“Good Neighbor” Modeling Technical Support Document for 8-Hour Ozone State Implementation Plans Using MOG’s 4kei Modeling Platform

Final Technical Support Document

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1.0 INTRODUCTION

1.1 OVERVIEW

Sections 110(a)(1) and (2) of the Clean Air Act (CAA) require all states to adopt and submit to the U. S. Environmental Protection Agency (EPA) any revisions to their infrastructure State Implementation Plans (SIP) which provide for the implementation, maintenance and enforcement of a new or revised national ambient air quality standard (NAAQS). CAA section 110(a)(2)(D)(i)(I) requires each state to prohibit emissions that will significantly contribute to nonattainment of a NAAQS, or interfere with maintenance of a NAAQS, in a downwind state. The EPA revised the ozone NAAQS in March 2008 and completed the designation process to identify nonattainment areas in July 2012. Under this revision, the 8-hour ozone NAAQS form is the three year average of the fourth highest daily maximum 8-hour ozone concentrations with a threshold not to be exceeded of 0.075 ppm (75 ppb).

On October 1, 2015, EPA promulgated a revision to the ozone NAAQS, lowering the level of both the primary and secondary standards to 70 parts per billion (ppb) (80 FR 65292). Consequently, pursuant to CAA section 110(a), good neighbor SIPs for this revised NAAQS are, due by October 1, 2018.

This document provides a technical support document for 4km air quality modeling and results recently conducted by Alpine Geophysics, LLC (Alpine) under contract to the Midwest Ozone Group (MOG) for purposes of individual state review and preparation of 8-hour ozone modeling analysis in support of revisions of the 2008 and 2015 8-hour ozone Good Neighbor State Implementation Plans (GNS).

This document describes updated modeling activities performed and results developed in order for a state to determine and demonstrate whether they significantly contribute to nonattainment or interfere with maintenance of the 2008 or 2015 ozone NAAQS in a neighboring state. Our initial modeling effort was developed using EPA's national 12km modeling domain (12US2) and further refined as described in this report with two 4km modeling domains over a Mid-Atlantic region and Lake Michigan.

A comprehensive draft Modeling Protocol for the 12km 8-hour ozone SIP revision study was prepared and provided to EPA for comment and review. Based on EPA comments, the draft document was revised (Alpine, 2017a) to include many of the comments and recommendations submitted, most importantly, but not limited to, using EPA's 2023en modeling platform (EPA, 2017a). This 2023en modeling platform represents EPA's estimation of a projected "base case" for demonstration of compliance with final CSAPR update seasonal EGU NOx budgets.
This 4km modeling exercise largely utilized the same platform configuration with new meteorological data prepared for the 4km domains and 4km emissions processed for the two 4km domains to support both attainment demonstration and source apportionment simulations.

1.2 STUDY BACKGROUND

Section 110(a)(2)(D)(i)(I) of the CAA requires that states address the interstate transport of pollutants and ensure that emissions within the state do not contribute significantly to nonattainment in, or interfere with maintenance by, any other state.

On October 26, 2016, EPA published in the Federal Register (81 FR 74504) a final update to the Cross-State Air Pollution Rule (CSAPR) for the 2008 ozone NAAQS. In this final update, EPA outlines its four-tiered approach to addressing the interstate transport of pollution related to the ozone NAAQS, or states' Good Neighbor responsibilities. EPA's approach determines which states contribute significantly to nonattainment areas or significantly interfere with air quality in maintenance areas in downwind states. EPA has determined that if a state's contribution to downwind air quality problems is below one percent of the applicable NAAQS, then it does not consider that state to be significantly contributing to the downwind area's nonattainment or maintenance concerns. EPA's approach to addressing interstate transport has been shaped by public notice and comment and refined in response to court decisions.

As part of the final CSAPR update, EPA released regional air quality modeling to support the 2008 ozone NAAQS attainment date of 2017, indicating which states significantly contribute to nonattainment or maintenance area air quality problems in other states. To make these determinations, the EPA projected future ozone nonattainment and maintenance receptors, then conducted state-level ozone source apportionment modeling to determine which states contributed pollution over a pre-identified "contribution threshold."

A follow-up technical memorandum was issued by EPA on October 27, 2017 (Page, 2017) that provided supplemental information on interstate SIP submissions for the 2008 ozone NAAQS. In this memorandum, EPA provided future year 2023 design value calculations and source contribution results with updated modeling and included background on the four-step process interstate transport framework that the EPA uses to address the good neighbor provision for regional pollutants. The document also explains EPA's choice of 2023 as the new analytic year for the 2008 ozone NAAQS, introduced the "no water" approach to calculating relative response factors (RRFs) at coastal sites, and confirmed that there are no monitoring sites, outside of California, that were projected to be in nonattainment or have maintenance problems with respect to the 2008 ozone NAAQS of 75 ppb in 2023.

Concurrent with EPA's modeling documented in the October 2017 memo, Alpine was conducting good neighbor SIP modeling for the Commonwealth of Kentucky (Alpine, 2017b) using EPA's 2023en modeling platform. This analysis confirmed EPA's "3x3 grid cell" findings and specifically noted that none of the problem monitors identified in EPA's final rule were predicted to be in nonattainment or have issues with maintenance in 2023 and therefore Kentucky (and by extension, any other upwind state) was not required to estimate its contribution to these monitors.

On March 27, 2018, EPA released a technical memorandum (Tsirigotis, 2018a) providing additional information on interstate SIP submissions for the 2015 ozone NAAQS. In this memo, EPA provided incremental results of their 12km modeling using a projection year of 2023, including updated source apportionment results, a “no water” grid cell RRF methodology, and a discussion of potential flexibilities in analytical approaches that an upwind state may consider in developing GNS. As discussed in greater detail in Section 1.3.3, the 2023 future year was selected as the analytic year in EPA’s modeling primarily because it aligned with the anticipated attainment year for Moderate ozone nonattainment areas and because it reflected the timeframe for implementing further emission reductions.

For many months, EPA has considered the appropriateness of the use of its 1% significance test to determine whether an upwind state significantly contributes to downwind non-attainment or interference with downwind maintenance areas. While EPA’s March 27, 2018 memo related to interstate transport state implementation plan submission involving the 2015 ozone NAAQS and provides a set of contributions by upwind states to downwind states, that data is not based on a particular significance threshold. Indeed, that memo identifies the significance threshold as one of the flexibilities that a state may wish to consider in the development of its Good Neighbor SIP. Specifically, EPA offers the following description of this flexibility:

> *Consideration of different contribution thresholds for different regions based on regional differences in the nature and extent of the transport problem.*

On August 31, 2018, EPA issued proposed new guidance (Tsirigotis, 2018b) in which it analyzed 1 ppb and 2 ppb alternatives to the 1% significance level that it has historically used. In that memo, EPA offers the following statement:

> *Based on the data and analysis summarized here, the EPA believes that a threshold of 1 ppb may be appropriate for states to use to develop SIP revisions addressing the good neighbor provisions for the 2015 ozone NAAQS.*

On October 19, 2018, EPA issued final guidance (Tsirigotis, 2018c) in the form of a memorandum entitled “Considerations or Identifying Maintenance Receptors for Use in Clean Air Act Section 110(a)(2)(D)(i)(I) Interstate Transport State Implementation Plan Submissions for the 2015 Ozone National Ambient Air Quality Standards”. That guidance recognizes an alternative methodology for making the determination of the monitor’s status as a maintenance monitor.

EPA’s goal in providing these new guidance documents and data was to assist states’ efforts to develop GNS for the 2015 ozone NAAQS.

Using EPA’s 12km modeling platform, a number of monitors in the eastern U.S. were found to be in nonattainment of the 2015 ozone NAAQS with multiple states demonstrating contribution to projected downwind nonattainment area air quality over the 1% threshold at EPA-identified nonattainment or maintenance monitors. These EPA-identified monitors (Tsirigotis, 2018a) are provided in Table 1-1 along with their 3-yr design value for the period 2014-2016.

As EPA found that multiple state contributions to projected downwind maintenance problems at these monitors is above the 1% threshold and thus significant, additional analyses are required to identify these upwind state responsibilities under the Good Neighbor Provisions for the various ozone NAAQS.

Table 1-1. EPA-identified eastern U.S. nonattainment and maintenance monitors.

			Ozone 8hr Design Value (ppb)						
Monitor	State	County	2009-2013 Avg	2009-2013 Max	2023en "3x3" Avg	2023en "3x3" Max	2023en "No Water" Avg	2023en "No Water" Max	2014-2016
90010017	CT	Fairfield	80.3	83	69.8	72.1	68.9	71.2	80
90013007	CT	Fairfield	84.3	89	71.2	75.2	71.0	75.0	81
90019003	CT	Fairfield	83.7	87	72.7	75.6	73.0	75.9	85
90099002	CT	New Haven	85.7	89	71.2	73.9	69.9	72.6	76
240251001	MD	Harford	90.0	93	71.4	73.8	70.9	73.3	73
260050003	MI	Allegan	82.7	86	69.0	71.8	69.0	71.7	75
261630019	MI	Wayne	78.7	81	69.0	71.0	69.0	71.0	72
360810124	NY	Queens	78.0	80	70.1	71.9	70.2	72.0	69
360850067	NY	Richmond	81.3	83	71.9	73.4	67.1	68.5	76
361030002	NY	Suffolk	83.3	85	72.5	74.0	74.0	75.5	72
480391004	TX	Brazoria	88.0	89	74.0	74.9	74.0	74.9	75
481210034	TX	Denton	84.3	87	69.7	72.0	69.7	72.0	80
482011024	TX	Harris	80.3	83	70.4	72.8	70.4	72.8	79
482011034	TX	Harris	81.0	82	70.8	71.6	70.8	71.6	73
482011039	TX	Harris	82.0	84	71.8	73.6	71.8	73.5	67
484392003	TX	Tarrant	87.3	90	72.5	74.8	72.5	74.8	73
550790085	WI	Milwaukee	80.0	82	65.4	67.0	71.2	73.0	71
551170006	WI	Sheboygan	84.3	87	70.8	73.1	72.8	75.1	79

1.2.2 Purpose

This document primarily serves to provide the air quality modeling and source apportionment results for two 4km grid domains in support of revisions that states may make to their 2008 or 2015 8-hour ozone Good Neighbor State Implementation Plan (GNS). This document establishes that many of the eastern state receptors demonstrate modeled attainment using a finer grid 4km modeling domain (compared to 12km results). In addition, this document demonstrates the significance of international transport, that emissions activities within some states will not significantly contribute to nonattainment or interfere with maintenance of the 2008 or 2015 ozone NAAQS in a neighboring state, and that there may be options available to other states that do demonstrate significant contribution at air quality monitoring sites that qualify as nonattainment or maintenance.

1.3 OVERVIEW OF MODELING APPROACH

The GNS 8-Hour ozone SIP modeling in this technical support document includes an ozone simulation study using the 12 km grid based on EPA's 2023en modeling platform and preliminary source contribution assessment (EPA, 2016b) supplemented with two additional fully nested 4km modeling domains over the Mid-Atlantic region and Lake Michigan.

1.3.1 Episode Selection

Episode selection is an important component of an 8-hour ozone attainment demonstration. EPA guidance recommends that 10 days be used to project 8-hour ozone Design Values at each critical monitor. The May 1 through August 31 2011 ozone season period was selected for the ozone SIP modeling primarily due to the following reasons:

- It is aligned with the 2011 NEI year, which is the latest NEI modeled in a regulatory platform.
- It is not an unusually low ozone concentration year.
- Ambient meteorological and air quality data are available.
- A 2011 12 km CAMx modeling platform was available from the EPA that was leveraged for the GNS ozone SIP modeling.

More details of the summer 2011 episode selection and justification using criteria in EPA's modeling guidance are contained in Section 3.

1.3.2 Model Selection

Details on the rationale for model selection are provided in Section 2. The Weather Research Forecast (WRF) prognostic meteorological model was selected for the GNS ozone modeling using both the EPA 12US2 grid and two additional 4km modeling grids. Additional emission modeling was not required for the 12km simulation as the 2023en platform was provided to Alpine in pre-merged CAMx ready format. For both the base and future years, 4km subgrids were created using the EPA-provided SMOKE emissions input files and the CONUS 4km spatial surrogates developed by EPA for their 2014 modeling platform[1].

Emissions processing was completed by EPA for the 12km domain and Alpine for the two 4km domains using the SMOKE emissions model for most source categories. The exceptions are that BEIS model was used for biogenic emissions and there are special processors for fires, windblown dust, lightning and sea salt emissions. The MOVES2014 on-road mobile source emissions model was used with SMOKE-MOVES to generate on-road mobile source emissions with EPA generated vehicle activity data provided in the NAAQS NODA. The same version of the CAMx photochemical grid model was also used. The setup is based on the same WRF/SMOKE/BEIS/CAMx modeling system used in the EPA 2023en platform modeling with the exception that analysis nudging and cumulus parameterization were not used for the 4km domains.

1.3.3 Base and Future Year Emissions Data

The 2023 future year was selected for the attainment demonstration modeling based upon OAQPS Director Steven Page's October 27, 2017 memo (Page, 2017, page 4) to Regional Air

1 https://www.epa.gov/air-emissions-modeling/2014-version-71-platform

Directors. In this memo, Director Page identified the two primary reasons the EPA selected 2023 for their 2008 NAAQS modeling; (1) the D.C. Circuit Court's response to *North Carolina v. EPA* in considering downwind attainment dates for the 2008 NAAQS, and (2) EPA's consideration of the timeframes that may be required for implementing further emission reductions as expeditiously as possible. The 2011 base case and 2023 future year emissions were based upon EPA's "en" inventories with no adjustment. This platform has been identified by EPA as the base case for compliance with the final CSAPR update seasonal EGU NOx emission budgets.

1.3.4 Input Preparation and QA/QC

Quality assurance (QA) and quality control (QC) of the emissions datasets are some of the most critical steps in performing air quality modeling studies. Because emissions processing is tedious, time consuming and involves complex manipulation of many different types of large databases, rigorous QA measures are a necessity to prevent errors in emissions processing from occurring. The GNS 8-Hour ozone modeling study utilized EPA's pre-QA/QC'd emissions platform that followed a multistep emissions QA/QC approach for the 12km domain. Additional tabular and graphical review of the 4km emissions was conducted to ensure consistency with the 12km modeling results on spatial, temporal, and speciated levels.

