Final Report

DALLAS – FT. WORTH TRANSPORT PROJECT

Prepared for

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EXECUTIVE SUMMARY

BACKGROUND

Ozone concentrations in the Dallas – Ft. Worth (DFW) area have exceeded the National Ambient Air Quality Standard (NAAQS) for many years. Tarrant, Dallas, Denton, and Collin counties (the four "core" counties) were originally classified as "moderate" nonattainment with respect to the 1-hour ozone NAAQS in 1991. This four county region is currently designated as a serious 1-hour ozone nonattainment area with an attainment date of 2005.

In 1997, EPA promulgated a new, 8-hour average ozone standard which is generally more stringent than the previous 1-hour standard. Texas is currently developing a Transitional SIP which will address attainment of both the 1-hour and 8-hour standards. This SIP is due to be submitted in 2004. Texas and EPA are currently in discussions concerning the boundaries of the new 8-hour DFW nonattainment area. EPA proposed including all twelve counties that constitute the DFW Consolidated Metropolitan Statistical Area (CMSA) in the new nonattainment area whereas Texas recommended excluding five of the outlying CMSA counties from the new nonattainment area.

High ozone events in the DFW area are influenced by NOx and VOC emissions from sources within the four core county region, by emissions from counties just outside of this region, and by transport of ozone and ozone precursors from other parts of Texas and neighboring states. Modeling of the August, 1999 high ozone episode conducted in support of the current SIP revision demonstrated the importance of NOx sources and regional transport. Transport from sources located in counties surrounding the central DFW area may or may not be subject to nonattainment area controls such as emission offset requirements depending on where the nonattainment area boundary is ultimately drawn. In addition, transport from upwind locations will change in future years in response to economic growth and implementation of emission control measures affecting those locations. Due to their potential significance, additional information is needed on the relative impacts of transport from these sources on violations of the ozone NAAQS in DFW.

A series of data analysis and photochemical modeling studies were reviewed to evaluate the impact of ozone and ozone precursor transport on ozone violations in DFW. The objectives of these analyses were:

- To assemble the available technical information relevant to the role of transport in DFW ozone nonattainment.
- To develop quantitative valuations of the contributions of sources located outside the four core counties to exceedances of the ozone standard using a variety of methods applied to the most recent available ozone modeling database for the DFW area (the 13-22 August 1999 episode period).
- To review results from the various technical approaches applied in this study and their relative strengths and weaknesses so as to provide guidance and assistance to policy-makers in setting the new nonattainment area boundaries and, subsequently, in developing local and regional emission control strategies.

DATA ANALYSES

Exploratory analyses of emissions, meteorological, and air quality data considered for this study included:

- Examination of ozone precursor emission budgets and ozone monitoring data in counties that are part of the DFW CMSA.
- Comparisons of historical trends in emissions and ambient ozone levels in DFW.
- Comparison of the frequencies of ozone exceedances by day of week.
- Examination of aircraft data from flights over DFW and vicinity and other portions of East Texas.
- Examination of back trajectories indicating the paths taken by air parcels arriving at DFW on the afternoons of high and low ozone days during the ozone season.
- Application of the Trajectory Mass Balance (TrMB) method for estimating source contributions to ozone to selected receptor sites in DFW.
- Examination of animated point source plume trajectories for selected days.

Results from these analyses clearly indicate the important contribution to peak 1-hour and 8-hour ozone levels of NOx emissions from sources located upwind of the four core DFW counties (Dallas, Denton, Collin, and Tarrant). Specifically, the analyses show that:

- Under prevailing wind directions during high ozone events, upwind sources lie to the east, southeast, and south of the core urban area, consistent with the spatial pattern of measured ozone design values.

- Trajectory analyses show that high ozone events in DFW are associated with slow moving air parcels originating primarily from east, southeast and south of the metropolitan area.

- Quantitative estimates of the relative contributions of different source regions within and outside of Texas to ozone concentrations in DFW obtained from the TrMB method are difficult to interpret because of technical limitations of the technique.

- Animated plume trajectories show plumes from sources just upwind of the four core DFW counties traveling over the urban area during high ozone episodes but provide no quantitative estimates of the contribution of a source to observed ozone levels.

- Comparisons of trends in ambient ozone concentrations with trends in VOC and NOx emissions and comparisons of weekday versus weekend ozone levels both indicate that ozone levels in DFW are sensitive to changes in NOx emissions and relatively insensitive to changes in anthropogenic VOC emissions.

- Data from aircraft measurement programs show that conditions in some parts of eastern Texas are favorable for formation of ozone in plumes from large isolated (point) sources of NO_x: ozone increases of 30 – 35 ppb have been observed in such plumes. These large industrial facilities are important sources of NOx emissions outside of the core urban area.

- Aircraft data also show that transport of elevated regional background ozone into the DFW CMSA is significant, approaching 80 - 90 ppb under certain conditions and

typically amounting to about 50% of the ozone measured in the center of the urban plume downwind of the city.

- Examination of 1999 emission budgets for counties in the DFW CMSA reveals that large NOx point sources are present in several outlying counties. Ellis Co. had the highest point source NOx emissions of any CMSA county and total NOx emissions from all sources in Ellis Co. were the highest of any county outside of the four "core" counties.

When considering the above results, it is important to keep in mind that high emissions do not necessarily produce high ozone impacts: the emissions must be upwind of the ozone impact area of concern and the emissions, when mixed with those from other sources, must have the right mix of precursors (VOC and NOx) to form ozone. Our results show that Ellis Co. is frequently upwind of DFW on high ozone days, and aircraft data show that point source NOx emissions can produce ozone in eastern Texas when VOCs are available from biogenic sources. Large biogenic VOC source regions are upwind of Ellis Co. and DFW under southeasterly winds.

MODELING ANALYSES

A series of modeling analyses were conducted to supplement the data analysis results described above and provide quantitative estimates of the contributions of different sources to ozone levels in DFW. This included:

- Source apportionment modeling of the 15 – 22 August 1999 episode with CAMx using the OSAT and APCA methodologies.
- Zero-out modeling of selected source regions under the 15 – 22 August 1999 episode for comparison with the source apportionment results.

Due to nonlinear chemical mechanisms involved in ozone formation, there is no one unique or single "correct" way to apportion ozone among sources, but there are several approaches that can be used with the CAMx photochemical model: Ozone Source Apportionment Technology (OSAT); Anthropogenic Precursor Culpability Assessment (APCA); and Zero-out differences. OSAT and APCA represent two different ways of apportioning the total predicted ozone at a given place and time to groups of sources. The methods differ only in the manner in which biogenic sources are treated: under OSAT, attributions are based solely on what precursors were present when the ozone is formed. APCA modifies the OSAT method to account for the fact that biogenic emissions are not considered to be controllable, and therefore APCA attributes ozone to controllable (anthropogenic) emissions whenever possible. Zero-out differences are simply equal to the difference in predicted ozone between a model run with all sources included and a model run in which emissions from a selected group of sources have been set to zero.

Each of these modeling approaches has its own interpretation and associated strengths and weaknesses. Taken together, results from these analyses provide a variety of quantitative data on anthropogenic source contributions that can be used by policy-makers to inform decisions on nonattainment area boundaries and control strategy development. In interpreting these results, it is necessary to keep in mind that there is no unique way to assess the contribution to ozone exceedances of different sources of precursor emissions due to nonlinearities in ozone chemistry. For the same reason, ozone source contributions do not provide quantitative predictions of the impact of any specific emission control strategies. However, the APCA and zero-out modeling

do reveal consistent patterns in the relative contributions of source areas supporting the reliability of these results as a guide for control strategy development. Our results show that:

- OSAT results identify biogenic emissions as a major contributor to ozone formation, reflecting the high contribution of biogenics to total VOC emissions. APCA reduces the apportionment of ozone to biogenic emissions to near zero and increases the apportionments to anthropogenic (NOx) emissions to compensate.
- The APCA and zero-out results are consistent with one another in terms of rank ordering of source regions and the locations of maximum impacts and areas of influence.
- APCA results indicate that emissions within the 4 core counties are the largest anthropogenic emissions contributor and are responsible for about one third of elevated ozone levels in DFW. The continental ozone background (i.e., model boundary contributions) and transport from upwind areas each also contribute about one third of elevated ozone levels in DFW.
- The zero-out differences are smaller than APCA apportionments and do not sum to total ozone, thus emphasizing that zero-out run differences do not represent source apportionments.
- The zero-out ozone differences are always smaller in magnitude than the corresponding APCA ozone apportionments because zero-out does not account for the non-controllable nature of biogenic emissions, among other reasons. The zero-out results generally suggest slightly greater importance for local emissions (4 core counties) and lesser importance for distant sources (continental ozone background).
- APCA and zero-out both show that transport from upwind source areas is an important contributor to elevated ozone in DFW. Since aircraft data show that transported ozone can reach 80-90 ppb, reductions in ozone transport will likely be necessary for DFW to demonstrate attainment of the ozone standard.
- The APCA and zero-out results both indicate that Ellis Co. is the largest ozone contributor of the 12 counties surrounding the 4 core DFW counties. Outside of this 16 county region, Northeast Texas and Central Texas are the next most important source regions within Texas, followed by the Houston/Galveston/Beaumont/Port Arthur nonattainment area.
- Of the three neighboring states most frequently upwind on high ozone days (LA, AR, OK), Louisiana provides the largest ozone contribution.
- The APCA and zero-out results reveal plumes of ozone contributions from large industrial combustion sources in Ellis Co. that are shown to overlap regions of maximum ozone on more than one occasion during the 15 – 22 August 1999 episode.
- The APCA and zero-out results were analyzed to see how frequently source areas contributed more than 2 ppb to 8-hour ozone above 85 ppb in the 4 core counties. Of the surrounding DFW counties, Ellis Co. was the most frequent contributor above 2 ppb, contributing more than 2 ppb 26% of the time in the APCA results and 9% of the time in the zero-out results. Central Texas, Northeast Texas, and the Houston-Galveston/Beaumont-Port Arthur areas each contribute more than 2 ppb over 55% of the time in the APCA results and more than 46% of the time in the zero-out results.

In addition to the APCA and zero-out modeling described above, a sensitivity analysis was performed in which we modeled the potential impact of new industrial NOx sources on DFW ozone levels without regard to emission changes to existing sources which will occur in conjunction with operation at the new sources. A survey of new sources for which permits have

been issued in the DFW CMSA and surrounding counties indicates that these sources are estimated to emit approximately 30 tons/day of NOx which amounts to approximately 60% of the total point source NOx in the four core counties or, equivalently, 5% of total NOx from all sources in the four core counties in 1999. Results from a CAMx sensitivity run in which these new sources were added to the 1999 inventory show that ozone in the CMSA is sensitive to the additional NOx, with episode maximum 8-hour ozone increasing by as much as 4 ppb in some locations.

In summary, it is clear that NO_x sources located outside the four-core counties (Dallas, Collin, Denton and Tarrant) play an important role in ozone nonattainment in DFW. The impacts of these sources will need to be considered in the design of any attainment strategy, as will the influence of NO_x control strategies being implemented in other parts of eastern Texas and surrounding states.

1. INTRODUCTION

Ozone concentrations in the Dallas – Ft. Worth (DFW) area have exceeded the National Ambient Air Quality Standard (NAAQS) for many years. Tarrant, Dallas, Denton, and Collin counties (the four "core" counties) were originally classified as "moderate" nonattainment with respect to the 1-hour ozone NAAQS in 1991 (see **Figure 1-1**). Having failed to reach attainment by the deadline established for "moderate" areas, these four counties were upgraded to "serious" nonattainment in 1996 with a revised attainment deadline in 1999. However, the area again failed to reach attainment by this deadline and a revised State Implementation Plan (SIP) was submitted to EPA in April, 2000 which focused in part on the role of local NOx sources and transport of ozone and ozone precursors from outside the DFW area (particularly from Houston – Galveston) in generating ozone exceedances in DFW. Texas requested an extension of the attainment date to 2007 to allow DFW to take advantage of emission controls scheduled to be in place in Houston – Galveston by that date. Citing court rulings that EPA did not have the authority to grant attainment date extensions for two other cities (Baton Rouge and St. Louis), EPA has taken no action to approve the 2000 SIP submittal. DFW is thus currently designated as a serious 1-hour ozone nonattainment area with an attainment date of 2005.

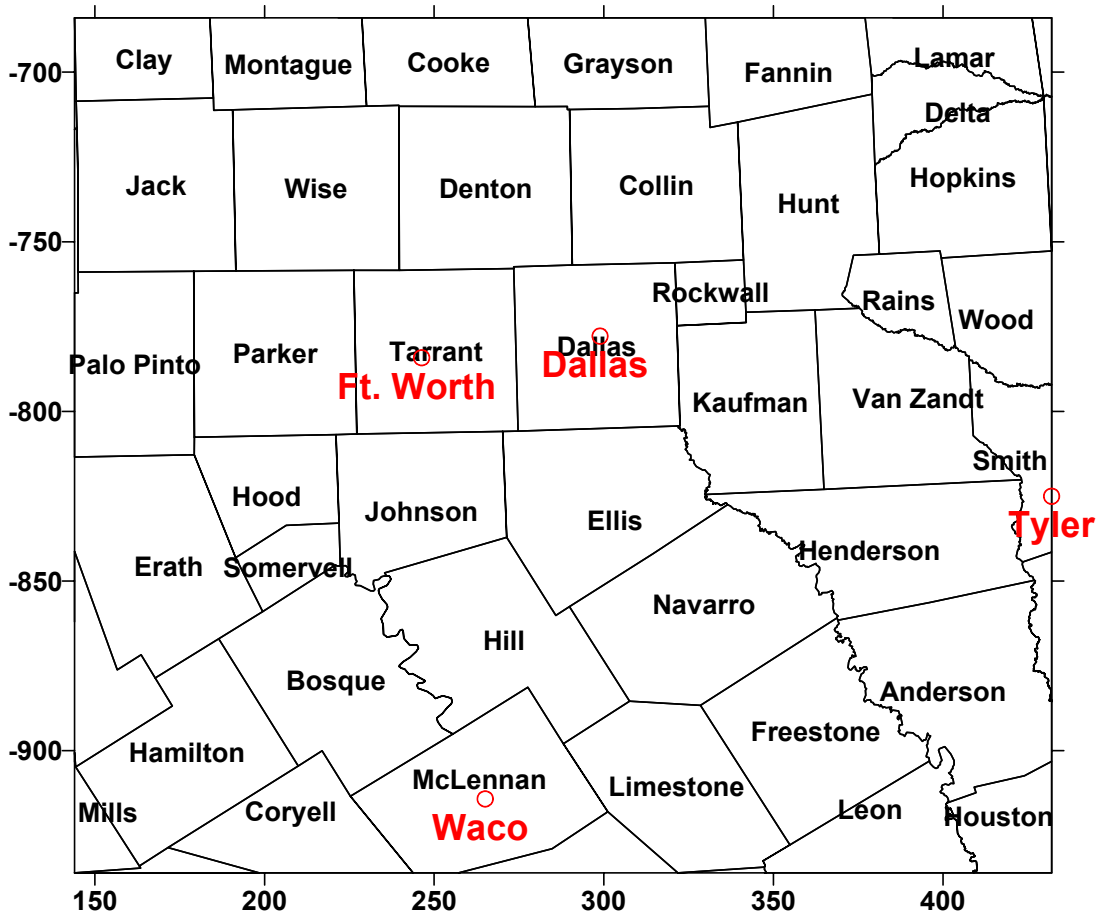
In 1997, EPA promulgated a new, 8-hour average ozone standard which is generally more stringent than the previous 1-hour standard. Texas is currently developing a Transitional SIP which will address attainment of both the 1-hour and 8-hour standards. This SIP is due to be submitted in 2004. Texas and EPA are currently in discussions concerning the boundaries of the new 8-hour DFW nonattainment area. EPA proposed including all twelve counties that constitute the DFW Consolidated Metropolitan Statistical Area (CMSA) in the new nonattainment area whereas Texas recommended excluding five of the outlying CMSA counties from the new nonattainment area boundary.

High ozone events in the DFW area are influenced by NOx and VOC emissions from sources within the four core county region, by emissions from counties just outside of this region, and by transport of ozone and ozone precursors from other parts of Texas and neighboring states. Modeling of the August, 1999 high ozone episode conducted in support of the current SIP revision has demonstrated the importance of NOx sources and regional transport. The modeling domain is shown in **Figure 1-2**. NOx sources located in counties surrounding the central DFW area may or may not be subject to nonattainment area controls depending on the where the nonattainment area boundary is ultimately drawn. Transport from more distant locations will change in future years in response to economic growth and emission control measures affecting those locations. Due their potential significance, additional information is needed on the relative impacts of transport from these sources on violations of the ozone NAAQS in DFW.

We undertook a series of data analysis and photochemical modeling studies to evaluate the impact of ozone and ozone precursor transport on ozone violations in DFW. The objectives of this study are:

- To assemble the available technical information relevant to the role of transport in ozone nonattainment for DFW.
- To develop quantitative valuations of the contributions of sources located outside the four core counties to exceedances of the ozone standard using a variety of methods applied to the most recent available ozone modeling database for the DFW area (the 13-22 August 1999 episode period).

