC
13 encourages the EPA to explore the feasibility of a quantitative risk
14 assessment based on the long-term epidemiology. The agency may
15 find that such an REA is not feasible or that it may not
16 substantially improve the understanding of health risk attributable
17 to long-term NO₂ exposures, in which case the CASAC would
18 request a clear explanation for this finding.

19

20 *4.4.2.3 Staff Conclusions Regarding Potential Support for a Quantitative Risk Assessment*

21 In response to the CASAC’s advice, we have further explored potential support for a risk
22 assessment based on information from epidemiologic studies of long-term NO₂ exposures. In
23 doing so, we note the determination in the final ISA that “[t]here is likely to be a causal
24 relationship between long-term NO₂ exposure and respiratory effects based on evidence for the
25 development of asthma” (U.S. EPA, 2016, pp. 1-20). While this causal determination provides
26 the initial motivation for considering a potential quantitative risk assessment of asthma
27 incidence, we also evaluate other factors important for the conduct and interpretation of such an
28 assessment. These additional factors generally relate to the availability of required information,
29 the degree to which that information is subject to important uncertainties and, given those
30 uncertainties, the degree to which an assessment would be likely to improve our understanding
31 of NO₂-associated health risks. Table 4-3 below discusses our consideration of these factors.

Table 4-3. Factors to Consider in Conducting a Risk Assessment.

Description of Factors	Staff’s Consideration of Factors	Conclusions
<p>Availability of U.S. Studies: Our consideration of epidemiologic studies for the purpose of quantitative risk assessment is focused on studies conducted in the U.S. While studies conducted outside of the U.S. form an important part of the overall evidence base supporting ISA causal determinations, when quantifying risks in the U.S. it is important to use concentration-response relationships from epidemiologic studies that reflect U.S. population demographics, air quality and exposure patterns, monitoring networks (i.e., when monitors are used as exposure surrogates), healthcare systems (i.e., particularly for outcomes based on administrative databases), and baseline incidence rates. While potential differences in such factors between the U.S. and other countries do not preclude the qualitative use of non-U.S. studies in drawing overall conclusions regarding the strength of the scientific evidence, these differences can add considerable uncertainty into quantitative risk estimates.</p>	<p>To identify studies that could support quantitative risk assessment, we focus primarily on the U.S. studies determined in the ISA to provide “key evidence” supporting the causal determination for long-term NO₂ exposures and respiratory effects (U.S. EPA, 2016, Table 6-5). While a number of the key epidemiologic studies identified in the ISA were not conducted within the U.S. (U.S. EPA, 2016, Table 6-5), two key U.S. studies are available (Jerrett et al., 2008; Clougherty et al., 2007). The multi-community study by Jerrett et al. (2008) reports associations with asthma development across several California communities, while the single-city study by Clougherty et al. (2007) reports an association between asthma development and long-term NO₂ exposure in Boston.</p> <p>Although uncertainties and limitations in the other U.S. studies of long-term NO₂ exposures resulted in the ISA placing less emphasis on them, we also consider the potential for these studies to provide an appropriate basis for a quantitative risk assessment. In particular, the multicity study by Nishimura et al. (2013) reports associations between long-term NO₂ concentrations and asthma incidence, based on five U.S. cities, and the multi-community study by McConnell et al. (2010) reports associations across several California communities (study population overlaps with Jerrett et al., 2008).</p>	<p>Our further consideration of potential support for a quantitative risk assessment focuses on the two key U.S. epidemiologic study identified in the ISA (Jerrett et al., 2008; Clougherty et al., 2007). While recognizing the additional uncertainty, we also consider the U.S. studies assessed in the ISA that were not identified as key studies (McConnell et al., 2010; Nishimura et al., 2013).</p>

<p>Exposure Characterization: The choice of exposure surrogate in an epidemiologic study can affect the relationship estimated to exist between ambient pollutant exposures and the health outcome of interest. The ISA identifies potential exposure measurement error as an important uncertainty in interpreting epidemiologic studies. Unlike studies of short-term NO₂, in which exposure measurement error tends to bias associations toward the null, in studies of long-term NO₂, exposure measurement error could also bias reported associations away from the null (U.S. EPA, 2016, Table A-1).</p> <p>Beyond consideration of the potential for exposure measurement error, when conducting a risk assessment based on a concentration-response function from an epidemiologic study, the approach used in the study to estimate pollutant exposures is an important consideration. In cases where it is not feasible to use the same, or substantially similar, approach to estimate exposures in the risk assessment, additional uncertainty is introduced into risk estimates.</p>	<p>U.S. epidemiologic studies use various approaches to estimate long-term NO₂ exposures. Specifically, Nishimura et al. (2013) and McConnell et al. (2010) use air quality data from central-site ambient monitors in study communities. In contrast, Jerrett et al. (2008) and Clougherty et al. (2007) placed passive NO₂ samplers in study areas. Jerrett et al. (2008) placed samplers in the yards of study volunteers for 2 weeks in the summer (mid-August) and 2 weeks in the fall–winter season (mid-November). Four week averages in each location were used to represent long-term NO₂ exposures. Clougherty et al. (2007) placed samplers in locations across study communities for one week per month, and these data were then used to build a LUR model of estimated children’s residential exposures.</p>	<p>It is unlikely that we could recreate ambient exposure surrogates based on passive samplers at subjects' homes or other locations, as was done in the studies by Clougherty et al. (2007) and Jerrett et al. (2008). Use of concentration-response functions from these studies to estimate risks based on data from the ambient NO₂ monitoring network would introduce substantial uncertainty into risk estimates, limiting the degree to which such estimates could inform policy judgments.</p> <p>Of the U.S. studies, the exposure surrogates employed by Nishimura et al. (2013) and McConnell et al. (2010) could be applied most readily to a potential quantitative risk assessment, though these surrogates based on central-site monitors may also be more prone to exposure measurement error (U.S. EPA, 2016, p. 6-18). The ambient monitoring data used in these studies is based on central-site monitors in study communities. Ambient data from</p>
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		<p>central site monitors is publically available through the EPA's Air Quality System (AQS). Use of such data would be consistent with exposure surrogates in previous NAAQS reviews (e.g., U.S. EPA, 2011; U.S. EPA, 2014).</p>
<p>Baseline Incidence: Epidemiology-based effect estimates used in modeling risk typically relate a unit change in the ambient concentration of a pollutant to a resulting change in the incidence of the health outcome being assessed. Thus, a critical input to a risk assessment is information on the baseline incidence of the health outcome in the study population being assessed and in the study area where the risk assessment is being conducted.</p>	<p>Jerrett et al. (2008), McConnell et al. (2010) and Nishimura et al. (2013) all reported associations with asthma incidence in children, though the age ranges of the children differed between studies (and Nishimura reports results up to age 21). Nishimura et al. (2013) evaluated associations specifically in Latino and African American children. National-level age-stratified asthma prevalence is available within BenMAP-CE (U.S. EPA, 2015c, Table D-10; CDC, 2008),¹⁰⁵ though age-stratified information on specific racial or ethnic groups is more limited. Currently, we have access to this data nationally, but not by state. We currently do not have data on asthma incidence, which would be the more appropriate baseline metric for asthma development. Asthma incidence rates are likely to diverge from asthma prevalence rates.</p> <p>Clougherty et al. (2007) reported an association with asthma incidence in children in the Boston area who are exposed to high levels of violence.</p>	<p>Information on baseline prevalence, though not incidence, is likely available for the populations and outcomes evaluated by Jerrett et al. (2008), McConnell et al. (2010), and Nishimura et al. (2013). In addition, the use of prevalence rather than incidence would add uncertainty to quantitative risk estimates.</p> <p>Neither baseline incidence nor prevalence information is available for the population evaluated by Clougherty et al. (2007), therefore, we cannot estimate risks based on information from this study.</p>

¹⁰⁵ BenMAP-CE stands for “Environmental Benefits Mapping and Analysis Program – Community Edition.” The BenMAP software and associated documentation are available for download at <http://www2.epa.gov/benmap>.

	Neither baseline incidence nor prevalence rates are available for this population.	
<p>Shape of Concentration-Response Function: An understanding of the slope of the concentration-response generated from the effect estimates is necessary to accurately understand the relationship between the outcome and exposure over a range of ambient concentrations. Uncertainty in the shape of the concentration-response function adds uncertainty to risk estimates.</p>	<p>In the case of NO₂ and the development of asthma, information regarding the shape of the concentration-response function is very limited. According to the final ISA (U.S. EPA, 2016, p. 6-64), “[i]n limited analysis of the concentration-response relationship, results did not consistently indicate a linear relationship in the range of ambient NO₂ concentrations examined (Shima et al., 2002; Carlsten et al., 2011).” The ISA further notes that “these studies did not conduct analyses to evaluate whether there is a threshold for effects” (U.S. EPA, 2016, p. 6-64).</p>	<p>Given the few studies that have evaluated this issue for NO₂ and asthma incidence, and the ambiguous results reported by those studies, there is considerable uncertainty regarding the shape of the concentration-response function for NO₂ and asthma incidence. This includes uncertainty as to whether a threshold exists below which effects are not observed.</p>
<p>Control for Potential Confounding: High correlations between multiple co-occurring pollutants complicates the interpretation of health effect associations with any individual pollutant within the mixture. The potential for copollutant confounding is of particular concern for studies of health effects associated with long-term ambient concentrations of NO₂, given the relatively high correlations between NO₂ and other traffic-related pollutants, including PM_{2.5}.</p>	<p>In considering this issue, the ISA concludes that “[e]pidemiologic studies of asthma development in children have not clearly characterized potential confounding by PM_{2.5} or traffic-related pollutants [e.g., CO, BC/EC, volatile organic compounds (VOCs)]” (U.S. EPA, 2016, p. 6-64). The ISA further notes that “[i]n the longitudinal studies, correlations with PM_{2.5} and BC were often high (e.g., $r = 0.7-0.96$), and no studies of asthma incidence evaluated copollutant models to address copollutant confounding, making it difficult to evaluate the independent effect of NO₂” (U.S. EPA, 2016, p. 6-64).</p>	<p>While studies of long-term NO₂ and asthma incidence contribute qualitatively to the ISA’s causal determination, these studies do not provide a reliable basis for quantifying the magnitude of the NO₂ contribution to asthma development. Therefore, any NO₂ risk estimates developed from these studies would be subject to considerable uncertainty. If an NO₂ risk assessment were conducted based on studies of long-term NO₂, there would be particular uncertainty regarding the extent to which NO₂ risk estimates reflect the magnitude of NO₂</p>

		health impacts rather than the health impacts of traffic-related pollutants as a whole.
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1 After considering the factors discussed above, we conclude that a quantitative risk
2 assessment based on epidemiologic studies of long-term NO₂ exposures is not supported in this
3 review. This conclusion is based on our consideration of the available evidence for associations
4 between long-term NO₂ and the development of asthma, including consideration of the
5 uncertainties that would be inherent in any risk estimates based on that evidence. In particular,
6 we note most of the available epidemiologic studies of long-term NO₂ and asthma incidence are
7 not appropriate for quantitative risk assessment because they were not conducted in the U.S. Of
8 the studies that were conducted in the U.S., most of which were not emphasized in the ISA's
9 determination of a causal relationship due to important uncertainties, most used exposure metrics
10 that are not readily transferable to a quantitative risk assessment or they evaluated populations
11 for which information on baseline incidence is not available (Table 4-3). The two U.S. studies
12 that are the exception to these limitations (i.e., McConnell et al., 2010; Nishimura et al., 2013)
13 are still subject to broader uncertainties related to the potential for co-pollutant confounding of
14 the NO₂ association, potential bias due to exposure measurement error, and the shape of the
15 concentration-response function.

16 With regard to the potential for copollutant confounding in particular, we note the high
17 correlations between long-term NO₂ concentrations and the long-term concentrations of other
18 traffic-related pollutants (U.S. EPA, 2016, Section 6.2.2.1, Table 6-1). Given these correlations,
19 study authors often interpreted associations with NO₂ as reflecting associations with a marker of
20 traffic-related pollution more broadly (e.g., Jerrett et al., 2008; McConnell et al., 2010). Based on
21 our consideration of all of the above information, we conclude that quantitative risk estimates of
22 long-term NO₂-associated asthma development, if developed, would be subject to considerable
23 uncertainty and would likely not be informative, beyond what can be learned from our
24 consideration of the studies themselves (Chapter 3). Thus, we have not conducted such an
25 assessment in this draft PA.

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1 standards. Section 5.4 highlights areas for additional research and data collection in order to
2 reduce uncertainties in future reviews of the primary NO₂ NAAQS.

3 **5.1 EVIDENCE-BASED CONSIDERATIONS**

4 As discussed in Chapter 3, in considering the evidence available in the current review
5 with regard to adequacy of the current 1-hour and annual NO₂ standards, we first consider the
6 nature of the health effects attributable to NO₂ exposures (Sections 3.2.1, 3.3.1). In doing so, we
7 address the following questions:

- 8 • **To what extent does the currently available scientific evidence alter or strengthen our**
9 **conclusions from the last review regarding health effects attributable to ambient NO₂**
10 **exposures? Are previously identified uncertainties reduced or do important uncertainties**
11 **remain? Have new uncertainties been identified?**

12 As described in greater detail in Sections 3.2.1 and 3.3.1, we address these questions for both
13 short-term and long-term NO₂ exposures, with a focus on health endpoints for which the ISA
14 concludes that the evidence indicates there is a “causal” or “likely to be a causal” relationship.

15 In answering the questions above with regard to short-term NO₂ exposures, section 3.2.1
16 notes that, as in the last review, the strongest evidence continues to come from studies examining
17 respiratory effects. In particular, the ISA concludes that evidence indicates a “causal”
18 relationship between short-term NO₂ exposure and respiratory effects, based on evidence related
19 to asthma exacerbation. While this conclusion reflects a strengthening of the causal
20 determination, compared to the last review, this strengthening is based largely on a more specific
21 integration of the evidence related to asthma exacerbations rather than on the availability of new,
22 stronger evidence. Though some evidence has become available since the last review, as
23 summarized below, this evidence has not fundamentally altered our understanding of the
24 relationship between short-term NO₂ exposures and respiratory effects.

25 The strongest evidence supporting this ISA conclusion comes from controlled human
26 exposure studies demonstrating NO₂-induced increases in AR in individuals with asthma. Most
27 of the controlled human exposure studies assessed in the ISA were available in the last review,
28 particularly studies of non-specific AR. As in the last review, there remains uncertainty due to
29 the lack of an apparent dose-response relationship between NO₂ exposures and AR and
30 uncertainty in the potential adversity of NO₂-induced increases in AR. While clear guidance on
31 the adversity of increased AR is lacking, the newly available meta-analysis by Brown (2015) has
32 partially addressed this uncertainty by demonstrating the potential for clinically relevant NO₂-

1 induced increases in AR.¹⁰⁶ Supporting evidence for a range of NO₂-associated respiratory
2 effects also comes from epidemiologic studies. While recent epidemiologic studies provide some
3 new evidence based on improved exposure characterizations and co-pollutant modeling, these
4 studies are consistent with the evidence from the last review and do not fundamentally alter our
5 understanding of the respiratory effects associated with ambient NO₂ exposures. Due to
6 limitations in the available epidemiologic methods, uncertainty remains in the current review
7 regarding the potential for confounding by traffic-related copollutants (i.e., PM_{2.5}, EC/BC, CO).
8 Thus, while some new evidence is available in this review, that new evidence has not
9 substantially altered our understanding of the respiratory effects that occur following short-term
10 NO₂ exposures.

11 In answering the questions above with regard to long-term NO₂ exposures, Section 3.3.1
12 notes the ISA conclusion that there is “likely to be a causal relationship” between long-term NO₂
13 exposure and respiratory effects, based largely on the evidence for asthma development in
14 children. New epidemiologic studies of asthma development have increasingly utilized improved
15 exposure assessment methods (i.e., measured or modeled at or near children’s homes and
16 followed for many years), which partly reduces uncertainties from the last review related to
17 exposure measurement error. Explicit integration of evidence for individual outcome categories
18 (e.g. asthma incidence, respiratory infection) provides an improved characterization of biological
19 plausibility and mode of action. This improved characterization includes the assessment of new
20 evidence supporting a role for repeated short-term NO₂ exposures in the development of asthma.
21 High correlations between long-term average ambient concentrations of NO₂ and long-term
22 concentrations of other traffic-related pollutants, together with the lack of epidemiologic studies
23 evaluating copollutant models that include traffic-related pollutants, remains a concern in
24 interpreting associations with asthma development. Specifically, the extent to which NO₂ may be
25 serving primarily as a surrogate for the broader traffic-related pollutant mix remains unclear.
26 Thus, while the evidence for respiratory effects related to long-term NO₂ exposures has become
27 stronger since the last review, there remain important uncertainties to consider in evaluating this
28 evidence within the context of the adequacy of the current standards.

¹⁰⁶ As described in Chapter 3, consideration of clinical relevance in the ISA is based on evidence from clinical studies evaluating efficacy of inhaled corticosteroids that are used to prevent bronchoconstriction and airway responsiveness. Generally, a change of at least one doubling dose is considered to be an indication, but not validation, of clinical relevance (this represents a decline in AR as the dose to induce AR is doubled). Based on this, a halving of the provocative dose is taken in the ISA to represent an increase in AR that is an indication of clinical relevance.

1 Given the evaluation of the evidence in the ISA and the causal determinations (Sections
2 3.2 and 3.3), our further consideration of the evidence focuses on studies of asthma
3 exacerbations (short-term exposures) and asthma development (long-term exposures). We next
4 consider what these bodies of evidence indicate with regard to the basic elements of the primary
5 NO₂ standards. In particular, we consider the following question:

- 6 • **To what extent does the available evidence for respiratory effects attributable to either**
7 **short- or long-term NO₂ exposures support or call into question the basic elements of**
8 **the current primary NO₂ standards?**

9 In addressing this question, we evaluate the evidence in the context of the indicator, averaging
10 times, levels, and forms of the current standards. Each of these elements is discussed below.

11 *Indicator*

12 The indicator for both the current annual and 1-hour NAAQS for oxides of nitrogen is
13 NO₂. While the presence of gaseous species other than NO₂ has long been recognized (e.g.,
14 Section 2.1), no alternative to NO₂ has been advanced as being a more appropriate surrogate for
15 ambient gaseous oxides of nitrogen. Both previous and recent controlled human exposure studies
16 and animal toxicology studies provide specific evidence for health effects following exposure to
17 NO₂. Similarly, the large majority of epidemiologic studies report health effect associations with
18 NO₂, as opposed to other gaseous oxides of nitrogen, though the degree to which monitored NO₂
19 reflects actual NO₂ levels, as opposed to NO₂ plus other gaseous oxides of nitrogen, can vary
20 (Section 2.2). In addition, because emissions that lead to the formation of NO₂ generally also
21 lead to the formation of other NO_x oxidation products, measures leading to reductions in
22 population exposures to NO₂ can generally be expected to lead to reductions in population
23 exposures to other gaseous oxides of nitrogen. Therefore, an NO₂ standard can also be expected
24 to provide some degree of protection against potential health effects that may be independently
25 associated with other gaseous oxides of nitrogen even though such effects are not discernable
26 from currently available studies. Given these considerations, we reach the preliminary
27 conclusion that it is appropriate in the current review to consider retaining the NO₂ indicator for
28 standards meant to protect against exposures to gaseous oxides of nitrogen.

29 *Averaging time*

30 The current primary NO₂ standards are based on 1-hour and annual averaging times.
31 Together, these standards are intended to protect against short- and long-term NO₂ exposures.

32 In establishing the 1-hour standard in the last review, the Administrator considered
33 evidence from both experimental and epidemiologic studies. She noted that controlled human

1 exposure studies and animal toxicological studies provided evidence that NO₂ exposures from
2 less than one hour up to three hours can result in respiratory effects such as increased AR and
3 inflammation. These included five controlled human exposure studies evaluating the potential for
4 increased AR following 1-hour exposures to 100 ppb NO₂ in people with asthma. In addition,
5 epidemiologic studies had reported health effect associations with both 1-hour and 24-hour NO₂
6 concentrations, without indicating that either of these averaging periods was more closely linked
7 with reported effects. Thus, the available experimental evidence provided support for
8 considering an averaging time of shorter duration than 24 hours while the epidemiologic
9 evidence provided support for considering both 1-hour and 24-hour averaging times. Given this
10 evidence, the Administrator concluded that, at a minimum, a primary concern with regard to
11 averaging time was the level of protection provided against 1-hour NO₂ exposures. Based on
12 available analyses of NO₂ air quality, she further concluded that a standard with a 1-hour
13 averaging time could also be effective at protecting against effects associated with 24-hour NO₂
14 exposures (75 FR 6502, February, 9, 2010).

15 Based on the considerations summarized above, the Administrator judged that it was
16 appropriate to set a new NO₂ standard with a 1-hour averaging time. She concluded that such a
17 standard would be expected to effectively limit short-term (e.g., 1- to 24-hours) NO₂ exposures
18 that had been linked to adverse respiratory effects. She also retained the existing annual standard
19 to continue to provide protection against effects potentially associated with long-term exposures
20 to oxides of nitrogen (75 FR 6502, February, 9, 2010). These decisions were consistent with
21 CASAC advice to establish a short-term primary standard for oxides of nitrogen based on using
22 1-hour maximum NO₂ concentrations and to retain the current annual standard (Samet, 2008, p. 2;
23 Samet, 2009, p. 2).

24 As in the last review, support for a standard with a 1-hour averaging time comes from
25 both the experimental and epidemiologic evidence. Controlled human exposure studies evaluated
26 in the ISA continue to provide evidence that NO₂ exposures from less than 1-hour up to three
27 hours can result in increased AR in individuals with asthma (U.S. EPA, 2016, Tables 5-1 and 5-
28 2). These controlled human exposure studies provide key evidence supporting the ISA's
29 determination that "[a] causal relationship exists between short-term NO₂ exposure and
30 respiratory effects based on evidence for asthma exacerbation" (U.S. EPA, 2016, p. 1-17). In
31 addition, the epidemiologic literature assessed in the ISA provides support for short-term
32 averaging times ranging from 1-hour up to 24-hours (e.g., U.S. EPA, 2016 Figures 5-3, 5-4 and
33 Table 5-12). Consistent with the evidence in the last review, the ISA concludes that there is no
34 indication of a stronger association for any particular short-term duration of NO₂ exposure (U.S.
35 EPA, 2016, section 1.6.1). Thus, a 1-hour averaging time reasonably reflects the exposure

1 durations used in the controlled human exposure studies that provide the strongest support for the
2 ISA’s determination of a causal relationship. In addition, a standard with a 1-hour averaging time
3 is expected to provide protection against the range of short-term exposure durations that have
4 been associated with respiratory effects in epidemiologic studies (i.e., 1-hour to 24-hours). When
5 taken together, we reach the preliminary conclusion that the combined evidence from
6 experimental and epidemiologic studies continues to support an NO₂ standard with a 1-hour
7 averaging time to protect against health effects related to short-term NO₂ exposures.

8 With regard to protecting against long-term exposures, the evidence supports considering
9 the overall protection provided by the combination of the annual and 1-hour standards. The
10 current annual standard was originally promulgated in 1971 (36 FR 8186, April 30, 1971), based
11 on epidemiologic studies reporting associations between respiratory disease and long-term
12 exposure to NO₂. The annual standard was retained in subsequent reviews, in large part to
13 provide a margin of safety against the serious effects reported in animal studies using long-term
14 exposures to high NO₂ concentrations (i.e. above 8,000 ppb) (U.S. EPA, 1995).

15 As described above, evidence newly available in the current review demonstrates
16 associations between long-term NO₂ exposures and asthma development in children, based on
17 NO₂ concentrations averaged over year of birth, year of diagnosis, or entire lifetime. Supporting
18 evidence indicates that repeated short-term NO₂ exposures could contribute to this asthma
19 development. In particular, the ISA states that “findings for short-term NO₂ exposure support an
20 effect on asthma development by describing a potential role for repeated exposures to lead to
21 recurrent inflammation and allergic responses,” which are “identified as key early events in the
22 proposed mode of action for asthma development” (U.S. EPA, 2016, p. 6-64 and p. 6-65). Taken
23 together, the evidence supports the potential for recurrent short-term NO₂ exposures to contribute
24 to the asthma development that has been reported in epidemiologic studies to be associated with
25 long-term exposures. Thus, in establishing standards to protect against adverse health effects
26 related to long-term NO₂ exposures, we reach the preliminary conclusion that the evidence
27 supports the consideration of both 1-hour and annual averaging times.

28 *Level and form*

29 In considering the extent to which evidence supports or calls into question the levels or
30 forms of the current NO₂ standards, we revisit the following specific questions addressed in
31 Chapter 3 of this draft PA:

- 32 • **To what extent does the evidence indicate adverse respiratory effects attributable to**
33 **short- or long-term NO₂ exposures lower than previously identified or that would be**
34 **allowed by the current standards?**

1 In addressing this question in Chapter 3, we consider the range of NO₂ exposure concentrations
2 that have been evaluated in experimental studies (controlled human exposure and animal
3 toxicology) and the ambient NO₂ concentrations in locations where epidemiologic studies have
4 reported associations with adverse outcomes.

5 Controlled human exposure studies demonstrate the potential for increased AR in some
6 people with asthma following 30-minute to 1-hour exposures to NO₂ concentrations near those in
7 the ambient air (Section 3.2.2).¹⁰⁷ In evaluating the NO₂ exposure concentrations at which
8 increased AR has been observed, we consider both the group mean results reported in individual
9 studies and the results from a recent meta-analysis evaluating individual-level data (Brown,
10 2015; U.S. EPA, 2016, Section 5.2.2.1). Group mean responses in individual studies, and the
11 variability in those responses, can provide insight into the extent to which observed changes in
12 AR are due to NO₂ exposures, rather than to chance alone, and have the advantage of being
13 based on the same exposure conditions. The meta-analysis can aid in identifying trends in
14 individual-level responses across studies and can have the advantage of increased power to
15 detect effects, even in the absence of statistically significant effects in individual studies.

16 As discussed in more detail in Section 3.2.2.1, individual studies consistently report
17 statistically significant NO₂-induced increases in AR following resting exposures to NO₂
18 concentrations at or above 250 ppb, but not following exposures to NO₂ concentrations at or
19 below 200 ppb. When individual-level data from these studies were combined in a meta-analysis,
20 Brown (2015) reported that significant majorities of study participants experienced increased AR
21 following resting exposures to NO₂ concentrations from 100 to 530 ppb. In some affected
22 individuals, the magnitudes of these increases were large enough to have potential clinical
23 relevance. Following exposures to 100 ppb NO₂ specifically, the lowest exposure concentration
24 evaluated, a marginally significant majority of study participants experienced increased AR.¹⁰⁸
25 Important limitations in this evidence include the lack of an apparent dose-response relationship
26 between NO₂ and AR and uncertainty in the adversity of the reported increases in AR. These
27 uncertainties become increasingly important at the lower NO₂ exposure concentrations (i.e., at or

¹⁰⁷ As discussed in Chapter 3, experimental studies have not reported other respiratory effects following short-term exposures to NO₂ concentrations at or near those found in the ambient air. In addition, experimental studies examining asthma-related effects attributable to long-term NO₂ exposures are limited to exposures to NO₂ concentrations well-above those found in the ambient air and well-above those that could occur under the current standards (i.e. $\geq 1,000$ ppb).

¹⁰⁸ When the analysis was restricted only to non-specific AR following exposures to 100 ppb NO₂, the percentage who experienced increased AR was larger and statistically significant. In contrast, when the analysis was restricted only to specific AR following exposures to 100 ppb NO₂, the majority of study participants did not experience increased AR (U.S. EPA, 2016; Brown 2015).

1 near 100 ppb), as the evidence for NO₂-induced increases in AR becomes less consistent across
2 studies.

3 With regard to the epidemiologic evidence from U.S. and Canadian studies, as described
4 in Sections 3.2.2.2 and 3.3.2.1, we consider the ambient NO₂ concentrations in locations where
5 such studies have examined associations with asthma-related hospital admissions or emergency
6 department visits (short-term) or with asthma incidence (long-term). In particular, we consider
7 the extent to which NO₂-health effect associations are consistent, precise, statistically significant,
8 and present for distributions of ambient NO₂ concentrations that likely would have met the
9 current standards. To the extent NO₂-health effect associations are reported in study areas that
10 would likely have met the current standards, the evidence supports the potential for the current
11 standards to allow the NO₂-associated effects indicated by those studies. In the absence of
12 studies reporting associations in locations meeting the current NO₂ standards, there is greater
13 uncertainty regarding the potential for reported effects to be caused by NO₂ exposures that occur
14 with air quality meeting those standards. We also note consideration of important uncertainties in
15 the evidence, including the potential for copollutant confounding and exposure measurement
16 error, and the extent to which near-road NO₂ concentrations are reflected in the available air
17 quality data.

18 With regard to epidemiologic studies of short-term NO₂ exposures, as discussed in
19 Section 3.2.2.2, we note the following. First, the only recent multicity study evaluated (Stieb et
20 al., 2009), which had maximum 1-hour DVs ranging from 67 to 242 ppb, did not report a
21 positive association between NO₂ and ED visits. In addition, of the single-city studies (see Figure
22 3-1) that reported positive and relatively precise associations between NO₂ and asthma hospital
23 admissions and ED visits, most locations had NO₂ concentrations likely to have violated the
24 current 1-hour NO₂ standard over at least part of the study period. In addition, had near-road NO₂
25 monitors been in place during study periods, DVs would likely have been higher. Thus, it is
26 likely that even the one study location with a maximum DV of 100 ppb (Atlanta) would have
27 violated the existing 1-hour standard during study periods.¹⁰⁹ For the study locations with
28 maximum DVs below 100 ppb, mixed results have been reported, with associations that are
29 generally statistically non-significant and imprecise. As with the studies reporting more precise
30 associations, near-road monitors were not in place during these study periods. If they had been, it
31 is unclear whether 1-hour DVs would have been below 100 ppb. In drawing conclusions based

¹⁰⁹ While recent relationships between near-road and non-near-road concentrations in Atlanta likely do not reflect the relationships present during study periods (i.e., when NO_x emissions from traffic sources and other sources were higher), we note that 1-hour NO₂ concentrations in 2015 in Atlanta were higher than concentrations at all of the non-near-road monitors in the area (Figure 2-9).

1 on this epidemiologic evidence, we must also consider the potential for copollutant confounding
2 as ambient NO₂ concentrations are often highly correlated with other pollutants. This can
3 complicate attempts to distinguish between independent effects of NO₂ and effects of the broader
4 pollutant mixture. While this has been addressed to some extent in available studies, uncertainty
5 remains for the most relevant copollutants (e.g., those related to traffic such as PM_{2.5}, EC/BC,
6 and CO). Taken together, we reach the preliminary conclusion that available U.S. and Canadian
7 epidemiologic studies of hospital admissions and emergency department visits do not indicate
8 the occurrence of NO₂-associated effects in locations and time periods with NO₂ concentrations
9 that would have met the current 1-hour NO₂ standard (i.e., with its level of 100 ppb and 98th
10 percentile form).

11 In giving further consideration specifically to the form of 1-hour standard, we note that
12 the available evidence and information is consistent with that informing consideration of form in the
13 last review. The last review focused on the upper percentiles of the distribution of NO₂
14 concentrations based, in part, on evidence for health effects associated with short-term NO₂
15 exposures from experimental studies which provided information on specific exposure
16 concentrations that were linked to respiratory effects. In that review, the EPA specified a 98th
17 percentile form, rather than a 99th percentile, for the new the 1-hour standard. In combination with
18 the 1-hour averaging time and 100 ppb level, a 98th percentile form was judged to provide
19 appropriate public health protection. In addition, compared to the 99th percentile, a 98th percentile
20 form was expected to provide greater regulatory stability.¹¹⁰ A 98th percentile form is also consistent
21 with our consideration of uncertainties in the health effects that have the potential to occur at 100
22 ppb. Specifically, when combined with the 1-hour averaging time and the level of 100 ppb, the 98th
23 percentile form limits, but does not eliminate, the potential for exposures to 100 ppb NO₂.¹¹¹

24 In addressing the question posed above with regard to health effects related to long-term
25 NO₂ exposures, we first consider the basis for the current annual standard. It was originally set to
26 protect against NO₂-associated respiratory disease in children reported in a series of
27 epidemiologic studies (36 FR 8186, April 30, 1973). In subsequent reviews, the EPA has
28 retained the annual standard, judging that it provides protection with an adequate margin of
29 safety against the serious effects that have been reported in animal studies following long-term
30 exposures to NO₂ concentrations above 1,000 ppb. In the 2010 review, the EPA noted that,
31 though some evidence supported the need to limit long-term exposures to NO₂, the evidence for

¹¹⁰ As noted in the last review, a less stable form could result in more frequent year-to-year shifts between meeting and violating the standard, potentially disrupting ongoing air quality planning without achieving public health goals (75 FR 6493, February 9, 2010).

¹¹¹ The 98th percentile corresponds to about the 7th or 8th highest daily maximum 1-hour NO₂ concentration in a year.

1 adverse health effects attributable to long-term NO₂ exposures did not support changing the level
2 of the annual standard.

3 In the current review, the strengthened “likely to be causal” relationship between long-
4 term NO₂ exposures and respiratory effects is supported by epidemiologic studies of asthma
5 development. While these studies strengthen the evidence for effects of long-term exposures,
6 compared to the last review, they are subject to important uncertainties, including the potential
7 for confounding by traffic-related copollutants. The potential for such confounding is particularly
8 important to consider when interpreting epidemiologic studies of long-term NO₂ exposures given
9 (1) the relatively high correlations observed between long-term ambient concentrations of NO₂
10 and long-term concentrations of other roadway-associated pollutants; (2) the general lack of
11 information from copollutant models on the potential for NO₂ associations that are independent
12 of other traffic-related pollutants or mixtures; and (3) the general lack of experimental support
13 for effects following long-term exposures to NO₂ concentrations near those in the ambient air. In
14 effect, this makes it difficult to understand if the observed effects are independently related to
15 exposure to ambient concentrations of NO₂. The epidemiologic evidence from several U.S. and
16 Canadian studies is also subject to uncertainty with regard to the extent to which the studies
17 accurately characterized exposures of the study populations, further limiting what these studies
18 can tell us regarding the adequacy of the current standards.

19 While we recognize the above uncertainties, we consider what studies of long-term NO₂
20 and asthma development can tell us with regard to the adequacy of the current NO₂ standards. As
21 discussed above for short-term exposures, we consider the degree to which the evidence
22 indicates adverse respiratory effects associated with long-term NO₂ exposures in locations that
23 would have met the NAAQS. As summarized in Section 3.3.1, the causal determination for long-
24 term exposures is supported both by studies of long-term NO₂ exposures and studies indicating a
25 potential role in asthma development for repeated short-term exposures to high NO₂
26 concentrations. As such, when considering the ambient NO₂ concentrations present during study
27 periods, we consider these concentrations within the context of both the 1-hour and annual NO₂
28 standards. As discussed in Section 3.3.2.1 for epidemiologic studies conducted in the U.S. and
29 Canada, while annual DVs in study locations were often below 53 ppb, maximum 1-hour DVs in
30 most locations were near or above 100 ppb.^{112, 113} Because these study-specific DVs are based

¹¹² Mean 1-hour DVs from the study periods were also near or above 100 ppb in many study locations.

¹¹³ As discussed in Chapter 2, analyses demonstrate that a 1-hour NO₂ DV (based on three-year averages of 98th percentiles of annual distributions of daily maximum 1-hour NO₂ concentrations) of 100 ppb corresponds to an annual DV (based on annual average NO₂ concentrations) at or below about 35 ppb.

1 on the area-wide NO₂ monitors in place during study periods, they likely do not reflect near-road
2 NO₂ concentrations, which are expected to be higher. Had near-road monitors been in place
3 during study periods, NO₂ DVs based on near-road concentrations likely would have been higher
4 in many locations, and would have been more likely to exceed the level of the annual and/or 1-
5 hour standard(s).

6 Overall, the evidence does not provide strong support for NO₂-attributable asthma
7 development in children in locations with NO₂ concentrations at or below the levels of the
8 annual and 1-hour standards. The strongest evidence informing the level at which effects may
9 occur comes from U.S. and Canadian epidemiologic studies that are subject to critical
10 uncertainty related to copollutant confounding and exposure assessment. Even if these
11 fundamental uncertainties were to be dismissed, our evaluation indicates that most of the
12 locations included in epidemiologic studies of long-term NO₂ exposure and asthma incidence
13 would likely have violated either one or both of the current NO₂ standards, over at least parts of
14 the study periods.

15 In revisiting the question posed above, we note that (1) experimental studies do not
16 indicate adverse respiratory effects attributable to either short- or long-term NO₂ exposures lower
17 than previously identified and that (2) epidemiologic studies do not provide support for
18 associations between adverse effects and ambient NO₂ concentrations that would have met the
19 current standards. Taken together, we reach the preliminary conclusion that the available
20 evidence does not support the need for increased protection against short- or long-term NO₂
21 exposures, beyond that provided by the existing standards. Therefore, we have not identified
22 potential alternative standard levels or forms for consideration.

23 **5.2 AIR QUALITY-, EXPOSURE- AND RISK-BASED CONSIDERATIONS**

24 As described in Chapter 4, beyond our consideration of the scientific evidence, we also
25 consider the extent to which quantitative analyses of NO₂ air quality, exposures or health risks
26 could inform conclusions on the adequacy of the public health protection provided by the current
27 primary NO₂ standards. Conducting such quantitative analyses, if appropriate, could inform
28 judgments about the public health impacts of NO₂-related health effects and could help to place
29 the evidence for specific effects into a broader public health context. To this end, in the REA
30 Planning Document (U.S. EPA, 2015) and in this draft PA we have evaluated the extent to which
31 the available evidence and information provide support for conducting new or updated analyses
32 of NO₂ exposures and/or health risks, beyond the analyses conducted in the 2008 REA (U.S.
33 EPA, 2008). In doing so, we carefully considered the assessments developed as part of the last
34 review of the primary NO₂ NAAQS (U.S. EPA, 2008) and the newly available scientific and

1 technical information, particularly considering the degree to which updated analyses in the
2 current review are likely to substantially add to our understanding of NO₂ exposures and/or
3 health risks. We have also considered the CASAC advice and public input received on the REA
4 Planning Document (see Chapter 4).

5 As discussed above and in the REA Planning Document (U.S. EPA, 2015, Section 2.1.1),
6 an important uncertainty identified in the 2008 REA was the characterization of 1-hour NO₂
7 concentrations around major roadways. The 2008 REA estimated NO₂ concentrations on/near
8 roads by applying literature-derived adjustment factors to NO₂ concentrations at area-wide
9 monitoring sites. A key consideration in the current review is the extent to which newly available
10 information could reduce uncertainties with regard to NO₂ concentrations around major roads.
11 As discussed in Section 2.3.2, data from recently deployed near-road NO₂ monitors provide an
12 improved understanding of such ambient NO₂ concentrations. Therefore, in this draft PA we
13 have conducted updated analyses comparing ambient NO₂ concentrations (i.e., as surrogates of
14 potential exposures) to health-based benchmarks, with a particular focus on study areas where
15 near-road monitors have been deployed.¹¹⁴

16 When considering analyses comparing NO₂ air quality with health-based benchmarks, we
17 focus on the following specific questions:

- 18 • **To what extent are ambient NO₂ concentrations that may be of public health**
19 **concern estimated to occur in locations meeting the current NO₂ standards? What**
20 **are the important uncertainties associated with those estimates?**

21 As discussed in Section 4.2, benchmarks are based on information from controlled human
22 exposure studies of NO₂ exposures and AR. In identifying specific NO₂ benchmarks, and
23 considering the weight to place on each, we consider both the group mean results reported in
24 individual studies and the results of a meta-analysis that combined data from multiple studies
25 (Brown, 2015; U.S. EPA, 2016, Section 5.2.2.1), as described above.

26 When taken together, the results of individual controlled human exposure studies and of
27 the meta-analysis by Brown (2015) support consideration of NO₂ benchmarks between 100 and
28 300 ppb, based largely on studies of non-specific AR in people with asthma exposed at rest. As
29 discussed in more detail in Section 4.2.1.1, benchmarks from the upper end of this range are
30 supported by the results of individual studies, the majority of which reported statistically

¹¹⁴ We have not conducted more complex NO₂ exposure and risk assessments in this review. As discussed above (Sections 4.3, 4.4) and in the REA Planning document (U.S. EPA, 2015), such updated assessments would be unlikely to substantially improve our understanding of NO₂ exposures and health risks associated with the current standards, beyond what we know from the air quality-benchmark comparisons described in Chapter 4 (Section 4.2) and the risk assessment conducted in the last review.

1 significant increases in AR following NO₂ exposures at or above 250 ppb, and by the results of
2 the meta-analysis by Brown (2015). Benchmarks from the lower end of this range, including 100
3 ppb, are supported by the results of the meta-analysis, even though individual studies do not
4 consistently report statistically significant NO₂-induced increases in AR at these lower
5 concentrations. In particular, individual studies have not generally reported significant increases
6 in AR following resting exposures to 100 ppb NO₂, but the meta-analysis indicates that a
7 marginally significant majority of study participants experienced an increase in AR following
8 exposures to 100 ppb NO₂ (Brown, 2015).¹¹⁵ While there are a variety of factors that likely
9 underlie the observed variability, they are not fully known and the variability remains an
10 uncertainty in evaluating these results.

11 In further considering the potential public health implications of exposures to NO₂
12 concentrations at or above benchmarks, we also note the discussion of uncertainties in Section
13 3.2.2.1. As discussed in more detail in that section, there is no indication of a dose-response
14 relationship between NO₂ and AR in people with asthma, regardless of the challenge type (i.e.,
15 specific or non-specific) or exposure conditions (i.e., resting or exercising) (Goodman, 2009;
16 Brown, 2015). Though the lack of an apparent dose-response relationship does not necessarily
17 indicate the lack of an NO₂ effect, it adds uncertainty to our interpretation of the controlled
18 human exposure studies of AR. An additional uncertainty is the clinical relevance of the reported
19 NO₂-induced increases in AR. While the meta-analysis by Brown (2015) has partially addressed
20 this uncertainty by demonstrating that approximately 25% of study volunteers, from a subset of
21 studies, experienced a halving of the provocative dose, clear guidelines on the clinical relevance
22 of AR have not been established.

23 Thus, while we consider benchmarks from 100 to 300 ppb, uncertainties in the evidence
24 from controlled human exposure studies suggest that caution is appropriate when interpreting the
25 potential public health implications of 1-hour NO₂ concentrations at these benchmarks. While
26 this is true even for the higher benchmarks (i.e., given the lack of an apparent dose-response
27 relationship and uncertainty with regard to adversity), it is particularly the case for the 100 ppb
28 benchmark, where the results of individual studies are inconsistent.

29 As discussed in Section 4.2, analyses of unadjusted air quality, which meets the current
30 standards in all locations, indicate almost no potential for 1-hour exposures to NO₂
31 concentrations at or above any of the benchmarks examined, including 100 ppb. Analyses of air

¹¹⁵ Results were statistically significant when analyses were restricted to non-specific AR, but not when analyses were restricted to specific AR.

1 quality adjusted upwards to just meet the current 1-hour standard¹¹⁶ indicate no potential for 1-
2 hour exposures to NO₂ concentrations at or above 200 ppb (or 300 ppb), and almost no potential
3 for exposures at or above 150 ppb. This is the case for both averaged estimates and estimates in
4 worst-case years, including at near-road monitoring sites within a few meters of heavily
5 trafficked roads. With respect to the lowest benchmark evaluated, analyses estimate that there is
6 potential for exposures to 1-hour NO₂ concentrations at or above 100 ppb on some days (i.e.,
7 about one to 10 days per year, on average). As described above, this result is consistent with our
8 expectations, given that the current 1-hour standard, with its 98th percentile form, is expected to
9 limit, but not eliminate, the occurrence of 1-hour NO₂ concentrations of 100 ppb.

10 Thus, the current 1-hour NO₂ standard is expected to allow virtually no potential for
11 exposures to the NO₂ concentrations that have been shown most consistently to increase AR in
12 people with asthma, even under worst-case conditions across a variety of study areas with among
13 the highest NO_x emissions in the U.S. Such NO₂ concentrations are not estimated to occur, even
14 at monitoring sites adjacent to some of the most heavily trafficked roadways. In addition, the
15 current standard provides protection against NO₂ exposures that have the potential to exacerbate
16 asthma symptoms, but for which the evidence indicates greater uncertainty in both the
17 occurrence of such exacerbations and in their severity, should they occur. Given the results of
18 these analyses, and the uncertainties inherent in their interpretation, we conclude that there is
19 little potential for exposures to ambient NO₂ concentrations that would be of public health
20 concern in locations meeting the current 1-hour standard.

21 **5.3 PRELIMINARY CONCLUSION ON THE ADEQUACY OF THE CURRENT** 22 **STANDARDS**

23 The overarching question guiding our consideration of the available evidence and
24 information for the current review is:

- 25 • **Does the available scientific evidence and information support or call into question the**
26 **adequacy of the public health protection afforded by the current primary NO₂**
27 **standards?**

28 Staff has reached the preliminary conclusion that the current body of evidence, in combination
29 with the available information from quantitative analyses, supports the adequacy of the public
30 health protection provided by the current primary NO₂ standards and does not call into question

¹¹⁶ In all study areas, ambient NO₂ concentrations required smaller upward adjustments to just meet the 1-hour standard than to just meet the annual standard. Therefore, as noted above (Section 4.2.1), when adjusting air quality to just meet the current NO₂ NAAQS, we applied the adjustment needed to just meet the 1-hour standard.

1 any of the elements of the current standards. Staff further reaches the preliminary conclusion that
2 it is appropriate to consider retaining the current standards, without revision, in this review. In
3 reaching these preliminary conclusions we particularly note the following:

- 4 • The strongest evidence for NO₂-related effects comes from controlled human
5 exposure studies, and a meta-analysis of individual-level data from those studies,
6 demonstrating the potential for people with asthma to experience NO₂-induced
7 increases in AR following exposures under resting conditions from 100 to 530 ppb.
8 While increases in AR are considered to be a hallmark of asthma and can lead to
9 poorer control of symptoms, there is uncertainty in the potential implications of these
10 results due to the lack of an apparent dose-response relationship and the lack of clear
11 guidelines on the clinical relevance of increased AR. There is additional uncertainty
12 at the lower end of this range because, while the meta-analysis indicates that the
13 majority of study volunteers with asthma experienced increased AR following resting
14 exposures to 100 ppb NO₂, individual studies do not consistently report NO₂-induced
15 increases in AR at this exposure concentration.
16
- 17 • Epidemiologic studies conducted in the U.S. and Canada do not indicate associations
18 of asthma-related hospital admissions or emergency department visits with exposure
19 to short-term NO₂ concentrations in locations that would meet the current standards.
20 This is particularly the case given that NO₂ concentrations near the most heavily-
21 trafficked roadways are not likely reflected by the NO₂ concentrations measured at
22 monitors in operation during study years. We additionally note that there is potential
23 for copollutant confounding contributing to some uncertainty regarding the extent to
24 which the observed effects can be attributed independently to NO₂ exposure.
25
- 26 • Epidemiologic studies reporting associations between long-term NO₂ exposures and
27 asthma development are subject to important uncertainties that limit the extent to
28 which these studies provide insight into the adequacy of the public health protection
29 provided by the current standards. These uncertainties include the potential for
30 copollutant confounding, given the high correlations between long-term averages of
31 NO₂ and other traffic-related pollutants, and the potential for exposure measurement
32 error. Even if these uncertainties were to be dismissed, epidemiologic studies
33 conducted in the U.S. and Canada do not indicate associations of asthma incidence
34 with exposures to long-term NO₂ in locations that would have met the current
35 standards. This is particularly the case given that NO₂ concentrations near the most
36 heavily-trafficked roadways are not likely reflected by monitors in operation during
37 study years.
38
- 39 • The current 1-hour NO₂ standard is expected to allow virtually no potential for
40 exposures to the NO₂ concentrations that have been shown most consistently to
41 increase AR in people with asthma (i.e., above 200 ppb), even under worst-case
42 conditions across a variety of study areas with among the highest NO_x emissions in
43 the U.S. Such NO₂ concentrations were not estimated to occur, even at monitoring
44 sites adjacent to some of the most heavily trafficked roadways.

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- The current 1-hour standard is expected to limit, though not eliminate, the potential for exposures to 1-hour concentrations at or above 100 ppb. Thus, the current standard provides protection against NO₂ exposures that have the potential to exacerbate asthma symptoms, but for which the evidence indicates uncertainty in the occurrence of such exacerbations and in their severity, should they occur.

We additionally note that different public health policy judgments could lead to different conclusions regarding the extent to which the current standards protect the public health. Such judgments include those related to the appropriate degree of public health protection that should be afforded as well as the appropriate weight to be given to various aspects of the evidence and information, including how to consider uncertainties.

As noted in Chapter 1 above, in establishing primary standards that, in the Administrator’s judgment, are requisite to protect public health with an adequate margin of safety, the Administrator seeks to establish standards that are neither more nor less stringent than necessary for this purpose. The Act does not require that primary standards be set at a zero-risk level, but rather at a level that reduces risk sufficiently so as to protect public health with an adequate margin of safety.

In this context, we recognize that the uncertainties and limitations associated with the many aspects of the estimated relationships between NO₂ exposures and potentially adverse respiratory effects are amplified with consideration of increasingly lower NO₂ concentrations. In staff’s view, there is appreciable uncertainty in the extent to which reductions in asthma exacerbations or asthma incidence would result from alternative NO₂ standards with levels lower than those of the current standards. Thus, the basis for any consideration of alternative lower standard levels would reflect different public health policy judgments as to the appropriate approach for weighing uncertainties in the evidence.

Based on all of the above considerations, we reach the preliminary conclusion that it is appropriate to consider retaining the current standards, without revision, in this review. The available evidence and information do not support the identification of potential alternative standards that provide a different degree of public health protection. In light of this conclusion, we have not identified potential alternative standards for consideration. Our final conclusions will additionally be informed by the CASAC’s advice and public input on this draft PA.

5.4 KEY UNCERTAINTIES AND AREAS FOR FUTURE RESEARCH AND DATA COLLECTION

The uncertainties and limitations that remain in the review of the primary NO₂ standards are primarily related to understanding the range of ambient concentrations over which we have confidence in the observed health effects from the epidemiologic and controlled human exposure studies. In this section, we highlight areas for future health-related research, model development, and data collection activities to address these uncertainties and limitations in the current body of scientific evidence. These efforts, if undertaken, could provide important evidence for informing future NO₂ NAAQS reviews and, in particular, consideration of possible alternative averaging times, levels, and/or forms. In some cases, research in these areas can go beyond aiding standard setting to informing the development of more efficient and effective control strategies. We note, however, that a full set of research recommendations to meet standards implementation and strategy development needs is beyond the scope of this discussion.

Interpretation of Epidemiologic Evidence

In the current review, epidemiologic studies provide the strongest evidence for effects that can clearly be considered adverse.¹¹⁷ Adversity is an important aspect that is considered in developing conclusions on adequacy of the public health protection provided by the current standards and in informing the Administrator's judgment on the need for revision to the current standards. However, the capacity of the epidemiologic evidence to provide further clarity regarding concentrations at which potentially adverse effects are likely to occur is limited by inherent uncertainties in the evidence. Most notably for the current review is the potential for copollutant confounding given the high correlations in concentrations between NO₂ and other traffic-related copollutants. While this uncertainty is partly reduced by evidence from controlled human exposures studies demonstrating independent effects of NO₂ in eliciting increases in AR, it is still an important consideration in regards to specific ambient concentrations and the likelihood that effects will occur in locations at or below the current standard. It is a key issue for studies of long-term NO₂ exposures as correlations between co-occurring pollutants are often higher for long-term average concentrations. Further, experimental evidence to address this uncertainty is limited and largely based on concentrations higher than those in the ambient air.

¹¹⁷ Adversity, or the potential adversity, of the effect(s) associated with a pollutant, is an important aspect that is considered in developing conclusions on adequacy of the public health protection provided by the current standards and in informing the Administrator's judgment on the need for revision to the current standards.

1 *Data Collection and Methods Development*

2 Investigation of longer trends in near-road air quality will be possible as more data
3 become available from the near-road monitoring network. In general, the approach used in
4 epidemiologic studies to assign exposure has important implications for interpretation of study
5 results. As discussed in Chapter 3, epidemiologic studies based on measurements from an area-
6 wide monitor are subject to greater uncertainty than studies based on other monitoring methods
7 that better represent personal exposures, including exposures from time spent near major
8 roadways. Thus, future studies that use air quality inputs that more adequately capture personal
9 exposures, including those from near-road environments, will provide insight regarding the role
10 of these micro-environmental exposures in causing health effects compared to the area-wide
11 concentrations that are often used in the currently available evidence. This may be achieved
12 through using data from the near-road monitoring network in place of or in combination with
13 area-wide measurements or through application of more sophisticated exposure assessment
14 methods (e.g., land-use regression). Similarly, our ability to understand or predict the potential
15 for exposures to high NO₂ concentrations is limited. Future research and analyses that evaluate
16 spatial and temporal gradients related to roadway emissions and NO_x chemistry will address
17 uncertainty and be useful in the policy-making context to the extent that such evidence
18 contributes to improved exposure estimates.

19 *Interpretation of Results for Airway Responsiveness in Controlled Human Exposure Studies*

20 A final key uncertainty in evidence available in this review of the NO₂ standards is the
21 extent to which NO₂-induced increases in AR are expected to occur at ambient concentrations
22 and if increases in AR can be considered adverse. The meta-analysis demonstrates that a
23 majority of study volunteers in controlled human exposures studies experience NO₂-induced
24 increases in AR following exposures ranging from 100-600 ppb. These results support the
25 determination of a causal relationship for respiratory effects attributable to short-term NO₂
26 exposures as do results from individual studies. However, when considering the evidence from
27 individual studies, there is inconsistency across results, particularly at concentrations less than
28 200 ppb. Of these studies, future research examining AR in individuals with asthma following
29 exposures to 100 ppb and below could provide clarity. In addition, it would be informative for
30 future studies to consider the magnitude and severity of increases in AR to inform consideration
31 of adversity and clinical relevance.

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APPENDIX A
NITROGEN DIOXIDE AIR QUALITY

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1 **A1. CALCULATION OF ANNUAL AND 1-HOUR NO₂ DESIGN VALUES**
2

3 The following procedures were used to calculate annual and 1-hour design values (DVs) for
4 NO₂.

- 5 • Raw hourly NO₂ data was downloaded from the following sources:
 - 6 - EPA's AQS database (parameter code 42602)
 - 7 - Canadian NAPs network website (<http://maps-cartes.ec.gc.ca>)
 - 8 - US SEARCH network ftp site (<ftp://mail.atmospheric-research.com>)
- 9
- 10 • Two types of DVs were calculated for each site in each of the 3 networks.
- 11 • Annual DV:
 - 12 - For each site and year, the annual DV is the mean hourly concentration.
 - 13 - 75% of hours in the year must be present for the annual DV to be valid.
- 14 • Hourly DV:
 - 15 - Daily max was identified for each sampling day for each site
 - 16 - Two different methods were used to calculate 98th percentile values:
 - 17 - Using days with 18 or more hourly samples
 - 18 - Using days with 1 or more hourly samples
- 19
- 20 • The final 98th percentile reported is the maximum of the 2 methods for each site and
21 year.
- 22
- 23 • DV for each 3-year window was calculated by averaging the annual final 98th percentile
24 values.
- 25
- 26 • Hourly DV were considered valid if they meet the following criteria:
 - 27 - Each day must have samples for $\geq 75\%$ of hours to be valid.
 - 28 - 75% of days in a quarter must be valid for the quarter to be valid.
 - 29 - A year must have had 4 complete quarters for it to be valid.
 - 30 - A DV must have had 3 valid years to be valid.
- 31

32 **A 2. ANNUAL AND HOURLY DESIGN VALUES FOR SELECT EPIDEMIOLOGIC**
33 **STUDIES**
34

35 Design values (DVs) have been calculated for locations of select epidemiologic studies
36 examining respiratory effects associated with NO₂ exposures. These studies were identified from
37 the Integrated Science Assessment for Oxides of Nitrogen – Health Criteria. Calculations were
38 based on methods outlined above.

39
40 The DVs reported in the tables below are the highest DVs in the specified location for each year
41 as calculated according to the methods above. The respective completeness of the hourly and
42 annual DVs are also reported. For annual DVs, this is reported as the percentage of complete
43 days in the year. For hourly DVs, this is reported as the number of complete quarters (75% of

1 hours in a day, 75% of days in a quarter) for the 3-year period (the specified year and two years
2 before).

3
4 The DVs reported in this technical memo are limited to the locations where key epidemiologic
5 studies in the current review of the Primary NO₂ NAAQS have been conducted. For each
6 city/CBSA, the respective study(ies) and relevant study details are reported, including the
7 monitor IDs that were used in determining DVs

8
9 **2.1 Short-Term Epidemiologic Studies For Asthma-Related Emergency**
10 **Department Visits And Hospital Admissions**

- 11
- Atlanta, GA Strickland et al. (2010) - Pediatric asthma ED visits (5-17 yr) 1993-2004 (entire years)
- Exposure assignment: “Daily concentrations of ambient 1-hour maximum [NO₂]...were obtained from several networks of ambient monitors...We used population-weighting to combine daily pollutant measurements across monitors.”
-Design values: We used 5 specific AQS monitors and a SEARCH monitor for which we were able to obtain data to compute design values based on personal communication with author. (131210001, 131210047, 131210048, 132230003, 162470001, SEARCH monitor on Jefferson Street)
 - Strickland et al. (2011) -Pediatric asthma ED visits (5-17 yr) 1993-2004 (May-Oct)
-Exposure assignment: NO₂ concentrations obtained from 3 networks of stationary monitors. Three exposure metrics used: (1) one downtown monitor was selected as central site, (2) all monitors used to calculate unweighted average of pollutant concentrations for all monitors, and (3) population-weighted average concentration.
- Design values: We used the same monitors indicated in the Strickland et al. (2010) paper. (131210001, 131210047, 131210048, 132230003, 162470001, SEARCH monitor on Jefferson Street)
 - Peel et al. (2005) - Asthma ED visits across all ages and in children (2-18 yr) (January 1993- August 2000)
- Exposure assignment: Average of NO₂ concentrations from monitors for several monitoring networks

1992	-		1992	29 (390350033)	81.3
1993	89 (390350033)	8	1993	28 (390350060)	90.1
1994	92 (390350033)	4	1994	28 (390350060)	92.6
1995	83 (390350060)	12	1995	27 (390350060)	93.7
1996	83 (390610035)	4	1996	29 (390610037)	98.9
Cincinnati					
1991	-		1991	17 (210371001)	94.2
1992	-		1992	15 (210371001)	94.4
1993	77 (390610035)	10	1993	18 (210371001)	89.5
1994	76 (390610035)	12	1994	20 (210371001)	92.6
1995	80 (390610037)	4	1995	20 (210371001)	94.2
1996	83 (390610035)	4	1996	19 (210371001)	94.2

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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- New York City, Ito et al. (2007)
NY

 - Asthma ED visits, all ages, 1999-2002 (entire years)
 - Exposure assignment: Average NO₂ concentrations from 15 monitors
 - Design values: We used the 15 monitors closest to city center that were in operation during study years (360050073, 360050080, 360050083, 360050110, 360610010, 360610056, 360810097, 360810098, 360810124, 340130011, 340130016, 340131003, 340170006, 340230011, 340390004)
- Bronx/Manhattan, ATSDR 2006
NY

 - Asthma ED visits, all ages, Bronx: January 1999-November 2000, Manhattan: September 1999-November 2000
 - Exposure assignment: NO₂ concentrations from a monitor in the Bronx and a monitor in Manhattan
 - Design values: We used the monitors specified by location in the study (360050073, 360610010)
 - Design values for these encompass years before the study period.

3

4

Table A-5. Hourly and Annual Design Values for New York, NY from 1999-2002.

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%) ^b
New York City (including Newark, NJ)					
1999	-		1999	42 (340390004)	97.8
2000	-		2000	41 (340390004)	98
2001	102 (340390004)	12	2001	40 (340390004)	97.1

2002	101 (340390004)	12	2002	40 (340390004)	92.6
Bronx					
1999	94 (360050073)	1	1999	32 (360050073)	25.4
2000	94 (360050073)	1	2000	N/A	
Manhattan					
1999	86 (360610010)	11	1999	36 (360610010)	89
2000	86 (360610010)	11	2000	36 (360610010)	92

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

- 1
- Edmonton, Canada, Villeneuve et al. (2007) -Asthma emergency department visits, all ages > 2 yr, 1992-2002 (entire years)
-Exposure assignment: Average NO₂ concentration across three monitoring stations
-Design values: We used the three NAPS monitors in Edmonton (90121, 90122, 90130)

2

3 **Table A-6. Hourly and Annual Design Values for Edmonton, Canada from 1992-2002.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters^a	Year	Max DV (Monitor ID)	Completeness (%)^b
1992	-		1992	36 (90122)	99.5
1993	-		1993	27 (90130)	95.2
1994	242 (90122)	12	1994	27 (90130)	97.6
1995	87 (90122)	12	1995	27 (90130)	97.1
1996	96 (90122)	12	1996	25 (90130)	97.2
1997	96 (90122)	12	1997	26 (90130)	93.3
1998	100 (90122)	12	1998	27 (90130)	98
1999	86 (90122)	12	1999	24 (90130)	99.4
2000	74 (90122)	12	2000	25 (90130)	98.9
2001	70 (90122)	12	2001	25 (90130)	98
2002	76 (90122)	12	2002	25 (90130)	98.3

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

- 4
- Toronto, Canada, Burnett et al. (1999) -Hospital admissions, all ages, 1980-1994 (entire years)
-Exposure assignment: Average NO₂ concentration across four monitoring stations that are not likely influence by a local source (site-specific) (reference Burnett et al. JAWMA 1998 (48))
-Design values: We identified study monitors using the map provided in the reference study (60403, 60410, 60413, 60418). We also used other NAPS monitors in

metro Toronto as they were also representative of potential population exposures (60401, 60402, 60412, 60414, 60417, 60419, 60420, 60421, 60422, 60423, 60424, 60425)

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Table A-7. Hourly and Annual Design Values for Toronto, Canada from 1980-1994.

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%) ^b
1980	-		1980	36 (60403)	95.4
1981	-		1981	36 (60403)	95
1982	127 (60412)	8	1982	34 (60412)	89.4
1983	120 (60412)	10	1983	30 (60414)	97.5
1984	123 (60412)	12	1984	36 (60412)	95.6
1985	113 (60412)	10	1985	38 (60412)	38.7
1986	115 (60412)	6	1986	34 (60418)	97
1987	110 (60412)	2	1987	32 (60403)	94.6
1988	130 (60412)	3	1988	38 (60422)	56.9
1989	120 (60412)	7	1989	33 (60403)	97.9
1990	117 (60403)	12	1990	30 (60403)	81.2
1991	110 (60403)	12	1991	30 (60422)	91.7
1992	220 (60403)	12	1992	45 (60422)	95.6
1993	227 (60403)	12	1993	31 (60420)	28.7
1994	223 (60403)	12	1994	30 (60424)	99.4

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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- Multicity (Montreal, Ottawa, Edmonton, St. John, Halifax, Toronto, Vancouver) Stieb et al. (2009) - Asthma ED visits, all ages, 1992-2003 (entire years)
- Exposure assignment: Average NO₂ concentrations from all monitors in each city.
- Design values: All monitors in the NAPS database for each city were used.

5
6

Table A-8. Hourly and Annual Design Values for 7 Canadian cities from 1992-2003.

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%) ^b
Montreal 1997-2002					

1997	-		1997	31 (50115)	96.8
1998	-		1998	28 (50115)	96.7
1999	85 (50109)	12	1999	29 (50109)	98.9
2000	83 (50109)	12	2000	26 (50109)	92
2001	78 (50109)	10	2001	30 (50109)	55
2002	76 (50109)	8	2002	26 (50109)	77.5
Ottawa (60101, 60104) 1992-2000					
1992	-		1992	72 (60101)	14.3
1993	-		1993	24 (60101)	98.3
1994	198 (60101)	9	1994	25 (60101)	98.9
1995	78 (60101)	12	1995	25 (60101)	95.8
1996	74 (60101)	10	1996	23 (60101)	66.5
1997	70 (60101)	7	1997	25 (60101)	15.8
1998	73 (60101)	7	1998	25 (60101)	93.9
1999	83 (60101)	7	1999	33 (60101)	59.5
2000	82 (60101)	10	2000	22 (60101)	90.1
Edmonton 1992-2002					
1992	-		1992	36 (90122)	99.5
1993	-		1993	27 (90130)	95.2
1994	242 (90122)	12	1994	27 (90130)	97.6
1995	87 (90122)	12	1995	27 (90130)	97.1
1996	96 (90122)	12	1996	25 (90130)	97.2
1997	96 (90122)	11	1997	26 (90122)	93.3
1998	100 (90122)	11	1998	27 (90130)	98
1999	86 (90122)	11	1999	24 (90130)	99.4
2000	74 (90122)	12	2000	25 (90130)	98.9
2001	70 (90122)	12	2001	25 (90130)	98
2002	76 (90122)	12	2002	25 (90122)	95.7
St. John 1992-1996					
1992	-		1992	14 (10102)	88.7
1993	-		1993	15 (10102)	83.9
1994	96 (10102)	7	1994	15 (10102)	21
1995	50 (10102)	4	1995	21 (10102)	1.7
1996	48 (10102)	1	1996	#N/A	
Halifax 1999-2002					
1999	-		1999	#N/A	
2000	-		2000	18 (30118)	83.5
2001	67 (30118)	6	2001	17 (30118)	76
2002	61(30118)	9	2002	17 (30118)	80
Toronto 1999-2003					
1999	-		1999	28 (60430)	79.7
2000	-		2000	30 (60430)	33.1
2001	94 (60423)	7	2001	31 (60403)	11.4
2002	98 (60423)	4	2002	26 (60429)	81.3
2003	84 (60429)	9	2003	27 (60429)	92.3

Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%) ^b
2003	82 (360050110)	9	2003	30 (360050110)	78.4
2004	79 (360050110)	11	2004	30 (360050110)	97.4
2005	78 (360050110)	11	2005	29 (360050110)	89.1

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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- Fresno/Clovis, CA Mann et al. (2010) - Wheeze in asthmatic children (6-11 yr), Nov 2000-April 2005 (subgroup analyses for boys with intermittent asthma and atopy)
- NO₂ central site (CARB monitoring stations used in study; AQS data used for DVs)

4

5 **Table A-11. Hourly and Annual Design Values for Fresno, CA from 2000-2005.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%) ^b
2000	-		2000	21 (60190008)	93.8
2001	-		2001	21 (60190008)	94.8
2002	74 (60190008)	12	2002	20 (60190008)	94.4
2003	77 (60190008)	12	2003	19 (60190008)	94.6
2004	72 (60190008)	12	2004	17 (60190008)	94.7
2005	71 (60190008)	12	2005	17 (60190008)	90.2

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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- Multicity O'Connor et al. (2008) - Wheeze/cough, slow play, and missed school in children with asthma (5-12 yr), Aug 1998 – July 2001
- NO₂ central site (monitors near residences)

8

9 **Table A-12. Hourly and Annual Design Values for 7 U.S. cities from 1998-2001.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of	Year	Max DV (Monitor ID)	Completeness (%) ^b

Tolbert et al. (2007) - Respiratory ED visits, all ages, March 1994 – Dec 2004

- Average of NO₂ concentrations across monitors (5 AQS monitors + SEARCH, operational 1998)

Peel et al. (2005) - Respiratory ED visits, all ages, Jan 1993 - Aug 2000)

- Average of NO₂ concentrations across monitors (5 AQS monitors + SEARCH, operational 1998))

1

2 **Table A-13. Hourly and Annual Design Values for Atlanta, GA for 1993-2004**

Hourly			Annual		
Year	Max DV (Monitor ID) ^a	Number of Complete Quarters ^b	Year	Max DV (Monitor ID) ^a	Completeness (%) ^c
1993	-		1993	25 (131210048)	57.3
1994	-		1994	23 (131210048)	83.2
1995	76 (131210048)	9	1995	19 (131210048)	96.3
1996	83 (131210048)	11	1996	27 (131210048)	98.4
1997	88 (131210048)	11	1997	25 (131210048)	87.5
1998	99 (JST)	2	1998	26 (JST)	36.5
1999	100 (JST)	5	1999	26 (JST)	80
2000	95 (JST)	9	2000	23 (JST)	95.1
2001	86 (131210048)	12	2001	23 (JST)	97.5
2002	86 (131210048)	12	2002	19 (JST)	97.9
2003	81 (131210048)	12	2003	20 (JST)	89
2004	75 (131210048)	12	2004	20 (JST)	92

^aJST refers to the SEARCH network monitor in Atlanta, GA located on Jefferson Street

^bIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^cValid annual DVs require 75% completeness

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- Toronto, Canada Burnett et al. (2001) - Pediatric respiratory hospital admissions (< 2 yr), 1980-1994
- Average NO₂ concentrations across 4 monitors with continuous data and not influence by any local source (16 monitors from NAPS database; some monitors with high DV likely influenced by traffic)

5

6 **Table A-14. Hourly and Annual Design Values for Toronto, Canada from 1980-1994.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%)
1980	-		1980	36 (60403)	95.4

1981	-		1981	36 (60403)	95
1982	127 (60412)	8	1982	34 (60412)	89.4
1983	120 (60412)	10	1983	30 (60403)	93.8
1983	120 (60412)	10	1983	30 (60403)	97.5
1984	123 (60412)	12	1984	36 (60412)	95.6
1985	113 (60412)	10	1985	38 (60412)	38.7
1986	115 (60412)	6	1986	34 (60418)	97
1987	110 (60412)	2	1987	32 (60403)	94.6
1988	130 (60422)	3	1988	38 (60422)	56.9
1989	120 (60422)	7	1989	33 (60403)	97.9
1990	117 (60403)	12	1990	30 (60403)	81.2
1991	110 (60403)	12	1991	30 (60422)	91.7
1992	220 (60423)	12	1992	45 (60422)	95.6
1993	227 (60423)	12	1993	31 (60420)	28.7
1994	223 (60423)	12	1994	30 (60424)	99.4

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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- Vancouver, Canada, Yang et al. (2003) - Respiratory hospital admissions (< 3 yr and ≥ 65 yr), 1986-1998
- Average NO₂ concentrations from 30 monitors from the British Columbia network (DVs from 7 NAPS monitors)

2 **Table A-15. Hourly and Annual Design Values for Toronto, Canada from 1986-1998.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%)
1986	-		1986	37 (100118)	11.3
1987	-		1987	29 (100112)	93.8
1988	104	8 (100120)	1988	33 (100108)	23.7
1989	100	12 (100110)	1989	31 (100112)	94
1990	90	12 (100110)	1990	31 (100112)	92.1
1991	85	12 (100110)	1991	33 (100112)	92.4
1992	230	11 (100108)	1992	60 (100112)	89.8
1993	241	8 (100108)	1993	31 (100108)	23.6
1994	322	4 (100108)	1994	24 (100112)	97.6
1995	104	1 (100108)	1995	26 (100112)	97.7
1996	66	12 (100121)	1996	27 (100112)	97.8
1997	68	12 (1001120)	1997	29 (100112)	97.5
1998	67	12 (1001120)	1998	29 (100112)	97.4

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

1

Fung et al. (2006) - Respiratory hospital admissions, 1995-1999
 - Average of NO₂ concentrations across monitors in city
 -% increase per 30 ppb increment of NO₂: 8.6 (4.2, 13.3)

2 **Table A-16. Hourly and Annual Design Values for Toronto, Canada from 1995-1999.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%)
1995	-		1995	26 (100112)	97.7
1996	-		1996	27 (100112)	97.8
1997	68 (100112)	12	1997	29 (100112)	97.5
1998	67 (100112)	12	1998	29 (100112)	97.4
1999	66 (100120)	5	1999	32 (100120)	3.4

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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- Multicity Dales et al. (2009) - Pediatric respiratory hospital admissions (0-24 days), 1986-2000
 - NO₂ concentrations across all monitors in cities

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6 **Table A-17. Hourly and Annual Design Values for 11 Canadian cities from 1986-2000.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%)
Calgary					
1986	-		1986	34 (90227)	97.6
1987	-		1987	34 (90227)	98.9
1988	110 (90227)	12	1988	35 (90227)	98.8
1989	105 (90227)	12	1989	35 (90227)	98.9
1990	103 (90227)	12	1990	34 (90227)	94
1991	95 (90227)	12	1991	37 (90227)	98.6
1992	338 (90218)	8	1992	49 (90218)	99
1993	250 (90218)	12	1993	31 (90227)	99
1994	254 (90218)	12	1994	29 (90227)	98.9
1995	86 (90227)	12	1995	28 (90227)	98.9
1996	93 (90218)	12	1996	29 (90227)	98.7
1997	98 (90218)	12	1997	30 (90227)	99.4

1998	106 (90218)	12	1998	31 (90227)	98.5
1999	95 (90218)	12	1999	28 (90227)	97.9
2000	86 (90218)	12	2000	28 (90227)	99.2
Edmonton					
1986	-		1986	30 (90130)	95.6
1987	-		1987	31 (90130)	99.5
1988	86 (90130)	12	1988	28 (90130)	98.2
1989	78 (90130)	12	1989	26 (90130)	94.5
1990	80 (90122)	12	1990	27 (90130)	97.9
1991	100 (90121)	4	1991	29 (90130)	98.7
1992	243 (90122)	12	1992	36 (90122)	99.5
1993	239 (90122)	12	1993	27 (90130)	95.2
1994	242 (90122)	12	1994	27 (90130)	97.6
1995	87 (90122)	12	1995	27 (90130)	97.1
1996	96 (90122)	12	1996	25 (90130)	97.2
1997	96 (90122)	11	1997	26 (90122)	93.3
1998	100 (90122)	11	1998	27 (90130)	98
1999	86 (90122)	11	1999	24 (90130)	99.4
2000	74 (90122)	12	2000	25 (90130)	98.9
Halifax					
1986	-		1986	5 (30115)	97.6
1987	-		1987	19 (30117)	72.6
1988	62 (30117)	6	1988	21 (30117)	65.1
1989	60 (30117)	9	1989	17 (30117)	88
1990	58 (30177)	6	1990	21 (30118)	7.8
1991	62 (30118)	4	1991	22 (30118)	90.8
1992	148 (30118)	8	1992	40 (30118)	93.4
1993	154 (30118)	11	1993	21 (30118)	91.4
1994	148 (30118)	10	1994	18 (30118)	86
1995	61 (30118)	10	1995	19 (30118)	82.4
1996	55 (30118)	9	1996	18 (30118)	86.7
1997	58 (30118)	7	1997	#N/A	
1998	59 (30118)	7	1998	21 (30118)	96.3
1999	64 (30118)	4	1999	#N/A	
2000	59 (30118)	7	2000	18 (30118)	83.5
London					
1986	-		1986	26 (60901)	86.1
1987	-		1987	21 (60901)	94.8
1988	73 (60901)	12	1988	20 (60901)	97.6
1989	70 (60901)	12	1989	22 (60901)	98.6
1990	70 (60901)	12	1990	21 (60901)	97.9
1991	70 (60901)	12	1991	19 (60901)	98.9
1992	113 (60901)	12	1992	13 (60901)	99.2
1993	113 (60901)	12	1993	20 (60901)	97.9
1994	113 (60901)	12	1994	23 (60901)	98.7

1995	70 (60901)	10	1995	22 (60901)	46.5
1996	70 (60901)	6	1996	18 (60903)	98.2
1997	70 (60901)	2	1997	18 (60903)	90.7
1998	59 (60903)	10	1998	18 (60903)	99.4
1999	63 (60903)	10	1999	19 (60903)	96.7
2000	65 (60903)	11	2000	17 (60903)	86.7
Ottawa					
1986	-		1986	36 (60101)	96
1987	-		1987	37 (60101)	97.8
1988	93 (60101)	12	1988	34 (60101)	95.4
1989	93 (60101)	12	1989	38 (60101)	97.8
1990	92 (60101)	12	1990	31 (60101)	99
1991	96 (60101)	8	1991	20 (60104)	48.3
1992	263 (60101)	5	1992	72 (60101)	14.3
1993	258 (60101)	5	1993	24 (60101)	98.3
1994	198 (60101)	9	1994	25 (60101)	98.9
1995	78 (60101)	12	1995	25 (60101)	95.8
1996	74 (60101)	10	1996	23 (60101)	66.5
1997	70 (60101)	7	1997	25 (60101)	15.8
1998	73 (60101)	7	1998	25 (60101)	93.9
1999	83 (60101)	7	1999	33 (60101)	59.5
2000	82 (60101)	10	2000	22 (60101)	90.1
St. John					
1986	N/A		1986	N/A	
1987	N/A		1987	N/A	
1988	N/A		1988	N/A	
1989	N/A		1989	N/A	
1990	57 (10102)	3	1990	15 (10102)	93.1
1991	56 (10102)	6	1991	14 (10102)	92.9
1992	99 (10102)	9	1992	14 (10102)	88.7
1993	98 (10102)	9	1993	15 (10102)	83.9
1994	96 (10102)	7	1994	15 (10102)	21
1995	50 (10102)	4	1995	21 (10102)	1.7
1996	48 (10102)	1	1996	N/A	
1997	43 (10102)	2	1997	8 (10102)	40.3
1998	32 (10102)	6	1998	5 (10102)	93.4
1999	35 (10102)	9	1999	7 (10102)	88.1
2000	36 (10102)	10	2000	8 (10102)	92.8
Toronto					
1986	-		1986	34 (60418)	97
1987	-		1987	32 (60403)	94.6
1988	130 (60422)	3	1988	38 (60422)	56.9
1989	120 (60422)	7	1989	33 (60403)	97.9
1990	117 (60403)	12	1990	30 (60403)	81.2
1991	110 (60403)	12	1991	30 (60422)	91.7

1992	220 (60423)	12	1992	45 (60422)	95.6
1993	227 (60423)	12	1993	31 (60420)	28.7
1994	223 (60423)	12	1994	30 (60424)	99.4
1995	120 (60420)	1	1995	32 (60425)	13.8
1996	108 (60423)	12	1996	34 (60425)	99.3
1997	103 (60423)	11	1997	35 (60425)	59.3
1998	87 (60423)	11	1998	30 (60403)	97.5
1999	91 (60425)	2	1999	28 (60403)	79.7
2000	89 (60423)	11	2000	30 (60430)	33.1
Vancouver					
1986	-		1986	37 (100118)	11.3
1987	-		1987	30 (100112)	93.8
1988	104 (100120)	8	1988	33 (100108)	23.7
1989	100 (100110)	12	1989	31 (100112)	94
1990	90 (100110)	12	1990	31 (100112)	92.1
1991	85 (100110)	12	1991	33 (100112)	92.4
1992	230 (100108)	11	1992	60 (100112)	89.8
1993	241 (100108)	8	1993	31 (100108)	23.6
1994	322 (100108)	4	1994	24 (100112)	97.6
1995	104 (100108)	1	1995	26 (100112)	97.7
1996	66 (100121)	12	1996	27 (100112)	97.8
1997	68 (100112)	12	1997	29 (100112)	97.5
1998	67 (100112)	12	1998	29 (100112)	97.4
1999	66 (100120)	5	1999	32 (100120)	3.4
2000	67 (100120)	1	2000	27 (100112)	97.9
Winnipeg					
1986	-		1986	20 (70119)	84.7
1987	-		1987	20 (70119)	87.2
1988	66 (70119)	11	1988	19 (70119)	93.5
1989	60 (70119)	12	1989	19 (70119)	93.9
1990	59 (70119)	12	1990	15 (70119)	90.9
1991	57.3 (70118)	12	1991	17 (70119)	93.9
1992	132 (70119)	11	1992	14 (70119)	81.7
1993	-		1993	17 (70119)	93
1994	-		1994	17 (70119)	89.4
1995	57 (70119)	12	1995	18 (70119)	94.3
1996	55 (70119)	12	1996	18 (70119)	94
1997	60 (70119)	12	1997	18 (70119)	94.3
1998	62 (70119)	12	1998	17 (70119)	93.7
1999	65 (70119)	12	1999	18 (70119)	94
2000	61 (70119)	12	2000	16 (70119)	93.7
Windsor					
1986	-		1986	25 (60204)	92.9
1987	-		1987	27 (60204)	88.4
1988	97 (60204)	11	1988	30 (60204)	29.6

1989	90 (60204)	11	1989	28 (60204)	82.2
1990	87 (60204)	12	1990	25 (60204)	95
1991	83 (60204)	12	1991	25 (60204)	96.4
1992	123 (60204)	12	1992	18 (60204)	98.2
1993	127 (60204)	12	1993	26 (60204)	98.7
1994	130 (60204)	12	1994	28 (60204)	99.5
1995	87 (60204)	12	1995	25 (60204)	98.3
1996	79 (60204)	12	1996	26 (60204)	99.3
1997	71 (60204)	12	1997	24 (60204)	94.6
1998	66 (60204)	12	1998	24 (60204)	98.7
1999	67 (60204)	12	1999	23 (60204)	98.2
2000	67 (60204)	12	2000	22 (60204)	97.4
Hamilton					
1986	N/A		1986	27 (60501)	91.8
1987	N/A		1987	30 (60501)	14.6
1988	80 (60515)	11	1988	25 (60511)	95.4
1989	77 (60515)	11	1989	26(60512)	98.9
1990	73 (60515)	12	1990	22 (60512)	98.6
1991	70 (60515)	12	1991	22 (60512)	98.8
1992	160 (60515)	12	1992	28 (60515)	98.7
1993	163 (60515)	11	1993	23 (60511)	98.2
1994	163 (60515)	11	1994	23 (60511)	94.2
1995	73 (60515)	10	1995	24 (60511)	98.6
1996	67 (60515)	11	1996	22 (60511)	89.8
1997	66 (60515)	11	1997	19 (60511)	77
1998	68 (60515)	12	1998	23 (60515)	79.6
1999	78 (60511)	8	1999	28 (60511)	74.5
2000	80 (60511)	9	2000	23 (60511)	90

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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- Multicity Cakmak et al. 2011 - Respiratory hospital admissions, April 1993- March 2000
- NO₂ concentrations across all monitors in cities

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Table A-18. Hourly and Annual Design Values for 10 Canadian Cities from 1993-2000.