1.3.5 Meteorology Input Preparation and QA/QC

The CAMx 2011 12 km meteorological inputs are based on WRF meteorological modeling conducted by EPA. Details on the EPA 2011 WRF application and evaluation are provided by EPA (EPA 2014d). Additional WRF simulations were conducted to generate meteorological data fields to support the 4km modeling domains. A performance evaluation of this incremental modeling was prepared (Alpine, 2018a) and confirmed adequacy of the files for SIP attainment and contribution analyses.

1.3.6 Initial and Boundary Conditions Development

Initial concentrations (IC) and Boundary Conditions (BC) are important inputs to the CAMx model. We ran 15 days of model spin-up before the first high ozone days occur in the modeling domain so the ICs are washed out of the modeling domain before the first high ozone day of the May-August 2011 modeling period. The lateral boundary and initial species concentrations are provided by a three dimensional global atmospheric chemistry model, GEOS-Chem (Yantosca, 2004) standard version 8-03-02 with 8-02-01 chemistry.

The 4km domains were modeled as two-way interactive nests within the 12km simulation and therefore were provided with updated boundary conditions at each integration time step and provided up-scale feedback from the 4km domains to the 12km domain.

1.3.7 Air Quality Modeling Input Preparation and QA/QC

Each step of the air quality modeling was subjected to QA/QC procedures. These procedures included verification of model configurations, confirmation that the correct data were used and processed correctly, and other procedures.

1.3.8 Model Performance Evaluation

The Model Performance Evaluation (MPE) relied on the 12km CAMx MPE from EPA's associated modeling platforms. EPA's MPE recommendations in their ozone modeling guidance (EPA, 2018) were followed in this evaluation. Many of EPA's MPE procedures have already been performed by EPA in their CAMx 2011 modeling database being used in the GNS ozone SIP modeling. An additional MPE was prepared by Alpine (Alpine, 2018c) to support the 4km domains and confirmed the adequacy of the analysis for SIP and contribution analyses.

1.3.9 Diagnostic Sensitivity Analyses

Since no issues were identified in confirming Alpine's 12km CAMx runs compared to EPA's using the same modeling platform and configuration, additional diagnostic sensitivity analyses were not required.

2.0 MODEL SELECTION

This section documents the models used in this 8-hour ozone GNS SIP modeling study. The selection methodology presented in this chapter mirrors EPA's and other's regulatory modeling in support of the 2008 Ozone NAAQS Preliminary Interstate Transport Assessment (Page, 2017; Alpine, 2017; EPA, 2016b) and technical memorandum providing additional information on the Interstate SIP submissions for the 2015 Ozone NAAQS (Tsirigotis, 2018a).

Unlike previous ozone modeling guidance that specified a particular ozone model (e.g., EPA, 1991 that specified the Urban Airshed Model; Morris and Myers, 1990), the EPA now recommends that models be selected for ozone SIP studies on a "case-by-case" basis. The latest EPA ozone guidance (EPA, 2018) explicitly mentions the CMAQ and CAMx PGMs as the most commonly used PGMs that would satisfy EPA's selection criteria but notes that this is not an exhaustive list and does not imply that they are "preferred" over other PGMs that could also be considered and used with appropriate justification. EPA's current modeling guidelines lists the following criteria for model selection (EPA, 2018):

- It should not be proprietary;
- It should have received a scientific peer review;
- It should be appropriate for the specific application on a theoretical basis;
- It should be used with data bases which are available and adequate to support its application;
- It should be shown to have performed well in past modeling applications;
- It should be applied consistently with an established protocol on methods and procedures;
- It should have a user's guide and technical description;
- The availability of advanced features (e.g., probing tools or science algorithms) is desirable; and
- When other criteria are satisfied, resource considerations may be important and are a legitimate concern.

For the GNS 8-hour ozone modeling, we used the WRF/SMOKE/MOVES2014/BEIS/CAMx/OSAT modeling system was used as the primary tool for demonstrating attainment of the ozone NAAQS at downwind monitors at downwind problem monitors. The utilized modeling system satisfies all of EPA's selection criteria. A description of the key models to be used in the GNS ozone SIP modeling follows.

WRF/ARW: The Weather Research and Forecasting (WRF)[2] Model is a mesoscale numerical weather prediction system designed to serve both operational forecasting and atmospheric research needs (Skamarock, 2004; 2006; Skamarock et al., 2005). The Advanced Research WRF (ARW) version of WRF was used in this ozone modeling study. It features multiple dynamical cores, a 3-dimensional variational (3DVAR) data assimilation system, and a software architecture allowing for computational parallelism and system extensibility. WRF is suitable

[2] http://www.wrf-model.org/index.php

for a broad spectrum of applications across scales ranging from meters to thousands of kilometers. The effort to develop WRF has been a collaborative partnership, principally among the National Center for Atmospheric Research (NCAR), the National Oceanic and Atmospheric Administration (NOAA), the National Centers for Environmental Prediction (NCEP) and the Forecast Systems Laboratory (FSL), the Air Force Weather Agency (AFWA), the Naval Research Laboratory, the University of Oklahoma, and the Federal Aviation Administration (FAA). WRF allows researchers the ability to conduct simulations reflecting either real data or idealized configurations. WRF provides operational forecasting a model that is flexible and efficient computationally, while offering the advances in physics, numerics, and data assimilation contributed by the research community.

SMOKE: The Sparse Matrix Operator Kernel Emissions (SMOKE)[3] modeling system is an emissions modeling system that generates hourly gridded speciated emission inputs of mobile, non-road, area, point, fire and biogenic emission sources for photochemical grid models (Coats, 1995; Houyoux and Vukovich, 1999). As with most 'emissions models', SMOKE is principally an emission processing system and not a true emissions modeling system in which emissions estimates are simulated from 'first principles'. This means that, with the exception of mobile and biogenic sources, its purpose is to provide an efficient, modern tool for converting an existing base emissions inventory data into the hourly gridded speciated formatted emission files required by a photochemical grid model. SMOKE was used by EPA to prepare 2023en emission inputs for non-road mobile, area and point sources. These files were adopted and used as-is for this analysis.

SMOKE-MOVES: SMOKE-MOVES uses an Emissions Factor (EF) Look-Up Table from MOVES, gridded vehicle miles travelled (VMT) and other activity data and hourly gridded meteorological data (typically from WRF) and generates hourly gridded speciated on-road mobile source emissions inputs.

MOVES2014: MOVES2014[4] is EPA's latest on-road mobile source emissions model that was first released in July 2014 (EPA, 2014a,b,c). MOVES2014 includes the latest on-road mobile source emissions factor information. Emission factors developed by EPA were used in this analysis.

BEIS: Biogenic emissions were modeled by EPA using version 3.61 of the Biogenic Emission Inventory System (BEIS). First developed in 1988, BEIS estimates volatile organic compound (VOC) emissions from vegetation and nitric oxide (NO) emissions from soils. Because of resource limitations, recent BEIS development has been restricted to versions that are built within the Sparse Matrix Operational Kernel Emissions (SMOKE) system.

CAMx: The Comprehensive Air quality Model with Extensions (CAMx[5]) is a state-of-science "One-Atmosphere" photochemical grid model capable of addressing ozone, particulate matter (PM), visibility and acid deposition at regional scale for periods up to one year (ENVIRON,

3 http://www.smoke-model.org/index.cfm
4 http://www.epa.gov/otaq/models/moves/
5 http://www.camx.com

2015[6]). CAMx is a publicly available open-source computer modeling system for the integrated assessment of gaseous and particulate air pollution. Built on today's understanding that air quality issues are complex, interrelated, and reach beyond the urban scale, CAMx is designed to (a) simulate air quality over many geographic scales, (b) treat a wide variety of inert and chemically active pollutants including ozone, inorganic and organic $PM_{2.5}$ and PM_{10} and mercury and toxics, (c) provide source-receptor, sensitivity, and process analyses and (d) be computationally efficient and easy to use. The U.S. EPA has approved the use of CAMx for numerous ozone and PM State Implementation Plans throughout the U.S., and has used this model to evaluate regional mitigation strategies including those for most recent regional rules (e.g., Transport Rule, CAIR, NO_X SIP Call, etc.). CAMx Version 6.40 was used in this study.

OSAT: The Ozone Source Apportionment Technique (OSAT) tool of CAMx was selected to develop source contribution and significant contribution calculations and was applied for this analysis.

SMAT-CE: The Software for the Modeled Attainment Test - Community Edition (SMAT-CE)[7] is an EPA developed PC-based software tool that can perform the modeled attainment tests for particulate matter and ozone, and calculate changes in visibility at Class I areas as part of the reasonable progress analysis for regional haze. Version 1.2 (Beta) was used in this analysis.

6 http://www.camx.com/files/camxusersguide_v6-20.pdf

7 https://www.epa.gov/scram/photochemical-modeling-tools

3.0 EPISODE SELECTION

EPA’s most recent 8-hour ozone modeling guidance (EPA, 2018) contains recommended procedures for selecting modeling episodes The GNS ozone SIP revision modeling used the May through end of August 2011 modeling period because it satisfies the most criteria in EPA’s modeling guidance episode selection discussion.

EPA guidance recommends that 10 days be used to project 8-hour ozone Design Values at each critical monitor. The May through August 2011 period has been selected for the ozone SIP modeling primarily due to being aligned with the 2011 NEI year, not being an unusually low ozone year and availability of a 2011 12 km CAMx modeling platform from the EPA NAAQS NODA.

4.0 MODELING DOMAIN SELECTION

This section summarizes the modeling domain definitions for the GNS 8-hour ozone modeling, including the domain coverage, resolution, and map projection. It also discusses emissions, aerometric, and other data available for use in model input preparation and performance testing.

4.1 HORIZONTAL DOMAINS

The GNS ozone SIP modeling used a 12 km continental U.S. (12US2) domain and two 4 km subnested domains; one over the Mid-Atlantic region and another over Lake Michigan and surrounding states.

The 12 km nested grid modeling domain configuration is shown in Figure 4-1 with the two 4km domains represented in Figure 4-2. The 12km domain shown in Figure 4-1 represents the CAMx 12km air quality and SMOKE/BEIS emissions modeling domain. The WRF meteorological modeling was run on larger 12 km modeling domains than used for CAMx as demonstrated in EPA's meteorological model performance evaluation document (EPA, 2014d). The WRF meteorological modeling domains are defined larger than the air quality modeling domains because meteorological models can sometimes produce artifacts in the meteorological variables near the boundaries as the prescribed boundary conditions come into dynamic balance with the coupled equations and numerical methods in the meteorological model.

Figure 4-1. Map of 12km CAMx modeling domains. Source: EPA NAAQS NODA.

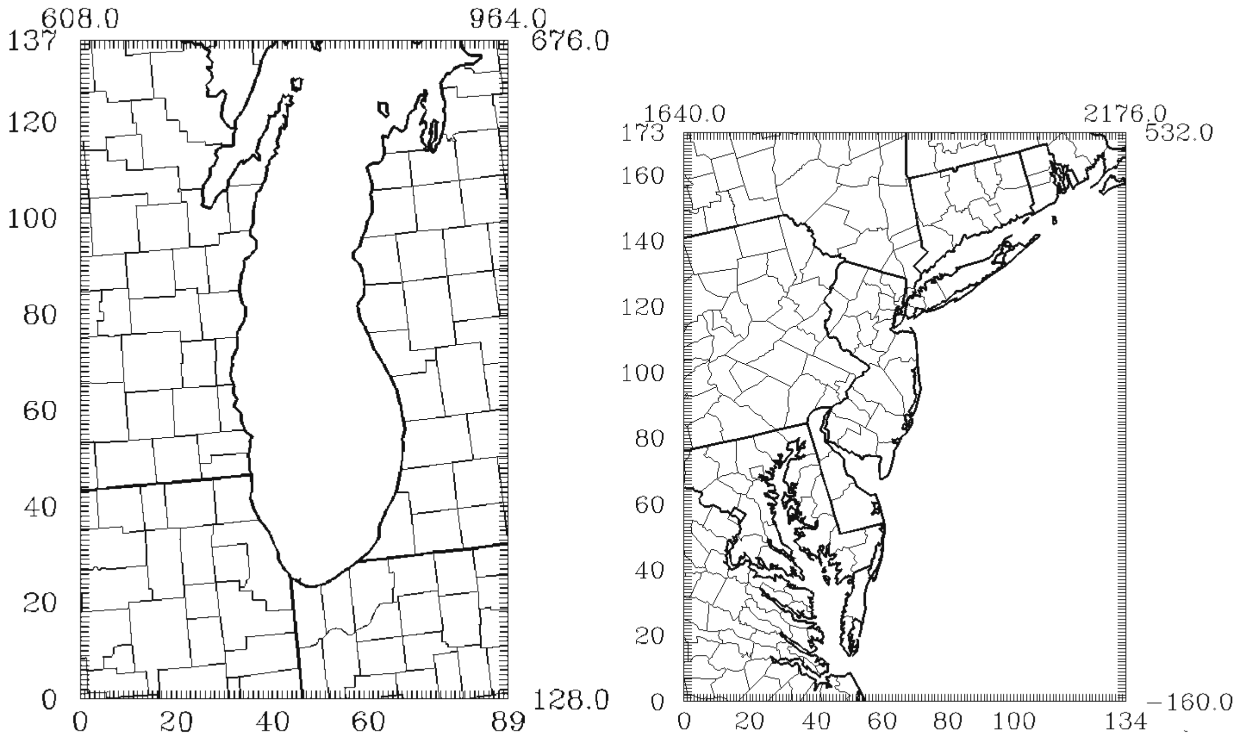

Figure 4-2. Maps of 4km CAMx modeling domains. Lake Michigan (left) and Mid-Atlantic (right).

4.2 VERTICAL MODELING DOMAIN

The CAMx vertical structure is primarily defined by the vertical layers used in the WRF meteorological modeling. The WRF model employs a terrain following coordinate system defined by pressure, using multiple layer interfaces that extend from the surface to 50 mb (approximately 19 km above sea level). EPA and Alpine ran WRF using 35 vertical layers. A layer averaging scheme is adopted for CAMx simulations whereby multiple WRF layers are combined into one CAMx layer to reduce the air quality model computational time. Table 4-1 displays the approach for collapsing the WRF 35 vertical layers to 25 vertical layers in CAMx for the 12km and 4km grid domains.

Table 4-1. WRF and CAMx layers and their approximate height above ground level.

