Streamlining Carbon Monoxide Project-Level Air Quality Analyses with Programmatic Agreements

Prepared for

AASHTO Committee on Environment and Sustainability

Prepared by

Edward Carr
Seth Hartley
John Hader
ICF

George Noel
Andrew Eilbert
Volpe Transportation Systems Center

&

Leo Tidd
WSP USA

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Disclaimer

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Executive Summary

This report summarizes the approach taken to develop a template programmatic agreement (PA) and associated technical support document (TSD) that may be applied by state Departments of Transportation (DOTs) to screen proposed transportation improvement projects for potential carbon monoxide (CO) impacts, in keeping with the National Environmental Policy Act (NEPA) and associated Federal Highway Administration (FHWA) guidance.[1] The template PA and TSD developed in this study are provided as Appendices B and C respectively to this report. Multiple options for implementation are available to state DOTs. All modeling here is conducted with MOVES2014a and CAL3QHCR.

Implementation Options: Three primary options are available to state DOTs for implementing the template PA and TSD in their respective jurisdictions. For each option, state DOTs may modify the terms of the PA at their discretion before executing it with their respective FHWA division offices. Several optional ways that state DOTs may wish to include are provided in the template PA for this purpose.

1. The simplest and lowest-cost implementation option is for state DOTs that do not need or want to update either: a) the underlying emission and dispersion modeling from the templates or b) the background concentrations or persistence factors. These state DOTs typically will need only to make editorial changes to the template text (e.g., to insert the name of the state, and select which if any of the optional terms to include) and then execute the PA with their respective FHWA division offices.

Note: If *either* background concentrations or persistence factors are higher than assumed for the template PA and TSD, then state-specific values should be used for those respective parameters. This approach is outlined in Option 2.

2. For state DOTs that need or want to use state-specific background concentrations and/or persistence factors, the template PA and TSD provide a simple means for incorporating those values without having to update the detailed underlying emission and dispersion modeling. Those state DOTs for the most part need only to make editorial changes to the template text (as noted for Option #1), specify the state-specific background concentration(s) and/or persistence factor(s) as appropriate, update the project screening tables for projects which qualify, and then execute the PA with their respective FHWA division offices.

3. The most labor-intensive option is for state DOTs that need or want to use state-specific modeling. For these state DOTs, the original modeling files developed for this template PA and TSD (and provided online with the project report) can be updated with state-specific input data and the emission and/or dispersion models re-run as needed. Once the state-specific modeling has been completed and the project screening tables

[1] FHWA Technical Advisory T 6640.8A, "*Guidance for Preparing and Processing Environmental and Section 4(F) Documents*", October 30, 1987. See: https://www.environment.fhwa.dot.gov/legislation/nepa/guidance_preparing_env_documents.aspx

updated along with the PA and TSD, the customized PA can be executed with the FHWA Division office.

Related to this option, a pilot study was conducted as part of this project. The pilot study served both to evaluate the draft template PA and TSD developed in this study and to assess the time and cost for implementation involving state-specific modeling. A summary of the lessons learned from the pilot study are provided below. Copies of the state-specific PA and TSD developed in the pilot are provided in Appendices F and G.

While this option requires additional effort, it offers the primary advantage that state DOTs may add facility type, configurations and emissions based on their state-specific modeling, and so expand coverage.

Pilot Study (Example of Implementation Option #3): A pilot study was conducted in which the draft template PA and TSD developed in this NCHRP study were customized (including state-specific modeling) to create a state-specific PA for the Georgia Department of Transportation (GDOT). The pilot study serves as an example of the level of effort and data needed to customize the template PA and TSD for state-specific conditions. It provides state DOTs with a concrete example of the necessary resources, time commitments and approvals needed to secure an approved PA when updating the emission and dispersion modeling to use local state-specific modeling inputs.

For the GDOT PA and TSD, MOVES runs were based on conservative state-specific maximum temperatures, age distribution, fuel formulations, and inspection and maintenance program to represent possible worst-case conditions within the state. Dispersion modeling was conducted following the national scale approach, incorporating local conditions and same facility types (intersections, freeways, arterials, and interchanges). GDOT determined state-specific values for background CO concentrations and persistence factors. Once updated with worst-case modeling results based on Georgia-specific data, the resulting PA and TSD was then executed with FHWA Georgia.

Key lessons learned from the development of state-specific PA for Georgia DOT include:

- Obtaining or generating updates to local data and parameters can be labor intensive if they are not readily available. Time should be planned for coordinating with the state environmental agency for this purpose and to maintain consistency.
- Background pollutant concentration values and persistence factors are important to determining which types of projects can meet air quality standards. Historical values should be reviewed and updated as needed given recent trends in CO concentrations and changes in hourly traffic flow volumes.
- Allow adequate time for both PA and TSD analysis and review. The modeling process alone could take several months, including time to identify, collect, and in some cases generate the necessary modeling inputs. Significant additional time may be needed for review and comment on the draft PA and TSD by the state DOT and FHWA division office before the agreement is executed.

The PA and TSD templates developed in this study are provided in Appendices B and C respectively. They are updated versions originally developed in a prior National Cooperative Highway Research Program (NCHRP) study.[2] State DOTs that have implemented the templates from that prior study need only repeat the process for the new templates.

For background, this study expanded upon the NCHRP Task 78 work by: (1) updating the analysis with the latest version of the MOVES emission model, and (2) expanding coverage to include other project configurations (skew angles for intersections and interchanges), and expanding the range of road grades. To better inform implementation, this study also conducted a pilot program, as summarized above.

The NCHRP templates developed in this study also complement work undertaken by the Federal Highway Administration (FHWA) to develop a similar tool to be applied for purposes of the EPA transportation conformity rule (40 CFR Parts 51 and 93.)[3]

[2] ICF, Zamurs and Associates, and Volpe Transportation Center, NCHRP 25-25/Task 78, "*Programmatic Agreements for Project-Level Air Quality Analyses*", 2015.
See: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

[3] In a parallel effort conducted following the initiation of the NCHRP Task 78 study, FHWA developed a categorical finding (CF) for CO that could be implemented in areas subject to EPA transportation conformity rule, i.e., in areas in which a PA designed for NEPA applications typically would not be applicable but the functionally-equivalent CF could be applied. State DOTs could then use the NCHRP PA for NEPA and the FHWA CF for conformity. The FHWA CF is however limited to intersections only, and does not provide the same coverage of other facility types as in the template PA.

1. Introduction

Project-level carbon monoxide (CO) analyses are conducted by state Departments of Transportation (DOTs) for proposed transportation improvement projects, pursuant to the National Environmental Policy Act (NEPA) and associated Federal Highway Administration (FHWA) guidance.[4] As increasingly more stringent motor vehicle emissions standards established by the Environmental Protection Agency (EPA) along with improved fuel quality standards over the past few decades have resulted in dramatically reduced CO emission rates from motor vehicles and ambient air concentrations, CO analyses for most projects now show CO concentrations well below the national ambient air quality standard (NAAQS). In order to create a more efficient and cost-effective process for CO analyses, given that the results are effectively known in advance (i.e., the NAAQS would be met by a substantial margin), state DOTs need a more streamline clearance process for CO for purposes of NEPA.

One effective approach commonly taken by state DOTs is to rely on a programmatic agreement (PA) for CO, which is typically executed between a state DOT and the FHWA Division office. PAs are commonly used in NEPA for a variety of environmental subjects (not just air quality) to streamline processes and save time and cost for unnecessary analyses. A PA for CO is typically based upon "worst-case" modeling assumptions for common facility types (e.g., intersections) that result in conservatively high estimates for CO emission rates and near-road ambient concentrations that exceed what would be expected in practice. Facility types and configurations for which the modeled worst-case concentrations would still meet the NAAQS can be specified in the PA as ones that can be screened using designated criteria (e.g., number of lanes, road grade etc.) The worst-case modeling may be documented in a Technical Support Document (TSD). Proposed projects that meet the criteria specified in the PA based on the worst-case modeling documented in the TSD can reasonably be screened by state DOTs and require project-specific CO modeling.

Historically, at the national level, work began on the development of a template PA and TSD with a National Cooperative Highway Research Project (NCHRP) ("Task 78") study[5] initiated in 2012 to build upon successful state experiences[6] in streamlining project-level air quality clearances for purposes of NEPA with state-specific PAs. The intent was to create a national template PA and associated TSD that state DOTs could customize and implement for their respective jurisdictions, relieving the state DOTs of the burden of modeling and providing consistency nationally in how projects may be screened for CO. Completed in 2015, the NCHRP

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[4] FHWA Technical Advisory T 6640.8A, "*Guidance for Preparing and Processing Environmental And Section 4(F) Documents*", October 30, 1987. See: https://www.environment.fhwa.dot.gov/legislation/nepa/guidance_preparing_env_documents.aspx

[5] ICF, Zamurs and Associates, and Volpe Transportation Center, NCHRP 25-25/Task 78, "*Programmatic Agreements for Project-Level Air Quality Analyses*", 2015. See: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

[6] As noted in the 2015 NCHRP 25-25 Task 78 report, its template PA & TSD were modeled on the 2009 Virginia DOT PA and TSD following a review of state agreements in place at that time. The 2015 NCHRP templates however did not include skew angles that had been included in the Virginia DOT version, due to limited funding. This update to the 2015 NCHRP templates includes both skew angles and road grades.

Task 78 study examined a variety of project types and conditions in order and identified multiple highway facility types and configurations that would not reasonably be expected to result in violation of the CO NAAQS. It tested even the remote possibility of CO ambient air quality standard violations using worst-case modeling (following FHWA guidance on worst-case assumptions) and maintaining consistency as appropriate with EPA guidance for CO hot-spot analyses.[7] It applied EPA-approved emission and dispersion models, namely MOVES2010b as the emission model and CAL3QHC (version 04244) as the dispersion model.

Subsequently, the PA and TSD templates developed in the NCHRP Task 78 study were updated in a second NCHRP study (this study "Task 104").[8] The NCHRP Task 104 study, which was completed in 2020, covered a greater range of road grades compared to the original Task 78 Templates and also added coverage of a range of skew angles. As with the NCHRP Task 78 study, the modeling for the NCHRP Task 104 update was conducted using EPA-approved emission and dispersion models for project-level CO screening analyses. MOVES2014a was applied as the emission model (which was updated by EPA in the interim period since the original NCHRP Task 78 study was completed), and CAL3QHC (version 04244) was again applied as the dispersion model. This PA and TSD are based on the updated templates developed in the NCHRP Task 104 study.

In a parallel effort conducted following the initiation of the NCHRP Task 78 study, the FHWA developed a categorical finding (CF) that could be implemented in areas subject to EPA conformity requirements for CO, i.e., in areas in which a PA designed for NEPA applications typically would not be applicable but the functionally-equivalent CF could be applied. State DOTs could then use the NCHRP PA for NEPA and the FHWA CF for conformity. Completed in 2014, the FHWA CF[9] documented conditions for a single facility type (i.e., urban intersections) in areas subject to conformity requirements for CO that would not require project-specific emission and dispersion modeling. The FHWA CF was based on a set of worst-case assumptions similar in concept to those applied in the NCHRP PAs. In 2017, FHWA published a revision[10] to its original 2014 CF based on updated emission modeling (with MOVES2014a) and the CAL3QHC dispersion model. However, the FHWA CF remained limited to large urban intersections; its coverage was not expanded to include the additional highway facility types and configurations covered by this PA. The 2017 FHWA CF is applicable to all states and territories (except California) that are subject to conformity requirements for CO[11].

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[7] US EPA, *Guideline for Modeling Carbon Monoxide from Roadway Intersections*, EPA-454/R-92-005, Nov. 1992; and *Using MOVES in Project-Level Carbon Monoxide Analyses*, EPA-420-C-10-041 December 2010

[8] E. Carr, S. Hartley, G. Noel & A. Eilbert, NCHRP 25-25 Task 104, "*Streamlining Carbon Monoxide Project-Level Air Quality Analyses with Programmatic Agreements*", 2020. http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4100

[9] FHWA Carbon Monoxide Categorical Hot-Spot Finding *(Superseded)*, February 2014. Available at: http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/

[10] FHWA Carbon Monoxide Categorical Hot-Spot Finding, 2017. Available at: https://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf_2017/index.cfm

[11] State DOTs have encouraged FHWA to explore options for expanding its CF, e.g., by incorporating the project types and configurations covered by this template PA, minimizing the set of criteria for its application (excluding worst-case assumptions as criteria, for example), and also, very importantly, explicitly making the CF applicable for NEPA in addition to conformity (in effect making it both a PA and a CF). For this purpose, certain of the

Based on the modeling conducted for this study, the project settings that were the most promising candidates for inclusion in a PA were identified. These project types are:

- Freeways
- Arterials
- Intersections
- Interchanges

The analysis presented in this report includes maximum traffic volumes and use of worst-case meteorology for each project setting, leading to the maximum possible CO concentrations for each facility. Details and layouts for each of these project settings are discussed further below.

The identified project types are the four most commonly included in state DOT capital programs and frequently undergo a hot-spot analysis in environmental documents. The PA and TSD templates are only applicable to the project types and conditions modeled for this study and do not apply to other project types and conditions.

Research Objectives

This research was initiated to update and expand the templates for the Programmatic Agreement (PA) and Technical Support Document (TSD) previously developed under NCHRP 25-25, Task 78[12]. This included updating the analysis to current conditions (using the latest emission model) and expanding coverage of project configurations. All analyses are performed using a "worst case analysis" screening approach.

Another objective of the research was to work with a state DOT in developing a pilot program to better understand how a state can implement a PA and identify the level of effort and time needed to gain approval of the PA using a concrete example for the adoption process. Resources then previously expended on CO analysis can be diverted to other needs.

More specifically, this research was initiated to:

1. Expand the coverage of the Task 78 template PA and TSD to include other facility configurations (skew angles for intersections and interchanges) as well as a greater range of road grades
4. Update the analysis to be based on the latest version of the MOVES model, which EPA updated in the time since the modeling for the Task 78 study was done: and
5. Aid implementation test the updated draft template PA and TSD in a pilot program with a state DOT, and report on the processes, timeline and overall findings.

modeling inputs for the NCHRP Task 104 update were made consistent as appropriate with the inputs applied in the 2017 FHWA CF. Details are provided in the TSD.

[12] https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

Report Contents

Section 1 of the report provides background and introduction on the need for the study along with a discussion on the objectives for the research.

Section 2 describes how to implement various options for developing state-specific PA and TSD for CO project-level analyses. It also provides and overview on how to use the TSD and PA. analysis.

Section 3 describes the modeling performed for the state-specific pilot study and the development of the PA and TSD for CO project-level analyses for the state. It provides details on the inputs used in the MOVES emission modeling for freeway, arterials, and interchanges used in Georgia specific project-level analysis.

Section 4 presents a summary of the lessons learned from developing the state-specific PA and TSD.

Appendix A *Organization* of the modeling files *for A*ppendix D and E

Appendix B the PA template that can be used to develop a state specific PA.

Appendix C the TSD template that can be used to develop a state specific TSD.

Appendix D MOVES model input parameters used in the TSD.

Appendix E CAL3QHC model input parameters used in the TSD.

Appendix F the PA for Georgia Department of Transportation

Appendix G the TSD for Georgia Department of Transportation

2. Application of Template PA and TSD

The national programmatic agreement (PA) template and technical support document (TSD) template are attached as Appendices B and C respectively to this report. These PA and TSD templates can be used to develop state-specific PAs and TSDs with the inclusion of relevant state-specific data and information. Editable versions of the PA and TSD templates can also be downloaded from the project page at https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4100

Summary of the Programmatic Agreement (PA) Template

The PA template in Appendix B is a relatively brief document that describes the basis for the PA and the types of projects and conditions that are covered by the PA—namely, those projects that do not exceed the CO NAAQS. It also contains examples of administrative items such as time frames and procedures for revising the PA. The PA is in the form of a memorandum between the state DOT and the corresponding FHWA Division Office. Once executed (signed by both parties), the document officiates an agreement under which project types that fall within the purview of the PA do not require project-specific air quality modeling for CO. The draft templates of the PA and TSD are provided as guides. It is anticipated that the exact language of a state PA and inclusion of additional elements that may not be in the draft templates will be agreed to by state DOTs and their corresponding FHWA Division Offices.

The draft template was developed based on national inputs and conservative assumptions generally applicable on a national level. A State DOT may elect to modify the PA specific to their situation. It can do so by either performing A) or B) as described below:

A) Choosing to incorporate local data for persistence factor and background concentrations.

If a state DOT chooses to do this the PA may still be applied if it is adjusted as follows:

1. For the project type and condition of interest, determine from Appendix B's modeling results tables whether a one-hour concentration value is listed (not shown as ~~strikethrough~~).
    a. If a one-hour concentration is <u>not</u> listed (shown as ~~strikethrough~~), project-specific modeling may be needed.
    b. If a one-hour concentration is listed as plain text, then proceed to step 2.
2. The one-hour concentration listed in the tables is for the project contribution only. Therefore:
    a. To determine the one-hour concentration for comparison to the NAAQS use the following equation:

        One-hour concentration (ppm) = One-Hour concentration from the table

        + Local Background Concentration (One-Hour)

b. To determine the corresponding eight-hour concentration for comparison to the NAAQS:

Eight-hour concentration (ppm) = One-Hour concentration from the table x Local

Persistence Factor + Local Background Concentration (Eight-Hour)

3. Compare the calculated one- and eight-hour concentrations to the applicable NAAQS. If both concentrations are less than the applicable NAAQS, then the project is covered by the PA. The eight-hour NAAQS is typically the limiting value.

4. If the project is covered by the PA with the adjusted persistence factor and/or background concentrations, the qualitative text provided at the end of the PA should be included (modified if needed for the project) in the project record and relevant environmental documents.

B) In addition to deriving state-specific values for persistence factor and background concentration (Option A, described above), performing state specific emissions modeling to account for local vehicle mix, age distribution, inspection and maintenance (I/M) program, fuel type, etc.

1. The one-hour concentration listed in the tables is for the project contribution only. Therefore:

a. To determine the one-hour concentration for comparison to the NAAQS:

One-hour concentration (ppm)

= One-Hour concentration from the state-specific emissions as input to the state-specific dispersion modeling + Local Background Concentration (One-Hour)

b. To determine the corresponding eight-hour concentration for comparison to the NAAQS:

Eight-hour concentration (ppm)

= One-Hour concentration from above x Local Persistence Factor

+ Local Background Concentration (Eight-Hour)

2. Compare the calculated one- and eight-hour concentrations to the applicable NAAQS. If both concentrations are less than the applicable NAAQS, then the project is covered by the PA. Note the eight-hour NAAQS is typically the limiting value.

3. If the project is covered by the PA based on state-specific modeling, the qualitative text provided at the end of the PA should be included (modified if needed for the project) in the project record and environmental documents.

Summary of the Technical Support Document (TSD) Template

The TSD in Appendix C provides relevant information to fully explain and support the PA. It details the basis for using CO emissions analysis, CO emissions inventory, and ambient CO levels to show the decreasing likelihood that CO emissions from the operation of a highway project will result in a CO concentration exceeding ambient air quality standards. It also contains a brief history of CO modeling for highway projects, focusing on the conservative "worst-case" approach to these analyses. The TSD, most importantly, contains detailed information regarding the project setting and traffic activity levels, the MOVES emission modeling, and the CAL3QHC air quality modeling that was done to support the PA. The TSD also includes the model input and output files and provides the basis for selection of the background CO values and persistence factor used in the model. Finally, the TSD lists the project types and the conditions determined by the modeling results under which the projects could not lead to a violation of CO air quality standards.

The results are presented in the TSD as follows:

- Freeways and arterials by location, grade, and number of lanes.
- Signalized intersections by setting, grade, and skew angle; and
- Interchanges by location, number of lanes, intersection grade, and distance between Freeway and Intersection.

Implementation Options

Three primary options are available to state DOTs for implementing the template PA and TSD in their respective jurisdictions. For each option, state DOTs may modify the terms of the PA at their discretion before executing it with their respective FHWA division offices. Several optional terms that state DOTs may wish to include are provided in the template PA for this purpose.

1. The simplest and lowest-cost implementation option is for state DOTs that do not need or want to update either: a) the underlying emission and dispersion modeling from the templates or b) the background concentrations or persistence factors. These state DOTs typically will need only to make editorial changes to the template text (e.g., to insert the name of the state, and select which if any of the optional terms to include) and then execute the PA with their respective FHWA division offices.

<u>Note</u>: If *either* background concentrations or persistence factors are higher than assumed for the template PA and TSD, then state-specific values should be used for those respective parameters. This approach is outlined in Option 2.

1. For state DOTs that need or want to use state-specific background concentrations and/or persistence factors, the template PA and TSD provide a simple means for incorporating those values without having to update the detailed underlying emission and dispersion modeling. Those state DOTs for the most part need only to make editorial changes to the template text (as noted for Option #1), specify the state-specific

background concentration(s) and/or persistence factor(s) as appropriate, and then execute the PA with their respective FHWA division offices.

2. The most labor-intensive option is for state DOTs that need or want to use state-specific modeling. For these state DOTs, the original modeling files developed for this template PA and TSD (and provided online with the project report) can be updated with state-specific input data and the emission and/or dispersion models re-run as needed. Once the state-specific modeling has been completed and the template PA and TSD updated accordingly, the customized PA can be executed with the FHWA Division office.

While this option may be labor-intensive, it offers the primary advantage that state DOTs may add facility type and configurations based on their own modeling, and so expand coverage. The use of state-specific worst-case modeling inputs may also potentially result in increased coverage relative to the templates.

As a means to both field test the draft template PA and TSD developed in this study, and to better assess the time and cost for implementation involving state-specific modeling, a pilot study was conducted as part of this NCHRP study, which is documented in the next section.

3. State-Specific Project-Level Programmatic Agreements (PAs) for Carbon Monoxide (CO) Hot-Spot Analyses for State DOTs.

Background

In general, PAs have been identified as an effective way to reduce costs through reducing unnecessary analyses. The national PA and TSD templates developed in Section 2 were evaluated by partnering with a test state to update and improve the usefulness of PAs for project-level CO analysis. ICF coordinated with Georgia Department of Transportation (GDOT) to prepare customized PA and TSD documents based on state-specific data and information.

The modeling results are based on national worst-case modeling assumptions and inputs. For some states, based on climatic or other state-specific circumstances, the modeling assumptions and inputs may be overly conservative. Use of state-specific assumptions and inputs could result in a larger set of project types and conditions covered by a PA. A state has the option of using the modeling files (MOVES and CAL3QHC) that are part of this study, modifying them to be state-specific, and running the modified files to determine the outcomes with state specific parameters. The state may also model additional project conditions and/or types to determine if those additional projects should be included within their state-specific PA. Some additional project types that could be considered for a state may include auxiliary lanes, HOV lanes, metered on-ramps, roundabouts, and parking lots.

Participation by a state DOT in the pilot program was designed to ensure that necessary resources or additional guidance will be included, both for the hotspot modeling technical issues and within the larger NEPA context. Another avenue that a state DOTs could pursue is a tiered structure as part of the PA that would enable state DOTs to quickly screen out smaller projects, while having moderately larger projects potentially screened out as well, but requiring additional information such as opening year, mid planning year, and horizon year, along with peak traffic volumes for each year.

Georgia-Specific PA and TSD

Preparing Georgia specific PA and TSD documents included tailoring both documents and underlying modeling for conditions in the state. MOVES simulations were made to conservatively represent conditions in the state by modifying input databases provided by GDOT to correspond to conditions in a variety of Georgia counties with the same array of conditions used to develop the national PA and TSD templates. Temperature, relative humidity, age distribution, fuel descriptions, and inspection and maintenance programs were developed by the state to represent local conditions. Dispersion modeling was conducted following the national scale approach, incorporating local conditions which included GDOT values for background concentrations and persistence factors. Table 1 identifies all MOVES input parameters which were Georgia based (highlighted in red) that replaced national default

values. The Georgia specific PA and TSD are provided as part of the final set of deliverables for this project (see Appendix F and G).

Table 1 – Georgia-Specific MOVES input parameters

Parameter	Freeway	Arterial	Intersection
Scale	Project Level		
Year	2020		
Month	January		
Time Span - Hour	08:00 AM		
Time Span - Day	Weekday		
Geographic Bounds	Custom Domain		
Temperature	60° Fahrenheit		
Relative Humidity	50%		
Fuel Formulation	Data for each county supplied by Georgia based on their CO project-level analysis from MOVES defaults for January for Gasoline, Diesel, E-85 (for Light-Duty Vehicles only), and CNG (for Transit Buses only)		
Fleet Mix	Fractions supplied by Georgia Department of Transportation based on their CO project-level analysis (one distribution per county used for every link).[13] Results were taken by road type from the most conservative emission rate across all modeled counties.		
Age Distribution	Data for each county supplied by Georgia based on their CO project-level analysis, originally derived from IHS Automotive (formerly R.L. Polk) vehicle registrations for the state in 2014.		
Link Source Type Distribution	SourceTypeHourFraction supplied by Georgia Department of Transportation based on their CO project-level analysis (one distribution per county used for every link). All 13 sourceTypeID used.		
Road Type	Urban and Rural Restricted Access	Urban and Rural Unrestricted Access	Urban and Rural Unrestricted Access
Link Average Speed	74mph highest emission rate between 15-75 mph	15 mph for grades less than or equal to 6%; 52mph for arterials at 7% grade; coverage range 15-52 mph	15 mph approach and idle (intersection) for all cases other than rural intersections at 7% grade, which used a speed of 45mph; coverage range from 15-45 mph
Grade	Multiple Grades between ±0% to ±7%	Multiple Grades between ±0% to ±7%	Multiple Grades between ±0% to ±6%
Inspection & Maintenance	Data supplied by Georgia based on their CO project-level analysis pulled from MOVES defaults for Fulton County, other counties did not include I/M programs		

[13] Further information can be found in Technical Support Document from the Georgia Department of Transportation (GDOT), Office of Environmental Services, *FHWA-GDOT Agreement for Project-Level Air Quality Analyses for Carbon Monoxide*, February 2017.

The eight-hour CO background concentrations identified by GDOT for use in this analysis is 3 ppm for urban settings and 1 ppm for rural settings. GDOT uses a persistence factor of 0.6 for all detailed CO air quality analyses.

The purpose of the state pilot program was to identify areas where the national template can be refined to make state-level implementation easier for other states to adopt and implement as well as identify the level of effort to perform the analysis. The national PA and TSD is written in a form that readily allows “drop in” of state specific information, including contacts, local parameters, and other information to allow customization of the templates. The specific modeling updates that were required are those on which the MOVES and CAL3QHC modeling rely, and those required for computation of total project impacts used for comparison to the national ambient air quality standards. No changes were made to the key terms of the PA for GDOT application.

4. Summary of Lessons Learned

This section documents the key lessons learned from the pilot program with GDOT for state-level implementation.

Below is a list of the key lessons learned while working with GDOT:

- The national PA and TSD documents were found to satisfy the needs for most facility types within the state.
- There were no recommended changes to the national templates.
- Adequate time needs to be planned for in the review process along with obtaining the necessary approval of the language for the state-specific PA and TSD.
- Overall GDOT found the national PA and TSD was simplified and easier for users than the current GDOT PA. Thus, GDOT adopted the approach used in the national PA and TSD in the updated Georgia specific PA and TSD.
- Coordinate with the state DOT administration early in the process to identify and get concurrence on the facility types that should be covered within the PA and TSD documents. These documents are designed to prioritize the most common facility types in most states.
- Work with an experienced DOT air quality specialist that has had experience with issues in demonstrating compliance with the CO air quality standards.
- Rely on local data and parameters. States have historically developed local parameters for use in the modeling and analyses. It is important to coordinate with the states to collect and use these parameters when creating state-specific PA and TSD documents. The emissions analysis is particularly reliant on state data, usually provided as input from the state environmental agency for use as input to MOVES for emission factor development. Time should be planned in coordinating with the both the environmental agency and the DOT to maintain consistency and approval.
- A comparison should be made between the modeled CO concentration for the state PA and the CO modeled concentrations for the national PA for intersections, arterials and freeways. In the case of GDOT the intersection results ranged from the same to 22% decrease for the Georgia PA with differences largest for the higher roadway grades. Arterials saw the largest changes with results ranging from 17 to 30% decrease for the Georgia PA over the national PA. Freeways saw only a modest decrease ranging from the same to 13% lower. Overall, these results suggest that a substantial additional number of potential projects will be cleared with the use of a state-specific PA.
- Background pollutant concentration values and persistence factors are important to determining which types of projects can meet air quality standards. State DOTs and environmental agencies have historically developed these values to help in clearing projects. However, historical values should be reviewed and updated as needed given recent trends in CO concentrations and changes in diurnal traffic flow volumes. This will

help to ensure that the resulting PA and TSD are based on the most current understanding of background and persistence.

Table 3 below show the estimated level of effort and time duration needed in developing and receiving approval on a state-customized PA and TSD. If the state uses the NCHRP national modeling with the only modeling adjustment being to use local background and persistence factors, the MOVES and CAL3QHC modeling steps can be removed from the level of effort and time duration. The overall duration could also be compressed if periods for review were shortened.

Table 2 – Estimated Level of Effort in Developng State-Specific PA and TSD

Processing Steps	Level of Effort (hours)	Comment
State-specific CO trends	12	
Applying MOVES2014 for project-level analysis for freeways, arterials, intersections, grades, speeds, four counties	80	This effort would require up to 50% additional effort for someone not already familiar with project level MOVES modeling
CAL3QHC	70	Someone unfamiliar with CAL3QHC would need 20 additional hours
Background concentration	8	Assumes developed previously, but updating needed
Persistence factor (historic)	4	Assumes methodology previously developed, but updating needed
Table development and results reporting and QA/QC	16	Assumes same facilities as in national PA and TSD
Draft PA and TSD (internal review)	20	Assumes using PA and TSD template
Final PA and TSD (ready for external review)	16	

Table 3 – Estimated Level of Effort and Schedule in Preparing and Approving State-Specific PA and TSD

Steps in the PA and TSD process	Estimated LOE (hours)	Duration (weeks)	Comment
Data Gathering	16	1	CO trends, CO background data, MOVES inputs
Conduct MOVES and CAL3QHC dispersion modeling	150	10	
Background and Persistence factors	12	2	Assumes previously developed methodology only needs to be updated
Table development QA/QC	16	1	
TSD and PA document preparation	20	3	Based on using national template
Review by Environmental Administrator (EA)	16	2	Time required for management review (low priority)
Review by GDOT division of engineering and chief engineer	16	12	Time required for management review (low priority)

Table 3 – Estimated Level of Effort and Schedule in Preparing and Approving State-Specific PA and TSD

Steps in the PA and TSD process	Estimated LOE (hours)	Duration (weeks)	Comment
Reply to review comments	12	2	
Review by FHWA Georgia Division	12	6	Time for review by state FHWA office
Reply to review comments	12	2	
Final Review be GDOT EA and FHWA Georgia Division	8	4	Review for changes requested only – ready for signature and approval

Appendix A: Modeling File Organization

For reference by state DOTs that decide to conduct state-specific modeling, the emission and dispersion modeling files provided with the deliverables for this study are organized and have naming conventions as outlined below.

<text and tables>

CAL3QHCR files are organized under Appendix E. These are organized in folders according to road type (arterials, freeway, interchanges, and intersections). Within each the file name describes the scenario. For example, in the intersection folder "CAL3QHC_90_deg7%_U.in2" is the CAL3QHCR input file for a 90-degree intersection in the urban setting at a **7%** grade. Note that interchanges include both the freeway (**FW**) and intersection (**IN**) components to complete the modeling, which are stored in separate folders.

Inputs to the MOVES modeling are included in Appendix D. These are csv or spreadsheet files that together make up the MOVES input database and the MOVES link type description. The files NCHRP_20per_truck_restricted.mrs and NCHRP_20per_truck_unrestricted.mrs are the MOVES runspec (control) files for restricted and unrestricted road types, respectively. In addition, Appendix C.1 contains a complete listing of 2020 MOVES output emission factors by 1-mph increments of speed, by road type, and grades considered in the modeling.

Appendix B: Programmatic Agreement Template

Programmatic Agreement Template

The coloring scheme in the draft programmatic agreement (PA) template, and its associated technical support document (TSD), is as follows:

Black text = Text that generally will not need to be modified and can be used for a national PA and for individual state PAs;

Red text = Information (e.g. report or study citations) at a Federal or state level that is not yet complete and can be added at a later date when a national PA or state PA is finalized;

Blue text = Text to be added containing information relevant to a particular state in order to allow completion of a state –specific PA and its associated TSD.

STATE DOT LETTERHEAD

Date

From: Chief Engineer (or other appropriate Executive such as the Environmental Division Administrator or Manager), State Department of Transportation
To: FHWA Division Administrator, State Division

The purpose of this memorandum is to establish a Programmatic Agreement (PA) between the STATE Department of Transportation (DOT) and the STATE Division of the Federal Highway Administration (FHWA) to streamline analyses of potential carbon monoxide (CO) impacts for highway projects undergoing environmental studies for purposes of the National Environmental Policy Act (NEPA). Other relevant agencies (list) have participated in the development and/or review of this PA and support its use. This PA establishes the types of projects and project conditions that will not require project-specific modeling or a quantitative air quality analysis to document that they do not cause a violation of the National Ambient Air Quality Standards (NAAQS) for CO. Rather, these project types and conditions will require only a general qualitative statement that references this agreement and associated technical support document (TSD), which present worst-case modeling results for CO that would cover the specific project type and condition.

Basis of Agreement: This PA was developed based on an extensive history of modeling potential CO impacts for highway projects at both the state and national levels. In support of its capital program, STATE DOT has been performing CO emissions analyses of highway projects since the late 1970s. These analyses, in most cases, have not resulted in identification of violations of CO air quality standards as a result of the completion of a highway project. As evidenced by ongoing reductions in monitored ambient CO concentrations and the continuing implementation of the Federal Motor Vehicle Emission Control Program, future project-level CO analyses are expected to find little, if any, possibility of potential violations of CO ambient air quality standards caused by the completion of a highway project.

Historically, at the national level, work began on the development of a template PA and TSD with a National Cooperative Highway Research Project (NCHRP) ("Task 78") study[14] initiated in 2012 to build upon successful state experiences[15] in streamlining project-level air quality clearances for purposes of NEPA with state-specific PAs. The intent was to create a national template PA and associated TSD that state DOTs could customize and implement for their respective jurisdictions, relieving the state DOTs of the burden of modeling and providing

[14] ICF, Zamurs and Associates, and Volpe Transportation Center, NCHRP 25-25/Task 78, "*Programmatic Agreements for Project-Level Air Quality Analyses*", 2015.
See: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

[15] As noted in the 2015 NCHRP 25-25 Task 78 report, following a review of state agreements in place at that time, the 2009 Virginia DOT PA and TSD were selected as the model for the new national template. Due to limited funding, however, the 2015 NCHRP Task 78 templates did not include skew angles, which had been included in the Virginia DOT version. This update to the 2015 NCHRP templates includes both skew angles and road grades.

consistency nationally in how projects may be screened for CO. Completed in 2015, the NCHRP Task 78 study examined a variety of project types and conditions in order and identified multiple highway facility types and configurations that would not reasonably be expected to result in violation of the CO NAAQS. It tested even the remote possibility of CO ambient air quality standard violations using worst-case modeling (following FHWA guidance on worst-case assumptions) and maintaining consistency as appropriate with EPA guidance for CO hot-spot analyses.[16] It applied EPA-approved emission and dispersion models, namely MOVES2010b as the emission model and CAL3QHC (version 04244) as the dispersion model.

Subsequently, the PA and TSD templates developed in the NCHRP Task 78 study were updated in a second NCHRP study ("Task 104").[17] The NCHRP Task 104 study, which was completed in 2020, covered a greater range of road grades compared to the original Task 78 Templates and also added coverage of a range of intersection skew angles. As with the NCHRP Task 78 study, the modeling for the NCHRP Task 104 update was conducted using EPA-approved emission and dispersion models for project-level CO screening analyses. MOVES2014a was applied as the emission model (which was updated by EPA in the interim period since the original NCHRP Task 78 study was completed), and CAL3QHC (version 04244) was again applied as the dispersion model. This PA and TSD are based on the updated templates developed in the NCHRP Task 104 study.

In a parallel effort conducted following the initiation of the NCHRP Task 78 study, the FHWA developed a categorical finding (CF) that could be implemented in areas subject to EPA conformity requirements for CO, i.e., in areas in which a PA designed for NEPA applications typically would not be applicable but the functionally-equivalent CF could be applied. State DOTs could then use the NCHRP PA for NEPA and the FHWA CF for conformity. Completed in 2014, the FHWA CF[18] documented conditions for a single facility type (i.e., urban intersections) in areas subject to conformity requirements for CO that would not require project-specific emission and dispersion modeling. The FHWA CF was based on a set of worst-case assumptions similar in concept to those applied in the NCHRP PAs. In 2017, FHWA published a revision[19] to its original 2014 CF based on updated emission modeling (with MOVES2014a) and the CAL3QHC dispersion model. However, the FHWA CF large remained limited to large urban intersections; it coverage was not expanded to include the additional highway facility types and configurations covered by this PA. The 2017 FHWA CF is applicable to all states and territories (except California) that are subject to conformity requirements for CO[20].

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[16] US EPA, *Guideline for Modeling Carbon Monoxide from Roadway Intersections*, EPA-454/R-92-005, Nov. 1992; and *Using MOVES in Project-Level Carbon Monoxide Analyses*, EPA-420-C-10-041 December 2010

[17] E. Carr, S. Hartley, G. Noel & A. Eilbert, NCHRP 25-25 Task 104, "*Streamlining Carbon Monoxide Project-Level Air Quality Analyses with Programmatic Agreements*", 2020. http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4100

[18] FHWA Carbon Monoxide Categorical Hot-Spot Finding *(Superseded)*, February 2014. Available at: http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/

[19] FHWA Carbon Monoxide Categorical Hot-Spot Finding, 2017. Available at: https://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf_2017/index.cfm

[20] State DOTs have encouraged FHWA to explore options for expanding its CF, e.g., by incorporating the project types and configurations covered by this template PA.

Application of the PA: The PA may be applied directly with no additional calculations if the following are applicable:

1. If the project meets the minimum technical criteria for the PA to be applied without change, namely:
    a. The CO NAAQS have not changed from what was in effect at the time when this agreement was implemented and upon which the modeling was based (35 ppm for the one-hour and 9 ppm for the eight-hour).
    b. Background concentration not more than the default of 2.4 ppm (eight-hour standard) that was taken for this PA. If not, proceed to Step 3 to calculate state-specific concentrations.
    c. Persistence factor not greater than the EPA default of 0.7 that was taken for this PA. If not, proceed to Step 3 to calculate state-specific concentrations.

FOR USING THE TEMPLATE TABLES WITHOUT CHANGE (WITH NO STATE-SPECIFIC BACKGROUND CONCNTRATIONS, PERSISTENCE FACTOR OR MODELING)

1. If, for the project configuration and conditions of interest (road grade, speed, etc.), a one-hour concentration value is listed in the appropriate attached table (**Table B-1** for freeways and arterials; **Table B-2** for intersections; **Table B-3** for interchanges). If it is listed, then the project is covered by the PA, provided that the minimum criteria specified above are also met.

FOR STATE-SPECIFIC BACKGROUND CONCENTRATIONS AND/OR PERSISTENCE FACTOR, BUT NOT STATE-SPECIFIC MODELING

1. For the project type and condition of interest, determine from the appropriate table (**Table B-1** for freeways and arterials; **Table B-2** for intersections; **Table B-3** for interchanges)**Error! Reference source not found.** whether a one-hour concentration value is listed.
    a. If a one-hour concentration is not listed, project-specific modeling is needed.
    b. If a one-hour concentration is listed, then proceed to the next step.
2. The one-hour concentration listed in the tables is for the project contribution only. Therefore:
    a. To determine the one-hour concentration for comparison to the NAAQS use the following equation:

        One-hour concentration (ppm) = One-Hour concentration from the table

        + Local Background Concentration (One-Hour)

    b. To determine the corresponding eight-hour concentration for comparison to the NAAQS:

Eight-hour concentration (ppm) = One-Hour concentration from the table x Local Persistence Factor + Local Background Concentration (Eight-Hour)

3. Compare the calculated one- and eight-hour concentrations to the applicable NAAQS. If both concentrations are less than the applicable NAAQS, then the project is covered by the PA. The eight-hour NAAQS is typically the limiting value.
4. If the project is covered by the PA with the adjusted persistence factor and/or background concentrations, the qualitative text provided at the end of the PA should be included (modified if needed for the project) in the project record and relevant environmental documents.

FOR STATE-SPECIFIC MODELING (State specific emissions modeling to account for local vehicle mix, inspection and maintenance (I/M) program, fuel type, etc.)

1. For the project type and condition of interest, determine from the appropriate table (**Table B-1** for freeways and arterials; **Table B-2** for intersections; **Table B-3** for interchanges)**Error! Reference source not found.** whether a one-hour concentration value is listed.
   a. If a one-hour concentration is <u>not</u> listed, project-specific modeling is needed.
   b. If a one-hour concentration is listed, then proceed to the next step.
2. The one-hour concentration listed in the tables is for the project contribution only. Therefore:
   a. In this case, to determine the one-hour concentration for comparison to the NAAQS:

      One-hour concentration (ppm)

      = One-Hour concentration from the state-specific emissions as input to the state-specific dispersion modeling + Local Background Concentration (One-Hour)

   b. To determine the corresponding eight-hour concentration for comparison to the NAAQS:

      Eight-hour concentration (ppm)

      = One-Hour concentration from above x Local Persistence Factor

      + Local Background Concentration (Eight-Hour)
3. Compare the calculated one- and eight-hour concentrations to the applicable NAAQS. If both concentrations are less than the applicable NAAQS, then the project is covered by the PA. Note the eight-hour NAAQS is typically the limiting value.
4. If the project is covered by the PA based on state-specific modeling, the qualitative text provided at the end of the PA should be included (modified if needed for the project) in the project record and environmental documents.

Project Types and Conditions: This PA applies to the following project types and associated project conditions:

Freeways and Arterials

Table B-1, attached, shows the conditions for urban and rural arterials and freeways that would meet the one- and eight-hour NAAQS and would be covered by this PA[21]. The table shows one-hour concentrations, not including background concentrations. The populated cells of the table correspond to the lane and grade combinations for arterials and freeways which, even under worst-case conditions, would not result in exceedances of the 8-hour NAAQS for CO. Where the table entries are *strikethrough*, the corresponding configuration would *not* meet the NAAQS based on worst-case modeling and would *not* be covered by this PA. Project-specific modeling would typically need to be conducted to show compliance with the NAAQS in these cases.

For example, for a transportation improvement project for an urban freeway for which the build scenario has 10 total lanes, average road grades of 3% or less, and a posted speed of 50 mph, **Table B-1** shows a maximum contribution of 8.0 ppm for the one-hour CO standard. Since a CO concentration is shown in the table for this project type and configuration, the project is covered by this PA and does not require project-specific modeling for CO. Conversely, the same freeway with 14-lanes would *not* be covered by this PA, as the table entry is *strikethrough* for that configuration.

Note: this PA covers lanes widths of 12 feet or more for freeway and arterial project types.

Intersections

Table B-2,[22] attached, shows the maximum 1-hour CO concentrations for urban and rural intersections that, with the applied, conservative 8-hour national CO background level of 2.4 ppm and persistence factor of 0.7, do not produce modeled CO concentrations that could result in exceedances of the 8-hour CO NAAQS.

All of the reported values in Table B-2 correspond with an intersection that with a given grade (or less), six approach lanes or less, and posted approach speeds in the 15-45 mph range (not less than 15 mph) would not produce modeled concentrations that would result in exceedances of the 8-hour CO NAAQS. Any such project would be covered by this PA and would not require project-specific CO modeling to demonstrate compliance with the CO NAAQS. Conversely, for example, a project with no reported value, say seven approach lanes, an 8% grade and/or a 10-mph posted approach speed would *not* be covered by this PA.

For reference, and as documented in the TSD, the intersection analysis assumes four approach lanes in each direction, four departure lanes in each direction, and two left turn lanes for each approach. Additionally, after testing a variety of configurations, the worst-case configuration for the intersection was determined to be one on the side of a hill, angled (at 45°) so that the

[21] These findings apply to scenarios with average speed ranging from 15 to 56 mph for arterials and 19 to 75 mph for freeways. For application of the PA, posted speeds may be assumed in place of forecast speeds.

[22] These findings apply to scenarios with average speed ranging from 15 to 45 mph for intersections. For application of the PA, posted speeds may be assumed in place of forecast speeds.

northbound approach and westbound approaches are both uphill. Road grades were modeled for a range of zero to seven percent. The angle between the approach and departure lanes were modeled at a standard 90-degree angle, as well as skew angles of 60°, 45°, 30°, and 15° angles. The analysis placed the skew at the intersection with the highest emission rates which is associated with the upgrade links. The right lanes in each direction were modeled as including both through and right turn movements and included left-turn queue idling. The same MOVES model inputs and assumptions were used for both the freeway and arterial analyses. Similar CAL3QHC model inputs and assumptions were also used, although intersections were modeled with lanes 11 feet wide in all cases[23].

Interchanges with Adjacent Intersections

Table B-3 shows 1-hour CO concentrations for various interchange scenarios that, with the applied 8-hour CO background level and persistence factor, do not produce modeled concentrations that could result in exceedances of the 8-hour NAAQS for CO. Where the table entries are *strikethrough*, the corresponding configuration would *not* meet the NAAQS based on worst-case modeling and would *not* be covered by this PA. Project-specific modeling would typically need to be conducted to show compliance with the NAAQS in these cases. Although intersections were considered on either side of the freeway, Table B-3 only reports the higher of these. The same speed limitations for freeways and arterials from above also apply here.

For example, for a 2-lane freeway with an adjacent intersection with a grade of 3% in a rural location that is located not less than 20 feet from the nearest edge of the freeway lanes, and connected with a 45 degree angled road segment has a one-hour concentration listed of 8.1 ppm, as shown in Table B-3(a). Since a concentration is listed for this project configuration, the project would be covered by this PA and not require project-specific modeling. Conversely, the table entry is *strikethrough* for the same interchange with an intersection that has a 6% road grade, which therefore would *not* be covered by this PA.

Note: This is a very conservative approach for ramp intersections adjacent to freeway interchanges, which typically have only one- or two-lane ramps approaching or departing from the intersection.

For reference, and as documented in the TSD, interchanges were analyzed using the MOVES and CALQHC models, with a combination of the grade separated intersection and freeway separated at various distances. The intersection and freeway analyses geometry and traffic inputs are as described in the preceding cases, other than for a simplified receptor set. Interchange scenarios were modeled with the freeway at a 0% grade and intersection (the non-freeway portion) at a 0, 1, 3, 4, 5, 6 and 7% grade. Both rural and urban locations were considered. The total number of freeway lanes analyzed ranged from 2 to 12 lanes, in 2 lane increments. As above, intersection remains a signalized six lane intersection. A variety of assumed distances between the edge of the nearest freeway travel lane to the edge of the nearest travel lane on the intersection were analyzed. These included distances of 20, 30, 60,

[23] As part of NCHRP 25-25, Task 78 sensitivity testing showed that only a few percentage points higher CO concentration was found when using 11-foot lane widths rather than standard 12-foot width.

80, 100, 125, 150, 175, 300, 500 and 1,000 feet. The roadway link connecting the freeway to the intersection was modeled at skew angles of 90, 60, and 45-degree angles. Intersections were considered on either side of the freeway.

Exempt Projects: Projects that would qualify as exempt under one or more of the categories specified in the federal transportation conformity rule (whether or not conformity applies for the area in which the project is located) do not require project-specific modeling for CO for purposes of NEPA. In the case of these exempt projects, a qualitative statement as provided below is to be included in the project environmental document or record.

Project Alternatives: This PA is intended to cover all build alternatives for the above-listed projects, as well as the no-build alternative. If one or more alternatives are not included in the list of project types above, STATE DOT and STATE Division of FHWA will coordinate to determine the applicability of the PA to that alternative(s). It may be that one alternative that is covered by the PA would effectively represent the worst-case for all of the alternatives, e.g., if one alternative has more congested conditions than the others. As appropriate and as both agencies agree, other agencies (such as the Regional EPA office or the STATE Air Agency) may be brought in to assist in the coordination.

Project Types Not Covered by This PA: Examples of project types that are not specifically covered by this PA include but are not limited to: park and ride lots, parking garages, intermodal transfer yards, tunnels, intersections that have more than four legs, and intersections with approach speeds less than 15 mph. If a project type is not covered by the PA, project-specific air quality modeling may be needed.

For those project types and conditions where applicability of this PA is not certain, STATE DOT and STATE Division of FHWA will coordinate to determine the applicability. As appropriate and as both agencies agree, other agencies (such as the Regional EPA office or the STATE Air Agency) may be brought in to assist in the coordination.

Years of Analysis: This PA covers projects of the types and conditions listed above whose opening year (year of completion) is 2020 or later.

Technical Approach: The modeling and the assumptions used in the modeling to support this PA are described in detail in the accompanying Technical Support Document (TSD). In general, a worst-case modeling approach was applied following EPA guidance. In all cases EPA's MOVES2014a emission model was used to generate emission estimates and CAL3QHC (version 04244) was used for the dispersion analysis. EPA's current guidance for modeling CO Hot-Spots (*Guideline for Modeling Carbon Monoxide from Roadway Intersections*, U. S. EPA, EPA-454/R-92-005, November 1992) was also applied. The assumptions and inputs used in the model were worst-case or highly conservative, leading to higher emission estimates and less dispersion (that is, greater forecast ambient concentrations) than would be expected under real-world conditions. Consequently, if a project does not cause a modeled exceedance of the NAAQS with these worst-case or conservative inputs and assumptions, then it may be stated with high confidence that an exceedance under real-world conditions would not be expected. Finally, STATE DOT consulted with the STATE AIR AGENCY to determine appropriate values for CO

background concentrations and persistence factor. These values were used to arrive at an 8-hour total CO concentration for comparison with the 8-hour CO ambient air quality standard.

Safety Margin from Worst-Case Modeling Assumptions: The safety margin for the modeling for this agreement is substantial, as documented in the TSD. It includes: 1) the differences in modeling results based on worst-case modeling assumptions as applied for this PA relative to what they would have been using typical or representative inputs, and 2) wide margins between the NAAQS and typical near-road concentrations, as observed in long-term trend data from EPA monitoring stations. Note the use of multiple worst-case modeling assumptions versus just one or a few has a cumulative effect that markedly increases modeled air concentrations over what might be expected.

For emission modeling, worst-case modeling assumptions include:

1. emission factors for 2020 were used for all future years, despite that emission factors are projected to decline over time with continued fleet turnover from vehicles built to meet more stringent EPA Tier 3 emission standards,
2. exclusion of emission inspection and maintenance program benefits as applicable,
3. single unit gasoline truck percentages, and
4. high ambient temperature.

For dispersion modeling, worst-case modeling assumptions include:

1. maximum capacity traffic volumes,
2. receptor locations on the edge of the roadway right-of-way,
3. geometric assumptions that serve to concentrate traffic, emissions and concentrations to the greatest extent possible, including:
    a. a “hillside” configuration for intersection modeling,
    b. zero vertical separation for the interchange and mainline roadway, and
    c. zero median widths for arterial streets and minimum distance for highways,
4. interchange ramps with more lanes than would typically be expected,
5. low 1.0 m/s wind speeds, and
6. background concentrations are assumed the same in the future, whereas they are expected to decline given continued fleet turnover nationally to vehicles constructed to more stringent EPA Tier 3 emission standards.

Each of these conservative choices for the emission estimate and dispersion modeling assumptions is discuss in the technical support document.

A State DOT may add one or more of following optional terms in a state-specific PA:

Projects of De Minimis Scope: Projects that do not change (add, remove or relocate) roadway capacity or transit services do not require either qualitative or quantitative project-level air quality analyses for purposes of NEPA.

Mutual Applicability of the PA and FHWA Categorical Finding for CO for NEPA Applications: The STATE DOT at its discretion may apply the PA and the currently-available FHWA categorical finding for CO either individually or together (without one limiting the utility of the other in clearing projects) for air quality clearances for purposes of NEPA.

Locally Administered Projects: This PA may also be applied for locally administered projects, i.e., those implemented by cities, towns and counties within STATE. For the project's environmental document or record, the local agency will include a statement that the project under review meets the project types and conditions covered in the PA (including data and information as necessary to support that determination) and will conclude with one of the statements (or a similar statement, as appropriate to the project) provided in the Administrative Record section below.

Interpolation or Proration: As the modeling results presented in this PA are for specific roadway configurations (number of lanes, skew angle, road grade etc.), interpolation or proration of the data presented in the tables may be necessary for application of this PA and may be conducted as appropriate at the discretion of the STATE DOT, in consultation and coordination with the FHWA Division office as appropriate.

Substantive Difference: A "substantive" difference, change or variance is defined here as one that would significantly affect the modeling results and/or the analysis to the degree that it would reasonably be expected to change a finding, determination or conclusion that all applicable requirements for the air quality analysis for the project would be met and the project cleared, with the determination to be made by the STATE DOT (in consultation with the FHWA Division office as appropriate) consistent with the general terms of this PA.

Enduring Applicability of the PA in the Absence of Substantive Changes to the Models or Guidance: This PA may continue to be applied by the STATE DOT if EPA updates its official emission and/or dispersion models and/or associated guidance for CO screening analyses from the ones applied for this PA (MOVES2014a and CAL3QHC version 04244, respectively) if there is a reasonable expectation or it can otherwise be shown or concluded that the update(s) to the model(s) and/or associated guidance would not substantively change the modeled CO emission rates and/or ambient concentrations and hence not on the underlying modeling, criteria or conclusions for this PA.

Administrative Record: For the project's environmental document or record, the STATE DOT will include a statement that the project under review meets the project types and conditions covered in the PA and will conclude with one of the two following statements (or similar):

"The project does not exceed the project types and conditions listed in the agreement between the Federal Highway Administration and the STATE Department of Transportation for streamlining the project-level air quality analysis process for carbon monoxide. Modeling using "worst-case" parameters has been conducted for these project types and conditions. It has

been determined that projects such as this one may reasonably be expected to not significantly impact air quality and cause or contribute to a new violation, increase the frequency or severity of an existing violation, or delay timely attainment of the National Ambient Air Quality Standards for carbon monoxide."

Or

"An air quality analysis is not necessary as this project will not increase traffic volumes, reduce source-receptor distances, or change other existing conditions to such a degree as to jeopardize attainment of the National Ambient Air Quality Standard for carbon monoxide."

Future Revisions: STATE DOT and STATE Division of FHWA recognize that project level air quality analysis methodologies may change over time. This may include new or updated emission or dispersion models, background CO levels, and/or associated worst-case modeling assumptions. STATE DOT will consult as appropriate with STATE Division of FHWA regarding any changes.

Termination of Agreement: Should either the STATE DOT or the STATE Division of FHWA determine it is necessary to terminate the PA, they may do so by written notification to the other party. The PA will terminate 30 days after the date of the notification. Projects that have been cleared on the basis of the PA before the effective termination date may maintain that clearance and not require project-specific modeling for CO.

Value of the PA: The PA is beneficial to both STATE DOT and STATE Division of FHWA. It reduces costs by eliminating unnecessary analyses, enhances efficiency and certainty in the environmental review process, and helps ensure project scope and scheduling.

Attachment to the Programmatic Agreement

Tables of results are presented in this Attachment. In each case, scenarios that lead to project level exceedances with the modeling described in the Technical Support Document are shown in red with the values crossed through.

Table B-1. One-hour CO Concentrations (ppm) for Freeways and Arterials* in Urban and Rural Locations of Varying Lane and Grade Configuration (not including background concentrations).

Facility Type	Location	Number of Lanes	Grade (percent)							
			0	1	2	3	4	5	6	7
Arterials	Rural	2	3	3	3.3	3.4	3.7	4	4.4	4.8
Arterials	Rural	4	6.5	6.9	7.3	7.7	8.4	9	~~9.9~~	~~10.5~~
Arterials	Rural	6	8.7	9.3	~~9.9~~	~~10.5~~	~~11.4~~	~~12.3~~	~~13.4~~	~~14.6~~
Arterials	Rural	8	~~10.7~~	~~11.3~~	~~12.1~~	~~12.8~~	~~14~~	~~15.1~~	~~16.5~~	~~17.9~~
Arterials	Rural	10	~~12.3~~	~~13.1~~	~~14.1~~	~~15~~	~~16.2~~	~~17.6~~	~~19.2~~	~~20.8~~
Arterials	Rural	12	~~13.6~~	~~14.6~~	~~15.8~~	~~16.7~~	~~18.2~~	~~19.7~~	~~21.6~~	~~23.4~~
Arterials	Urban	2	1.8	1.9	2.1	2.1	2.3	2.4	2.7	2.8
Arterials	Urban	4	4	4.3	4.6	4.9	5.2	5.7	6.2	6.7
Arterials	Urban	6	5.5	5.7	6.2	6.7	7.2	7.7	8.5	9.2
Arterials	Urban	8	6.6	7.1	7.6	8.1	8.8	~~9.6~~	~~10.5~~	~~11.4~~
Arterials	Urban	10	7.5	8.2	8.8	9.4	~~10.3~~	~~11.1~~	~~12.3~~	~~13.3~~
Arterials	Urban	12	8.4	9.1	~~9.8~~	~~10.5~~	~~11.5~~	~~12.5~~	~~13.8~~	~~15~~
Freeways	Rural	2	1.4	1.7	1.9	2.1	2.4	2.8	3	3.2
Freeways	Rural	4	3.7	4.2	5	5.7	6.6	7.5	8.2	8.6
Freeways	Rural	6	5.3	6.1	7.1	8.2	~~9.5~~	~~10.8~~	~~11.8~~	~~12.4~~
Freeways	Rural	8	6.6	7.6	9.2	~~10.6~~	~~12.2~~	~~13.9~~	~~15.2~~	~~16.1~~
Freeways	Rural	10	7.8	9.1	~~10.9~~	~~12.6~~	~~14.7~~	~~16.7~~	~~18.3~~	~~19.3~~
Freeways	Rural	12	8.9	~~10.4~~	~~12.5~~	~~14.6~~	~~16.9~~	~~19.3~~	~~21.1~~	~~22.4~~
Freeways	Rural	14	~~9.8~~	~~11.5~~	~~13.9~~	~~16.3~~	~~18.9~~	~~21.6~~	~~23.7~~	~~25~~
Freeways	Rural	16	~~10.7~~	~~12.6~~	~~15.2~~	~~17.8~~	~~20.7~~	~~23.6~~	~~25.9~~	~~27.4~~
Freeways	Rural	18	~~11.3~~	~~13.6~~	~~16.4~~	~~19.1~~	~~22.3~~	~~25.6~~	~~28~~	~~29.6~~
Freeways	Rural	20	~~12~~	~~14.3~~	~~17.5~~	~~20.4~~	~~23.7~~	~~27.2~~	~~29.8~~	~~31.6~~
Freeways	Rural	22	~~12.5~~	~~15.1~~	~~18.4~~	~~21.5~~	~~25.1~~	~~28.7~~	~~31.6~~	~~33.5~~
Freeways	Urban	2	0.9	1	1.1	1.3	1.5	1.7	1.9	1.9
Freeways	Urban	4	2.3	2.6	3.1	3.6	4.1	4.7	5.2	5.5
Freeways	Urban	6	3.2	3.7	4.5	5.2	6	6.9	7.6	8
Freeways	Urban	8	4	4.8	5.8	6.7	7.8	8.9	~~9.7~~	~~10.4~~
Freeways	Urban	10	4.8	5.7	6.8	8	9.3	~~10.7~~	~~11.8~~	~~12.4~~
Freeways	Urban	12	5.4	6.5	7.8	9.2	~~10.7~~	~~12.3~~	~~13.5~~	~~14.3~~
Freeways	Urban	14	5.9	7.2	8.8	~~10.3~~	~~11.9~~	~~13.8~~	~~15.1~~	~~16~~
Freeways	Urban	16	6.4	7.8	~~9.5~~	~~11.2~~	~~13.1~~	~~15~~	~~16.5~~	~~17.5~~
Freeways	Urban	18	6.9	8.4	~~10.3~~	~~12.1~~	~~14.1~~	~~16.2~~	~~17.8~~	~~18.9~~
Freeways	Urban	20	7.2	8.9	~~10.9~~	~~12.9~~	~~15~~	~~17.2~~	~~19~~	~~20.1~~
Freeways	Urban	22	7.5	9.3	~~11.5~~	~~13.5~~	~~15.8~~	~~18.2~~	~~20~~	~~21.2~~

Notes: Red strikethrough values indicated exceedances of the standard.

* These findings apply to scenarios with average speed ranging from 15 to 56 mph for arterials and 19 to 75 mph for freeways, for which posted speeds in those ranges may be applied as reasonable proxies.

Table B-2. One-hour CO concentrations (not including background concentrations) for Rural and Urban Intersections* at Varying Skew Angles and Intersection Grades for a Six Approach Lane Intersection

Location	Skew Angle	Grade (Percent)							
		0	1	2	3	4	5	6	7
Rural	15	8.6	9.1	~~9.8~~	~~10.2~~	~~11.1~~	~~11.9~~	~~13~~	~~13.9~~
Rural	30	6.3	6.7	7.1	7.5	8.2	8.8	9.4	~~10.1~~
Rural	45	6.2	6.4	6.9	7.2	7.8	8.4	9	~~9.9~~
Rural	60	5.6	5.9	6.2	6.5	7	7.5	8	8.7
Rural	90	5.4	5.6	6	6.3	6.8	7.3	7.8	8.4
Urban	15	4.7	4.9	5.3	5.6	6.1	6.7	7.1	7.7
Urban	30	4.5	4.8	5	5.5	6.1	6.4	6.7	7.2
Urban	45	4.1	4.4	4.6	4.8	5.2	5.7	6.2	6.5
Urban	60	3.8	4.1	4.3	4.5	5	5.3	5.9	6.3
Urban	90	3.6	3.9	4.1	4.3	4.5	5	5.4	5.9

Notes: Red strikethrough values indicated exceedances of the standard.
* These findings apply to scenarios with average speed ranging from 15 to 45 mph for intersections, for which posted speeds in that range may be applied as a reasonable proxy.

Table B-3 (a). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 45° Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	2	0%	6.9	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.2
Rural	2	1%	7.3	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.5
Rural	2	2%	7.7	7.3	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Rural	2	3%	8.1	7.6	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Rural	2	4%	8.5	8.1	8	8	8	8	8	8	8	8	7.9
Rural	2	5%	8.9	8.8	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Rural	2	6%	~~9.7~~	9.4	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Rural	2	7%	~~10.3~~	~~10.3~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~
Rural	4	0%	9.4	7.9	7.1	7	6.9	6.8	6.8	6.8	6.6	6.6	6.4
Rural	4	1%	~~9.8~~	8.3	7.3	7.2	7.1	7	7	7	6.9	6.8	6.7
Rural	4	2%	~~10.2~~	8.7	7.7	7.7	7.7	7.6	7.5	7.5	7.5	7.3	7.3
Rural	4	3%	~~10.6~~	9.1	8	8	8	7.9	7.8	7.8	7.8	7.6	7.6
Rural	4	4%	~~11~~	~~9.5~~	8.5	8.5	8.5	8.4	8.4	8.4	8.3	8.2	8.1
Rural	4	5%	~~11.4~~	~~9.9~~	9.2	9.2	9.2	9.1	9	9	9	8.8	8.8

Table B-3 (a). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 45° Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	4	6%	~~12.2~~	~~10.7~~	~~9.8~~	~~9.8~~	~~9.8~~	~~9.7~~	~~9.6~~	~~9.6~~	~~9.6~~	9.4	9.4
Rural	4	7%	~~12.7~~	~~11.2~~	~~10.7~~	~~10.7~~	~~10.7~~	~~10.6~~	~~10.5~~	~~10.5~~	~~10.5~~	~~10.3~~	~~10.3~~
Rural	6	0%	~~10.5~~	8.7	7.7	7.6	7.5	7.3	7.2	7.2	6.9	6.8	6.6
Rural	6	1%	~~10.9~~	9.1	7.9	7.8	7.7	7.5	7.4	7.4	7.1	7	6.8
Rural	6	2%	~~11.3~~	~~9.5~~	8.3	8.2	8.1	7.9	7.9	7.9	7.7	7.5	7.3
Rural	6	3%	~~11.7~~	~~9.9~~	8.6	8.5	8.4	8.2	8.2	8.2	8	7.8	7.6
Rural	6	4%	~~12.1~~	~~10.3~~	9.1	9	8.9	8.8	8.8	8.8	8.5	8.4	8.2
Rural	6	5%	~~12.5~~	~~10.7~~	~~9.7~~	~~9.5~~	~~9.5~~	9.4	9.4	9.4	9.2	9	8.8
Rural	6	6%	~~13.3~~	~~11.5~~	~~10.3~~	~~10.1~~	~~10.1~~	~~10~~	~~10~~	~~10~~	~~9.8~~	~~9.6~~	9.4
Rural	6	7%	~~13.8~~	~~12~~	~~11.2~~	~~11~~	~~11~~	~~10.9~~	~~10.9~~	~~10.9~~	~~10.7~~	~~10.5~~	~~10.3~~
Rural	8	0%	~~11.4~~	9.4	8.3	8.1	8	7.8	7.6	7.4	7.3	7	6.8
Rural	8	1%	~~11.8~~	~~9.8~~	8.5	8.3	8.2	8	7.8	7.6	7.5	7.2	7
Rural	8	2%	~~12.2~~	~~10.2~~	8.9	8.7	8.6	8.4	8.2	8.1	8	7.8	7.5
Rural	8	3%	~~12.6~~	~~10.6~~	9.2	9	8.9	8.7	8.5	8.4	8.3	8.1	7.8
Rural	8	4%	~~13~~	~~11~~	~~9.7~~	~~9.5~~	9.4	9.2	9	9	8.9	8.6	8.4
Rural	8	5%	~~13.4~~	~~11.4~~	~~10.2~~	~~10~~	~~9.9~~	~~9.7~~	~~9.7~~	~~9.6~~	~~9.5~~	9.3	9
Rural	8	6%	~~14.2~~	~~12.2~~	~~10.8~~	~~10.6~~	~~10.5~~	~~10.3~~	~~10.3~~	~~10.2~~	~~10.1~~	~~9.9~~	~~9.6~~
Rural	8	7%	~~14.7~~	~~12.7~~	~~11.6~~	~~11.5~~	~~11.4~~	~~11.2~~	~~11.2~~	~~11.1~~	~~11~~	~~10.8~~	~~10.5~~
Rural	10	0%	~~12~~	~~9.9~~	8.8	8.6	8.4	8.1	7.9	7.7	7.4	7.2	7
Rural	10	1%	~~12.4~~	~~10.3~~	9	8.8	8.6	8.3	8.1	7.9	7.7	7.4	7.2
Rural	10	2%	~~12.8~~	~~10.7~~	9.4	9.2	9	8.7	8.6	8.4	8.3	7.9	7.7
Rural	10	3%	~~13.2~~	~~11.1~~	~~9.7~~	~~9.5~~	9.3	9	8.9	8.7	8.6	8.2	8
Rural	10	4%	~~13.6~~	~~11.5~~	~~10.2~~	~~10~~	~~9.8~~	~~9.5~~	9.4	9.2	9.1	8.8	8.6
Rural	10	5%	~~14~~	~~11.9~~	~~10.7~~	~~10.5~~	~~10.3~~	~~10.2~~	~~10.1~~	~~9.9~~	~~9.8~~	9.4	9.2
Rural	10	6%	~~14.8~~	~~12.7~~	~~11.3~~	~~11.1~~	~~10.9~~	~~10.8~~	~~10.7~~	~~10.5~~	~~10.4~~	~~10~~	~~9.8~~
Rural	10	7%	~~15.3~~	~~13.2~~	~~12~~	~~11.8~~	~~11.8~~	~~11.7~~	~~11.6~~	~~11.4~~	~~11.3~~	~~10.9~~	~~10.7~~
Rural	12	0%	~~12.6~~	~~11~~	9.3	9.1	8.8	8.5	8.2	8	7.6	7.5	7.1
Rural	12	1%	~~13~~	~~11.1~~	~~9.5~~	9.3	9	8.7	8.4	8.3	7.9	7.7	7.3
Rural	12	2%	~~13.4~~	~~11.1~~	~~9.9~~	~~9.7~~	9.4	9.1	8.9	8.9	8.5	8.2	7.9
Rural	12	3%	~~13.8~~	~~11.4~~	~~10.2~~	~~10~~	~~9.7~~	9.4	9.2	9.2	8.8	8.5	8.2
Rural	12	4%	~~14.2~~	~~11.8~~	~~10.7~~	~~10.5~~	~~10.2~~	~~9.9~~	~~9.7~~	~~9.7~~	9.3	9.1	8.7
Rural	12	5%	~~14.6~~	~~12.2~~	~~11.2~~	~~11~~	~~10.7~~	~~10.5~~	~~10.4~~	~~10.4~~	~~10~~	~~9.7~~	9.4
Rural	12	6%	~~15.4~~	~~13~~	~~11.8~~	~~11.6~~	~~11.3~~	~~11.1~~	~~11~~	~~11~~	~~10.6~~	~~10.3~~	~~10~~

Table B-3 (a). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 45° Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	12	7%	~~15.9~~	~~13.5~~	~~12.5~~	~~12.3~~	~~12.2~~	~~12~~	~~11.9~~	~~11.9~~	~~11.5~~	~~11.2~~	~~10.9~~
Urban	2	0%	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.1	4.1
Urban	2	1%	4.8	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.4	4.4
Urban	2	2%	5.1	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.6	4.6
Urban	2	3%	5.3	5.1	5	5	5	5	5	5	4.9	4.8	4.8
Urban	2	4%	5.7	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.3	5.2	5.2
Urban	2	5%	6.2	6	5.9	5.9	5.9	5.9	5.9	5.9	5.8	5.7	5.7
Urban	2	6%	6.7	6.5	6.4	6.4	6.4	6.4	6.4	6.4	6.3	6.2	6.2
Urban	2	7%	7	6.8	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.5	6.5
Urban	4	0%	5.9	5.2	4.7	4.7	4.6	4.6	4.5	4.5	4.4	4.3	4.2
Urban	4	1%	6.2	5.5	5	5	5	5	4.9	4.8	4.8	4.6	4.6
Urban	4	2%	6.5	5.8	5.2	5.2	5.2	5.2	5.1	5	5	4.8	4.8
Urban	4	3%	6.7	6	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5	4.9
Urban	4	4%	6.9	6.2	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.4	5.3
Urban	4	5%	7.3	6.6	6.3	6.3	6.2	6.2	6.1	6.1	6	5.9	5.8
Urban	4	6%	7.8	7.1	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.4	6.3
Urban	4	7%	8.2	7.5	7.1	7.1	7.1	7.1	7	6.9	6.9	6.7	6.7
Urban	6	0%	6.8	5.9	5	5	4.9	4.8	4.8	4.7	4.6	4.4	4.2
Urban	6	1%	7.1	6.2	5.3	5.3	5.2	5.2	5.2	5.1	5	4.8	4.6
Urban	6	2%	7.4	6.5	5.5	5.5	5.4	5.4	5.4	5.3	5.2	5	4.8
Urban	6	3%	7.6	6.7	5.7	5.7	5.6	5.5	5.5	5.5	5.3	5.1	4.9
Urban	6	4%	7.8	6.9	6.1	6.1	6	5.9	5.9	5.8	5.7	5.5	5.3
Urban	6	5%	8.2	7.3	6.6	6.6	6.5	6.4	6.4	6.3	6.2	6	5.8
Urban	6	6%	8.7	7.8	7.1	7.1	7	6.9	6.9	6.8	6.7	6.5	6.3
Urban	6	7%	9.1	8.2	7.4	7.4	7.3	7.3	7.3	7.2	7.1	6.9	6.7
Urban	8	0%	7.4	6.4	5.3	5.3	5.2	5.1	5	5	4.8	4.6	4.4
Urban	8	1%	7.7	6.7	5.7	5.7	5.5	5.5	5.4	5.4	5.2	5	4.8
Urban	8	2%	8	7	5.9	5.9	5.7	5.7	5.6	5.6	5.4	5.2	5
Urban	8	3%	8.2	7.2	6	6	5.9	5.8	5.8	5.7	5.5	5.3	5.1
Urban	8	4%	8.4	7.4	6.4	6.4	6.3	6.2	6.1	6.1	5.9	5.7	5.5
Urban	8	5%	8.8	7.8	6.9	6.9	6.8	6.7	6.6	6.6	6.4	6.2	6
Urban	8	6%	9.3	8.3	7.4	7.4	7.3	7.2	7.1	7.1	6.9	6.7	6.5
Urban	8	7%	~~9.7~~	8.7	7.8	7.8	7.6	7.6	7.5	7.5	7.3	7.1	6.9

Table B-3 (a). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 45º Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Urban	10	0%	7.9	7.2	5.6	5.5	5.5	5.3	5.3	5.2	5	4.7	4.4
Urban	10	1%	8.2	7.4	6	5.9	5.9	5.7	5.7	5.6	5.4	5.1	4.8
Urban	10	2%	8.5	7.5	6.2	6.1	6.1	5.9	5.9	5.8	5.6	5.3	5
Urban	10	3%	8.7	7.7	6.4	6.3	6.2	6.1	6	6	5.7	5.4	5.1
Urban	10	4%	8.9	7.9	6.7	6.6	6.6	6.4	6.4	6.3	6.1	5.8	5.5
Urban	10	5%	9.3	8.2	7.2	7.1	7.1	6.9	6.9	6.8	6.6	6.3	6
Urban	10	6%	~~9.8~~	8.7	7.7	7.6	7.6	7.4	7.4	7.3	7.1	6.8	6.5
Urban	10	7%	~~10.2~~	9.1	8.1	8	8	7.8	7.8	7.7	7.5	7.2	6.9
Urban	12	0%	8.6	7.8	6	5.8	5.7	5.6	5.5	5.5	5.1	4.9	4.4
Urban	12	1%	8.8	8	6.4	6.2	6.1	6	5.9	5.9	5.5	5.3	4.8
Urban	12	2%	9	8.1	6.6	6.4	6.3	6.2	6.1	6.1	5.7	5.5	5
Urban	12	3%	9.2	8.3	6.7	6.6	6.5	6.4	6.3	6.2	5.8	5.6	5.1
Urban	12	4%	9.4	8.5	7.1	6.9	6.8	6.7	6.6	6.6	6.2	6	5.5
Urban	12	5%	~~9.8~~	8.8	7.6	7.4	7.3	7.2	7.1	7.1	6.7	6.5	6
Urban	12	6%	~~10.3~~	9.2	8.1	7.9	7.8	7.7	7.6	7.6	7.2	7	6.5
Urban	12	7%	~~10.7~~	~~9.6~~	8.5	8.3	8.2	8.1	8	8	7.6	7.4	6.9

Notes: Red strikethrough values indicated exceedances of the standard.
* These findings apply to scenarios with the intersection average speed ranging from 15 to 45 mph and the freeway average speed ranging from 19 to 75 mph, for which posted speeds in those ranges may be applied as reasonable proxies.