Year			Max DV (Monitor ID)		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%)
Calgary					
1993	-		1993	31 (90227)	99

1994	-		1994	29 (90227)	98.9
1995	86 (90227)	12	1995	28 (90227)	98.9
1996	93 (90218)	12	1996	29 (90227)	98.7
1997	98 (90218)	12	1997	30 (90227)	99.4
1998	106 (90218)	12	1998	31 (90227)	98.5
1999	95 (90218)	12	1999	28 (90227)	97.9
2000	86 (90218)	12	2000	28 (90227)	99.2
Edmonton					
1993	-		1993	27 (90130)	95.2
1994	-		1994	27 (90130)	97.6
1995	87 (90122)	12	1995	27 (90130)	97.1
1996	96 (90122)	12	1996	25 (90130)	97.2
1997	96 (90122)	11	1997	26 (90130)	93.3
1998	100 (90122)	11	1998	27 (90130)	98
1999	86 (90122)	11	1999	24 (90130)	99.4
2000	74 (90122)	12	2000	25 (90130)	98.9
Halifax					
1993	-		1993	21 (30118)	91.4
1994	-		1994	18 (30118)	86
1995	61 (30118)	10	1995	19 (30118)	82.4
1996	55 (30118)	9	1996	18 (30118)	86.7
1997	58 (30118)	7	1997	N/A	#N/A
1998	59 (30118)	7	1998	21 (30118)	96.3
1999	64 (30118)	4	1999	N/A	#N/A
2000	59 (30118)	7	2000	18 (30118)	83.5
London					
1993	-		1993	20 (60901)	97.9
1994	-		1994	23 (60901)	98.7
1995	70 (60901)	10	1995	22 (60901)	46.5
1996	70 (60901)	6	1996	18 (60903)	98.2
1997	70 (60901)	2	1997	18 (60903)	90.7
1998	59 (60903)	10	1998	18 (60903)	99.4
1999	63 (60903)	10	1999	20 (60903)	96.7
2000	65 (60903)	11	2000	17 (60903)	86.7
Ottawa					
1993	-		1993	24 (60101)	98.3
1994	-		1994	25 (60101)	98.9
1995	78 (60101)	12	1995	25 (60101)	95.8
1996	74 (60101)	10	1996	23 (60101)	66.5
1997	70 (60101)	7	1997	25 (60101)	15.8
1998	73 (60101)	7	1998	25 (60101)	93.9
1999	83 (60101)	7	1999	33 (60101)	59.5
2000	82 (60101)	10	2000	22 (60101)	90.1
St. John					
1993	-		1993	15.2 (10102)	83.9

1994	-		1994	15.3 (10102)	21
1995	50 (10102)	4	1995	21.3 (10102)	1.7
1996	48 (10102)	1	1996	N/A	N/A
1997	43 (10102)	2	1997	8.2 (10102)	40.3
1998	32 (10102)	6	1998	4.8 (10102)	93.4
1999	35 (10102)	9	1999	6.6 (10102)	88.1
2000	36 (10102)	10	2000	8.2 (10102)	92.8
Toronto					
1993	-		1993	31 (60420)	28.7
1994	-		1994	30 (60424)	99.4
1995	120 (60420)	1	1995	32 (60425)	13.8
1996	108 (60423)	12	1996	34 (60425)	99.3
1997	103 (60423)	11	1997	35 (60425)	59.3
1998	87 (60423)	11	1998	30 (60403)	97.5
1999	91 (60425)	2	1999	28 (60403)	79.7
2000	89 (60423)	11	2000	30 (60430)	33.1
Vancouver					
1993	-		1993	31 (100108)	23.6
1994	-		1994	24 (100112)	97.6
1995	104 (100108)	1	1995	26 (100112)	97.7
1996	66 (100121)	12	1996	27 (100112)	97.8
1997	68 (100112)	12	1997	29 (100112)	97.5
1998	67 (100112)	12	1998	29 (100112)	97.4
1999	66 (100120)	5	1999	32 (100120)	3.4
2000	67(100120)	1	2000	27 (100112)	97.9
Winnipeg					
1993	-		1993	17 (70119)	93
1994	-		1994	17 (70119)	89.4
1995	57 (70119)	12	1995	18 (70119)	94.3
1996	55 (70119)	12	1996	18 (70119)	94
1997	60 (70119)	12	1997	187 (70119)	94.3
1998	62 (70119)	12	1998	17 (70119)	93.7
1999	65 (70119)	12	1999	18 (70119)	94
2000	61 (70119)	12	2000	16 (70119)	93.7
Windsor					
1993	-		1993	26 (60204)	98.7
1994	-		1994	28 (60204)	99.5
1995	87 (60204)	12	1995	25 (60204)	98.3
1996	79 (60204)	12	1996	26 (60204)	99.3
1997	71 (60204)	12	1997	24 (60204)	96.4
1998	66 (60204)	12	1998	24 (60204)	98.7
199	68 (60204)	12	1999	23 (60204)	98.2
2000	67 (60204)	12	2000	22 (60204)	97.4

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2.3 Design Values In Locations For Long-Term Epidemiologic Studies Of Asthma Incidence In Children

- Vancouver, British Columbia
 Carlsten et al. 2011
 - LUR used to estimate annual concentrations at birth residential address (birth year exposure) for each subject; Air pollution estimates for 1995 generated from 2003 annual averages; Asthma assessed at 7 yrs
 -The 1-hour design value for this study encompasses years before the study period (i.e. 1993 and 1994)

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Table A-19. Hourly and Annual Design Values for Vancouver, British Columbia in 1995.

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID) ^a	Completeness (%) ^b
1995	104 (100108)	1	1995	26 (100112)	97.7

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid
^bValid annual DVs require 75% completeness

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- British Columbia
 Clark et al. (2010)
 - LUR, central site monitors, and IDW used for postal code level exposure assignment for duration of pregnancy and first year of life (1999-2000); Asthma assessed at 36-59 mos
 - Methods from manuscript indicated that exposure measures were collected from 22 monitors for NO and NO₂, but only 7 monitors from the NAPS Canadian database had data for use in our approach.
 -The 1-hour design values for this study encompass years before the study period.

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Table A-20. Hourly and Annual Design Values for Vancouver, British Columbia from 1999-2000.

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%) ^b
1999	66 (100120)	5	1999	32 (100120)	3.7
2000	67 (100120)	1	2000	27 (100112)	97.9

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid
^bValid annual DVs require 75% completeness

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- Boston Clougherty et al. (2007) - LUR model based on 1 week of monitoring per month from 1987-2004 at 28 sampling sites was used to assign residential exposure for exposure in year of asthma diagnosis; Mean age of asthma diagnosis 6.8 yrs
- Cohort from East Boston; AQS monitor 250250021 was used as representative based on study map

1

2 **Table A-21. Hourly and Annual Design Values for East Boston from 1987-1994.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID) ^a	Completeness (%) ^b
1987	-		1987	37 (250250021)	92.1
1988	-		1988	33 (250250021)	94.2
1989	91 (250250021)	12	1989	32 (250250021)	98.6
1990	90 (250250021)	12	1990	32 (250250021)	97.8
1991	84 (250250021)	12	1991	32 (250250021)	97.2
1992	81 (250250021)	12	1992	30 (250250021)	96.6
1993	79 (250250021)	12	1993	32 (250250021)	97.2
1994	79 (250250021)	11	1994	30 (250250021)	87.5
1995	76 (250250021)	11	1995	27 (250250021)	96.7
1996	83 (250250021)	11	1996	28 (250250021)	97
1997	82 (250250021)	12	1997	27 (250250021)	97.1
1998	83 (250250021)	12	1998	28 (250250021)	95.6
1999	75 (250250021)	11	1999	27 (250250021)	85.5
2000	72 (250250021)	11	2000	22 (250250021)	86.2
2001	64 (250250021)	10	2001	21 (250250021)	89
2002	60 (250250021)	10	2002	23 (250250021)	82.8
2003	54 (250250021)	6	2003	32 (250250021)	0
2004	54 (250250021)	3	2004	N/A	

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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- Multicity (San Francisco, Houston, Chicago, Bronx, Puerto Rico) Nishimura et al. (2013) - IDW with 4 closest monitors within 50 km of residence used for exposure assignment
- AQS study monitors identified by visual approximation from study maps

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6 **Table A-22. Hourly and Annual Design Values for 5 U.S. Cities from 1986-2008.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID)	Completeness (%) ^b
Chicago, IL					
1986	-		1986	42 (170310040)	95.6
1987	-		1987	43 (170310040)	76.6
1988	131 (170310053)	0	1988	34 (170310063)	38.9
1989	180 (170310053)	0	1989	34 (170310039)	96.6
1990	94 (170310039)	12	1990	31 (170310039)	98.5
1991	88 (170310039)	12	1991	32 (170310039)	98.4
1992	84 (170310039)	12	1992	30 (170310039)	89.3
1993	82 (170310039)	12	1993	31 (170310063)	89.2
1994	82 (170310063)	11	1994	34 (170310039)	62.8
1995	83 (170310063)	12	1995	32 (170310063)	98.4
1996	87 (170310039)	3	1996	31 (170310063)	95.7
1997	88 (170310063)	12	1997	34 (170310063)	97.5
1998	89 (170310037)	3	1998	32 (170310063)	95.3
1999	88 (170310063)	12	1999	32 (170310063)	98.4
2000	87 (170310063)	12	2000	32 (170310063)	94.7
2001	86.3 (170310063)	12	2001	32 (170310063)	98.7
2002	90 (170310063)	12	2002	32 (170310063)	98.8
2003	87 (170310063)	12	2003	31 (170310063)	96.9
2004	86 (170310063)	12	2004	29 (170310063)	96.6
2005	83 (170310063)	12	2005	30 (170310063)	95.7
Houston, TX					
1986	-		1986	28 (482011037)	57
1987	-		1987	30 (482011037)	93
1988	110 (482011037)	10	1988	28 (482011037)	91
1989	110 (482011037)	12	1989	28 (482011037)	84.3
1990	107 (482011037)	11	1990	29 (482011037)	71.3
1991	103 (482011037)	11	1991	28 (482011037)	85.6
1992	97 (482011037)	11	1992	28 (482011037)	80.3
1993	-		1993	24 (482011037)	81.6
1994	-		1994	28 (482011037)	82.6
1995	86 (482011037)	10	1995	26 (482011037)	76.4
1996	81 (482011037)	10	1996	23 (482011037)	87.2
1997	79 (482010047)	11	1997	25 (482011037)	81.3
1998	79 (482010047)	11	1998	23 (482011035)	87.4
1999	80 (482010047)	10	1999	24 (482010047)	83.2
2000	76 (482010047)	10	2000	21 (482011037)	93.2
2001	79 (482011037)	9	2001	29 (482011037)	22.1
2002	82 (482011037)	5	2002	18 (482010047)	88.2
2003	86 (482011037)	1	2003	18 (482010047)	96

2004	62 (482010047)	12	2004	19 (482011034)	96.7
2005	62 (482010047)	12	2005	18 (482010047)	92.9
New York, NY					
1986	-		1986	49 (360610056)	68.6
1987	-		1987	43 (360610056)	40.7
1988	129 (360610056)	6	1988	44 (360610056)	44.5
1989	131 (360610056)	7	1989	49 (360610056)	94.3
1990	128 (360610056)	10	1990	46 (360610056)	96
1991	121 (360610056)	10	1991	47 (360610056)	96
1992	113 (360610056)	7	1992	36 (360610056)	59.4
1993	110 (360610056)	6	1993	43 (360610056)	87.1
1994	114 (360610056)	7	1994	46 (360610056)	86.6
1995	113 (360610056)	10	1995	42 (360610056)	94.4
1996	110 (360610056)	11	1996	42 (360610056)	86.1
1997	99 (360610056)	12	1997	40 (360610056)	94.6
1998	96 (360050080)	11	1998	40 (360610056)	91.2
1999	95 (360050080)	11	1999	41 (360610056)	97
2000	94 (360050073)	1	2000	38 (360610056)	95.5
2001	94 (360050073)	1	2001	38 (360610056)	39.1
2002	96 (360610010)	5	2002	38 (360610010)	95.5
2003	105 (360610010)	1	2003	38 (360610056)	58.5
2004	79 (360050110)	11	2004	35 (360610056)	62.6
2005	78 (360050110)	11	2005	37 (360610056)	97.3
San Francisco, CA					
1986	-		1986	24 (060410001)	98.5
1987	-		1987	24 (060750005)	97.3
1988	90 (060750005)	12	1988	26 (060750005)	96.5
1989	93 (060750005)	10	1989	26 (060750005)	87.9
1990	87 (060750005)	10	1990	21 (060750005)	88.3
1991	87 (060750005)	10	1991	24 (060750005)	99.1
1992	83 (060750005)	11	1992	22 (060750005)	97.5
1993	77 (060750005)	12	1993	24 (060750005)	93.1
1994	74 (060750005)	12	1994	22 (060750005)	96.8
1995	70 (060750005)	12	1995	21 (060750005)	97.2
1996	70 (060750005)	12	1996	22 (060750005)	96.8
1997	65 (060750005)	12	1997	20 (060750005)	93.6
1998	63 (060750005)	12	1998	20 (060750005)	95.1
1999	63 (060750005)	12	1999	21 (060750005)	94.6
2000	64 (060750005)	12	2000	20 (060750005)	95
2001	65 (060750005)	12	2001	19 (060750005)	95
2002	61 (060750005)	12	2002	19 (060750005)	93.3
2003	60 (060750005)	12	2003	18 (060750005)	94.3
2004	57 (060750005)	12	2004	17 (060750005)	92.3
2005	55 (060750005)	12	2005	16 (060750005)	94.9
Puerto Rico					

1986	N/A		1986	N/A	
1987	N/A		1987	N/A	
1988	N/A		1988	N/A	
1989	N/A		1989	N/A	
1990	N/A		1990	N/A	
1991	N/A		1991	N/A	
1992	N/A		1992	N/A	
1993	N/A		1993	N/A	
1994	N/A		1994	N/A	
1995	N/A		1995	N/A	
1996	N/A		1996	N/A	
1997	83 (720330006)	0	1997	20 (720330006)	16.4
1998	83 (720330006)	1	1998	12 (720330006)	64.8
1999	67 (720330006)	2	1999	7.3 (720330006)	66.6
2000	80 (720330006)	4	2000	18 (720330006)	75.5
2001	71 (720330006)	6	2001	9 (721270009)	87.5
2002	68 (720330006)	8	2002	7 (721270009)	92.2
2003	41 (720330006)	6	2003	7 (721270009)	60.2
2004	29 (720330008)	0	2004	11 (720330008)	18.1
2005	32 (720330008)	2	2005	9 (721270009)	72.2

^bIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid
^cValid annual DVs require 75% completeness

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- Southern CA McConnell et al. (2010)
 - Community central site monitors and line source dispersion models used for residential and school NO_x; Kindergarten and 1st grade children (4.8-9 yrs) enrolled in 2002-2003 and followed for 3 yrs (2002-2006)
 - Models include TRP show independent, significant association for TRP and attenuation of NO₂ effect
 - DVs were identified for Santa Maria, Santa Barbara, Alpine, Los Angeles CBSA, and Riverside CBSA. Several study communities were located in the Los Angeles CBSA (Long Beach, Anaheim, Mira Loma, and Glendora) and several others in the Riverside CBSA (San Dimas, Upland, Lake Arrowhead, San Bernardino, Riverside, and Lake Elsinore). The high DVs for each year were taken for these CBSAs rather than the study communities due to their close proximity and inability to determine specific community monitors.

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4 **Table A-23. Hourly and Annual Design Values for Southern California Communities for**
 5 **2002-2006.**

Hourly			Annual		
Year	Max DV (Monitor ID)	Number of Complete Quarters ^a	Year	Max DV (Monitor ID) ^a	Completeness (%) ^b
Santa Barbara, CA					
2002	-		2002	N/A	
2003	-		2003	15 (60830011)	36.1
2004	52 (60830011)	6	2004	13 (60830011)	92.8
2005	50 (60830011)	10	2005	12 (60830011)	95.1
2006	48 (60830011)	11	2006	11 (60830011)	55.1
Santa Maria, CA					
2002	-		2002	11 (60831008)	43.2
2003	-		2003	11 (60831008)	92.7
2004	42 (60831008)	10	2004	10 (60831008)	85.2
2005	41 (60831008)	12	2005	10 (60831008)	94.5
2006	37 (60831008)	10	2006	8 (60831008)	55.1
Alpine, CA					
2002	-		2002	13 (60731006)	93.5
2003	-		2003	14 (60731006)	87.1
2004	54 (60731006)	11	2004	12 (60731006)	94.1
2005	51 (60731006)	11	2005	11 (60731006)	92.2
2006	46 (60731006)	12	2006	10 (60731006)	94
Los Angeles-Long Beach, CA					
2002	-		2002	40 (60371002)	93.2
2003	-		2003	35 (60371002)	90.7
2004	121 (60370030)	2	2004	34 (60371103)	85.4
2005	101 (60371103)	11	2005	31 (60371301)	93.5
2006	92 (60371602)	2	2006	31 (60371301)	94.1
Riverside, CA					
2002	-		2002	36 (60711004)	94.5
2003	-		2003	34 (60711004)	94.8
2004	95 (60711004)	12)	2004	31 (60711004)	94.8
2005	92 (60711004)	12	2005	31 (60711004)	94.7
2006	98 (60711004)	12	2006	31 (60711004)	88

^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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Jerrett et al. (2008)

- LUR model based on Palmes tubes outside homes for 2 weeks in summer and winter used for exposure assessment; children were enrolled at age 10 in 1993 or 1996 and followed for 8 yrs or until high school graduation
 -DV's were identified for Santa Maria, Lompoc, Santa Barbara, Alpine, Atascadero, Los Angeles CBSA, and Riverside CBSA. Several study communities were located in the Los Angeles CBSA

(Long Beach, Anaheim, Mira Loma, and Glendora) and several others in the Riverside CBSA (San Dimas, Upland, Lake Arrowhead, San Bernardino, Riverside, and Lake Elsinore). The high DVs for each year were taken for these CBSAs rather than the study communities due to their close proximity and inability to determine specific community monitors.

1 **Table A-24. Hourly and Annual Design Values for Southern California Communities from**
 2 **1993-2004.**

Hourly			Annual		
Year	Max DV (Monitor ID) ^a	Number of Complete Quarters ^b	Year	Max DV (Monitor ID) ^a	Completeness (%) ^c
Santa Maria					
1993	-		1993	7 (060831010)	93.3
1994	-		1994	7 (060831010)	93.3
1995	45 (060831007)	4	1995	12 (060831007)	92.6
1996	45 (060831007)	7	1996	12 (060831007)	88.5
1997	45 (060831007)	11	1997	13 (060831007)	95.1
1998	43 (060831007)	11	1998	12 (060831007)	93.6
1999	44 (060831007)	11	1999	11 (060831007)	89.7
2000	42 (060831007)	8	2000	13 (060831007)	14.6
2001	43 (060831007)	4	2001	15 (060831008)	0.1
2002	37 (060831008)	6	2002	11 (060831008)	43.2
2003	38 (060831008)	6	2003	11 (060831008)	92.7
2004	42 (060831008)	10	2004	10 (060831008)	85.2
Lompoc, CA					
1993	-	12	1993	9 (060832004)	92
1994	-	12	1994	9 (060832004)	92.3
1995	39 (060831013)	12	1995	7 (060832004)	93.5
1996	36 (060831013)	12	1996	7 (060832004)	91.8
1997	36 (060831013)	12	1997	7 (060832004)	90.7
1998	35 (060831013)	12	1998	7 (060832004)	92.5
1999	35 (060831013)	12	1999	7 (060832004)	93.4
2000	33 (060831013)	12	2000	6 (060832004)	92.1
2001	33 (060831013)	12	2001	6 (060832004)	93.7
2002	31 (060831013)	11	2002	4 (060832004)	79.8
2003	32 (060831013)	11	2003	6 (060832004)	92.9
2004	31 (060831013)	11	2004	6 (060832004)	93.3
Riverside, CA					
1993	-		1993	42 (060711004)	94.9
1994	-		1994	41 (060711004)	95
1995	140 (060711004)	12	1995	46 (060711004)	95.1
1996	137 (060711004)	11	1996	38 (060711004)	77.1
1997	127 (060711004)	11	1997	36 (060712002)	90.6

1998	112 (060711004)	11	1998	36 (060712002)	95.5
1999	111 (060650012)	11	1999	39 (060711004)	95.8
2000	134 (060650012)	12	2000	38 (060711004)	95.9
2001	142 (060650012)	12	2001	37 (060711004)	95.7
2002	135 (060650012)	12	2002	36 (060711004)	94.5
2003	107 (060650012)	12	2003	34 (060711004)	94.8
2004	95 (060711004)	12	2004	31 (060711004)	94.8
Los Angeles-Long Beach, CA					
1993	-		1993	50 (060371701)	92.8
1994	-		1994	48 (060371701)	94
1995	149 (060371701)	12	1995	46 (060711004)	95.1
1996	145 (060374002)	12	1996	42 (060371701)	94.2
1997	140 (060374002)	12	1997	43 (060371701)	95.4
1998	129 (060374002)	12	1998	43 (060371701)	94.9
1999	127 (060371701)	12	1999	51 (060371701)	95.4
2000	125 (060371701)	12	2000	44 (060371701)	95.8
2001	116 (060371701)	12	2001	37 (060371701)	95.7
2002	106 (060374002)	12	2002	36 (060371701)	95
2003	104 (060374002)	12	2003	35 (060371701)	95.2
2004	105 (060374002)	12	2004	31 (060371701)	94.2
Alpine, CA (San Diego CBSA)					
1993	-		1993	14 (060731006)	97.7
1994	-		1994	13 (060731006)	96.2
1995	61 (060731006)	12	1995	13 (060731006)	97.8
1996	61 (060731006)	12	1996	12 (060731006)	94.5
1997	60 (060731006)	11	1997	11 (060731006)	61.9
1998	54 (060731006)	11	1998	12 (060731006)	93.2
1999	57 (060731006)	11	1999	15 (060731006)	91.3
2000	59 (060731006)	12	2000	15 (060731006)	83.4
2001	59 (060731006)	12	2001	14 (060731006)	94.8
2002	56 (060731006)	12	2002	13 (060731006)	93.5
2003	55 (060731006)	11	2003	14 (060731006)	87.1
2004	54 (060731006)	11	2004	12 (060731006)	94.1
Atascadero, CA (San Luis Obispo CBSA)					
1993	-		1993	14 (060798001)	95.1
1994	-		1994	14 (060798001)	93
1995	55 (060798001)	12	1995	12 (060798001)	94.4
1996	52 (060798001)	12	1996	12 (060798001)	94.5
1997	52 (060798001)	12	1997	12 (060798001)	92.3
1998	51 (060798001)	12	1998	11 (060798001)	94.9
1999	56 (060798001)	12	1999	14 (060798001)	93.8
2000	55 (060798001)	12	2000	12 (060798001)	93.6
2001	54 (060798001)	12	2001	11 (060798001)	87.5
2002	51 (060798001)	12	2002	11 (060798001)	92.2
2003	50 (060798001)	12	2003	9 (060798001)	95.2

2004	48 (060798001)	12	2004	8 (060798001)	95.1
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^aIn the respective 3-year period (12 quarters) for the hourly DV; 9 or more quarters (75%) are required for a DV to be valid

^bValid annual DVs require 75% completeness

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A3. DISTRIBUTIONS OF DAILY MAXIMUM 1-HOUR NO₂ CONCENTRATIONS FOR LOCATIONS OF SHORT-TERM EPIDEMIOLOGIC STUDIES

Table A-25: Distribution of daily maximum 1-hour concentrations of NO₂ (ppb) for locations of U.S. epidemiologic studies of short-term hospital admissions and emergency department visits.

	U.S. Study Locations (years)							
	Atlanta (1993-2000)	Atlanta (1994-2004)	Atlanta (1993-2004) (May-Oct.)	Bronx (1999-2000)	Manhattan (1999-2000)	Detroit (2004-2006)	Los Angeles (1992-1995)	New York (1999-2002)
5 th	22	22	21	25	32	16	30	38
10 th	26	26	25	28	35	18	36	42
50 th	44	43	42	41	47	33	60	59
75 th	57	55	54	50	56	40	90	72
90 th	70	68	64	62	66	47	120	85
98 th	92	90	85	80	82	57	177	108
99 th	100	99	92	85	90	60	197	114

Shaded columns represent study locations/years for studies in Figure 3-1 with DVs ≤ 100 ppb.

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A4. TRENDS IN 1-HOUR AND ANNUAL NO₂ DESIGN VALUES

13 Figures 2-3 and 2-4 present different properties of trends of annual and hourly DVs from
 14 1980-2015. For both of these graphics, only DVs considered "valid" by the completeness criteria
 15 in the CFR were used. In Figure 2-3, five percentiles (5, 25, 50, 75, and 95) of the year-specific
 16 distributions of DVs across the U.S. were calculated and plotted. In Figure 2-4, the correlation
 17 between valid DVs and year are calculated and categorized into one of three bins: increasing,
 18 decreasing, or insignificant. This calculation used the cor.test() function included in the R
 19 statistical package to return the Spearman correlation ("r") and associated p-value for each NO₂

1 monitoring site and DV type. If the p-value was greater than 0.05, then the trend was deemed
2 insignificant. If the p-value was less than or equal to 0.05, then the sign of the r-value was used
3 to determine the direction of the trend: positive for increasing and negative for decreasing.

4 5 **A5. EVALUATION OF ROADWAY GRADIENTS OF NO₂ CONCENTRATIONS** 6 **FROM 1980-2015** 7

8 Figures 2-5 and 2-6 were generated by plotting boxplots of NO₂ DVs from urban areas as a
9 function of bins of distances in meters from the nearest major road. A monitor was considered
10 "Urban" if it resided inside the boundary of a core-based statistical area (CBSA) as defined by
11 the U.S. Census Bureau in 2014 (<https://www.census.gov/geo/maps-data/data/tiger-line.html>).
12 These distances were determined using 2012 data from the Highway Performance Monitoring
13 System (HPMS) created by the Federal Highway Administration
14 (<http://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm>). The R statistical program
15 (<https://www.r-project.org/>) and the gDistance() function in the rgeos package ([https://CRAN.R-
16 project.org/package=rgeos](https://CRAN.R-project.org/package=rgeos)) were used calculate the distances between monitor long/lat points
17 and the nearest road in the HPMS shapefile. (sentence about the HPMS file is all "major" roads).
18 The distances and DV datasets were then merged together by monitors and input to graphical
19 commands to produce the boxplots in Figures 2-5 and 2-6. All DVs, both valid and invalid
20 according the CFR completeness criteria, were included in the boxplots to more robustly explore
21 the physical relationship between NO₂ concentrations and distance from vehicular sources.

22 23 **A6. COMPARISON OF DISTRIBUTION OF NO₂ CONCENTRATIONS FROM** 24 **NEAR-ROAD MONITORS AND NON-NEAR-ROAD MONITORS FOR 2013-2015** 25

26 Figures 2-7, 2-8 and 2-9 were created by calculating the 10th, 25th, 50th, 75th, 90th, 98th, and
27 99th percentiles of annual NO₂₋₁ concentrations at each monitor in a CBSA that contained a
28 monitor in the EPA Near Road Network. No consideration was given to data completeness for
29 these calculations. If more than one monitor of each given type (i.e. near road or non-near road)
30 was present in a CBSA, only data from the monitor with the highest 98th percentile of that type
31 was included. The above percentiles were then graphed as the boxplots specific to each CBSA,
32 road type and year as shown in Figures 2-7 through 2-9.

33 34 **A7. RELATIONSHIP BETWEEN 1-HOUR AND ANNUAL NO₂ DESIGN VALUES**

35 Figure 2-10 was generated by plotting DVs from monitors and years where both the annual and
36 hourly DV was valid according to the CFR completeness criteria. Regression statistics (slope,
37 intercept and R²) were calculated using the lm() function included in the R statistical package.

APPENDIX B
**COMPARISONS OF NO₂ AIR QUALITY AND HEALTH-
BASED BENCHMARKS**

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1 **B1. INTRODUCTION**

2 This document provides the detailed results of an air quality characterization (AQC)
3 performed as part of the primary NO₂ NAAQS review. Ambient concentration measurements
4 (1980-2015), along with adjusted and simulated ambient concentrations, were evaluated using
5 approaches described in Chapter 2 of the NO₂ REA planning document (REA PD; US EPA,
6 2015). The approaches and data sets used in this characterization were also informed by review
7 by the CASAC (Roux and Frey, 2015) and public comments, with appropriate modifications
8 noted here.

9 As indicated in the REA PD (section 2.1.1), there is a substantially improved body of
10 information available in the current review to inform an updated characterization of 1-hour
11 ambient NO₂ concentrations. In particular, data from recently deployed NO₂ monitors near major
12 roads, combined with new information from monitoring and modeling studies of NO₂
13 concentration gradients around roads, add to our understanding of ambient NO₂ concentrations in
14 near-road and on-road environments. This new information, combined with recent information
15 on NO_x emissions provides important perspective, beyond what was available from the last
16 review, on the extent to which NO₂ exposures could have potentially important implications for
17 public health.

18 We evaluated ambient NO₂ concentrations and compared them with health-based
19 benchmarks, with a particular focus on updating analyses of concentrations occurring near roads.
20 The following sections describe our technical approach used to conduct these analyses (Section
21 B2) including a representativeness evaluation of the study areas selected for focused analysis.
22 Then, the number of days per year having daily maximum 1-hour (DM1H) concentrations at or
23 above the selected benchmarks was evaluated using historical (1980-2015) unadjusted ambient
24 monitoring data and several adjusted and simulated air quality scenarios using recent (2010-
25 2015) ambient monitoring data in selected urban study areas (Section B3). Section B4 follows in
26 identifying reference material used in developing this document. And finally, detailed
27 supplemental data are provided in Section B5 to support the analyses presented in Sections B2
28 and B3.

1 **B2. APPROACH**

2 This air quality characterization (AQC) requires benchmark concentrations of interest, the
3 identification of a study area(s) of interest, and the characterization of respective air quality.
4 Further, the overall representativeness of the characterization is informed by ambient monitoring
5 physical attributes and local NO_x emission source information. Each of these fundamental
6 components of the AQC, the data and approaches used, and an overview of the air quality
7 benchmark summary metrics are described in the following sections. SAS version 9.4
8 (SAS/STAT 13.2; SAS, 2015) was used to process all ambient monitor data files and to perform
9 all mathematical and statistical analyses of NO₂ concentration data.

10 **2.1 AIR QUALITY BENCHMARK LEVELS**

11 The primary goal of this NO₂ AQC is to inform policy decisions regarding the likelihood
12 that the existing or potential alternative standards would allow for exposures to ambient NO₂
13 concentrations that could be of concern for public health. To facilitate such an analysis, we
14 evaluated the daily maximum 1-hour (DM1H) ambient NO₂ concentrations adjusted to just meet
15 the existing NO₂ standards at varying air quality benchmark levels. We identified air quality
16 benchmark levels based on the range of data from controlled human exposure studies of non-
17 specific airway responsiveness in people with asthma.¹ Because there are few instances where 1-
18 hour ambient concentrations could go above 200 ppb when considering concentrations that just
19 meet the existing standards, we focused on the lower end of this range and selected three air
20 quality benchmark levels of 100, 150 and 200 ppb. Instances when ambient concentrations in
21 selected study areas are at or above these levels are counted and summarized, as detailed in
22 section 2.4.3.

¹ The majority of study volunteers experienced increased airway responsiveness following exposures to NO₂ concentrations of 100-300 ppb (or higher) for 30 minutes to 2 hours.

2.2 AMBIENT MONITORING DATA

All of the existing ambient NO₂ monitoring data from 1980-2015 are considered in this AQC. Hourly ambient concentration data were obtained from the U.S. EPA's AirData and Air Quality System (AQS) Data Mart websites.² Any replicate NO₂ measures occurring at the same monitoring site (though having multiple parameter occurrence codes or POCs) were averaged. Except for the newly designated near-road monitors, only monitors having a complete year of data were used in our analyses. Ascertaining a complete year of monitoring data is a multi-step process. First, valid days are defined as those having at least 18 hours of measurements. Next, a valid quarter is identified as having at least 75% of valid days within a three-month calendar period (68-70 days). Finally, where all four quarters in a calendar year are valid, the year of monitoring data was considered complete. The near-road monitoring data were used as reported for any year available, regardless of how many hours/days observations were collected.

2.3 STUDY AREAS

We have conducted updated analyses comparing NO₂ air quality to benchmarks in several study areas. Our selection of study areas focused on CBSAs having newly designated near-road monitors, CBSAs having the highest NO₂ design values (thus requiring the smallest adjustment to just meet the existing 1-hour standard) and CBSAs with a relatively large number of NO₂ monitors overall (i.e., providing improved spatial characterization). Additional considerations for evaluating representativeness of selected study areas include CBSA population, ranking of total NO_x emissions and mobile source NO_x emissions, and that they include a wide range of other non-mobile sources having relatively high NO_x emissions. The specific steps taken to select the study areas and how they were evaluated for representativeness are described below.

2.3.1 Selection approach

While all of the existing ambient monitoring data from 1980-2015 are considered in this AQC, particular adjusted air quality scenarios (i.e., air quality adjusted to just meet the existing

² Data for 1990-2015 obtained from http://aqsdrl.epa.gov/aqsweb/aqstmp/airdata/download_files.html#Raw. Data for 1980-1989 downloaded from https://aqs.epa.gov/aqsweb/documents/data_mart_welcome.html.

1 standards) and simulated microenvironmental evaluations (i.e., on-road NO₂ concentrations)
2 warranted the defining of a specific geographic domain, or study area. For added context
3 regarding the potential exposed population, the core-based statistical area (CBSA) was chosen as
4 the fundamental geographic area. The following are the approach steps used to identify CBSAs
5 to consider evaluating in the study area focused portion of this AQC, followed by the application
6 of this approach to select study areas.

- 7 1. CBSAs were defined at a county level using delineation files available from the U.S.
8 Census Bureau.³
- 9 2. All available ambient NO₂ monitor design values⁴ were linked with CBSA definitions
10 using the state and county level identifiers contained in the first five digits of the
11 ambient monitor IDs.⁵ CBSAs having at least one monitor design value were retained
12 for further selection steps.
- 13 3. The single year 98th percentile DM1H was calculated for all near-road monitors in
14 any CBSA for 2014 and 2015.⁶ This near-road monitor summary statistic was then
15 merged with the CBSA-monitor design value data, again using the appropriate state
16 and county level identifiers.
- 17 4. This combined CBSA-design value-near road data were then grouped into one of two
18 study area selection pools:

³ The counties comprising each CBSA are listed at <http://www.census.gov/population/metro/data/def.html>, as defined by the Office of Management and Budget (OMB) (<http://www.whitehouse.gov/sites/default/files/omb/bulletins/2013/b-13-01.pdf>). Instances where only a portion of the county was identified as part of a given CBSA by the OMB memo, it was assumed in this analysis that the entire county was part of the CBSA in an effort to be more inclusive in developing the study area selection pools.

⁴ A spreadsheet file containing annual average and 98th percentile daily maximum 1-hour (DM1H) design values was obtained from <http://www.epa.gov/airtrends/values.html>. The file obtained contains design values for 2005-2014, though only years 2010-2014 were used from this file in identifying CBSAs as part of the study area selection pool. Design values for 2015 were calculated using complete year ambient monitor data available as part of this analysis.

⁵ Each ambient monitor ID has 9 characters (XXYYYZZZZ) as follows: 'XX' indicates the U.S. State code, 'YYY' is used to identify the county code, and 'ZZZZ' is used for the monitor number.

⁶ The near-road monitor IDs and attributes were obtained from <http://www3.epa.gov/ttnamti1/nearroad.html>.

- 1 a. *Near-road CBSAs*. CBSAs having a newly designated near-road monitor and
2 reporting NO₂ concentrations were given preference for inclusion in an initial
3 study area selection pool. Because most of the near-road monitors began
4 operating in 2014, all near-road NO₂ concentration data were considered
5 usable regardless as to whether or not a complete year was available to
6 maximize the amount of near-road data available for analysis. Fifty CBSAs
7 were identified as part of this initial selection pool (Table B2-1).
- 8 b. *Other CBSAs*. CBSAs not having a newly designated near-road monitor,⁷ or
9 CBSAs not having reported concentrations at a newly designated near-road
10 monitor though having at least one design value were included in this group.
11 One-hundred twenty-seven CBSAs were identified as part of this group (not
12 shown).
- 13 5. The top twenty⁸ near-road CBSAs were identified from the “near-road CBSA” group
14 using a rank value, generated using the following quantitative information:
- 15 a. For each CBSA, the maximum design value and the total number of monitors
16 reporting a design value was obtained for all analysis years considered (i.e.,
17 2010-2015) and the 98th percentile DM1H near-road monitor concentration for
18 2014 and 2015 were retained. This yielded upwards to twenty-two variables⁹
19 describing each CBSA.

⁷ There are a few CBSAs that have an existing monitor sited in close proximity to a major roadway, though not necessarily meeting the new near-road monitor designation requirements. For example, a Chicago, IL monitor (ID 170313103) is about 20 meters from a major road (see US EPA, 2008a; 2008 REA Appendix A, Table A-7). It is possible NO₂ concentrations from this monitor (and other monitors in close proximity to a major road) can be used in a manner similar to that of the formally designated near-road monitors and supplement our characterization of the near-road and on-road microenvironments.

⁸ This number of “identified CBSA” (i.e., 20) was subjectively chosen for analysis tractability while also retaining a generally geographically diverse and high NO₂ concentration representative collection of CBSAs from the near-road CBSAs group.

⁹ Considered here are the six annual average design values, four 3-year average 98th percentile DM1H design values, number of monitors in each of six years, number of monitors in four 3-year periods, and the 98th percentile DM1H values for the near-road monitor in 2014 and 2015.

- 1 b. A global mean value for each of these twenty-two variables was calculated.
2 Each individual CBSA variable value was then normalized by the global mean
3 variable value.
4 c. A rank value for each CBSA was calculated as an equally weighted sum of the
5 mean normalized variable values, though relative to unity (i.e., the average
6 CBSA rank value would equal 1). The rank values were then sorted in
7 descending order with the top twenty near-road CBSA¹⁰ presented in Table
8 B2-2.

9 6. Twenty additional CBSAs were then identified using a rank value generated using the
10 same variables and approach listed in step 5, though considering the following
11 modifications:

- 12 a. Not included in the calculation of the rank value was the 98th percentile
13 DM1H concentration from a newly designated near-road monitor, thus there
14 were upwards to twenty variables describing each CBSA.
15 b. CBSAs evaluated in this step were those in the “other CBSA” group (step 4b)
16 and any “near-road CBSA” not identified in step 5 (i.e., totaling 157 CBSAs).
17 c. The rank values were sorted in descending order with the top twenty
18 “additional CBSA” provided in Table B2-3.

19
20 We prioritized the order by which the above identified CBSAs could be evaluated for the
21 benchmark analysis, rather than proceed with performing analyses using all 40 CBSAs. First, all
22 twenty “near-road CBSAs” in Table B2-2 were selected as study areas, again, based on their
23 having the newly sited near-road monitors and associated NO₂ concentration measurements.
24 Next, because Detroit MI and Richmond VA have new near-road measurement data and add to
25 the overall U.S. geographic representation, these CBSAs were selected as a study area from the
26 “additional CBSA” top twenty list. We then selected one CBSA (Chicago, IL) from the list of

¹⁰ The use of unweighted variables in calculating the rank value places emphasis on within-CBSA spatial representation and areas measuring the highest NO₂ concentrations. Justification for this emphasis would include, 1) when properly sited regarding the most important direct source or precursor emissions, the greater the number of monitors in a CBSA would better represent ambient concentrations than in CBSAs having fewer monitors, 2) monitors having the highest concentrations would require the smallest adjustment upwards to just meet the existing standard, possibly limiting uncertainty in generated results, and 3) the risk associated with highest concentrations (even considering unadjusted concentrations) is by definition of greatest importance when performing an assessment that uses health effect benchmark concentrations.

1 additional CBSAs, largely based on it further enhancing overall U.S. geographic representation,
 2 and having the highest population of the remaining CBSAs identified for analysis (see below). In
 3 addition, while Chicago does not have any new near-road measurement data available, we were
 4 interested in evaluating results that could be generated using historically sited monitors that are
 5 situated near a major road. Thus, a total of twenty-three study areas were selected for the focused
 6 analysis in this AQC (Figure B2-1). If other study areas are determined as useful in
 7 characterizing air quality for future assessments as part of this review, the 17 CBSAs remaining
 8 from the list of “additional CBSAs” above, along with any new near-road CBSAs (e.g., perhaps
 9 those having newly available 2016 near-road NO₂ measurements) would likely be considered
 10 first in selecting additional study areas.

11 **Table B2-1. CBSAs having NO₂ measurement data from the newly designated near-road**
 12 **monitoring sites (2014-2015).**

CBSA Name	Abbr.	CBSA Name	Abbr.
Atlanta-Sandy Springs-Roswell, GA	ATLA	Milwaukee-Waukesha-West Allis, WI	MILW
Austin-Round Rock, TX	AUST	Minneapolis-St. Paul-Bloomington, MN-WI	MINE
Baltimore-Columbia-Towson, MD	BALT	Nashville-Davidson--Murfreeseboro--Franklin, TN	NASH
Birmingham-Hoover, AL	BIRM	New Orleans-Metairie, LA	NORL
Boise City, ID	BOIS	New York-Newark-Jersey City, NY-NJ-PA	NYNY
Boston-Cambridge-Newton, MA-NH	BOST	Oklahoma City, OK	OKLA
Buffalo-Cheektowaga-Niagara Falls, NY	BUFF	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	PHIL
Charlotte-Concord-Gastonia, NC-SC	CHAR	Phoenix-Mesa-Scottsdale, AZ	PHOE
Cincinnati, OH-KY-IN	CINC	Pittsburgh, PA	PITT
Cleveland-Elyria, OH	CLEV	Portland-Vancouver-Hillsboro, OR-WA	PORT
Columbus, OH	COLO	Providence-Warwick, RI-MA	PROV
Dallas-Fort Worth-Arlington, TX	DALL	Raleigh, NC	RALE
Denver-Aurora-Lakewood, CO	DENV	Richmond, VA	RICH
Des Moines-West Des Moines, IA	DESM	Riverside-San Bernardino-Ontario, CA	RIVR
Detroit-Warren-Dearborn, MI	DETR	Rochester, NY	RONY
Hartford-West Hartford-East Hartford, CT	HART	Sacramento--Roseville--Arden-Arcade, CA	SACR
Houston-The Woodlands-Sugar Land, TX	HOUS	San Antonio-New Braunfels, TX	SANA
Indianapolis-Carmel-Anderson, IN	INDI	San Diego-Carlsbad, CA	SAND
Jacksonville, FL	JACK	San Francisco-Oakland-Hayward, CA	SANF
Kansas City, MO-KS	KANS	San Jose-Sunnyvale-Santa Clara, CA	SANJ
Las Vegas-Henderson-Paradise, NV	LASV	San Juan-Carolina-Caguas, PR	SJPR
Los Angeles-Long Beach-Anaheim, CA	LOSA	Seattle-Tacoma-Bellevue, WA	SEAT
Louisville/Jefferson County, KY-IN	LOUI	St. Louis, MO-IL	STLO
Memphis, TN-MS-AR	MEMP	Tampa-St. Petersburg-Clearwater, FL	TAMP
Miami-Fort Lauderdale-West Palm Beach, FL	MIAM	Washington-Arlington-Alexandria, DC-VA-MD-WV	WASH

1 **Table B2-2. The top twenty near-road CBSAs identified for analysis based on 2010-2015 design values, number of monitors in operation,**
 2 **and near-road NO₂ concentrations.**

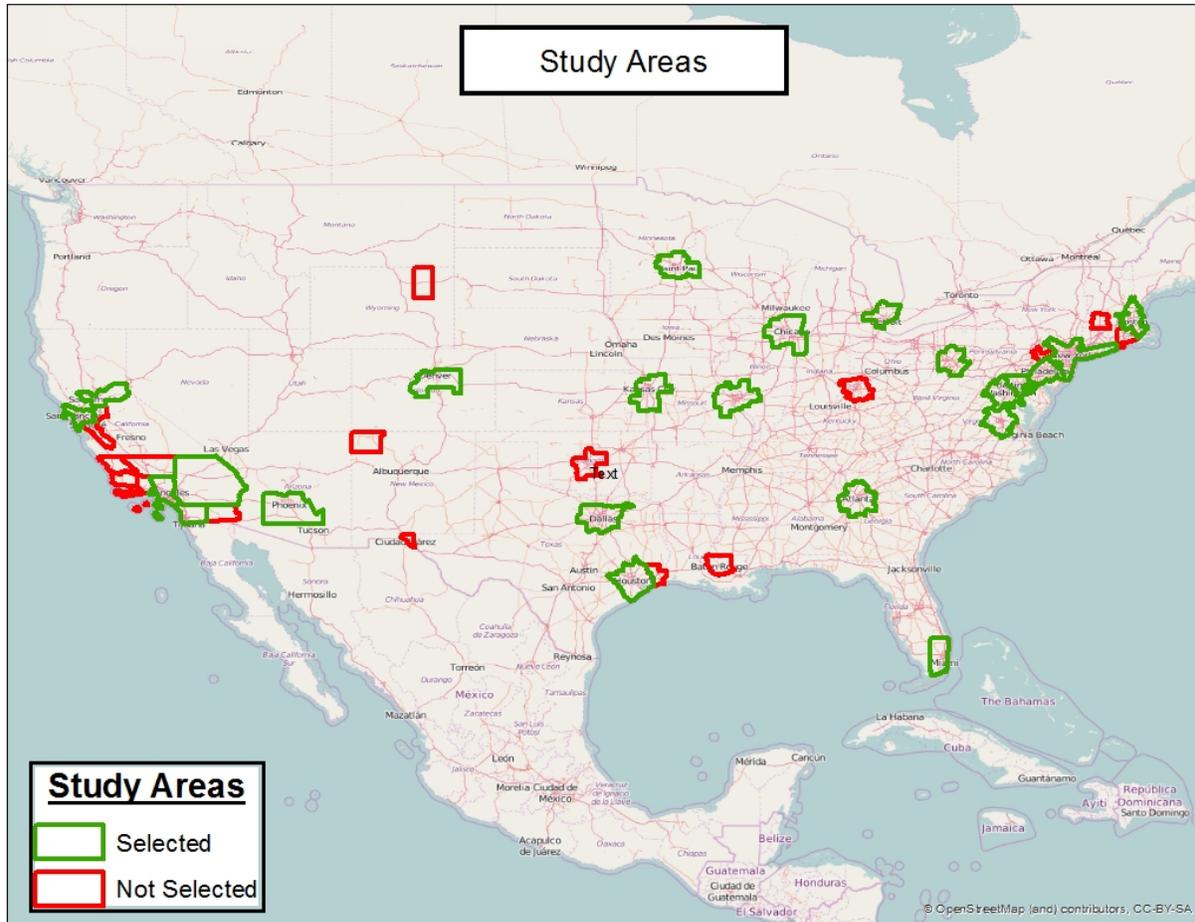
CBSA/ Study Area ¹	Number of Ambient Monitors in Area with Valid Data										Max Annual Average NO ₂						Max 98 th pct 1-hr daily max NO ₂				2014 near-road monitor		2015 near-road monitor		Study area rank value ³
	2010	2011	2012	2013	2014	2015	2010- 2012	2011- 2013	2012- 2014	2013- 2015	2010	2011	2012	2013	2014	2015	2010- 2012	2011- 2013	2012- 2014	2013- 2015	days (n) ²	98 th pct DM1H NO ₂	days (n) ²	98 th pct DM1H NO ₂	
HOUS	16	16	16	16	16	13	9	9	11	13	15	14	15	13	13	11	60	59	56	52	344	48.8	261	59.2	3.16
LOSA	16	14	9	13	16	15	4	4	5	7	26	25	21	23	22	22	67	64	63	62	361	66	255	74.8	2.74
DALL	11	14	11	11	11	10	9	9	8	8	13	13	12	12	10	10	56	53	49	47	274	40	365	44.9	2.48
SANF	10	10	11	10	9	9	8	8	8	8	16	16	15	17	14	14	74	68	61	57	334	51.7	365	48.9	2.45
NYNY	10	7	8	8	9	8	5	6	7	7	22	25	22	22	22	22	70	67	66	66	184	90	365	67	2.37
RIVR	12	9	11	11	13	11	6	3	2	1	23	21	22	21	20	19	72	62	53	50	0	0	153	77.2	2.15
SAND	8	8	8	8	6	6	6	5	4	4	21	20	20	19	13	14	73	73	57	56	0	0	269	52	1.89
PHOE	6	5	5	5	5	4	4	4	4	4	25	25	26	25	25	22	66	64	64	63	322	59	121	64	1.84
SACR	8	8	8	6	7	7	7	4	4	5	12	13	12	10	11	11	51	50	48	50	0	0	80	52	1.71
BOST	5	5	6	5	5	6	5	4	3	4	19	20	19	18	17	17	51	50	49	51	365	53	362	50	1.64
WASH	7	6	6	7	6	5	5	4	2	3	18	16	17	13	11	13	55	51	48	48	0	0	212	47.1	1.52
PHIL	5	4	5	5	5	4	3	3	1	3	23	20	18	17	18	18	65	61	39	49	358	51.4	357	47.8	1.45
PITT	5	5	5	6	4	3	4	4	1	2	15	16	14	11	10	10	53	49	36	42	122	39.7	365	44.8	1.27
DENV	2	2	2	2	2	3	0	1	2	2	28	24	25	24	23	22	0	62	72	72	361	69.6	92	73.15	1.27
ATLA	3	3	3	3	3	3	3	3	3	3	14	13	12	9	11	10	56	51	49	48	200	49.95	363	54.1	1.16
MINE	3	3	3	3	3	3	2	3	3	3	10	9	11	9	9	8	46	44	45	46	365	48	362	48	1.06
BALT	2	2	2	2	2	1	2	2	2	1	18	18	16	15	16	11	57	52	52	46	275	50.6	352	49.8	1.03
KANS	3	3	3	3	2	2	3	1	1	1	15	15	14	13	13	13	53	52	51	51	358	45.6	352	44.5	1.02
STLO	3	3	2	3	4	2	0	2	2	2	13	13	14	11	12	11	0	53	49	46	365	58.2	364	47.4	0.97
MIAM	5	5	3	4	3	2	2	2	2	2	10	8	8	8	9	5	47	46	46	44	0	0	56	40	0.95

3 ¹ abbreviated CBSA name to allow for extended number of columns (see Table B2-1 for complete CBSA title).
 4 ² not used in calculating the rank value, included for information purposes only. Also, where more than one near road monitor was operating in a study area, the number of days corresponds
 5 to the monitor having the greatest 98th pct DM1H (i.e., it is possible that the other near road monitor had a greater number of days where measurements were collected).
 6 ³ CBSA's are sorted by descending rank value.
 7

1 **Table B2-3. The top twenty additional CBSAs identified for analysis based on 2010-2015 design values and number of monitors in operation.**

CBSA Title	Number of Ambient Monitors in Area with Valid Data										Max Annual Average NO ₂						Max 98 th pct 1-hr daily max NO ₂				Study area rank value ¹
	2010	2011	2012	2013	2014	2015	2010-2012	2011-2013	2012-2014	2013-2015	2010	2011	2012	2013	2014	2015	2010-2012	2011-2013	2012-2014	2013-2015	
Santa Maria-Santa Barbara, CA	11	11	11	11	11	10	11	10	10	9	9	9	10	10	8	8	43	36	36	36	6.57
Baton Rouge, LA	10	8	8	8	8	6	7	7	7	5	13	12	11	10	11	9	54	52	48	41	4.88
Chicago-Naperville-Elgin, IL-IN-WI	6	5	6	5	6	5	2	0	1	3	25	23	22	21	21	18	62	0	47	63	3.07
Beaumont-Port Arthur, TX	4	4	4	4	4	4	4	4	4	4	8	7	6	6	6	5	37	35	33	33	2.75
Springfield, MA	3	3	3	3	3	3	3	3	3	3	15	16	14	14	13	13	47	46	42	46	2.55
Farmington, NM	4	3	3	3	3	3	2	3	3	3	12	13	13	12	11	11	38	41	37	36	2.39
Bakersfield, CA	4	3	3	4	3	4	3	2	1	1	14	15	15	14	13	12	58	46	48	45	2.32
El Paso, TX	3	2	2	3	3	3	1	1	2	3	17	17	16	14	14	14	61	59	57	58	2.20
Detroit-Warren-Dearborn, MI	1	1	3	3	3	4	1	1	2	3	12	12	19	18	16	18	48	44	45	50	2.10
San Luis Obispo-Paso Robles-Arroyo Grande, CA	3	3	3	3	3	2	3	3	3	2	6	6	7	7	6	3	38	38	39	31	2.05
Richmond, VA	3	3	3	2	2	3	3	2	1	1	12	10	10	8	8	14	52	47	43	41	1.94
Gillette, WY	3	3	4	4	4	3	1	1	1	3	7	6	8	9	10	7	32	32	35	49	1.93
Oklahoma City, OK	2	2	2	2	3	2	2	2	2	1	9	10	9	9	7	7	54	54	51	45	1.75
Oxnard-Thousand Oaks-Ventura, CA	2	2	2	2	2	2	2	2	2	2	10	9	10	9	9	8	38	37	39	38	1.73
Stockton-Lodi, CA	2	2	2	2	2	2	1	1	1	1	14	15	14	16	13	12	51	53	55	53	1.71
San Jose-Sunnyvale-Santa Clara, CA	1	2	2	2	1	2	1	2	1	1	14	15	13	15	13	18	50	51	53	50	1.71
El Centro, CA	2	2	2	2	2	2	1	1	1	1	14	14	14	13	12	11	62	64	47	44	1.67
Allentown-Bethlehem-Easton, PA-NJ	1	2	2	2	2	1	1	2	2	1	11	14	13	13	13	12	40	45	45	48	1.66
Cincinnati, OH-KY-IN	2	2	1	2	3	3	1	1	1	1	15	13	4	12	23	22	32	30	31	32	1.66
Providence-Warwick, RI-MA	1	1	2	2	2	3	1	1	1	2	10	11	10	10	10	22	42	43	42	46	1.61

2 ¹ CBSA's are sorted by descending rank value.



1
 2 **Figure B2-1. The 40 CBSAs identified as potentially useful to inform the air quality**
 3 **characterization, including the 23 selected study areas for focused analyses.**

4
 5 **2.3.2 Representativeness evaluation**

6 The geographical locations of the study areas should adequately represent areas across the
 7 U.S. having seasonal, atmospheric, or other influential factors that could contribute to variability
 8 in NO₂ concentrations and potential exposures. Figure B2-1 provides perspective to such an
 9 assessment showing reasonable geographic representation by the 23 selected study areas for the

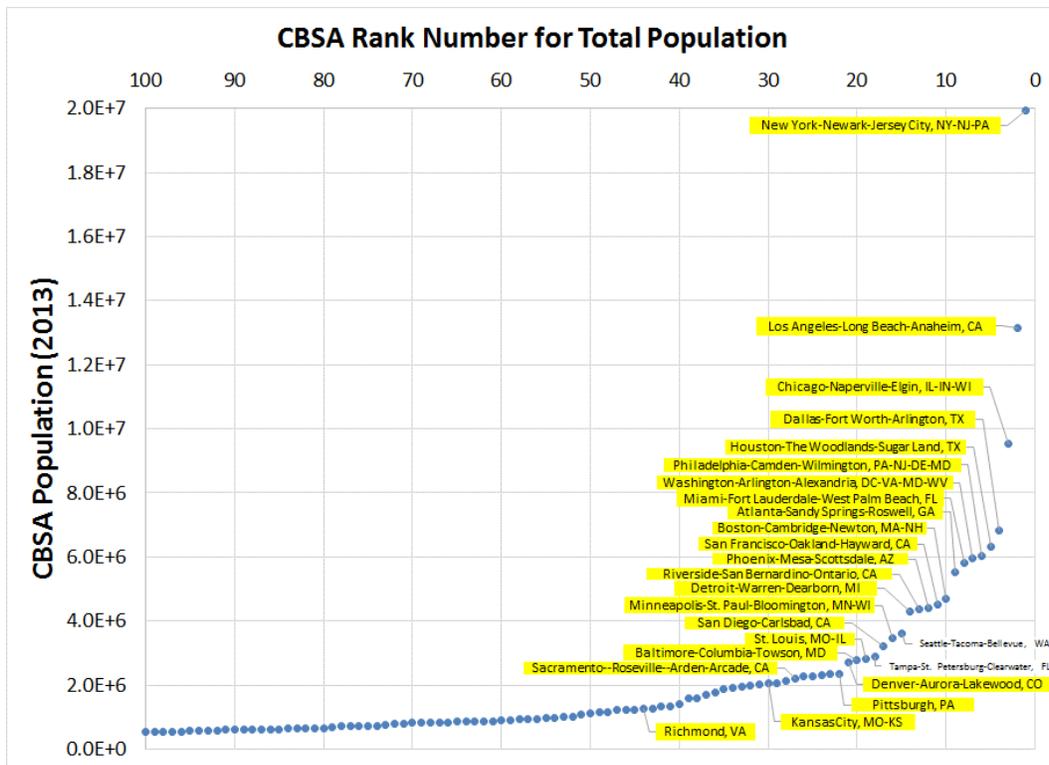
1 continental U.S., except for the upper northwestern U.S.,¹¹ even when considering the pool of
2 “other CBSAs” not having a newly designated near-road monitor. Obviously, the NO₂ design
3 values and number of ambient monitors operating in any northwestern CBSAs did not rise to a
4 level necessitating their consideration as a study area of particular interest. Regarding the study
5 area selection pool of 50 “near-road CBSAs”, the three available northwestern CBSAs (Portland-
6 Vancouver-Hillsboro, OR-WA; Seattle-Tacoma-Bellevue, WA; Boise City, ID) had the 32nd,
7 45th and 47th highest rank values using the above selection criteria, respectively. When
8 considering the rank value of available northwestern CBSAs in the “other CBSAs” data set, only
9 Gillette, WY (12th highest) was ranked within the top 50.

10 The selected study areas should also capture areas where large portions of the U.S.
11 population reside, as this would better represent potential risks to populations at a local, urban,
12 and national scales as well as increasing the likelihood for appropriately representing important
13 study groups (e.g., children with asthma). To evaluate population representativeness, data were
14 obtained from the U.S. Census Bureau to characterize the 2013 population in the 23 selected
15 study areas relative to that of other CBSAs.¹² In total, the 23 selected study areas include just
16 over 124 million people or nearly 40% of total U.S. population. When considering the 17
17 additional CBSAs identified as potentially useful to inform the AQC, another 14 million people
18 could be included to the total population considered, thus comprising approximately 44% of the
19 total U.S. population.

20 The individual CBSA population values were ranked by descending population, with the
21 top 100 CBSAs retained and plotted in Figure B2-2. For perspective, all 23 selected study areas
22 are named and highlighted in the figure. Also named in the figure are CBSAs within the top 20
23 CBSAs for population (if any other than the 23 selected study areas). This analysis indicates the
24 selected study areas are representative of the most populated CBSAs in the U.S., having 18 of
25 the top 20 populated CBSAs in the U.S.

¹¹ Considered here are the states of Washington, Oregon, Idaho, Wyoming, Montana. As an example of the limitations to number of monitors having complete year data, the Portland-Vancouver-Hillsboro, OR-WA CBSA had 1 monitor available in each of the years evaluated. Annual average and 3-year 98th percentile DM1H NO₂ concentrations were about 9 ppb and 35 ppb, respectively.

¹² Data were downloaded from <http://www.census.gov/popest/data/metro/totals/2013/CSA-EST2013-alldata.html>. Two files were used and processed to generate population data that included all study areas: CSA-EST2013-alldata_USCENSUS.txt and CBSA-EST2013-alldata_USCENSUS.txt. Population data were available for a total of 382 CBSAs.



1
 2 **Figure B2-2. The top 100 CBSAs ranked by 2013 population. Highlighted and named are**
 3 **the 23 selected study areas; also named are those CBSAs ranked in the top 20.**

4 Information on NO_x emissions¹³ was used to inform our characterization of the important
 5 sources potentially contributing to monitored NO₂ concentrations. The recent EPA’s National
 6 Emissions Inventory (NEI), the 2011 NEI¹⁴ is the most comprehensive source of emissions data
 7 to identify, categorize, and evaluate NO_x emissions and emission source types. At a national
 8 level, anthropogenic sources account for more than 90% of NO_x emissions (US EPA, 2016,
 9 section 2.3.1, Figure 2-3). Motor vehicles are the largest source, with on-road and off-road
 10 mobile sources contributing nearly 60% of the total NO_x emissions nationally. Other important
 11 sources include fuel combustion-utilities (14% of total), fuel combustion-other (11% of total),

¹³ Oxidized nitrogen compounds are emitted to the atmosphere primarily as NO, with NO converting to NO₂ following its reaction with O₃. Collectively, NO and NO₂ are referred to as NO_x (U.S. EPA, 2008b, section 2.2).

¹⁴ The NEI is a national compilation of emissions estimates from all source sectors, collected from state, local, and tribal air agencies as well as those developed by EPA. The NEI is developed on a tri-annual basis, with 2011 being the most recent base year currently available and referred to as 2011 NEI. The next NEI base year will be 2014 and will be available in late 2016. For information on the NEI, see <http://www.epa.gov/ttn/chief/eiinformation.html>.

1 and biogenics and wildfires (8% of total). Compared to the national averages, urban areas have
2 greater contributions to total NO_x emissions from both on-road and off-road mobile sources and
3 smaller contributions from other sources (US EPA, 2016, Figure 2-4, Table 2-1). For example, in
4 the 21 largest CBSAs in the U.S., more than half of the urban NO_x emissions are from on-road
5 mobile sources, and when combined with off-road mobile sources, account for more than three
6 quarters of total emissions in these large CBSAs (US EPA, 2016, section 2.3.2).

7 While this emissions summary at a national level is useful, the most important emission
8 sources can vary substantially across smaller spatial scales. We evaluated the NO_x emissions in
9 all 177 CBSAs having ambient NO₂ concentration measurements (and emissions data were
10 reported), including the 23 selected study areas to determine the total emissions and emission
11 sources represented by the CBSAs that were selected as study areas. Two data sets were used to
12 accomplish this, generated using the 2011 National Emissions Inventory (NEI)¹⁵ as follows:

- 13 1. *County level emissions.* This data set contains NO_x emissions (in tons per year)
14 aggregated to the county level. Over 50 sectors are identified, including various
15 mobile (e.g., “Mobile - Non-Road Equipment – Diesel”) and industrial emission
16 sources (e.g., Industrial Processes - Pulp & Paper). Emissions were summed based on
17 the counties comprising each CBSA that had at least one ambient monitor in operation
18 during 2010-2015.¹⁶ Using this data set we calculated total NO_x emissions, total

¹⁵ Data downloaded from: [http://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-
nei-data](http://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-
nei-data). Additional processing was performed here to characterize facilities that did not have entries for the ‘facility
type’ field. Of the approximately 23,000 NO_x facilities, nearly 13,000 were missing a facility type. Information
from the available facility name and the NAICS codes were used to generate the facility type where missing, using
the existing list of facility types. The majority of updates, designated as important primarily based on high total
facility emissions, regarded the characterization of Mines/Quarries, Compressor Stations, Gas Plants, and Chemical
Plants. Details regarding these updates to the data file used are available upon request.

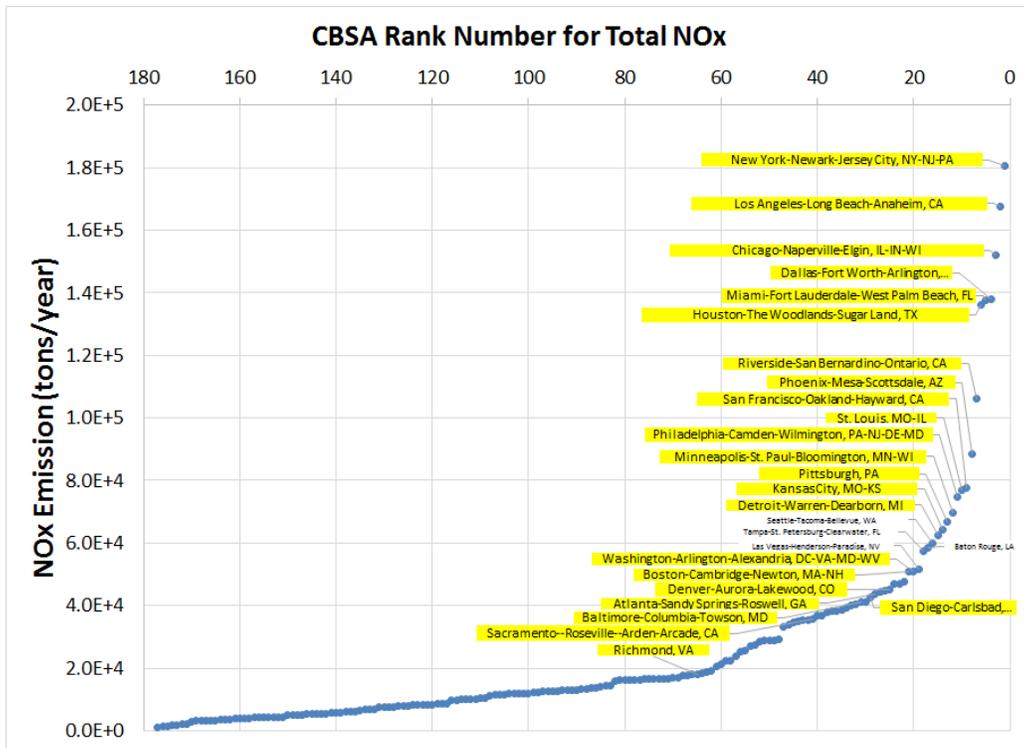
¹⁶ We felt that by using emissions from only those counties that had ambient monitors would best represent the
emission levels and source types that could influence available ambient monitoring concentrations. It is possible that
ambient monitors could be proximal to one or more other counties in a CBSA, resulting in potentially
mischaracterizing or underestimating emissions and the influence of particular source types, however, we felt that
including emissions from all counties in each CBSA would more likely result in a greater mischaracterization, and

1 mobile source NO_x emissions,¹⁷ and percent mobile source NO_x emissions relative to
2 total for each CBSA. Results for the 177 CBSAs were ranked for each of these three
3 emissions variables and plotted in Figure B2-3 to Figure B2-5. In each of these
4 figures, all 23 of the selected study areas are named and highlighted to indicate where
5 these areas are ranked relative to the other 154 CBSAs. Any CBSA within the top 20
6 ranked emissions are also named (approximating an upper 90th percentile of CBSAs).