CAMx Layer	WRF Layers	Sigma P	Pressure (mb)	Approx. Height (m AGL)
25	35	0.00	50.00	17,556
	34	0.05	97.50	14,780
24	33	0.10	145.00	12,822
	32	0.15	192.50	11,282
23	31	0.20	240.00	10,002
	30	0.25	287.50	8,901
22	29	0.30	335.00	7,932
	28	0.35	382.50	7,064
21	27	0.40	430.00	6,275
	26	0.45	477.50	5,553
20	25	0.50	525.00	4,885
	24	0.55	572.50	4,264
19	23	0.60	620.00	3,683
18	22	0.65	667.50	3,136
17	21	0.70	715.00	2,619
16	20	0.74	753.00	2,226
15	19	0.77	781.50	1,941
14	18	0.80	810.00	1,665
13	17	0.82	829.00	1,485
12	16	0.84	848.00	1,308
11	15	0.86	867.00	1,134
10	14	0.88	886.00	964
9	13	0.90	905.00	797
	12	0.91	914.50	714
8	11	0.92	924.00	632
	10	0.93	933.50	551
7	9	0.94	943.00	470
	8	0.95	952.50	390
6	7	0.96	962.00	311
5	6	0.97	971.50	232
4	5	0.98	981.00	154
	4	0.99	985.75	115
3	3	0.99	990.50	77
2	2	1.00	995.25	38
1	1	1.00	997.63	19

4.3 DATA AVAILABILITY

The CAMx modeling systems requires emissions, meteorology, surface characteristics, initial and boundary conditions (IC/BC), and ozone column data for defining the inputs.

4.3.1 Emissions Data

Without exception, the 2011 base year and 2023 base case emissions inventories for ozone modeling for this analysis were based on emissions obtained from the EPA's "en" modeling platform. This platform was obtained from EPA, via LADCO, in late September of 2017 and represents EPA's best estimate of all promulgated national, regional, and local control strategies, including final implementation of the seasonal EGU NOx emission budgets outlined in CSAPR.

4.3.2 Air Quality

Data from ambient monitoring networks for gas species are used in the model performance evaluation. Table 4-2 summarizes routine ambient gaseous and PM monitoring networks available in the U.S.

4.3.4 Meteorological Data

The 12km meteorological data were generated by EPA using the WRF prognostic meteorological model (EPA, 2014d). Alpine adjusted the physics options and configurations EPA used for the 12km domain to be appropriate for the 4km domain.. WRF was run on a continental U.S. 12 km grid for the NAAQS NODA platform and for two subnested 4km domains as described in earlier sections.

4.3.5 Initial and Boundary Conditions Data

The lateral boundary and initial species concentrations are provided by a three dimensional global atmospheric chemistry model, GEOS-Chem (Yantosca, 2004) standard version 8-03-02 with 8-02-01 chemistry. The global GEOS-Chem model simulates atmospheric chemical and physical processes driven by assimilated meteorological observations from the NASA's Goddard Earth Observing System (GEOS-5; additional information available at: http://gmao.gsfc.nasa.gov/GEOS/ and http://wiki.seas.harvard.edu/geos-chem/index.php/GEOS-5). This model was run for 2011 with a grid resolution of 2.0 degrees x 2.5 degrees (latitude-longitude). The predictions were used to provide one-way dynamic boundary concentrations at one-hour intervals and an initial concentration field for the CAMx simulations. The 2011 boundary concentrations from GEOS-Chem will be used for the 2011 and 2023 model simulations.

The 4km domains were run as two-way interactive nests within the 12km simulation and therefore provided with updated boundary conditions at each integration time step and provided up-scale feedback from the 4km domains to the 12km domain.

Table 4-2. Overview of routine ambient data monitoring networks.

Monitoring Network	Chemical Species Measured	Sampling Period	Data Availability/Source
The Interagency Monitoring of Protected Visual Environments (IMPROVE)	Speciated PM25 and PM10 (see species mappings)	1 in 3 days; 24 hr average	
Clean Air Status and Trends Network (CASTNET)	Speciated PM25, Ozone (see species mappings)	Approximately 1-week average	http://www.epa.gov/castnet/data.html
National Atmospheric Deposition Program (NADP)	Wet deposition (hydrogen (acidity as pH), sulfate, nitrate, ammonium, chloride, and base cations (such as calcium, magnesium, potassium and sodium)), Mercury	1-week average	http://nadp.sws.uiuc.edu/
Air Quality System (AQS) or Aerometric Information Retrieval System (AIRS)	CO, NO2, O3, SO2, PM25, PM10, Pb	Typically hourly average	http://www.epa.gov/air/data/
Chemical Speciation Network (CSN)	Speciated PM	24-hour average	http://www.epa.gov/ttn/amtic/amticpm.html
Photochemical Assessment Monitoring Stations (PAMS)	Varies for each of 4 station types.		http://www.epa.gov/ttn/amtic/pamsmain.html
National Park Service Gaseous Pollutant Monitoring Network	Acid deposition (Dry; SO4, NO3, HNO3, NH4, SO2), O3, meteorological data	Hourly	http://www2.nature.nps.gov/ard/gas/netdata1.htm

5.0 MODEL INPUT PREPARATION PROCEDURES

This section summarizes the procedures used in developing the meteorological, emissions, and air quality inputs to the CAMx model for the GNS 8-hour ozone modeling on the 12 km and 4 km grids for the May through August 2011 period. Both the 12 km and 4 km CAMx modeling databases are based on the EPA "en" platform (EPA, 2017a; Page, 2017) databases. While some of the data prepared by EPA for this platform are new, many of the files are largely based on the NAAQS NODA platform. More details on the NAAQS NODA 2011 CAMx database development are provided in EPA documentation as follows:

- Technical Support Document (TSD) Preparation of Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform (EPA, 2016a).
- Meteorological Model Performance for Annual 2011 WRF v3.4 Simulation (EPA, 2014d).
- Air Quality Modeling Technical Support Document for the 2015 Ozone NAAQS Preliminary Interstate Transport Assessment (EPA, 2016b).

The modeling procedures used in the modeling are consistent with over 20 years of EPA ozone modeling guidance documents (e.g., EPA, 1991; 1999; 2005a; 2007; 2014e, 2018), other recent 8-hour ozone modeling studies conducted for various State and local agencies using these or other state-of-science modeling tools (see, for example, Morris et al., 2004a,b, 2005a,b; 2007; 2008a,b,c; Tesche et al., 2005a,b; Stoeckenius et al., 2009; ENVIRON, Alpine and UNC, 2013; Adelman, Shanker, Yang and Morris, 2014; 2015), as well as the methods used by EPA in support of the recent Transport analysis (EPA, 2010; 2015b, 2016b, 2018).

5.1 METEOROLOGICAL INPUTS

5.1.1 WRF Model Science Configuration

For the 12km domain, Version 3.4 of the WRF model, Advanced Research WRF (ARW) core (Skamarock, 2008) was used for generating the 2011 simulations. Selected physics options include Pleim-Xiu land surface model, Asymmetric Convective Model version 2 planetary boundary layer scheme, KainFritsch cumulus parameterization utilizing the moisture-advection trigger (Ma and Tan, 2009), Morrison double moment microphysics, and RRTMG longwave and shortwave radiation schemes (Gilliam and Pleim, 2010). The WRF model configuration was prepared by EPA (EPA, 2014d).

The 4km domains were prepared using a nested WRF 3.9 simulation with domains shown in Figure 5-1. This domain, a 36km continental domain and a 12km domain that extends from the western border of the Dakotas off the eastern seaboard has two focused 4km domains over Lake Michigan and the Mid-Atlantic states. The WRF configuration options used in the 4km simulation were the same as those used by EPA, with the exception that no cumulus parameterization and grid nudging was used on the 4km domains. A summary of the 4km WRF application and evaluation are presented elsewhere (Alpine, 2018a).

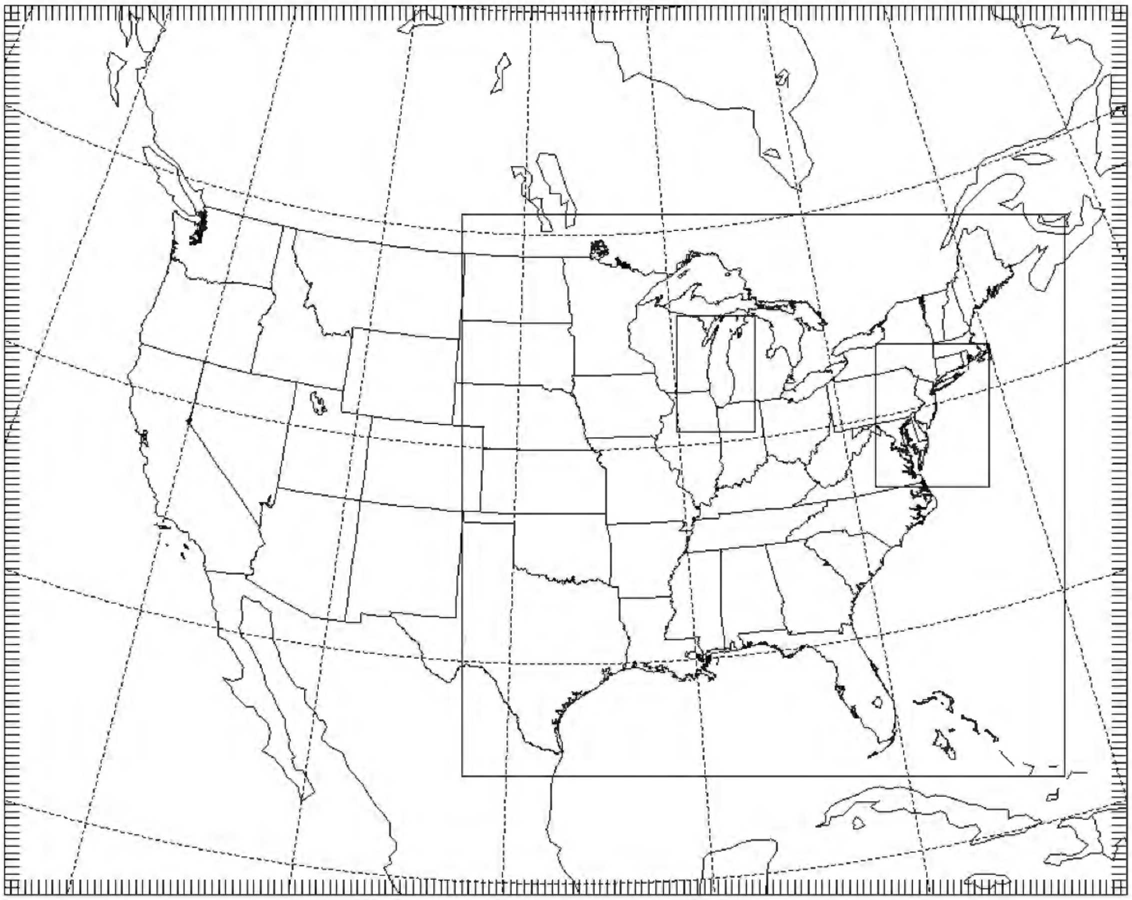

Figure 5-1. Map of WRF domains. The outer domain is the 36km CONUS domain, the large domain is the 12km domain and the inner are the Lake Michigan (left) and Mid-Atlantic (right) 4km domains.

5.1.2 WRF Input Data Preparation Procedures

For the 4km domain a summary of the WRF input data preparation procedures that were used are listed in EPA's documentation (EPA, 2014d). A summary of the 4km WRF application and evaluation are presented elsewhere (Alpine, 2018a).

5.1.3 WRF Model Performance Evaluation

The WRF model evaluation approach was based upon a combination of qualitative and quantitative analyses. The quantitative analysis was divided into monthly summaries of 2-m temperature, 2-m mixing ratio, and 10-m wind speed using the boreal seasons to help generalize the model bias and error relative to a set of standard model performance benchmarks. The qualitative approach was to compare spatial plots of model estimated monthly total precipitation with the monthly PRISM precipitation. The WRF model performance evaluation for the 12km domain is provided in EPA's documentation (EPA, 2014d). A separate MPE for the 4km WRF simulations was prepared by Alpine (Alpine, 2018a). This evaluation is comprised of a quantitative and qualitative evaluation of WRF generated fields. The quantitative model performance evaluation of WRF using surface meteorological measurements was performed using the publicly available METSTAT[8] evaluation tool. METSTAT calculates statistical performance metrics for bias, error and correlation for surface winds, temperature and mixing ratio and can produce time series of predicted and observed meteorological variables and performance statistics. Alpine also conducted a qualitative comparison of WRF estimated precipitation with the Climate Prediction Center (CPC) retrospective analysis data.

5.1.4 WRFCAMx/MCIP Reformatting Methodology

The WRF meteorological model output data was processed to provide inputs for the CAMx photochemical grid model. The WRFCAMx processor maps WRF meteorological fields to the format required by CAMx. It also calculates turbulent vertical exchange coefficients (Kv) that define the rate and depth of vertical mixing in CAMx. The methodology used by EPA to reform the meteorological data into CAMx format is provided in documentation provided with the wrfcamx conversion utility.

The meteorological data generated by the WRF simulations were processed by EPA using WRFCAMx v4.3 (Ramboll Environ, 2014) meteorological data processing program to create model-ready meteorological inputs to CAMx. The 4km domains were processed using WRFCAMx v4.6[9]. In running WRFCAMx, vertical eddy diffusivities (Kv) were calculated using the Yonsei University (YSU) (Hong and Dudhia, 2006) mixing scheme with a minimum Kv of 0.1 m2/sec except for urban grid cells where the minimum Kv was reset to 1.0 m2/sec within the lowest 200 m of the surface in order to enhance mixing associated with the night time “urban heat island” effect. In addition, all domains used the subgrid convection and subgrid stratoform stratiform cloud options in our wrfcamx.

5.2 EMISSION INPUTS

5.2.1 Available Emissions Inventory Datasets

EPA’s 2011 base year and 2023 future year emission inventories from the “en” modeling platform (EPA, 2017a) were used for all categories without exception.

5.2.2 Development of CAMx-Ready Emission Inventories

CAMx-ready emission inputs were generated by EPA mainly by the SMOKE and BEIS emissions models. CAMx requires two emission input files for each day: (1) low level gridded emissions that are emitted directly into the first layer of the model from sources at the surface with little or no plume rise; and (2) elevated point sources (stacks) with plume rise calculated from stack parameters and meteorological conditions. For this analysis, CAMx was operated using version 6 revision 4 of the Carbon Bond chemical mechanism (CB6r4).