Table B-3 (b). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 60º Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	2	0%	6.7	6.2	6	6	6	6	6	5.9	5.8	5.6	5.6
Rural	2	1%	7	6.5	6.3	6.3	6.3	6.3	6.3	6.2	6.1	5.9	5.9
Rural	2	2%	7.4	6.8	6.6	6.6	6.6	6.6	6.6	6.5	6.4	6.2	6.2
Rural	2	3%	7.8	7.1	6.9	6.9	6.9	6.9	6.9	6.8	6.7	6.5	6.5
Rural	2	4%	8.2	7.6	7.4	7.4	7.4	7.4	7.4	7.3	7.2	7	7
Rural	2	5%	8.8	8.1	7.9	7.9	7.9	7.9	7.9	7.8	7.7	7.5	7.5
Rural	2	6%	9.4	8.7	8.4	8.4	8.4	8.4	8.4	8.3	8.2	8	8
Rural	2	7%	~~9.9~~	9.3	9.1	9.1	9.1	9.1	9.1	9	8.9	8.7	8.7
Rural	4	0%	9.1	7.6	6.9	6.8	6.7	6.6	6.5	6.4	6	5.8	5.6

Table B-3 (b). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 60º Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	4	1%	9.4	7.9	7.2	7.1	7	6.9	6.8	6.7	6.3	6.1	5.9
Rural	4	2%	~~9.8~~	8.3	7.5	7.4	7.3	7.2	7.1	7	6.6	6.4	6.2
Rural	4	3%	~~10.2~~	8.7	7.8	7.7	7.6	7.5	7.4	7.3	6.9	6.7	6.5
Rural	4	4%	~~10.6~~	9.1	8.3	8.2	8.1	8	7.9	7.8	7.4	7.2	7
Rural	4	5%	~~11.2~~	~~9.7~~	8.8	8.7	8.6	8.5	8.4	8.3	7.9	7.7	7.5
Rural	4	6%	~~11.8~~	~~10.3~~	9.3	9.2	9.1	9	8.9	8.8	8.4	8.2	8
Rural	4	7%	~~12.3~~	~~10.8~~	~~10~~	~~9.9~~	~~9.8~~	~~9.7~~	~~9.6~~	~~9.5~~	9.1	8.9	8.7
Rural	6	0%	~~10.3~~	8.5	7.5	7.4	7.3	7.1	6.9	6.7	6.3	6	5.8
Rural	6	1%	~~10.6~~	8.8	7.8	7.7	7.6	7.4	7.2	7	6.6	6.3	6.1
Rural	6	2%	~~11~~	9.2	8.1	8	7.9	7.7	7.5	7.3	6.9	6.6	6.4
Rural	6	3%	~~11.4~~	~~9.6~~	8.4	8.3	8.2	8	7.8	7.6	7.2	6.9	6.7
Rural	6	4%	~~11.8~~	~~10~~	8.9	8.8	8.7	8.5	8.3	8.1	7.7	7.4	7.2
Rural	6	5%	~~12.4~~	~~10.6~~	9.4	9.3	9.2	9	8.8	8.6	8.2	7.9	7.7
Rural	6	6%	~~13~~	~~11.2~~	~~9.9~~	~~9.8~~	~~9.7~~	~~9.5~~	9.3	9.1	8.7	8.4	8.2
Rural	6	7%	~~13.5~~	~~11.7~~	~~10.6~~	~~10.5~~	~~10.4~~	~~10.2~~	~~10~~	~~9.8~~	9.4	9.1	8.9
Rural	8	0%	~~11.1~~	9.2	8.1	7.9	7.8	7.6	7.4	7.2	6.5	6.2	6
Rural	8	1%	~~11.4~~	~~9.5~~	8.4	8.2	8.1	7.9	7.7	7.5	6.8	6.5	6.3
Rural	8	2%	~~11.8~~	~~9.9~~	8.7	8.5	8.4	8.2	8	7.8	7.1	6.8	6.6
Rural	8	3%	~~12.2~~	~~10.3~~	9	8.8	8.7	8.5	8.3	8.1	7.4	7.1	6.9
Rural	8	4%	~~12.6~~	~~10.7~~	~~9.5~~	9.3	9.2	9	8.8	8.6	7.9	7.6	7.4
Rural	8	5%	~~13.2~~	~~11.3~~	~~10~~	~~9.8~~	~~9.7~~	~~9.5~~	9.3	9.1	8.4	8.1	7.9
Rural	8	6%	~~13.8~~	~~11.9~~	~~10.5~~	~~10.3~~	~~10.2~~	~~10~~	~~9.8~~	~~9.6~~	8.9	8.6	8.4
Rural	8	7%	~~14.3~~	~~12.4~~	~~11.2~~	~~11~~	~~10.9~~	~~10.7~~	~~10.5~~	~~10.3~~	~~9.6~~	9.3	9.1
Rural	10	0%	~~11.8~~	~~9.7~~	8.6	8.4	8.1	7.9	7.7	7.5	6.6	6.4	6.2
Rural	10	1%	~~12.1~~	~~10~~	8.9	8.7	8.4	8.2	8	7.8	6.9	6.7	6.5
Rural	10	2%	~~12.5~~	~~10.4~~	9.2	9	8.7	8.5	8.3	8.1	7.2	7	6.8
Rural	10	3%	~~12.9~~	~~10.8~~	~~9.5~~	9.3	9	8.8	8.6	8.4	7.5	7.3	7.1
Rural	10	4%	~~13.3~~	~~11.2~~	~~10~~	~~9.8~~	~~9.5~~	9.3	9.1	8.9	8	7.8	7.6
Rural	10	5%	~~13.9~~	~~11.8~~	~~10.5~~	~~10.3~~	~~10~~	~~9.8~~	~~9.6~~	9.4	8.5	8.3	8.1
Rural	10	6%	~~14.5~~	~~12.4~~	~~11~~	~~10.8~~	~~10.5~~	~~10.3~~	~~10.1~~	~~9.9~~	9	8.8	8.6
Rural	10	7%	~~15~~	~~12.9~~	~~11.7~~	~~11.5~~	~~11.2~~	~~11~~	~~10.8~~	~~10.6~~	~~9.7~~	~~9.5~~	9.3
Rural	12	0%	~~12.3~~	~~10.7~~	9.1	8.9	8.6	8.2	8	7.8	6.8	6.7	6.4
Rural	12	1%	~~12.6~~	~~10.8~~	9.4	9.2	8.9	8.5	8.3	8.1	7.1	7	6.7

Table B-3 (b). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 60º Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	12	2%	~~13~~	~~10.9~~	~~9.7~~	~~9.5~~	9.2	8.8	8.6	8.4	7.4	7.3	7
Rural	12	3%	~~13.4~~	~~11.1~~	~~10~~	~~9.8~~	~~9.5~~	9.1	8.9	8.7	7.7	7.6	7.3
Rural	12	4%	~~13.8~~	~~11.5~~	~~10.5~~	~~10.3~~	~~10~~	~~9.6~~	9.4	9.2	8.2	8.1	7.8
Rural	12	5%	~~14.4~~	~~12.1~~	~~11~~	~~10.8~~	~~10.5~~	~~10.1~~	~~9.9~~	~~9.7~~	8.7	8.6	8.3
Rural	12	6%	~~15~~	~~12.7~~	~~11.5~~	~~11.3~~	~~11~~	~~10.6~~	~~10.4~~	~~10.2~~	9.2	9.1	8.8
Rural	12	7%	~~15.5~~	~~13.2~~	~~12.2~~	~~12~~	~~11.7~~	~~11.3~~	~~11.1~~	~~10.9~~	~~9.9~~	~~9.8~~	~~9.5~~
Urban	2	0%	4.4	4.1	4	4	4	4	4	4	3.8	3.8	3.8
Urban	2	1%	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.1	4.1	4.1
Urban	2	2%	4.8	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.3	4.3	4.3
Urban	2	3%	5.1	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.5	4.5	4.5
Urban	2	4%	5.5	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5	5	5
Urban	2	5%	5.8	5.6	5.5	5.5	5.5	5.5	5.5	5.5	5.3	5.3	5.3
Urban	2	6%	6.4	6.2	6.1	6.1	6.1	6.1	6.1	6.1	5.9	5.9	5.9
Urban	2	7%	6.8	6.6	6.5	6.5	6.5	6.5	6.5	6.5	6.3	6.3	6.3
Urban	4	0%	5.8	5.1	4.4	4.4	4.3	4.2	4.2	4.2	4	4	3.8
Urban	4	1%	5.9	5.2	4.7	4.7	4.6	4.5	4.5	4.5	4.3	4.3	4.1
Urban	4	2%	6.2	5.5	4.9	4.9	4.8	4.7	4.7	4.7	4.5	4.5	4.3
Urban	4	3%	6.5	5.8	5.1	5.1	5	4.9	4.9	4.9	4.7	4.7	4.5
Urban	4	4%	6.8	6.1	5.6	5.6	5.5	5.4	5.4	5.4	5.2	5.2	5
Urban	4	5%	7.1	6.4	5.9	5.9	5.8	5.7	5.7	5.7	5.5	5.5	5.3
Urban	4	6%	7.6	6.9	6.5	6.5	6.4	6.3	6.3	6.3	6.1	6.1	5.9
Urban	4	7%	7.9	7.2	6.9	6.9	6.8	6.7	6.7	6.7	6.5	6.5	6.3
Urban	6	0%	6.7	5.8	4.8	4.7	4.6	4.5	4.4	4.4	4.2	4	3.8
Urban	6	1%	6.8	5.9	5	5	4.9	4.8	4.7	4.7	4.5	4.3	4.1
Urban	6	2%	7.1	6.2	5.2	5.2	5.1	5	4.9	4.9	4.7	4.5	4.3
Urban	6	3%	7.4	6.5	5.5	5.4	5.3	5.2	5.1	5.1	4.9	4.7	4.5
Urban	6	4%	7.7	6.8	5.9	5.9	5.8	5.7	5.6	5.6	5.4	5.2	5
Urban	6	5%	8	7.1	6.2	6.2	6.1	6	5.9	5.9	5.7	5.5	5.3
Urban	6	6%	8.5	7.6	6.8	6.8	6.7	6.6	6.5	6.5	6.3	6.1	5.9
Urban	6	7%	8.8	7.9	7.2	7.2	7.1	7	6.9	6.9	6.7	6.5	6.3
Urban	8	0%	7.3	6.4	5.1	4.9	4.9	4.7	4.7	4.6	4.4	4.2	4
Urban	8	1%	7.4	6.4	5.3	5.2	5.2	5	5	4.9	4.7	4.5	4.3
Urban	8	2%	7.7	6.7	5.5	5.4	5.4	5.2	5.2	5.1	4.9	4.7	4.5

Table B-3 (b). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 60º Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Urban	8	3%	8	7	5.8	5.6	5.6	5.4	5.4	5.3	5.1	4.9	4.7
Urban	8	4%	8.3	7.3	6.2	6.1	6.1	5.9	5.9	5.7	5.5	5.4	5.2
Urban	8	5%	8.6	7.6	6.5	6.4	6.4	6.2	6.2	6	5.8	5.7	5.5
Urban	8	6%	9.1	8.1	7.1	7	7	6.8	6.8	6.6	6.4	6.3	6.1
Urban	8	7%	9.4	8.4	7.5	7.4	7.4	7.2	7.2	7	6.8	6.7	6.5
Urban	10	0%	7.9	7.2	5.6	5.2	5.1	5	4.9	4.9	4.5	4.3	4
Urban	10	1%	7.9	7.2	5.6	5.5	5.4	5.3	5.2	5.2	4.8	4.6	4.3
Urban	10	2%	8.2	7.5	5.9	5.7	5.6	5.5	5.4	5.4	5	4.8	4.5
Urban	10	3%	8.5	7.6	6.2	5.9	5.8	5.7	5.6	5.6	5.3	5	4.7
Urban	10	4%	8.8	7.9	6.5	6.4	6.2	6.1	6.1	5.9	5.7	5.4	5.2
Urban	10	5%	9.1	8	6.8	6.7	6.5	6.4	6.4	6.2	6	5.7	5.5
Urban	10	6%	~~9.6~~	8.5	7.3	7.3	7.1	7	7	6.8	6.6	6.3	6.1
Urban	10	7%	~~9.9~~	8.8	7.7	7.7	7.5	7.4	7.4	7.2	7	6.7	6.5
Urban	12	0%	8.6	7.8	6	5.6	5.4	5.3	5.2	5.1	4.7	4.4	4.2
Urban	12	1%	8.6	7.8	6	5.8	5.7	5.6	5.5	5.4	5	4.7	4.5
Urban	12	2%	8.9	8.1	6.3	6	5.9	5.8	5.7	5.6	5.2	4.9	4.7
Urban	12	3%	9	8.2	6.4	6.2	6.1	6	5.9	5.8	5.4	5.2	4.9
Urban	12	4%	9.3	8.5	6.7	6.6	6.4	6.4	6.2	6.1	5.8	5.6	5.4
Urban	12	5%	~~9.6~~	8.6	7	6.9	6.7	6.7	6.5	6.4	6.1	5.9	5.7
Urban	12	6%	~~10.1~~	9	7.6	7.5	7.3	7.3	7.1	7	6.7	6.5	6.3
Urban	12	7%	~~10.4~~	9.3	8	7.9	7.7	7.7	7.5	7.4	7.1	6.9	6.7

Notes: Red strikethrough values indicated exceedances of the standard

* These findings apply to scenarios with average speed ranging from 15 to 56 mph for arterials and 19 to 75 mph for freeways, for which posted speeds in those ranges may be applied as reasonable proxies.

Table B-3 (c). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 90o Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	2	0%	6.7	6	5.8	5.8	5.8	5.8	5.8	5.6	5.6	5.6	5.4
Rural	2	1%	7	6.3	6	6	6	6	6	5.8	5.8	5.7	5.6
Rural	2	2%	7.4	6.7	6.4	6.4	6.4	6.4	6.4	6.2	6.2	6.2	6
Rural	2	3%	7.8	7.1	6.7	6.7	6.7	6.7	6.7	6.5	6.5	6.3	6.3
Rural	2	4%	8.1	7.4	7.2	7.2	7.2	7.2	7.2	7	7	6.8	6.8

Table B-3 (c). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 90o Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	2	5%	8.8	8.1	7.7	7.7	7.7	7.7	7.7	7.5	7.5	7.3	7.3
Rural	2	6%	9.4	8.7	8.2	8.2	8.2	8.2	8.2	8	8	7.8	7.8
Rural	2	7%	~~9.9~~	9.2	8.8	8.8	8.8	8.8	8.8	8.6	8.6	8.4	8.4
Rural	4	0%	9	7.6	6.7	6.6	6.5	6.4	6.3	6.2	5.8	5.8	5.6
Rural	4	1%	9.3	7.9	6.9	6.8	6.7	6.6	6.5	6.4	6	5.9	5.7
Rural	4	2%	~~9.7~~	8.3	7.3	7.2	7.1	7	6.9	6.8	6.4	6.4	6.2
Rural	4	3%	~~10.1~~	8.7	7.6	7.5	7.4	7.3	7.2	7.1	6.7	6.5	6.3
Rural	4	4%	~~10.4~~	9	8.1	8	7.9	7.8	7.7	7.6	7.2	6.9	6.8
Rural	4	5%	~~11.1~~	~~9.7~~	8.6	8.5	8.4	8.3	8.2	8.1	7.7	7.4	7.3
Rural	4	6%	~~11.7~~	~~10.3~~	9.1	9	8.9	8.8	8.7	8.6	8.2	7.9	7.8
Rural	4	7%	~~12.2~~	~~10.8~~	~~9.7~~	~~9.6~~	~~9.5~~	9.4	9.3	9.2	8.8	8.5	8.4
Rural	6	0%	~~10.3~~	8.5	7.3	7.1	7	6.9	6.7	6.5	6	6	5.8
Rural	6	1%	~~10.6~~	8.8	7.5	7.3	7.2	7.1	6.9	6.7	6.2	6.1	5.9
Rural	6	2%	~~11~~	9.2	7.9	7.7	7.6	7.5	7.3	7.1	6.6	6.6	6.4
Rural	6	3%	~~11.4~~	~~9.6~~	8.2	8	7.9	7.8	7.6	7.4	6.9	6.7	6.5
Rural	6	4%	~~11.7~~	~~9.9~~	8.7	8.5	8.4	8.3	8.1	7.9	7.4	7.1	6.9
Rural	6	5%	~~12.4~~	~~10.6~~	9.2	9	8.9	8.8	8.6	8.4	7.9	7.5	7.3
Rural	6	6%	~~13~~	~~11.2~~	~~9.7~~	~~9.5~~	9.4	9.3	9.1	8.9	8.4	8	7.8
Rural	6	7%	~~13.5~~	~~11.7~~	~~10.3~~	~~10.1~~	~~10~~	~~9.9~~	~~9.7~~	~~9.5~~	9	8.6	8.4
Rural	8	0%	~~11.1~~	9	7.9	7.7	7.5	7.2	7.1	6.9	6.3	6.2	6
Rural	8	1%	~~11.4~~	9.3	8.1	7.9	7.7	7.4	7.3	7.1	6.4	6.3	6.1
Rural	8	2%	~~11.8~~	~~9.7~~	8.5	8.3	8.1	7.8	7.7	7.5	6.9	6.8	6.6
Rural	8	3%	~~12.2~~	~~10.1~~	8.8	8.6	8.4	8.1	8	7.8	7.1	6.9	6.7
Rural	8	4%	~~12.5~~	~~10.4~~	9.3	9.1	8.9	8.6	8.5	8.3	7.6	7.3	7.1
Rural	8	5%	~~13.2~~	~~11.1~~	~~9.8~~	~~9.6~~	9.4	9.1	9	8.8	8.1	7.7	7.5
Rural	8	6%	~~13.8~~	~~11.7~~	~~10.3~~	~~10.1~~	~~9.9~~	~~9.6~~	~~9.5~~	9.3	8.6	8.2	8
Rural	8	7%	~~14.3~~	~~12.2~~	~~10.9~~	~~10.7~~	~~10.5~~	~~10.2~~	~~10.1~~	~~9.9~~	9.2	8.8	8.6
Rural	10	0%	~~11.8~~	~~9.5~~	8.4	8.2	7.9	7.7	7.5	7.2	6.5	6.3	6
Rural	10	1%	~~12.1~~	~~9.8~~	8.6	8.4	8.1	7.9	7.7	7.4	6.6	6.4	6.1
Rural	10	2%	~~12.5~~	~~10.2~~	9	8.8	8.5	8.3	8.1	7.8	7.1	6.9	6.6
Rural	10	3%	~~12.9~~	~~10.6~~	9.3	9.1	8.8	8.6	8.4	8.1	7.3	7	6.7
Rural	10	4%	~~13.2~~	~~10.9~~	~~9.8~~	~~9.6~~	9.3	9.1	8.9	8.6	7.8	7.4	7.1
Rural	10	5%	~~13.9~~	~~11.6~~	~~10.3~~	~~10.1~~	~~9.8~~	~~9.6~~	9.4	9.1	8.3	7.8	7.5

Table B-3 (c). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 90o Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	10	6%	~~14.5~~	~~12.2~~	~~10.8~~	~~10.6~~	~~10.3~~	~~10.1~~	~~9.9~~	~~9.6~~	8.8	8.3	8
Rural	10	7%	~~15~~	~~12.7~~	~~11.4~~	~~11.2~~	~~10.9~~	~~10.7~~	~~10.5~~	~~10.2~~	9.4	8.9	8.6
Rural	12	0%	~~12.3~~	~~10.6~~	8.9	8.5	8.3	8	7.8	7.5	6.7	6.5	6.2
Rural	12	1%	~~12.6~~	~~10.7~~	9.1	8.7	8.5	8.2	8	7.7	6.8	6.6	6.3
Rural	12	2%	~~13~~	~~10.7~~	~~9.5~~	9.1	8.9	8.6	8.4	8.1	7.3	7.1	6.8
Rural	12	3%	~~13.4~~	~~11~~	~~9.8~~	9.4	9.2	8.9	8.7	8.4	7.4	7.2	6.9
Rural	12	4%	~~13.7~~	~~11.3~~	~~10.3~~	~~9.9~~	~~9.7~~	9.4	9.2	8.9	7.9	7.6	7.3
Rural	12	5%	~~14.4~~	~~12~~	~~10.8~~	~~10.4~~	~~10.2~~	~~9.9~~	~~9.7~~	9.4	8.4	8	7.7
Rural	12	6%	~~15~~	~~12.6~~	~~11.3~~	~~10.9~~	~~10.7~~	~~10.4~~	~~10.2~~	~~9.9~~	8.9	8.5	8.2
Rural	12	7%	~~15.5~~	~~13.1~~	~~11.9~~	~~11.5~~	~~11.3~~	~~11~~	~~10.8~~	~~10.5~~	~~9.5~~	9.1	8.8
Urban	2	0%	4.5	4.2	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.6	3.6
Urban	2	1%	4.6	4.3	4.1	4.1	4.1	4.1	4.1	4.1	3.9	3.9	3.9
Urban	2	2%	4.9	4.6	4.3	4.3	4.3	4.3	4.3	4.3	4.1	4.1	4.1
Urban	2	3%	5.2	4.9	4.6	4.5	4.5	4.5	4.5	4.5	4.3	4.3	4.3
Urban	2	4%	5.4	5.1	4.8	4.7	4.7	4.7	4.7	4.7	4.5	4.5	4.5
Urban	2	5%	5.8	5.5	5.2	5.2	5.2	5.2	5.2	5.2	5	5	5
Urban	2	6%	6.3	6	5.7	5.6	5.6	5.6	5.6	5.6	5.4	5.4	5.4
Urban	2	7%	6.7	6.4	6.1	6.1	6.1	6.1	6.1	6.1	5.9	5.9	5.9
Urban	4	0%	5.9	5.2	4.5	4.2	4.2	4	4	4	3.9	3.8	3.8
Urban	4	1%	6	5.3	4.6	4.5	4.4	4.3	4.3	4.3	4.1	4.1	4
Urban	4	2%	6.3	5.6	4.9	4.7	4.6	4.5	4.5	4.5	4.3	4.3	4.1
Urban	4	3%	6.6	5.9	5.2	4.9	4.9	4.7	4.7	4.7	4.5	4.5	4.3
Urban	4	4%	6.8	6.1	5.4	5.1	5.1	4.9	4.9	4.9	4.7	4.7	4.5
Urban	4	5%	7.2	6.5	5.8	5.6	5.5	5.4	5.4	5.4	5.2	5.2	5
Urban	4	6%	7.7	7	6.3	6	6	5.8	5.8	5.8	5.6	5.6	5.4
Urban	4	7%	8.1	7.4	6.7	6.5	6.4	6.3	6.3	6.3	6.1	6.1	5.9
Urban	6	0%	6.8	5.9	4.9	4.6	4.4	4.3	4.2	4.2	4	4	3.8
Urban	6	1%	6.9	6	5	4.8	4.7	4.6	4.5	4.5	4.3	4.2	4
Urban	6	2%	7.2	6.3	5.3	5	4.9	4.8	4.7	4.7	4.5	4.3	4.1
Urban	6	3%	7.5	6.6	5.6	5.3	5.1	5	4.9	4.9	4.7	4.5	4.3
Urban	6	4%	7.7	6.8	5.8	5.5	5.3	5.2	5.1	5.1	4.9	4.7	4.5
Urban	6	5%	8.1	7.2	6.2	5.9	5.8	5.7	5.6	5.6	5.4	5.2	5
Urban	6	6%	8.6	7.7	6.7	6.4	6.2	6.1	6	6	5.8	5.6	5.4
Urban	6	7%	9	8.1	7.1	6.8	6.7	6.6	6.5	6.5	6.3	6.1	5.9

Table B-3 (c). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 90o Skew Angle (not including background concentrations)*

Location	Number of Lanes	Intersection Grade	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Urban	8	0%	7.4	6.4	5.2	4.9	4.7	4.5	4.5	4.4	4.2	4.1	4
Urban	8	1%	7.5	6.5	5.3	5	5	4.8	4.8	4.6	4.4	4.3	4.2
Urban	8	2%	7.8	6.8	5.6	5.3	5.2	5	5	4.8	4.6	4.4	4.3
Urban	8	3%	8.1	7.1	5.9	5.6	5.4	5.2	5.2	5	4.8	4.6	4.5
Urban	8	4%	8.3	7.3	6.1	5.8	5.6	5.4	5.4	5.2	5	4.8	4.7
Urban	8	5%	8.7	7.7	6.5	6.2	6.1	5.9	5.9	5.7	5.5	5.3	5.2
Urban	8	6%	9.2	8.2	7	6.7	6.5	6.3	6.3	6.1	5.9	5.7	5.6
Urban	8	7%	~~9.6~~	8.6	7.4	7.1	7	6.8	6.8	6.6	6.4	6.2	6.1
Urban	10	0%	7.9	7.1	5.6	5.2	4.9	4.7	4.7	4.6	4.4	4.2	4
Urban	10	1%	8	7.2	5.7	5.3	5.1	5	4.9	4.8	4.6	4.4	4.2
Urban	10	2%	8.3	7.5	6	5.6	5.3	5.2	5.1	5	4.7	4.5	4.3
Urban	10	3%	8.6	7.6	6.3	5.9	5.6	5.4	5.3	5.2	4.9	4.7	4.5
Urban	10	4%	8.8	7.8	6.5	6.1	5.8	5.6	5.5	5.4	5.1	4.9	4.7
Urban	10	5%	9.2	8.1	6.9	6.5	6.2	6.1	6	5.9	5.6	5.4	5.2
Urban	10	6%	~~9.7~~	8.6	7.4	7	6.7	6.5	6.4	6.3	6	5.8	5.6
Urban	10	7%	~~10.1~~	9	7.8	7.4	7.1	7	6.9	6.8	6.5	6.3	6.1
Urban	12	0%	8.5	7.7	5.9	5.4	5.1	5	4.9	4.8	4.6	4.4	4.2
Urban	12	1%	8.6	7.8	6	5.5	5.3	5.3	5.1	5	4.8	4.6	4.4
Urban	12	2%	8.9	8.1	6.3	5.8	5.5	5.5	5.3	5.2	4.9	4.7	4.5
Urban	12	3%	9.1	8.2	6.5	6	5.7	5.7	5.5	5.4	5.1	4.9	4.7
Urban	12	4%	9.3	8.4	6.7	6.2	5.9	5.9	5.7	5.6	5.3	5.1	4.9
Urban	12	5%	~~9.7~~	8.7	7.1	6.6	6.4	6.4	6.2	6.1	5.8	5.6	5.4
Urban	12	6%	~~10.2~~	9.1	7.6	7.1	6.8	6.8	6.6	6.5	6.2	6	5.8
Urban	12	7%	~~10.6~~	~~9.5~~	8	7.5	7.3	7.3	7.1	7	6.7	6.5	6.3

* These findings apply to scenarios with average speed ranging from 15 to 56 mph for arterials and 19 to 75 mph for freeways, for which posted speeds in those ranges may be applied as reasonable proxies.

Appendix C: Technical Support Document Template

Technical Support Document Template

As described earlier, the coloring scheme in the draft PA template, and its associated TSD, is as follows:

Black text = Text that generally will not need to be modified and can be used for a national PA and for individual state PAs;

Red text = Information (e.g. report or study citations) at a Federal or state level that is not yet complete and can be added at a later date when a national PA or state PA is finalized;

Blue text = Text to be added containing information relevant to a particular state in order to allow completion of a state –specific PA and its associated TSD.

FHWA-STATE DOT AGREEMENT ON PROJECT-LEVEL CARBON MONOXIDE AIR QUALITY ANALYSIS

TECHNICAL SUPPORT DOCUMENT

Prepared by

STATE DOT

Environmental Office

March 2020

1. Executive Summary

This Technical Support Document (TSD) provides background and technical information in support of the Programmatic Agreement (PA) between the STATE DOT and the STATE Division of FHWA related to project level carbon monoxide (CO) air quality analysis. This TSD and the associated PA establish which project types and conditions are not expected to exceed CO National Ambient Air Quality Standards (NAAQS) and therefore do not require a project-specific quantitative air quality analysis.

The analyses described in this TSD demonstrate, with a high degree of confidence, that implementation of these project types under the conditions listed could not cause or contribute to a violation of the ambient air standards for CO. The project types covered are freeways, arterials, interchanges and intersections.

It is recognized that, from time to time, new emission or dispersion models may be developed and approved or that underlying ambient or technical conditions may change. As necessary, this TSD will be updated to reflect any substantive changes.

2. Background

2.1 Air Quality Standards for CO

Under the Clean Air Act, EPA is required to set National Ambient Air Quality Standards for six principal air pollutants, including CO (**Table 1**). The standards are set to avoid adverse impacts to public health and the environment. The Clean Air Act identifies two types of national ambient air quality standards. Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly with an adequate margin of safety. Secondary standards provide public welfare protection, including protecting against decreased visibility and damage to animals, crops, vegetation, and buildings. There are currently no secondary standards for CO.

Table 1 – Current National Ambient Air Quality Standards (NAAQS) for Carbon Monoxide (CO)

Pollutant [final rule cite]	Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide [76 FR 54293, Aug 31, 2011]	Primary	8-hour	9 ppm	Not to be exceeded more than once per year
		1-hour	35 ppm	

Source: https://www.epa.gov/co-pollution/national-ambient-air-quality-standards-naaqs-carbon-monoxide-co

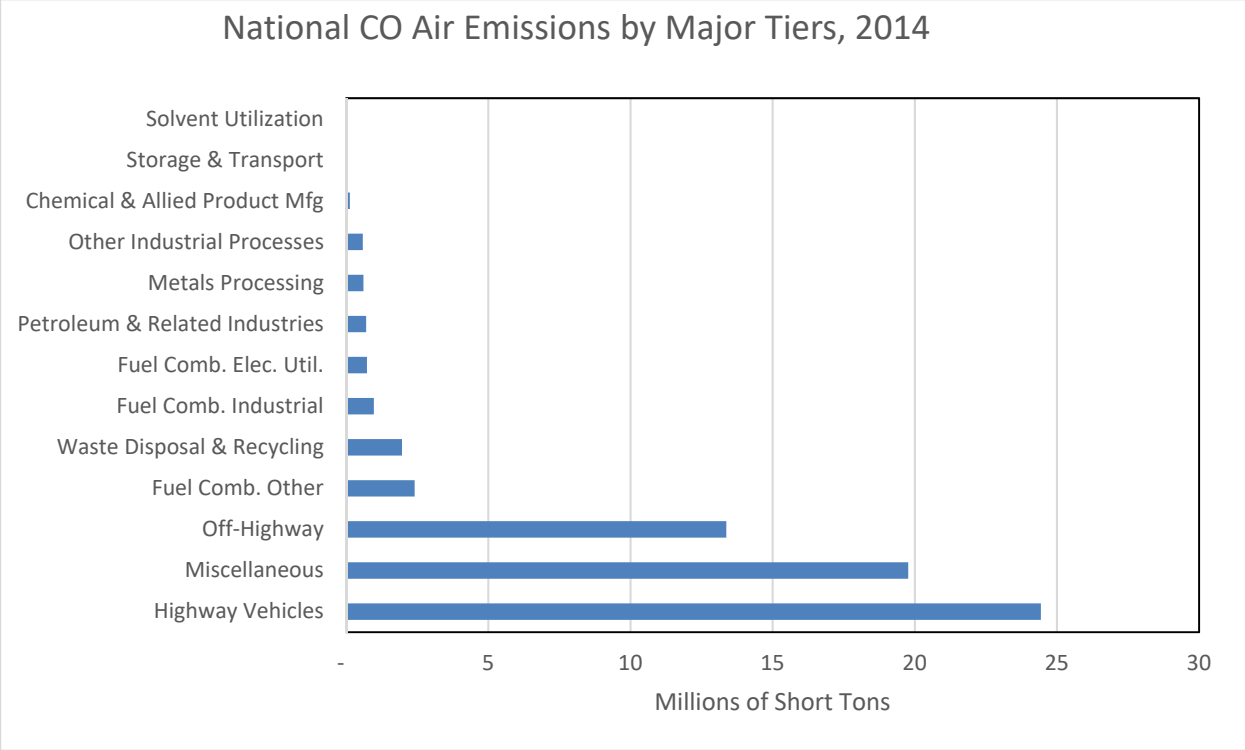
EPA designates geographic regions as in attainment or nonattainment of the NAAQS. Generally, regions that met NAAQS when the standards were promulgated and have continued to meet those standards for a given pollutant are designated attainment areas. Regions that were deemed out of compliance when NAAQS were promulgated and that continue to exceed the NAAQS for a given pollutant are designated nonattainment areas. Regions that were previously out of compliance with the standard but have since come into compliance are designated maintenance

areas. As of September 27, 2010, all former CO nonattainment areas were determined to be in compliance for CO, and so have been re-designated as maintenance areas.

States with nonattainment or maintenance areas were required under the Clean Air Act to develop State Implementation Plans (SIPs) adopting transportation conformity requirements at least as stringent as the federal requirements. Some states also adopted additional requirements beyond those prescribed under the Clean Air Act. INSERT INFO ABOUT STATES COMPLIANCE STANDING. INSERT STATE REQUIREMENTS FROM CONFORMITY SIPS, IF ANY.

2.2 Highway Projects & CO Requirements

Nationally, annual CO emissions in the US total over 82 million short tons. Mobile sources, including gasoline fueled cars, trucks, buses and off-road vehicles, are responsible for approximately 51% of this total.



Source: 2014 National Emission Inventory[1]

Figure 1 – National Carbon Monoxide Emission Inventory

A similar situation exists at the state level. In STATE – INSERT IFORMATION ON STATE CO INVENTORY AS APPROPRIATE.

INSERT FIGURE OR TABLE ON STATE CO INVENTORY

Because of the significant CO pollution attributable to mobile sources, transportation agencies have been required to examine the effect of their highway projects on CO levels in the project area. Indeed, under Section 176(c) of the Clean Air Act (the conformity provision), in order to

[1] https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data

proceed, certain highway projects are required to demonstrate that the incremental addition of CO emissions as a result of the project will not cause or contribute to a violation of the CO NAAQS. The analysis necessary to demonstrate this is typically performed during the environmental studies undertaken to examine environmental impacts of the project.

For transportation projects involving federal funding or action, the environmental analysis is performed pursuant to the requirements of the National Environmental Policy Act (NEPA). Enacted on January 1, 1970, NEPA established a national environmental policy focused on federal activities with the goal of balancing a sustainable environment with other essential present and future needs. NEPA established a requirement for federal agencies to consider the potential environmental consequences of their proposals, document the analysis, and make this information available to the public for comment prior to implementation. NEPA also requires Federal agencies to use an interdisciplinary approach in planning and decision making for any action that adversely impacts the environment. As implemented by FHWA, this means investigating and avoiding potential impacts to the social and natural environment (such as a violation of the CO NAAQS) when considering approval of proposed transportation projects. FHWA's policy and regulations implementing NEPA are found at 23 CFR § 771.105.

Many states have enacted a state version of NEPA to cover state actions and funding. Like NEPA, the state versions typically require an examination of potential environmental impacts and appropriate action to mitigate these impacts to the extent practicable. INSERT HERE INFORMATION ABOUT STATE ENVIRONMENTAL REQUIREMENTS.

As mentioned above, regions of the nation that did not meet the NAAQS for CO when the standards were promulgated were designated as nonattainment areas under the Clean Air Act. Those areas have since all reached attainment of the CO standard based on monitoring or modeling studies and most are now designated as maintenance areas. However, under Section 176(c) of the Clean Air Act (the transportation conformity provision), certain transportation projects in maintenance areas are required to demonstrate that the project will not cause or contribute to a violation of the CO standard.

2.3 Decline in CO Concentrations

The likelihood of highway projects leading to violations of the CO NAAQS has been significantly reduced over the last few decades. Indeed, vehicle miles traveled (VMT) have seen a long-term general increase over time.

Figure 2 shows the trend in VMT at a national level. This has also been the case at the state level.

Background CO concentrations are critical in determining a project's impact in terms of NAAQS. At the national level, background CO concentrations have seen significant decreases over the past two decades or more. Indeed, the nationwide network of CO air quality monitoring sites have reported a 80% decline in the 90th percentile of maximum 8-hour CO concentration from 9.7 ppm, above the NAAQS for CO (9 ppm—see 9.5 **Table 1**) in 1990 to 1.9 ppm, well below the NAAQS for CO, in 2016 (Figure 3). Similar reductions have been found at the state level.

INSERT INFORMATION AND FIGURE OR TABLE, IF APPLICABLE, REGARDING STATE CO MONITORING DATA.

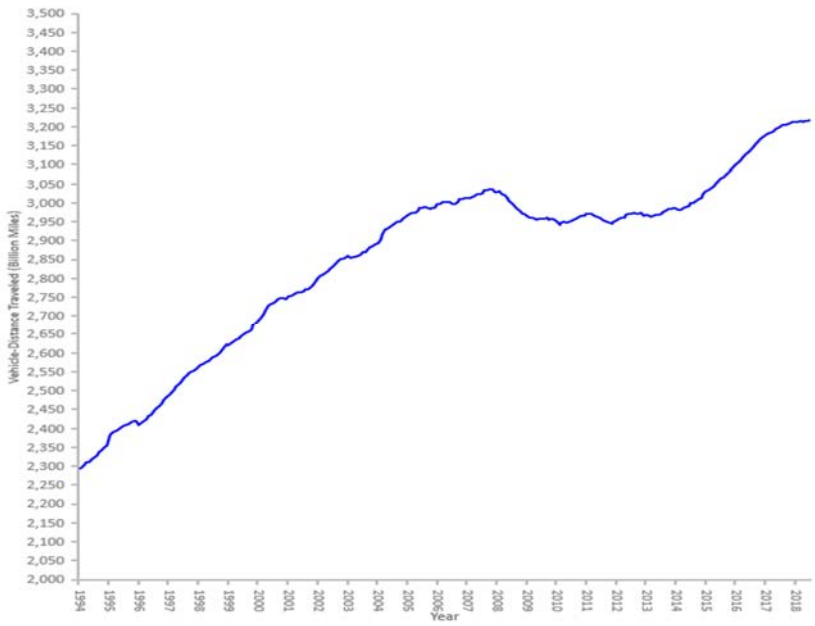


Figure 2 - Total National VMT (in billions of miles) on All Highways, 1994-2018. Source: FHWA.[2]

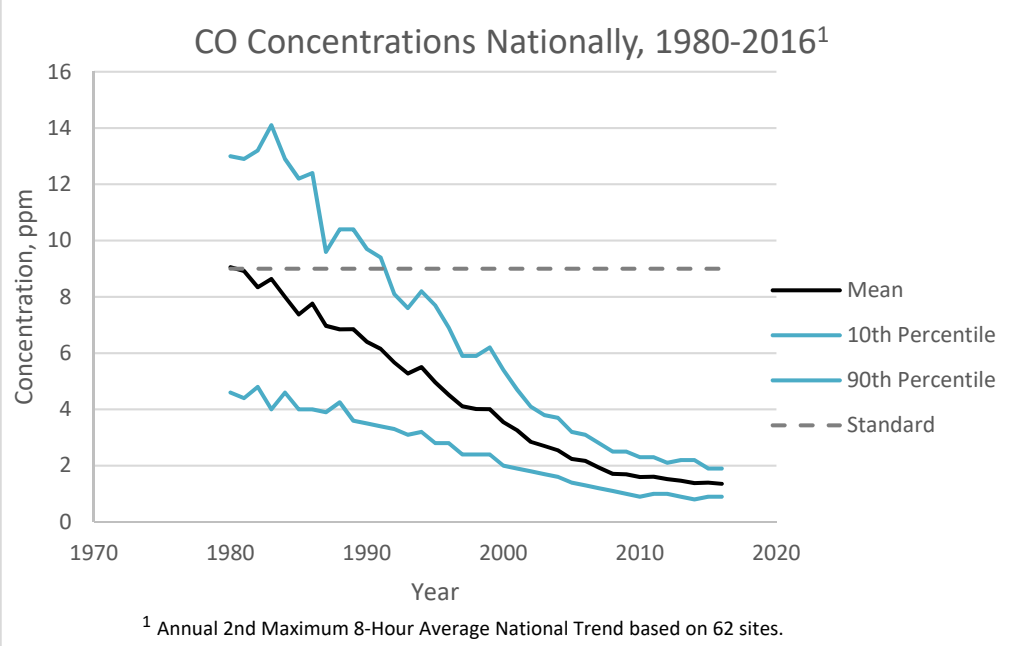


Figure 3 - National Trends in CO Concentration, 1980-2016 (Annual 2nd High 8-hour average N=62).[3]

The largest contributor to the substantial reductions in CO concentrations has been the Federal Motor Vehicle Emission Control Program, which sets emission limits for on-road vehicles. This program since implementation has been responsible for a 95% reduction in CO emissions from

[2] FHWA Office of Highway Policy Information, Traffic Volume Trends. Available at: https://www.fhwa.dot.gov/policyinformation/travel_monitoring/18jultvt/figure1.cfm.

[3] The black line represents the average of all sites, the top blue line the 90th percentile concentration and the bottom the 10th percentile. Source: EPA Air Trends. Available at: http://www.epa.gov/airtrends/carbon.html.

light-duty vehicles. Additional CO emissions reductions are expected to result from EPA's Tier 3 Control Program, enacted in April 2014, which places limits on the sulfur content of gasoline. Although CO emission rates are not directly regulated under the Tier 3 Control Program, the additional stringency on sulfur content in gasoline will reduce CO emissions by extending the effective life of vehicle catalysts. When fully implemented, by 2030, Tier 3 is expected to produce an additional 24% reduction in CO emissions (**Table 2**).

Table 2 – Projected CO Reductions from EPA's Tier 3 Program

	[Annual U.S. tons]	
	2018	2030
Reduction from pre-Tier 3 fleet due to sulfur standard	122,171	17,734
Reduction from Tier 3 fleet due to vehicle and sulfur standards	156,708	3,440,307
Total reduction	278,879	3,458,041
Percent reduction in on road CO emissions	2%	24%

Source: https://www.federalregister.gov/articles/2014/04/28/2014-06954/control-of-air-pollution-from-motor-vehicles-tier-3-motor-vehicle-emission-and-fuel-standards

The low ambient CO concentrations and the anticipated continued decline of these concentrations suggest that violations of the current CO NAAQS are unlikely today and into the future. As a result, any changes to local CO concentrations resulting from highway projects are highly unlikely to cause or contribute to a violation of these standards. It is reasonable, therefore, to reduce CO analyses for highway projects to the maximum extent while still monitoring situations that could lead to high levels of ambient CO concentrations.

3. Regulatory Context and Prior Programmatic Agreements

3.1 Regulatory Requirements and Guidance

For highway projects involving federal funding or action, project-level CO analyses are performed pursuant to the National Environmental Policy Act (NEPA). Enacted on January 1, 1970, NEPA established a national environmental policy requiring federal agencies to take consideration of the environmental impact of proposed projects in their planning and decision making. Specifically, NEPA established a requirement for federal agencies to perform an environmental assessment that considers the potential environmental consequences of their proposed projects. If the environmental assessment finding is that the project will have significant impact, then the federal agency must prepare an environmental impact statement (EIS). The EIS details the environmental consequences of the project and provides reasonable alternatives or amendments that would mitigate these impacts. NEPA requirements encompass any project, public or private, that receives federal funding, though it is the burden of the federal agency to perform the analysis. When applied to FHWA highway projects, NEPA requires consideration of potential environmental impacts—including violation of CO NAAQS, when considering approval of the projects. FHWA's policy and regulations implementing NEPA are found at 23 CFR § 771.105.

Nineteen states have enacted a state version of NEPA to cover state funded projects. Thus, for state level highway projects, CO analysis may be required in accordance with state NEPA analogues. Like NEPA, the state versions typically require an examination of potential environmental impacts and proposal of efforts to mitigate these impacts to a practical extent. States may also require CO analyses in order for a project to comply with transportation conformity requirements. Project transportation conformity requirements are found in 40 CFR Parts 51 and 93. INSERT HERE INFORMATION ABOUT STATE ENVIRONMENTAL REQUIREMENTS.

Guidance related to performing these analyses may be found in the FHWA Technical Advisory T6640.8A (October 30, 1987). With respect to air quality, the guidance recognizes that microscale air quality analyses may be performed for some projects but does not offer any methodological guidance beyond adding background concentrations to the project contribution or the preferred alternative to arrive at a total CO concentration for comparison to the NAAQS. Using this general guidance, many states developed their own guidelines and procedures tailored to state policies and air quality status.

The EPA transportation conformity rule requires project-level ("hot-spot") analyses for CO for areas subject to conformity for that pollutant. As a means to streamline analyses, the conformity rule provides the option of a categorical finding (CF), which is analogous to a PA that may be executed for purposes of NEPA but with key differences: 1) A CF is applicable for areas subject to conformity for CO (and not for NEPA), and is approved by FHWA in consultation with EPA, and not state DOTs, and 2) a PA is applicable for NEPA (not areas subject to conformity for CO) and is typically executed between a state DOT and its respective FHWA Division office. The option exists in concept for a CF for CO to also be designated as applicable for NEPA (i.e., making it both a CF and an PA), although this has not been done to date.

3.1.1 Prior Work on Programmatic Agreements for CO

Historically, PAs have been implemented by state DOTs to address a range of environmental topics (e.g., NEPA, noise, air quality). At the national level, work began on the development of a template PA and TSD for CO with a National Cooperative Highway Research Project (NCHRP) ("Task 78") study[4] initiated in 2012 by state DOTs to build upon successful state experiences[5] in streamlining project-level air quality clearances for purposes of NEPA with state-specific PAs. The intent was to create a national template PA and associated TSD for CO that state DOTs could customize and implement for their respective jurisdictions. A national template would save state DOTs the cost of development of a PA and TSD for CO and also serve to provide greater consistency nationally in how projects are screened for CO. Completed in 2015, the NCHRP Task 78 study examined a variety of project types and conditions in order and identified multiple highway facility types and configurations that would not reasonably be expected to result in violation of the CO NAAQS. It tested even the remote possibility of CO ambient air quality standard violations using worst-case modeling (following FHWA guidance on worst-case assumptions) and maintaining consistency as appropriate with EPA guidance for CO hot-spot analyses.[6] It applied EPA-approved emission and

[4] ICF, Zamurs and Associates, and Volpe Transportation Center, NCHRP 25-25/Task 78, "*Programmatic Agreements for Project-Level Air Quality Analyses*", 2015. See: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

[5] As noted in the 2015 NCHRP 25-25 Task 78 report, following a review of state agreements in place at that time, the 2009 Virginia DOT PA and TSD were selected as the model for the new national template. Due to limited funding, however, the 2015 NCHRP Task 78 templates did not include skew angles, which had been included in the Virginia DOT version. This update to the 2015 NCHRP Task 78 templates includes both skew angles and road grades.

[6] US EPA, Guideline for Modeling Carbon Monoxide from Roadway Intersections, EPA-454/R-92-005, Nov. 1992; and Using

dispersion models, namely MOVES2010b as the emission model and CAL3QHC (version 04244) as the dispersion model.

Subsequently, the PA and TSD templates developed in the NCHRP Task 78 study were updated in a second NCHRP study ("Task 104").[7] The NCHRP Task 104 study, which was completed in 2020, covered a greater range of road grades compared to the original Task 78 Templates and also added coverage of a range of intersection skew angles. As with the NCHRP Task 78 study, the modeling for the NCHRP Task 104 update was conducted using EPA-approved emission and dispersion models for project-level CO screening analyses. MOVES2014a was applied as the emission model (which was updated by EPA in the interim period since the original NCHRP Task 78 study was completed), and CAL3QHC (version 04244) was again applied as the dispersion model. This PA and TSD are based on the updated templates developed in the NCHRP Task 104 study.

For reference, in a parallel effort conducted following the initiation of the NCHRP Task 78 study, the FHWA developed a categorical finding (CF) that could be implemented in areas subject to EPA conformity requirements for CO, i.e., in areas in which a PA designed for NEPA applications typically would not be applicable but the functionally-equivalent CF could be applied. State DOTs could then use the NCHRP PA for NEPA and the FHWA CF for conformity. Completed in 2014, the FHWA CF[8] documented conditions for a single facility type (i.e., urban intersections) in areas subject to conformity requirements for CO that would not require project-specific emission and dispersion modeling. The FHWA CF was based on a set of worst-case assumptions similar in concept to those applied in the NCHRP PAs. In 2017, FHWA published a revision[9] to its original 2014 CF based on updated emission modeling (with MOVES2014a) and the CAL3QHC dispersion model. However, the FHWA CF remained limited to large urban intersections; its coverage was not expanded to include the additional highway facility types and configurations covered by this PA. The 2017 FHWA CF is applicable to all states and territories (except California) that are subject to conformity requirements for CO[10].

4. Modeling

The models used in CO air quality analysis have evolved over time. For emissions, the MOBILE series of models were used predominantly until the 2010 release of the first version of MOVES (Motor Vehicle Emission Simulator). Similarly, dispersion models have undergone changes over time. Highway sources have historically been treated as line sources using Gaussian dispersion to deliver CO from the source to the receptor. The HIWAY and CALINE series of models were developed to allow for modeling of roadways. However, it was realized that congested intersections, with most vehicles experiencing idling and acceleration and deceleration associated with a traffic signal, may be more of a concern for CO levels than free-flowing highways. To

MOVES in Project-Level Carbon Monoxide Analyses, EPA-420-C-10-041 December 2010

[7] E. Carr, S. Hartley, G. Noel & A. Eilbert, NCHRP 25-25 Task 104, "*Streamlining Carbon Monoxide Project-Level Air Quality Analyses with Programmatic Agreements*", 2020. http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4100

[8] FHWA Carbon Monoxide Categorical Hot-Spot Finding *(Superseded)*, February 2014. Available at: http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/

[9] FHWA Carbon Monoxide Categorical Hot-Spot Finding, 2017. Available at: https://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf_2017/index.cfm

[10] State DOTs have encouraged FHWA to explore options for expanding its CF, e.g., by incorporating the project types and configurations covered by this template PA, and also, very importantly, explicitly making the CF applicable for NEPA in addition to conformity, i.e., in effect making it both a PA and CF. For this purpose, certain of the modeling inputs for this (2020 NCHRP Task 104) update were made consistent as appropriate with the inputs applied in the 2017 FHWA CF.

account for intersection scenarios, queuing algorithms were added to dispersion models, resulting in the current series of CAL3QHC and CAL3QHC(R) models. This analysis used MOVES (version MOVES2014a) and CAL3QHC (version 042440) for emissions and dispersion modeling, respectively.

INSERT TEXT OF STATE SITUATION. TOPICS COULD INCLUDE: CHRONOLOGY OF GUIDANCE AND PROCEDURES, PREVIOUS AGREEMENTS, DOCUMENT STATUS OF PROJECT-LEVEL MODELING. A DISCUSSION ON THE CAPITAL PROGRAM (I.E. TYPES OF PROJECTS, MAJOR VS MINOR PROJECTS) WITHIN THE STATE TO SHOW SMALL PERCENTAGE OF PROJECTS WITH NEED FOR AIR QUALITY ANALYSIS

The assumptions and inputs to the modeling process were conservative and/or worst-case. Conservative here refers to a modeling approach that, by design, tends to over predict concentrations. If a project does not cause a violation with these conservative inputs and assumptions, then a violation under “real-world” conditions is extremely unlikely to occur. This is standard practice in transportation air quality modeling. Further discussion of how this conservative emissions and air dispersion modeling was conducted is provided in the remainder of this section.

The use of a number of conservative modeling inputs effectively provides a l safety margin for the PA. Given the degree of conservatism, the criteria to be specified in the PA for its application to proposed projects may reasonably be limited to only the most critical. For example:

- The PA may not specify meteorological data as criteria for its application for proposed projects, as worst-case meteorological inputs (e.g., low winds speed) were assumed for the dispersion modeling for the TSD.
- The PA may specify limits on the number of freeway lanes as a criterion but not project-specific forecast traffic volumes, as worst-case volumes per lane for each facility type were assumed for the modeling for the TSD.
- Similarly, the criteria for application of the PA may reasonably be based on posted speeds (within specified speed ranges) as a reasonable proxy for forecast speeds.

4.1 Emissions Modeling

Emission modeling was performed using the MOVES model (version MOVES2014a). The emissions parameters for MOVES were specified in the Run Specification file (Runspec) and in the Project Data Manager (PDM). All applications of the MOVES model were conducted at the project level scale. Multiple MOVES runs were conducted for varying roadway grades to establish CO emissions rates. Other MOVES input parameters such as temperature and relative humidity were fixed to be conservative and consistent with the dispersion modeling component of the analysis (see section 4.3.3). **Table 3** describes the input parameters that were used in the Runspec and PDM for the MOVES component of the analysis. Appendix C-1 lists the emission factors from the application of the MOVES model for all combinations of speeds, roadway type and grade based on the input parameters discussed in this section.

Table 3 – MOVES Input Parameters by Scenario

Parameter	Freeway	Arterial	Intersection
Scale	Project Level Domain		
Year	2020		
Month	January		
Time Span - Hour	08:00 AM		
Time Span - Day	Weekday		
Geographic Bounds	Custom Domain		
Temperature	78° Fahrenheit		
Relative Humidity	100%		
Fuel Formulation	Gasoline – Formulation ID - 3505		
	Diesel – Formulation ID - 25005		
	CNG – Formulation ID - 30		
Fleet Mix	All Emission Source Type and Fuel Combinations for 2020 (refer to Table 4 and Table 5)		
Age Distribution	2020 National Default		
Link Source Type Distribution	Variable - Based on 2020 National Default VMT for Urban and Rural Restricted Access Road Type with Truck Percentage adjustments	Variable - Based on 2020 National Default VMT for Urban and Rural Unrestricted Access Road Type with Truck Percentage adjustments	Variable - Based on 2020 National Default VMT for Urban and Rural Unrestricted Access Road Type with Truck Percentage adjustments
Road Type	Urban and Rural Restricted Access	Urban and Rural Unrestricted Access	Urban and Rural Unrestricted Access
Link Average Speed	19 to 75 mph, with 74mph having the highest emission rate	15 to 56 mph, with 15 mph having the highest emission rate	15 to 56 mph, with 15 mph approach and idle having the highest emission rate
Grade	Multiple Grades between ±0% to ±7%		
Inspection & Maintenance	None		

4.1.1 Relative Humidity

A value of 100% relative humidity was used and was only applicable for the emission modeling, which yields the highest CO emission rates for any temperature over 75 degrees Fahrenheit.

4.1.2 Temperature

Sensitivity tests with MOVES show that emission rates are sensitive to high temperatures for

running exhaust and crankcase exhaust emissions (Figure 4)[11]. MOVES2014a predicts higher CO beginning at T > 75 degrees Fahrenheit due to air conditioning use. A review of historical meteorological data (2014-2016) from the top 35 non-overlapping 8-hour CO monitored values from all CO reporting sites in the United States showed that the 8-hour average temperature was never higher than 78 degrees Fahrenheit, after excluding four high CO readings due to nearby wildfires. To be conservative, 78 degrees Fahrenheit was then used in the analysis.

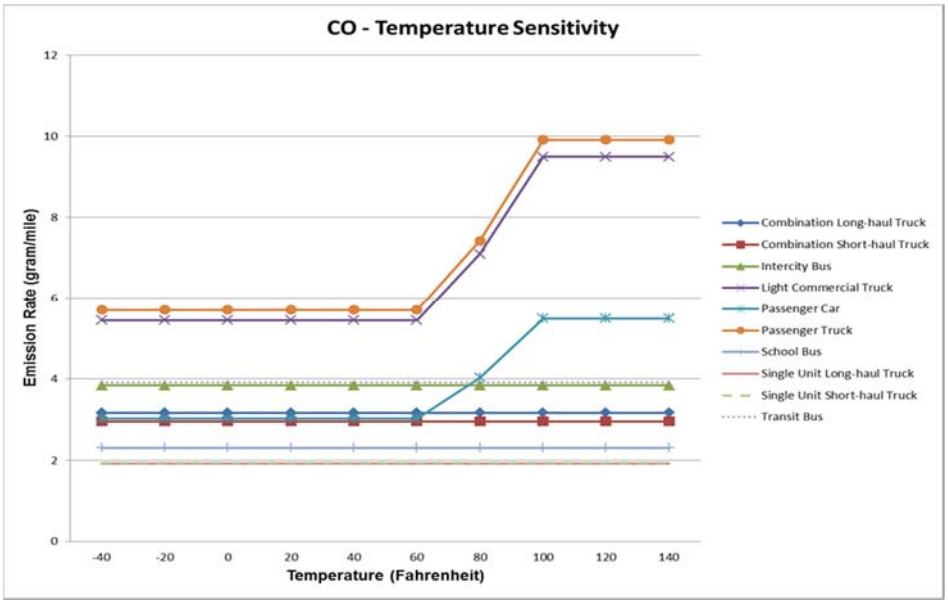


Figure 4 - Sensitivity of CO Emission Rates to Temperature

4.1.3 Link Source Type Hour Distribution

The national default Link Source Type Hour Distribution was obtained from a national scale MOVES run for the 2020 calendar year. Using the vehicle miles traveled (VMT) information from the 'movesActivityOutput' table within the output database, the Link Source Type Hour Distributions were transformed into a Source Type Hour Fraction for intersection, arterial, and freeway scenarios.

Gasoline vehicle types typically have higher CO emission rates compared to diesel vehicle types within MOVES. The Source Type Hour Fractions of heavy-duty trucks for the all road types were adjusted to yield higher CO emission rates. As a worst-case assumption, the Source Type Hour Fractions of short-haul and long-haul trucks were modeled as totaling 20% for all road types. Typically, most heavy-duty trucks will utilize diesel fuel. However, gasoline usage among heavy duty trucks produce significantly higher CO emission rates. In order to yield higher CO emission rates, and as an added worst-case assumption, <u>all</u> short and long-haul trucks were modeled as <u>gasoline powered</u>. It is also more likely that Single Unit Short-Haul and Single-Unit Long-Haul Trucks utilize gasoline than Combination Short-Haul Trucks (Gasoline Combination Long-Haul Trucks cannot be modeled in MOVES). As a further worst-case assumption, given that gasoline usage among Combination Short-Haul Trucks is extremely low and gasoline Combination Long-

[11] See http://ntl.bts.gov/lib/46000/46500/46598/DOT-VNTSC-FHWA-12-05.pdf and http://www.epa.gov/ttnchie1/conference/ei19/session6/choi.pdf

Haul Trucks are not modeled with MOVES, their Source Type Hour Fractions were set to zero for the all scenarios.

Single Unit Short-Haul Trucks have a significantly higher gasoline usage percentage than Single Unit Long-Haul Trucks. However, gasoline Single Unit Long-Haul Trucks have a significantly higher CO emission rate compared to gasoline Single Unit Short Haul Trucks. As another worst-case assumption, given these factors, a 50/50 proportional split between Single Unit Short-Haul Truck and Single Unit Long-Haul Trucks was assumed.

These two adjustments are reflected in Table 4 for the worst-case Link Source Type Hour Fractions utilized for the freeway, arterial, and intersection scenarios.

Table 4 – Worst-Case Link Source Type Hour Fractions

Source Type ID	Description	Source Type Hour Fraction			
		Rural Restricted Access	Rural Unrestricted Access	Urban Restricted Access	Urban Unrestricted Access
11	Motorcycle	0.005148815	0.006517137	0.004624823	0.005437676
21	Passenger Car	0.351670565	0.350773406	0.356868392	0.356671678
31	Passenger Truck	0.351670565	0.350773406	0.356868392	0.356671678
32	Light Commercial Truck	0.078288293	0.083983908	0.074416577	0.075599511
41	Intercity Bus	0.000886219	0.000596595	0.000521725	0.000449224
42	Transit Bus	0.001753513	0.001202121	0.001050873	0.000910747
43	School Bus	0.0048217	0.003306813	0.002890741	0.002505633
51	Refuse Truck	0.004170256	0.001595545	0.001659885	0.000819345
52*	Single Unit Short-haul Truck	0.1	0.1	0.1	0.1
53*	Single Unit Long-haul Truck	0.1	0.1	0.1	0.1
54	Motor Home	0.001590074	0.001251068	0.001098592	0.000934507
61*	Combination Short-haul Truck	0	0	0	0
62*	Combination Long-haul Truck	0	0	0	0

* Worst-case values were assumed for these inputs.

Table 5 lists the source type and fuel type combinations that were modeled in all scenarios. All fuel type and source type combinations were chosen in the runspec files to account for all VMT. There were not any electric or E-85 vehicles modeled.

Table 5 – Fuel Types Listed For Source Types

Source Types	Fuel Type(s)
Motorcycle	Gasoline
Passenger Car	Diesel Fuel, Gasoline, Electricity, Gasoline
Passenger Truck	Diesel Fuel, Gasoline, Electricity, Gasoline
Light Commercial Truck	Diesel Fuel, Gasoline, Electricity, Gasoline

Table 5 – Fuel Types Listed For Source Types

Refuse Truck	Diesel Fuel and Gasoline
Motor Home	Diesel Fuel and Gasoline
School Bus	Diesel Fuel and Gasoline
Transit Bus	Diesel Fuel, Gasoline, CNG
Intercity Bus	Diesel Fuel
Single Unit Short-haul Truck	Diesel Fuel and Gasoline
Single Unit Long-haul Truck	Diesel Fuel and Gasoline
Combination Short-haul Truck	Diesel Fuel and Gasoline
Combination Long-haul Truck	Diesel Fuel

4.1.4 Age Distribution

The 2020 national default age distribution was utilized and is consistent with the analysis year that was modeled.

4.1.5 Mileage Accumulation Rates

No adjustments were made to weight the modeled fleet average emission factor for CO based on annual average mileage accumulation rates by model year. The MOVES model does this for automatically for regional modeling but not for project-level. Weighting is needed as mileage accumulation rates tend to decline with vehicle age (older vehicles are driven less, on average), and newer vehicles are automatically set to comply with more stringent emission standards. As a result, unweighted fleet average emission factors for CO tend to be higher than emission factors weighted based on mileage accumulation. Therefore, the use of unweighted factors for this analysis serves as another worst-case modeling assumption.

4.1.6 Fuel Supply and Formulation

Fuel formulation parameters can significantly affect CO emission rates. The FHWA CF determined the effects of certain fuel parameters on CO emission rates. Fuel parameters that can affect CO emission rates include Reid vapor pressure (RVP), sulfur content, ethanol (ETOH), percent of fuel evaporated at 200° and 300° Fahrenheit (E200/E300), and distillation parameters T50 and T90. The FHWA CF found that fuel formulation ID 3812 yields higher CO emission rates than other relevant fuel formulations. As previously noted, for consistency, this study applied the same worst-case assumptions for certain inputs as the FHWA CF. Fuel formulation is one example where the inputs were made consistent. Table 6 lists the fuel formulation that was used in both the FHWA CF and this analysis.

Table 6 – Worst-Case Fuel formulation

Fuel Type	Fuel Formulation ID	RVP	Sulfur Content (ppm)	ETOH Volume	e200	e300	T50	T90
Diesel	20	0	11	0	0	0	-	-
Gasoline	3505	13.92	10	10	56.12	84.2	187.33	323.96
CNG	30	0	0	0	0	0	0	0

4.1.7 Link Average Speed and Operating Mode Distribution

When average speed is utilized in the 'Links' input file, entered through the MOVES' PDM, MOVES creates an operating mode distribution based upon the default drive schedules located in the default database. This operating mode distribution was used to represent the freeways, arterials and intersection scenarios. The speeds used in the analysis for each facility type are shown in **Table 3**.

4.1.8 Emissions Processes

The 'Running Exhaust' and 'Crankcase Running Exhaust' emissions process were utilized in the intersection, freeway, and arterial scenarios.

4.1.9 Inspection and Maintenance Program

An inspection and maintenance (I/M) program produces CO emissions rate benefits. As a worst-case assumption, emission reduction benefits that would be obtained from I/M programs were not included in this analysis.

4.2 Dispersion Modeling

The dispersion modeling was conducted following FHWA guidance on worst-case modeling as well as EPA's 1992 Guidance for CO determinations. The modeling was conducted using CAL3QHC (version 04244)[12], with the modeling inputs made consistent as noted above with the approach used by the FHWA CF (which was for intersections). As done for emissions modeling, the dispersion modeling used conservative and, in many cases, worst-case inputs and assumptions. The modeling approach is described in greater detail below for each facility type assessed in this document.

4.2.1 Intersections, Freeways, and Arterials

Table 7 provides a summary of those input parameters that are EPA CO screening values for near roadway dispersion modeling. Other inputs, or those that vary by facility type, are given in bullet format.

Table 7 – Simple Modeling Defaults for CAL3QHC

Source Types	Fuel Type(s)

[12] CAL3QHC modeling was completed without the use of FHWA's CAL3i graphical user interface.