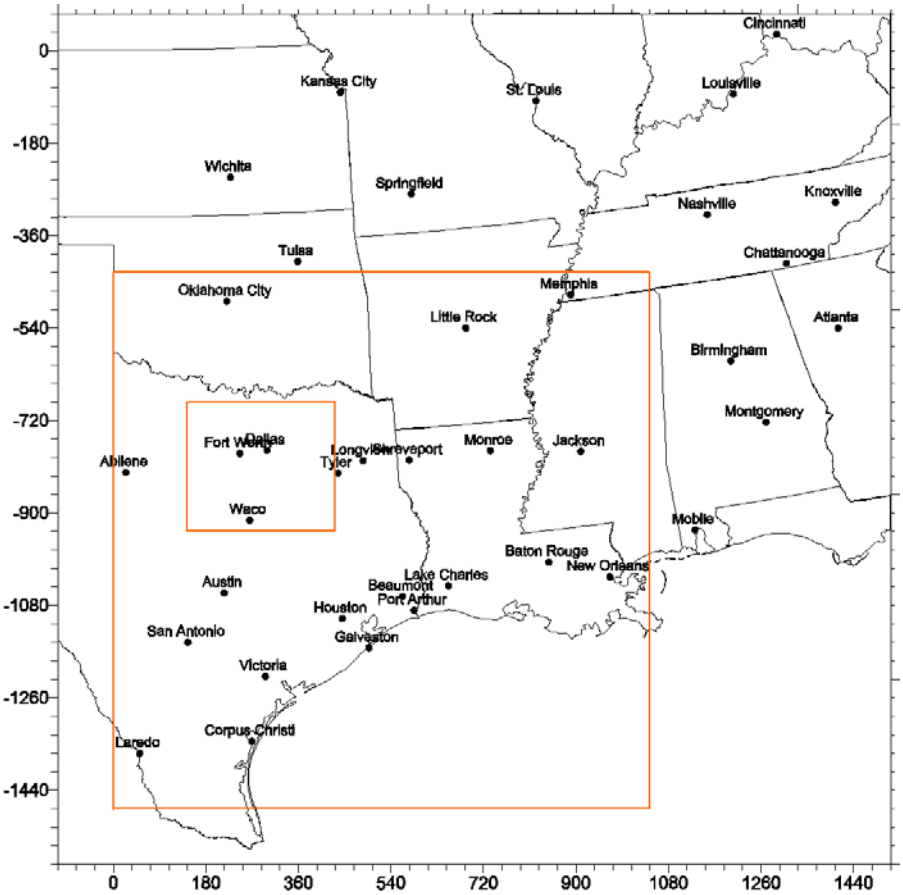
- To review results from the various technical approaches applied in this study and their relative strengths and weaknesses so as to provide guidance and assistance to policy-makers in setting the new nonattainment area boundaries and, later on, in developing local and regional emission control strategies.



CAMx GRID DIMENSIONS
LCP Grid with reference origin at (40N, 100W)

4 km Grid: 72 x 63 cells from (144, -936) to (432, -684)

Figure 1-1. Map of Dallas – Ft. Worth and surrounding region with county boundaries and locations of selected major cities. Map boundaries correspond to the CAMx photochemical model 4 km fine grid domain used to model the August 19999 episode (see Section 4).



CAMx GRID DIMENSIONS
LCP Grid with reference origin at (40 N, 100 W)

36 km Grid: 45 x 46 cells from (-108, -1584) to (1512, 72)
12 km Grid: 87 x 87 cells from (0, -1476) to (1044, -432)
4 km Grid: 72 x 63 cells from (144, -936) to (432, -684)

(nested grid dimensions do not include buffer cells)

Figure 1-2. CAMx modeling domain for the August 1999 episode showing the 36-km regional grid and the nested 12-km and 4-km fine grids.

2. EMISSIONS AND AIR QUALITY

Emissions and air quality data in the DFW area were gathered, summarized and evaluated with respect to the potential impact of ozone precursor emissions from sources outside the four core counties on peak ozone in the region. Results are presented in the following sub-sections.

EMISSIONS

The most detailed and comprehensive emission inventory data available are for 1999 because this is the base year for current ozone modeling activities in the DFW area. A summary of county-level NOx emissions by major source category for the 12 DFW CMSA counties has been prepared by TCEQ, 2003 (**Figure 2-1**). Dallas and Tarrant counties have the largest NOx totals by a wide margin. Of the remaining counties, Ellis has the highest total. Point sources in Ellis and Hood counties contribute considerable amounts of point source NOx to the CMSA total. In particular, Ellis Co. has the highest point source NOx emissions of any CMSA county. Large NOx point sources are also present in several other outlying counties as shown in **Figure 2-2** (county and city names for this region are shown in Figure 1-1).

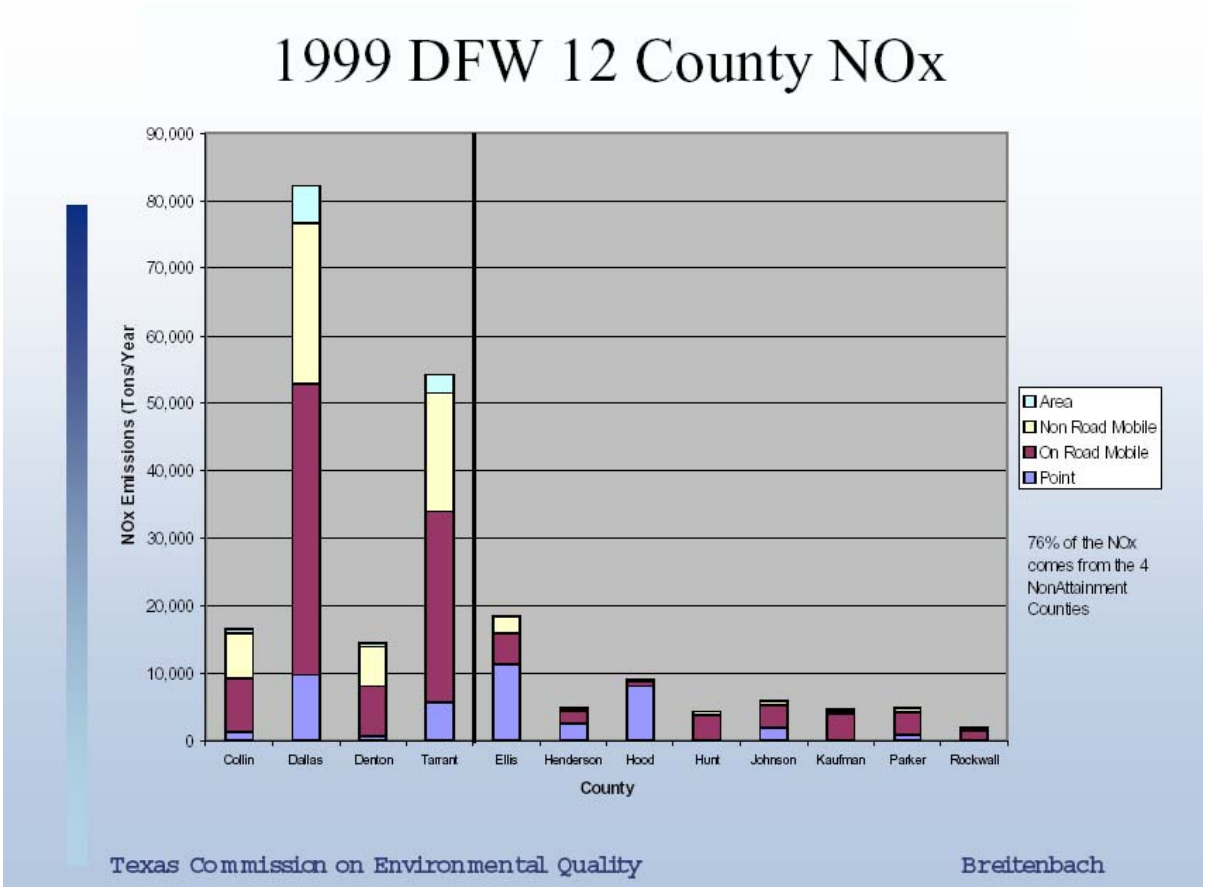


Figure 2-1. NOx emissions in 12-county Dallas-Ft. Worth Consolidated Metropolitan Statistical Area (Source: TCEQ, 2003).

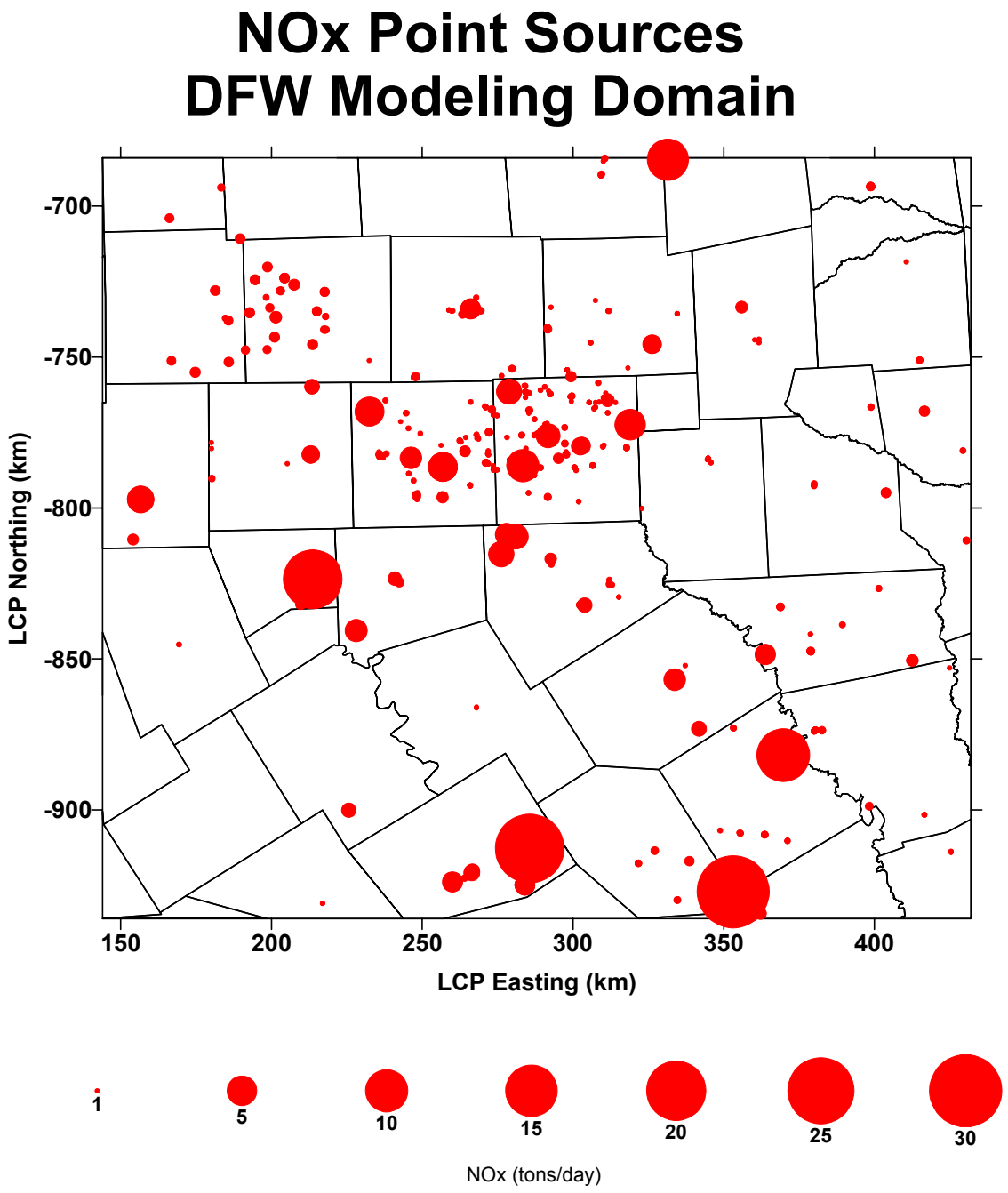


Figure 2-2. NOx point sources in the DFW fine grid modeling domain (1999 modeling inventory).

Biogenic Emissions

Biogenic VOC emissions are important in the DFW area because they are relatively large in magnitude relative to anthropogenic VOC emissions, are not controllable, and therefore lead to NOx control being the most effective ozone control strategy in the DFW area. Evidence for the effectiveness of NOx control comes from both ambient data and modeling analyses presented below. **Figure 2-3** shows the spatial distribution of biogenic VOC emissions in the DFW fine grid ozone modeling domain. This figure shows that areas with relatively high biogenic VOC emissions lay to the southeast and east of the DFW area, which means that when winds are out of these directions there is greater potential for biogenic VOCs to interact with NOx emissions in the DFW area and form ozone. Back trajectory analyses presented in Section 3 below show that winds from the southeast and east are associated with high ozone conditions in the DFW area (likely due to a combination of factors).

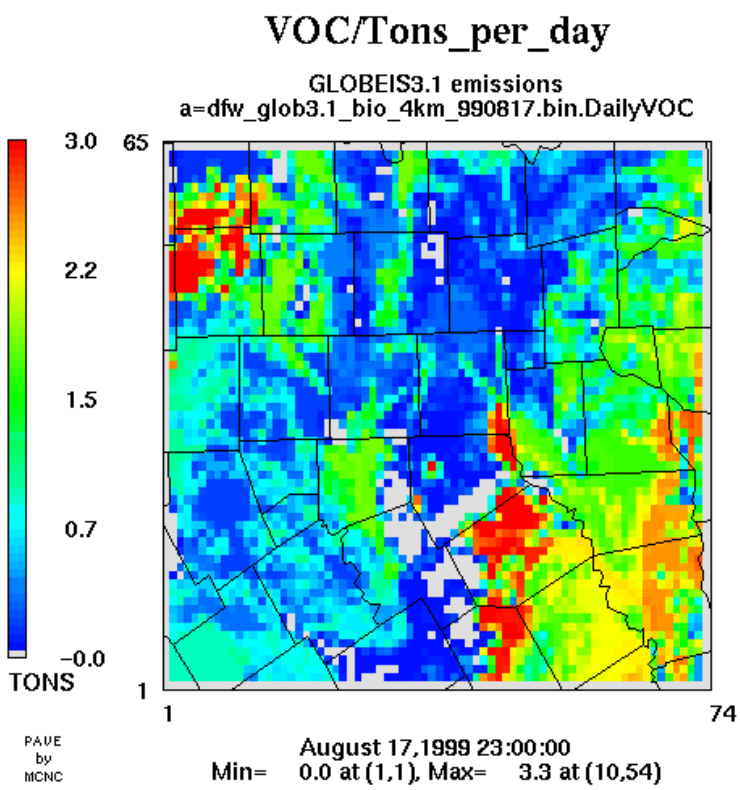


Figure 2-3. Biogenic VOC emissions in the DFW fine grid modeling domain (August 17, 1999 modeling inventory).

New Sources

In preparation for CAMx modeling of the DFW area for a future year (2007) scenario, TCEQ surveyed permit application data and information from the Texas Energy Council for sources that have begun or are scheduled to begin operations during 1999 – 2007. New electric generating units at nine facilities located in eight different counties along with one new industrial source (a cement kiln in Ellis Co.) were identified via this process within the 30 county region consisting of the 12 county DFW CMSA and all surrounding counties. Together, these new sources are estimated to produce 30 tons/day of NOx or 11,000 tons/year which is, for example, about as much as the Ellis County point source NOx emissions for 1999 as shown in Figure 2-1. A CAMx modeling analysis was performed to examine the sensitivity of DFW ozone to emissions from these new sources; details are presented in Section 4 below.

AIR QUALITY

Ozone concentrations in DFW have historically violated both the 1-hour and 8-hour NAAQS. Recent air quality data were summarized by ENVIRON (2002). An updated summary of 8-hour ozone design values is presented in **Table 2-1**.[1] During the most recent attainment period (2001 – 2003), 13 of the 17 reporting sites recorded a violation of the 8-hour standard. Ellis, Hood, Kaufman, and Rockwall counties did not violate the standard during this period but Collin, Dallas, Denton, Johnson, Parker, and Tarrant did. No data or incomplete data were recorded in Henderson and Hunt counties.[2] Annual 4th highest daily maximum values at monitors in Ellis, Hood, Kaufman and Rockwall counties are shown in **Figure 2-4**. Ellis County recorded the highest value in this set of counties in every year except 2001 when it recorded the lowest; the sharp dip in 2001 was not matched at the other monitoring sites in this group or at other sites in DFW, making it unlikely that the 2001 minimum at Ellis resulted entirely from regional scale changes in emissions or weather patterns. Valid daily maximum 8-hour averages were recorded in Ellis Co. on 243 of the 245 days during the 2001 ozone monitoring season so missing data is not an issue. Based on this information, the low reading in 2001 cannot be tied to any specific cause and may simply reflect random variations in the annual 4th highest value at this site. In any event, the low 2001 value is solely responsible for producing attainment in Ellis Co. in the most recent three year period. The 4th highest value in 2004 will have to be less than 79 ppb to achieve attainment for the 2002-2004 period.

Figure 2-5 illustrates the spatial distribution of 8-hour design values in DFW for the 2001 – 2003 attainment period. Areas which violate the 8-hour standard cover most of the metropolitan region with the highest values falling along the Tarrant – Denton county line and the lowest values southeast of Dallas. Monitoring data is not available north of central Denton County or in Wise or Palo Pinto counties, making it difficult to determine the full downwind extent of the area of 8-hour violations and thus the potential for sources in the other surrounding counties to contribute to these violations.

[1] The design value for the 8-hour ozone standard is defined as the average over three consecutive years of the annual fourth highest daily maximum 8-hour average concentration. A violation occurs when this value equals or exceeds 85 ppb.

[2] The first year of monitoring data in Hunt county meeting EPA's completeness criteria was 2003; the 4th highest daily maximum 8-hour average concentration in 2003 was 77 ppb.