Additional emission modeling was not required for the 12km simulation as the 2023en platform was provided to Alpine in pre-merged near CAMx ready format. For the base and future years, 4km subgrids were created using the EPA-provided SMOKE emissions input files and the CONUS 4km spatial surrogates developed by EPA for the 2014 platform modeling.

8 http://www.camx.com/download/support-software.aspx

9 http://www.camx.com/getmedia/7f3ee9dc-d430-42d6-90d5-dedb3481313f/wrfcamx-11jul17.tgz

5.2.2.1 Episodic Biogenic Source Emissions

Biogenic emissions were generated by EPA using the BEIS biogenic emissions model within SMOKE. BEIS uses high resolution GIS data on plant types and biomass loadings and the WRF surface temperature fields, and solar radiation (modeled or satellite-derived) to develop hourly emissions for biogenic species on the 12 km grids. BEIS generates gridded, speciated, temporally allocated emission files.

5.2.2.2 Point Source Emissions

2011 point source emissions were from the 2011 "en" modeling platform. Point sources were developed in two categories: (1) major point sources with Continuous Emissions Monitoring (CEM) devices; and (2) point sources without CEMs. For point sources with continuous emissions monitoring (CEM) data, day-specific hourly NOx and SO2 emissions were used for the 2011 base case emissions scenario. The VOC, CO and PM emissions for point sources with CEM data were based on the annual emissions temporally allocated to each hour of the year using the CEM hourly heat input. The locations of the point sources were converted to the LCP coordinate system used in the modeling. They were processed by EPA using SMOKE to generate the temporally varying (i.e., day-of-week and hour-of-day) speciated emissions needed by CAMx, using profiles by source category from the EPA "en" modeling platform. Because the elevated point source locations are allocated directly to the grid, rather than by spatial surrogate, rerunning the elevated emissions for the 4km grids was not required.

5.2.2.3 Area and Non-Road Source Emissions

2011 area and non-road emissions were from the 2011 "en" modeling platform. The area and non-road sources were spatially allocated to the grid using an appropriate surrogate distribution (e.g., population for home heating, etc.). The area sources were temporally allocated by month and by hour of day using the EPA source-specific temporal allocation factors. The SMOKE source-specific CB6 speciation allocation profiles were also used.

5.2.2.4 Wildfires, Prescribed Burns, Agricultural Burns

Fire emissions in 2011NEIv2 were developed based on Version 2 of the Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation (SMARTFIRE) system (Sullivan, et al., 2008). SMARTFIRE2 was the first version of SMARTFIRE to assign all fires as either prescribed burning or wildfire categories. In past inventories, a significant number of fires were published as unclassified, which impacted the emissions values and diurnal emissions pattern. Recent updates to SMARTFIRE include improved emission factors for prescribed burning.

5.2.2.5 On-Road Motor Vehicle Emissions

On-road motor vehicle emissions were processed using the SMOKE-MOVES module. The MOVES emissions factors table for the 2011 on-road segments were combined with the 2011 4km meteorology and 4km spatial surrogates to create actual 4km resolution for the on-road emissions.

5.2.2.6 QA/QC and Emissions Merging

EPA processed the emissions by major source category in several different "streams", including area sources, on-road mobile sources, non-road mobile sources, biogenic sources, non-CEM point sources, CEM point sources using day-specific hourly emissions, and emissions from fires. Separate Quality Assurance (QA) and Quality Control (QC) were performed for each stream of emissions processing and in each step following the procedures utilized by EPA. SMOKE includes advanced quality assurance features that include error logs when emissions are dropped or added. In addition, we generated visual displays that included spatial plots of the hourly emissions for each major species (e.g., NOX, VOC, some speciated VOC, SO2, NH3, PM and CO). Emissions for the 4km subgrids were reprocessed using the same emissions streams, lookup and cross reference tables, and adjustment factors as used by the EPA.

Scripts to perform the emissions merging of the appropriate biogenic, on-road, non-road, area, low-level, fire, and point emission files were written to generate the CAMx-ready two-dimensional day and domain-specific hourly speciated gridded emission inputs. The point source and, as available elevated fire, emissions were processed into the day-specific hourly speciated emissions in the CAMx-ready point source format.

The resultant CAMx model-ready emissions were subjected to a final QA using spatial maps to assure that: (1) the emissions were merged properly; (2) CAMx inputs contain the same total emissions; and (3) to provide additional QA/QC information.

In addition, the 4km subgrid nest results were compared with the results from original EPA files that had been windowed from the 12km to the 4km domains. This provided assurance that all of the segments were being represented properly in the new subgrids.

5.2.3 Use of the Plume-in-Grid (PiG) Subgrid-Scale Plume Treatment

Consistent with the EPA 2011 modeling platform, no PiG subgrid-scale plume treatment was used.

5.2.4 Future-Year Emissions Modeling

Future-year emission inputs were generated by processing the 2023 emissions data provided with EPA's "en" modeling platform without exception.

5.3 PHOTOCHEMICAL MODELING INPUTS

5.3.1 CAMx Science Configuration and Input Configuration

Version of CAMx (Version 6.40) was used in the GNS ozone modeling. The CAMx model setup used is defined by EPA in its air quality modeling technical support documents (EPA, 2016b, 2017, 2018).

6.0 MODEL PERFORMANCE EVALUATION

The CAMx 2011 base case model estimates are compared against the observed ambient ozone and other concentrations to establish that the model is capable of reproducing the current year observed concentrations so it is likely a reliable tool for estimating future year ozone levels.

6.1 MODEL PERFORMACE EVALUATION

6.1.1 Overview of EPA Model Performance Evaluation Recommendations

EPA current (EPA, 2018) ozone modeling guidance recommendations for model performance evaluation (MPE) describes a MPE framework that has four components:

- Operation evaluation that includes statistical and graphical analysis aimed at determining how well the model simulates observed concentrations (i.e., does the model get the right answer).
- Diagnostic evaluation that focuses on process-oriented evaluation and whether the model simulates the important processes for the air quality problem being studied (i.e., does the model get the right answer for the right reason).
- Dynamic evaluation that assess the ability of the model air quality predictions to correctly respond to changes in emissions and meteorology.
- Probabilistic evaluation that assess the level of confidence in the model predictions through techniques such as ensemble model simulations.

EPA's guidance recommends that "At a minimum, a model used in an attainment demonstration should include a complete operational MPE using all available ambient monitoring data for the base case model simulations period". And goes on to say "*Where practical, the MPE should also include some level of diagnostic evaluation*." EPA notes that there is no single definite test for evaluation model performance, but instead there are a series of statistical and graphical MPE elements to examine model performance in as many ways as possible while building a "weight of evidence" (WOE) that the model is performing sufficiently well for the air quality problem being studied.

6.1.2 MPE Results

Because this 2011 ozone modeling is using a CAMx 2011 modeling database developed by EPA, we include by reference the air quality modeling performance evaluation as conducted by EPA (EPA, 2016b) on the national 12km domain. Alpine additionally conducted an MPE on the 4km domains (Alpine, 2018b) that generated results consistent with the 12km simulation and configuration.

In summary, EPA conducted an operational model performance evaluation for ozone to examine the ability of the CAMx v6.32 and v.6.40 modeling systems to simulate 2011 measured concentrations. This evaluation focused on graphical analyses and statistical metrics of model predictions versus observations. Details on the evaluation methodology, the calculation of performance statistics, and results are provided in Appendix A of that report.

Overall, the ozone model performance statistics for the CAMx v6.32 2011 simulation are similar to those from the CAMx v6.20 2011 simulation performed by EPA for the final CSAPR Update. The 2011 CAMx model performance statistics are within or close to the ranges found in other recent peer-reviewed applications (Simon et al, 2012). As described in Appendix A of the AQ TSD, the predictions from the 2011 modeling platform correspond closely to observed concentrations in terms of the magnitude, temporal fluctuations, and geographic differences for 8-hour daily maximum ozone.

Alpine conducted a separate operational model performance evaluation for the two 4km modeling domains (Alpine, 2018c) and found that 4km domains for the 2011en platform performed similarly to EPA's 12km MPE that fell within or close to the ranges found in other recent peer-reviewed applications (Simon et al, 2012). Thus, the model performance results demonstrate the scientific credibility of the two 4km domains using the 2011 modeling platform chosen and used for this analysis. These results provide confidence in the ability of the modeling platform to provide a reasonable projection of expected future year ozone concentrations and contributions over the two 4km grids.

7.0 FUTURE YEAR MODELING

This chapter discusses the future year modeling used in the GNS 8-hour ozone modeling effort.

7.1 FUTURE YEAR TO BE SIMULATED

As discussed in Section 1, to support the 2008 and 2015 ozone NAAQS preliminary interstate transport assessment, EPA conducted air quality modeling to project ozone concentrations at individual monitoring sites to 2023 and to estimate state-by-state contributions to those 2023 concentrations. The projected 2023 ozone concentrations were used to identify ozone monitoring sites that are projected to be nonattainment or have maintenance problems for the two ozone NAAQS in 2023 and for which upwind states have been identified as significant contributors.

7.2 FUTURE YEAR GROWTH AND CONTROLS

In September 2017, EPA released the revised "en" modeling platform that was the source for the 2023 future year emissions in this analysis. This platform has been identified by EPA as the base case for compliance with the final CSAPR update seasonal EGU NOx emission budgets. Additionally, there were several emission categories and model inputs/options that were held constant at 2011 levels as follows:

- Biogenic emissions.
- Wildfires, Prescribed Burns and Agricultural Burning (open land fires).
- Windblown dust emissions.
- Sea Salt.
- 36 km CONUS domain Boundary Conditions (BCs).
- 2011 12 km meteorological conditions.
- All model options and inputs other than emissions.

The effects of climate change on the future year meteorological conditions were not accounted. It has been argued that global warming could increase ozone due to higher temperatures producing more biogenic VOC and faster photochemical reactions (the so called climate penalty). However, the effects of inter-annual variability in meteorological conditions will be more important than climate change given the 12 year difference between the base (2011) and future (2023) years. It has also been noted that the level of ozone being transported into the U.S. from Asia has also increased.

7.3 FUTURE YEAR BASELINE AIR QUALITY SIMULATIONS

A 2023 future year base case CAMx simulation was conducted and 2023 ozone design value projection calculations were made based on EPA's latest ozone modeling guidance (EPA, 2018) for the 12US2 and two 4km modeling domains in this analysis.

7.3.1 Identification of Future Nonattainment and Maintenance Receptors

The ozone predictions from the 2011 and 2023 CAMx model simulations were used to project 2009-2013 average and maximum ozone design values to 2023 following the approach described in the EPA's guidance for attainment demonstration modeling (EPA, 2018). Using the approach in the final CSAPR Update, the 2023 projected average and maximum design values were evaluated in conjunction with the most recent measured ozone design values (i.e., 2015-2017) to identify sites that may warrant further consideration as potential nonattainment or maintenance sites in 2023.

If the approach in the CSAPR Update is applied to evaluate the projected design values, those sites with 2023 average design values that exceed the NAAQS (i.e., 2023 average design values of 71 ppb or greater) and that are currently measuring nonattainment would be considered to be nonattainment receptors in 2023. Similarly, with the CSAPR Update approach, monitoring sites with a projected 2023 maximum design value that exceeds the NAAQS would be projected to be maintenance receptors in 2023. In the CSAPR Update approach, maintenance-only receptors include both those monitoring sites where the projected 2023 average design value is below the NAAQS, but the maximum design value is above the NAAQS, and monitoring sites with projected 2023 average design values that exceed the NAAQS, but for which current design values based on measured data do not exceed the NAAQS.

As documented in EPA's March 2018 technical memorandum (Tsirigotis, 2018a), EPA used results of CAMx v6.40 to model emissions in 2011 and 2023 to project base period 2009-2013 average and maximum ozone design values to 2023 at monitoring sites nationwide. In projecting these future year design values, EPA applied its own modeling guidance, which recommends using model predictions from the "3x3" array of grid cells surrounding the location of the monitoring site. In response to comments submitted on the January 2017 NODA and other analyses, EPA also projected 2023 design values based on a modified version of the "3x3" approach for those monitoring sites located in coastal areas (Tsirigotis, 2018a). This modeling was intended as an alternate approach to addressing complex meteorological monitor locations without having to rerun the simulations on finer grid scales.

Alpine's applied approach in developing and using 4km grid domains further followed EPA's guidance recommendation that "grid resolution finer than 12 km would generally be more appropriate for areas with a combination of complex meteorology, strong gradients in emissions sources, and/or land-water interfaces in or near the nonattainment area(s)." (EPA, 2018).

The finer grid resolution and the Software for the Modeled Attainment Test - Community Edition (SMAT-CE) tool was used consistent with EPA's 12km attainment demonstration modeling methods calculating relative response factors and "3x3" neighborhoods (EPA, 2018). Alpine also prepared 2023 projected average and maximum design values in conjunction with the most recent measured ozone design values (2015-2017) to identify sites in these 4km domains that may warrant further consideration as potential nonattainment or maintenance sites in 2023.

After applying the approach outlined in the final CSAPR update (and described above) to evaluate the projected design values from the 4km analysis, a list of nonattainment and maintenance monitors located within these two 4km domains resulting from the approach were developed. Modeled nonattainment monitors defined using Alpine's 4km simulation are provided in Table 7-1 along with their calculated 2023 average and maximum design values from both EPA's "no water" calculation approach and Alpine's 4km simulation (4kei) and most current 2015-2017 design values. Similarly, Table 7-2 presents the modeled maintenance monitors with their calculated average and maximum design values from both simulations and the most current 2015-2017 design value data. Monitors originally designated as nonattainment or maintenance by EPA using their "no water" calculation and found to be neither nonattainment or maintenance using Alpine's 4km modeling are presented in Table 7-3. A full list of monitor locations and modeled average and maximum ozone design values for the 4km domain modeling is provided in Appendix A of this report.

