APPENDIX R

OZONE DESIGN VALUE-BASED ATTAINMENT DEMONSTRATION METHODOLOGY: APPLICATION OF TWO OZONE NONATTAINMENT AREAS IN TEXAS

DALLAS/FORT WORTH ATTAINMENT DEMONSTRATION

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Ozone Design Value-Based Attainment Demonstration Methodology: Application to Two Ozone Nonattainment Areas in Texas

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ABSTRACT

Since the inception of the 1990 Federal Clean Air Act (FCAA) Amendments, the discrepancy between the deterministic test for demonstrating modeled attainment of the one-hour National Ambient Air Quality Standard (NAAQS) and the monitoring-based attainment determination has been apparent. The monitoring-based demonstration is based on the design value and allows some eccedences of the ozone standard, while the deterministic modeled attainment test allows no eccedences of the standard at any location in the modeling domain during the time period simulated. The latter criterion is perceived by many to be much more stringent than the former, and the attainment demonstration modeling in Texas has indicated that reductions of over 80 percent in nitrogen oxides (NO_x) emissions may be required in some cases to demonstrate attainment.

The U. S. Environmental Protection Agency (EPA) has recently developed methods which relate modeled output more directly to the ozone design value of an area. Two such methods, one designed for application by one-hour nonattainment areas in the Ozone Transportation Assessment Group region and one designed for areas seeking transitional status under the eight-hour standard have recently been released. Texas has adapted this concept for its one-hour nonattainment areas, and has applied it to modeling performed for two nonattainment areas in eastern Texas. This paper details the calculation of a predicted design value based on model results, and compares the attainment requirements using the methodology based on the ozone design value with those using the deterministic test methodology based on the modeled area-wide maximum ozone concentration.

INTRODUCTION

As defined in the 1990 FCAA Amendments, the ozone design value for an area is based on the number of expected exceedances at a monitor, where an exceedance is defined as a monitored one-hour average ozone concentration exceeding 0.12 parts/million (ppm). A violation of the ozone NAAQS occurs whenever the number of expected exceedances at a monitor is greater than one per year. The number of expected exceedances is a statistical measure of air quality, which can be estimated using observed data. The statistic used to estimate the expected exceedances at a monitor is the ozone design value, defined simply as the fourth-highest monitored one-hour average ozone concentration at that monitor in a three-year period (in practice, the calculation is adjusted for periods when the monitor is not functioning). A violation (based on this statistic) then

occurs whenever the design value exceeds the one-hour standard of 0.12 ppm. The design value for an area is defined as the highest design value of all monitors in the area, and the area is in violation if the design value at any monitor is in violation. Areas in violation of the NAAQS would then be subject to being declared nonattainment by EPA.

One obvious problem with determining a violation in this manner is that the design value, based on only three years of observations, is highly subject to fluctuations caused by weather, hence areas whose expected exceedances are near one may experience attainment flip-flop [1]. A second problem occurs when using photochemical modeling results to demonstrate attainment of the NAAQS. The EPA Guidance [2] for demonstrating attainment requires that modeled one-hour ozone concentrations not exceed 0.12 ppm anywhere in the modeling domain for the duration of the episode modeled. This procedure is clearly inconsistent with the procedure by which the design value is calculated, and is in fact much more stringent [3]. Four of the principal discrepancies are:

1. The design value calculation allows measurements that exceed the standard (up to three in three years at each monitor), while the Guideline attainment demonstration methodology allows no exceedances at all.
2. The design value is based on monitors which represent only a small fraction of the area, while the model domain normally covers the entirety of the nonattainment area, along with some surrounding territory.
3. Modeled episodes often represent the most severe episodes observed over five or more years, while the design value is based on the fourth-highest concentration in a three-year period. Thus, modeled episodes typically represent more severe episode days than those defining the design value.
4. The Guideline methodology does not account for any model bias. If the model over-predicts in the base case, it is likely that an artificially stringent level of control will be required (conversely, under-prediction by the model could lead to insufficient control, if the modeling was approved by the appropriate EPA Region).