Table 2-1. Eight-hour ozone design values for monitors in DFW area (shaded values are above the level of the 8-hour standard).[3]

County	City	CAMS	Design Values (ppb)			
			1998-2000	1999-2001	2000-2002	2001-2003
Collin	Frisco	C31	101	99	93	88
Collin	Anna	C68			83	80
Dallas	Dallas	C60,C401	93	92	91	90
Dallas	Dallas	C63		93	89	86
Dallas	Dallas	C402	88	82	82	83
Dallas	Sunnyvale	C74				83
Denton	Denton	C56	102	101	99	97
Ellis	Midlothian	C94	97	88	86	82
Hood	Granbury	C73			84	84
Johnson	Cleburne	C77			89	90
Kaufman	Kaufman	C71			70	73
Parker	Weatherford	C76			86	89
Rockwall	Rockwall	C69			83	81
Tarrant	Arlington	C57	95	86		
Tarrant	Eagle Mountain Lake	C75			95	96
Tarrant	Fort Worth	C13	99	97	96	96
Tarrant	Fort Worth	C17	97	97	98	100
Tarrant	Grapevine	C70			95	100

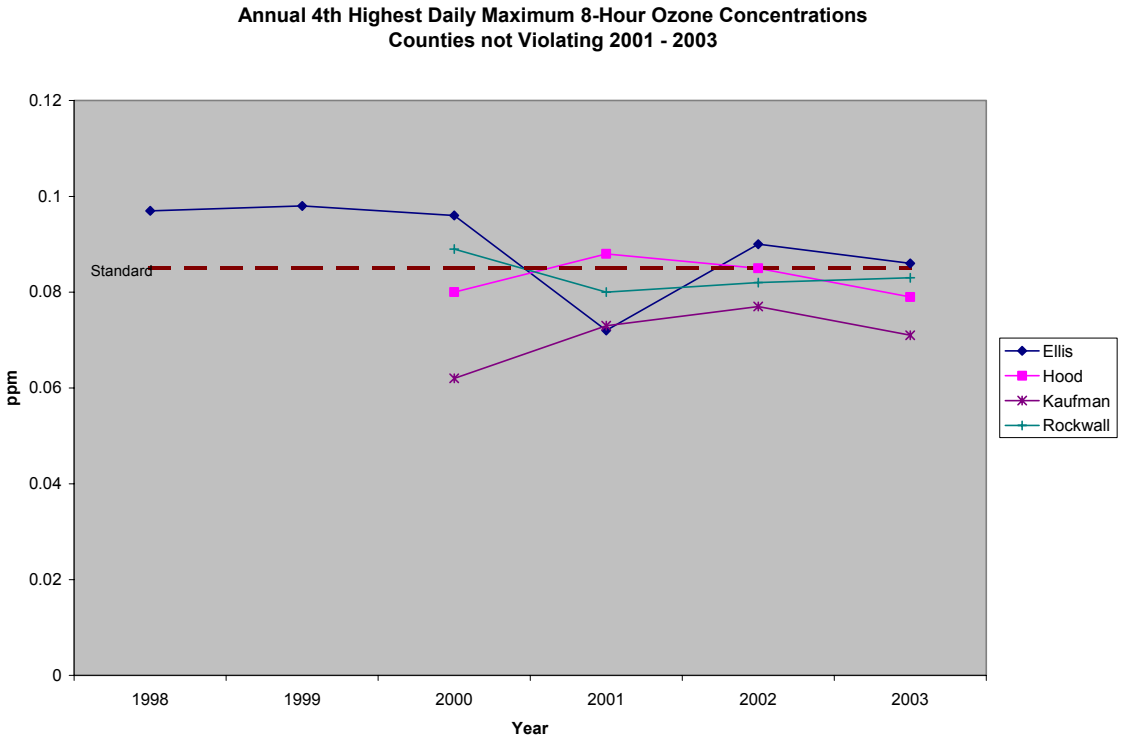


Figure 2-4. Annual 4th highest daily maximum 8-hour ozone concentrations at monitoring sites that did not violate the 8-hour standard in the 2001-2003 attainment period.

[3] Only design values meeting the data completeness criteria in 40 CFR 50 Appendix I are shown. Annual 4th highest daily maximum 8-hour concentrations were downloaded from the U.S. Environmental Protection Agency Air Quality System by Zhaohua Fang, Texas Commission on Environmental Quality, 12 February 2004.

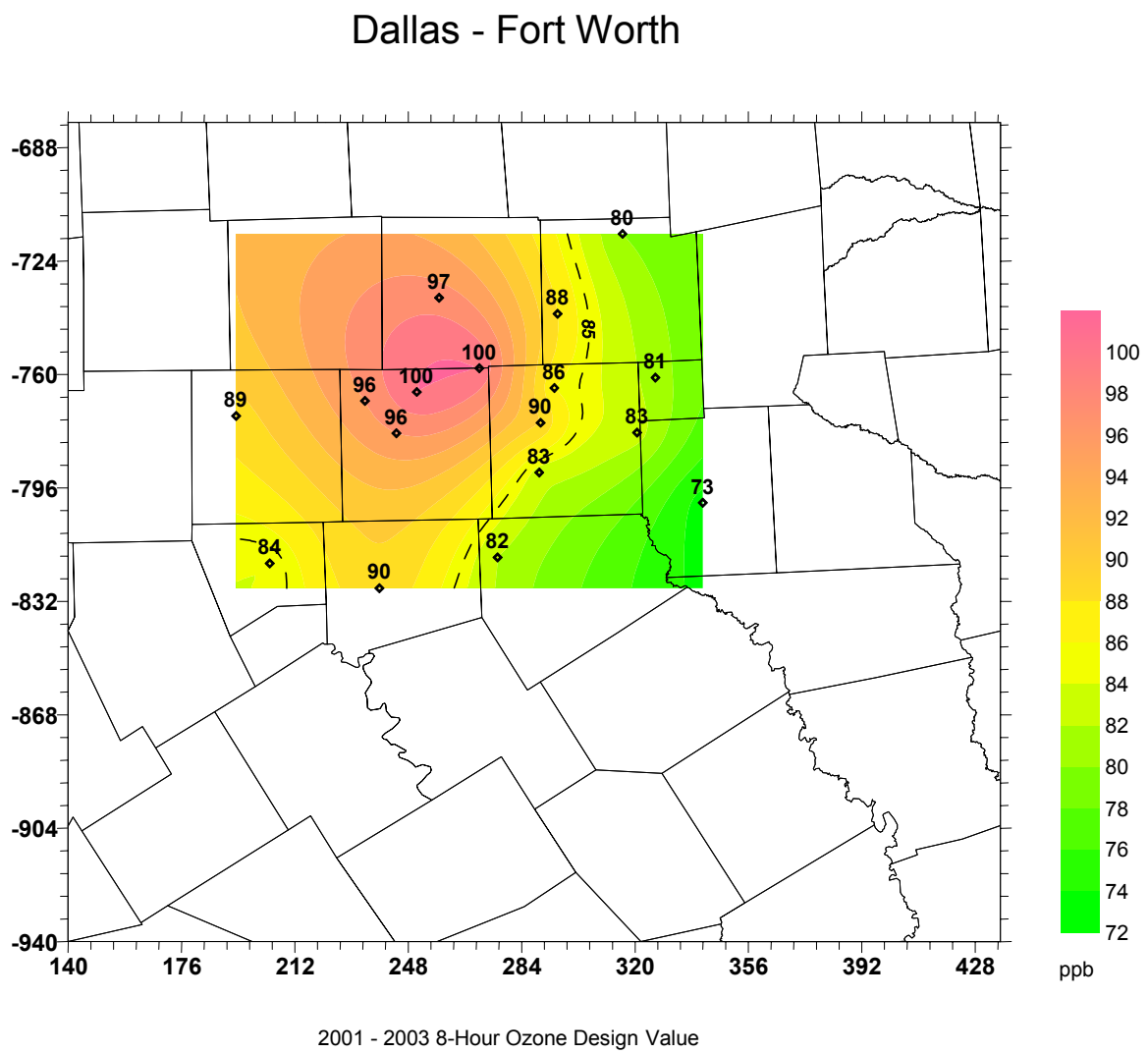


Figure 2-5. Spatial distribution of 8-hour ozone design values in DFW for 2001 – 2003.

Trends

Trends in reported DFW anthropogenic VOC and NOx emissions are illustrated in **Figure 2-6**. VOC emissions declined 32% over the period while total NOx emissions have remained largely unchanged. Trends in 8-hour ozone design values at monitors with substantially complete data records back to at least 1995 are shown in **Figure 2-7**.

These results show no obvious trend in ozone between 1990 and 2003, indicating that the anthropogenic VOC reductions have had no discernable impact on the ozone design value. These trends are consistent with the conclusion that ozone formation in DFW is largely NOx limited and that NOx reductions will be required to reach attainment. Of course, it is possible that VOC reductions greater than the 32% decline reported for the 1990 – 2000 period could produce some ozone reductions. However, biogenic VOC emissions constitute approximately 65% of total VOC emissions in the 12 county DFW CMSA[4] thus significantly limiting the

[4] Based on 13 – 22 August 1999 average daily emissions (Mansell et al., 2003).

fractional impact of anthropogenic control measures on total VOC emissions. For example, to reduce total VOC by just 25%, anthropogenic VOC would have to be reduced by 71%.

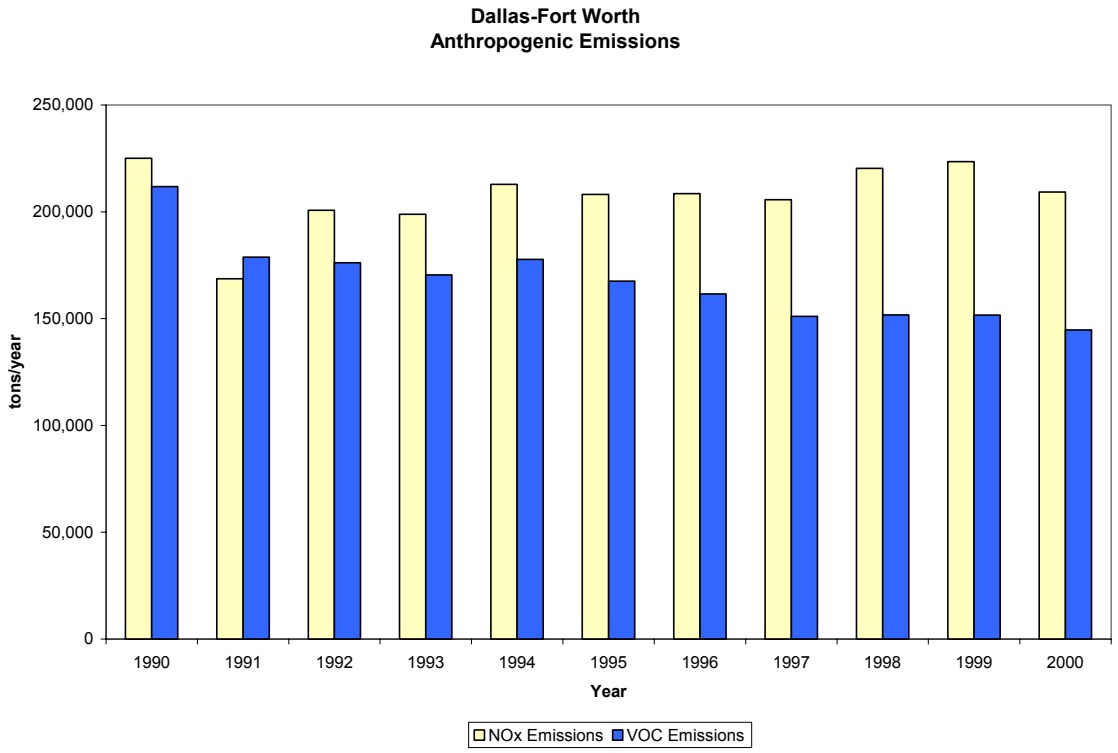


Figure 2-6. Trends in anthropogenic VOC and NOx emissions in the DFW nonattainment area.

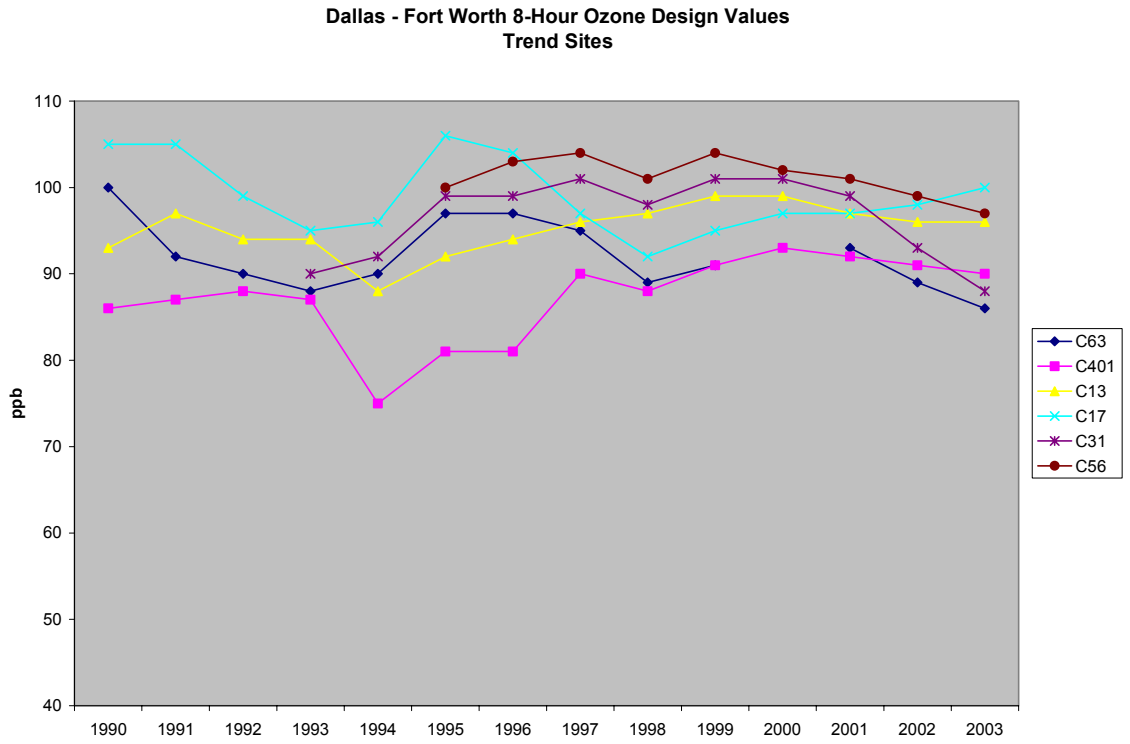


Figure 2-7. Trends in 8-hour ozone design values at monitors in the DFW area with no more than one missing year between 1995 and 2003 (design values are three year running averages of annual 4th highest daily maximum 8-hour average).

Weekday/Weekend Comparisons

Ozone levels in many cities vary between weekdays and weekends in response to variations in emissions. Although changes in emissions by day of week are complex and likely to vary from city to city, studies conducted to date indicate that the most significant change is a sharp reduction in heavy-duty vehicle activity resulting in reduced NOx emissions and that this reduction is most pronounced on Sunday mornings (Lawson, 2003).

A summary of 1-hour and 8-hour ozone exceedances days by day of week for 1990 – 2000s is presented in **Figure 2-8**. Exceedances of the 1-hour standard were nearly non-existent on Sunday during this period whereas they were relatively more common during other days. Exceedances of the 8-hour standard were also less frequent on Sundays but the difference is less dramatic. A reduced frequency of 1-hour ozone exceedances is therefore consistent with the conclusion that ozone formation in DFW is NOx limited and is suggestive of the potential efficacy of NOx reductions.

Although an analysis of "average" ozone concentrations by day of week based on May – October 1997-2001 data at eight monitoring sites in DFW reported by Lawson (2003) indicated no difference in ozone by day of week, the exact meaning of "average ozone" was not described by Lawson and day-of-week differences in ozone are known to be sensitive to summary statistic formulations. Nevertheless, the less dramatic difference between Sundays and other days for 8-hour exceedances as compared to 1-hour exceedances and the report by Lawson of no difference

in "average" ozone suggests that local mobile source NOx reductions on Sunday primarily impact the highest ozone concentrations and may have less of an impact on lower values, including values which influence the 8-hour design value. A more in-depth analysis of day-of-week effects in DFW is needed to expand upon these results.

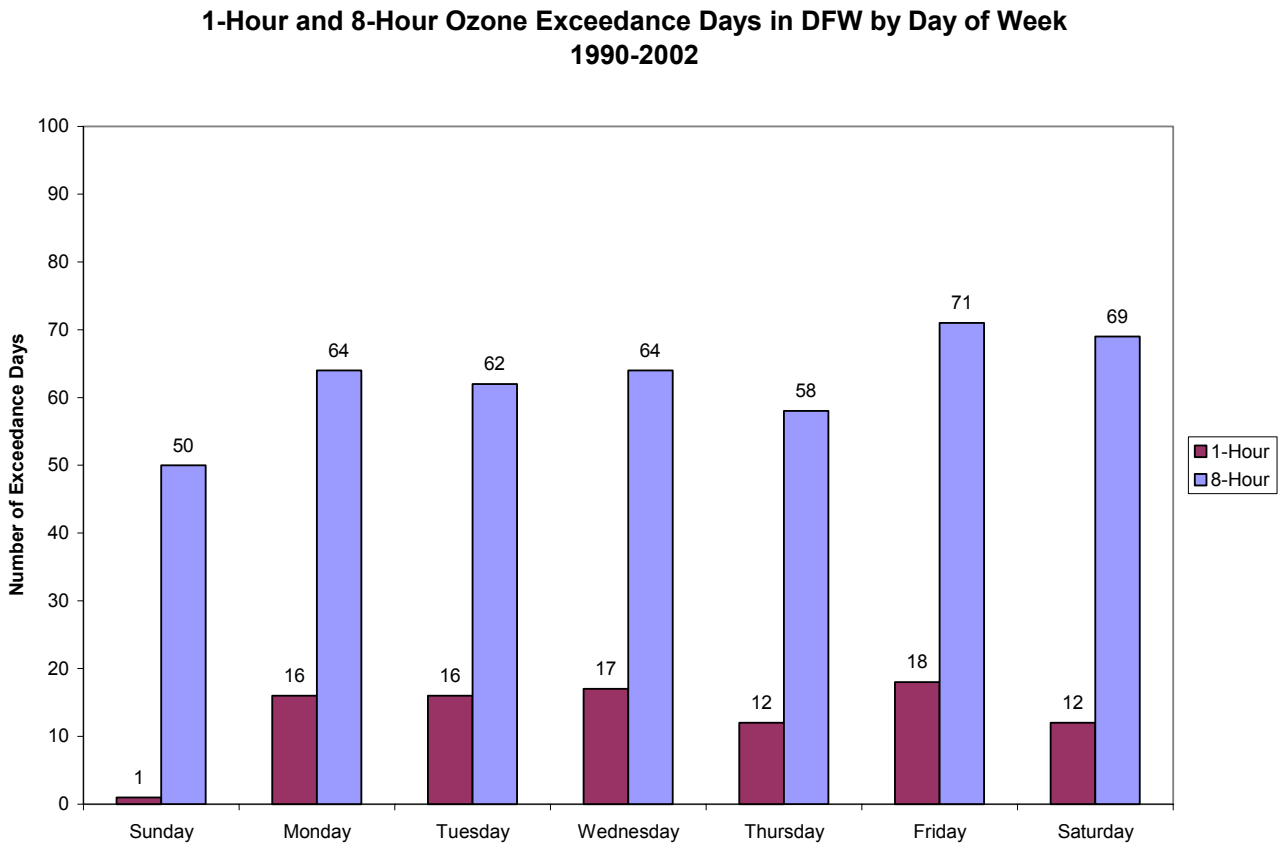


Figure 2-8. Number of days exceeding 1-hour and 8-hour ozone standards by day of week, 1990 - 2002 (source: Zhaohua Fang, personal communication, January 2004).