Table 7-1. Alpine 4km Modeling-identified nonattainment monitors in the 4km domains.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		Alpine Updated 4kei Modeling		
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	2015-2017 DV
551170006	WI	Sheboygan	84.3	72.8	75.1	71.5	73.8	80

Table 7-2. Alpine 4km Modeling-identified maintenance monitors in the 4km domains.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		Alpine Updated 4kei Modeling		
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	2015-2017 DV
90013007	CT	Fairfield	84.3	71.0	75.0	69.2	73.1	83
90019003	CT	Fairfield	83.7	73.0	75.9	68.3	71.0	83
90099002	CT	New Haven	85.7	69.9	72.6	68.9	71.5	82
240251001	MD	Harford	90.0	70.9	73.3	70.9	73.3	75
260050003	MI	Allegan	82.7	69.0	71.7	70.0	72.8	73
340150002	NJ	Gloucester	84.3	68.2	70.4	68.8	71.0	74
360850067	NY	Richmond	81.3	67.1	68.5	69.6	71.0	76
361030002	NY	Suffolk	83.3	74.0	75.5	70.6	72.0	76

Table 7-3. Alpine 4km modeling-identified attainment monitors in the 4km domains previously identified by EPA as nonattainment or maintenance.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		Alpine Updated 4kei Modeling		2015-2017 DV
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	
90010017	CT	Fairfield	80.3	68.9	71.2	66.8	69.0	79
90110124	CT	New London	80.3	67.3	70.4	66.0	69.1	76
360810124	NY	Queens	78.0	70.2	72.0	68.5	70.2	74
421010024	PA	Philadelphia	83.3	67.3	70.3	67.5	70.5	78
550790085	WI	Milwaukee	80.0	71.2	73.0	67.1	68.8	71

The procedures for calculating projected 2023 average and maximum design values are described in Section 3.2 of EPA's air quality technical support document (EPA, 2016b). The only noted differences are that Alpine used 4km modeling results, compared to EPA's 12km, compared modeled design values with 3yr design values from 2015-2017, and did not remove "no water" cells from the 4km calculation as further described in the March 2018 memorandum.

8.0 OZONE CONTRIBUTION MODELING

Alpine further performed region and source category-level ozone source apportionment modeling using the CAMx Ozone Source Apportionment Technology (OSAT) technique to provide information regarding the expected contribution of 2023 base case NOx and VOC emissions from each category within each region to projected 2023 concentrations at downwind air quality monitors. This OSAT modeling was conducted for both the Lake Michigan and the Mid-Atlantic 4km domains.

The source apportionment model run tracked the ozone formed from each of the following contribution categories (i.e., "tags"):

- Regions –NOx and VOC emissions from each state or state group tracked individually using the category "tags" listed below;
    - Biogenic/Fires;
    - Anthropogenic Emissions;
- Boundary and Initial Concentrations – concentrations transported into the modeling domain (e.g., international transport, stratospheric intrusion, domain initialization conditions);
- Canada, Mexico, and over water domains – anthropogenic emissions from sources in the portions of Canada and Mexico included in the modeling domain and from sources in the Pacific and Atlantic Oceans or from the Gulf of Mexico or Great Lakes associated with offshore or ocean going (C3) commercial marine vessel activities.

The contribution modeling conducted for this analysis provided contribution to ozone from source regions, informed by MOG's 12km OSAT modeling and displayed in Figure 8-1, for each noted source category individually. In contrast to EPA's contribution modeling using the OSAT/Anthropogenic Precursor Culpability Analysis (APCA) technique, Alpine's OSAT technique assigns ozone formed from biogenic VOC and NOx emissions that reacts with anthropogenic NOx and VOC to the biogenic category. EPA's technique of using OSAT/APCA assigns to the anthropogenic emission total the combined ozone formed from reactions between biogenic VOC and NOx with anthropogenic NOx and VOC. Alpine's position on the selection of the OSAT technique has been documented elsewhere[10].

[10] http://midwestozonegroup.com/files/SourceApportionmentScenarioModelingResultsandComparisontothe2017CrossStateAirPollutionRuleModelingPlatform.pdf

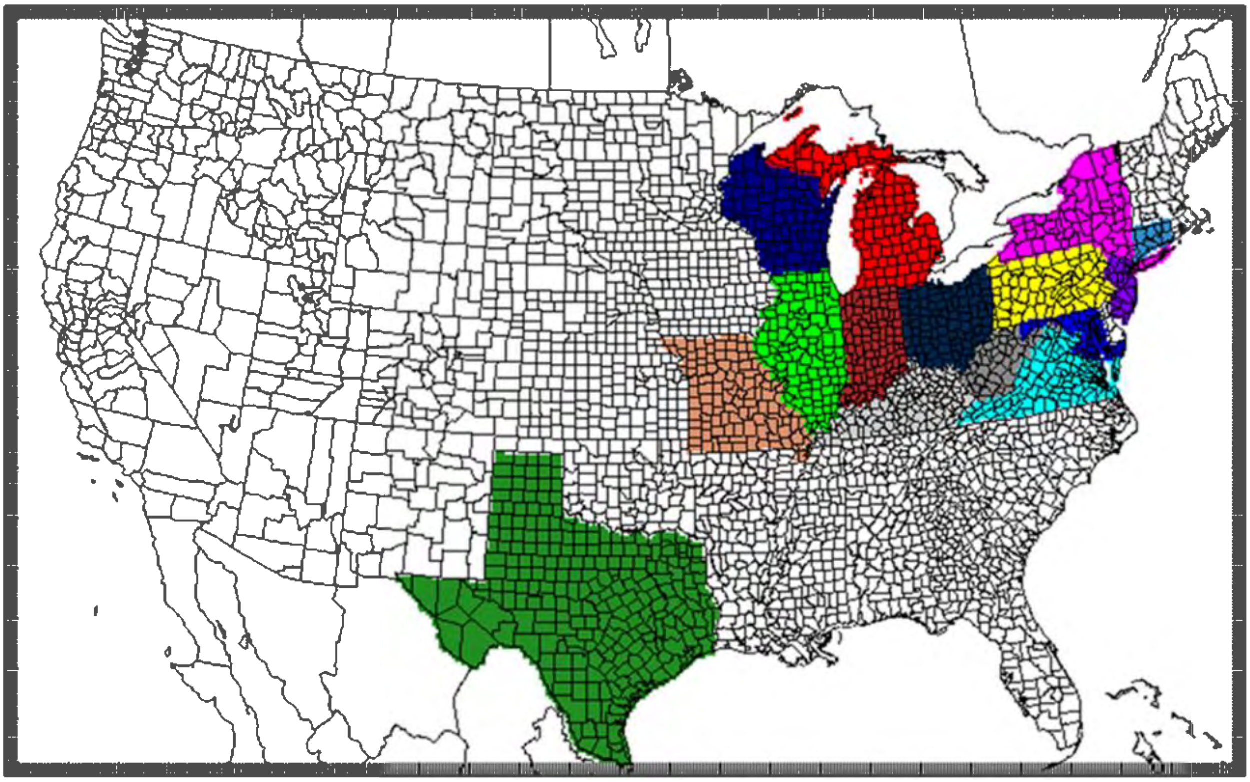

Figure 8-1. OSAT regions for 4km source contribution modeling.

Consistent with EPA's approach, the 4km CAMx OSAT model run was performed for the period May 1 through September 30 using the projected 2023 base case emissions and 2011 meteorology for this time period. The hourly contributions from each tag were processed to calculate an 8-hour average contribution metric. Alpine used EPA's SMAT-CE tool and top ten future year modeled days (across the "3x3" neighborhood for each monitor) to develop source apportioned concentration files from which contribution metrics were calculated.

The following approach was used in preparing the SMAT-CE input files, running the SMAT-CE software, and analysing the results:

1. Ozone SMAT was run for the 2023 future case using base case 2011 and future year 2023 full model SMAT input files. This prepares the 2023 output files which were used as the basis for comparison with the "tagged" SMAT-CE output described below.
2. Alpine then created future year, tag-specific SMAT-CE input files by subtracting the 2023 hourly tags from the hourly full model concentration files. This simple arithmetic was implemented using standard IOAPI utility programs and generated regional, source category-based tagged SMAT input files. After the hourly files were created, the same processing stream as was used in Step 1 was used create the tagged SMAT-CE input files from the hourly model concentration files.
3. SMAT-CE was then run (in batch mode) for each future year tag-specific input file generated in Step 2 using the base case 2011 SMAT-CE input file as the base year. In these runs, SMAT-CE was configured identically as in Step 1 except for using the future

year "tagged" input files. These individual runs generated SMAT-CE output files that contain the forecasted ozone data absent the tagged contribution.

4. The ozone concentration (on the 10 highest modeled days for the future year) for each tag was calculated from the SMAT-CE future year base case output file and each of the tag output files. The ozone contribution impacts of each tag will be computed by subtracting the SMAT-CE output absent the tag (created in Step 3) from the full model SMAT output file (created in Step 1).
5. The aggregate of all the individual anthropogenic "tagged" contributions were added to develop a state-total contribution concentration to compare against significant contribution thresholds (e.g., 1% of NAAQS).

This process for calculating the contribution metric uses the contribution modeling outputs in a "relative sense" to apportion the projected 2023 average design value at each monitoring location into contributions from each individual tag and is consistent with the updated methodology documented in EPA's March 2018 memorandum. It is important to note that Alpine's 4km contribution results utilize the approach described by EPA in basing the average future year contribution on future year modeled values.

8.1 OZONE CONTRIBUTION MODELING RESULTS

The contributions from each tagged state's anthropogenic contribution to individually identified 4km domain nonattainment and maintenance receptors are provided in Tables 8-1 and 8-2, respectively.

The EPA has historically found that the 1 percent threshold is appropriate for identifying interstate transport linkages for states collectively contributing to downwind ozone nonattainment or maintenance problems because that threshold captures a high percentage of the total pollution transport affecting downwind receptors.

Based on the approach used in CSAPR and the CSAPR Update, upwind states that contribute ozone in amounts at or above the 1 percent of the NAAQS threshold to a particular downwind nonattainment or maintenance receptor would be considered to be "linked" to that receptor in step 2 of the CSAPR framework for purposes of further analysis in step 3 to determine whether and what emissions from the upwind state contribute significantly to downwind nonattainment and interfere with maintenance of the NAAQS at the downwind receptors. For the 2008 ozone NAAQS, the value of a 1 percent threshold would be 0.75 ppb. For the 2015 ozone NAAQS the value of a 1 percent threshold would be 0.70 ppb.

Table 8-1. Ozone contribution (ppb) from region-specific anthropogenic emissions to 4km determined nonattainment monitor.

			4km (4kei) Modeling – Ozone Concentrations and Contribution (ppb)																		
Monitor	State	County	2011 DVb	2023 DVf (Avg)	2023 DVf (Max)	CT	MD	NJ	NY	PA	VA/ DC	IL	IN	MI	OH	WI	WV	KY	MO	TX	Can/ Mex/ Water	BC/ IC
551170006	WI	Sheboygan	84.3	71.5	73.8	0.00	0.01	0.00	0.03	0.14	0.04	12.42	7.66	1.26	0.96	2.24	0.11	0.68	0.98	1.35	0.69	14.68

Table 8-2. Ozone contribution (ppb) from region-specific anthropogenic emissions to 4km determined maintenance monitors.

			4km (4kei) Modeling – Ozone Concentrations and Contribution (ppb)																			
Monitor	State	County	2011 DVb	2023 DVf (Avg)	2023 DVf (Max)	CT	MD	NJ	NY	PA	VA/ DC	IL	IN	MI	OH	WI	WV	KY	MO	TX	Can/ Mex/ Water	BC/ IC
90013007	CT	Fairfield	84.3	69.2	73.1	3.77	1.80	5.71	9.73	5.04	0.93	0.88	0.85	0.73	1.83	0.18	0.52	0.43	0.27	0.64	1.28	14.64
90019003	CT	Fairfield	83.7	68.3	71.0	2.47	2.16	7.28	10.19	5.54	1.32	0.69	0.65	0.56	1.64	0.18	0.61	0.35	0.17	0.45	1.26	14.38
90099002	CT	New Haven	85.7	68.9	71.5	6.25	1.18	4.56	9.26	4.36	0.74	0.76	0.70	0.96	1.49	0.24	0.43	0.37	0.21	0.45	1.52	13.51
240251001	MD	Harford	90.0	70.9	73.3	0.00	18.82	0.02	0.00	2.78	3.66	1.07	1.88	0.27	3.09	0.08	2.57	2.13	0.41	0.86	0.42	11.64
260050003	MI	Allegan	82.7	70.0	72.8	0.00	0.00	0.00	0.00	0.04	0.02	18.60	5.92	0.95	0.51	1.73	0.03	0.76	1.88	1.68	0.40	11.01
340150002	NJ	Gloucester	84.3	68.8	71.0	0.04	1.78	7.45	0.66	10.20	0.92	1.56	2.01	0.69	4.05	0.23	0.94	1.20	0.52	1.17	0.89	12.98
360850067	NY	Richmond	81.3	69.6	71.0	0.13	1.75	10.70	4.61	5.05	1.62	1.09	0.92	1.16	1.88	0.51	0.66	0.60	0.37	0.99	2.29	14.01
361030002	NY	Suffolk	83.3	70.6	72.0	0.55	1.33	7.49	11.08	5.85	1.31	1.06	0.90	0.92	2.23	0.24	0.74	0.55	0.31	0.76	0.96	15.61

9.0 SELECTED SIP REVISION APPROACHES

EPA has established a four-step framework to address the requirements of the good neighbor provision for ozone NAAQS in preparing SIP revisions;

1. Identify downwind air quality problems;
2. Identify upwind states that contribute enough to those downwind air quality problems to warrant further review and analysis;
3. Identify the emissions reductions necessary (if any), considering cost and air quality factors, to prevent an identified upwind state from contributing significantly to those downwind air quality problems; and
4. Adopt permanent and enforceable measures needed to achieve those emissions reductions.

EPA also notes (Tsirogotis, 2018a,b,c) that in applying this framework or other approaches consistent with the CAA, various analytical approaches may be used to assess each step. EPA also notes that, in developing their own rules, states have the flexibility to follow the familiar four-step transport framework or alternative frameworks, so long as their chosen approach has adequate technical justification and is consistent with the requirements of the CAA. EPA then goes on to provide a list of potential flexibilities that states may consider during the SIP revision process.

This section identifies certain alternate approaches using the 4km data generated in this modeling analysis or other 12km data generated by EPA that states may wish to consider in the development of their GNS revisions for the 2008 or 2015 ozone NAAQS. Certain of these approaches are based on the 4km data generated in this modeling analysis. In cases in which 4 km data is not available, the alternatives presented are based on EPA's 12 km modeling data.