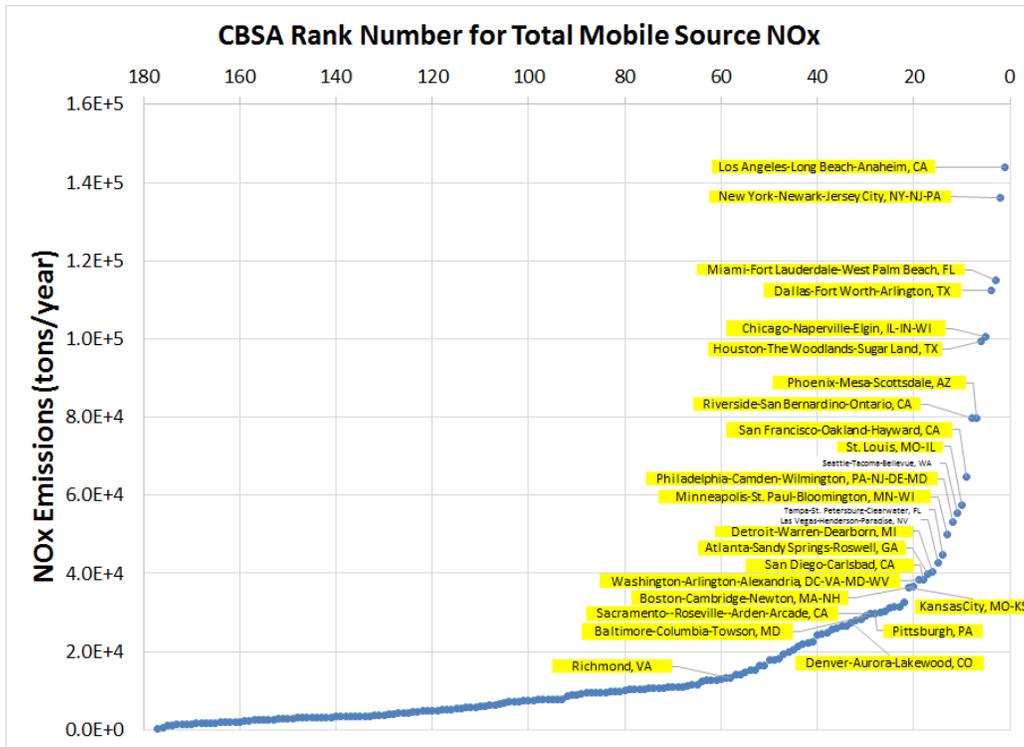
7
8 Clearly, the study areas selected for focused analyses in this AQC are among those
9 CBSAs having the highest total and mobile source NO_x emissions (Figure B2-3 and
10 Figure B2-4). The top 15 CBSAs having the greatest NO_x emissions were selected as
11 study areas and nearly all of the study areas are within the 80th percentile or above for
12 both total and mobile source emissions. The percent of total NO_x contributed by
13 mobile sources considering the 23 study areas varied (Figure B2-5), and for the most
14 part, did so in a similar fashion as that exhibited by most CBSAs, ranging from about
15 65-85% of total NO_x emissions. This range in mobile source contribution indicates the
16 23 selected study areas may contain a variety of important NO_x emission source
17 types, albeit relatively smaller in magnitude when compared with mobile source
18 emissions alone. Three selected study areas (Atlanta, Phoenix, and San Diego CBSAs)
19 were ranked within the top 10 CBSAs providing reasonable representation of CBSAs
20 where nearly all NO_x emissions are from mobile sources. About half of the selected
21 study areas had a mobile source emissions contribution of 65-75%, again, providing
22 representation of most CBSAs, while representation of lesser mobile source
23 influenced areas are provided by the Denver (61%), Kansas City (57%), and
24 Pittsburgh (45%) study areas. While there are a collection of CBSAs having greater
25 relative contributions from non-mobile sources, their lack of representation is of
26 limited importance considering the overall low total emissions in these CBSAs.

clearly overestimating emission levels and source types that might influence monitor concentrations. For the purposes of this broad study area evaluation, this assumption was judged as reasonable.

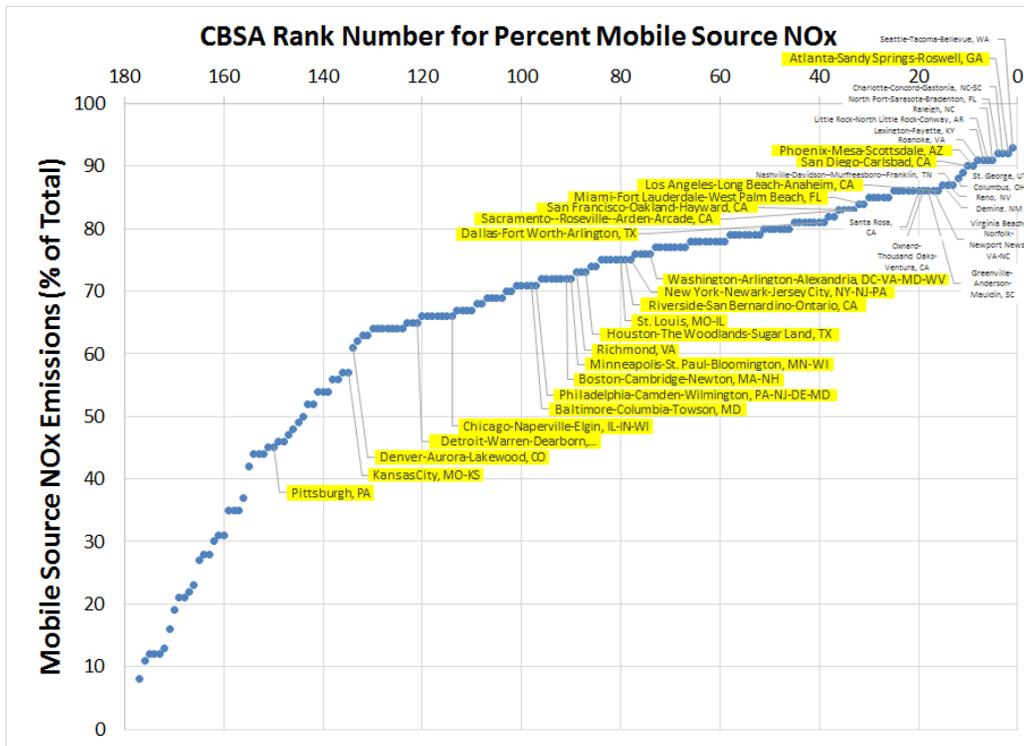
¹⁷ All sectors having a description beginning with the word “Mobile” were included in the mobile source NO_x emission sum. Recognizing this includes both on-road and non-road sources, analyses were also performed using only the “Mobile – On-Road” data. Results for the Mobile – On-Road emissions were effectively the same as presented here for all mobile sources, i.e., the rank order of the study areas/CBSA were the same, only differed in that the total emissions and percent values were less.



1
 2 **Figure B2-3. CBSAs ranked by total NO_x emissions. Highlighted and named are the 23**
 3 **selected study areas; also named are those CBSA ranked in the top 20.**



4
 5 **Figure B2-4. CBSAs ranked by mobile source NO_x emissions. Highlighted and are**
 6 **the 23 selected study areas; also named are those CBSA ranked in the top 20.**



1
 2 **Figure B2-5. CBSAs ranked by percent all mobile source NO_x emissions. Highlighted and**
 3 **named are the 23 selected study areas; also named are those CBSA ranked in the top 20.**

4
 5 2. *Facility level emissions.* This data set contains NO_x emissions (in tons per year) at the
 6 individual facility level, also using only those emissions in counties that had at least
 7 one ambient monitor in operation during 2010-2015. A total of 72 facility types were
 8 identified here based on general source categories such as ‘electricity generation via
 9 combustion’ (EGUs), ‘chemical plant’ and ‘compressor station’. Facilities without a
 10 source description were aggregated into a ‘not characterized’ facility type. To identify
 11 the most important sources in each CBSA, first the NO_x emissions (tons/year) were
 12 summed by facility type. In addition, the maximum individual emission (tons/year)
 13 was retained for each facility type. The top 20 facility types were identified
 14 considering first the total NO_x emissions, then considering the maximum NO_x
 15 emissions for each facility types (Table B2-4). Eighteen of the same facility types
 16 were within the top 20 emission sources considering both metrics.

17
 18

1 **Table B2-4. The top twenty facility types ranked by total NO_x emissions.**

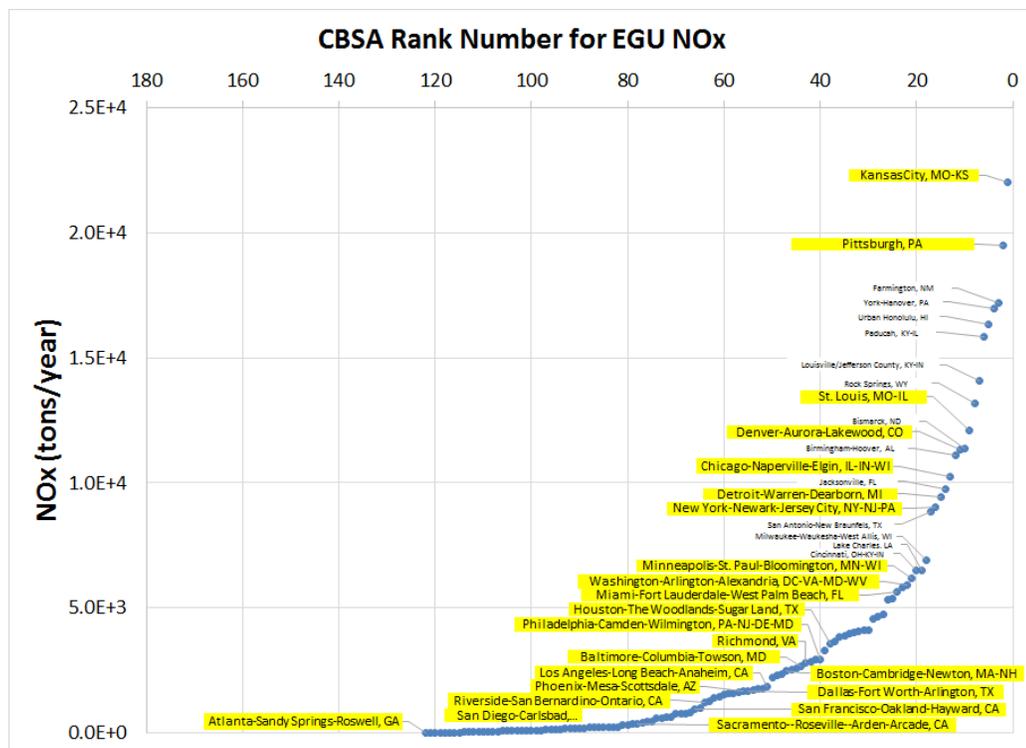
Facility Type	Facilities (n)	Total NO _x (tpy)	Facility Maximum NO _x (tpy)
Electricity Generation via Combustion	670	399292	17104
Airport	4323	96060	5485
Chemical Plant	372	52784	9113
Petroleum Refinery	82	52568	3655
Portland Cement Manufacturing	34	35230	2542
Mines/Quarries	124	34778	11726
Rail Yard	307	33745	1328
Compressor Station	512	33148	1583
not characterized	10804	30897	1688
Municipal Waste Combustor	49	28102	1617
Steel Mill	71	23197	4813
Gas Plant	73	15642	2268
Mineral Processing Plant	29	13929	2942
Pulp and Paper Plant	54	12415	2036
Institutional (school, hospital, prison, etc.) ¹	843	9705	739
Glass Plant	36	9393	2364
Chlor-alkali Plant	7	6936	6194
Fertilizer Plant	34	6815	2857
Coke Battery	9	6814	3075
Plastic, Resin, or Rubber Products Plant ²	195	6215	1221

2 ¹ Ranked 26th for facility maximum.

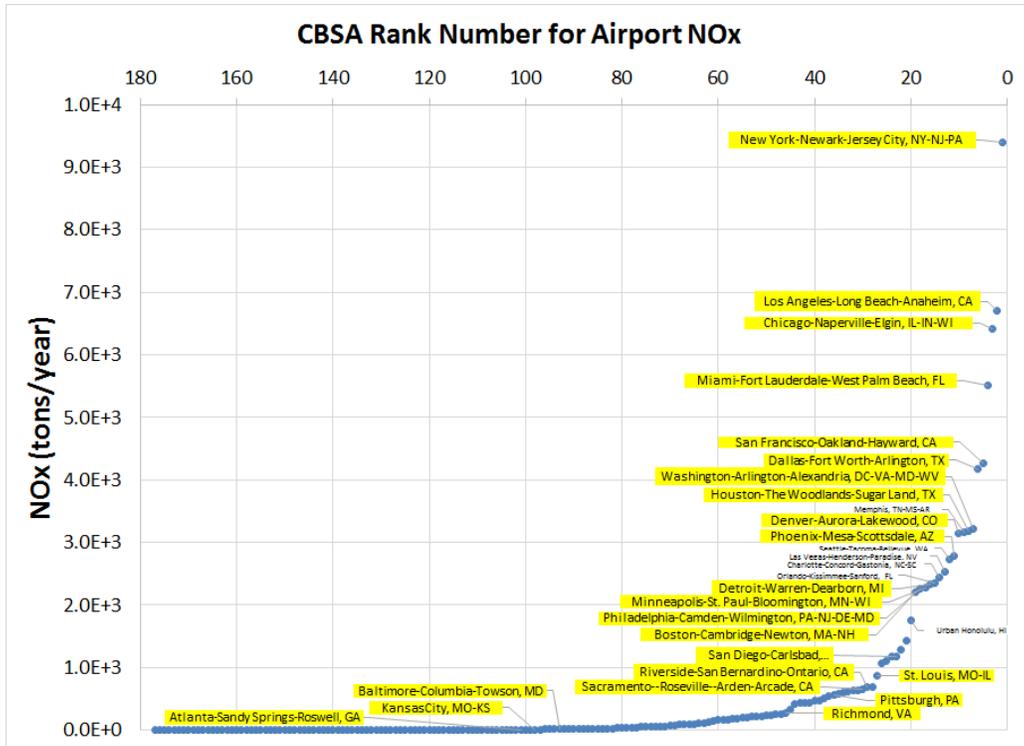
3 ² Ranked 21st for facility maximum.

4
5 By far, EGUs contribute the most NO_x emissions compared to any other facility type,
6 emitting over four times that of the 2nd greatest emission facility type (i.e., airports).
7 Facilities having emissions originating from a ‘chemical plant’ contributed to the 3rd
8 greatest amount of NO_x emissions, though constituting approximately half of those by
9 ‘airports’. The NO_x emissions were evaluated considering each of the 177 CBSAs,
10 considering each of the top 20 facility types (see supplemental data in Section B5),
11 with Figures provided here of the top three facility types (Figure B2-6 to Figure
12 B2-8). Reasonable representation is given by the selected study areas regarding each
13 of the most important facility types, particularly considering the relative importance of
14 these facility emissions with respect to mobile source contributions (i.e., being
15 significantly lower in terms of emissions). For instance, the Houston CBSA has the
16 greatest NO_x emissions contributed by chemical plants (~13,000 tpy, Figure B2-8),
17 though this amount is small when compared with total mobile source NO_x emissions
18 in the CBSA (~100,000 tpy, Figure B2-4). A few facility types were not well
19 represented by the selected study areas: ‘mines/quarries’, ‘gas plant’ and ‘mineral

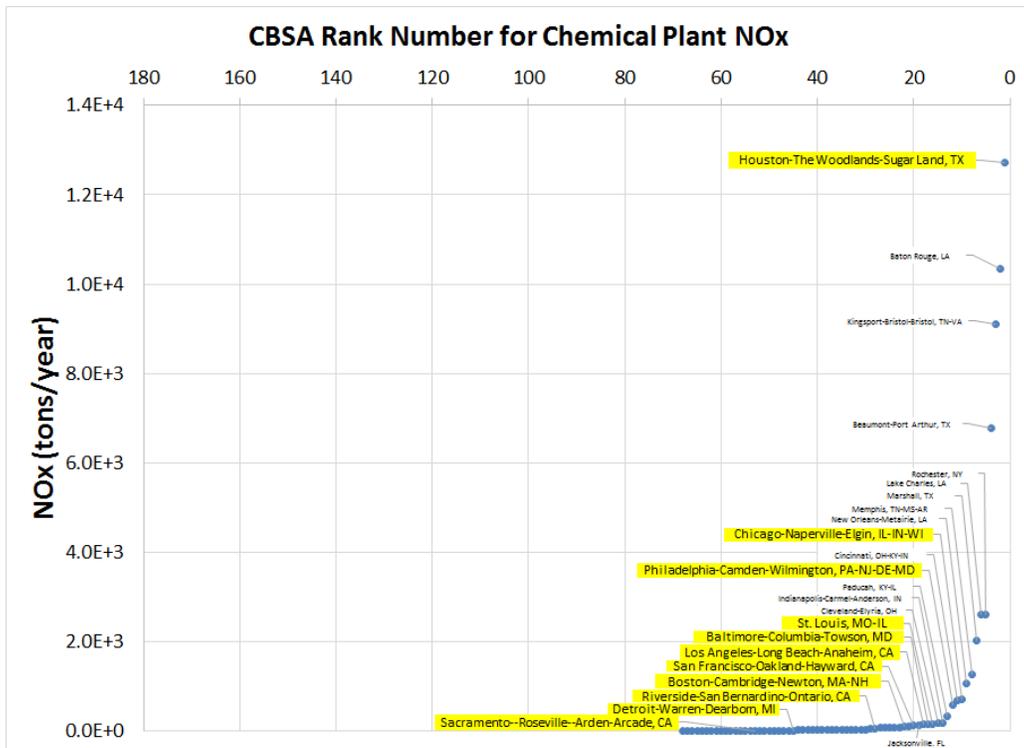
1 processing', facility types on frequent occasion located in the upper northwestern U.S.
 2 (see Table B5-3, Table B5-6, and Table B5-7). Considering the amount of NO_x
 3 emissions from these particular facilities relative to the most important emissions
 4 nationwide, lack of representation by the selected study areas was considered as
 5 having limited influence to our overall study objectives. Furthermore, on occasion it
 6 may appear peculiar that a certain emission source is not apparent in selected study
 7 area, but this is a function of the data used for this this analysis. For example, while
 8 the Hartsfield-Jackson Atlanta International Airport NO_x emissions are greater than
 9 4,000 tpy, the data are not included in this assessment because the facility is actually
 10 located in Clayton County, a county that does not have an ambient monitor.
 11



12
 13 **Figure B2-6. CBSAs ranked by NO_x emissions from electricity generation via combustion.**
 14 **Highlighted and named are the 23 selected study areas; also named are CBSA ranked in**
 15 **the top 20.**



1
 2 **Figure B2-7. CBSAs ranked by NO_x emissions from airports. Highlighted and named are**
 3 **the 23 selected study areas; also named are CBSA ranked in the top 20.**



4
 5 **Figure B2-8. CBSAs ranked by NO_x emissions from chemical plants. Highlighted and**
 6 **named are 11 of the 23 selected study areas (all other study areas had no emissions for this**
 7 **facility type); also named are CBSA ranked in the top 20.**

1 **2.3.3 Ambient monitor attributes**

2 We evaluated the attributes of all individual ambient monitors in each of the 23 study
3 areas. For added context and historical perspective, data for monitors in operation currently
4 (2010-2015) and for those operating at any time since 1990 are provided. The attributes for each
5 set of ambient monitors are summarized in Section 5.2 (monitors used for focused analysis) and
6 Section 5.3 (monitors not used for focused study area analysis). For monitors used in the focused
7 analysis, figures are also provided showing a satellite view of each the design and near-road
8 monitors.

9 **2.4 ESTIMATED AMBIENT NO₂ CONCENTRATIONS**

10 This section describes the approaches used to extend the information provided by the
11 ambient monitor measurement data alone, by developing additional air quality standard scenarios
12 and addressing selected high-concentration environments that may not necessarily be captured
13 by the existing monitoring network. The approach describing how air quality would be adjusted
14 to just meet the existing is provided in section 2.4.1. This is followed by a discussion of how we
15 plan on using the ambient monitors combined with factors to characterize NO₂ concentrations
16 across urban study areas, including those occurring near-roads and on-roads (section 2.4.2). The
17 final section (2.4.3) discusses the calculation of the air quality benchmarks and summary output
18 metrics of interest.

19 **2.4.1 Adjusting air quality to just meet the existing standards**

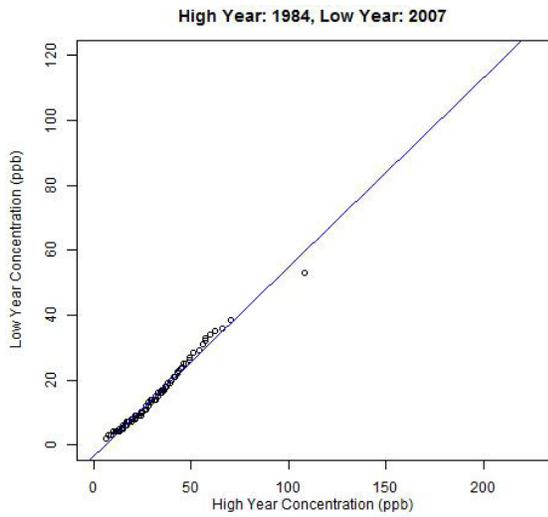
20 Unadjusted air quality represent ambient conditions as they are at the time of
21 measurement. While unadjusted air quality presents perspective regarding existing conditions, it
22 does not necessarily provide the specific effect that just meeting a specific standard has on
23 ambient concentrations, exposures, and health risk. To evaluate the ability of a specific air
24 quality standard to protect public health, ambient NO₂ concentrations need to be adjusted such
25 that they simulate levels of NO₂ that would just meet the existing standards (i.e., 100 ppb, 98th
26 percentile DM1H averaged across 3-years; 53 ppb, annual average) or potential alternative
27 standards. Such adjustments allow for comparisons of the level of public health protection that
28 could be associated with just meeting the existing and potential alternative standards.

29 All areas of the United States currently have ambient NO₂ levels below the existing
30 standards, albeit to varying degrees. Therefore, to simulate just meeting the existing NO₂
31 standards, NO₂ air quality levels in all study areas must be adjusted upward. Based on evaluating
32 changes in the distribution in air quality over time, a two-step adjustment approach was used to
33 adjust the recent ambient concentrations in each study area to just meet the existing standards.
34 For this two-step adjustment approach, a proportional approach was used, as described in the
35 REA Planning document (and used in the 2008 REA), though here the proportional adjustment

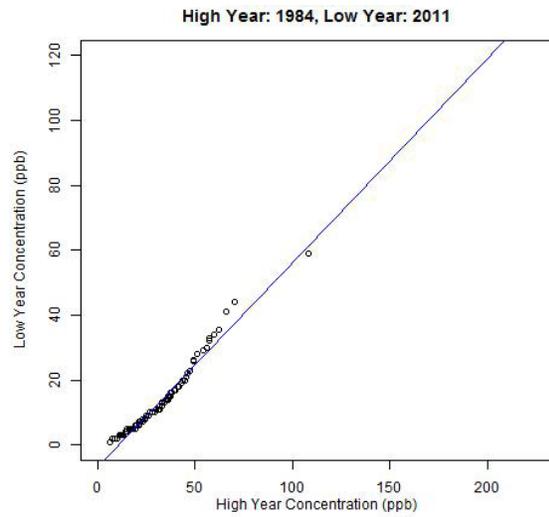
1 was only applied to concentrations up to and including the 98th percentile DM1H (adjustment
2 step 1). This was based on the observation that concentration changes over time (historical, high
3 concentration years compared with recent, low concentration years) occur in a largely
4 proportional manner (e.g., Figure B2-9).

5 An additional modification to address observed deviations from linearity that could occur
6 at the upper percentile concentrations was used for concentrations above the 98th percentile
7 (adjustment step 2). In this way, this two-step approach utilizes the simplicity of the proportional
8 approach used in the 2008 REA but addresses more fully, the observed changes in peak
9 concentration distributions to better capture the distribution of high NO₂ concentrations when
10 adjusting air quality to meet the existing standards.

11



12



13

14 **Figure B2-9. Distribution of DM1H NO₂ concentrations (0 – 100th percentile) in the New**
15 **York/New Jersey study area monitor ID 340273001 for a high-concentration year (1984)**
16 **versus a low-concentration year (2007) adapted from Rizzo (2008) (left panel) and updated**
17 **comparison with a recent low-concentration year (2011) (right panel).**

18

19

20

1 To calculate the proportional adjustment factors used for step 1 to estimate concentrations
2 up to and including the 98th percentile DM1H:

- 3 1. Using design values for each monitor having recent (2010-2015) and complete air
4 quality and considering both the 1-hour and annual standards,¹⁸ calculate the
5 proportional adjustment factor needed to just meet the existing standards by dividing
6 the standard level by the appropriate monitor design value. Then, identify the monitor
7 in each study area having lowest adjustment factor for each year/3-year period (i.e.,
8 indicating the area design value monitor and the controlling standard).¹⁹
- 9 2. Calculate 98th percentile DM1H concentrations for the near-road monitor (where data
10 are available in a single year)²⁰ and for the highest concentration monitor in each
11 study area for the same years available, using the full concentration distribution and
12 for where simultaneous measurements exist between the two monitor types.
- 13 3. Select the set of proportional adjustment factors based on overall consistency in area
14 design value monitor identity, consistency and reasonableness in the factor level, and
15 whether the limited new near road monitor data available indicate the potential for a
16 dramatically different adjustment factor.

17
18 The collection of all proportional adjustment factors calculated and those used for each
19 study area are provided in two tables; those using the 3-year average design value data (Table
20 B2-5) and/or the single year near-road/highest monitor data (Table B2-6) for adjusting individual
21 years. Table B2-7 indicates the decision process and selection reasoning, where judgements were
22 made beyond simply choosing any available design value. In all instances where design values
23 were calculated, the DM1H concentrations resulted in the lowest adjustment factors, thus
24 indicating the hourly standard is the controlling standard in each of the 23 selected study areas.

¹⁸ See <http://www.epa.gov/airtrends/values.html>. For this draft AQC, 2014 was the most recent complete year data available. The period 2010-2014 includes five annual design values and three 3-year averaged hourly design values. Design values for 2015 were calculated here using complete year ambient monitor data available.

¹⁹ Often times, only one of the two existing standards (1-hour or annual) would be the controlling standard in a particular area, and is identified by the monitor design value that is arithmetically closest to the particular standard. Based on the level and form of the existing standard DM1H standard, it is expected to be the controlling standard.

²⁰ Only two near-road monitors had three years of continuous monitoring available for this review (one each in Detroit and St. Louis). Therefore, in most study areas design values DM1H standard cannot be calculated using the near-road monitor data. It remains informative to calculate similar averaging time metrics for each monitor (near-road and area-wide) using years where a comparable statistics can be calculated.

1 **Table B2-5. Proportional adjustment factors calculated from ambient monitor design values in each of the 23 selected study**
 2 **areas.**

CBSA_Title	Adjustment Factors Calculated Using Annual Design Values						Adjustment Factors Calculated Using DM1H Design Values			
	2010	2011	2012	2013	2014	2015	2010-12	2011-13	2012-14	2013-15
Atlanta-Sandy Springs-Roswell, GA	3.786	4.077	4.417	5.889	4.818	2.650	1.786	1.961	2.041	2.083
Baltimore-Columbia-Towson, MD	2.944	2.944	3.313	3.533	2.944	2.944	1.754	1.923	1.923	2.174
Boston-Cambridge-Newton, MA-NH	2.789	2.650	2.789	2.944	3.118	3.118	1.961	2.000	2.041	1.961
Chicago-Naperville-Elgin, IL-IN-WI	2.120	2.304	2.409	2.524	2.524	2.944	1.613		2.128	1.587
Dallas-Fort Worth-Arlington, TX	4.077	4.077	4.417	4.417	5.300	5.300	1.786	1.887	2.041	2.128
Denver-Aurora-Lakewood, CO	1.893	2.208	2.120	2.208	2.120	1.963		1.613	1.389	1.389
Detroit-Warren-Dearborn, MI	4.417	4.417	2.789	2.944	3.313	2.944	2.083	2.273	2.222	2.000
Houston-The Woodlands-Sugar Land, TX	3.533	3.786	3.533	4.077	4.077	4.077	1.667	1.695	1.786	1.923
Kansas City, MO-KS	3.533	3.533	3.786	4.077	4.077	4.077	1.887	1.923	1.961	1.961
Los Angeles-Long Beach-Anaheim, CA	2.038	2.120	2.524	2.304	1.963	2.120	1.493	1.563	1.587	1.613
Miami-Fort Lauderdale-West Palm Beach, FL	5.300	6.625	6.625	6.625	5.889	10.600	2.128	2.174	2.174	2.273
Minneapolis-St. Paul-Bloomington, MN-WI	5.300	5.889	4.818	5.889	3.313	3.786	2.174	2.273	2.222	2.174
New York-Newark-Jersey City, NY-NJ-PA	2.409	2.120	2.409	2.409	2.409	2.409	1.429	1.493	1.515	1.515
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2.304	2.650	2.944	3.118	2.944	2.944	1.538	1.639	2.564	2.041
Phoenix-Mesa-Scottsdale, AZ	2.120	2.120	2.038	2.120	2.120	2.409	1.515	1.563	1.563	1.587
Pittsburgh, PA	3.533	3.313	3.786	4.818	5.300	4.077	1.887	2.041	2.778	2.381
Richmond, VA	4.417	5.300	5.300	6.625	6.625	3.786	1.923	2.128	2.326	2.439
Riverside-San Bernardino-Ontario, CA	2.304	2.524	2.409	2.524	2.650	1.767	1.389	1.613	1.887	2.000
Sacramento--Roseville--Arden-Arcade, CA	4.417	4.077	4.417	5.300	4.818	4.818	1.961	2.000	2.083	2.000
San Diego-Carlsbad, CA	2.524	2.650	2.650	2.789	4.077	3.786	1.370	1.370	1.754	1.786
San Francisco-Oakland-Hayward, CA	3.313	3.313	3.533	3.118	3.118	2.944	1.351	1.471	1.639	1.754
St. Louis, MO-IL	4.077	4.077	3.786	3.786	3.786	4.077		1.887	2.041	1.923
Washington-Arlington-Alexandria, DC-VA-MD-WV	2.944	3.313	3.118	4.077	4.818	4.077	1.818	1.961	2.083	2.083

3 Highlighted are the factors used to adjust ambient NO₂ concentrations to just meet the existing (controlling) standard, up to and including the 98th percentile DM1H concentrations.
 4 Where additional data were available to inform the calculation of factors missing or not used from this table (not highlighted), those factors can be found highlighted in Table B2-
 5 6.

1 **Table B2-6. Proportional adjustment factors calculated from the single year 98th percentile DM1H NO₂ at the highest near-**
 2 **road (NR) and highest concentration area wide (AW) monitor in each of the 23 selected study areas.**

CBSA_Title	Based on Simultaneous 1-hr Measurements						Based on All Available 1-hr Measurements ²											
	Adjustment Factors						Number of Samples (n)						Adjustment Factors					
	2013		2014		2015 ¹		2013		2014		2015		2013		2014		2015	
	AW	NR	AW	NR	AW	NR	AW	NR	AW	NR	AW	NR	AW	NR	AW	NR	AW	NR
Atlanta-Sandy Springs-Roswell, GA			2.203	1.988	2.083	2.028	361		358	200	355	363	2.331		1.901	2.002	2.083	1.848
Baltimore-Columbia-Towson, MD			2.070	1.976	1.848	1.965	359		353	275	341	352	2.141		1.942	1.976	1.848	2.008
Boston-Cambridge-Newton, MA-NH	2.041	2.222	1.613	1.786	1.852	2.000	356	202	181	365	365	362	2.000	2.273	1.613	1.887	1.852	2.000
Chicago-Naperville-Elgin, IL-IN-WI							356		359		365		1.563		1.493		1.603	
Dallas-Fort Worth-Arlington, TX			2.119	2.500	2.203	2.227	363		364	274	361	365	2.028		2.105	2.500	2.203	2.227
Denver-Aurora-Lakewood, CO	1.479	1.650	1.305	1.445	1.433	1.567	365	213	365	361	365	359	1.479	1.621	1.305	1.437	1.397	1.567
Detroit-Warren-Dearborn, MI	2.326	2.083	1.961	2.000	2.062	2.381	365	360	364	364	61	361	2.326	2.083	1.961	1.961	2.062	2.000
Houston-The Woodlands-Sugar Land, TX			1.949	2.049	1.852	1.869	359		365	344	349	261	1.739		1.923	2.049	1.852	1.689
Kansas City, MO-KS	2.262	2.519	1.957	2.193	1.912	2.247	354	171	365	358	365	352	2.079	2.457	1.898	2.193	1.912	2.247
Los Angeles-Long Beach-Anaheim, CA			1.179	1.502	1.582	1.629	336		340	361	353	255	1.404		1.179	1.515	1.553	1.337
Miami-Fort Lauderdale-West Palm Beach					2.941	2.500	344		364		341	56	2.273		2.000		2.326	2.500
Minneapolis-St. Paul-Bloomington, MN-WI	2.632	2.222	2.000	2.083	2.294	2.083	363	271	365	365	361	362	2.326	2.222	2.000	2.083	2.294	2.083
New York-Newark-Jersey City, NY-NJ-PA			1.695	1.111	1.479	1.493	365		363	184	365	365	1.613		1.429	1.111	1.479	1.493
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD			1.695	1.946	1.587	2.053	355		310	358	345	357	1.942		1.695	1.946	1.587	2.092
Phoenix-Mesa-Scottsdale, AZ			1.587	1.695	1.639	1.887	362		365	322	363	365	1.587		1.563	1.695	1.639	1.887
Pittsburgh, PA			2.564	2.519	2.273	2.232	365		42	122	357	365	2.488		2.222	2.519	2.273	2.232
Richmond, VA	2.725	2.174	2.320	2.237	2.538	2.141	350	92	347	269	352	353	2.497	2.174	2.299	2.237	2.625	2.160
Riverside-San Bernardino-Ontario, CA					1.513	1.370	334		330		358	360	1.580		1.572		1.513	1.370
Sacramento--Roseville--Arden-Arcade, CA					2.083	1.923	363		351		365	80	1.916		1.901		2.198	1.923
San Diego-Carlsbad, CA					1.961	1.923	357		220		365	269	1.333		1.429		1.887	1.923
San Francisco-Oakland-Hayward, CA			1.976	1.934	1.880	2.045	365		365	334	365	365	1.678		1.727	1.934	1.880	2.045
St. Louis, MO-IL	2.041	1.951	2.198	1.718	2.203	2.110	365	365	361	365	352	364	1.980	1.951	2.198	1.718	2.203	2.110
Washington-Arlington-Alexandria, DC-VA-MD-WV					1.961	2.132	365		72		316	212	1.570		1.587		1.730	2.123

3 ¹ Used data from the first near road monitor in operation in the area where data were collected from more than one near road monitor in 2015 or where the value was used in
 4 adjustment as an alternative to the factor generated using the design value.

5 ² Used data from either the near-road monitor having the greatest number of days monitored in 2015 or the monitor having the lowest adjustment factor when the number of days
 6 monitored was similar.

7 Highlighted are the factors used to adjust ambient NO₂ concentrations to just meet the existing (controlling) standard, up to and including the 98th percentile DM1H concentrations.

1 **Table B2-7. Information supporting the selection of proportional factors used to adjust**
 2 **ambient concentrations (up to and including the 98th percentile DM1H) to just meet the**
 3 **existing standard.**

CBSA Title	Adjustment Factor (AF) Selection Reasoning	Comparison of near-road (NR) to area wide (AW) 98 th pct derived adjustment factors	
		simultaneous measurement hours	all measurement hours
Atlanta-Sandy Springs-Roswell, GA	Same monitor (13089002) had valid design values for all four periods. NR AFs are lower though generally similar in value. Preliminary results show on-road estimation (2015) unusually higher than expected, likely a function of the DV based AFs. Will use the 2013-15 DV for 2013-14, for 2015 use the lower value (130890003) generated from the two NR monitors.	NR1<AW (2014-15), NR2<AW (2015)	AW<NR1 (2014), NR1<AW (2015), NR2<AW (2015)
Baltimore-Columbia-Towson, MD	One monitor (245100040) had valid design values for three averaging periods 2010-14 (2015 incomplete but had ~7,900 1-hr samples), monitor (240053001) for 2013-2015 period had higher AF. Used avg. of single year calculated AFs for 2013-15 period (245100040).	NR<AW (2014); AW<NR (2015)	AW<NR (2014-15)
Boston-Cambridge-Newton, MA-NH	Same monitor (250250002) had valid design values for first 3 averaging periods. Similar AF value for 2013-15 period (250250042).	AW<NR (2013-15)	AW<NR (2013-15)
Chicago-Naperville-Elgin, IL-IN-WI	No design value for 2011-13. Adjustment factor for 2012-14 (different monitor 17034201) unusually high compared to single year 98th pct values for highest monitors in those years (170314002, 170310076 which are similar to adjustment for 2010-12 period). DV for 2013-15 similar to 2010-12. Only evaluating two 3-yr periods, 10-12 and 13-15.		
Dallas-Fort Worth-Arlington, TX	One monitor (484391002) had valid design value for first three averaging periods across 2010-14, used monitor 481130069 DV for 2013-15 (also had same DV for 2012-14 as 484391002).	AW<NR1 (2014-15), AW<NR2 (2015)	AW<NR1 (2014-15), AW<NR2 (2015)
Denver-Aurora-Lakewood, CO	No design value for 2010-12; for 2011-13 (080013001) AF somewhat higher than 2012-14 and 2013-15 (080310002).	AW<NR1 (2013-15), AW<NR2 (2015)	AW<NR1 (2013-15), NR2<AW (2015)
Detroit-Warren-Dearborn, MI	Same area design value monitor for first three averaging periods across 2010-14 (261630019), NR monitor (261630093) has complete year data for 2013-15 period and used for AF.	NR1<AW (2013), AW<NR1(2014-15), AW<NR2 (2015)	NR1<AW (2013-15), AW<NR2 (2015)
Houston-The Woodlands-Sugar Land, TX	Same monitor (482010075) had valid design values for first three averaging periods across 2010-14. DV for 482010416 (and 482011015) used for 2013-14 (though somewhat higher than prior years), lowest near-road AF (4882011052) used for 2015.	AW<NR1 (2014-15), NR2<AW (2015)	AW<NR1 (2014-15), NR2<AW (2015)
Kansas City, MO-KS	Same monitor (290950034) had valid design values for all four periods.	AW<NR (2013-15)	AW<NR (2013-15)
Los Angeles-Long Beach-Anaheim, CA	Same monitor (060371701) had valid design values for all four periods. Near road 060374008 adjustment was quite lower though for 2015 and used for that single year adjustment.	AW<NR1 (2014-15); NR2<AW (2015)	AW<NR1 (2014-15); NR2<AW (2015)
Miami-Fort Lauderdale-West Palm Beach, FL	Same monitor (120864002) had valid design values for first three averaging periods across 2010-14. Other monitor (120118002) similar value for 2013-15.	NR<AW (2015)	AW<NR (2015)

CBSA_Title	Adjustment Factor (AF) Selection Reasoning	Comparison of near-road (NR) to area wide (AW) 98 th pct derived adjustment factors	
		simultaneous measurement hours	all measurement hours
Minneapolis-St. Paul-Bloomington, MN-WI	Valid, similar design values for all averaging periods. For 2011-13 (270370020); 2012-14 and 2013-15 (270031002); both had exact same adjustment used for 2010-12. NR (270530962) full distribution quite lower in 2015. Averaging all 2013-2015 NR data for adjustment using both NR monitors (270370480 and 270530962).	NR1<AW (2013), AW<NR1 (2014) NR1<AW (2015), AW<NR2 (2015)	NR1<AW (2013), AW<NR1 (2014-15), NR2<AW (2015)
New York-Newark-Jersey City, NY-NJ-PA	Same monitor (340390004) had valid design values for all four periods.	NR<AW (2014) but unusual conc on 1 day, AW<NR (2015)	NR<AW (2014) but unusual conc on 1 day, AW<NR (2015)
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	Calculated AF for 2012-14 (420170012) and 2013-15 (340070002) much higher than 2010-12 and 2011-13 (421010004). Single year AF for max monitor in 2013 (also unusually high, though is 421010004). Using single year adjustments for 2013-2015 (421010004). Not evaluating 2012-14 period.	AW<NR1 (2014-15), AW<NR2 (2015)	AW<NR1 (2014-15), AW<NR2 (2015)
Phoenix-Mesa-Scottsdale, AZ	Same monitor (040133010) had valid design values for all four periods.	AW<NR1 (2014-15) NR2<AW (2015)	AW<NR1 (2014-15) NR2<AW (2015)
Pittsburgh, PA	2012-14 AF (421250005) unusually high compared with 2010-12 and 2011-13 (420030010); 2013-15 (420070014) is closer though still higher than 2010-12 and 2011-13. Max mon in 2014 (420031005) has smaller AF than 2012-14 value and that calculated using NR monitor, though only has 42 days. Thus, 3 periods will be evaluated (2010-12, 2011-13, 2013-15).	NR<AW (2014-15), but close in value	AW<NR (2014), NR<AW (2015)
Richmond, VA	Same monitor (510360002) had valid design values for all four periods, though NR (517600025) consistently lower for each year of 2013-2015. Used avg. of these three years to generate AF for 2013-15 period.	NR<AW (2013-15)	NR<AW (2013-15)
Riverside-San Bernardino-Ontario, CA	Four different monitors initially used for AFs, with each progressively increasing in value from about 1.4 to 2.0. Use of 2.0 resulted in unusually high concentrations at NR monitors for 2015, also unusually high concentrations for the area wide monitors in 2012 using the 12_14 value of 1.887. For 12_14, averaging the 11_13 (060712002) and 10_12 values (060710001). For 2013_15 period, combining single year values from highest monitor in first two years (060712002, 2014; 060710001, 2013) and averaging. For 2015, using factor derived from the near-road monitor (060710026) having the greatest number of days with measurements. Note, AF used is highly influential in on-road estimations as well.	NR<AW both NR mons (2015) - NR2 1/2 year	NR<AW both NR mons (2015) - NR2 1/2 year
Sacramento--Roseville--Arden-Arcade, CA	Two monitors (060670006 and 060670010) have valid design values over at least two periods each, similar in value. Used to evaluate all four periods.	NR<AW (2015), similar though NR only 80 days	AW<NR (2015)
San Diego-Carlsbad, CA	Two monitors (060732007, 2010-12 and 2011-13; 060731010, 2012-14 and 2013-15) have valid design values over period though some difference in value, particularly when compared with the 2013-14 single year values for 060732007. Using the mean of 2013-14 060732007 value for 2013-14 (in 2012-14 period), using 2013-15 design value from 060731010 to simulate 2015 only for 2013-15 period.	NR<AW (2015) though similar	AW<NR (2015) though similar

CBSA_Title	Adjustment Factor (AF) Selection Reasoning	Comparison of near-road (NR) to area wide (AW) 98 th pct derived adjustment factors	
		simultaneous measurement hours	all measurement hours
San Francisco-Oakland-Hayward, CA	Same monitor (060750005) had valid design values for all four periods	NR<AW (2014), AW<NR (2015) but close in value	AW<NR (2014-15)
St. Louis, MO-IL	No design value for 2010-12. Valid design values for 2011-13 and 2012-14 for same monitor (2951000086). Near road monitor (295100094) is area design value monitor for 2013-15, similar values to earlier years.	NR1<AW (2013-15), AW<NR2 (2015)	NR1<AW (2013-15), AW<NR2 (2015)
Washington-Arlington-Alexandria, DC-VA-MD-WV	Two monitors (110010041, 2010-12 and 2011-13; 110010043, 2012-14 and 2013-15) have valid design values over period with generally small differences.	AW<NR (2015)	AW<NR (2015)

1
2 To calculate the second set of factors used for adjusting the ambient concentrations above
3 the 98th percentile DM1H to just meet the existing standard, the following approach was used:

- 4 1. For each monitor, using recent, complete year ambient monitor concentrations (2003-
5 2015)²¹, divide the DM1H concentrations that are above the 98th percentile DM1H²²
6 by the 98th percentile DM1H, considering each year separately.
- 7 2. Generate the mean ratio for each DM1H across all years available²³ for each
8 individual monitor by averaging the values calculated in step 1.
- 9 3. Where ratios cannot be reasonably calculated for an individual monitor (i.e., the
10 monitor is newly sited, such as the near-road monitors), ratios from the area design
11 value monitor are used.

12 There is general consistency in the adjustment factor across monitors upwards to about the
13 4th highest maximum, but beyond this point up to the maximum DM1H adjustment factor there is
14 increasing variability in the factor across the monitors (Table B2-8). The maximum adjustment
15 factor by far exhibited the widest range of values within each study area and across study areas.
16 When comparing the overall distribution of the area design value monitor ratios to the other area-
17 wide monitor ratios within each study area, the area design value monitor had the highest ratios

²¹ The collection of years used to calculate the upper percentile concentration ratios (2003-2015) was based on the “NOx SIP CALL” (63 FR 57354) finalized October 27, 1998 that required reduction measures to be in place for most of the U.S. by 2003.

²² For a full year of ambient data, there would be 365 or 366 DM1H concentrations. Therefore, upwards to seven unique ratios could be calculated using these seven days having DM1H concentrations above the 98th percentile DM1H.

²³ Thus, an adjustment factor for each monitor and DM1H was calculated by averaging across the, at most, 13 ratio values (years).

1 in 7 of study areas (Baltimore, Detroit, Denver, Miami, Richmond, St. Louis, and Washington
 2 DC). In 7 study areas the area design value monitor had some of the lowest ratios (Atlanta,
 3 Boston, Houston, Kansas, Los Angeles, Pittsburgh, and Sacramento), while the remaining 8
 4 study areas had their design value monitor ratios falling within the middle of the collection of
 5 area-wide monitors. Given the observed range of these adjustment factors, it is possible that, if
 6 the variability in upper percentile concentrations at the area design value monitors is not
 7 appropriately reflecting that of the near-road monitors, there could be an under-/over-estimation
 8 in the number of days per year at or above benchmark levels when considering the near-road and
 9 on-road results.

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 11
 12

Table B2-8. Individual monitor-based factors calculated for use in adjusting DM1H ambient NO₂ concentrations above the 98th percentile DM1H in the 23 selected study areas.

CBSA	Site ID	Adjustment factor derived from ratio of DM1H concentrations to 98 th percentile DM1H, averaged across years 2003-2015						
		1 st DM1H	2 nd DM1H	3 rd DM1H	4 th DM1H	5 th DM1H	6 th DM1H	7 th DM1H
Atlanta-Sandy Springs-Roswell, GA	130890003 ^a	1.258	1.167	1.123	1.09	1.061	1.03	1.018
	131210056 ^a	1.258	1.167	1.123	1.09	1.061	1.03	1.018
	130890002 ^b	1.258	1.167	1.123	1.09	1.061	1.03	1.018
	132230003	1.529	1.333	1.268	1.202	1.141	1.058	1.028
	132470001	1.361	1.25	1.179	1.135	1.113	1.04	1.022
Baltimore-Columbia-Towson, MD	240270006 ^a	1.253	1.156	1.120	1.076	1.054	1.026	1.016
	240053001	1.232	1.130	1.096	1.057	1.033	1.019	1.006
	245100040 ^b	1.253	1.156	1.120	1.076	1.054	1.026	1.016
Boston-Cambridge-Newton, MA-NH	250250044 ^a	1.242	1.149	1.1	1.076	1.056	1.037	1.013
	250092006	1.259	1.179	1.137	1.092	1.064	1.049	1.024
	250094005	1.407	1.367	1.301	1.158	1.144	1.117	1.079
	250095005	1.179	1.132	1.093	1.070	1.047	1.031	1.016
	250213003	1.387	1.369	1.205	1.189	1.118	1.053	1.019
	250250002 ^b	1.242	1.149	1.100	1.076	1.056	1.037	1.013
	250250040	1.754	1.266	1.178	1.124	1.064	1.034	1.023
	250250042	1.278	1.199	1.142	1.093	1.077	1.04	1.018
Chicago-Naperville-Elgin, IL-IN-WI	330150018	1.670	1.300	1.185	1.163	1.053	1.026	1.018
	170310063	1.278	1.179	1.104	1.067	1.046	1.028	1.014
	170310076	1.325	1.212	1.146	1.099	1.058	1.032	1.014
	170313103	1.295	1.163	1.104	1.077	1.047	1.032	1.009
	170314002	1.249	1.178	1.147	1.117	1.070	1.029	1.017
	170314201	1.258	1.165	1.118	1.098	1.055	1.034	1.019
Dallas-Fort Worth-Arlington, TX	180890022	1.308	1.231	1.126	1.083	1.040	1.018	1.010
	484391053 ^a	1.249	1.158	1.124	1.092	1.049	1.032	1.011
	481131067 ^a	1.249	1.158	1.124	1.092	1.049	1.032	1.011
	481130069	1.247	1.167	1.111	1.068	1.058	1.033	1.025
	481130075	1.198	1.143	1.101	1.062	1.045	1.025	1.008
	481130087	1.279	1.138	1.095	1.072	1.047	1.024	1.012
	481210034	1.304	1.191	1.142	1.099	1.058	1.037	1.016
	481390016	1.295	1.158	1.084	1.048	1.039	1.022	1.015
	481391044	1.209	1.155	1.101	1.072	1.046	1.025	1.018
	482311006	1.244	1.146	1.125	1.100	1.071	1.046	1.026
482570005	1.292	1.208	1.151	1.101	1.061	1.050	1.023	
483670081	1.718	1.224	1.154	1.143	1.112	1.046	1.027	

CBSA	Site ID	Adjustment factor derived from ratio of DM1H concentrations to 98 th percentile DM1H, averaged across years 2003-2015						
		1 st DM1H	2 nd DM1H	3 rd DM1H	4 th DM1H	5 th DM1H	6 th DM1H	7 th DM1H
	484390075	1.170	1.163	1.100	1.036	1.019	1.012	1.012
	484391002 ^b	1.249	1.158	1.124	1.092	1.049	1.032	1.011
	484392003	1.235	1.096	1.090	1.070	1.052	1.034	1.027
	484393009	1.215	1.162	1.107	1.058	1.039	1.028	1.012
	484393011	1.211	1.127	1.094	1.072	1.037	1.028	1.017
Denver-Aurora-Lakewood, CO	080310028 ^a	1.428	1.163	1.134	1.103	1.069	1.033	1.021
	080310027 ^a	1.428	1.163	1.134	1.103	1.069	1.033	1.021
	080013001	1.305	1.188	1.134	1.097	1.063	1.030	1.012
	080310002 ^b	1.428	1.163	1.134	1.103	1.069	1.033	1.021
	080310026	1.136	1.108	1.072	1.054	1.034	1.030	1.008
Detroit-Warren-Dearborn, MI	261630095 ^a	1.292	1.160	1.109	1.076	1.053	1.030	1.018
	261630019 ^b	1.292	1.160	1.109	1.076	1.053	1.030	1.018
	261630093	1.302	1.119	1.109	1.050	1.020	1.015	1.013
	261630094	1.194	1.119	1.087	1.071	1.048	1.027	1.012
Houston-The Woodlands-Sugar Land, TX	482011052 ^a	1.310	1.178	1.129	1.087	1.049	1.031	1.018
	482011066 ^a	1.310	1.178	1.129	1.087	1.049	1.031	1.018
	480391004	1.292	1.231	1.145	1.096	1.072	1.041	1.026
	480391016	1.341	1.182	1.125	1.105	1.071	1.042	1.037
	481671034	1.302	1.216	1.149	1.113	1.083	1.069	1.019
	482010024	1.300	1.166	1.099	1.067	1.035	1.016	1.009
	482010026	1.564	1.370	1.267	1.180	1.109	1.064	1.019
	482010029	1.545	1.293	1.195	1.137	1.093	1.037	1.013
	482010047	1.366	1.217	1.143	1.089	1.051	1.035	1.013
	482010055	1.219	1.148	1.114	1.081	1.05	1.028	1.009
	482010075 ^b	1.310	1.178	1.129	1.087	1.049	1.031	1.018
	482010416	1.260	1.133	1.098	1.082	1.047	1.034	1.018
	482011015	1.476	1.173	1.135	1.086	1.056	1.029	1.012
	482011034	1.441	1.221	1.151	1.100	1.055	1.043	1.016
	482011035	1.343	1.172	1.122	1.081	1.056	1.030	1.008
	482011039	1.406	1.211	1.144	1.091	1.049	1.032	1.011
	482011050	1.605	1.401	1.220	1.149	1.109	1.045	1.025
483390078	1.478	1.287	1.186	1.140	1.104	1.051	1.032	
Kansas City, MO-KS	290950042 ^a	1.417	1.223	1.163	1.135	1.077	1.039	1.021
	201070002	1.682	1.495	1.313	1.233	1.171	1.100	1.023
	202090021	1.396	1.181	1.099	1.056	1.036	1.020	1.013
	290950034 ^b	1.417	1.223	1.163	1.135	1.077	1.039	1.021
Los Angeles-Long Beach-Anaheim, CA	060374008 ^a	1.242	1.146	1.099	1.076	1.042	1.029	1.013
	060590008 ^a	1.242	1.146	1.099	1.076	1.042	1.029	1.013
	060370002	1.248	1.166	1.141	1.096	1.07	1.047	1.018
	060370016	1.272	1.184	1.134	1.097	1.071	1.039	1.020
	060370113	1.290	1.159	1.124	1.093	1.074	1.035	1.019
	060371103	1.357	1.214	1.160	1.117	1.060	1.032	1.017
	060371201	1.343	1.185	1.116	1.060	1.033	1.022	1.009
	060371302	1.197	1.151	1.122	1.082	1.066	1.030	1.011
	060371602	1.237	1.172	1.104	1.058	1.035	1.023	1.018
	060371701 ^b	1.242	1.146	1.099	1.076	1.042	1.029	1.013
	060372005	1.415	1.267	1.168	1.130	1.099	1.062	1.036
	060374002	1.404	1.256	1.136	1.100	1.062	1.038	1.006
	060374006	1.399	1.156	1.128	1.063	1.042	1.027	1.017
	060375005	1.354	1.189	1.140	1.105	1.069	1.037	1.017
	060376012	1.339	1.201	1.163	1.109	1.064	1.034	1.018
	060379033	1.219	1.146	1.081	1.051	1.027	1.014	1.009
060590007	1.295	1.186	1.143	1.092	1.062	1.033	1.018	

CBSA	Site ID	Adjustment factor derived from ratio of DM1H concentrations to 98 th percentile DM1H, averaged across years 2003-2015						
		1 st DM1H	2 nd DM1H	3 rd DM1H	4 th DM1H	5 th DM1H	6 th DM1H	7 th DM1H
	060591003	1.297	1.212	1.150	1.105	1.062	1.040	1.02
	060595001	1.280	1.151	1.104	1.075	1.049	1.045	1.015
Minneapolis-St. Paul-Bloomington, MN-WI	270370480 ^a	1.352	1.231	1.163	1.111	1.080	1.031	1.025
	270530962 ^a	1.352	1.231	1.163	1.111	1.080	1.031	1.025
	270031002	1.202	1.151	1.093	1.064	1.053	1.030	1.010
	270370020 ^b	1.352	1.231	1.163	1.111	1.080	1.031	1.025
	270370423	1.561	1.205	1.121	1.097	1.069	1.044	1.015
Miami-Fort Lauderdale-West Palm Beach, FL	120110035 ^a	1.808	1.235	1.100	1.079	1.067	1.034	1.022
	120110031	1.569	1.375	1.177	1.114	1.072	1.045	1.010
	120118002	1.566	1.210	1.142	1.103	1.077	1.049	1.028
	120860027	1.290	1.178	1.134	1.089	1.062	1.046	1.026
	120864002 ^b	1.808	1.235	1.100	1.079	1.067	1.034	1.022
	120990020	1.263	1.194	1.169	1.153	1.067	1.025	1.000
New York-Newark-Jersey City, NY-NJ-PA	340030010 ^a	1.442	1.270	1.154	1.097	1.060	1.038	1.020
	340030006	1.218	1.157	1.116	1.066	1.046	1.015	1.015
	340130003	1.290	1.225	1.178	1.116	1.077	1.038	1.024
	340131003	1.377	1.240	1.172	1.115	1.077	1.038	1.020
	340170006	1.731	1.280	1.225	1.133	1.083	1.048	1.015
	340230011	1.326	1.175	1.118	1.088	1.067	1.038	1.014
	340273001	1.437	1.255	1.175	1.148	1.101	1.064	1.042
	340390004 ^b	1.442	1.270	1.154	1.097	1.060	1.038	1.020
	360050110	1.402	1.207	1.158	1.109	1.078	1.051	1.019
	360050133	1.207	1.165	1.112	1.069	1.040	1.023	1.013
	360590005	1.486	1.325	1.203	1.141	1.094	1.045	1.021
	360810124	1.420	1.253	1.149	1.072	1.039	1.023	1.009
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	421010076 ^a	1.377	1.205	1.142	1.084	1.057	1.035	1.013
	421010075 ^a	1.377	1.205	1.142	1.084	1.057	1.035	1.013
	100032004	1.575	1.228	1.147	1.109	1.072	1.023	
	340070002 ^c	1.238	1.130	1.097	1.059	1.049	1.043	1.013
	420170012	1.309	1.179	1.102	1.075	1.037	1.029	1.011
	420450002	1.485	1.308	1.140	1.090	1.048	1.030	1.023
	421010004 ^b	1.377	1.205	1.142	1.084	1.057	1.035	1.013
	421010047	1.546	1.354	1.195	1.141	1.091	1.041	1.013
Phoenix-Mesa-Scottsdale, AZ	040134020 ^a	1.300	1.194	1.102	1.066	1.053	1.036	1.017
	040134019 ^a	1.300	1.194	1.102	1.066	1.053	1.036	1.017
	040130019	1.250	1.152	1.112	1.078	1.054	1.028	1.016
	040133002	1.147	1.084	1.064	1.050	1.038	1.029	1.014
	040133003	1.177	1.116	1.071	1.051	1.029	1.024	1.003
	040133010 ^b	1.300	1.194	1.102	1.066	1.053	1.036	1.017
	040134011	1.384	1.252	1.155	1.119	1.073	1.046	1.021
	040139997	1.156	1.095	1.055	1.045	1.028	1.019	1.017
Pittsburgh, PA	420031376 ^a	1.199	1.144	1.088	1.067	1.043	1.021	1.015
	420030008	1.230	1.132	1.097	1.066	1.050	1.037	1.020
	420030010 ^b	1.199	1.144	1.088	1.067	1.043	1.021	1.015
	420031005	1.454	1.243	1.179	1.123	1.088	1.050	1.028
	420031008	1.101	1.043	1.043	1.043	1.043	1.014	1.014
	420070014	1.265	1.189	1.142	1.106	1.066	1.036	1.022
	421250005	1.368	1.170	1.124	1.103	1.061	1.037	1.012
	421255200	1.185	1.161	1.161	1.093	1.069	1.047	1.023
Richmond, VA	517600025 ^a	1.349	1.214	1.178	1.125	1.087	1.063	1.033
	510360002 ^b	1.349	1.214	1.178	1.125	1.087	1.063	1.033
	510870014	1.194	1.125	1.087	1.066	1.049	1.035	1.013
	517600024	1.357	1.162	1.095	1.062	1.050	1.025	1.015

CBSA	Site ID	Adjustment factor derived from ratio of DM1H concentrations to 98 th percentile DM1H, averaged across years 2003-2015						
		1 st DM1H	2 nd DM1H	3 rd DM1H	4 th DM1H	5 th DM1H	6 th DM1H	7 th DM1H
Riverside-San Bernardino-Ontario, CA	060710027 ^a	1.334	1.194	1.122	1.079	1.053	1.035	1.017
	060710026 ^a	1.334	1.194	1.122	1.079	1.053	1.035	1.017
	060650009	1.251	1.161	1.117	1.084	1.058	1.034	1.012
	060650012	1.250	1.112	1.066	1.045	1.033	1.025	1.014
	060651003	1.212	1.104	1.099	1.072	1.032	1.019	1.007
	060651016	1.862	1.451	1.379	1.219	1.210	1.027	1.018
	060655001	1.238	1.156	1.074	1.058	1.037	1.020	1.005
	060658001	1.220	1.158	1.104	1.060	1.037	1.019	1.011
	060658005	1.286	1.127	1.096	1.056	1.037	1.030	1.022
	060659001	1.239	1.169	1.120	1.097	1.060	1.041	1.018
	060710001	1.189	1.120	1.080	1.062	1.040	1.029	1.011
	060710306	1.245	1.187	1.091	1.055	1.029	1.015	1.008
	060711004	1.223	1.156	1.123	1.089	1.053	1.036	1.017
	060711234	1.246	1.180	1.137	1.081	1.054	1.033	1.023
	060712002 ^b	1.334	1.194	1.122	1.079	1.053	1.035	1.017
060719004	1.349	1.188	1.127	1.093	1.053	1.031	1.009	
Sacramento--Roseville--Arden-Arcade, CA	060670015 ^a	1.207	1.124	1.092	1.072	1.054	1.023	1.010
	060610006	1.203	1.143	1.103	1.074	1.067	1.042	1.017
	060670002	1.504	1.210	1.125	1.073	1.051	1.030	1.012
	060670006 ^b	1.207	1.124	1.092	1.072	1.054	1.023	1.010
	060670010	1.225	1.131	1.098	1.070	1.049	1.038	1.014
	060670011	1.391	1.223	1.158	1.107	1.068	1.039	1.019
	060670012	1.288	1.192	1.131	1.098	1.066	1.036	1.025
	060670014	1.328	1.182	1.144	1.079	1.051	1.035	1.029
061130004	1.268	1.188	1.126	1.097	1.070	1.053	1.030	
San Diego-Carlsbad, CA	060731017 ^a	1.281	1.213	1.129	1.078	1.060	1.043	1.018
	060730001	1.197	1.118	1.089	1.066	1.047	1.033	1.012
	060730003	1.259	1.106	1.082	1.057	1.035	1.017	1.003
	060730006	1.348	1.182	1.154	1.105	1.064	1.046	1.019
	060731002	1.281	1.152	1.092	1.069	1.042	1.021	1.010
	060731006	1.411	1.232	1.150	1.117	1.067	1.042	1.009
	060731008	1.312	1.224	1.137	1.095	1.055	1.028	1.010
	060731010	1.245	1.182	1.130	1.091	1.053	1.019	1.008
	060731014	1.196	1.118	1.078	1.039	1.020	1.000	1.000
	060731016	1.239	1.153	1.095	1.080	1.058	1.037	1.000
060732007 ^b	1.281	1.213	1.129	1.078	1.06	1.043	1.018	
San Francisco-Oakland-Hayward, CA	060010012 ^a	1.325	1.150	1.092	1.077	1.056	1.035	1.016
	060010007	1.245	1.165	1.103	1.079	1.052	1.028	1.010
	060010009	1.274	1.193	1.145	1.083	1.063	1.032	1.025
	060010011	1.233	1.160	1.097	1.073	1.051	1.034	1.014
	060012004	1.200	1.168	1.136	1.099	1.053	1.030	1.020
	060012005	2.050	1.262	1.204	1.158	1.090	1.086	1.009
	060130002	1.250	1.159	1.116	1.082	1.056	1.031	1.019
	060131002	1.233	1.176	1.133	1.097	1.058	1.043	1.017
	060131004	1.311	1.183	1.131	1.107	1.056	1.034	1.012
	060132007	1.335	1.107	1.082	1.067	1.061	1.034	1.027
	060410001	1.227	1.138	1.101	1.073	1.052	1.035	1.012
	060750005 ^b	1.325	1.150	1.092	1.077	1.056	1.035	1.016
060811001	1.299	1.189	1.137	1.082	1.066	1.049	1.023	
St. Louis, MO-IL	291890016 ^a	1.332	1.158	1.095	1.061	1.034	1.016	1.011
	295100094 ^a	1.332	1.158	1.095	1.061	1.034	1.016	1.011
	171630010	1.317	1.151	1.113	1.065	1.044	1.022	1.017
	171630900	1.179	1.143	1.119	1.096	1.068	1.044	1.029

CBSA	Site ID	Adjustment factor derived from ratio of DM1H concentrations to 98 th percentile DM1H, averaged across years 2003-2015						
		1 st DM1H	2 nd DM1H	3 rd DM1H	4 th DM1H	5 th DM1H	6 th DM1H	7 th DM1H
	295100085	1.185	1.141	1.125	1.105	1.068	1.064	1.020
	295100086 ^b	1.332	1.158	1.095	1.061	1.034	1.016	1.011
Washington-Arlington-Alexandria, DC-VA-MD-WV	110010051 ^a	1.490	1.334	1.209	1.140	1.096	1.060	1.032
	110010025	1.269	1.135	1.103	1.057	1.040	1.022	1.007
	110010041 ^b	1.490	1.334	1.209	1.140	1.096	1.060	1.032
	110010043	1.347	1.219	1.138	1.078	1.059	1.033	1.018
	110010050	1.211	1.139	1.052	1.020	1.020	1.010	1.000
	240330030	1.236	1.154	1.081	1.059	1.048	1.009	1.002
	510130020	1.211	1.132	1.089	1.066	1.050	1.038	1.020
	511071005	1.220	1.141	1.090	1.057	1.028	1.019	1.008
	511530009	1.333	1.255	1.124	1.078	1.053	1.034	1.012
	515100009	1.190	1.136	1.113	1.069	1.038	1.031	1.020
515100021	1.166	1.129	1.086	1.066	1.050	1.031	1.013	

^a The near-road monitor used the ratios derived from the monitor having the highest design value.

^b The area design value monitor ratios used for adjustments made to upper percentile concentrations at the near-road monitor.

^c Monitor ID 340070003 (operating during 2003-2008) is sited in close proximity to newly sited monitor ID 340070002 (operating during 2012-2015). The data from both monitors were combined to calculate ratios.

Regarding the application of these factors used to adjust air quality to just meet the existing 1-hr standard, the following two steps were applied.

- Adjust all DM1H concentrations proportionally, up to and including the 98th percentile DM1H, at all monitors and for each single year in each study area using the appropriate study area and year adjustment factors derived from Table B2-5 and Table B2-6 multiplied by the DM1H concentrations. Thus, for all of the proposed study areas selected in this air quality assessment, a single proportional factor, derived from one monitor in a study area, is used to adjust concentrations (up to and including the DM1H 98th percentile) measured at all of the other monitors in that study area. The monitor having the highest design value will have adjusted concentrations that just meet the existing hourly standard (a 3-year average DM1H 98th percentile of 100 ppb), while all other monitors will have adjusted hourly concentrations/design values less than that value.²⁴ Because there is overlap in the 3-

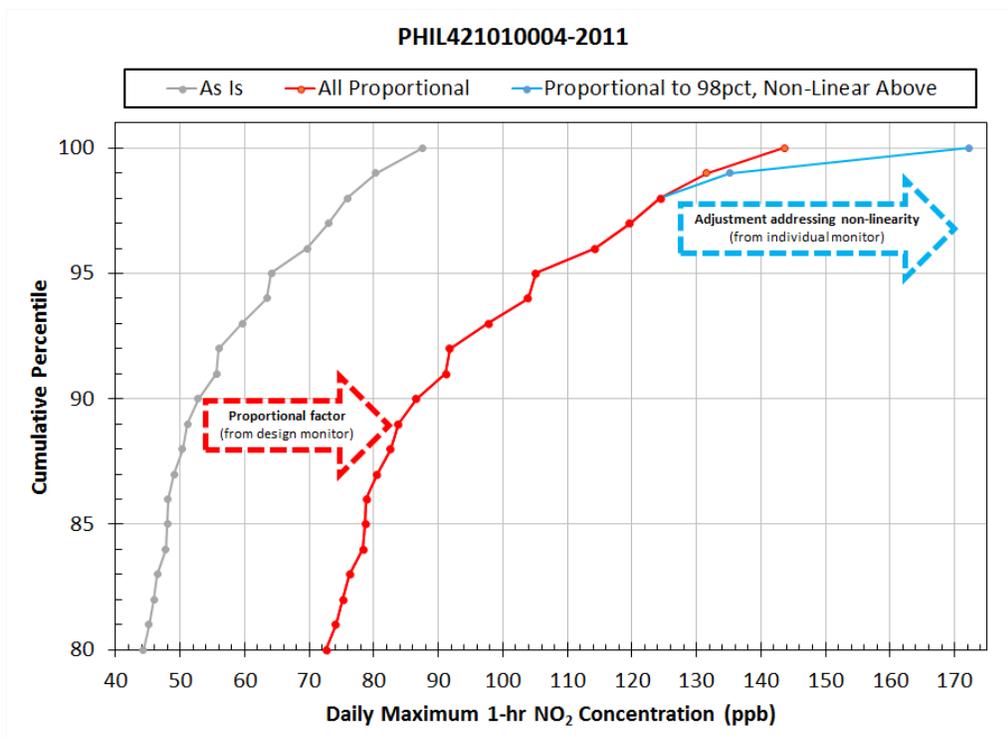
²⁴ Ideally this is how the standard would work but this is not always the case considering the suite of monitors in operation at any one time in the study areas. The design value for the hourly standard requires three consecutive years of ambient concentrations meeting the completeness criteria. For instance, a monitor may not have met completeness criteria for one year, but during two of the three years it could have concentrations (the full distribution including the 98th percentile) greater than the monitor used to calculate the highest design value. Effectively when adjusting concentrations to just meet the standard, the area design value monitor will have a DM1H 98th percentile average concentration of 100 ppb while this other monitor in this hypothetical situation will have a DM1H 98th percentile average concentration greater than 100 ppb. It is also possible each of the two individual years within that three year averaging period have a DM1H 98th percentile greater than 100 ppb.

1 year averaging periods considered here, there will be instances where multiple values
2 are generated for a single year of data. For example, for each monitor in operation
3 during 2012, three separate estimates of adjusted air quality could be calculated for
4 that year, using the unique adjustment factors derived from each of the three 3-year
5 periods (2010-2012, 2011-2013, and 2012-2014), where available.

- 6 2. For all DM1H concentrations above the 98th percentile DM1H at each individual
7 monitor, the adjusted 98th percentile DM1H concentration from step 1 is multiplied
8 by the suite of mean ratios from Table B2-8 to develop the series of days having
9 DM1H concentrations above the 98th percentile DM1H. As described above, there are
10 up to seven DM1H ratios, thus upward to seven adjusted concentrations are estimated
11 above the 98th percentile DM1H for each monitoring year.

12
13 As an example, the results of applying these two adjustments are illustrated in Figure
14 B2-10 for one year of ambient concentrations (2011) measured at the monitor (ID 421010004).
15 Plotted in this figure are the unadjusted DM1H concentrations, concentrations adjusted to just
16 meet the existing hourly standard using a proportional factor alone (the approach used in the
17 2008 REA), and concentrations adjusted to just meet the existing hourly standard using a
18 proportional factor and additional factors for estimating concentrations above the 98th percentile
19 DM1H. In this figure, concentrations at or above the DM1H 80th percentile are plotted to
20 highlight this portion of the distribution.

21 Using the proportional adjustment alone for this year (an increase of 63.9%, Table B2-5,
22 based on the 2011-2013 averaging period) appropriately increases the 80th and 100th DM1H
23 unadjusted concentrations of 44 and 88 ppb (gray line, Figure B2-10) to 73 and 144 ppb (red
24 line, Figure B2-10). When addressing deviations from linearity above the 98th percentile, the
25 suite of ratios used from Table B2-8 extend the upper percentile concentrations to somewhat
26 higher concentrations (blue line, Figure B2-10) when compared with that using a proportional
27 factor alone to adjust all concentrations. For example and by design, the proportionally adjusted
28 98th percentile DM1H concentration of 124 ppb is used with the maximum DM1H adjustment
29 factor of 1.377 to estimate a maximum DM1H concentration of about 172 ppb for this new air
30 quality distribution.



1
 2 **Figure B2-10. Distribution of unadjusted (as is) 2011 ambient NO₂ concentrations, that**
 3 **adjusted using a proportional factor alone (all proportional), and that adjusted using a**
 4 **combined proportional factor and ratio approach (proportional to 98th percentile, non-**
 5 **linear above) in the Philadelphia study area at monitor ID 421010004.**

6 **2.4.2 Simulating on-road concentrations**

7 The newly designated near-road monitors would best characterize NO₂ concentrations
 8 occurring around roadways, when compared to the monitoring information available in the last
 9 review. Based on this newly available data, as well as overall consistency in the information
 10 obtained from the types of monitoring and modeling analyses described in the REA Planning
 11 document, we have concluded that the near-road data would also serve as the basis for estimating
 12 on-road concentrations, generally expected to be similar to or perhaps greater than the near-road
 13 concentrations.

14 We developed a series of simulation factors to estimate on-road ambient NO₂
 15 concentrations from the near-road monitor data, based on measurement data and a statistical
 16 model developed from a near-road study. The simulation factors were derived from a statistical
 17 model similar to that developed in the 2008 REA, though using newly available near-road
 18 monitoring data collected in Las Vegas, NV. Details of the statistical model development and on-
 19 road simulation factor output is fully described in Richmond-Bryant et al. (2016), while
 20 information regarding the measurement data collection are found in Kimbrough et al. (2013).
 21 Fundamentally, based on their forms and the data used to construct these types of statistical

1 models, the simulation factors derived will generate on-road concentrations that will be greater
2 than that of the ambient monitor concentrations used to approximate them. That said,
3 uncertainties remain for where and when the maximum concentrations could occur at fine
4 temporal and spatial scales based on influential factors such as local meteorological conditions
5 (e.g., wind speed and direction) and NO_x conversion rates.