Aircraft Data

Formation of ozone in plumes from large NOx sources is a complex process involving numerous factors. As pointed out by Ryerson et al. (2001), since ozone formation efficiency (moles ozone produced per mole NOx) is a strong function of the VOC/NOx ratio, formation of ozone in NOx point source plumes is sensitive to the amount and overall reactivity of VOCs in the environment into which the plume is dispersing relative to the NOx concentration in the plume. This explains why the amount of ozone observed in plumes from different sources may vary widely even under similar meteorological conditions and why the amount of ozone formed in a plume from a given source will vary from day to day in response to changes in dispersion conditions.

Data from instrumented aircraft are available from five flights which took place over the DFW area between 2 October and 13 October 2003. These flight data have been well summarized by Boyer and McDowell (2004a,b). Unfortunately, these flights did not encounter high levels of

ozone and can therefore offer no information on conditions associated with ozone exceedances. Daily maximum 8-hour average ozone over the routine monitoring network was less than 65 ppb on four of the five flight days and peaked at 75 ppb on 4 October. NOy plumes from Ellis Co. NOx sources were observed on the 2 October and 4 October flights but with minimal ozone formation. An urban NOy plume and associated weak ozone plume was observed downwind of DFW during the 10 and 13 October flights.

Aircraft data were also collected by a team from Baylor University in various locations over eastern Texas between 1997 and 1999. Aircraft data were collected over DFW on 17 days. MacDonald et al. (2001) analyzed data from six of the DFW flights; results are summarized below:

- 31 August 1998: generally easterly winds, concentrations on eastern edge of CMSA were 60 – 80 ppb averaging 69 ppb. Maximum ozone was observed east of Fort Worth with a maximum 10 sec average of 126 ppb indicating an urban area production of 57 ppb; plume width was estimated at 120 km; the surface monitoring network peak 1-hour ozone was 116 ppb at CAMS-13.
- 21 August 1997: Transport winds were from the east and south; regional background ozone upwind of DFW was about 55 ppb; the downwind peak was 149 ppb located over central and southern Tarrant County indicating an urban area production of 94 ppb.
- 16 July 1998: Background ozone was about 72 ppb; the urban area peak was 136 ppb but no obvious flow direction can be seen in the ozone concentration pattern and a trajectory analysis was not available for this day.
- 17 July 1998: The highest ozone observed over the surface monitoring network was a 1-hour peak of 138 ppb at CAMS-57 in Tarrant Co. whereas the flight pattern took the aircraft east and south of DFW; data presented by MacDonald et al. (2001) provide some evidence of ozone plumes from rural NOx sources.
- 18 September 1998: Urban ozone plume (peak 120 ppb) was observed SW of Ft. Worth on this day beyond reach of surface monitoring network.
- 19 September 1998: Broad urban ozone peak was observed NNW of DFW (peak 136 ppb); upwind ozone concentrations were about 70 ppb indicating an urban area production of 66 ppb.

Results summarized above support the conclusion of MacDonald and co-workers that concentrations along the upwind boundary of the DFW CMSA constitute about 50% of the peak ozone downwind of the CMSA during the high ozone days examined.

MacDonald et al. (2001) also examined data from six flights designed to measure ozone production within rural NOx point source plumes in eastern Texas[t]. Well defined plumes were identified during three of these flights which measured NOx, ozone, and SO_2 downwind of the Big Brown coal-fired power plant in Freestone Co. southeast of Dallas, the Alcoa-Tugco refinery complex northeast of Austin, and plumes from the Texas Eastman chemical plant and Martin Lake power plant in northeastern Texas. Ozone production of 30 to 35 ppb was observed at maximum measured downwind distances of 50 to 80 km within each of these plumes (see

[t] Several of these sources have since reduced their NOx emissions (TNRCC, 2002).

summary of results in **Table 2-2**). Maximum plume widths ranged from 10 to 70 km. The flight data did not always include the farthest downwind extent of ozone production so these downwind distances and ozone production values may represent lower bounds in some cases. Since MacDonald et al. only reported results for flights during which ozone production in point source plumes could be identified, these results do not provide any indication of how frequently ozone production of this magnitude occurs in these sorts of plumes. Nevertheless, it is clear from this and the other studies cited above that ozone production of at least 30 ppb is achievable within NOx point source plumes in rural eastern Texas during the summer season and such production levels may in fact be quite common during weather patterns associated with high ozone events.

Table 2-2. Summary of results from analysis of Baylor aircraft flights downwind of major point sources in eastern Texas (adapted from MacDonald et al., 2001).

Flight	Date	Source(s)	Location	Maximum Observed Width (km)	Maximum Observed Length (km)	Background Ozone Conc. (ppb)	Peak Ozone Conc. (ppb)	Ozone Production (ppb)
39	8/25/97	Big Brown	Central Texas	15	80	55	85	30
39	8/25/97	Alcoa–Tugco	Central Texas	10	50	70	100	30
42	8/28/97	Texas Eastman–SWEPCO–Martin Lake	Northeast Texas	70	50	70	105	35

Vizuete (2002) analyzed data from a NOAA Lockheed Electra aircraft flight conducted over NE Texas during the TEXAQS 2000 study. This flight covered an area about 100 miles east of Dallas, near Longview, and the data are included here to document the potential for ozone formation in NOx plumes from major sources in eastern Texas. Data from the 3 September 2000 flight provide a good illustration of ozone formation in NOx plumes in this area (see **Figure 2-9**). Plumes were identified in the flight data by looking for SO_2 concentration peaks at locations downwind of major NOx sources such as the Monticello, Welsh, or Martin Lake power plants. SO_2 and ozone concentrations along the aircraft flight path are shown along with the locations of the NOx point sources in Figure 2-9. Ozone concentrations are indicated by the color scale and the thickness of the line indicates the magnitude of the SO_2 concentration. NOx point sources are indicated by circles with sizes proportional to the magnitude of NOx emissions. Winds were out of the northwest during this flight. Varying amounts of ozone formation are evident downwind of the Monticello, Welsh and Martin Lake power plants. These ozone peaks appear on a regional background of 80 ppb ozone, producing peaks in excess of the 1-hour standard (124 ppb). NOx emissions at these plants have been reduced since 1999 by the installation of low-NOx burner technology. While this flight path did not cover the DFW area, these results serve to illustrate the potential for major NOx sources to form high ozone in eastern Texas under the right conditions. However, the efficiency of ozone formation in NOx plumes may be different in the DFW area as compared to the region covered by this particular flight.

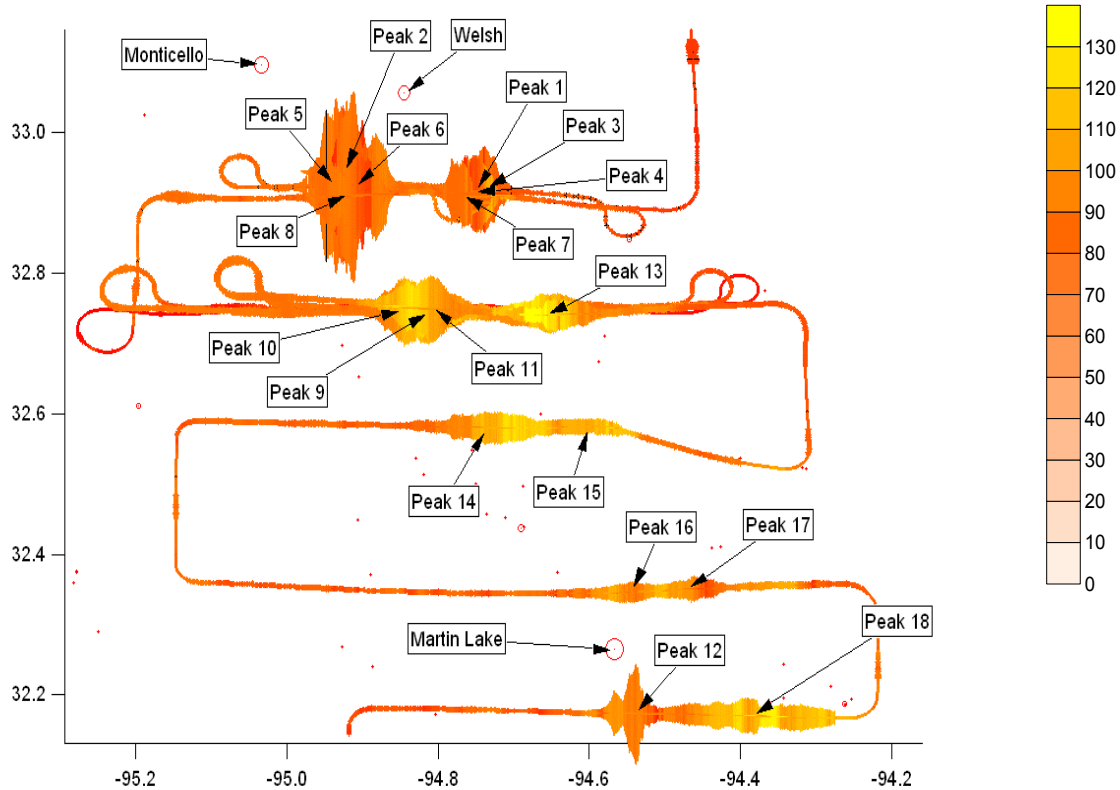


Figure 2-9. NOAA Electra aircraft flight path near Longview on 3 September 2000 showing ozone concentrations represented by the color scale. The thickness of the line indicates the magnitude of the SO_2 concentration along the flight path. The circles locate NOx point sources whose magnitude is indicated by the diameter of the circle (from Vizuete, 2002).

3. TRAJECTORY ANALYSES

Air parcel trajectory paths over a multi-state area centered on Dallas-Ft. Worth (DFW) were analyzed over two historic periods to evaluate potential source-receptor relationships associated with exceedances of the 8-hour ozone standard in DFW. Analyses included mapping of back trajectories and a statistical model of the association between trajectory paths and ozone concentrations. We also examined local back trajectories from major point sources in DFW calculated from local surface wind data on selected high ozone days.

Trajectory Climatology for DFW

Back trajectories are model results that show the path taken by a hypothetical air parcel to arrive at a specific place and time. Back trajectories with endpoints in the DFW area were summarized as a function of daily maximum 8-hour ozone. Trajectories were computed using the NOAA HySplit model based on archived forecast model winds (see www.arl.noaa.gov/ready/hysplit4.html). Trajectory results for all days during 1993 – 1998 with maximum 8-hour average ozone greater than or equal to 85 ppb are shown in **Figure 3-1.** Most trajectories arrive in DFW from the east, southeast, or south.

A more detailed trajectory analysis based on data from June – September 2000, 2001 and 2002 was also prepared. Trajectory endpoint heights of 100 and 500 m and ending times of 13:00, 14:00, and 15:00 CST were used to provide a broad indication of the paths taken by air parcels arriving in DFW on mid-afternoons during the ozone season. These trajectory data were compiled for use in this study by TCEQ staff (Mercado, 2004). Hourly waypoints along each trajectory were located on a (20 km) grid overlaid on the CAMx 36 km modeling domain and the total number of waypoints during each day within each 20 km grid cell noted. These values provide a spatial pattern of trajectory "residence times" for each day which can be correlated with the day's maximum 8-hour ozone concentration.

Total residence times for trajectories arriving in DFW on the afternoon of high ozone days (defined as days with 8-hour maximum ozone of at least 100 ppb) are illustrated in **Figure 3-2**. A similar plot was prepared showing total residence times for low ozone days (defined as days with 8-hour maximum ozone of no more than 50 ppb); the resulting plot is displayed in **Figure 3-3**. Relative to low ozone days, trajectories on high ozone days are shorter and spend more time just to the south and southeast of DFW. Trajectories on low ozone days cover greater distances from DFW and are indicative of a dominant flow from the western Gulf of Mexico.

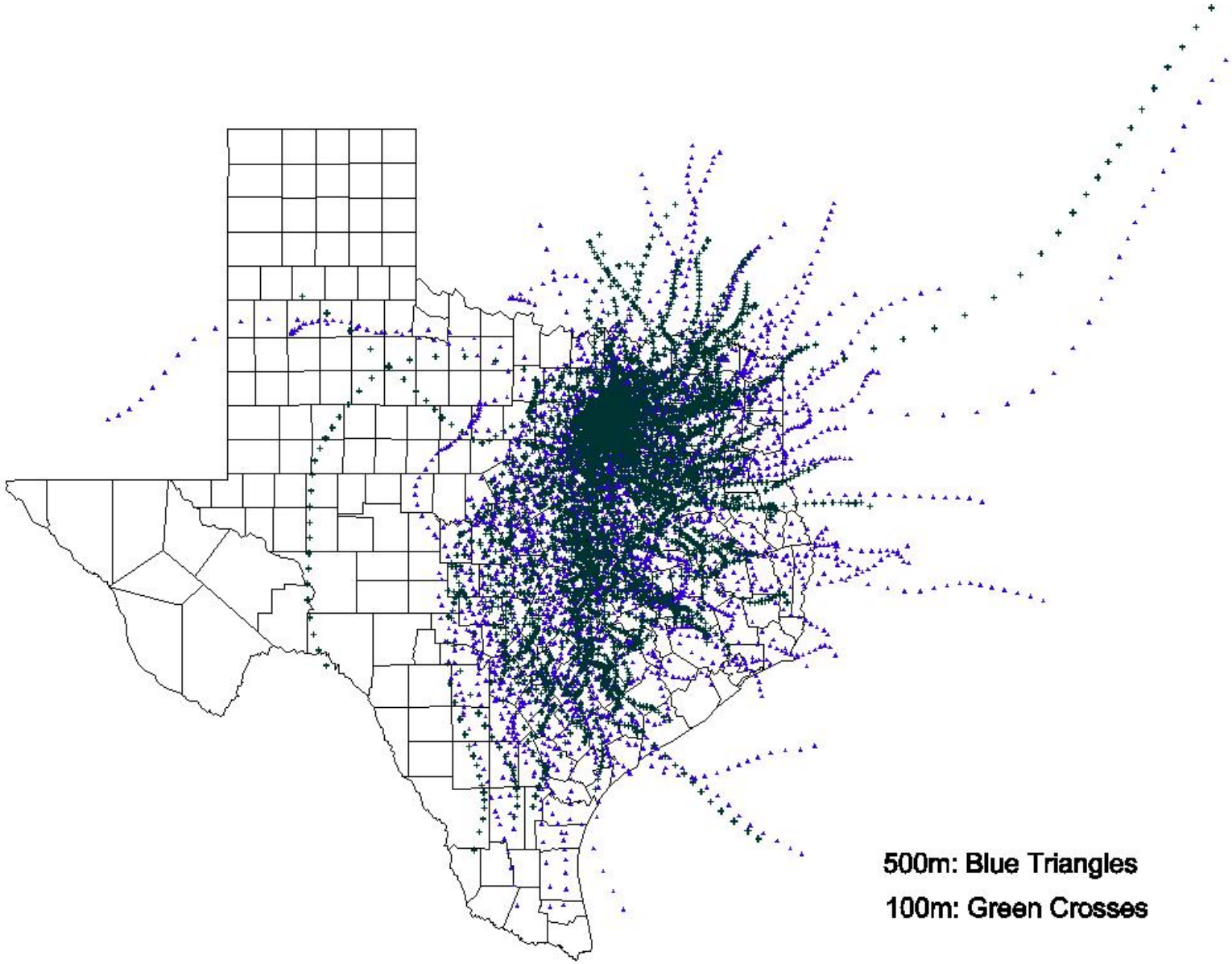


Figure 3-1. Air parcel 32 hour back trajectory hourly locations for parcels arriving in DFW on afternoon of high 8-hour ozone days (concentrations greater than or equal to 85 ppb) during 1993 – 1998 (Source: Sharon McDonald, Texas Commission on Environmental Quality).