9.1 RELIANCE UPON ALTERNATIVE, EQUALLY CREDIBLE, MODELING DATA

EPA's March 27, 2018 memorandum sets forth both the agency's "3 x 3" modeling data first published in its memorandum of October 27, 2017, as well as its modified "No Water" approach. In addition to these two EPA data sets, this document provides 4km modeling results (using the "3 x 3" approach). MOG has also sponsored 12US2 modeling data consistent with EPA's "3 x 3" modeling based upon a 12km grid which was suggested by EPA in its proposed approval of the 2008 ozone NAAQS Good Neighbor SIP for Kentucky.

Should EPA determine that each of these data sets is of "SIP quality" and meets the regulatory requirements necessary to be used by a state in demonstrating attainment with the NAAQS, a state should be permitted to select from among these data to represent conditions best representative of the current state-of-science.

As an example, a comparison of the March 2018 "no water" data presented by EPA compared to the 4km data documented in this report ("4kei") is provided. Looking at the list of nonattainment and maintenance monitors in the New York metro area (specifically New York and Connecticut), one can observe that selection of the finer grid resolution 4km results shows a demonstrated attainment (2023 average DV < 71 ppb) of the 2015 ozone NAAQS at all monitors in these two states. It is recognized that the three monitors identified by EPA as nonattainment would become reclassified as maintenance using the 4km results.

Table 9-1. Alternate modeling results comparison for New York and Connecticut monitors.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		Alpine 4kei Modeling		
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	2015-2017 DV
90010017	CT	Fairfield	80.3	68.9	71.2	66.8	69.0	79
90013007	CT	Fairfield	84.3	71.0	75.0	69.2	73.1	83
90019003	CT	Fairfield	83.7	73.0	75.9	68.3	71.0	83
90099002	CT	New Haven	85.7	69.9	72.6	68.9	71.5	82
90110124	CT	New London	80.3	67.3	70.4	66.0	69.1	76
360850067	NY	Richmond	81.3	67.1	68.5	69.6	71.0	76
361030002	NY	Suffolk	83.3	74.0	75.5	70.6	72.0	76

In this instance, the selection of an equally credible modeling platform and projected design values would demonstrate modeled attainment of the NAAQS and prevent an upwind state from having to go beyond Step 1 of the four-step framework. The uncertainty involved with selecting a single modeling simulation to base such significant policy decisions, such as Good Neighbor demonstrations, should be weighed against the opportunity to select other platforms and simulations with consideration given to state methods that rely on multiple sources of data when found to be of technical merit.

9.2 NORTH AMERICAN INTERNATIONAL ANTHROPOGENIC CONTRIBUTION

EPA includes in its March 27, 2018 memorandum:

> *"EPA recognizes that a number of non-U.S. and non-anthropogenic sources contribute to downwind nonattainment and maintenance receptors."*

In source contribution modeling conducted both by Alpine and EPA, the relative impact contributions of anthropogenic emissions located within the 36km modeling domain are explicitly tracked and reported. Using these values provided in the OSAT or OSAT/APCA source contribution results, states seeking to avoid prohibited over-control may wish to consider removing that portion of the projected design value that is explicitly attributed to international anthropogenic contribution. At multiple monitors in the eastern U.S., this value may be enough to demonstrate attainment with the 2008 or 2015 ozone NAAQS.

As an example, see the calculations below for the Sheboygan, WI monitor using 4km OSAT results from this analysis.

Table 9-2. Sheboygan, WI monitor (551170006) design values for 2011 base case and MOG 4kei 2023 projection year scenario with and without Canadian/Mexican/International CMV contribution.

Scenario	MDA8 DV (ppb)	2023 Can / Mex / CMV Contribution (ppb)	2023 DV (ppb) w/o Can/Mex
2011 Base Year	84.3	-	-
2023 MOG 4kei OSAT	71.5	0.69	70.8

Using this air quality monitor as an example, it can be observed that by accounting for the anthropogenic contribution of emissions from Canada, Mexico, and international CMVs (tracked as a single tag), this scenario demonstrates attainment with the 2015 ozone NAAQS (<71 ppb). This step would allow a state to stop at Step 1 of the four-factor process.

9.3 RELIEF FROM ADDITIONAL PERCENTAGE OF BOUNDARY CONDITIONS

The EPA, in its March 2018 memorandum, notes that in an effort to fully understand the role of background ozone levels and to appropriately account for international transport, “EPA recognizes that a number of non-U.S. and non-anthropogenic sources contribution to downwind nonattainment and maintenance receptors.” Under Step 3 of the four-step process, states could take the opportunity to request relief from a portion of the source apportioned amounts from the boundary condition category.

It is recognized that the boundary condition category is not only reflective of international anthropogenic emission contribution to modeled nonattainment or maintenance monitor concentrations and is additionally comprised of international biogenic emissions, stratospheric concentrations of ozone, ozone from methane, and even emissions created within the U.S. boundaries that leave the modeling domain and are reentrained during the modeling episode. However, assuming that some percentage of these boundary conditions are from international anthropogenic sources, a state may reasonably consider accounting for these contributions using the same mechanism for relief as described in the previous section.

As an example, considering some selected monitors designated by EPA in its March 2018 memorandum as nonattainment (Table 9-3). Using OSAT/APCA contribution results for the three noted monitors, contributions from Mexico and Canada range between 0.44 and 1.24 ppb and boundary conditions have modeled contribution of between 24.02 and 24.67 ppb. Should a state request relief from the Mexican and Canadian contribution (as noted above) and request relief from a reasonable proportion of the boundary condition values (presumed to be of international anthropogenic origin), all of these monitors could also demonstrate attainment with the 70 ppb NAAQS.

Table 9-3. International Contribution to Select Nonattainment Monitors and Anticipated Average Ozone Design Values (ppb) with Reasonable Proportion of Boundary Condition Relief.

Site ID	State	County	2023 Avg DV	Mex/Can Contrib.	Boundary Contrib.	2023 DV 2% Relief	2023 DV 5% Relief	2023 DV 7% Relief	2023 DV 11% Relief
480391004	Texas	Brazoria	74.0	0.44	24.02	73.0	72.3	71.8	70.9
484392003	Texas	Tarrant	72.5	1.24	24.38	70.7	70.0	69.5	68.5
482011039	Texas	Harris	71.8	0.47	24.67	70.8	70.0	69.6	68.6

In this particular example, assuming a reasonable 2% of the boundary conditions as international anthropogenic contribution, two of the three Texas monitors show demonstrated attainment with the 2015 NAAQS. With an assumption that 11% of the contribution from modeled boundary conditions could be attributed to international anthropogenic contribution to the Texas monitors, all three of the selected EPA-identified nonattainment monitors would show attainment with the 70 ppb NAAQS.

9.4 ALTERNATE SIGNIFICANCE THRESHOLD

Some states argue that significant contribution threshold of 1% of NAAQS (0.70 ppb for 2015 ozone NAAQS) value is arbitrary and has never been supported by any scientific argument. Concerns have been raised that this value is more stringent than current 2016 EPA Significant Impact Level (SIL) guidance of 1.0 ppb which is designed as an individual source or group of sources' contribution limit (Boylan, 2018).

In its August 31, 2018 memo (Tsirogitis, 2018b), EPA compared two additional ozone concentration contribution thresholds; 1 ppb and 2 ppb. The purpose of the analysis described in the memo was to determine alternate, appropriate screening thresholds for states to consider in preparing their SIP revisions. Ultimately in the document, EPA noted that "a threshold of 1 ppb may be appropriate for states to use to develop SIP revisions addressing the good neighbor provision for the 2015 ozone NAAQS."

As a result of this guidance provided by EPA, there is a potential for states to submit SIP revision citing 1 ppb or 2 ppb or SIL as acceptable for total state anthropogenic contribution threshold. In these cases, under Step 2 of the four-step process, states may wish to review their contribution to downwind receptors and request relief from the 1% threshold in lieu of using an alternate value. In the example below, we review Texas nonattainment and maintenance monitors as defined by EPA's March 2018 memo. In the Table 9-4, we have also included the OSAT/APCA contributions documented by EPA in that memo.

Table 9-4. EPA 12km OSAT/APCA contributions to Texas nonattainment and maintenance monitors. Blue + orange + red cells indicate states contributing with 1% threshold. Orange + red cells indicate states contributing with > 1ppb threshold. Red cells indicate states contributing with > 2 ppb threshold.

			Ozone DV (ppb)		EPA OSAT/APCA Contribution (ppb)					
Site ID	State	County	2023 Avg DV	2023 Max DV	AR	IL	LA	MS	MO	OK
480391004	Texas	Brazoria	74.0	74.9	0.90	1.00	3.80	0.63	0.88	0.90
484392003	Texas	Tarrant	72.5	74.8	0.78	0.29	1.71	0.27	0.38	1.71
482011039	Texas	Harris	71.8	73.5	0.99	0.88	4.72	0.79	0.88	0.58
482010024	Texas	Harris	70.4	72.8	0.29	0.34	3.06	0.50	0.38	0.20
481210034	Texas	Denton	69.7	72.0	0.58	0.23	1.92	0.33	0.24	1.23
482011034	Texas	Harris	70.8	71.6	0.54	0.51	3.38	0.39	0.63	0.68

As can be seen in this example, should the significant contribution threshold be raised from 1% of NAAQS (0.70 ppb) to a greater than 1.0 ppb limit, Arkansas, Illinois, Mississippi, and Missouri would all have their contribution linkages broken to all six monitors and the only state linked to the monitor with the highest design value (Brazoria) would be Louisiana, with significant contribution (3.80 ppb) greater than all other 1% linked states combined (3.68 ppb). Should the threshold be raised to 2 ppb, the linkage from Oklahoma to all of the noted Texas receptors would be broken as would the linkage from Louisiana to two of the Texas monitors.

9.5 PROPORTIONAL CONTROL BY CONTRIBUTION ("RED LINES")

In EPA's March 2018 memorandum, the agency also recognizes that consideration can be given to states based on their relative significant impact to downwind air quality monitors compared to other significant contributing states and whether the contribution values are sufficiently different enough that each state should be given a proportional responsibility for assisting in downwind attainment. Under an analysis like this, reductions should be allocated in proportion to the size of their contribution to downwind nonattainment.

Using the Sheboygan, WI (551170006) monitor and the OSAT-derived significant contribution results from the 4km modeling from Table 8-1, we see the following calculations based on the required 0.6 ppb reduction necessary for this monitor to demonstrate attainment with the 2015 ozone NAAQS.

In the example for Sheboygan, each significantly contributing (based on 1% NAAQS) upwind State must (1) achieve less than 0.70 ppb significant contribution or (2) the monitor must achieve attainment (70.9 ppb). From these assumptions, the reduction necessary for attainment is 0.6 ppb from 71.5 ppb 2023 base case average design value.

Table 9-5. Proportional contribution and reductions associated with significantly contributing upwind states to Sheboygan, WI (551170006) monitor in 4km modeling domain.

	Relative Contribution			Required Reduction
Region	**ppb**	**%**		**ppb**
IL	12.42	50.4		0.30
IN	7.66	31.1		0.19
TX	1.35	5.5		0.03
MI	1.26	5.1		0.03
MO	0.98	4.0		0.02
OH	0.96	3.9		0.02
Total	**24.63**	**100%**		**0.60**

Using this monitor as an example, one can see that as a result of the proportional reduction requirement associated with the relative significant contribution from each upwind state, a range of approximately 0.02 ppb (from Missouri and Ohio) to a 0.30 ppb reduction (from Illinois) would be calculated using this method. From these results, each upwind state would then need to craft a GNS revision to generate reductions associated with this proportional amount.

Similarly, using the Brazoria, TX (480391004) monitor and the OSAT/APCA-derived significant contribution results from EPA's 12km modeling (Tsirigotis, 2018a), one can see the following calculations (Table 9-6) based on the required 3.1 ppb reduction necessary for this monitor to demonstrate attainment with the 2015 ozone NAAQS.

Table 9-6. Proportional contribution and reductions associated with significantly contributing upwind states to Brazoria, TX (480391004) monitor in 12km modeling domain.

	Relative Contribution			Required Reduction
Region	**Ppb**	**%**		**ppb**
LA	3.80	51%		1.57
IL	1.00	13%		0.41
AR	0.90	12%		0.37
OK	0.90	12%		0.37
MO	0.88	12%		0.36
Total	**7.48**	**100%**		**3.10**

In this example, each significantly contributing (again based on 1% NAAQS) upwind State must also (1) achieve the 0.70 ppb significant contribution or (2) the monitor must achieve attainment (70.9 ppb). From these assumptions, the reduction necessary for attainment is 3.1 ppb from 74.0 ppb 2023 base case average design value.

Using this monitor, one can see that as a result of the proportional reduction requirement associated with the relative significant contribution from each upwind state, a range of 3.80 ppb (from Louisiana) to a 0.88 ppb reduction (from Missouri) would be calculated using this method. From these results, each upwind state would then need to craft a GNS revision to generate reductions associated with this proportional amount.

9.6 ALTERNATE CONSIDERATION IN IDENTIFYING MAINTENANCE MONITORS

On October 19, 2018, EPA issued a memorandum (Tsirigotis, 2018c) to allow states to evaluate the status of monitoring sites initially identified as potential maintenance monitors and to determine if observed ozone concentrations, meteorological conditions, and emission projections meet parameters that would allow classification of these receptors as attainment.

Per EPA's memo, a modeled demonstration would need to show that using an alternative base year period would lead to a projected future year design value at or below a concentration of 70.9 ppb which is necessary to demonstrate modeled attainment of the 2015 70 ppb ozone NAAQS. If that demonstration is successful, EPA would expect states to include with their SIP demonstration submission technical analyses showing that:

1. meteorological conditions in the area of the monitoring site were conducive to ozone formation during the period of clean data or during the alternative base period design value used for projections;
2. ozone concentrations have been trending downward at the site since 2011 (and ozone precursor emissions of nitrogen oxide (NOx) and volatile organic compounds (VOC) have also decreased); and
3. emissions are expected to continue to decline in the upwind states out to the attainment date of the receptor.

EPA has provided meteorological data (Tsirigotis, 2018c) to support #1 above and elsewhere has also provided historical emission trends[11] and emission projections[12] that demonstrate continued decline of ozone precursors through 2023 to support #3. Modeled ozone concentration data from EPA's 12km and MOG's updated 4km modeling, as well as historical observed concentrations to support investigating the #2 condition are identified.