The disparity between the monitored and modeled attainment tests prompted EPA to develop the concept of “Weight of Evidence” [4], which allows states to use ancillary information and supplementary analyses to demonstrate attainment, even though the deterministic test described above fails to meet the Guideline criteria. One analysis method which helps to reconcile the monitored and modeled attainment tests was developed by Cox and Chiu [5]. This method accounts for discrepancy 3 above by normalizing the model results relative to episode severity. More recently, in its draft guidance for demonstrating attainment of the eight-hour ozone standard [7], EPA has developed a modeled attainment test which is directly related to the ozone design value (note that the definition of design value for eight-hour ozone is different from that of the one-hour design value). While the details of this methodology have not been finalized by EPA at this writing, the general concept is to use the model results in a relative, rather than absolute, fashion. The change in modeled concentrations in the vicinity of a monitoring site is used to adjust the monitor's design value to calculate a predicted future design value (DV_F).

Future Ozone Design Value Calculation for One-Hour Ozone Attainment Demonstration

The Texas Natural Resources Conservation Commission (TNRCC) has adapted the methodology proposed in the EPA's draft guidance [6] and later amended in the EPA's summary of peer review comments on the draft guidance [7] for use in one-hour nonattainment areas in Texas. This section describes the methodology using an example case for the DFW nonattainment area.

The ozone photochemical modeling in this example was conducted with 4 kilometer (km.) × 4 km. fine grid cells in the DFW nonattainment area and its vicinity for two ozone episodes: June 18 - 22, 1995 and June 30 - July 4, 1996. There are eight ozone monitoring sites in the nonattainment area. The following steps were taken to calculated the predicted future ozone design values.

Step 1. The current one-hour ozone design values, noted as DV_C, were calculated for the years 1995-1997 at each monitoring site (Table 1).

Step 2. The model-predicted current daily maximum one-hour ozone concentrations in the vicinity of each monitoring site, noted as P_C, were obtained from the base case model outputs. The P_C value for a monitoring site is defined as the maximum modeled ozone concentration in the 9×9 array of grid cells (4 km. × 4 km.) centered at the site. Table 2 lists the P_C values at each of eight ozone monitoring sites in the DFW nonattainment area for eight modeling days (excluding the modeling start-up days). A P_C value that meets the following condition was excluded for the further calculation:

$$1)\ DV_C \geq 125ppb \text{ and } P_C < 100ppb \quad \text{or} \quad (2)\ DV_C < 125ppb \text{ and } P_C < (DV_C - 20)ppb$$

This condition is applied to exclude modeled values which are much lower than the corresponding monitor's design value, since such model results will likely show little response to emissions reductions. P_C values meeting the above condition are listed in parentheses "(...)" in Table 2. The mean P_C values averaged over days for each monitor are also shown in the last row of Table 2.

Step 3. The model predicted future daily maximum one-hour ozone concentrations in the vicinity of each monitoring site, noted as P_F, were obtained from the future case model outputs in the same manner as were the P_C values. Table 3 lists the P_F values for a future year case, assuming a reduction of 30 percent NO_x and 15 percent volatile organic compound (VOC) from the projected 1999 anthropogenic emissions in the DFW nonattainment area. The P_F values corresponding to the P_C values excluded in Table 1 are also shown in parentheses in Table 3, and these values are excluded from the further calculation. The mean P_F values averaged over days are also shown in the last row of Table 3.

Step 4. In this final step, the relative reduction factor (RRF) for each monitor was calculated by dividing each P_F value by its corresponding P_C value for each modeling day and each monitor (Table 4). The average RRF for each monitor is shown in the next-to-last row of Table 4. The future ozone DV_F was then calculated by multiplying the DV_C value by the mean RRF for each monitor. The DV_F values are shown in the last row of Table 4. The maximum of the DV_F values (shown in bold) is the area's predicted future design value.

In its summary of peer review comments on the draft guidance [7], EPA indicates that it plans to amend the methodology illustrated above in its final draft guidance. The planned amendment changes how RRF values are calculated: instead of calculating a RRF for each individual day at a monitor, the average P_C and P_F values (shown in the last rows of Table 2 and 3) are used to calculate a single RRF value for a monitor. We denote this approach as "*ratio of means*", and the approach in the original draft guidance as "*mean of ratios*". Table 5 lists the RRF and DV_F values calculated using "ratio-of-means" approach. The two approaches yield very similar DV_F values, which is also demonstrated by other sensitivity tests [7]. The "ratio-of-means" approach will be used in the further discussion in this paper .