Back Trajectory Residence Time Analysis

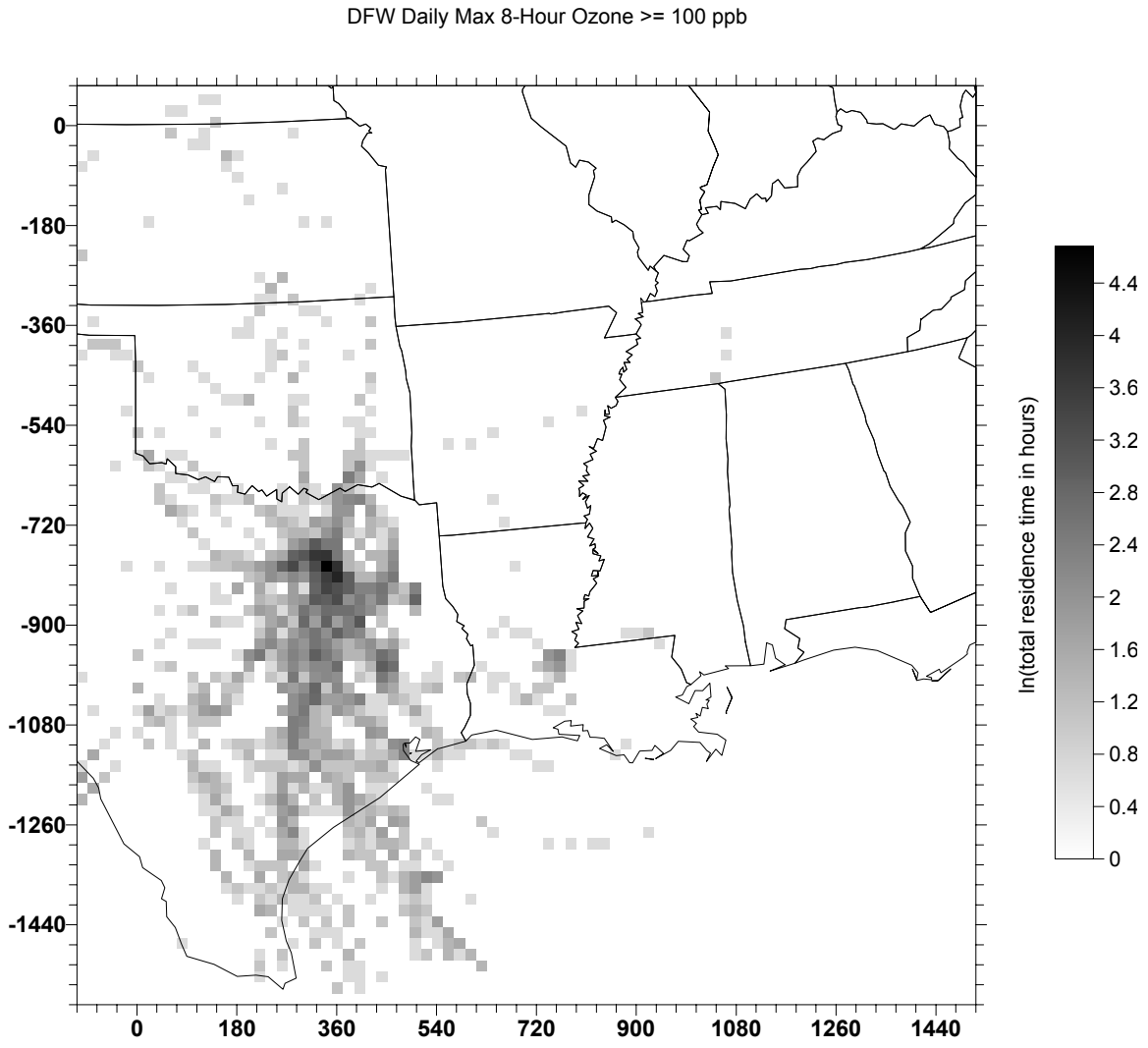


Figure 3-2. Trajectory residence time analysis for high ozone days in DFW (daily maximum 8-hour ozone greater than or equal to 100 ppb).

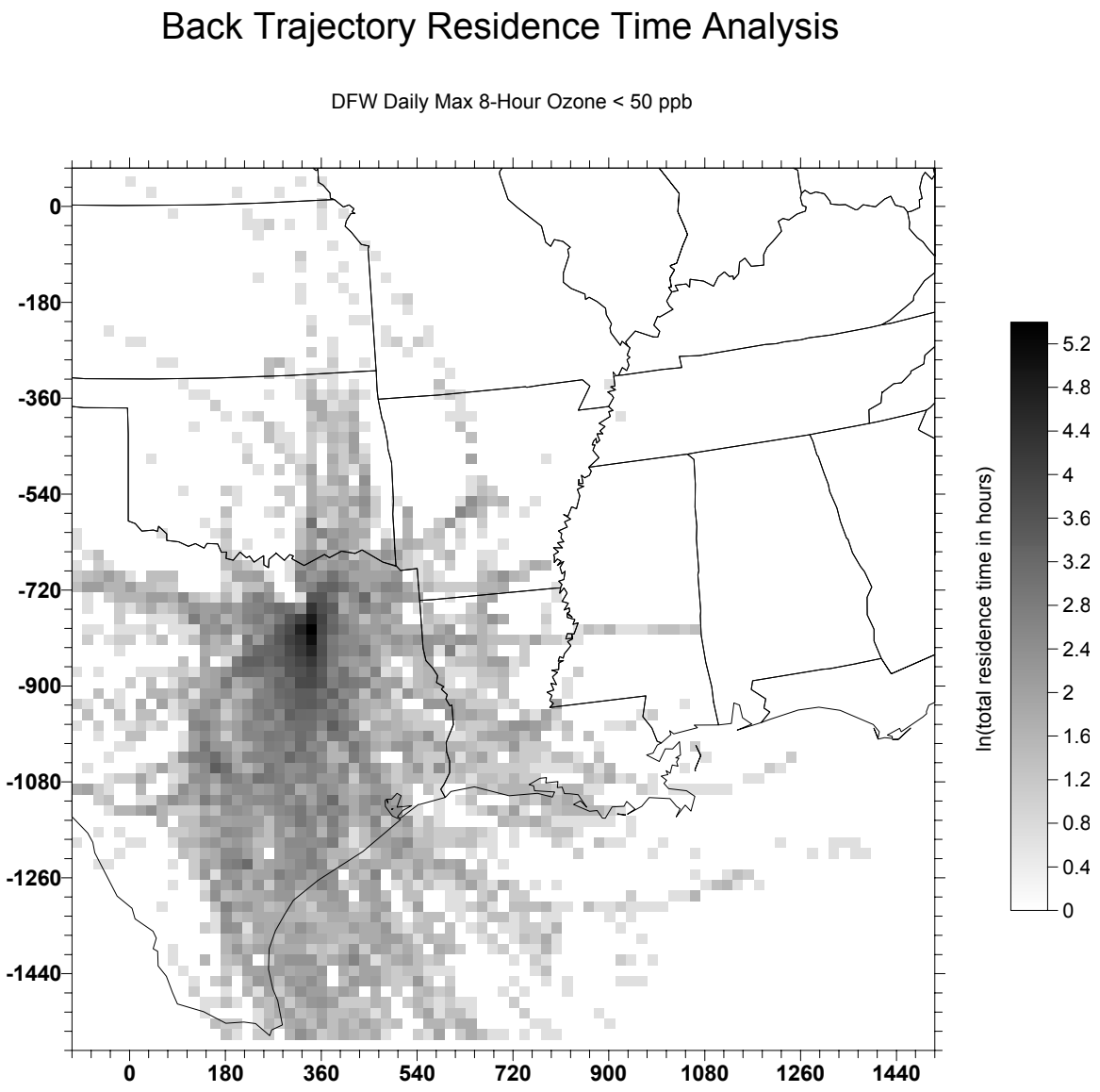


Figure 3-3. Trajectory residence time analysis for low ozone days in DFW (daily maximum 8-hour ozone less than 50 ppb).

Transport Mass Balance Model

Mercado (2003) prepared a preliminary application of the Trajectory Mass Balance (TrMB) model described by Iyer (1986) and applied to PM source apportionment in the BRAVO study by Gephart (2002) to the problem of source apportionment for ozone in DFW. The TrMB method is a receptor analysis technique originally developed for estimating source contributions for sulfate aerosol. This method is based on the length of time back trajectories from the receptor point of interest are calculated to have resided in each of several source regions defined for purposes of the analysis and relies on various simplifying assumptions concerning the transport, chemical transformation, and fate of the species being apportioned. Pun and Seigneur (2003) describe and evaluate these assumptions in the context of sulfate source apportionment. Application of the technique to apportionment of ozone introduces considerably more significant

uncertainties in view of the cyclical, non-linear, and potentially rapid reaction mechanisms involved in ozone formation. Since these effects are not explicitly treated by the TrMB model, quantitative ozone apportionment results using TrMB must be interpreted with caution. Nevertheless, the trajectory residence time patterns used in calculating the ozone apportionments may potentially provide useful qualitative information on the correlation of different regional transport patterns with ozone concentrations.

Mercado defined ten source regions around the Anna (C68) monitor in northern Collin county (see **Figure 3-4**) and computed percent contributions from each source region to afternoon 8-hour ozone averages during the 2000, 2001, and 2003 ozone seasons. Results are listed in **Table 3-1**.

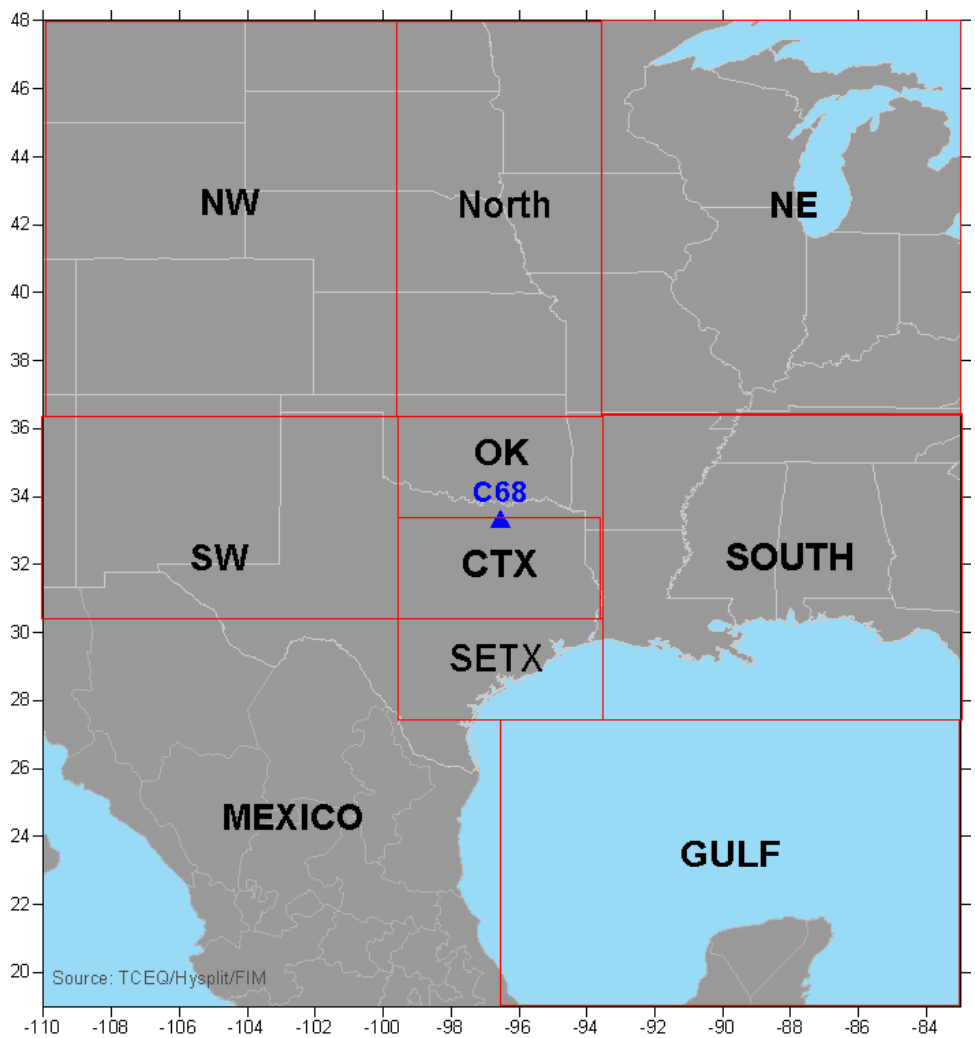


Figure 3-4. Source regions for the TrMB analysis by Mercado (2003).

Table 3-1. Source contributions from TrMB analysis (from Mercado, 2003).

Region	Percent Contribution (w/emissions)
CTX	23%
GULF	9%
MEXICO	5%
NE	4%
NORTH	10%
OK	14%
SETX	16%
SOUTH	11%
SW	7%
TOTAL	100%

Relatively small contributions are calculated for the North, NW, SW, and MEXICO source regions. This is consistent with results from the trajectory analyses described above which indicate transport from these more distant regions is not common during high ozone events in DFW. CTX is the source region with the largest contribution, followed by SETX, OK, and SOUTH. Qualitatively, this is consistent with the conclusion that sources in the CTX region (which includes Dallas and Ft. Worth) are the largest contributors to ozone at Anna. Since all trajectories must pass through either OK or CTX to arrive at the monitoring site, however, quantitative differences between source contributions from these regions relative to contributions from the other regions can be expected to be subject to large uncertainties.

We reanalyzed Mercado's TrMB results for Anna and performed a similar analysis for the Kaufman Co. monitoring site (located in Region #12 in **Figure 3-5**) using a different configuration of source regions designed to match the source regions used in the CAMx source apportionment and zero-out analyses discussed in Section 4 below. Source regions used in the reanalysis are listed in **Table 3-2**; the region numbers in this table are keyed to the map in Figure 3-5; the resulting source contributions are listed in **Table 3-3**. Regression statistics showed good model fits for both sites, with r-square values of 0.89 and 0.88 for Anna and Kaufman, respectively. Individual contributions do not sum to quite 100% since the regression fits introduce some error but the remaining unattributed contributions are negligible.

While the individual percent contributions shown in Table 3-3 are subject to considerable uncertainty for the reasons discussed above, the relative pattern of contributions appears to be reasonable in light of the relationships between transport patterns and ozone in DFW described in Section 2. Central and Northeast Texas are more important source regions for Kaufman than for Anna because Kaufman is typically upwind of the DFW area on high ozone days whereas Anna is more frequently downwind of DFW during such events. This in turn is consistent with a higher estimated contribution from the DFW vicinity at Anna as compared to Kaufman. The Anna and Kaufman monitoring sites were selected for this analysis by TCEQ because these sites are locations near the boundaries of the DFW CMSA and thus influenced more by source regions outside the CMSA than other sites in the area. The Kaufman site is near the exterior edge of the CMSA and does not experience the high concentrations observed at some other sites in DFW. For the 2000 – 2002 period analyzed, the highest 8-hour average concentration at Kaufman was 82 ppb. Similarly, the Anna monitor is located near the northeast corner of the CMSA. The highest 8-hour average at this site was 104 ppb.

In reviewing these results, it is important to remember that certain source regions pairs are subject to co-linearity because trajectories from one of the regions must typically pass through the other (for example, trajectories from OK must typically pass through DFW to reach Kaufman). Inspection of regression diagnostics shows that the source region pairs for which co-linearity is particularly strong for both monitors are: OK-DFW, HGBPA-Central TX, and Other-OK. The relative size of the source contributions for these source region pairs are not well determined due to co-linearity. For example, it is difficult to distinguish between contributions from Central TX and HGBPA and the results in Table 3-2 should *not* be interpreted to mean that the contribution from sources in Central TX is five or six times greater than the contribution from HGBPA.

Table 3-2. Source regions used in TrMB analysis.

Area Abbreviation	Area Definition	Area Number(s) *
DFW Vicinity	Dallas Core Counties (Collin, Dallas, Denton, Tarrant) plus 12 surrounding counties (Wise, Parker, Hood, Johnson, Ellis, Kaufman, Rockwall, Cooke, Grayson, Hunt, Henderson, Fannin)	1-16
NE TX	Northeast Texas	17
HGBPA	Houston/Galveston/Beaumont/Port-Arthur (11 Counties)	18
Central Texas	Central Eastern Texas	19
OK	Oklahoma	20
AR	Arkansas	21
LA	Louisiana	22
South Texas	Near Non-attainment areas (Austin, San Antonio, Victoria, Corpus Christi)	23
West Texas	Texas (excluding area 1-19 and 23	24
Other States	Other areas	25

* See Figure 3-4.

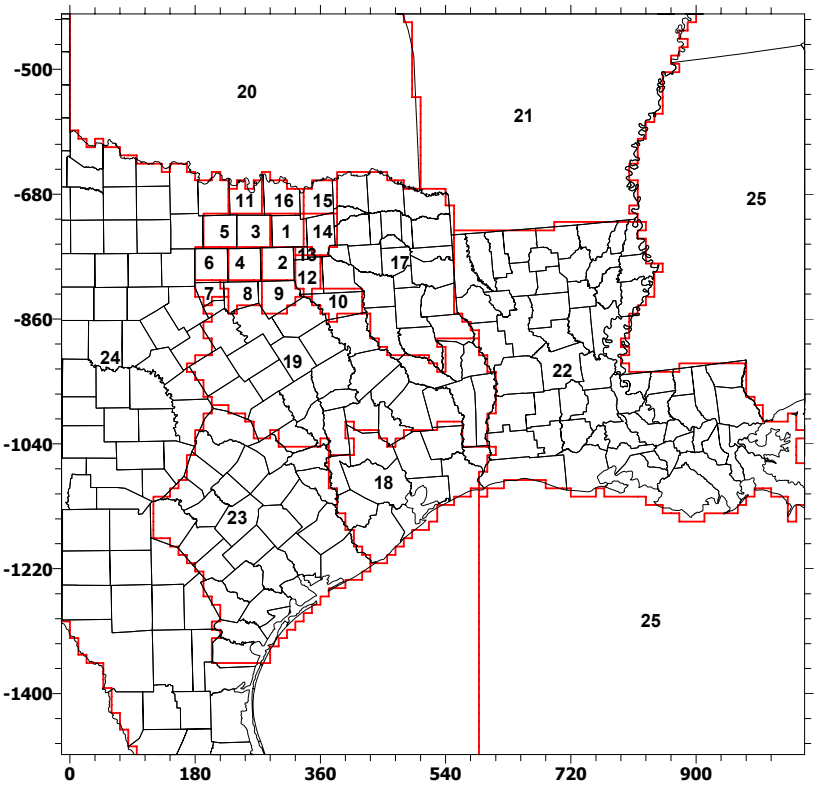


Figure 3-5. Numbered source regions referenced in Table 3-2.