Presented below is an example analysis of current data related to criteria established in EPA's memo for determining whether it is appropriate for a monitor to be classified as a maintenance monitor. A more in-depth analysis covering additional monitors can be found in Alpine's report titled "Addressing Maintenance Monitor Flexibilities Using the 2023 Cross-State Air Pollution Rule Closeout Modeling Platform - Revised December 2018" (Alpine, 2018d).

11 https://www.epa.gov/air-emissions-inventories/air-pollutant-emissions-trends-data

12 https://www.epa.gov/air-emissions-modeling/additional-updates-2011-and-2023-emissions-version-63-platform-technical

9.6.1 Utilization of alternative base period design values results in a projection of clean data for all monitors.

As a first step in demonstrating whether a monitor should be properly characterized as a maintenance receptor, 2023 ozone design values using alternate base year concentrations (from the three, three-year time periods between 2009 – 2013) for example monitor 90013007 (Fairfield, CT) is presented in the following table. These data demonstrate that this monitor has at least one alternate base year period design value that results in a 2023 projection equal to or lower than the 70.9 ppb threshold satisfying this condition.

Table 9-7. Alternate Base Year Projections of 2023 ozone Design Values (ppb) from Alpine 4km Modeling for Fairfield, CT Monitor 90013007.

				2023 Ozone Design Value (ppb)					
Monitor	State	County	DVb (2011)	DVf (Ave)	DVf (Max)	DVf (Max 2009/11)	DVf (Max 2010/12)	DVf (Max 2011/13)
90013007	Connecticut	Fairfield	84.3	69.2	73.1	64.8	69.8	73.1

9.6.2 Meteorological conditions of the monitors were conducive to ozone formation.

One of the criteria established in EPA's guidance memo (Tsirigotis, 2018c) for approving an alternative demonstration of a monitor's maintenance status is that the "meteorological conditions in the area of the monitoring site were conducive to ozone formation during the period of clean data or during the alternative base period design value used for projections."

EPA goes on to offer the following general comment on meteorological conditions:

> *"In general, below average temperatures are on indication that meteorological conditions are unconducive for ozone formation, whereas above average temperatures are an indication that meteorology is conducive to ozone formation. Within a particular summer season, the degree that meteorology is conducive for ozone formation can vary from region to region and fluctuate with time within a particular region. For example, the temperature-related information presented below suggests that summer meteorology was generally conducive for ozone formation in 2010, 2011, 2012 and 2016 in most regions. In contrast, the summer of 2009 was generally unconducive for ozone formation, overall, in most regions."*

Significantly, the alternative demonstration set forth in this example can be based upon an alternative base year period involving the years 2010 through 2012. EPA has recognized that the meteorology in these years was conducive to ozone formation in the northeast.

By basing model projections for the attainment year of 2023 on alternative base period design values for ozone conducive year (2010-2012), this monitor meets the meteorological threshold of the memorandum.

9.6.3 Ozone concentrations are trending downward.

As an additional supporting case to the flexibility in identifying maintenance monitors, EPA guidance provides that a state would need to show that "ozone concentrations have been trending downward at the site since 2011". Table 9-8 below presents 4th high ozone concentration data[13] measured at the noted receptor and a calculated slope between 2011 and the most recently EPA-approved 4th high concentrations from 2017. Table 9-9 presents a count of the number of ozone exceedance days for the monitor per year relative to the 2015 70 ppb ozone NAAQS. For this example, negative slopes, indicating the necessary downward trends, are demonstrated for both of these metrics which satisfies the required condition of trending downward concentrations.

Table 9-8. 4th High Ozone Concentrations (ppb) and Slope Calculation for Fairfield, CT Monitor 90013007.

			4th High Ozone Concentration (ppb)							
Monitor	State	County	2011	2012	2013	2014	2015	2016	2017	Slope (2011-2017) (ppb/yr)
90013007	Connecticut	Fairfield	87	90	90	74	86	83	81	-1.29

Table 9-9. Daily Ozone Exceedance Counts and Slope Calculation for Fairfield, CT Monitor 90013007.

			Daily Ozone Exceedance Counts							
Monitor	State	County	2011	2012	2013	2014	2015	2016	2017	Slope (2011-2017
90013007	Connecticut	Fairfield	13	19	17	8	15	14	11	-0.64

9.6.4 Emissions of ozone precursors have been trending downwards since 2011 and are expected to continue to decline out to the attainment date of the receptor.

NOx and VOC emissions across the CSAPR region have been dramaticaly reduced in recent years. These emission reductions are expected to continue as the result of "on-the-books" regulatory programs already required by states on their own sources, "on-the-way" regulatory programs that have already been identified by state regulatory agencies as efforts that they must undertake as well as from the effectiveness of a variety of EPA programs including the CSAPR Update Rule.

13 https://www.epa.gov/air-trends/air-quality-design-values

Presented below are tables developed from EPA modeling platform summaries[14] illustrating the estimated total anthropogenic emission reduction emission reduction in the several eastern states.

As can be seen in the Table 9-10, total annual anthropogenic NOx emissions are predicted to decline by 29% between 2011 and 2017 over the CSAPR domain and by 43% (an additional 1.24 million tons) between 2011 and 2023.

Table 9-10. Final CSAPR Update Modeling Platform Anthropogenic NOx Emissions (Annual Tons).

	Annual Anthropogenic NOx Emissions (Tons)			Emissions Delta (2017-2011)		Emissions Delta (2023-2011)	
State	**2011**	**2017**	**2023**	**Tons**	**%**	**Tons**	**%**
Alabama	359,797	220,260	184,429	139,537	-39%	175,368	-49%
Arkansas	232,185	168,909	132,148	63,276	-27%	100,037	-43%
Illinois	506,607	354,086	293,450	152,521	-30%	213,156	-42%
Indiana	444,421	317,558	243,954	126,863	-29%	200,467	-45%
Iowa	240,028	163,126	124,650	76,901	-32%	115,377	-48%
Kansas	341,575	270,171	172,954	71,404	-21%	168,621	-49%
Kentucky	327,403	224,098	171,194	103,305	-32%	156,209	-48%
Louisiana	535,339	410,036	373,849	125,303	-23%	161,490	-30%
Maryland	165,550	108,186	88,383	57,364	-35%	77,167	-47%
Michigan	443,936	296,009	228,242	147,927	-33%	215,694	-49%
Mississippi	205,800	128,510	105,941	77,290	-38%	99,859	-49%
Missouri	376,256	237,246	192,990	139,010	-37%	183,266	-49%
New Jersey	191,035	127,246	101,659	63,789	-33%	89,376	-47%
New York	388,350	264,653	230,001	123,696	-32%	158,349	-41%
Ohio	546,547	358,107	252,828	188,439	-34%	293,719	-54%
Oklahoma	427,278	308,622	255,341	118,656	-28%	171,937	-40%
Pennsylvania	562,366	405,312	293,048	157,054	-28%	269,318	-48%
Tennessee	322,578	209,873	160,166	112,705	-35%	162,411	-50%
Texas	1,277,432	1,042,256	869,949	235,176	-18%	407,482	-32%
Virginia	313,848	199,696	161,677	114,152	-36%	152,171	-48%
West Virginia	174,219	160,102	136,333	14,117	-8%	37,886	-22%
Wisconsin	268,715	178,927	140,827	89,788	-33%	127,888	-48%
CSAPR States	**8,651,264**	**6,152,990**	**4,914,012**	**2,498,274**	**-29%**	**3,737,252**	**-43%**

As can be seen in the Table 9-11, total annual anthropogenic VOC emissions are predicted to decline by 9% between 2011 and 2017 over the CSAPR domain and by 15% (an additional 1.43 million tons) between 2011 and 2023.

14 83 Fed. Reg. 7716 (February 22, 2018).

Table 9-11. Final CSAPR Update Modeling Platform Anthropogenic VOC Emissions (Annual Tons).

	Annual Anthropogenic VOC Emissions (Tons)			Emissions Delta (2017-2011)		Emissions Delta (2023-2011)	
State	2011	2017	2023	Tons	%	Tons	%
Alabama	393,465	328,996	306,583	64,468	-16%	86,882	-22%
Arkansas	342,779	312,750	295,210	30,029	-9%	47,569	-14%
Illinois	372,137	320,543	294,087	51,594	-14%	78,049	-21%
Indiana	284,378	226,734	200,827	57,644	-20%	83,551	-29%
Iowa	191,201	158,520	144,326	32,681	-17%	46,875	-25%
Kansas	461,871	457,042	388,734	4,828	-1%	73,137	-16%
Kentucky	273,603	236,383	214,051	37,220	-14%	59,551	-22%
Louisiana	692,238	647,568	586,378	44,670	-6%	105,860	-15%
Maryland	125,468	105,316	95,511	20,152	-16%	29,957	-24%
Michigan	450,276	350,937	301,599	99,339	-22%	148,677	-33%
Mississippi	274,537	236,316	213,200	38,221	-14%	61,338	-22%
Missouri	377,268	331,054	307,386	46,214	-12%	69,882	-19%
New Jersey	183,091	152,805	141,113	30,286	-17%	41,978	-23%
New York	417,438	337,078	301,794	80,361	-19%	115,645	-28%
Ohio	391,315	306,215	303,144	85,101	-22%	88,172	-23%
Oklahoma	607,943	561,947	538,770	45,996	-8%	69,172	-11%
Pennsylvania	376,322	317,876	293,703	58,446	-16%	82,618	-22%
Tennessee	290,998	231,537	207,178	59,461	-20%	83,820	-29%
Texas	2,194,868	2,324,259	2,244,343	(129,391)	6%	(49,475)	2%
Virginia	295,360	254,049	235,605	41,311	-14%	59,755	-20%
West Virginia	139,516	173,841	172,511	(34,324)	25%	(32,995)	24%
Wisconsin	288,296	231,988	204,074	56,308	-20%	84,222	-29%
CSAPR States	9,424,368	8,603,753	7,990,125	820,614	-9%	1,434,242	-15%

EPA's October 19, 2018 guidance memo offers states the option of using an alternative method of identifying maintenance monitors to be addressed in their Good Neighbor SIPs related to the 2015 ozone NAAQS. The example presented above illustrates that when current data is applied to the various criteria identified by EPA, states are provided with the basis for requesting EPA to determine that it is no longer necessary to consider any of the subject monitors as maintenance monitors for purposes related to the 2015 ozone NAAQS.

9.7 ADRESSING MAINTENANCE WITH 10 YEAR EMISSION PROJECTION

As an alternative to maintenance monitors being accorded the same weight as nonattainment monitors, states may choose to indicate that no additional control would be needed to address a maintenance monitor if the upwind state can show that either the monitor is likely to remain in attainment for a period of 10 years or that the upwind state's emissions will not increase for

10 years after the attainment date. Such an approach is consistent with Section 175A of the Clean Air Act which provides:

> *(a) Plan revision*
> *Each State which submits a request under section 7407 (d) of this title for redesignation of a nonattainment area for any air pollutant as an area which has attained the national primary ambient air quality standard for that air pollutant shall also submit a revision of the applicable State implementation plan to provide for the maintenance of the national primary ambient air quality standard for such air pollutant in the area concerned for at least 10 years after the redesignation. The plan shall contain such additional measures, if any, as may be necessary to ensure such maintenance.*

It is also consistent with the John Calcagni memorandum of September 4, 1992 (Calcagni, 1992), entitled "Procedures for Processing Requests to Redesignate Areas to Attainment", which contains the following statement on page 9:

> *"A State may generally demonstrate maintenance of the NAAQS by either showing that future emissions of a pollutant or its precursors will not exceed the level of the attainment inventory, or by modeling to show that the future mix of source and emission rates will not cause a violation of the NAAQS. Under the Clean Air Act, many areas are required to submit modeled attainment demonstrations to show that proposed reductions in emissions will be sufficient to attain the applicable NAAQS. For these areas, the maintenance demonstration should be based upon the same level of modeling. In areas where no such modeling was required, the State should be able to rely on the attainment inventory approach. In both instances, the demonstration should be for a period of 10 years following the redesignation. "*

Using the Harford, MD (240251001) monitor as an example, one would look at the upwind states that were determined to contribute significantly to this receptor in the 2023 model simulation (Table 8-2).

As seen in Table 9-12, any of the following linked states may then make the claim that as their emissions are projected to decrease over a ten year period (the following example is illustrative in nature and uses a twelve year trend based on EPA's 2023en modeling platform summaries[15]) and would demonstrate maintenance of the NAAQS by showing that their future emissions of a pollutant or its precursors will not exceed the level of the attainment inventory.

[15] ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/reports/2011en_and_2023en/2023en_cb6v2_v6_11g_state_sector_totals.xlsx

Table 9-12. Emission trend of annual anthropogenic NOx emissions (tons) for 1% linked states to Harford, MD monitor.