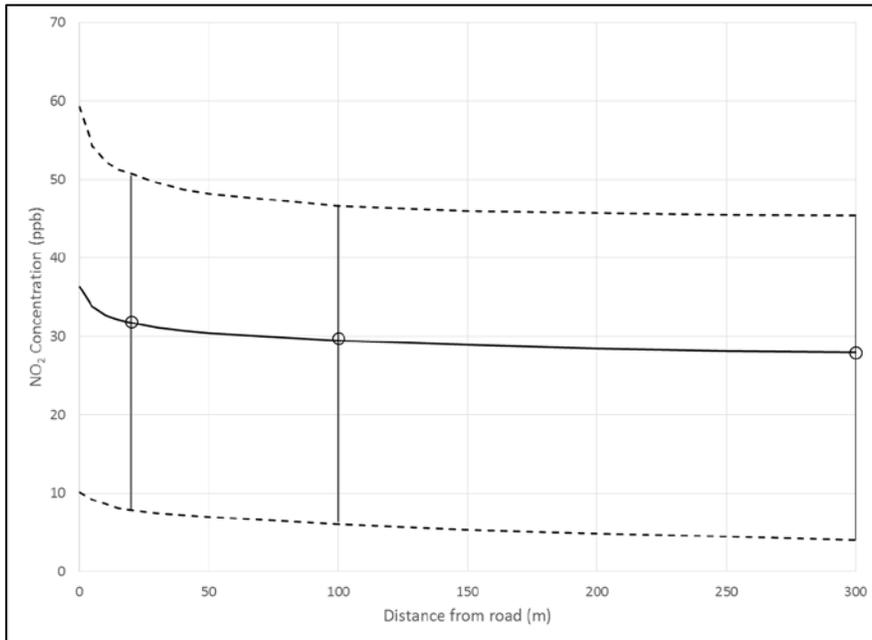
6 Briefly, near-road measurements of air quality, traffic, and meteorology were collected at
7 a study area located adjacent to Interstate-15 (I-15) in Las Vegas NV during Dec. 2008 to Jan.
8 2010. Downwind sampling sites were located approximately 20 m, 100 m, and 300 m east of the
9 interstate. Logit-ln functions were developed, considering the influence of local meteorological
10 conditions (e.g., wind direction and approximate mixing heights).²⁵ The logit-ln functions were
11 then used to estimate on-road NO₂ concentrations and concentrations predicted at varying
12 distances from the road (i.e., 5, 10, 20, and 30 meters).²⁶ Using each hourly prediction,
13 statistically modeled on-road NO₂ concentrations were compared to the modeled near-road
14 concentrations to calculate the percent increase in on-road concentrations. As a reminder, while
15 modeled and observed concentration agreement was reasonable (Figure B2-11), there were no
16 on-road measurement collected as part of this study, thus an evaluation of the modeled on-road
17 concentrations could not be performed and remains as an uncertainty.

18 To a limited extent (and as discussed in the ISA Section 2.5.3.1 that describes near-road
19 concentration gradients), concentration level can affect the value of the on-road simulation factor
20 generated using the Las Vegas study data. In general, lower concentration quintiles have greater
21 percent differences between on-road and away-from-road concentrations than higher
22 concentration quintiles. Therefore, the distributions of percent increases were stratified by the
23 near-road concentration distribution quintiles. Because upper percentile concentrations are those
24 that will most likely lead to the majority of concentrations at or above benchmark levels, here we
25 selected the factors derived from the upper quantiles (i.e., when near-road concentrations at or
26 above the 80th percentile). Meteorological conditions also affect the value of the estimated

²⁵ We evaluated five model scenarios considering atmospheric conditions and wind direction: 1) all wind and atmospheric stability conditions combined, 2) winds from the west (210°-330°, where the monitors were downwind of the highway), 3) winds from the east (30°-150°, where the monitors were upwind of the highway), 4) inversion conditions (convective mixing height less than 300 m), and 5) non-inversion conditions (convective mixing height greater than 300 m).

²⁶ It is possible to generate on-road simulation factors to use for any monitor distance (e.g., 80 m, 200 m from the road), though the principal objective here was to develop factors to apply to the new near-road monitor concentration data.

1 simulation factor; study conditions where winds were predominantly from the west (downwind
 2 from the road) combined with the presence of atmospheric inversions had a lower percent
 3 difference between on-road and away-from-road concentrations than when winds were
 4 perpendicular to the road combined with conditions associated with greater mixing heights. In
 5 considering these differing meteorological conditions, and seeking a generally conservative
 6 though simple approach using these results to simulate on-road NO₂ concentrations here, we
 7 chose three values for estimating on-road concentrations for each distance, based on the two
 8 lowest and highest median values, and the average of these two median values. These on-road
 9 simulation factors are provided in Table B2-9.



10
 11 **Figure B2-11. Predicted and observed NO₂ concentrations for winds from the west using**
 12 **based on data from a Las Vegas NV near-road measurement study. Predicted median**
 13 **(solid), predicted 98th and 2nd percentile (dotted), observed median (circles), and observed**
 14 **98th and 2nd percentiles (error bars) are shown.**

15
 16 **Table B2-9. Factors used to simulate on-road NO₂ concentrations from near-road monitors**
 17 **sited at varying distance from a major road.**

Distance from Road (meters)	Average upwards adjustment from near-road concentrations given selected simulation factor used ¹		
	Low	Mid	High
5	7%	9%	11%
10	9%	12%	15%
20	12%	16%	19%
30	13%	17%	21%

18 ¹ based on Las Vegas, NV near-road measurement study data (see Appendix A of NO₂ REA PD).

2.4.3 Calculating number of days at or above benchmark levels

As was discussed above in section 2.4.1, we have identified 1-hour concentrations ranging from 100, 150, and 200 ppb as the air quality benchmark levels to consider in this air quality assessment. The complete distribution of DM1H concentrations are used to calculate the number of days per year concentrations are at or above these benchmark levels at each monitor, for all air quality scenarios, and within each study area. Specifically for this draft AQC, we generated NO₂ air quality benchmark analysis results for 22 study areas having new near-road monitor data and one study area (Chicago) not yet having a newly designated near-road monitor. The mean and maximum number of days per year having concentrations at or above benchmark levels were calculated using 2010-2015 air quality for two ambient monitor types (i.e., area wide, near road) and for where on-road concentrations were simulated.²⁷ The five air quality scenarios include *as is* ambient concentrations (unadjusted concentrations, for all years where measured/estimated), CS1012 (2010-2012 air quality adjusted upwards to just meet the existing standard across the three-year period), CS1113 (2011-2013, similarly adjusted), CS1214 (2012-2014, similarly adjusted), and CS1315 (2013-2015, similarly adjusted).

The number of days per year a DM1H exceeds a particular benchmark level are counted for each monitor in operation. Then these results were summarized using two metrics as follows:

- 1) *Site-Year Metric*. Consistent with the NO₂ and SO₂ REAs (US EPA, 2009; US EPA, 2010, respectively) the first summary result metric is based on monitor site-years of data, whereas daily exceedances are calculated as such (and considers all individual site-years in the period of interest, neither weighted by site or year). Because the means are calculated using data from all monitors in a study area (not just the area design value monitor), the mean value for this metric would very likely be less than 7 days per year.²⁸ This mean metric can represent, on-average, the number of days per year at any one site in the study area we could have an exceedance over that averaging period. The maximum is the single monitor worst air quality year for that

²⁷ The number of monitoring days per year can vary, even considering the use of monitors designated as having a valid year of data. The number of days per year having a concentrations at or above benchmark levels was not adjusted considering this fact, that is to say, if fewer than 365 days were monitored (e.g., only 344 days were available), the number of benchmark exceedances was not increased by a factor of 1.06. It was assumed that the valid monitoring year reasonably represented what would be considered a complete year. The same approach was used for the near-road/on-road calculations, that is to say, if only 183 days had valid measurement data, the number of days above benchmarks was not increased by a factor of 1.99 to reflect a full 365 day period. When presented alone, the near-road/on-road DM1H concentrations at or above benchmarks are generally presented as “number of days” rather than “number of days per year”.

²⁸ Based on the form of the standard, a value of 7 days per year would expected considering the adjusted area design value monitor concentrations alone and that all three years of data within the 3-year averaging period meet completeness criteria.

1 study area. These results are presented using the phrase ‘*site-year*’ with calculations
2 performed for the area wide and near-road monitors separately. Because the on-road
3 data were mainly limited to measurements during 2014-15 and were mostly from a
4 single monitor in each study area, these data were presented for those individual years
5 (means and maximums are not calculated).
6

7 For example, the number of days per year having DM1H concentrations above
8 benchmarks in the St. Louis study area is presented in Table B2-10. Means were
9 rounded to the nearest integer, though for values <0.50, rather than round to zero, a
10 value of 0.50 was designated to distinguish it from instances where there were no (or
11 0) days where the DM1H was at or above the benchmarks during the period of
12 interest. Presented in the summary figures that follow in Section B3 are the mean and
13 maximum values for each of the air quality scenarios, in each study area, for the area-
14 wide and near-road monitor data. Because there were three simulation factors (low,
15 mid, high) used in calculating the on-road concentrations, the results are presented in
16 a summary figure for each study area, considering 2014 and 2015 individually (the
17 years where ambient monitors had the greatest number of measurements within the
18 2013-2015 adjusted air quality scenario).
19

20 An important feature to note is that there can be variability in the concentrations
21 within CBSAs, based on both the year to year variability in concentrations and the
22 adjustment factor used. For example when considering monitor 295100086, within
23 the 3-year averaging period of 2012-14 and using the same series of adjustment
24 factors for that period, the number of days per year having concentrations at or above
25 100 ppb is 14, 9, and 2 for years 2012, 2013, and 2014, respectively (Table B2-10),
26 resulting in a coefficient of variation (COV) of about 72%. When considering
27 benchmark exceedances at the same monitor and within the same year, though across
28 the three different averaging periods encompassing that year (e.g., 2013 – benchmark
29 exceedances of 4, 9, and 5), the resulting COV is about 44%. In this latter instance,
30 the three proportional adjustment factors of 1.887, 2.041, and 1.923 (Table B2-5)
31 exhibited much less variability (COV ~ 5%), though when applied to the same exact
32 ambient concentrations, the slightly higher adjustment factor increased the estimated
33 concentrations above the benchmark levels by a factor of about 2 when compared
34 with results from the other averaging periods.
35

1 **Table B2-10. Example site-year metric results in the St. Louis study area: number of days**
 2 **per year 1-hour NO₂ concentrations are at or above 100 ppb, by monitor, year, and air**
 3 **quality scenario along with summary statistics.**

Site ID	year	DMAX_days	Number of days per year 1-hour NO ₂ concentration ≥ 100 ppb			
			asis	CS1113	CS1214	CS1315
Area-wide						
171630010	2010	363	0			
	2011	346	0	0		
	2013	351	0	1	1	1
	2014	365	0		2	1
	2015	356	0			0
171630900	2011	361	0	0		
	2012	365	0	0	0	
	2013	365	0	0	0	0
	2014	359	0		0	0
295100085	2014	361	0		4	1
295100086	2011	349	0	8		
	2012	350	0	6	14	
	2013	365	0	4	9	5
	2014	365	0		2	1
	2015	352	0			2
mean			0	2	4	2
max			0	8	14	5
Near-road						
295100094	2013	365	0	5	11	6
	2014	365	0		21	10
	2015	364	0			2
291890016	2015	357	0			1
mean			0	5	16	5
max			0	5	21	10
On-road						
Monitor used	year	scenario	low	mid	high	
295100094	2013	As is	0	0	0	
	2013	CS1315	21	26	37	
	2014	As is	0	0	0	
	2014	CS1315	30	37	39	
	2015	As is	0	0	0	
	2015	CS1315	13	17	26	
291890016	2015	As is	0	0	0	
	2015	CS1315	4	5	8	

4 Highlighted are the summary statistics provided in the results figures that follow in Section B3.

5

1 2) *CBSA-wide Metric*. A new frame of reference was developed for this draft AQC to
2 account for all days having concentrations at or above benchmarks in each study area.
3 Rather than consider the monitors singularly (as in the above site-year calculation),
4 the calendar year for the study area as a whole was considered, that is, there could be
5 days where more than one monitor has a DM1H at or above a benchmark, though at
6 times, the exceedances occur on different days of the year. Further, there could be
7 days where more than one monitor exceeded a given benchmark on the same day. To
8 analyze the data for each year and study area, the days of the year having a DM1H
9 concentration at or above a benchmark were retained for each monitor, then
10 combined to yield a CBSA-wide calendar record for all unique days where a
11 benchmark was exceeded (i.e., exceedances occurring at any monitor in the CBSA,
12 including the near-road monitor). The mean value is calculated here as the average of
13 the 3 years considered in the 3-year averaging period for each study area, the
14 maximum is the single worst air quality year in the study area. Of course, because it is
15 a calendar record and includes instances where benchmark exceedances are not
16 restricted to a single monitoring site (but now the days per year is CBSA-wide), the
17 number of days per year at or above a benchmark calculated using this CBSA-wide
18 metric is greater than that generated using the site-year metric, and the means are
19 typically at or above that would be expected to occur at an area design value monitor
20 when concentrations are adjusted to just meet the existing standard (i.e., greater than
21 7 days per year). This mean metric represents ‘on-average’ the number of days per
22 year somewhere across the study area the DM1H was at or above a benchmark level
23 across the 3-year period. Again, the maximum number of days is the worst air quality
24 year for that study area. These same two statistics (mean and maximum) were
25 calculated for the number of days in the study area having two monitors having
26 DM1H concentrations at or above the benchmarks, though occurring on the same day.
27 And finally, this CBSA-wide metric was expanded to also include all three
28 concentration locations (area-wide, near-road and on-road). Because most locations
29 only had the 2014-15 near road data (and hence 2014-15 on-road estimates), the
30 results are presented for the 2013-2015 period. Also, only the on-road concentrations
31 simulated using the ‘mid’ factor were used for the CBSA-wide metric.

32 An example is provided below, continuing with the St. Louis study area results. The
33 summary data are first presented in Table B2-11. These summary data are what would be
34 presented in figures in Section B3, though would also include results for the other study areas.
35 Results are shown for the 100 ppb benchmark only, because as in most study areas, exceedances
36 of the higher benchmarks occurred much less frequently, if at all. In this study area, there were

1 no simulated on-road concentrations at or above any benchmarks when considering the
 2 unadjusted as is air quality, thus this data is not shown. The data from which the summary means
 3 and maximums were calculated are derived from Table B2-12, which in turn were generated
 4 based on the individual monitor DM1H concentrations presented in Table B2-13. The CBSA-
 5 wide metric calculation including the simulated on-road concentrations is calculated in a similar
 6 manner, though in addition to the concentrations at all monitors also includes the concentrations
 7 on days when the simulated on-road concentrations are at or above the benchmark levels (not
 8 shown). As expected given that the on-road concentration simulation is based on the near-road
 9 monitor data, at a minimum the benchmark exceedances occur on the same days the near-road
 10 monitor had a DM1H concentration at or above a benchmark level. Though most often, the
 11 number of days per year DM1H on-road concentrations are at or above benchmarks is greater
 12 than that estimated for the near-road monitor.

13

14 **Table B2-11. Example CBSA-wide metric results in the St. Louis study area: summary**
 15 **statistics for the number of days per year where NO₂ concentration ≥ 100 ppb - anytime in**
 16 **the study area and for instances when it occurred on the same day at two monitoring**
 17 **locations.**

CBSA-wide metric	Number of days per year where DM1H NO ₂ concentration ≥ 100 ppb									
	mean					maximum				
	As is	CS1012	CS1113	CS1214	CS1315	As is	CS1012	CS1113	CS1214	CS1315
Any monitor in CBSA	0	No DV	7	17	8	0	No DV	8	23	13
At two monitors (2 x 100 ppb)	0	No DV	1	3	1	0	No DV	3	5	4

18 Presented are the summary statistics provided in the results figures that follow in Section B3.

19

20 **Table B2-12. Example CBSA-wide metric results in the St. Louis study area: number of**
 21 **days per year where NO₂ concentrations ≥ 100 ppb - data stratified by averaging period**
 22 **and year.**

Year	Number of days per year where DM1H NO ₂ concentration ≥ 100 ppb		Number of Monitors (n)	3-year averaging period
	Any monitor in study area	At two monitors on same day		
2011	8	0	3	1113
2012	6	0	2	1113
2013	6	3	4	1113
2012	14	0	2	1214
2013	15	5	4	1214
2014	23	5	5	1214
2013	7	4	4	1315
2014	13	0	5	1315
2015	5	0	4	1315

1 **Table B2-13. Example CBSA-wide metric results in the St. Louis study area: NO₂**
 2 **concentrations stratified by averaging period, year, month, day, and monitor on days**
 3 **where NO₂ concentrations ≥ 100 ppb.**

year	month	day	Daily maximum 1-hour NO ₂ on days when concentrations ≥ 100 ppb					
			mon171630010	mon171630900	mon295100086	mon295100094	mon295100085	mon291890016
2011-2013 (CS1113) averaging period								
2011	1	2	45.3	15.9	114.7			
2011	1	3	37.7	50.9	139.5			
2011	1	5	47.2	56.8	104.7			
2011	1	25	80.4	63.0	101.1			
2011	2	3	72.9	67.0	111.1			
2011	2	4	67.9	61.5	108.3			
2011	10	4	69.8	78.8	121.3			
2011	10	22	39.6	83.0	106.4			
2012	1	6		48.7	100.3			
2012	3	28		59.6	114.3			
2012	4	1		11.3	108.1			
2012	6	13		54.0	102.1			
2012	8	23		46.2	104.7			
2012	9	4		32.6	131.4			
2013	2	23	91.2	63.2	110.4	128.8		
2013	2	24	104.4	71.4	126.9	112.0		
2013	3	15	73.6	42.5	101.1	105.9		
2013	3	22	24.5	14.7	43.8	100.0		
2013	3	28	34.0	18.3	57.0	102.6		
2013	4	4	88.2	62.3	104.4	98.3		
2012-2014 (CS1214) averaging period								
2012	1	6		52.7	108.5			
2012	2	17		52.0	107.9			
2012	3	28		64.5	123.6			
2012	4	1		12.2	116.9			
2012	4	8		45.1	101.8			
2012	5	12		45.1	103.1			
2012	5	14		45.3	106.5			
2012	5	22		61.6	100.4			
2012	6	9		20.2	103.3			
2012	6	13		58.4	110.4			
2012	8	23		50.0	113.3			
2012	9	4		35.3	142.2			
2012	11	15		67.9	100.6			
2012	11	16		65.7	101.8			
2013	1	15	55.1	42.5	103.1	56.1		
2013	2	16	75.5	38.2	88.4	105.7		

year	month	day	Daily maximum 1-hour NO ₂ on days when concentrations ≥ 100 ppb					
			mon171630010	mon171630900	mon295100086	mon295100094	mon295100085	mon291890016
2013	2	23	98.7	68.4	119.4	139.3		
2013	2	24	112.9	77.2	137.3	121.1		
2013	3	15	79.6	45.9	109.4	114.6		
2013	3	22	26.5	15.9	47.4	108.2		
2013	3	27	73.5	74.9	106.6	100.2		
2013	3	28	36.7	19.8	61.6	111.0		
2013	3	29	91.3	40.4	104.7	69.4		
2013	4	2	87.2	37.8	104.2	90.7		
2013	4	3	81.6	23.9	100.0	89.1		
2013	4	4	95.4	67.4	112.9	106.3		
2013	4	5	79.6	55.3	94.1	101.3		
2013	9	6		34.9	58.8	100.2		
2013	10	28	81.6	58.2	91.6	104.6		
2014	1	28	71.4	56.3	58.2	108.1	77.1	
2014	2	7	115.6	75.2	58.8	86.0	50.2	
2014	2	11	83.7	53.3	59.0	130.1	89.2	
2014	2	12	97.7	79.2	75.9	120.7	105.9	
2014	2	13	101.0	71.7	82.5	137.6	99.2	
2014	2	14	91.6	61.8	54.3	120.1	84.1	
2014	3	1	81.6	44.9	68.8	100.9	80.0	
2014	3	4	93.4	65.7	66.9	103.0	110.0	
2014	3	6	87.8	73.6	75.3	126.0	91.0	
2014	3	7	87.8	69.1	79.8	102.8	80.8	
2014	3	10	81.6	37.4	48.4	118.8	79.2	
2014	3	13	63.3	54.9	58.8	103.9	80.4	
2014	3	15	81.6	44.9	64.3	100.2	85.7	
2014	3	20	87.8	33.1	70.0	103.0	78.0	
2014	4	11	65.3	41.2	70.8	100.9	102.7	
2014	4	20	57.1	42.2	88.2	101.9	80.0	
2014	4	21	46.9	26.9	85.5	110.3	94.7	
2014	7	11	34.7	25.1	32.0	100.0	51.2	
2014	9	25	44.9	47.8	70.2	122.9	84.9	
2014	9	26	49.0	51.6	117.7	97.2	92.9	
2014	9	27	51.0	63.7	102.3	106.1	104.5	
2014	11	24	30.6	14.1	25.1	158.2	32.7	
2014	12	12	44.7	34.9	57.6	104.0	57.1	
2013-2015 (CS1315) averaging period								
2013	2	23	93.0	64.4	112.5	131.2		
2013	2	24	106.3	72.8	129.3	114.1		
2013	3	15	75.0	43.3	103.0	107.9		
2013	3	22	25.0	15.0	44.6	101.9		

year	month	day	Daily maximum 1-hour NO ₂ on days when concentrations ≥ 100 ppb					
			mon171630010	mon171630900	mon295100086	mon295100094	mon295100085	mon291890016
2013	3	27	69.2	70.5	100.5	94.4		
2013	3	28	34.6	18.7	58.1	104.6		
2013	4	4	89.9	63.5	106.4	100.2		
2014	1	28	67.3	53.1	54.8	101.8	72.7	
2014	2	7	108.9	70.8	55.4	81.1	47.3	
2014	2	11	78.8	50.2	55.6	122.6	84.0	
2014	2	12	92.0	74.6	71.5	113.7	99.8	
2014	2	13	95.2	67.6	77.7	129.6	93.5	
2014	2	14	86.3	58.3	51.2	113.1	79.2	
2014	3	4	88.0	61.9	63.1	97.0	103.6	
2014	3	6	82.7	69.4	71.0	118.7	85.8	
2014	3	10	76.9	35.2	45.6	111.9	74.6	
2014	4	21	44.2	25.4	80.6	103.9	89.2	
2014	9	25	42.3	45.0	66.2	115.8	80.0	
2014	9	26	46.2	48.7	110.9	91.5	87.5	
2014	11	24	28.8	13.3	23.7	149.0	30.8	
2015	3	2			88.2	105.6		71.3
2015	3	7	80.3		101.1	89.8		96.9
2015	3	31	72.9		87.1	99.8		111.4
2015	4	1	58.7		79.0	121.4		79.2
2015	9	25	69.2		116.3	55.8		61.5

1 Highlighted are the DM1H NO₂ concentrations that were used in counting the number of days per year at or above
2 benchmark levels summarized in Table B2-11 and Table B2-12.

1 **B3. RESULTS**

2 This section contains the analysis results for the AQC. An overview of the two distinct
3 analyses is presented in this section followed by sections detailing the analytical results along
4 with a brief discussion.

5 For the first analysis, we used the historical (1980-2015) unadjusted (as is) air quality to
6 provide context for the benchmark exceedance calculations, focusing here on instances where
7 ambient concentrations have been at or just around the level of the existing 1-hour standard. It is
8 worth noting that the historical measurement data are representative of real air quality scenarios
9 that existed at the time the monitoring took place and that changes in emissions control and
10 atmospheric conditions that have occurred since that time would preclude us from drawing
11 complete conclusions about the number of exceedances associated with a given 98th percentile
12 DM1H NO₂ concentration, if attempting to use such information as a prediction for future air
13 quality. Nevertheless, using these unadjusted ambient concentration data remain informative
14 given the general consistencies in the overall concentration distribution over time at each
15 monitor and what would be expected regarding the number of exceedances given the form of the
16 existing 1-hour standard (i.e., for a complete year of data, on average, there would be about 7
17 days having concentrations at or above the 98th percentile DM1H value of 100 ppb) and the
18 approach used to adjust concentrations to just meet the existing 1-hour standard.

19 For the second analysis, i.e., the core results for the AQC in the selected study areas, we
20 used the most recently available (2010-2015) ambient NO₂ monitoring data. Exceedances of
21 benchmark levels are calculated for the five air quality scenarios (unadjusted as is ambient
22 concentrations and three sets of concentrations adjusted to just meeting the existing 1-hour
23 standard) and for the three distinct ambient concentration types (area-wide, near-road, and
24 simulated on-road).

25 **3.1 ANALYSIS OF HISTORICAL (1980-2015) AIR QUALITY**

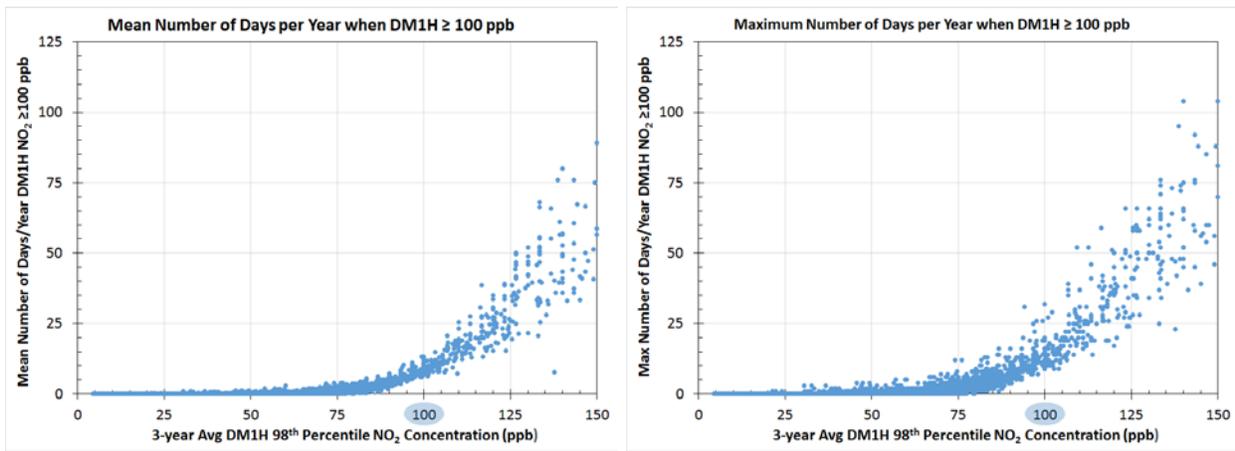
26 For this analysis, we first calculated all of the rolling 3-year average 98th percentile
27 DM1H values for all individual monitors in operation from 1980-2015 that met the completeness
28 criteria described above (section 2.2). Historical data were used to ensure that concentrations
29 would be at or around the level of the existing hourly standard. Counted first were the number of
30 days per year NO₂ concentrations were at or above the 1-hour benchmark levels (i.e., 100, 150,
31 and 200, if any) for the individual years within each 3-year averaging period. Then the mean
32 number of days per year was calculated (thus, the average of the observed number of days for
33 each monitor across the 3-year averaging period). Also identified were the maximum number of

1 days per year NO₂ concentrations were at or above the 1-hour air quality benchmark levels (thus,
2 the highest observed number of exceedances at each monitor for a single year in the averaging
3 period) given the 3-year average 98th percentile DM1H for that monitor. Results of this analysis
4 are presented in Figure B3-1.

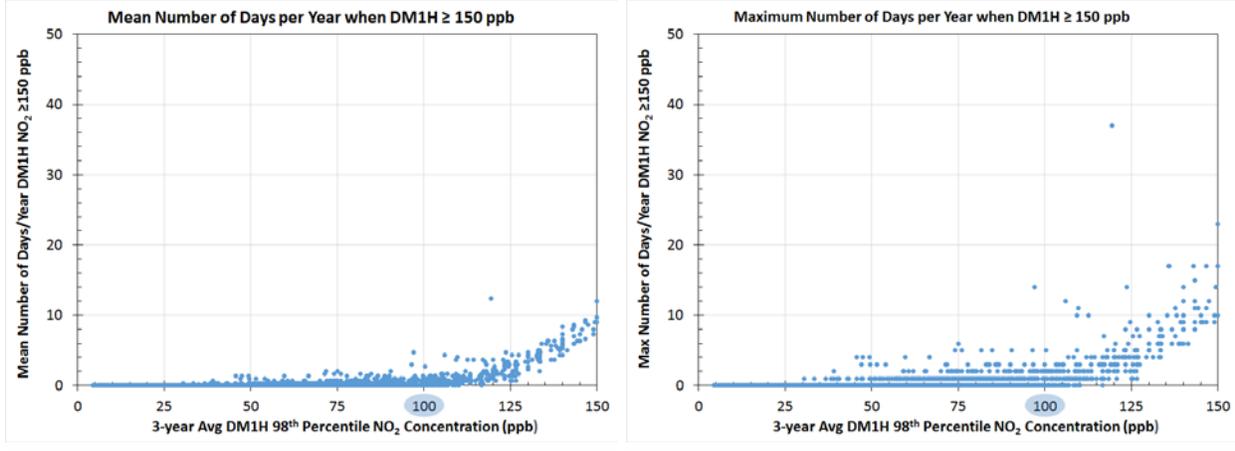
5 Based on the analysis of all available historical NO₂ ambient monitored concentrations
6 and considering the form, level, and averaging time of the existing 1-hour standard, on average
7 across a 3-year period, the number of days/year where the DM1H was ≥ 100 ppb ranged from
8 about 6 to 13 days (Figure B3-1, top left panel). This mean number of days per year, on average,
9 corresponds well with general expectations described above (i.e., on average there could be
10 about 8 days/year at or above the 100 ppb benchmark given the form of the standard). The
11 maximum number of days in a single year that the DM1H was ≥ 100 ppb ranged from about 10
12 to 20 days (Figure B3-1, top right panel). When considering the 150 ppb benchmark, there are
13 far fewer days per year exceeding that level when considering ambient concentration at the
14 existing standard. In most instances, the mean number of days per year where the DM1H was \geq
15 150 was less than two (Figure B3-1, middle left panel), while the maximum number of days per
16 year at or above the same benchmark was less than five (Figure B3-1, middle right panel).
17 Furthermore, and according to this analysis of all available historical ambient measurement data,
18 exceeding a 1-hour benchmark level of 200 ppb is a rare occurrence when considering the form
19 and level of the existing 1-hour standard. For example, of the 23 instances a monitor had a 3-year
20 average 98th percentile DM1H of 100 ppb, there were no exceedances of the 200 ppb benchmark
21 on 19 of these occasions (Figure B3-1, bottom right panel). When averaging across the 3-year
22 period, the mean number of days per year having DM1H NO₂ concentrations at or above 200
23 ppb drops to 1 or less, again with most monitors recording no concentrations at or above the 200
24 ppb 1-hour benchmark.

25 It should be noted that for this analysis of historical ambient NO₂ concentrations, monitors
26 in the California CBSAs (Los Angeles, San Francisco, etc.) constitute the bulk of the data where
27 the 3-year average 98th percentile DM1H concentrations were at or above 100 ppb. However, the
28 results of this analysis when excluding these areas are similar (data not shown), albeit with a
29 generally tighter range of values than when including the monitoring data in California (e.g., the
30 mean number of days per year having DM1H ≥ 100 ppb ranged from about 6 to 9). When
31 considering data only from the 23 selected study areas (not shown), the number of days per year
32 having DM1H at or above benchmarks and given a particular 3-year average 98th percentile
33 DM1H is also consistent with that presented in Figure B3-1.

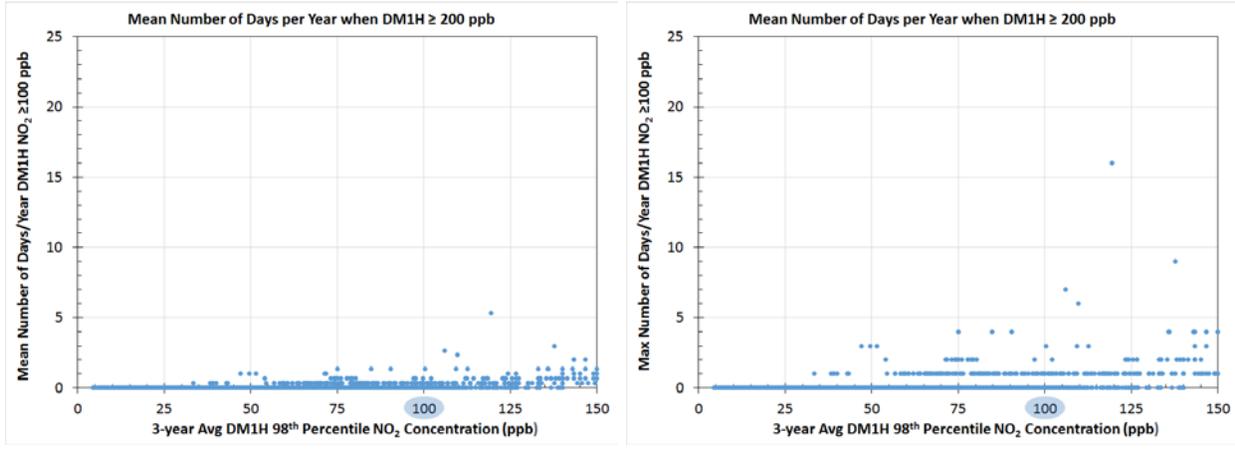
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3



4

5 **Figure B3-1. The mean (left panel) and maximum (right panel) number of days per year**
 6 **where DM1H NO₂ concentration was ≥ 100 ppb (top panel), ≥ 150 ppb (middle panel), and**
 7 **≥ 200 ppb (bottom panel) associated with 3-year average 98th percentile DM1H NO₂**
 8 **concentrations, using valid-year 1980-2015 ambient monitor data.**

3.2 ANALYSIS OF RECENT AIR QUALITY (2010-2015) IN SELECTED STUDY AREAS

A total of five air quality scenarios were evaluated in each of the 23 selected study areas (i.e., unadjusted as is ambient NO₂ concentrations and NO₂ concentrations adjusted to just meet the existing hourly standard for four 3-year averaging periods) considering the area-wide and near-road monitoring data available for 2010-2015. We also simulated on-road NO₂ concentrations based on the available near-road monitoring data.²⁹ Counted were the number of days per year the DM1H ambient concentrations exceeded the 1-hour benchmark levels of 100, 150, and 200 ppb, considering the area-wide, near-road and on-road concentrations. Because most study areas had very few days where concentrations were at or above the 150 ppb benchmark level, the results presented in this section are for the 100 ppb benchmark level only. Complete results for the 100 ppb benchmark and the other benchmarks are provided in tables in the Section B5. Presented in each figure in this section are the mean and maximum number of days per year considering the study area data on a site-year basis, and CBSA-wide basis, as was described in Section 2.4.3.

Figure B3-2 presents the results for the site-year metric, considering the area-wide monitors only. Note that where a value does not appear in this Figure for a particular study area, in all instances, that is because it is equal to zero (no benchmark exceedances). Further, any non-zero mean values that were less than 1 though not rounding upwards to 1 are presented as equal to 0.5. When considering the unadjusted (as is) air quality, very few exceedances of the 100 ppb benchmark were observed during the recent area-wide monitor data analyzed. The maximum observed values in a single year was seven (Riverside CA) and three (Houston), while most study areas had a one or no days per year DM1H concentrations \geq 100 ppb.

When considering air quality adjusted to just meet the existing standard, the results were generally similar for the four different 3-year averaging periods. In general, the average number of days per year having 1-hr NO₂ concentrations at or above 100 ppb ranged from about 2 to 5 in the majority of study areas, while the maximum number of days above this same benchmark was generally about 10 days per year, consistent with the expected number of days per year when

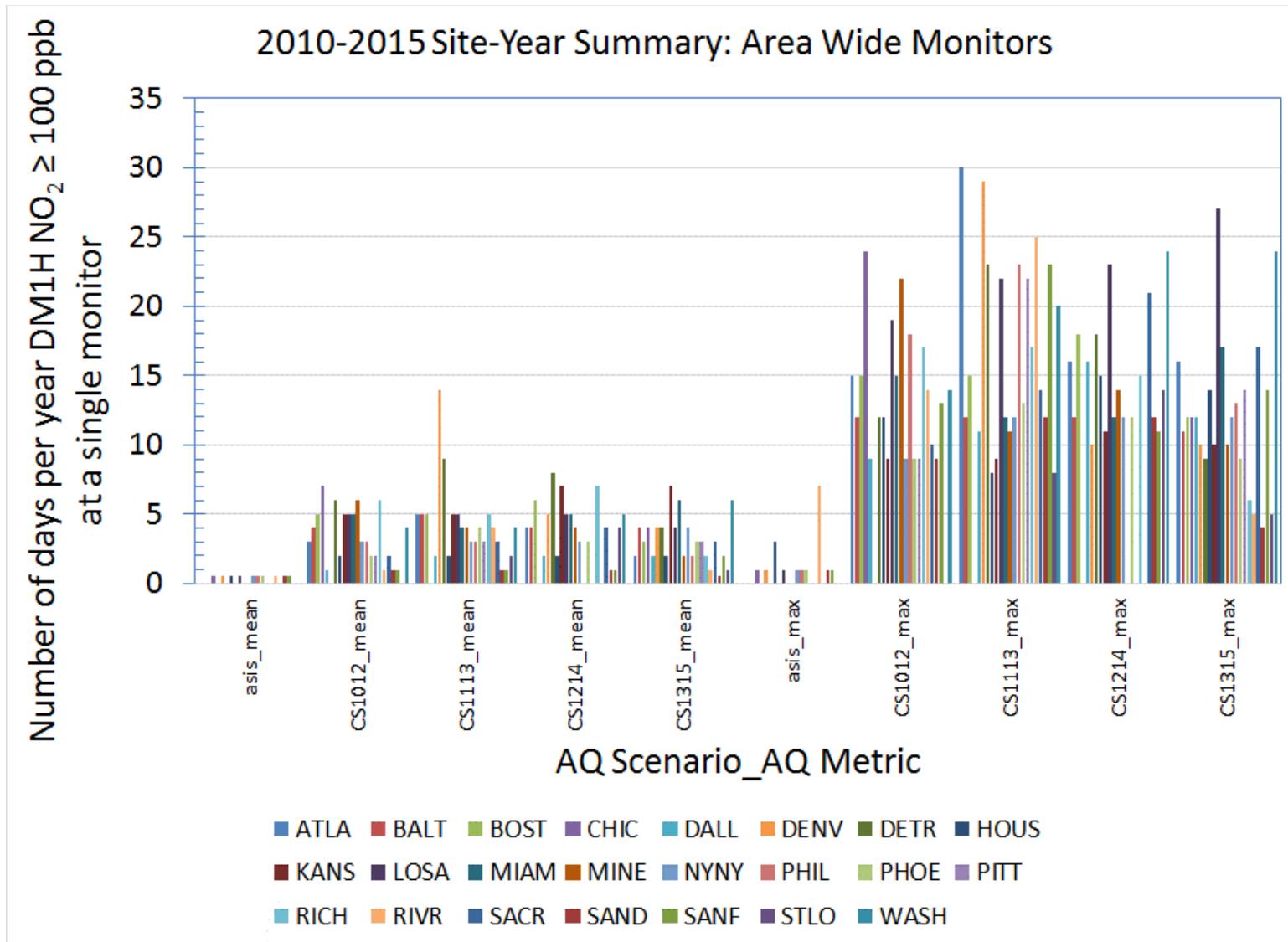
²⁹ A few study areas had 2013 data, many more had 2014 data, while all had but one (Chicago) had 2015 data. Where available, 2013 data were included in the analysis and generation of results though the focus of the near-road and on-road analysis is on 2014-15.

1 considering the complete suite of monitors in each study area, the elements of the 1-hr standard,
2 and the procedure used to adjust air quality, as discussed above.

3 Figure B3-3 presents the results for the site-year metric, considering the near-road
4 monitors only. Note that where a value does not appear in this figure for a particular study area
5 and considering the unadjusted (as is) air quality, in all instances, that is because it is equal to
6 zero (i.e., no benchmark exceedances) because all study areas had measured concentrations at
7 some time during the 2010-2015 data analysis period. Where a value does not appear in this
8 figure for a particular study area and considering the adjusted air quality scenarios, in all but one
9 instance,³⁰ that is because there were no near-road data available in that 3-year averaging period.
10 Therefore, in considering these results, compared with the results generated using the area-wide
11 monitors (Figure B3-2), inferences should be limited to results generated using the unadjusted
12 concentrations, and the 2013-2015 3-year averaging period.

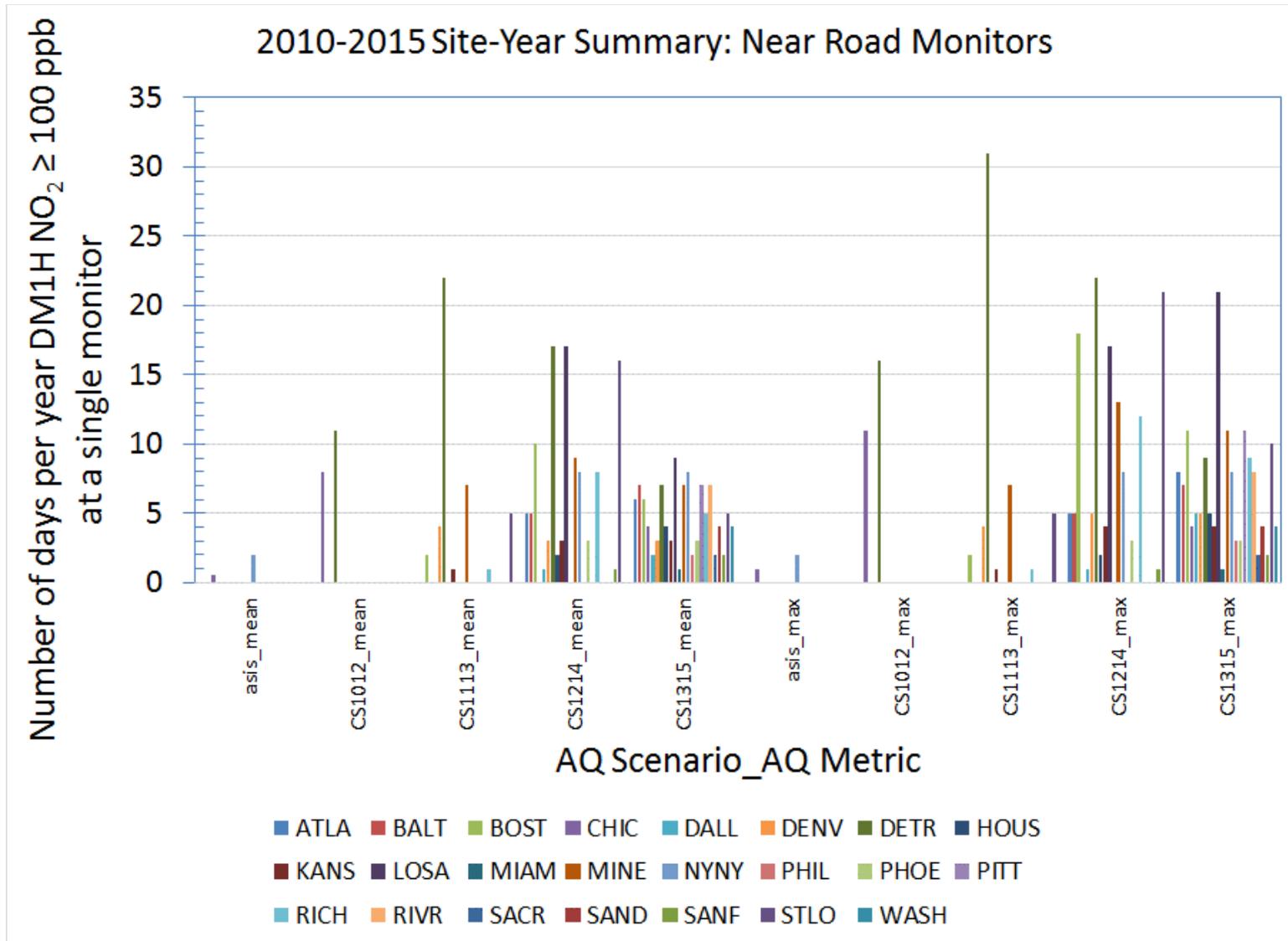
13 There were very few simulated on-road concentrations at or above the 1-hour 100 ppb
14 benchmark considering the unadjusted as is air quality (results not shown). Only the Chicago,
15 Denver, Los Angeles, Miami, New York/Jersey, and Riverside study areas were estimated to
16 have at least one day in the monitored year, with the New York/Jersey study area also having one
17 day per year at or above the 150 and 200 ppb benchmark levels (data shown in Table B5-58).
18 Figure B3-4 and Figure B3-5 show the number of days where the simulated on-road DM1H NO₂
19 concentration was at or above the 100 ppb benchmark considering 2014 and 2015 air quality
20 adjusted to just meet the existing 1-hour standard, respectively. In general, most study areas had
21 between 10 to 20 days in the year ≥ 100 ppb and there was limited variability in the range of
22 values estimated using the three simulation factors. Of the few study areas having > 20 days in
23 the year, Baltimore, Minneapolis, Pittsburgh, and Richmond required some of the greatest
24 upward adjustments to simulate just meeting the existing standard, i.e., adjustment factors used
25 in these study areas were ≥ 2 (Table B2-5), while most other study area adjustment factors were
26 generally within 1.5 to 1.9. In addition, the Minneapolis study area used the highest on-road
27 simulation factors because both monitors were sited about 30 meters from the road (Table B2-9).

³⁰ The Chicago study area had no (zero) days per year with a DM1H ≥ 100 ppb during the 2011-2013 3-year averaging period.



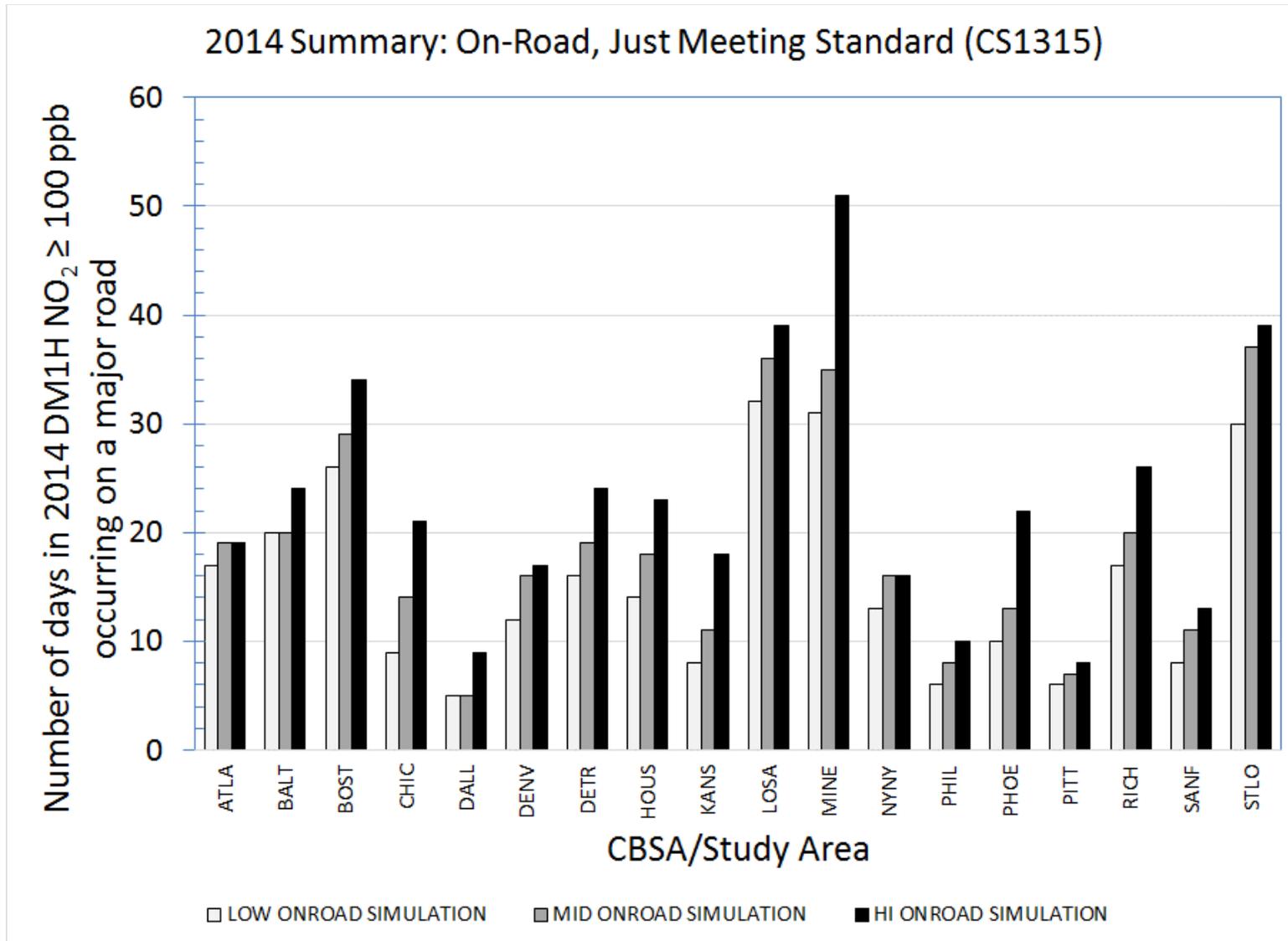
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2 **Figure B3-2. Mean and maximum number of days per year where DM1H NO₂ concentration at or above 100 ppb: 2010-2015**
 3 **area-wide monitor site-year summary.**

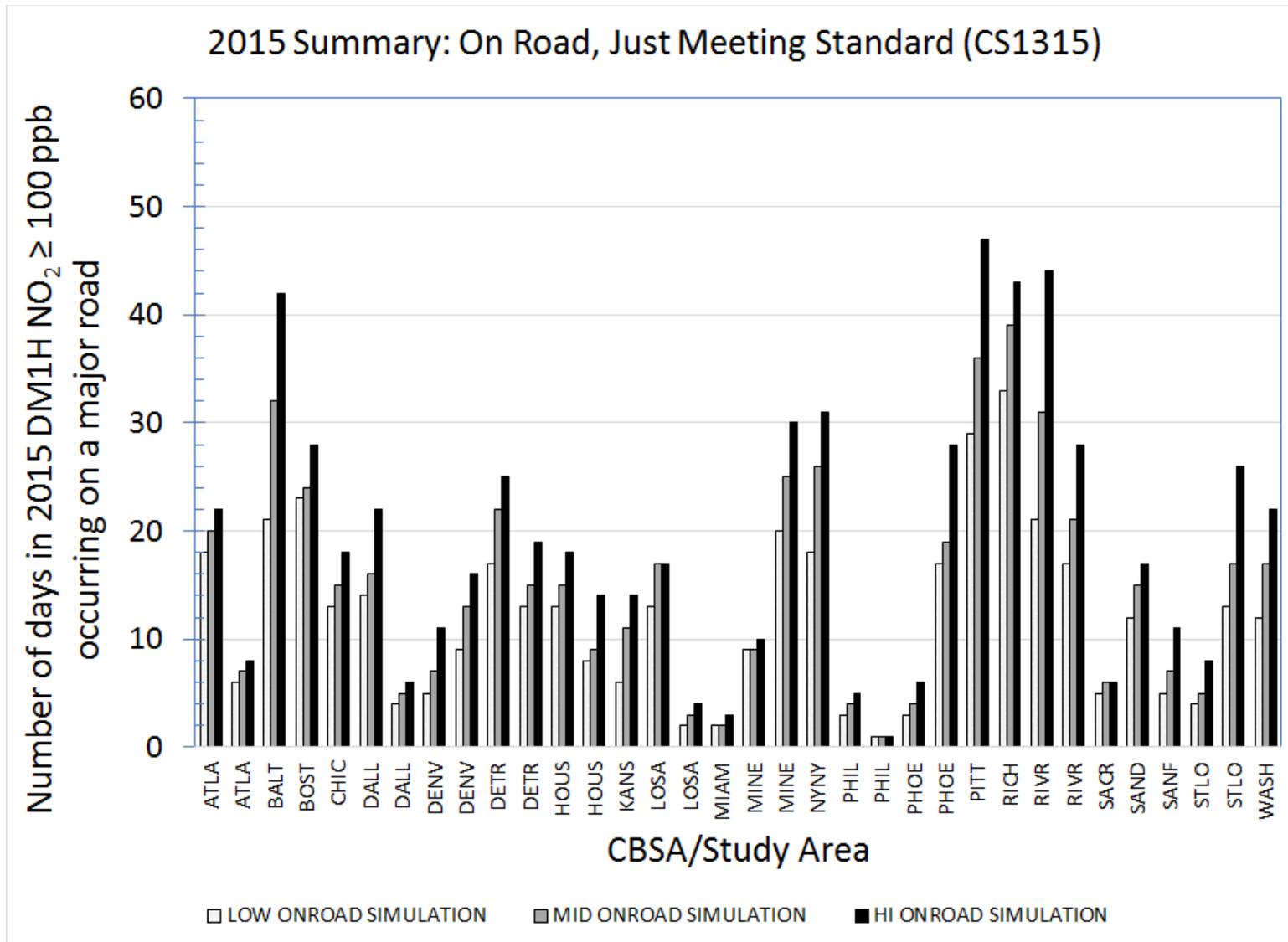


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2 **Figure B3-3. Mean and maximum number of days per year where DM1H NO₂ concentration at or above 100 ppb: 2010-2015**
 3 **near-road monitor site-year summary.**



1
 2 **Figure B3-4. Number of days in the year where DM1H NO₂ concentration at or above 100 ppb: simulated on-road**
 3 **concentrations (2014) based on near-road monitor data and using three simulation factors.**



1
 2 **Figure B3-5. Number of days in the year where DM1H NO₂ concentration at or above 100 ppb: simulated on-road**
 3 **concentrations (2015) based on near-road monitor data and using three simulation factors.**

1 As expected, there were a greater number of benchmark exceedances considering the
2 CBSA-wide metric (Figure B3-6) compared to results generated using the site-year metric
3 (Figure B3-2 and Figure B3-3). This is because the CBSA-wide metric accounts for the total
4 number of days in the study area when DM1H NO₂ concentrations go above benchmark levels,
5 not just those estimated to occur at a single monitor at a time but considering all monitors
6 simultaneously operating in the study area. The difference between the two result metrics is an
7 indicator of how the peak NO₂ concentrations vary by day across the study area, and in most
8 instances, the variability is driven by the highest concentrations occurring at the area design
9 value monitor and/or the near-road monitor within a study area. On average, most study areas
10 had about 10 to 15 days per year at or above the 100 ppb benchmark, while the maximum
11 number of days per year was about 20 when considering the CBSA-wide metric, generally about
12 a factor or two greater than that estimated using the site-year metric. The number days per year
13 where DM1H NO₂ concentrations were at or above benchmark levels and occurring at more than
14 one site on the same day was much less; on average 3 days per year DM1H NO₂ concentrations
15 were at or above 100 ppb, while the maximum number of days per year was about 5 (Figure
16 B3-7), thus indicating simultaneous-site exceedances about a third or less of the time there was at
17 least one day at or above 100 ppb.

18 The CBSA-wide metric was also expanded to include the benchmark exceedances
19 resulting from the simulated on-road concentrations (Figure B3-8) in addition to consideration of
20 the near-road and area-wide CBSA-wide results discussed above. Because the majority of near-
21 road data were from 2014-2015, only the results for the 2013-2015 3-year averaging period are
22 shown. CBSA-wide results considering the area-wide and near-road monitors (Figure B3-8, top
23 panels) are identical to that shown in Figure B3-6 and Figure B3-7 for that 3-year averaging
24 period. They were reproduced in this figure for comparison with the CBSA-wide results that also
25 include exceedances from all three concentration types (i.e., area-wide, near-road, and simulated
26 on-road) (Figure B3-8, bottom panels). For most study areas, there were about 5 to 10 additional
27 days per year in the CBSA (on average and for the maximum) having concentrations at or above
28 the 100 ppb benchmark level, when including the simulated on-road concentrations to the
29 CBSA-wide metric (visually compare the top left to bottom left panels Figure B3-8). Again,
30 there fewer days per year where concentrations are at or above the 100 ppb benchmark level and
31 occurring at two or more locations on the same day (e.g., at both an area-wide and near-road
32 monitor), though when including the simulated on-road concentrations in the CBSA-wide metric
33 (Figure B3-8, bottom right panel), the number of occurrences is about twice that of the results
34 generated using the area-wide and near-road data alone (Figure B3-8, top right panel)

35

1 **3.3 UNCERTAINTY CHARACTERIZATION**

2 Overall, there were a number of assumptions made in this AQC, potentially leading to
3 uncertainty in the results. Assumptions were well informed and controlled to reduce uncertainties
4 to the maximum extent possible such as, 1) selection of study areas having the greatest number
5 of monitors and highest concentrations, thereby reducing the uncertainty in the spatial
6 representation of ambient concentrations and adjustments made to meet the existing standards, 2)
7 a systematic selection of the most appropriate factors used to adjust concentrations to just meet
8 the existing standard considering both the varying degree of completeness of the area-wide
9 monitors and the limited availability of near-road monitor concentrations, and 3) the use of
10 newly designated near-road monitor data to best characterize near-road and on-road
11 concentrations.

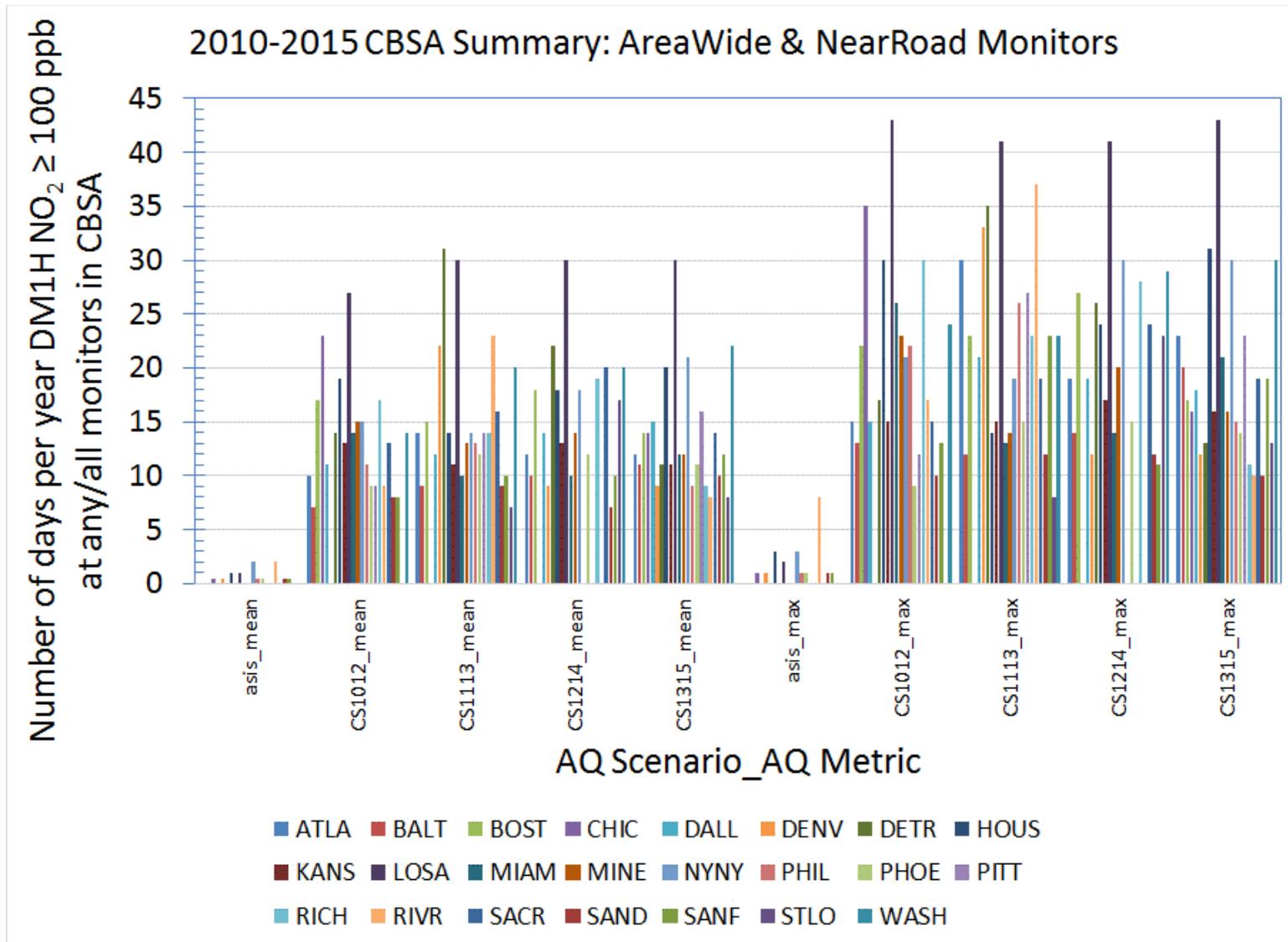
12 The direction of influence these assumptions and modeling approaches could have on the
13 results of this AQC would vary, and be marked as either under- or over-estimations in
14 concentrations and number of days at or above benchmark levels, while also potentially having
15 varied magnitudes. For instance, it is a worthwhile reminder that in some study areas, the near-
16 road monitor did not have a full monitoring year of data (e.g., in 2014 the NYNJ CBSA near-
17 road monitor had concentrations for 184 days). Depending on the time of year and hour of days
18 concentrations were recorded for that or any other near-road monitor having an incomplete year
19 (e.g., maximum concentrations typically occur during the fall/winter early morning weekday
20 commute hours), it is possible that having a full year of near-road data could lead to a different
21 number of benchmark exceedances for each of the summary calculations presented here. In the
22 absence of having a robust data near-road dataset describing more specifically when or where
23 peak concentrations would occur (the particular days or periods of the year), we felt at this early
24 stage of the monitor implementation it was best to characterize the near-road data and simulated
25 on-road concentrations simply using the actual number of monitored days in the year rather than
26 including predicted concentrations for the days the near-road monitor was not in operation.

27 Another important uncertainty regards the design values used to generate factors for
28 adjusting concentrations to just meet the existing standard. Individual results presented for St.
29 Louis (section 2.4.3) indicated that small variation in adjustment factors used (COV of ~5%)
30 could have a much greater effect (i.e., a factor of two) in the estimated number of days at or
31 above the 100 ppb benchmark, even considering the same distribution of ambient concentrations.
32 While appropriate steps were taken to account for instances where the highest monitor in
33 operation was included in the calculation of these adjustment factors, having a very limited
34 number of years (or even days in a year) available for the near-road monitors in most instances
35 led to the use of area-wide monitor design values to calculate the adjustment factors. It is
36 possible that having complete year data for the near-road monitors in each of the study areas

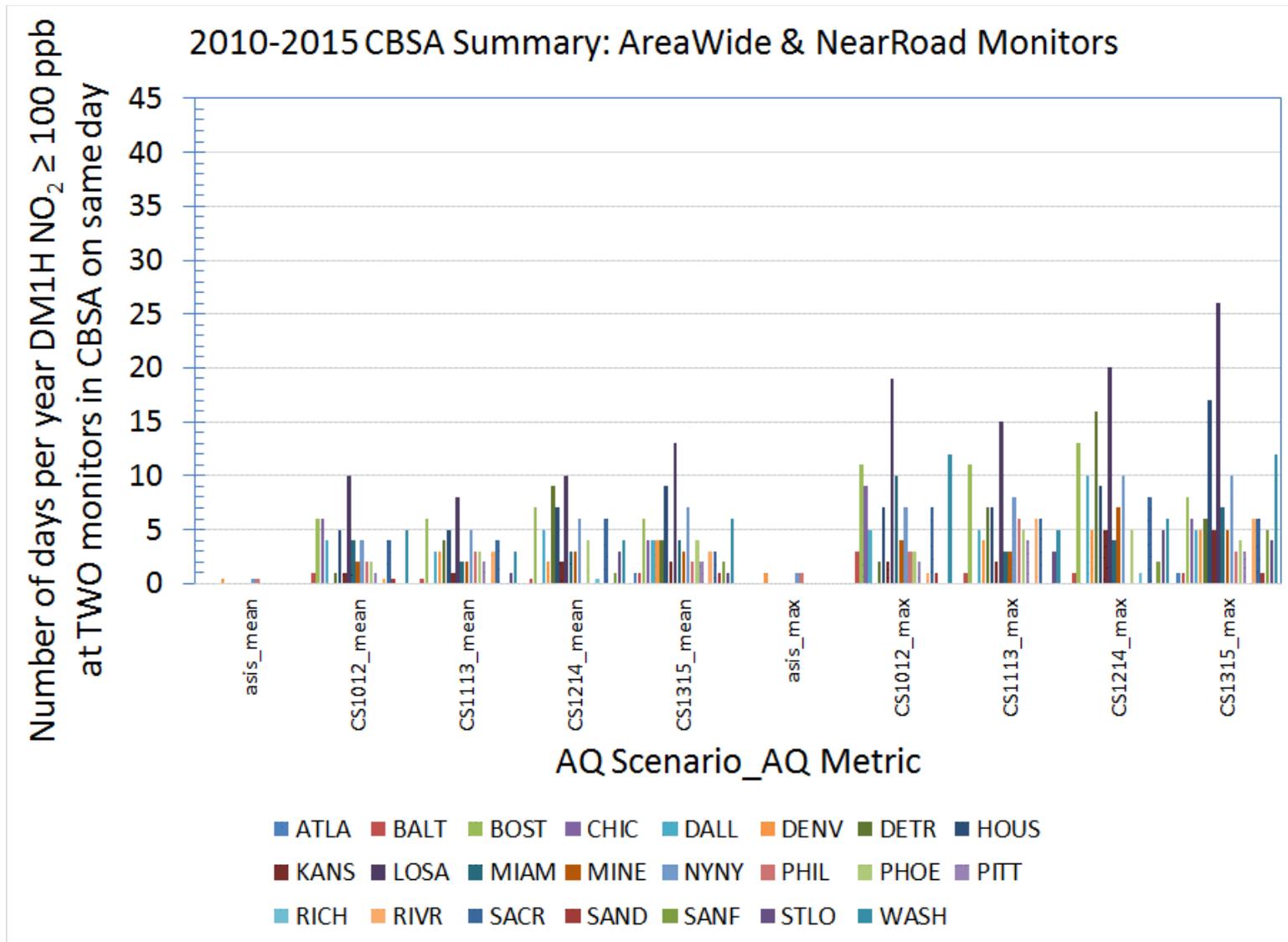
1 could result their use as the area design value monitor, such as what has been realized during the
2 2013-15 averaging period in the Detroit and St. Louis study areas. By not having several
3 complete years of near-road data available for this analysis, it is possible that both near-road and
4 on-road concentrations are overestimated, particularly in instances where available comparisons
5 indicate the area design value monitor concentrations are less than that at the near-road monitor.
6 Further contributing to the uncertainty in adjusted concentrations were inconsistencies in the area
7 design value monitor in some study area (e.g., Philadelphia) due to absence of meeting
8 completeness criteria across several averaging periods. Often times, pseudo single-year design
9 values were calculated from the highest available monitor (sometime near-road other time near-
10 road) and used to estimate the adjustment factors to overcome this uncertainty, other times the
11 adjustment factor was not used and the period was not simulated.

12 It is also possible that the upper (>98th) percentile DM1H ratios developed from the area
13 design value monitor and used to adjust upper percentile concentrations for the near-road
14 monitors (and hence, on-road concentrations) could lead to undesired variability in near-road and
15 on-road concentrations. However, when comparing the ratio values derived from the area design
16 value monitor to ratios observed at the other area-wide monitors within each study area, the
17 majority fell within the range exhibited by the area-wide monitors, suggesting the magnitude of
18 influence is limited. Even when ratios derived from the area design value monitor were at the
19 maximum range of values, they are considered reasonable approximations, because in most
20 areas, the observed variability in the upper percentile concentrations at the near-road monitors is
21 expected to be similar to that observed at the highest monitors in the study areas.

22 And finally, as mentioned earlier in describing the approach to simulating on-road
23 concentrations using factors derived from a statistical model along with the near-road monitored
24 concentrations, in some instances could lead to overestimations in the estimated number of days
25 at or above the benchmark levels occurring on-roads. This is in part because the model-derived
26 factors used assume concentrations on-roads are always greater than those occurring away from
27 roads. It is possible that for some near-road monitors sited in close proximity to the road (i.e.,
28 within 10 meters), that measured near-road concentrations reasonably approximate
29 concentrations occurring on-roads. Further, while a range of on-road simulation factors were
30 used to represent potentially important influential conditions (e.g., atmospheric stability and
31 wind direction), the application of the factors was candid, not accounting for the complexities
32 associated with these conditions at each monitor for every hour measurements were recorded.
33 This along with not accounting for the variability in the estimated factors (the mean of each the
34 low, mid and high conditions was used rather than the full distribution of values) would also
35 contribute to uncertainty in the estimated concentrations, likely resulting in both under and over
36 estimations.