Table 3-3. TrMB source contributions for Kaufman and Anna monitoring sites**.**

Region	Estimated Contributions	
	Kaufman	Anna
DFW Vicinity	15.7%	27.9%
NE TX	11.9%	6.1%
HGBPA	4.2%	2.2%
Central Texas	20.6%	12.6%
West Texas	12.5%	12.5%
OK	6.5%	10.6%
AR	3.5%	3.9%
LA	3.4%	2.6%
South Texas	7.4%	8.2%
Other States	11.8%	10.8%
Unattributed	2.6%	2.6%
TOTAL	97.4%	97.4%

Point Source Plume Trajectories

Trajectory calculations described above are based on wind fields computed on modeling grid with a horizontal resolution of 40 km. These results thus cannot be used to reliably identify impacts of sources within or near the DFW area on local ozone exceedance days. However, hourly wind direction and speed data are collected at a number of monitoring sites within the DFW area and these data can be used to derive higher resolution wind fields for local transport

analyses. TCEQ routinely prepares "plume animation" displays for high ozone episodes in DFW using these data. An example of a 1-hour snapshot from such a display is presented in **Figure 3-6**. Locations of major point sources are indicated by the large colored circles. Plume centerlines are drawn originating from these sources for each hour starting at 1:00 CST, with the hourly positions indicated by small circles along the centerlines. The direction of travel of the plumes is determined from a spatial interpolation of local wind observations (the wind observations are indicated by the short straight black lines extending from monitoring site locations; numbers next to these locations display the hourly average ozone concentration in ppb; see plume animations associated with any of the high ozone events listed at http://www.tnrcc.state.tx.us/updated/air/monops/airpollevents/2004/sigevents_2004.html for more details). An animation of the point source plumes is created by drawing a diagram such as Figure 3-6 for each hour of the day and displaying the results sequentially.

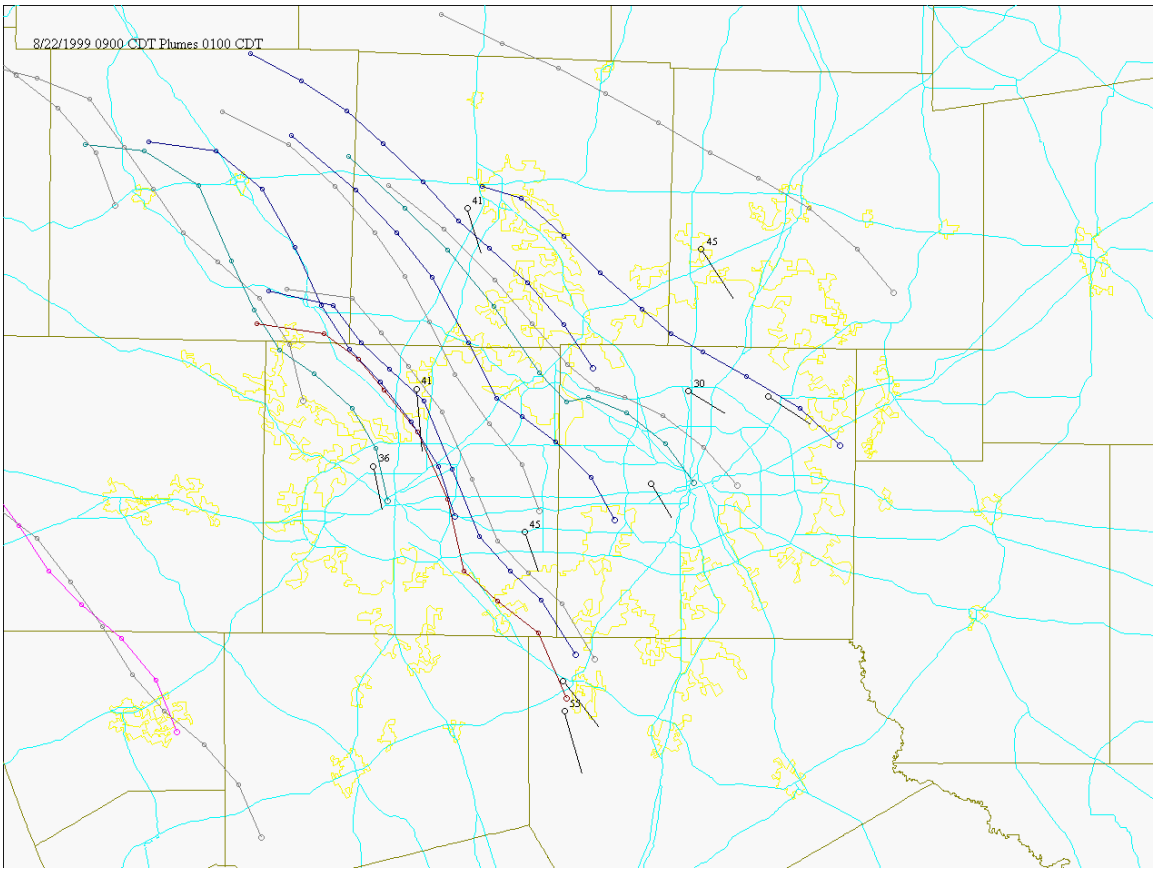


Figure 3-6. Plume display for 09:00 CDT 22 August 1999 (plumes released 01:00 CDT).

Plume animations for DFW prepared for selected days by TCEQ were examined for evidence of source contributions to ozone peaks. Plumes from some sources, particularly those in Ellis, Dallas, and Tarrant counties were seen to travel over the region of elevated observed ozone concentrations on several occasions. In other cases, however, observed ozone levels did not exceed the 8-hour standard although trajectory paths were similar to those on an exceedance day, most likely because other meteorological factors such as the height of the mixed layer were not conducive to formation of high ozone concentrations.

Plume animations are in effect a simplified 2-dimensional form of a plume "slug" model in which hourly elongated puffs or plume segments are released and transported horizontally by the interpolated wind field. Diffusion, dispersion, vertical transport, chemical transformation, and deposition are ignored in this simple model. These animations can be useful for identifying potential impacts of point sources on ozone exceedances. However, primarily because they don't provide information on ozone formation from the emissions of any particular source, the mere coincidence of a plume passage and a high ozone reading is not proof of a direct ozone impact from the source. In addition, primarily because dispersion processes are not accounted for, the position of the hourly average plume becomes increasingly uncertain as one moves further back in time along the centerline (i.e., away from the source).

TRAJECTORY ANALYSES CONCLUSIONS

Several important conclusions can be reached on the basis of results presented above:

- Under prevailing wind directions during high ozone events, upwind sources lie to the east, southeast, and south of the core urban area, consistent with the spatial pattern of measured ozone design values.

- Trajectory analyses show that high ozone events in DFW are associated with slow moving air parcels originating primarily from east, southeast and south of the metropolitan area.

- Quantitative estimates of the relative contributions of different source regions within and outside of Texas to ozone concentrations in DFW obtained from the TrMB method are difficult to interpret because of technical limitations of the technique discussed above.

- Animated plume trajectories show plumes from sources just upwind of the four core DFW counties traveling over the urban area during high ozone episodes but provide no quantitative estimates of the contribution of a source to observed ozone levels.

4. OZONE SOURCE APPORTIONMENT AND SENSITIVITY MODELING

Photochemical models such as CAMx are typically used in the SIP development process to directly evaluate the impact of specific alternative emission control strategies on ozone levels. A variety of modeling tools are also available for analyzing the contributions to ozone of precursor emissions and transported ozone from different source regions. These tools provide information which can assist in the development of candidate control strategies. A brief description of several source contribution modeling tools and their relative advantages and disadvantages is presented in this section, followed by results from the application of these tools to evaluation of the contributions of sources in counties surrounding the four core DFW counties, other parts of Texas, and neighboring states. In addition to these results, in Section 5 we present results of a model sensitivity analysis which examines the ozone impact of additional emissions from new industrial sources located in and around DFW.

METHODS FOR EVALUATING SOURCE CONTRIBUTIONS IN CAMx

Ambient measurements and ozone models both provide information on total ozone levels. Since ozone is formed from VOC and NOx precursor emissions it would be useful to understand which emissions are causing high ozone levels so that effective emission control strategies can be designed. In other words, we would like to apportion the total ozone among all of the sources that participated in forming the ozone. Unfortunately, ozone source apportionment is difficult because ozone formation involves the interaction between emissions that likely came from different sources, e.g., anthropogenic NOx interacting with biogenic VOC. There is no one unique or "correct" way to apportion ozone among sources, but there are several approaches that can be used with CAMx:

- Ozone Source Apportionment Technology (OSAT).
- Anthropogenic Precursor Culpability Assessment (APCA).
- Zero-out differences.

Ozone Source Apportionment Technology (OSAT)

The OSAT method provides information about the relationships between ozone concentrations and sources of precursors in the form of ozone source apportionments. Source apportionment requires that the sum of all source contributions add up to exactly 100% of the total ozone so all of the ozone is accounted for. OSAT satisfies this requirement by attributing all new ozone production to precursors that are present at the point where the ozone is formed in CAMx. The OSAT attribution considers all potential sources of ozone in the simulation, i.e., emissions, boundary conditions and initial conditions. The emissions attribution can be broken out by geographic area and/or source category. The OSAT attribution of ozone production to the precursors that were present when the ozone was formed takes account of whether the ozone chemistry was sensitive to VOCs or NOx, and VOC reactivity differences. The OSAT methods are described in the CAMx User's Guide (ENVIRON, 2004) and in Dunker et al., (2002b).

Anthropogenic Precursor Culpability Assessment (APCA)

The APCA method is closely related to the OSAT method described above. The difference between the OSAT and APCA schemes can be summarized as follows. OSAT apportions ozone formation based solely on what precursors were present when the ozone is formed. APCA modifies the OSAT method to account for the fact that biogenic emissions are not considered to be controllable, and therefore APCA attributes ozone to controllable (anthropogenic) emissions whenever possible. The differences between OSAT and APCA are discussed in more detail below when results from the two methods are compared.

Zero-Out Differences

In the zero-out method the emissions for a particular source or group of sources are removed from the inventory (zeroed out), CAMx is re-run, and the change in ozone is measured relative to the base case. This zero-out ozone difference is a measure of the ozone contribution of the source, and the procedure can be repeated for several or all sources to build up a picture of relative source contributions to ozone. As discussed below, there are difficulties in interpreting the zero-out differences as source apportionments because the sum of the zero-out differences over all sources does not equal the total ozone. Nevertheless, the zero-out method has been widely used to evaluate source contributions to ozone.

STRENGTHS AND LIMITATIONS OF OSAT, APCA AND ZERO-OUT

As discussed above, there is no "correct" way to quantify the contribution of different source categories to ozone in a model like CAMx or in the real world. This study uses several different approaches and compares the results to look for consistent patterns. The OSAT, APCA and zero-out methods used with CAMx have different strengths and limitations that should be taken into account. The OSAT and APCA methods are discussed together because they are closely related.

The OSAT and APCA methods have several strengths:

- OSAT and APCA source contributions always sum to 100% of the modeled ozone so that all of the ozone is exactly accounted for and OSAT/APCA are directly interpretable as source apportionments.
- The OSAT and APCA apportionments are based on precursors from a specific source being present at the time and place where ozone was formed in the model.
- OSAT attributes ozone production based on whether the chemistry is VOC or NOx sensitive.
- The advantage of APCA over OSAT is taking account of the non-controllable nature of biogenic emissions. APCA seeks to minimize the contribution of biogenic sources (usually VOCs) by attributing ozone to the anthropogenic emissions (usually NOx) that interacted with the biogenic emissions.
- A practical advantage of OSAT and APCA is high computational efficiency, which means that more detailed source contributions (more geographic resolution, more source categories) can be identified with a set amount of project resources.

Limitations of OSAT and APCA are:

- Because ozone formation is non-linear, the OSAT and APCA source apportionments cannot be used to predict the effects of a specific strategy or calculate what emission reductions are needed to achieve a specific target ozone level.
- A limitation of OSAT can be attributing large amounts of ozone production to biogenic emission sources that are not controllable.

The strengths of the zero-out method are:

- The method is easy to explain and many people find the approach intuitively obvious and reasonable.
- The zero-out differences are directly related to the participation of emissions in ozone formation.
- The method is simple to apply with any model.

Limitations of the zero-out method are:

- The zero-out method requires changing the emissions, which in turn changes the chemistry of ozone formation.
- The sum of the zero-out differences over all sources will not necessarily add up to 100% of the modeled ozone.
- Zero-out differences may be negative for some sources. This makes sense in terms of source sensitivity, but does not make sense as source apportionment.
- For the three reasons listed above, zero-out results can be difficult to interpret as source apportionments. In this study, we refer to the zero-out results as differences rather than apportionments.
- A limitation of zero-out can be attributing large amounts of ozone production to biogenic emission sources that are not controllable.
- Because ozone formation is non-linear, the zero-out differences cannot be used to predict the effects of a specific strategy or calculate what emission reductions are needed to achieve a specific target ozone level. In particular, zeroing out all anthropogenic emissions represents an unrealistic control strategy which produces results that cannot be interpolated to correspond to a more modest (and realistic) strategy.

An important limitation noted above that is common to OSAT, APCA and zero-out is that the results cannot be used to predict the effects of a specific strategy or calculate what emission reductions are needed to achieve a specific target ozone level. This is the difference between source apportionment and source sensitivity, which is an important technical issue that requires more explanation.

The amount of ozone formed by precursor emissions (NOx or VOC) is related to the amount of precursor emissions multiplied by the production efficiency i.e., ozone produced per precursor emitted. The ozone production efficiency is not a constant factor but depends upon many things, such as the type of emissions (NOx vs. VOC, specific type of VOC), the meteorology and the other precursors present in the atmosphere (e.g., the VOC/NOx ratio). As emissions are reduced, the ozone production efficiency also changes, and so the effect of emission controls may be greater or lesser than expected simply on the basis of the tons of emissions reduced.

APPROACH

OSAT and APCA source apportionment modeling and zero-out modeling were used to analyze the impacts of emissions from individual counties and other regions in Texas and neighboring states to ozone in the DFW area based on simulations of the 13 – 22 August 1999 ozone episode. ENVIRON previously conducted CAMx modeling analyses of this episode in support of the latest SIP revision. This episode was selected for SIP development because it is typical of high ozone events in DFW and includes multiple days with both 1-hour and 8-hour ozone exceedances (Mansell et al., 2003). However, the transport patterns and contributions determined here are related to the meteorology of the modeling period. Details of application of OSAT and APCA techniques to the 1999 DFW modeling were originally reported by Mansell et al. (2003).

APCA and zero-out results were both summarized on the basis of apportionments of (in the case of APCA) and changes in (in the case of zero-out) ozone concentrations in each CAMx surface layer grid cell and time period during which the predicted running 8-hour average concentration is greater than 85 ppb.[1] Source contributions to ozone levels below 85 ppb are not of interest since these values do not contribute to nonattainment of the 8-hour ozone standard. A particular source may contribute substantially to nearby ozone levels but this would not play a role in the attainment status if the nearby ozone levels do not exceed 85 ppb. Results were generated separately for grid cell-hours in two receptor regions: the four core counties (Dallas, Collin, Denton, Tarrant) and the twelve counties comprising the DFW CMSA.

OSAT and APCA source apportionment estimates were developed for 25 separate source regions plus boundary conditions and initial conditions. Boundaries are for the 36 km domain as shown in Figure 1-2. Separate estimates were obtained for each of four source categories: biogenics, elevated points, on-road mobile, and other anthropogenic (OAN) sources (which include area, off-road mobile, and low-level point sources).

In addition to evaluation of source contributions using the OSAT, APCA, and zero-out methods, a sensitivity analysis was performed using CAMx to examine the impact on ozone levels of new sources constructed within and around the DFW area since 1999.

COMPARISON OF OSAT AND APCA RESULTS

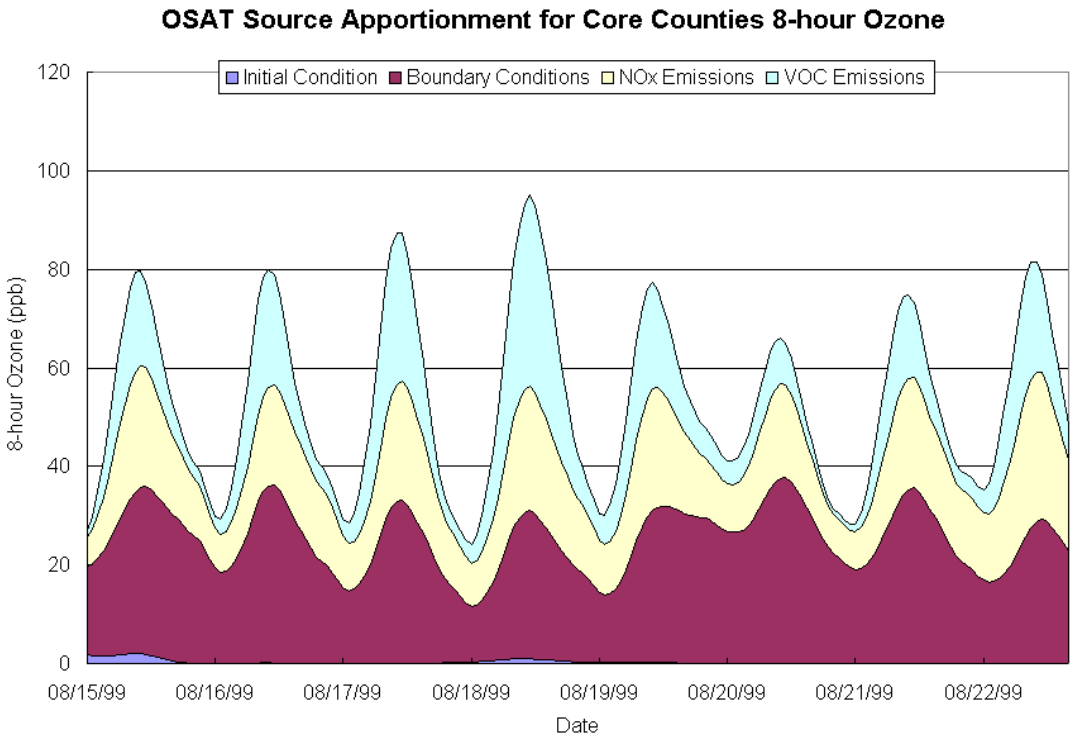
Figures 4-1 and 4-2 compare the OSAT and APCA apportionments for 8-hour ozone in the 4 Core counties. Figure 4-1 shows the 8-hour ozone apportionment to initial conditions (ICs), boundary conditions (BCs), VOC emissions and NOx emissions. The IC/BC contributions are almost identical between OSAT and APCA. The IC contribution is negligible because two spin-up days (August 13th and 14th) have removed the influence of the ICs by August 15th. The contribution of the BCs ranges from about 15 ppb to 35 ppb, which is consistent with the CAMx ozone boundary condition being set at 40 ppb. The contribution of the BCs in the DFW area is lower than 40 ppb because some boundary ozone is lost to chemical reactions and deposition between the boundaries and DFW.