	Annual Anthropogenic NOx Emissions			
State	**2011 (Tons)**	**2023 (Tons)**	**Change (Tons)**	**Change (%)**
District of Columbia	9,404	4,569	-4,834	-51%
Illinois	506,607	293,450	-213,156	-42%
Indiana	444,421	243,954	-200,467	-45%
Kentucky	327,403	171,194	-156,209	-48%
Ohio	546,547	252,828	-293,719	-54%
Pennsylvania	562,366	293,048	-269,318	-48%
Texas	1,277,432	869,949	-407,482	-32%
Virginia	313,848	161,677	-152,171	-48%
West Virginia	174,219	136,333	-37,886	-22%

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Appendix A

4km Modeling (4kei) Results for Mid-Atlantic and Lake Michigan Domains Compared To EPA 12km "No Water" Design Value Calculations from March 2018 Memorandum

Table A-1. 4km and EPA "No Water" 12km Design Value Results for Monitors Located in 4km Mid-Atlantic and Lake Michigan Modeling Domains.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		4km (4kei) Modeling		
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	2015-2017 DV
90010017	Connecticut	Fairfield	80.3	68.9	71.2	66.8	69.0	79
90011123	Connecticut	Fairfield	81.3	66.4	67.8	65.2	66.6	77
90013007	Connecticut	Fairfield	84.3	71.0	75.0	69.2	73.1	83
90019003	Connecticut	Fairfield	83.7	73.0	75.9	68.3	71.0	83
90031003	Connecticut	Hartford	73.7	60.7	61.7	60.3	61.3	72
90050005	Connecticut	Litchfield	70.3	57.2	57.8	56.8	57.3	72
90070007	Connecticut	Middlesex	79.3	64.7	66.1	63.8	65.2	79
90090027	Connecticut	New Haven	74.3	61.9	65.0	61.8	64.9	77
90099002	Connecticut	New Haven	85.7	69.9	72.6	68.9	71.5	82
90110124	Connecticut	New London	80.3	67.3	70.4	66.0	69.1	76
90131001	Connecticut	Tolland	75.3	61.4	62.8	61.3	62.7	71
100010002	Delaware	Kent	74.3	57.6	60.5	58.4	61.4	66
100031007	Delaware	New Castle	76.3	59.2	62.0	59.8	62.7	67
100031010	Delaware	New Castle	78.0	61.2	61.2	61.7	61.7	74
100031013	Delaware	New Castle	77.7	60.8	62.6	61.6	63.5	71
100051002	Delaware	Sussex	77.3	59.7	62.6	60.5	63.4	65
100051003	Delaware	Sussex	77.7	61.1	63.7	61.7	64.3	67
110010041	District Of Columbia	District of Columbia	76.0	58.7	61.7	60.5	63.6	N/A
110010043	District Of Columbia	District of Columbia	80.7	62.3	64.8	65.2	67.9	71
170310001	Illinois	Cook	72.0	63.2	64.9	60.3	62.0	73
170310032	Illinois	Cook	77.7	66.6	69.5	57.7	60.1	72
170310064	Illinois	Cook	71.3	61.1	64.3	55.1	58.0	N/A
170310076	Illinois	Cook	71.7	62.7	64.7	61.1	63.0	72

Table A-1. 4km and EPA "No Water" 12km Design Value Results for Monitors Located in 4km Mid-Atlantic and Lake Michigan Modeling Domains.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		4km (4kei) Modeling		2015-2017 DV
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	
170311003	Illinois	Cook	69.7	62.4	64.4	59.7	61.7	67
170311601	Illinois	Cook	71.3	61.5	63.9	62.2	64.5	69
170314002	Illinois	Cook	71.7	62.3	64.3	62.3	64.3	68
170314007	Illinois	Cook	65.7	58.0	60.0	55.7	57.6	71
170314201	Illinois	Cook	75.7	66.8	68.8	62.6	64.5	72
170317002	Illinois	Cook	76.0	66.8	70.3	59.7	62.8	73
170436001	Illinois	DuPage	66.3	57.9	59.4	58.6	60.1	70
170890005	Illinois	Kane	69.7	62.8	63.9	60.5	61.6	69
170971007	Illinois	Lake	79.3	63.4	65.6	60.2	62.2	73
171110001	Illinois	McHenry	69.7	61.8	62.9	59.8	60.9	69
171971011	Illinois	Will	64.0	55.6	56.5	54.7	55.5	65
172012001	Illinois	Winnebago	67.3	57.5	58.0	57.5	58.1	66
180390007	Indiana	Elkhart	67.7	54.6	56.5	55.0	56.9	64
180890022	Indiana	Lake	66.7	58.3	60.3	55.2	57.1	68
180890030	Indiana	Lake	69.7	61.9	64.8	55.6	58.2	N/A
180892008	Indiana	Lake	68.0	60.4	60.4	56.8	56.8	N/A
180910005	Indiana	LaPorte	79.3	67.2	70.4	65.4	68.4	N/A
180910010	Indiana	LaPorte	69.7	58.9	60.9	57.7	59.6	67
181270024	Indiana	Porter	70.3	61.8	63.3	59.3	60.8	69
181270026	Indiana	Porter	63.0	54.4	55.3	53.2	54.0	69
181410015	Indiana	St. Joseph	69.3	56.9	59.9	57.6	60.7	70
181411007	Indiana	St. Joseph	64.0	52.5	52.5	52.5	52.5	N/A
240030014	Maryland	Anne Arundel	83.0	63.4	66.4	64.9	68.0	N/A
240051007	Maryland	Baltimore	79.0	63.9	66.3	61.6	64.0	N/A

Table A-1. 4km and EPA "No Water" 12km Design Value Results for Monitors Located in 4km Mid-Atlantic and Lake Michigan Modeling Domains.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		4km (4kei) Modeling		2015-2017 DV
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	
240053001	Maryland	Baltimore	80.7	65.3	67.9	63.9	66.5	73
240090011	Maryland	Calvert	79.7	63.2	65.9	64.0	66.7	67
240130001	Maryland	Carroll	76.3	58.8	60.9	59.4	61.5	69
240150003	Maryland	Cecil	83.0	64.5	66.8	65.2	67.5	74
240170010	Maryland	Charles	79.0	61.6	64.7	63.2	66.4	69
240199991	Maryland	Dorchester	75.0	59.4	59.4	59.7	59.7	65
240210037	Maryland	Frederick	76.3	59.6	61.8	60.4	62.5	69
240251001	Maryland	Harford	90.0	70.9	73.3	70.9	73.3	75
240259001	Maryland	Harford	79.3	62.2	64.3	62.4	64.5	73
240290002	Maryland	Kent	78.7	61.2	63.7	61.2	63.8	70
240313001	Maryland	Montgomery	75.7	60.0	61.0	60.0	61.1	68
240330030	Maryland	Prince George's	79.0	60.5	62.8	61.0	63.3	70
240338003	Maryland	Prince George's	82.3	63.2	66.8	64.0	67.7	71
240339991	Maryland	Prince George's	80.0	61.0	61.0	61.9	61.9	69
245100054	Maryland	Baltimore (City)	73.7	59.4	60.4	59.2	60.2	69
250051002	Massachusetts	Bristol	74.0	61.2	61.2	60.8	60.8	N/A
250070001	Massachusetts	Dukes	77.0	64.1	66.6	64.8	67.4	N/A
250130008	Massachusetts	Hampden	73.7	59.3	59.5	60.4	60.7	71
260050003	Michigan	Allegan	82.7	69.0	71.7	70.0	72.8	73
260190003	Michigan	Benzie	73.0	60.6	62.3	60.3	61.9	68
260210014	Michigan	Berrien	79.7	66.9	68.8	66.3	68.2	73
260270003	Michigan	Cass	76.7	62.0	63.1	61.5	62.6	72
260810020	Michigan	Kent	73.0	59.8	61.4	60.0	61.7	68
261010922	Michigan	Manistee	72.3	60.5	61.9	59.6	61.0	67

Table A-1. 4km and EPA "No Water" 12km Design Value Results for Monitors Located in 4km Mid-Atlantic and Lake Michigan Modeling Domains.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		4km (4kei) Modeling		2015-2017 DV
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	
261050007	Michigan	Mason	73.3	60.7	62.1	60.6	62.0	68
261210039	Michigan	Muskegon	79.7	65.8	67.7	66.7	68.6	74
261390005	Michigan	Ottawa	76.0	62.3	64.0	63.0	64.7	68
340010006	New Jersey	Atlantic	74.3	58.6	60.0	60.2	61.5	64
340030006	New Jersey	Bergen	77.0	64.1	65.0	65.5	66.4	74
340071001	New Jersey	Camden	82.7	66.3	69.8	65.9	69.3	68
340110007	New Jersey	Cumberland	72.0	57.0	59.4	57.1	59.5	66
340130003	New Jersey	Essex	78.0	64.3	67.6	63.4	66.7	68
340150002	New Jersey	Gloucester	84.3	68.2	70.4	68.8	71.0	74
340170006	New Jersey	Hudson	77.0	64.6	65.4	65.3	66.2	70
340190001	New Jersey	Hunterdon	78.0	62.0	63.6	60.8	62.4	72
340210005	New Jersey	Mercer	78.3	63.2	65.4	62.7	64.9	71
340219991	New Jersey	Mercer	76.0	60.4	60.4	58.5	58.5	73
340230011	New Jersey	Middlesex	81.3	65.0	68.0	64.5	67.4	75
340250005	New Jersey	Monmouth	80.0	64.1	66.5	65.4	67.9	68
340273001	New Jersey	Morris	76.3	62.4	63.8	62.6	64.0	69
340290006	New Jersey	Ocean	82.0	65.8	68.2	64.8	67.2	73
340315001	New Jersey	Passaic	73.3	61.3	62.7	59.9	61.3	68
340410007	New Jersey	Warren	66.0	54.0	54.0	50.9	50.9	65
360050133	New York	Bronx	74.0	63.3	65.0	63.8	65.6	70
360270007	New York	Dutchess	72.0	58.6	60.2	57.0	58.6	67
360610135	New York	New York	73.3	64.2	66.5	62.9	65.2	70
360715001	New York	Orange	67.0	55.3	56.9	54.2	55.8	65
360790005	New York	Putnam	70.0	58.4	59.2	56.7	57.5	70

Table A-1. 4km and EPA "No Water" 12km Design Value Results for Monitors Located in 4km Mid-Atlantic and Lake Michigan Modeling Domains.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		4km (4kei) Modeling		2015-2017 DV
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	
360810124	New York	Queens	78.0	70.2	72.0	68.5	70.2	74
360850067	New York	Richmond	81.3	67.1	68.5	69.6	71.0	76
360870005	New York	Rockland	75.0	62.0	62.8	63.7	64.5	72
361030002	New York	Suffolk	83.3	74.0	75.5	70.6	72.0	76
361030004	New York	Suffolk	78.0	65.2	66.9	63.8	65.4	76
361030009	New York	Suffolk	78.7	67.6	68.7	66.5	67.5	69
361192004	New York	Westchester	75.3	63.8	64.4	64.6	65.2	73
420110006	Pennsylvania	Berks	71.7	56.2	58.8	55.8	58.4	66
420110011	Pennsylvania	Berks	76.3	58.9	61.0	59.9	62.1	70
420170012	Pennsylvania	Bucks	80.3	64.6	66.8	64.4	66.6	80
420290100	Pennsylvania	Chester	76.3	58.7	60.8	59.9	62.0	73
420430401	Pennsylvania	Dauphin	69.0	54.7	54.7	54.9	54.9	65
420431100	Pennsylvania	Dauphin	74.7	58.3	60.1	59.1	61.0	66
420450002	Pennsylvania	Delaware	75.7	60.3	62.1	60.7	62.6	71
420710007	Pennsylvania	Lancaster	77.0	60.1	62.4	60.6	63.0	70
420710012	Pennsylvania	Lancaster	78.0	60.2	63.3	60.6	63.7	66
420750100	Pennsylvania	Lebanon	76.0	58.6	58.6	59.0	59.0	69
420770004	Pennsylvania	Lehigh	76.0	59.5	61.1	59.4	61.0	70
420890002	Pennsylvania	Monroe	66.7	52.9	55.6	52.6	55.2	67
420910013	Pennsylvania	Montgomery	76.3	61.0	62.4	62.0	63.4	72
420950025	Pennsylvania	Northampton	76.0	58.5	60.6	58.8	59.6	70
420958000	Pennsylvania	Northampton	69.7	54.8	55.9	54.7	55.7	69
421010004	Pennsylvania	Philadelphia	66.0	53.9	57.1	54.2	57.5	N/A
421010024	Pennsylvania	Philadelphia	83.3	67.3	70.3	67.5	70.5	78

Table A-1. 4km and EPA “No Water” 12km Design Value Results for Monitors Located in 4km Mid-Atlantic and Lake Michigan Modeling Domains.

			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		4km (4kei) Modeling		2015-2017 DV
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	
421011002	Pennsylvania	Philadelphia	80.0	64.7	64.7	65.3	65.3	N/A
421330008	Pennsylvania	York	72.3	56.9	58.3	58.3	59.7	66
421330011	Pennsylvania	York	74.3	58.0	60.1	58.8	61.0	70
440030002	Rhode Island	Kent	73.7	60.4	60.7	59.5	59.7	72
440071010	Rhode Island	Providence	74.0	59.5	61.1	59.9	61.6	70
440090007	Rhode Island	Washington	76.3	62.6	64.0	62.3	63.7	71
510130020	Virginia	Arlington	81.7	64.9	68.3	66.1	69.6	71
510330001	Virginia	Caroline	71.7	56.0	57.6	55.2	57.0	61
510360002	Virginia	Charles	75.7	59.4	62.0	61.1	63.7	61
510410004	Virginia	Chesterfield	72.0	56.8	59.2	55.6	58.0	62
510590030	Virginia	Fairfax	82.3	65.1	68.1	66.2	69.1	71
510850003	Virginia	Hanover	73.7	56.9	58.6	55.3	57.1	63
510870014	Virginia	Henrico	75.0	58.8	61.2	57.7	60.0	65
511071005	Virginia	Loudoun	73.0	57.8	59.4	58.7	60.3	68
511530009	Virginia	Prince William	70.0	56.2	57.8	54.8	56.3	66
511790001	Virginia	Stafford	73.0	57.1	59.4	57.0	59.4	62
515100009	Virginia	Alexandria City	80.0	63.4	65.8	64.7	67.1	N/A
516500008	Virginia	Hampton City	74.0	56.9	58.4	54.8	56.3	65
518000004	Virginia	Suffolk City	71.3	56.2	57.5	56.5	57.9	61
550290004	Wisconsin	Door	75.7	63.3	65.2	63.8	65.7	73
550590019	Wisconsin	Kenosha	81.0	64.8	67.2	59.6	61.8	78
550610002	Wisconsin	Kewaunee	75.0	64.5	67.1	64.6	67.2	69
550710007	Wisconsin	Manitowoc	78.7	67.6	68.7	66.6	67.7	74
550790010	Wisconsin	Milwaukee	69.7	60.6	62.6	60.2	62.2	65

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			Ozone Design Value (ppb)					
				EPA "No Water" 12km Modeling		4km (4kei) Modeling		
Monitor	State	County	DVb (2011)	DVf (2023) Ave	DVf (2023) Max	DVf (2023) Ave	DVf (2023) Max	2015-2017 DV
550790026	Wisconsin	Milwaukee	74.7	66.5	69.4	65.2	68.1	67
550790085	Wisconsin	Milwaukee	80.0	71.2	73.0	67.1	68.8	71
550890008	Wisconsin	Ozaukee	76.3	67.2	70.5	65.0	68.2	71
550890009	Wisconsin	Ozaukee	74.7	63.6	65.5	63.3	65.2	73
551010017	Wisconsin	Racine	77.7	62.2	64.8	58.2	60.7	N/A
551170006	Wisconsin	Sheboygan	84.3	72.8	75.1	71.5	73.8	80
551330027	Wisconsin	Waukesha	66.7	58.1	60.1	57.8	59.8	65