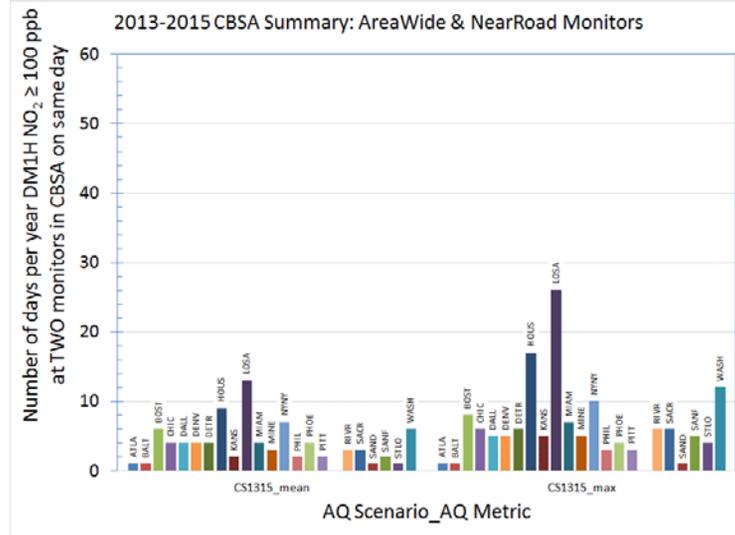
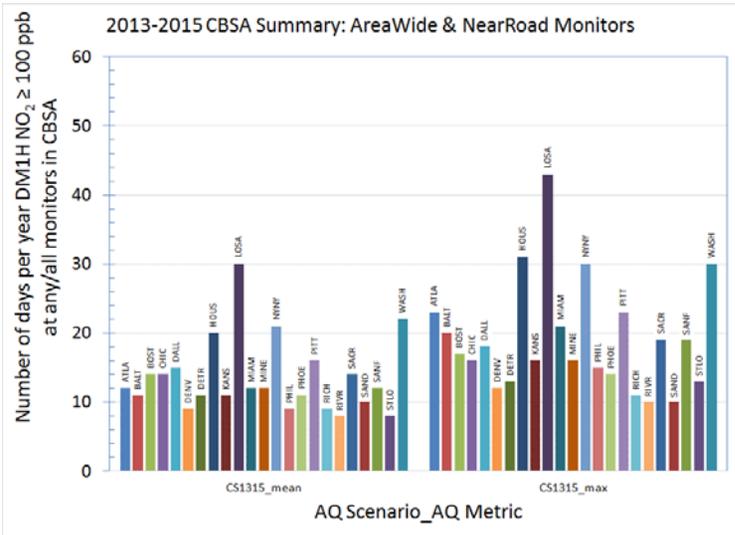


1
 2 **Figure B3-6. Mean and maximum number of days per year where DM1H NO₂ concentration at or above 100 ppb at any site:**
 3 **2010-2015 CBSA-wide summary using area-wide and near-road monitors.**

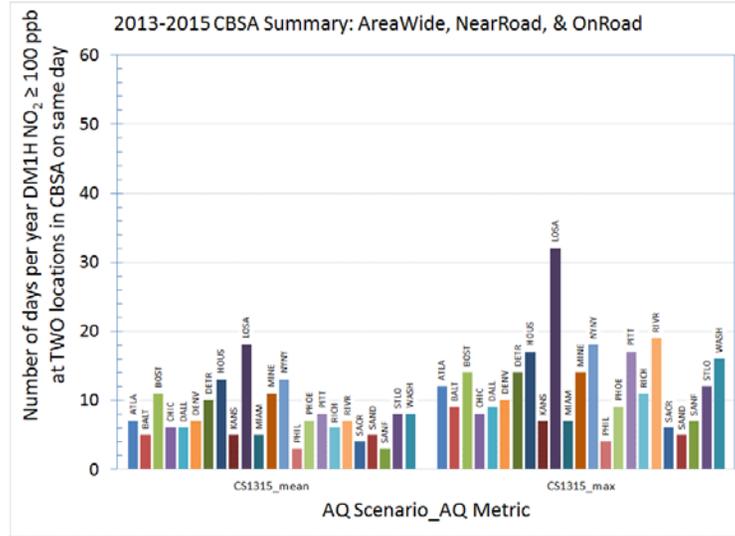
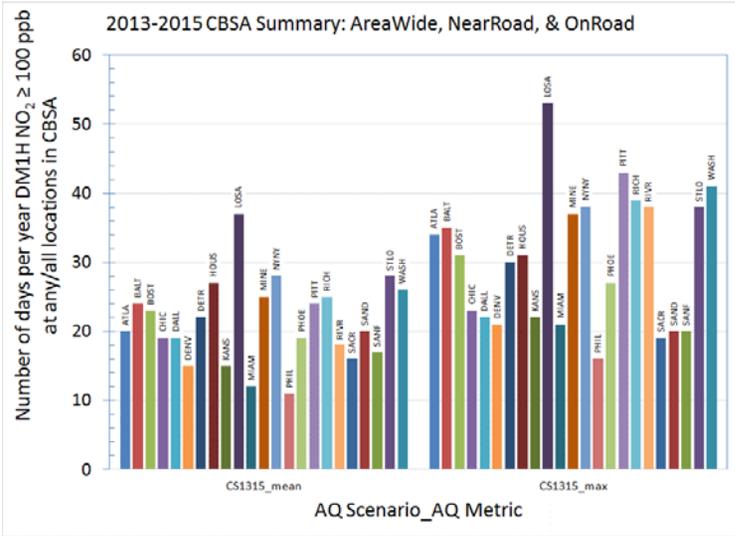


1
 2 **Figure B3-7. Mean and maximum number of days per year where DM1H NO₂ concentration at or above 100 ppb at more than**
 3 **one location on the same day: 2010-2015 CBSA-wide summary using area-wide and near-road monitors.**

1



2



3 **Figure B3-8. Mean and maximum number of days per year where DM1H NO₂ concentration at or above 100 ppb: CBSA-wide**
 4 **summary using area-wide and near-road monitors (top panels), using area-wide, near-road, and on-road (bottom panels), at**
 5 **any location (left panels), at more than one location on the same day (right panels).**

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1 **B5. SUPPLEMENTAL DATA**

2 **5.1 CBSA RANKED NO_x EMISSION TABLES FOR TOP 20 FACILITY**
 3 **TYPES**

4 **Table B5-1. CBSA ranked NO_x emissions for top 20 facility types: electricity via**
 5 **combustion and airports.**

1. Electricity Generation via Combustion		2. Airports	
CBSA	NO _x (tpy)	CBSA	NO _x (tpy)
Kansas City, MO-KS	22053	New York-Newark-Jersey City, NY-NJ-PA	9396
Pittsburgh, PA	19492	Los Angeles-Long Beach-Anaheim, CA	6713
Farmington, NM	17204	Chicago-Naperville-Elgin, IL-IN-WI	6424
York-Hanover, PA	16965	Miami-Fort Lauderdale-West Palm Beach, FL	5518
Urban Honolulu, HI	16330	San Francisco-Oakland-Hayward, CA	4266
Paducah, KY-IL	15825	Dallas-Fort Worth-Arlington, TX	4171
Louisville/Jefferson County, KY-IN	14108	Washington-Arlington-Alexandria, DC-VA-MD-WV	3214
Rock Springs, WY	13179	Houston-The Woodlands-Sugar Land, TX	3178
St. Louis, MO-IL	12118	Memphis, TN-MS-AR	3173
Bismarck, ND	11366	Denver-Aurora-Lakewood, CO	3153
Denver-Aurora-Lakewood, CO	11310	Phoenix-Mesa-Scottsdale, AZ	2789
Birmingham-Hoover, AL	11091	Seattle-Tacoma-Bellevue, WA	2733
Chicago-Naperville-Elgin, IL-IN-WI	10251	Las Vegas-Henderson-Paradise, NV	2541
Jacksonville, FL	9757	Charlotte-Concord-Gastonia, NC-SC	2435
Detroit-Warren-Dearborn, MI	9431	Orlando-Kissimmee-Sanford, FL	2352
New York-Newark-Jersey City, NY-NJ-PA	9007	Detroit-Warren-Dearborn, MI	2326
San Antonio-New Braunfels, TX	8845	Minneapolis-St. Paul-Bloomington, MN-WI	2287
Milwaukee-Waukesha-West Allis, WI	6906	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2260
Lake Charles, LA	6505	Boston-Cambridge-Newton, MA-NH	2216
Cincinnati, OH-KY-IN	6490	Urban Honolulu, HI	1758

6 Highlighted are those selected as study areas.

7

1 **Table B5-2. CBSA ranked NO_x emissions for top 20 facility types: chemical plants and**
 2 **petroleum refineries.**

3. Chemical Plant		4. Petroleum Refineries	
CBSA	NO _x (tpy)	CBSA	NO _x (tpy)
Houston-The Woodlands-Sugar Land, TX	12719	Houston-The Woodlands-Sugar Land, TX	7971
Baton Rouge, LA	10345	Beaumont-Port Arthur, TX	5554
Kingsport-Bristol-Bristol, TN-VA	9113	Lake Charles, LA	4726
Beaumont-Port Arthur, TX	6778	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	4533
Rochester, NY	2610	Los Angeles-Long Beach-Anaheim, CA	3918
Lake Charles, LA	2590	San Francisco-Oakland-Hayward, CA	3204
Marshall, TX	2031	Mount Vernon-Anacortes, WA	2983
Memphis, TN-MS-AR	1267	Chicago-Naperville-Elgin, IL-IN-WI	2548
New Orleans-Metairie, LA	1053	Baton Rouge, LA	2253
Chicago-Naperville-Elgin, IL-IN-WI	695	Gulfport-Biloxi-Pascagoula, MS	2177
Cincinnati, OH-KY-IN	688	Vallejo-Fairfield, CA	1969
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	570	Minneapolis-St. Paul-Bloomington, MN-WI	1296
Paducah, KY-IL	336	Urban Honolulu, HI	1272
Indianapolis-Carmel-Anderson, IN	175	New York-Newark-Jersey City, NY-NJ-PA	1143
Cleveland-Elyria, OH	165	Huntington-Ashland, WV-KY-OH	1023
St. Louis, MO-IL	158	Tulsa, OK	987
Baltimore-Columbia-Towson, MD	150	Salt Lake City, UT	703
Los Angeles-Long Beach-Anaheim, CA	136	Denver-Aurora-Lakewood, CO	670
Jacksonville, FL	114	El Paso, TX	628
San Francisco-Oakland-Hayward, CA	111	Memphis, TN-MS-AR	532

3 Highlighted are those selected as study areas.

1 **Table B5-3. CBSA ranked NO_x emissions for top 20 facility types: Portland cement**
 2 **manufacturing and mines/quarries.**

5. Portland Cement Manufacturing		6. Mines/Quarries	
CBSA	NO _x (tpy)	CBSA	NO _x (tpy)
Riverside-San Bernardino-Ontario, CA	4831	Gillette, WY	28560
Allentown-Bethlehem-Easton, PA-NJ	3621	Salt Lake City, UT	4478
San Antonio-New Braunfels, TX	3439	Rock Springs, WY	446
Bakersfield, CA	3390	Birmingham-Hoover, AL	386
Dallas-Fort Worth-Arlington, TX	3077	Cheyenne, WY	154
Austin-Round Rock, TX	2245	Riverside-San Bernardino-Ontario, CA	125
Birmingham-Hoover, AL	1819	Las Vegas-Henderson-Paradise, NV	118
San Jose-Sunnyvale-Santa Clara, CA	1755	Riverton, WY	92
Miami-Fort Lauderdale-West Palm Beach, FL	1663	Urban Honolulu, HI	69
Tucson, AZ	1634	Cleveland-Elyria, OH	68
Davenport-Moline-Rock Island, IA-IL	1605	Glenwood Springs, CO	54
Reading, PA	1225	Nashville-Davidson--Murfreesboro--Franklin, TN	25
Louisville/Jefferson County, KY-IN	1097	Carlsbad-Artesia, NM	21
Seattle-Tacoma-Bellevue, WA	918	Minneapolis-St. Paul-Bloomington, MN-WI	20
Rapid City, SD	900	Casper, WY	19
Albuquerque, NM	718	Worcester, MA-CT	16
Kansas City, MO-KS	647	Baltimore-Columbia-Towson, MD	14
Waco, TX	465	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	11
York-Hanover, PA	158	Kansas City, MO-KS	10
Bozeman, MT	13	San Diego-Carlsbad, CA	9

3 Highlighted are those selected as study areas.

4

1 **Table B5-4. CBSA ranked NO_x emissions for top 20 facility types: rail yards and**
 2 **compressor stations.**

7. Rail Yard		8. Compressor Station	
CBSA	NO _x (tpy)	CBSA	NO _x (tpy)
Chicago-Naperville-Elgin, IL-IN-WI	3005	Hobbs, NM	5208
Memphis, TN-MS-AR	2022	Glenwood Springs, CO	4516
Houston-The Woodlands-Sugar Land, TX	1950	Farmington, NM	3105
Dallas-Fort Worth-Arlington, TX	1714	Gillette, WY	2358
Kansas City, MO-KS	1714	Oklahoma City, OK	2135
Riverside-San Bernardino-Ontario, CA	1264	Rock Springs, WY	1725
Austin-Round Rock, TX	1197	Riverside-San Bernardino-Ontario, CA	1648
Salt Lake City, UT	1180	Indianapolis-Carmel-Anderson, IN	1583
St. Louis, MO-IL	867	Dallas-Fort Worth-Arlington, TX	1198
Atlanta-Sandy Springs-Roswell, GA	856	Denver-Aurora-Lakewood, CO	659
Buffalo-Cheektowaga-Niagara Falls, NY	757	Carlsbad-Artesia, NM	639
Denver-Aurora-Lakewood, CO	662	Baton Rouge, LA	610
Birmingham-Hoover, AL	661	Birmingham-Hoover, AL	509
Cincinnati, OH-KY-IN	636	Harrisburg-Carlisle, PA	502
Portland-Vancouver-Hillsboro, OR-WA	595	Athens, OH	501
Stockton-Lodi, CA	569	Chicago-Naperville-Elgin, IL-IN-WI	482
Sacramento--Roseville--Arden-Arcade, CA	557	Marshall, TX	481
Little Rock-North Little Rock-Conway, AR	550	Reading, PA	444
Pittsburgh, PA	547	York-Hanover, PA	444
Beaumont-Port Arthur, TX	540	Riverton, WY	392

3 Highlighted are those selected as study areas.

4

1 **Table B5-5. CBSA ranked NO_x emissions for top 20 facility types: sources not**
 2 **characterized and municipal waste combustors.**

9. Not Characterized		10. Municipal Waste Combustor	
CBSA	NO _x (tpy)		NO _x (tpy)
Chicago-Naperville-Elgin, IL-IN-WI	3827	Miami-Fort Lauderdale-West Palm Beach, FL	4994
Riverside-San Bernardino-Ontario, CA	1539	New York-Newark-Jersey City, NY-NJ-PA	3058
New York-Newark-Jersey City, NY-NJ-PA	1464	Tampa-St. Petersburg-Clearwater, FL	2552
Baltimore-Columbia-Towson, MD	1456	Boston-Cambridge-Newton, MA-NH	2494
Pensacola-Ferry Pass-Brent, FL	1365	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2308
Minneapolis-St. Paul-Bloomington, MN-WI	1004	Detroit-Warren-Dearborn, MI	1617
Los Angeles-Long Beach-Anaheim, CA	891	Bridgeport-Stamford-Norwalk, CT	1220
Santa Maria-Santa Barbara, CA	838	Baltimore-Columbia-Towson, MD	1184
Bakersfield, CA	693	Indianapolis-Carmel-Anderson, IN	1076
Austin-Round Rock, TX	667	Hartford-West Hartford-East Hartford, CT	1064
San Francisco-Oakland-Hayward, CA	614	Urban Honolulu, HI	1043
Denver-Aurora-Lakewood, CO	588	Worcester, MA-CT	865
Dallas-Fort Worth-Arlington, TX	567	Minneapolis-St. Paul-Bloomington, MN-WI	594
Miami-Fort Lauderdale-West Palm Beach, FL	548	Lancaster, PA	577
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	534	Tulsa, OK	564
Houston-The Woodlands-Sugar Land, TX	529	York-Hanover, PA	498
Las Vegas-Henderson-Paradise, NV	528	Washington-Arlington-Alexandria, DC-VA-MD-WV	471
Baton Rouge, LA	497	Los Angeles-Long Beach-Anaheim, CA	424
San Diego-Carlsbad, CA	492	Modesto, CA	317
Rock Springs, WY	491	Ogden-Clearfield, UT	261

3 Highlighted are those selected as study areas.

4

1 **Table B5-6. CBSA ranked NO_x emissions for top 20 facility types: steel mills and gas**
 2 **plants.**

11. Steel Mill		12. Gas Plant	
CBSA	NO _x (tpy)	CBSA	NO _x (tpy)
Chicago-Naperville-Elgin, IL-IN-WI	10939	Hobbs, NM	5051
Detroit-Warren-Dearborn, MI	2776	Farmington, NM	4053
Pittsburgh, PA	1886	Rock Springs, WY	1404
Cleveland-Elyria, OH	1291	Gillette, WY	1041
Huntington-Ashland, WV-KY-OH	1243	Longview, TX	571
Baltimore-Columbia-Towson, MD	1166	Carlsbad-Artesia, NM	556
Birmingham-Hoover, AL	1095	Evanston, WY	392
Harrisburg-Carlisle, PA	310	Bakersfield, CA	372
Dallas-Fort Worth-Arlington, TX	298	Riverton, WY	359
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	261	Baton Rouge, LA	274
Reading, PA	239	Beaumont-Port Arthur, TX	259
El Paso, TX	234	Marshall, TX	212
Beaumont-Port Arthur, TX	230	San Antonio-New Braunfels, TX	198
Seattle-Tacoma-Bellevue, WA	205	Kingsport-Bristol-Bristol, TN-VA	162
Portland-Vancouver-Hillsboro, OR-WA	193	Dallas-Fort Worth-Arlington, TX	160
Fort Wayne, IN	170	Casper, WY	145
Memphis, TN-MS-AR	125	Oklahoma City, OK	128
Longview, TX	113	Cheyenne, WY	98
Jacksonville, FL	78	Houston-The Woodlands-Sugar Land, TX	88
Charlotte-Concord-Gastonia, NC-SC	53	Minneapolis-St. Paul-Bloomington, MN-WI	63

3 Highlighted are those selected as study areas.
 4

1 **Table B5-7. CBSA ranked NO_x emissions for top 20 facility types: mineral processing**
 2 **plants and pulp and paper plants.**

13. Mineral Processing Plant		14. Pulp and Paper Plant	
CBSA	NO _x (tpy)	CBSA	NO _x (tpy)
Rock Springs, WY	7689	Columbia, SC	2036
Riverside-San Bernardino-Ontario, CA	1872	York-Hanover, PA	1721
Las Vegas-Henderson-Paradise, NV	1200	Pensacola-Ferry Pass-Brent, FL	1654
State College, PA	940	Duluth, MN-WI	1255
Corsicana, TX	705	Baton Rouge, LA	1132
Detroit-Warren-Dearborn, MI	547	Charleston-North Charleston, SC	952
Manitowoc, WI	389	Kingsport-Bristol-Bristol, TN-VA	818
Fort Smith, AR-OK	221	Beaumont-Port Arthur, TX	752
Bakersfield, CA	159	Portland-South Portland, ME	463
Cincinnati, OH-KY-IN	60	Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	459
Little Rock-North Little Rock-Conway, AR	44	Riverside-San Bernardino-Ontario, CA	140
Baltimore-Columbia-Towson, MD	26	Memphis, TN-MS-AR	125
Salinas, CA	22	Cincinnati, OH-KY-IN	117
Boston-Cambridge-Newton, MA-NH	18	Dallas-Fort Worth-Arlington, TX	74
Chicago-Naperville-Elgin, IL-IN-WI	16	San Jose-Sunnyvale-Santa Clara, CA	68
Minneapolis-St. Paul-Bloomington, MN-WI	5	Reading, PA	61
Tampa-St. Petersburg-Clearwater, FL	5	New York-Newark-Jersey City, NY-NJ-PA	59
Los Angeles-Long Beach-Anaheim, CA	4	Owensboro, KY	59
Oxnard-Thousand Oaks-Ventura, CA	4	Oxnard-Thousand Oaks-Ventura, CA	55
Glenwood Springs, CO	2	Tulsa, OK	52

3 Highlighted are those selected as study areas.

4

1 **Table B5-8. CBSA ranked NO_x emissions for top 20 facility types: institutional (e.g.,**
 2 **schools, hospitals, prisons) and gas plants.**

15. Institutional (school, hospital, prison, etc.)		16. Glass Plant	
CBSA	NO _x (tpy)	CBSA	NO _x (tpy)
Chicago-Naperville-Elgin, IL-IN-WI	797	Corsicana, TX	2364
New York-Newark-Jersey City, NY-NJ-PA	769	Pittsburgh, PA	1128
Lansing-East Lansing, MI	739	Nashville-Davidson--Murfreeseboro--Franklin, TN	850
Nashville-Davidson--Murfreeseboro--Franklin, TN	602	Waco, TX	781
South Bend-Mishawaka, IN-MI	580	Fresno, CA	619
Worcester, MA-CT	347	Jacksonville, FL	484
Fairbanks, AK	339	Chicago-Naperville-Elgin, IL-IN-WI	464
Los Angeles-Long Beach-Anaheim, CA	294	Portland-Vancouver-Hillsboro, OR-WA	407
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	287	Stockton-Lodi, CA	404
Boston-Cambridge-Newton, MA-NH	279	Atlanta-Sandy Springs-Roswell, GA	350
Minneapolis-St. Paul-Bloomington, MN-WI	269	San Francisco-Oakland-Hayward, CA	328
State College, PA	258	Madera, CA	327
Lexington-Fayette, KY	251	Seattle-Tacoma-Bellevue, WA	299
Denver-Aurora-Lakewood, CO	231	Worcester, MA-CT	230
Cincinnati, OH-KY-IN	198	Modesto, CA	195
Portland-South Portland, ME	197	Los Angeles-Long Beach-Anaheim, CA	70
San Francisco-Oakland-Hayward, CA	175	Houston-The Woodlands-Sugar Land, TX	42
Washington-Arlington-Alexandria, DC-VA-MD-WV	175	Providence-Warwick, RI-MA	36
Baltimore-Columbia-Towson, MD	148	Tulsa, OK	10
Provo-Orem, UT	131	Charleston-North Charleston, SC	4

3 Highlighted are those selected as study areas.

4

1 **Table B5-9. CBSA ranked NO_x emissions for top 20 facility types: chlor-alkali plants and**
 2 **fertilizer plants.**

17. Chlor-Alkali Plant		18. Fertilizer Plant	
CBSA	NO _x (tpy)	CBSA	NO _x (tpy)
Lake Charles, LA	6194	Baton Rouge, LA	3793
Wichita, KS	508	Cheyenne, WY	1718
Baton Rouge, LA	170	Gulfport-Biloxi-Pascagoula, MS	322
Cleveland, TN	44	Tampa-St. Petersburg-Clearwater, FL	319
Houston-The Woodlands-Sugar Land, TX	18	Pittsburgh, PA	243
Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	2	Rock Springs, WY	132
		Provo-Orem, UT	106
		Carlsbad-Artesia, NM	74
		Sacramento--Roseville--Arden-Arcade, CA	36
		Cincinnati, OH-KY-IN	19
		Salisbury, MD-DE	16
		Fresno, CA	15
		Houston-The Woodlands-Sugar Land, TX	12
		Riverside-San Bernardino-Ontario, CA	4
		Stockton-Lodi, CA	3
		Chico, CA	1
		Merced, CA	1
		Nashville-Davidson--Murfreesboro--Franklin, TN	1
		Vallejo-Fairfield, CA	1
		Winston-Salem, NC	1

3 Highlighted are those selected as study areas.

4

1 **Table B5-10. CBSA ranked NO_x emissions for top 20 facility types: coke battery and**
 2 **plastic, resin, or rubber product plants.**

19. Coke Battery		20. Plastic, Resin, or Rubber Products Plant	
CBSA	NO _x (tpy)	CBSA	NO _x (tpy)
Pittsburgh, PA	3502	Baton Rouge, LA	2009
Birmingham-Hoover, AL	1839	Louisville/Jefferson County, KY-IN	778
Chicago-Naperville-Elgin, IL-IN-WI	859	Stockton-Lodi, CA	633
Huntington-Ashland, WV-KY-OH	355	Marshall, TX	465
Buffalo-Cheektowaga-Niagara Falls, NY	153	Beaumont-Port Arthur, TX	459
Erie, PA	106	Houston-The Woodlands-Sugar Land, TX	379
		Springfield, MA	335
		Cincinnati, OH-KY-IN	190
		Lake Charles, LA	167
		Greenville-Anderson-Mauldin, SC	117
		Salt Lake City, UT	115
		Pittsburgh, PA	79
		Philadelphia-Camden-Wilmington, PA-NJ-DE-MD	58
		Buffalo-Cheektowaga-Niagara Falls, NY	54
		Providence-Warwick, RI-MA	46
		Portland-Vancouver-Hillsboro, OR-WA	39
		Dallas-Fort Worth-Arlington, TX	37
		Denver-Aurora-Lakewood, CO	31
		Chicago-Naperville-Elgin, IL-IN-WI	29
		New Haven-Milford, CT	29

3 Highlighted are those selected as study areas.

4

5.2 ATTRIBUTES OF AMBIENT NO₂ MONITORS USED FOR THE 2010-2015 ANALYSIS

Brief descriptions of the attributes, the sources of data, and any data processing steps follow provided in section 5.2.

1. *Ambient monitor meta-data.* Data sets containing general attributes (e.g., geographic coordinates, local land use, monitor setting, etc.) were obtained from AQS³¹ and from querying the AQS database directly.³² The land-use field indicates the prevalent land use within ¼ mile of the monitoring site.³³ The measurement scale represents the air volumes associated with the monitoring area dimensions.³⁴ The monitor objective describes the monitor in terms of its attempt to generally characterize health effects, photochemical activity, transport, or welfare effects.³⁵ Monitors most useful for evaluating public health would be characterized as having a monitor objective of population exposure and/or highest concentration. In addition, county land areas (mi²) were estimated from the U.S. Census Bureau.³⁶
2. *NO_x source emissions data.* For characterizing mobile source emissions associated with each ambient monitor, the same county file described above for evaluating emissions across all CBSAs was used. Presented separately in this analysis are the

³¹ https://www3.epa.gov/airdata/ad_maps.html

³² <https://aqs.epa.gov/api>.

³³ Land-use is characterized here as either agricultural (AGRIC), commercial (COMM), desert (DESERT), forest (FOREST), Industrial (INDUS), military reservation (MILIT), mobile (MOBILE), residential (RESID), or unknown (UNK).

³⁴ Measurement scales for monitors typically are characterized as microscale (in close proximity, up to 100 m from a source), middle (100 m to 0.5 km), neighborhood (500 m to 4 km), or urban (4 to 50 km).

³⁵ Objectives for monitors are characterized here as population exposure (POP_EXP), highest concentration (HI_CONC), source oriented (SOURCE), general/background (GEN/BKGR), extreme downwind (DOWNWND), maximum ozone concentration (MAX_O3), maximum precursor emissions (MAX_PRE), other (OTH), unknown (UNK), or upwind background (UP_BKGR), regional transport (REG TRANS), quality assurance (QUAL ASSUR).

³⁶ <https://www.census.gov/support/USACdataDownloads.html#LND>. For land area, variable 'LND110210D' was used.

1 NO_x emissions from on-road, non-road, and air-craft/marine/locomotive (AML)
2 mobile sources as well as the total NO_x and percent NO_x contributed by all mobile
3 sources combined. For characterizing facility NO_x emissions potentially associated
4 with measured concentrations at each monitor, the ‘facility-level by pollutant’
5 summary file containing emissions for the entire U.S. was downloaded from the 2011
6 NEI.³⁷ For each ambient monitor, all facilities within a 5 km radius were identified,
7 then having in their emissions summed based on facility type. Facility types having
8 aggregated emissions greater than or equal to 10 tpy were retained.

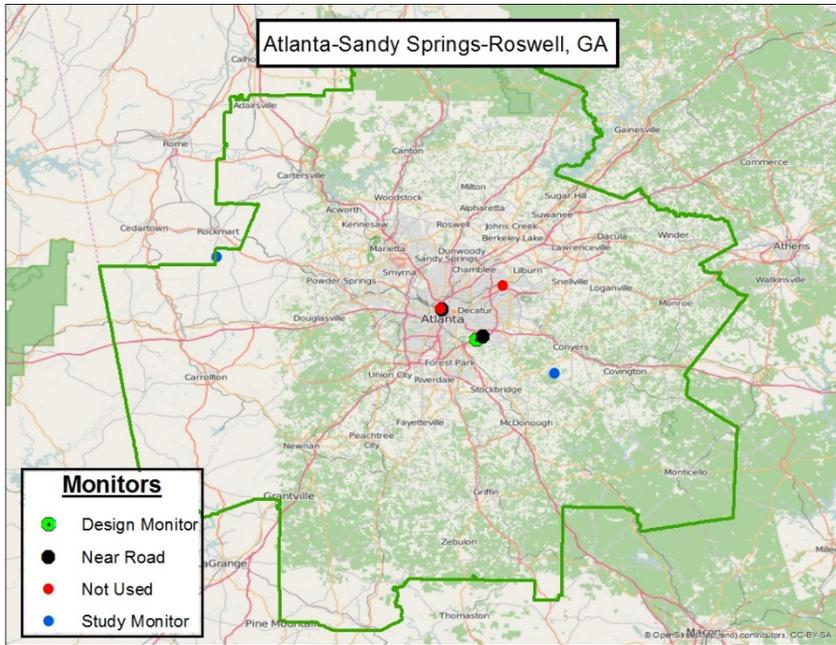
- 9 3. *Annual average daily traffic data.* For characterizing ambient monitor distances to
10 roads for all monitors (except for the new near-road monitors), we used shapefiles
11 obtained from the U.S. Department of Transportation (U.S. DOT) Federal Highway
12 Administration (FHA) 2011 Highway Performance Monitoring System (HPMS).³⁸ Of
13 relevance here were annual average daily traffic (AADT) data for all roadways³⁹ and
14 their identities, where available. These data were mapped using ArcMap version
15 10.3.1 and then joined to NO₂ ambient monitors by using the ‘Generate near Table’
16 function. This analysis used a 1000 meter search radius to join a monitor to the 100
17 segments of road identified by the HPMS closest to it, and all data were projected to
18 North American Lambert Conformal Conic, GCS North American 1983. From this
19 output, two metrics were developed. The first was developed using the road closest to
20 the monitor, while the second was developed using the road having the maximum
21 AADT. For both of these metrics, the AADT value, the road distance from the
22 monitor, and the road identity were retained.

23 *Monitor map locations:* A plot of all the monitors in each study area is provided using
24 ArcGIS. Individual satellite views of the near-road and area design value monitors were
25 generated using google maps and the respective monitor latitudes (lat) and longitudes (lon).

³⁷ http://aqsdrl.epa.gov/aqsweb/aqstmp/airdata/download_files.html#Meta. Note that for historical monitoring data, the 2011 NEI may not necessarily represent actual emissions when the monitor was in operation during earlier years.

³⁸ <https://www.fhwa.dot.gov/policyinformation/hpms/shapefiles.cfm>.

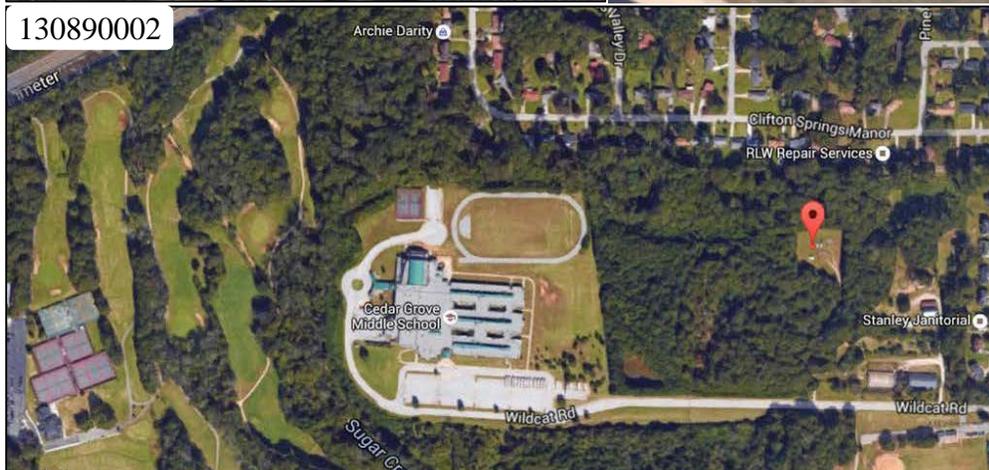
³⁹ Roads are those characterized as part of the HPMS-defined Federal-Aid System and include 1) interstate, 2) principal arterial – other freeways and expressways, 3) principal arterial – other, minor arterial, 4) major collector, 5) urban minor collector, and 6) other highways that are designated as part of the National Highway System.



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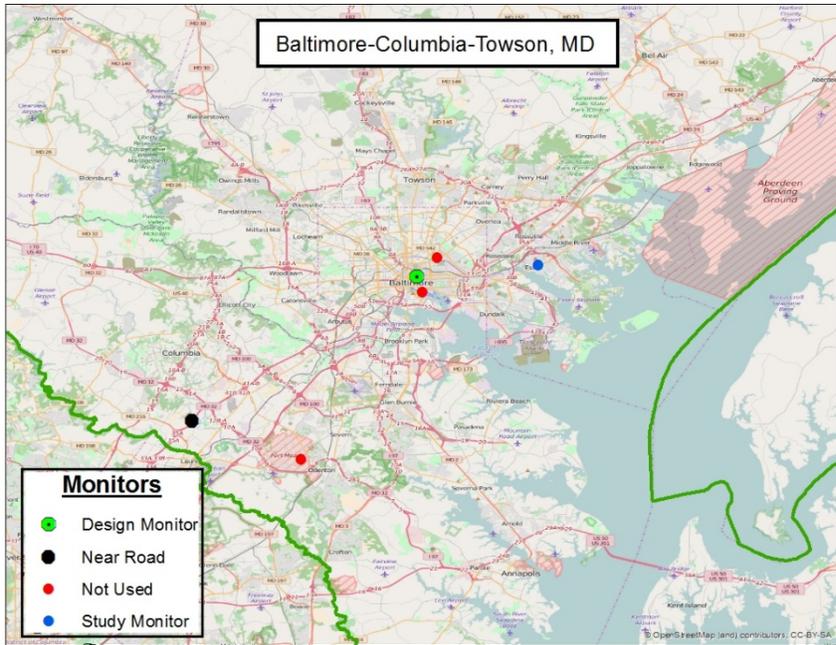
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Figure B5-1. Map of all monitors (1990-2015) in the Atlanta study area (top panel) and satellite views of near-road (middle panels) and area design value monitor (bottom panel).

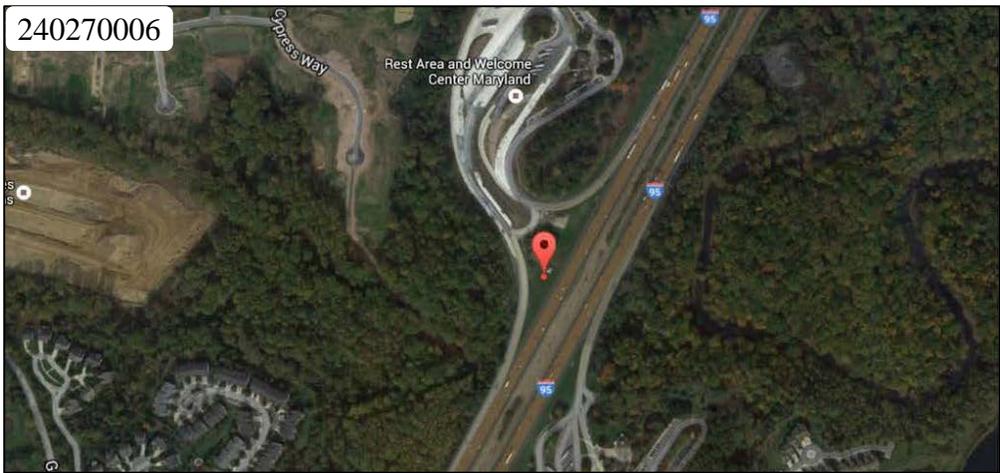
1 **Table B5-11. Attributes of ambient monitors within the Atlanta study area having recent**
 2 **(2010-2015) valid-year NO₂ concentrations.**

stateabbr	GA	GA	GA	GA	GA	
countyname	DeKalb	DeKalb	Fulton	Paulding	Rockdale	
siteid	130890002	130890003	131210056	132230003	132470001	
Lat	33.68797	33.69861	33.77832	33.9285	33.59108	
Lon	-84.29048	-84.27261	-84.39142	-85.04534	-84.06529	
year_start	1978	2014	2014	1995	1994	
year_end	2016	2016	2016	2015	2015	
Elevation_m	308	238	286	417	219	
land_use	RESID	COMM	MOBILE	AGRIC	AGRIC	
scale	URBAN	MICRO	MICRO	URBAN	URBAN	
objective1	POP_EXP	HI_CONC	SOURCE	UP_BKGR	MAX_O3	
objective2	MAX_PRE	REG TRANS	POP_EXP	GEN/BKGR	POP_EXP	
objective3	HI_CONC	QUAL ASSUR		POP_EXP	GEN/BKGR	
cnty_landarea_2010	268	268	527	312	130	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	597	30	2	.	.	
road_closest	285	285	85	.	.	
aadt_closest	140820	146000	284920	.	.	
dist_aadtmax	.	642	.	.	.	
road_aadtmax	.	285	.	.	.	
aadt_aadtmax	.	141700	.	.	.	
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	11230	11230	16404	1780	1529	
NonRoad_mobile_nox	1962	1962	3939	410	329	
AML_mobile_nox	376	376	1560	297	30	
total_nox	14719	14719	23989	2688	2112	
pct_mobile_nox	92.2	92.2	91.3	92.5	89.4	
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Landfill	45	45	.	.	.	
Rail_Yard	.	.	28	.	.	
						Area design value monitor
						Near-road monitor

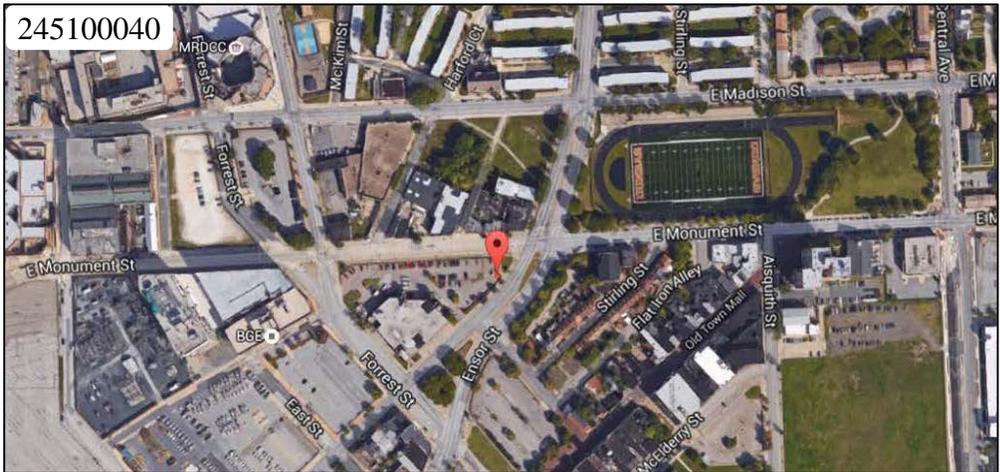
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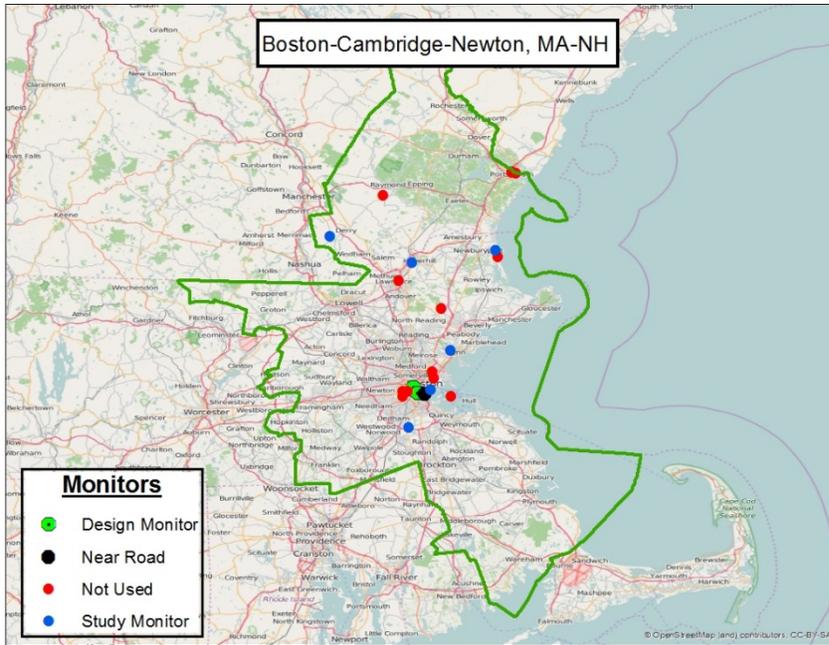
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Figure B5-2. Map of all monitors (1990-2015) in the Baltimore study area (top panel) and satellite views of near-road (middle panel) and area design value monitor (bottom panel).

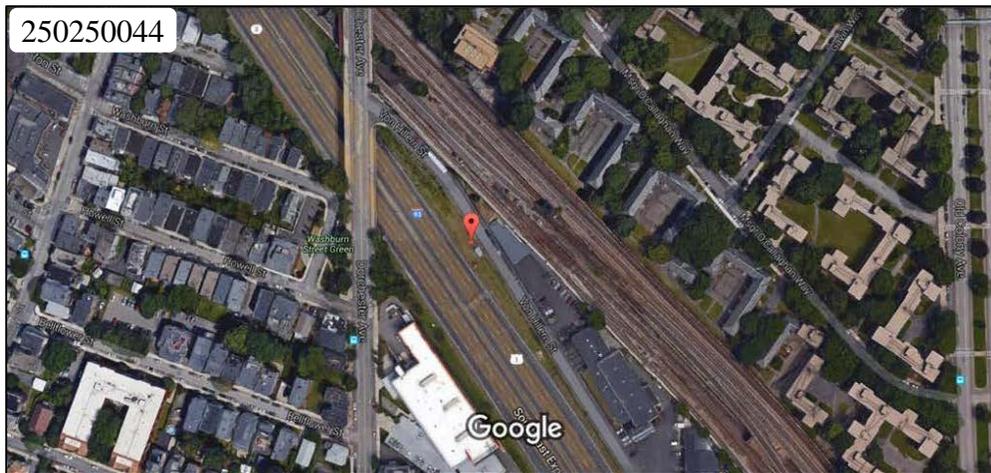
1 **Table B5-12. Attributes of ambient monitors within the Baltimore study area having recent**
 2 **(2010-2015) valid-year NO₂ concentrations.**

stateabbr	MD	MD	MD			
countyname	Baltimore	Howard	Balt. (City)			
siteid	240053001	240270006	245100040			
Lat	39.31083	39.14309	39.29773			
Lon	-76.47444	-76.84608	-76.60460			
year_start	1971	2014	1981			
year_end	2016	2016	2016			
Elevation_m	5	10	12			
land_use	RESID	RESID	RESID			
scale	NBHOOD	MICRO	MID			
objective1	POP_EXP	HI_CONC	HI_CONC			
objective2	MAX_PRE	SOURCE	POP_EXP			
objective3	HI_CONC	GEN/BKGR				
cnty_landarea_2010	598	251	81			
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	181	16	13			
road_closest	150	95	1470			
aadt_closest	29222	186750	9391			
dist_aadtmax	593	.	655			
road_aadtmax	150	.	83			
aadt_aadtmax	29932	.	102860			
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	11198	5298	4573			
NonRoad_mobile_nox	3463	991	646			
AML_mobile_nox	1333	216	1385			
total_nox	22136	8474	10421			
pct_mobile_nox	72.3	76.8	63.4			
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Municipal_Waste_Combustor	.	.	1134			
Steam_Heating_Facility	.	.	153			
Sugar_Mill	.	.	126			
Institutional_school_hospital_	.	.	98			
Chemical_Plant	.	.	70			
Rail_Yard	.	.	74			
Electricity_Generation_via_Combu	.	.	40			
not_characterized	36	23	10			
Military_Base	.	.	.			
Wastewater_Treatment_Facility	31	.	.			
Mineral_Processing_Plant	.	.	.			
						Area design value monitor
						Near-road monitor

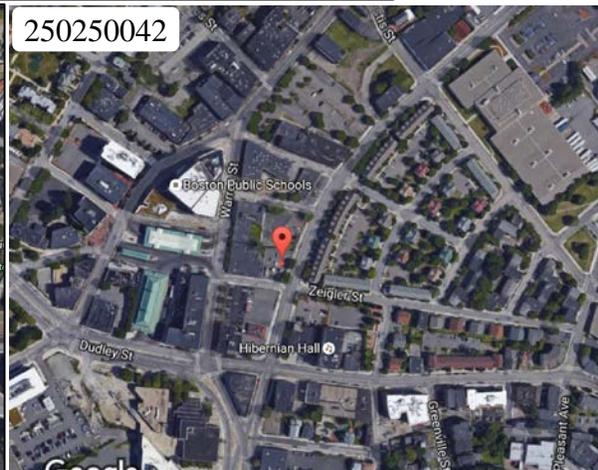
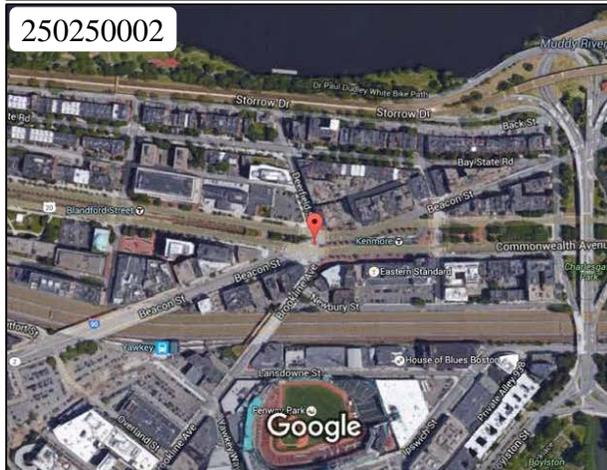
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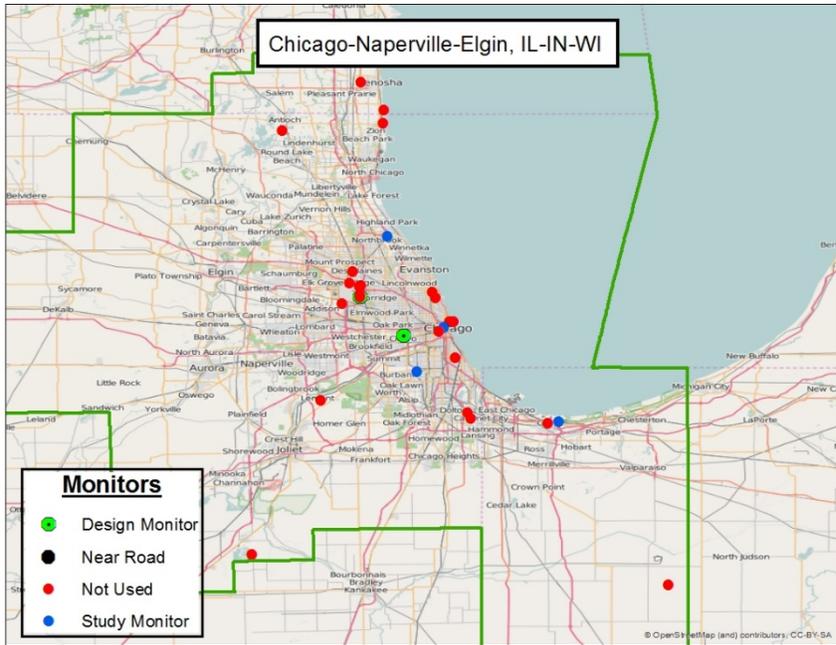
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Figure B5-3. Map of all monitors (1990-2015) in the Boston study area (top panel) and satellite views of near-road (middle panel) and area design value monitor (bottom panels).

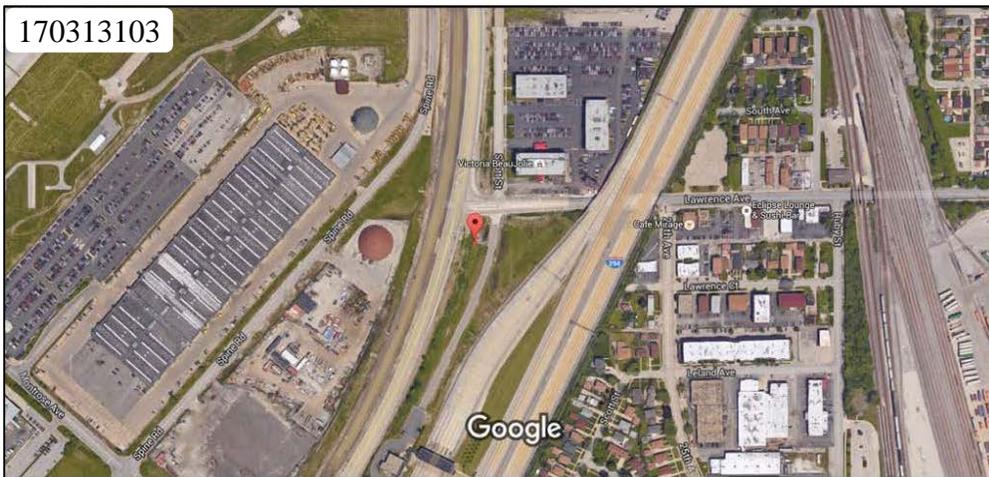
1 **Table B5-13. Attributes of ambient monitors within the Boston study area having recent**
 2 **(2010-2015) valid-year NO₂ concentrations.**

stateabbr	MA	MA	MA	MA	MA	MA
countyname	Essex	Essex	Essex	Norfolk	Suffolk	Suffolk
siteid	250092006	250094005	250095005	250213003	250250002	250250040
Lat	42.47464	42.81441	42.77084	42.21177	42.34887	42.34025
Lon	-70.97082	-70.81778	-71.10229	-71.11397	-71.09716	-71.03835
year_start	1993	2010	2003	2002	1975	1992
year_end	2016	2016	2012	2016	2016	2014
Elevation_m	52	2	0	192	6	0
land_use	COMM	RESID	RESID	FOREST	COMM	INDUS
scale	URBAN	URBAN	NBHOOD	REGION	MICRO	NBHOOD
objective1	POP_EXP	MAX_O3	POP_EXP	GEN/BKGR	HI_CONC	POP_EXP
objective2	MAX_PRE			UP_BKGR	POP_EXP	
objective3	HI_CONC			POP_EXP		
cnty_landarea_2010	493	493	493	396	58	58
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	486	.	.	469	7	216
road_closest	363	.	.	138	20	121
aadt_closest	13142	.	.	14059	20942	8618
dist_aadtmax	.	.	.	892	117	663
road_aadtmax	.	.	.	93	90	90
aadt_aadtmax	.	.	.	164568	127957	67804
County Level NO_x Emissions (tpy)						
OnRoad_mobile_nox	6568	6568	6568	6685	3201	3201
NonRoad_mobile_nox	2473	2473	2473	2009	2094	2094
AML_mobile_nox	860	860	860	619	5446	5446
total_nox	15750	15750	15750	12261	14015	14015
pct_mobile_nox	62.9	62.9	62.9	76	76.6	76.6
NO_x Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Airport	.	.	.	.	.	2203
Municipal_Waste_Combustor	705	.	1021	.	.	.
Steam_Heating_Facility	.	.	.	.	182	182
Institutional_school_hospital_	.	.	.	.	209	145
Electricity_Generation_via_Combu	.	.	.	.	253	41
Rail_Yard	.	.	.	.	20	.
Wastewater_Treatment_Facility	.	.	.	.	.	.
Aircraft_Aerospace_or_Related	156	.	.	.	.	.
Fabricated_Metal_Products_Plant	.	.	.	.	42	42
not_characterized	.	.	.	.	27	27
Textile_Yarn_or_Carpet_Plant	.	.	.	.	.	.
Military_Base
Mineral_Processing_Plant
						Area design value monitor
						Near-road monitor

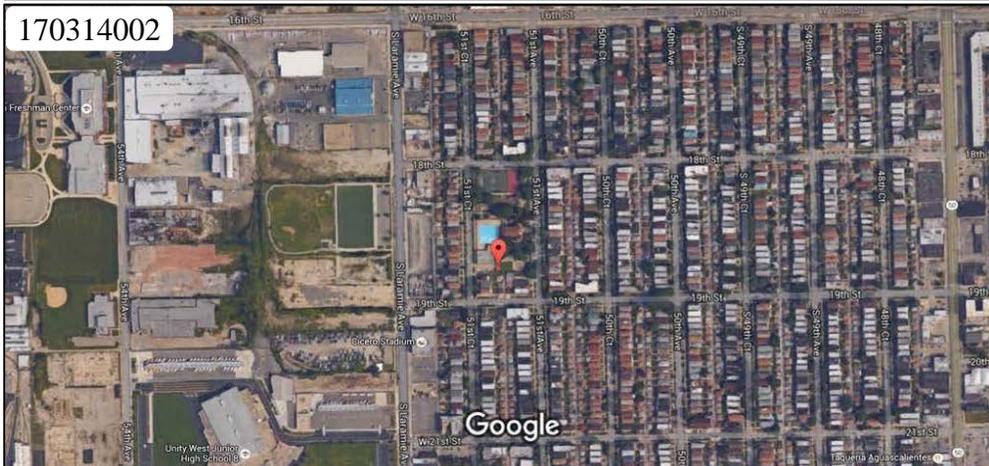
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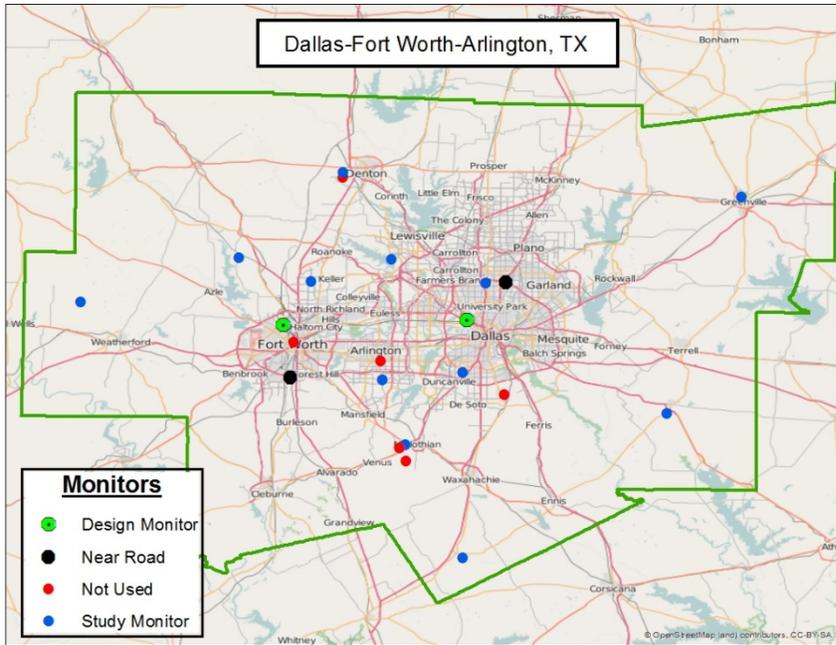


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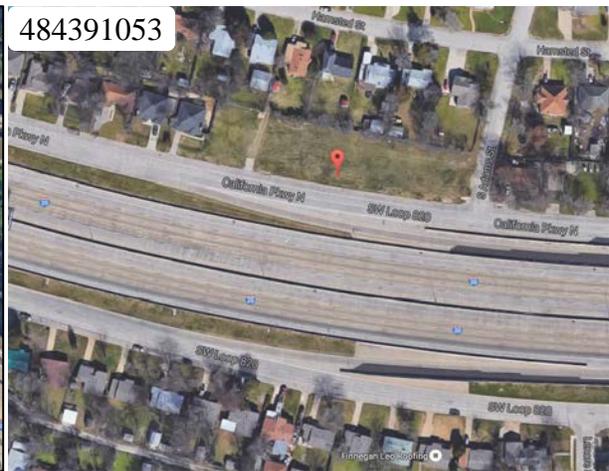


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4 **Figure B5-4. Map of all monitors (1990-2015) in the Chicago study area (top panel) and**
 5 **satellite views of near-road (middle panel) and area design value monitor (bottom panel).**



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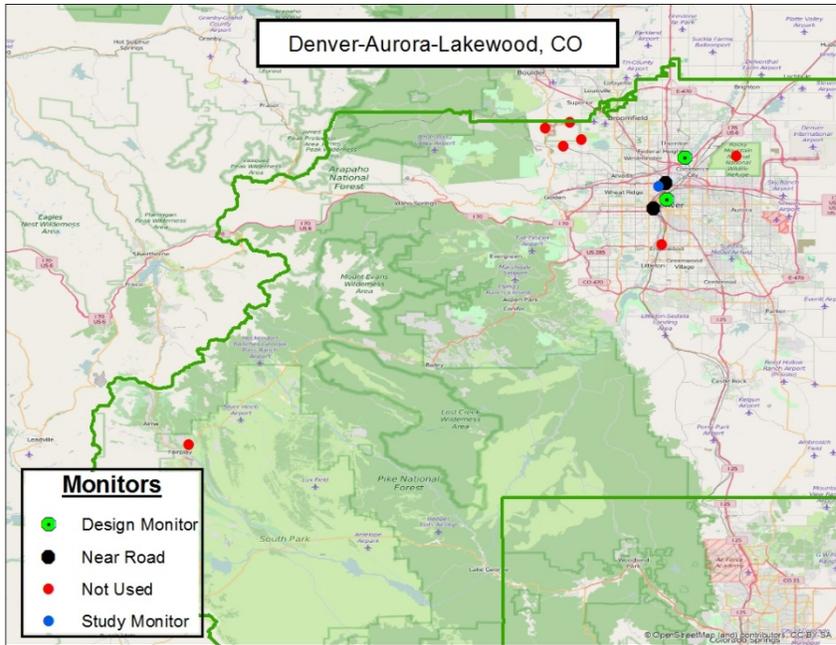
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Figure B5-5. Map of all monitors (1990-2015) in the Dallas study area (top panel) and satellite views of near-road (middle panels) and area design value monitor (bottom panels).

1 **Table B5-15, continued. Attributes of ambient monitors within the Dallas study area**
 2 **having recent (2010-2015) valid-year NO₂ concentrations.**

stateabbr	TX	TX	TX	TX	TX	TX
countyname	Ellis	Hunt	Kaufman	Parker	Tarrant	Tarrant
siteid	481391044	482311006	482570005	483670081	484390075	484391002
Lat	32.17542	33.15309	32.56497	32.86877	32.98789	32.80582
Lon	-96.87019	-96.11557	-96.31769	-97.90593	-97.47718	-97.35657
year_start	2007	2003	2000	2010	2010	1975
year_end	2016	2016	2016	2012	2012	2016
Elevation_m	165	161	128	347	241	203
land_use	AGRIC	RESID	COMM	RESID	RESID	COMM
scale	URBAN	NBHOOD	NBHOOD	NA	NA	NBHOOD
objective1	UP_BKGR	GEN/BKGR	POP_EXP	POP_EXP	MAX_O3	MAX_PRE
objective2		POP_EXP	UP_BKGR	SOURCE	HI_CONC	POP_EXP
objective3		UP_BKGR	GEN/BKGR	GEN/BKGR	POP_EXP	HI_CONC
cnty_landarea_2010	935	840	781	903	864	864
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	.	141	253	.	.	450
road_closest	.	69	34	.	.	287
aadt_closest	.	3100	13200	.	.	21000
dist_aadtmax	.	996	563	.	.	.
road_aadtmax	.	34	34	.	.	.
aadt_aadtmax	.	9100	16200	.	.	.
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	5173	2894	2984	3270	24824	24824
NonRoad_mobile_nox	854	627	765	624	4976	4976
AML_mobile_nox	272	58	194	258	7457	7457
total_nox	11530	4450	5774	5893	45082	45082
pct_mobile_nox	54.6	80.4	68.3	70.5	82.6	82.6
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Portland_Cement_Manufacturing	.	.	.	.	.	.
Airport	.	.	.	.	.	30
Rail_Yard	.	.	.	.	.	510
Steel_Mill	.	.	.	.	.	.
Compressor_Station	.	.	.	.	37	70
Electricity_Generation_via_Combu	.	43	.	.	.	.
not_characterized	.	.	.	.	37	.
Bakeries	.	.	.	.	.	.
Breweries_Distilleries_Wineries	.	.	.	.	.	.
Pharmaceutical_Manufacturing	.	.	.	.	.	.
Automobile_Truck_or_Parts_Plant
		Area design value monitor				
		Near-road monitor				

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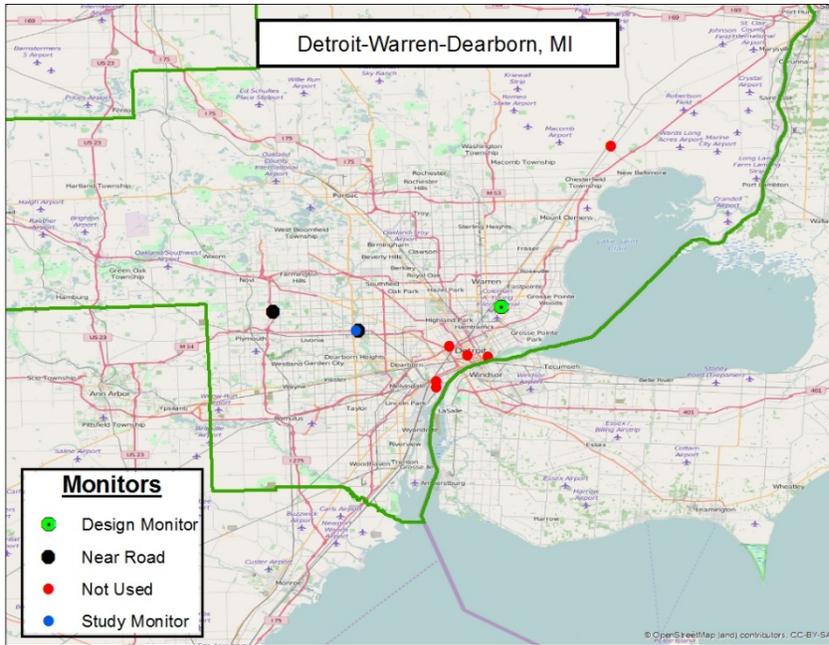
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4 **Figure B5-6. Map of all monitors (1990-2015) in the Denver study area (top panel) and**
 5 **satellite views of near-road (middle panels) and area design value monitor (bottom panels).**

1 **Table B5-16. Attributes of ambient monitors within the Denver study area having recent**
 2 **(2010-2015) valid-year NO₂ concentrations.**

stateabbr	CO	CO	CO	CO	CO	
countyname	Adams	Denver	Denver	Denver	Denver	
siteid	080013001	080310002	080310026	080310027	080310028	
Lat	39.83812	39.75118	39.77949	39.73217	39.78610	
Lon	-104.94984	-104.98763	-105.00518	-105.01530	-104.98860	
year_start	1975	1972	2014	2013	2015	
year_end	2016	2016	2016	2016	2016	
Elevation_m	1554	1593	1602	1583	1587	
land_use	AGRIC	COMM	RESID	COMM	COMM	
scale	URBAN	NBHOOD	NBHOOD	MICRO	MICRO	
objective1	POP_EXP	HI_CONC	POP_EXP	POP_EXP	POP_EXP	
objective2	GEN/BKGR	POP_EXP				
objective3						
cnty_landarea_2010	1168	153	153	153	153	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	996	19	394	9	6	
road_closest	76	0	70	25	25	
aadt_closest	56000	16000	120000	249000	192000	
dist_aadtmax	.	338	399	.	627	
road_aadtmax	.	0	70	.	25	
aadt_aadtmax	.	27000	123000	.	240000	
<i>County Level NO_x Emissions (tpy)</i>						
OnRoad_mobile_nox	8763	9618	9618	9618	9618	
NonRoad_mobile_nox	1974	2723	2723	2723	2723	
AML_mobile_nox	838	3556	3556	3556	3556	
total_nox	25245	20042	20042	20042	20042	
pct_mobile_nox	45.9	79.3	79.3	79.3	79.3	
<i>NO_x Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Electricity_Generation_via_Combu	8996	249	9245	249	9180	
Rail_Yard	.	473	661	188	661	
Petroleum_Refinery	670	.	.	.	670	
Food_Products_Processing_Plant	11	85	96	.	96	
Dry_Cleaner__Perchloroethylene	.	54	54	54	54	
Wastewater_Treatment_Facility	66	.	.	.	66	
Hot_Mix_Asphalt_Plant	50	20	42	20	42	
Institutional_school_hospital_	.	21	11	21	11	
Petroleum_Storage_Facility	14	.	.	.	14	
Bakeries	.	12	.	12	.	
Lumber_Sawmill	.	.	18	.	18	
not_characterized	17	124	124	98	141	
Chemical_Plant	.	.	.	.	.
Compressor_Station	.	.	.	.	.
Landfill	.	.	.	.	.
Brick_Structural_Clay_or_Clay	
						Area design value monitor
						Near-road monitor

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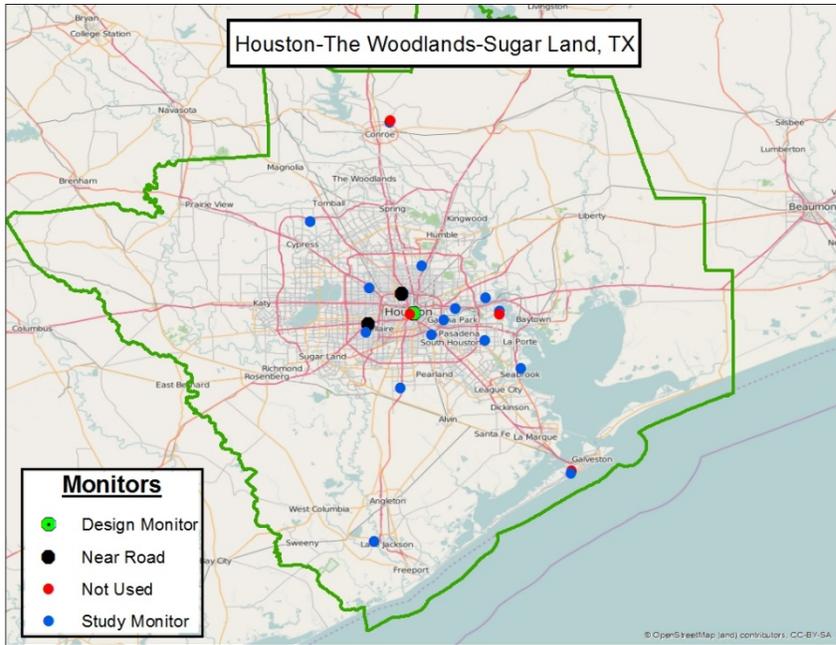


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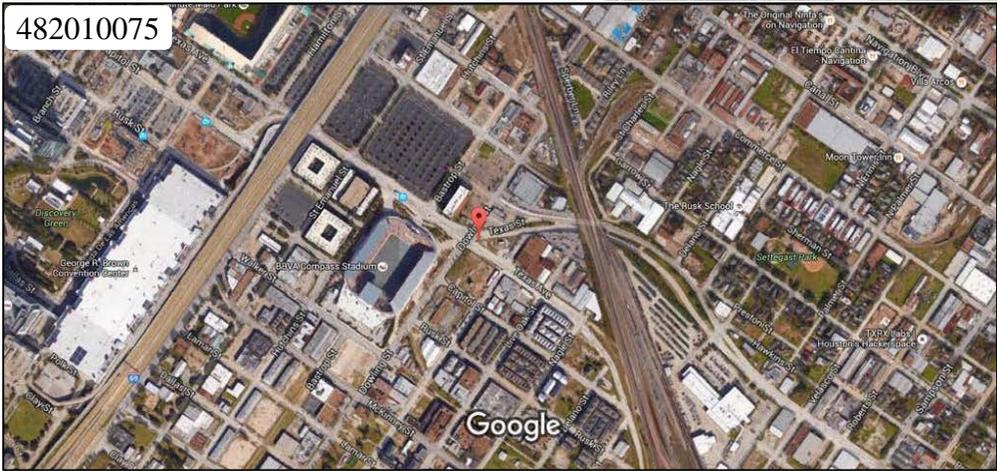
4 **Figure B5-7. Map of all monitors (1990-2015) in the Detroit study area (top panel) and**
 5 **satellite views of near-road (middle panels) and area design value monitor (bottom panel)**



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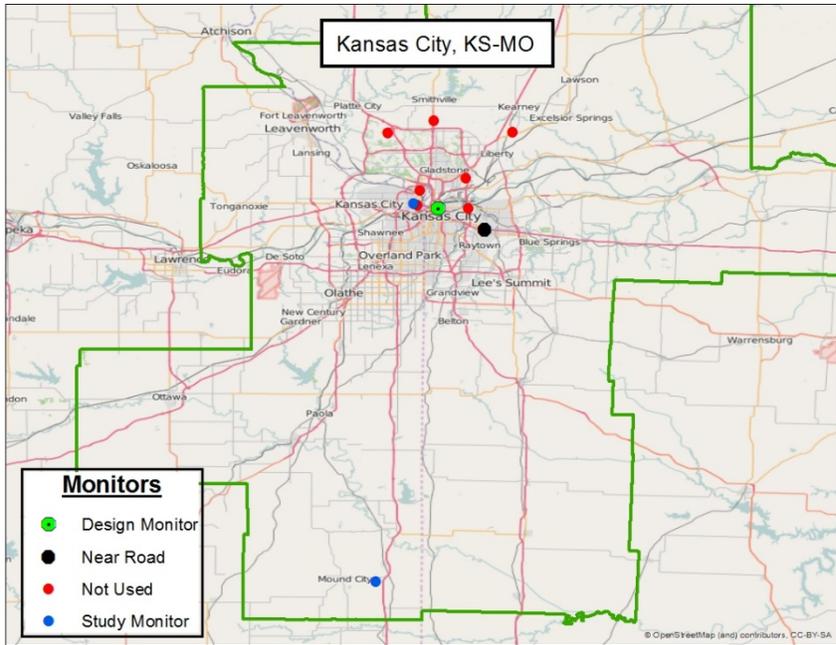


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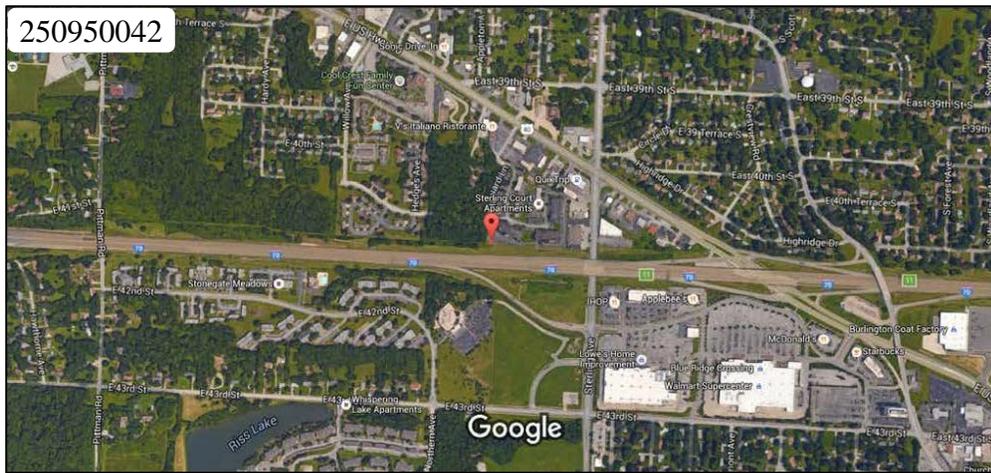
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Figure B5-8. Map of all monitors (1990-2015) in the Houston study area (top panel) and satellite views of near-road (middle panels) and area design value monitor (bottom panel).