[1] Model results for 15 – 22 August 1999 are included in these calculations. The 13 and 14th are model "spin up" days and are not intended for source apportionment calculations.

Figure 4-1 shows that VOC and NOx emissions are the main contributor to ozone in the 4 Core counties, especially at times of 8-hour ozone in the middle of the day. At the top of Figure 4-1, OSAT shows that the relative contributions of NOx and VOC emissions are comparable on most days. However, the VOC emissions are dominated by biogenic sources that are not considered controllable. The APCA method recognizes this fact, and reassigns ozone apportionments to biogenic VOCs to the NOx emissions that interacted with the biogenic VOCs to form ozone. The APCA analysis shown in the bottom of Figure 4-1 apportions most of the ozone production to NOx emissions and very little to VOC emissions. This difference between the APCA and OSAT results shows that ozone in DFW area may be sensitive to VOC emissions, but because the VOCs are dominated by biogenic sources, the only effective way to reduce ozone will be NOx reduction. Because the modeled ozone levels are sensitive to the biogenic emission levels, ozone may not be very responsive to initial reductions in NOx emissions, even though NOx reduction is the most viable control strategy. This means that the modeled ozone levels may be unresponsive (or stiff) to small or moderate NOx emissions reductions.

Figure 4-2 shows the OSAT and APCA apportionments of 8-hour ozone in the 4 Core counties to 4 major emissions categories (biogenic, motor vehicle, area/off-road/low points, and elevated point sources). The IC and BC contributions are also shown in Figure 4-2 and are identical to Figure 4-1. Biogenic emissions are identified by OSAT as a major contributor to ozone formation reflecting the high contribution of biogenic emissions to VOC emissions. APCA reduces the apportionment of ozone to biogenic emissions to almost zero and increases the apportionments to anthropogenic (NOx) emissions to compensate. The small APCA contribution for biogenic emissions is from biogenic VOCs interacting with biogenic NOx, and is limited by the small amount of biogenic NOx available. The relative contributions of the anthropogenic emission categories will be discussed in more detail below.

This comparison of OSAT and APCA results shows that it is important to account for the role of biogenic emissions in the DFW area. The APCA results take into account that biogenic emissions are not controllable and so APCA is more policy-relevant than OSAT and OSAT results are not considered beyond this point.



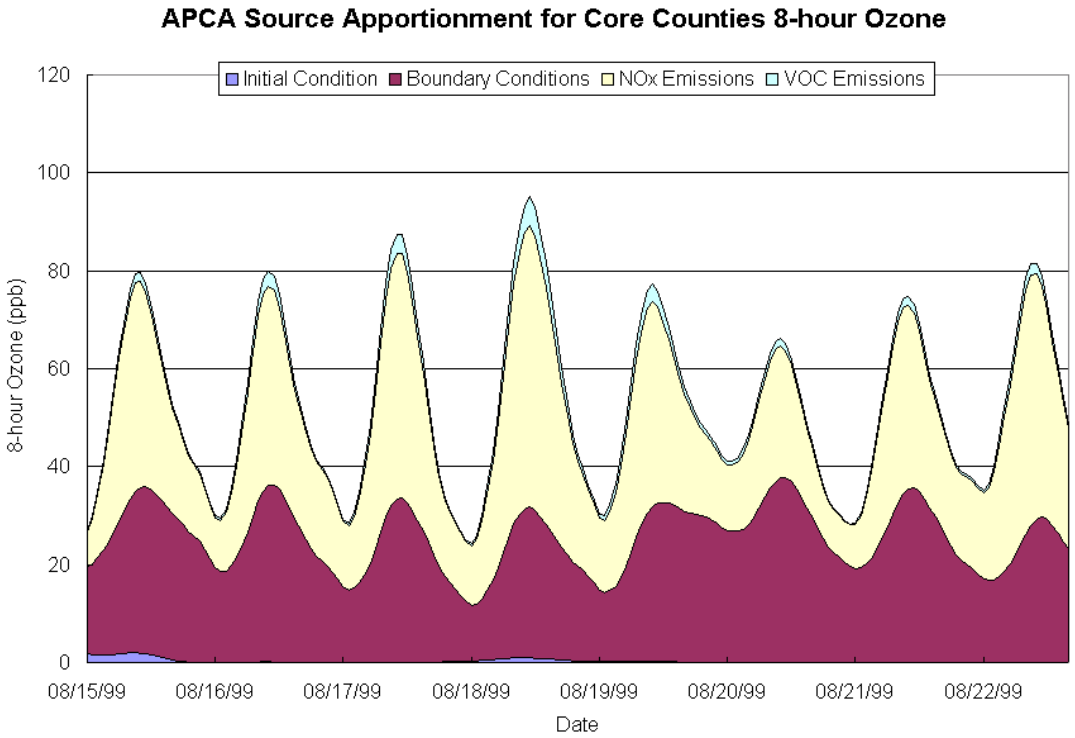
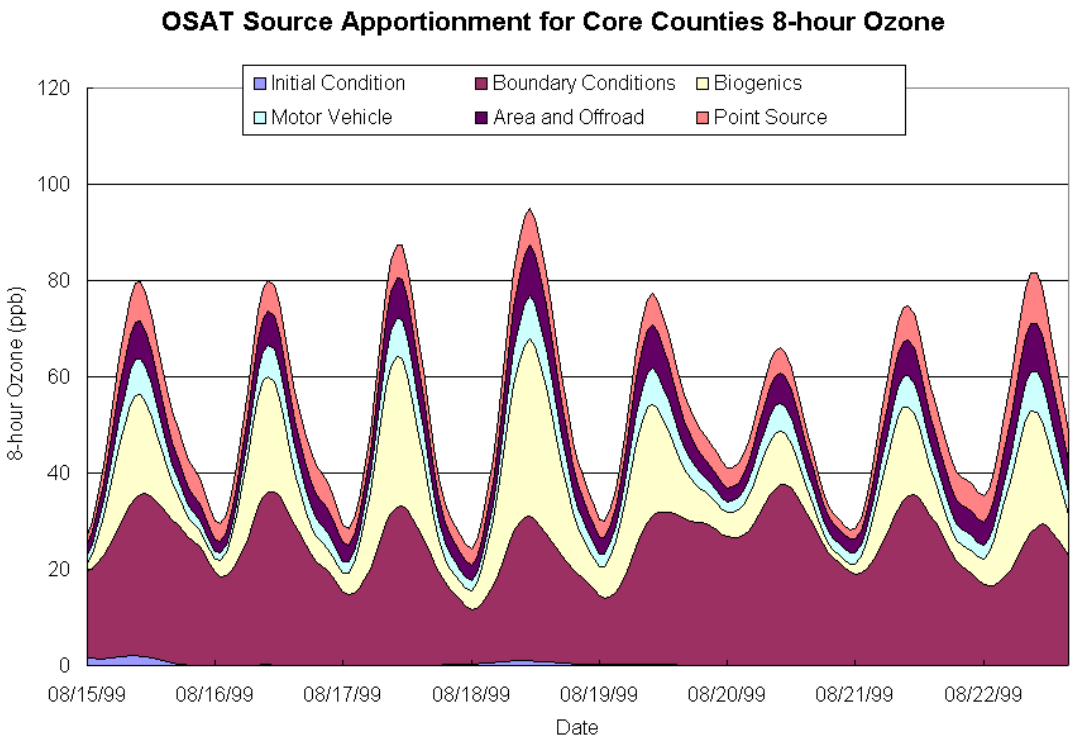


Figure 4-1. Source apportionment to VOC and NOx for 8-hour ozone in the 4 Core Counties with OSAT (top) and APCA (bottom).



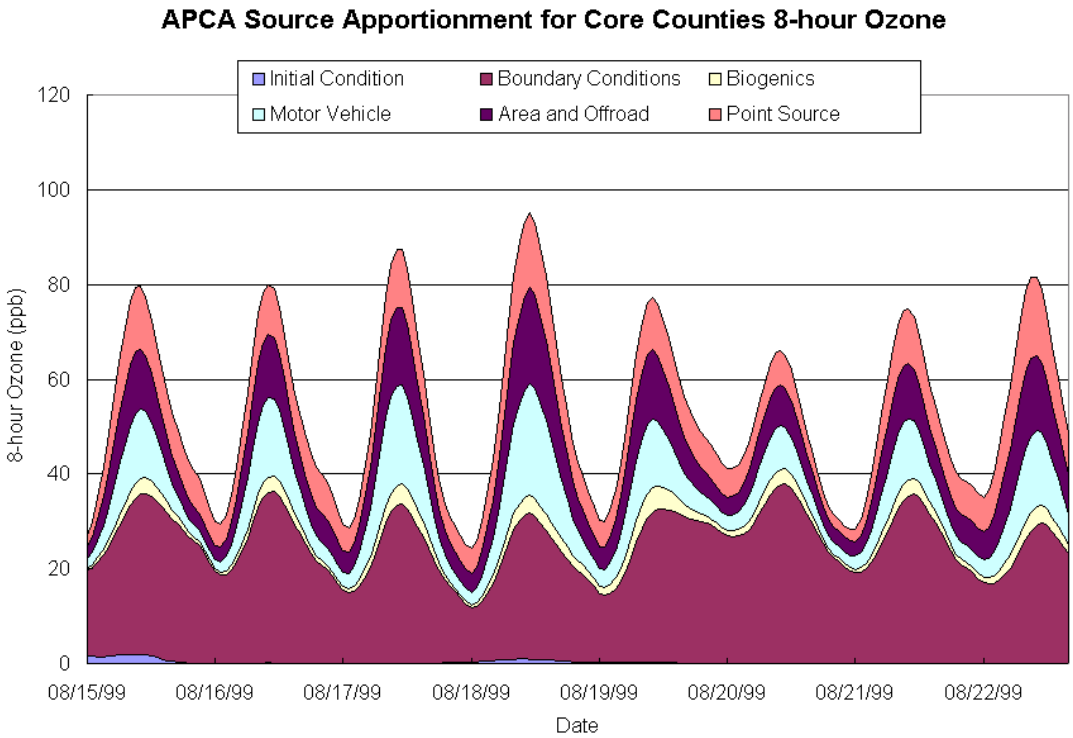


Figure 4-2. Source category apportionment for 8-hour ozone in the 4 Core Counties with OSAT (top) and APCA (bottom).

SUMMARY OF APCA RESULTS

APCA and zero-out results were both summarized on the basis of apportionments of (APCA) and changes in (zero-out) ozone concentrations in each CAMx surface layer grid cell and time period during which the predicted running 8-hour average concentration is greater than 85 ppb.[2] Source contributions to ozone levels below 85 ppb are of less interest since these values do not contribute to nonattainment of the 8-hour ozone standard. A particular source may contribute substantially to nearby ozone levels but this would not play a role in the attainment status if the nearby ozone levels do not exceed 85 ppb. Results were generated separately for two receptor regions: the four core counties (Dallas, Collin, Denton, Tarrant) and the twelve counties comprising the DFW CMSA. Modeling results for the four-core county receptor area are shown and discussed in this section of the report. The results for the twelve county CMSA receptor area, which overall are very similar to the 4county results, are shown in Appendix A.

Average apportionments to individual source regions of all predicted 8-hour average ozone concentrations in the four core counties greater than 85 ppb are summarized in **Table 4-1**. Also shown are the apportionments to initial conditions (IC) and the north, south, east, west, and top boundary conditions used in the model run.

The largest contribution to predicted 8-hour ozone exceedances comes from emissions within the four core counties (35.85 ppb of 94.51 ppb). Of the core counties, the largest contribution is from Dallas county (16.00 ppb) and the second largest is from Tarrant county (12.06 ppb). The contributions from the 8 counties surrounding the 4 core counties are all smaller than any of the core county contributions. However, taken together the total contribution from the surrounding 8 counties (4.66 ppb) is 13% of the contribution of the core counties. Of the 12 counties surrounding the four core counties, emissions from Ellis Co. are by far the single largest contributor to the predicted 8-hour ozone exceedances. Of the different source categories within Ellis Co., elevated point sources contribute more than all other categories combined. In fact, the elevated point sources in Ellis Co. contribute more than the elevated point sources in any other county except Dallas and Tarrant.

Ozone transport from other regions within Texas and from neighboring states also contributes to modeled ozone exceedances in DFW. The main contributing upwind regions in Texas are Central Texas, Northeast Texas and the Houston/Beaumont area. The main contributing states are Louisiana and Arkansas.

Given the importance of contributions from Ellis Co. point sources noted above, we examined the spatial distribution of maximum 8-hour average Ellis Co. source contributions relative to the spatial distribution of the episode maximum 8-hour average total ozone, i.e., the combined ozone impact of all sources (see **Figure 4-3**). As seen in the top panel of this figure, regions of elevated 8-hour total ozone lie to the north, west, and southwest of Dallas – Ft. Worth, reflecting the local transport patterns that occurred on different days during the episode. The spatial distribution of the modeled maximum 8-hour ozone (Figure 4-3, top) can be compared to the observed pattern of 8-hour ozone design values (Figure 2-4) which shows that the August 15 – 22, 1999 episode period is fairly representative of high ozone conditions in the DFW area. Contributions from Ellis Co. sources (bottom panel) are highest close to the major NOx sources

[2] Model results for 15 – 22 August 1999 are included in these calculations. The 13 and 14th are model "spin up" days and are not intended for source apportionment calculations.

located in the northwestern corner of the county and smaller contributions from these sources are seen to extend out into the regions of maximum total ozone seen in the top panel. It is important to recognize that these results are for episode maximum values of total ozone (top panel) and source contribution (bottom panel) so the time of occurrence of the total ozone maximum in any one-grid cell as depicted in the top panel may not coincide with the time of the maximum Ellis Co. elevated point source contribution depicted in the bottom panel.

Table 4-1. Average source apportionments to 8-hour ozone in the four core counties from CAMx APCA modeling for all 8-hour average predictions greater than 85 ppb (Source: Mansell et al., 2003).

	Source Category											
Region	Initial	BC East	BC North	BC South	BC Top	BC West	Biogenic	Elev Pts	On Road	Other Anthro	Totals	Area Totals
Collin							0.24	0.31	1.51	1.46	**3.52**	
Dallas							0.11	2.16	8.55	5.18	**16.00**	
Denton							0.21	0.26	2.38	1.42	**4.27**	
Tarrant							0.09	1.10	6.46	4.41	**12.06**	**35.85**
Cooke							0.00	0.00	0.01	0.01	**0.02**	
Ellis							0.14	0.89	0.46	0.24	**1.73**	
Fannin							0.02	0.00	0.01	0.01	**0.04**	
Grayson							0.02	0.03	0.02	0.02	**0.09**	
Henderson							0.03	0.05	0.07	0.11	**0.26**	
Hood							0.00	0.20	0.01	0.01	**0.22**	
Hunt							0.07	0.01	0.18	0.06	**0.32**	
Johnson							0.05	0.06	0.25	0.24	**0.60**	
Kaufman							0.13	0.00	0.46	0.20	**0.79**	
Parker							0.00	0.01	0.10	0.07	**0.18**	
Rockwall							0.04	0.00	0.22	0.06	**0.32**	
Wise							0.00	0.00	0.01	0.08	**0.09**	**4.66**
Central Texas							0.74	1.51	0.67	0.96	**3.88**	
Northeast Texas							0.27	1.72	0.63	1.13	**3.75**	
South Texas							0.10	0.13	0.06	0.15	**0.44**	
HGBPA							0.10	1.16	0.52	0.74	**2.52**	
West Texas							0.02	0.02	0.01	0.04	**0.09**	**10.68**
Arkansas							0.21	0.65	0.50	0.72	**2.08**	
Louisiana							0.23	2.15	0.72	1.59	**4.69**	
Oklahoma							0.04	0.11	0.12	0.14	**0.41**	
Other States							0.33	1.82	0.76	1.22	**4.13**	**11.31**
Boundary Conditions		1.90	10.56	0.94	16.66	1.25					**31.31**	
Initial Conditions	0.70										**0.70**	**32.01**
Grand Total	**0.70**	**1.90**	**10.56**	**0.94**	**16.66**	**1.25**	**3.19**	**14.35**	**24.69**	**20.27**	**94.51**	**94.51**

Care is needed in interpreting Figure 4-3 because the maximum 8-hour ozone levels (top) do not necessarily occur at the same time as the maximum Ellis County contribution (bottom). To eliminate the potential temporal differences between values shown in the top and bottom panels in **Figure 4-3**, we examined maps of total ozone and Ellis Co. source contributions for individual hours selected from among periods with high 8-hour total ozone. An example is presented in **Figure 4-4** which shows total ozone (top panel) and the Ellis Co. elevated source contribution (bottom panel) for 13:00 CST on 22 August 1999. The plume of ozone contributions from NW Ellis Co. is clearly visible extending to the northwest into Tarrant and Wise counties. Although the maximum source contributions (up to 8.4 ppb) occur in SE Tarrant county, contributions on the order of 3 ppb extend into the region of high total ozone in northern Tarrant and southern Wise Co. In fact, a plume of elevated total ozone extending from these sources is visible in SE and central Tarrant Co. Similar ozone plumes just downwind of other large point sources can also be seen in the left panel, most notably in Limestone Co. SSE of Dallas. This ozone plume appears to be associated with a large point source located just to the SE (near the southern border of the map). Although these results do not show what, if any, contribution this source (or any other source outside of Ellis Co.) made to DFW 8-hour exceedances on this particular day, additional APCA modeling results could be generated to address this question.