Comparison of Attainment Demonstration Methodologies

In this section, we compare the attainment requirements using the methodology based on the ozone design value, with those using the deterministic test methodology based on the modeled area-wide maximum ozone concentration. The comparisons were performed for two Texas one-hour ozone nonattainment areas: DFW and Houston/Galveston areas.

Dallas-Fort Worth Nonattainment Area

Modeling analysis was performed for the DFW area by projecting emissions to the area's attainment date of 1999 and applying mandated reductions. Further analyses indicated that additional reductions of NO_x from anthropogenic emissions in the DFW area would be necessary for the area to reach attainment and reductions of VOC would also be helpful. Therefore, modeling was conducted to determine the level of anthropogenic NO_x emission reduction required, assuming a concurrent 25 percent anthropogenic VOC emission reduction. Figure 1 illustrates the levels of NO_x emission reduction required to attain the one-hour NAAQS (125 ppb) for both the traditional and design value-based approaches.

The colored thin lines in Figure 1 are predicted area-wide maximum ozone concentrations for a series of NO_x reductions from projected 1999 anthropogenic emissions in DFW area for six modeling days in June, 1995 and July, 1996. For July 3, 1996, the modeled day requiring the largest reductions to demonstrate attainment, the graph shows that a NO_x reduction of over 70 percent would be required to demonstrate attainment under the Guideline's deterministic test method.

The bold line in Figure 1 is the predicted future ozone design value for the DFW area for the same series of anthropogenic NO_x emission reductions. The anthropogenic NO_x emission reduction requirement using the ozone design value methodology is on the order of 40 percent, which, clearly, is much lower than that using the deterministic test methodology. While all of the discrepancies between the modeled and monitored attainment determinations listed earlier play a part in the large disparity of the two attainment requirements, the most important factor is probably a positive bias of about 12 percent exhibited by the model on July 3, 1996 (shown in orange in Figure 1) against other modeling days. The DV_F has the agreeable property of automatically correcting for bias in model predictions, both positive and negative.

Houston/Galveston Nonattainment Area

Similar modeling analyses were conducted for the HG ozone nonattainment area. Figure 2 shows peak one-hour modeled future ozone concentrations in the area, plotted against a series of

anthropogenic NO_x emission reduction, concurrent with a 15 percent anthropogenic VOC emission reduction. The projection year is 2007, the HG area's attainment date.

The colored thin lines in Figure 2 show the model predicted maximum ozone concentrations in the HG area for four modeling days in September, 1993. The required level of reductions, using the Guideline's deterministic test methodology, is determined by September 8, 1993, the day requiring the maximum reduction (the "tail" seen on the graph for September 11, 1993 is due to a region of transported ozone that does not respond to local controls, hence was not considered in determining the required control level). For the HG area, the required reduction of NO_x is then seen to be around 85 percent using (additional analyses performed by TNRCC indicate that the actual reduction requirement is somewhere between 65 percent and 85 percent [8], but these analyses will not be discussed here).

The bold line in Figure 2 shows the model-predicted future ozone design values for the HG nonattainment area for the same series of NO_x reductions. Unlike the situation for the DFW area, this figure indicates that the control requirement based on the ozone design values is similar to the requirement based on the deterministic test method, and in fact is slightly higher. In this case, the particular episode modeled produced relatively low predicted ozone concentrations at some monitoring sites with high design values. Because the predicted ozone at these sites was low to begin with, it did not respond strongly to modeled NO_X reductions, resulting in RRF values close to unity. Since these sites had high ozone design values, the future design values remained well above the standard even for large reductions of NO_X. Since this analysis only used data from four modeling days of a single episode, the result should be regard as preliminary and inconclusive. However, this result does indicate that some further retooling of the future design value calculation may be required.