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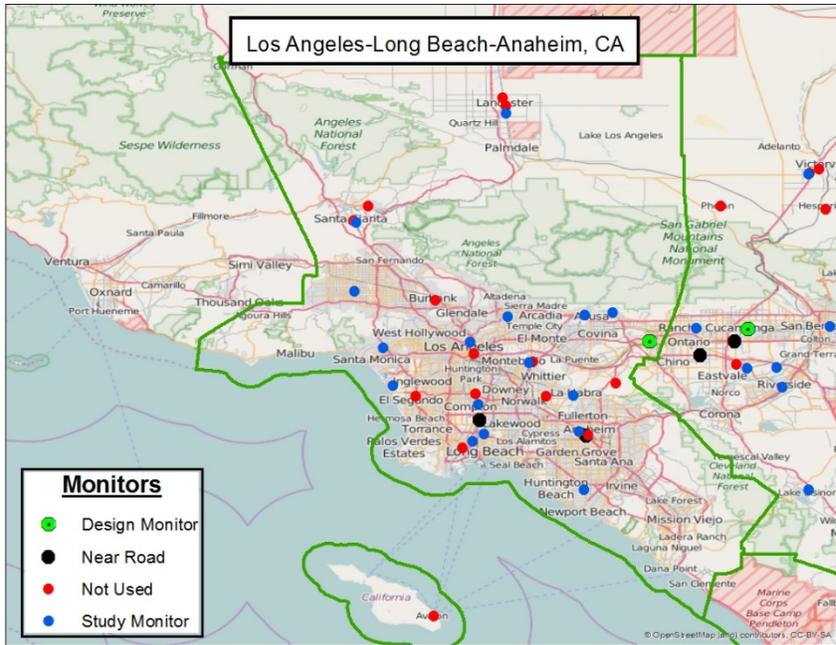


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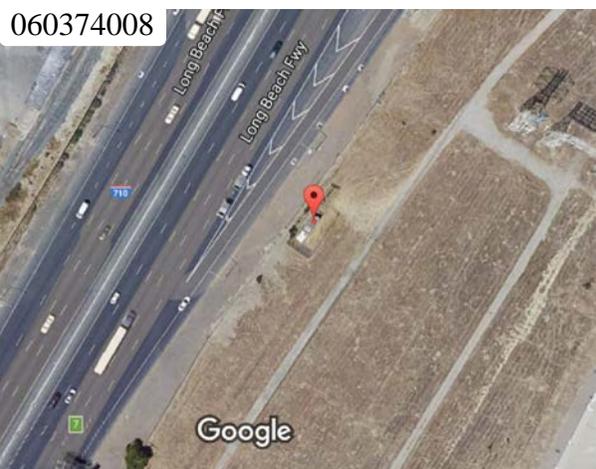
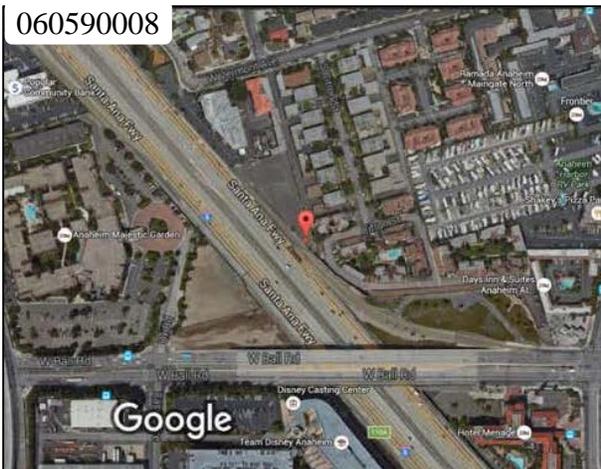


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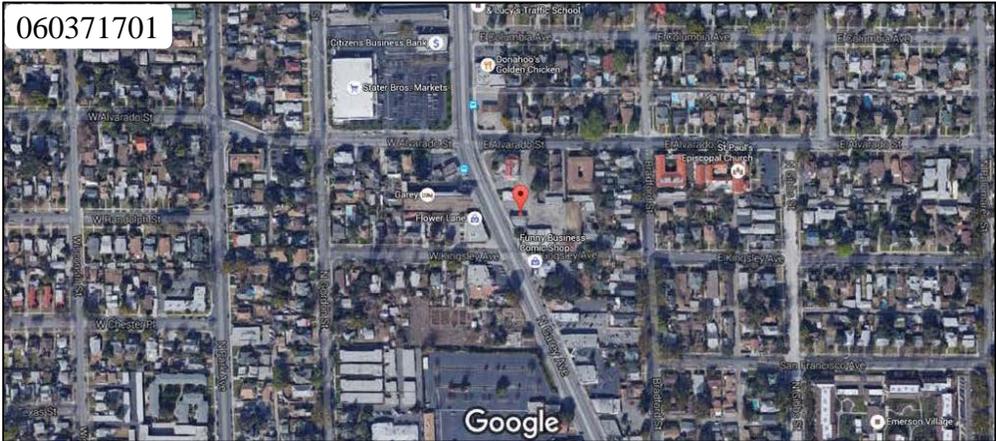
4 **Figure B5-9. Map of all monitors (1990-2015) in the Kansas City study area (top panel) and**
 5 **satellite views of near-road (middle panel) and area design value monitor (bottom panel).**



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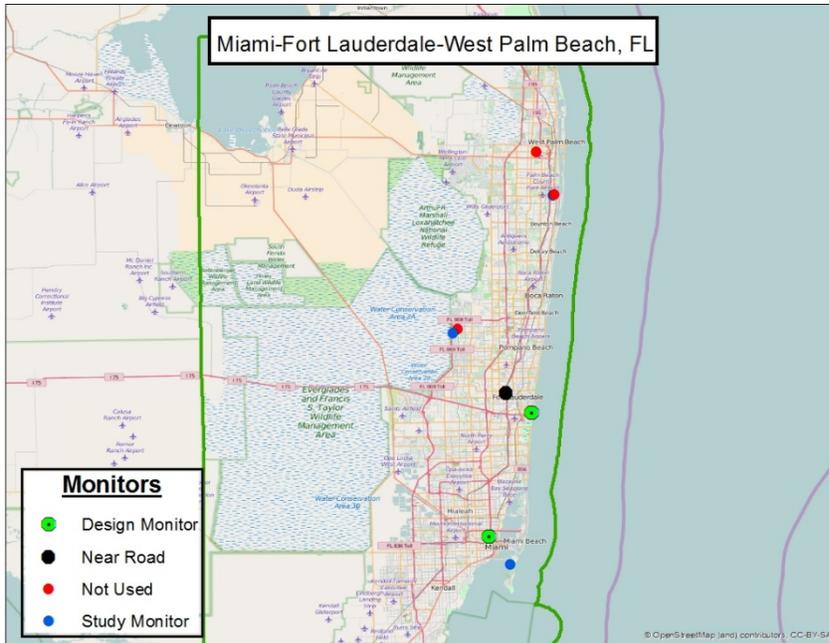


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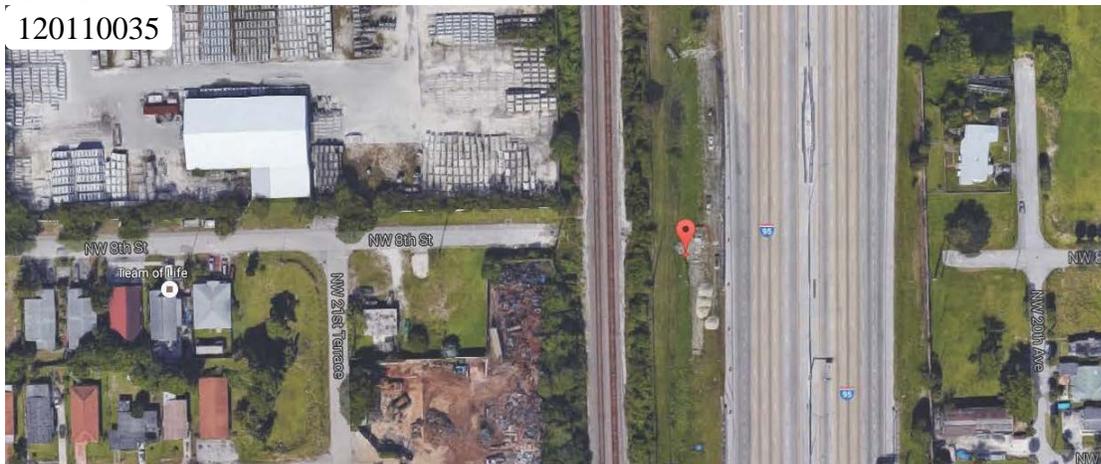


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4 **Figure B5-10. Map of all monitors (1990-2015) in the Los Angeles study area (top panel)**
 5 **and satellite views of near-road (middle panels) and area design value monitor (bottom**
 6 **panel).**



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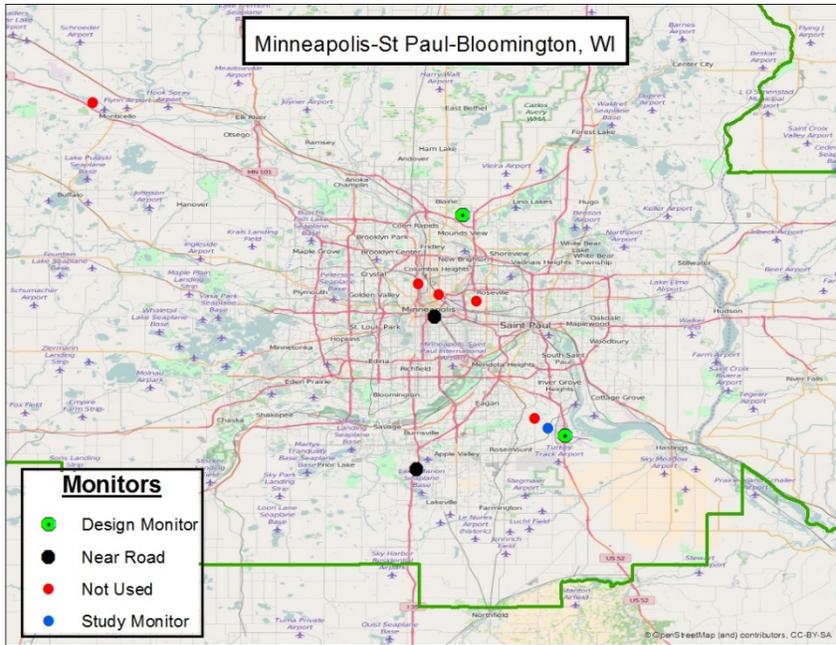


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4 **Figure B5-11. Map of all monitors (1990-2015) in the Miami study area (top panel) and**
 5 **satellite views of near-road (middle panels) and area design value monitor (bottom panels).**



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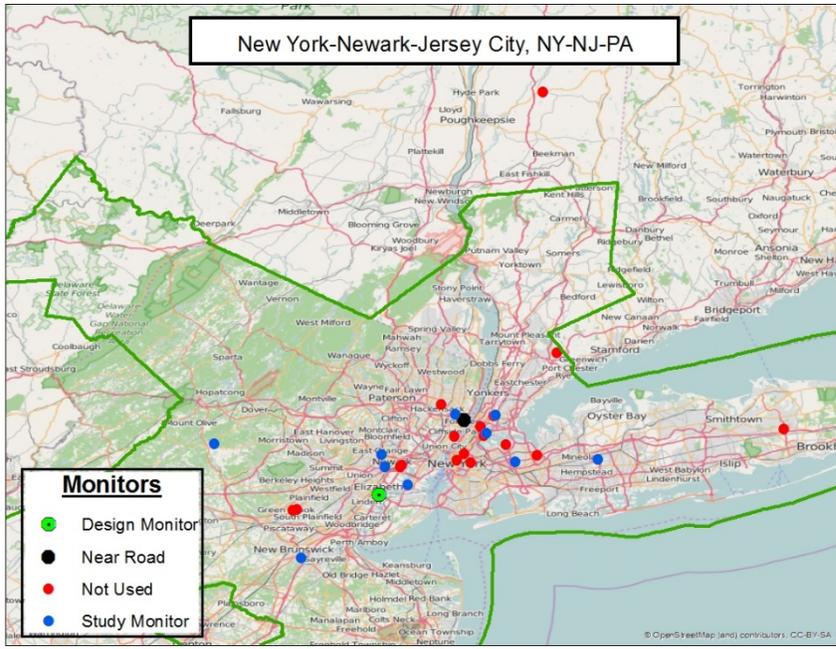


3

4 **Figure B5-12. Map of all monitors (1990-2015) in the Minneapolis study area (top panel)**
 5 **and satellite views of near-road (middle panels) and area design value monitor (bottom**
 6 **panels).**

1 **Table B5-22. Attributes of ambient monitors within the Minneapolis study area having**
 2 **recent (2010-2015) valid-year NO₂ concentrations.**

stateabbr	MN	MN	MN	MN	MN	
countyname	Anoka	Dakota	Dakota	Dakota	Hennepin	
siteid	270031002	270370020	270370423	270370480	270530962	
Lat	45.13768	44.76323	44.77553	44.70612	44.96524	
Lon	-93.20761	-93.03255	-93.06299	-93.28580	-93.25476	
year_start	1979	1974	1993	2014	2013	
year_end	2016	2016	2016	2016	2016	
Elevation_m	280	288	272	312	259	
land_use	COMM	INDUS	INDUS	COMM	RESID	
scale	URBAN	NBHOOD	NBHOOD	MID	MID	
objective1	GEN/BKGR	POP_EXP	SOURCE	SOURCE	SOURCE	
objective2	HI_CONC	SOURCE	WELF IMP			
objective3	POP_EXP	WELF IMP	POP_EXP			
cnty_landarea_2010	423	562	562	562	554	
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	.	81	.	30	32	
road_closest	.	52	.	35	94	
aadt_closest	.	34741	.	87000	277000	
dist_aadtmax	.	231	.	.	.	
road_aadtmax	.	52	.	.	.	
aadt_aadtmax	.	45818	.	.	.	
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	6662	7604	7604	7604	21967	
NonRoad_mobile_nox	1507	2061	2061	2061	5495	
AML_mobile_nox	1183	295	295	295	3168	
total_nox	11073	19738	19738	19738	39010	
pct_mobile_nox	84.5	50.5	50.5	50.5	78.5	
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Petroleum_Refinery	.	1296	1296	.	.	
Municipal_Waste_Combustor	.	.	.	.	594	
Electricity_Generation_via_Combu	.	87	87	.	332	
Institutional_school_hospital_	.	.	.	.	174	
Rail_Yard	.	.	.	.	111	
Pulp_and_Paper_Plant	.	.	.	.	339	
Gas_Plant	.	.	63	.	.	
Secondary_Aluminum_Smelting_Refi	.	29	29	.	.	
Steam_Heating_Facility	.	.	.	.	15	
not_characterized	133	49	49	.	.	
Printing_Publishing_Facility	.	.	.	.	.
Food_Products_Processing_Plant	
						Area design value monitor
						Near-road monitor



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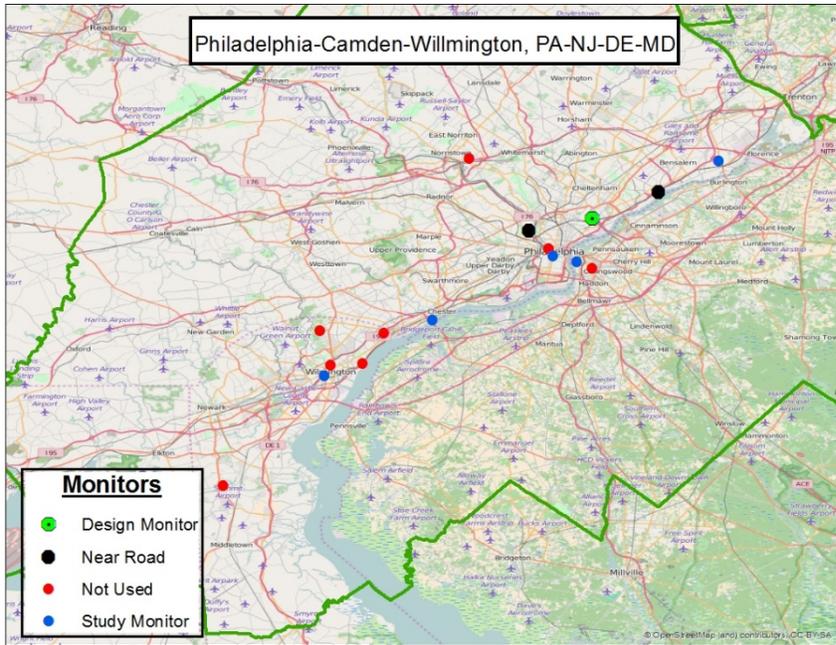


2

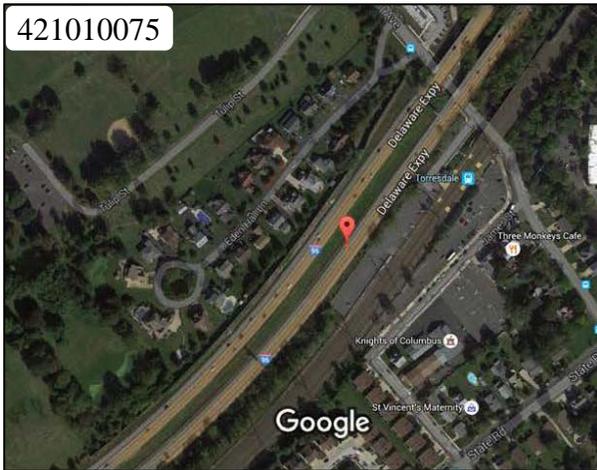


3

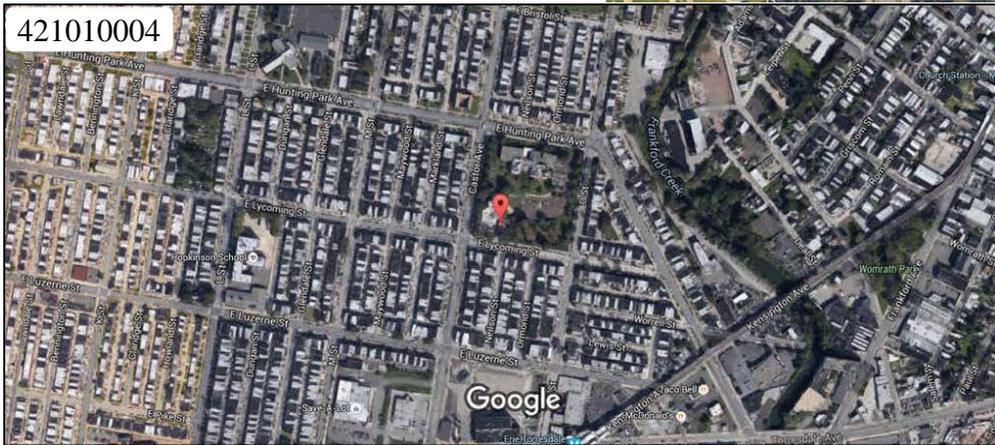
4 **Figure B5-13. Map of all monitors (1990-2015) in the New York/Jersey study area (top**
 5 **panel) and satellite views of near-road (middle panel) and area design value monitor**
 6 **(bottom panel).**



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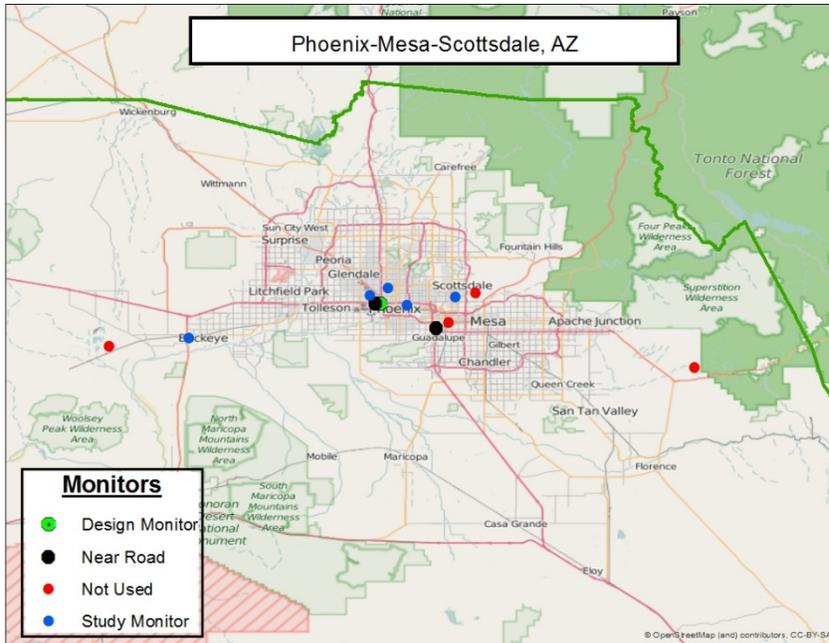


2

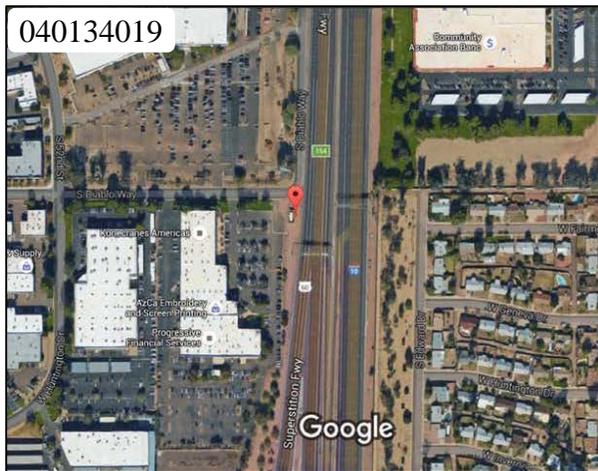


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4 **Figure B5-14. Map of all monitors (1990-2015) in the Philadelphia study area (top panel)**
 5 **and satellite views of near-road (middle panels) and area design value monitor (bottom**
 6 **panel).**



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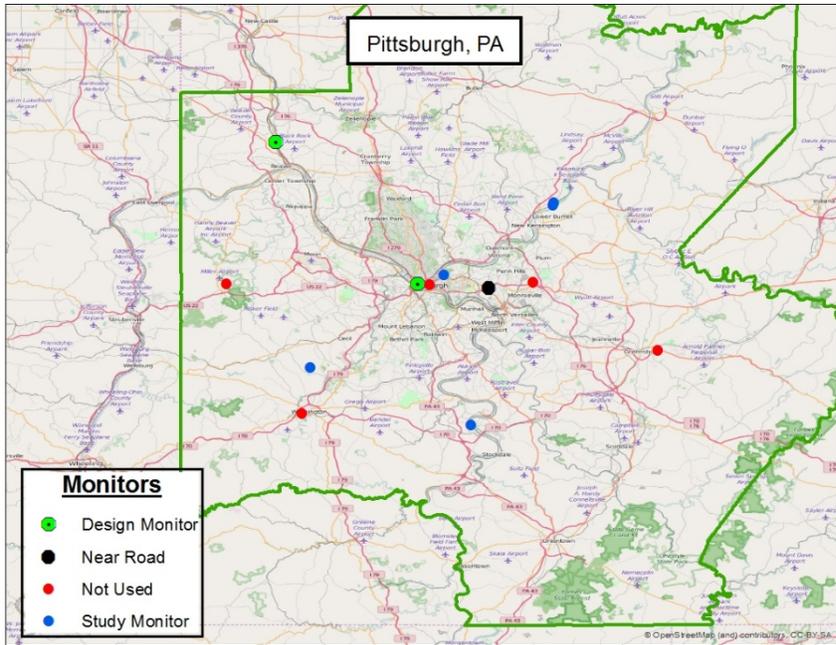


2



3

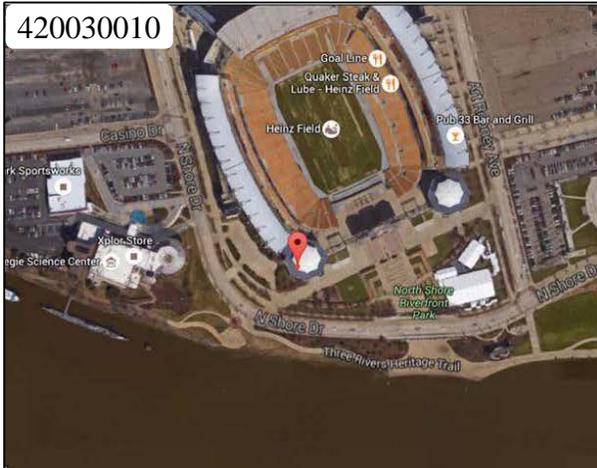
4 **Figure B5-15. Map of all monitors (1990-2015) in the Phoenix study area (top panel) and**
 5 **satellite views of near-road (middle panels) and area design value monitor (bottom panel).**



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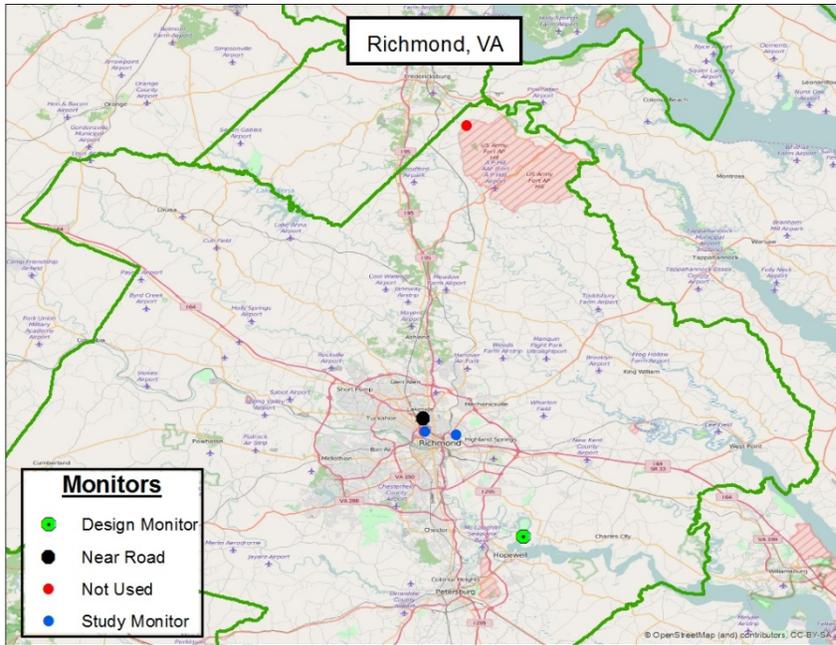


2



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4 **Figure B5-16. Map of all monitors (1990-2015) in the Pittsburgh study area (top panel) and**
 5 **satellite views of near-road (middle panel) and area design value monitor (bottom panels).**



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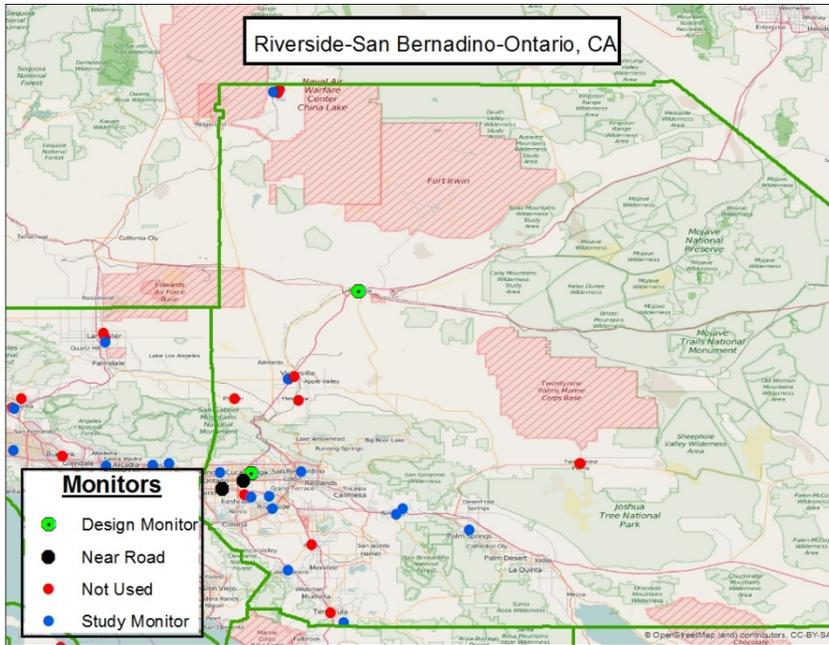


3

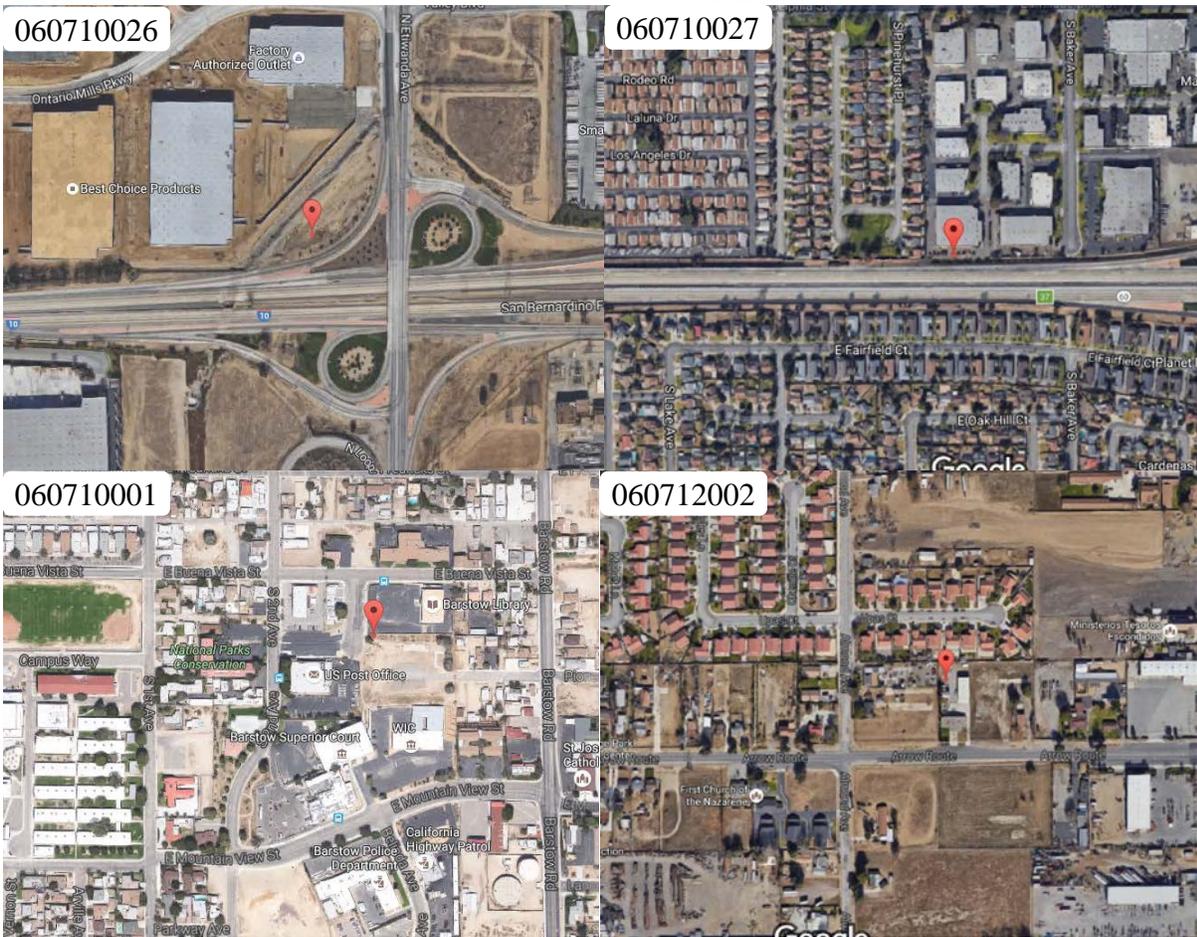
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Figure B5-17. Map of all monitors (1990-2015) in the Richmond study area (top panel) and satellite views of near-road (middle panel) and area design value monitor (bottom panel).



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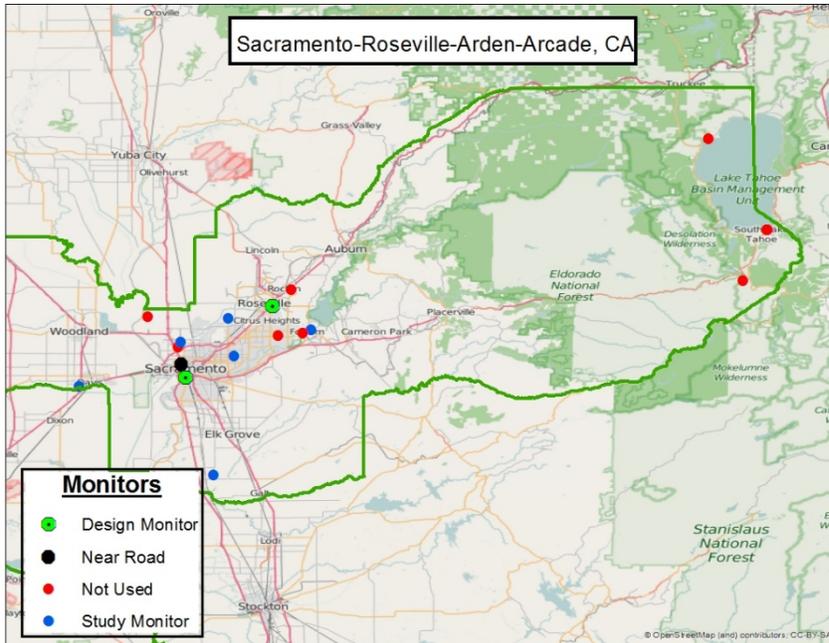
3

4

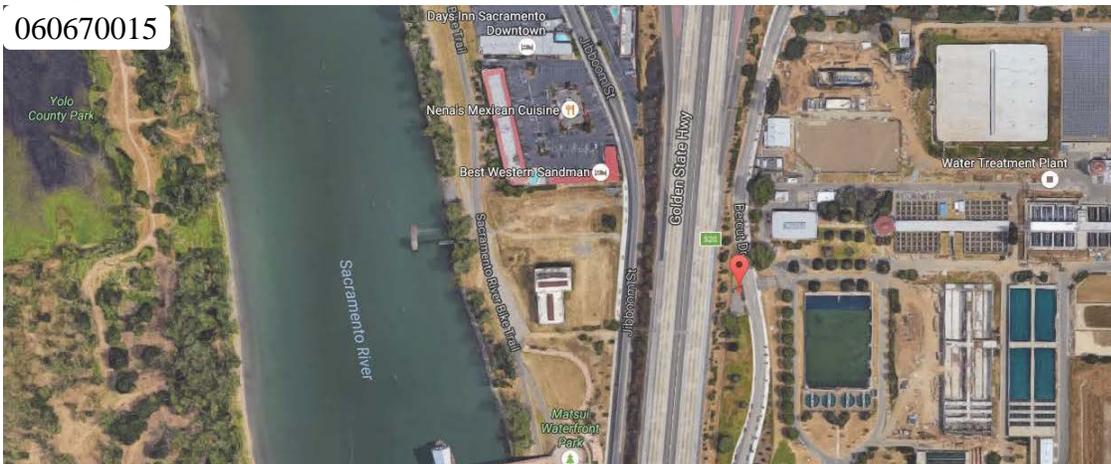
5

6

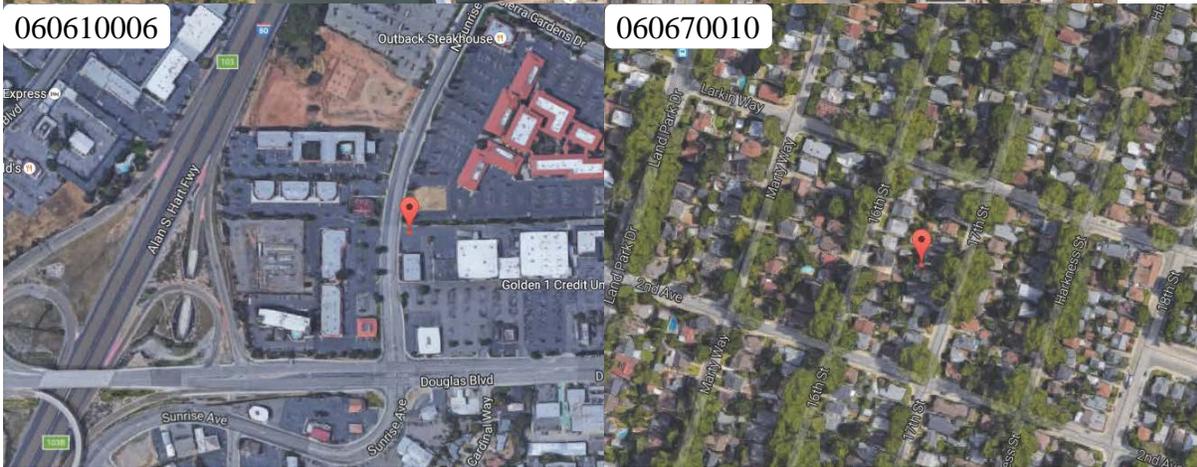
Figure B5-18. Map of all monitors (1990-2015) in the Riverside study area (top panel) and satellite views of two near-road (middle panels) and area design value monitor (bottom panel).



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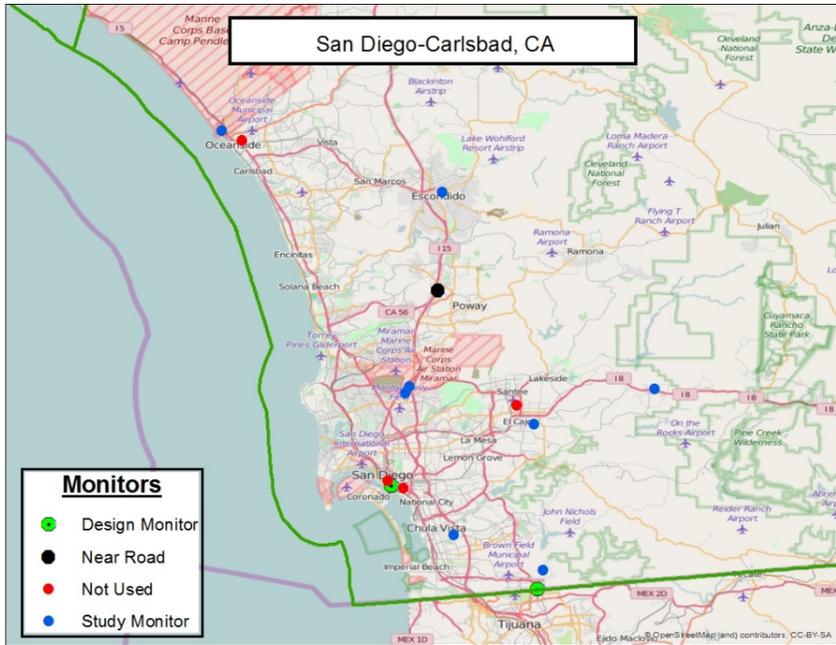


2

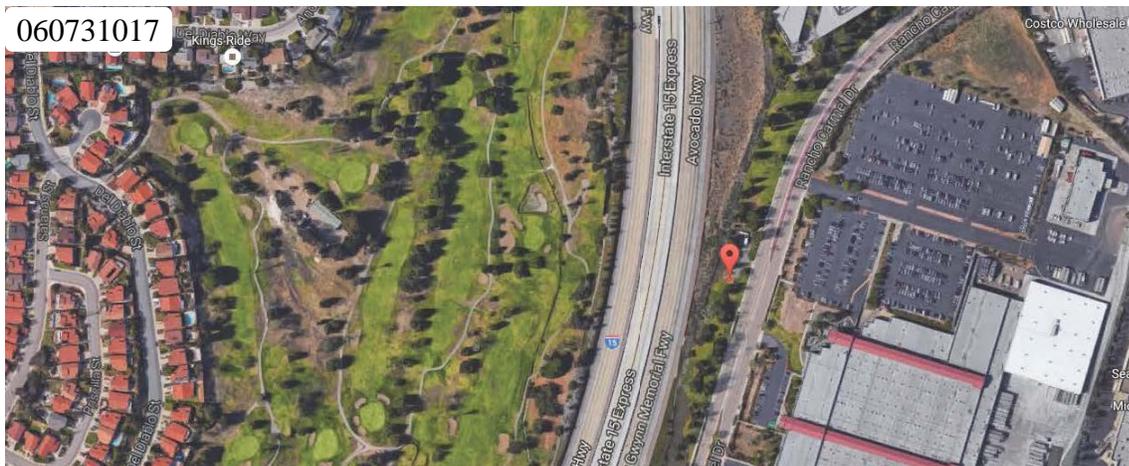


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4 **Figure B5-19. Map of all monitors (1990-2015) in the Sacramento study area (top panel)**
 5 **and satellite views of near-road (middle panels) and area design value monitor (bottom**
 6 **panel).**



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Figure B5-20. Map of all monitors (1990-2015) in the San Diego study area (top panel) and satellite views of near-road (middle panel) and area design value monitor (bottom panels).

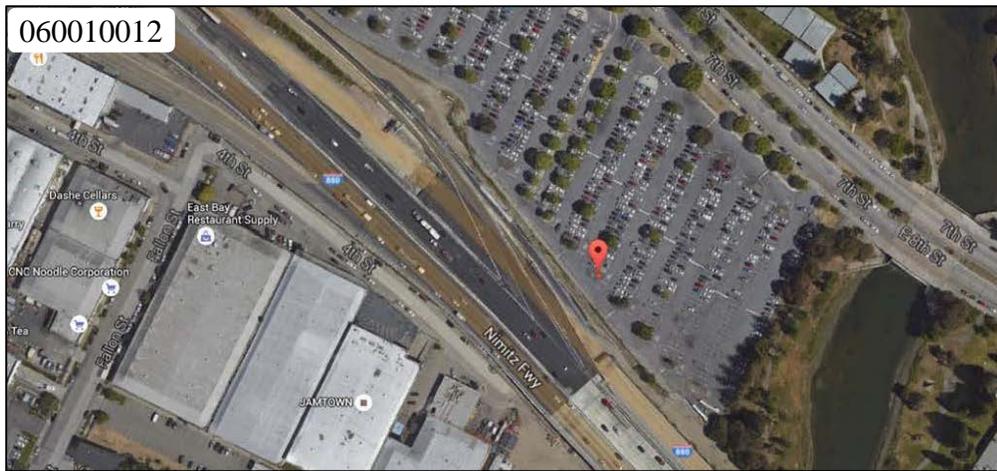
1 **Table B5-30, continued. Attributes of ambient monitors within the San Diego study area**
 2 **having recent (2010-2015) valid-year NO₂ concentrations.**

stateabbr	CA	CA	CA	CA	CA	
countyname	San Diego					
siteid	060731010	060731014	060731016	060731017	060732007	
Lat	32.70149	32.57936	32.84547	32.98544	32.55216	
Lon	-117.14965	-116.92949	-117.12389	-117.08218	-116.93777	
year_start	2005	2014	2011	2015	1990	
year_end	2016	2016	2016	2016	2014	
Elevation_m	3	185	132	218	155	
land_use	COMM	COMM	MILIT	COMM	MOBILE	
scale	NBHOOD	NBHOOD	NBHOOD	NBHOOD	MICRO	
objective1	GEN/BKGR	GEN/BKGR	GEN/BKGR	GEN/BKGR	POP_EXP	
objective2	POP_EXP	POP_EXP	POP_EXP		SOURCE	
objective3			MAX_PRE			
cnty_landarea_2010	4207	4207	4207	4207	4207	
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	387	.	404	37	61	
road_closest	5	.	163	15	905	
aadt_closest	161000	.	138000	223000	48500	
dist_aadtmax	964	.	429	801	244	
road_aadtmax	5	.	15	15	905	
aadt_aadtmax	208000	.	174000	225000	52000	
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	27531	27531	27531	27531	27531	
NonRoad_mobile_nox	7428	7428	7428	7428	7428	
AML_mobile_nox	3491	3491	3491	3491	3491	
total_nox	42700	42700	42700	42700	42700	
OnRoad_mobile_nox	90	90	90	90	90	
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
pct_mobile_nox	.	.	57	.	.	
Electricity_Generation_via_Combu	11	.	22	.	.	
Military_Base	38	.	.	.	.
Pharmaceutical_Manufacturing	13	.	.	.	.
Ship_Boat_Manufacturing_or_Repai	88	.	141	.	.	
not_characterized	.	.	57	.	.	
						Area design value monitor
						Near-road monitor

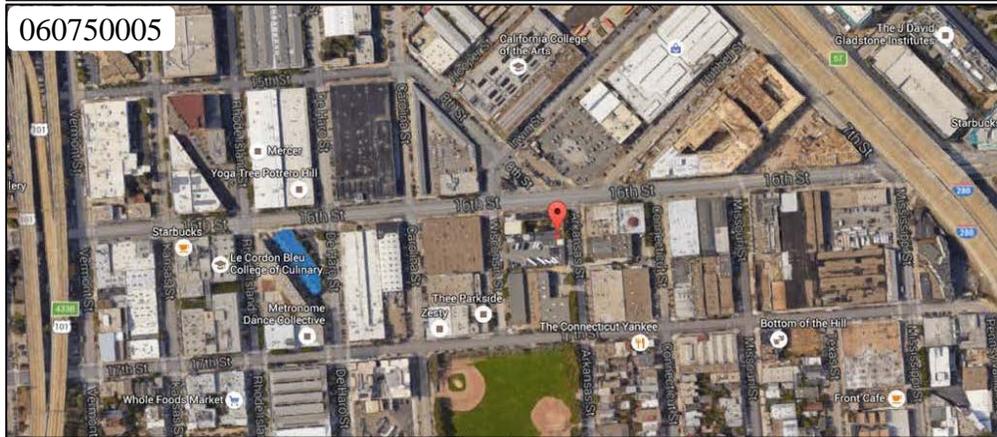
3



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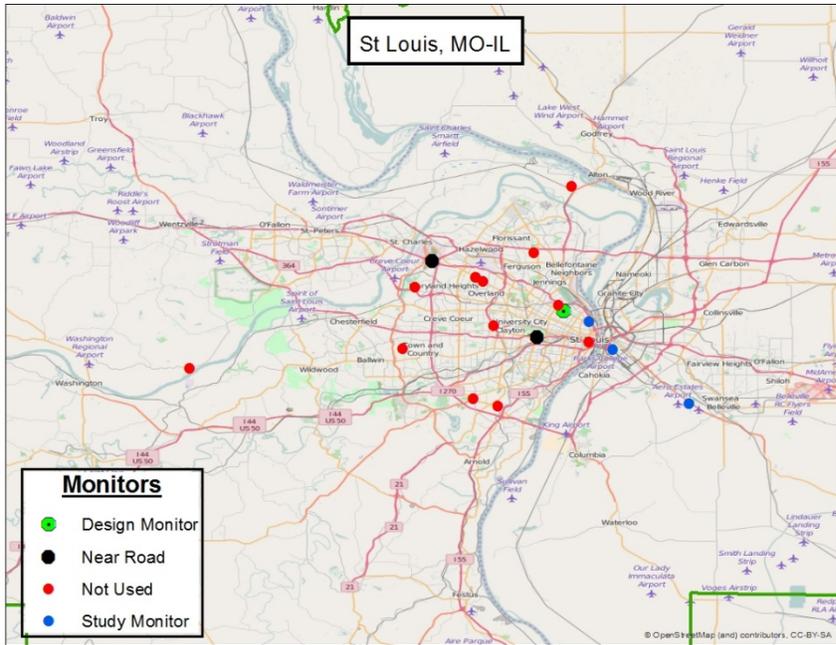


2

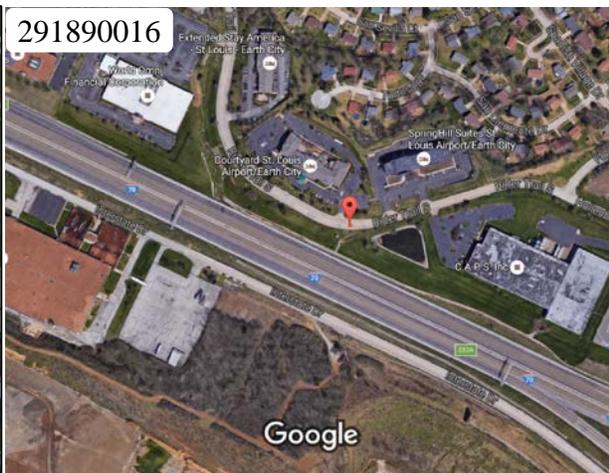


3

4 **Figure B5-21. Map of all monitors (1990-2010) in the San Francisco study area (top panel)**
 5 **and satellite views of near-road (middle panel) and area design value monitor (bottom**
 6 **panel).**



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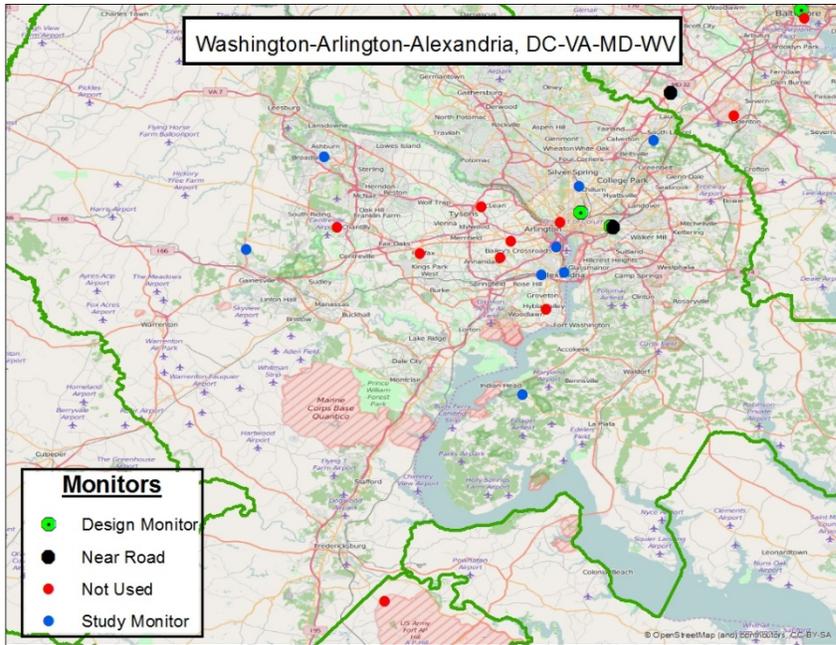


2



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4 **Figure B5-22. Map of all monitors (1990-2015) in the St. Louis study area (top panel) and**
 5 **satellite views of near-road (middle panel) and area design value monitor (bottom panel).**



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Figure B5-23. Map of all monitors (1990-2015) in the Washington DC study area (top panel) and satellite views of near-road (middle panel) and area design value monitors (bottom panels).

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1 **Table B5-33, continued. Attributes of ambient monitors within the Washington DC study**
 2 **area having recent (2010-2015) valid-year NO₂ concentrations.**

stateabbr	VA	VA	VA	VA	VA	
countyname	Arlington	Loudoun	Prince	Alexandria	Alexandria	
siteid	510130020	511071005	511530009	515100009	515100021	
Lat	38.85770	39.02473	38.85287	38.81040	38.80650	
Lon	-77.05922	-77.48925	-77.63462	-77.04435	-77.08640	
year_start	1977	1998	1994	1975	2012	
year_end	2016	2016	2016	2012	2016	
Elevation_m	16	88	117	9	61	
land_use	COMM	RESID	RESID	RESID	COMM	
scale	NA	NBHOOD	URBAN	NA	NBHOOD	
objective1	POP_EXP	POP_EXP	POP_EXP	POP_EXP	POP_EXP	
objective2						
objective3						
cnty_landarea_2010	26	516	336	15	15	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	588	.	.	113	162	
road_closest	1	.	.	400	236	
aadt_closest	51469	.	.	32550	34262	
dist_aadtmax	933	.	.	507	526	
road_aadtmax	395	.	.	90005	95	
aadt_aadtmax	199159	.	.	49465	153908	
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	1214	2121	3931	682	682	
NonRoad_mobile_nox	1203	2253	1390	127	127	
AML_mobile_nox	1243	1765	297	142	142	
total_nox	4065	6893	6863	2278	2278	
pct_mobile_nox	90	89.1	81.9	41.8	41.8	
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Airport	1311	.	.	.	.
Electricity_Generation_via_Combu	599	.	.	558	558	
Municipal_Waste_Combustor	.	.	.	.	471	
Steam_Heating_Facility	195	.	.	.	.
Military_Base	.	.	.	25	.	
not_characterized	.	17	.	15	.	
Institutional_school_hospital_	14	.	.	.	.
Rail_Yard	.	.	.	.	.
Hot_Mix_Asphalt_Plant	.	.	.	.	11	
						Area design value monitor
						Near-road monitor

3

1 **5.3 ATTRIBUTES OF HISTORICAL (1990-2009) OR OTHER AMBIENT**
 2 **NO₂ MONITORS NOT USED FOR THE 2010-2015 ANALYSIS**

3 **Table B5-34. Attributes of ambient monitors within the Atlanta study area not used for the**
 4 **2010-2015 analysis.**

stateabbr	GA	GA				
countyname	DeKalb	Fulton				
siteid	130893001	131210048				
Lat	33.84574	33.77933				
Lon	-84.21340	-84.39576				
year_start	1990	1982				
year_end	2006	2009				
Elevation_m	0	290				
land_use	RESID	COMM				
scale	NBHOOD	NBHOOD				
objective1	POP_EXP	HI_CONC				
objective2	GEN/BKGR	POP_EXP				
objective3						
cnty_landarea_2010	268	527				
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	.	408				
road_closest	.	0				
aadt_closest	.	22130				
dist_aadtmax	.	430				
road_aadtmax	.	75				
aadt_aadtmax	.	348900				
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	11230	16404				
NonRoad_mobile_nox	1962	3939				
AML_mobile_nox	376	1560				
total_nox	14719	23989				
pct_mobile_nox	92.2	91.3				
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Landfill	.	.				
Rail_Yard	.	224				
		Monitor not used for 2010-2015 analysis (either historical data or were incomplete)				

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1 **Table B5-35. Attributes of ambient monitors within the Baltimore study area not used for**
 2 **the 2010-2015 analysis.**

stateabbr	MD	MD	MD			
countyname	Balt. (City)	Balt. (City)	Anne Arundel			
siteid	245100050	245100051	240030019			
Lat	39.31861	39.28150	39.10111			
Lon	-76.58250	-76.59858	-76.72944			
year_start	1995	1997	1980			
year_end	2001	1999	2003			
Elevation_m	49	5	46			
land_use	RESID	COMM	COMM			
scale	REGION	REGION	URBAN			
objective1	POP_EXP	POP_EXP	UP_BKGR			
objective2	MAX_PRE	HI_CONC	POP_EXP			
objective3	HI_CONC		GEN/BKGR			
cnty_landarea_2010	81	81	415			
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	325	305	.			
road_closest	1	1230	.			
aadt_closest	21791	12671	.			
dist_aadtmax	643	387	.			
road_aadtmax	147	1383	.			
aadt_aadtmax	29041	35501	.			
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	4573	4573	7673			
NonRoad_mobile_nox	646	646	1967			
AML_mobile_nox	1385	1385	3129			
total_nox	10421	10421	20731			
pct_mobile_nox	63.4	63.4	61.6			
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Municipal_Waste_Combustor	.	1134	.			
Steam_Heating_Facility	50	153	.			
Sugar_Mill	.	126	.			
Institutional_school_hospital_	113	81	.			
Chemical_Plant	.	70	.			
Rail_Yard	.	74	.			
Electricity_Generation_via_Combu	25	40	.			
not_characterized	10	10	.			
Military_Base	.	.	52			
Wastewater_Treatment_Facility	.	.	.			
Mineral_Processing_Plant	.	19	.			
		Monitor not used for 2010-2015 analysis (either historical data or were incomplete)				

3

1 **Table B5-36. Attributes of ambient monitors within the Boston study area not used for the**
 2 **2010-2015 analysis.**

stateabbr	MA	MA	MA	MA	MA	MA	MA	
countyname	Essex	Essex	Norfolk	Norfolk	Suffolk	Suffolk	Suffolk	
siteid	250090005	250094004	250210008	250210009	250250021	250250035	250250036	
Lat	42.70954	42.79027	42.33343	42.31676	42.37783	42.33343	42.33343	
Lon	-71.14589	-70.80835	-71.13283	-71.13283	-71.02714	-71.11616	-71.11616	
year_start	1981	1994	1982	1982	1980	1982	1983	
year_end	2002	2009	1993	1995	2002	1995	1995	
Elevation_m	46	1	0	0	6	0	0	
land_use	RESID	RESID	RESID	RESID	RESID	RESID	RESID	
scale	NA	URBAN	MID	MICRO	NBHOOD	NA	NA	
objective1	HI_CONC	POP_EXP			HI_CONC			
objective2	GEN/BKGR	MAX_O3			POP_EXP			
objective3	POP_EXP	SOURCE						
cnty_landarea_2010	493	493	396	396	58	58	58	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>								
dist_closest	654	.	468	962	19	161	161	
road_closest	495	.	9	411	476	129	129	
aadt_closest	101413	.	34568	42018	37596	17696	17696	
dist_aadtmax	810	.	.	.	27	222	222	
road_aadtmax	495	.	.	.	90	9	9	
aadt_aadtmax	114788	.	.	.	67804	42578	42578	
<i>County Level NOx Emissions (tpy)</i>								
OnRoad_mobile_nox	6568	6568	6685	6685	3201	3201	3201	
NonRoad_mobile_nox	2473	2473	2009	2009	2094	2094	2094	
AML_mobile_nox	860	860	619	619	5446	5446	5446	
total_nox	15750	15750	12261	12261	14015	14015	14015	
pct_mobile_nox	62.9	62.9	76	76	76.6	76.6	76.6	
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>								
Airport	.	.	.	.	2203	.	.
Municipal_Waste_Combustor	768	.	.	.	.	.	.
Steam_Heating_Facility	.	.	.	.	182	.	.
Institutional_school_hospital_	.	.	258	127	.	258	258	
Electricity_Generation_via_Combu	.	.	212	121	353	253	253	
Rail_Yard	.	.	20	20	.	20	20	
Wastewater_Treatment_Facility	.	.	.	.	.	.	.
Aircraft_Aerospace_or_Related	.	.	.	.	.	.	.
Fabricated_Metal_Products_Plant	.	.	.	.	42	.	.
not_characterized	.	.	.	.	48	.	.
Textile_Yarn_or_Carpet_Plant	26	.	.	.	.	.	.
Military_Base	.	.	.	.	.	.	.
Mineral_Processing_Plant	.	.	.	.	.	.	.
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)					

1 **Table B5-37. Attributes of ambient monitors within the Chicago study area not used for the**
 2 **2010-2015 analysis.**

stateabbr	IL	IL	IL	IL	IL	IL
countyname	Cook	Cook	Cook	Cook	Cook	Cook
siteid	170310037	170310039	170310064	170310071	170310072	170310075
Lat	41.97948	41.89448	41.79079	41.86670	41.89581	41.96420
Lon	-87.67006	-87.62033	-87.60165	-87.64977	-87.60768	-87.65867
year_start	1981	1978	1992	1992	1995	1997
year_end	1996	1994	2000	1994	2011	2001
Elevation_m	183	180	180	180	181	180
land_use	RESID	COMM	RESID	COMM	COMM	RESID
scale	NA	NBHOOD	NBHOOD	NBHOOD	NBHOOD	NBHOOD
objective1		POP_EXP	POP_EXP	POP_EXP	MAX_PRE	POP_EXP
objective2		HI_CONC			HI_CONC	
objective3					SOURCE	
cnty_landarea_2010	945	945	945	945	945	945
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	829	108	377	52	505	144
road_closest	14	0	0	0	0	0
aadt_closest	36980	25225	5263	27906	12414	20978
dist_aadtmax	.	987	498	502	750	913
road_aadtmax	.	41	0	90	41	41
aadt_aadtmax	.	151051	29992	266664	127514	104309
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	54900	54900	54900	54900	54900	54900
NonRoad_mobile_nox	19402	19402	19402	19402	19402	19402
AML_mobile_nox	12900	12900	12900	12900	12900	12900
total_nox	113148	113148	113148	113148	113148	113148
pct_mobile_nox	77.1	77.1	77.1	77.1	77.1	77.1
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Steel_Mill	.	17	.	.	.	.
Airport	.	.	.	.	.	.
Electricity_Generation_via_Combu	.	.	.	1118	.	.
Rail_Yard	.	.	21	185	.	.
Institutional_school_hospital_	.	232	73	232	97	.
Chemical_Plant	.	.	.	.	.	.
Landfill	.	.	.	.	.	.
Industrial_Machinery_or_Equipmen	.	.	.	.	.	.
Steam_Heating_Facility	.	12	.	12	12	.
Wastewater_Treatment_Facility	.	.	.	.	.	.
Food_Products_Processing_Plant	.	.	.	.	.	.
Hot_Mix_Asphalt_Plant	.	.	.	.	.	.
not_characterized	.	114	.	87	87	.
Glass_Plant	.	.	.	.	.	.
Calcined_Pet_Coke_Plant	.	.	.	.	.	.
Automobile_Truck_or_Parts_Plant	.	.	.	.	.	.
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)			

3

1 **Table B5-37, continued. Attributes of ambient monitors within the Chicago study area not**
 2 **used for the 2010-2015 analysis.**

stateabbr	IL	IL	IL	IL	IL	IL
countyname	Cook	Cook	Cook	Cook	Cook	Cook
siteid	170311002	170311601	170313101	170313102	170313601	170314003
Lat	41.61642	41.66812	41.96528	41.97003	41.99670	42.03892
Lon	-87.55782	-87.99057	-87.87633	-87.87645	-87.87951	-87.89896
year_start	1978	1981	1984	1988	1988	1985
year_end	1991	1991	1997	1990	1990	1990
Elevation_m	179	226	197	197	197	197
land_use	RESID	RESID	MOBILE	COMM	COMM	RESID
scale	NA	NBHOOD	MID	MID	NBHOOD	NA
objective1		POP_EXP	HI_CONC	HI_CONC	GEN/BKGR	POP_EXP
objective2					POP_EXP	
objective3						
cnty_landarea_2010	945	945	945	945	945	945
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	103	.	29	24	180	468
road_closest	83	.	12	12	90	12
aadt_closest	19200	.	43900	39100	173242	16005
dist_aadtmax	669	.	152	378	.	827
road_aadtmax	83	.	294	294	.	12
aadt_aadtmax	26600	.	190046	190046	.	21000
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	54900	54900	54900	54900	54900	54900
NonRoad_mobile_nox	19402	19402	19402	19402	19402	19402
AML_mobile_nox	12900	12900	12900	12900	12900	12900
total_nox	113148	113148	113148	113148	113148	113148
pct_mobile_nox	77.1	77.1	77.1	77.1	77.1	77.1
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Steel_Mill	.	.	.	.	.	.
Airport	.	.	5261	5261	5261	.
Electricity_Generation_via_Combu	.	.	.	.	.	.
Rail_Yard	268	.	440	440	48	.
Institutional_school_hospital_	.	.	.	.	.	19
Chemical_Plant	12	.	.	.	.	.
Landfill	33	.	.	.	.	21
Industrial_Machinery_or_Equipmen	.	.	.	.	.	.
Steam_Heating_Facility	.	.	.	.	.	.
Wastewater_Treatment_Facility	.	.	.	.	.	.
Food_Products_Processing_Plant	.	.	12	12	.	.
Hot_Mix_Asphalt_Plant	.	.	.	.	11	.
not_characterized	.	.	72	83	73	14
Glass_Plant	412	.	.	.	.	.
Calcined_Pet_Coke_Plant	.	145	.	.	.	.
Automobile_Truck_or_Parts_Plant	.	.	.	.	.	.
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)			

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1 **Table B5-37, continued. Attributes of ambient monitors within the Chicago study area not**
 2 **used for the 2010-2015 analysis.**

stateabbr	IL	IL	IL	IL	IL	IL
countyname	Cook	Cook	Cook	DuPage	Lake	Lake
siteid	170314004	170314005	170318003	170431003	170971003	170971007
Lat	41.99947	42.00503	41.63142	41.94753	42.44585	42.46757
Lon	-87.87506	-87.90896	-87.56810	-87.92868	-88.10342	-87.81005
year_start	1988	1988	1991	1987	1990	1994
year_end	1991	1990	2002	1990	1991	2002
Elevation_m	197	0	179	201	253	178
land_use	MOBILE	COMM	RESID	COMM	AGRIC	FOREST
scale	MID	NBHOOD	NBHOOD	NBHOOD	URBAN	URBAN
objective1	HI_CONC	HI_CONC	POP_EXP	HI_CONC	HI_CONC	POP_EXP
objective2				POP_EXP		DOWNWIND
objective3						HI_CONC
cnty_landarea_2010	945	945	945	328	444	444
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	254	403	690	.	644	.
road_closest	90	72	0	.	59	.
aadt_closest	173242	39700	12612	.	13500	.
dist_aadtmax	.	500	806	.	.	.
road_aadtmax	.	90	94	.	.	.
aadt_aadtmax	.	161039	139053	.	.	.
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	54900	54900	54900	13656	8378	8378
NonRoad_mobile_nox	19402	19402	19402	4770	5355	5355
AML_mobile_nox	12900	12900	12900	1293	878	878
total_nox	113148	113148	113148	24391	20709	20709
pct_mobile_nox	77.1	77.1	77.1	80.8	70.6	70.6
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Steel_Mill	.	.	.	.	.	.
Airport	5261	5261	.	5261	.	.
Electricity_Generation_via_Combu	.	.	.	.	.	.
Rail_Yard	48	.	268	392	.	.
Institutional_school_hospital_	19	.	.	.	.	.
Chemical_Plant	.	.	12	.	.	.
Landfill	.	.	33	.	.	.
Industrial_Machinery_or_Equipmen	.	.	.	.	.	.
Steam_Heating_Facility	.	.	.	.	.	.
Wastewater_Treatment_Facility	.	.	.	.	.	.
Food_Products_Processing_Plant	.	.	.	12	.	.
Hot_Mix_Asphalt_Plant	.	11	.	.	.	.
not_characterized	73	79	.	58	.	.
Glass_Plant	.	.	412	.	.	.
Calcined_Pet_Coke_Plant	.	.	.	.	.	.
Automobile_Truck_or_Parts_Plant	.	.	18	.	.	.
						Monitor not used for 2010-2015 analysis (either historical data or were incomplete)

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1 **Table B5-37, continued. Attributes of ambient monitors within the Chicago study area not**
 2 **used for the 2010-2015 analysis.**

stateabbr	IL	IN	IN	WI	WI	
countyname	Will	Jasper	Lake	Kenosha	Kenosha	
siteid	171971011	180730003	180891016	550590016	550590019	
Lat	41.22154	41.13585	41.60031	42.58585	42.50472	
Lon	-88.19097	-86.98777	-87.33476	-87.87508	-87.80930	
year_start	1995	1975	1989	1979	1990	
year_end	2007	1990	1997	1992	1990	
Elevation_m	181	215	183	220	187	
land_use	AGRIC	AGRIC	RESID	RESID	RESID	
scale	REGION	REGION	NBHOOD	NA	NA	
objective1	GEN/BKGR	HI_CONC	POP_EXP		HI_CONC	
objective2	UP_BKGR	POP_EXP	HI_CONC		POP_EXP	
objective3	POP_EXP				REG TRANS	
cnty_landarea_2010	837	560	499	272	272	
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	.	.	187	290	.	
road_closest	.	.	53	158	.	
aadt_closest	.	.	8793	18674	.	
dist_aadtmax	.	.	528	623	.	
road_aadtmax	.	.	90	31	.	
aadt_aadtmax	.	.	35251	46107	.	
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	9714	2153	9294	2312	2312	
NonRoad_mobile_nox	4244	449	2652	687	687	
AML_mobile_nox	1315	64	1450	284	284	
total_nox	29376	10617	38995	6691	6691	
pct_mobile_nox	52	25.1	34.4	49.1	49.1	
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Steel_Mill	.	.	4336	.	.	
Airport	.	.	.	.	.
Electricity_Generation_via_Combu	21	.	.	.	.
Rail_Yard	.	.	.	.	.
Institutional_school_hospital_	.	.	.	.	.
Chemical_Plant	.	.	.	.	.
Landfill	.	.	.	.	.
Industrial_Machinery_or_Equipmen	.	.	.	.	.
Steam_Heating_Facility	.	.	.	.	.
Wastewater_Treatment_Facility	.	.	.	.	.
Food_Products_Processing_Plant	.	.	.	.	.
Hot_Mix_Asphalt_Plant	.	.	.	.	.
not_characterized	.	.	.	.	.
Glass_Plant	.	.	.	.	.
Calcined_Pet_Coke_Plant	.	.	.	.	.
Automobile_Truck_or_Parts_Plant	.	.	.	.	.
	Monitor not used for 2010-2015 analysis (either historical data or were incomplete)					

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1 **Table B5-38. Attributes of ambient monitors within the Dallas study area not used for the**
 2 **2010-2015 analysis.**

stateabbr	TX	TX	TX	TX	TX	TX	TX
countyname	Dallas	Dallas	Denton	Ellis	Ellis	Tarrant	Tarrant
siteid	481130045	481130055	481210033	481390015	481390017	484390057	484391003
Lat	32.91972	32.61639	33.20623	32.43694	32.47361	32.70694	32.75972
Lon	-96.80806	-96.75694	-97.19557	-97.02500	-97.04250	-97.09361	-97.32806
year_start	1973	1981	1996	1996	2004	1998	1975
year_end	1998	1994	1997	2007	2006	2001	1996
Elevation_m	195	132	0	0	0	0	186
land_use	RESID	UNK	INDUS	AGRIC	RESID	RESID	COMM
scale	URBAN	NA	URBAN	NBHOOD	NA	NBHOOD	NBHOOD
objective1	POP_EXP		GEN/BKGR	UP_BKGR	POP_EXP	POP_EXP	HI_CONC
objective2			HI_CONC	HI_CONC	SOURCE	HI_CONC	POP_EXP
objective3				GEN/BKGR	REG		
cnty_landarea_2010	871	871	878	935	935	864	864
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>							
dist_closest	396	794	.	.	.	118	4
road_closest	289	342	.	.	.	303	347
aadt_closest	23000	13800	.	.	.	39000	35000
dist_aadtmax	970	.	.	.	.	.	838
road_aadtmax	635	.	.	.	.	.	35
aadt_aadtmax	209000	.	.	.	.	.	173390
<i>County Level NOx Emissions (tpy)</i>							
OnRoad_mobile_nox	36623	36623	7555	5173	5173	24824	24824
NonRoad_mobile_nox	8462	8462	1685	854	854	4976	4976
AML_mobile_nox	1141	1141	1608	272	272	7457	7457
total_nox	51422	51422	13785	11530	11530	45082	45082
pct_mobile_nox	89.9	89.9	78.7	54.6	54.6	82.6	82.6
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>							
Portland_Cement_Manufacturing	.	.	.	1087	1087	.	.
Airport	.	.	23	.	.	24	.
Rail_Yard	.	.	.	.	.	151	467
Steel_Mill	.	.	.	298	298	.	.
Compressor_Station	.	.	.	.	26	.	16
Electricity_Generation_via_Combu	.	.	.	164	164	.	.
not_characterized	.	.	.	.	.	.	.
Bakeries	.	.	.	.	.	.	.
Breweries_Distilleries_Wineries	.	.	.	.	.	.	.
Pharmaceutical_Manufacturing	.	.	.	.	.	.	.
Automobile_Truck_or_Parts_Plant	.	.	.	.	.	55	.
							Monitor not used for 2010-2015 analysis (either historical data or were incomplete)

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4

1 **Table B5-39. Attributes of ambient monitors within the Denver study area not used for the**
 2 **2010-2015 analysis.**

stateabbr	CO	CO	CO	CO	CO	CO	CO
countyname	Adams	Arapahoe	Jefferson	Jefferson	Jefferson	Jefferson	Park
siteid	080017015	080050003	080590006	080590008	080590009	080590010	080930002
Lat	39.84249	39.65721	39.91280	39.87639	39.86193	39.89971	39.24028
Lon	-	-	-	-	-	-	-
year_start	1987	1988	1995	1992	1995	1995	2015
year_end	1994	1996	1999	2001	1999	2001	2016
Elevation_m	1605	1654	1802	1718	1848	1877	3027
land_use	COMM	COMM	INDUS	INDUS	INDUS	AGRIC	FOREST
scale	NBHOOD	NBHOOD	NA	NBHOOD	NBHOOD	NBHOOD	NA
objective1	GEN/BKGR	POP_EXP	GEN/BKGR	GEN/BKGR	GEN/BKGR		GEN/BKGR
objective2	POP_EXP	HI_CONC	POP_EXP				
objective3			HI_CONC				
cnty_landarea_2010	1168	798	764	764	764	764	2194
AADT information (distance in meters, road/highway/interstate number, AADT value)							
dist_closest	.	150	.	.	58	67	330
road_closest	.	85	.	.	72	93	285
aadt_closest	.	70000	.	.	3900	17000	4100
dist_aadtmax	.	341	.	.	.	.	.
road_aadtmax	.	85	.	.	.	.	.
aadt_aadtmax	.	78000	.	.	.	.	.
County Level NOx Emissions (tpy)							
OnRoad_mobile_nox	8763	8397	8825	8825	8825	8825	700
NonRoad_mobile_nox	1974	2016	2226	2226	2226	2226	99
AML_mobile_nox	838	285	259	259	259	259	0
total_nox	25245	13022	14406	14406	14406	14406	1438
pct_mobile_nox	45.9	82.2	78.5	78.5	78.5	78.5	55.6
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)							
Electricity_Generation_via_Combu	.	1999	.	.	19	19	.
Rail_Yard	.	.	.	.	.	.	.
Petroleum_Refinery	.	.	.	.	.	.	.
Food_Products_Processing_Plant	.	.	.	.	.	.	.
Dry_Cleaner__Perchloroethylene	.	.	.	.	.	.	.
Wastewater_Treatment_Facility	.	84	.	.	.	.	.
Hot_Mix_Asphalt_Plant	.	19	.	.	.	.	.
Institutional_school_hospital_	.	16	.	.	.	.	.
Petroleum_Storage_Facility	.	.	.	.	.	.	.
Bakeries	.	.	.	.	.	.	.
Lumber_Sawmill	.	.	.	.	.	.	.
not_characterized	.	.	131	.	.	118	.
Chemical_Plant	12	.	.	.	.	.	.
Compressor_Station	.	.	15	.	.	.	.
Landfill	.	.	.	.	27	.	.
Brick_Structural_Clay_or_Clay	.	16	.	.	.	.	.
							Monitor not used for 2010-2015 analysis (either historical data or were incomplete)

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1 **Table B5-40. Attributes of ambient monitors within the Detroit study area not used for the**
 2 **2010-2015 analysis.**

stateabbr	MI	MI	MI	MI	MI	MI
countyname	Macomb	Wayne	Wayne	Wayne	Wayne	Wayne
siteid	260990009	261630016	261630029	261630062	261631010	261631011
Lat	42.73139	42.35781	42.33809	42.34087	42.29077	42.28010
Lon	-82.79346	-83.09603	-83.02353	-83.06242	-83.12066	-83.12012
year_start	1993	1974	1988	1993	2015	2015
year_end	1998	2007	1990	1993	2016	2016
Elevation_m	189	191	183	610	0.1	0.1
land_use	COMM	RESID	COMM	RESID	INDUS	INDUS
scale	NA	NBHOOD	MID	NA	MICRO	MICRO
objective1	HI_CONC	POP_EXP	HI_CONC	POP_EXP	MAX_O3	MAX_O3
objective2	POP_EXP	HI_CONC	POP_EXP			
objective3	DOWNWND					
cnty_landarea_2010	479	612	612	612	612	612
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	.	111	21	273	147	498
road_closest	.	0	0	0	0	0
aadt_closest	.	4190	19600	11554	8001	6630
dist_aadtmax	.	653	.	518	602	608
road_aadtmax	.	94	.	75	75	0
aadt_aadtmax	.	152200	.	102200	95200	14446
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	12634	29767	29767	29767	29767	29767
NonRoad_mobile_nox	3670	7051	7051	7051	7051	7051
AML_mobile_nox	108	3496	3496	3496	3496	3496
total_nox	20833	62423	62423	62423	62423	62423
pct_mobile_nox	78.8	64.6	64.6	64.6	64.6	64.6
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Electricity_Generation_via_Combu	.	.	.	.	3865	3865
Steel_Mill	.	.	.	.	2776	2776
Municipal_Waste_Combustor	.	1617	1617	1617	.	.
Mineral_Processing_Plant	.	.	.	.	547	547
Petroleum_Refinery	.	.	.	.	412	412
Wastewater_Treatment_Facility	.	.	.	.	246	246
Steam_Heating_Facility	.	126	126	126	.	.
Automobile_Truck_or_Parts_Plant	.	197	.	197	51	51
Institutional_school_hospital_	.	77	51	77	.	.
Rail_Yard	.	.	.	.	106	106
not_characterized	.	.	12	12	.	.
Landfill	47	.	.	.	.	.
	Monitor not used for 2010-2015 analysis (either historical data or were incomplete)					

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1 **Table B5-41. Attributes of ambient monitors within the Houston study area not used for**
 2 **the 2010-2015 analysis.**

stateabbr	TX	TX	TX	TX		
countyname	Galveston	Harris	Harris	Montgomery		
siteid	481670014	482011037	482011041	483390089		
Lat	29.26332	29.75111	29.75167	30.35389		
Lon	-94.85657	-95.36139	-95.08361	-95.42167		
year_start	1996	1978	2002	1999		
year_end	2007	2001	2003	2001		
Elevation_m	0	16	0	0		
land_use	COMM	COMM	COMM	COMM		
scale	MID	NBHOOD	MID	MID		
objective1	UP_BKGR	HI_CONC	GEN/BKGR	GEN/BKGR		
objective2	GEN/BKGR	POP_EXP	HI_CONC	REG TRANS		
objective3	REG TRANS					
cnty_landarea_2010	378	1703	1703	1042		
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	.	307	454	.		
road_closest	.	59	0	.		
aadt_closest	.	188200	1830	.		
dist_aadtmax	.	663	.	.		
road_aadtmax	.	45	.	.		
aadt_aadtmax	.	247520	.	.		
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	2958	49330	49330	5948		
NonRoad_mobile_nox	996	13105	13105	1208		
AML_mobile_nox	4215	14455	14455	448		
total_nox	12353	98983	98983	9429		
pct_mobile_nox	66.1	77.7	77.7	80.6		
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Chemical_Plant	.	.	1552	.		
Petroleum_Refinery	.	.	.	.
Electricity_Generation_via_Combu	.	.	236	.		
Airport	.	.	.	.
Rail_Yard	.	269	.	.		
Plastic_Resin_or_Rubber_Produc	.	.	153	.		
Food_Products_Processing_Plant	.	97	.	.		
Wastewater_Treatment_Facility	.	75	.	.		
Petroleum_Storage_Facility	.	.	.	.
Glass_Plant	.	.	.	.
Chlor_alkali_Plant	.	.	18	.		
Breweries_Distilleries_Wineries	.	.	.	.
Fertilizer_Plant	.	.	.	.
Foundries_Iron_and_Steel	.	.	.	.
Landfill	.	.	28	.		
not_characterized	.	.	57	.		
Foundries_non_ferrous	.	.	.	.
Monitor not used for 2010-2014 analysis (either historical data or were incomplete)						

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1 **Table B5-42. Attributes of ambient monitors within the Kansas City study area not used**
 2 **for the 2010-2015 analysis.**

stateabbr	KS	KS	MO	MO	MO	MO	MO	
countyname	Wyandotte	Wyandotte	Clay	Clay	Clay	Jackson	Platte	
siteid	202090001	202090020	290470005	290470006	290470025	290950038	291650023	
Lat	39.11306	39.15139	39.30309	39.33191	39.18392	39.10417	39.30003	
Lon	-94.62468	-94.61773	-94.37662	-94.58084	-94.49774	-94.49222	-94.70024	
year_start	1977	1992	1981	2002	1977	1994	1977	
year_end	1999	1998	2010	2004	2002	1996	2004	
Elevation_m	256	228	314	303	283	0	293	
land_use	COMM	INDUS	AGRIC	AGRIC	RESID	INDUS	MOBILE	
scale	NBHOOD	NA	URBAN	NA	NBHOOD	NA	NA	
objective1	POP_EXP	HI_CONC	POP_EXP	POP_EXP	POP_EXP		POP_EXP	
objective2	HI_CONC	POP_EXP			HI_CONC			
objective3								
cnty_landarea_2010	152	152	397	397	397	604	420	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>								
dist_closest	193	359	847	290	383	114	.	
road_closest	69	69	0	169	435	0	.	
aadt_closest	9910	14300	16057	16672	66763	18542	.	
dist_aadtmax	717	.	943	290	.	465	.	
road_aadtmax	70	.	0	169	.	435	.	
aadt_aadtmax	44600	.	20342	18823	.	87490	.	
<i>County Level NOx Emissions (tpy)</i>								
OnRoad_mobile_nox	4241	4241	6048	6048	6048	13680	3523	
NonRoad_mobile_nox	449	449	769	769	769	3213	552	
AML_mobile_nox	2877	2877	797	797	797	3026	1843	
total_nox	16058	16058	9065	9065	9065	28515	8838	
pct_mobile_nox	47.1	47.1	84	84	84	69.9	67	
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>								
Electricity_Generation_via_Combu	4392	3175	.	.	.	1425	.	
Rail_Yard	1172	221	.	.	.	308	.	
Mineral_Wool_Plant	158	158	.	.	.	.	.
Automobile_Truck_or_Parts_Plant	43	43	.	.	82	.	.	
Food_Products_Processing_Plant	21	.	.	.	.	.	.
Chemical_Plant	12	.	.	.	.	48	.
Wet_Corn_Mill	32	32	.	.	.	.	.
Municipal_Waste_Combustor	11	11	.	.	.	.	.
Petroleum_Storage_Facility	11	11	.	.	.	.	.
not_characterized	.	16	.	.	.	.	.
Wastewater_Treatment_Facility	.	.	.	.	.	13	.
Airport	.	.	.	.	.	.	683
Steam_Heating_Facility	.	.	.	.	.	.	18
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)					