Table 7 – Simple Modeling Defaults for CAL3QHC

Wind Speed	1.0 m/s
Wind Direction	Varying wind direction 0 to 350 degrees at 10-degree increments
Atmospheric Stability Class	Urban – stability Class D; Rural – Stability Class E
Mixing Height	1000 meters
Receptor Heights	1.8 meters

- For urban modeling, a surface roughness (z0) of 108 cm (3.54 ft) was used, corresponding to a single-family residential setting. The single-family residential setting is the least rough setting for an urban environment and is conservative. The recommended surface roughness in urban areas can vary from 108 to 370 cm (3.54 to 12.1 ft). For rural areas, a surface roughness of 1.0 cm (0.03 ft) was used, which corresponds to a moderately short grass height (6-8 cm; 0.20-0.26 ft) as identified in the Kansas prairie grass[13]. Shorter grass heights are unlikely to be found most rural locations.
- Receptor Placement
  - Freeways and Arterials:
    - Receptors were modeled per the CAL3QHC and 1992 EPA Guidance and were located starting at 20 feet from the outside lane for freeways to account for off-road safety clearance. Receptors were located starting at 10 feet from roadway edge for arterials (where the general public has access and within the limitations of the model to predict valid concentrations).
    - Receptors were evaluated perpendicular to and at the center of the defined link to avoid end effects.
    - Receptors were placed on both sides of the roadway at increments of 10 feet for freeways and 25 feet for arterials, extending out to 295 feet from the roadway. These were modeled to establish decreasing CO concentrations with distance from the roadway edge.
  - Intersections:
    - Receptors were modeled per the CAL3QHC and 1992 EPA Guidance and began at 10 feet from roadway edge.
    - Receptors were placed in each quadrant consistent with the 1992 CO Guideline[14]

[13] Businger, J.A., J.C. Wingaard, Y. U. Isumi and E. F. Bradley, 1971 "Flux Profile Relationships in the Atmospheric Surface Layer", *J. Atm Sci.,* 28:181-191.

[14] U.S. Environmental Protection Agency, Guideline for Modeling Carbon Monoxide from Roadway Intersections, EPA-454/R-92-005, Office of Air Quality Planning and Standards, November 1992.

to ensure the worst-case concentrations were identified. The closest receptor was grid spacing started at the corner, 10 feet from each roadway and then at 25 feet and 50 feet from the roadway edge (along the adjacent roadway leg), and at the mid-block position.

- Figure 5 shows a typical intersection receptor configuration with link geometry.

- Link Geometries and Traffic Activity Levels
  - Freeways and Arterials
    - Links 5,000 feet in length were evaluated to avoid end effects.
    - Freeway facilities were evaluated from 2 to 22 total lanes, in two lane increments. Arterials were evaluated from 2 to 12 total lanes, in two lane increments.
    - Median width was 3.3 feet for freeways and 0 feet for arterials
    - Lane width was 12 feet in all cases.
    - Traffic volumes were conservatively modeled as 2,400 vehicles-per-lane-per-hour for multi-lane freeways and 2,200 vehicles-per-lane-per-hour for multi-lane arterials. Two lane arterials and freeways were modeled at 1,700 vehicles-per-lane-per-hour.
    - Grades from ±0 to ±7 percent were modeled, with one leg uphill and one leg downhill.
    - Figure 6 shows a typical modeling scenario.
  - Intersections.
    - Approach and departure links extended 3,000 feet from the center of the intersection to ensure end effects at receptor locations are not encountered.
    - Links were input for the start and end locations per the guidance in the CAL3QHC User Manual. Figure 7 shows an example of the link placement for the six-lane intersection with 4 through lane and 2 left turn lanes per approach for a right-angle (90-degree skew) intersection.
    - Lane width was conservatively modeled as 11 feet in all cases.
    - In addition to the right-angle intersections, skew angles of 60°, 45°, 30°, and 15° angles were considered. Figure 8 shows this configuration for a 60-degree skew.
    - Queue lengths were determined by CAL3QHC internal algorithm.
    - Grades from ±0 to ±7 percent were modeled, with a side-of-a-hill configuration, where the northbound approach and the westbound approach are up hill.
    - Turn movement were 15% left turn and 5% right turn.
    - Signalization cycle length of 130 seconds with average green time length of 14

seconds for left turn and average green time length for right and through of 41 seconds

- Traffic volume of 2,640 vehicles per hour on each approach

4.2.2 Interchanges

Threshold PA CO concentration levels for the interchange configuration were analyzed using the MOVES and CALQHC models, with a combination of the grade separated intersection and freeway separated at various distances. A variable number of freeway lanes (even number of lanes ranging from 2 -12 lanes) were simulated. Likewise, various distances from the edge of the nearest freeway travel lane to the edge of the nearest travel lane of the interchange ramp (20, 30, 60, 80, 100, 125, 150, 175, 300, 500 and 1,000 feet) were simulated. The roadway link connecting the freeway to the intersection was modeled at skew angles of 90-, 60-, and 45-degree angles. Intersections were considered on either side of the freeway. Figure 8 shows the layout of the interchange for a 90-degree skew angle and with the intersection on the right side of the freeway. This modeling combines the impacts from the freeway and intersection modeling to determine the CO contribution for an interchange project for any given combination of the modeled number of freeway lanes and distances from the freeway to the interchange. That is, two separate modeling applications were conducted, and the results combined. Due to the skew angle, receptors for each cannot simply be added based on distance between the facility types. The results shown here represent a combination of the two facility types that considered receptor location, geometry (skew, left/right orientation, and distance between the facilities), road grade, setting (urban or rural) and wind directions in an R-based program that combined CAL3QHCR results with appropriate pairing and determined the overall peak concentrations from the combined facilities. Grade effects for the interchange were modeled for the non-freeway portion of the interchange from ±0 to ±7 percent grade. The total of the freeway contribution, intersection contribution, and background are to be directly compared to the CO NAAQS.

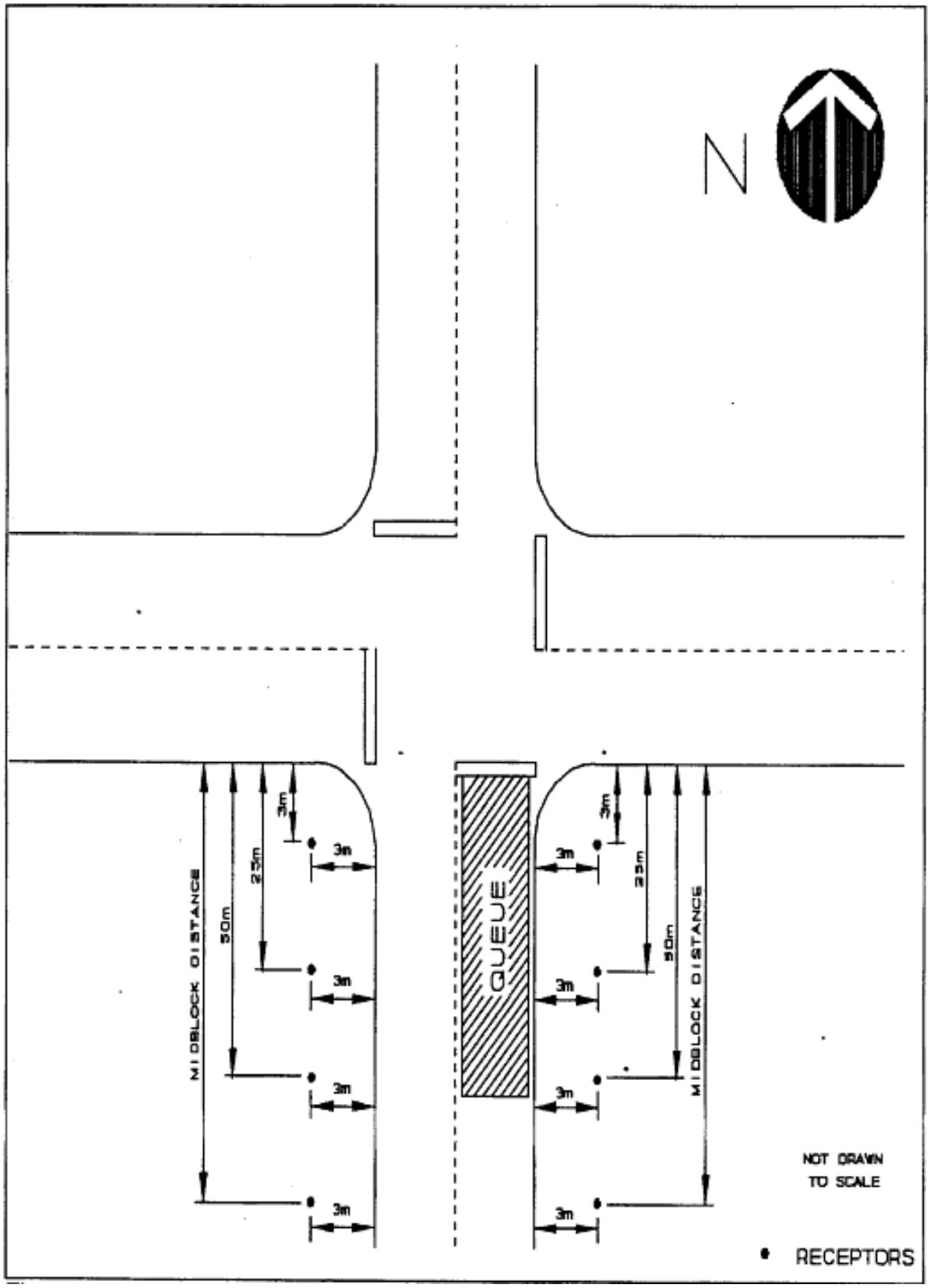


Figure 5 - Intersection configuration used for modeling with link placement

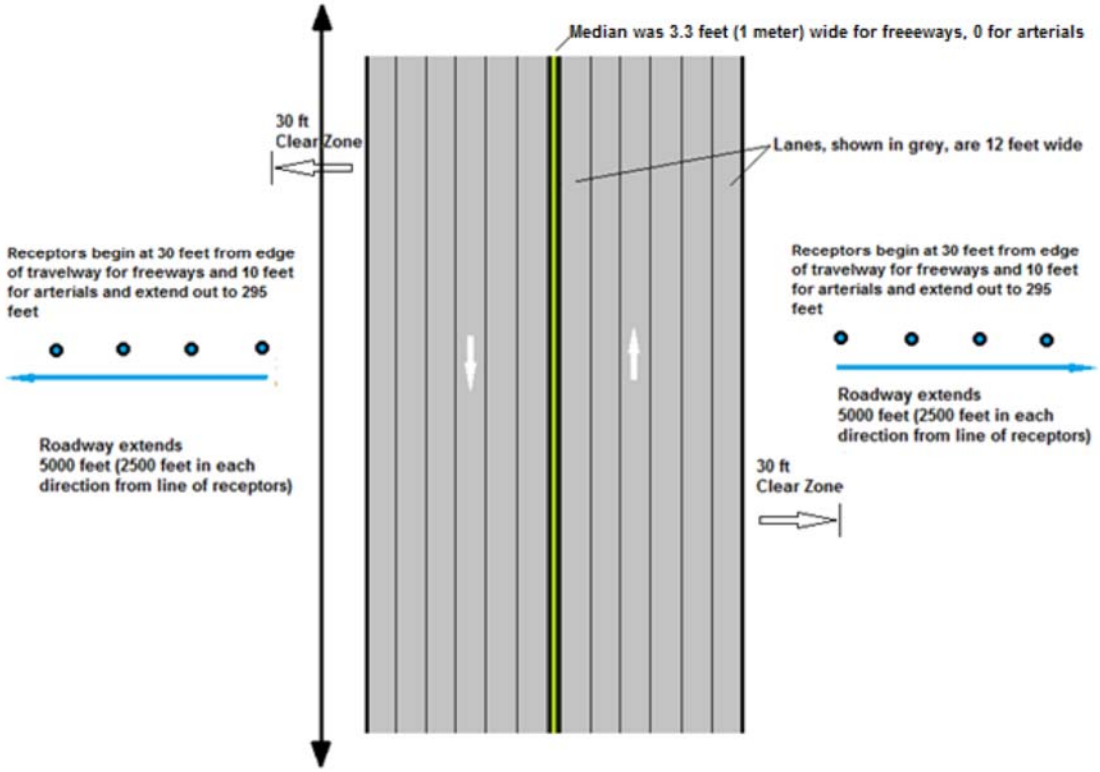
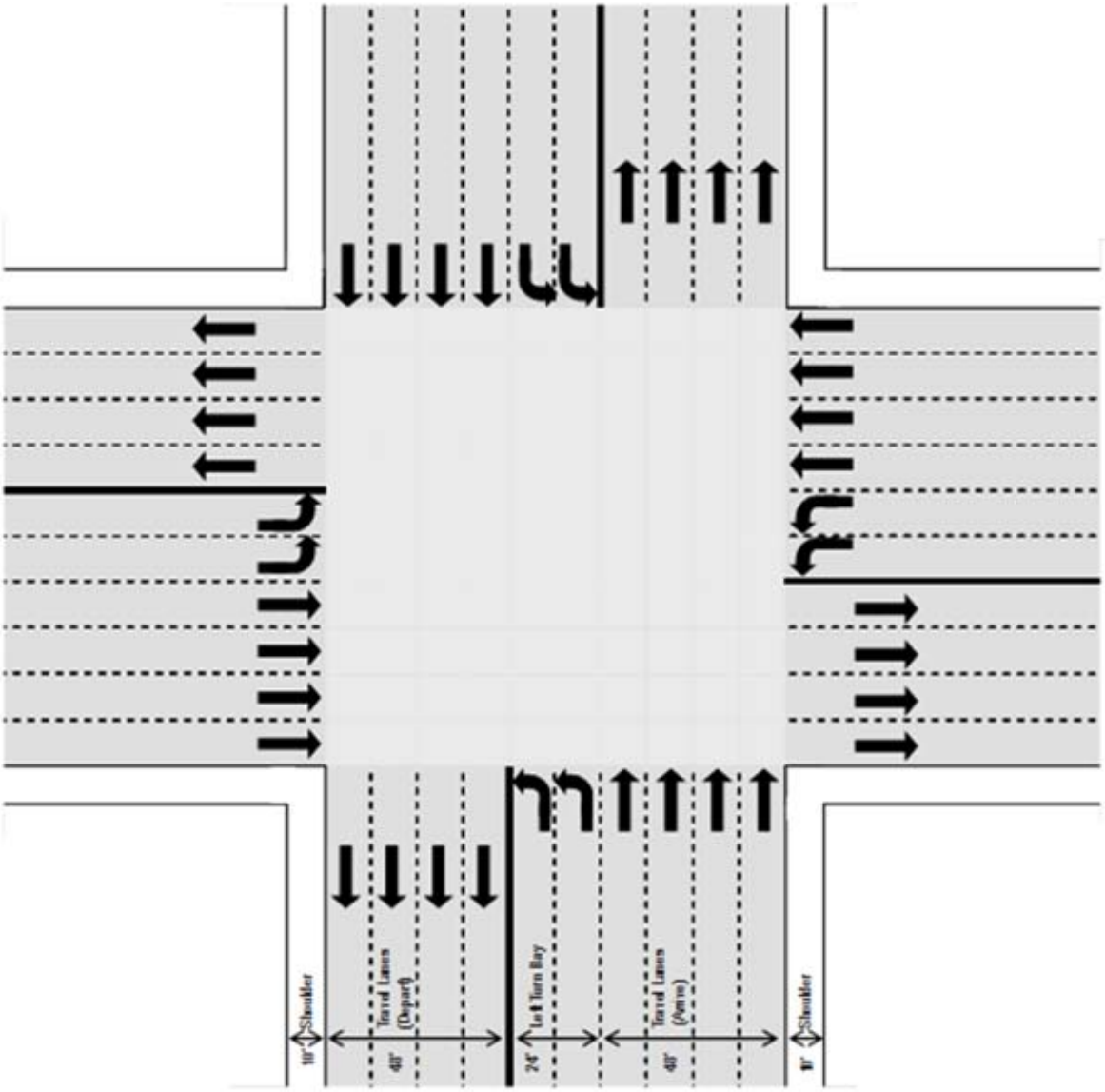


Figure 6 - Typical Modeling Layout for Freeways and Arterials



Note: Each oncoming direction has 4 approach and 2 left turn lanes as well as 4 departure lanes.

Figure 7 - Intersection Geometry Modeled

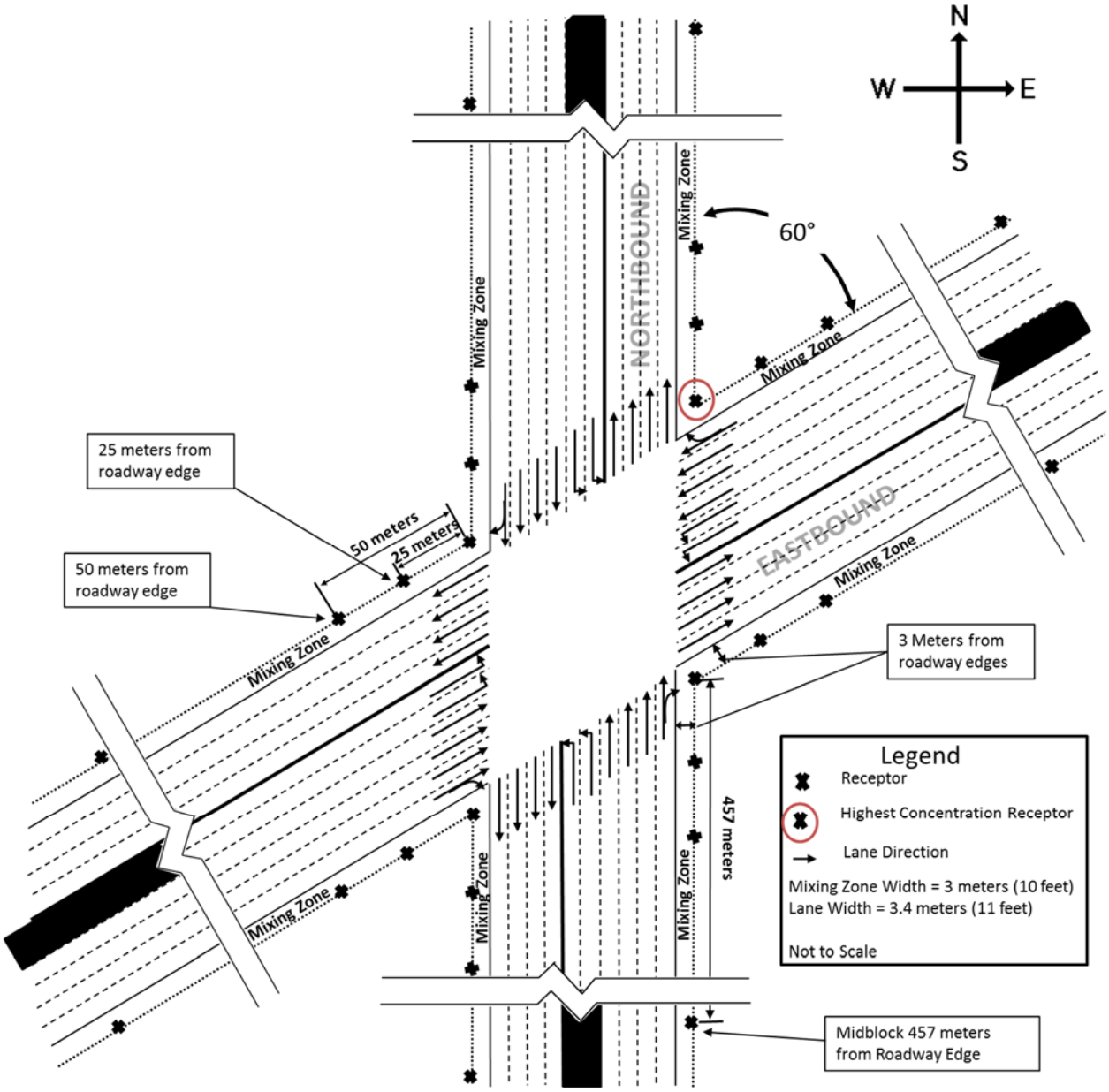


Figure 8 - Geometry Modeled for 60-degree Skew Intersection

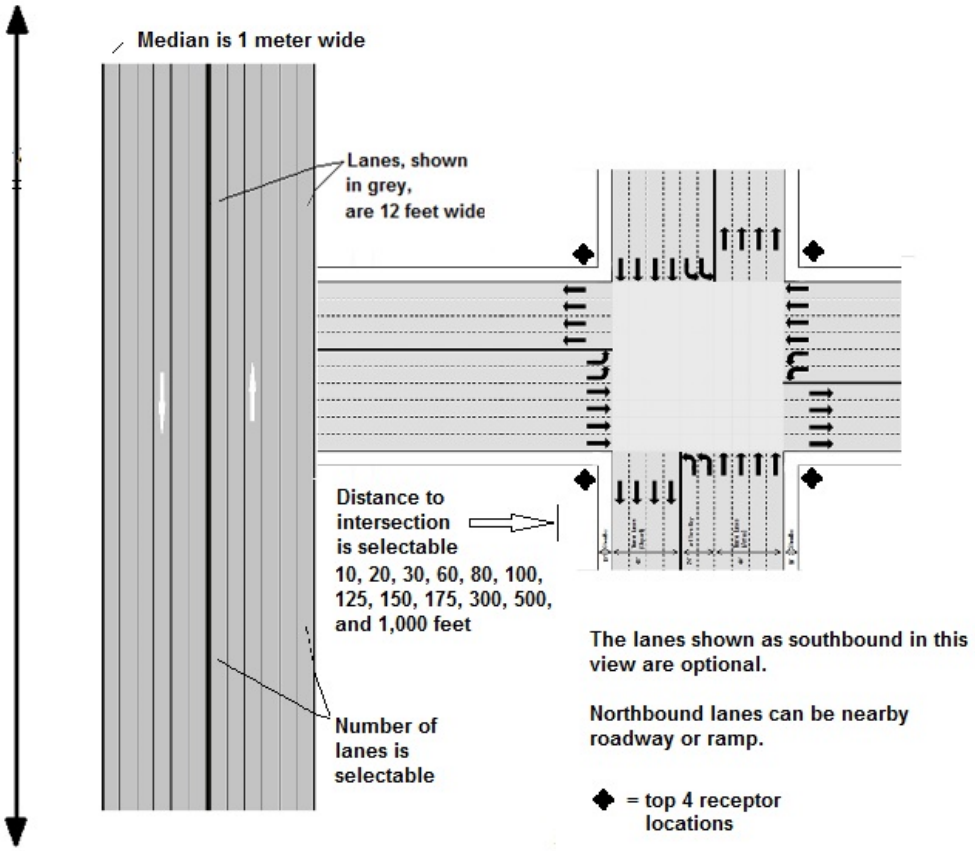


Figure 9 - Interchange Configuration with Nearby Freeway and Intersection/Ramp Layout

4.2.3 Background Concentrations

THE BACKGROUND DISCUSSION CAN EITHER USE THE FIRST PARAGRAPH IF STATE CO MONITORING DATA IS USED TO DETERMINE BACKGROUND OR THE SECOND PARAGRAPH WHICH USED THE NATIONAL BACKGROUND.

FOR STATE BACKGROUND

Background concentrations were determined from data collected over the previous calendar year by STATE AIR AGENCY operated ambient CO monitors. The 2nd highest non-overlapping representative monitored CO concentrations from the most recent calendar year was used to arrive at a background concentration value to be used for project analysis. This method produced a 1-hour background concentration of 4.4 ppm and an 8-hour background concentration of 2.4 ppm.

(Add state-specific text and tables as needed)

FOR NATIONAL BACKGROUND

To develop a realistic nationwide CO background concentration estimate, observed data for 8-hour and 1-hour average CO concentrations were extracted from EPA's AirData for each of the three most recent years (2014-2016). AirData is a database of air monitoring data. Datasets

representing the 1-hour average, 8-hour average, and annual summary statistics from all reporting sites are available.[15]

To determine a nationally representative background concentration, we chose a form consistent with the CO design value (the 2nd highest non-overlapping observed CO concentrations) and the form of the CO national ambient air quality standards (NAAQS) from each of the nation's CO monitoring stations. We determined the range of reported DVs from all stations in AirData, excluding those in Mexico and Puerto Rico, from 2014-2016. Table shows the 90th, 95th, and 99th percentiles from the reported DVs from each station in the record meeting a 75% data completeness threshold. To accommodate the recent trend and be consistent with the form of the DV, Table shows the maximum from the three most recent years for each of those percentages.

Based on this review, it was determined that a reasonably conservative value, applicable to almost any location nationwide, is the highest 95th percentile CO concentration from the past three years (Table 8). Using this value, the representative 1-hour background concentration was determined to be 4.4 ppm and the representative 8-hour background concentration was determined to be 2.4 ppm.

Table 8 – Nationwide Network of CO Monitoring Stations Ranked Concentrations 2014-2016

Percentile	2011	2012	2013	Highest
2nd High Maximum 8-hour CO Concentrations (ppm)				
99th	3.4	2.9	3.7	3.7
95th	2.4	2.3	2.2	2.4
90th	2.0	2.0	1.8	2.0
2nd High Maximum 1-hour CO Concentrations (ppm)				
99th	6.5	5.7	7.2	7.2
95th	4.3	4.4	4.2	4.4
90th	3.2	3.1	2.9	3.2

Source: USEPA AIRData (2018)

FUTURE BACKGROUND

For future years mobile sources are expected to remain the primary source of CO emissions nationwide. EPA provides for the option to adjust for future CO concentrations as a result of emissions rate changes in the mobile source fleet, Continued fleet turnover at a national level to vehicles constructed to more stringent EPA emission standards may reasonably be expected to result in reduced emission rates in the future. However, to preserve the conservative, "worst-case" approach, no reductions in future emission rates and background levels were assumed for this study. Thus, the results presented in the following Section are representative of years 2020 and later.

[15] This analysis was based on tabular pre-generated data files available at: https://aqs.epa.gov/aqsweb/airdata/download_files.html.

4.2.4 Persistence Factor

In order to compare results to the 8-hour CO standard, the total CO concentration for a given scenario is conservatively estimated by multiplying the 1-hour modeled project contribution CO concentration by the persistence factor and then adding the 8-hour CO background concentration:

$$Total\ 8-hour\ CO = 1-hour\ project\ contribution\ \ x\ \ persistence\ factor\ +\ 8-hour\ background$$

The persistence factor accounts for variability in traffic (i.e., less traffic during off peak hours) and meteorological conditions (i.e., changes in wind speed, wind direction, and temperature) between the 1-hour time frame and the 8-hour time frame. The persistence factor is the ratio between the maximum 1-hour concentration and the resulting maximum 8-hour concentration in the 8-hour time frame containing the maximum 1-hour concentration. The persistence factor recommended by EPA for a local area is derived from the average of the highest 10 non-overlapping 8-hour CO concentrations over the previous three years.

Where representative monitoring data is not available, EPA recommends the use of a persistence factor of 0.7. For this study, the persistence factor was determined from an examination of data from the ambient CO monitors operated by the STATE AIR AGENCY. Analysis following EPA methodology of CO monitoring data for the latest three years yielded a persistence factor of <value>. OR based on EPA recommended factor of 0.7 as local representative CO monitoring data were unavailable.

Examination of state or local air quality monitoring data may yield persistence factors that are different than the national default value of 0.7. If a state or local specific persistence factor is developed, it would be multiplied by the maximum 1-hour concentration and added to the state or local specific 8-hour background concentration to determine compliance with the 8-hour CO NAAQS.

4.3 Comparison with the CO NAAQS

Each scenario (facility type, configuration, and number of lanes, road grade and traffic volume) was modeled, and the results compared with the current 1- and 8-hour CO NAAQS to determine if the scenario met or exceeded the standards. The comparison began with project scenarios that yielded the highest modeled concentrations and were iterated downward to determine which scenario first passes. The results from the comparison are a set of tables which identify those projects which pass a specific scenario. These results are the basis for the highway project types and conditions identified in the programmatic agreement.

As the respective margin between background concentrations and the NAAQS are much higher for the 1-hour NAAQS than the 8-hour, the latter (8-hour) standard is controlling. As a result, projects are screened based on compliance with the 8-hour NAAQS.

To compare results to the 8-hour CO standard, the total CO concentration for a given scenario is derived by multiplying the 1-hour modeled CO concentration by the persistence factor and then adding the 8-hour CO background concentration, as follows.

$$Total\ 8-hour\ CO = 1-hour\ project\ contribution\ \ x\ \ persistence\ factor\ +\ 8-hour\ background$$

5. Results

Modeling results for the project types and conditions discussed above are presented here. Tables of results are presented in the Attachment to the TSD Section 6.1, below. In each case, scenarios that lead to project level exceedances with the modeling described in Section 4 are shown in red with the values crossed through.

5.1 Freeway and Arterials

Based on the MOVES2014a and CAL3QHC (version 04244) inputs and assumptions described above, the maximum 1-hour CO concentrations for urban and rural arterials and freeways were calculated for varying lane, urban or rural setting, and grade combinations. Table shows the lane and grade combinations for arterials and freeways in urban and rural locations that do not produce emissions sufficient to result in an exceedance of the 8-hour CO standard[16].

In all cases, the 8-hour CO standard is the limiting case. Thus, freeway and arterial projects with lane and grade conditions less than or equal to those shown as in compliance through Table 8 also do not require project-specific modeling to demonstrate compliance with the 1-hour CO ambient standard.

5.2 Intersections

Table , shows the maximum 1-hour CO concentrations for six approach lane (2 left turn lanes and 4 through lanes), urban and rural intersections that, with the applied, conservative 8-hour national CO background level of 2.4 ppm and persistence factor of 0.7, do not produce modeled CO concentrations that could result in exceedances of the 8-hour CO NAAQS. That is, intersection projects of this size or smaller, and with grade and skew angle less than or equal to the prescribed, would not result in an exceedance of the CO NAAQS. These results assume the same background and persistence factors previously discussed.

Intersections with posted speeds under 15 mph and/or with five or more legs are not covered by the PA, although they may be added in a future update.

5.3 Interchanges

Table 10 (a), (b), and (c), attached, show the one-hour CO concentrations for these interchange scenarios that, with the assumed 8-hour CO background level and persistence factor, do not produce modeled concentrations that would cause or contribute to an exceedance of the 8-hour CO ambient air standard (NAAQS) and therefore will not require project-specific CO modeling to demonstrate compliance with the ambient CO standards (NAAQS). Although intersections were considered on either side of the freeway, Table 10, only reports the higher of these. The same speed limitations for freeways and arterials from above also apply here.

The intersection geometry is the same as in the intersection case, with six lanes on each approach (4 approach, 2 left turn) and 4 departure lanes, with grades from 0 to 7 percent. This is a conservative approach for this type of project because freeway interchanges generally have a one-

[16] Based on an 8-hour CO background concentration of 2.4 ppm and a persistence factor of 0.7

or two-lane ramp approaching or departing from the intersection. The freeway was modeled at a 0% grade. Both rural and urban locations were modeled.

The table columns represent varying distances from the edge of the nearest freeway travel lane to the edge of the nearest parallel roadway. For the 90-degree skew case, this is also the length of the interchange ramp. The table rows represent the setting (urban or rural), varying numbers of travel lanes on the freeway, and the skew angle of the interchange ramp.

Thus, a rural interchange with a 2-lane freeway and an adjacent intersection that is located not less than 20 feet from the nearest edge of the freeway lanes, connected with a 45 degree angled road segment, and has an intersection grade of 3 percent or less has a one-hour concentration listed of 8.1 ppm. Since a concentration is listed for this project configuration, it does not exceed the 8-hour CO standard and therefore does not require project-specific CO modeling to demonstrate compliance with the ambient CO standards.

6. Project Documentation and Other Terms of Agreement

For the project types and conditions listed above, the project environmental documentation will not require a quantitative air quality analysis for CO., highway projects that meet the above-listed project conditions and types may address air quality requirements qualitatively with statements such as:

> "The proposed project does not exceed the project types and conditions listed in the Programmatic Agreement between the Federal Highway Administration and the STATE Department of Transportation for streamlining the project-level air quality analysis process for carbon monoxide. Modeling using "worst-case" parameters has been conducted for these project types and conditions. It has been determined that projects, such as this one, for which the conditions are not exceeded, would not significantly impact air quality and would not cause or contribute to a new violation, increase the frequency or severity of an existing violation, or delay timely attainment of the National Ambient Air Quality Standards for carbon monoxide."

Or

> "An air quality analysis is not necessary as this project will not increase traffic volumes, reduce source-receptor distances, or change other existing conditions to such a degree as to jeopardize attainment of the National Ambient Air Quality Standards for carbon monoxide."

The technical analysis to support the Programmatic Agreement between the STATE Division of FHWA and the STATE Department of Transportation only extends to the project types and conditions listed above. Projects of different types or project having substantially different conditions may require project-specific modeling to document compliance with the CO NAAQS.

The STATE Department of Transportation will coordinate with STATE Division of FHWA (and the STATE AIR QUALITY AGENCY) when underlying assumptions related to the Programmatic Agreement may change. This could include, but is not limited to:

- Project types and/or conditions not covered by the Programmatic Agreement;

- Updates to emission or dispersion models or release of new, relevant models;
- Updates to model inputs and/or planning assumptions

6.1 Attachment to the Technical Support Document

Table 8 – One-hour CO Concentrations (ppm) for Freeways and Arterials[a] in Urban and Rural Locations of Varying Lane and Grade Configuration (not including background concentrations)

Facility Type	Location	Number of Lanes	Grade (Percent)							
			0	1	2	3	4	5	6	7
Arterials	Rural	2	3	3	3.3	3.4	3.7	4	4.4	4.8
Arterials	Rural	4	6.5	6.9	7.3	7.7	8.4	9	~~9.9~~	~~10.5~~
Arterials	Rural	6	8.7	9.3	~~9.9~~	~~10.5~~	~~11.4~~	~~12.3~~	~~13.4~~	~~14.6~~
Arterials	Rural	8	~~10.7~~	~~11.3~~	~~12.1~~	~~12.8~~	~~14~~	~~15.1~~	~~16.5~~	~~17.9~~
Arterials	Rural	10	~~12.3~~	~~13.1~~	~~14.1~~	~~15~~	~~16.2~~	~~17.6~~	~~19.2~~	~~20.8~~
Arterials	Rural	12	~~13.6~~	~~14.6~~	~~15.8~~	~~16.7~~	~~18.2~~	~~19.7~~	~~21.6~~	~~23.4~~
Arterials	Urban	2	1.8	1.9	2.1	2.1	2.3	2.4	2.7	2.8
Arterials	Urban	4	4	4.3	4.6	4.9	5.2	5.7	6.2	6.7
Arterials	Urban	6	5.5	5.7	6.2	6.7	7.2	7.7	8.5	9.2
Arterials	Urban	8	6.6	7.1	7.6	8.1	8.8	~~9.6~~	~~10.5~~	~~11.4~~
Arterials	Urban	10	7.5	8.2	8.8	9.4	~~10.3~~	~~11.1~~	~~12.3~~	~~13.3~~
Arterials	Urban	12	8.4	9.1	~~9.8~~	~~10.5~~	~~11.5~~	~~12.5~~	~~13.8~~	~~15~~
Freeways	Rural	2	1.4	1.7	1.9	2.1	2.4	2.8	3	3.2
Freeways	Rural	4	3.7	4.2	5	5.7	6.6	7.5	8.2	8.6
Freeways	Rural	6	5.3	6.1	7.1	8.2	~~9.5~~	~~10.8~~	~~11.8~~	~~12.4~~
Freeways	Rural	8	6.6	7.6	9.2	~~10.6~~	~~12.2~~	~~13.9~~	~~15.2~~	~~16.1~~
Freeways	Rural	10	7.8	9.1	~~10.9~~	~~12.6~~	~~14.7~~	~~16.7~~	~~18.3~~	~~19.3~~
Freeways	Rural	12	8.9	~~10.4~~	~~12.5~~	~~14.6~~	~~16.9~~	~~19.3~~	~~21.1~~	~~22.4~~
Freeways	Rural	14	~~9.8~~	~~11.5~~	~~13.9~~	~~16.3~~	~~18.9~~	~~21.6~~	~~23.7~~	~~25~~
Freeways	Rural	16	~~10.7~~	~~12.6~~	~~15.2~~	~~17.8~~	~~20.7~~	~~23.6~~	~~25.9~~	~~27.4~~
Freeways	Rural	18	~~11.3~~	~~13.6~~	~~16.4~~	~~19.1~~	~~22.3~~	~~25.6~~	~~28~~	~~29.6~~
Freeways	Rural	20	~~12~~	~~14.3~~	~~17.5~~	~~20.4~~	~~23.7~~	~~27.2~~	~~29.8~~	~~31.6~~
Freeways	Rural	22	~~12.5~~	~~15.1~~	~~18.4~~	~~21.5~~	~~25.1~~	~~28.7~~	~~31.6~~	~~33.5~~
Freeways	Urban	2	0.9	1	1.1	1.3	1.5	1.7	1.9	1.9
Freeways	Urban	4	2.3	2.6	3.1	3.6	4.1	4.7	5.2	5.5
Freeways	Urban	6	3.2	3.7	4.5	5.2	6	6.9	7.6	8
Freeways	Urban	8	4	4.8	5.8	6.7	7.8	8.9	~~9.7~~	~~10.4~~
Freeways	Urban	10	4.8	5.7	6.8	8	9.3	~~10.7~~	~~11.8~~	~~12.4~~
Freeways	Urban	12	5.4	6.5	7.8	9.2	~~10.7~~	~~12.3~~	~~13.5~~	~~14.3~~
Freeways	Urban	14	5.9	7.2	8.8	~~10.3~~	~~11.9~~	~~13.8~~	~~15.1~~	~~16~~
Freeways	Urban	16	6.4	7.8	~~9.5~~	~~11.2~~	~~13.1~~	~~15~~	~~16.5~~	~~17.5~~
Freeways	Urban	18	6.9	8.4	~~10.3~~	~~12.1~~	~~14.1~~	~~16.2~~	~~17.8~~	~~18.9~~
Freeways	Urban	20	7.2	8.9	~~10.9~~	~~12.9~~	~~15~~	~~17.2~~	~~19~~	~~20.1~~

Table 8 – One-hour CO Concentrations (ppm) for Freeways and Arterials[a] in Urban and Rural Locations of Varying Lane and Grade Configuration (not including background concentrations)

Freeways	Urban	22	7.5	9.3	~~11.5~~	~~13.5~~	~~15.8~~	~~18.2~~	~~20~~	~~21.2~~

Notes: Red strikethrough values indicated exceedances of the standard.

[a] These findings apply to scenarios with average speed ranging from 15 to 56 mph for arterials and 19 to 75 mph for freeways, for which posted speeds in this range may be applied as a reasonable proxy.

Table 9 – One-Hour CO Concentrations (not including background concentrations) for Rural and Urban Intersections[b] at Varying Skew Angles and Intersection Grades for a Six Approach Lane Intersection

Location	Skew Angle	Grade (Percent)							
		0	1	2	3	4	5	6	7
Rural	15	8.6	9.1	~~9.8~~	~~10.2~~	~~11.1~~	~~11.9~~	~~13~~	~~13.9~~
Rural	30	6.3	6.7	7.1	7.5	8.2	8.8	9.4	~~10.1~~
Rural	45	6.2	6.4	6.9	7.2	7.8	8.4	9	~~9.9~~
Rural	60	5.6	5.9	6.2	6.5	7	7.5	8	8.7
Rural	90	5.4	5.6	6	6.3	6.8	7.3	7.8	8.4
Urban	15	4.7	4.9	5.3	5.6	6.1	6.7	7.1	7.7
Urban	30	4.5	4.8	5	5.5	6.1	6.4	6.7	7.2
Urban	45	4.1	4.4	4.6	4.8	5.2	5.7	6.2	6.5
Urban	60	3.8	4.1	4.3	4.5	5	5.3	5.9	6.3
Urban	90	3.6	3.9	4.1	4.3	4.5	5	5.4	5.9

Notes: Red strikethrough values indicated exceedances of the standard.

[b] These findings apply to scenarios with average speed ranging from 15 to 45 mph for intersections, for which posted speeds in this range may be applied as a reasonable proxy

Table 10(a) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 45° Skew Angle (not including background concentrations)[c]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	2	0%	6.9	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.2
Rural	2	1%	7.3	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.5
Rural	2	2%	7.7	7.3	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
Rural	2	3%	8.1	7.6	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
Rural	2	4%	8.5	8.1	8	8	8	8	8	8	8	8	7.9
Rural	2	5%	8.9	8.8	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6
Rural	2	6%	~~9.7~~	9.4	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Rural	2	7%	~~10.3~~	~~10.3~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~	~~10.1~~
Rural	4	0%	9.4	7.9	7.1	7	6.9	6.8	6.8	6.8	6.6	6.6	6.4
Rural	4	1%	~~9.8~~	8.3	7.3	7.2	7.1	7	7	7	6.9	6.8	6.7
Rural	4	2%	~~10.2~~	8.7	7.7	7.7	7.7	7.6	7.5	7.5	7.5	7.3	7.3
Rural	4	3%	~~10.6~~	9.1	8	8	8	7.9	7.8	7.8	7.8	7.6	7.6
Rural	4	4%	~~11~~	~~9.5~~	8.5	8.5	8.5	8.4	8.4	8.4	8.3	8.2	8.1
Rural	4	5%	~~11.4~~	~~9.9~~	9.2	9.2	9.2	9.1	9	9	9	8.8	8.8
Rural	4	6%	~~12.2~~	~~10.7~~	~~9.8~~	~~9.8~~	~~9.8~~	~~9.7~~	~~9.6~~	~~9.6~~	~~9.6~~	9.4	9.4
Rural	4	7%	~~12.7~~	~~11.2~~	~~10.7~~	~~10.7~~	~~10.7~~	~~10.6~~	~~10.5~~	~~10.5~~	~~10.5~~	~~10.3~~	~~10.3~~
Rural	6	0%	~~10.5~~	8.7	7.7	7.6	7.5	7.3	7.2	7.2	6.9	6.8	6.6
Rural	6	1%	~~10.9~~	9.1	7.9	7.8	7.7	7.5	7.4	7.4	7.1	7	6.8
Rural	6	2%	~~11.3~~	~~9.5~~	8.3	8.2	8.1	7.9	7.9	7.9	7.7	7.5	7.3
Rural	6	3%	~~11.7~~	~~9.9~~	8.6	8.5	8.4	8.2	8.2	8.2	8	7.8	7.6
Rural	6	4%	~~12.1~~	~~10.3~~	9.1	9	8.9	8.8	8.8	8.8	8.5	8.4	8.2
Rural	6	5%	~~12.5~~	~~10.7~~	~~9.7~~	~~9.5~~	~~9.5~~	9.4	9.4	9.4	9.2	9	8.8
Rural	6	6%	~~13.3~~	~~11.5~~	~~10.3~~	~~10.1~~	~~10.1~~	~~10~~	~~10~~	~~10~~	~~9.8~~	~~9.6~~	9.4
Rural	6	7%	~~13.8~~	~~12~~	~~11.2~~	~~11~~	~~11~~	~~10.9~~	~~10.9~~	~~10.9~~	~~10.7~~	~~10.5~~	~~10.3~~
Rural	8	0%	~~11.4~~	9.4	8.3	8.1	8	7.8	7.6	7.4	7.3	7	6.8

Table 10(a) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 45° Skew Angle (not including background concentrations)[c]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	8	1%	~~11.8~~	~~9.8~~	8.5	8.3	8.2	8	7.8	7.6	7.5	7.2	7
Rural	8	2%	~~12.2~~	~~10.2~~	8.9	8.7	8.6	8.4	8.2	8.1	8	7.8	7.5
Rural	8	3%	~~12.6~~	~~10.6~~	9.2	9	8.9	8.7	8.5	8.4	8.3	8.1	7.8
Rural	8	4%	~~13~~	~~11~~	~~9.7~~	~~9.5~~	9.4	9.2	9	9	8.9	8.6	8.4
Rural	8	5%	~~13.4~~	~~11.4~~	~~10.2~~	~~10~~	~~9.9~~	~~9.7~~	~~9.7~~	~~9.6~~	~~9.5~~	9.3	9
Rural	8	6%	~~14.2~~	~~12.2~~	~~10.8~~	~~10.6~~	~~10.5~~	~~10.3~~	~~10.3~~	~~10.2~~	~~10.1~~	~~9.9~~	~~9.6~~
Rural	8	7%	~~14.7~~	~~12.7~~	~~11.6~~	~~11.5~~	~~11.4~~	~~11.2~~	~~11.2~~	~~11.1~~	~~11~~	~~10.8~~	~~10.5~~
Rural	10	0%	~~12~~	~~9.9~~	8.8	8.6	8.4	8.1	7.9	7.7	7.4	7.2	7
Rural	10	1%	~~12.4~~	~~10.3~~	9	8.8	8.6	8.3	8.1	7.9	7.7	7.4	7.2
Rural	10	2%	~~12.8~~	~~10.7~~	9.4	9.2	9	8.7	8.6	8.4	8.3	7.9	7.7
Rural	10	3%	~~13.2~~	~~11.1~~	~~9.7~~	~~9.5~~	9.3	9	8.9	8.7	8.6	8.2	8
Rural	10	4%	~~13.6~~	~~11.5~~	~~10.2~~	~~10~~	~~9.8~~	~~9.5~~	9.4	9.2	9.1	8.8	8.6
Rural	10	5%	~~14~~	~~11.9~~	~~10.7~~	~~10.5~~	~~10.3~~	~~10.2~~	~~10.1~~	~~9.9~~	~~9.8~~	9.4	9.2
Rural	10	6%	~~14.8~~	~~12.7~~	~~11.3~~	~~11.1~~	~~10.9~~	~~10.8~~	~~10.7~~	~~10.5~~	~~10.4~~	~~10~~	~~9.8~~
Rural	10	7%	~~15.3~~	~~13.2~~	~~12~~	~~11.8~~	~~11.8~~	~~11.7~~	~~11.6~~	~~11.4~~	~~11.3~~	~~10.9~~	~~10.7~~
Rural	12	0%	~~12.6~~	~~11~~	9.3	9.1	8.8	8.5	8.2	8	7.6	7.5	7.1
Rural	12	1%	~~13~~	~~11.1~~	~~9.5~~	9.3	9	8.7	8.4	8.3	7.9	7.7	7.3
Rural	12	2%	~~13.4~~	~~11.1~~	~~9.9~~	~~9.7~~	9.4	9.1	8.9	8.9	8.5	8.2	7.9
Rural	12	3%	~~13.8~~	~~11.4~~	~~10.2~~	~~10~~	~~9.7~~	9.4	9.2	9.2	8.8	8.5	8.2
Rural	12	4%	~~14.2~~	~~11.8~~	~~10.7~~	~~10.5~~	~~10.2~~	~~9.9~~	~~9.7~~	~~9.7~~	9.3	9.1	8.7
Rural	12	5%	~~14.6~~	~~12.2~~	~~11.2~~	~~11~~	~~10.7~~	~~10.5~~	~~10.4~~	~~10.4~~	~~10~~	~~9.7~~	9.4
Rural	12	6%	~~15.4~~	~~13~~	~~11.8~~	~~11.6~~	~~11.3~~	~~11.1~~	~~11~~	~~11~~	~~10.6~~	~~10.3~~	~~10~~
Rural	12	7%	~~15.9~~	~~13.5~~	~~12.5~~	~~12.3~~	~~12.2~~	~~12~~	~~11.9~~	~~11.9~~	~~11.5~~	~~11.2~~	~~10.9~~
Urban	2	0%	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.2	4.1	4.1
Urban	2	1%	4.8	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.4	4.4

Table 10(a) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 45° Skew Angle (not including background concentrations)[c]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Urban	2	2%	5.1	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.8	4.6	4.6
Urban	2	3%	5.3	5.1	5	5	5	5	5	5	4.9	4.8	4.8
Urban	2	4%	5.7	5.5	5.4	5.4	5.4	5.4	5.4	5.4	5.3	5.2	5.2
Urban	2	5%	6.2	6	5.9	5.9	5.9	5.9	5.9	5.9	5.8	5.7	5.7
Urban	2	6%	6.7	6.5	6.4	6.4	6.4	6.4	6.4	6.4	6.3	6.2	6.2
Urban	2	7%	7	6.8	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.5	6.5
Urban	4	0%	5.9	5.2	4.7	4.7	4.6	4.6	4.5	4.5	4.4	4.3	4.2
Urban	4	1%	6.2	5.5	5	5	5	5	4.9	4.8	4.8	4.6	4.6
Urban	4	2%	6.5	5.8	5.2	5.2	5.2	5.2	5.1	5	5	4.8	4.8
Urban	4	3%	6.7	6	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5	4.9
Urban	4	4%	6.9	6.2	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.4	5.3
Urban	4	5%	7.3	6.6	6.3	6.3	6.2	6.2	6.1	6.1	6	5.9	5.8
Urban	4	6%	7.8	7.1	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.4	6.3
Urban	4	7%	8.2	7.5	7.1	7.1	7.1	7.1	7	6.9	6.9	6.7	6.7
Urban	6	0%	6.8	5.9	5	5	4.9	4.8	4.8	4.7	4.6	4.4	4.2
Urban	6	1%	7.1	6.2	5.3	5.3	5.2	5.2	5.2	5.1	5	4.8	4.6
Urban	6	2%	7.4	6.5	5.5	5.5	5.4	5.4	5.4	5.3	5.2	5	4.8
Urban	6	3%	7.6	6.7	5.7	5.7	5.6	5.5	5.5	5.5	5.3	5.1	4.9
Urban	6	4%	7.8	6.9	6.1	6.1	6	5.9	5.9	5.8	5.7	5.5	5.3
Urban	6	5%	8.2	7.3	6.6	6.6	6.5	6.4	6.4	6.3	6.2	6	5.8
Urban	6	6%	8.7	7.8	7.1	7.1	7	6.9	6.9	6.8	6.7	6.5	6.3
Urban	6	7%	9.1	8.2	7.4	7.4	7.3	7.3	7.3	7.2	7.1	6.9	6.7
Urban	8	0%	7.4	6.4	5.3	5.3	5.2	5.1	5	5	4.8	4.6	4.4
Urban	8	1%	7.7	6.7	5.7	5.7	5.5	5.5	5.4	5.4	5.2	5	4.8
Urban	8	2%	8	7	5.9	5.9	5.7	5.7	5.6	5.6	5.4	5.2	5

Table 10(a) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 45° Skew Angle (not including background concentrations)[c]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Urban	8	3%	8.2	7.2	6	6	5.9	5.8	5.8	5.7	5.5	5.3	5.1
Urban	8	4%	8.4	7.4	6.4	6.4	6.3	6.2	6.1	6.1	5.9	5.7	5.5
Urban	8	5%	8.8	7.8	6.9	6.9	6.8	6.7	6.6	6.6	6.4	6.2	6
Urban	8	6%	9.3	8.3	7.4	7.4	7.3	7.2	7.1	7.1	6.9	6.7	6.5
Urban	8	7%	~~9.7~~	8.7	7.8	7.8	7.6	7.6	7.5	7.5	7.3	7.1	6.9
Urban	10	0%	7.9	7.2	5.6	5.5	5.5	5.3	5.3	5.2	5	4.7	4.4
Urban	10	1%	8.2	7.4	6	5.9	5.9	5.7	5.7	5.6	5.4	5.1	4.8
Urban	10	2%	8.5	7.5	6.2	6.1	6.1	5.9	5.9	5.8	5.6	5.3	5
Urban	10	3%	8.7	7.7	6.4	6.3	6.2	6.1	6	6	5.7	5.4	5.1
Urban	10	4%	8.9	7.9	6.7	6.6	6.6	6.4	6.4	6.3	6.1	5.8	5.5
Urban	10	5%	9.3	8.2	7.2	7.1	7.1	6.9	6.9	6.8	6.6	6.3	6
Urban	10	6%	~~9.8~~	8.7	7.7	7.6	7.6	7.4	7.4	7.3	7.1	6.8	6.5
Urban	10	7%	~~10.2~~	9.1	8.1	8	8	7.8	7.8	7.7	7.5	7.2	6.9
Urban	12	0%	8.6	7.8	6	5.8	5.7	5.6	5.5	5.5	5.1	4.9	4.4
Urban	12	1%	8.8	8	6.4	6.2	6.1	6	5.9	5.9	5.5	5.3	4.8
Urban	12	2%	9	8.1	6.6	6.4	6.3	6.2	6.1	6.1	5.7	5.5	5
Urban	12	3%	9.2	8.3	6.7	6.6	6.5	6.4	6.3	6.2	5.8	5.6	5.1
Urban	12	4%	9.4	8.5	7.1	6.9	6.8	6.7	6.6	6.6	6.2	6	5.5
Urban	12	5%	~~9.8~~	8.8	7.6	7.4	7.3	7.2	7.1	7.1	6.7	6.5	6
Urban	12	6%	~~10.3~~	9.2	8.1	7.9	7.8	7.7	7.6	7.6	7.2	7	6.5
Urban	12	7%	~~10.7~~	~~9.6~~	8.5	8.3	8.2	8.1	8	8	7.6	7.4	6.9

Notes: Red strikethrough values indicated exceedances of the standard

c. These findings apply to scenarios with the intersection average speed ranging from 15 to 45 mph and the freeway average speed ranging from 19 to 75 mph, for which posted speeds in these ranges may be applied as reasonable proxies

Table 10(b) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 60° Skew Angle (not including background concentrations)[d]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	2	0%	6.7	6.2	6	6	6	6	6	5.9	5.8	5.6	5.6
Rural	2	1%	7	6.5	6.3	6.3	6.3	6.3	6.3	6.2	6.1	5.9	5.9
Rural	2	2%	7.4	6.8	6.6	6.6	6.6	6.6	6.6	6.5	6.4	6.2	6.2
Rural	2	3%	7.8	7.1	6.9	6.9	6.9	6.9	6.9	6.8	6.7	6.5	6.5
Rural	2	4%	8.2	7.6	7.4	7.4	7.4	7.4	7.4	7.3	7.2	7	7
Rural	2	5%	8.8	8.1	7.9	7.9	7.9	7.9	7.9	7.8	7.7	7.5	7.5
Rural	2	6%	9.4	8.7	8.4	8.4	8.4	8.4	8.4	8.3	8.2	8	8
Rural	2	7%	~~9.9~~	9.3	9.1	9.1	9.1	9.1	9.1	9	8.9	8.7	8.7
Rural	4	0%	9.1	7.6	6.9	6.8	6.7	6.6	6.5	6.4	6	5.8	5.6
Rural	4	1%	9.4	7.9	7.2	7.1	7	6.9	6.8	6.7	6.3	6.1	5.9
Rural	4	2%	~~9.8~~	8.3	7.5	7.4	7.3	7.2	7.1	7	6.6	6.4	6.2
Rural	4	3%	~~10.2~~	8.7	7.8	7.7	7.6	7.5	7.4	7.3	6.9	6.7	6.5
Rural	4	4%	~~10.6~~	9.1	8.3	8.2	8.1	8	7.9	7.8	7.4	7.2	7
Rural	4	5%	~~11.2~~	~~9.7~~	8.8	8.7	8.6	8.5	8.4	8.3	7.9	7.7	7.5
Rural	4	6%	~~11.8~~	~~10.3~~	9.3	9.2	9.1	9	8.9	8.8	8.4	8.2	8
Rural	4	7%	~~12.3~~	~~10.8~~	~~10~~	~~9.9~~	~~9.8~~	~~9.7~~	~~9.6~~	~~9.5~~	9.1	8.9	8.7
Rural	6	0%	~~10.3~~	8.5	7.5	7.4	7.3	7.1	6.9	6.7	6.3	6	5.8
Rural	6	1%	~~10.6~~	8.8	7.8	7.7	7.6	7.4	7.2	7	6.6	6.3	6.1
Rural	6	2%	~~11~~	9.2	8.1	8	7.9	7.7	7.5	7.3	6.9	6.6	6.4
Rural	6	3%	~~11.4~~	~~9.6~~	8.4	8.3	8.2	8	7.8	7.6	7.2	6.9	6.7
Rural	6	4%	~~11.8~~	~~10~~	8.9	8.8	8.7	8.5	8.3	8.1	7.7	7.4	7.2
Rural	6	5%	~~12.4~~	~~10.6~~	9.4	9.3	9.2	9	8.8	8.6	8.2	7.9	7.7
Rural	6	6%	~~13~~	~~11.2~~	~~9.9~~	~~9.8~~	~~9.7~~	~~9.5~~	9.3	9.1	8.7	8.4	8.2
Rural	6	7%	~~13.5~~	~~11.7~~	~~10.6~~	~~10.5~~	~~10.4~~	~~10.2~~	~~10~~	~~9.8~~	9.4	9.1	8.9
Rural	8	0%	~~11.1~~	9.2	8.1	7.9	7.8	7.6	7.4	7.2	6.5	6.2	6

Table 10(b) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 60° Skew Angle (not including background concentrations)[d]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	8	1%	~~11.4~~	~~9.5~~	8.4	8.2	8.1	7.9	7.7	7.5	6.8	6.5	6.3
Rural	8	2%	~~11.8~~	~~9.9~~	8.7	8.5	8.4	8.2	8	7.8	7.1	6.8	6.6
Rural	8	3%	~~12.2~~	~~10.3~~	9	8.8	8.7	8.5	8.3	8.1	7.4	7.1	6.9
Rural	8	4%	~~12.6~~	~~10.7~~	~~9.5~~	9.3	9.2	9	8.8	8.6	7.9	7.6	7.4
Rural	8	5%	~~13.2~~	~~11.3~~	~~10~~	~~9.8~~	~~9.7~~	~~9.5~~	9.3	9.1	8.4	8.1	7.9
Rural	8	6%	~~13.8~~	~~11.9~~	~~10.5~~	~~10.3~~	~~10.2~~	~~10~~	~~9.8~~	~~9.6~~	8.9	8.6	8.4
Rural	8	7%	~~14.3~~	~~12.4~~	~~11.2~~	~~11~~	~~10.9~~	~~10.7~~	~~10.5~~	~~10.3~~	~~9.6~~	9.3	9.1
Rural	10	0%	~~11.8~~	~~9.7~~	8.6	8.4	8.1	7.9	7.7	7.5	6.6	6.4	6.2
Rural	10	1%	~~12.1~~	~~10~~	8.9	8.7	8.4	8.2	8	7.8	6.9	6.7	6.5
Rural	10	2%	~~12.5~~	~~10.4~~	9.2	9	8.7	8.5	8.3	8.1	7.2	7	6.8
Rural	10	3%	~~12.9~~	~~10.8~~	~~9.5~~	9.3	9	8.8	8.6	8.4	7.5	7.3	7.1
Rural	10	4%	~~13.3~~	~~11.2~~	~~10~~	~~9.8~~	~~9.5~~	9.3	9.1	8.9	8	7.8	7.6
Rural	10	5%	~~13.9~~	~~11.8~~	~~10.5~~	~~10.3~~	~~10~~	~~9.8~~	~~9.6~~	9.4	8.5	8.3	8.1
Rural	10	6%	~~14.5~~	~~12.4~~	~~11~~	~~10.8~~	~~10.5~~	~~10.3~~	~~10.1~~	~~9.9~~	9	8.8	8.6
Rural	10	7%	~~15~~	~~12.9~~	~~11.7~~	~~11.5~~	~~11.2~~	~~11~~	~~10.8~~	~~10.6~~	~~9.7~~	~~9.5~~	9.3
Rural	12	0%	~~12.3~~	~~10.7~~	9.1	8.9	8.6	8.2	8	7.8	6.8	6.7	6.4
Rural	12	1%	~~12.6~~	~~10.8~~	9.4	9.2	8.9	8.5	8.3	8.1	7.1	7	6.7
Rural	12	2%	~~13~~	~~10.9~~	~~9.7~~	~~9.5~~	9.2	8.8	8.6	8.4	7.4	7.3	7
Rural	12	3%	~~13.4~~	~~11.1~~	~~10~~	~~9.8~~	~~9.5~~	9.1	8.9	8.7	7.7	7.6	7.3
Rural	12	4%	~~13.8~~	~~11.5~~	~~10.5~~	~~10.3~~	~~10~~	~~9.6~~	9.4	9.2	8.2	8.1	7.8
Rural	12	5%	~~14.4~~	~~12.1~~	~~11~~	~~10.8~~	~~10.5~~	~~10.1~~	~~9.9~~	~~9.7~~	8.7	8.6	8.3
Rural	12	6%	~~15~~	~~12.7~~	~~11.5~~	~~11.3~~	~~11~~	~~10.6~~	~~10.4~~	~~10.2~~	9.2	9.1	8.8
Rural	12	7%	~~15.5~~	~~13.2~~	~~12.2~~	~~12~~	~~11.7~~	~~11.3~~	~~11.1~~	~~10.9~~	~~9.9~~	~~9.8~~	~~9.5~~
Urban	2	0%	4.4	4.1	4	4	4	4	4	4	3.8	3.8	3.8
Urban	2	1%	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.1	4.1	4.1

Table 10(b) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 60° Skew Angle (not including background concentrations)[d]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Urban	2	2%	4.8	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.3	4.3	4.3
Urban	2	3%	5.1	4.8	4.7	4.7	4.7	4.7	4.7	4.7	4.5	4.5	4.5
Urban	2	4%	5.5	5.3	5.2	5.2	5.2	5.2	5.2	5.2	5	5	5
Urban	2	5%	5.8	5.6	5.5	5.5	5.5	5.5	5.5	5.5	5.3	5.3	5.3
Urban	2	6%	6.4	6.2	6.1	6.1	6.1	6.1	6.1	6.1	5.9	5.9	5.9
Urban	2	7%	6.8	6.6	6.5	6.5	6.5	6.5	6.5	6.5	6.3	6.3	6.3
Urban	4	0%	5.8	5.1	4.4	4.4	4.3	4.2	4.2	4.2	4	4	3.8
Urban	4	1%	5.9	5.2	4.7	4.7	4.6	4.5	4.5	4.5	4.3	4.3	4.1
Urban	4	2%	6.2	5.5	4.9	4.9	4.8	4.7	4.7	4.7	4.5	4.5	4.3
Urban	4	3%	6.5	5.8	5.1	5.1	5	4.9	4.9	4.9	4.7	4.7	4.5
Urban	4	4%	6.8	6.1	5.6	5.6	5.5	5.4	5.4	5.4	5.2	5.2	5
Urban	4	5%	7.1	6.4	5.9	5.9	5.8	5.7	5.7	5.7	5.5	5.5	5.3
Urban	4	6%	7.6	6.9	6.5	6.5	6.4	6.3	6.3	6.3	6.1	6.1	5.9
Urban	4	7%	7.9	7.2	6.9	6.9	6.8	6.7	6.7	6.7	6.5	6.5	6.3
Urban	6	0%	6.7	5.8	4.8	4.7	4.6	4.5	4.4	4.4	4.2	4	3.8
Urban	6	1%	6.8	5.9	5	5	4.9	4.8	4.7	4.7	4.5	4.3	4.1
Urban	6	2%	7.1	6.2	5.2	5.2	5.1	5	4.9	4.9	4.7	4.5	4.3
Urban	6	3%	7.4	6.5	5.5	5.4	5.3	5.2	5.1	5.1	4.9	4.7	4.5
Urban	6	4%	7.7	6.8	5.9	5.9	5.8	5.7	5.6	5.6	5.4	5.2	5
Urban	6	5%	8	7.1	6.2	6.2	6.1	6	5.9	5.9	5.7	5.5	5.3
Urban	6	6%	8.5	7.6	6.8	6.8	6.7	6.6	6.5	6.5	6.3	6.1	5.9
Urban	6	7%	8.8	7.9	7.2	7.2	7.1	7	6.9	6.9	6.7	6.5	6.3
Urban	8	0%	7.3	6.4	5.1	4.9	4.9	4.7	4.7	4.6	4.4	4.2	4
Urban	8	1%	7.4	6.4	5.3	5.2	5.2	5	5	4.9	4.7	4.5	4.3
Urban	8	2%	7.7	6.7	5.5	5.4	5.4	5.2	5.2	5.1	4.9	4.7	4.5

Table 10(b) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 60° Skew Angle (not including background concentrations)[d]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Urban	8	3%	8	7	5.8	5.6	5.6	5.4	5.4	5.3	5.1	4.9	4.7
Urban	8	4%	8.3	7.3	6.2	6.1	6.1	5.9	5.9	5.7	5.5	5.4	5.2
Urban	8	5%	8.6	7.6	6.5	6.4	6.4	6.2	6.2	6	5.8	5.7	5.5
Urban	8	6%	9.1	8.1	7.1	7	7	6.8	6.8	6.6	6.4	6.3	6.1
Urban	8	7%	9.4	8.4	7.5	7.4	7.4	7.2	7.2	7	6.8	6.7	6.5
Urban	10	0%	7.9	7.2	5.6	5.2	5.1	5	4.9	4.9	4.5	4.3	4
Urban	10	1%	7.9	7.2	5.6	5.5	5.4	5.3	5.2	5.2	4.8	4.6	4.3
Urban	10	2%	8.2	7.5	5.9	5.7	5.6	5.5	5.4	5.4	5	4.8	4.5
Urban	10	3%	8.5	7.6	6.2	5.9	5.8	5.7	5.6	5.6	5.3	5	4.7
Urban	10	4%	8.8	7.9	6.5	6.4	6.2	6.1	6.1	5.9	5.7	5.4	5.2
Urban	10	5%	9.1	8	6.8	6.7	6.5	6.4	6.4	6.2	6	5.7	5.5
Urban	10	6%	~~9.6~~	8.5	7.3	7.3	7.1	7	7	6.8	6.6	6.3	6.1
Urban	10	7%	~~9.9~~	8.8	7.7	7.7	7.5	7.4	7.4	7.2	7	6.7	6.5
Urban	12	0%	8.6	7.8	6	5.6	5.4	5.3	5.2	5.1	4.7	4.4	4.2
Urban	12	1%	8.6	7.8	6	5.8	5.7	5.6	5.5	5.4	5	4.7	4.5
Urban	12	2%	8.9	8.1	6.3	6	5.9	5.8	5.7	5.6	5.2	4.9	4.7
Urban	12	3%	9	8.2	6.4	6.2	6.1	6	5.9	5.8	5.4	5.2	4.9
Urban	12	4%	9.3	8.5	6.7	6.6	6.4	6.4	6.2	6.1	5.8	5.6	5.4
Urban	12	5%	~~9.6~~	8.6	7	6.9	6.7	6.7	6.5	6.4	6.1	5.9	5.7
Urban	12	6%	~~10.1~~	9	7.6	7.5	7.3	7.3	7.1	7	6.7	6.5	6.3
Urban	12	7%	~~10.4~~	9.3	8	7.9	7.7	7.7	7.5	7.4	7.1	6.9	6.7

Notes: Red strikethrough values indicated exceedances of the standard

[d] These findings apply to scenarios with the intersection average speed ranging from 15 to 45 mph and the freeway average speed ranging from 19 to 75 mph, for which posted speeds in these ranges may be applied as reasonable proxies

Table 10(c) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 90º Skew Angle (not including background concentrations)[e]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	2	0%	6.7	6	5.8	5.8	5.8	5.8	5.8	5.6	5.6	5.6	5.4
Rural	2	1%	7	6.3	6	6	6	6	6	5.8	5.8	5.7	5.6
Rural	2	2%	7.4	6.7	6.4	6.4	6.4	6.4	6.4	6.2	6.2	6.2	6
Rural	2	3%	7.8	7.1	6.7	6.7	6.7	6.7	6.7	6.5	6.5	6.3	6.3
Rural	2	4%	8.1	7.4	7.2	7.2	7.2	7.2	7.2	7	7	6.8	6.8
Rural	2	5%	8.8	8.1	7.7	7.7	7.7	7.7	7.7	7.5	7.5	7.3	7.3
Rural	2	6%	9.4	8.7	8.2	8.2	8.2	8.2	8.2	8	8	7.8	7.8
Rural	2	7%	~~9.9~~	9.2	8.8	8.8	8.8	8.8	8.8	8.6	8.6	8.4	8.4
Rural	4	0%	9	7.6	6.7	6.6	6.5	6.4	6.3	6.2	5.8	5.8	5.6
Rural	4	1%	9.3	7.9	6.9	6.8	6.7	6.6	6.5	6.4	6	5.9	5.7
Rural	4	2%	~~9.7~~	8.3	7.3	7.2	7.1	7	6.9	6.8	6.4	6.4	6.2
Rural	4	3%	~~10.1~~	8.7	7.6	7.5	7.4	7.3	7.2	7.1	6.7	6.5	6.3
Rural	4	4%	~~10.4~~	9	8.1	8	7.9	7.8	7.7	7.6	7.2	6.9	6.8
Rural	4	5%	~~11.1~~	~~9.7~~	8.6	8.5	8.4	8.3	8.2	8.1	7.7	7.4	7.3
Rural	4	6%	~~11.7~~	~~10.3~~	9.1	9	8.9	8.8	8.7	8.6	8.2	7.9	7.8
Rural	4	7%	~~12.2~~	~~10.8~~	~~9.7~~	~~9.6~~	~~9.5~~	9.4	9.3	9.2	8.8	8.5	8.4
Rural	6	0%	~~10.3~~	8.5	7.3	7.1	7	6.9	6.7	6.5	6	6	5.8
Rural	6	1%	~~10.6~~	8.8	7.5	7.3	7.2	7.1	6.9	6.7	6.2	6.1	5.9
Rural	6	2%	~~11~~	9.2	7.9	7.7	7.6	7.5	7.3	7.1	6.6	6.6	6.4
Rural	6	3%	~~11.4~~	~~9.6~~	8.2	8	7.9	7.8	7.6	7.4	6.9	6.7	6.5
Rural	6	4%	~~11.7~~	~~9.9~~	8.7	8.5	8.4	8.3	8.1	7.9	7.4	7.1	6.9
Rural	6	5%	~~12.4~~	~~10.6~~	9.2	9	8.9	8.8	8.6	8.4	7.9	7.5	7.3
Rural	6	6%	~~13~~	~~11.2~~	~~9.7~~	~~9.5~~	9.4	9.3	9.1	8.9	8.4	8	7.8
Rural	6	7%	~~13.5~~	~~11.7~~	~~10.3~~	~~10.1~~	~~10~~	~~9.9~~	~~9.7~~	~~9.5~~	9	8.6	8.4
Rural	8	0%	~~11.1~~	9	7.9	7.7	7.5	7.2	7.1	6.9	6.3	6.2	6