CONCLUSION

Based on applications to two Texas ozone nonattainment areas, it is seen that the DV_F-based attainment demonstration methodology may agree reasonably well with the Guideline's deterministic test method, but also may differ substantially. In the case of DFW the discrepancy between the two methods appears to be largely due to the DV_F method's built-in bias correction, which is a major advantage over the Guideline's methodology.

It should be noted that the DV_F methodology cannot replace the Guideline methodology in one-hour attainment demonstrations, but can be submitted as a Weight-of-Evidence argument. The methodology, which will likely become the guideline methodology for eight-hour attainment demonstrations, is appealing because it relates modeling results directly to the ozone design value. However, because the DV_F methodology uses modeling somewhat indirectly, some practitioners might be tempted to de-emphasize the importance of base case model performance and "getting the right answer for the right reason". The authors caution strongly against adopting a cavalier attitude towards model development. The key factor in any modeling application is how the model responds to projected changes in the emissions input. But it is precisely this response that is the basis of the DV_F calculation. Thus, it is as important as ever to adequately develop, test, and analyze the base modeling before testing controls.

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Table 1. Current ozone design values for 1995-1997 at eight monitors in the DFW nonattainment area.

Site Code	DANC	DCLC	DHIC	DTMA	FRIC	FWMC	KELC	TX44
DV_C (ppb)	134	129	121	139	132	133	131	134

Table 2. Model predicted current maximum ozone concentrations (ppb) in the vicinity of each monitor in the DFW nonattainment area (values in parentheses were excluded from the RRF calculation).

Site Code	DANC	DCLC	DHIC	DTMA	FRIC	FWMC	KELC	TX44
06/19/95	(93.8)	(97.7)	(84.8)	101.2	(93.8)	(93.1)	(96.3)	(83.5)
06/20/95	115.7	118.8	106.4	118.8	116.7	101.0	106.0	(97.6)
06/21/95	126.2	126.2	123.6	121.6	126.2	107.1	112.1	107.2
06/22/95	127.6	127.6	120.1	121.3	127.6	106.4	106.4	107.3
07/01/96	(92.9)	101.5	(81.3)	101.5	(98.9)	(85.8)	(88.5)	(80.8)
07/02/96	105.1	109.9	(93.4)	106.7	109.9	(91.7)	(94.4)	(85.2)
07/03/96	146.6	119.4	146.8	108.4	114.7	146.8	148.2	146.8
07/04/96	129.7	129.7	125.0	102.3	129.7	(95.4)	100.2	114.3
Average	125.2	119.0	124.4	110.2	120.8	115.3	114.6	118.9

Table 3. Model predicted future maximum ozone concentrations (ppb) in the vicinity of each monitor in the DFW nonattainment area (values in parentheses were excluded from the RRF calculation).

Site Code	DANC	DCLC	DHIC	DTMA	FRIC	FWMC	KELC	TX44
06/19/95	(89.6)	(92.3)	(84.4)	94.5	(88.1)	(87.4)	(91.0)	(80.9)
06/20/95	107.9	109.2	103.4	109.2	107.3	93.7	98.2	(94.4)
06/21/95	118.6	118.6	118.6	113.1	118.5	99.4	102.6	104.2
06/22/95	119.8	119.8	117.1	113.0	119.8	98.8	98.8	103.4
07/01/96	(89.9)	95.1	(81.9)	95.1	(94.5)	(80.9)	(83.5)	(79.6)
07/02/96	98.7	101.5	(92.6)	98.8	101.5	(85.3)	(87.8)	(82.1)
07/03/96	133.5	117.1	134.5	100.7	108.7	136.3	136.3	134.5
07/04/96	118.5	118.5	115.5	95.1	118.5	(88.3)	93.7	108.9

Average	116.2	111.4	117.8	102.4	112.4	107.1	105.9	112.7

Table 4. RRF and DV_F values of eight monitors in the DFW nonattainment area ("mean-of-ratios" approach).