1 **Table B5-43. Attributes of ambient monitors within the Los Angeles study area not used**
 2 **for the 2010-2015 analysis.**

stateabbr	CA	CA	CA	CA	CA	CA	CA
countyname	Los Angeles	Los Angeles	Los Angeles	Los Angeles	Los Angeles	Los Angeles	Los Angeles
siteid	060370019	060370030	060370031	060370206	060371002	060371301	060371601
Lat	33.34225	34.03528	33.78611	33.95835	34.17605	33.92899	34.01407
Lon	-	-	-	-	-	-	-
year_start	1990	2001	2001	1992	1980	1980	1978
year_end	1990	2002	2002	1996	2014	2008	2005
Elevation_m	3	65	0	300	168	27	75
land_use	RESID	RESID	RESID	COMM	COMM	COMM	COMM
scale	NA	NA	NA	MID	NA	NA	NBHOOD
objective1		POP_EXP	POP_EXP		POP_EXP	HI_CONC	MAX_PRE
objective2					GEN/BKGR	POP_EXP	POP_EXP
objective3					UP_BKGR		HI_CONC
cnty_landarea_2010	4058	4058	4058	4058	4058	4058	4058
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>							
dist_closest	.	286	513	.	573	365	378
road_closest	.	5	0	.	5	105	605
aadt_closest	.	229000	29500	.	204000	228000	252000
dist_aadtmax	.	406	.	.	780	410	825
road_aadtmax	.	10	.	.	5	105	605
aadt_aadtmax	.	300000	.	.	215000	233000	256000
<i>County Level NOx Emissions (tpy)</i>							
OnRoad_mobile_nox	80322	80322	80322	80322	80322	80322	80322
NonRoad_mobile_nox	17796	17796	17796	17796	17796	17796	17796
AML_mobile_nox	17817	17817	17817	17817	17817	17817	17817
total_nox	135857	135857	135857	135857	135857	135857	135857
pct_mobile_nox	85.3	85.3	85.3	85.3	85.3	85.3	85.3
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>							
Airport	.	.	.	.	336	.	.
Petroleum_Refinery	.	.	2357	.	.	21	.
Rail_Yard	.	240	22	.	.	.	.
Calcined_Pet_Coke_Plant	.	.	201	.	.	.	.
Wastewater_Treatment_Facility	.	.	91	.	.	.	.
Electricity_Generation_via_Combu	69	19	45	24	36	.	.
Oil_or_Gas_Field_On_shore_	.	.	.	.	.	.	.
Institutional_school_hospital_	.	.	.	.	.	.	.
Steam_Heating_Facility	.	.	.	.	.	.	.
Chemical_Plant	.	.	50	.	.	47	.
Foundries_Iron_and_Steel	.	.	.	.	.	.	.
Foundries_non_ferrous	.	.	.	.	.	15	.
Breweries_Distilleries_Wineries	.	.	.	.	.	.	.
Hot_Mix_Asphalt_Plant	.	.	.	.	.	12	.
Petroleum_Storage_Facility	.	.	11	.	.	.	.
Landfill	.	.	.	51	.	.	108
Food_Products_Processing_Plant	.	21	.	.	.	.	.
Glass_Plant	.	66	.	.	.	.	.
Secondary_Lead_Smelting_Plant	.	31	.	.	.	.	.
not_characterized	.	15	65	.	23	.	.
Municipal_Waste_Combustor	.	.	304	.	.	.	.
Aircraft_Aerospace_or_Related	.	.	.	.	.	.	.
	Monitor not used for 2010-2015 analysis (either historical data or were incomplete)						

1 **Table B5-43, continued. Attributes of ambient monitors within the Los Angeles study area**
 2 **not used for the 2010-2015 analysis.**

stateabbr	CA	CA	CA	CA	CA	CA	CA
countyname	Los Angeles	Los Angeles	Los Angeles	Los Angeles	Los Angeles	Los Angeles	Orange
siteid	060372401	060374101	060375001	060376002	060377001	060379002	060590001
Lat	33.92362	34.42666	33.92288	34.38750	34.71221	34.68999	33.82135
Lon	-	-	-	-	-	-	-
year_start	1980	1989	1979	1989	1980	1990	1971
year_end	1993	1990	2004	2001	1990	2001	2001
Elevation_m	58	383	21	375	709	725	128
land_use	RESID	RESID	COMM	COMM	COMM	COMM	RESID
scale	NA	NBHOOD	NA	MID	NA	MID	URBAN
objective1	HI_CONC	POP_EXP	POP_EXP	POP_EXP		POP_EXP	POP_EXP
objective2			MAX_O3	GEN/BKGR			
objective3							
cnty_landarea_2010	CA	CA	CA	CA	CA	CA	CA
AAOT information (distance in meters, road/highway/interstate number, AAOT value)							
dist_closest	4058	4058	4058	4058	4058	4058	791
road_closest	.	.	139	.	.	.	463
aadt_closest	.	.	405	.	.	.	5
dist_aadtmax	.	.	239000	.	.	.	267000
road_aadtmax	.	.	779	.	.	.	.
aadt_aadtmax	.	.	405	.	.	.	.
County Level NOx Emissions (tpy)							
OnRoad_mobile_nox	80322	80322	80322	80322	80322	80322	19742
NonRoad_mobile_nox	17796	17796	17796	17796	17796	17796	6422
AML_mobile_nox	17817	17817	17817	17817	17817	17817	1921
total_nox	135857	135857	135857	135857	135857	135857	31763
pct_mobile_nox	85.3	85.3	85.3	85.3	85.3	85.3	88.4
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)							
Airport	.	.	5533	.	.	.	.
Petroleum_Refinery	.	.	649	.	.	.	.
Rail_Yard	.	.	.	.	.	.	.
Calcined_Pet_Coke_Plant	.	.	.	.	.	.	.
Wastewater_Treatment_Facility	.	.	.	.	.	.	.
Electricity_Generation_via_Combu	45	.	.	.	.	.	.
Oil_or_Gas_Field_On_shore_	.	66	.	66	.	.	.
Institutional_school_hospital_	.	.	.	.	.	.	.
Steam_Heating_Facility	.	.	.	.	.	.	.
Chemical_Plant	.	.	.	.	.	.	.
Foundries_Iron_and_Steel	.	.	.	.	.	.	.
Foundries_non_ferrous	.	.	.	.	.	.	.
Breweries_Distilleries_Wineries	.	.	.	.	.	.	.
Hot_Mix_Asphalt_Plant	.	.	.	.	.	.	.
Petroleum_Storage_Facility	.	.	.	.	.	.	.
Landfill	.	.	.	.	.	.	.
Food_Products_Processing_Plant	.	.	.	.	.	.	.
Glass_Plant	.	.	.	.	.	.	.
Secondary_Lead_Smelting_Plant	.	.	.	.	.	.	.
not_characterized	.	.	42	.	.	.	24
Municipal_Waste_Combustor	.	.	.	.	.	.	.
Aircraft_Aerospace_or_Related	.	.	11	.	.	.	.
	Monitor not used for 2010-2015 analysis (either historical data or were incomplete)						

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1 **Table B5-44. Attributes of ambient monitors within the Miami study area not used for the**
 2 **2010-2015 analysis.**

stateabbr	FL	FL	FL			
countyname	Broward	Palm Beach	Palm Beach			
siteid	120110003	120990021	120991004			
Lat	26.28147	26.59381	26.69340			
Lon	-80.28255	-80.05849	-80.09921			
year_start	1990	2015	1979			
year_end	1998	2016	2008			
Elevation_m	3	9	0			
land_use	INDUS	INDUS	RESID			
scale	NBHOOD	URBAN	MID			
objective1	HI_CONC	MAX_O3	HI_CONC			
objective2	POP_EXP	HI_CONC	POP_EXP			
objective3						
cnty_landarea_2010	1210	1970	1970			
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	894	.	.			
road_closest	0	.	.			
aadt_closest	17600	.	.			
dist_aadtmax	895	.	.			
road_aadtmax	0	.	.			
aadt_aadtmax	35000	.	.			
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	22197	16775	16775			
NonRoad_mobile_nox	5885	7625	7625			
AML_mobile_nox	8072	4059	4059			
total_nox	43997	35647	35647			
pct_mobile_nox	82.2	79.8	79.8			
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Airport	.	.	388			
Electricity_Generation_via_Combu	.	18	.			
Institutional_school_hospital_	.	.	.			
Petroleum_Storage_Facility	.	.	.			
Wastewater_Treatment_Facility	.	.	.			
		Monitor not used for 2010-2015 analysis (either historical data or were incomplete)				

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1 **Table B5-45. Attributes of ambient monitors within the Minneapolis study area not used**
 2 **for the 2010-2015 analysis.**

stateabbr	MN	MN	MN	MN	MN	
countyname	Dakota	Hennepin	Hennepin	Ramsey	Wright	
siteid	270370428	270530953	270530957	271230864	271710007	
Lat	44.79219	45.00247	45.02108	44.99191	45.32913	
Lon	-93.08549	-93.24772	-93.28217	-93.18328	-93.83608	
year_start	1991	1989	1996	1989	1979	
year_end	1992	1996	2002	2002	1997	
Elevation_m	294	256	0	305	288	
land_use	AGRIC	COMM	INDUS	RESID	AGRIC	
scale	MID	MID	MID	URBAN	NA	
objective1	POP_EXP	POP_EXP	HI_CONC	POP_EXP		
objective2	SOURCE	HI_CONC				
objective3						
cnty_landarea_2010	562	554	554	152	661	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	.	781	5	.	899	
road_closest	.	35	0	.	94	
aadt_closest	.	109340	3441	.	43196	
dist_aadtmax	.	.	107	.	.	
road_aadtmax	.	.	94	.	.	
aadt_aadtmax	.	.	124250	.	.	
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	7604	21967	21967	9912	3496	
NonRoad_mobile_nox	2061	5495	5495	1700	1041	
AML_mobile_nox	295	3168	3168	1435	698	
total_nox	19738	39010	39010	16428	6143	
pct_mobile_nox	50.5	78.5	78.5	79.4	85.2	
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Petroleum_Refinery	1296	.	.	.	.
Municipal_Waste_Combustor	.	594	594	.	.	
Electricity_Generation_via_Combu	87	404	72	.	.	
Institutional_school_hospital_	.	145	21	155	.	
Rail_Yard	.	253	358	111	.	
Pulp_and_Paper_Plant	.	.	.	339	.	
Gas_Plant	63	.	.	.	.
Secondary_Aluminum_Smelting_Refi	.	.	.	.	.
Steam_Heating_Facility	.	15	.	.	.	
not_characterized	.	11	.	11	.	
Printing_Publishing_Facility	31	.	.	.	.
Food_Products_Processing_Plant	.	20	.	20	.	
		Monitor not used for 2010-2015 analysis (either historical data or were incomplete)				

1 **Table B5-46. Attributes of ambient monitors within the New York/Jersey study area not**
 2 **used for the 2010-2015 analysis.**

stateabbr	NJ	NJ	NJ	NJ	NJ	NJ
countyname	Bergen	Bergen	Essex	Essex	Union	Union
siteid	340030001	340030005	340130011	340130016	340390008	340395001
Lat	40.80843	40.89858	40.72667	40.72222	40.59803	40.60173
Lon	-73.99236	-74.02990	-74.14374	-74.14694	-74.45381	-74.44107
year_start	1982	2000	1984	2001	1995	1980
year_end	1998	2007	1999	2003	1997	1994
Elevation_m	61	6	3	3	18	19
land_use	RESID	RESID	INDUS	INDUS	RESID	RESID
scale	NA	NBHOOD	NA	NBHOOD	NBHOOD	NBHOOD
objective1		POP_EXP	POP_EXP	POP_EXP	POP_EXP	POP_EXP
objective2			HI_CONC			
objective3						
cnty_landarea_2010	233	233	126	126	103	103
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	965	244	218	16	17	343
road_closest	63	4	1	1	28	28
aadt_closest	17535	106918	67959	67959	10995	10995
dist_aadtmax	965	244	920	984	466	.
road_aadtmax	63	4	95	95	28	.
aadt_aadtmax	22502	113560	221613	115451	18357	.
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	8080	8080	5162	5162	4874	4874
NonRoad_mobile_nox	3313	3313	2070	2070	1346	1346
AML_mobile_nox	1070	1070	3355	3355	3479	3479
total_nox	15763	15763	14172	14172	13636	13636
pct_mobile_nox	79.1	79.1	74.7	74.7	71.1	71.1
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Airport	.	.	2984	2984	.	.
Electricity_Generation_via_Combu	894	.	442	442	.	.
Municipal_Waste_Combustor	.	.	758	758	.	.
Petroleum_Refinery	.	.	.	.	.	.
Institutional_school_hospital_	111	15	74	74	.	.
Wastewater_Treatment_Facility	369	.	14	14	.	.
Breweries_Distilleries_Wineries	.	.	.	68	.	.
Petroleum_Storage_Facility	.	.	.	.	.	.
Pharmaceutical_Manufacturing	.	.	.	.	.	.
Fabricated_Metal_Products_Plant	.	.	10	10	.	.
Compressor_Station	95	.	.	.	.	.
Steam_Heating_Facility	69	.	.	.	.	.
not_characterized	68	.	24	24	.	.
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)			

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1 **Table B5-46, continued. Attributes of ambient monitors in the New York/Jersey study area**
 2 **not used for the 2010-2015 analysis.**

stateabbr	NY	NY	NY	NY	NY	NY
countyname	Bronx	Bronx	Bronx	Dutchess	Kings	New York
siteid	360050073	360050080	360050083	360270007	360470011	360610010
Lat	40.81149	40.83606	40.86585	41.78555	40.73277	40.73955
Lon	-73.90958	-73.92009	-73.88083	-73.74136	-73.94722	-73.98569
year_start	1997	1990	1995	1993	1978	1976
year_end	1999	2000	2007	1993	1996	2001
Elevation_m	15	20	24	98	9	38
land_use	RESID	RESID	COMM	AGRIC	INDUS	RESID
scale	NA	NBHOOD	NA	NA	NBHOOD	NBHOOD
objective1	POP_EXP	HI_CONC	GEN/BKGR	POP_EXP	HI_CONC	POP_EXP
objective2	GEN/BKGR	POP_EXP	POP_EXP	GEN/BKGR	GEN/BKGR	HI_CONC
objective3	QUAL ASSUR	GEN/BKGR			POP_EXP	
cnty_landarea_2010	42	42	42	796	71	23
ADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	423	170	82	619	154	57
road_closest	0	0	0	44	0	0
aadt_closest	5300	20300	11500	10400	22000	18200
dist_aadtmax	701	973	700	.	936	946
road_aadtmax	87	95	0	.	495	0
aadt_aadtmax	132100	152100	112700	.	79400	138500
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	4297	4297	4297	2626	6463	5664
NonRoad_mobile_nox	1767	1767	1767	909	4537	7424
AML_mobile_nox	708	708	708	180	1004	6085
total_nox	9912	9912	9912	5090	19011	33400
pct_mobile_nox	68.3	68.3	68.3	73	63.1	57.4
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Airport	.	.	.	.	.	12
Electricity_Generation_via_Combu	1048	.	.	.	2462	2906
Municipal_Waste_Combustor	.	.	.	.	.	.
Petroleum_Refinery	.	.	.	.	.	.
Institutional_school_hospital_	248	108	249	.	222	201
Wastewater_Treatment_Facility	346	346	.	.	14	14
Breweries_Distilleries_Wineries	.	.	.	.	.	.
Petroleum_Storage_Facility	.	.	.	.	.	.
Pharmaceutical_Manufacturing	.	.	.	.	.	.
Fabricated_Metal_Products_Plant	.	.	.	.	.	.
Compressor_Station	11	11	.	.	.	.
Steam_Heating_Facility	69	69	.	.	381	381
not_characterized	166	166	232	.	170	149
						Monitor not used for 2010-2015 analysis (either historical data or were incomplete)

1 **Table B5-46, continued. Attributes of ambient monitors in the New York/Jersey study area**
 2 **not used for the 2010-2015 analysis.**

stateabbr	NY	NY	NY	NY	NY	
countyname	New York	Queens	Queens	Suffolk	Westchester	
siteid	360610056	360810097	360810098	361030009	361195003	
Lat	40.75912	40.75527	40.78420	40.82799	41.04500	
Lon	-73.96661	-73.75861	-73.84757	-73.05754	-73.70333	
year_start	1985	1998	1998	1999	1992	
year_end	2008	2001	2006	2010	1993	
Elevation_m	17	0	6	45	15	
land_use	COMM	RESID	RESID	RESID	RESID	
scale	MID	NA	NA	NA	URBAN	
objective1	HI_CONC	GEN/BKGR	GEN/BKGR	POP_EXP	POP_EXP	
objective2	GEN/BKGR		SOURCE	GEN/BKGR		
objective3	POP_EXP					
cnty_landarea_2010	23	109	109	912	431	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	68	189	138	160	.	
road_closest	0	0	0	0	.	
aadt_closest	23300	5600	5000	81700	.	
dist_aadtmax	647	642	550	875	.	
road_aadtmax	0	495	0	495	.	
aadt_aadtmax	135800	150100	15600	166100	.	
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	5664	11095	11095	16911	8518	
NonRoad_mobile_nox	7424	4060	4060	6367	2766	
AML_mobile_nox	6085	6546	6546	8122	371	
total_nox	33400	29220	29220	39142	16263	
pct_mobile_nox	57.4	74.3	74.3	80.2	71.7	
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Airport	12	.	1694	.	131	
Electricity_Generation_via_Combu	2835	.	274	301	.	
Municipal_Waste_Combustor	.	.	.	.	.
Petroleum_Refinery	.	.	.	.	.
Institutional_school_hospital_	300	18	41	.	.	
Wastewater_Treatment_Facility	14	.	108	.	.	
Breweries_Distilleries_Wineries	.	.	.	.	.
Petroleum_Storage_Facility	.	.	.	.	.
Pharmaceutical_Manufacturing	.	.	.	.	.
Fabricated_Metal_Products_Plant	.	.	.	.	.
Compressor_Station	.	.	11	.	.	
Steam_Heating_Facility	363	.	.	.	.
not_characterized	202	33	14	.	.	
						Monitor not used for 2010-2015 analysis (either historical data or were incomplete)

1 **Table B5-47. Attributes of ambient monitors within the Philadelphia study area not used**
 2 **for the 2010-2015 analysis.**

stateabbr	DE	DE	DE	DE	DE	NJ
countyname	New Castle	New Castle	New Castle	New Castle	New Castle	Camden
siteid	100031003	100031007	100031010	100032002	100033001	340070003
Lat	39.76111	39.55130	39.81722	39.75789	39.81233	39.92304
Lon	-75.49194	-75.73200	-75.56389	-75.54603	-75.45520	-75.097617
year_start	1992	1992	2013	1977	1977	1979
year_end	2000	1999	2014	1992	1992	2008
Elevation_m	65	20	0	46	30	7.6
land_use	RESID	AGRIC	AGRIC	COMM	RESID	RESID
scale	NA	NA	NA	NBHOOD	NBHOOD	NBHOOD
objective1	HI_CONC	POP_EXP	POP_EXP	POP_EXP	HI_CONC	POP_EXP
objective2	POP_EXP	GEN/BKGR		HI_CONC		HI_CONC
objective3		UP_BKGR				
cnty_landarea_2010	426	426	426	426	426	221
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	253	560	.	374	49	512
road_closest	495	301	.	202	95	605
aadt_closest	73574	21601	.	8387	48906	23085
dist_aadtmax	.	855	.	578	386	838
road_aadtmax	.	301	.	95	95	30
aadt_aadtmax	.	38941	.	100551	118099	57822
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	6459	6459	6459	6459	6459	5353
NonRoad_mobile_nox	1748	1748	1748	1748	1748	1150
AML_mobile_nox	1805	1805	1805	1805	1805	1088
total_nox	13991	13991	13991	13991	13991	9431
pct_mobile_nox	71.6	71.6	71.6	71.6	71.6	80.5
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Petroleum_Refinery	.	.	.	.	2146	.
Municipal_Waste_Combustor	.	.	.	20	.	297
Electricity_Generation_via_Combu	948	.	.	948	963	26
Chemical_Plant	27	.	.	27	.	14
Pulp_and_Paper_Plant	.	.	.	.	.	.
Institutional_school_hospital_	.	.	.	.	.	.
Wastewater_Treatment_Facility	.	.	.	.	.	14
Steam_Heating_Facility	.	.	.	.	.	.
Petroleum_Storage_Facility	.	.	.	.	.	.
Military_Base	.	.	.	.	.	.
Automobile_Truck_or_Parts_Plant	.	.	.	.	.	.
not_characterized	.	.	180	180	54	13
Steel_Mill	.	.	.	.	166	.
Hot_Mix_Asphalt_Plant	.	.	.	.	.	.
Pharmaceutical_Manufacturing	.	.	.	.	.	.
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)			

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1 **Table B5-47, continued. Attributes of ambient monitors within the Philadelphia study area**
 2 **not used for the 2010-2015 analysis.**

stateabbr	PA	PA				
countyname	Montgomery	Philadelphia				
siteid	420910013	421010029				
Lat	40.11222	39.95733				
Lon	-75.30917	-75.17268				
year_start	1973	1975				
year_end	2008	2005				
Elevation_m	53	25				
land_use	RESID	COMM				
scale	NBHOOD	NBHOOD				
objective1	POP_EXP	POP_EXP				
objective2		HI_CONC				
objective3						
cnty_landarea_2010	483	134				
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	569	198				
road_closest	276	0				
aadt_closest	63476	23842				
dist_aadtmax	.	586				
road_aadtmax	.	76				
aadt_aadtmax	.	144789				
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	9533	10201				
NonRoad_mobile_nox	3076	2480				
AML_mobile_nox	219	2160				
total_nox	16546	21065				
pct_mobile_nox	77.5	70.5				
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Petroleum_Refinery	.	.				
Municipal_Waste_Combustor	735	.				
Electricity_Generation_via_Combu	.	353				
Chemical_Plant	.	.				
Pulp_and_Paper_Plant	.	.				
Institutional_school_hospital_	.	66				
Wastewater_Treatment_Facility	.	.				
Steam_Heating_Facility	.	24				
Petroleum_Storage_Facility	.	.				
Military_Base	.	.				
Automobile_Truck_or_Parts_Plant	.	.				
not_characterized	53	.				
Steel_Mill	85	.				
Hot_Mix_Asphalt_Plant	16	.				
Pharmaceutical_Manufacturing	26	.				
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)			

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1 **Table B5-48. Attributes of ambient monitors within the Phoenix study area not used for the**
 2 **2010-2015 analysis.**

stateabbr	AZ	AZ	AZ	AZ		
countyname	Maricopa	Maricopa	Maricopa	Pinal		
siteid	040134005	040139993	040139994	040218001		
Lat	33.41240	33.34885	33.48889	33.29347		
Lon	-111.93473	-112.83110	-111.86250	-111.28559		
year_start	2000	1996	1991	2001		
year_end	2003	2004	1999	2006		
Elevation_m	352	265	0	634		
land_use	RESID	INDUS	AGRIC	DESERT		
scale	NA	NA	NA	NA		
objective1	POP_EXP	GEN/BKGR	UP_BKGR	DOWNWND		
objective2				HI_CONC		
objective3				REG TRANS		
cnty_landarea_2010	9200	9200	9200	5366		
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	522	.	.	.		
road_closest	0	.	.	.		
aadt_closest	25583	.	.	.		
dist_aadtmax	906	.	.	.		
road_aadtmax	0	.	.	.		
aadt_aadtmax	36152	.	.	.		
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	56748	56748	56748	9273		
NonRoad_mobile_nox	18998	18998	18998	1575		
AML_mobile_nox	3999	3999	3999	1775		
total_nox	88464	88464	88464	14883		
pct_mobile_nox	90.1	90.1	90.1	84.8		
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Airport	.	.	.	.
Electricity_Generation_via_Combu	83	343	.	.		
Rail_Yard	.	.	.	.
		Monitor not used for 2010-2015 analysis (either historical data or were incomplete)				

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1 **Table B5-49. Attributes of ambient monitors within the Pittsburgh study area not used for**
 2 **the 2010-2014 analysis.**

stateabbr	PA	PA	PA	PA	PA	
countyname	Allegheny	Allegheny	Washington	Washington	Westmoreland	
siteid	420030003	420030031	421255001	421255200	421290008	
Lat	40.45010	40.44337	40.44528	40.26896	40.30469	
Lon	-79.77096	-79.99029	-80.42083	-80.24400	-79.50567	
year_start	1987	1980	1998	2012	1997	
year_end	1992	2001	2008	2016	2008	
Elevation_m	11	268	335	327	0	
land_use	RESID	COMM	AGRIC	AGRIC	COMM	
scale	NBHOOD	NBHOOD	REGION	NBHOOD	URBAN	
objective1	POP_EXP	POP_EXP	REG TRANS	SOURCE	POP_EXP	
objective2		HI_CONC	GEN/BKGR	POP_EXP	REG TRANS	
objective3			POP_EXP			
cnty_landarea_2010	730	730	857	857	1028	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	563	66	.	.	177	
road_closest	376	579	.	.	30	
aadt_closest	52875	54441	.	.	34536	
dist_aadtmax	.	.	.	.	186	
road_aadtmax	.	.	.	.	30	
aadt_aadtmax	.	.	.	.	44067	
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	13259	13259	3024	3024	4743	
NonRoad_mobile_nox	4029	4029	856	856	1147	
AML_mobile_nox	3322	3322	686	686	1458	
total_nox	35455	35455	10067	10067	12939	
pct_mobile_nox	58.1	58.1	45.4	45.4	56.8	
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Steel_Mill	.	.	.	.	.
Food_Products_Processing_Plant	.	212	.	.	.	
Steam_Heating_Facility	.	166	.	.	.	
Institutional_school_hospital_	.	36	.	.	.	
Wastewater_Treatment_Facility	.	.	.	.	.
Hot_Mix_Asphalt_Plant	.	18	.	.	.	
Electricity_Generation_via_Combu	.	33	.	.	.	
Foundries_Iron_and_Steel	.	13	.	.	.	
Glass_Plant	.	.	.	.	.
Chemical_Plant	.	.	.	.	.
Coke_Battery	.	.	.	.	.
not_characterized	.	15	.	.	.	
Landfill	.	.	.	.	.
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)			

1 **Table B5-50. Attributes of ambient monitors within the Richmond study area not used for**
 2 **the 2010-2015 analysis.**

stateabbr	VA	VA				
countyname	Caroline	Richmond City				
siteid	510330001	517600021				
Lat	38.20087	37.56320				
Lon	-77.37742	-77.46721				
year_start	1993	1981				
year_end	2012	1997				
Elevation_m	68	58				
land_use	FOREST	COMM				
scale	URBAN	NA				
objective1	HI_CONC	HI_CONC				
objective2	UP_BKGR					
objective3	GEN/BKGR					
cnty_landarea_2010	528	60				
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	.	178				
road_closest	.	161				
aadt_closest	.	22386				
dist_aadtmax	.	342				
road_aadtmax	.	33				
aadt_aadtmax	.	22984				
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	2472	2719				
NonRoad_mobile_nox	166	396				
AML_mobile_nox	407	315				
total_nox	3486	6928				
pct_mobile_nox	87.3	49.5				
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Pulp_and_Paper_Plant	.	.				
Rail_Yard	.	115				
Institutional_school_hospital_	.	10				
not_characterized	65	24				
		Monitor not used for 2010-2015 analysis (either historical data or were incomplete)				

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1 **Table B5-51. Attributes of ambient monitors within the Riverside study area not used for**
 2 **the 2010-2015 analysis.**

stateabbr	CA	CA	CA	CA	CA	CA
countyname	Riverside	Riverside	Riverside	San Bernardino	San Bernardino	San Bernardino
siteid	060650004	060650006	060656001	060710006	060710012	060710014
Lat	34.00700	33.49170	33.78942	35.75995	34.42613	34.51250
Lon	-	-	-	-117.37478	-117.56394	-117.33088
year_start	2007	1991	1988	1979	1987	1991
year_end	2011	1993	1990	1994	1998	1999
Elevation_m	70	341	439	506	4100	876
land_use	RESID	RESID	COMM	INDUS	COMM	RESID
scale	NA	MID	NA	NA	NA	NA
objective1	POP_EXP		POP_EXP		REG TRANS	REG TRANS
objective2						
objective3						
cnty_landarea_2010	7206	7206	7206	20057	20057	20057
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	.	64	177	.	.	580
road_closest	.	15	215	.	.	18
aadt_closest	.	152000	82000	.	.	40000
dist_aadtmax	.	.	250	.	.	797
road_aadtmax	.	.	215	.	.	15
aadt_aadtmax	.	.	99000	.	.	85000
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	25868	25868	25868	31067	31067	31067
NonRoad_mobile_nox	5541	5541	5541	5646	5646	5646
AML_mobile_nox	2215	2215	2215	9344	9344	9344
total_nox	37367	37367	37367	68863	68863	68863
pct_mobile_nox	90	90	90	66.9	66.9	66.9
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Mineral_Processing_Plant	.	.	.	1865	.	.
Electricity_Generation_via_Combu	.	.	.	620	.	.
Airport	.	.	.	.	.	.
Rail_Yard	.	.	.	.	.	.
Pulp_and_Paper_Plant	140	.	.	.	.	.
Fabricated_Metal_Products_Plant	20	.	.	.	.	.
Food_Products_Processing_Plant	.	.	.	.	.	.
Foundries_non_ferrous	.	.	.	.	.	.
not_characterized	.	.	.	.	.	.
Municipal_Waste_Combustor	11	.	.	.	.	.
Portland_Cement_Manufacturing	.	.	.	.	.	.
Primary_Aluminum_Plant	17	.	.	.	.	.
Secondary_Aluminum_Smelting_Refi	.	.	.	.	.	.
Steel_Mill	.	.	.	.	.	.
Institutional_school_hospital_	.	.	.	.	.	.
						Monitor not used for 2010-2015 analysis (either historical data or were incomplete)

1 **Table B5-51, continued. Attributes of ambient monitors within the Riverside study area not**
 2 **used for the 2010-2015 analysis.**

stateabbr	CA	CA	CA	CA	CA	
countyname	San Bernardino	San Bernardino	San Bernardino	San Bernardino	San Bernardino	
siteid	060710015	060710017	060711101	060714001	060717002	
Lat	35.77495	34.14195	34.14195	34.41807	34.52333	
Lon	-117.36756	-116.05584	-116.05917	-117.28560	-117.30449	
year_start	1993	1993	1992	1979	1981	
year_end	1997	1998	1993	1998	1991	
Elevation_m	498	607	650	1006	895	
land_use	INDUS	MOBILE	AGRIC	RESID	COMM	
scale	NA	NA	NA	NA	NA	
objective1		REG TRANS		REG TRANS		
objective2		POP_EXP		POP_EXP		
objective3				UP_BKGR		
cnty_landarea_2010	20057	20057	20057	20057	20057	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	.	665	669	.	.	
road_closest	.	62	62	.	.	
aadt_closest	.	7100	13000	.	.	
dist_aadtmax	.	708	.	.	.	
road_aadtmax	.	62	.	.	.	
aadt_aadtmax	.	13000	.	.	.	
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	31067	31067	31067	31067	31067	
NonRoad_mobile_nox	5646	5646	5646	5646	5646	
AML_mobile_nox	9344	9344	9344	9344	9344	
total_nox	68863	68863	68863	68863	68863	
pct_mobile_nox	66.9	66.9	66.9	66.9	66.9	
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Mineral_Processing_Plant	1865	.	.	.	.
Electricity_Generation_via_Combu	620	.	.	.	.
Airport	.	.	.	.	.
Rail_Yard	.	.	.	.	.
Pulp_and_Paper_Plant	.	.	.	.	.
Fabricated_Metal_Products_Plant	.	.	.	.	.
Food_Products_Processing_Plant	.	.	.	.	.
Foundries_non_ferrous	.	.	.	.	.
not_characterized	.	.	.	.	.
Municipal_Waste_Combustor	.	.	.	.	.
Portland_Cement_Manufacturing	.	.	.	.	33	
Primary_Aluminum_Plant	.	.	.	.	.
Secondary_Aluminum_Smelting_Refi	.	.	.	.	.
Steel_Mill	.	.	.	.	.
Institutional_school_hospital	.	.	.	.	.
						Monitor not used for 2010-2015 analysis (either historical data or were incomplete)

1 **Table B5-52. Attributes of ambient monitors within the Sacramento study area not used for**
 2 **the 2010-2015 analysis.**

stateabbr	CA	CA	CA	CA	CA	CA
countyname	El Dorado	El Dorado	El Dorado	Placer	Placer	Sacramento
siteid	060170009	060170011	060170012	060610007	060613001	060670001
Lat	38.94574	38.94498	38.81161	39.18407	38.78879	38.66713
Lon	-119.96796	-119.97061	-120.03308	-120.12298	-121.21773	-121.25134
year_start	1981	1992	1999	2002	1991	1979
year_end	1992	2004	2004	2004	1996	1993
Elevation_m	1911	1905	2250	1	75	52
land_use	COMM	COMM	FOREST	COMM	RESID	RESID
scale	NA	NA	NA	URBAN	NA	NA
objective1		POP_EXP	HI_CONC	POP_EXP	POP_EXP	POP_EXP
objective2			GEN/BKGR			
objective3						
cnty_landarea_2010	1708	1708	1708	1407	1407	965
ADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	28	86	183	.	321	.
road_closest	50	50	50	.	80	.
aadt_closest	30500	30500	8900	.	89000	.
dist_aadtmax	479	185	.	.	486	.
road_aadtmax	50	50	.	.	80	.
aadt_aadtmax	33000	33000	.	.	113000	.
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	1886	1886	1886	4760	4760	12361
NonRoad_mobile_nox	721	721	721	1492	1492	3122
AML_mobile_nox	94	94	94	1150	1150	1821
total_nox	3637	3637	3637	9158	9158	19897
pct_mobile_nox	74.3	74.3	74.3	80.8	80.8	87
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Airport	.	.	.	.	.	.
Rail_Yard	.	.	.	.	.	.
Institutional_school_hospital_	.	.	.	.	.	.
not_characterized	27	27	.	.	.	.
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)			

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1 **Table B5-52, continued. Attributes of ambient monitors within the Sacramento study area**
 2 **not used for the 2010-2015 analysis.**

stateabbr	CA	CA	CA			
countyname	Sacramento	Sacramento	Sacramento			
siteid	060670013	060671001	060675002			
Lat	38.63685	38.67490	38.71685			
Lon	-121.51440	-121.18689	-121.59301			
year_start	1998	1979	1989			
year_end	2008	1996	1997			
Elevation_m	5	57	30			
land_use	COMM	COMM	AGRIC			
scale	NA	NA	NBHOOD			
objective1	HI_CONC	HI_CONC	POP_EXP			
objective2	POP_EXP					
objective3						
cnty_landarea_2010	965	965	965			
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	704	.	.			
road_closest	5	.	.			
aadt_closest	140000	.	.			
dist_aadtmax	878	.	.			
road_aadtmax	80	.	.			
aadt_aadtmax	144000	.	.			
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	12361	12361	12361			
NonRoad_mobile_nox	3122	3122	3122			
AML_mobile_nox	1821	1821	1821			
total_nox	19897	19897	19897			
pct_mobile_nox	87	87	87			
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Airport	.	.	586			
Rail_Yard	.	.	.			
Institutional_school_hospital_	.	.	.			
not_characterized	.	.	.			
		Monitor not used for 2010-2015 analysis (either historical data or were incomplete)				

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1 **Table B5-53. Attributes of ambient monitors within the San Diego study area not used for**
 2 **the 2010-2015 analysis.**

stateabbr	CA	CA	CA	CA		
countyname	San Diego	San Diego	San Diego	San Diego		
siteid	060730005	060731007	060731009	060731018		
Lat	33.20269	32.70922	32.69866	32.81798		
Lon	-117.36680	-117.15484	-117.13309	-116.96813		
year_start	1979	1989	1999	2014		
year_end	2001	2005	2001	2016		
Elevation_m	37	6	0	119		
land_use	UNK	COMM	RESID	COMM		
scale	NBHOOD	NBHOOD	NA	NBHOOD		
objective1	POP_EXP	HI_CONC	POP_EXP	SOURCE		
objective2		POP_EXP		GEN/BKGR		
objective3				POP_EXP		
cnty_landarea_2010	4207	4207	4207	4207		
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	505	575	369	670		
road_closest	5	5	5	67		
aadt_closest	192000	162000	159000	83000		
dist_aadtmax	.	589	686	.		
road_aadtmax	.	5	5	.		
aadt_aadtmax	.	208000	161000	.		
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	27531	27531	27531	27531		
NonRoad_mobile_nox	7428	7428	7428	7428		
AML_mobile_nox	3491	3491	3491	3491		
total_nox	42700	42700	42700	42700		
pct_mobile_nox	90	90	90	90		
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Electricity_Generation_via_Combu	.	.	.	.
Military_Base	.	11	11	.		
Pharmaceutical_Manufacturing	.	38	38	.		
Ship_Boat_Manufacturing_or_Repai	.	13	13	.		
not_characterized	.	88	66	.		
		Monitor not used for 2010-2015 analysis (either historical data or were incomplete)				

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1 **Table B5-54. Attributes of ambient monitors within the San Francisco study area not used**
 2 **for the 2010-2015 analysis.**

stateabbr	CA	CA	CA	CA	CA	CA
countyname	Alameda	Alameda	Alameda	Contra Costa	Contra Costa	Contra Costa
siteid	060010003	060010010	060011001	060130003	060130010	060131003
Lat	37.68490	37.76023	37.53583	37.94992	38.03122	37.96420
Lon	-121.76590	-122.19358	-121.96182	-122.35719	-122.13288	-122.34030
year_start	1980	2001	1973	1972	2001	1997
year_end	2000	2003	2010	1997	2003	2002
Elevation_m	150	10	17	23	36	15
land_use	COMM	RESID	RESID	COMM	COMM	COMM
scale	NA	NBHOOD	URBAN	NA	NBHOOD	NA
objective1	HI_CONC	POP_EXP	POP_EXP	POP_EXP	POP_EXP	POP_EXP
objective2	POP_EXP			HI_CONC	WELF IMP	
objective3						
cnty_landarea_2010	739	739	739	716	716	716
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	.	137	.	.	.	916
road_closest	.	185	.	.	.	80
aadt_closest	.	24000	.	.	.	186000
dist_aadtmax	.	.	.	.	.	.
road_aadtmax	.	.	.	.	.	.
aadt_aadtmax	.	.	.	.	.	.
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	19032	19032	19032	9307	9307	9307
NonRoad_mobile_nox	3158	3158	3158	2074	2074	2074
AML_mobile_nox	3507	3507	3507	1973	1973	1973
total_nox	28381	28381	28381	20714	20714	20714
pct_mobile_nox	90.5	90.5	90.5	64.5	64.5	64.5
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Petroleum_Refinery	.	941	.	.	.	.
Airport	.	.	.	.	.	.
Electricity_Generation_via_Combu	.	327	.	.	.	.
Glass_Plant	.	.	.	127	65	127
Rail_Yard	.	.	.	.	.	.
Wastewater_Treatment_Facility	.	36	.	.	.	.
Foundries_Iron_and_Steel	.	.	.	.	.	.
Pharmaceutical_Manufacturing	.	.	.	33	.	39
not_characterized	.	.	.	24	.	24
Landfill	.	.	.	.	13	.
Hot_Mix_Asphalt_Plant	.	.	.	.	.	.
Chemical_Plant	.	.	.	.	.	.
Institutional_school_hospital_	.	941	.	.	.	.
		Monitor not used for 2010-2015 analysis (either historical data or were incomplete)				

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1 **Table B5-54, continued. Attributes of ambient monitors within the San Francisco study**
 2 **area not used for the 2010-2015 analysis.**

stateabbr	CA	CA				
countyname	Contra Costa	San Francisco				
siteid	060133001	060750006				
Lat	38.02926	37.73380				
Lon	-121.89687	-122.38240				
year_start	1967	2004				
year_end	2008	2005				
Elevation_m	2	82				
land_use	RESID	RESID				
scale	NBHOOD	NBHOOD				
objective1	HI_CONC	POP_EXP				
objective2	POP_EXP					
objective3						
cnty_landarea_2010	716	47				
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	.	.				
road_closest	.	.				
aadt_closest	.	.				
dist_aadtmax	.	.				
road_aadtmax	.	.				
aadt_aadtmax	.	.				
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	9307	4623				
NonRoad_mobile_nox	2074	1474				
AML_mobile_nox	1973	5065				
total_nox	20714	12406				
pct_mobile_nox	64.5	90				
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Petroleum_Refinery	.	.				
Airport	.	.				
Electricity_Generation_via_Combu	350	.				
Glass_Plant	.	.				
Rail_Yard	.	.				
Wastewater_Treatment_Facility	.	74				
Foundries_Iron_and_Steel	.	.				
Pharmaceutical_Manufacturing	.	.				
not_characterized	17	.				
Landfill	.	.				
Hot_Mix_Asphalt_Plant	.	.				
Chemical_Plant	56	.				
Institutional_school_hospital_	.	10				
	Monitor not used for 2010-2015 analysis (either historical data or were incomplete)					

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1 **Table B5-55. Attributes of ambient monitors within the St. Louis study area not used for**
 2 **the 2010-2015 analysis.**

stateabbr	MO	MO	MO	MO	MO	MO	MO	
countyname	Saint Charles	Saint Charles	Saint Louis	Saint Louis	Saint Louis	Saint Louis	Saint Louis	
siteid	291830010	291831002	291890001	291890004	291890006	291890014	291893001	
Lat	38.58192	38.87255	38.52172	38.53278	38.61366	38.71090	38.65026	
Lon	-90.83531	-90.22649	-90.34371	-90.38243	-90.49594	-90.47590	-90.35046	
min_year	1994	1975	1977	1998	1978	2005	1970	
max_year	1998	2010	1998	2010	2005	2010	2010	
Elevation_m	0	131	183	183	175	193	161	
land_use	AGRIC	AGRIC	RESID	RESID	RESID	RESID	COMM	
scale	NA	URBAN	NA	NA	NA	NBHOOD	NA	
objective1		POP_EXP	POP_EXP	POP_EXP	POP_EXP	POP_EXP	POP_EXP	
objective2		MAX_O3		QUAL				
objective3		HI_CONC						
cnty_landarea_2010	560	560	508	508	508	508	508	
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>								
dist_closest	.	905	143	131	.	539	75	
road_closest	.	67	50	50	.	364	170	
aadt_closest	.	26451	30939	19136	.	27533	114639	
aadt_aadtmax	.	.	927	187	.	.	.	
road_aadtmax	.	.	55	30	.	.	.	
dist_aadtmax	.	.	111855	27183	.	.	.	
<i>County Level NOx Emissions (tpy)</i>								
OnRoad_mobile_nox	7867	7867	25063	25063	25063	25063	25063	
NonRoad_mobile_nox	1714	1714	4697	4697	4697	4697	4697	
AML_mobile_nox	580	580	1902	1902	1902	1902	1902	
total_nox	18373	18373	39486	39486	39486	39486	39486	
pct_mobile_nox	55.3	55.3	80.2	80.2	80.2	80.2	80.2	
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>								
Breweries_Distilleries_Wineries	.	.	.	.	.	.	.
Rail_Yard	.	.	.	.	.	.	.
Electricity_Generation_via_Combu	9891	.	.	.	.	.	.
Wastewater_Treatment_Facility	.	.	.	.	.	89	.
Institutional_school_hospital_	.	.	.	.	.	.	20
Ethanol_Biorefineries_Soy_Biodie	.	.	.	.	.	.	.
Chemical_Plant	.	.	.	.	.	.	.
Pharmaceutical_Manufacturing	.	.	.	.	.	.	.
Landfill	.	.	.	.	.	11	.
Steam_Heating_Facility	.	.	.	.	.	.	.
Petroleum_Storage_Facility	.	.	.	.	.	.	.
not_characterized	.	.	.	.	.	.	22
Aircraft_Aerospace_or_Related	.	.	.	.	.	.	.
Airport	.	.	.	.	.	.	.
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)					

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1 **Table B5-55, continued. Attributes of ambient monitors within the St. Louis study area not**
 2 **used for the 2010-2015 analysis.**

stateabbr	MO	MO	MO	MO	MO	MO
countyname	Saint Louis	Saint Louis	Saint Louis	Saint Louis	St. Louis City	St. Louis City
siteid	291895001	291897001	291897002	291897003	295100072	295100080
Lat	38.76616	38.72755	38.72727	38.72096	38.62422	38.65864
Lon	-90.28593	-90.37955	-90.37955	-90.36713	-90.19871	-90.24426
min_year	1978	1976	1990	2001	1981	1982
max_year	2005	1990	2001	2004	2005	1999
Elevation_m	168	168	168	0	154	152
land_use	COMM	RESID	RESID	RESID	COMM	RESID
scale	NA	NA	NA	NBHOOD	NA	NBHOOD
objective1	POP_EXP	POP_EXP	POP_EXP	POP_EXP	POP_EXP	POP_EXP
objective2	QUAL		SOURCE	HI_CONC		HI_CONC
objective3	HI_CONC					
cnty_landarea_2010	508	508	508	508	62	62
AADT information (distance in meters, road/highway/interstate number, AADT value)						
dist_closest	433	77	53	103	70	483
road_closest	0	0	0	0	0	0
aadt_closest	39856	32999	32999	32999	16662	12582
aadt_aadtmax	536	.	.	.	880	.
road_aadtmax	270	.	.	.	55	.
dist_aadtmax	137862	.	.	.	99609	.
County Level NOx Emissions (tpy)						
OnRoad_mobile_nox	25063	25063	25063	25063	6296	6296
NonRoad_mobile_nox	4697	4697	4697	4697	663	663
AML_mobile_nox	1902	1902	1902	1902	1590	1590
total_nox	39486	39486	39486	39486	10691	10691
pct_mobile_nox	80.2	80.2	80.2	80.2	80	80
NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)						
Breweries_Distilleries_Wineries	.	.	.	.	467	.
Rail_Yard	.	.	.	.	411	421
Electricity_Generation_via_Combu	.	.	.	.	285	.
Wastewater_Treatment_Facility	.	.	.	.	.	81
Institutional_school_hospital_	.	.	.	.	.	49
Ethanol_Biorefineries_Soy_Biodie	.	.	.	.	49	.
Chemical_Plant	.	.	.	.	27	93
Pharmaceutical_Manufacturing	.	.	.	.	43	43
Landfill	.	.	.	.	58	.
Steam_Heating_Facility	.	.	.	.	20	.
Petroleum_Storage_Facility	.	.	.	.	14	.
not_characterized	.	13	13	13	12	25
Aircraft_Aerospace_or_Related	.	24	24	24	.	.
Airport	.	858	858	858	.	.
Monitor not used for 2010-2015 analysis (either historical data or were incomplete)						

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1 **Table B5-56. Attributes of ambient monitors within the Washington DC study area not**
 2 **used for the 2010-2015 analysis.**

stateabbr	DC	VA	VA	VA	VA	VA
countyname	DoColumbia	Fairfax	Fairfax	Fairfax	Fairfax	Fairfax
siteid	110010017	510590005	510590018	510590031	510591004	510591005
Lat	38.90372	38.89410	38.74232	38.76835	38.86817	38.83738
Lon	-77.05137	-77.46520	-77.07743	-77.18347	-77.14276	-77.16338
min_year	1975	1977	1979	2016	1973	2002
max_year	1996	2009	1997	2016	2001	2009
Elevation_m	20	76	10	73.5	110	116
land_use	COMM	RESID	RESID	COMM	COMM	RESID
scale	NBHOOD	NBHOOD	NA	MICRO	NA	NA
objective1	POP_EXP	POP_EXP	POP_EXP	HI_CONC	POP_EXP	POP_EXP
objective2	HI_CONC			POP_EXP		
objective3						
cnty_landarea_2010	61	391	391	391	391	391
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	52	.	580	69	94	57
road_closest	0	.	1	7900	50	244
aadt_closest	29208	.	56482	52319	48102	29542
aadt_aadtmax	395	.	.	411	498	973
road_aadtmax	0	.	.	95	50	244
dist_aadtmax	96163	.	.	231651	59759	35060
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	4739	8221	8221	8221	8221	8221
NonRoad_mobile_nox	2364	2905	2905	2905	2905	2905
AML_mobile_nox	223	358	358	358	358	358
total_nox	9418	15236	15236	15236	15236	15236
pct_mobile_nox	77.8	75.4	75.4	75.4	75.4	75.4
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Airport	.	.	.	.	.	.
Electricity_Generation_via_Combu	.	.	.	.	.	.
Municipal_Waste_Combustor	.	.	.	.	.	.
Steam_Heating_Facility	301	.	.	.	.	.
Military_Base	.	.	.	.	.	.
not_characterized	.	.	.	.	.	59
Institutional_school_hospital_	27	.	.	.	.	.
Rail_Yard	.	.	.	.	.	.
Hot_Mix_Asphalt_Plant	.	.	.	.	.	11
						Monitor not used for 2010-2015 analysis (either historical data or were incomplete)

3

1 **Table B5-56, continued. Attributes of ambient monitors within the Washington DC study**
 2 **area not used for the 2010-2015 analysis.**

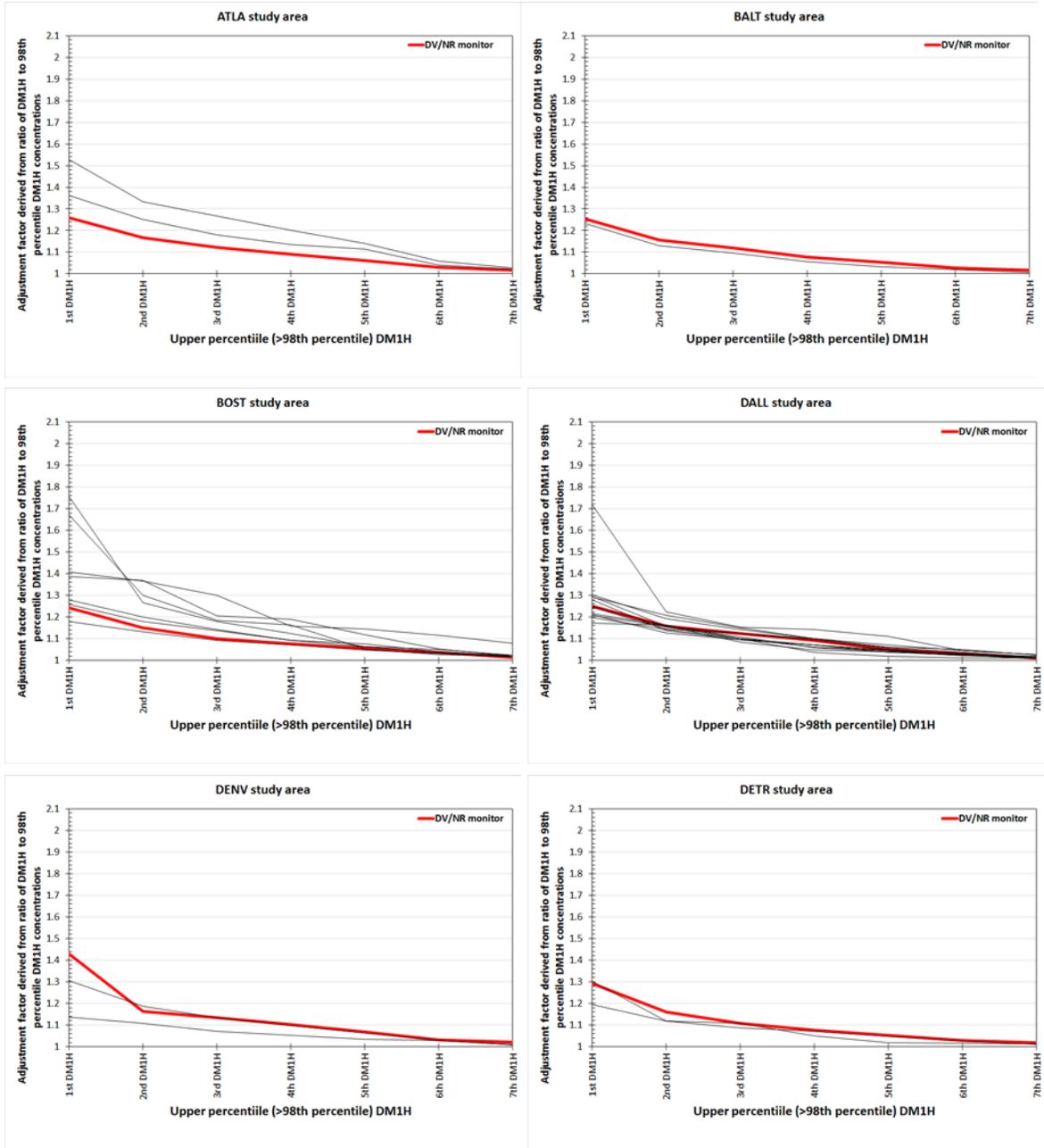
stateabbr	VA	VA				
countyname	Fairfax	Fairfax City				
siteid	510595001	516000005				
Lat	38.93260	38.84483				
Lon	-77.19822	-77.31165				
min_year	1973	1973				
max_year	2009	1992				
Elevation_m	105	125				
land_use	RESID	RESID				
scale	NBHOOD	NA				
objective1	POP_EXP	POP_EXP				
objective2						
objective3						
cnty_landarea_2010	391	6				
<i>AADT information (distance in meters, road/highway/interstate number, AADT value)</i>						
dist_closest	74	304				
road_closest	123	236				
aadt_closest	41718	43148				
aadt_aadtmax	853	.				
road_aadtmax	495	.				
dist_aadtmax	193959	.				
<i>County Level NOx Emissions (tpy)</i>						
OnRoad_mobile_nox	8221	156				
NonRoad_mobile_nox	2905	50				
AML_mobile_nox	358	0				
total_nox	15236	265				
pct_mobile_nox	75.4	77.9				
<i>NOx Emissions by Source Type (summed tons per year (tpy), sources within 5 Km emitting at least 10 tpy)</i>						
Airport	.	.				
Electricity_Generation_via_Combu	.	.				
Municipal_Waste_Combustor	.	.				
Steam_Heating_Facility	.	.				
Military_Base	.	.				
not_characterized	.	.				
Institutional_school_hospital_	.	.				
Rail_Yard	.	.				
Hot_Mix_Asphalt_Plant	.	.				
			Monitor not used for 2010-2015 analysis (either historical data or were incomplete)			

3

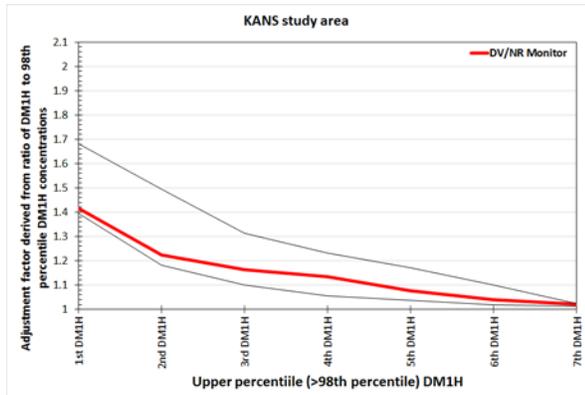
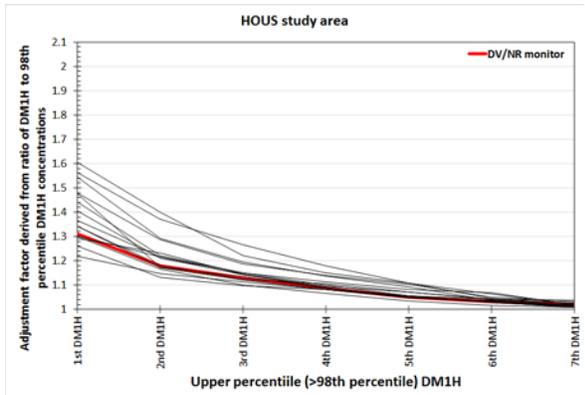
4

5.4 UPPER (>98TH) PERCENTILE DM1H CONCENTRATION RATIOS: COMPARISON OF AREA DESIGN VALUE MONITOR TO ALL AREA-WIDE MONITORS BY STUDY AREA

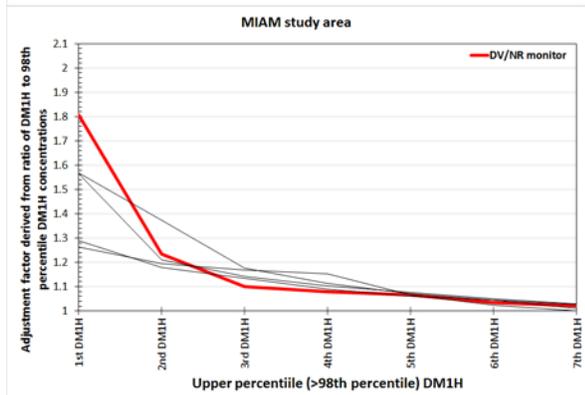
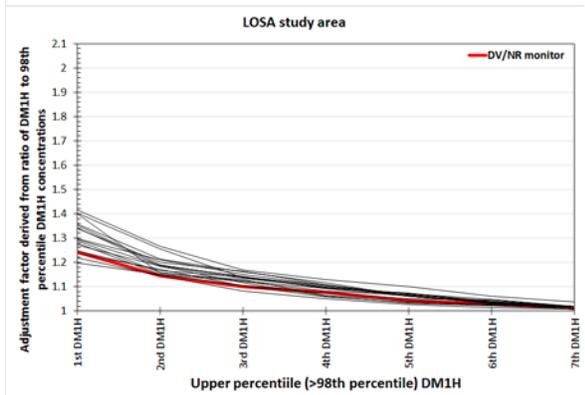
The following is a visual representation of the data found in Table B2-8, constructed to facilitate the comparison of the ratios derived from the area design value monitor relative to other area-wide monitors. As a reminder, the near-road monitors typically had only 1 full year of data, the motivation for using the ratios derived from the area design value monitor to adjust the upper (>98th) percentile DM1H concentrations at each near-road monitor.



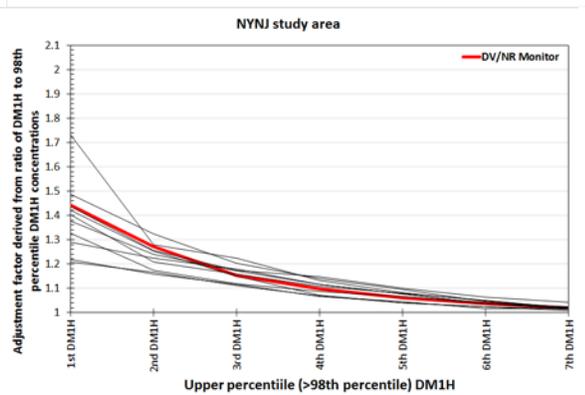
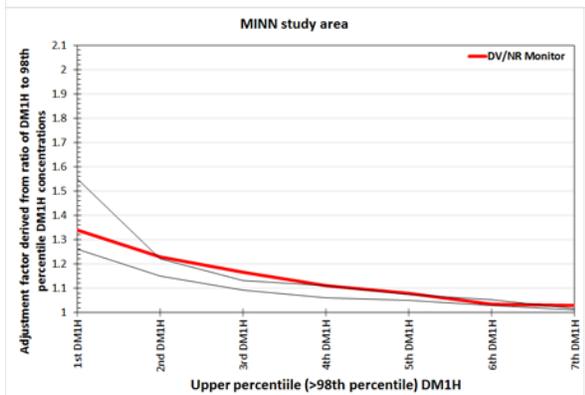
1



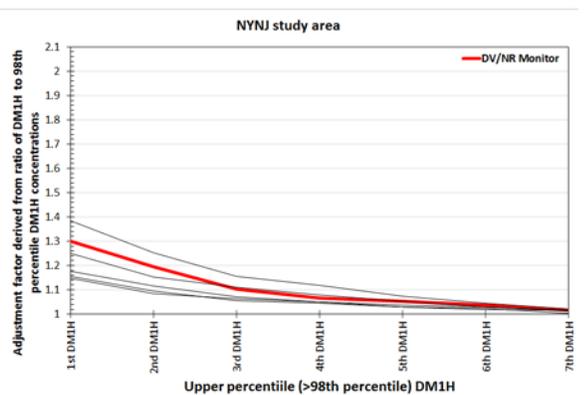
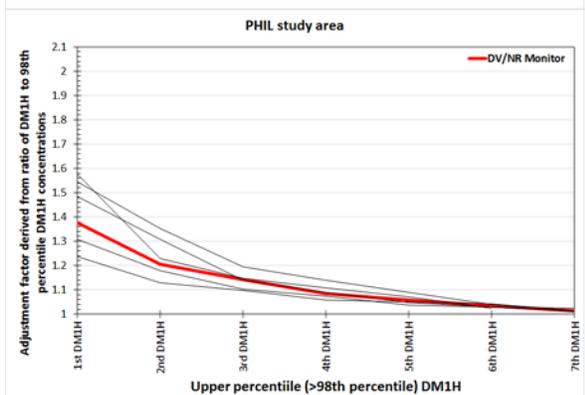
2

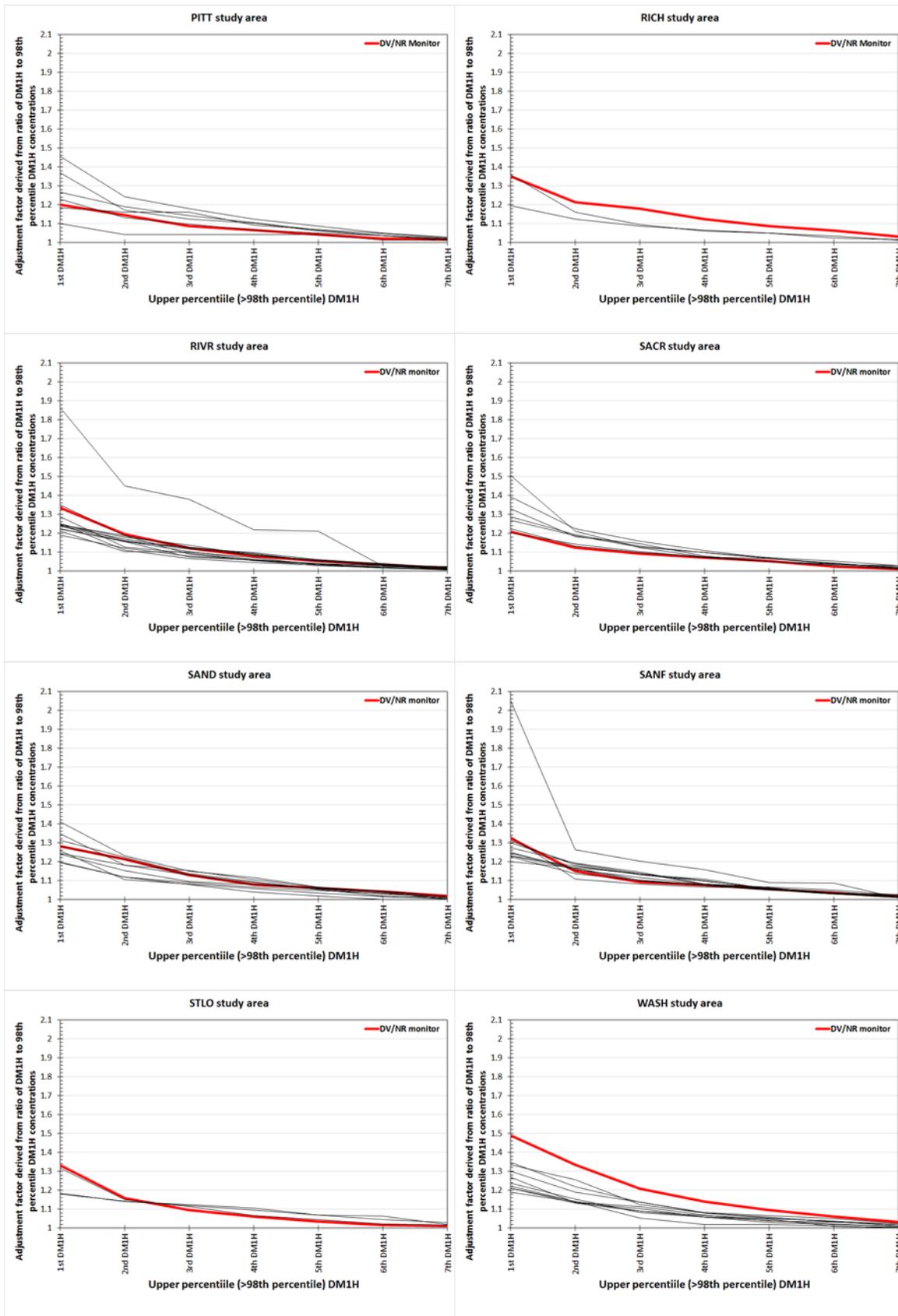


3



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4

1 **5.5 NUMBER OF DAYS PER YEAR NO₂ CONCENTRATIONS WERE AT OR ABOVE 1-HOUR**
2 **BENCHMARK LEVELS: SITE-YEAR SUMMARY TABLES (2010 – 2015)**
3

4 **Table B5-57. Number of days per year NO₂ concentrations were at or above benchmark levels: area-wide and near-road site-**
5 **year summary table (2010-2015).**

CBSA Abbr.	Monitor Type	1-hr Benchmark (ppb)	Number of monitor site-years					Mean number of days per year at or above benchmark level					Maximum number of days per year at or above benchmark level				
			asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
ATLA	area_wide	100	18	9	9	9	9	0	3	5	4	2	0	15	30	16	16
BALT	area_wide	100	11	6	6	6	5	0	4	5	4	4	0	12	12	12	11
BOST	area_wide	100	31	15	15	11	16	0	5	5	6	3	0	15	15	18	12
CHIC	area_wide	100	23	11	0	0	12	0.5	7			4	1	24			12
DALL	area_wide	100	64	34	33	29	30	0	1	2	2	2	0	9	11	16	12
DENV	area_wide	100	11	0	5	6	7	0.5		14	5	4	1		29	10	10
DETR	area_wide	100	10	4	5	6	6	0	6	9	8	4	0	12	23	18	9
HOUS	area_wide	100	85	40	40	44	45	0.5	2	2	2	2	3	12	8	15	14
KANS	area_wide	100	14	9	7	6	5	0	5	5	7	7	0	9	9	11	10
LOSA	area_wide	100	65	30	26	27	35	0.5	5	5	5	4	1	19	22	23	27
MIAM	area_wide	100	20	12	10	8	8	0	5	4	5	6	0	15	12	12	17
MINE	area_wide	100	17	8	9	9	9	0	6	4	4	2	0	22	11	14	10
NYNY	area_wide	100	48	23	22	24	25	0.5	3	3	3	4	1	9	12	12	12
PHIL	area_wide	100	26	13	14	0	13	0.5	3	3		2	1	18	23		13
PHOE	area_wide	100	28	15	14	14	13	0.5	2	4	3	3	1	9	13	12	9
PITT	area_wide	100	25	13	15	0	16	0	2	3		3	0	9	22		14
RICH	area_wide	100	14	9	8	6	5	0	6	5	7	2	0	17	17	15	6
RIVR	area_wide	100	49	24	18	0	25	0.5	1	4		1	7	14	25		5
SACR	area_wide	100	42	23	21	20	19	0	2	3	4	3	0	10	14	21	17
SAND	area_wide	100	41	22	21	20	19	0.5	1	1	1	0.5	1	9	12	12	4
SANF	area_wide	100	55	29	28	28	26	0.5	1	1	1	2	1	13	23	11	14
STLO	area_wide	100	15	0	8	9	9	0		2	4	1	0		8	14	5
WASH	area_wide	100	33	18	17	15	15	0	4	4	5	6	0	14	20	24	24
ATLA	area_wide	150	18	9	9	9	9	0	0	0	0	0	0	0	0	0	0
BALT	area_wide	150	11	6	6	6	5	0	0	0	0	0	0	0	0	0	0
BOST	area_wide	150	31	15	15	2	16	0	0.5	0.5	1	0.5	0	1	1	1	1
CHIC	area_wide	150	23	11	0	0	12	0	0			0	0	0			0
DALL	area_wide	150	64	34	33	29	30	0	0	0	0	0	0	0	0	0	0
DENV	area_wide	150	11	0	5	1	7	0		0.5	1	0.5	0		1	1	1

CBSA Abbr.	Monitor Type	1-hr Benchmark (ppb)	Number of monitor site-years					Mean number of days per year at or above benchmark level					Maximum number of days per year at or above benchmark level				
			asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
DETR	area_wide	150	10	4	5	6	6	0	0	0	0	0	0	0	0	0	0
HOUS	area_wide	150	85	40	40	44	45	0	0.5	0	0	0	0	2	0	0	0
KANS	area_wide	150	14	9	7	6	5	0	0	0	0	0	0	0	0	0	0
LOSA	area_wide	150	65	30	26	27	35	0	0.5	0.5	0.5	0.5	0	1	1	1	1
MIAM	area_wide	150	20	12	10	8	8	0	0.5	0.5	1	0.5	0	1	1	1	1
MINE	area_wide	150	17	8	9	9	9	0	0.5	0.5	0.5	0	0	2	3	2	0
NYNY	area_wide	150	48	23	22	24	25	0.5	0.5	0.5	0.5	0.5	1	1	1	1	1
PHIL	area_wide	150	26	13	14	0	13	0	0.5	0.5		0.5	0	1	1		1
PHOE	area_wide	150	28	15	14	14	13	0	0	0	0	0	0	0	0	0	0
PITT	area_wide	150	25	13	15	0	16	0	0	0		0	0	0	0		0
RICH	area_wide	150	14	9	8	6	5	0	0	0.5	0.5	0	0	0	1	1	0
RIVR	area_wide	150	49	24	18	0	25	0	0.5	0.5		0	0	1	8		0
SACR	area_wide	150	42	23	21	20	19	0	0	0	0	0	0	0	0	0	0
SAND	area_wide	150	41	22	21	20	19	0	0	0	0	0	0	0	0	0	0
SANF	area_wide	150	55	29	28	28	26	0	0	0.5	0	0	0	0	1	0	0
STLO	area_wide	150	15	0	8	9	9	0		0	0	0	0		0	0	0
WASH	area_wide	150	33	18	17	15	15	0	0.5	0.5	0.5	0.5	0	1	1	1	1
ATLA	area_wide	200	18	9	9	9	9	0	0	0	0	0	0	0	0	0	0
BALT	area_wide	200	11	6	6	6	5	0	0	0	0	0	0	0	0	0	0
BOST	area_wide	200	31	15	15	15	16	0	0	0	0	0	0	0	0	0	0
CHIC	area_wide	200	23	11	0	0	12	0	0			0	0	0			0
DALL	area_wide	200	64	34	33	29	30	0	0	0	0	0	0	0	0	0	0
DENV	area_wide	200	11	0	5	6	7	0		0	0	0	0		0	0	0
DETR	area_wide	200	10	4	5	6	6	0	0	0	0	0	0	0	0	0	0
HOUS	area_wide	200	85	40	40	44	45	0	0	0	0	0	0	0	0	0	0
KANS	area_wide	200	14	9	7	6	5	0	0	0	0	0	0	0	0	0	0
LOSA	area_wide	200	65	30	26	27	35	0	0	0	0	0	0	0	0	0	0
MIAM	area_wide	200	20	12	10	8	8	0	0	0	0	0	0	0	0	0	0
MINE	area_wide	200	17	8	9	9	9	0	0	0	0	0	0	0	0	0	0
NYNY	area_wide	200	48	23	22	24	25	0	0	0	0	0	0	0	0	0	0
PHIL	area_wide	200	26	13	14	0	13	0	0	0		0	0	0	0		0
PHOE	area_wide	200	28	15	14	14	13	0	0	0	0	0	0	0	0	0	0
PITT	area_wide	200	25	13	15	0	16	0	0	0		0	0	0	0		0
RICH	area_wide	200	14	9	8	6	5	0	0	0	0	0	0	0	0	0	0
RIVR	area_wide	200	49	24	18	0	25	0	0	0		0	0	0	0		0
SACR	area_wide	200	42	23	21	20	19	0	0	0	0	0	0	0	0	0	0
SAND	area_wide	200	41	22	21	20	19	0	0	0	0	0	0	0	0	0	0
SANF	area_wide	200	55	29	28	28	26	0	0	0	0	0	0	0	0	0	0

CBSA Abbr.	Monitor Type	1-hr Benchmark (ppb)	Number of monitor site-years					Mean number of days per year at or above benchmark level					Maximum number of days per year at or above benchmark level				
			asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
STLO	area_wide	200	15	0	8	9	9	0		0	0	0	0		0	0	0
WASH	area_wide	200	33	18	17	15	15	0	0	0	0	0	0	0	0	0	0
ATLA	near_road	100	3	0	0	1	3	0			5	6	0			5	8
BALT	near_road	100	2	0	0	1	2	0			5	7	0			5	7
BOST	near_road	100	3	0	1	2	3	0		2	10	6	0		2	18	11
CHIC	near_road	100	5	3	0	0	2	0.5	8			4	1	11			4
DALL	near_road	100	3	0	0	1	3	0			1	2	0			1	5
DENV	near_road	100	4	0	1	2	4	0		4	3	3	0		4	5	5
DETR	near_road	100	6	2	3	3	4	0	11	22	17	7	0	16	31	22	9
HOUS	near_road	100	3	0	0	1	3	0			2	4	0			2	5
KANS	near_road	100	3	0	1	2	3	0		1	3	3	0		1	4	4
LOSA	near_road	100	3	0	0	1	3	0			17	9	0			17	21
MIAM	near_road	100	1	0	0	0	1	0				1	0				1
MINE	near_road	100	4	0	1	2	4	0		7	9	7	0		7	13	11
NYNY	near_road	100	2	0	0	1	2	2			8	8	2			8	8
PHIL	near_road	100	3	0	0	0	3	0				2	0				3
PHOE	near_road	100	3	0	0	1	3	0			3	3	0			3	3
PITT	near_road	100	2	0	0	0	2	0				7	0				11
RICH	near_road	100	3	0	1	2	3	0		1	8	5	0		1	12	9
RIVR	near_road	100	2	0	0	0	2	0				7	0				8
SACR	near_road	100	1	0	0	0	1	0				2	0				2
SAND	near_road	100	1	0	0	0	1	0				4	0				4
SANF	near_road	100	2	0	0	1	2	0			1	2	0			1	2
STLO	near_road	100	4	0	1	2	4	0		5	16	5	0		5	21	10
WASH	near_road	100	1	0	0	0	1	0				4	0				4
ATLA	near_road	150	3	0	0	1	3	0			0	0	0			0	0
BALT	near_road	150	2	0	0	1	2	0			0	0	0			0	0
BOST	near_road	150	3	0	1	0	3	0		0		0	0		0		0
CHIC	near_road	150	5	3	0	0	2	0	0			0	0	0			0
DALL	near_road	150	3	0	0	1	3	0			0	0	0			0	0
DENV	near_road	150	4	0	1	0	4	0		0		0	0		0		0
DETR	near_road	150	6	2	3	3	4	0	1	1	0.5	0	0	1	1	1	0
HOUS	near_road	150	3	0	0	1	3	0			0	0	0			0	0
KANS	near_road	150	3	0	1	2	3	0		0	0	0	0		0	0	0
LOSA	near_road	150	3	0	0	1	3	0			0	0	0			0	0
MIAM	near_road	150	1	0	0	0	1	0				1	0				1
MINE	near_road	150	4	0	1	2	4	0		0	0	0	0		0	0	0
NYNY	near_road	150	2	0	0	1	2	1			3	2	1			3	3