Table 10(c) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 90º Skew Angle (not including background concentrations)[e]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Rural	8	1%	~~11.4~~	9.3	8.1	7.9	7.7	7.4	7.3	7.1	6.4	6.3	6.1
Rural	8	2%	~~11.8~~	~~9.7~~	8.5	8.3	8.1	7.8	7.7	7.5	6.9	6.8	6.6
Rural	8	3%	~~12.2~~	~~10.1~~	8.8	8.6	8.4	8.1	8	7.8	7.1	6.9	6.7
Rural	8	4%	~~12.5~~	~~10.4~~	9.3	9.1	8.9	8.6	8.5	8.3	7.6	7.3	7.1
Rural	8	5%	~~13.2~~	~~11.1~~	~~9.8~~	~~9.6~~	9.4	9.1	9	8.8	8.1	7.7	7.5
Rural	8	6%	~~13.8~~	~~11.7~~	~~10.3~~	~~10.1~~	~~9.9~~	~~9.6~~	~~9.5~~	9.3	8.6	8.2	8
Rural	8	7%	~~14.3~~	~~12.2~~	~~10.9~~	~~10.7~~	~~10.5~~	~~10.2~~	~~10.1~~	~~9.9~~	9.2	8.8	8.6
Rural	10	0%	~~11.8~~	~~9.5~~	8.4	8.2	7.9	7.7	7.5	7.2	6.5	6.3	6
Rural	10	1%	~~12.1~~	~~9.8~~	8.6	8.4	8.1	7.9	7.7	7.4	6.6	6.4	6.1
Rural	10	2%	~~12.5~~	~~10.2~~	9	8.8	8.5	8.3	8.1	7.8	7.1	6.9	6.6
Rural	10	3%	~~12.9~~	~~10.6~~	9.3	9.1	8.8	8.6	8.4	8.1	7.3	7	6.7
Rural	10	4%	~~13.2~~	~~10.9~~	~~9.8~~	~~9.6~~	9.3	9.1	8.9	8.6	7.8	7.4	7.1
Rural	10	5%	~~13.9~~	~~11.6~~	~~10.3~~	~~10.1~~	~~9.8~~	~~9.6~~	9.4	9.1	8.3	7.8	7.5
Rural	10	6%	~~14.5~~	~~12.2~~	~~10.8~~	~~10.6~~	~~10.3~~	~~10.1~~	~~9.9~~	~~9.6~~	8.8	8.3	8
Rural	10	7%	~~15~~	~~12.7~~	~~11.4~~	~~11.2~~	~~10.9~~	~~10.7~~	~~10.5~~	~~10.2~~	9.4	8.9	8.6
Rural	12	0%	~~12.3~~	~~10.6~~	8.9	8.5	8.3	8	7.8	7.5	6.7	6.5	6.2
Rural	12	1%	~~12.6~~	~~10.7~~	9.1	8.7	8.5	8.2	8	7.7	6.8	6.6	6.3
Rural	12	2%	~~13~~	~~10.7~~	~~9.5~~	9.1	8.9	8.6	8.4	8.1	7.3	7.1	6.8
Rural	12	3%	~~13.4~~	~~11~~	~~9.8~~	9.4	9.2	8.9	8.7	8.4	7.4	7.2	6.9
Rural	12	4%	~~13.7~~	~~11.3~~	~~10.3~~	~~9.9~~	~~9.7~~	9.4	9.2	8.9	7.9	7.6	7.3
Rural	12	5%	~~14.4~~	~~12~~	~~10.8~~	~~10.4~~	~~10.2~~	~~9.9~~	~~9.7~~	9.4	8.4	8	7.7
Rural	12	6%	~~15~~	~~12.6~~	~~11.3~~	~~10.9~~	~~10.7~~	~~10.4~~	~~10.2~~	~~9.9~~	8.9	8.5	8.2
Rural	12	7%	~~15.5~~	~~13.1~~	~~11.9~~	~~11.5~~	~~11.3~~	~~11~~	~~10.8~~	~~10.5~~	~~9.5~~	9.1	8.8
Urban	2	0%	4.5	4.2	3.9	3.8	3.8	3.8	3.8	3.8	3.7	3.6	3.6
Urban	2	1%	4.6	4.3	4.1	4.1	4.1	4.1	4.1	4.1	3.9	3.9	3.9

Table 10(c) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 90º Skew Angle (not including background concentrations)[e]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Urban	2	2%	4.9	4.6	4.3	4.3	4.3	4.3	4.3	4.3	4.1	4.1	4.1
Urban	2	3%	5.2	4.9	4.6	4.5	4.5	4.5	4.5	4.5	4.3	4.3	4.3
Urban	2	4%	5.4	5.1	4.8	4.7	4.7	4.7	4.7	4.7	4.5	4.5	4.5
Urban	2	5%	5.8	5.5	5.2	5.2	5.2	5.2	5.2	5.2	5	5	5
Urban	2	6%	6.3	6	5.7	5.6	5.6	5.6	5.6	5.6	5.4	5.4	5.4
Urban	2	7%	6.7	6.4	6.1	6.1	6.1	6.1	6.1	6.1	5.9	5.9	5.9
Urban	4	0%	5.9	5.2	4.5	4.2	4.2	4	4	4	3.9	3.8	3.8
Urban	4	1%	6	5.3	4.6	4.5	4.4	4.3	4.3	4.3	4.1	4.1	4
Urban	4	2%	6.3	5.6	4.9	4.7	4.6	4.5	4.5	4.5	4.3	4.3	4.1
Urban	4	3%	6.6	5.9	5.2	4.9	4.9	4.7	4.7	4.7	4.5	4.5	4.3
Urban	4	4%	6.8	6.1	5.4	5.1	5.1	4.9	4.9	4.9	4.7	4.7	4.5
Urban	4	5%	7.2	6.5	5.8	5.6	5.5	5.4	5.4	5.4	5.2	5.2	5
Urban	4	6%	7.7	7	6.3	6	6	5.8	5.8	5.8	5.6	5.6	5.4
Urban	4	7%	8.1	7.4	6.7	6.5	6.4	6.3	6.3	6.3	6.1	6.1	5.9
Urban	6	0%	6.8	5.9	4.9	4.6	4.4	4.3	4.2	4.2	4	4	3.8
Urban	6	1%	6.9	6	5	4.8	4.7	4.6	4.5	4.5	4.3	4.2	4
Urban	6	2%	7.2	6.3	5.3	5	4.9	4.8	4.7	4.7	4.5	4.3	4.1
Urban	6	3%	7.5	6.6	5.6	5.3	5.1	5	4.9	4.9	4.7	4.5	4.3
Urban	6	4%	7.7	6.8	5.8	5.5	5.3	5.2	5.1	5.1	4.9	4.7	4.5
Urban	6	5%	8.1	7.2	6.2	5.9	5.8	5.7	5.6	5.6	5.4	5.2	5
Urban	6	6%	8.6	7.7	6.7	6.4	6.2	6.1	6	6	5.8	5.6	5.4
Urban	6	7%	9	8.1	7.1	6.8	6.7	6.6	6.5	6.5	6.3	6.1	5.9
Urban	8	0%	7.4	6.4	5.2	4.9	4.7	4.5	4.5	4.4	4.2	4.1	4
Urban	8	1%	7.5	6.5	5.3	5	5	4.8	4.8	4.6	4.4	4.3	4.2
Urban	8	2%	7.8	6.8	5.6	5.3	5.2	5	5	4.8	4.6	4.4	4.3

Table 10(c) – One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 90º Skew Angle (not including background concentrations)[e]

Location	Number of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
			20	30	60	80	100	125	150	175	300	500	1000
Urban	8	3%	8.1	7.1	5.9	5.6	5.4	5.2	5.2	5	4.8	4.6	4.5
Urban	8	4%	8.3	7.3	6.1	5.8	5.6	5.4	5.4	5.2	5	4.8	4.7
Urban	8	5%	8.7	7.7	6.5	6.2	6.1	5.9	5.9	5.7	5.5	5.3	5.2
Urban	8	6%	9.2	8.2	7	6.7	6.5	6.3	6.3	6.1	5.9	5.7	5.6
Urban	8	7%	~~9.6~~	8.6	7.4	7.1	7	6.8	6.8	6.6	6.4	6.2	6.1
Urban	10	0%	7.9	7.1	5.6	5.2	4.9	4.7	4.7	4.6	4.4	4.2	4
Urban	10	1%	8	7.2	5.7	5.3	5.1	5	4.9	4.8	4.6	4.4	4.2
Urban	10	2%	8.3	7.5	6	5.6	5.3	5.2	5.1	5	4.7	4.5	4.3
Urban	10	3%	8.6	7.6	6.3	5.9	5.6	5.4	5.3	5.2	4.9	4.7	4.5
Urban	10	4%	8.8	7.8	6.5	6.1	5.8	5.6	5.5	5.4	5.1	4.9	4.7
Urban	10	5%	9.2	8.1	6.9	6.5	6.2	6.1	6	5.9	5.6	5.4	5.2
Urban	10	6%	~~9.7~~	8.6	7.4	7	6.7	6.5	6.4	6.3	6	5.8	5.6
Urban	10	7%	~~10.1~~	9	7.8	7.4	7.1	7	6.9	6.8	6.5	6.3	6.1
Urban	12	0%	8.5	7.7	5.9	5.4	5.1	5	4.9	4.8	4.6	4.4	4.2
Urban	12	1%	8.6	7.8	6	5.5	5.3	5.3	5.1	5	4.8	4.6	4.4
Urban	12	2%	8.9	8.1	6.3	5.8	5.5	5.5	5.3	5.2	4.9	4.7	4.5
Urban	12	3%	9.1	8.2	6.5	6	5.7	5.7	5.5	5.4	5.1	4.9	4.7
Urban	12	4%	9.3	8.4	6.7	6.2	5.9	5.9	5.7	5.6	5.3	5.1	4.9
Urban	12	5%	~~9.7~~	8.7	7.1	6.6	6.4	6.4	6.2	6.1	5.8	5.6	5.4
Urban	12	6%	~~10.2~~	9.1	7.6	7.1	6.8	6.8	6.6	6.5	6.2	6	5.8
Urban	12	7%	~~10.6~~	~~9.5~~	8	7.5	7.3	7.3	7.1	7	6.7	6.5	6.3

Notes: Red strikethrough values indicated exceedances of the standard

[e] These findings apply to scenarios with the intersection average speed ranging from 15 to 45 mph and the freeway average speed ranging from 19 to 75 mph, for which posted speeds in these ranges may be applied as reasonable proxies

Appendix C-1 MOVES Emission Factors Used in TSD

Table C-1 – CO Idle Emission Rates Used in the Modeling, in Grams Per Vehicle-Hour, 2020

Road Type	Speed	Grams Per Vehicle Hour
Urban Unrestricted	0	13.67
Rural Unrestricted	0	13.82
Urban Restricted	0	13.60
Rural Restricted	0	13.71

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Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	1	0	63.70	63.70	Urban Unrestricted	1	7	70.01	30.00	Rural Restricted	1	4	68.70	40.00
Rural Unrestricted	2	0	31.93	31.93	Urban Unrestricted	2	7	35.88	15.20	Rural Restricted	2	4	34.94	20.26
Rural Unrestricted	3	0	22.10	22.10	Urban Unrestricted	3	7	28.02	11.01	Rural Restricted	3	4	25.79	14.43
Rural Unrestricted	4	0	17.61	17.61	Urban Unrestricted	4	7	25.31	9.14	Rural Restricted	4	4	21.81	11.67
Rural Unrestricted	5	0	15.05	15.05	Urban Unrestricted	5	7	23.76	7.96	Rural Restricted	5	4	19.49	9.97
Rural Unrestricted	6	0	13.52	13.52	Urban Unrestricted	6	7	22.81	7.08	Rural Restricted	6	4	18.03	8.81
Rural Unrestricted	7	0	12.43	12.43	Urban Unrestricted	7	7	22.13	6.46	Rural Restricted	7	4	16.99	7.97
Rural Unrestricted	8	0	11.61	11.61	Urban Unrestricted	8	7	21.62	5.99	Rural Restricted	8	4	16.20	7.35
Rural Unrestricted	9	0	10.97	10.97	Urban Unrestricted	9	7	21.23	5.63	Rural Restricted	9	4	15.53	6.88
Rural Unrestricted	10	0	10.46	10.46	Urban Unrestricted	10	7	20.91	5.33	Rural Restricted	10	4	14.84	6.56
Rural Unrestricted	11	0	10.06	10.06	Urban Unrestricted	11	7	20.73	5.09	Rural Restricted	11	4	14.32	6.27
Rural Unrestricted	12	0	9.77	9.77	Urban Unrestricted	12	7	20.75	4.87	Rural Restricted	12	4	14.00	5.98
Rural Unrestricted	13	0	9.52	9.52	Urban Unrestricted	13	7	20.77	4.68	Rural Restricted	13	4	13.72	5.73
Rural Unrestricted	14	0	9.31	9.31	Urban Unrestricted	14	7	20.79	4.53	Rural Restricted	14	4	13.49	5.52
Rural Unrestricted	15	0	9.13	9.13	Urban Unrestricted	15	7	20.80	4.39	Rural Restricted	15	4	13.28	5.33
Rural Unrestricted	16	0	8.98	8.98	Urban Unrestricted	16	7	20.81	4.26	Rural Restricted	16	4	13.17	5.13
Rural Unrestricted	17	0	8.87	8.87	Urban Unrestricted	17	7	20.80	4.14	Rural Restricted	17	4	13.26	4.87
Rural Unrestricted	18	0	8.77	8.77	Urban Unrestricted	18	7	20.79	4.03	Rural Restricted	18	4	13.34	4.63
Rural Unrestricted	19	0	8.62	8.62	Urban Unrestricted	19	7	20.85	3.87	Rural Restricted	19	4	13.41	4.42
Rural Unrestricted	20	0	8.41	8.41	Urban Unrestricted	20	7	20.97	3.64	Rural Restricted	20	4	13.47	4.23
Rural Unrestricted	21	0	8.20	8.20	Urban Unrestricted	21	7	21.08	3.43	Rural Restricted	21	4	13.50	4.06
Rural Unrestricted	22	0	7.95	7.95	Urban Unrestricted	22	7	21.14	3.20	Rural Restricted	22	4	13.52	3.89
Rural Unrestricted	23	0	7.73	7.73	Urban Unrestricted	23	7	21.19	2.99	Rural Restricted	23	4	13.54	3.74
Rural Unrestricted	24	0	7.52	7.52	Urban Unrestricted	24	7	21.24	2.79	Rural Restricted	24	4	13.56	3.60
Rural Unrestricted	25	0	7.37	7.37	Urban Unrestricted	25	7	21.25	2.66	Rural Restricted	25	4	13.51	3.54
Rural Unrestricted	26	0	7.31	7.31	Urban Unrestricted	26	7	21.15	2.60	Rural Restricted	26	4	13.40	3.55
Rural Unrestricted	27	0	7.29	7.29	Urban Unrestricted	27	7	21.01	2.56	Rural Restricted	27	4	13.30	3.56
Rural Unrestricted	28	0	7.26	7.26	Urban Unrestricted	28	7	20.87	2.52	Rural Restricted	28	4	13.21	3.56
Rural Unrestricted	29	0	7.24	7.24	Urban Unrestricted	29	7	20.75	2.48	Rural Restricted	29	4	13.12	3.57
Rural Unrestricted	30	0	7.22	7.22	Urban Unrestricted	30	7	20.63	2.45	Rural Restricted	30	4	13.04	3.58
Rural Unrestricted	31	0	7.20	7.20	Urban Unrestricted	31	7	20.52	2.42	Rural Restricted	31	4	13.04	3.58
Rural Unrestricted	32	0	7.02	7.02	Urban Unrestricted	32	7	20.48	2.31	Rural Restricted	32	4	12.95	3.50
Rural Unrestricted	33	0	6.71	6.71	Urban Unrestricted	33	7	20.27	2.13	Rural Restricted	33	4	12.71	3.34
Rural Unrestricted	34	0	6.42	6.42	Urban Unrestricted	34	7	20.07	1.97	Rural Restricted	34	4	12.49	3.19
Rural Unrestricted	35	0	6.24	6.24	Urban Unrestricted	35	7	20.04	1.87	Rural Restricted	35	4	12.42	3.11
Rural Unrestricted	36	0	6.13	6.13	Urban Unrestricted	36	7	20.10	1.81	Rural Restricted	36	4	12.46	3.08
Rural Unrestricted	37	0	6.03	6.03	Urban Unrestricted	37	7	20.16	1.76	Rural Restricted	37	4	12.50	3.05
Rural Unrestricted	38	0	5.93	5.93	Urban Unrestricted	38	7	20.22	1.71	Rural Restricted	38	4	12.53	3.02
Rural Unrestricted	39	0	5.84	5.84	Urban Unrestricted	39	7	20.28	1.66	Rural Restricted	39	4	12.57	2.99
Rural Unrestricted	40	0	5.75	5.75	Urban Unrestricted	40	7	20.33	1.61	Rural Restricted	40	4	12.60	2.96

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	41	0	5.67	5.67	Urban Unrestricted	41	7	20.38	1.57	Rural Restricted	41	4	12.63	2.93
Rural Unrestricted	42	0	5.59	5.59	Urban Unrestricted	42	7	20.43	1.53	Rural Restricted	42	4	12.66	2.91
Rural Unrestricted	43	0	5.51	5.51	Urban Unrestricted	43	7	20.47	1.49	Rural Restricted	43	4	12.68	2.89
Rural Unrestricted	44	0	5.44	5.44	Urban Unrestricted	44	7	20.52	1.45	Rural Restricted	44	4	12.71	2.86
Rural Unrestricted	45	0	5.37	5.37	Urban Unrestricted	45	7	20.54	1.42	Rural Restricted	45	4	12.71	2.84
Rural Unrestricted	46	0	5.29	5.29	Urban Unrestricted	46	7	20.52	1.39	Rural Restricted	46	4	12.69	2.83
Rural Unrestricted	47	0	5.22	5.22	Urban Unrestricted	47	7	20.51	1.35	Rural Restricted	47	4	12.68	2.80
Rural Unrestricted	48	0	5.15	5.15	Urban Unrestricted	48	7	20.50	1.32	Rural Restricted	48	4	12.68	2.77
Rural Unrestricted	49	0	5.09	5.09	Urban Unrestricted	49	7	20.49	1.29	Rural Restricted	49	4	12.68	2.75
Rural Unrestricted	50	0	5.07	5.07	Urban Unrestricted	50	7	20.47	1.26	Rural Restricted	50	4	12.67	2.72
Rural Unrestricted	51	0	5.06	5.06	Urban Unrestricted	51	7	20.46	1.23	Rural Restricted	51	4	12.67	2.70
Rural Unrestricted	52	0	5.04	5.04	Urban Unrestricted	52	7	20.45	1.21	Rural Restricted	52	4	12.67	2.68
Rural Unrestricted	53	0	5.03	5.03	Urban Unrestricted	53	7	20.46	1.18	Rural Restricted	53	4	12.66	2.65
Rural Unrestricted	54	0	5.01	5.01	Urban Unrestricted	54	7	20.54	1.16	Rural Restricted	54	4	12.66	2.63
Rural Unrestricted	55	0	5.00	5.00	Urban Unrestricted	55	7	20.63	1.13	Rural Restricted	55	4	12.66	2.61
Rural Unrestricted	56	0	4.97	4.97	Urban Unrestricted	56	7	20.72	1.11	Rural Restricted	56	4	12.66	2.59
Rural Unrestricted	57	0	4.94	4.94	Urban Unrestricted	57	7	20.83	1.08	Rural Restricted	57	4	12.68	2.56
Rural Unrestricted	58	0	4.91	4.91	Urban Unrestricted	58	7	20.93	1.05	Rural Restricted	58	4	12.69	2.54
Rural Unrestricted	59	0	4.88	4.88	Urban Unrestricted	59	7	21.03	1.02	Rural Restricted	59	4	12.72	2.52
Rural Unrestricted	60	0	4.85	4.85	Urban Unrestricted	60	7	21.12	1.00	Rural Restricted	60	4	12.84	2.51
Rural Unrestricted	61	0	4.85	4.85	Urban Unrestricted	61	7	21.27	0.97	Rural Restricted	61	4	12.97	2.49
Rural Unrestricted	62	0	4.89	4.89	Urban Unrestricted	62	7	21.44	0.96	Rural Restricted	62	4	13.12	2.46
Rural Unrestricted	63	0	4.92	4.92	Urban Unrestricted	63	7	21.61	0.94	Rural Restricted	63	4	13.27	2.43
Rural Unrestricted	64	0	4.98	4.98	Urban Unrestricted	64	7	21.77	0.92	Rural Restricted	64	4	13.41	2.41
Rural Unrestricted	65	0	5.11	5.11	Urban Unrestricted	65	7	21.93	0.90	Rural Restricted	65	4	13.72	2.40
Rural Unrestricted	66	0	5.22	5.22	Urban Unrestricted	66	7	22.09	0.88	Rural Restricted	66	4	14.12	2.41
Rural Unrestricted	67	0	5.33	5.33	Urban Unrestricted	67	7	22.24	0.86	Rural Restricted	67	4	14.47	2.40
Rural Unrestricted	68	0	5.44	5.44	Urban Unrestricted	68	7	22.38	0.85	Rural Restricted	68	4	14.78	2.38
Rural Unrestricted	69	0	5.55	5.55	Urban Unrestricted	69	7	22.52	0.83	Rural Restricted	69	4	15.07	2.36
Rural Unrestricted	70	0	5.65	5.65	Urban Unrestricted	70	7	22.66	0.81	Rural Restricted	70	4	15.37	2.34
Rural Unrestricted	71	0	5.76	5.76	Urban Unrestricted	71	7	22.79	0.80	Rural Restricted	71	4	15.65	2.32
Rural Unrestricted	72	0	5.85	5.85	Urban Unrestricted	72	7	22.92	0.78	Rural Restricted	72	4	15.92	2.30
Rural Unrestricted	73	0	5.96	5.96	Urban Unrestricted	73	7	23.05	0.76	Rural Restricted	73	4	16.20	2.28
Rural Unrestricted	74	0	6.20	6.20	Urban Unrestricted	74	7	23.08	0.77	Rural Restricted	74	4	16.52	2.31
Rural Unrestricted	75	0	6.87	6.87	Urban Unrestricted	75	7	22.78	0.85	Rural Restricted	75	4	16.83	2.47
Urban Unrestricted	1	0	63.50	63.50	Rural Unrestricted	1	8	70.48	29.13	Urban Restricted	1	4	68.56	39.87
Urban Unrestricted	2	0	31.83	31.83	Rural Unrestricted	2	8	36.19	14.74	Urban Restricted	2	4	34.87	20.19
Urban Unrestricted	3	0	22.03	22.03	Rural Unrestricted	3	8	28.71	10.59	Urban Restricted	3	4	25.73	14.39
Urban Unrestricted	4	0	17.56	17.56	Rural Unrestricted	4	8	26.38	8.69	Urban Restricted	4	4	21.76	11.63
Urban Unrestricted	5	0	15.01	15.01	Rural Unrestricted	5	8	25.07	7.49	Urban Restricted	5	4	19.45	9.94

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	6	0	13.49	13.49	Rural Unrestricted	6	8	24.29	6.60	Urban Restricted	6	4	17.99	8.78
Urban Unrestricted	7	0	12.40	12.40	Rural Unrestricted	7	8	23.73	5.96	Urban Restricted	7	4	16.95	7.95
Urban Unrestricted	8	0	11.58	11.58	Rural Unrestricted	8	8	23.31	5.48	Urban Restricted	8	4	16.18	7.33
Urban Unrestricted	9	0	10.94	10.94	Rural Unrestricted	9	8	22.98	5.11	Urban Restricted	9	4	15.50	6.86
Urban Unrestricted	10	0	10.44	10.44	Rural Unrestricted	10	8	22.71	4.82	Urban Restricted	10	4	14.81	6.54
Urban Unrestricted	11	0	10.04	10.04	Rural Unrestricted	11	8	22.59	4.57	Urban Restricted	11	4	14.30	6.25
Urban Unrestricted	12	0	9.75	9.75	Rural Unrestricted	12	8	22.70	4.37	Urban Restricted	12	4	13.97	5.96
Urban Unrestricted	13	0	9.50	9.50	Rural Unrestricted	13	8	22.79	4.19	Urban Restricted	13	4	13.69	5.72
Urban Unrestricted	14	0	9.30	9.30	Rural Unrestricted	14	8	22.86	4.04	Urban Restricted	14	4	13.46	5.50
Urban Unrestricted	15	0	9.11	9.11	Rural Unrestricted	15	8	22.93	3.91	Urban Restricted	15	4	13.25	5.32
Urban Unrestricted	16	0	8.97	8.97	Rural Unrestricted	16	8	22.97	3.80	Urban Restricted	16	4	13.14	5.12
Urban Unrestricted	17	0	8.86	8.86	Rural Unrestricted	17	8	22.97	3.68	Urban Restricted	17	4	13.23	4.86
Urban Unrestricted	18	0	8.76	8.76	Rural Unrestricted	18	8	22.97	3.58	Urban Restricted	18	4	13.31	4.62
Urban Unrestricted	19	0	8.61	8.61	Rural Unrestricted	19	8	23.14	3.44	Urban Restricted	19	4	13.39	4.41
Urban Unrestricted	20	0	8.40	8.40	Rural Unrestricted	20	8	23.52	3.26	Urban Restricted	20	4	13.45	4.22
Urban Unrestricted	21	0	8.19	8.19	Rural Unrestricted	21	8	23.85	3.08	Urban Restricted	21	4	13.48	4.05
Urban Unrestricted	22	0	7.94	7.94	Rural Unrestricted	22	8	24.11	2.89	Urban Restricted	22	4	13.50	3.88
Urban Unrestricted	23	0	7.71	7.71	Rural Unrestricted	23	8	24.36	2.72	Urban Restricted	23	4	13.52	3.73
Urban Unrestricted	24	0	7.50	7.50	Rural Unrestricted	24	8	24.58	2.56	Urban Restricted	24	4	13.54	3.59
Urban Unrestricted	25	0	7.35	7.35	Rural Unrestricted	25	8	24.76	2.44	Urban Restricted	25	4	13.49	3.53
Urban Unrestricted	26	0	7.29	7.29	Rural Unrestricted	26	8	24.62	2.37	Urban Restricted	26	4	13.38	3.54
Urban Unrestricted	27	0	7.27	7.27	Rural Unrestricted	27	8	24.31	2.31	Urban Restricted	27	4	13.28	3.55
Urban Unrestricted	28	0	7.25	7.25	Rural Unrestricted	28	8	24.02	2.25	Urban Restricted	28	4	13.19	3.55
Urban Unrestricted	29	0	7.23	7.23	Rural Unrestricted	29	8	23.75	2.20	Urban Restricted	29	4	13.10	3.56
Urban Unrestricted	30	0	7.21	7.21	Rural Unrestricted	30	8	23.50	2.15	Urban Restricted	30	4	13.02	3.57
Urban Unrestricted	31	0	7.19	7.19	Rural Unrestricted	31	8	23.27	2.10	Urban Restricted	31	4	13.02	3.57
Urban Unrestricted	32	0	7.00	7.00	Rural Unrestricted	32	8	23.32	2.01	Urban Restricted	32	4	12.94	3.49
Urban Unrestricted	33	0	6.69	6.69	Rural Unrestricted	33	8	23.21	1.88	Urban Restricted	33	4	12.70	3.33
Urban Unrestricted	34	0	6.39	6.39	Rural Unrestricted	34	8	23.10	1.76	Urban Restricted	34	4	12.47	3.18
Urban Unrestricted	35	0	6.21	6.21	Rural Unrestricted	35	8	23.14	1.68	Urban Restricted	35	4	12.41	3.10
Urban Unrestricted	36	0	6.10	6.10	Rural Unrestricted	36	8	23.27	1.62	Urban Restricted	36	4	12.45	3.07
Urban Unrestricted	37	0	5.99	5.99	Rural Unrestricted	37	8	23.39	1.57	Urban Restricted	37	4	12.49	3.04
Urban Unrestricted	38	0	5.89	5.89	Rural Unrestricted	38	8	23.51	1.52	Urban Restricted	38	4	12.53	3.01
Urban Unrestricted	39	0	5.80	5.80	Rural Unrestricted	39	8	23.62	1.47	Urban Restricted	39	4	12.56	2.98
Urban Unrestricted	40	0	5.71	5.71	Rural Unrestricted	40	8	23.72	1.42	Urban Restricted	40	4	12.59	2.95
Urban Unrestricted	41	0	5.62	5.62	Rural Unrestricted	41	8	23.82	1.38	Urban Restricted	41	4	12.62	2.92
Urban Unrestricted	42	0	5.54	5.54	Rural Unrestricted	42	8	23.91	1.34	Urban Restricted	42	4	12.65	2.90
Urban Unrestricted	43	0	5.46	5.46	Rural Unrestricted	43	8	24.00	1.30	Urban Restricted	43	4	12.68	2.87
Urban Unrestricted	44	0	5.40	5.40	Rural Unrestricted	44	8	24.09	1.26	Urban Restricted	44	4	12.71	2.85
Urban Unrestricted	45	0	5.35	5.35	Rural Unrestricted	45	8	24.14	1.22	Urban Restricted	45	4	12.71	2.83

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	46	0	5.29	5.29	Rural Unrestricted	46	8	24.16	1.18	Urban Restricted	46	4	12.69	2.82
Urban Unrestricted	47	0	5.24	5.24	Rural Unrestricted	47	8	24.19	1.15	Urban Restricted	47	4	12.69	2.79
Urban Unrestricted	48	0	5.19	5.19	Rural Unrestricted	48	8	24.21	1.11	Urban Restricted	48	4	12.68	2.76
Urban Unrestricted	49	0	5.14	5.14	Rural Unrestricted	49	8	24.23	1.08	Urban Restricted	49	4	12.68	2.74
Urban Unrestricted	50	0	5.09	5.09	Rural Unrestricted	50	8	24.16	1.05	Urban Restricted	50	4	12.68	2.71
Urban Unrestricted	51	0	5.04	5.04	Rural Unrestricted	51	8	24.09	1.02	Urban Restricted	51	4	12.67	2.69
Urban Unrestricted	52	0	5.00	5.00	Rural Unrestricted	52	8	24.03	0.99	Urban Restricted	52	4	12.67	2.67
Urban Unrestricted	53	0	4.96	4.96	Rural Unrestricted	53	8	23.96	0.97	Urban Restricted	53	4	12.67	2.64
Urban Unrestricted	54	0	4.95	4.95	Rural Unrestricted	54	8	23.90	0.94	Urban Restricted	54	4	12.67	2.62
Urban Unrestricted	55	0	4.94	4.94	Rural Unrestricted	55	8	23.84	0.92	Urban Restricted	55	4	12.67	2.60
Urban Unrestricted	56	0	4.92	4.92	Rural Unrestricted	56	8	23.81	0.90	Urban Restricted	56	4	12.67	2.58
Urban Unrestricted	57	0	4.89	4.89	Rural Unrestricted	57	8	23.79	0.88	Urban Restricted	57	4	12.69	2.55
Urban Unrestricted	58	0	4.87	4.87	Rural Unrestricted	58	8	23.78	0.86	Urban Restricted	58	4	12.70	2.53
Urban Unrestricted	59	0	4.84	4.84	Rural Unrestricted	59	8	23.76	0.84	Urban Restricted	59	4	12.74	2.51
Urban Unrestricted	60	0	4.81	4.81	Rural Unrestricted	60	8	23.74	0.83	Urban Restricted	60	4	12.85	2.50
Urban Unrestricted	61	0	4.83	4.83	Rural Unrestricted	61	8	23.77	0.81	Urban Restricted	61	4	12.99	2.47
Urban Unrestricted	62	0	4.86	4.86	Rural Unrestricted	62	8	23.82	0.80	Urban Restricted	62	4	13.14	2.45
Urban Unrestricted	63	0	4.90	4.90	Rural Unrestricted	63	8	23.86	0.78	Urban Restricted	63	4	13.29	2.42
Urban Unrestricted	64	0	4.97	4.97	Rural Unrestricted	64	8	23.90	0.76	Urban Restricted	64	4	13.43	2.40
Urban Unrestricted	65	0	5.09	5.09	Rural Unrestricted	65	8	23.93	0.74	Urban Restricted	65	4	13.74	2.39
Urban Unrestricted	66	0	5.20	5.20	Rural Unrestricted	66	8	23.95	0.72	Urban Restricted	66	4	14.14	2.40
Urban Unrestricted	67	0	5.32	5.32	Rural Unrestricted	67	8	23.98	0.71	Urban Restricted	67	4	14.49	2.38
Urban Unrestricted	68	0	5.43	5.43	Rural Unrestricted	68	8	24.00	0.69	Urban Restricted	68	4	14.80	2.36
Urban Unrestricted	69	0	5.53	5.53	Rural Unrestricted	69	8	24.02	0.67	Urban Restricted	69	4	15.10	2.35
Urban Unrestricted	70	0	5.64	5.64	Rural Unrestricted	70	8	24.04	0.65	Urban Restricted	70	4	15.40	2.33
Urban Unrestricted	71	0	5.74	5.74	Rural Unrestricted	71	8	24.06	0.63	Urban Restricted	71	4	15.68	2.31
Urban Unrestricted	72	0	5.84	5.84	Rural Unrestricted	72	8	24.08	0.62	Urban Restricted	72	4	15.96	2.29
Urban Unrestricted	73	0	5.94	5.94	Rural Unrestricted	73	8	24.11	0.60	Urban Restricted	73	4	16.24	2.27
Urban Unrestricted	74	0	6.19	6.19	Rural Unrestricted	74	8	24.11	0.60	Urban Restricted	74	4	16.56	2.29
Urban Unrestricted	75	0	6.86	6.86	Rural Unrestricted	75	8	23.94	0.64	Urban Restricted	75	4	16.87	2.46
Rural Unrestricted	1	1	65.92	48.31	Urban Unrestricted	1	8	70.27	28.94	Rural Restricted	1	5	69.46	32.28
Rural Unrestricted	2	1	33.15	24.67	Urban Unrestricted	2	8	36.08	14.65	Rural Restricted	2	5	35.43	16.43
Rural Unrestricted	3	1	23.27	18.42	Urban Unrestricted	3	8	28.64	10.52	Rural Restricted	3	5	26.58	12.02
Rural Unrestricted	4	1	18.80	15.66	Urban Unrestricted	4	8	26.33	8.64	Rural Restricted	4	5	22.88	10.00
Rural Unrestricted	5	1	16.23	13.83	Urban Unrestricted	5	8	25.02	7.45	Rural Restricted	5	5	20.73	8.73
Rural Unrestricted	6	1	14.65	12.38	Urban Unrestricted	6	8	24.25	6.56	Rural Restricted	6	5	19.37	7.79
Rural Unrestricted	7	1	13.52	11.34	Urban Unrestricted	7	8	23.69	5.93	Rural Restricted	7	5	18.40	7.12
Rural Unrestricted	8	1	12.67	10.56	Urban Unrestricted	8	8	23.28	5.46	Rural Restricted	8	5	17.67	6.62
Rural Unrestricted	9	1	12.01	9.95	Urban Unrestricted	9	8	22.95	5.09	Rural Restricted	9	5	17.01	6.23
Rural Unrestricted	10	1	11.48	9.47	Urban Unrestricted	10	8	22.69	4.80	Rural Restricted	10	5	16.26	5.93

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	11	1	11.11	9.07	Urban Unrestricted	11	8	22.57	4.55	Rural Restricted	11	5	15.73	5.66
Rural Unrestricted	12	1	10.93	8.75	Urban Unrestricted	12	8	22.68	4.35	Rural Restricted	12	5	15.43	5.38
Rural Unrestricted	13	1	10.78	8.48	Urban Unrestricted	13	8	22.77	4.18	Rural Restricted	13	5	15.18	5.15
Rural Unrestricted	14	1	10.66	8.25	Urban Unrestricted	14	8	22.85	4.03	Rural Restricted	14	5	14.97	4.94
Rural Unrestricted	15	1	10.54	8.05	Urban Unrestricted	15	8	22.91	3.90	Rural Restricted	15	5	14.78	4.77
Rural Unrestricted	16	1	10.43	7.88	Urban Unrestricted	16	8	22.95	3.78	Rural Restricted	16	5	14.70	4.58
Rural Unrestricted	17	1	10.31	7.74	Urban Unrestricted	17	8	22.95	3.67	Rural Restricted	17	5	14.87	4.32
Rural Unrestricted	18	1	10.20	7.61	Urban Unrestricted	18	8	22.95	3.57	Rural Restricted	18	5	15.01	4.09
Rural Unrestricted	19	1	10.06	7.43	Urban Unrestricted	19	8	23.12	3.43	Rural Restricted	19	5	15.14	3.88
Rural Unrestricted	20	1	9.87	7.19	Urban Unrestricted	20	8	23.50	3.25	Rural Restricted	20	5	15.26	3.70
Rural Unrestricted	21	1	9.68	6.96	Urban Unrestricted	21	8	23.84	3.07	Rural Restricted	21	5	15.33	3.54
Rural Unrestricted	22	1	9.44	6.76	Urban Unrestricted	22	8	24.11	2.88	Rural Restricted	22	5	15.37	3.38
Rural Unrestricted	23	1	9.23	6.58	Urban Unrestricted	23	8	24.35	2.71	Rural Restricted	23	5	15.41	3.24
Rural Unrestricted	24	1	9.03	6.41	Urban Unrestricted	24	8	24.57	2.55	Rural Restricted	24	5	15.45	3.11
Rural Unrestricted	25	1	8.88	6.28	Urban Unrestricted	25	8	24.76	2.43	Rural Restricted	25	5	15.42	3.05
Rural Unrestricted	26	1	8.80	6.21	Urban Unrestricted	26	8	24.61	2.36	Rural Restricted	26	5	15.33	3.05
Rural Unrestricted	27	1	8.73	6.18	Urban Unrestricted	27	8	24.30	2.30	Rural Restricted	27	5	15.25	3.05
Rural Unrestricted	28	1	8.67	6.15	Urban Unrestricted	28	8	24.02	2.24	Rural Restricted	28	5	15.18	3.05
Rural Unrestricted	29	1	8.62	6.12	Urban Unrestricted	29	8	23.75	2.19	Rural Restricted	29	5	15.11	3.05
Rural Unrestricted	30	1	8.56	6.09	Urban Unrestricted	30	8	23.50	2.14	Rural Restricted	30	5	15.05	3.05
Rural Unrestricted	31	1	8.52	6.07	Urban Unrestricted	31	8	23.26	2.09	Rural Restricted	31	5	15.08	3.05
Rural Unrestricted	32	1	8.30	5.89	Urban Unrestricted	32	8	23.24	2.00	Rural Restricted	32	5	15.04	2.96
Rural Unrestricted	33	1	7.93	5.60	Urban Unrestricted	33	8	23.05	1.86	Rural Restricted	33	5	14.87	2.79
Rural Unrestricted	34	1	7.59	5.32	Urban Unrestricted	34	8	22.88	1.73	Rural Restricted	34	5	14.70	2.62
Rural Unrestricted	35	1	7.40	5.16	Urban Unrestricted	35	8	22.85	1.65	Rural Restricted	35	5	14.68	2.55
Rural Unrestricted	36	1	7.32	5.08	Urban Unrestricted	36	8	22.92	1.59	Rural Restricted	36	5	14.75	2.52
Rural Unrestricted	37	1	7.24	4.99	Urban Unrestricted	37	8	22.99	1.53	Rural Restricted	37	5	14.81	2.50
Rural Unrestricted	38	1	7.16	4.92	Urban Unrestricted	38	8	23.05	1.48	Rural Restricted	38	5	14.86	2.48
Rural Unrestricted	39	1	7.09	4.84	Urban Unrestricted	39	8	23.10	1.43	Rural Restricted	39	5	14.92	2.46
Rural Unrestricted	40	1	7.02	4.77	Urban Unrestricted	40	8	23.16	1.38	Rural Restricted	40	5	14.97	2.45
Rural Unrestricted	41	1	6.95	4.70	Urban Unrestricted	41	8	23.21	1.33	Rural Restricted	41	5	15.02	2.43
Rural Unrestricted	42	1	6.89	4.64	Urban Unrestricted	42	8	23.26	1.29	Rural Restricted	42	5	15.07	2.41
Rural Unrestricted	43	1	6.83	4.58	Urban Unrestricted	43	8	23.30	1.24	Rural Restricted	43	5	15.11	2.40
Rural Unrestricted	44	1	6.78	4.52	Urban Unrestricted	44	8	23.36	1.21	Rural Restricted	44	5	15.16	2.38
Rural Unrestricted	45	1	6.71	4.46	Urban Unrestricted	45	8	23.40	1.17	Rural Restricted	45	5	15.17	2.37
Rural Unrestricted	46	1	6.63	4.41	Urban Unrestricted	46	8	23.40	1.13	Rural Restricted	46	5	15.16	2.35
Rural Unrestricted	47	1	6.56	4.35	Urban Unrestricted	47	8	23.41	1.10	Rural Restricted	47	5	15.15	2.32
Rural Unrestricted	48	1	6.48	4.30	Urban Unrestricted	48	8	23.41	1.06	Rural Restricted	48	5	15.15	2.28
Rural Unrestricted	49	1	6.42	4.25	Urban Unrestricted	49	8	23.42	1.03	Rural Restricted	49	5	15.15	2.25
Rural Unrestricted	50	1	6.39	4.23	Urban Unrestricted	50	8	23.42	1.00	Rural Restricted	50	5	15.14	2.22

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	51	1	6.37	4.21	Urban Unrestricted	51	8	23.43	0.97	Rural Restricted	51	5	15.14	2.19
Rural Unrestricted	52	1	6.35	4.19	Urban Unrestricted	52	8	23.43	0.94	Rural Restricted	52	5	15.13	2.16
Rural Unrestricted	53	1	6.33	4.17	Urban Unrestricted	53	8	23.44	0.91	Rural Restricted	53	5	15.13	2.13
Rural Unrestricted	54	1	6.31	4.15	Urban Unrestricted	54	8	23.43	0.89	Rural Restricted	54	5	15.13	2.11
Rural Unrestricted	55	1	6.29	4.13	Urban Unrestricted	55	8	23.43	0.87	Rural Restricted	55	5	15.12	2.08
Rural Unrestricted	56	1	6.26	4.10	Urban Unrestricted	56	8	23.45	0.86	Rural Restricted	56	5	15.12	2.05
Rural Unrestricted	57	1	6.23	4.08	Urban Unrestricted	57	8	23.49	0.85	Rural Restricted	57	5	15.11	2.01
Rural Unrestricted	58	1	6.20	4.05	Urban Unrestricted	58	8	23.53	0.83	Rural Restricted	58	5	15.10	1.98
Rural Unrestricted	59	1	6.17	4.02	Urban Unrestricted	59	8	23.56	0.82	Rural Restricted	59	5	15.13	1.95
Rural Unrestricted	60	1	6.14	4.00	Urban Unrestricted	60	8	23.59	0.81	Rural Restricted	60	5	15.32	1.93
Rural Unrestricted	61	1	6.18	3.99	Urban Unrestricted	61	8	23.66	0.80	Rural Restricted	61	5	15.56	1.91
Rural Unrestricted	62	1	6.27	3.99	Urban Unrestricted	62	8	23.76	0.78	Rural Restricted	62	5	15.83	1.88
Rural Unrestricted	63	1	6.35	3.98	Urban Unrestricted	63	8	23.85	0.77	Rural Restricted	63	5	16.10	1.86
Rural Unrestricted	64	1	6.49	4.00	Urban Unrestricted	64	8	23.92	0.76	Rural Restricted	64	5	16.36	1.84
Rural Unrestricted	65	1	6.72	4.05	Urban Unrestricted	65	8	23.94	0.74	Rural Restricted	65	5	16.65	1.83
Rural Unrestricted	66	1	6.94	4.10	Urban Unrestricted	66	8	23.97	0.72	Rural Restricted	66	5	16.95	1.83
Rural Unrestricted	67	1	7.16	4.15	Urban Unrestricted	67	8	23.99	0.70	Rural Restricted	67	5	17.28	1.82
Rural Unrestricted	68	1	7.37	4.20	Urban Unrestricted	68	8	24.02	0.68	Rural Restricted	68	5	17.60	1.80
Rural Unrestricted	69	1	7.57	4.24	Urban Unrestricted	69	8	24.04	0.66	Rural Restricted	69	5	17.92	1.78
Rural Unrestricted	70	1	7.77	4.29	Urban Unrestricted	70	8	24.06	0.65	Rural Restricted	70	5	18.23	1.76
Rural Unrestricted	71	1	7.96	4.33	Urban Unrestricted	71	8	24.08	0.63	Rural Restricted	71	5	18.53	1.74
Rural Unrestricted	72	1	8.15	4.37	Urban Unrestricted	72	8	24.10	0.61	Rural Restricted	72	5	18.82	1.72
Rural Unrestricted	73	1	8.34	4.42	Urban Unrestricted	73	8	24.13	0.60	Rural Restricted	73	5	19.11	1.70
Rural Unrestricted	74	1	8.65	4.55	Urban Unrestricted	74	8	24.13	0.59	Rural Restricted	74	5	19.34	1.70
Rural Unrestricted	75	1	9.31	4.98	Urban Unrestricted	75	8	23.96	0.63	Rural Restricted	75	5	19.27	1.79
Urban Unrestricted	1	1	65.72	48.13	Rural Unrestricted	1	9	71.10	27.05	Urban Restricted	1	5	69.32	32.16
Urban Unrestricted	2	1	33.05	24.58	Rural Unrestricted	2	9	36.58	13.70	Urban Restricted	2	5	35.35	16.37
Urban Unrestricted	3	1	23.20	18.35	Rural Unrestricted	3	9	29.46	9.88	Urban Restricted	3	5	26.52	11.98
Urban Unrestricted	4	1	18.75	15.62	Rural Unrestricted	4	9	27.49	8.16	Urban Restricted	4	5	22.84	9.97
Urban Unrestricted	5	1	16.18	13.79	Rural Unrestricted	5	9	26.43	7.04	Urban Restricted	5	5	20.69	8.69
Urban Unrestricted	6	1	14.61	12.34	Rural Unrestricted	6	9	25.85	6.20	Urban Restricted	6	5	19.33	7.76
Urban Unrestricted	7	1	13.48	11.31	Rural Unrestricted	7	9	25.44	5.60	Urban Restricted	7	5	18.36	7.10
Urban Unrestricted	8	1	12.64	10.53	Rural Unrestricted	8	9	25.13	5.14	Urban Restricted	8	5	17.64	6.60
Urban Unrestricted	9	1	11.98	9.93	Rural Unrestricted	9	9	24.88	4.79	Urban Restricted	9	5	16.98	6.21
Urban Unrestricted	10	1	11.45	9.44	Rural Unrestricted	10	9	24.69	4.51	Urban Restricted	10	5	16.23	5.92
Urban Unrestricted	11	1	11.08	9.05	Rural Unrestricted	11	9	24.62	4.28	Urban Restricted	11	5	15.70	5.65
Urban Unrestricted	12	1	10.91	8.73	Rural Unrestricted	12	9	24.79	4.08	Urban Restricted	12	5	15.40	5.37
Urban Unrestricted	13	1	10.76	8.46	Rural Unrestricted	13	9	24.93	3.92	Urban Restricted	13	5	15.15	5.13
Urban Unrestricted	14	1	10.64	8.23	Rural Unrestricted	14	9	25.05	3.78	Urban Restricted	14	5	14.94	4.93
Urban Unrestricted	15	1	10.53	8.03	Rural Unrestricted	15	9	25.15	3.66	Urban Restricted	15	5	14.75	4.76

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	16	1	10.41	7.87	Rural Unrestricted	16	9	25.20	3.54	Urban Restricted	16	5	14.67	4.57
Urban Unrestricted	17	1	10.29	7.72	Rural Unrestricted	17	9	25.19	3.44	Urban Restricted	17	5	14.84	4.31
Urban Unrestricted	18	1	10.18	7.60	Rural Unrestricted	18	9	25.18	3.35	Urban Restricted	18	5	14.98	4.08
Urban Unrestricted	19	1	10.04	7.42	Rural Unrestricted	19	9	25.46	3.22	Urban Restricted	19	5	15.12	3.87
Urban Unrestricted	20	1	9.85	7.17	Rural Unrestricted	20	9	26.07	3.03	Urban Restricted	20	5	15.24	3.69
Urban Unrestricted	21	1	9.66	6.95	Rural Unrestricted	21	9	26.63	2.86	Urban Restricted	21	5	15.31	3.53
Urban Unrestricted	22	1	9.43	6.75	Rural Unrestricted	22	9	27.12	2.67	Urban Restricted	22	5	15.35	3.37
Urban Unrestricted	23	1	9.21	6.56	Rural Unrestricted	23	9	27.57	2.50	Urban Restricted	23	5	15.39	3.23
Urban Unrestricted	24	1	9.01	6.40	Rural Unrestricted	24	9	27.98	2.35	Urban Restricted	24	5	15.42	3.11
Urban Unrestricted	25	1	8.86	6.26	Rural Unrestricted	25	9	28.32	2.23	Urban Restricted	25	5	15.40	3.04
Urban Unrestricted	26	1	8.78	6.20	Rural Unrestricted	26	9	28.16	2.14	Urban Restricted	26	5	15.31	3.04
Urban Unrestricted	27	1	8.71	6.16	Rural Unrestricted	27	9	27.73	2.07	Urban Restricted	27	5	15.23	3.04
Urban Unrestricted	28	1	8.65	6.13	Rural Unrestricted	28	9	27.34	2.00	Urban Restricted	28	5	15.16	3.04
Urban Unrestricted	29	1	8.60	6.10	Rural Unrestricted	29	9	26.97	1.94	Urban Restricted	29	5	15.09	3.04
Urban Unrestricted	30	1	8.55	6.08	Rural Unrestricted	30	9	26.63	1.88	Urban Restricted	30	5	15.03	3.04
Urban Unrestricted	31	1	8.50	6.05	Rural Unrestricted	31	9	26.31	1.83	Urban Restricted	31	5	15.06	3.04
Urban Unrestricted	32	1	8.29	5.87	Rural Unrestricted	32	9	26.30	1.75	Urban Restricted	32	5	15.03	2.95
Urban Unrestricted	33	1	7.92	5.58	Rural Unrestricted	33	9	26.14	1.65	Urban Restricted	33	5	14.86	2.78
Urban Unrestricted	34	1	7.58	5.30	Rural Unrestricted	34	9	26.00	1.56	Urban Restricted	34	5	14.70	2.62
Urban Unrestricted	35	1	7.39	5.14	Rural Unrestricted	35	9	25.99	1.49	Urban Restricted	35	5	14.68	2.54
Urban Unrestricted	36	1	7.31	5.05	Rural Unrestricted	36	9	26.07	1.43	Urban Restricted	36	5	14.74	2.52
Urban Unrestricted	37	1	7.23	4.96	Rural Unrestricted	37	9	26.15	1.38	Urban Restricted	37	5	14.80	2.50
Urban Unrestricted	38	1	7.15	4.88	Rural Unrestricted	38	9	26.22	1.34	Urban Restricted	38	5	14.86	2.48
Urban Unrestricted	39	1	7.08	4.81	Rural Unrestricted	39	9	26.28	1.29	Urban Restricted	39	5	14.92	2.46
Urban Unrestricted	40	1	7.01	4.73	Rural Unrestricted	40	9	26.35	1.25	Urban Restricted	40	5	14.97	2.44
Urban Unrestricted	41	1	6.95	4.66	Rural Unrestricted	41	9	26.41	1.21	Urban Restricted	41	5	15.02	2.42
Urban Unrestricted	42	1	6.89	4.60	Rural Unrestricted	42	9	26.47	1.17	Urban Restricted	42	5	15.07	2.40
Urban Unrestricted	43	1	6.83	4.54	Rural Unrestricted	43	9	26.52	1.13	Urban Restricted	43	5	15.12	2.39
Urban Unrestricted	44	1	6.77	4.48	Rural Unrestricted	44	9	26.57	1.10	Urban Restricted	44	5	15.16	2.37
Urban Unrestricted	45	1	6.69	4.42	Rural Unrestricted	45	9	26.60	1.06	Urban Restricted	45	5	15.18	2.36
Urban Unrestricted	46	1	6.61	4.37	Rural Unrestricted	46	9	26.59	1.03	Urban Restricted	46	5	15.17	2.34
Urban Unrestricted	47	1	6.53	4.32	Rural Unrestricted	47	9	26.58	1.00	Urban Restricted	47	5	15.16	2.31
Urban Unrestricted	48	1	6.45	4.27	Rural Unrestricted	48	9	26.58	0.97	Urban Restricted	48	5	15.16	2.27
Urban Unrestricted	49	1	6.38	4.22	Rural Unrestricted	49	9	26.57	0.94	Urban Restricted	49	5	15.16	2.24
Urban Unrestricted	50	1	6.31	4.17	Rural Unrestricted	50	9	26.48	0.91	Urban Restricted	50	5	15.16	2.21
Urban Unrestricted	51	1	6.24	4.13	Rural Unrestricted	51	9	26.39	0.89	Urban Restricted	51	5	15.15	2.18
Urban Unrestricted	52	1	6.17	4.09	Rural Unrestricted	52	9	26.30	0.86	Urban Restricted	52	5	15.15	2.15
Urban Unrestricted	53	1	6.12	4.05	Rural Unrestricted	53	9	26.22	0.84	Urban Restricted	53	5	15.15	2.12
Urban Unrestricted	54	1	6.12	4.04	Rural Unrestricted	54	9	26.14	0.82	Urban Restricted	54	5	15.15	2.10
Urban Unrestricted	55	1	6.12	4.03	Rural Unrestricted	55	9	26.06	0.80	Urban Restricted	55	5	15.14	2.07

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	56	1	6.12	4.02	Rural Unrestricted	56	9	26.00	0.78	Urban Restricted	56	5	15.14	2.04
Urban Unrestricted	57	1	6.10	4.00	Rural Unrestricted	57	9	25.95	0.76	Urban Restricted	57	5	15.13	2.00
Urban Unrestricted	58	1	6.09	3.99	Rural Unrestricted	58	9	25.90	0.75	Urban Restricted	58	5	15.12	1.97
Urban Unrestricted	59	1	6.07	3.97	Rural Unrestricted	59	9	25.85	0.73	Urban Restricted	59	5	15.16	1.94
Urban Unrestricted	60	1	6.06	3.95	Rural Unrestricted	60	9	25.80	0.72	Urban Restricted	60	5	15.34	1.92
Urban Unrestricted	61	1	6.12	3.95	Rural Unrestricted	61	9	25.80	0.70	Urban Restricted	61	5	15.58	1.90
Urban Unrestricted	62	1	6.22	3.95	Rural Unrestricted	62	9	25.83	0.69	Urban Restricted	62	5	15.86	1.87
Urban Unrestricted	63	1	6.32	3.96	Rural Unrestricted	63	9	25.86	0.67	Urban Restricted	63	5	16.13	1.85
Urban Unrestricted	64	1	6.47	3.98	Rural Unrestricted	64	9	25.86	0.66	Urban Restricted	64	5	16.39	1.83
Urban Unrestricted	65	1	6.70	4.03	Rural Unrestricted	65	9	25.78	0.64	Urban Restricted	65	5	16.68	1.82
Urban Unrestricted	66	1	6.92	4.08	Rural Unrestricted	66	9	25.70	0.63	Urban Restricted	66	5	16.99	1.82
Urban Unrestricted	67	1	7.14	4.13	Rural Unrestricted	67	9	25.62	0.61	Urban Restricted	67	5	17.31	1.81
Urban Unrestricted	68	1	7.35	4.18	Rural Unrestricted	68	9	25.55	0.60	Urban Restricted	68	5	17.64	1.79
Urban Unrestricted	69	1	7.55	4.22	Rural Unrestricted	69	9	25.48	0.58	Urban Restricted	69	5	17.96	1.77
Urban Unrestricted	70	1	7.75	4.27	Rural Unrestricted	70	9	25.41	0.57	Urban Restricted	70	5	18.27	1.75
Urban Unrestricted	71	1	7.95	4.31	Rural Unrestricted	71	9	25.34	0.55	Urban Restricted	71	5	18.57	1.73
Urban Unrestricted	72	1	8.13	4.35	Rural Unrestricted	72	9	25.27	0.54	Urban Restricted	72	5	18.87	1.71
Urban Unrestricted	73	1	8.33	4.40	Rural Unrestricted	73	9	25.21	0.53	Urban Restricted	73	5	19.16	1.69
Urban Unrestricted	74	1	8.64	4.53	Rural Unrestricted	74	9	25.14	0.52	Urban Restricted	74	5	19.39	1.69
Urban Unrestricted	75	1	9.30	4.96	Rural Unrestricted	75	9	24.95	0.53	Urban Restricted	75	5	19.32	1.78
Rural Unrestricted	1	2	67.31	42.80	Urban Unrestricted	1	9	70.88	26.86	Rural Restricted	1	6	69.91	31.04
Rural Unrestricted	2	2	33.95	21.86	Urban Unrestricted	2	9	36.47	13.61	Rural Restricted	2	6	35.73	15.75
Rural Unrestricted	3	2	24.20	16.36	Urban Unrestricted	3	9	29.38	9.82	Rural Restricted	3	6	27.13	11.36
Rural Unrestricted	4	2	19.88	13.97	Urban Unrestricted	4	9	27.44	8.11	Rural Restricted	4	6	23.66	9.33
Rural Unrestricted	5	2	17.40	12.36	Urban Unrestricted	5	9	26.38	7.00	Rural Restricted	5	6	21.66	8.08
Rural Unrestricted	6	2	15.91	11.08	Urban Unrestricted	6	9	25.81	6.17	Rural Restricted	6	6	20.42	7.19
Rural Unrestricted	7	2	14.84	10.17	Urban Unrestricted	7	9	25.40	5.57	Rural Restricted	7	6	19.53	6.55
Rural Unrestricted	8	2	14.03	9.48	Urban Unrestricted	8	9	25.10	5.12	Rural Restricted	8	6	18.86	6.07
Rural Unrestricted	9	2	13.41	8.95	Urban Unrestricted	9	9	24.86	4.77	Rural Restricted	9	6	18.24	5.70
Rural Unrestricted	10	2	12.91	8.52	Urban Unrestricted	10	9	24.66	4.49	Rural Restricted	10	6	17.51	5.41
Rural Unrestricted	11	2	12.55	8.18	Urban Unrestricted	11	9	24.60	4.26	Rural Restricted	11	6	16.99	5.16
Rural Unrestricted	12	2	12.38	7.89	Urban Unrestricted	12	9	24.77	4.07	Rural Restricted	12	6	16.73	4.90
Rural Unrestricted	13	2	12.24	7.65	Urban Unrestricted	13	9	24.91	3.90	Rural Restricted	13	6	16.51	4.69
Rural Unrestricted	14	2	12.11	7.44	Urban Unrestricted	14	9	25.03	3.76	Rural Restricted	14	6	16.32	4.50
Rural Unrestricted	15	2	12.00	7.26	Urban Unrestricted	15	9	25.14	3.64	Rural Restricted	15	6	16.16	4.34
Rural Unrestricted	16	2	11.90	7.10	Urban Unrestricted	16	9	25.19	3.53	Rural Restricted	16	6	16.16	4.16
Rural Unrestricted	17	2	11.80	6.95	Urban Unrestricted	17	9	25.18	3.43	Rural Restricted	17	6	16.53	3.91
Rural Unrestricted	18	2	11.71	6.82	Urban Unrestricted	18	9	25.17	3.34	Rural Restricted	18	6	16.86	3.68
Rural Unrestricted	19	2	11.57	6.63	Urban Unrestricted	19	9	25.45	3.21	Rural Restricted	19	6	17.15	3.48
Rural Unrestricted	20	2	11.39	6.36	Urban Unrestricted	20	9	26.06	3.02	Rural Restricted	20	6	17.42	3.30

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	21	2	11.22	6.12	Urban Unrestricted	21	9	26.62	2.85	Rural Restricted	21	6	17.56	3.14
Rural Unrestricted	22	2	11.03	5.90	Urban Unrestricted	22	9	27.11	2.66	Rural Restricted	22	6	17.54	3.00
Rural Unrestricted	23	2	10.85	5.69	Urban Unrestricted	23	9	27.57	2.49	Rural Restricted	23	6	17.53	2.88
Rural Unrestricted	24	2	10.69	5.51	Urban Unrestricted	24	9	27.98	2.34	Rural Restricted	24	6	17.51	2.76
Rural Unrestricted	25	2	10.54	5.37	Urban Unrestricted	25	9	28.32	2.22	Rural Restricted	25	6	17.45	2.70
Rural Unrestricted	26	2	10.44	5.31	Urban Unrestricted	26	9	28.16	2.13	Rural Restricted	26	6	17.36	2.69
Rural Unrestricted	27	2	10.38	5.28	Urban Unrestricted	27	9	27.73	2.06	Rural Restricted	27	6	17.28	2.67
Rural Unrestricted	28	2	10.32	5.26	Urban Unrestricted	28	9	27.34	2.00	Rural Restricted	28	6	17.20	2.66
Rural Unrestricted	29	2	10.27	5.23	Urban Unrestricted	29	9	26.97	1.93	Rural Restricted	29	6	17.12	2.65
Rural Unrestricted	30	2	10.22	5.21	Urban Unrestricted	30	9	26.63	1.87	Rural Restricted	30	6	17.06	2.64
Rural Unrestricted	31	2	10.17	5.19	Urban Unrestricted	31	9	26.31	1.82	Rural Restricted	31	6	17.11	2.63
Rural Unrestricted	32	2	10.00	5.02	Urban Unrestricted	32	9	26.24	1.74	Rural Restricted	32	6	17.11	2.53
Rural Unrestricted	33	2	9.71	4.75	Urban Unrestricted	33	9	26.03	1.63	Rural Restricted	33	6	16.95	2.36
Rural Unrestricted	34	2	9.43	4.49	Urban Unrestricted	34	9	25.83	1.54	Rural Restricted	34	6	16.80	2.20
Rural Unrestricted	35	2	9.27	4.34	Urban Unrestricted	35	9	25.77	1.46	Rural Restricted	35	6	16.80	2.11
Rural Unrestricted	36	2	9.18	4.28	Urban Unrestricted	36	9	25.80	1.41	Rural Restricted	36	6	16.89	2.07
Rural Unrestricted	37	2	9.10	4.21	Urban Unrestricted	37	9	25.83	1.35	Rural Restricted	37	6	16.98	2.03
Rural Unrestricted	38	2	9.02	4.15	Urban Unrestricted	38	9	25.86	1.30	Rural Restricted	38	6	17.06	1.99
Rural Unrestricted	39	2	8.94	4.10	Urban Unrestricted	39	9	25.89	1.26	Rural Restricted	39	6	17.14	1.96
Rural Unrestricted	40	2	8.87	4.04	Urban Unrestricted	40	9	25.91	1.21	Rural Restricted	40	6	17.21	1.93
Rural Unrestricted	41	2	8.80	3.99	Urban Unrestricted	41	9	25.94	1.17	Rural Restricted	41	6	17.29	1.89
Rural Unrestricted	42	2	8.73	3.94	Urban Unrestricted	42	9	25.96	1.13	Rural Restricted	42	6	17.35	1.86
Rural Unrestricted	43	2	8.67	3.89	Urban Unrestricted	43	9	25.98	1.09	Rural Restricted	43	6	17.42	1.84
Rural Unrestricted	44	2	8.61	3.85	Urban Unrestricted	44	9	26.04	1.05	Rural Restricted	44	6	17.48	1.81
Rural Unrestricted	45	2	8.53	3.81	Urban Unrestricted	45	9	26.09	1.01	Rural Restricted	45	6	17.51	1.78
Rural Unrestricted	46	2	8.45	3.77	Urban Unrestricted	46	9	26.10	0.98	Rural Restricted	46	6	17.50	1.75
Rural Unrestricted	47	2	8.36	3.73	Urban Unrestricted	47	9	26.12	0.95	Rural Restricted	47	6	17.54	1.71
Rural Unrestricted	48	2	8.28	3.69	Urban Unrestricted	48	9	26.13	0.92	Rural Restricted	48	6	17.59	1.67
Rural Unrestricted	49	2	8.20	3.66	Urban Unrestricted	49	9	26.14	0.89	Rural Restricted	49	6	17.63	1.63
Rural Unrestricted	50	2	8.17	3.64	Urban Unrestricted	50	9	26.15	0.86	Rural Restricted	50	6	17.67	1.59
Rural Unrestricted	51	2	8.15	3.62	Urban Unrestricted	51	9	26.17	0.83	Rural Restricted	51	6	17.71	1.56
Rural Unrestricted	52	2	8.13	3.61	Urban Unrestricted	52	9	26.18	0.80	Rural Restricted	52	6	17.74	1.53
Rural Unrestricted	53	2	8.10	3.60	Urban Unrestricted	53	9	26.17	0.78	Rural Restricted	53	6	17.78	1.49
Rural Unrestricted	54	2	8.08	3.58	Urban Unrestricted	54	9	26.10	0.76	Rural Restricted	54	6	17.81	1.46
Rural Unrestricted	55	2	8.06	3.57	Urban Unrestricted	55	9	26.03	0.75	Rural Restricted	55	6	17.85	1.43
Rural Unrestricted	56	2	8.05	3.55	Urban Unrestricted	56	9	25.97	0.74	Rural Restricted	56	6	17.88	1.40
Rural Unrestricted	57	2	8.06	3.53	Urban Unrestricted	57	9	25.93	0.72	Rural Restricted	57	6	17.92	1.37
Rural Unrestricted	58	2	8.06	3.50	Urban Unrestricted	58	9	25.88	0.71	Rural Restricted	58	6	17.96	1.34
Rural Unrestricted	59	2	8.06	3.48	Urban Unrestricted	59	9	25.84	0.70	Rural Restricted	59	6	18.02	1.31
Rural Unrestricted	60	2	8.07	3.46	Urban Unrestricted	60	9	25.80	0.69	Rural Restricted	60	6	18.16	1.30

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	61	2	8.14	3.44	Urban Unrestricted	61	9	25.81	0.68	Rural Restricted	61	6	18.37	1.28
Rural Unrestricted	62	2	8.25	3.42	Urban Unrestricted	62	9	25.84	0.67	Rural Restricted	62	6	18.61	1.26
Rural Unrestricted	63	2	8.36	3.40	Urban Unrestricted	63	9	25.88	0.67	Rural Restricted	63	6	18.85	1.25
Rural Unrestricted	64	2	8.55	3.39	Urban Unrestricted	64	9	25.87	0.65	Rural Restricted	64	6	19.09	1.24
Rural Unrestricted	65	2	8.87	3.40	Urban Unrestricted	65	9	25.79	0.64	Rural Restricted	65	6	19.36	1.22
Rural Unrestricted	66	2	9.18	3.42	Urban Unrestricted	66	9	25.71	0.62	Rural Restricted	66	6	19.67	1.22
Rural Unrestricted	67	2	9.49	3.43	Urban Unrestricted	67	9	25.64	0.61	Rural Restricted	67	6	19.95	1.20
Rural Unrestricted	68	2	9.78	3.44	Urban Unrestricted	68	9	25.56	0.59	Rural Restricted	68	6	20.21	1.18
Rural Unrestricted	69	2	10.07	3.45	Urban Unrestricted	69	9	25.49	0.58	Rural Restricted	69	6	20.47	1.17
Rural Unrestricted	70	2	10.35	3.46	Urban Unrestricted	70	9	25.42	0.56	Rural Restricted	70	6	20.72	1.15
Rural Unrestricted	71	2	10.62	3.46	Urban Unrestricted	71	9	25.35	0.55	Rural Restricted	71	6	20.97	1.13
Rural Unrestricted	72	2	10.88	3.47	Urban Unrestricted	72	9	25.29	0.54	Rural Restricted	72	6	21.20	1.11
Rural Unrestricted	73	2	11.13	3.48	Urban Unrestricted	73	9	25.23	0.52	Rural Restricted	73	6	21.43	1.10
Rural Unrestricted	74	2	11.37	3.56	Urban Unrestricted	74	9	25.16	0.52	Rural Restricted	74	6	21.54	1.10
Rural Unrestricted	75	2	11.74	3.87	Urban Unrestricted	75	9	24.97	0.53	Rural Restricted	75	6	21.19	1.19
Urban Unrestricted	1	2	67.11	42.61	Rural Unrestricted	1	10	71.55	25.53	Urban Restricted	1	6	69.77	30.93
Urban Unrestricted	2	2	33.85	21.76	Rural Unrestricted	2	10	36.89	12.92	Urban Restricted	2	6	35.65	15.69
Urban Unrestricted	3	2	24.14	16.29	Rural Unrestricted	3	10	30.24	9.26	Urban Restricted	3	6	27.07	11.31
Urban Unrestricted	4	2	19.82	13.92	Rural Unrestricted	4	10	28.78	7.58	Urban Restricted	4	6	23.62	9.30
Urban Unrestricted	5	2	17.36	12.32	Rural Unrestricted	5	10	28.09	6.50	Urban Restricted	5	6	21.62	8.05
Urban Unrestricted	6	2	15.87	11.05	Rural Unrestricted	6	10	27.86	5.69	Urban Restricted	6	6	20.38	7.16
Urban Unrestricted	7	2	14.80	10.14	Rural Unrestricted	7	10	27.70	5.11	Urban Restricted	7	6	19.49	6.53
Urban Unrestricted	8	2	14.00	9.46	Rural Unrestricted	8	10	27.58	4.68	Urban Restricted	8	6	18.83	6.05
Urban Unrestricted	9	2	13.38	8.93	Rural Unrestricted	9	10	27.49	4.34	Urban Restricted	9	6	18.21	5.69
Urban Unrestricted	10	2	12.88	8.50	Rural Unrestricted	10	10	27.40	4.07	Urban Restricted	10	6	17.48	5.40
Urban Unrestricted	11	2	12.53	8.15	Rural Unrestricted	11	10	27.39	3.85	Urban Restricted	11	6	16.96	5.14
Urban Unrestricted	12	2	12.36	7.87	Rural Unrestricted	12	10	27.50	3.67	Urban Restricted	12	6	16.70	4.89
Urban Unrestricted	13	2	12.21	7.63	Rural Unrestricted	13	10	27.59	3.52	Urban Restricted	13	6	16.48	4.68
Urban Unrestricted	14	2	12.09	7.42	Rural Unrestricted	14	10	27.66	3.39	Urban Restricted	14	6	16.29	4.49
Urban Unrestricted	15	2	11.98	7.24	Rural Unrestricted	15	10	27.73	3.28	Urban Restricted	15	6	16.13	4.33
Urban Unrestricted	16	2	11.88	7.08	Rural Unrestricted	16	10	27.78	3.17	Urban Restricted	16	6	16.12	4.15
Urban Unrestricted	17	2	11.78	6.93	Rural Unrestricted	17	10	27.82	3.07	Urban Restricted	17	6	16.50	3.90
Urban Unrestricted	18	2	11.69	6.80	Rural Unrestricted	18	10	27.85	2.98	Urban Restricted	18	6	16.83	3.67
Urban Unrestricted	19	2	11.56	6.61	Rural Unrestricted	19	10	28.24	2.86	Urban Restricted	19	6	17.13	3.47
Urban Unrestricted	20	2	11.37	6.35	Rural Unrestricted	20	10	29.06	2.70	Urban Restricted	20	6	17.40	3.29
Urban Unrestricted	21	2	11.20	6.11	Rural Unrestricted	21	10	29.80	2.55	Urban Restricted	21	6	17.54	3.13
Urban Unrestricted	22	2	11.01	5.88	Rural Unrestricted	22	10	30.43	2.39	Urban Restricted	22	6	17.52	3.00
Urban Unrestricted	23	2	10.83	5.68	Rural Unrestricted	23	10	31.01	2.24	Urban Restricted	23	6	17.51	2.87
Urban Unrestricted	24	2	10.67	5.49	Rural Unrestricted	24	10	31.55	2.10	Urban Restricted	24	6	17.49	2.75
Urban Unrestricted	25	2	10.52	5.35	Rural Unrestricted	25	10	32.01	2.00	Urban Restricted	25	6	17.44	2.69