Site Code	**DANC**	**DCLC**	**DHIC**	**DTMA**	**FRIC**	**FWMC**	**KELC**	**TX44**
06/19/95				0.93				
06/20/95	0.93	0.92	0.97	0.92	0.92	0.93	0.93	
06/21/95	0.94	0.94	0.96	0.93	0.94	0.93	0.92	0.97
06/22/95	0.94	0.94	0.98	0.93	0.94	0.93	0.93	0.96
07/01/96		0.94		0.94				
07/02/96	0.94	0.92		0.93	0.92			
07/03/96	0.91	0.98	0.92	0.93	0.95	0.93	0.92	0.92
07/04/96	0.91	0.91	0.92	0.93	0.91		0.94	0.95
Mean RRF	0.93	0.94	0.95	0.93	0.93	0.93	0.93	0.95
DV_F	124.5	120.8	114.9	**129.2**	122.8	123.4	121.2	127.5

Table 5. RRF and DV_F values of eight monitors in the DFW nonattainment area ("ratio-of-means" approach).

Site Code	**DANC**	**DCLC**	**DHIC**	**DTMA**	**FRIC**	**FWMC**	**KELC**	**TX44**
RRF	0.93	0.94	0.95	0.93	0.93	0.93	0.92	0.95
DV_F	124.4	120.7	114.6	**129.2**	122.8	123.4	121.1	127.1

Figure 1: Model-predicted DFW area maximum ozone concentrations and DV_F for various NO_X emission reductions (assuming a concurrent 25% VOC emission reduction).