CBSA Abbr.	Monitor Type	1-hr Benchmark (ppb)	Number of monitor site-years					Mean number of days per year at or above benchmark level					Maximum number of days per year at or above benchmark level				
			asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
PHIL	near_road	150	3	0	0	0	3	0				0	0				0
PHOE	near_road	150	3	0	0	1	3	0			0	0	0			0	0
PITT	near_road	150	2	0	0	0	2	0				0	0				0
RICH	near_road	150	3	0	1	2	3	0		0	0	0	0		0	0	0
RIVR	near_road	150	2	0	0	0	2	0				0	0				0
SACR	near_road	150	1	0	0	0	1	0				0	0				0
SAND	near_road	150	1	0	0	0	1	0				0	0				0
SANF	near_road	150	2	0	0	1	2	0			0	0	0			0	0
STLO	near_road	150	4	0	1	2	4	0		0	1	0	0		0	1	0
WASH	near_road	150	1	0	0	0	1	0				0	0				0
ATLA	near_road	200	3	0	0	1	3	0			0	0	0			0	0
BALT	near_road	200	2	0	0	1	2	0			0	0	0			0	0
BOST	near_road	200	3	0	1	2	3	0		0	0	0	0		0	0	0
CHIC	near_road	200	5	3	0	0	2	0	0			0	0	0			0
DALL	near_road	200	3	0	0	1	3	0			0	0	0			0	0
DENV	near_road	200	4	0	1	2	4	0		0	0	0	0		0	0	0
DETR	near_road	200	6	2	3	3	4	0	0	0	0	0	0	0	0	0	0
HOUS	near_road	200	3	0	0	1	3	0			0	0	0			0	0
KANS	near_road	200	3	0	1	2	3	0		0	0	0	0		0	0	0
LOSA	near_road	200	3	0	0	1	3	0			0	0	0			0	0
MIAM	near_road	200	1	0	0	0	1	0				0	0				0
MINE	near_road	200	4	0	1	2	4	0		0	0	0	0		0	0	0
NYNY	near_road	200	2	0	0	1	2	1			0	0	1			0	0
PHIL	near_road	200	3	0	0	0	3	0				0	0				0
PHOE	near_road	200	3	0	0	1	3	0			0	0	0			0	0
PITT	near_road	200	2	0	0	0	2	0				0	0				0
RICH	near_road	200	3	0	1	2	3	0		0	0	0	0		0	0	0
RIVR	near_road	200	2	0	0	0	2	0				0	0				0
SACR	near_road	200	1	0	0	0	1	0				0	0				0
SAND	near_road	200	1	0	0	0	1	0				0	0				0
SANF	near_road	200	2	0	0	1	2	0			0	0	0			0	0
STLO	near_road	200	4	0	1	2	4	0		0	0	0	0		0	0	0
WASH	near_road	200	1	0	0	0	1	0				0	0				0

1 **5.6 NUMBER OF DAYS NO₂ CONCENTRATIONS WERE AT OR**
2 **ABOVE 1-HOUR BENCHMARK LEVELS: SIMULATED ON-ROAD**
3 **CONCENTRATIONS (2014-2015 ONLY)**
4

5 **Table B5-58. Number of days NO₂ concentrations were at or above benchmark levels:**
6 **simulated on-road concentrations for 2014.**

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
ATLA	131210056	hi -11%	2014	200	100	0	19
BALT	240270006	hi -19%	2014	275	100	0	24
BOST	250250044	hi -15%	2014	365	100	0	34
CHIC	170313103	hi -19%	2014	360	100	1	21
DALL	481131067	hi -21%	2014	274	100	0	9
DENV	080310027	hi -15%	2014	361	100	1	17
DETR	261630093	hi -15%	2014	364	100	0	24
HOUS	482011066	hi -21%	2014	344	100	0	23
KANS	290950042	hi -19%	2014	358	100	0	18
LOSA	060590008	hi -15%	2014	361	100	0	39
MINE	270530962	hi -21%	2014	365	100	0	51
NYNY	340030010	hi -19%	2014	184	100	4	16
PHIL	421010075	hi -15%	2014	358	100	0	10
PHOE	040134019	hi -15%	2014	322	100	0	22
PITT	420031376	hi -19%	2014	122	100	0	8
RICH	517600025	hi -19%	2014	269	100	0	26
SANF	060010012	hi -19%	2014	334	100	0	13
STLO	295100094	hi -21%	2014	365	100	0	39
ATLA	131210056	low- 7%	2014	200	100	0	17
BALT	240270006	low-12%	2014	275	100	0	20
BOST	250250044	low- 9%	2014	365	100	0	26
CHIC	170313103	low-12%	2014	360	100	1	9
DALL	481131067	low-13%	2014	274	100	0	5
DENV	080310027	low- 9%	2014	361	100	1	12
DETR	261630093	low- 9%	2014	364	100	0	16
HOUS	482011066	low-13%	2014	344	100	0	14
KANS	290950042	low-12%	2014	358	100	0	8
LOSA	060590008	low- 9%	2014	361	100	0	32
MINE	270530962	low-13%	2014	365	100	0	31
NYNY	340030010	low-12%	2014	184	100	4	13
PHIL	421010075	low- 9%	2014	358	100	0	6
PHOE	040134019	low- 9%	2014	322	100	0	10
PITT	420031376	low-12%	2014	122	100	0	6
RICH	517600025	low-12%	2014	269	100	0	17
SANF	060010012	low-12%	2014	334	100	0	8
STLO	295100094	low-13%	2014	365	100	0	30
ATLA	131210056	mid- 9%	2014	200	100	0	19
BALT	240270006	mid-16%	2014	275	100	0	20
BOST	250250044	mid-12%	2014	365	100	0	29
CHIC	170313103	mid-16%	2014	360	100	1	14
DALL	481131067	mid-17%	2014	274	100	0	5
DENV	080310027	mid-12%	2014	361	100	1	16
DETR	261630093	mid-12%	2014	364	100	0	19
HOUS	482011066	mid-17%	2014	344	100	0	18

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
KANS	290950042	mid-16%	2014	358	100	0	11
LOSA	060590008	mid-12%	2014	361	100	0	36
MINE	270530962	mid-17%	2014	365	100	0	35
NYNY	340030010	mid-16%	2014	184	100	4	16
PHIL	421010075	mid-12%	2014	358	100	0	8
PHOE	040134019	mid-12%	2014	322	100	0	13
PITT	420031376	mid-16%	2014	122	100	0	7
RICH	517600025	mid-16%	2014	269	100	0	20
SANF	060010012	mid-16%	2014	334	100	0	11
STLO	295100094	mid-17%	2014	365	100	0	37
ATLA	131210056	hi -11%	2014	200	150	0	0
BALT	240270006	hi -19%	2014	275	150	0	0
BOST	250250044	hi -15%	2014	365	150	0	0
CHIC	170313103	hi -19%	2014	360	150	0	0
DALL	481131067	hi -21%	2014	274	150	0	0
DENV	080310027	hi -15%	2014	361	150	0	1
DETR	261630093	hi -15%	2014	364	150	0	1
HOUS	482011066	hi -21%	2014	344	150	0	0
KANS	290950042	hi -19%	2014	358	150	0	1
LOSA	060590008	hi -15%	2014	361	150	0	1
MINE	270530962	hi -21%	2014	365	150	0	2
NYNY	340030010	hi -19%	2014	184	150	2	4
PHIL	421010075	hi -15%	2014	358	150	0	0
PHOE	040134019	hi -15%	2014	322	150	0	0
PITT	420031376	hi -19%	2014	122	150	0	0
RICH	517600025	hi -19%	2014	269	150	0	1
SANF	060010012	hi -19%	2014	334	150	0	0
STLO	295100094	hi -21%	2014	365	150	0	2
ATLA	131210056	low- 7%	2014	200	150	0	0
BALT	240270006	low-12%	2014	275	150	0	0
BOST	250250044	low- 9%	2014	365	150	0	0
CHIC	170313103	low-12%	2014	360	150	0	0
DALL	481131067	low-13%	2014	274	150	0	0
DENV	080310027	low- 9%	2014	361	150	0	1
DETR	261630093	low- 9%	2014	364	150	0	0
HOUS	482011066	low-13%	2014	344	150	0	0
KANS	290950042	low-12%	2014	358	150	0	0
LOSA	060590008	low- 9%	2014	361	150	0	0
MINE	270530962	low-13%	2014	365	150	0	1
NYNY	340030010	low-12%	2014	184	150	1	4
PHIL	421010075	low- 9%	2014	358	150	0	0
PHOE	040134019	low- 9%	2014	322	150	0	0
PITT	420031376	low-12%	2014	122	150	0	0
RICH	517600025	low-12%	2014	269	150	0	0
SANF	060010012	low-12%	2014	334	150	0	0
STLO	295100094	low-13%	2014	365	150	0	1
ATLA	131210056	mid- 9%	2014	200	150	0	0
BALT	240270006	mid-16%	2014	275	150	0	0
BOST	250250044	mid-12%	2014	365	150	0	0
CHIC	170313103	mid-16%	2014	360	150	0	0
DALL	481131067	mid-17%	2014	274	150	0	0
DENV	080310027	mid-12%	2014	361	150	0	1
DETR	261630093	mid-12%	2014	364	150	0	0
HOUS	482011066	mid-17%	2014	344	150	0	0

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
KANS	290950042	mid-16%	2014	358	150	0	0
LOSA	060590008	mid-12%	2014	361	150	0	0
MINE	270530962	mid-17%	2014	365	150	0	1
NYNY	340030010	mid-16%	2014	184	150	2	4
PHIL	421010075	mid-12%	2014	358	150	0	0
PHOE	040134019	mid-12%	2014	322	150	0	0
PITT	420031376	mid-16%	2014	122	150	0	0
RICH	517600025	mid-16%	2014	269	150	0	1
SANF	060010012	mid-16%	2014	334	150	0	0
STLO	295100094	mid-17%	2014	365	150	0	2
ATLA	131210056	hi -11%	2014	200	200	0	0
BALT	240270006	hi -19%	2014	275	200	0	0
BOST	250250044	hi -15%	2014	365	200	0	0
CHIC	170313103	hi -19%	2014	360	200	0	0
DALL	481131067	hi -21%	2014	274	200	0	0
DENV	080310027	hi -15%	2014	361	200	0	0
DETR	261630093	hi -15%	2014	364	200	0	0
HOUS	482011066	hi -21%	2014	344	200	0	0
KANS	290950042	hi -19%	2014	358	200	0	0
LOSA	060590008	hi -15%	2014	361	200	0	0
MINE	270530962	hi -21%	2014	365	200	0	0
NYNY	340030010	hi -19%	2014	184	200	1	2
PHIL	421010075	hi -15%	2014	358	200	0	0
PHOE	040134019	hi -15%	2014	322	200	0	0
PITT	420031376	hi -19%	2014	122	200	0	0
RICH	517600025	hi -19%	2014	269	200	0	0
SANF	060010012	hi -19%	2014	334	200	0	0
STLO	295100094	hi -21%	2014	365	200	0	0
ATLA	131210056	low- 7%	2014	200	200	0	0
BALT	240270006	low-12%	2014	275	200	0	0
BOST	250250044	low- 9%	2014	365	200	0	0
CHIC	170313103	low-12%	2014	360	200	0	0
DALL	481131067	low-13%	2014	274	200	0	0
DENV	080310027	low- 9%	2014	361	200	0	0
DETR	261630093	low- 9%	2014	364	200	0	0
HOUS	482011066	low-13%	2014	344	200	0	0
KANS	290950042	low-12%	2014	358	200	0	0
LOSA	060590008	low- 9%	2014	361	200	0	0
MINE	270530962	low-13%	2014	365	200	0	0
NYNY	340030010	low-12%	2014	184	200	1	1
PHIL	421010075	low- 9%	2014	358	200	0	0
PHOE	040134019	low- 9%	2014	322	200	0	0
PITT	420031376	low-12%	2014	122	200	0	0
RICH	517600025	low-12%	2014	269	200	0	0
SANF	060010012	low-12%	2014	334	200	0	0
STLO	295100094	low-13%	2014	365	200	0	0
ATLA	131210056	mid- 9%	2014	200	200	0	0
BALT	240270006	mid-16%	2014	275	200	0	0
BOST	250250044	mid-12%	2014	365	200	0	0
CHIC	170313103	mid-16%	2014	360	200	0	0
DALL	481131067	mid-17%	2014	274	200	0	0
DENV	080310027	mid-12%	2014	361	200	0	0
DETR	261630093	mid-12%	2014	364	200	0	0
HOUS	482011066	mid-17%	2014	344	200	0	0

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
KANS	290950042	mid-16%	2014	358	200	0	0
LOSA	060590008	mid-12%	2014	361	200	0	0
MINE	270530962	mid-17%	2014	365	200	0	0
NYNY	340030010	mid-16%	2014	184	200	1	2
PHIL	421010075	mid-12%	2014	358	200	0	0
PHOE	040134019	mid-12%	2014	322	200	0	0
PITT	420031376	mid-16%	2014	122	200	0	0
RICH	517600025	mid-16%	2014	269	200	0	0
SANF	060010012	mid-16%	2014	334	200	0	0
STLO	295100094	mid-17%	2014	365	200	0	0

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2

1 **Table B5-59. Number of days NO₂ concentrations were at or above benchmark levels:**
 2 **simulated on-road concentrations for 2015.**

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
ATLA	130890003	hi -21%	2015	363	100	0	22
ATLA	131210056	hi -11%	2015	362	100	0	8
BALT	240270006	hi -19%	2015	352	100	0	42
BOST	250250044	hi -15%	2015	362	100	0	28
CHIC	170313103	hi -19%	2015	358	100	0	18
DALL	481131067	hi -21%	2015	365	100	0	22
DALL	484391053	hi -19%	2015	295	100	0	6
DENV	080310027	hi -15%	2015	359	100	0	11
DENV	080310028	hi -15%	2015	92	100	0	16
DETR	261630093	hi -15%	2015	361	100	0	25
DETR	261630095	hi -21%	2015	362	100	0	19
HOUS	482011052	hi -19%	2015	261	100	0	18
HOUS	482011066	hi -21%	2015	365	100	0	14
KANS	290950042	hi -19%	2015	352	100	0	14
LOSA	060374008	hi -15%	2015	255	100	1	17
LOSA	060590008	hi -15%	2015	364	100	0	4
MIAM	120110035	hi -21%	2015	56	100	1	3
MINE	270370480	hi -21%	2015	363	100	0	10
MINE	270530962	hi -21%	2015	362	100	0	30
NYNY	340030010	hi -19%	2015	365	100	1	31
PHIL	421010075	hi -15%	2015	357	100	0	5
PHIL	421010076	hi -19%	2015	163	100	0	1
PHOE	040134019	hi -15%	2015	365	100	0	6
PHOE	040134020	hi -19%	2015	121	100	0	28
PITT	420031376	hi -19%	2015	365	100	0	47
RICH	517600025	hi -19%	2015	353	100	0	43
RIVR	060710026	hi -21%	2015	360	100	2	44
RIVR	060710027	hi -15%	2015	153	100	0	28
SACR	060670015	hi -19%	2015	80	100	0	6
SAND	060731017	hi -21%	2015	269	100	0	17
SANF	060010012	hi -19%	2015	365	100	0	11
STLO	291890016	hi -21%	2015	357	100	0	8
STLO	295100094	hi -21%	2015	364	100	0	26
WASH	110010051	hi -19%	2015	212	100	0	22
ATLA	130890003	low-13%	2015	363	100	0	18
ATLA	131210056	low- 7%	2015	362	100	0	6
BALT	240270006	low-12%	2015	352	100	0	21
BOST	250250044	low- 9%	2015	362	100	0	23
CHIC	170313103	low-12%	2015	358	100	0	13
DALL	481131067	low-13%	2015	365	100	0	14
DALL	484391053	low-12%	2015	295	100	0	4
DENV	080310027	low- 9%	2015	359	100	0	5
DENV	080310028	low- 9%	2015	92	100	0	9
DETR	261630093	low- 9%	2015	361	100	0	17
DETR	261630095	low-13%	2015	362	100	0	13
HOUS	482011052	low-12%	2015	261	100	0	13
HOUS	482011066	low-13%	2015	365	100	0	8
KANS	290950042	low-12%	2015	352	100	0	6
LOSA	060374008	low- 9%	2015	255	100	1	13
LOSA	060590008	low- 9%	2015	364	100	0	2

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
MIAM	120110035	low-13%	2015	56	100	1	2
MINE	270370480	low-13%	2015	363	100	0	9
MINE	270530962	low-13%	2015	362	100	0	20
NYNY	340030010	low-12%	2015	365	100	1	18
PHIL	421010075	low- 9%	2015	357	100	0	3
PHIL	421010076	low-12%	2015	163	100	0	1
PHOE	040134019	low- 9%	2015	365	100	0	3
PHOE	040134020	low-12%	2015	121	100	0	17
PITT	420031376	low-12%	2015	365	100	0	29
RICH	517600025	low-12%	2015	353	100	0	33
RIVR	060710026	low-13%	2015	360	100	0	21
RIVR	060710027	low- 9%	2015	153	100	0	17
SACR	060670015	low-12%	2015	80	100	0	5
SAND	060731017	low-13%	2015	269	100	0	12
SANF	060010012	low-12%	2015	365	100	0	5
STLO	291890016	low-13%	2015	357	100	0	4
STLO	295100094	low-13%	2015	364	100	0	13
WASH	110010051	low-12%	2015	212	100	0	12
ATLA	130890003	mid-17%	2015	363	100	0	20
ATLA	131210056	mid- 9%	2015	362	100	0	7
BALT	240270006	mid-16%	2015	352	100	0	32
BOST	250250044	mid-12%	2015	362	100	0	24
CHIC	170313103	mid-16%	2015	358	100	0	15
DALL	481131067	mid-17%	2015	365	100	0	16
DALL	484391053	mid-16%	2015	295	100	0	5
DENV	080310027	mid-12%	2015	359	100	0	7
DENV	080310028	mid-12%	2015	92	100	0	13
DETR	261630093	mid-12%	2015	361	100	0	22
DETR	261630095	mid-17%	2015	362	100	0	15
HOUS	482011052	mid-16%	2015	261	100	0	15
HOUS	482011066	mid-17%	2015	365	100	0	9
KANS	290950042	mid-16%	2015	352	100	0	11
LOSA	060374008	mid-12%	2015	255	100	1	17
LOSA	060590008	mid-12%	2015	364	100	0	3
MIAM	120110035	mid-17%	2015	56	100	1	2
MINE	270370480	mid-17%	2015	363	100	0	9
MINE	270530962	mid-17%	2015	362	100	0	25
NYNY	340030010	mid-16%	2015	365	100	1	26
PHIL	421010075	mid-12%	2015	357	100	0	4
PHIL	421010076	mid-16%	2015	163	100	0	1
PHOE	040134019	mid-12%	2015	365	100	0	4
PHOE	040134020	mid-16%	2015	121	100	0	19
PITT	420031376	mid-16%	2015	365	100	0	36
RICH	517600025	mid-16%	2015	353	100	0	39
RIVR	060710026	mid-17%	2015	360	100	1	31
RIVR	060710027	mid-12%	2015	153	100	0	21
SACR	060670015	mid-16%	2015	80	100	0	6
SAND	060731017	mid-17%	2015	269	100	0	15
SANF	060010012	mid-16%	2015	365	100	0	7
STLO	291890016	mid-17%	2015	357	100	0	5
STLO	295100094	mid-17%	2015	364	100	0	17
WASH	110010051	mid-16%	2015	212	100	0	17
ATLA	130890003	hi -21%	2015	363	150	0	1

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
ATLA	131210056	hi -11%	2015	362	150	0	0
BALT	240270006	hi -19%	2015	352	150	0	0
BOST	250250044	hi -15%	2015	362	150	0	0
CHIC	170313103	hi -19%	2015	358	150	0	0
DALL	481131067	hi -21%	2015	365	150	0	0
DALL	484391053	hi -19%	2015	295	150	0	0
DENV	080310027	hi -15%	2015	359	150	0	0
DENV	080310028	hi -15%	2015	92	150	0	1
DETR	261630093	hi -15%	2015	361	150	0	0
DETR	261630095	hi -21%	2015	362	150	0	1
HOUS	482011052	hi -19%	2015	261	150	0	1
HOUS	482011066	hi -21%	2015	365	150	0	0
KANS	290950042	hi -19%	2015	352	150	0	0
LOSA	060374008	hi -15%	2015	255	150	0	0
LOSA	060590008	hi -15%	2015	364	150	0	0
MIAM	120110035	hi -21%	2015	56	150	0	1
MINE	270370480	hi -21%	2015	363	150	0	0
MINE	270530962	hi -21%	2015	362	150	0	2
NYNY	340030010	hi -19%	2015	365	150	1	2
PHIL	421010075	hi -15%	2015	357	150	0	0
PHIL	421010076	hi -19%	2015	163	150	0	0
PHOE	040134019	hi -15%	2015	365	150	0	0
PHOE	040134020	hi -19%	2015	121	150	0	1
PITT	420031376	hi -19%	2015	365	150	0	1
RICH	517600025	hi -19%	2015	353	150	0	1
RIVR	060710026	hi -21%	2015	360	150	0	1
RIVR	060710027	hi -15%	2015	153	150	0	1
SACR	060670015	hi -19%	2015	80	150	0	0
SAND	060731017	hi -21%	2015	269	150	0	0
SANF	060010012	hi -19%	2015	365	150	0	0
STLO	291890016	hi -21%	2015	357	150	0	0
STLO	295100094	hi -21%	2015	364	150	0	0
WASH	110010051	hi -19%	2015	212	150	0	2
ATLA	130890003	low-13%	2015	363	150	0	0
ATLA	131210056	low- 7%	2015	362	150	0	0
BALT	240270006	low-12%	2015	352	150	0	0
BOST	250250044	low- 9%	2015	362	150	0	0
CHIC	170313103	low-12%	2015	358	150	0	0
DALL	481131067	low-13%	2015	365	150	0	0
DALL	484391053	low-12%	2015	295	150	0	0
DENV	080310027	low- 9%	2015	359	150	0	0
DENV	080310028	low- 9%	2015	92	150	0	1
DETR	261630093	low- 9%	2015	361	150	0	0
DETR	261630095	low-13%	2015	362	150	0	0
HOUS	482011052	low-12%	2015	261	150	0	0
HOUS	482011066	low-13%	2015	365	150	0	0
KANS	290950042	low-12%	2015	352	150	0	0
LOSA	060374008	low- 9%	2015	255	150	0	0
LOSA	060590008	low- 9%	2015	364	150	0	0
MIAM	120110035	low-13%	2015	56	150	0	1
MINE	270370480	low-13%	2015	363	150	0	0
MINE	270530962	low-13%	2015	362	150	0	1
NYNY	340030010	low-12%	2015	365	150	1	1

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
PHIL	421010075	low- 9%	2015	357	150	0	0
PHIL	421010076	low-12%	2015	163	150	0	0
PHOE	040134019	low- 9%	2015	365	150	0	0
PHOE	040134020	low-12%	2015	121	150	0	0
PITT	420031376	low-12%	2015	365	150	0	0
RICH	517600025	low-12%	2015	353	150	0	1
RIVR	060710026	low-13%	2015	360	150	0	1
RIVR	060710027	low- 9%	2015	153	150	0	1
SACR	060670015	low-12%	2015	80	150	0	0
SAND	060731017	low-13%	2015	269	150	0	0
SANF	060010012	low-12%	2015	365	150	0	0
STLO	291890016	low-13%	2015	357	150	0	0
STLO	295100094	low-13%	2015	364	150	0	0
WASH	110010051	low-12%	2015	212	150	0	1
ATLA	130890003	mid-17%	2015	363	150	0	0
ATLA	131210056	mid- 9%	2015	362	150	0	0
BALT	240270006	mid-16%	2015	352	150	0	0
BOST	250250044	mid-12%	2015	362	150	0	0
CHIC	170313103	mid-16%	2015	358	150	0	0
DALL	481131067	mid-17%	2015	365	150	0	0
DALL	484391053	mid-16%	2015	295	150	0	0
DENV	080310027	mid-12%	2015	359	150	0	0
DENV	080310028	mid-12%	2015	92	150	0	1
DETR	261630093	mid-12%	2015	361	150	0	0
DETR	261630095	mid-17%	2015	362	150	0	0
HOUS	482011052	mid-16%	2015	261	150	0	1
HOUS	482011066	mid-17%	2015	365	150	0	0
KANS	290950042	mid-16%	2015	352	150	0	0
LOSA	060374008	mid-12%	2015	255	150	0	0
LOSA	060590008	mid-12%	2015	364	150	0	0
MIAM	120110035	mid-17%	2015	56	150	0	1
MINE	270370480	mid-17%	2015	363	150	0	0
MINE	270530962	mid-17%	2015	362	150	0	1
NYNY	340030010	mid-16%	2015	365	150	1	1
PHIL	421010075	mid-12%	2015	357	150	0	0
PHIL	421010076	mid-16%	2015	163	150	0	0
PHOE	040134019	mid-12%	2015	365	150	0	0
PHOE	040134020	mid-16%	2015	121	150	0	1
PITT	420031376	mid-16%	2015	365	150	0	0
RICH	517600025	mid-16%	2015	353	150	0	1
RIVR	060710026	mid-17%	2015	360	150	0	1
RIVR	060710027	mid-12%	2015	153	150	0	1
SACR	060670015	mid-16%	2015	80	150	0	0
SAND	060731017	mid-17%	2015	269	150	0	0
SANF	060010012	mid-16%	2015	365	150	0	0
STLO	291890016	mid-17%	2015	357	150	0	0
STLO	295100094	mid-17%	2015	364	150	0	0
WASH	110010051	mid-16%	2015	212	150	0	2
ATLA	130890003	hi -21%	2015	363	200	0	0
ATLA	131210056	hi -11%	2015	362	200	0	0
BALT	240270006	hi -19%	2015	352	200	0	0
BOST	250250044	hi -15%	2015	362	200	0	0
CHIC	170313103	hi -19%	2015	358	200	0	0

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
DALL	481131067	hi -21%	2015	365	200	0	0
DALL	484391053	hi -19%	2015	295	200	0	0
DENV	080310027	hi -15%	2015	359	200	0	0
DENV	080310028	hi -15%	2015	92	200	0	0
DETR	261630093	hi -15%	2015	361	200	0	0
DETR	261630095	hi -21%	2015	362	200	0	0
HOUS	482011052	hi -19%	2015	261	200	0	0
HOUS	482011066	hi -21%	2015	365	200	0	0
KANS	290950042	hi -19%	2015	352	200	0	0
LOSA	060374008	hi -15%	2015	255	200	0	0
LOSA	060590008	hi -15%	2015	364	200	0	0
MIAM	120110035	hi -21%	2015	56	200	0	0
MINE	270370480	hi -21%	2015	363	200	0	0
MINE	270530962	hi -21%	2015	362	200	0	0
NYNY	340030010	hi -19%	2015	365	200	0	0
PHIL	421010075	hi -15%	2015	357	200	0	0
PHIL	421010076	hi -19%	2015	163	200	0	0
PHOE	040134019	hi -15%	2015	365	200	0	0
PHOE	040134020	hi -19%	2015	121	200	0	0
PITT	420031376	hi -19%	2015	365	200	0	0
RICH	517600025	hi -19%	2015	353	200	0	0
RIVR	060710026	hi -21%	2015	360	200	0	0
RIVR	060710027	hi -15%	2015	153	200	0	0
SACR	060670015	hi -19%	2015	80	200	0	0
SAND	060731017	hi -21%	2015	269	200	0	0
SANF	060010012	hi -19%	2015	365	200	0	0
STLO	291890016	hi -21%	2015	357	200	0	0
STLO	295100094	hi -21%	2015	364	200	0	0
WASH	110010051	hi -19%	2015	212	200	0	0
ATLA	130890003	low-13%	2015	363	200	0	0
ATLA	131210056	low- 7%	2015	362	200	0	0
BALT	240270006	low-12%	2015	352	200	0	0
BOST	250250044	low- 9%	2015	362	200	0	0
CHIC	170313103	low-12%	2015	358	200	0	0
DALL	481131067	low-13%	2015	365	200	0	0
DALL	484391053	low-12%	2015	295	200	0	0
DENV	080310027	low- 9%	2015	359	200	0	0
DENV	080310028	low- 9%	2015	92	200	0	0
DETR	261630093	low- 9%	2015	361	200	0	0
DETR	261630095	low-13%	2015	362	200	0	0
HOUS	482011052	low-12%	2015	261	200	0	0
HOUS	482011066	low-13%	2015	365	200	0	0
KANS	290950042	low-12%	2015	352	200	0	0
LOSA	060374008	low- 9%	2015	255	200	0	0
LOSA	060590008	low- 9%	2015	364	200	0	0
MIAM	120110035	low-13%	2015	56	200	0	0
MINE	270370480	low-13%	2015	363	200	0	0
MINE	270530962	low-13%	2015	362	200	0	0
NYNY	340030010	low-12%	2015	365	200	0	0
PHIL	421010075	low- 9%	2015	357	200	0	0
PHIL	421010076	low-12%	2015	163	200	0	0
PHOE	040134019	low- 9%	2015	365	200	0	0
PHOE	040134020	low-12%	2015	121	200	0	0

CBSA Abbrev.	Near-road monitor site ID	Upwards Adjustment	Year	Number of monitored days in year	1-hour Benchmark (ppb)	Number of days at or above benchmark level	
						asis	CS1315
PITT	420031376	low-12%	2015	365	200	0	0
RICH	517600025	low-12%	2015	353	200	0	0
RIVR	060710026	low-13%	2015	360	200	0	0
RIVR	060710027	low- 9%	2015	153	200	0	0
SACR	060670015	low-12%	2015	80	200	0	0
SAND	060731017	low-13%	2015	269	200	0	0
SANF	060010012	low-12%	2015	365	200	0	0
STLO	291890016	low-13%	2015	357	200	0	0
STLO	295100094	low-13%	2015	364	200	0	0
WASH	110010051	low-12%	2015	212	200	0	0
ATLA	130890003	mid-17%	2015	363	200	0	0
ATLA	131210056	mid- 9%	2015	362	200	0	0
BALT	240270006	mid-16%	2015	352	200	0	0
BOST	250250044	mid-12%	2015	362	200	0	0
CHIC	170313103	mid-16%	2015	358	200	0	0
DALL	481131067	mid-17%	2015	365	200	0	0
DALL	484391053	mid-16%	2015	295	200	0	0
DENV	080310027	mid-12%	2015	359	200	0	0
DENV	080310028	mid-12%	2015	92	200	0	0
DETR	261630093	mid-12%	2015	361	200	0	0
DETR	261630095	mid-17%	2015	362	200	0	0
HOUS	482011052	mid-16%	2015	261	200	0	0
HOUS	482011066	mid-17%	2015	365	200	0	0
KANS	290950042	mid-16%	2015	352	200	0	0
LOSA	060374008	mid-12%	2015	255	200	0	0
LOSA	060590008	mid-12%	2015	364	200	0	0
MIAM	120110035	mid-17%	2015	56	200	0	0
MINE	270370480	mid-17%	2015	363	200	0	0
MINE	270530962	mid-17%	2015	362	200	0	0
NYNY	340030010	mid-16%	2015	365	200	0	0
PHIL	421010075	mid-12%	2015	357	200	0	0
PHIL	421010076	mid-16%	2015	163	200	0	0
PHOE	040134019	mid-12%	2015	365	200	0	0
PHOE	040134020	mid-16%	2015	121	200	0	0
PITT	420031376	mid-16%	2015	365	200	0	0
RICH	517600025	mid-16%	2015	353	200	0	0
RIVR	060710026	mid-17%	2015	360	200	0	0
RIVR	060710027	mid-12%	2015	153	200	0	0
SACR	060670015	mid-16%	2015	80	200	0	0
SAND	060731017	mid-17%	2015	269	200	0	0
SANF	060010012	mid-16%	2015	365	200	0	0
STLO	291890016	mid-17%	2015	357	200	0	0
STLO	295100094	mid-17%	2015	364	200	0	0
WASH	110010051	mid-16%	2015	212	200	0	0

1 **5.7 NUMBER (AND PERCENT) OF DAYS PER YEAR NO₂ CONCENTRATIONS WERE AT OR**
 2 **ABOVE 1-HOUR BENCHMARK LEVELS: CBSA-WIDE SUMMARY TABLES (2010 – 2015)**

3 **Table B5-60. Number of monitors used for calculations: area-wide and near-road monitor CBSA-wide summary table (2010-**
 4 **2015).**

CBSA Abbrev.	Mean number of monitors per year ^a					Maximum number of monitors per year ^a				
	asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
ATLA	4	3	3	3	4	5	3	3	4	5
BALT	2	2	2	2	2	3	2	2	3	3
BOST	6	5	5	6	6	7	5	6	6	7
CHIC	5	5			5	6	6			5
DALL	11	11	11	10	11	14	14	14	11	12
DENV	3		2	3	4	5		3	3	5
DETR	3	2	3	3	3	4	3	3	3	4
HOUS	15	13	13	15	16	17	16	16	17	17
KANS	3	3	3	3	3	3	3	3	3	3
LOSA	11	10	9	9	13	17	13	10	12	17
MIAM	4	4	3	3	3	5	5	5	3	3
MINE	4	3	3	4	4	5	3	4	4	5
NYNY	8	8	7	8	9	10	9	8	10	10
PHIL	5	4	5		5	6	5	6		6
PHOE	5	5	5	5	5	6	5	5	6	6
PITT	5	4	5		5	6	5	6		6
RICH	3	3	3	3	3	3	3	3	3	3
RIVR	9	8	6		9	13	11	7		13
SACR	7	8	7	7	7	8	8	8	8	8
SAND	7	7	7	4	2	8	8	7	7	7
SANF	10	10	9	10	9	11	11	11	11	10
STLO	3		3	4	4	5		4	5	5
WASH	6	6	6	5	5	7	7	6	6	6

5 ^a associated with summary results presented in Table B5-61.

1 **Table B5-61. Mean and maximum number of days per year NO₂ concentrations were at or above 1-hour benchmark levels:**
 2 **area-wide and near-road CBSA-wide summary table (2010-2015).**

CBSA Abbrev.	1-hour Benchmark /Metric	Mean number of days per year at or above benchmark level					Maximum number of days per year at or above benchmark level				
		asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
ATLA	100ppb	0	10	14	12	12	0	15	30	19	23
BALT	100ppb	0	7	9	10	11	0	13	12	14	20
BOST	100ppb	0	17	15	18	14	0	22	23	27	17
CHIC	100ppb	0.5	23			14	1	35			16
DALL	100ppb	0	11	12	14	15	0	15	21	19	18
DENV	100ppb	0.5		22	9	9	1		33	12	12
DETR	100ppb	0	14	31	22	11	0	17	35	26	13
HOUS	100ppb	1	19	14	18	20	3	30	14	24	31
KANS	100ppb	0	13	11	13	11	0	15	15	17	16
LOSA	100ppb	1	27	30	30	30	2	43	41	41	43
MIAM	100ppb	0	14	10	10	12	0	26	13	14	21
MINE	100ppb	0	15	13	14	12	0	23	14	20	16
NYNY	100ppb	2	15	14	18	21	3	21	19	30	30
PHIL	100ppb	0.5	11	13		9	1	22	26		15
PHOE	100ppb	0.5	9	12	12	11	1	9	15	15	14
PITT	100ppb	0	9	14		16	0	12	27		23
RICH	100ppb	0	17	14	19	9	0	30	23	28	11
RIVR	100ppb	2	9	23		8	8	17	37		10
SACR	100ppb	0	13	16	20	14	0	15	19	24	19
SAND	100ppb	0.5	8	9	7	10	1	10	12	12	10
SANF	100ppb	0.5	8	10	10	12	1	13	23	11	19
STLO	100ppb	0		7	17	8	0		8	23	13
WASH	100ppb	0	14	20	20	22	0	24	23	29	30
ATLA	150ppb	0	0	0	0	0	0	0	0	0	0
BALT	150ppb	0	0	0	0	0	0	0	0	0	0
BOST	150ppb	0	1	1	1	0.5	0	1	1	1	1
CHIC	150ppb	0	0			0	0	0			0
DALL	150ppb	0	0	0	0	0	0	0	0	0	0
DENV	150ppb	0		1	0.5	0.5	0		1	1	1

CBSA Abbrev.	1-hour Benchmark /Metric	Mean number of days per year at or above benchmark level					Maximum number of days per year at or above benchmark level				
		asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
DETR	150ppb	0	0.5	1	0.5	0	0	1	1	1	0
HOUS	150ppb	0	1	0	0	0	0	2	0	0	0
KANS	150ppb	0	0	0	0	0	0	0	0	0	0
LOSA	150ppb	0	0.5	1	0.5	0.5	0	1	1	1	1
MIAM	150ppb	0	1	1	1	1	0	2	1	2	2
MINE	150ppb	0	1	1	1	0	0	2	3	2	0
NYNY	150ppb	1	1	1	2	2	2	1	2	5	5
PHIL	150ppb	0	1	1		0.5	0	2	2		1
PHOE	150ppb	0	0	0	0	0	0	0	0	0	0
PITT	150ppb	0	0	0		0	0	0	0		0
RICH	150ppb	0	0	0.5	0.5	0	0	0	1	1	0
RIVR	150ppb	0	0.5	3		0	0	1	8		0
SACR	150ppb	0	0	0	0	0	0	0	0	0	0
SAND	150ppb	0	0	0	0	0	0	0	0	0	0
SANF	150ppb	0	0	0.5	0	0	0	0	1	0	0
STLO	150ppb	0		0	0.5	0	0		0	1	0
WASH	150ppb	0	0.5	0.5	1	0.5	0	1	1	1	1
ATLA	200ppb	0	0	0	0	0	0	0	0	0	0
BALT	200ppb	0	0	0	0	0	0	0	0	0	0
BOST	200ppb	0	0	0	0	0	0	0	0	0	0
CHIC	200ppb	0	0			0	0	0			0
DALL	200ppb	0	0	0	0	0	0	0	0	0	0
DENV	200ppb	0		0	0	0	0		0	0	0
DETR	200ppb	0	0	0	0	0	0	0	0	0	0
HOUS	200ppb	0	0	0	0	0	0	0	0	0	0
KANS	200ppb	0	0	0	0	0	0	0	0	0	0
LOSA	200ppb	0	0	0	0	0	0	0	0	0	0
MIAM	200ppb	0	0	0	0	0	0	0	0	0	0
MINE	200ppb	0	0	0	0	0	0	0	0	0	0
NYNY	200ppb	0.5	0	0	0	0	1	0	0	0	0
PHIL	200ppb	0	0	0		0	0	0	0		0
PHOE	200ppb	0	0	0	0	0	0	0	0	0	0

CBSA Abbrev.	1-hour Benchmark /Metric	Mean number of days per year at or above benchmark level					Maximum number of days per year at or above benchmark level				
		asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
PITT	200ppb	0	0	0		0	0	0	0	0	0
RICH	200ppb	0	0	0	0	0	0	0	0	0	0
RIVR	200ppb	0	0	0		0	0	0	0		0
SACR	200ppb	0	0	0	0	0	0	0	0	0	0
SAND	200ppb	0	0	0	0	0	0	0	0	0	0
SANF	200ppb	0	0	0	0	0	0	0	0	0	0
STLO	200ppb	0		0	0	0	0		0	0	0
WASH	200ppb	0	0	0	0	0	0	0	0	0	0
ATLA	2x100	0	0	0	0	1	0	0	0	0	1
BALT	2x100	0	1	0.5	0.5	1	0	3	1	1	1
BOST	2x100	0	6	6	7	6	0	11	11	13	8
CHIC	2x100	0	6			4	0	9			6
DALL	2x100	0	4	3	5	4	0	5	5	10	5
DENV	2x100	0.5		3	2	4	1		4	5	5
DETR	2x100	0	1	4	9	4	0	2	7	16	6
HOUS	2x100	0	5	5	7	9	0	7	7	9	17
KANS	2x100	0	1	1	2	2	0	2	2	5	5
LOSA	2x100	0	10	8	10	13	0	19	15	20	26
MIAM	2x100	0	4	2	3	4	0	10	3	4	7
MINE	2x100	0	2	2	3	3	0	4	3	7	5
NYNY	2x100	0.5	4	5	6	7	1	7	8	10	10
PHIL	2x100	0.5	2	3		2	1	3	6		3
PHOE	2x100	0	2	3	4	4	0	3	5	5	4
PITT	2x100	0	1	2		2	0	2	4		3
RICH	2x100	0	0	0	0.5	0	0	0	0	1	0
RIVR	2x100	0	0.5	3		3	0	1	6		6
SACR	2x100	0	4	4	6	3	0	7	6	8	6
SAND	2x100	0	0.5	0	0	1	0	1	0	0	1
SANF	2x100	0	0	0	1	2	0	0	0	2	5
STLO	2x100	0		1	3	1	0		3	5	4
WASH	2x100	0	5	3	4	6	0	12	5	6	12

1 **Table B5-62. Mean and maximum number of data point locations used for calculations:**
 2 **area-wide, near-road, and simulated on-road CBSA-wide summary table (2013-2015).**

CBSA Abbrev.	Mean number of data point locations per year		Maximum number of data point locations per year	
	asis	CS1315	asis	CS1315
ATLA	4	5	7	7
BALT	3	3	4	4
BOST	6	7	8	8
CHIC	5	5	6	6
DALL	12	12	14	14
DENV	3	5	7	7
DETR	4	5	6	6
HOUS	15	17	18	18
KANS	3	4	4	4
LOSA	12	14	19	19
MIAM	4	3	5	4
MINE	4	6	7	7
NYNY	9	10	11	11
PHIL	5	6	8	8
PHOE	6	6	8	8
PITT	5	5	6	6
RICH	3	4	4	4
RIVR	9	10	15	15
SACR	7	7	9	9
SAND	7	3	8	8
SANF	10	10	11	11
STLO	4	6	6	6
WASH	6	6	7	7

3 ^a associated with summary results presented in Table B6-63 and B5-64.

4

1 **Table B5-63. Mean and maximum number of days per year NO₂ concentrations were at or**
 2 **above 1-hour benchmark levels: area-wide, near-road, and simulated on-road CBSA-wide**
 3 **summary table (2013-2015).**

CBSA Abbrev.	1-hr Benchmark/Metric	Mean number of days per year at or above benchmark level		Maximum number of days per year at or above benchmark level	
		asis	CS1315	asis	CS1315
ATLA	100ppb	0	20	0	34
BALT	100ppb	0	24	0	35
BOST	100ppb	0	23	0	31
CHIC	100ppb	0.5	19	1	23
DALL	100ppb	0	19	0	22
DENV	100ppb	0.5	15	1	21
DETR	100ppb	0	22	0	30
HOUS	100ppb	1	27	3	31
KANS	100ppb	0	15	0	22
LOSA	100ppb	1	37	2	53
MIAM	100ppb	0.5	12	1	21
MINE	100ppb	0	25	0	37
NYNY	100ppb	2	28	4	38
PHIL	100ppb	0.5	11	1	16
PHOE	100ppb	0.5	19	1	27
PITT	100ppb	0	24	0	43
RICH	100ppb	0	25	0	39
RIVR	100ppb	2	18	8	38
SACR	100ppb	0	16	0	19
SAND	100ppb	0.5	20	1	20
SANF	100ppb	0.5	17	1	20
STLO	100ppb	0	28	0	38
WASH	100ppb	0	26	0	41
ATLA	150ppb	0	0	0	0
BALT	150ppb	0	0	0	0
BOST	150ppb	0	0.5	0	1
CHIC	150ppb	0	0	0	0
DALL	150ppb	0	0	0	0
DENV	150ppb	0	1	0	1
DETR	150ppb	0	0	0	0
HOUS	150ppb	0	0.5	0	1
KANS	150ppb	0	0	0	0
LOSA	150ppb	0	0.5	0	1
MIAM	150ppb	0	1	0	2
MINE	150ppb	0	1	0	1
NYNY	150ppb	1	2	2	6
PHIL	150ppb	0	0.5	0	1
PHOE	150ppb	0	0.5	0	1
PITT	150ppb	0	0	0	0
RICH	150ppb	0	1	0	1
RIVR	150ppb	0	1	0	2
SACR	150ppb	0	0	0	0
SAND	150ppb	0	0	0	0
SANF	150ppb	0	0	0	0
STLO	150ppb	0	1	0	2
WASH	150ppb	0	1	0	2

ATLA	200ppb	0	0	0	0	1
BALT	200ppb	0	0	0	0	
BOST	200ppb	0	0	0	0	
CHIC	200ppb	0	0	0	0	
DALL	200ppb	0	0	0	0	
DENV	200ppb	0	0	0	0	
DETR	200ppb	0	0	0	0	
HOUS	200ppb	0	0	0	0	
KANS	200ppb	0	0	0	0	
LOSA	200ppb	0	0	0	0	
MIAM	200ppb	0	0	0	0	
MINE	200ppb	0	0	0	0	
NYNY	200ppb	0.5	1	1	2	
PHIL	200ppb	0	0	0	0	
PHOE	200ppb	0	0	0	0	
PITT	200ppb	0	0	0	0	
RICH	200ppb	0	0	0	0	
RIVR	200ppb	0	0	0	0	
SACR	200ppb	0	0	0	0	
SAND	200ppb	0	0	0	0	
SANF	200ppb	0	0	0	0	
STLO	200ppb	0	0	0	0	
WASH	200ppb	0	0	0	0	
ATLA	2x100	0	7	0	12	
BALT	2x100	0	5	0	9	
BOST	2x100	0	11	0	14	
CHIC	2x100	0.5	6	1	8	
DALL	2x100	0	6	0	9	
DENV	2x100	0.5	7	1	10	
DETR	2x100	0	10	0	14	
HOUS	2x100	0	13	0	17	
KANS	2x100	0	5	0	7	
LOSA	2x100	0	18	0	32	
MIAM	2x100	0	5	0	7	
MINE	2x100	0	11	0	14	
NYNY	2x100	1	13	2	18	
PHIL	2x100	0.5	3	1	4	
PHOE	2x100	0	7	0	9	
PITT	2x100	0	8	0	17	
RICH	2x100	0	6	0	11	
RIVR	2x100	0	7	0	19	
SACR	2x100	0	4	0	6	
SAND	2x100	0	5	0	5	
SANF	2x100	0	3	0	7	
STLO	2x100	0	8	0	12	
WASH	2x100	0	8	0	16	

1 **Table B5-64. Percent of days per year NO₂ concentrations were at or above 1-hour benchmark levels: area-wide and near-**
 2 **road CBSA-wide summary table.**

CBSA Abbrev.	1-hour Benchmark /Metric	Mean percent of days per year at or above benchmark level					Maximum percent of days per year at or above benchmark level				
		asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
ATLA	100ppb	0	2.7	3.8	3.4	3.4	0	4.1	8.2	5.2	6.3
BALT	100ppb	0	2	2.4	2.7	3.1	0	3.6	3.3	3.8	5.5
BOST	100ppb	0	4.8	4.1	4.9	3.8	0	6	6.3	7.4	4.7
CHIC	100ppb	0.1	6.2			3.7	0.3	9.6			4.4
DALL	100ppb	0	2.9	3.4	3.7	4.1	0	4.1	5.8	5.2	4.9
DENV	100ppb	0.1		6.1	2.4	2.4	0.3		9	3.3	3.3
DETR	100ppb	0	3.9	8.6	5.9	2.9	0	4.6	9.6	7.1	3.6
HOUS	100ppb	0.1	5.1	3.7	4.9	5.4	0.8	8.2	3.8	6.6	8.5
KANS	100ppb	0	3.7	3	3.6	2.9	0	4.1	4.1	4.6	4.4
LOSA	100ppb	0.1	7.4	8.1	8.3	8.3	0.6	11.8	11.2	11.2	11.8
MIAM	100ppb	0	3.9	2.7	2.8	3.2	0	7.1	3.6	3.8	5.8
MINE	100ppb	0	4	3.7	3.9	3.2	0	6.3	3.8	5.5	4.4
NYNY	100ppb	0.5	4.1	3.7	4.8	5.8	0.8	5.8	5.2	8.2	8.2
PHIL	100ppb	0.1	3.1	3.5		2.4	0.3	6	7.1		4.1
PHOE	100ppb	0.1	2.4	3.4	3.3	3	0.3	2.5	4.1	4.1	3.8
PITT	100ppb	0	2.4	3.7		4.3	0	3.3	7.4		6.3
RICH	100ppb	0	4.8	3.9	5.2	2.5	0	8.2	6.3	7.7	3
RIVR	100ppb	0.5	2.4	6.3		2.3	2.2	4.6	10.1		2.7
SACR	100ppb	0	3.5	4.5	5.5	3.9	0	4.1	5.2	6.6	5.2
SAND	100ppb	0.1	2.2	2.4	1.8	2.7	0.3	2.7	3.3	3.3	2.7
SANF	100ppb	0.1	2.1	2.8	2.7	3.3	0.3	3.6	6.3	3	5.2
STLO	100ppb	0		1.8	4.7	2.3	0		2.2	6.3	3.6
WASH	100ppb	0	3.8	5.4	5.4	6	0	6.6	6.3	8	8.2
ATLA	150ppb	0	0	0	0	0	0	0	0	0	0
BALT	150ppb	0	0	0	0	0	0	0	0	0	0
BOST	150ppb	0	0.1	0.3	0.1	0.1	0	0.3	0.3	0.3	0.3
CHIC	150ppb	0	0			0	0	0			0
DALL	150ppb	0	0	0	0	0	0	0	0	0	0
DENV	150ppb	0		0.1	0.1	0.1	0		0.3	0.3	0.3

CBSA Abbrev.	1-hour Benchmark /Metric	Mean percent of days per year at or above benchmark level					Maximum percent of days per year at or above benchmark level				
		asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
DETR	150ppb	0	0.1	0.1	0.1	0	0	0.3	0.3	0.3	0
HOUS	150ppb	0	0.1	0	0	0	0	0.6	0	0	0
KANS	150ppb	0	0	0	0	0	0	0	0	0	0
LOSA	150ppb	0	0.1	0.1	0.1	0.1	0	0.3	0.3	0.3	0.3
MIAM	150ppb	0	0.4	0.3	0.4	0.4	0	0.6	0.3	0.6	0.6
MINE	150ppb	0	0.1	0.3	0.1	0	0	0.6	0.8	0.6	0
NYNY	150ppb	0.1	0.1	0.1	0.5	0.5	0.6	0.3	0.6	1.4	1.4
PHIL	150ppb	0	0.1	0.1		0.1	0	0.6	0.6		0.3
PHOE	150ppb	0	0	0	0	0	0	0	0	0	0
PITT	150ppb	0	0	0		0	0	0	0		0
RICH	150ppb	0	0	0.1	0.1	0	0	0	0.3	0.3	0
RIVR	150ppb	0	0.1	0.7		0	0	0.3	2.2		0
SACR	150ppb	0	0	0	0	0	0	0	0	0	0
SAND	150ppb	0	0	0	0	0	0	0	0	0	0
SANF	150ppb	0	0	0.1	0	0	0	0	0.3	0	0
STLO	150ppb	0		0	0.1	0	0		0	0.3	0
WASH	150ppb	0	0.1	0.1	0.1	0.1	0	0.3	0.3	0.3	0.3
ATLA	200ppb	0	0	0	0	0	0	0	0	0	0
BALT	200ppb	0	0	0	0	0	0	0	0	0	0
BOST	200ppb	0	0	0	0	0	0	0	0	0	0
CHIC	200ppb	0	0			0	0	0			0
DALL	200ppb	0	0	0	0	0	0	0	0	0	0
DENV	200ppb	0		0	0	0	0		0	0	0
DETR	200ppb	0	0	0	0	0	0	0	0	0	0
HOUS	200ppb	0	0	0	0	0	0	0	0	0	0
KANS	200ppb	0	0	0	0	0	0	0	0	0	0
LOSA	200ppb	0	0	0	0	0	0	0	0	0	0
MIAM	200ppb	0	0	0	0	0	0	0	0	0	0
MINE	200ppb	0	0	0	0	0	0	0	0	0	0
NYNY	200ppb	0.1	0	0	0	0	0.3	0	0	0	0
PHIL	200ppb	0	0	0		0	0	0	0		0
PHOE	200ppb	0	0	0	0	0	0	0	0	0	0

CBSA Abbrev.	1-hour Benchmark /Metric	Mean percent of days per year at or above benchmark level					Maximum percent of days per year at or above benchmark level				
		asis	CS1012	CS1113	CS1214	CS1315	asis	CS1012	CS1113	CS1214	CS1315
PITT	200ppb	0	0	0		0	0	0	0	0	0
RICH	200ppb	0	0	0	0	0	0	0	0	0	0
RIVR	200ppb	0	0	0		0	0	0	0		0
SACR	200ppb	0	0	0	0	0	0	0	0	0	0
SAND	200ppb	0	0	0	0	0	0	0	0	0	0
SANF	200ppb	0	0	0	0	0	0	0	0	0	0
STLO	200ppb	0		0	0	0	0		0	0	0
WASH	200ppb	0	0	0	0	0	0	0	0	0	0
ATLA	2X100	0	0	0	0	0.1	0	0	0	0	0.3
BALT	2X100	0	0.3	0.1	0.1	0.1	0	0.8	0.3	0.3	0.3
BOST	2X100	0	1.6	1.7	2	1.7	0	3	3	3.6	2.2
CHIC	2X100	0	1.6			1.1	0	2.5			1.6
DALL	2X100	0	1.1	0.8	1.5	1.2	0	1.4	1.4	2.7	1.4
DENV	2X100	0.1		0.7	0.6	1	0.3		1.1	1.4	1.4
DETR	2X100	0	0.3	1.2	2.4	1	0	0.6	1.9	4.4	1.6
HOUS	2X100	0	1.3	1.5	2	2.6	0	1.9	1.9	2.5	4.7
KANS	2X100	0	0.1	0.1	0.5	0.6	0	0.6	0.6	1.4	1.4
LOSA	2X100	0	2.8	2.1	2.7	3.7	0	5.2	4.1	5.5	7.1
MIAM	2X100	0	1	0.6	0.7	1.2	0	2.7	0.8	1.1	1.9
MINE	2X100	0	0.6	0.5	0.7	0.9	0	1.1	0.8	1.9	1.4
NYNY	2X100	0.1	1.2	1.5	1.7	2	0.3	1.9	2.2	2.7	2.7
PHIL	2X100	0.1	0.6	0.7		0.5	0.3	0.8	1.6		0.8
PHOE	2X100	0	0.5	0.9	1	1	0	0.8	1.4	1.4	1.1
PITT	2X100	0	0.4	0.5		0.6	0	0.6	1.1		0.8
RICH	2X100	0	0	0	0.1	0	0	0	0	0.3	0
RIVR	2X100	0	0.1	0.8		0.8	0	0.3	1.6		1.6
SACR	2X100	0	1.2	1.2	1.7	0.9	0	1.9	1.6	2.2	1.6
SAND	2X100	0	0.1	0	0	0.3	0	0.3	0	0	0.3
SANF	2X100	0	0	0	0.3	0.5	0	0	0	0.6	1.4
STLO	2X100	0		0.3	0.9	0.4	0		0.8	1.4	1.1
WASH	2X100	0	1.4	0.8	1	1.7	0	3.3	1.4	1.6	3.3

**5.8 DATA FOR INDIVIDUAL NEAR-ROAD MONITORS 2014 AND 2015:
AS IS AND ADJUSTED TO JUST MEET THE EXISTING STANDARD**

Table B5-65. Number per year NO₂ concentrations were at or above 1-hour benchmark levels: individual near-road monitor data where monitor was in operation for at least 300 days in year 2014 and/or 2015.

CBSA Abbrev.	Monitor site id	1-hr benchmark	Number of days per year DM1H at or above benchmark level			
			As Is air quality 2014	As Is air quality 2015	Adjusted air quality 2014	Adjusted air quality 2015
ATLA	130890003	100 ppb		0		7
ATLA	131210056	100 ppb		0		3
BALT	240270006	100 ppb		0		7
BOST	250250044	100 ppb	0	0	11	6
CHIC	170313103	100 ppb	1	0	4	4
DALL	481131067	100 ppb		0		5
DENV	080310027	100 ppb	0	0	5	3
DETR	261630093	100 ppb	0	0	9	9
DETR	261630095	100 ppb		0		5
HOUS	482011066	100 ppb	0	0	4	3
KANS	290950042	100 ppb	0	0	4	3
LOSA	060590008	100 ppb	0	0	21	1
MINE	270370480	100 ppb		0		3
MINE	270530962	100 ppb	0	0	11	10
NYNY	340030010	100 ppb		1		8
PHIL	421010075	100 ppb	0	0	3	2
PHOE	040134019	100 ppb	0	0	3	2
PITT	420031376	100 ppb		0		11
RICH	517600025	100 ppb		0		9
RIVR	060710026	100 ppb		0		8
SANF	060010012	100 ppb	0	0	2	1
STLO	291890016	100 ppb		0		1
STLO	295100094	100 ppb	0	0	10	2
ATLA	130890003	150 ppb		0		0
ATLA	131210056	150 ppb		0		0
BALT	240270006	150 ppb		0		0
BOST	250250044	150 ppb	0	0	0	0
CHIC	170313103	150 ppb	0	0	0	0
DALL	481131067	150 ppb		0		0
DENV	080310027	150 ppb	0	0	0	0
DETR	261630093	150 ppb	0	0	0	0
DETR	261630095	150 ppb		0		0
HOUS	482011066	150 ppb	0	0	0	0

CBSA Abbrev.	Monitor site id	1-hr benchmark	Number of days per year DM1H at or above benchmark level			
			As Is air quality 2014	As Is air quality 2015	Adjusted air quality 2014	Adjusted air quality 2015
KANS	290950042	150 ppb	0	0	0	0
LOSA	060590008	150 ppb	0	0	0	0
MINE	270370480	150 ppb		0		0
MINE	270530962	150 ppb	0	0	0	0
NYNY	340030010	150 ppb		1		0
PHIL	421010075	150 ppb	0	0	0	0
PHOE	040134019	150 ppb	0	0	0	0
PITT	420031376	150 ppb		0		0
RICH	517600025	150 ppb		0		0
RIVR	060710026	150 ppb		0		0
SANF	060010012	150 ppb	0	0	0	0
STLO	291890016	150 ppb		0		0
STLO	295100094	150 ppb	0	0	0	0
ATLA	130890003	200 ppb		0		0
ATLA	131210056	200 ppb		0		0
BALT	240270006	200 ppb		0		0
BOST	250250044	200 ppb	0	0	0	0
CHIC	170313103	200 ppb	0	0	0	0
DALL	481131067	200 ppb		0		0
DENV	080310027	200 ppb	0	0	0	0
DETR	261630093	200 ppb	0	0	0	0
DETR	261630095	200 ppb		0		0
HOUS	482011066	200 ppb	0	0	0	0
KANS	290950042	200 ppb	0	0	0	0
LOSA	060590008	200 ppb	0	0	0	0
MINE	270370480	200 ppb		0		0
MINE	270530962	200 ppb	0	0	0	0
NYNY	340030010	200 ppb		0		0
PHIL	421010075	200 ppb	0	0	0	0
PHOE	040134019	200 ppb	0	0	0	0
PITT	420031376	200 ppb		0		0
RICH	517600025	200 ppb		0		0
RIVR	060710026	200 ppb		0		0
SANF	060010012	200 ppb	0	0	0	0
STLO	291890016	200 ppb		0		0
STLO	295100094	200 ppb	0	0	0	0

5.9 COMPARISON OF CURRENT RESULTS WITH 2008 REA

We compared the site-year results generated in this AQC to those generated in the 2008 REA. In general, the estimated number of days per year at or above benchmark levels is similar when evaluating the area-wide and the near-road monitors, considering both the mean and upper percentile values (Table B5-66). The mean number of days per year at or above 100 ppb was about 5, while the maximum number of days per year above that same level ranged from about 10 to 20. There were very few instances where concentrations were at or above the 150 ppb and 200 ppb benchmark levels, regardless of which analytical data set or monitor type was considered.

There are however large differences in the number of days per year at or above benchmark levels when considering the simulated on-road concentrations, whereas the 2008 REA results were consistently higher than those generated in the current AQC. For example, the 2008 REA estimated, on average, 30 to 150 days per year at or above the 100 ppb 1-hour benchmark on-road in the subset of comparable study areas, along with an upper percentile estimate of ranging from about 100 to 300 days per year. In the current AQC, the mean and mean number of days where estimated concentrations were at or above the 100 ppb benchmark ranged from about 5 to 20, with a maximum of just around 40 days per year. In addition, the number of days having concentrations at or above the higher benchmark levels (i.e., 150 and 200 ppb) were estimated to occur more frequently when considering the 2008 REA results compared with the current AQC.

This relatively lower range of values estimated in this AQC is to some extent a function of the fewer number of days monitored for the new near-road monitors, with many having what would be considered an incomplete year of monitor data (Table B5-58 and Table B5-59). All data used in the 2008 REA adhered to the standard completeness criteria, while for the current analysis, this restriction was relaxed for the near-road monitors such that we could include the maximum number of days/years of near-road data possible. To a greater extent though, the difference is likely the result of the monitor data used to simulate the on-road NO₂ concentrations. Here we used the near-road monitors, sited in close proximity to major roads combined with a statistical approach to estimate the on-road concentrations. A similar approach was used in the 2008 REA, though based on the form of the statistical model used, monitors at greater distances from roads (i.e., at least 100 m from a road) were used to estimate the on-road concentrations. The 2008 REA statistical model assumed monitors sited 100 m or greater from a road was a reasonable distance to not have a direct influence from road emissions, though recognized as an important uncertainty in that assessment (2008 REA, section 7.4.6).

1 In reviewing the current monitor attribute data provided in Table B5-11 through Table
2 B5-33 (and also Table B5-34 through Table B5-56), while it is possible that at a distance of 100
3 meters or more from a major road these monitors could have limited direct contribution from
4 roadway emissions, there remains the potential for other source emissions to substantially
5 influence concentrations measured at the monitors that were not accounted for before simulating
6 the on-road concentrations. For example, monitor ID 420450002 located in the Philadelphia
7 study area was assumed to be not influenced by roadway emissions based on its siting of 322 m
8 from a major road (Table B5-24) and NO₂ concentrations from this monitor were used to
9 simulate the on-road concentrations. However, in identifying all NO_x emission sources within a
10 5 km radius of that monitor, it is possible that NO₂ concentrations measured at that monitor
11 could be influenced by emissions from one or more facilities, including NO_x emissions from
12 electricity generation (via combustion), petroleum refineries, and municipal waste combustion.
13 Using this monitor and other monitors⁴⁰ that could potentially be influenced by significant
14 facility emissions would tend to overestimate the number of days per year simulated on-road
15 NO₂ concentrations were at or above benchmark levels.

⁴⁰ For example monitor ID 421010029 also in the Philadelphia study area (Table B5-47) is within 5 km of an electricity generating unit(s) having summed NO_x emissions of 353 tons per year.

1 **Table B5-66. Mean and maximum number of days per year NO₂ concentrations exceed 1-**
 2 **hour benchmark levels: comparison of current air quality characterization with 2008 REA.**

Study Area	Source of Results ¹	Monitor Distance from Road or Category ²	AQ Data Years	Site-Years ³	Number of days per year at or above benchmark level ⁴					
					≥100 ppb		≥150 ppb		≥ 200 ppb	
					Mean	p99/max	Mean	p99/max	Mean	p99/max
Atlanta	Current	Area-wide	2010-12	9	3	15	0	0	0	0
			2011-13	9	5	30	0	0	0	0
			2012-14	9	4	16	0	0	0	0
			2013-15	9	2	16	0	0	0	0
	2008 REA	≥100 m	2001-03	14	2	15	0	1	0	1
		>20m-<100m	2001-03	0	-	-	-	-	-	-
	Current	Near-road	2013-15	3	6	8	0	0	0	0
	2008 REA	≤20m	2001-03	0	-	-	-	-	-	-
	Current	On-road	2014	1	19	-	0	-	0	-
			2015	2	14	20	0	0	0	0
2008 REA	On-/Near-road	2001-03	1400	46	229	10	104	2	38	
Boston	Current	Area-wide	2010-12	15	5	15	0.5	1	0	0
			2011-13	15	5	15	0.5	1	0	0
			2012-14	11	6	18	1	1	0	0
			2013-15	16	3	12	0.5	1	0	0
	2008 REA	≥100 m	2001-03	6	0	1	0	0	0	0
		>20m-<100m	2001-03	14	3	11	0	0	0	0
	Current	Near-road	2013-15	3	6	11	0	0	0	0
	2008 REA	≤20m	2001-03	5	2	6	0	1	0	0
	Current	On-road	2014	1	29	-	0	-	0	-
			2015	1	24	-	0	-	0	-
2008 REA	On-/Near-road	2001-03	600	26	131	3	25	0	6	
Chicago	Current	Area-wide	2010-12	11	7	24	0	0	0	0
			2011-13	0	-	-	-	-	-	-
			2012-14	0	-	-	-	-	-	-
			2013-15	12	4	12	0	0	0	0
	2008 REA	≥100 m	2001-03	9	1	4	0	1	0	0
		>20m-<100m	2001-03	6	7	21	1	3	0	0
	Current	Near-road	2013-15	2	4	4	0	0	0	0
	2008 REA	≤20m	2001-03	4	2	6	0	0	0	0
	Current	On-road	2014	1	14	-	0	-	0	-
			2015	1	15	-	0	-	0	-
2008 REA	On-/Near-road	2001-03	900	83	257	18	106	4	49	
Denver	Current	Area-wide	2010-12	0	-	-	-	-	-	-

Study Area	Source of Results ¹	Monitor Distance from Road or Category ²	AQ Data Years	Site-Years ³	Number of days per year at or above benchmark level ⁴					
					≥100 ppb		≥150 ppb		≥ 200 ppb	
					Mean	p99/max	Mean	p99/max	Mean	p99/max
			2011-13	5	14	29	0.5	1	0	0
			2012-14	6	5	10	1	1	0	0
			2013-15	7	4	10	0.5	1	0	0
	2008 REA	≥100 m	2001-03	2	2	2	0	0	0	0
		>20m-<100m	2001-03	0	-	-	-	-	-	-
	Current	Near-road	2013-15	4	3	5	0	0	0	0
	2008 REA	≤20m	2001-03	2	7	10	2	3	0	0
	Current	On-road	2014	1	16	-	1	-	0	-
			2015	2	10	13	0.5	1	0	0
	2008 REA	On-/Near-road	2001-03	200	99	269	19	103	4	37
Detroit	Current	Area-wide	2010-12	4	6	12	0	0	0	0
			2011-13	5	9	23	0	0	0	0
			2012-14	6	8	18	0	0	0	0
			2013-15	6	4	9	0	0	0	0
	2008 REA	≥100 m	2001-03	6	3	7	2	7	1	4
		>20m-<100m	2001-03	0	-	-	-	-	-	-
	Current	Near-road	2013-15	4	7	9	0	0	0	0
	2008 REA	≤20m	2001-03	0	-	-	-	-	-	-
	Current	On-road	2014	1	19	-	0	-	0	-
			2015	2	19	22	0	0	0	0
2008 REA	On-/Near-road	2001-03	600	59	186	13	57	5	28	
Los Angeles	Current	Area-wide	2010-12	30	5	19	0.5	1	0	0
			2011-13	26	5	22	0.5	1	0	0
			2012-14	27	5	23	0.5	1	0	0
			2013-15	35	4	27	0.5	1	0	0
	2008 REA	≥100 m	2001-03	51	1	10	0	5	0	0
		>20m-<100m	2001-03	35	1	7	0	1	0	1
	Current	Near-road	2013-15	3	9	21	0	0	0	0
	2008 REA	≤20m	2001-03	9	1	3	0	0	0	0
	Current	On-road	2014	1	36	-	0	-	0	-
			2015	2	10	17	0	0	0	0
2008 REA	On-/Near-road	2001-03	5100	33	160	6	55	1	20	
Miami	Current	Area-wide	2010-12	12	5	15	0.5	1	0	0
			2011-13	10	4	12	0.5	1	0	0
			2012-14	8	5	12	1	1	0	0
			2013-15	8	6	17	0.5	1	0	0

Study Area	Source of Results ¹	Monitor Distance from Road or Category ²	AQ Data Years	Site-Years ³	Number of days per year at or above benchmark level ⁴					
					≥100 ppb		≥150 ppb		≥ 200 ppb	
					Mean	p99/max	Mean	p99/max	Mean	p99/max
	2008 REA	≥100 m	2001-03	6	4	14	0	2	0	0
		>20m-<100m	2001-03	3	8	15	0	1	0	0
	Current	Near-road	2013-15	1	1	-	1	-	0	-
	2008 REA	≤20m	2001-03	3	1	1	0	0	0	0
	Current	On-road	2015	1	2	-	1	-	0	-
	2008 REA	On-/Near-road	2001-03	600	78	189	19	110	5	48
New York	Current	Area-wide	2010-12	23	3	9	0.5	1	0	0
			2011-13	22	3	12	0.5	1	0	0
			2012-14	24	3	12	0.5	1	0	0
			2013-15	25	4	12	0.5	1	0	0
	2008 REA	≥100 m	2001-03	26	1	5	0	0	0	0
		>20m-<100m	2001-03	13	3	13	0	2	0	0
	Current	Near-road	2013-15	2	8	8	2	3	0	0
	2008 REA	≤20m	2001-03	7	1	2	0	0	0	0
	Current	On-road	2014	1	16	-	4	-	2	-
			2015	1	26	-	1	-	0	-
2008 REA	On-/Near-road	2001-03	2600	57	226	10	73	3	34	
Philadelphia	Current	Area-wide	2010-12	13	3	18	0.5	1	0	0
			2011-13	14	3	23	0.5	1	0	0
			2012-14	0	-	-	-	-	-	-
			2013-15	13	2	13	0.5	1	0	0
	2008 REA	≥100 m	2001-03	14	3	15	0	1	0	1
		>20m-<100m	2001-03	7	5	11	0	0	0	0
	Current	Near-road	2013-15	3	2	3	0	0	0	0
	2008 REA	≤20m	2001-03	0	-	-	-	-	-	-
	Current	On-road	2014	1	8	-	0	-	0	-
			2015	2	3	4	0	0	0	0
2008 REA	On-/Near-road	2001-03	1400	116	294	27	137	7	68	
Phoenix	Current	Area-wide	2010-12	15	2	9	0	0	0	0
			2011-13	14	4	13	0	0	0	0
			2012-14	14	3	12	0	0	0	0
			2013-15	13	3	9	0	0	0	0
	2008 REA	≥100 m	2001-03	5	1	2	0	0	0	0
		>20m-<100m	2001-03	2	0	0	0	0	0	0
	Current	Near-road	2013-15	3	3	3	0	0	0	0
	2008 REA	≤20m	2001-03	3	6	11	0	0	0	0

Study Area	Source of Results ¹	Monitor Distance from Road or Category ²	AQ Data Years	Site-Years ³	Number of days per year at or above benchmark level ⁴					
					≥100 ppb		≥150 ppb		≥ 200 ppb	
					Mean	p99/max	Mean	p99/max	Mean	p99/max
	Current	On-road	2014	1	13	-	0	-	0	-
			2015	2	12	19	0.5	1	0	0
	2008 REA	On-/Near-road	2001-03	500	153	337	35	206	6	48
St. Louis	Current	Area-wide	2010-12	0	-	-	-	-	-	-
			2011-13	8	2	8	0	0	0	0
			2012-14	9	4	14	0	0	0	0
			2013-15	9	1	5	0	0	0	0
	2008 REA	≥100 m	2001-03	9	3	15	0	1	0	0
		>20m-<100m	2001-03	11	2	11	0	0	0	0
	Current	Near-road	2013-15	4	5	10	0	0	0	0
	2008 REA	≤20m	2001-03	6	3	6	0	1	0	0
	Current	On-road	2014	1	37	-	2	-	0	-
			2015	2	11	17	0	0	0	0
2008 REA	On-/Near-road	2001-03	900	125	288	28	153	7	51	
Washington DC	Current	Area-wide	2010-12	18	4	14	0.5	1	0	0
			2011-13	17	4	20	0.5	1	0	0
			2012-14	15	5	24	0.5	1	0	0
			2013-15	15	6	24	0.5	1	0	0
	2008 REA	≥100 m	2001-03	18	4	11	0	0	0	0
		>20m-<100m	2001-03	10	2	5	0	0	0	0
	Current	Near-road	2013-15	1	4	4	0	0	0	0
	2008 REA	≤20m	2001-03	4	6	9	0	1	0	0
	Current	On-road	2015	1	17	-	2	-	0	-
	2008 REA	On-/Near-road	2001-03	1800	109	310	27	168	7	63

¹ Data compared are from the AQC performed for this current NO₂ review and the AQC conducted for the 2008 REA. Shading is added where data can generally be compared for the two sets of results.

² For the current AQC, the results are separated into three groups: all area-wide monitors regardless of their distance to major roads, the formally designated near-road monitor, and simulated on-road concentrations (where concentrations from the newly designated near-road monitors served as the basis for the estimation). For the 2008 NO₂ REA AQC, three generally similar groups of data are presented: area-wide monitors (though having two categories for describing their distance in meters (m) from a major road, Tables 7-23 (≥100 m) and 7-24 (>20 m to <100 m), near-road monitors (based on monitors sited ≤20 m from a major road, Table 7-25), and simulated on-road concentrations (where concentrations from monitors sited ≥100 m from a major road served as the basis for the estimation, Table 7-28).

³ In general, the average number of monitors operating per year within the three-year group can be estimated by dividing the number of site-years by the area-wide and near-road data. When using the on-road data, divide by 300.

⁴ The mean number of exceedances represents the sum of benchmark exceedances occurring at all monitors in a particular location divided by the total site-years across the three-year monitoring period. The p99 (2008 REA AQC) and maximum (Current AQC) represent an upper estimate of the number of days/year having a benchmark exceedance at a particular monitoring site for a single year within the monitoring period.

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