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	26	2	10.42	5.30	Rural Unrestricted	26	10	31.87	1.93	Urban Restricted	26	6	17.34	2.68
Urban Unrestricted	27	2	10.36	5.27	Rural Unrestricted	27	10	31.42	1.87	Urban Restricted	27	6	17.26	2.67
Urban Unrestricted	28	2	10.30	5.24	Rural Unrestricted	28	10	31.00	1.81	Urban Restricted	28	6	17.18	2.65
Urban Unrestricted	29	2	10.25	5.22	Rural Unrestricted	29	10	30.62	1.75	Urban Restricted	29	6	17.11	2.64
Urban Unrestricted	30	2	10.20	5.20	Rural Unrestricted	30	10	30.25	1.70	Urban Restricted	30	6	17.04	2.63
Urban Unrestricted	31	2	10.16	5.18	Rural Unrestricted	31	10	29.92	1.65	Urban Restricted	31	6	17.09	2.62
Urban Unrestricted	32	2	9.97	5.00	Rural Unrestricted	32	10	29.81	1.58	Urban Restricted	32	6	17.10	2.52
Urban Unrestricted	33	2	9.67	4.72	Rural Unrestricted	33	10	29.57	1.48	Urban Restricted	33	6	16.94	2.35
Urban Unrestricted	34	2	9.39	4.46	Rural Unrestricted	34	10	29.34	1.39	Urban Restricted	34	6	16.80	2.19
Urban Unrestricted	35	2	9.22	4.31	Rural Unrestricted	35	10	29.25	1.32	Urban Restricted	35	6	16.80	2.10
Urban Unrestricted	36	2	9.12	4.24	Rural Unrestricted	36	10	29.25	1.28	Urban Restricted	36	6	16.90	2.06
Urban Unrestricted	37	2	9.03	4.17	Rural Unrestricted	37	10	29.25	1.24	Urban Restricted	37	6	16.98	2.02
Urban Unrestricted	38	2	8.94	4.11	Rural Unrestricted	38	10	29.25	1.20	Urban Restricted	38	6	17.07	1.99
Urban Unrestricted	39	2	8.86	4.05	Rural Unrestricted	39	10	29.25	1.16	Urban Restricted	39	6	17.15	1.95
Urban Unrestricted	40	2	8.78	3.99	Rural Unrestricted	40	10	29.25	1.12	Urban Restricted	40	6	17.22	1.92
Urban Unrestricted	41	2	8.70	3.94	Rural Unrestricted	41	10	29.25	1.09	Urban Restricted	41	6	17.30	1.89
Urban Unrestricted	42	2	8.63	3.88	Rural Unrestricted	42	10	29.25	1.05	Urban Restricted	42	6	17.36	1.86
Urban Unrestricted	43	2	8.56	3.83	Rural Unrestricted	43	10	29.25	1.02	Urban Restricted	43	6	17.43	1.83
Urban Unrestricted	44	2	8.50	3.79	Rural Unrestricted	44	10	29.25	0.99	Urban Restricted	44	6	17.49	1.80
Urban Unrestricted	45	2	8.43	3.75	Rural Unrestricted	45	10	29.21	0.96	Urban Restricted	45	6	17.52	1.77
Urban Unrestricted	46	2	8.35	3.72	Rural Unrestricted	46	10	29.14	0.93	Urban Restricted	46	6	17.52	1.74
Urban Unrestricted	47	2	8.27	3.68	Rural Unrestricted	47	10	29.08	0.90	Urban Restricted	47	6	17.56	1.70
Urban Unrestricted	48	2	8.19	3.65	Rural Unrestricted	48	10	29.01	0.88	Urban Restricted	48	6	17.61	1.66
Urban Unrestricted	49	2	8.12	3.61	Rural Unrestricted	49	10	28.95	0.85	Urban Restricted	49	6	17.65	1.62
Urban Unrestricted	50	2	8.04	3.58	Rural Unrestricted	50	10	28.79	0.83	Urban Restricted	50	6	17.69	1.59
Urban Unrestricted	51	2	7.98	3.55	Rural Unrestricted	51	10	28.62	0.81	Urban Restricted	51	6	17.73	1.55
Urban Unrestricted	52	2	7.91	3.53	Rural Unrestricted	52	10	28.46	0.79	Urban Restricted	52	6	17.77	1.52
Urban Unrestricted	53	2	7.86	3.50	Rural Unrestricted	53	10	28.30	0.77	Urban Restricted	53	6	17.81	1.49
Urban Unrestricted	54	2	7.86	3.50	Rural Unrestricted	54	10	28.16	0.75	Urban Restricted	54	6	17.84	1.46
Urban Unrestricted	55	2	7.86	3.49	Rural Unrestricted	55	10	28.01	0.73	Urban Restricted	55	6	17.88	1.43
Urban Unrestricted	56	2	7.88	3.48	Rural Unrestricted	56	10	27.89	0.71	Urban Restricted	56	6	17.92	1.40
Urban Unrestricted	57	2	7.91	3.46	Rural Unrestricted	57	10	27.77	0.69	Urban Restricted	57	6	17.96	1.37
Urban Unrestricted	58	2	7.93	3.45	Rural Unrestricted	58	10	27.66	0.68	Urban Restricted	58	6	18.00	1.34
Urban Unrestricted	59	2	7.96	3.43	Rural Unrestricted	59	10	27.56	0.66	Urban Restricted	59	6	18.06	1.31
Urban Unrestricted	60	2	7.98	3.42	Rural Unrestricted	60	10	27.45	0.64	Urban Restricted	60	6	18.20	1.29
Urban Unrestricted	61	2	8.07	3.41	Rural Unrestricted	61	10	27.41	0.63	Urban Restricted	61	6	18.41	1.27
Urban Unrestricted	62	2	8.21	3.39	Rural Unrestricted	62	10	27.40	0.62	Urban Restricted	62	6	18.65	1.26
Urban Unrestricted	63	2	8.34	3.38	Rural Unrestricted	63	10	27.40	0.60	Urban Restricted	63	6	18.90	1.24
Urban Unrestricted	64	2	8.53	3.37	Rural Unrestricted	64	10	27.34	0.59	Urban Restricted	64	6	19.13	1.23
Urban Unrestricted	65	2	8.86	3.39	Rural Unrestricted	65	10	27.19	0.58	Urban Restricted	65	6	19.41	1.22

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	66	2	9.17	3.40	Rural Unrestricted	66	10	27.05	0.57	Urban Restricted	66	6	19.71	1.21
Urban Unrestricted	67	2	9.48	3.41	Rural Unrestricted	67	10	26.91	0.55	Urban Restricted	67	6	20.00	1.20
Urban Unrestricted	68	2	9.77	3.42	Rural Unrestricted	68	10	26.77	0.54	Urban Restricted	68	6	20.27	1.18
Urban Unrestricted	69	2	10.06	3.43	Rural Unrestricted	69	10	26.64	0.53	Urban Restricted	69	6	20.53	1.16
Urban Unrestricted	70	2	10.34	3.44	Rural Unrestricted	70	10	26.51	0.52	Urban Restricted	70	6	20.78	1.14
Urban Unrestricted	71	2	10.61	3.45	Rural Unrestricted	71	10	26.38	0.51	Urban Restricted	71	6	21.02	1.12
Urban Unrestricted	72	2	10.87	3.46	Rural Unrestricted	72	10	26.26	0.50	Urban Restricted	72	6	21.26	1.11
Urban Unrestricted	73	2	11.12	3.47	Rural Unrestricted	73	10	26.15	0.49	Urban Restricted	73	6	21.49	1.09
Urban Unrestricted	74	2	11.37	3.54	Rural Unrestricted	74	10	26.04	0.48	Urban Restricted	74	6	21.60	1.10
Urban Unrestricted	75	2	11.74	3.85	Rural Unrestricted	75	10	25.84	0.49	Urban Restricted	75	6	21.25	1.18
Rural Unrestricted	1	3	68.25	41.78	Urban Unrestricted	1	10	71.33	25.35	Rural Restricted	1	7	70.06	30.02
Rural Unrestricted	2	3	34.61	21.25	Urban Unrestricted	2	10	36.77	12.83	Rural Restricted	2	7	35.91	15.22
Rural Unrestricted	3	3	25.26	15.63	Urban Unrestricted	3	10	30.16	9.19	Rural Restricted	3	7	27.76	10.93
Rural Unrestricted	4	3	21.20	13.14	Urban Unrestricted	4	10	28.72	7.53	Rural Restricted	4	7	24.66	8.94
Rural Unrestricted	5	3	18.81	11.54	Urban Unrestricted	5	10	28.04	6.46	Rural Restricted	5	7	22.87	7.68
Rural Unrestricted	6	3	17.28	10.33	Urban Unrestricted	6	10	27.82	5.66	Rural Restricted	6	7	21.77	6.76
Rural Unrestricted	7	3	16.18	9.47	Urban Unrestricted	7	10	27.67	5.08	Rural Restricted	7	7	20.98	6.10
Rural Unrestricted	8	3	15.35	8.82	Urban Unrestricted	8	10	27.55	4.65	Rural Restricted	8	7	20.39	5.60
Rural Unrestricted	9	3	14.71	8.32	Urban Unrestricted	9	10	27.46	4.32	Rural Restricted	9	7	19.79	5.21
Rural Unrestricted	10	3	14.19	7.91	Urban Unrestricted	10	10	27.38	4.05	Rural Restricted	10	7	18.99	4.91
Rural Unrestricted	11	3	13.83	7.57	Urban Unrestricted	11	10	27.37	3.83	Rural Restricted	11	7	18.41	4.65
Rural Unrestricted	12	3	13.67	7.24	Urban Unrestricted	12	10	27.48	3.65	Rural Restricted	12	7	18.11	4.42
Rural Unrestricted	13	3	13.53	6.97	Urban Unrestricted	13	10	27.57	3.50	Rural Restricted	13	7	17.85	4.22
Rural Unrestricted	14	3	13.41	6.73	Urban Unrestricted	14	10	27.65	3.37	Rural Restricted	14	7	17.63	4.05
Rural Unrestricted	15	3	13.30	6.53	Urban Unrestricted	15	10	27.72	3.26	Rural Restricted	15	7	17.44	3.91
Rural Unrestricted	16	3	13.22	6.36	Urban Unrestricted	16	10	27.77	3.16	Rural Restricted	16	7	17.48	3.74
Rural Unrestricted	17	3	13.14	6.21	Urban Unrestricted	17	10	27.81	3.06	Rural Restricted	17	7	18.09	3.50
Rural Unrestricted	18	3	13.08	6.09	Urban Unrestricted	18	10	27.84	2.97	Rural Restricted	18	7	18.63	3.28
Rural Unrestricted	19	3	12.97	5.91	Urban Unrestricted	19	10	28.24	2.85	Rural Restricted	19	7	19.12	3.09
Rural Unrestricted	20	3	12.83	5.66	Urban Unrestricted	20	10	29.06	2.69	Rural Restricted	20	7	19.55	2.91
Rural Unrestricted	21	3	12.69	5.42	Urban Unrestricted	21	10	29.80	2.54	Rural Restricted	21	7	19.79	2.77
Rural Unrestricted	22	3	12.53	5.17	Urban Unrestricted	22	10	30.44	2.38	Rural Restricted	22	7	19.76	2.63
Rural Unrestricted	23	3	12.38	4.93	Urban Unrestricted	23	10	31.02	2.23	Rural Restricted	23	7	19.73	2.50
Rural Unrestricted	24	3	12.25	4.72	Urban Unrestricted	24	10	31.55	2.09	Rural Restricted	24	7	19.71	2.39
Rural Unrestricted	25	3	12.11	4.59	Urban Unrestricted	25	10	32.02	1.99	Rural Restricted	25	7	19.66	2.32
Rural Unrestricted	26	3	12.02	4.55	Urban Unrestricted	26	10	31.88	1.92	Rural Restricted	26	7	19.58	2.31
Rural Unrestricted	27	3	11.97	4.53	Urban Unrestricted	27	10	31.43	1.86	Rural Restricted	27	7	19.51	2.29
Rural Unrestricted	28	3	11.92	4.52	Urban Unrestricted	28	10	31.01	1.80	Rural Restricted	28	7	19.45	2.28
Rural Unrestricted	29	3	11.88	4.50	Urban Unrestricted	29	10	30.62	1.74	Rural Restricted	29	7	19.39	2.27
Rural Unrestricted	30	3	11.84	4.48	Urban Unrestricted	30	10	30.26	1.69	Rural Restricted	30	7	19.34	2.26

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	31	3	11.80	4.47	Urban Unrestricted	31	10	29.92	1.65	Rural Restricted	31	7	19.43	2.24
Rural Unrestricted	32	3	11.65	4.33	Urban Unrestricted	32	10	29.75	1.57	Rural Restricted	32	7	19.47	2.14
Rural Unrestricted	33	3	11.35	4.10	Urban Unrestricted	33	10	29.44	1.46	Rural Restricted	33	7	19.35	1.99
Rural Unrestricted	34	3	11.06	3.88	Urban Unrestricted	34	10	29.15	1.36	Rural Restricted	34	7	19.23	1.84
Rural Unrestricted	35	3	10.93	3.75	Urban Unrestricted	35	10	29.00	1.30	Rural Restricted	35	7	19.26	1.75
Rural Unrestricted	36	3	10.89	3.69	Urban Unrestricted	36	10	28.95	1.25	Rural Restricted	36	7	19.40	1.71
Rural Unrestricted	37	3	10.85	3.63	Urban Unrestricted	37	10	28.90	1.20	Rural Restricted	37	7	19.52	1.67
Rural Unrestricted	38	3	10.82	3.57	Urban Unrestricted	38	10	28.85	1.15	Rural Restricted	38	7	19.65	1.63
Rural Unrestricted	39	3	10.78	3.51	Urban Unrestricted	39	10	28.81	1.11	Rural Restricted	39	7	19.76	1.59
Rural Unrestricted	40	3	10.75	3.46	Urban Unrestricted	40	10	28.76	1.07	Rural Restricted	40	7	19.87	1.55
Rural Unrestricted	41	3	10.72	3.41	Urban Unrestricted	41	10	28.72	1.03	Rural Restricted	41	7	19.97	1.52
Rural Unrestricted	42	3	10.69	3.37	Urban Unrestricted	42	10	28.68	1.00	Rural Restricted	42	7	20.07	1.49
Rural Unrestricted	43	3	10.66	3.32	Urban Unrestricted	43	10	28.64	0.96	Rural Restricted	43	7	20.16	1.46
Rural Unrestricted	44	3	10.63	3.28	Urban Unrestricted	44	10	28.66	0.93	Rural Restricted	44	7	20.25	1.43
Rural Unrestricted	45	3	10.59	3.24	Urban Unrestricted	45	10	28.66	0.91	Rural Restricted	45	7	20.31	1.40
Rural Unrestricted	46	3	10.53	3.21	Urban Unrestricted	46	10	28.63	0.88	Rural Restricted	46	7	20.33	1.37
Rural Unrestricted	47	3	10.48	3.19	Urban Unrestricted	47	10	28.59	0.85	Rural Restricted	47	7	20.38	1.33
Rural Unrestricted	48	3	10.42	3.16	Urban Unrestricted	48	10	28.56	0.83	Rural Restricted	48	7	20.44	1.30
Rural Unrestricted	49	3	10.37	3.13	Urban Unrestricted	49	10	28.53	0.81	Rural Restricted	49	7	20.49	1.27
Rural Unrestricted	50	3	10.38	3.13	Urban Unrestricted	50	10	28.50	0.78	Rural Restricted	50	7	20.55	1.24
Rural Unrestricted	51	3	10.39	3.12	Urban Unrestricted	51	10	28.47	0.76	Rural Restricted	51	7	20.60	1.21
Rural Unrestricted	52	3	10.40	3.11	Urban Unrestricted	52	10	28.44	0.74	Rural Restricted	52	7	20.65	1.18
Rural Unrestricted	53	3	10.41	3.11	Urban Unrestricted	53	10	28.39	0.72	Rural Restricted	53	7	20.69	1.15
Rural Unrestricted	54	3	10.42	3.10	Urban Unrestricted	54	10	28.24	0.71	Rural Restricted	54	7	20.74	1.13
Rural Unrestricted	55	3	10.43	3.10	Urban Unrestricted	55	10	28.09	0.69	Rural Restricted	55	7	20.78	1.10
Rural Unrestricted	56	3	10.46	3.08	Urban Unrestricted	56	10	27.95	0.68	Rural Restricted	56	7	20.84	1.07
Rural Unrestricted	57	3	10.52	3.06	Urban Unrestricted	57	10	27.83	0.67	Rural Restricted	57	7	20.91	1.04
Rural Unrestricted	58	3	10.57	3.04	Urban Unrestricted	58	10	27.72	0.65	Rural Restricted	58	7	20.98	1.01
Rural Unrestricted	59	3	10.62	3.02	Urban Unrestricted	59	10	27.60	0.64	Rural Restricted	59	7	21.04	0.98
Rural Unrestricted	60	3	10.67	3.00	Urban Unrestricted	60	10	27.49	0.63	Rural Restricted	60	7	21.08	0.96
Rural Unrestricted	61	3	10.74	2.98	Urban Unrestricted	61	10	27.44	0.62	Rural Restricted	61	7	21.17	0.94
Rural Unrestricted	62	3	10.82	2.96	Urban Unrestricted	62	10	27.43	0.61	Rural Restricted	62	7	21.30	0.93
Rural Unrestricted	63	3	10.89	2.94	Urban Unrestricted	63	10	27.42	0.60	Rural Restricted	63	7	21.42	0.91
Rural Unrestricted	64	3	11.05	2.92	Urban Unrestricted	64	10	27.36	0.59	Rural Restricted	64	7	21.54	0.90
Rural Unrestricted	65	3	11.36	2.91	Urban Unrestricted	65	10	27.21	0.57	Rural Restricted	65	7	21.70	0.88
Rural Unrestricted	66	3	11.67	2.89	Urban Unrestricted	66	10	27.07	0.56	Rural Restricted	66	7	21.89	0.87
Rural Unrestricted	67	3	11.97	2.88	Urban Unrestricted	67	10	26.93	0.55	Rural Restricted	67	7	22.06	0.86
Rural Unrestricted	68	3	12.26	2.87	Urban Unrestricted	68	10	26.79	0.54	Rural Restricted	68	7	22.22	0.84
Rural Unrestricted	69	3	12.54	2.86	Urban Unrestricted	69	10	26.66	0.53	Rural Restricted	69	7	22.38	0.82
Rural Unrestricted	70	3	12.81	2.85	Urban Unrestricted	70	10	26.53	0.51	Rural Restricted	70	7	22.53	0.81

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	71	3	13.07	2.84	Urban Unrestricted	71	10	26.40	0.50	Rural Restricted	71	7	22.68	0.79
Rural Unrestricted	72	3	13.33	2.83	Urban Unrestricted	72	10	26.28	0.49	Rural Restricted	72	7	22.82	0.78
Rural Unrestricted	73	3	13.58	2.82	Urban Unrestricted	73	10	26.17	0.48	Rural Restricted	73	7	22.96	0.76
Rural Unrestricted	74	3	13.85	2.86	Urban Unrestricted	74	10	26.06	0.48	Rural Restricted	74	7	23.00	0.77
Rural Unrestricted	75	3	14.18	3.13	Urban Unrestricted	75	10	25.86	0.48	Rural Restricted	75	7	22.70	0.85
Urban Unrestricted	1	3	68.05	41.58	Rural Restricted	1	0	63.57	63.57	Urban Restricted	1	7	69.92	29.90
Urban Unrestricted	2	3	34.51	21.16	Rural Restricted	2	0	31.88	31.88	Urban Restricted	2	7	35.84	15.16
Urban Unrestricted	3	3	25.19	15.56	Rural Restricted	3	0	21.86	21.86	Urban Restricted	3	7	27.70	10.89
Urban Unrestricted	4	3	21.15	13.09	Rural Restricted	4	0	17.11	17.11	Urban Restricted	4	7	24.61	8.90
Urban Unrestricted	5	3	18.77	11.50	Rural Restricted	5	0	14.40	14.40	Urban Restricted	5	7	22.83	7.65
Urban Unrestricted	6	3	17.24	10.29	Rural Restricted	6	0	12.76	12.76	Urban Restricted	6	7	21.73	6.73
Urban Unrestricted	7	3	16.14	9.44	Rural Restricted	7	0	11.59	11.59	Urban Restricted	7	7	20.95	6.07
Urban Unrestricted	8	3	15.32	8.79	Rural Restricted	8	0	10.72	10.72	Urban Restricted	8	7	20.36	5.58
Urban Unrestricted	9	3	14.68	8.29	Rural Restricted	9	0	10.05	10.05	Urban Restricted	9	7	19.76	5.20
Urban Unrestricted	10	3	14.17	7.89	Rural Restricted	10	0	9.53	9.53	Urban Restricted	10	7	18.96	4.89
Urban Unrestricted	11	3	13.81	7.55	Rural Restricted	11	0	9.12	9.12	Urban Restricted	11	7	18.38	4.63
Urban Unrestricted	12	3	13.65	7.22	Rural Restricted	12	0	8.82	8.82	Urban Restricted	12	7	18.07	4.40
Urban Unrestricted	13	3	13.51	6.95	Rural Restricted	13	0	8.57	8.57	Urban Restricted	13	7	17.81	4.21
Urban Unrestricted	14	3	13.39	6.72	Rural Restricted	14	0	8.36	8.36	Urban Restricted	14	7	17.59	4.04
Urban Unrestricted	15	3	13.28	6.51	Rural Restricted	15	0	8.17	8.17	Urban Restricted	15	7	17.40	3.90
Urban Unrestricted	16	3	13.20	6.34	Rural Restricted	16	0	8.02	8.02	Urban Restricted	16	7	17.45	3.73
Urban Unrestricted	17	3	13.12	6.20	Rural Restricted	17	0	7.90	7.90	Urban Restricted	17	7	18.06	3.49
Urban Unrestricted	18	3	13.06	6.07	Rural Restricted	18	0	7.79	7.79	Urban Restricted	18	7	18.61	3.27
Urban Unrestricted	19	3	12.96	5.89	Rural Restricted	19	0	7.69	7.69	Urban Restricted	19	7	19.10	3.08
Urban Unrestricted	20	3	12.81	5.64	Rural Restricted	20	0	7.61	7.61	Urban Restricted	20	7	19.54	2.90
Urban Unrestricted	21	3	12.67	5.41	Rural Restricted	21	0	7.51	7.51	Urban Restricted	21	7	19.78	2.76
Urban Unrestricted	22	3	12.51	5.15	Rural Restricted	22	0	7.35	7.35	Urban Restricted	22	7	19.75	2.62
Urban Unrestricted	23	3	12.36	4.92	Rural Restricted	23	0	7.20	7.20	Urban Restricted	23	7	19.72	2.49
Urban Unrestricted	24	3	12.23	4.71	Rural Restricted	24	0	7.07	7.07	Urban Restricted	24	7	19.70	2.38
Urban Unrestricted	25	3	12.09	4.57	Rural Restricted	25	0	6.99	6.99	Urban Restricted	25	7	19.65	2.32
Urban Unrestricted	26	3	12.00	4.54	Rural Restricted	26	0	6.96	6.96	Urban Restricted	26	7	19.57	2.30
Urban Unrestricted	27	3	11.95	4.52	Rural Restricted	27	0	6.93	6.93	Urban Restricted	27	7	19.50	2.29
Urban Unrestricted	28	3	11.90	4.50	Rural Restricted	28	0	6.90	6.90	Urban Restricted	28	7	19.44	2.27
Urban Unrestricted	29	3	11.86	4.49	Rural Restricted	29	0	6.87	6.87	Urban Restricted	29	7	19.38	2.26
Urban Unrestricted	30	3	11.82	4.47	Rural Restricted	30	0	6.85	6.85	Urban Restricted	30	7	19.33	2.25
Urban Unrestricted	31	3	11.79	4.46	Rural Restricted	31	0	6.83	6.83	Urban Restricted	31	7	19.42	2.23
Urban Unrestricted	32	3	11.61	4.32	Rural Restricted	32	0	6.67	6.67	Urban Restricted	32	7	19.47	2.14
Urban Unrestricted	33	3	11.30	4.08	Rural Restricted	33	0	6.39	6.39	Urban Restricted	33	7	19.35	1.98
Urban Unrestricted	34	3	11.01	3.86	Rural Restricted	34	0	6.13	6.13	Urban Restricted	34	7	19.23	1.83
Urban Unrestricted	35	3	10.86	3.74	Rural Restricted	35	0	5.97	5.97	Urban Restricted	35	7	19.27	1.75

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	36	3	10.81	3.67	Rural Restricted	36	0	5.89	5.89	Urban Restricted	36	7	19.41	1.70
Urban Unrestricted	37	3	10.76	3.61	Rural Restricted	37	0	5.81	5.81	Urban Restricted	37	7	19.54	1.66
Urban Unrestricted	38	3	10.71	3.55	Rural Restricted	38	0	5.74	5.74	Urban Restricted	38	7	19.66	1.62
Urban Unrestricted	39	3	10.67	3.49	Rural Restricted	39	0	5.67	5.67	Urban Restricted	39	7	19.77	1.58
Urban Unrestricted	40	3	10.63	3.44	Rural Restricted	40	0	5.60	5.60	Urban Restricted	40	7	19.89	1.55
Urban Unrestricted	41	3	10.59	3.39	Rural Restricted	41	0	5.54	5.54	Urban Restricted	41	7	19.99	1.52
Urban Unrestricted	42	3	10.55	3.34	Rural Restricted	42	0	5.47	5.47	Urban Restricted	42	7	20.09	1.48
Urban Unrestricted	43	3	10.52	3.30	Rural Restricted	43	0	5.42	5.42	Urban Restricted	43	7	20.19	1.45
Urban Unrestricted	44	3	10.51	3.26	Rural Restricted	44	0	5.36	5.36	Urban Restricted	44	7	20.28	1.42
Urban Unrestricted	45	3	10.49	3.22	Rural Restricted	45	0	5.30	5.30	Urban Restricted	45	7	20.33	1.39
Urban Unrestricted	46	3	10.45	3.20	Rural Restricted	46	0	5.25	5.25	Urban Restricted	46	7	20.36	1.36
Urban Unrestricted	47	3	10.42	3.18	Rural Restricted	47	0	5.19	5.19	Urban Restricted	47	7	20.41	1.33
Urban Unrestricted	48	3	10.38	3.15	Rural Restricted	48	0	5.15	5.15	Urban Restricted	48	7	20.47	1.29
Urban Unrestricted	49	3	10.35	3.13	Rural Restricted	49	0	5.10	5.10	Urban Restricted	49	7	20.53	1.26
Urban Unrestricted	50	3	10.32	3.11	Rural Restricted	50	0	5.06	5.06	Urban Restricted	50	7	20.58	1.23
Urban Unrestricted	51	3	10.30	3.09	Rural Restricted	51	0	5.01	5.01	Urban Restricted	51	7	20.63	1.20
Urban Unrestricted	52	3	10.27	3.07	Rural Restricted	52	0	4.97	4.97	Urban Restricted	52	7	20.68	1.17
Urban Unrestricted	53	3	10.25	3.06	Rural Restricted	53	0	4.93	4.93	Urban Restricted	53	7	20.73	1.15
Urban Unrestricted	54	3	10.28	3.06	Rural Restricted	54	0	4.89	4.89	Urban Restricted	54	7	20.78	1.12
Urban Unrestricted	55	3	10.30	3.05	Rural Restricted	55	0	4.86	4.86	Urban Restricted	55	7	20.82	1.10
Urban Unrestricted	56	3	10.35	3.04	Rural Restricted	56	0	4.81	4.81	Urban Restricted	56	7	20.88	1.07
Urban Unrestricted	57	3	10.42	3.03	Rural Restricted	57	0	4.75	4.75	Urban Restricted	57	7	20.96	1.04
Urban Unrestricted	58	3	10.49	3.01	Rural Restricted	58	0	4.70	4.70	Urban Restricted	58	7	21.03	1.01
Urban Unrestricted	59	3	10.55	2.99	Rural Restricted	59	0	4.65	4.65	Urban Restricted	59	7	21.09	0.98
Urban Unrestricted	60	3	10.62	2.97	Rural Restricted	60	0	4.63	4.63	Urban Restricted	60	7	21.13	0.96
Urban Unrestricted	61	3	10.70	2.96	Rural Restricted	61	0	4.65	4.65	Urban Restricted	61	7	21.22	0.94
Urban Unrestricted	62	3	10.78	2.94	Rural Restricted	62	0	4.70	4.70	Urban Restricted	62	7	21.35	0.92
Urban Unrestricted	63	3	10.87	2.92	Rural Restricted	63	0	4.74	4.74	Urban Restricted	63	7	21.47	0.91
Urban Unrestricted	64	3	11.04	2.90	Rural Restricted	64	0	4.78	4.78	Urban Restricted	64	7	21.59	0.89
Urban Unrestricted	65	3	11.35	2.89	Rural Restricted	65	0	4.91	4.91	Urban Restricted	65	7	21.75	0.88
Urban Unrestricted	66	3	11.66	2.87	Rural Restricted	66	0	5.09	5.09	Urban Restricted	66	7	21.94	0.87
Urban Unrestricted	67	3	11.96	2.86	Rural Restricted	67	0	5.23	5.23	Urban Restricted	67	7	22.11	0.85
Urban Unrestricted	68	3	12.25	2.85	Rural Restricted	68	0	5.35	5.35	Urban Restricted	68	7	22.28	0.84
Urban Unrestricted	69	3	12.53	2.84	Rural Restricted	69	0	5.47	5.47	Urban Restricted	69	7	22.43	0.82
Urban Unrestricted	70	3	12.80	2.83	Rural Restricted	70	0	5.59	5.59	Urban Restricted	70	7	22.59	0.80
Urban Unrestricted	71	3	13.07	2.82	Rural Restricted	71	0	5.70	5.70	Urban Restricted	71	7	22.74	0.79
Urban Unrestricted	72	3	13.33	2.81	Rural Restricted	72	0	5.81	5.81	Urban Restricted	72	7	22.88	0.77
Urban Unrestricted	73	3	13.58	2.80	Rural Restricted	73	0	5.92	5.92	Urban Restricted	73	7	23.02	0.76
Urban Unrestricted	74	3	13.85	2.85	Rural Restricted	74	0	6.17	6.17	Urban Restricted	74	7	23.07	0.77
Urban Unrestricted	75	3	14.18	3.12	Rural Restricted	75	0	6.85	6.85	Urban Restricted	75	7	22.76	0.85

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	1	4	68.84	40.14	Urban Restricted	1	0	63.42	63.42	Rural Restricted	1	8	70.31	28.98
Rural Unrestricted	2	4	35.01	20.33	Urban Restricted	2	0	31.80	31.80	Rural Restricted	2	8	36.12	14.67
Rural Unrestricted	3	4	25.98	14.67	Urban Restricted	3	0	21.80	21.80	Rural Restricted	3	8	28.32	10.47
Rural Unrestricted	4	4	22.19	12.15	Urban Restricted	4	0	17.06	17.06	Rural Restricted	4	8	25.54	8.51
Rural Unrestricted	5	4	19.99	10.60	Urban Restricted	5	0	14.36	14.36	Rural Restricted	5	8	23.96	7.26
Rural Unrestricted	6	4	18.62	9.53	Urban Restricted	6	0	12.73	12.73	Rural Restricted	6	8	22.99	6.34
Rural Unrestricted	7	4	17.63	8.76	Urban Restricted	7	0	11.57	11.57	Rural Restricted	7	8	22.31	5.68
Rural Unrestricted	8	4	16.89	8.19	Urban Restricted	8	0	10.69	10.69	Rural Restricted	8	8	21.79	5.19
Rural Unrestricted	9	4	16.32	7.74	Urban Restricted	9	0	10.02	10.02	Rural Restricted	9	8	21.24	4.81
Rural Unrestricted	10	4	15.85	7.38	Urban Restricted	10	0	9.50	9.50	Rural Restricted	10	8	20.42	4.51
Rural Unrestricted	11	4	15.52	7.07	Urban Restricted	11	0	9.10	9.10	Rural Restricted	11	8	19.85	4.26
Rural Unrestricted	12	4	15.35	6.75	Urban Restricted	12	0	8.80	8.80	Rural Restricted	12	8	19.59	4.05
Rural Unrestricted	13	4	15.21	6.48	Urban Restricted	13	0	8.55	8.55	Rural Restricted	13	8	19.36	3.87
Rural Unrestricted	14	4	15.08	6.26	Urban Restricted	14	0	8.34	8.34	Rural Restricted	14	8	19.17	3.72
Rural Unrestricted	15	4	14.97	6.06	Urban Restricted	15	0	8.15	8.15	Rural Restricted	15	8	19.00	3.59
Rural Unrestricted	16	4	14.87	5.88	Urban Restricted	16	0	8.00	8.00	Rural Restricted	16	8	19.10	3.43
Rural Unrestricted	17	4	14.78	5.71	Urban Restricted	17	0	7.88	7.88	Rural Restricted	17	8	19.85	3.20
Rural Unrestricted	18	4	14.70	5.56	Urban Restricted	18	0	7.77	7.77	Rural Restricted	18	8	20.52	2.99
Rural Unrestricted	19	4	14.59	5.35	Urban Restricted	19	0	7.68	7.68	Rural Restricted	19	8	21.12	2.81
Rural Unrestricted	20	4	14.44	5.07	Urban Restricted	20	0	7.59	7.59	Rural Restricted	20	8	21.66	2.64
Rural Unrestricted	21	4	14.33	4.81	Urban Restricted	21	0	7.49	7.49	Rural Restricted	21	8	21.99	2.50
Rural Unrestricted	22	4	14.28	4.53	Urban Restricted	22	0	7.33	7.33	Rural Restricted	22	8	22.03	2.38
Rural Unrestricted	23	4	14.24	4.28	Urban Restricted	23	0	7.19	7.19	Rural Restricted	23	8	22.06	2.26
Rural Unrestricted	24	4	14.20	4.05	Urban Restricted	24	0	7.06	7.06	Rural Restricted	24	8	22.10	2.16
Rural Unrestricted	25	4	14.10	3.91	Urban Restricted	25	0	6.98	6.98	Rural Restricted	25	8	22.11	2.09
Rural Unrestricted	26	4	13.98	3.87	Urban Restricted	26	0	6.94	6.94	Rural Restricted	26	8	22.10	2.06
Rural Unrestricted	27	4	13.88	3.85	Urban Restricted	27	0	6.91	6.91	Rural Restricted	27	8	22.09	2.03
Rural Unrestricted	28	4	13.78	3.84	Urban Restricted	28	0	6.89	6.89	Rural Restricted	28	8	22.09	2.00
Rural Unrestricted	29	4	13.69	3.83	Urban Restricted	29	0	6.86	6.86	Rural Restricted	29	8	22.08	1.97
Rural Unrestricted	30	4	13.61	3.82	Urban Restricted	30	0	6.83	6.83	Rural Restricted	30	8	22.07	1.95
Rural Unrestricted	31	4	13.54	3.80	Urban Restricted	31	0	6.81	6.81	Rural Restricted	31	8	22.21	1.92
Rural Unrestricted	32	4	13.42	3.70	Urban Restricted	32	0	6.65	6.65	Rural Restricted	32	8	22.29	1.84
Rural Unrestricted	33	4	13.15	3.52	Urban Restricted	33	0	6.38	6.38	Rural Restricted	33	8	22.21	1.72
Rural Unrestricted	34	4	12.90	3.35	Urban Restricted	34	0	6.12	6.12	Rural Restricted	34	8	22.13	1.61
Rural Unrestricted	35	4	12.81	3.25	Urban Restricted	35	0	5.96	5.96	Rural Restricted	35	8	22.19	1.54
Rural Unrestricted	36	4	12.83	3.19	Urban Restricted	36	0	5.88	5.88	Rural Restricted	36	8	22.34	1.49
Rural Unrestricted	37	4	12.85	3.14	Urban Restricted	37	0	5.80	5.80	Rural Restricted	37	8	22.49	1.45
Rural Unrestricted	38	4	12.86	3.09	Urban Restricted	38	0	5.73	5.73	Rural Restricted	38	8	22.62	1.41
Rural Unrestricted	39	4	12.88	3.05	Urban Restricted	39	0	5.65	5.65	Rural Restricted	39	8	22.75	1.37
Rural Unrestricted	40	4	12.89	3.00	Urban Restricted	40	0	5.59	5.59	Rural Restricted	40	8	22.87	1.33

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	41	4	12.90	2.96	Urban Restricted	41	0	5.52	5.52	Rural Restricted	41	8	22.99	1.30
Rural Unrestricted	42	4	12.92	2.92	Urban Restricted	42	0	5.46	5.46	Rural Restricted	42	8	23.10	1.26
Rural Unrestricted	43	4	12.93	2.88	Urban Restricted	43	0	5.40	5.40	Rural Restricted	43	8	23.20	1.23
Rural Unrestricted	44	4	12.94	2.85	Urban Restricted	44	0	5.35	5.35	Rural Restricted	44	8	23.30	1.20
Rural Unrestricted	45	4	12.93	2.82	Urban Restricted	45	0	5.29	5.29	Rural Restricted	45	8	23.37	1.17
Rural Unrestricted	46	4	12.89	2.79	Urban Restricted	46	0	5.23	5.23	Rural Restricted	46	8	23.41	1.14
Rural Unrestricted	47	4	12.86	2.76	Urban Restricted	47	0	5.18	5.18	Rural Restricted	47	8	23.42	1.10
Rural Unrestricted	48	4	12.83	2.74	Urban Restricted	48	0	5.14	5.14	Rural Restricted	48	8	23.43	1.07
Rural Unrestricted	49	4	12.81	2.71	Urban Restricted	49	0	5.09	5.09	Rural Restricted	49	8	23.44	1.04
Rural Unrestricted	50	4	12.82	2.70	Urban Restricted	50	0	5.05	5.05	Rural Restricted	50	8	23.45	1.01
Rural Unrestricted	51	4	12.83	2.69	Urban Restricted	51	0	5.00	5.00	Rural Restricted	51	8	23.46	0.98
Rural Unrestricted	52	4	12.85	2.68	Urban Restricted	52	0	4.96	4.96	Rural Restricted	52	8	23.47	0.95
Rural Unrestricted	53	4	12.87	2.67	Urban Restricted	53	0	4.92	4.92	Rural Restricted	53	8	23.48	0.92
Rural Unrestricted	54	4	12.88	2.66	Urban Restricted	54	0	4.89	4.89	Rural Restricted	54	8	23.49	0.90
Rural Unrestricted	55	4	12.89	2.66	Urban Restricted	55	0	4.85	4.85	Rural Restricted	55	8	23.50	0.87
Rural Unrestricted	56	4	12.92	2.64	Urban Restricted	56	0	4.80	4.80	Rural Restricted	56	8	23.53	0.85
Rural Unrestricted	57	4	12.94	2.63	Urban Restricted	57	0	4.75	4.75	Rural Restricted	57	8	23.57	0.83
Rural Unrestricted	58	4	12.97	2.62	Urban Restricted	58	0	4.69	4.69	Rural Restricted	58	8	23.62	0.81
Rural Unrestricted	59	4	13.00	2.61	Urban Restricted	59	0	4.65	4.65	Rural Restricted	59	8	23.64	0.79
Rural Unrestricted	60	4	13.02	2.59	Urban Restricted	60	0	4.63	4.63	Rural Restricted	60	8	23.60	0.78
Rural Unrestricted	61	4	13.08	2.57	Urban Restricted	61	0	4.65	4.65	Rural Restricted	61	8	23.59	0.77
Rural Unrestricted	62	4	13.15	2.55	Urban Restricted	62	0	4.69	4.69	Rural Restricted	62	8	23.61	0.75
Rural Unrestricted	63	4	13.22	2.52	Urban Restricted	63	0	4.73	4.73	Rural Restricted	63	8	23.63	0.74
Rural Unrestricted	64	4	13.39	2.50	Urban Restricted	64	0	4.77	4.77	Rural Restricted	64	8	23.65	0.73
Rural Unrestricted	65	4	13.74	2.48	Urban Restricted	65	0	4.90	4.90	Rural Restricted	65	8	23.73	0.71
Rural Unrestricted	66	4	14.08	2.45	Urban Restricted	66	0	5.08	5.08	Rural Restricted	66	8	23.86	0.70
Rural Unrestricted	67	4	14.42	2.43	Urban Restricted	67	0	5.23	5.23	Rural Restricted	67	8	23.92	0.68
Rural Unrestricted	68	4	14.74	2.40	Urban Restricted	68	0	5.35	5.35	Rural Restricted	68	8	23.94	0.67
Rural Unrestricted	69	4	15.06	2.38	Urban Restricted	69	0	5.47	5.47	Rural Restricted	69	8	23.96	0.65
Rural Unrestricted	70	4	15.36	2.36	Urban Restricted	70	0	5.58	5.58	Rural Restricted	70	8	23.98	0.64
Rural Unrestricted	71	4	15.66	2.34	Urban Restricted	71	0	5.70	5.70	Rural Restricted	71	8	24.00	0.62
Rural Unrestricted	72	4	15.95	2.32	Urban Restricted	72	0	5.81	5.81	Rural Restricted	72	8	24.02	0.61
Rural Unrestricted	73	4	16.24	2.30	Urban Restricted	73	0	5.92	5.92	Rural Restricted	73	8	24.05	0.60
Rural Unrestricted	74	4	16.57	2.32	Urban Restricted	74	0	6.17	6.17	Rural Restricted	74	8	24.05	0.59
Rural Unrestricted	75	4	16.88	2.49	Urban Restricted	75	0	6.85	6.85	Rural Restricted	75	8	23.88	0.63
Urban Unrestricted	1	4	68.64	39.95	Rural Restricted	1	1	65.80	48.14	Urban Restricted	1	8	70.18	28.85
Urban Unrestricted	2	4	34.91	20.23	Rural Restricted	2	1	33.09	24.59	Urban Restricted	2	8	36.04	14.60
Urban Unrestricted	3	4	25.91	14.61	Rural Restricted	3	1	23.01	18.12	Urban Restricted	3	8	28.25	10.42
Urban Unrestricted	4	4	22.14	12.10	Rural Restricted	4	1	18.26	15.06	Urban Restricted	4	8	25.49	8.47
Urban Unrestricted	5	4	19.95	10.56	Rural Restricted	5	1	15.52	13.04	Urban Restricted	5	8	23.91	7.23

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	6	4	18.58	9.49	Rural Restricted	6	1	13.82	11.47	Urban Restricted	6	8	22.96	6.32
Urban Unrestricted	7	4	17.60	8.73	Rural Restricted	7	1	12.61	10.34	Urban Restricted	7	8	22.28	5.66
Urban Unrestricted	8	4	16.86	8.16	Rural Restricted	8	1	11.70	9.49	Urban Restricted	8	8	21.77	5.17
Urban Unrestricted	9	4	16.29	7.72	Rural Restricted	9	1	11.01	8.86	Urban Restricted	9	8	21.21	4.79
Urban Unrestricted	10	4	15.83	7.36	Rural Restricted	10	1	10.48	8.43	Urban Restricted	10	8	20.39	4.49
Urban Unrestricted	11	4	15.50	7.05	Rural Restricted	11	1	10.12	8.07	Urban Restricted	11	8	19.82	4.25
Urban Unrestricted	12	4	15.33	6.73	Rural Restricted	12	1	9.94	7.79	Urban Restricted	12	8	19.55	4.04
Urban Unrestricted	13	4	15.18	6.47	Rural Restricted	13	1	9.80	7.55	Urban Restricted	13	8	19.33	3.86
Urban Unrestricted	14	4	15.06	6.24	Rural Restricted	14	1	9.67	7.34	Urban Restricted	14	8	19.13	3.71
Urban Unrestricted	15	4	14.95	6.04	Rural Restricted	15	1	9.56	7.17	Urban Restricted	15	8	18.96	3.58
Urban Unrestricted	16	4	14.86	5.86	Rural Restricted	16	1	9.45	7.00	Urban Restricted	16	8	19.06	3.42
Urban Unrestricted	17	4	14.76	5.70	Rural Restricted	17	1	9.32	6.82	Urban Restricted	17	8	19.82	3.19
Urban Unrestricted	18	4	14.68	5.55	Rural Restricted	18	1	9.21	6.66	Urban Restricted	18	8	20.50	2.98
Urban Unrestricted	19	4	14.57	5.34	Rural Restricted	19	1	9.11	6.52	Urban Restricted	19	8	21.10	2.80
Urban Unrestricted	20	4	14.42	5.06	Rural Restricted	20	1	9.02	6.39	Urban Restricted	20	8	21.65	2.63
Urban Unrestricted	21	4	14.31	4.79	Rural Restricted	21	1	8.92	6.27	Urban Restricted	21	8	21.98	2.49
Urban Unrestricted	22	4	14.26	4.52	Rural Restricted	22	1	8.75	6.15	Urban Restricted	22	8	22.02	2.37
Urban Unrestricted	23	4	14.22	4.27	Rural Restricted	23	1	8.59	6.05	Urban Restricted	23	8	22.06	2.25
Urban Unrestricted	24	4	14.18	4.04	Rural Restricted	24	1	8.45	5.95	Urban Restricted	24	8	22.09	2.15
Urban Unrestricted	25	4	14.08	3.89	Rural Restricted	25	1	8.35	5.89	Urban Restricted	25	8	22.11	2.08
Urban Unrestricted	26	4	13.96	3.86	Rural Restricted	26	1	8.30	5.84	Urban Restricted	26	8	22.10	2.05
Urban Unrestricted	27	4	13.86	3.84	Rural Restricted	27	1	8.24	5.80	Urban Restricted	27	8	22.09	2.02
Urban Unrestricted	28	4	13.76	3.83	Rural Restricted	28	1	8.19	5.77	Urban Restricted	28	8	22.09	1.99
Urban Unrestricted	29	4	13.68	3.82	Rural Restricted	29	1	8.15	5.73	Urban Restricted	29	8	22.08	1.96
Urban Unrestricted	30	4	13.60	3.80	Rural Restricted	30	1	8.11	5.70	Urban Restricted	30	8	22.07	1.94
Urban Unrestricted	31	4	13.52	3.79	Rural Restricted	31	1	8.08	5.67	Urban Restricted	31	8	22.21	1.91
Urban Unrestricted	32	4	13.40	3.68	Rural Restricted	32	1	7.91	5.52	Urban Restricted	32	8	22.30	1.83
Urban Unrestricted	33	4	13.13	3.50	Rural Restricted	33	1	7.58	5.26	Urban Restricted	33	8	22.22	1.71
Urban Unrestricted	34	4	12.88	3.32	Rural Restricted	34	1	7.26	5.01	Urban Restricted	34	8	22.14	1.60
Urban Unrestricted	35	4	12.80	3.22	Rural Restricted	35	1	7.11	4.88	Urban Restricted	35	8	22.21	1.53
Urban Unrestricted	36	4	12.81	3.16	Rural Restricted	36	1	7.05	4.82	Urban Restricted	36	8	22.36	1.49
Urban Unrestricted	37	4	12.83	3.11	Rural Restricted	37	1	7.00	4.76	Urban Restricted	37	8	22.51	1.44
Urban Unrestricted	38	4	12.84	3.06	Rural Restricted	38	1	6.95	4.70	Urban Restricted	38	8	22.65	1.40
Urban Unrestricted	39	4	12.86	3.01	Rural Restricted	39	1	6.91	4.65	Urban Restricted	39	8	22.78	1.36
Urban Unrestricted	40	4	12.87	2.96	Rural Restricted	40	1	6.86	4.60	Urban Restricted	40	8	22.90	1.33
Urban Unrestricted	41	4	12.88	2.92	Rural Restricted	41	1	6.82	4.55	Urban Restricted	41	8	23.02	1.29
Urban Unrestricted	42	4	12.89	2.88	Rural Restricted	42	1	6.78	4.50	Urban Restricted	42	8	23.13	1.26
Urban Unrestricted	43	4	12.90	2.84	Rural Restricted	43	1	6.74	4.46	Urban Restricted	43	8	23.24	1.23
Urban Unrestricted	44	4	12.91	2.80	Rural Restricted	44	1	6.70	4.42	Urban Restricted	44	8	23.34	1.20
Urban Unrestricted	45	4	12.88	2.78	Rural Restricted	45	1	6.66	4.38	Urban Restricted	45	8	23.41	1.17

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	46	4	12.84	2.75	Rural Restricted	46	1	6.60	4.33	Urban Restricted	46	8	23.45	1.13
Urban Unrestricted	47	4	12.79	2.73	Rural Restricted	47	1	6.54	4.29	Urban Restricted	47	8	23.46	1.10
Urban Unrestricted	48	4	12.75	2.71	Rural Restricted	48	1	6.48	4.25	Urban Restricted	48	8	23.48	1.07
Urban Unrestricted	49	4	12.71	2.68	Rural Restricted	49	1	6.42	4.20	Urban Restricted	49	8	23.49	1.03
Urban Unrestricted	50	4	12.67	2.66	Rural Restricted	50	1	6.37	4.16	Urban Restricted	50	8	23.50	1.00
Urban Unrestricted	51	4	12.64	2.65	Rural Restricted	51	1	6.31	4.12	Urban Restricted	51	8	23.51	0.97
Urban Unrestricted	52	4	12.60	2.63	Rural Restricted	52	1	6.26	4.09	Urban Restricted	52	8	23.52	0.94
Urban Unrestricted	53	4	12.58	2.61	Rural Restricted	53	1	6.21	4.05	Urban Restricted	53	8	23.53	0.92
Urban Unrestricted	54	4	12.63	2.61	Rural Restricted	54	1	6.17	4.01	Urban Restricted	54	8	23.54	0.89
Urban Unrestricted	55	4	12.67	2.60	Rural Restricted	55	1	6.12	3.98	Urban Restricted	55	8	23.55	0.87
Urban Unrestricted	56	4	12.72	2.60	Rural Restricted	56	1	6.07	3.94	Urban Restricted	56	8	23.58	0.84
Urban Unrestricted	57	4	12.78	2.59	Rural Restricted	57	1	6.01	3.90	Urban Restricted	57	8	23.63	0.82
Urban Unrestricted	58	4	12.83	2.58	Rural Restricted	58	1	5.96	3.86	Urban Restricted	58	8	23.67	0.81
Urban Unrestricted	59	4	12.88	2.57	Rural Restricted	59	1	5.92	3.83	Urban Restricted	59	8	23.70	0.79
Urban Unrestricted	60	4	12.93	2.57	Rural Restricted	60	1	5.95	3.82	Urban Restricted	60	8	23.65	0.77
Urban Unrestricted	61	4	13.01	2.55	Rural Restricted	61	1	6.05	3.82	Urban Restricted	61	8	23.65	0.76
Urban Unrestricted	62	4	13.11	2.53	Rural Restricted	62	1	6.19	3.83	Urban Restricted	62	8	23.67	0.75
Urban Unrestricted	63	4	13.20	2.51	Rural Restricted	63	1	6.33	3.84	Urban Restricted	63	8	23.69	0.74
Urban Unrestricted	64	4	13.38	2.49	Rural Restricted	64	1	6.46	3.85	Urban Restricted	64	8	23.71	0.72
Urban Unrestricted	65	4	13.73	2.46	Rural Restricted	65	1	6.63	3.90	Urban Restricted	65	8	23.79	0.71
Urban Unrestricted	66	4	14.08	2.44	Rural Restricted	66	1	6.82	3.98	Urban Restricted	66	8	23.92	0.69
Urban Unrestricted	67	4	14.41	2.41	Rural Restricted	67	1	7.04	4.04	Urban Restricted	67	8	23.98	0.68
Urban Unrestricted	68	4	14.74	2.39	Rural Restricted	68	1	7.26	4.10	Urban Restricted	68	8	24.00	0.66
Urban Unrestricted	69	4	15.05	2.37	Rural Restricted	69	1	7.48	4.16	Urban Restricted	69	8	24.02	0.65
Urban Unrestricted	70	4	15.36	2.35	Rural Restricted	70	1	7.69	4.22	Urban Restricted	70	8	24.05	0.63
Urban Unrestricted	71	4	15.66	2.32	Rural Restricted	71	1	7.90	4.27	Urban Restricted	71	8	24.07	0.62
Urban Unrestricted	72	4	15.95	2.30	Rural Restricted	72	1	8.10	4.33	Urban Restricted	72	8	24.09	0.61
Urban Unrestricted	73	4	16.24	2.28	Rural Restricted	73	1	8.30	4.38	Urban Restricted	73	8	24.11	0.59
Urban Unrestricted	74	4	16.57	2.30	Rural Restricted	74	1	8.62	4.53	Urban Restricted	74	8	24.11	0.59
Urban Unrestricted	75	4	16.89	2.47	Rural Restricted	75	1	9.27	4.96	Urban Restricted	75	8	23.94	0.63
Rural Unrestricted	1	5	69.61	32.44	Urban Restricted	1	1	65.65	48.04	Rural Restricted	1	9	70.94	26.91
Rural Unrestricted	2	5	35.49	16.51	Urban Restricted	2	1	33.01	24.54	Rural Restricted	2	9	36.51	13.63
Rural Unrestricted	3	5	26.75	12.21	Urban Restricted	3	1	22.95	18.08	Rural Restricted	3	9	29.04	9.77
Rural Unrestricted	4	5	23.23	10.36	Urban Restricted	4	1	18.21	15.03	Rural Restricted	4	9	26.59	7.97
Rural Unrestricted	5	5	21.17	9.18	Urban Restricted	5	1	15.48	13.01	Rural Restricted	5	9	25.24	6.81
Rural Unrestricted	6	5	19.88	8.31	Urban Restricted	6	1	13.79	11.44	Rural Restricted	6	9	24.47	5.94
Rural Unrestricted	7	5	18.96	7.69	Urban Restricted	7	1	12.58	10.31	Rural Restricted	7	9	23.92	5.31
Rural Unrestricted	8	5	18.26	7.22	Urban Restricted	8	1	11.68	9.47	Rural Restricted	8	9	23.51	4.84
Rural Unrestricted	9	5	17.72	6.86	Urban Restricted	9	1	10.99	8.84	Rural Restricted	9	9	23.01	4.48
Rural Unrestricted	10	5	17.29	6.57	Urban Restricted	10	1	10.46	8.41	Rural Restricted	10	9	22.18	4.18

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	11	5	17.00	6.30	Urban Restricted	11	1	10.09	8.06	Rural Restricted	11	9	21.61	3.94
Rural Unrestricted	12	5	16.92	6.03	Urban Restricted	12	1	9.92	7.77	Rural Restricted	12	9	21.34	3.74
Rural Unrestricted	13	5	16.84	5.80	Urban Restricted	13	1	9.78	7.53	Rural Restricted	13	9	21.12	3.56
Rural Unrestricted	14	5	16.78	5.60	Urban Restricted	14	1	9.65	7.33	Rural Restricted	14	9	20.93	3.41
Rural Unrestricted	15	5	16.73	5.43	Urban Restricted	15	1	9.54	7.15	Rural Restricted	15	9	20.76	3.29
Rural Unrestricted	16	5	16.67	5.27	Urban Restricted	16	1	9.43	6.98	Rural Restricted	16	9	20.92	3.14
Rural Unrestricted	17	5	16.59	5.13	Urban Restricted	17	1	9.30	6.80	Rural Restricted	17	9	21.88	2.91
Rural Unrestricted	18	5	16.52	5.00	Urban Restricted	18	1	9.19	6.64	Rural Restricted	18	9	22.73	2.71
Rural Unrestricted	19	5	16.49	4.81	Urban Restricted	19	1	9.09	6.50	Rural Restricted	19	9	23.50	2.53
Rural Unrestricted	20	5	16.52	4.54	Urban Restricted	20	1	9.00	6.37	Rural Restricted	20	9	24.19	2.37
Rural Unrestricted	21	5	16.55	4.29	Urban Restricted	21	1	8.90	6.25	Rural Restricted	21	9	24.58	2.24
Rural Unrestricted	22	5	16.61	4.03	Urban Restricted	22	1	8.73	6.14	Rural Restricted	22	9	24.61	2.13
Rural Unrestricted	23	5	16.67	3.79	Urban Restricted	23	1	8.57	6.04	Rural Restricted	23	9	24.63	2.03
Rural Unrestricted	24	5	16.73	3.57	Urban Restricted	24	1	8.43	5.94	Rural Restricted	24	9	24.65	1.93
Rural Unrestricted	25	5	16.72	3.43	Urban Restricted	25	1	8.33	5.87	Rural Restricted	25	9	24.64	1.87
Rural Unrestricted	26	5	16.54	3.39	Urban Restricted	26	1	8.28	5.83	Rural Restricted	26	9	24.59	1.83
Rural Unrestricted	27	5	16.31	3.37	Urban Restricted	27	1	8.22	5.79	Rural Restricted	27	9	24.54	1.79
Rural Unrestricted	28	5	16.10	3.35	Urban Restricted	28	1	8.18	5.75	Rural Restricted	28	9	24.50	1.76
Rural Unrestricted	29	5	15.91	3.33	Urban Restricted	29	1	8.13	5.72	Rural Restricted	29	9	24.47	1.73
Rural Unrestricted	30	5	15.72	3.31	Urban Restricted	30	1	8.09	5.68	Rural Restricted	30	9	24.43	1.70
Rural Unrestricted	31	5	15.55	3.30	Urban Restricted	31	1	8.07	5.66	Rural Restricted	31	9	24.56	1.66
Rural Unrestricted	32	5	15.49	3.18	Urban Restricted	32	1	7.89	5.51	Rural Restricted	32	9	24.67	1.60
Rural Unrestricted	33	5	15.29	2.98	Urban Restricted	33	1	7.56	5.25	Rural Restricted	33	9	24.62	1.51
Rural Unrestricted	34	5	15.11	2.80	Urban Restricted	34	1	7.25	5.00	Rural Restricted	34	9	24.57	1.42
Rural Unrestricted	35	5	15.07	2.70	Urban Restricted	35	1	7.09	4.87	Rural Restricted	35	9	24.65	1.36
Rural Unrestricted	36	5	15.11	2.65	Urban Restricted	36	1	7.04	4.81	Rural Restricted	36	9	24.82	1.32
Rural Unrestricted	37	5	15.16	2.61	Urban Restricted	37	1	6.99	4.75	Rural Restricted	37	9	24.98	1.28
Rural Unrestricted	38	5	15.20	2.57	Urban Restricted	38	1	6.94	4.69	Rural Restricted	38	9	25.13	1.24
Rural Unrestricted	39	5	15.24	2.53	Urban Restricted	39	1	6.89	4.64	Rural Restricted	39	9	25.27	1.20
Rural Unrestricted	40	5	15.27	2.49	Urban Restricted	40	1	6.85	4.59	Rural Restricted	40	9	25.41	1.16
Rural Unrestricted	41	5	15.31	2.46	Urban Restricted	41	1	6.81	4.54	Rural Restricted	41	9	25.54	1.13
Rural Unrestricted	42	5	15.34	2.43	Urban Restricted	42	1	6.77	4.49	Rural Restricted	42	9	25.66	1.10
Rural Unrestricted	43	5	15.37	2.40	Urban Restricted	43	1	6.73	4.45	Rural Restricted	43	9	25.78	1.07
Rural Unrestricted	44	5	15.40	2.37	Urban Restricted	44	1	6.69	4.41	Rural Restricted	44	9	25.89	1.04
Rural Unrestricted	45	5	15.41	2.34	Urban Restricted	45	1	6.65	4.36	Rural Restricted	45	9	25.96	1.01
Rural Unrestricted	46	5	15.38	2.30	Urban Restricted	46	1	6.59	4.32	Rural Restricted	46	9	26.01	0.98
Rural Unrestricted	47	5	15.36	2.27	Urban Restricted	47	1	6.53	4.28	Rural Restricted	47	9	25.97	0.95
Rural Unrestricted	48	5	15.34	2.25	Urban Restricted	48	1	6.47	4.23	Rural Restricted	48	9	25.92	0.92
Rural Unrestricted	49	5	15.32	2.22	Urban Restricted	49	1	6.41	4.19	Rural Restricted	49	9	25.87	0.89
Rural Unrestricted	50	5	15.36	2.20	Urban Restricted	50	1	6.36	4.15	Rural Restricted	50	9	25.83	0.86

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	51	5	15.40	2.18	Urban Restricted	51	1	6.30	4.11	Rural Restricted	51	9	25.79	0.84
Rural Unrestricted	52	5	15.44	2.17	Urban Restricted	52	1	6.26	4.08	Rural Restricted	52	9	25.74	0.81
Rural Unrestricted	53	5	15.47	2.15	Urban Restricted	53	1	6.21	4.04	Rural Restricted	53	9	25.70	0.79
Rural Unrestricted	54	5	15.51	2.13	Urban Restricted	54	1	6.16	4.00	Rural Restricted	54	9	25.66	0.76
Rural Unrestricted	55	5	15.54	2.12	Urban Restricted	55	1	6.12	3.97	Rural Restricted	55	9	25.63	0.74
Rural Unrestricted	56	5	15.57	2.10	Urban Restricted	56	1	6.06	3.93	Rural Restricted	56	9	25.60	0.72
Rural Unrestricted	57	5	15.60	2.07	Urban Restricted	57	1	6.01	3.89	Rural Restricted	57	9	25.59	0.70
Rural Unrestricted	58	5	15.62	2.05	Urban Restricted	58	1	5.95	3.85	Rural Restricted	58	9	25.58	0.68
Rural Unrestricted	59	5	15.64	2.02	Urban Restricted	59	1	5.91	3.82	Rural Restricted	59	9	25.55	0.67
Rural Unrestricted	60	5	15.67	2.00	Urban Restricted	60	1	5.94	3.81	Rural Restricted	60	9	25.48	0.66
Rural Unrestricted	61	5	15.75	1.98	Urban Restricted	61	1	6.04	3.81	Rural Restricted	61	9	25.46	0.65
Rural Unrestricted	62	5	15.88	1.95	Urban Restricted	62	1	6.19	3.82	Rural Restricted	62	9	25.47	0.64
Rural Unrestricted	63	5	16.00	1.93	Urban Restricted	63	1	6.32	3.83	Rural Restricted	63	9	25.48	0.63
Rural Unrestricted	64	5	16.21	1.90	Urban Restricted	64	1	6.46	3.84	Rural Restricted	64	9	25.49	0.63
Rural Unrestricted	65	5	16.58	1.88	Urban Restricted	65	1	6.63	3.89	Rural Restricted	65	9	25.52	0.61
Rural Unrestricted	66	5	16.93	1.85	Urban Restricted	66	1	6.82	3.97	Rural Restricted	66	9	25.55	0.60
Rural Unrestricted	67	5	17.28	1.83	Urban Restricted	67	1	7.03	4.04	Rural Restricted	67	9	25.52	0.58
Rural Unrestricted	68	5	17.62	1.81	Urban Restricted	68	1	7.26	4.10	Rural Restricted	68	9	25.45	0.57
Rural Unrestricted	69	5	17.94	1.79	Urban Restricted	69	1	7.48	4.16	Rural Restricted	69	9	25.38	0.56
Rural Unrestricted	70	5	18.26	1.77	Urban Restricted	70	1	7.69	4.21	Rural Restricted	70	9	25.32	0.55
Rural Unrestricted	71	5	18.56	1.75	Urban Restricted	71	1	7.90	4.27	Rural Restricted	71	9	25.26	0.54
Rural Unrestricted	72	5	18.86	1.73	Urban Restricted	72	1	8.10	4.32	Rural Restricted	72	9	25.20	0.53
Rural Unrestricted	73	5	19.16	1.71	Urban Restricted	73	1	8.30	4.38	Rural Restricted	73	9	25.15	0.52
Rural Unrestricted	74	5	19.39	1.71	Urban Restricted	74	1	8.63	4.52	Rural Restricted	74	9	25.08	0.52
Rural Unrestricted	75	5	19.32	1.80	Urban Restricted	75	1	9.28	4.95	Rural Restricted	75	9	24.89	0.53
Urban Unrestricted	1	5	69.41	32.26	Rural Restricted	1	2	67.18	42.65	Urban Restricted	1	9	70.79	26.78
Urban Unrestricted	2	5	35.39	16.42	Rural Restricted	2	2	33.89	21.79	Urban Restricted	2	9	36.43	13.56
Urban Unrestricted	3	5	26.68	12.15	Rural Restricted	3	2	23.92	16.12	Urban Restricted	3	9	28.97	9.72
Urban Unrestricted	4	5	23.17	10.31	Rural Restricted	4	2	19.28	13.50	Urban Restricted	4	9	26.54	7.93
Urban Unrestricted	5	5	21.13	9.14	Rural Restricted	5	2	16.61	11.76	Urban Restricted	5	9	25.19	6.78
Urban Unrestricted	6	5	19.84	8.27	Rural Restricted	6	2	14.99	10.38	Urban Restricted	6	9	24.43	5.91
Urban Unrestricted	7	5	18.92	7.66	Rural Restricted	7	2	13.83	9.40	Urban Restricted	7	9	23.89	5.29
Urban Unrestricted	8	5	18.23	7.19	Rural Restricted	8	2	12.95	8.67	Urban Restricted	8	9	23.48	4.82
Urban Unrestricted	9	5	17.69	6.83	Rural Restricted	9	2	12.28	8.10	Urban Restricted	9	9	22.98	4.46
Urban Unrestricted	10	5	17.26	6.55	Rural Restricted	10	2	11.76	7.68	Urban Restricted	10	9	22.15	4.17
Urban Unrestricted	11	5	16.98	6.28	Rural Restricted	11	2	11.40	7.34	Urban Restricted	11	9	21.57	3.93
Urban Unrestricted	12	5	16.89	6.01	Rural Restricted	12	2	11.21	7.05	Urban Restricted	12	9	21.31	3.72
Urban Unrestricted	13	5	16.82	5.78	Rural Restricted	13	2	11.06	6.82	Urban Restricted	13	9	21.08	3.55
Urban Unrestricted	14	5	16.76	5.58	Rural Restricted	14	2	10.93	6.61	Urban Restricted	14	9	20.89	3.40
Urban Unrestricted	15	5	16.71	5.41	Rural Restricted	15	2	10.81	6.43	Urban Restricted	15	9	20.72	3.28