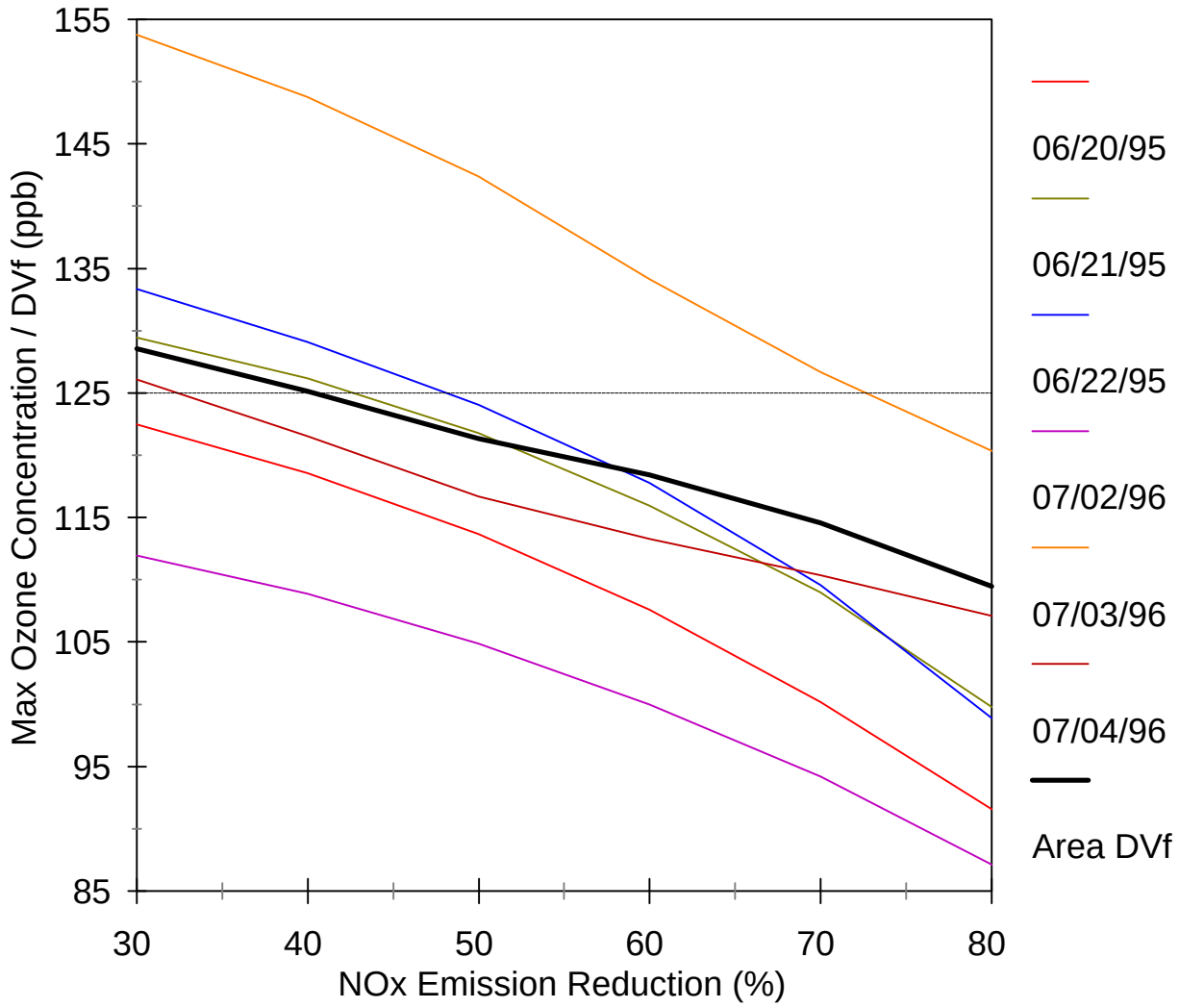
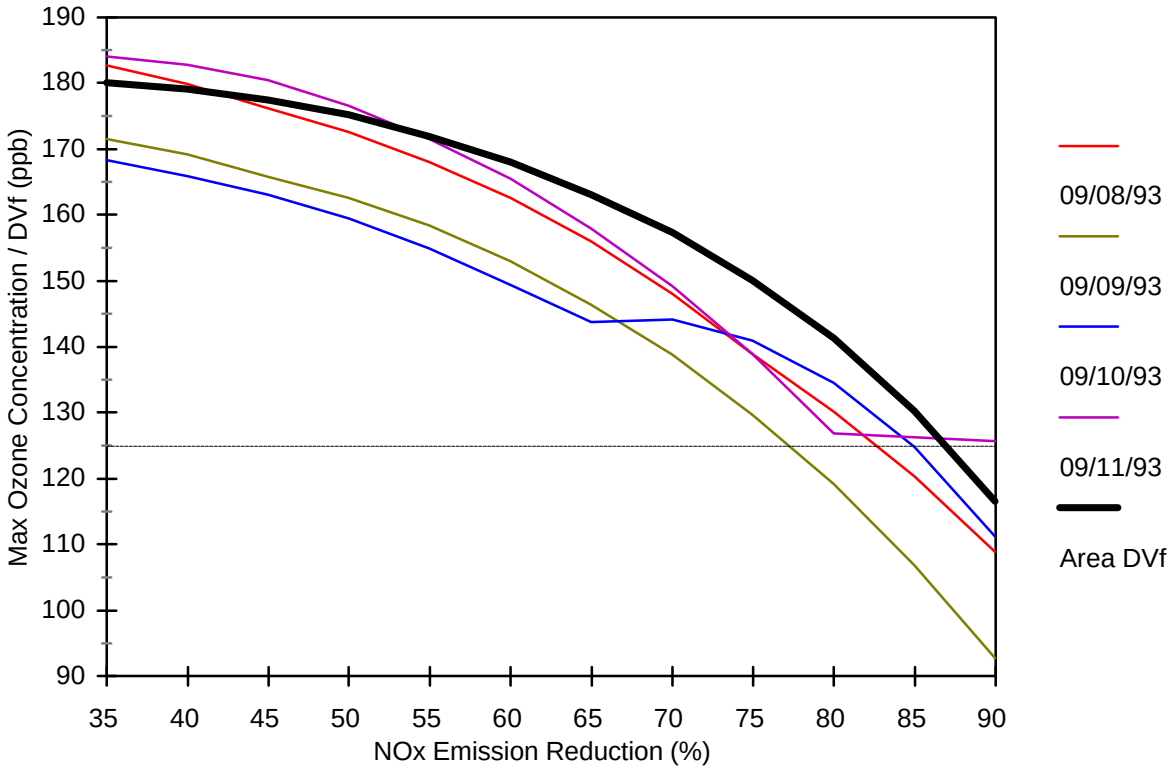
Figure 2: Model-predicted HG area maximum ozone concentrations and DV_F for various NO_X reductions (assuming a concurrent 15 percent VOC reduction).