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	16	5	16.65	5.26	Rural Restricted	16	2	10.71	6.25	Urban Restricted	16	9	20.88	3.13
Urban Unrestricted	17	5	16.57	5.12	Rural Restricted	17	2	10.64	6.04	Urban Restricted	17	9	21.85	2.90
Urban Unrestricted	18	5	16.50	4.99	Rural Restricted	18	2	10.57	5.85	Urban Restricted	18	9	22.71	2.70
Urban Unrestricted	19	5	16.47	4.80	Rural Restricted	19	2	10.51	5.68	Urban Restricted	19	9	23.48	2.52
Urban Unrestricted	20	5	16.50	4.53	Rural Restricted	20	2	10.46	5.53	Urban Restricted	20	9	24.18	2.36
Urban Unrestricted	21	5	16.53	4.28	Rural Restricted	21	2	10.39	5.39	Urban Restricted	21	9	24.58	2.23
Urban Unrestricted	22	5	16.60	4.02	Rural Restricted	22	2	10.27	5.26	Urban Restricted	22	9	24.60	2.12
Urban Unrestricted	23	5	16.66	3.78	Rural Restricted	23	2	10.17	5.14	Urban Restricted	23	9	24.63	2.02
Urban Unrestricted	24	5	16.71	3.56	Rural Restricted	24	2	10.07	5.03	Urban Restricted	24	9	24.65	1.93
Urban Unrestricted	25	5	16.70	3.42	Rural Restricted	25	2	9.97	4.96	Urban Restricted	25	9	24.64	1.86
Urban Unrestricted	26	5	16.52	3.38	Rural Restricted	26	2	9.87	4.93	Urban Restricted	26	9	24.59	1.82
Urban Unrestricted	27	5	16.30	3.36	Rural Restricted	27	2	9.79	4.91	Urban Restricted	27	9	24.55	1.79
Urban Unrestricted	28	5	16.09	3.34	Rural Restricted	28	2	9.70	4.88	Urban Restricted	28	9	24.51	1.75
Urban Unrestricted	29	5	15.89	3.32	Rural Restricted	29	2	9.63	4.86	Urban Restricted	29	9	24.47	1.72
Urban Unrestricted	30	5	15.71	3.30	Rural Restricted	30	2	9.55	4.84	Urban Restricted	30	9	24.44	1.69
Urban Unrestricted	31	5	15.53	3.29	Rural Restricted	31	2	9.53	4.83	Urban Restricted	31	9	24.56	1.66
Urban Unrestricted	32	5	15.47	3.17	Rural Restricted	32	2	9.41	4.69	Urban Restricted	32	9	24.68	1.59
Urban Unrestricted	33	5	15.26	2.97	Rural Restricted	33	2	9.17	4.44	Urban Restricted	33	9	24.63	1.50
Urban Unrestricted	34	5	15.08	2.78	Rural Restricted	34	2	8.94	4.21	Urban Restricted	34	9	24.59	1.42
Urban Unrestricted	35	5	15.03	2.67	Rural Restricted	35	2	8.82	4.09	Urban Restricted	35	9	24.68	1.36
Urban Unrestricted	36	5	15.07	2.63	Rural Restricted	36	2	8.77	4.05	Urban Restricted	36	9	24.85	1.31
Urban Unrestricted	37	5	15.11	2.58	Rural Restricted	37	2	8.73	4.01	Urban Restricted	37	9	25.01	1.27
Urban Unrestricted	38	5	15.14	2.54	Rural Restricted	38	2	8.69	3.97	Urban Restricted	38	9	25.16	1.23
Urban Unrestricted	39	5	15.18	2.50	Rural Restricted	39	2	8.65	3.93	Urban Restricted	39	9	25.31	1.20
Urban Unrestricted	40	5	15.21	2.46	Rural Restricted	40	2	8.61	3.90	Urban Restricted	40	9	25.44	1.16
Urban Unrestricted	41	5	15.24	2.42	Rural Restricted	41	2	8.57	3.87	Urban Restricted	41	9	25.58	1.13
Urban Unrestricted	42	5	15.27	2.39	Rural Restricted	42	2	8.54	3.84	Urban Restricted	42	9	25.70	1.09
Urban Unrestricted	43	5	15.30	2.36	Rural Restricted	43	2	8.51	3.81	Urban Restricted	43	9	25.82	1.06
Urban Unrestricted	44	5	15.32	2.33	Rural Restricted	44	2	8.48	3.78	Urban Restricted	44	9	25.93	1.03
Urban Unrestricted	45	5	15.31	2.30	Rural Restricted	45	2	8.43	3.75	Urban Restricted	45	9	26.01	1.01
Urban Unrestricted	46	5	15.28	2.28	Rural Restricted	46	2	8.37	3.73	Urban Restricted	46	9	26.06	0.98
Urban Unrestricted	47	5	15.25	2.25	Rural Restricted	47	2	8.30	3.69	Urban Restricted	47	9	26.02	0.95
Urban Unrestricted	48	5	15.22	2.23	Rural Restricted	48	2	8.24	3.65	Urban Restricted	48	9	25.97	0.92
Urban Unrestricted	49	5	15.19	2.20	Rural Restricted	49	2	8.17	3.62	Urban Restricted	49	9	25.93	0.89
Urban Unrestricted	50	5	15.16	2.18	Rural Restricted	50	2	8.12	3.59	Urban Restricted	50	9	25.88	0.86
Urban Unrestricted	51	5	15.13	2.16	Rural Restricted	51	2	8.06	3.55	Urban Restricted	51	9	25.84	0.83
Urban Unrestricted	52	5	15.11	2.14	Rural Restricted	52	2	8.00	3.52	Urban Restricted	52	9	25.80	0.81
Urban Unrestricted	53	5	15.10	2.12	Rural Restricted	53	2	7.95	3.49	Urban Restricted	53	9	25.76	0.78
Urban Unrestricted	54	5	15.17	2.11	Rural Restricted	54	2	7.90	3.46	Urban Restricted	54	9	25.72	0.76
Urban Unrestricted	55	5	15.25	2.09	Rural Restricted	55	2	7.85	3.43	Urban Restricted	55	9	25.69	0.74

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	56	5	15.31	2.07	Rural Restricted	56	2	7.82	3.40	Urban Restricted	56	9	25.66	0.71
Urban Unrestricted	57	5	15.38	2.05	Rural Restricted	57	2	7.80	3.36	Urban Restricted	57	9	25.65	0.70
Urban Unrestricted	58	5	15.44	2.03	Rural Restricted	58	2	7.78	3.33	Urban Restricted	58	9	25.64	0.68
Urban Unrestricted	59	5	15.49	2.00	Rural Restricted	59	2	7.78	3.30	Urban Restricted	59	9	25.61	0.66
Urban Unrestricted	60	5	15.55	1.98	Rural Restricted	60	2	7.85	3.29	Urban Restricted	60	9	25.55	0.65
Urban Unrestricted	61	5	15.67	1.96	Rural Restricted	61	2	7.99	3.28	Urban Restricted	61	9	25.53	0.65
Urban Unrestricted	62	5	15.83	1.94	Rural Restricted	62	2	8.17	3.27	Urban Restricted	62	9	25.54	0.64
Urban Unrestricted	63	5	15.98	1.91	Rural Restricted	63	2	8.34	3.25	Urban Restricted	63	9	25.55	0.63
Urban Unrestricted	64	5	16.21	1.89	Rural Restricted	64	2	8.51	3.24	Urban Restricted	64	9	25.56	0.62
Urban Unrestricted	65	5	16.58	1.87	Rural Restricted	65	2	8.74	3.25	Urban Restricted	65	9	25.58	0.61
Urban Unrestricted	66	5	16.93	1.84	Rural Restricted	66	2	9.01	3.27	Urban Restricted	66	9	25.62	0.59
Urban Unrestricted	67	5	17.28	1.82	Rural Restricted	67	2	9.31	3.29	Urban Restricted	67	9	25.58	0.58
Urban Unrestricted	68	5	17.62	1.80	Rural Restricted	68	2	9.63	3.32	Urban Restricted	68	9	25.52	0.57
Urban Unrestricted	69	5	17.94	1.78	Rural Restricted	69	2	9.93	3.35	Urban Restricted	69	9	25.45	0.56
Urban Unrestricted	70	5	18.26	1.76	Rural Restricted	70	2	10.23	3.37	Urban Restricted	70	9	25.39	0.55
Urban Unrestricted	71	5	18.57	1.74	Rural Restricted	71	2	10.52	3.40	Urban Restricted	71	9	25.32	0.54
Urban Unrestricted	72	5	18.87	1.72	Rural Restricted	72	2	10.81	3.42	Urban Restricted	72	9	25.26	0.53
Urban Unrestricted	73	5	19.17	1.70	Rural Restricted	73	2	11.08	3.45	Urban Restricted	73	9	25.21	0.52
Urban Unrestricted	74	5	19.40	1.70	Rural Restricted	74	2	11.34	3.54	Urban Restricted	74	9	25.14	0.52
Urban Unrestricted	75	5	19.34	1.78	Rural Restricted	75	2	11.71	3.85	Urban Restricted	75	9	24.95	0.53
Rural Unrestricted	1	6	70.06	31.21	Urban Restricted	1	2	67.04	42.52	Rural Restricted	1	10	71.38	25.40
Rural Unrestricted	2	6	35.80	15.82	Urban Restricted	2	2	33.82	21.72	Rural Restricted	2	10	36.82	12.86
Rural Unrestricted	3	6	27.43	11.50	Urban Restricted	3	2	23.86	16.07	Rural Restricted	3	10	29.83	9.18
Rural Unrestricted	4	6	24.29	9.58	Urban Restricted	4	2	19.23	13.46	Rural Restricted	4	10	27.89	7.47
Rural Unrestricted	5	6	22.48	8.39	Urban Restricted	5	2	16.57	11.72	Rural Restricted	5	10	26.92	6.38
Rural Unrestricted	6	6	21.36	7.54	Urban Restricted	6	2	14.95	10.35	Rural Restricted	6	10	26.51	5.55
Rural Unrestricted	7	6	20.57	6.94	Urban Restricted	7	2	13.79	9.38	Rural Restricted	7	10	26.21	4.96
Rural Unrestricted	8	6	19.97	6.49	Urban Restricted	8	2	12.92	8.64	Rural Restricted	8	10	25.99	4.52
Rural Unrestricted	9	6	19.50	6.13	Urban Restricted	9	2	12.26	8.08	Rural Restricted	9	10	25.54	4.17
Rural Unrestricted	10	6	19.13	5.85	Urban Restricted	10	2	11.74	7.66	Rural Restricted	10	10	24.56	3.89
Rural Unrestricted	11	6	18.90	5.60	Urban Restricted	11	2	11.37	7.32	Rural Restricted	11	10	23.81	3.65
Rural Unrestricted	12	6	18.88	5.35	Urban Restricted	12	2	11.19	7.04	Rural Restricted	12	10	23.30	3.46
Rural Unrestricted	13	6	18.87	5.14	Urban Restricted	13	2	11.03	6.80	Rural Restricted	13	10	22.87	3.30
Rural Unrestricted	14	6	18.86	4.96	Urban Restricted	14	2	10.90	6.60	Rural Restricted	14	10	22.50	3.16
Rural Unrestricted	15	6	18.85	4.80	Urban Restricted	15	2	10.79	6.42	Rural Restricted	15	10	22.18	3.04
Rural Unrestricted	16	6	18.83	4.66	Urban Restricted	16	2	10.69	6.24	Rural Restricted	16	10	22.35	2.90
Rural Unrestricted	17	6	18.80	4.52	Urban Restricted	17	2	10.62	6.03	Rural Restricted	17	10	23.70	2.67
Rural Unrestricted	18	6	18.77	4.39	Urban Restricted	18	2	10.55	5.84	Rural Restricted	18	10	24.90	2.47
Rural Unrestricted	19	6	18.77	4.22	Urban Restricted	19	2	10.49	5.67	Rural Restricted	19	10	25.97	2.29
Rural Unrestricted	20	6	18.80	3.99	Urban Restricted	20	2	10.44	5.52	Rural Restricted	20	10	26.93	2.13

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	21	6	18.82	3.77	Urban Restricted	21	2	10.37	5.38	Rural Restricted	21	10	27.47	2.01
Rural Unrestricted	22	6	18.82	3.55	Urban Restricted	22	2	10.25	5.24	Rural Restricted	22	10	27.45	1.91
Rural Unrestricted	23	6	18.82	3.34	Urban Restricted	23	2	10.14	5.12	Rural Restricted	23	10	27.43	1.81
Rural Unrestricted	24	6	18.82	3.16	Urban Restricted	24	2	10.05	5.01	Rural Restricted	24	10	27.42	1.73
Rural Unrestricted	25	6	18.77	3.03	Urban Restricted	25	2	9.95	4.95	Rural Restricted	25	10	27.38	1.67
Rural Unrestricted	26	6	18.65	2.98	Urban Restricted	26	2	9.85	4.92	Rural Restricted	26	10	27.32	1.64
Rural Unrestricted	27	6	18.50	2.94	Urban Restricted	27	2	9.76	4.89	Rural Restricted	27	10	27.26	1.61
Rural Unrestricted	28	6	18.37	2.91	Urban Restricted	28	2	9.68	4.87	Rural Restricted	28	10	27.21	1.59
Rural Unrestricted	29	6	18.24	2.88	Urban Restricted	29	2	9.61	4.85	Rural Restricted	29	10	27.16	1.56
Rural Unrestricted	30	6	18.13	2.85	Urban Restricted	30	2	9.53	4.83	Rural Restricted	30	10	27.11	1.54
Rural Unrestricted	31	6	18.02	2.83	Urban Restricted	31	2	9.51	4.81	Rural Restricted	31	10	27.21	1.51
Rural Unrestricted	32	6	17.98	2.71	Urban Restricted	32	2	9.39	4.68	Rural Restricted	32	10	27.26	1.45
Rural Unrestricted	33	6	17.80	2.52	Urban Restricted	33	2	9.15	4.43	Rural Restricted	33	10	27.16	1.35
Rural Unrestricted	34	6	17.63	2.35	Urban Restricted	34	2	8.92	4.20	Rural Restricted	34	10	27.06	1.27
Rural Unrestricted	35	6	17.61	2.25	Urban Restricted	35	2	8.81	4.08	Rural Restricted	35	10	27.09	1.21
Rural Unrestricted	36	6	17.67	2.19	Urban Restricted	36	2	8.76	4.04	Rural Restricted	36	10	27.21	1.17
Rural Unrestricted	37	6	17.74	2.14	Urban Restricted	37	2	8.72	4.00	Rural Restricted	37	10	27.32	1.14
Rural Unrestricted	38	6	17.80	2.09	Urban Restricted	38	2	8.68	3.96	Rural Restricted	38	10	27.42	1.10
Rural Unrestricted	39	6	17.86	2.04	Urban Restricted	39	2	8.64	3.92	Rural Restricted	39	10	27.52	1.07
Rural Unrestricted	40	6	17.91	2.00	Urban Restricted	40	2	8.60	3.89	Rural Restricted	40	10	27.62	1.04
Rural Unrestricted	41	6	17.97	1.96	Urban Restricted	41	2	8.56	3.86	Rural Restricted	41	10	27.71	1.01
Rural Unrestricted	42	6	18.02	1.92	Urban Restricted	42	2	8.53	3.83	Rural Restricted	42	10	27.79	0.98
Rural Unrestricted	43	6	18.06	1.88	Urban Restricted	43	2	8.50	3.80	Rural Restricted	43	10	27.87	0.95
Rural Unrestricted	44	6	18.11	1.84	Urban Restricted	44	2	8.47	3.77	Rural Restricted	44	10	27.95	0.93
Rural Unrestricted	45	6	18.12	1.80	Urban Restricted	45	2	8.42	3.74	Rural Restricted	45	10	27.99	0.90
Rural Unrestricted	46	6	18.11	1.76	Urban Restricted	46	2	8.36	3.72	Rural Restricted	46	10	27.99	0.88
Rural Unrestricted	47	6	18.09	1.72	Urban Restricted	47	2	8.29	3.68	Rural Restricted	47	10	27.96	0.85
Rural Unrestricted	48	6	18.08	1.68	Urban Restricted	48	2	8.23	3.64	Rural Restricted	48	10	27.93	0.83
Rural Unrestricted	49	6	18.07	1.64	Urban Restricted	49	2	8.17	3.61	Rural Restricted	49	10	27.89	0.80
Rural Unrestricted	50	6	18.13	1.62	Urban Restricted	50	2	8.11	3.57	Rural Restricted	50	10	27.86	0.78
Rural Unrestricted	51	6	18.19	1.59	Urban Restricted	51	2	8.05	3.54	Rural Restricted	51	10	27.83	0.76
Rural Unrestricted	52	6	18.26	1.56	Urban Restricted	52	2	8.00	3.51	Rural Restricted	52	10	27.81	0.74
Rural Unrestricted	53	6	18.32	1.54	Urban Restricted	53	2	7.95	3.48	Rural Restricted	53	10	27.78	0.72
Rural Unrestricted	54	6	18.37	1.52	Urban Restricted	54	2	7.90	3.45	Rural Restricted	54	10	27.75	0.70
Rural Unrestricted	55	6	18.43	1.49	Urban Restricted	55	2	7.85	3.42	Rural Restricted	55	10	27.73	0.68
Rural Unrestricted	56	6	18.49	1.47	Urban Restricted	56	2	7.82	3.39	Rural Restricted	56	10	27.71	0.66
Rural Unrestricted	57	6	18.55	1.44	Urban Restricted	57	2	7.79	3.35	Rural Restricted	57	10	27.71	0.64
Rural Unrestricted	58	6	18.61	1.42	Urban Restricted	58	2	7.77	3.32	Rural Restricted	58	10	27.71	0.63
Rural Unrestricted	59	6	18.66	1.40	Urban Restricted	59	2	7.77	3.29	Rural Restricted	59	10	27.66	0.61
Rural Unrestricted	60	6	18.72	1.37	Urban Restricted	60	2	7.85	3.28	Rural Restricted	60	10	27.46	0.60

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	61	6	18.84	1.35	Urban Restricted	61	2	7.99	3.27	Rural Restricted	61	10	27.32	0.59
Rural Unrestricted	62	6	19.01	1.34	Urban Restricted	62	2	8.17	3.26	Rural Restricted	62	10	27.22	0.58
Rural Unrestricted	63	6	19.17	1.32	Urban Restricted	63	2	8.34	3.24	Rural Restricted	63	10	27.12	0.57
Rural Unrestricted	64	6	19.37	1.30	Urban Restricted	64	2	8.51	3.23	Rural Restricted	64	10	27.03	0.57
Rural Unrestricted	65	6	19.63	1.27	Urban Restricted	65	2	8.74	3.24	Rural Restricted	65	10	26.94	0.55
Rural Unrestricted	66	6	19.89	1.25	Urban Restricted	66	2	9.01	3.26	Rural Restricted	66	10	26.86	0.54
Rural Unrestricted	67	6	20.15	1.23	Urban Restricted	67	2	9.31	3.28	Rural Restricted	67	10	26.75	0.52
Rural Unrestricted	68	6	20.39	1.21	Urban Restricted	68	2	9.63	3.31	Rural Restricted	68	10	26.63	0.52
Rural Unrestricted	69	6	20.63	1.19	Urban Restricted	69	2	9.94	3.34	Rural Restricted	69	10	26.51	0.51
Rural Unrestricted	70	6	20.86	1.16	Urban Restricted	70	2	10.24	3.36	Rural Restricted	70	10	26.40	0.50
Rural Unrestricted	71	6	21.08	1.14	Urban Restricted	71	2	10.54	3.39	Rural Restricted	71	10	26.28	0.49
Rural Unrestricted	72	6	21.30	1.13	Urban Restricted	72	2	10.82	3.42	Rural Restricted	72	10	26.18	0.49
Rural Unrestricted	73	6	21.51	1.11	Urban Restricted	73	2	11.09	3.44	Rural Restricted	73	10	26.08	0.48
Rural Unrestricted	74	6	21.60	1.11	Urban Restricted	74	2	11.35	3.53	Rural Restricted	74	10	25.98	0.48
Rural Unrestricted	75	6	21.25	1.20	Urban Restricted	75	2	11.73	3.84	Rural Restricted	75	10	25.78	0.48
Urban Unrestricted	1	6	69.86	31.02	Rural Restricted	1	3	68.11	41.63	Urban Restricted	1	10	71.23	25.26
Urban Unrestricted	2	6	35.69	15.73	Rural Restricted	2	3	34.54	21.18	Urban Restricted	2	10	36.73	12.78
Urban Unrestricted	3	6	27.36	11.44	Rural Restricted	3	3	25.02	15.38	Urban Restricted	3	10	29.76	9.13
Urban Unrestricted	4	6	24.23	9.54	Rural Restricted	4	3	20.70	12.65	Urban Restricted	4	10	27.84	7.43
Urban Unrestricted	5	6	22.43	8.35	Rural Restricted	5	3	18.15	10.90	Urban Restricted	5	10	26.88	6.34
Urban Unrestricted	6	6	21.32	7.51	Rural Restricted	6	3	16.50	9.60	Urban Restricted	6	10	26.47	5.53
Urban Unrestricted	7	6	20.53	6.91	Rural Restricted	7	3	15.33	8.66	Urban Restricted	7	10	26.18	4.94
Urban Unrestricted	8	6	19.94	6.46	Rural Restricted	8	3	14.44	7.96	Urban Restricted	8	10	25.96	4.50
Urban Unrestricted	9	6	19.47	6.11	Rural Restricted	9	3	13.74	7.44	Urban Restricted	9	10	25.52	4.16
Urban Unrestricted	10	6	19.10	5.83	Rural Restricted	10	3	13.13	7.06	Urban Restricted	10	10	24.53	3.87
Urban Unrestricted	11	6	18.88	5.58	Rural Restricted	11	3	12.69	6.73	Urban Restricted	11	10	23.78	3.64
Urban Unrestricted	12	6	18.86	5.33	Rural Restricted	12	3	12.47	6.43	Urban Restricted	12	10	23.27	3.45
Urban Unrestricted	13	6	18.85	5.12	Rural Restricted	13	3	12.27	6.17	Urban Restricted	13	10	22.83	3.29
Urban Unrestricted	14	6	18.84	4.94	Rural Restricted	14	3	12.11	5.95	Urban Restricted	14	10	22.46	3.15
Urban Unrestricted	15	6	18.83	4.79	Rural Restricted	15	3	11.96	5.75	Urban Restricted	15	10	22.14	3.03
Urban Unrestricted	16	6	18.81	4.64	Rural Restricted	16	3	11.88	5.57	Urban Restricted	16	10	22.32	2.89
Urban Unrestricted	17	6	18.78	4.51	Rural Restricted	17	3	11.92	5.35	Urban Restricted	17	10	23.68	2.66
Urban Unrestricted	18	6	18.76	4.38	Rural Restricted	18	3	11.95	5.15	Urban Restricted	18	10	24.88	2.46
Urban Unrestricted	19	6	18.75	4.21	Rural Restricted	19	3	11.97	4.98	Urban Restricted	19	10	25.96	2.28
Urban Unrestricted	20	6	18.78	3.98	Rural Restricted	20	3	12.00	4.82	Urban Restricted	20	10	26.94	2.12
Urban Unrestricted	21	6	18.80	3.76	Rural Restricted	21	3	11.99	4.67	Urban Restricted	21	10	27.48	2.00
Urban Unrestricted	22	6	18.80	3.54	Rural Restricted	22	3	11.91	4.51	Urban Restricted	22	10	27.46	1.90
Urban Unrestricted	23	6	18.80	3.33	Rural Restricted	23	3	11.84	4.36	Urban Restricted	23	10	27.44	1.81
Urban Unrestricted	24	6	18.80	3.15	Rural Restricted	24	3	11.78	4.22	Urban Restricted	24	10	27.43	1.72
Urban Unrestricted	25	6	18.76	3.02	Rural Restricted	25	3	11.70	4.16	Urban Restricted	25	10	27.39	1.67

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	26	6	18.63	2.97	Rural Restricted	26	3	11.61	4.16	Urban Restricted	26	10	27.33	1.64
Urban Unrestricted	27	6	18.49	2.93	Rural Restricted	27	3	11.53	4.17	Urban Restricted	27	10	27.27	1.61
Urban Unrestricted	28	6	18.36	2.90	Rural Restricted	28	3	11.45	4.17	Urban Restricted	28	10	27.22	1.58
Urban Unrestricted	29	6	18.23	2.87	Rural Restricted	29	3	11.38	4.17	Urban Restricted	29	10	27.17	1.56
Urban Unrestricted	30	6	18.12	2.84	Rural Restricted	30	3	11.32	4.18	Urban Restricted	30	10	27.13	1.53
Urban Unrestricted	31	6	18.01	2.82	Rural Restricted	31	3	11.30	4.18	Urban Restricted	31	10	27.22	1.51
Urban Unrestricted	32	6	17.93	2.70	Rural Restricted	32	3	11.18	4.07	Urban Restricted	32	10	27.28	1.44
Urban Unrestricted	33	6	17.70	2.51	Rural Restricted	33	3	10.91	3.87	Urban Restricted	33	10	27.18	1.35
Urban Unrestricted	34	6	17.49	2.34	Rural Restricted	34	3	10.65	3.67	Urban Restricted	34	10	27.08	1.26
Urban Unrestricted	35	6	17.43	2.23	Rural Restricted	35	3	10.55	3.57	Urban Restricted	35	10	27.12	1.21
Urban Unrestricted	36	6	17.46	2.18	Rural Restricted	36	3	10.53	3.53	Urban Restricted	36	10	27.24	1.17
Urban Unrestricted	37	6	17.49	2.13	Rural Restricted	37	3	10.52	3.49	Urban Restricted	37	10	27.35	1.13
Urban Unrestricted	38	6	17.52	2.08	Rural Restricted	38	3	10.51	3.45	Urban Restricted	38	10	27.46	1.10
Urban Unrestricted	39	6	17.54	2.03	Rural Restricted	39	3	10.49	3.42	Urban Restricted	39	10	27.56	1.06
Urban Unrestricted	40	6	17.57	1.98	Rural Restricted	40	3	10.48	3.39	Urban Restricted	40	10	27.66	1.03
Urban Unrestricted	41	6	17.59	1.94	Rural Restricted	41	3	10.47	3.36	Urban Restricted	41	10	27.75	1.00
Urban Unrestricted	42	6	17.62	1.90	Rural Restricted	42	3	10.46	3.33	Urban Restricted	42	10	27.84	0.97
Urban Unrestricted	43	6	17.64	1.86	Rural Restricted	43	3	10.45	3.30	Urban Restricted	43	10	27.92	0.95
Urban Unrestricted	44	6	17.69	1.82	Rural Restricted	44	3	10.44	3.27	Urban Restricted	44	10	28.00	0.92
Urban Unrestricted	45	6	17.72	1.79	Rural Restricted	45	3	10.42	3.25	Urban Restricted	45	10	28.04	0.90
Urban Unrestricted	46	6	17.72	1.74	Rural Restricted	46	3	10.37	3.24	Urban Restricted	46	10	28.04	0.87
Urban Unrestricted	47	6	17.72	1.71	Rural Restricted	47	3	10.35	3.21	Urban Restricted	47	10	28.02	0.85
Urban Unrestricted	48	6	17.71	1.67	Rural Restricted	48	3	10.33	3.18	Urban Restricted	48	10	27.98	0.82
Urban Unrestricted	49	6	17.71	1.63	Rural Restricted	49	3	10.31	3.16	Urban Restricted	49	10	27.95	0.80
Urban Unrestricted	50	6	17.71	1.60	Rural Restricted	50	3	10.28	3.13	Urban Restricted	50	10	27.92	0.78
Urban Unrestricted	51	6	17.71	1.56	Rural Restricted	51	3	10.27	3.11	Urban Restricted	51	10	27.90	0.76
Urban Unrestricted	52	6	17.71	1.53	Rural Restricted	52	3	10.25	3.09	Urban Restricted	52	10	27.87	0.73
Urban Unrestricted	53	6	17.73	1.50	Rural Restricted	53	3	10.23	3.06	Urban Restricted	53	10	27.84	0.71
Urban Unrestricted	54	6	17.85	1.48	Rural Restricted	54	3	10.21	3.04	Urban Restricted	54	10	27.82	0.70
Urban Unrestricted	55	6	17.97	1.46	Rural Restricted	55	3	10.19	3.02	Urban Restricted	55	10	27.79	0.68
Urban Unrestricted	56	6	18.09	1.44	Rural Restricted	56	3	10.21	2.99	Urban Restricted	56	10	27.78	0.66
Urban Unrestricted	57	6	18.21	1.42	Rural Restricted	57	3	10.24	2.96	Urban Restricted	57	10	27.78	0.64
Urban Unrestricted	58	6	18.33	1.40	Rural Restricted	58	3	10.27	2.92	Urban Restricted	58	10	27.78	0.62
Urban Unrestricted	59	6	18.44	1.38	Rural Restricted	59	3	10.32	2.89	Urban Restricted	59	10	27.74	0.61
Urban Unrestricted	60	6	18.54	1.36	Rural Restricted	60	3	10.42	2.88	Urban Restricted	60	10	27.53	0.60
Urban Unrestricted	61	6	18.72	1.34	Rural Restricted	61	3	10.54	2.87	Urban Restricted	61	10	27.39	0.59
Urban Unrestricted	62	6	18.93	1.32	Rural Restricted	62	3	10.67	2.86	Urban Restricted	62	10	27.29	0.58
Urban Unrestricted	63	6	19.14	1.31	Rural Restricted	63	3	10.79	2.84	Urban Restricted	63	10	27.19	0.57
Urban Unrestricted	64	6	19.37	1.29	Rural Restricted	64	3	10.91	2.83	Urban Restricted	64	10	27.10	0.56
Urban Unrestricted	65	6	19.64	1.26	Rural Restricted	65	3	11.15	2.83	Urban Restricted	65	10	27.01	0.55

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Urban Unrestricted	66	6	19.90	1.24	Rural Restricted	66	3	11.46	2.83	Urban Restricted	66	10	26.93	0.53
Urban Unrestricted	67	6	20.15	1.22	Rural Restricted	67	3	11.78	2.83	Urban Restricted	67	10	26.82	0.52
Urban Unrestricted	68	6	20.40	1.20	Rural Restricted	68	3	12.09	2.82	Urban Restricted	68	10	26.70	0.51
Urban Unrestricted	69	6	20.64	1.18	Rural Restricted	69	3	12.39	2.82	Urban Restricted	69	10	26.58	0.51
Urban Unrestricted	70	6	20.87	1.16	Rural Restricted	70	3	12.69	2.81	Urban Restricted	70	10	26.46	0.50
Urban Unrestricted	71	6	21.09	1.14	Rural Restricted	71	3	12.97	2.80	Urban Restricted	71	10	26.35	0.49
Urban Unrestricted	72	6	21.31	1.12	Rural Restricted	72	3	13.25	2.80	Urban Restricted	72	10	26.24	0.48
Urban Unrestricted	73	6	21.52	1.10	Rural Restricted	73	3	13.52	2.79	Urban Restricted	73	10	26.14	0.48
Urban Unrestricted	74	6	21.61	1.10	Rural Restricted	74	3	13.81	2.85	Urban Restricted	74	10	26.05	0.47
Urban Unrestricted	75	6	21.26	1.19	Rural Restricted	75	3	14.13	3.11	Urban Restricted	75	10	25.84	0.48
Rural Unrestricted	1	7	70.22	30.18	Urban Restricted	1	3	67.97	41.50					
Rural Unrestricted	2	7	35.98	15.30	Urban Restricted	2	3	34.47	21.11					
Rural Unrestricted	3	7	28.10	11.08	Urban Restricted	3	3	24.96	15.34					
Rural Unrestricted	4	7	25.37	9.19	Urban Restricted	4	3	20.65	12.61					
Rural Unrestricted	5	7	23.81	8.00	Urban Restricted	5	3	18.11	10.87					
Rural Unrestricted	6	7	22.85	7.12	Urban Restricted	6	3	16.46	9.57					
Rural Unrestricted	7	7	22.17	6.49	Urban Restricted	7	3	15.29	8.64					
Rural Unrestricted	8	7	21.66	6.02	Urban Restricted	8	3	14.41	7.94					
Rural Unrestricted	9	7	21.26	5.65	Urban Restricted	9	3	13.71	7.42					
Rural Unrestricted	10	7	20.93	5.35	Urban Restricted	10	3	13.10	7.04					
Rural Unrestricted	11	7	20.75	5.11	Urban Restricted	11	3	12.67	6.72					
Rural Unrestricted	12	7	20.77	4.89	Urban Restricted	12	3	12.44	6.41					
Rural Unrestricted	13	7	20.79	4.70	Urban Restricted	13	3	12.24	6.15					
Rural Unrestricted	14	7	20.80	4.54	Urban Restricted	14	3	12.08	5.93					
Rural Unrestricted	15	7	20.82	4.40	Urban Restricted	15	3	11.94	5.74					
Rural Unrestricted	16	7	20.82	4.27	Urban Restricted	16	3	11.85	5.55					
Rural Unrestricted	17	7	20.82	4.15	Urban Restricted	17	3	11.89	5.33					
Rural Unrestricted	18	7	20.81	4.04	Urban Restricted	18	3	11.92	5.14					
Rural Unrestricted	19	7	20.86	3.88	Urban Restricted	19	3	11.95	4.97					
Rural Unrestricted	20	7	20.99	3.65	Urban Restricted	20	3	11.98	4.81					
Rural Unrestricted	21	7	21.09	3.44	Urban Restricted	21	3	11.97	4.66					
Rural Unrestricted	22	7	21.15	3.21	Urban Restricted	22	3	11.89	4.50					
Rural Unrestricted	23	7	21.20	3.00	Urban Restricted	23	3	11.82	4.35					
Rural Unrestricted	24	7	21.25	2.80	Urban Restricted	24	3	11.75	4.21					
Rural Unrestricted	25	7	21.27	2.67	Urban Restricted	25	3	11.68	4.15					
Rural Unrestricted	26	7	21.17	2.61	Urban Restricted	26	3	11.59	4.15					
Rural Unrestricted	27	7	21.02	2.57	Urban Restricted	27	3	11.51	4.16					
Rural Unrestricted	28	7	20.89	2.53	Urban Restricted	28	3	11.43	4.16					
Rural Unrestricted	29	7	20.76	2.49	Urban Restricted	29	3	11.36	4.16					
Rural Unrestricted	30	7	20.64	2.46	Urban Restricted	30	3	11.30	4.17					

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	31	7	20.53	2.43	Urban Restricted	31	3	11.28	4.17					
Rural Unrestricted	32	7	20.56	2.32	Urban Restricted	32	3	11.16	4.06					
Rural Unrestricted	33	7	20.43	2.14	Urban Restricted	33	3	10.89	3.85					
Rural Unrestricted	34	7	20.30	1.98	Urban Restricted	34	3	10.64	3.66					
Rural Unrestricted	35	7	20.33	1.89	Urban Restricted	35	3	10.53	3.56					
Rural Unrestricted	36	7	20.45	1.83	Urban Restricted	36	3	10.52	3.52					
Rural Unrestricted	37	7	20.57	1.78	Urban Restricted	37	3	10.51	3.48					
Rural Unrestricted	38	7	20.68	1.73	Urban Restricted	38	3	10.50	3.44					
Rural Unrestricted	39	7	20.79	1.68	Urban Restricted	39	3	10.48	3.41					
Rural Unrestricted	40	7	20.89	1.63	Urban Restricted	40	3	10.47	3.38					
Rural Unrestricted	41	7	20.99	1.59	Urban Restricted	41	3	10.46	3.35					
Rural Unrestricted	42	7	21.08	1.55	Urban Restricted	42	3	10.45	3.32					
Rural Unrestricted	43	7	21.17	1.51	Urban Restricted	43	3	10.45	3.29					
Rural Unrestricted	44	7	21.25	1.47	Urban Restricted	44	3	10.44	3.26					
Rural Unrestricted	45	7	21.30	1.43	Urban Restricted	45	3	10.41	3.24					
Rural Unrestricted	46	7	21.32	1.39	Urban Restricted	46	3	10.37	3.23					
Rural Unrestricted	47	7	21.34	1.36	Urban Restricted	47	3	10.34	3.20					
Rural Unrestricted	48	7	21.35	1.32	Urban Restricted	48	3	10.32	3.17					
Rural Unrestricted	49	7	21.37	1.28	Urban Restricted	49	3	10.30	3.15					
Rural Unrestricted	50	7	21.36	1.26	Urban Restricted	50	3	10.28	3.12					
Rural Unrestricted	51	7	21.35	1.23	Urban Restricted	51	3	10.26	3.10					
Rural Unrestricted	52	7	21.33	1.20	Urban Restricted	52	3	10.25	3.08					
Rural Unrestricted	53	7	21.32	1.18	Urban Restricted	53	3	10.23	3.05					
Rural Unrestricted	54	7	21.31	1.16	Urban Restricted	54	3	10.21	3.03					
Rural Unrestricted	55	7	21.30	1.13	Urban Restricted	55	3	10.20	3.01					
Rural Unrestricted	56	7	21.31	1.11	Urban Restricted	56	3	10.21	2.98					
Rural Unrestricted	57	7	21.33	1.08	Urban Restricted	57	3	10.24	2.95					
Rural Unrestricted	58	7	21.34	1.05	Urban Restricted	58	3	10.27	2.91					
Rural Unrestricted	59	7	21.36	1.02	Urban Restricted	59	3	10.32	2.88					
Rural Unrestricted	60	7	21.38	1.00	Urban Restricted	60	3	10.43	2.87					
Rural Unrestricted	61	7	21.45	0.98	Urban Restricted	61	3	10.55	2.86					
Rural Unrestricted	62	7	21.55	0.96	Urban Restricted	62	3	10.67	2.84					
Rural Unrestricted	63	7	21.65	0.94	Urban Restricted	63	3	10.80	2.83					
Rural Unrestricted	64	7	21.76	0.93	Urban Restricted	64	3	10.92	2.82					
Rural Unrestricted	65	7	21.92	0.91	Urban Restricted	65	3	11.16	2.81					
Rural Unrestricted	66	7	22.08	0.89	Urban Restricted	66	3	11.47	2.82					
Rural Unrestricted	67	7	22.23	0.87	Urban Restricted	67	3	11.79	2.82					
Rural Unrestricted	68	7	22.37	0.85	Urban Restricted	68	3	12.11	2.81					
Rural Unrestricted	69	7	22.51	0.83	Urban Restricted	69	3	12.41	2.81					
Rural Unrestricted	70	7	22.65	0.82	Urban Restricted	70	3	12.71	2.80					

Table C-2 – CO Running Emission Rates Used in the Modeling for Upgrade and Downgrade Conditions, Respectively, in Grams Per Vehicle-Mile, 2020, by Speed and Grade

Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade	Road Type	Speed (MPH)	Grade (%)	Grams/Vehicle Mile Upgrade	Grams/Vehicle Mile Downgrade
Rural Unrestricted	71	7	22.78	0.80	Urban Restricted	71	3	13.00	2.79					
Rural Unrestricted	72	7	22.91	0.79	Urban Restricted	72	3	13.28	2.79					
Rural Unrestricted	73	7	23.03	0.77	Urban Restricted	73	3	13.55	2.78					
Rural Unrestricted	74	7	23.07	0.77	Urban Restricted	74	3	13.84	2.84					
Rural Unrestricted	75	7	22.76	0.86	Urban Restricted	75	3	14.17	3.11					

Appendix D: MOVES Model Inputs for TSD

Files available for download from the project web page at:
https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4100

Appendix E: CAL3QHC Model Inputs for TSD

Files available for download from the project web page at:
https://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4100

Appendix F: Georgia-Specific Programmatic Agreement

Russell R. McMurry, P.E.,
Commissioner
One Georgia Center
600 West
Peachtree
Street, NW
Atlanta,
GA 30308
(404) 631-1000 Main Office

January 24, 2020

Mr. Moises Marrero
Georgia Division Administrator
Federal Highway Administration, Atlanta Federal Center
61 Forsyth Street, S.W. Suite 17T100
Atlanta, Georgia 30303-3104 ATTN: Katy Allen, P.E

Dear Mr. Marrero:

The purpose of this letter is to request concurrence on the proposed Programmatic Agreement (PA) between the Georgia Department of Transportation (GDOT) and the Federal Highway Administration (FHWA). The PA will be executed upon the signature of both parties identified in the attached signature page (Attachment 1). The proposed PA and associated Technical Support Document (TSO) are provided as Attachments 2 and 3, respectively.

This new FHWA-GDOT PA specifies terms for using Carbon Monoxide (CO) screening modeling results for a variety of highway projects, an establishes the use of CO. screening modeling results to provide a quick quantitative analysis to determine whether a project has the potential to cause a localized violation of the National Ambient Air Quality Standards (NAAQS) for CO instead of using a time-consuming detailed microscale CO analysis for every potential action.

The FHWA-GDOT PA and TSO are based upon the National Cooperative Highway Research Project (NCHRP) study: *Programmatic Agreements for Project-Level Air Quality Analyses {2015)*[1], which provides the primary basis for this agreement, and builds upon the technical analysis presented in the 2014 categorical finding by examining a wider variety of project types and conditions that would not result in violation of current CO ambient air quality standards. As identified in the NCHRP study, additional associated studies tested the remote possibility of a CO ambient air quality standard violation using worst-case modeling and following appropriate EPA guidance for modeling CO hot-spots (e.g., *Guideline for Modeling Carbon Monoxide from Roadway Intersections,* U.S. EPA, EPA-454/R-92-005, November 1992; *Using MOVES in* Project-Level Carbon Monoxide Analyses, U.S. EPA, EPA-420-C-10-041 December 2010). These previous studies also used EPA-approved emission and dispersion models (MOVES201 Ob as the emission model and CAL3QHC [version 04244] as the dispersion model). This PA is presented as an update and expansion of the 2015 report. The modeling

[1] E. Carr, et al. NCH RP 25-25/Task 78, *"Programmatic Agreements for Project-Level Air Quality Analyses",* 2015. See: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

conducted in support of this PA includes the most recent EPA-approved emission and dispersion models for project level CO screening analyses, MOVES2014b as the emission model and CAL3QHC (version 04244) as the dispersion model.

Projects that use this PA and meet the established screening criteria will require only general qualitative statements to meet project-level air quality requirements that reference this agreement and the associated TSO, which presents worst-case modeling results for CO that would cover the specific project type and condition.

This PA would be beneficial to both GDOT and FHWA. It reduces costs by eliminating unnecessary intensive detailed air quality analyses, enhances efficiency and certainty in the environmental review process, and helps ensure project scope and scheduling.

While GDOT is requesting FHWA's approval for use of this PA, we have been made aware that the State of Georgia is no longer within the 20-year maintenance plan requiring in-depth project-level analyses for CO. As such, this request for approval of the PA is not intended to preclude GDOT from pursuing further updates to our processes for when and/or if project-level CO analyses are required for GDOT projects, as the initial coordination with FHWA for reviewing our current processes and the consideration of future revisions having already begun. However, without a firm date for when our processes would be expected to change, GDOT expects to benefit from the application of this PA for that interim.

If you have any questions about the proposed pA or technical questions about the TSO, please contact Miles Kemp at (404) 631-1127, or mkemp@dot.ga.gov.

Sincerely,

Russell R. McMurry, P
Commissioner

Attachments

Russell R. McMurry, P.E.,
Commissioner
One Georgia Center
600 West
Peachtree
Street, NW
Atlanta,
GA 30308
(404) 631-1000 Main Office

Attachment 2

FHWA-Georgia Department of Transportation Programmatic Agreement:

Streamlining Project-Level Carbon Monoxide Air Quality Analysis

PROGRAMMATIC AGREEMENT

Prepared by

Georgia Department of Transportation (GDOT)
Office of Environmental Services

Updated January 13. 2020

NCHRP 25-25, Task 104
Streamlining Carbon Monoxide Project-Level Air Quality Analyses with Programmatic Agreements

PROGRAMMATIC AGREEMENT FOR GEORGIA DEPARTMENT OF TRANSPORTATION

Prepared for:

AASHTO Committee on Environment and Sustainability
and
Georgia Department of Transportation

Prepared by:

Edward Carr, John Hader, and Seth Hartley
ICF

Andrew Eilbert
Volpe National Transportation Systems Center
Cambridge, MA

January 2020

PRIVILEGED DOCUMENT

This document not released for publication is furnished only for review to members of or participants in the work of CRP. This document is to be regarded as fully privileged, and dissemination of the information included herein must be approved by CRP.

Purpose of Agreement: The purpose of this proposed Programmatic Agreement (PA) between the Georgia Department of Transportation (GDOT) and the Federal Highway Administration (FHWA) is to specify terms for using CO screening modeling results for a variety of highway projects. The PA establishes the use of CO screening modeling results to provide a quick quantitative analysis determining whether a project has the potential to cause a localized violation of the National Ambient Air Quality Standards (NAAQS) for CO instead of using a time-consuming detailed microscale CO analysis for every potential action. Lower ambient CO concentrations and reduced CO emissions rates over the past decade have led to almost no cases of a project failing a CO quantitative analysis support the use of using a less resources and time to accomplish this task. The agreement provides screening level analysis for a wide variety of facility types including: intersections (both skewed and unskewed), freeways, arterials and interchanges. The only requirement for the use of PA is for the analyst to know the roadway facility type, number of lanes, roadway grade, and average speeds.

Projects that use this PA and pass will require only a general qualitative statement to meet project-level air quality requirements that references this agreement and the associated technical support document (TSD), which presents worst-case modeling results for CO that would cover the specific project type and condition.

Basis of Agreement: This PA was developed based on GDOT's extensive history of modeling potential CO impacts for highway projects. In support of its transportation program, GDOT has been performing CO emissions analyses of highway projects for decades. These analyses have not resulted in identification of violations of CO air quality standards as a result of the completion of a highway project. As evidenced by ongoing reductions in monitored ambient CO concentrations and the continuing implementation of the Federal Motor Vehicle Emission Control Program, future project- level CO analyses are expected to find little, if any, possibility of potential violations of CO ambient air quality standards caused by the completion of a highway project.

Recent efforts at the national level reinforce this conclusion. The *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February, 2014)[2] documented conditions for urban intersections in CO maintenance areas that did not require a specific project-level conformity determination but could rely on the categorical finding to make a project-level conformity determination. FHWA recently published (July 17, 2017)[3] an update to its 2014 categorical hotspot finding (CF) for CO based on federal guidelines. The CF work continued to focus on large, urban intersections using MOVES2014a and CAL3QHC, and the methodology is applicable to all states and territories, except California.

FHWA's update to the Federal CO CF included changes related to fuel formulation for gasoline vehicles included in EPA's updates to the fuel tables in the MOVES default database included in the revised model MOVES2014a. A tool has been developed that allows users to input key variables for their intersection configuration and receive a pass/fail finding based on CF work. The finding allows agencies whose projects are within the remaining CO maintenance areas and fall within a set range of parameters to bypass the preparation of a hotspot analysis as part of project-level conformity. Agencies are able to rely on the analysis already completed and approved by FHWA and EPA.

[2] See: http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/
[3] https://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf_2017/index.cfm

Similarly, the National Cooperative Highway Research Project (NCHRP) study: *Programmatic Agreements for Project-Level Air Quality Analyses (2015)*[4], which provides the primary basis for this agreement, built upon the technical analysis presented in the 2014 categorical finding and examined a wider variety of project types and conditions in order to identify those project types and conditions that could not result in violation of current CO ambient air quality standards. These studies tested the remote possibility of a CO ambient air quality standard violation using worst-case modeling and following appropriate EPA guidance for modeling CO hot-spots (e.g., *Guideline for Modeling Carbon Monoxide from Roadway Intersections*, U. S. EPA, EPA-454/R-92-005, November 1992; *Using MOVES in Project-Level Carbon Monoxide Analyses*, U.S.EPA, EPA-420-C-10-041 December 2010). The studies also used EPA-approved emission and dispersion models (MOVES2010b as the emission model and CAL3QHC (version 04244) as the dispersion model). The programmatic agreement presented here is an update and expansion of the 2015 report. The modeling conducted under this update includes the most recent EPA-approved emission and dispersion models for project level CO screening analyses, MOVES2014b as the emission model and CAL3QHC (version 04244) as the dispersion model.

Value of the PA: The PA is beneficial to both GDOT and FHWA. It reduces costs by eliminating unnecessary intensive detailed air quality analyses, enhances efficiency and certainty in the environmental review process, and helps ensure project scope and scheduling.

Relationship to the GDOT Environmental Procedures Manual : Nothing in this PA precludes or is intended to preclude the application of the models, methods, protocols, assumptions and data specified or otherwise referenced in the GDOT Environmental Procedures Manual and its associated online data repository and their respective future updates.

Application of the PA: The PA may be applied directly with no additional calculations if the following are applicable:

1. If the project meets the minimum technical criteria for the PA to be applied, namely:
    a. Background concentration not more than the default of 1 ppm (eight-hour standard) for projects in rural settings or 3 ppm (eight-hour) for projects in urban settings that was taken for this PA.
    b. Persistence factor not greater than the Georgia-specific default value of 0.6.
    c. That the vehicle fleet at the site is adequately represented by use of the state's most conservative vehicle fleet through representative grouping of all of the state's counties into four groups based on fleet age distribution and I/M programs.
    d. The CO NAAQS have not changed from what was in effect at the time when this agreement was implemented and upon which the modeling was based (35 ppm for the one-hour and 9 ppm for the eight-hour).
2. If, for the project configuration and conditions of interest (road grade, speed, etc.), a one-hour concentration value is listed in the appropriate attached table (Table A-1 for freeways

[4] E. Carr, et al. NCHRP 25-25/Task 78, "*Programmatic Agreements for Project-Level Air Quality Analyses*", 2015. See: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

and arterials; Table A-2 for intersections; Table A-3 for interchanges). Those that would exceed the 8- hour CO NAAQS value, when including the persistence and background values, are shown in red strikethrough. If it is listed in plain text, then the project is covered by the PA, provided that the minimum criteria specified above are also met.

3. If the project is covered by the PA, the qualitative text provided at the end of this document should be included (modified as appropriate for the project) in the project record and relevant environmental documents.

Project Types and Conditions: This PA applies to the following project types and associated project conditions:

Freeways and Arterials

Table A-1, attached, shows the conditions for urban and rural arterials and freeways that would meet the one- and eight-hour NAAQS and would be covered by this PA[5]. The table shows one-hour concentrations, not including background concentrations. The cells of the table populated with plain text correspond to the lane and grade combinations for arterials and freeways which, even under worst-case conditions, would not result in exceedances of the 8-hour NAAQS for CO. Where the table entries are *shown in red with strikethrough text*, the corresponding configuration would *not* meet the NAAQS based on worst-case modeling and would *not* be covered by this PA. Project-specific modeling would typically need to be conducted to show compliance with the NAAQS in these cases.

For example, for a transportation improvement project for an urban freeway for which the build scenario has 10 total lanes, average road grades of 4% or less, and peak hour (congested) operating speeds of 50 mph, Table A-1 shows a maximum contribution of 9.0 ppm for the one-hour CO standard. Since a CO concentration is shown in the table for this project type and configuration, the project is covered by this PA and does not require project-specific modeling for CO. Conversely, the same freeway with 14-lanes would *not* be covered by this PA, as the table entry is shown in *strikethrough* for that configuration.

The values shown in Table A-1 were determined using conservative or worst-case modeling inputs and assumptions for MOVES and CAL3QHC (see Technical Approach discussion, below). Concentrations for comparison to the eight-hour NAAQS were determined from the one-hour values shown using the GA state specific eight-hour background concentrations of 1.0 ppm and 3.0 ppm for rural and urban areas, respectively, and the GA state specific persistence factor of 0.6. The resulting eight-hour concentrations were used to identify which arterial and freeway configurations would meet the eight-hour NAAQS.

Note: this PA covers lanes widths of 12 feet or more for freeway and arterial project types.

Intersections

Intersections were examined using a similar approach to the conditions evaluated in the Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Findings (FHWA, February 2014 and FHWA, July 2017).[6] The same MOVES model inputs and assumptions were used

[5] These findings apply to scenarios with average speed ranging from 15 to 75 mph for freeways and 15-52 mph for arterials.
6 Federal Highway Administration, Carbon Monoxide Categorical Hot-Spot Finding Technical Report, June 2017, https://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf_2017/ technical_document.pdf

as for the freeway and arterial analyses. Similar CAL3QHC model inputs and assumptions were also used, although intersections were modeled with lanes 11 feet wide in all cases[7]. The intersection analysis assumes four approach lanes in each direction, four departure lanes in each direction, and two left turn lanes for each approach. The intersection case was modeled at a variety of grades (0° to 7°), with the intersection simulated as on the side of a hill configuration, where the northbound approach and the westbound approach are up hill. The analysis placed the skew at the intersection with the highest emission rates which is associated with the upgrade links. The angle between the approach and departure lanes were modeled at a standard 90 degree angle, and skew angles of 60°, 45°, 30°, and 15° angles. The right lanes in each direction were modeled as including both through and right turn movements and included queue idling.

Table A-2[8], attached, shows the maximum 1-hour CO concentrations for urban and rural intersections that, with the applied, conservative 8-hour CO background level of 1.0 ppm and 3.0 ppm for rural and urban areas, respectively, and the GA state specific persistence factor of 0.6, do not produce modeled CO concentrations that could result in exceedances of the 8-hour CO NAAQS.

All the reported values in Table A-2 correspond with an intersection that with a given grade (or less), six approach lanes or less, and forecast approach speeds in the 15-45 mph range (not less than 15 mph) would not produce modeled concentrations that would result in exceedances of the 8-hour CO NAAQS. Any such project would be covered by this PA and would not require project-specific CO modeling to demonstrate compliance with the CO NAAQS. Conversely, for example, a project with no reported value, say seven approach lanes, an 8% grade, and/or a 10 mph approach speed would *not* be covered by this PA.

Note: Highly congested intersections (where the average approach speed is less than 15 mph) and intersections with five or more legs are not included in the PA. Also, if the age of the fleet is older than the conservative representative age distribution included here then the PA is not applicable.

Interchanges with an Adjacent Intersection

Interchanges were analyzed using the MOVES and CAL3QHC models, with a combination of the grade separated intersection and freeway separated at various distances. The intersection and freeway analysis geometry and traffic inputs are as described in the preceding cases, other than for a simplified receptor set. Interchange scenarios were modeled with the freeway at a 0% grade and intersection at grades ranging from 0% to 7%. Both rural and urban locations were considered. The total number of freeway lanes analyzed ranged from 2 to 12 lanes, in 2 lane increments. As above, the intersection remains a signalized six lane intersection. A variety of assumed distances between the edge of the nearest freeway travel lane to the edge of the nearest travel lane on the intersection were analyzed. These included distances of 20, 30, 60, 80, 100, 125, 150, 175, 300, 500 and 1,000 feet. The roadway link connecting the freeway to the intersection was modeled at skew angles of 90, 60, and 45 degree angles. Intersections were considered on either side of the freeway.

Table A-3, attached, shows 1-hour CO concentrations for these interchange scenarios that, with the applied 8-hour CO background level and persistence factor, do not produce modeled

[7] As part of NCHRP 25-25, Task 78 sensitivity testing showed that only a few percentage points higher CO concentration was found when using 11 foot lane widths rather than standard 12 foot width.
[8] These findings apply to scenarios with average speed ranging from 15 to 45 mph for intersections.

concentrations that could result exceedances of the 8-hour NAAQS for CO. Where the table entries are *strikethrough*, the corresponding configuration would *not* meet the NAAQS based on worst-case modeling and would *not* be covered by this PA. Project-specific modeling would typically need to be conducted to show compliance with the NAAQS in these cases. Although intersections were considered on either side of the freeway, Table A-3 only reports the higher of these. The same speed limitations for freeways and arterials from above also apply here.

For example, for a 2-lane freeway with an adjacent intersection in a rural location that is located not less than 20 feet from the nearest edge of the freeway lanes, and connected with a 45 degree angled road segment at 0% grade has a one-hour concentration listed of 6.7 ppm. Since a concentration is listed for this project configuration, the project would be covered by this PA and not require project-specific modeling. Conversely, the table entry is in *strikethrough* for an 8 or greater lane freeway with an intersection at 7% grade, skewed at 45 degrees. Thus, these configurations would *not* be covered by this PA.

Note: This is a very conservative approach for ramp intersections adjacent to freeway interchanges, which typically have only one- or two-lane ramps approaching or departing from the intersection.

General Terms

Deference to Professional Judgment on Determinations of Substantive Differences: Consistent with our agreement for revising air studies, under this PA, FHWA will defer to the professional judgment of GDOT air quality staff to apply the agreement for projects that are substantively (as defined in the GDOT Environmental Procedures Manual) consistent with the intersection/interchange, freeway and arterial types and configurations specified in this agreement. For example, if an intersection has an arrangement like a diverging diamond, this PA may be applied using the criteria for 6 lanes (4 approach and 2 left turn bays) or regular diamond (with traffic approach volume splits that are adjusted for diverging diamonds) if the difference is not substantive in the professional opinion of GDOT air quality staff and therefore not expected to result in a modeled exceedance of the applicable NAAQS.

Projects of De Minimis Scope or Expected Impact: Projects that do not change (add, delete, relocate, or otherwise modify) roadway capacity, intermodal facilities, and/or transit service (i.e., are of de minims scope or expected impact) do not require either qualitative or quantitative project-level air quality analyses.

Exempt Projects: Projects that would qualify as exempt under one or more of the categories specified in the federal transportation conformity rule (whether or not conformity applies for the area in which the project is located) do not, under this agreement, require project-specific modeling for CO for purposes of NEPA. See the following link for qualified exempt projects:

https://www.fhwa.dot.gov/Environment/air_quality/conformity/laws_and_regs/rule.cfm#r126

Locally Administered Projects: This PA may also be applied for locally administered projects in Georgia. For the project's environmental document or record, the local agency will include a statement that the project under review meets the project or intersection types and configurations covered in the PA. Hence the PA (including data and information as necessary to support that determination) will conclude a reference to the PA (or a similar statement, as appropriate to the project) in the Administrative Record.

Project Types Not Covered by This PA: Examples of project types that are not specifically covered by this PA include but are not limited to: park and ride lots, parking garages, new intermodal transfer yards, tunnels, intersections that have more than four legs, and intersections with approach speeds less than 15 mph. If a project type is not covered by the PA, project-specific air quality modeling may be needed as is currently being done in Georgia for NEPA. For those project types and conditions where applicability of this PA is not certain, GDOT and FHWA will coordinate to determine its applicability.

Discretionary Modeling of Projects Otherwise Covered by this PA: This PA does not preclude GDOT from conducting, at its discretion, detailed project-specific modeling for CO for any project, even if the project would otherwise meet the criteria established in this agreement and therefore not require such modeling. Examples of such projects include (but are not limited to) ones for which an environmental impact statement (EIS) is being prepared and ones that may be considered higher profile, i.e., that involve or may involve a greater degree of public and/or stakeholder interest.

Years of Analysis: This PA covers projects of the types and conditions listed above whose opening year (year of completion) is 2020 or later.

Technical Approach: The modeling and the assumptions used in the modeling to support this PA are described in detail in the accompanying Technical Support Document (TSD). In general, a worst-case modeling approach was applied following EPA guidance. In all cases EPA's MOVES2014b emission model was used to generate emission estimates and CAL3QHC (version 04244) was used for the dispersion analysis. EPA's current guidance for modeling CO Hot-Spots (Guideline for Modeling Carbon Monoxide from Roadway Intersections, U. S. EPA, EPA-454/R-92-005, November 1992) was also applied. The assumptions and inputs used in the model were worst-case or highly conservative but specific to the state of GA, leading to higher emission estimates and less dispersion (that is, greater forecast ambient concentrations) than would be highly unlikely to occur simultaneously in real-world conditions. Consequently, if a project does not cause a modeled exceedance of the NAAQS with these worst-case or conservative inputs and assumptions, then it may be stated with high confidence that an exceedance under real-world conditions would not be expected. Finally, GDOT consulted with the Georgia Environmental Protection Division (GAEPD) in development of its Environmental Procedures Manual, which includes separate guidance on background concentrations and persistence factors to be applied for projects in Georgia. These values are used under this PA to arrive at an eight-hour total CO concentration for comparison with the eight-hour CO NAAQS.

Administrative Record: For the project's environmental document or record, the GDOT will include a statement that the project under review meets the project types and conditions covered in the PA and will conclude with one of the two following statements (or similar):

Projects that qualify as exempt and/or for Programmatic Categorical Exclusions:

The project is identified as being exempt from the requirement to determine conformity according to the federal transportation conformity rule and/or qualifies for a Programmatic Categorical Exclusion (PCE) according to the PCE Agreement in effect between the Federal Highway Administration and the Georgia Department of Transportation (August 26, 2018). Accordingly, it is concluded that the project would not significantly impact air quality and would not cause or contribute to a new violation, increase the frequency or severity of an existing violation, or delay timely attainment of any National Ambient Air Quality Standard for carbon monoxide. The GDOT

and FHWA entered into a Programmatic Categorical Exclusion Process Agreement on June 4, 2013 allowing GDOT to act on behalf of FHWA in ensuring compliance with all applicable federal and environmental related requirements for Class II- CE Actions as defined in Section 23 CFR 771.117 (as amended in the agreement).

Projects that meet the terms of this PA:

The project is consistent with (and does not exceed) the project types and conditions listed in this agreement between the Federal Highway Administration and the Georgia Department of Transportation for streamlining the project-level "air quality analysis process for carbon monoxide". The CO modeling using "worst-case" parameters has been applied for these roadway facility types and conditions. It has been determined that projects such as this one would not significantly impact air quality and would not cause or contribute to a new violation, increase the frequency or severity of an existing violation, or delay timely attainment of the National Ambient Air Quality Standard for carbon monoxide

or

An air quality analysis is not necessary as this project will not increase traffic volumes, reduce source-receptor distances, or change other existing conditions to such a degree as to jeopardize attainment of the National Ambient Air Quality Standard for carbon monoxide.

Future Revisions: GDOT and FHWA Georgia Division recognize that the applicable NAAQS and/or project level air quality analysis methodologies may change over time. The latter may include new or updated emission or dispersion models, background CO levels, and/or associated worst-case modeling assumptions. GDOT will consult as appropriate with FHWA Georgia Division regarding any changes that may be recommended as a result.

Amendments and Agreement:

1. This agreement will take effect as of the effective date of the signature of the FHWA Georgia Division Administrator, who shall sign the PA last.
2. Either signatory to this Agreement may request that it be amended at any time, whereupon the parties will consult to reach a consensus on the proposed amendment. Where no consensus can be reached, the Agreement will not be amended.

Dispute Resolution:

The Dispute Resolution process described in the current Stewardship and Oversight Agreement between FHWA and GDOT will be implemented in the event of a dispute between the signatory parties to this Agreement.

Termination of Agreement: Should either GDOT or FHWA Georgia Division determine that it is necessary to terminate the PA, they may do so by written notification to the other party. The PA will terminate 30 days after the date of the notification, provided that the parties consult during the period prior to termination to seek agreement on amendments or other actions that would avoid termination. Projects that have been cleared under the basis of the PA before the effective termination date may maintain that clearance and not require detailed, intensive project-specific modeling for CO.

Attachment to the Programmatic Agreement

Table A-1. One-hour CO Concentrations (ppm) for Freeways and Arterials[a] in Urban and Rural Locations of Varying Lane and Grade Configuration (not including background concentrations)

Facility Type	Location	Number of Lanes	Grade (percent)							
			0	1	2	3	4	5	6	7
Arterials	Rural	2	2.3	2.4	2.5	2.5	2.8	2.9	3.2	4.1
Arterials	Rural	4	5.2	5.4	5.5	5.8	6.2	6.6	7.2	9.3
Arterials	Rural	6	7	7.2	7.5	7.8	8.4	9	9.8	12.7
Arterials	Rural	8	8.6	8.7	9.1	9.6	10.4	11	12.1	~~15.6~~
Arterials	Rural	10	9.8	10.1	10.6	11.1	11.9	12.7	~~14.1~~	~~18.3~~
Arterials	Rural	12	11	11.3	11.9	12.4	13.3	~~14.2~~	~~15.8~~	~~20.5~~
Arterials	Urban	2	1.5	1.5	1.6	1.6	1.7	1.8	2	2.3
Arterials	Urban	4	3.2	3.3	3.5	3.6	3.9	4.2	4.6	5.5
Arterials	Urban	6	4.4	4.5	4.7	4.9	5.3	5.7	6.3	7.6
Arterials	Urban	8	5.3	5.5	5.8	6	6.5	6.9	7.7	9.4
Arterials	Urban	10	6.1	6.3	6.6	6.9	7.5	8	8.9	~~11.1~~
Arterials	Urban	12	6.7	7	7.4	7.7	8.4	9	10	~~12.5~~
Freeways	Rural	2	1.4	1.5	1.7	2	2.4	2.6	2.9	3
Freeways	Rural	4	3.5	3.9	4.7	5.5	6.3	7.2	7.8	8.1
Freeways	Rural	6	5	5.5	6.6	7.9	9.2	10.4	11.3	11.7
Freeways	Rural	8	6.2	7.1	8.5	10.1	11.8	~~13.4~~	~~14.5~~	~~15.1~~
Freeways	Rural	10	7.3	8.4	10.2	12.1	~~14.2~~	~~16.2~~	~~17.5~~	~~18.3~~
Freeways	Rural	12	8.4	9.6	11.6	~~14~~	~~16.4~~	~~18.7~~	~~20.2~~	~~21.1~~
Freeways	Rural	14	9.2	10.7	12.9	~~15.6~~	~~18.3~~	~~20.9~~	~~22.7~~	~~23.6~~
Freeways	Rural	16	10.1	11.7	~~14.2~~	~~17.1~~	~~20.1~~	~~22.9~~	~~24.9~~	~~26~~
Freeways	Rural	18	10.7	12.5	~~15.3~~	~~18.4~~	~~21.6~~	~~24.7~~	~~26.9~~	~~28~~
Freeways	Rural	20	11.3	13.3	~~16.3~~	~~19.6~~	~~23~~	~~26.4~~	~~28.6~~	~~29.9~~

Table A-1. One-hour CO Concentrations (ppm) for Freeways and Arterials[a] in Urban and Rural Locations of Varying Lane and Grade Configuration (not including background concentrations)

Facility Type	Location	Number of Lanes	Grade (percent)							
			0	1	2	3	4	5	6	7
Freeways	Rural	22	11.9	~~13.9~~	~~17.1~~	~~20.6~~	~~24.4~~	~~27.9~~	~~30.2~~	~~31.6~~
Freeways	Urban	2	0.8	0.9	1.1	1.2	1.4	1.7	1.8	1.8
Freeways	Urban	4	2.2	2.5	2.9	3.4	4	4.6	4.9	5.1
Freeways	Urban	6	3.1	3.5	4.2	5	5.8	6.6	7.3	7.5
Freeways	Urban	8	3.8	4.4	5.4	6.4	7.6	8.6	9.3	9.7
Freeways	Urban	10	4.5	5.2	6.4	7.7	9	~~10.3~~	~~11.2~~	~~11.7~~
Freeways	Urban	12	5.1	6	7.3	8.8	~~10.4~~	~~11.9~~	~~12.9~~	~~13.5~~
Freeways	Urban	14	5.6	6.7	8.1	9.9	~~11.6~~	~~13.3~~	~~14.4~~	~~15.1~~
Freeways	Urban	16	6.1	7.2	8.8	~~10.8~~	~~12.7~~	~~14.6~~	~~15.9~~	~~16.5~~
Freeways	Urban	18	6.4	7.8	9.6	~~11.5~~	~~13.6~~	~~15.7~~	~~17.1~~	~~17.8~~
Freeways	Urban	20	6.8	8.2	~~10.1~~	~~12.3~~	~~14.6~~	~~16.7~~	~~18.2~~	~~19~~
Freeways	Urban	22	7.1	8.6	~~10.7~~	~~13~~	~~15.4~~	~~17.6~~	~~19.2~~	~~20~~

[a] These findings apply to scenarios with average speed ranging from 15 to 52 mph for arterials and 15 to 75 mph for freeways.

Table A-2. One-hour CO Concentrations (not including background concentrations) for Rural and Urban Intersections[a] at Varying Skew Angles and Intersection Grades for a Six Approach Lane Intersection

Location	Skew Angle	Grade (Percent)							
		0	1	2	3	4	5	6	7
Rural	15	8.2	8.3	8.6	8.9	9.5	10	10.7	12.9
Rural	30	6	6.2	6.4	6.7	7.1	7.5	7.9	9.4
Rural	45	6.4	6.3	6.5	6.7	7	7.4	7.8	9
Rural	60	5.6	5.5	5.8	6	6.3	6.5	7	8.2
Rural	90	5.4	5.4	5.7	5.7	6.1	6.3	6.8	8
Urban	15	4.7	4.7	5.1	5.2	5.5	5.8	6.1	6.6
Urban	30	4.3	4.5	4.8	4.8	5.2	5.4	5.8	6.2
Urban	45	3.9	4	4.1	4.3	4.7	4.9	5.1	5.6
Urban	60	3.8	3.8	4	4	4.3	4.6	4.9	5.4
Urban	90	3.5	3.6	3.9	3.7	4.1	4.3	4.6	4.9

[a] These findings apply to scenarios with average speed ranging from 15 to 45 mph for intersections.

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	2	0%	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.4
Rural	45	2	1%	6.9	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.3
Rural	45	2	2%	7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.5
Rural	45	2	3%	7.2	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.7
Rural	45	2	4%	7.6	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7
Rural	45	2	5%	8	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.4
Rural	45	2	6%	8.4	8	8	8	8	8	8	8	8	8	7.8
Rural	45	2	7%	9.8	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Rural	60	2	0%	6.6	6.1	6	6	6	6	5.9	5.8	5.8	5.7	5.6
Rural	60	2	1%	6.8	6.1	5.9	5.9	5.9	5.9	5.8	5.7	5.7	5.7	5.5
Rural	60	2	2%	6.8	6.3	6.2	6.2	6.2	6.2	6.1	6	6	5.8	5.8
Rural	60	2	3%	7.2	6.5	6.4	6.4	6.4	6.4	6.3	6.2	6.2	6	6
Rural	60	2	4%	7.5	6.8	6.7	6.7	6.7	6.7	6.6	6.5	6.5	6.3	6.3
Rural	60	2	5%	7.8	7.1	6.9	6.9	6.9	6.9	6.8	6.7	6.7	6.5	6.5
Rural	60	2	6%	8.3	7.6	7.4	7.4	7.4	7.4	7.3	7.2	7.2	7	7
Rural	60	2	7%	9.6	8.9	8.6	8.6	8.6	8.6	8.5	8.4	8.4	8.2	8.2
Rural	90	2	0%	6.6	5.9	5.8	5.8	5.8	5.8	5.7	5.6	5.6	5.6	5.4
Rural	90	2	1%	6.7	6	5.8	5.8	5.8	5.8	5.7	5.6	5.6	5.6	5.4
Rural	90	2	2%	6.9	6.2	6.1	6.1	6.1	6.1	6	5.9	5.9	5.8	5.7
Rural	90	2	3%	7.1	6.4	6.1	6.1	6.1	6.1	6	5.9	5.9	5.8	5.7
Rural	90	2	4%	7.5	6.8	6.5	6.5	6.5	6.5	6.4	6.3	6.3	6.1	6.1
Rural	90	2	5%	7.8	7.1	6.7	6.7	6.7	6.7	6.6	6.5	6.5	6.3	6.3
Rural	90	2	6%	8.3	7.6	7.2	7.2	7.2	7.2	7.1	7	7	6.8	6.8
Rural	90	2	7%	9.6	8.9	8.4	8.4	8.4	8.4	8.3	8.2	8.2	8	8
Rural	45	4	0%	9	7.6	7	7	7	7	7	7	6.8	6.8	6.6

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	4	1%	9.2	7.8	6.9	6.9	6.9	6.9	6.9	6.9	6.7	6.7	6.5
Rural	45	4	2%	9.3	7.9	7.1	7.1	7.1	7.1	7.1	7.1	6.9	6.9	6.7
Rural	45	4	3%	9.5	8.1	7.3	7.3	7.3	7.3	7.3	7.3	7.1	7.1	6.9
Rural	45	4	4%	9.9	8.5	7.6	7.6	7.6	7.6	7.6	7.6	7.4	7.4	7.2
Rural	45	4	5%	10.3	8.9	8	8	8	8	8	8	7.8	7.8	7.6
Rural	45	4	6%	10.7	9.3	8.4	8.4	8.4	8.4	8.4	8.4	8.2	8.2	8
Rural	45	4	7%	12.1	10.7	9.8	9.8	9.7	9.6	9.6	9.6	9.5	9.4	9.2
Rural	60	4	0%	8.9	7.5	6.8	6.7	6.7	6.5	6.5	6.4	6	5.9	5.7
Rural	60	4	1%	9.1	7.7	6.7	6.6	6.6	6.4	6.4	6.3	5.9	5.9	5.7
Rural	60	4	2%	9.1	7.7	7	6.9	6.9	6.7	6.7	6.6	6.2	6	5.8
Rural	60	4	3%	9.5	8.1	7.2	7.1	7.1	6.9	6.9	6.8	6.4	6.2	6
Rural	60	4	4%	9.8	8.4	7.5	7.4	7.4	7.2	7.2	7.1	6.7	6.4	6.3
Rural	60	4	5%	10.1	8.7	7.7	7.6	7.6	7.4	7.4	7.3	6.9	6.6	6.5
Rural	60	4	6%	10.6	9.2	8.2	8.1	8.1	7.9	7.9	7.8	7.4	7.1	7
Rural	60	4	7%	11.9	10.5	9.4	9.3	9.3	9.1	9.1	9	8.6	8.3	8.2
Rural	90	4	0%	8.9	7.5	6.6	6.5	6.4	6.3	6.2	6.2	5.8	5.8	5.6
Rural	90	4	1%	9	7.6	6.6	6.5	6.4	6.3	6.2	6.2	5.8	5.8	5.6
Rural	90	4	2%	9.2	7.8	6.9	6.8	6.7	6.6	6.5	6.5	6.1	6	5.8
Rural	90	4	3%	9.4	8	6.9	6.8	6.7	6.6	6.5	6.5	6.1	6	5.8
Rural	90	4	4%	9.8	8.4	7.3	7.2	7.1	7	6.9	6.9	6.5	6.3	6.1
Rural	90	4	5%	10.1	8.7	7.5	7.4	7.3	7.2	7.1	7.1	6.7	6.5	6.3
Rural	90	4	6%	10.6	9.2	8	7.9	7.8	7.7	7.6	7.6	7.2	7	6.8
Rural	90	4	7%	11.9	10.5	9.2	9.1	9	8.9	8.8	8.8	8.4	8.1	8
Rural	45	6	0%	10.1	8.4	7.5	7.3	7.3	7.2	7.2	7.2	7.1	7	6.8
Rural	45	6	1%	10.3	8.6	7.4	7.3	7.2	7.1	7.1	7.1	7	6.9	6.7

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	6	2%	10.4	8.7	7.7	7.6	7.4	7.3	7.3	7.3	7.2	7.1	6.9
Rural	45	6	3%	10.6	8.9	7.8	7.7	7.6	7.5	7.5	7.5	7.4	7.3	7.1
Rural	45	6	4%	11	9.3	8.2	8.1	7.9	7.8	7.8	7.8	7.7	7.6	7.4
Rural	45	6	5%	11.4	9.7	8.5	8.3	8.3	8.2	8.2	8.2	8.1	8	7.8
Rural	45	6	6%	11.8	10.1	9	8.9	8.7	8.6	8.6	8.6	8.5	8.4	8.2
Rural	45	6	7%	13.2	11.5	10.2	10.1	10	10	10	10	9.8	9.6	9.4
Rural	60	6	0%	10	8.2	7.4	7.3	7.1	7	6.9	6.7	6.2	6.1	5.9
Rural	60	6	1%	10.2	8.4	7.3	7.2	7	6.9	6.8	6.6	6.1	6.1	5.9
Rural	60	6	2%	10.2	8.4	7.6	7.5	7.3	7.2	7.1	6.9	6.4	6.2	6
Rural	60	6	3%	10.6	8.8	7.8	7.7	7.5	7.4	7.3	7.1	6.6	6.4	6.2
Rural	60	6	4%	10.9	9.1	8.1	8	7.8	7.7	7.6	7.4	6.9	6.6	6.4
Rural	60	6	5%	11.2	9.4	8.3	8.2	8	7.9	7.8	7.6	7.1	6.8	6.6
Rural	60	6	6%	11.7	9.9	8.8	8.7	8.5	8.4	8.3	8.1	7.6	7.3	7.1
Rural	60	6	7%	13	11.2	10	9.9	9.7	9.6	9.5	9.3	8.8	8.4	8.2
Rural	90	6	0%	9.9	8.2	7.2	7.1	6.9	6.7	6.7	6.5	6	5.9	5.8
Rural	90	6	1%	10	8.3	7.2	7.1	6.9	6.7	6.7	6.5	6	5.9	5.8
Rural	90	6	2%	10.2	8.5	7.5	7.4	7.2	7	7	6.8	6.3	6.1	6
Rural	90	6	3%	10.4	8.7	7.5	7.4	7.2	7	7	6.8	6.3	6.1	6
Rural	90	6	4%	10.8	9.1	7.9	7.8	7.6	7.4	7.4	7.2	6.7	6.4	6.3
Rural	90	6	5%	11.1	9.4	8.1	8	7.8	7.6	7.6	7.4	6.9	6.6	6.5
Rural	90	6	6%	11.6	9.9	8.6	8.5	8.3	8.1	8.1	7.9	7.4	7.1	7
Rural	90	6	7%	12.9	11.2	9.8	9.7	9.5	9.3	9.3	9.1	8.6	8.2	8
Rural	45	8	0%	11	9	7.9	7.7	7.7	7.5	7.5	7.4	7.4	7.1	7
Rural	45	8	1%	11.2	9.2	8	7.8	7.6	7.4	7.4	7.3	7.3	7	6.9
Rural	45	8	2%	11.3	9.3	8.3	8.1	7.9	7.7	7.6	7.5	7.5	7.2	7.1

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	8	3%	11.5	9.5	8.4	8.2	8	7.8	7.8	7.7	7.7	7.4	7.3
Rural	45	8	4%	11.9	9.9	8.8	8.6	8.4	8.2	8.1	8	8	7.7	7.6
Rural	45	8	5%	12.3	10.3	9	8.8	8.7	8.5	8.5	8.4	8.4	8.1	8
Rural	45	8	6%	12.7	10.7	9.6	9.4	9.2	9	8.9	8.8	8.8	8.5	8.4
Rural	45	8	7%	~~14.1~~	12.1	10.8	10.6	10.4	10.3	10.2	10.2	10	9.8	9.6
Rural	60	8	0%	10.8	8.9	8	7.8	7.6	7.4	7.2	7	6.3	6.3	5.9
Rural	60	8	1%	11	9.1	7.9	7.7	7.5	7.3	7.1	6.9	6.3	6.3	5.9
Rural	60	8	2%	11	9.1	8.2	8	7.8	7.6	7.4	7.2	6.5	6.4	6
Rural	60	8	3%	11.4	9.5	8.4	8.2	8	7.8	7.6	7.4	6.7	6.6	6.2
Rural	60	8	4%	11.7	9.8	8.7	8.5	8.3	8.1	7.9	7.7	7	6.8	6.4
Rural	60	8	5%	12	10.1	8.9	8.7	8.5	8.3	8.1	7.9	7.2	7	6.6
Rural	60	8	6%	12.5	10.6	9.4	9.2	9	8.8	8.6	8.4	7.7	7.5	7.1
Rural	60	8	7%	~~13.8~~	11.9	10.6	10.4	10.2	10	9.8	9.6	8.9	8.4	8.2
Rural	90	8	0%	10.8	8.9	7.7	7.6	7.4	7.2	7	6.8	6.2	6	5.9
Rural	90	8	1%	10.9	9	7.7	7.6	7.4	7.2	7	6.8	6.2	6	5.9
Rural	90	8	2%	11.1	9.2	8	7.9	7.7	7.5	7.3	7.1	6.4	6.2	6.1
Rural	90	8	3%	11.3	9.4	8	7.9	7.7	7.5	7.3	7.1	6.4	6.2	6.1
Rural	90	8	4%	11.7	9.8	8.4	8.3	8.1	7.9	7.7	7.5	6.8	6.5	6.4
Rural	90	8	5%	12	10.1	8.6	8.5	8.3	8.1	7.9	7.7	7	6.7	6.6
Rural	90	8	6%	12.5	10.6	9.1	9	8.8	8.6	8.4	8.2	7.5	7.2	7.1
Rural	90	8	7%	~~13.8~~	11.9	10.3	10.2	10	9.8	9.6	9.4	8.7	8.2	8
Rural	45	10	0%	11.6	9.5	8.4	8.2	8	7.9	7.7	7.7	7.6	7.3	7.2
Rural	45	10	1%	11.8	9.7	8.5	8.3	8.1	7.8	7.6	7.6	7.5	7.2	7.1
Rural	45	10	2%	11.9	9.8	8.8	8.6	8.4	8.1	7.9	7.8	7.7	7.4	7.3
Rural	45	10	3%	12.1	10	8.9	8.7	8.5	8.2	8	8	7.9	7.6	7.5

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	10	4%	12.5	10.4	9.3	9.1	8.9	8.6	8.4	8.3	8.2	7.9	7.8
Rural	45	10	5%	12.9	10.8	9.5	9.3	9.1	8.9	8.7	8.7	8.6	8.3	8.2
Rural	45	10	6%	13.3	11.2	10.1	9.9	9.7	9.4	9.2	9.1	9	8.7	8.6
Rural	45	10	7%	~~14.7~~	12.6	11.3	11.1	10.9	10.7	10.6	10.5	10.3	10	9.8
Rural	60	10	0%	11.5	9.4	8.4	8.2	8.1	7.7	7.5	7.4	6.5	6.4	6.1
Rural	60	10	1%	11.7	9.6	8.3	8.1	8	7.6	7.4	7.3	6.5	6.4	6.1
Rural	60	10	2%	11.7	9.6	8.6	8.4	8.3	7.9	7.7	7.6	6.7	6.5	6.2
Rural	60	10	3%	12.1	10	8.8	8.6	8.5	8.1	7.9	7.8	6.9	6.7	6.4
Rural	60	10	4%	12.4	10.3	9.1	8.9	8.8	8.4	8.2	8.1	7.2	6.9	6.6
Rural	60	10	5%	12.7	10.6	9.3	9.1	9	8.6	8.4	8.3	7.4	7.1	6.8
Rural	60	10	6%	13.2	11.1	9.8	9.6	9.5	9.1	8.9	8.8	7.9	7.6	7.3
Rural	60	10	7%	~~14.5~~	12.4	11	10.8	10.7	10.3	10.1	10	9.1	8.5	8.4
Rural	90	10	0%	11.4	9.3	8.2	8	7.8	7.5	7.3	7.1	6.4	6.2	6
Rural	90	10	1%	11.5	9.4	8.2	8	7.8	7.5	7.3	7.1	6.4	6.2	6
Rural	90	10	2%	11.7	9.6	8.5	8.3	8.1	7.8	7.6	7.4	6.6	6.4	6.2
Rural	90	10	3%	11.9	9.8	8.5	8.3	8.1	7.8	7.6	7.4	6.6	6.4	6.2
Rural	90	10	4%	12.3	10.2	8.9	8.7	8.5	8.2	8	7.8	7	6.7	6.5
Rural	90	10	5%	12.6	10.5	9.1	8.9	8.7	8.4	8.2	8	7.2	6.9	6.7
Rural	90	10	6%	13.1	11	9.6	9.4	9.2	8.9	8.7	8.5	7.7	7.4	7.2
Rural	90	10	7%	~~14.4~~	12.3	10.8	10.6	10.4	10.1	9.9	9.7	8.9	8.3	8.1
Rural	45	12	0%	12	10.4	8.8	8.6	8.4	8.3	8.1	8	7.8	7.6	7.2
Rural	45	12	1%	12.2	10.3	8.9	8.7	8.4	8.2	8	7.9	7.7	7.5	7.1
Rural	45	12	2%	12.3	10.4	9.2	9	8.7	8.5	8.2	8.1	7.9	7.7	7.3
Rural	45	12	3%	12.5	10.5	9.3	9.1	8.8	8.6	8.4	8.3	8.1	7.9	7.5
Rural	45	12	4%	12.9	10.8	9.7	9.5	9.2	9	8.7	8.6	8.4	8.2	7.8

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	12	5%	13.3	11.2	9.9	9.7	9.4	9.3	9.1	9	8.8	8.6	8.2
Rural	45	12	6%	~~13.7~~	11.6	10.5	10.3	10	9.8	9.5	9.4	9.2	9	8.6
Rural	45	12	7%	~~15.1~~	13	11.7	11.5	11.2	11	10.9	10.8	10.6	10.2	9.8
Rural	60	12	0%	11.9	10.2	8.9	8.7	8.4	8.2	7.8	7.6	6.7	6.5	6.3
Rural	60	12	1%	12.1	10.1	8.8	8.6	8.3	8.1	7.7	7.5	6.7	6.5	6.3
Rural	60	12	2%	12.1	10.2	9.1	8.9	8.6	8.4	8	7.8	6.8	6.6	6.4
Rural	60	12	3%	12.5	10.3	9.3	9.1	8.8	8.6	8.2	8	7	6.8	6.6
Rural	60	12	4%	12.8	10.6	9.6	9.4	9.1	8.9	8.5	8.3	7.3	7	6.8
Rural	60	12	5%	13.1	10.9	9.8	9.6	9.3	9.1	8.7	8.5	7.5	7.2	7
Rural	60	12	6%	~~13.6~~	11.4	10.3	10.1	9.8	9.6	9.2	9	8	7.7	7.5
Rural	60	12	7%	~~14.9~~	12.7	11.5	11.3	11	10.8	10.4	10.2	9.2	8.8	8.4
Rural	90	12	0%	11.9	10.1	8.7	8.4	8.2	7.8	7.6	7.4	6.7	6.4	6.2
Rural	90	12	1%	12	10.1	8.7	8.4	8.2	7.8	7.6	7.4	6.7	6.4	6.2
Rural	90	12	2%	12.2	10.2	9	8.7	8.5	8.1	7.9	7.7	6.9	6.6	6.4
Rural	90	12	3%	12.4	10.2	9	8.7	8.5	8.1	7.9	7.7	6.9	6.6	6.4
Rural	90	12	4%	12.8	10.5	9.4	9.1	8.9	8.5	8.3	8.1	7.2	6.9	6.7
Rural	90	12	5%	13.1	10.8	9.6	9.3	9.1	8.7	8.5	8.3	7.4	7.1	6.9
Rural	90	12	6%	~~13.6~~	11.3	10.1	9.8	9.6	9.2	9	8.8	7.9	7.6	7.4
Rural	90	12	7%	~~14.9~~	12.6	11.3	11	10.8	10.4	10.2	10	9	8.5	8.3
Urban	45	2	0%	4.5	4.3	4.1	4.1	4.1	4.1	4.1	4.1	3.9	3.9	3.9
Urban	45	2	1%	4.5	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4	4
Urban	45	2	2%	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.1	4.1
Urban	45	2	3%	4.8	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.3	4.3
Urban	45	2	4%	5.2	5	4.9	4.9	4.9	4.9	4.9	4.9	4.7	4.7	4.7
Urban	45	2	5%	5.4	5.2	5.1	5.1	5.1	5.1	5.1	5.1	4.9	4.9	4.9

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	45	2	6%	5.6	5.4	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.1	5.1
Urban	45	2	7%	6.1	5.9	5.8	5.8	5.8	5.8	5.8	5.8	5.6	5.6	5.6
Urban	60	2	0%	4.3	4.1	4	4	4	4	4	4	3.8	3.8	3.8
Urban	60	2	1%	4.3	4.1	4	4	4	4	4	4	3.9	3.8	3.8
Urban	60	2	2%	4.5	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4	4	4
Urban	60	2	3%	4.5	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4	4	4
Urban	60	2	4%	4.8	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.3	4.3	4.3
Urban	60	2	5%	5.1	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.6	4.6	4.6
Urban	60	2	6%	5.4	5.2	5.1	5.1	5.1	5.1	5.1	5.1	4.9	4.9	4.9
Urban	60	2	7%	5.9	5.7	5.6	5.6	5.6	5.6	5.6	5.6	5.4	5.4	5.4
Urban	90	2	0%	4.1	3.9	3.7	3.7	3.7	3.7	3.7	3.7	3.5	3.5	3.5
Urban	90	2	1%	4.2	4	3.8	3.8	3.8	3.8	3.8	3.8	3.6	3.6	3.6
Urban	90	2	2%	4.4	4.2	4.1	4.1	4.1	4.1	4.1	4.1	3.9	3.9	3.9
Urban	90	2	3%	4.4	4.2	3.9	3.9	3.9	3.9	3.9	3.9	3.7	3.7	3.7
Urban	90	2	4%	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.1	4.1	4.1
Urban	90	2	5%	4.9	4.7	4.5	4.5	4.5	4.5	4.5	4.5	4.3	4.3	4.3
Urban	90	2	6%	5.3	5.1	4.8	4.8	4.8	4.8	4.8	4.8	4.6	4.6	4.6
Urban	90	2	7%	5.5	5.3	5.1	5.1	5.1	5.1	5.1	5.1	4.9	4.9	4.9
Urban	45	4	0%	5.9	5.2	4.6	4.5	4.4	4.3	4.3	4.3	4.1	4.1	3.9
Urban	45	4	1%	5.9	5.2	4.6	4.6	4.5	4.4	4.4	4.4	4.3	4.2	4.1
Urban	45	4	2%	5.9	5.2	4.7	4.7	4.7	4.7	4.6	4.5	4.5	4.3	4.2
Urban	45	4	3%	6.1	5.4	4.9	4.9	4.9	4.9	4.8	4.7	4.7	4.5	4.3
Urban	45	4	4%	6.3	5.6	5.3	5.3	5.2	5.1	5.1	5.1	4.9	4.9	4.7
Urban	45	4	5%	6.6	5.9	5.5	5.5	5.4	5.3	5.3	5.3	5.1	5.1	4.9
Urban	45	4	6%	6.9	6.2	5.7	5.7	5.7	5.7	5.6	5.5	5.5	5.3	5.1

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	45	4	7%	7.3	6.6	6.2	6.2	6.1	6	6	6	5.8	5.8	5.6
Urban	60	4	0%	5.6	4.9	4.4	4.4	4.3	4.2	4.2	4.2	4	4	3.8
Urban	60	4	1%	5.7	5	4.4	4.4	4.3	4.2	4.2	4.2	4.1	4	3.9
Urban	60	4	2%	5.8	5.1	4.6	4.6	4.5	4.4	4.4	4.4	4.2	4.2	4
Urban	60	4	3%	5.8	5.1	4.6	4.6	4.5	4.4	4.4	4.4	4.2	4.2	4
Urban	60	4	4%	6	5.3	4.9	4.9	4.8	4.7	4.7	4.7	4.5	4.5	4.3
Urban	60	4	5%	6.3	5.6	5.2	5.2	5.1	5	5	5	4.8	4.8	4.6
Urban	60	4	6%	6.6	5.9	5.5	5.5	5.4	5.3	5.3	5.3	5.1	5.1	4.9
Urban	60	4	7%	7.1	6.4	6	6	5.9	5.8	5.8	5.8	5.6	5.6	5.4
Urban	90	4	0%	5.5	4.8	4.1	4	4	3.9	3.9	3.9	3.7	3.7	3.7
Urban	90	4	1%	5.6	4.9	4.2	4.1	4.1	4	4	4	3.8	3.8	3.8
Urban	90	4	2%	5.7	5	4.5	4.4	4.4	4.3	4.3	4.3	4.1	4	3.9
Urban	90	4	3%	5.8	5.1	4.4	4.2	4.2	4.1	4.1	4.1	3.9	3.8	3.8
Urban	90	4	4%	6	5.3	4.7	4.6	4.6	4.5	4.5	4.5	4.3	4.2	4.1
Urban	90	4	5%	6.3	5.6	4.9	4.8	4.8	4.7	4.7	4.7	4.5	4.4	4.3
Urban	90	4	6%	6.7	6	5.3	5.1	5.1	5	5	5	4.8	4.7	4.6
Urban	90	4	7%	6.9	6.2	5.5	5.4	5.4	5.3	5.3	5.3	5.1	5	4.9
Urban	45	6	0%	6.6	5.8	4.9	4.7	4.6	4.6	4.5	4.5	4.3	4.1	3.9
Urban	45	6	1%	6.6	5.8	4.9	4.8	4.7	4.7	4.6	4.6	4.5	4.3	4.1
Urban	45	6	2%	6.6	5.8	5.1	5	5	4.9	4.9	4.8	4.7	4.5	4.2
Urban	45	6	3%	6.8	6	5.3	5.2	5.2	5.1	5.1	5	4.9	4.7	4.4
Urban	45	6	4%	7	6.2	5.6	5.5	5.4	5.4	5.3	5.3	5.1	4.9	4.7
Urban	45	6	5%	7.3	6.5	5.8	5.7	5.6	5.6	5.5	5.5	5.3	5.1	4.9
Urban	45	6	6%	7.6	6.8	6.1	6	6	5.9	5.9	5.8	5.7	5.5	5.2
Urban	45	6	7%	8	7.2	6.5	6.4	6.3	6.3	6.2	6.2	6	5.8	5.6

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	60	6	0%	6.3	5.5	4.7	4.6	4.5	4.5	4.4	4.4	4.2	4	3.8
Urban	60	6	1%	6.4	5.6	4.7	4.6	4.5	4.5	4.4	4.4	4.3	4.1	3.9
Urban	60	6	2%	6.5	5.7	4.9	4.8	4.7	4.7	4.6	4.6	4.4	4.2	4
Urban	60	6	3%	6.5	5.7	4.9	4.8	4.7	4.7	4.6	4.6	4.4	4.2	4
Urban	60	6	4%	6.7	5.9	5.2	5.1	5	5	4.9	4.9	4.7	4.5	4.3
Urban	60	6	5%	7	6.2	5.5	5.4	5.3	5.3	5.2	5.2	5	4.8	4.6
Urban	60	6	6%	7.3	6.5	5.8	5.7	5.6	5.6	5.5	5.5	5.3	5.1	4.9
Urban	60	6	7%	7.8	7	6.3	6.2	6.1	6.1	6	6	5.8	5.6	5.4
Urban	90	6	0%	6.2	5.5	4.5	4.3	4.2	4.2	4.1	4.1	3.9	3.9	3.7
Urban	90	6	1%	6.3	5.6	4.6	4.4	4.3	4.3	4.2	4.2	4	4	3.8
Urban	90	6	2%	6.4	5.7	4.8	4.7	4.6	4.6	4.5	4.4	4.3	4.1	3.9
Urban	90	6	3%	6.5	5.7	4.8	4.5	4.4	4.4	4.3	4.2	4.1	4	3.8
Urban	90	6	4%	6.7	5.9	5	4.9	4.8	4.8	4.7	4.6	4.5	4.3	4.1
Urban	90	6	5%	7	6.2	5.3	5.1	5	5	4.9	4.8	4.7	4.5	4.3
Urban	90	6	6%	7.4	6.6	5.7	5.4	5.3	5.3	5.2	5.1	5	4.8	4.6
Urban	90	6	7%	7.6	6.8	5.9	5.7	5.6	5.6	5.5	5.4	5.3	5.1	4.9
Urban	45	8	0%	7.3	6.3	5.3	5	4.8	4.8	4.7	4.6	4.4	4.2	4.1
Urban	45	8	1%	7.3	6.5	5.3	5.1	5	4.9	4.8	4.8	4.6	4.5	4.2
Urban	45	8	2%	7.3	6.5	5.4	5.4	5.2	5.2	5.1	5	4.8	4.6	4.3
Urban	45	8	3%	7.5	6.5	5.6	5.6	5.4	5.4	5.3	5.2	5	4.7	4.5
Urban	45	8	4%	7.7	6.8	5.8	5.8	5.6	5.6	5.5	5.4	5.2	4.9	4.7
Urban	45	8	5%	8	7	6	6	5.8	5.8	5.7	5.6	5.4	5.1	4.9
Urban	45	8	6%	8.3	7.3	6.4	6.4	6.2	6.2	6.1	6	5.8	5.5	5.3
Urban	45	8	7%	8.7	7.7	6.7	6.7	6.5	6.5	6.4	6.3	6.1	5.8	5.6
Urban	60	8	0%	6.9	6.1	5	4.9	4.7	4.7	4.6	4.5	4.2	4	3.9

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	60	8	1%	7	6.2	5.1	4.9	4.8	4.7	4.6	4.6	4.4	4.3	4
Urban	60	8	2%	7.1	6.3	5.2	5.1	4.9	4.9	4.8	4.7	4.4	4.3	4.2
Urban	60	8	3%	7.2	6.4	5.2	5.1	4.9	4.9	4.8	4.7	4.5	4.3	4.1
Urban	60	8	4%	7.3	6.5	5.4	5.4	5.2	5.2	5.1	5	4.8	4.5	4.4
Urban	60	8	5%	7.6	6.7	5.7	5.7	5.5	5.5	5.4	5.3	5	4.8	4.7
Urban	60	8	6%	7.9	7	6	6	5.8	5.8	5.7	5.6	5.4	5.3	5
Urban	60	8	7%	8.4	7.5	6.5	6.5	6.3	6.3	6.2	6.1	5.8	5.6	5.5
Urban	90	8	0%	7	6.2	4.9	4.6	4.4	4.4	4.3	4.3	4.1	3.9	3.9
Urban	90	8	1%	7.1	6.3	5	4.7	4.5	4.5	4.4	4.4	4.2	4	4
Urban	90	8	2%	7.2	6.4	5.1	5	4.8	4.8	4.7	4.6	4.3	4.1	4.1
Urban	90	8	3%	7.1	6.3	5.2	4.8	4.6	4.6	4.5	4.4	4.2	4	4
Urban	90	8	4%	7.3	6.5	5.4	5.2	5	5	4.9	4.8	4.5	4.3	4.3
Urban	90	8	5%	7.6	6.7	5.7	5.4	5.2	5.2	5.1	5	4.7	4.5	4.5
Urban	90	8	6%	8	7.1	6.1	5.7	5.5	5.5	5.4	5.3	5	4.8	4.6
Urban	90	8	7%	8.2	7.3	6.3	6	5.8	5.8	5.7	5.6	5.3	5.1	4.9
Urban	45	10	0%	7.8	6.9	5.6	5.2	5.1	5	5	4.8	4.6	4.3	4.1
Urban	45	10	1%	7.8	7.1	5.6	5.4	5.2	5.2	5.1	5	4.8	4.6	4.3
Urban	45	10	2%	7.8	7.1	5.7	5.6	5.5	5.4	5.4	5.2	5	4.7	4.4
Urban	45	10	3%	8	7.1	5.9	5.8	5.7	5.6	5.6	5.4	5.2	4.9	4.5
Urban	45	10	4%	8.2	7.4	6.1	6	5.9	5.8	5.7	5.6	5.3	5	4.7
Urban	45	10	5%	8.5	7.5	6.3	6.2	6.1	6	5.9	5.8	5.5	5.2	4.9
Urban	45	10	6%	8.8	7.8	6.7	6.6	6.5	6.4	6.4	6.2	6	5.7	5.3
Urban	45	10	7%	9.2	8.2	7	6.9	6.8	6.7	6.7	6.5	6.3	6	5.6
Urban	60	10	0%	7.5	6.8	5.3	5.1	5	4.9	4.8	4.7	4.4	4.1	3.9
Urban	60	10	1%	7.6	6.9	5.4	5.2	5	5	4.9	4.8	4.6	4.4	4.1

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	60	10	2%	7.7	7	5.5	5.3	5.2	5.1	5	4.9	4.6	4.4	4.2
Urban	60	10	3%	7.8	7.1	5.6	5.3	5.2	5.1	5.1	4.9	4.7	4.4	4.1
Urban	60	10	4%	7.9	7.2	5.7	5.6	5.5	5.4	5.4	5.2	5	4.7	4.4
Urban	60	10	5%	8.2	7.4	6	5.9	5.8	5.7	5.5	5.5	5.1	4.9	4.7
Urban	60	10	6%	8.5	7.6	6.3	6.2	6.1	6	5.9	5.8	5.6	5.4	5.1
Urban	60	10	7%	9	8	6.8	6.7	6.6	6.5	6.3	6.3	5.9	5.7	5.5
Urban	90	10	0%	7.6	6.9	5.4	5	4.7	4.6	4.5	4.4	4.3	4.1	3.9
Urban	90	10	1%	7.7	7	5.5	5.1	4.8	4.7	4.6	4.5	4.4	4.2	4
Urban	90	10	2%	7.8	7.1	5.6	5.2	5.1	5	4.8	4.8	4.5	4.3	4.1
Urban	90	10	3%	7.7	7	5.5	5.1	4.9	4.8	4.6	4.6	4.4	4.2	4
Urban	90	10	4%	7.9	7.2	5.7	5.4	5.3	5.2	5	5	4.7	4.5	4.3
Urban	90	10	5%	8.2	7.4	6	5.6	5.5	5.4	5.2	5.2	4.9	4.7	4.5
Urban	90	10	6%	8.6	7.6	6.4	6	5.8	5.7	5.5	5.5	5.1	4.8	4.6
Urban	90	10	7%	8.8	7.8	6.6	6.2	6.1	6	5.8	5.8	5.4	5.1	4.9
Urban	45	12	0%	8.2	7.5	5.9	5.5	5.4	5.3	5.2	5.1	4.8	4.5	4.3
Urban	45	12	1%	8.4	7.7	6.1	5.6	5.5	5.4	5.4	5.2	5	4.7	4.4
Urban	45	12	2%	8.4	7.7	6.1	5.9	5.8	5.7	5.6	5.5	5.2	4.8	4.4
Urban	45	12	3%	8.4	7.7	6.2	6.1	6	5.9	5.8	5.7	5.4	5	4.6
Urban	45	12	4%	8.7	8	6.4	6.2	6.1	6	5.9	5.8	5.5	5.1	4.9
Urban	45	12	5%	8.9	8.1	6.6	6.4	6.3	6.2	6.1	6	5.7	5.3	5.1
Urban	45	12	6%	9.2	8.3	7	6.9	6.8	6.7	6.6	6.5	6.2	5.8	5.4
Urban	45	12	7%	9.6	8.6	7.3	7.2	7.1	7	6.9	6.8	6.5	6.1	5.8
Urban	60	12	0%	8.1	7.4	5.8	5.3	5.2	5.1	5	4.9	4.6	4.3	4.1
Urban	60	12	1%	8.2	7.5	5.9	5.4	5.3	5.2	5.2	5	4.8	4.5	4.1
Urban	60	12	2%	8.3	7.6	6	5.5	5.4	5.3	5.2	5.1	4.8	4.6	4.4

Table A-3. One-hour CO Concentrations at Varying Intersection-Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[a]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	60	12	3%	8.4	7.7	6.1	5.6	5.5	5.4	5.3	5.2	4.9	4.5	4.3
Urban	60	12	4%	8.5	7.8	6.2	5.9	5.8	5.7	5.6	5.5	5.2	4.8	4.6
Urban	60	12	5%	8.7	8	6.4	6.1	6	5.8	5.8	5.6	5.3	5.1	4.9
Urban	60	12	6%	8.9	8.2	6.6	6.4	6.3	6.2	6.2	6	5.8	5.5	5.2
Urban	60	12	7%	9.4	8.4	7.1	6.9	6.8	6.6	6.6	6.4	6.1	5.9	5.7
Urban	90	12	0%	8.2	7.5	5.9	5.3	5	4.8	4.6	4.6	4.4	4.2	3.9
Urban	90	12	1%	8.3	7.6	6	5.4	5.1	4.9	4.7	4.7	4.5	4.3	4
Urban	90	12	2%	8.4	7.7	6.1	5.5	5.3	5.1	5	4.9	4.6	4.4	4.1
Urban	90	12	3%	8.3	7.6	6	5.4	5.1	4.9	4.8	4.7	4.5	4.3	4
Urban	90	12	4%	8.5	7.8	6.2	5.6	5.5	5.3	5.2	5.1	4.8	4.6	4.3
Urban	90	12	5%	8.7	8	6.4	5.8	5.7	5.5	5.4	5.3	5	4.8	4.5
Urban	90	12	6%	9	8.2	6.6	6.2	6	5.8	5.7	5.6	5.3	4.9	4.6
Urban	90	12	7%	9.2	8.3	6.8	6.4	6.3	6.1	6	5.9	5.6	5.2	4.9

[a] These findings apply to scenarios with the intersection average speed ranging from 15 to 45 mph and the freeway average speed ranging from 15 to 75 mph.

Appendix G: Georgia-Specific Technical Support Document

Russell R. McMurry, P.E.,
Commissioner
One Georgia Center
600 West
Peachtree
Street, NW
Atlanta,
GA 30308
(404) 631-1000 Main Office

Attachment

FHWA-Georgia Department of Transportation

Programmatic Agreement: Streamlining Project-Level Carbon Monoxide Air Quality Analysis

TECHNICAL SUPPORT DOCUMENTATION

Updated January 13, 2020

Prepared by

Georgia Department of

Transportation (GDOT)

Office of Environmental

Services

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1 Executive Summary

This Technical Support Document (TSD) provides background and technical information in support of the Programmatic Agreement (PA) between the Georgia Department of Transportation (GDOT) and the Georgia Division of the Federal Highway Administration (FHWA) related to project level carbon monoxide (CO) air quality analysis. This TSD and the associated PA establish which project types and conditions are not expected to exceed CO National Ambient Air Quality Standards (NAAQS) and therefore do not require a quantitative air quality analysis.

The PA was developed as a result of:

- A long history of analyzing highway projects for potential CO impacts by the GDOT
- Ongoing reductions in vehicle emissions
- Ongoing reductions in measured CO concentrations
- Recent activities at the federal level, which document the infeasibility of CO ambient air standards being exceeded by certain transportation project types and conditions.

The analyses described in this TSD demonstrate, with a high degree of confidence, that implementation of these project types under the conditions listed could not cause or contribute to a violation of the ambient air standards for CO. The project types covered are: freeways, arterials, interchanges and intersections.

It is recognized that, from time to time, new emission or dispersion models may be developed and approved or that underlying ambient or technical conditions may change. As necessary, this TSD will be updated to reflect these changes.

2 Background

2.1 Air Quality Standards for CO

Under the Clean Air Act, the U.S. Environmental Protection Agency (EPA) is required to set the National Ambient Air Quality Standards for six principal air pollutants, including CO (Table 1). The standards are set to avoid adverse impacts to public health and the environment. The Clean Air Act identifies two types of National Ambient Air Quality Standards. Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly with an adequate margin of safety. Secondary standards provide public welfare protection, including protecting against decreased visibility and damage to animals, crops, vegetation, and buildings. There are currently no secondary standards for CO.

Table 1 – Current National Ambient Air Quality Standards (NAAQS) for Carbon Monoxide (CO)

Pollutant [final rule cite]	Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide [76 FR 54293, Aug 31, 2011]	Primary	8-hour	9 ppm	Not to be exceeded more than once per year
		1-hour	35 ppm	

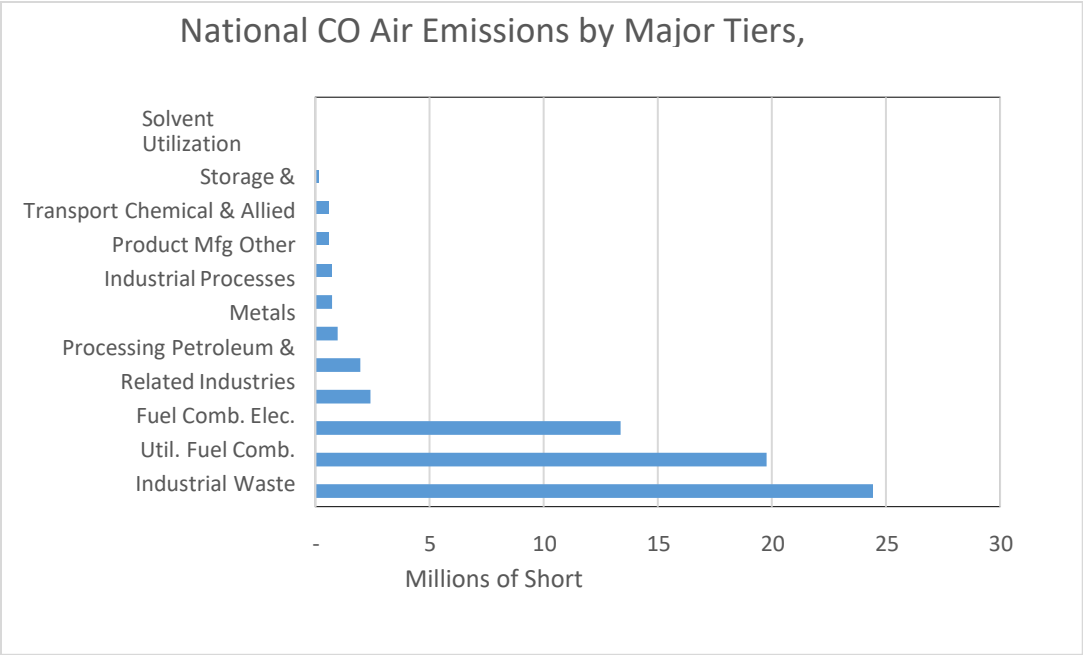
Source: https://www.epa.gov/co-pollution/national-ambient-air-quality-standards-naaqs-carbon-monoxide-co

EPA designates geographic regions as in attainment or nonattainment of the NAAQS. Generally, regions that met NAAQS when the standards were promulgated and have continued to meet those standards for a given pollutant are designated attainment areas. Regions that were deemed out of compliance when NAAQS were promulgated and that continue to exceed the NAAQS for a given pollutant are designated nonattainment areas. Regions that were previously out of compliance with the standard but have since come into compliance are designated maintenance areas. As of September 27, 2010, all former CO nonattainment areas were determined to be in compliance for CO, and so have been re- designated as maintenance areas. Currently, the state has no CO maintenance areas.

States with nonattainment or maintenance areas were required under the Clean Air Act to develop State Implementation Plans (SIPs) adopting transportation conformity requirements at least as stringent as the federal requirements. Some states also adopted additional requirements beyond those prescribed under the Clean Air Act.

2.2 Highway Projects & CO Requirements

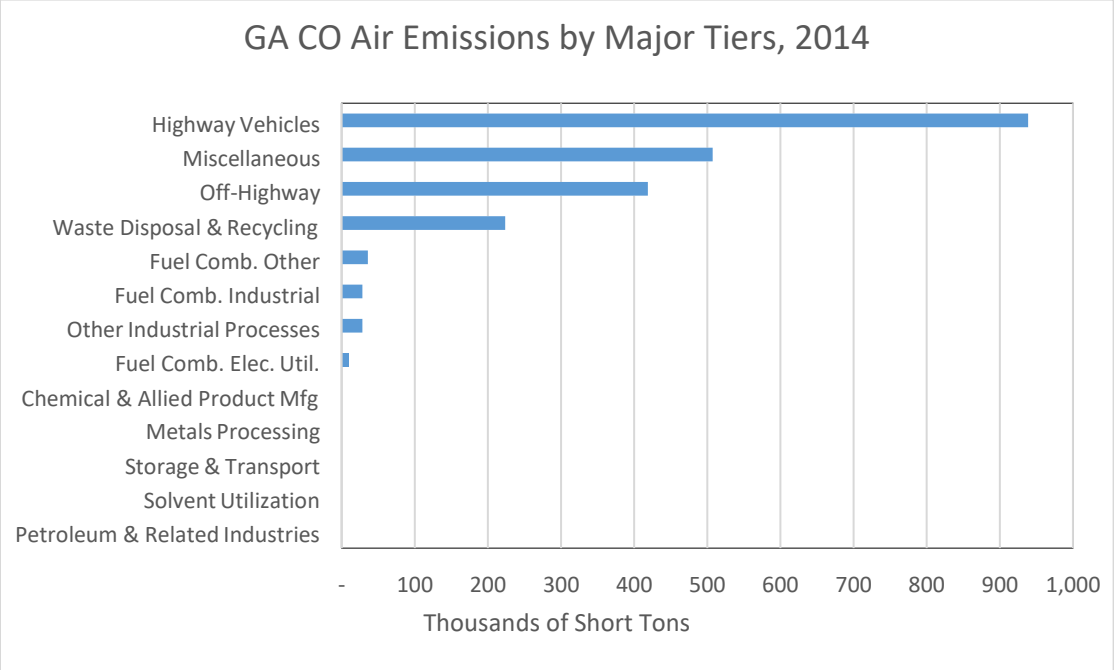
Nationally, annual CO emissions in the US total over 82 million short tons. Mobile sources, including gasoline fueled cars, trucks, buses and off-road vehicles, are responsible for approximately 51% of this total.



Source: 2014 National Notes: Emission Inventory[1]

Figure 1 – National Carbon Monoxide Emission Inventory

A similar situation exists at the state level. In GA, highway and off-highway vehicles dominate the emissions, accounting for 62% of the statewide releases, as shown in Figure 2.



Source: 2014 National Emission Inventory

Figure 2 – Georgia Carbon Monoxide Emission Inventory

[1] https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data

Because of the significant CO pollution attributable to mobile sources, transportation agencies have been required to examine the effect of their highway projects on CO levels in the project area. Indeed, under Section 176(c) of the Clean Air Act (the conformity provision), in order to proceed, certain highway projects are required to demonstrate that the incremental addition of CO emissions as a result of the project will not cause or contribute to a violation of the CO NAAQS. The analysis necessary to demonstrate this is typically performed during the environmental studies undertaken to examine environmental impacts of the project.

In addition, the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, July 2017)[2] documented conditions for urban intersections in CO maintenance areas that did not require a specific project-level hot-spot analysis but could instead rely on the categorical finding to determine whether the project was in compliance. This finding was the result of steadily declining ambient CO concentrations over the past several decades.

For transportation projects involving federal funding or action, the environmental analysis is performed pursuant to the requirements of the National Environmental Policy Act (NEPA). Enacted on January 1, 1970, NEPA established a national environmental policy focused on federal activities with the goal of balancing a sustainable environment with other essential present and future needs. NEPA established a requirement for federal agencies to consider the potential environmental consequences of their proposals, document the analysis, and make this information available to the public for comment prior to implementation. NEPA also requires Federal agencies to use an interdisciplinary approach in planning and decision making for any action that adversely impacts the environment. As implemented by FHWA, this means investigating and avoiding potential impacts to the social and natural environment (such as a violation of the CO NAAQS) when considering approval of proposed transportation projects. FHWA's policy and regulations implementing NEPA are found at 23 CFR § 771.105.

Many states have enacted a state version of NEPA to cover state actions and funding. Similar to NEPA, the state versions typically require an examination of potential environmental impacts and appropriate action to mitigate these impacts to the extent practicable.

As mentioned above, regions of the nation that did not meet the NAAQS for CO when the standards were promulgated were designated as nonattainment areas under the Clean Air Act. Those areas have since all reached attainment of the CO standard based on monitoring or modeling studies. Most are now designated as maintenance areas. However, under Section 176(c) of the Clean Air Act (the transportation conformity provision), certain transportation projects in maintenance areas are required to demonstrate that the project will not cause or contribute to a violation of the CO standard. However, the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, July 2017) documents conditions for urban intersections in CO maintenance areas that do not require a specific project-level hot-spot analysis but can instead rely on the categorical finding.

[2] See: https://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf_2017/index.cfm

2.3 Decline in CO Concentrations

The likelihood of highway projects leading to violations of the CO NAAQS has been significantly reduced over the last few decades. Indeed, while vehicle miles traveled (VMT) have seen a long-term general increase over time.

Figure 3 shows the trend in VMT at a national level. This has also been the case at the state level. For example, GA EPD shows a general reduction in total CO emissions in the last seven years, with a continuous reduction in highway vehicle CO emissions.[3]

Background CO concentrations are also critical in determining a project's impact in terms of NAAQS. At the national level, background CO concentrations have seen significant decreases over the past ~26 years. Indeed, the nationwide network of CO air quality monitoring sites have reported a 80% decline in the 90th percentile of maximum 8-hour CO concentration from 9.7 ppm, above the NAAQS for CO (9 ppm—see 9.5 Table 1) in 1990 to 1.9 ppm, well below the NAAQS for CO, in 2016 (Figure 4). This significant decrease in CO background concentrations allow much higher traffic volumes to be screened out under the programmatic agreement. Similar reductions have been found at the state level, as shown by Figure 5. Of the four sites shown here, all are considered urban other than Yorkville, which is suburban.[4]

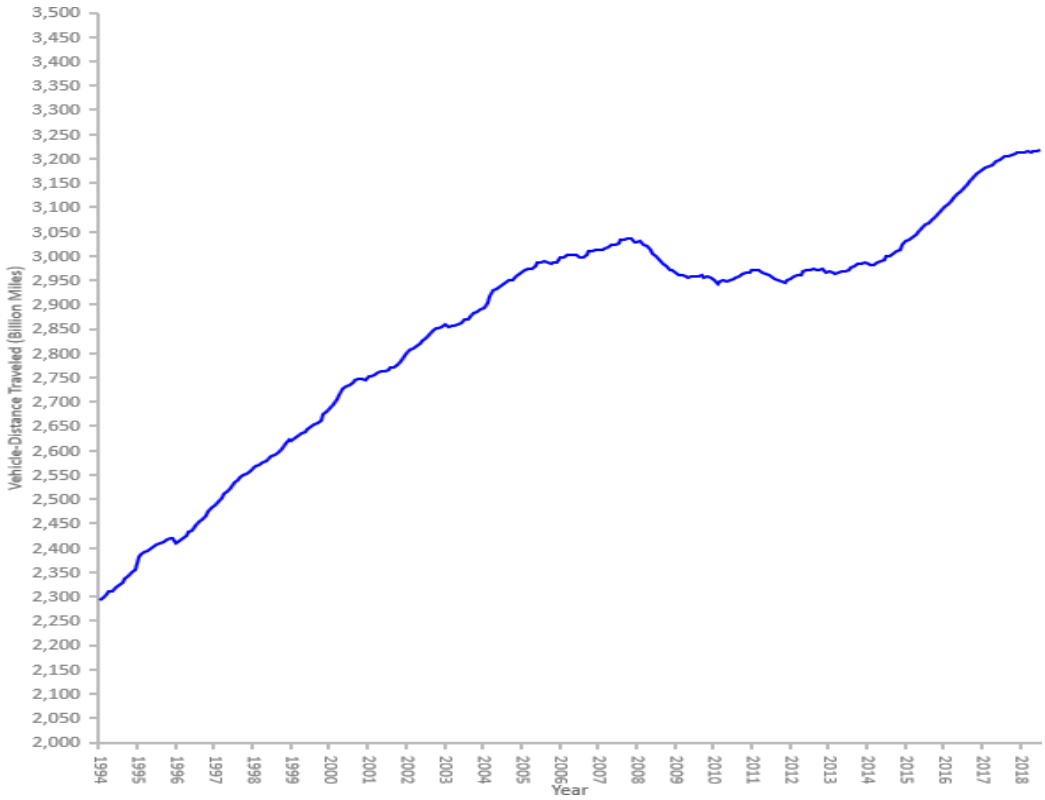


Figure 3 - Total National VMT (in billions of miles) on All Highways, 1994-2018. Source: FHWA.

[3] GA Air Quality Trends, GA EPD. Available at: https://airgeorgia.org/trends.html.

[4] FHWA-GDOT 2017 Programmatic Agreement for Project-Level Air Quality Analyses for CO Technical Support Document. [5] FHWA Office of Highway Policy Information, Traffic Volume Trends. Available at: https://www.fhwa.dot.gov/policyinformation/travel_monitoring/18jultvt/figure1.cfm.

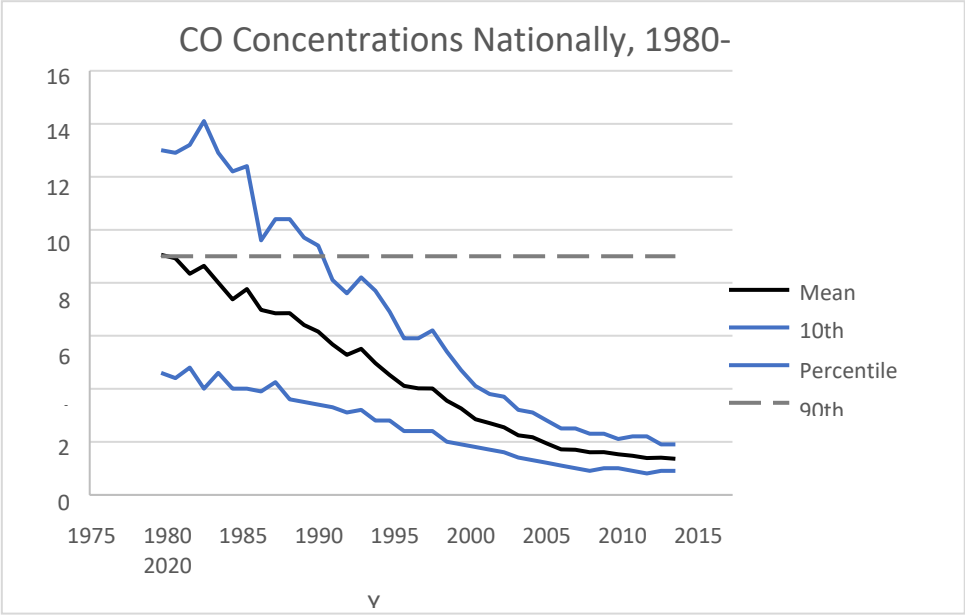
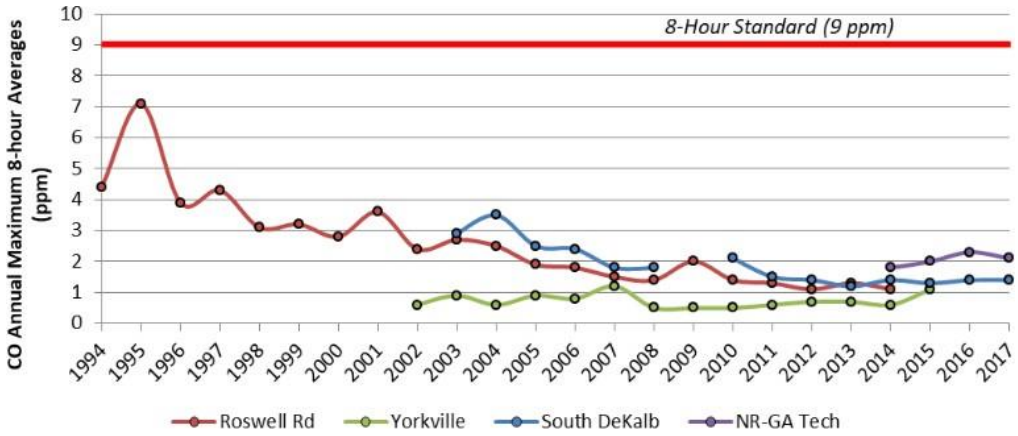


Figure 4 - National Trends in CO Concentration, 1980-2016 (Annual 2nd High 8-hour average N=62).[5]



Source: GA EPD Ambient Air Surveillance Report[6]

Figure 5 – Monitored Annual 8-hour Average Carbon Monoxide Concentrations in Georgia

The largest contributor to the substantial reductions in CO concentrations has been the Federal Motor Vehicle Emission Control Program, which sets emission limits for on-road vehicles. This program since implementation has been responsible for a 95% reduction in CO emissions from light-duty vehicles. Additional CO emissions reductions are expected to result from EPA's Tier 3 Control Program, enacted in April 2014, which places limits on the sulfur content of gasoline. Although CO emission rates are not directly regulated under the Tier 3 Control Program, the additional stringency on sulfur content in gasoline will reduce CO emissions by extending the effective life of vehicle catalysts. When fully implemented, by 2030, Tier 3 is expected to produce an additional 24% reduction in CO emissions nationally (Table 2).

[5] The black line represents the average of all sites, the top blue line the 90th percentile concentration and the bottom the 10th percentile. Source: EPA Air Trends. Available at: http://www.epa.gov/airtrends/carbon.html

[6] https://airgeorgia.org/docs/report17.pdf

Table 2 - Projected CO Reductions from EPA's Tier 3 Program

[Annual U.S. tons]		
	2018	2030
Reduction from pre-Tier 3 fleet due to sulfur standard	122,171	17,734
Reduction from Tier 3 fleet due to vehicle and sulfur standards	156,708	3,440,307
Total reduction	278,879	3,458,041
Percent reduction in on road CO emissions	2%	24%

Source: https://www.federalregister.gov/articles/2014/04/28/2014-06954/control-of-air-pollution-from-motor-vehicles- tier-3-motor-vehicle-emission-and-fuel-standards

The low ambient CO concentrations and the anticipated continued decline of these concentrations suggest that violations of the current CO NAAQS are unlikely today and into the future. As a result, any changes to local CO concentrations resulting from highway projects are highly unlikely to cause or contribute to a violation of these standards. It is efficient, therefore, to reduce CO analyses for highway projects to the maximum extent reasonable while still monitoring situations that could lead to high levels of ambient CO concentrations.

3 Status of CO Analyses

For highway projects involving federal funding or action, project-level CO analyses are performed pursuant to the requirements of the National Environmental Policy Act (NEPA). Enacted on January 1, 1970, NEPA established a national environmental policy requiring federal agencies to take consideration of the environmental impact of proposed projects in their planning and decision making. Specifically, NEPA established a requirement for federal agencies to perform an environmental assessment that considers the potential environmental consequences of their proposed projects. If the environmental assessment finding is that the project will have significant impact, then the federal agency must prepare an environmental impact statement (EIS). The EIS details the environmental consequences of the project and provides reasonable alternatives or amendments that would mitigate these impacts. NEPA requirements encompass any project, public or private, that receives federal funding, though it is the burden of the federal agency to perform the analysis. When applied to FHWA highway projects, NEPA requires consideration of potential environmental impacts—including violation of CO NAAQS, when considering approval of the projects. FHWA's policy and regulations implementing NEPA are found at 23 CFR § 771.105.

Nineteen states have enacted a state version of NEPA to cover state funded projects. Thus, for state level highway projects, CO analysis may be required in accordance with state NEPA analogues. Like NEPA, the state versions typically require an examination of potential environmental impacts and proposal of efforts to mitigate these impacts to a practical extent. States may also require CO analyses in order for a project to comply with transportation conformity requirements. Project transportation conformity requirements are found in 40 CFR Parts 51 and 93. In Georgia, the Georgia Environmental Policy Act (GEPA) requires preparation of an Environmental Effects Report to characterize impacts of a state (and some local) government agency actions. Note that the GEPA processes does not apply to federal actions that

require NEPA compliance.[7]

Guidance related to performing these analyses may be found in the FHWA Technical Advisory T6640.8A (October 30, 1987). With respect to air quality, the guidance recognizes that microscale air quality analyses may be performed for some projects but does not offer any methodological guidance beyond adding background concentrations to the project contribution or the preferred alternative to arrive at a total CO concentration for comparison to the NAAQS. Using this general guidance, many states developed their own guidelines and procedures tailored to state policies and air quality status.

The *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2017) documented conditions for urban intersections in CO maintenance areas that did not require a project-specific hot-spot analysis but could instead rely upon the categorical finding. The finding was based on extensive modeling of atmospheric, geometric, and traffic situations associated with urban intersections. The modeling procedures used to make this finding are detailed below.

4 Description of Modeling

The models used in CO air quality analysis have evolved over time. For emissions, the MOBILE series of models were used predominantly until the 2010 release of the first version of MOVES (Motor Vehicle Emission Simulator). Similarly, dispersion models have undergone changes over time. Highway sources have historically been treated as line sources using Gaussian dispersion to deliver CO from the source to the receptor. The HIWAY and CALINE series of models were developed to allow for modeling of roadways. However, it was realized that congested intersections, with most vehicles experiencing idling and acceleration and deceleration associated with a traffic signal, may be more of a concern for CO levels than free-flowing highways. To account for intersection scenarios, queuing algorithms were added to dispersion models, resulting in the current series of CAL3QHC and CAL3QHC(R) models. This analysis used MOVES (version MOVES2014b) and CAL3QHC (version 042440) for emissions and dispersion modeling, respectively.

The assumptions and inputs to the modeling process were conservative and/or worst-case. Conservative here refers to a modeling approach that, by design, tends to over-estimate concentrations. This approach leads to higher concentrations than might otherwise be expected. If a project does not cause a violation with these conservative inputs and assumptions, then a violation under “real-world” conditions is extremely unlikely to occur. This is standard practice in transportation air quality modeling. Further discussion of how this conservative emissions and air dispersion modeling was conducted is provided in the remainder of this section.

[7] Memorandum: Introducing Federal National Environmental Policy Act Practitioners to the Georgia Environmental Policy Act. Available at: https://ceq.doe.gov/docs/laws-regulations/state_information/GA_NEPA_Comparison_23Nov2015.pdf.

4.1 MOVES Modeling

Emission modeling was performed using the MOVES model (version MOVES2014b). The emissions parameters for MOVES were specified in the Run Specification file (Runspec) and in the Project Data Manager (PDM). All applications of the MOVES model were conducted at the project level scale. Multiple MOVES runs were conducted for varying roadway grades to establish CO emissions rates. Other MOVES input parameters such as temperature and relative humidity were fixed to be conservative and consistent with the dispersion modeling component of the analysis (see section 5 Background Concentration). Table 3 describes the input parameters that were used in the Runspec and PDM for the MOVES component of the analysis.

Table 3 - MOVES Input Parameters by Scenario

Parameter	Freeway	Arterial	Intersection
Scale	Project Level Domain		
Year	2020		
Month	January		
Time Span - Hour	8:00 AM		
Time Span - Day	Weekday		
Geographic Bounds	Custom Domain		
Temperature	60° Fahrenheit		
Relative Humidity	50%		
Fuel Formulation	Data for each county supplied by Georgia based on their CO project-level analysis from MOVES defaults for January for Gasoline, Diesel, E-85 (for Light-Duty Vehicles only), CNG (for Transit Buses only)		
Fleet Mix	Fractions supplied by Georgia Department of Transportation based on their CO project-level analysis (one distribution per county used for every link).[8] Results were taken by road type from the most conservative emissions across all modeled counties.		
Age Distribution	Data for each county supplied by Georgia based on their CO project-level analysis, originally derived from IHS Automotive (formerly R.L. Polk) vehicle registrations for the state in 2014		
Link Source Type Distribution	sourceTypeHourFraction supplied by Georgia Department of Transportation based on their CO project-level analysis (one distribution per county used for every link). All 13 sourceTypeID used.		
Road Type	Urban and Rural Restricted Access	Urban and Rural Unrestricted Access	Urban and Rural Unrestricted Access

[8] Further information can be found in Technical Support Document from the Georgia Department of Transportation (GDOT), Office of Environmental Services, *FHWA-GDOT Agreement for Project-Level Air Quality Analyses for Carbon Monoxide*, February 2017.

Table 3 - MOVES Input Parameters by Scenario

Link Average Speed	74mph highest emission rate between 15-75 mph	15 mph for grades less than or equal to 6%; 52mph for arterials at 7% grade; coverage range 15-52 mph	15 mph approach and idle (intersection) for all cases other than rural intersections at 7% grade, which used a speed of 45mph; coverage range from 15-45 mph
Grade	Multiple Grades between ±0% to ±7%	Multiple Grades between ±0% to ±7%	Multiple Grades between ±0% to ±6%
Inspection & Maintenance	Data supplied by Georgia based on their CO project-level analysis pulled from MOVES defaults for Fulton County, other counties did not include I/M programs		

4.1.1 Temperature and Relative Humidity

Notably, MOVES predicts higher CO at T > 75 degrees Fahrenheit due to air conditioning use but because CO is a winter air pollution problem in Georgia a high value of 60 degrees Fahrenheit was used in the analysis. Relative humidity has no effect on CO emissions for temperature less than 75 F and a value of 50% was used in the analysis.

4.1.2 Link Source Type Distribution

The Source Type Distribution was provided by GDOT for four counties: county ID values 13015 (Bartow County), 13121 (Fulton County), 13069 (Coffee County), and 13051 (Chatham County) from state-specific MOVES run for the 2020 calendar year. Each of these counties was run individually with these source type distribution values inputs unaltered for each of the four road types.

The emission rates produced for each of the four counties and four road types were analyzed, and the highest emission rates for each were modeled with CAL3QHC to determine the most conservative statewide emission rates to use in the PA.

4.1.3 Age Distribution

The 2020 age distribution for each county was supplied by GDOT based on their CO project-level analyses, originally derived from IHS Automotive (formerly R.L. Polk) vehicle registrations for the state in 2014.

4.1.4 Fuel Supply and Formulation

Fuel formulation parameters can significantly affect CO emission rates. The *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, July 2017) determined the effects of certain fuel parameters on CO emission rates. Fuel parameters that can affect CO emission rates include Reid vapor pressure (RVP), sulfur content, ethanol (ETOH), percent of fuel evaporated at 200° and 300° Fahrenheit (E200/E300), and distillation

parameters T50 and T90. The FHWA study identified fuel formulation ID 3812 yields the highest CO emission rates among fuel formulations.

This analysis relied on the fuel formulations used by GDOT for each of the four counties based on their CO project-level MOVES analysis for January. As documented in the previous GA CO TSD,[9] this fuel formulation for MOVES2014 produces values that are more realistic for the region and more conservative as a "dirtier" winter fuel. This study used default fuel for January for Georgia "PADD 1 – East Coast", which actually has higher Reid vapor pressure (RVP) with 1% of the fuel in MOVES 2014b assumed to be E15 and since there is mixed results on E15s impacts on emissions (higher evaporation but lower RVP), this small percentage was kept for a realistic portrayal. For CNG, 28001 is the fuel formulation ID with a sulfur level of 7.6 ppm which is conservative. Diesel fuel formulation ID is 25005 which is considered "biodiesel", but uses a high sulfur content of 15 ppm which is conservative.

Table 4 summarizes the fuel formulations used by county. As noted above, the most conservative of all counties was taken for each emission rate.

Table 4 - Fuel Formulation Used for the Analysis

Fuel Type	Fuel Formulation ID	RVP	Sulfur Content (ppm)	ETOH Volume	e200	e300	T50	T90
Diesel	25005	0	15	0	0	0	-	-
Gasoline	3812	11.3	10	10	55.73	87.09	199.29	320.59
CNG	28001	0	7.6	0	0	0	0	0

4.1.5 Link Average Speed and Operating Mode Distribution

When average speed is utilized in the 'Links' input file, entered through the MOVES' PDM, MOVES creates an operating mode distribution based upon the default drive schedules located in the default database. This operating mode distribution was used represent the freeways, arterials and intersection scenarios. The speeds used in the analysis for each facility type, along with the range over which this speed yields maximum emission rates, are shown in Table 3.

4.1.6 Emissions Processes

The 'Running Exhaust' and 'Crankcase Running Exhaust' emissions process were utilized in the intersection, freeway, and arterial scenarios.

4.1.7 Inspection and Maintenance Program

An inspection and maintenance (I/M) program produces CO emissions rate benefits. Data supplied by GDOT based on their CO project-level analysis included an I/M program for Fulton County in MOVES analysis, but not for other counties. As noted above, each county was run individually and the most conservative rate from each by road type used in the dispersion modeling.

[9] FHWA-GDOT 2017 Programmatic Agreement for Project Level Air Quality Analysis for CO.

4.2 Dispersion Modeling: CAL3QHC

The inputs for the dispersion modeling followed EPA's 1992 Guidance for CO determinations using CAL3QHC (version 04244) and were consistent with the approach used by the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* for intersections. As for emissions modeling, the dispersion modeling used conservative and, in many cases, worst-case inputs and assumptions. The modeling approach is described in greater detail below:

4.2.1 Intersections, Freeways, and Arterials

- As a conservative assumption, the wind speed was set to 1.0 m/s (the lower limit of CAL3QHC meaningful input)
- Wind direction was modeled every ten degrees from 0 to 350 degrees.
- A mixing height of 1000 m was used, consistent with standard modeling procedures. Sensitivity testing has shown that due to the close proximity of the receptors, mixing height has negligible influence on the dispersion analysis.
- For urban modeling, a surface roughness (z0) of 108 cm was used, corresponding to a single- family residential setting. The single-family residential setting is the least rough setting for an urban environment and is conservative. The recommended surface roughness in urban areas can vary from 108 to 370 cm. For rural areas, a surface roughness of 1.0 cm was used, which corresponds to a moderately short grass height (6-8 cm) as identified in the Kansas prairie grass. Shorter grass heights are unlikely to be found most rural locations.
- The 1992 EPA CO Guidelines specifies a stability class of D (neutral) for urban areas and E (stable) for rural areas. These guidelines were applied in the model.
- Receptor Placement
    - Freeways and Arterials:
        - Receptors were modeled per the CAL3QHC and 1992 EPA Guidance and were located starting at 20 feet from the outside lane for freeways to account for off-road safety clearance. Receptors were located starting at 10 feet from roadway edge for arterials (where the general public has access and within the limitations of the model to predict valid concentrations).
        - Receptors were evaluated perpendicular to and at the center of the defined link to avoid end effects.
        - Receptors were placed on both sides of the roadway at 10-foot increments for freeways and 25-foot increments for arterials, extending out to 295 feet from the roadway. These were modeled to establish decreasing CO concentrations with distance from the roadway edge.

- Intersections:
  - Receptors were modeled per the CAL3QHC and 1992 EPA Guidance and began at 10 feet from roadway edge.
  - Receptors were placed in each quadrant consistent with the 1992 CO Guideline[10] to ensure the worst-case concentrations were identified. The closest receptor was grid spacing started at the corner, 10 feet from each roadway and then at 25 feet and 50 feet from the roadway edge (along the adjacent roadway leg), and at the mid-block position.
  - Figure 6 shows a typical intersection receptor configuration with link geometry.

- Link Geometries and Activity Levels
  - Freeways and Arterials
    - 5,000-foot links were evaluated to avoid end effects.
    - Freeway facilities were evaluated from 2 to 22 total lanes, in two lane increments. Arterials were evaluated from 2 to 12 total lanes, in two lane increments.
    - Median width was 3.3 feet for freeways and 0 feet for arterials
    - Lane width was 12 feet in all cases.
    - Traffic volumes were conservatively modeled as 2,400 vehicles-per-lane-per-hour for multi-lane freeways and 2,200 vehicles-per-lane-per-hour for multi-lane arterials. Two lane arterials and freeways were modeled at 1,700 vehicles-per-lane-per-hour.
    - Grades from ±0 to ±7 percent were modeled, with one leg uphill and one leg downhill.
    - Figure 7 shows a typical modeling scenario.
  - Intersections.
    - Approach and departure links extended 3,000 feet from the center of the intersection to ensure end effects at receptor locations are not encountered.
    - Links were input for the start and end locations per the guidance in the CAL3QHC User Manual. Figure 8 shows an example of the link placement for the right-angle (90-degree skew) intersection.
    - Lane width was conservatively modeled as 11 feet in all cases.
    - In addition to the right-angle intersections, skew angles of 60°, 45°, 30°, and 15° angles were considered. Figure 9 shows this

[10] U.S. Environmental Protection Agency, Guideline for Modeling Carbon Monoxide from Roadway Intersections, EPA-454/R-92-005, Office of Air Quality Planning and Standards, November 1992.

configuration for a 60-degree skew.

- Queue lengths were determined by CAL3QHC internal algorithm.
- Grades from ±0 to ±7 percent were modeled, with a side-of-a-hill configuration, where the northbound approach and the westbound approach are up hill.
- Turn lanes were modeled per suggested guidance in the AASHTO Green Book.

4.2.2 Interchanges

Threshold PA CO concentration levels for the interchange configuration were analyzed using the MOVES and CAL3QHC models, with a combination of the grade separated intersection and freeway separated at various distances. A variable number of freeway lanes (even number of lanes ranging from 2 -12 lanes) were simulated. Likewise, various distances from the edge of the nearest freeway travel lane to the edge of the nearest travel lane of the interchange ramp (20, 30, 60, 80, 100, 125, 150, 175, 300, 500 and 1,000 feet) were simulated. The roadway link connecting the freeway to the intersection was modeled at skew angles of 90, 60, and 45-degree angles. Intersections were considered on either side of the freeway. Figure 9 shows the layout of the interchange for a 90-degree skew angle and with the intersection on the right side of the freeway. This modeling combines the impacts from the freeway and intersection modeling to determine the CO contribution for an interchange project for any given combination of the modeled number of freeway lanes and distances from the freeway to the interchange. The freeway component was always treated at 0 percent grade, while the intersection portion varied from ±0 to ±7 percent, with a side-of-a-hill configuration, consistent with the intersection alone setup described above. The total of the freeway contribution, intersection contribution, and background can then be directly compared to the CO NAAQS.

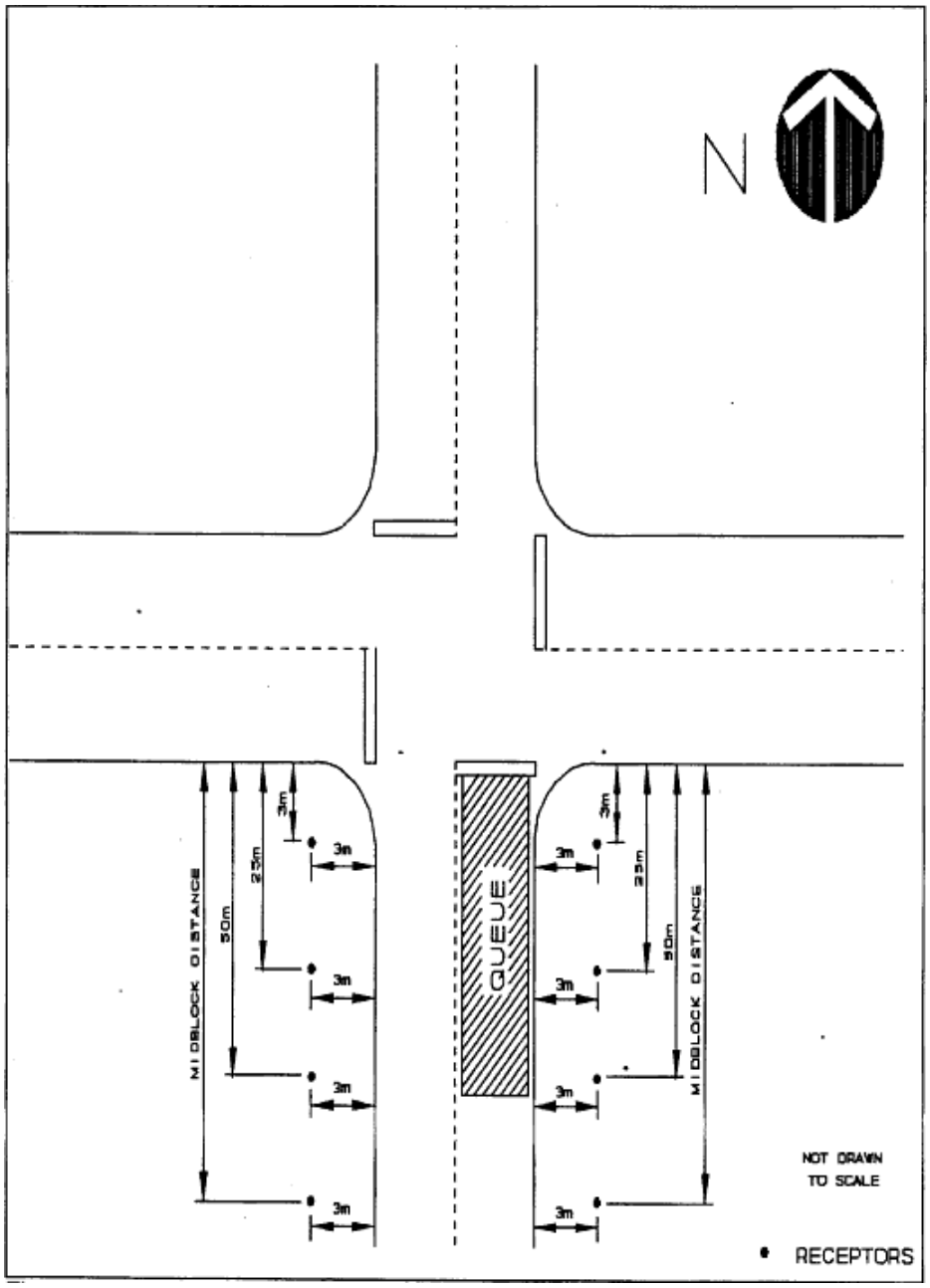


Figure 6 - Intersection configuration used for modeling with link placement

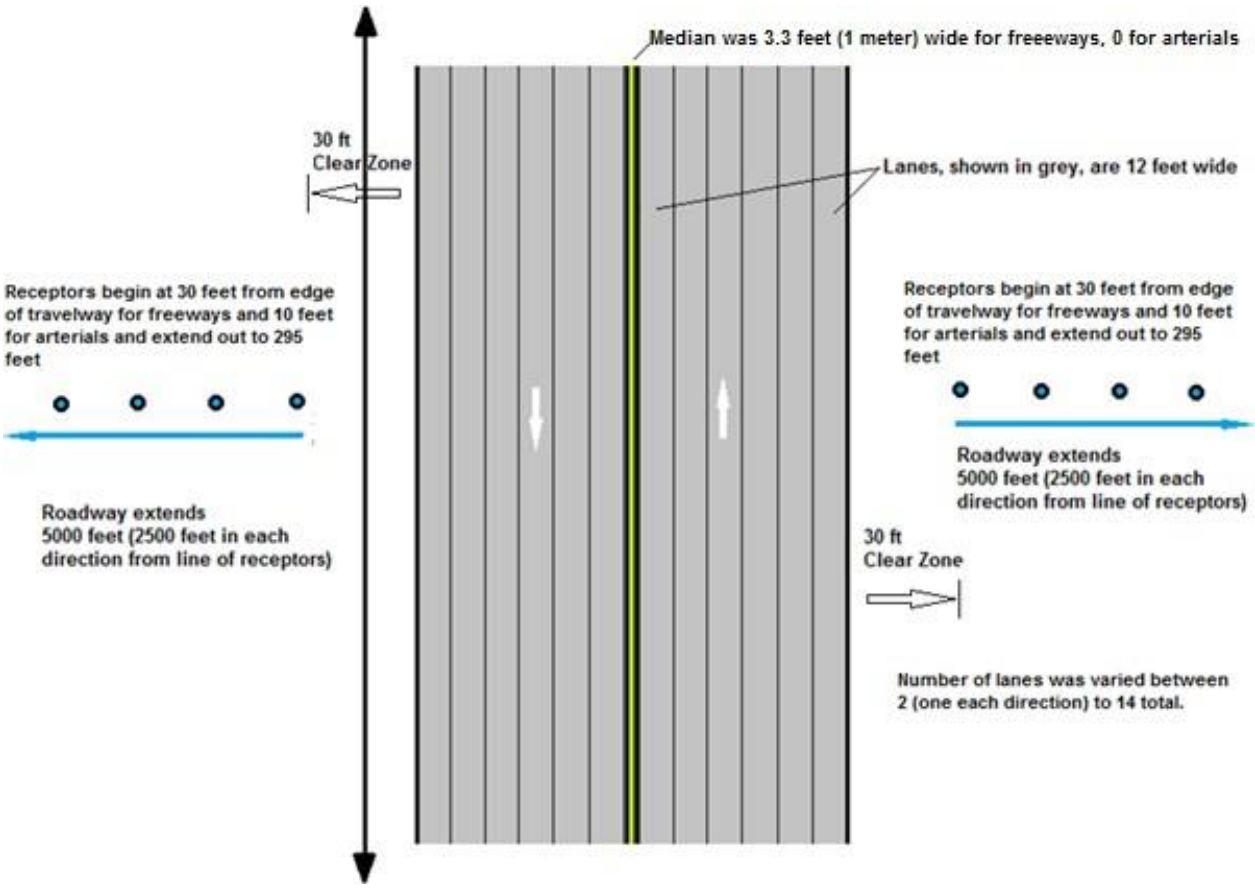
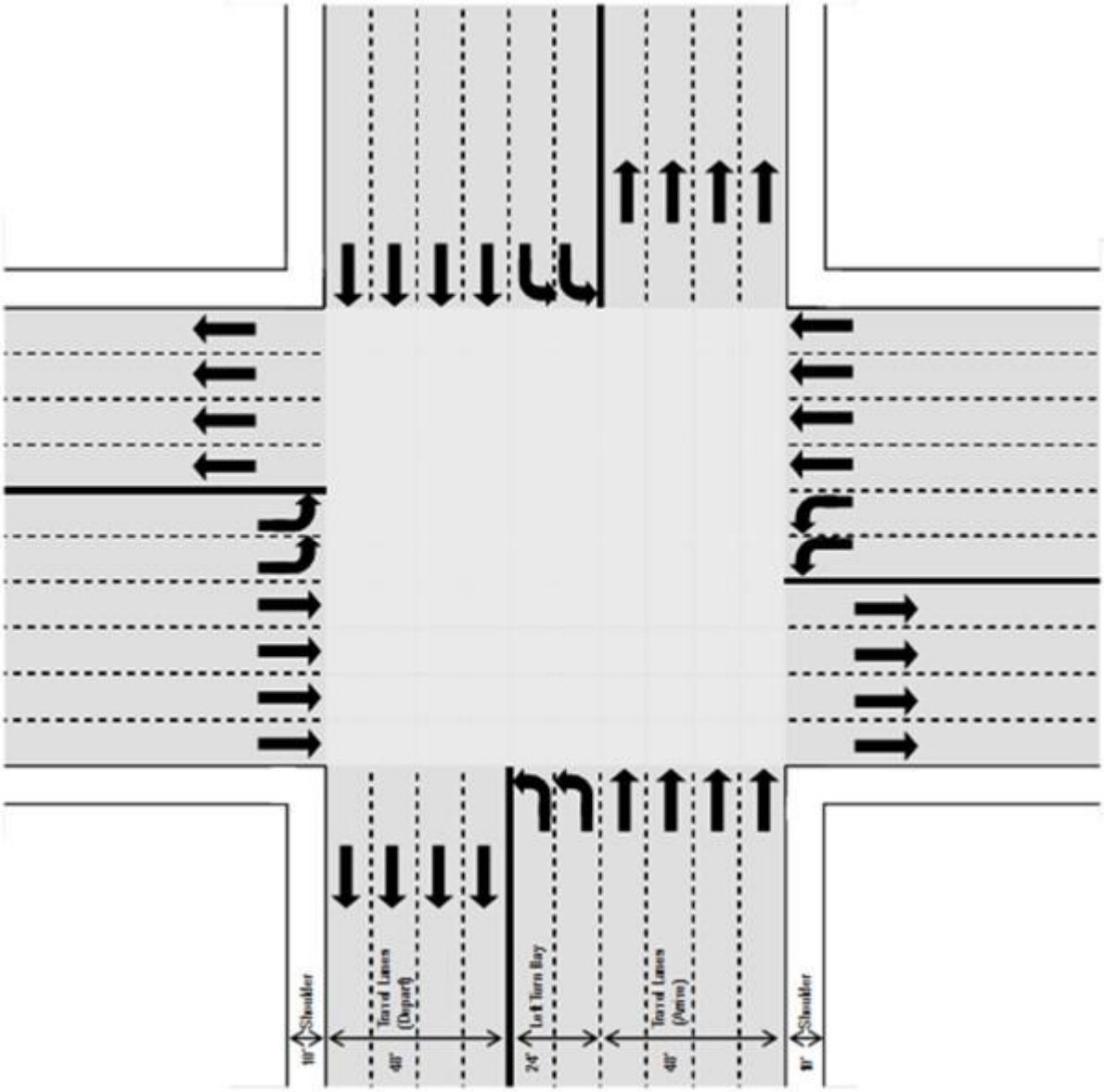


Figure 7 - Typical Modeling Layout for Freeways and Arterials



Notes: Each oncoming direction has 4 approach and 2 left turn lanes as well as 4 departure lanes.

Figure 8 - Intersection Geometry Modeled

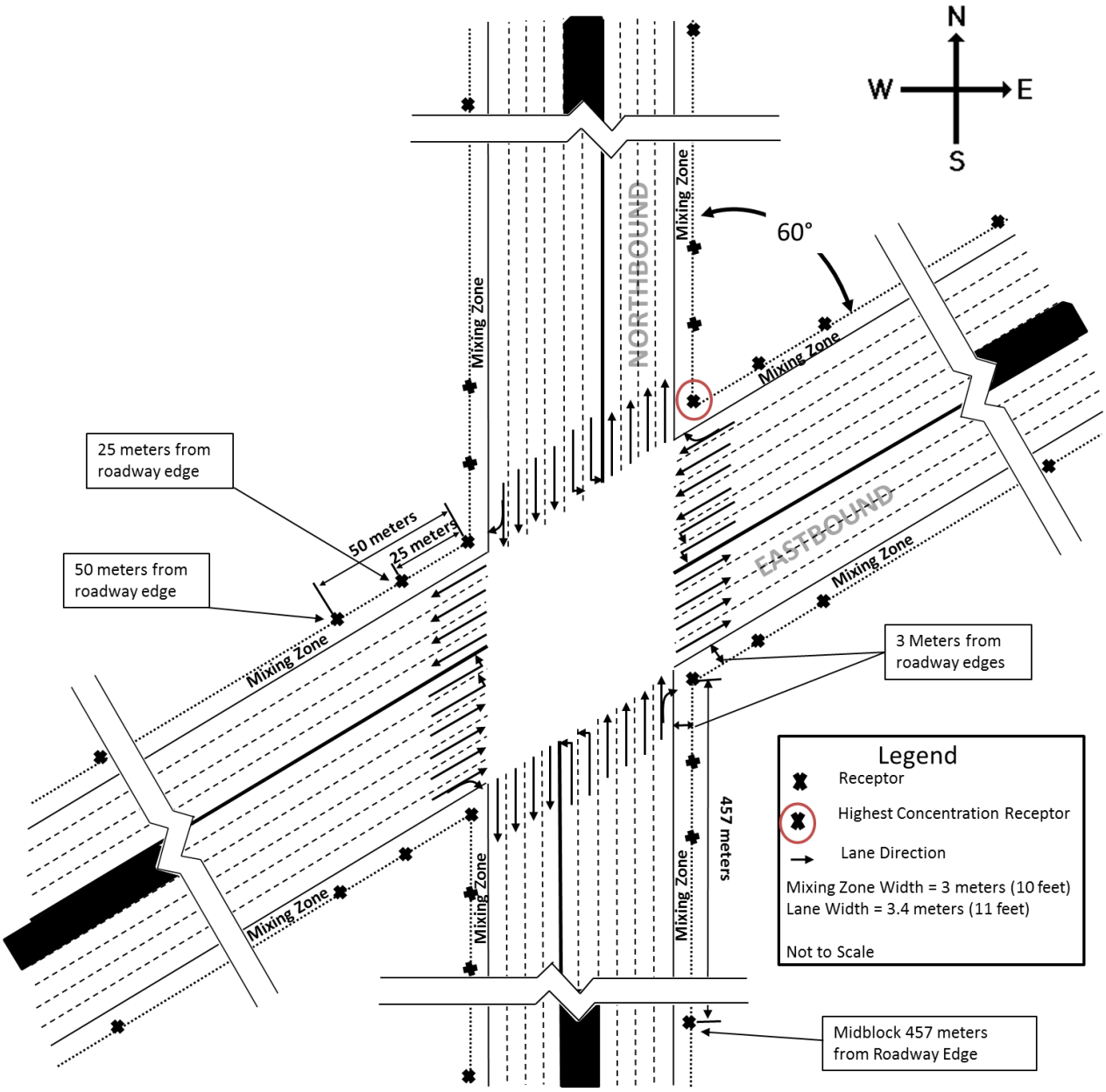


Figure 9 - Geometry Modeled for 60-degree Skew Intersection

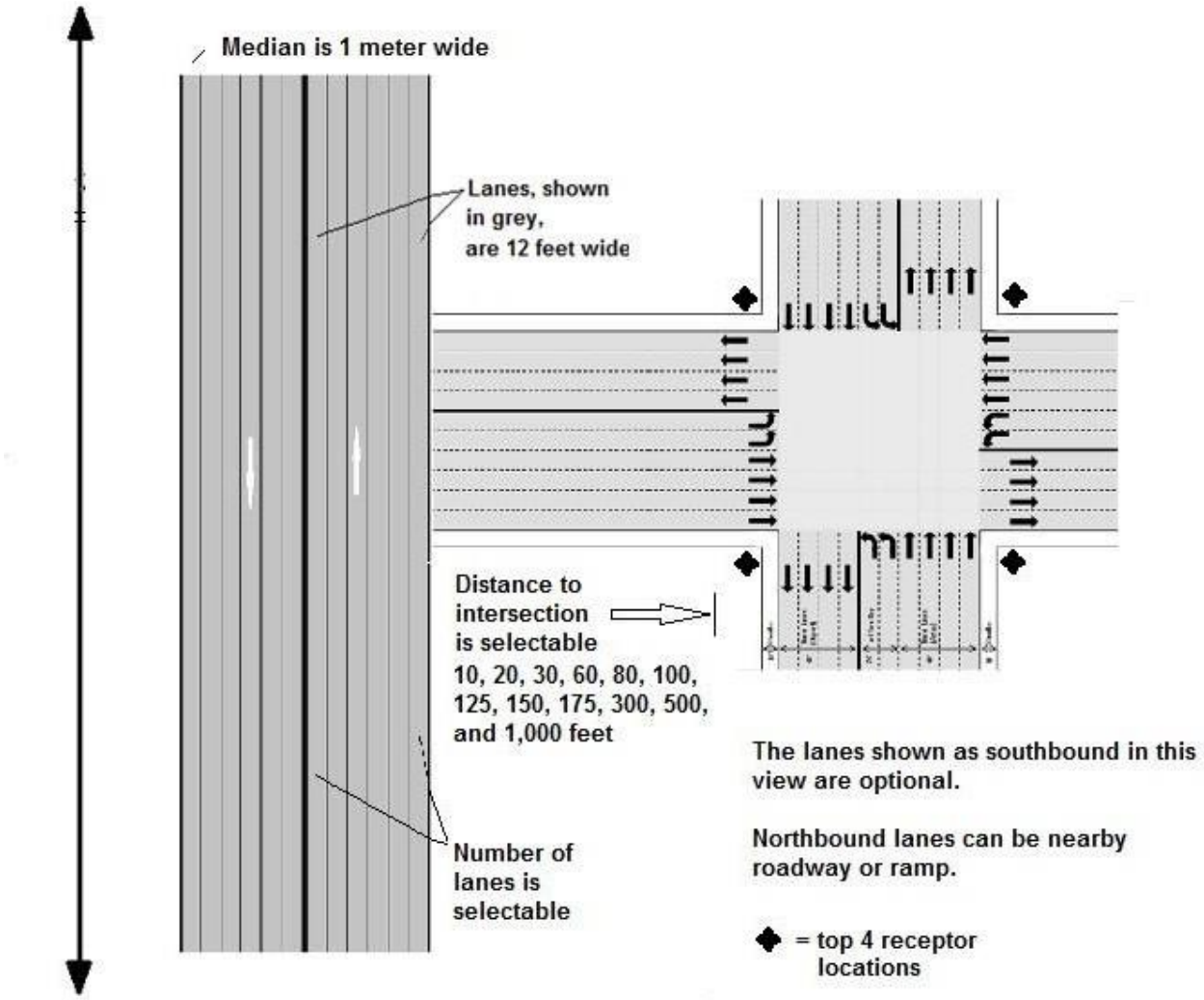


Figure 10 - Interchange Configuration with Nearby Freeway and Intersection/Ramp Layout

5 Background Concentration

For this analysis, 8-hour background concentrations of 3 ppm for urban and 1 ppm for rural areas were used. The urban background value is higher than the 95th percentile national value used in the national scale study as shown for the urban sites in Figure 5, confirming its conservativeness. No comparable, local, rural sites are available for comparison of the rural background value; however, the 1 ppm value is above the recent observed values at the suburban Yorkville site (0.6 ppm), confirming the conservativeness of the CO screening model's background concentrations for Georgia.

For future years mobile sources will remain the primary source of CO emissions nationwide. To adjust for future CO concentrations as a result of emissions rate changes in the mobile source fleet, the changes in CO emissions as projected by MOVES using the conservative gasoline fleet mix were previously explored. The expected trends suggest a reduction in future CO emissions. However, to preserve the conservative, "worst-case" approach, no reductions in future

background levels were assumed for this study. Thus, the results presented in the following Section are representative of years 2020 and later.

6 Persistence Factor

In order to derive an 8-hour CO concentration from the modeled 1-hour CO concentration, a persistence factor was applied to the modeled 1-hour concentration. The persistence factor accounts for variability in traffic (i.e., less traffic during off peak hours) and meteorological conditions (i.e., changes in wind speed, wind direction, and temperature) between the 1-hour time frame and the 8-hour time frame. The persistence factor is the ratio between the maximum 1-hour concentration and the resulting maximum 8-hour concentration in the 8-hour time frame containing the maximum 1-hour concentration. The persistence factor recommended by EPA for a local area is derived from the average of the highest 10 non-overlapping 8-hour CO concentrations over the previous three years.

GDOT uses a persistence factor of 0.6 for all detailed CO air quality analyses. This same factor was applied to this screening level analysis, consistent with that applied in the previous programmatic agreements.[11]

7 Results

The results of the emissions and dispersion modeling coupled with the selected background concentrations and persistence factor values produce an estimate of the impact of a given highway project in terms of CO concentration. These results can then be added to the representative background concentration and compared to NAAQS to determine if a potential project cannot produce CO concentrations high enough to result in an exceedance of the NAAQS and would therefore eligible for the programmatic agreement. The results for the project types and conditions discussed above are presented here.

7.1 Comparison to NAAQS

Results from the dispersion modeling for each facility type, possible geometries, and number of lanes, grade and volume were added to the representative background concentration value. These combined results were compared with the current 1 and 8-hour CO NAAQS to determine if the scenario met or exceeded the standard. The comparison began with project scenarios that yield the highest concentrations and were iterated downward to determine which scenario first passes. The results from the comparison are a set of tables which identify those projects which pass a specific scenario. These results are the basis for the highway project types and conditions identified in the programmatic agreement.

As the 8-hour standard is more conservative, projects were screened based only on that value. In order to compare results to the 8-hour CO standard, the total CO concentration for a given scenario is derived by multiplying the 1-hour modeled project contribution CO concentration by

[11] FHWA-GDOT 2017 Programmatic Agreement for Project-Level Air Quality Analyses for CO Technical Support Document

the persistence factor and then adding the 8-hour CO background concentration:

$$Total\ 8-hour\ CO = 1-hour\ project\ contribution\ \ x\ \ persistence\ factor\ +\ 8-hour\ background$$

7.2 Freeway and Arterials

Based on the MOVES2014b and CAL3QHC (version 04244) inputs and assumptions described above, the maximum 1-hour CO concentrations for urban and rural arterials and freeways were calculated for varying lane, urban or rural setting, and grade combinations. Table 5 shows the lane and grade combinations for arterials and freeways in urban and rural locations that do not produce emissions sufficient to result in an exceedance of the 8-hour CO standard[12].

In all cases, the 8-hour CO standard is the limiting case. Thus, freeway and arterial projects with lane and grade conditions less than or equal to those shown as in compliance through Table 5 also do not require project-specific modeling to demonstrate compliance with the 1-hour CO ambient standard.

7.3 Intersections

Table 6, shows the maximum 1-hour CO concentrations for six approach lane (2 left turn lanes and 4 through lanes), urban and rural intersections that, with the applied, conservative 8-hour urban and rural background level of 3 and 1 ppm and a persistence factor of 0.6, do not produce modeled CO concentrations that could result in exceedances of the 8-hour CO NAAQS. That is, intersection projects of this size or smaller, and with grade and skew angle less than or equal to the prescribed, would not a project-level air quality analysis to demonstrate compliance with CO ambient air quality standards (NAAQS). These results assume the same background and persistence factors previously discussed (sections 5 Background Concentration and 6 Persistence Factor).

Highly congested intersections (whose approach speed is less than 15 mph) and intersections with five or more legs are not covered by the PA, although they too may be added in a future update.

7.4 Interchanges

Table 7, attached, shows the one-hour CO concentrations for these interchange scenarios that, with the assumed 8-hour CO background level and persistence factor, do not produce modeled concentrations that would cause or contribute to an exceedance of the 8-hour CO ambient air standard (NAAQS) and therefore will not require project-specific CO modeling to demonstrate compliance with the ambient CO standards (NAAQS). Although intersections were considered on either side of the freeway, Table 7 only reports the higher of these values. The same speed

[12] Based on an 8-hour CO background concentration of 3 and 1 ppm for urban and rural locations, respectively, and a persistence factor of 0.6

limitations for freeways and arterials from above also apply here.

The intersection geometry is the same as in the intersection case, with six lanes on each approach (4 approach, 2 left turn) and 4 departure lanes, with a 0-7% grade. This is a conservative approach for this type of project because freeway interchanges generally have a one- or two-lane ramp approaching or departing from the intersection. The freeway was modeled at a 0% grade. Both rural and urban locations were modeled.

The table columns represent varying distances from the edge of the nearest freeway travel lane to the edge of the nearest parallel roadway. For the 90-degree skew case, this is also the length of the interchange ramp. The table rows represent the setting (urban or rural), varying numbers of travel lanes on the freeway, and the skew angle of the interchange ramp.

Thus, a rural interchange with a 2-lane freeway and an adjacent intersection that is located not less than 20 feet from the nearest edge of the freeway lanes and connected with a 45-degree angled road segment has a one-hour concentration listed of 6.7 ppm. Since a concentration is listed for this project configuration, it does not exceed the 8-hour CO standard and therefore does not require project-specific CO modeling to demonstrate compliance with the ambient CO standards.

8 Terms of Agreement

For the project types and conditions listed above, project environmental documentation will not require a quantitative air quality analysis for CO. Due to the extensive modeling work performed for the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014)[13] and the National Cooperative Highway Research Project 25-25, Task 78: *Programmatic Agreements for Project-Level Air Quality Analyses* (2015)[14], highway projects that meet the above-listed project conditions and types may address air quality requirements qualitatively with statements such as:

"The proposed project does not exceed the project types and conditions listed in the Programmatic Agreement between the Federal Highway Administration and the State of Georgia Department of Transportation for streamlining the project-level air quality analysis process for carbon monoxide. Modeling using "worst-case" parameters has been conducted for these project types and conditions. It has been determined that projects, such as this one, for which the conditions are not exceeded, would not significantly impact air quality and would not cause or contribute to a new violation, increase the frequency or severity of an existing violation, or delay timely attainment of the National Ambient Air Quality Standards for carbon monoxide."

Or

"An air quality analysis is not necessary as this project will not increase traffic volumes, reduce source-receptor distances, or change other existing conditions to such a degree as to jeopardize

13 See: http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf_2017
14 E. Carr et al., NCHRP 25-25/Task78, "Programmatic Agreements for Project-Level Air Quality Analyses", 2015. See: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

attainment of the National Ambient Air Quality Standards for carbon monoxide."

The technical analysis to support the Programmatic Agreement between the Georgia Division of FHWA and the Georgia Department of Transportation only extends to the project types and conditions listed above. Projects of different types or project having different conditions, i.e., parking lots and garages, tunnels, etc., may require detailed, time intensive project- specific modeling to document compliance with the CO NAAQS. In any case, GDOT may conduct, at its discretion, project-specific modeling for CO for any project, even if the project would otherwise meet the criteria established in this agreement and therefore not require such detailed modeling. Examples of such projects include (but are not limited to) ones for which an environmental impact statement (EIS) is being prepared and ones that may be considered higher profile, i.e., that involve or may involve a greater degree of public and/or stakeholder interest.

The Georgia Department of Transportation will coordinate with Georgia Division of FHWA (and the Georgia Environmental Protection Division) when underlying assumptions related to the Programmatic Agreement may change. This could include, but is not limited to:

- Project types and/or conditions not covered by the Programmatic Agreement;
- Updates to emission or dispersion models or release of new, relevant models;
- Updates to model inputs and/or planning assumptions.

8.1 Attachment to the Technical Support Document

Table 5 - One-hour CO Concentrations (ppm) for Freeways and Arterials[a] in Urban and Rural Locations of Varying Lane and Grade Configuration (not including background concentrations)

Facility Type	Location	Number of Lanes	Grade (percent)							
			0	1	2	3	4	5	6	7
Arterials	Rural	2	2.3	2.4	2.5	2.5	2.8	2.9	3.2	4.1
Arterials	Rural	4	5.2	5.4	5.5	5.8	6.2	6.6	7.2	9.3
Arterials	Rural	6	7	7.2	7.5	7.8	8.4	9	9.8	12.7
Arterials	Rural	8	8.6	8.7	9.1	9.6	10.4	11	12.1	~~15.6~~
Arterials	Rural	10	9.8	10.1	10.6	11.1	11.9	12.7	~~14.1~~	~~18.3~~
Arterials	Rural	12	11	11.3	11.9	12.4	13.3	~~14.2~~	~~15.8~~	~~20.5~~
Arterials	Urban	2	1.5	1.5	1.6	1.6	1.7	1.8	2	2.3
Arterials	Urban	4	3.2	3.3	3.5	3.6	3.9	4.2	4.6	5.5
Arterials	Urban	6	4.4	4.5	4.7	4.9	5.3	5.7	6.3	7.6
Arterials	Urban	8	5.3	5.5	5.8	6	6.5	6.9	7.7	9.4
Arterials	Urban	10	6.1	6.3	6.6	6.9	7.5	8	8.9	~~11.1~~
Arterials	Urban	12	6.7	7	7.4	7.7	8.4	9	10	~~12.5~~
Freeways	Rural	2	1.4	1.5	1.7	2	2.4	2.6	2.9	3
Freeways	Rural	4	3.5	3.9	4.7	5.5	6.3	7.2	7.8	8.1
Freeways	Rural	6	5	5.5	6.6	7.9	9.2	10.4	11.3	11.7
Freeways	Rural	8	6.2	7.1	8.5	10.1	11.8	~~13.4~~	~~14.5~~	~~15.1~~
Freeways	Rural	10	7.3	8.4	10.2	12.1	~~14.2~~	~~16.2~~	~~17.5~~	~~18.3~~
Freeways	Rural	12	8.4	9.6	11.6	~~14~~	~~16.4~~	~~18.7~~	~~20.2~~	~~21.1~~
Freeways	Rural	14	9.2	10.7	12.9	~~15.6~~	~~18.3~~	~~20.9~~	~~22.7~~	~~23.6~~
Freeways	Rural	16	10.1	11.7	~~14.2~~	~~17.1~~	~~20.1~~	~~22.9~~	~~24.9~~	~~26~~
Freeways	Rural	18	10.7	12.5	~~15.3~~	~~18.4~~	~~21.6~~	~~24.7~~	~~26.9~~	~~28~~
Freeways	Rural	20	11.3	13.3	~~16.3~~	~~19.6~~	~~23~~	~~26.4~~	~~28.6~~	~~29.9~~

Table 5 - One-hour CO Concentrations (ppm) for Freeways and Arterials[a] in Urban and Rural Locations of Varying Lane and Grade Configuration (not including background concentrations)

Facility Type	Location	Number of Lanes	Grade (percent)							
			0	1	2	3	4	5	6	7
Freeways	Rural	22	11.9	~~13.9~~	~~17.1~~	~~20.6~~	~~24.4~~	~~27.9~~	~~30.2~~	~~31.6~~
Freeways	Urban	2	0.8	0.9	1.1	1.2	1.4	1.7	1.8	1.8
Freeways	Urban	4	2.2	2.5	2.9	3.4	4	4.6	4.9	5.1
Freeways	Urban	6	3.1	3.5	4.2	5	5.8	6.6	7.3	7.5
Freeways	Urban	8	3.8	4.4	5.4	6.4	7.6	8.6	9.3	9.7
Freeways	Urban	10	4.5	5.2	6.4	7.7	9	~~10.3~~	~~11.2~~	~~11.7~~
Freeways	Urban	12	5.1	6	7.3	8.8	~~10.4~~	~~11.9~~	~~12.9~~	~~13.5~~
Freeways	Urban	14	5.6	6.7	8.1	9.9	~~11.6~~	~~13.3~~	~~14.4~~	~~15.1~~
Freeways	Urban	16	6.1	7.2	8.8	~~10.8~~	~~12.7~~	~~14.6~~	~~15.9~~	~~16.5~~
Freeways	Urban	18	6.4	7.8	9.6	~~11.5~~	~~13.6~~	~~15.7~~	~~17.1~~	~~17.8~~
Freeways	Urban	20	6.8	8.2	~~10.1~~	~~12.3~~	~~14.6~~	~~16.7~~	~~18.2~~	~~19~~
Freeways	Urban	22	7.1	8.6	~~10.7~~	~~13~~	~~15.4~~	~~17.6~~	~~19.2~~	~~20~~

[a] These findings apply to scenarios with average speed ranging from 15 to 52 mph for arterials and 15 to 75 mph for freeways.

Table 6 - One-hour CO Concentrations (not including background concentrations) for Rural and Urban Intersections[b] at Varying Skew Angles and Intersection Grades for a Six Approach Lane Intersection

Location	Skew Angle	Grade (Percent)							
		0	1	2	3	4	5	6	7
Rural	15	8.2	8.3	8.6	8.9	9.5	10	10.7	12.9
Rural	30	6	6.2	6.4	6.7	7.1	7.5	7.9	9.4
Rural	45	6.4	6.3	6.5	6.7	7	7.4	7.8	9
Rural	60	5.6	5.5	5.8	6	6.3	6.5	7	8.2
Rural	90	5.4	5.4	5.7	5.7	6.1	6.3	6.8	8
Urban	15	4.7	4.7	5.1	5.2	5.5	5.8	6.1	6.6
Urban	30	4.3	4.5	4.8	4.8	5.2	5.4	5.8	6.2
Urban	45	3.9	4	4.1	4.3	4.7	4.9	5.1	5.6
Urban	60	3.8	3.8	4	4	4.3	4.6	4.9	5.4
Urban	90	3.5	3.6	3.9	3.7	4.1	4.3	4.6	4.9

[b] These findings apply to scenarios with average speed ranging from 15 to 45 mph for intersections.

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	2	0%	6.7	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.4
Rural	45	2	1%	6.9	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.3
Rural	45	2	2%	7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.5
Rural	45	2	3%	7.2	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.7
Rural	45	2	4%	7.6	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7
Rural	45	2	5%	8	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.6	7.4
Rural	45	2	6%	8.4	8	8	8	8	8	8	8	8	8	7.8
Rural	45	2	7%	9.8	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2	9.2
Rural	60	2	0%	6.6	6.1	6	6	6	6	5.9	5.8	5.8	5.7	5.6
Rural	60	2	1%	6.8	6.1	5.9	5.9	5.9	5.9	5.8	5.7	5.7	5.7	5.5
Rural	60	2	2%	6.8	6.3	6.2	6.2	6.2	6.2	6.1	6	6	5.8	5.8
Rural	60	2	3%	7.2	6.5	6.4	6.4	6.4	6.4	6.3	6.2	6.2	6	6
Rural	60	2	4%	7.5	6.8	6.7	6.7	6.7	6.7	6.6	6.5	6.5	6.3	6.3
Rural	60	2	5%	7.8	7.1	6.9	6.9	6.9	6.9	6.8	6.7	6.7	6.5	6.5
Rural	60	2	6%	8.3	7.6	7.4	7.4	7.4	7.4	7.3	7.2	7.2	7	7
Rural	60	2	7%	9.6	8.9	8.6	8.6	8.6	8.6	8.5	8.4	8.4	8.2	8.2
Rural	90	2	0%	6.6	5.9	5.8	5.8	5.8	5.8	5.7	5.6	5.6	5.6	5.4
Rural	90	2	1%	6.7	6	5.8	5.8	5.8	5.8	5.7	5.6	5.6	5.6	5.4
Rural	90	2	2%	6.9	6.2	6.1	6.1	6.1	6.1	6	5.9	5.9	5.8	5.7
Rural	90	2	3%	7.1	6.4	6.1	6.1	6.1	6.1	6	5.9	5.9	5.8	5.7
Rural	90	2	4%	7.5	6.8	6.5	6.5	6.5	6.5	6.4	6.3	6.3	6.1	6.1
Rural	90	2	5%	7.8	7.1	6.7	6.7	6.7	6.7	6.6	6.5	6.5	6.3	6.3
Rural	90	2	6%	8.3	7.6	7.2	7.2	7.2	7.2	7.1	7	7	6.8	6.8
Rural	90	2	7%	9.6	8.9	8.4	8.4	8.4	8.4	8.3	8.2	8.2	8	8
Rural	45	4	0%	9	7.6	7	7	7	7	7	7	6.8	6.8	6.6

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	4	1%	9.2	7.8	6.9	6.9	6.9	6.9	6.9	6.9	6.7	6.7	6.5
Rural	45	4	2%	9.3	7.9	7.1	7.1	7.1	7.1	7.1	7.1	6.9	6.9	6.7
Rural	45	4	3%	9.5	8.1	7.3	7.3	7.3	7.3	7.3	7.3	7.1	7.1	6.9
Rural	45	4	4%	9.9	8.5	7.6	7.6	7.6	7.6	7.6	7.6	7.4	7.4	7.2
Rural	45	4	5%	10.3	8.9	8	8	8	8	8	8	7.8	7.8	7.6
Rural	45	4	6%	10.7	9.3	8.4	8.4	8.4	8.4	8.4	8.4	8.2	8.2	8
Rural	45	4	7%	12.1	10.7	9.8	9.8	9.7	9.6	9.6	9.6	9.5	9.4	9.2
Rural	60	4	0%	8.9	7.5	6.8	6.7	6.7	6.5	6.5	6.4	6	5.9	5.7
Rural	60	4	1%	9.1	7.7	6.7	6.6	6.6	6.4	6.4	6.3	5.9	5.9	5.7
Rural	60	4	2%	9.1	7.7	7	6.9	6.9	6.7	6.7	6.6	6.2	6	5.8
Rural	60	4	3%	9.5	8.1	7.2	7.1	7.1	6.9	6.9	6.8	6.4	6.2	6
Rural	60	4	4%	9.8	8.4	7.5	7.4	7.4	7.2	7.2	7.1	6.7	6.4	6.3
Rural	60	4	5%	10.1	8.7	7.7	7.6	7.6	7.4	7.4	7.3	6.9	6.6	6.5
Rural	60	4	6%	10.6	9.2	8.2	8.1	8.1	7.9	7.9	7.8	7.4	7.1	7
Rural	60	4	7%	11.9	10.5	9.4	9.3	9.3	9.1	9.1	9	8.6	8.3	8.2
Rural	90	4	0%	8.9	7.5	6.6	6.5	6.4	6.3	6.2	6.2	5.8	5.8	5.6
Rural	90	4	1%	9	7.6	6.6	6.5	6.4	6.3	6.2	6.2	5.8	5.8	5.6
Rural	90	4	2%	9.2	7.8	6.9	6.8	6.7	6.6	6.5	6.5	6.1	6	5.8
Rural	90	4	3%	9.4	8	6.9	6.8	6.7	6.6	6.5	6.5	6.1	6	5.8
Rural	90	4	4%	9.8	8.4	7.3	7.2	7.1	7	6.9	6.9	6.5	6.3	6.1
Rural	90	4	5%	10.1	8.7	7.5	7.4	7.3	7.2	7.1	7.1	6.7	6.5	6.3
Rural	90	4	6%	10.6	9.2	8	7.9	7.8	7.7	7.6	7.6	7.2	7	6.8
Rural	90	4	7%	11.9	10.5	9.2	9.1	9	8.9	8.8	8.8	8.4	8.1	8
Rural	45	6	0%	10.1	8.4	7.5	7.3	7.3	7.2	7.2	7.2	7.1	7	6.8
Rural	45	6	1%	10.3	8.6	7.4	7.3	7.2	7.1	7.1	7.1	7	6.9	6.7

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	6	2%	10.4	8.7	7.7	7.6	7.4	7.3	7.3	7.3	7.2	7.1	6.9
Rural	45	6	3%	10.6	8.9	7.8	7.7	7.6	7.5	7.5	7.5	7.4	7.3	7.1
Rural	45	6	4%	11	9.3	8.2	8.1	7.9	7.8	7.8	7.8	7.7	7.6	7.4
Rural	45	6	5%	11.4	9.7	8.5	8.3	8.3	8.2	8.2	8.2	8.1	8	7.8
Rural	45	6	6%	11.8	10.1	9	8.9	8.7	8.6	8.6	8.6	8.5	8.4	8.2
Rural	45	6	7%	13.2	11.5	10.2	10.1	10	10	10	10	9.8	9.6	9.4
Rural	60	6	0%	10	8.2	7.4	7.3	7.1	7	6.9	6.7	6.2	6.1	5.9
Rural	60	6	1%	10.2	8.4	7.3	7.2	7	6.9	6.8	6.6	6.1	6.1	5.9
Rural	60	6	2%	10.2	8.4	7.6	7.5	7.3	7.2	7.1	6.9	6.4	6.2	6
Rural	60	6	3%	10.6	8.8	7.8	7.7	7.5	7.4	7.3	7.1	6.6	6.4	6.2
Rural	60	6	4%	10.9	9.1	8.1	8	7.8	7.7	7.6	7.4	6.9	6.6	6.4
Rural	60	6	5%	11.2	9.4	8.3	8.2	8	7.9	7.8	7.6	7.1	6.8	6.6
Rural	60	6	6%	11.7	9.9	8.8	8.7	8.5	8.4	8.3	8.1	7.6	7.3	7.1
Rural	60	6	7%	13	11.2	10	9.9	9.7	9.6	9.5	9.3	8.8	8.4	8.2
Rural	90	6	0%	9.9	8.2	7.2	7.1	6.9	6.7	6.7	6.5	6	5.9	5.8
Rural	90	6	1%	10	8.3	7.2	7.1	6.9	6.7	6.7	6.5	6	5.9	5.8
Rural	90	6	2%	10.2	8.5	7.5	7.4	7.2	7	7	6.8	6.3	6.1	6
Rural	90	6	3%	10.4	8.7	7.5	7.4	7.2	7	7	6.8	6.3	6.1	6
Rural	90	6	4%	10.8	9.1	7.9	7.8	7.6	7.4	7.4	7.2	6.7	6.4	6.3
Rural	90	6	5%	11.1	9.4	8.1	8	7.8	7.6	7.6	7.4	6.9	6.6	6.5
Rural	90	6	6%	11.6	9.9	8.6	8.5	8.3	8.1	8.1	7.9	7.4	7.1	7
Rural	90	6	7%	12.9	11.2	9.8	9.7	9.5	9.3	9.3	9.1	8.6	8.2	8
Rural	45	8	0%	11	9	7.9	7.7	7.7	7.5	7.5	7.4	7.4	7.1	7
Rural	45	8	1%	11.2	9.2	8	7.8	7.6	7.4	7.4	7.3	7.3	7	6.9
Rural	45	8	2%	11.3	9.3	8.3	8.1	7.9	7.7	7.6	7.5	7.5	7.2	7.1

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	8	3%	11.5	9.5	8.4	8.2	8	7.8	7.8	7.7	7.7	7.4	7.3
Rural	45	8	4%	11.9	9.9	8.8	8.6	8.4	8.2	8.1	8	8	7.7	7.6
Rural	45	8	5%	12.3	10.3	9	8.8	8.7	8.5	8.5	8.4	8.4	8.1	8
Rural	45	8	6%	12.7	10.7	9.6	9.4	9.2	9	8.9	8.8	8.8	8.5	8.4
Rural	45	8	7%	~~14.1~~	12.1	10.8	10.6	10.4	10.3	10.2	10.2	10	9.8	9.6
Rural	60	8	0%	10.8	8.9	8	7.8	7.6	7.4	7.2	7	6.3	6.3	5.9
Rural	60	8	1%	11	9.1	7.9	7.7	7.5	7.3	7.1	6.9	6.3	6.3	5.9
Rural	60	8	2%	11	9.1	8.2	8	7.8	7.6	7.4	7.2	6.5	6.4	6
Rural	60	8	3%	11.4	9.5	8.4	8.2	8	7.8	7.6	7.4	6.7	6.6	6.2
Rural	60	8	4%	11.7	9.8	8.7	8.5	8.3	8.1	7.9	7.7	7	6.8	6.4
Rural	60	8	5%	12	10.1	8.9	8.7	8.5	8.3	8.1	7.9	7.2	7	6.6
Rural	60	8	6%	12.5	10.6	9.4	9.2	9	8.8	8.6	8.4	7.7	7.5	7.1
Rural	60	8	7%	~~13.8~~	11.9	10.6	10.4	10.2	10	9.8	9.6	8.9	8.4	8.2
Rural	90	8	0%	10.8	8.9	7.7	7.6	7.4	7.2	7	6.8	6.2	6	5.9
Rural	90	8	1%	10.9	9	7.7	7.6	7.4	7.2	7	6.8	6.2	6	5.9
Rural	90	8	2%	11.1	9.2	8	7.9	7.7	7.5	7.3	7.1	6.4	6.2	6.1
Rural	90	8	3%	11.3	9.4	8	7.9	7.7	7.5	7.3	7.1	6.4	6.2	6.1
Rural	90	8	4%	11.7	9.8	8.4	8.3	8.1	7.9	7.7	7.5	6.8	6.5	6.4
Rural	90	8	5%	12	10.1	8.6	8.5	8.3	8.1	7.9	7.7	7	6.7	6.6
Rural	90	8	6%	12.5	10.6	9.1	9	8.8	8.6	8.4	8.2	7.5	7.2	7.1
Rural	90	8	7%	~~13.8~~	11.9	10.3	10.2	10	9.8	9.6	9.4	8.7	8.2	8
Rural	45	10	0%	11.6	9.5	8.4	8.2	8	7.9	7.7	7.7	7.6	7.3	7.2
Rural	45	10	1%	11.8	9.7	8.5	8.3	8.1	7.8	7.6	7.6	7.5	7.2	7.1
Rural	45	10	2%	11.9	9.8	8.8	8.6	8.4	8.1	7.9	7.8	7.7	7.4	7.3
Rural	45	10	3%	12.1	10	8.9	8.7	8.5	8.2	8	8	7.9	7.6	7.5

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	10	4%	12.5	10.4	9.3	9.1	8.9	8.6	8.4	8.3	8.2	7.9	7.8
Rural	45	10	5%	12.9	10.8	9.5	9.3	9.1	8.9	8.7	8.7	8.6	8.3	8.2
Rural	45	10	6%	13.3	11.2	10.1	9.9	9.7	9.4	9.2	9.1	9	8.7	8.6
Rural	45	10	7%	~~14.7~~	12.6	11.3	11.1	10.9	10.7	10.6	10.5	10.3	10	9.8
Rural	60	10	0%	11.5	9.4	8.4	8.2	8.1	7.7	7.5	7.4	6.5	6.4	6.1
Rural	60	10	1%	11.7	9.6	8.3	8.1	8	7.6	7.4	7.3	6.5	6.4	6.1
Rural	60	10	2%	11.7	9.6	8.6	8.4	8.3	7.9	7.7	7.6	6.7	6.5	6.2
Rural	60	10	3%	12.1	10	8.8	8.6	8.5	8.1	7.9	7.8	6.9	6.7	6.4
Rural	60	10	4%	12.4	10.3	9.1	8.9	8.8	8.4	8.2	8.1	7.2	6.9	6.6
Rural	60	10	5%	12.7	10.6	9.3	9.1	9	8.6	8.4	8.3	7.4	7.1	6.8
Rural	60	10	6%	13.2	11.1	9.8	9.6	9.5	9.1	8.9	8.8	7.9	7.6	7.3
Rural	60	10	7%	~~14.5~~	12.4	11	10.8	10.7	10.3	10.1	10	9.1	8.5	8.4
Rural	90	10	0%	11.4	9.3	8.2	8	7.8	7.5	7.3	7.1	6.4	6.2	6
Rural	90	10	1%	11.5	9.4	8.2	8	7.8	7.5	7.3	7.1	6.4	6.2	6
Rural	90	10	2%	11.7	9.6	8.5	8.3	8.1	7.8	7.6	7.4	6.6	6.4	6.2
Rural	90	10	3%	11.9	9.8	8.5	8.3	8.1	7.8	7.6	7.4	6.6	6.4	6.2
Rural	90	10	4%	12.3	10.2	8.9	8.7	8.5	8.2	8	7.8	7	6.7	6.5
Rural	90	10	5%	12.6	10.5	9.1	8.9	8.7	8.4	8.2	8	7.2	6.9	6.7
Rural	90	10	6%	13.1	11	9.6	9.4	9.2	8.9	8.7	8.5	7.7	7.4	7.2
Rural	90	10	7%	~~14.4~~	12.3	10.8	10.6	10.4	10.1	9.9	9.7	8.9	8.3	8.1
Rural	45	12	0%	12	10.4	8.8	8.6	8.4	8.3	8.1	8	7.8	7.6	7.2
Rural	45	12	1%	12.2	10.3	8.9	8.7	8.4	8.2	8	7.9	7.7	7.5	7.1
Rural	45	12	2%	12.3	10.4	9.2	9	8.7	8.5	8.2	8.1	7.9	7.7	7.3
Rural	45	12	3%	12.5	10.5	9.3	9.1	8.8	8.6	8.4	8.3	8.1	7.9	7.5
Rural	45	12	4%	12.9	10.8	9.7	9.5	9.2	9	8.7	8.6	8.4	8.2	7.8

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Rural	45	12	5%	13.3	11.2	9.9	9.7	9.4	9.3	9.1	9	8.8	8.6	8.2
Rural	45	12	6%	~~13.7~~	11.6	10.5	10.3	10	9.8	9.5	9.4	9.2	9	8.6
Rural	45	12	7%	~~15.1~~	13	11.7	11.5	11.2	11	10.9	10.8	10.6	10.2	9.8
Rural	60	12	0%	11.9	10.2	8.9	8.7	8.4	8.2	7.8	7.6	6.7	6.5	6.3
Rural	60	12	1%	12.1	10.1	8.8	8.6	8.3	8.1	7.7	7.5	6.7	6.5	6.3
Rural	60	12	2%	12.1	10.2	9.1	8.9	8.6	8.4	8	7.8	6.8	6.6	6.4
Rural	60	12	3%	12.5	10.3	9.3	9.1	8.8	8.6	8.2	8	7	6.8	6.6
Rural	60	12	4%	12.8	10.6	9.6	9.4	9.1	8.9	8.5	8.3	7.3	7	6.8
Rural	60	12	5%	13.1	10.9	9.8	9.6	9.3	9.1	8.7	8.5	7.5	7.2	7
Rural	60	12	6%	~~13.6~~	11.4	10.3	10.1	9.8	9.6	9.2	9	8	7.7	7.5
Rural	60	12	7%	~~14.9~~	12.7	11.5	11.3	11	10.8	10.4	10.2	9.2	8.8	8.4
Rural	90	12	0%	11.9	10.1	8.7	8.4	8.2	7.8	7.6	7.4	6.7	6.4	6.2
Rural	90	12	1%	12	10.1	8.7	8.4	8.2	7.8	7.6	7.4	6.7	6.4	6.2
Rural	90	12	2%	12.2	10.2	9	8.7	8.5	8.1	7.9	7.7	6.9	6.6	6.4
Rural	90	12	3%	12.4	10.2	9	8.7	8.5	8.1	7.9	7.7	6.9	6.6	6.4
Rural	90	12	4%	12.8	10.5	9.4	9.1	8.9	8.5	8.3	8.1	7.2	6.9	6.7
Rural	90	12	5%	13.1	10.8	9.6	9.3	9.1	8.7	8.5	8.3	7.4	7.1	6.9
Rural	90	12	6%	~~13.6~~	11.3	10.1	9.8	9.6	9.2	9	8.8	7.9	7.6	7.4
Rural	90	12	7%	~~14.9~~	12.6	11.3	11	10.8	10.4	10.2	10	9	8.5	8.3
Urban	45	2	0%	4.5	4.3	4.1	4.1	4.1	4.1	4.1	4.1	3.9	3.9	3.9
Urban	45	2	1%	4.5	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4	4
Urban	45	2	2%	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.3	4.1	4.1
Urban	45	2	3%	4.8	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.3	4.3
Urban	45	2	4%	5.2	5	4.9	4.9	4.9	4.9	4.9	4.9	4.7	4.7	4.7
Urban	45	2	5%	5.4	5.2	5.1	5.1	5.1	5.1	5.1	5.1	4.9	4.9	4.9

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	45	2	6%	5.6	5.4	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.1	5.1
Urban	45	2	7%	6.1	5.9	5.8	5.8	5.8	5.8	5.8	5.8	5.6	5.6	5.6
Urban	60	2	0%	4.3	4.1	4	4	4	4	4	4	3.8	3.8	3.8
Urban	60	2	1%	4.3	4.1	4	4	4	4	4	4	3.9	3.8	3.8
Urban	60	2	2%	4.5	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4	4	4
Urban	60	2	3%	4.5	4.3	4.2	4.2	4.2	4.2	4.2	4.2	4	4	4
Urban	60	2	4%	4.8	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.3	4.3	4.3
Urban	60	2	5%	5.1	4.9	4.8	4.8	4.8	4.8	4.8	4.8	4.6	4.6	4.6
Urban	60	2	6%	5.4	5.2	5.1	5.1	5.1	5.1	5.1	5.1	4.9	4.9	4.9
Urban	60	2	7%	5.9	5.7	5.6	5.6	5.6	5.6	5.6	5.6	5.4	5.4	5.4
Urban	90	2	0%	4.1	3.9	3.7	3.7	3.7	3.7	3.7	3.7	3.5	3.5	3.5
Urban	90	2	1%	4.2	4	3.8	3.8	3.8	3.8	3.8	3.8	3.6	3.6	3.6
Urban	90	2	2%	4.4	4.2	4.1	4.1	4.1	4.1	4.1	4.1	3.9	3.9	3.9
Urban	90	2	3%	4.4	4.2	3.9	3.9	3.9	3.9	3.9	3.9	3.7	3.7	3.7
Urban	90	2	4%	4.6	4.4	4.3	4.3	4.3	4.3	4.3	4.3	4.1	4.1	4.1
Urban	90	2	5%	4.9	4.7	4.5	4.5	4.5	4.5	4.5	4.5	4.3	4.3	4.3
Urban	90	2	6%	5.3	5.1	4.8	4.8	4.8	4.8	4.8	4.8	4.6	4.6	4.6
Urban	90	2	7%	5.5	5.3	5.1	5.1	5.1	5.1	5.1	5.1	4.9	4.9	4.9
Urban	45	4	0%	5.9	5.2	4.6	4.5	4.4	4.3	4.3	4.3	4.1	4.1	3.9
Urban	45	4	1%	5.9	5.2	4.6	4.6	4.5	4.4	4.4	4.4	4.3	4.2	4.1
Urban	45	4	2%	5.9	5.2	4.7	4.7	4.7	4.7	4.6	4.5	4.5	4.3	4.2
Urban	45	4	3%	6.1	5.4	4.9	4.9	4.9	4.9	4.8	4.7	4.7	4.5	4.3
Urban	45	4	4%	6.3	5.6	5.3	5.3	5.2	5.1	5.1	5.1	4.9	4.9	4.7
Urban	45	4	5%	6.6	5.9	5.5	5.5	5.4	5.3	5.3	5.3	5.1	5.1	4.9
Urban	45	4	6%	6.9	6.2	5.7	5.7	5.7	5.7	5.6	5.5	5.5	5.3	5.1

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	45	4	7%	7.3	6.6	6.2	6.2	6.1	6	6	6	5.8	5.8	5.6
Urban	60	4	0%	5.6	4.9	4.4	4.4	4.3	4.2	4.2	4.2	4	4	3.8
Urban	60	4	1%	5.7	5	4.4	4.4	4.3	4.2	4.2	4.2	4.1	4	3.9
Urban	60	4	2%	5.8	5.1	4.6	4.6	4.5	4.4	4.4	4.4	4.2	4.2	4
Urban	60	4	3%	5.8	5.1	4.6	4.6	4.5	4.4	4.4	4.4	4.2	4.2	4
Urban	60	4	4%	6	5.3	4.9	4.9	4.8	4.7	4.7	4.7	4.5	4.5	4.3
Urban	60	4	5%	6.3	5.6	5.2	5.2	5.1	5	5	5	4.8	4.8	4.6
Urban	60	4	6%	6.6	5.9	5.5	5.5	5.4	5.3	5.3	5.3	5.1	5.1	4.9
Urban	60	4	7%	7.1	6.4	6	6	5.9	5.8	5.8	5.8	5.6	5.6	5.4
Urban	90	4	0%	5.5	4.8	4.1	4	4	3.9	3.9	3.9	3.7	3.7	3.7
Urban	90	4	1%	5.6	4.9	4.2	4.1	4.1	4	4	4	3.8	3.8	3.8
Urban	90	4	2%	5.7	5	4.5	4.4	4.4	4.3	4.3	4.3	4.1	4	3.9
Urban	90	4	3%	5.8	5.1	4.4	4.2	4.2	4.1	4.1	4.1	3.9	3.8	3.8
Urban	90	4	4%	6	5.3	4.7	4.6	4.6	4.5	4.5	4.5	4.3	4.2	4.1
Urban	90	4	5%	6.3	5.6	4.9	4.8	4.8	4.7	4.7	4.7	4.5	4.4	4.3
Urban	90	4	6%	6.7	6	5.3	5.1	5.1	5	5	5	4.8	4.7	4.6
Urban	90	4	7%	6.9	6.2	5.5	5.4	5.4	5.3	5.3	5.3	5.1	5	4.9
Urban	45	6	0%	6.6	5.8	4.9	4.7	4.6	4.6	4.5	4.5	4.3	4.1	3.9
Urban	45	6	1%	6.6	5.8	4.9	4.8	4.7	4.7	4.6	4.6	4.5	4.3	4.1
Urban	45	6	2%	6.6	5.8	5.1	5	5	4.9	4.9	4.8	4.7	4.5	4.2
Urban	45	6	3%	6.8	6	5.3	5.2	5.2	5.1	5.1	5	4.9	4.7	4.4
Urban	45	6	4%	7	6.2	5.6	5.5	5.4	5.4	5.3	5.3	5.1	4.9	4.7
Urban	45	6	5%	7.3	6.5	5.8	5.7	5.6	5.6	5.5	5.5	5.3	5.1	4.9
Urban	45	6	6%	7.6	6.8	6.1	6	6	5.9	5.9	5.8	5.7	5.5	5.2
Urban	45	6	7%	8	7.2	6.5	6.4	6.3	6.3	6.2	6.2	6	5.8	5.6

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	60	6	0%	6.3	5.5	4.7	4.6	4.5	4.5	4.4	4.4	4.2	4	3.8
Urban	60	6	1%	6.4	5.6	4.7	4.6	4.5	4.5	4.4	4.4	4.3	4.1	3.9
Urban	60	6	2%	6.5	5.7	4.9	4.8	4.7	4.7	4.6	4.6	4.4	4.2	4
Urban	60	6	3%	6.5	5.7	4.9	4.8	4.7	4.7	4.6	4.6	4.4	4.2	4
Urban	60	6	4%	6.7	5.9	5.2	5.1	5	5	4.9	4.9	4.7	4.5	4.3
Urban	60	6	5%	7	6.2	5.5	5.4	5.3	5.3	5.2	5.2	5	4.8	4.6
Urban	60	6	6%	7.3	6.5	5.8	5.7	5.6	5.6	5.5	5.5	5.3	5.1	4.9
Urban	60	6	7%	7.8	7	6.3	6.2	6.1	6.1	6	6	5.8	5.6	5.4
Urban	90	6	0%	6.2	5.5	4.5	4.3	4.2	4.2	4.1	4.1	3.9	3.9	3.7
Urban	90	6	1%	6.3	5.6	4.6	4.4	4.3	4.3	4.2	4.2	4	4	3.8
Urban	90	6	2%	6.4	5.7	4.8	4.7	4.6	4.6	4.5	4.4	4.3	4.1	3.9
Urban	90	6	3%	6.5	5.7	4.8	4.5	4.4	4.4	4.3	4.2	4.1	4	3.8
Urban	90	6	4%	6.7	5.9	5	4.9	4.8	4.8	4.7	4.6	4.5	4.3	4.1
Urban	90	6	5%	7	6.2	5.3	5.1	5	5	4.9	4.8	4.7	4.5	4.3
Urban	90	6	6%	7.4	6.6	5.7	5.4	5.3	5.3	5.2	5.1	5	4.8	4.6
Urban	90	6	7%	7.6	6.8	5.9	5.7	5.6	5.6	5.5	5.4	5.3	5.1	4.9
Urban	45	8	0%	7.3	6.3	5.3	5	4.8	4.8	4.7	4.6	4.4	4.2	4.1
Urban	45	8	1%	7.3	6.5	5.3	5.1	5	4.9	4.8	4.8	4.6	4.5	4.2
Urban	45	8	2%	7.3	6.5	5.4	5.4	5.2	5.2	5.1	5	4.8	4.6	4.3
Urban	45	8	3%	7.5	6.5	5.6	5.6	5.4	5.4	5.3	5.2	5	4.7	4.5
Urban	45	8	4%	7.7	6.8	5.8	5.8	5.6	5.6	5.5	5.4	5.2	4.9	4.7
Urban	45	8	5%	8	7	6	6	5.8	5.8	5.7	5.6	5.4	5.1	4.9
Urban	45	8	6%	8.3	7.3	6.4	6.4	6.2	6.2	6.1	6	5.8	5.5	5.3
Urban	45	8	7%	8.7	7.7	6.7	6.7	6.5	6.5	6.4	6.3	6.1	5.8	5.6
Urban	60	8	0%	6.9	6.1	5	4.9	4.7	4.7	4.6	4.5	4.2	4	3.9

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	60	8	1%	7	6.2	5.1	4.9	4.8	4.7	4.6	4.6	4.4	4.3	4
Urban	60	8	2%	7.1	6.3	5.2	5.1	4.9	4.9	4.8	4.7	4.4	4.3	4.2
Urban	60	8	3%	7.2	6.4	5.2	5.1	4.9	4.9	4.8	4.7	4.5	4.3	4.1
Urban	60	8	4%	7.3	6.5	5.4	5.4	5.2	5.2	5.1	5	4.8	4.5	4.4
Urban	60	8	5%	7.6	6.7	5.7	5.7	5.5	5.5	5.4	5.3	5	4.8	4.7
Urban	60	8	6%	7.9	7	6	6	5.8	5.8	5.7	5.6	5.4	5.3	5
Urban	60	8	7%	8.4	7.5	6.5	6.5	6.3	6.3	6.2	6.1	5.8	5.6	5.5
Urban	90	8	0%	7	6.2	4.9	4.6	4.4	4.4	4.3	4.3	4.1	3.9	3.9
Urban	90	8	1%	7.1	6.3	5	4.7	4.5	4.5	4.4	4.4	4.2	4	4
Urban	90	8	2%	7.2	6.4	5.1	5	4.8	4.8	4.7	4.6	4.3	4.1	4.1
Urban	90	8	3%	7.1	6.3	5.2	4.8	4.6	4.6	4.5	4.4	4.2	4	4
Urban	90	8	4%	7.3	6.5	5.4	5.2	5	5	4.9	4.8	4.5	4.3	4.3
Urban	90	8	5%	7.6	6.7	5.7	5.4	5.2	5.2	5.1	5	4.7	4.5	4.5
Urban	90	8	6%	8	7.1	6.1	5.7	5.5	5.5	5.4	5.3	5	4.8	4.6
Urban	90	8	7%	8.2	7.3	6.3	6	5.8	5.8	5.7	5.6	5.3	5.1	4.9
Urban	45	10	0%	7.8	6.9	5.6	5.2	5.1	5	5	4.8	4.6	4.3	4.1
Urban	45	10	1%	7.8	7.1	5.6	5.4	5.2	5.2	5.1	5	4.8	4.6	4.3
Urban	45	10	2%	7.8	7.1	5.7	5.6	5.5	5.4	5.4	5.2	5	4.7	4.4
Urban	45	10	3%	8	7.1	5.9	5.8	5.7	5.6	5.6	5.4	5.2	4.9	4.5
Urban	45	10	4%	8.2	7.4	6.1	6	5.9	5.8	5.7	5.6	5.3	5	4.7
Urban	45	10	5%	8.5	7.5	6.3	6.2	6.1	6	5.9	5.8	5.5	5.2	4.9
Urban	45	10	6%	8.8	7.8	6.7	6.6	6.5	6.4	6.4	6.2	6	5.7	5.3
Urban	45	10	7%	9.2	8.2	7	6.9	6.8	6.7	6.7	6.5	6.3	6	5.6
Urban	60	10	0%	7.5	6.8	5.3	5.1	5	4.9	4.8	4.7	4.4	4.1	3.9
Urban	60	10	1%	7.6	6.9	5.4	5.2	5	5	4.9	4.8	4.6	4.4	4.1

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	60	10	2%	7.7	7	5.5	5.3	5.2	5.1	5	4.9	4.6	4.4	4.2
Urban	60	10	3%	7.8	7.1	5.6	5.3	5.2	5.1	5.1	4.9	4.7	4.4	4.1
Urban	60	10	4%	7.9	7.2	5.7	5.6	5.5	5.4	5.4	5.2	5	4.7	4.4
Urban	60	10	5%	8.2	7.4	6	5.9	5.8	5.7	5.5	5.5	5.1	4.9	4.7
Urban	60	10	6%	8.5	7.6	6.3	6.2	6.1	6	5.9	5.8	5.6	5.4	5.1
Urban	60	10	7%	9	8	6.8	6.7	6.6	6.5	6.3	6.3	5.9	5.7	5.5
Urban	90	10	0%	7.6	6.9	5.4	5	4.7	4.6	4.5	4.4	4.3	4.1	3.9
Urban	90	10	1%	7.7	7	5.5	5.1	4.8	4.7	4.6	4.5	4.4	4.2	4
Urban	90	10	2%	7.8	7.1	5.6	5.2	5.1	5	4.8	4.8	4.5	4.3	4.1
Urban	90	10	3%	7.7	7	5.5	5.1	4.9	4.8	4.6	4.6	4.4	4.2	4
Urban	90	10	4%	7.9	7.2	5.7	5.4	5.3	5.2	5	5	4.7	4.5	4.3
Urban	90	10	5%	8.2	7.4	6	5.6	5.5	5.4	5.2	5.2	4.9	4.7	4.5
Urban	90	10	6%	8.6	7.6	6.4	6	5.8	5.7	5.5	5.5	5.1	4.8	4.6
Urban	90	10	7%	8.8	7.8	6.6	6.2	6.1	6	5.8	5.8	5.4	5.1	4.9
Urban	45	12	0%	8.2	7.5	5.9	5.5	5.4	5.3	5.2	5.1	4.8	4.5	4.3
Urban	45	12	1%	8.4	7.7	6.1	5.6	5.5	5.4	5.4	5.2	5	4.7	4.4
Urban	45	12	2%	8.4	7.7	6.1	5.9	5.8	5.7	5.6	5.5	5.2	4.8	4.4
Urban	45	12	3%	8.4	7.7	6.2	6.1	6	5.9	5.8	5.7	5.4	5	4.6
Urban	45	12	4%	8.7	8	6.4	6.2	6.1	6	5.9	5.8	5.5	5.1	4.9
Urban	45	12	5%	8.9	8.1	6.6	6.4	6.3	6.2	6.1	6	5.7	5.3	5.1
Urban	45	12	6%	9.2	8.3	7	6.9	6.8	6.7	6.6	6.5	6.2	5.8	5.4
Urban	45	12	7%	9.6	8.6	7.3	7.2	7.1	7	6.9	6.8	6.5	6.1	5.8
Urban	60	12	0%	8.1	7.4	5.8	5.3	5.2	5.1	5	4.9	4.6	4.3	4.1
Urban	60	12	1%	8.2	7.5	5.9	5.4	5.3	5.2	5.2	5	4.8	4.5	4.1
Urban	60	12	2%	8.3	7.6	6	5.5	5.4	5.3	5.2	5.1	4.8	4.6	4.4

Table 7 - One-hour CO Concentrations at Varying Freeway Distances, Skew Angle, and Lane Configurations (not including background concentrations)[c]

Location	Skew Angle	No. of Lanes	Intersection Grade (Percent)	Distance between Freeway and Intersection (ft)										
				20	30	60	80	100	125	150	175	300	500	1000
Urban	60	12	3%	8.4	7.7	6.1	5.6	5.5	5.4	5.3	5.2	4.9	4.5	4.3
Urban	60	12	4%	8.5	7.8	6.2	5.9	5.8	5.7	5.6	5.5	5.2	4.8	4.6
Urban	60	12	5%	8.7	8	6.4	6.1	6	5.8	5.8	5.6	5.3	5.1	4.9
Urban	60	12	6%	8.9	8.2	6.6	6.4	6.3	6.2	6.2	6	5.8	5.5	5.2
Urban	60	12	7%	9.4	8.4	7.1	6.9	6.8	6.6	6.6	6.4	6.1	5.9	5.7
Urban	90	12	0%	8.2	7.5	5.9	5.3	5	4.8	4.6	4.6	4.4	4.2	3.9
Urban	90	12	1%	8.3	7.6	6	5.4	5.1	4.9	4.7	4.7	4.5	4.3	4
Urban	90	12	2%	8.4	7.7	6.1	5.5	5.3	5.1	5	4.9	4.6	4.4	4.1
Urban	90	12	3%	8.3	7.6	6	5.4	5.1	4.9	4.8	4.7	4.5	4.3	4
Urban	90	12	4%	8.5	7.8	6.2	5.6	5.5	5.3	5.2	5.1	4.8	4.6	4.3
Urban	90	12	5%	8.7	8	6.4	5.8	5.7	5.5	5.4	5.3	5	4.8	4.5
Urban	90	12	6%	9	8.2	6.6	6.2	6	5.8	5.7	5.6	5.3	4.9	4.6
Urban	90	12	7%	9.2	8.3	6.8	6.4	6.3	6.1	6	5.9	5.6	5.2	4.9

[c] These findings apply to scenarios with the intersection average speed ranging from 15 to 45 mph and the freeway average speed ranging from 15 to 75 mph.