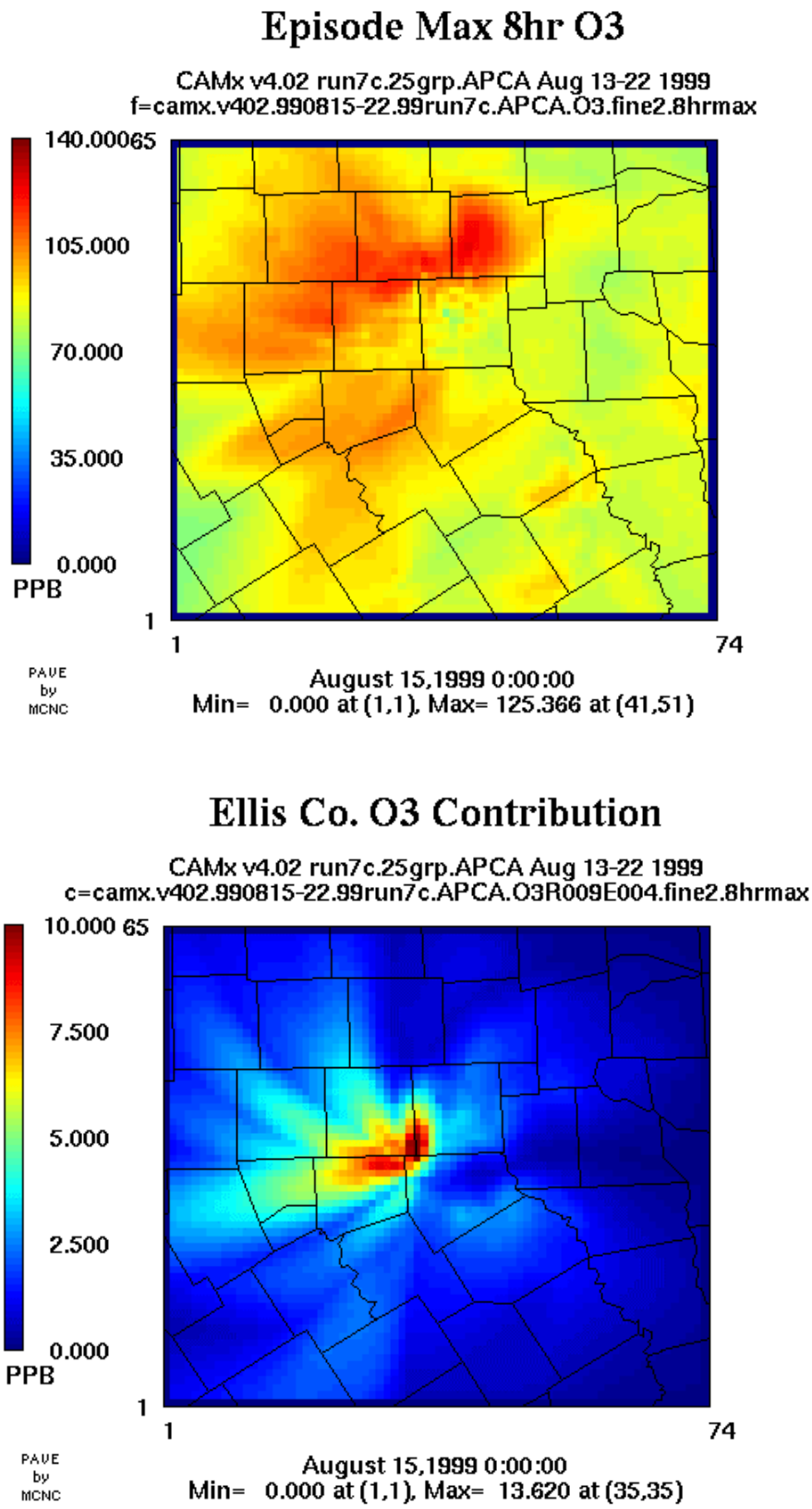
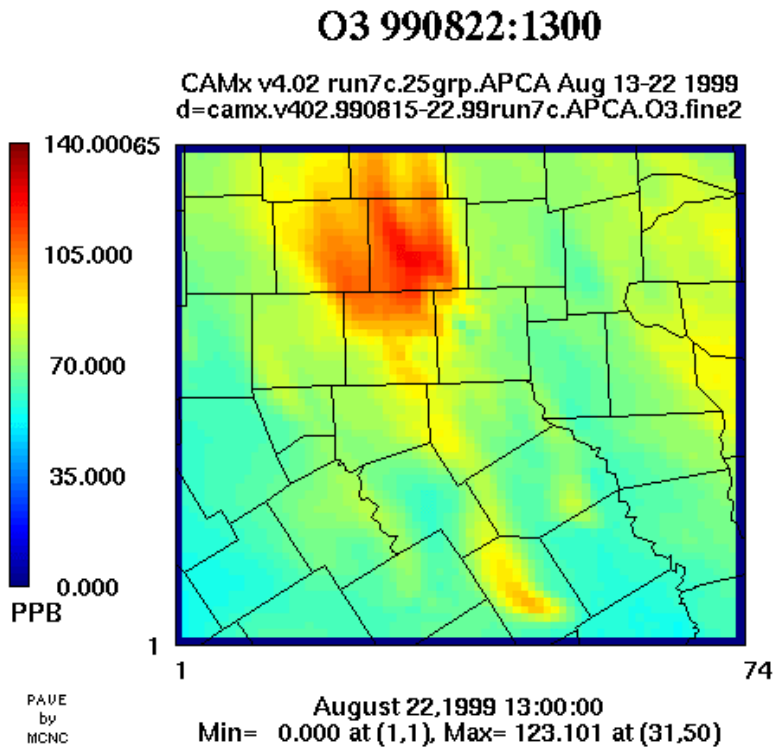


Figure 4-3. Episode maximum 8-hour average ozone (top panel) and episode maximum Ellis Co. source contribution to 8-hour ozone (bottom panel) for 15 - 22 August, 1999.



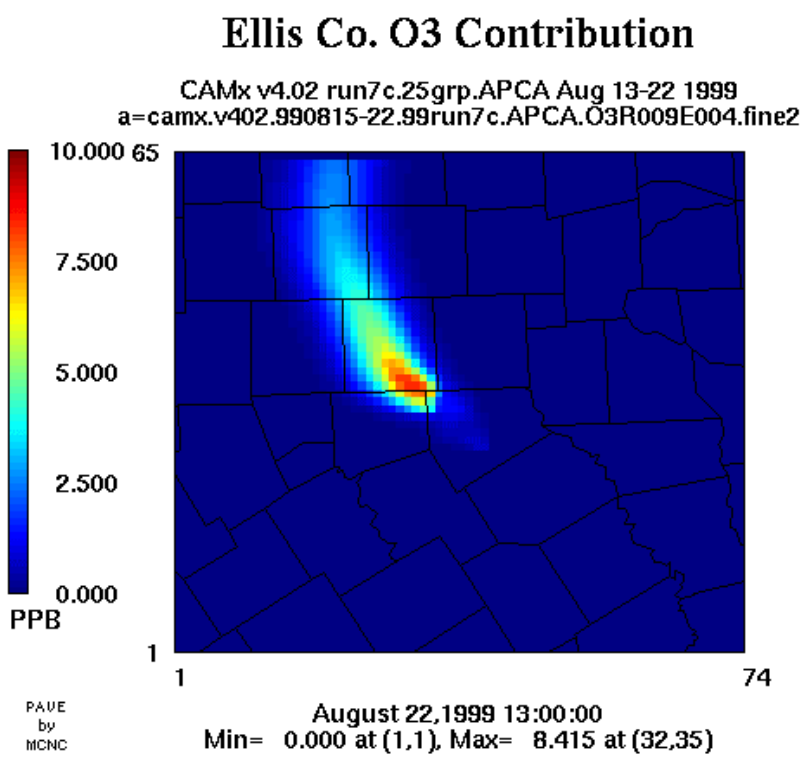


Figure 4-4. Predicted 1-hour average ozone concentrations (top panel) and ozone contribution from sources in Ellis Co. (bottom panel) for 13:00 CST on 22 August 1999.

COMPARISON OF ANTHROPOGENIC ATTRIBUTIONS WITH ZERO-OUT RESULTS

APCA source apportionment results presented above provide one way of looking at the contribution of different sources to high ozone concentrations. A selected set of zero-out runs were performed for comparison with the APCA source apportionments. For purposes of comparison with zero-out runs, contribution estimates for all anthropogenic sources were combined and contributions from anthropogenic emissions in individual counties in the DFW area were grouped together as follows:

- Four core counties (Collin, Dallas, Denton, Tarrant)
- Johnson
- Ellis
- Kaufman
- Remaining nine non-core counties (Wise, Parker, Hood, Henderson, Cooke, Rockwall, Hunt, Fannin, Grayson)
- Central Texas
- Northeast Texas
- Houston-Galveston/Beaumont-Port Arthur 11 Counties
- Arkansas
- Louisiana
- All Other areas of the CAMx modeling domain
- Boundary condition and top concentration

These groupings were chosen to reduce the number of zero-out runs to a manageable number. The areas exactly correspond to individual areas or combinations of areas from the APCA analysis so that the APCA and zero-out results can be directly compared.

Comparisons of APCA and zero-out results (**Table 4-2**) highlight some of the key differences between these two approaches to examining source contributions. In all cases, the zero-out differences are less than the source contribution estimates. These differences are partly due to the zero-out method where eliminating emissions from one source enhances the efficiency of ozone production from the remaining sources. Also, the zero-out method does not recognize the uncontrollable nature of biogenic emissions whereas APCA does account for this. Note that the sum of the zero-out differences is only about two-thirds of the total ozone level whereas the APCA sum matches the total predicted ozone. This further emphasizes the fact that zero-out differences do not provide an apportionment of ozone to different sources.

Additional APCA and Zero-Out Results

APCA and zero-out results presented above are for averages taken over all grid cell hours greater than 85 ppb. Spatial patterns in maximum APCA source apportionments and zero out run differences are compared for six different source regions in **Figure 4-5** (note that the color scales vary from one source region to the next). In each case, the spatial patterns are very similar and clearly show the downwind area of influence of each source region.

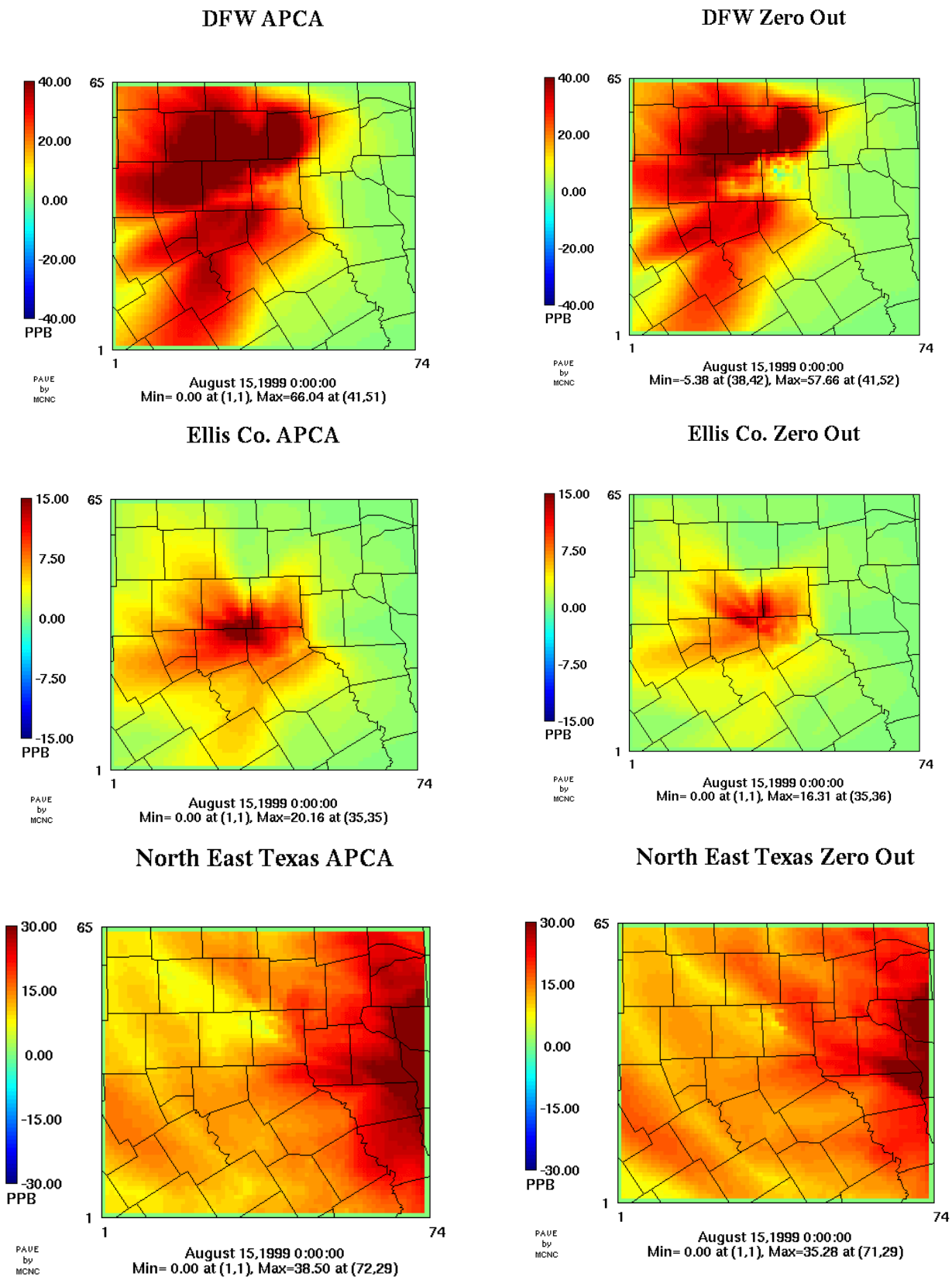


Figure 4-5. Episode maximum APCA anthropogenic source attributions (left panel) and zero-out run differences (right panel) for 15 – 22 August 1999 for the six selected source regions listed in table 4-2 ("DFW" refers to the four core counties).

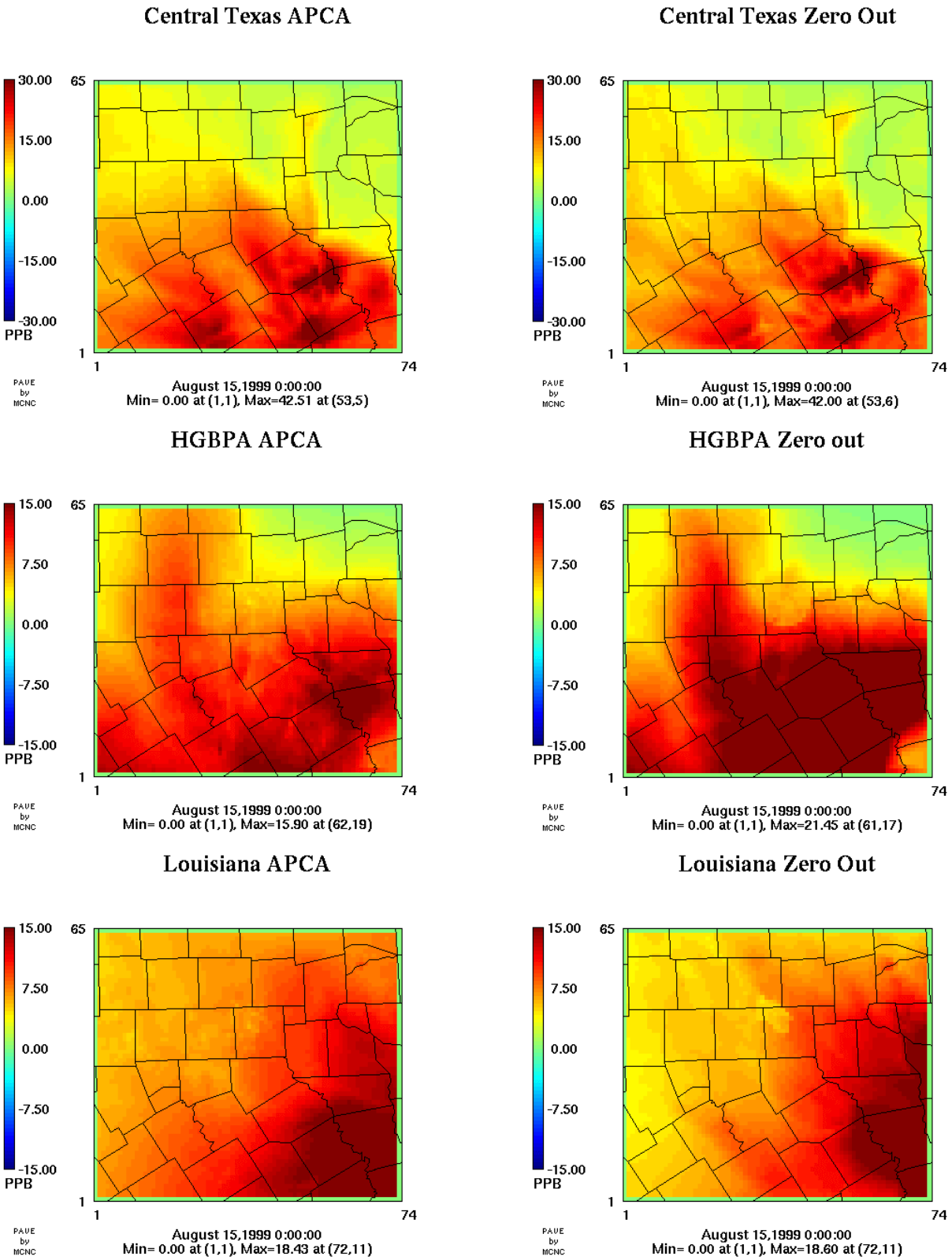


Figure 4-5. concluded. Episode maximum APCA anthropogenic source attributions (left panel) and zero-out run differences (right panel) for 15 – 22 August 1999 for the six selected source regions listed in table 4-2 ("DFW" refers to the four core counties).

Table 4-2. Average APCA ozone attributions and zero-out ozone differences over all grid cell hours in the four core counties with 8-hour average ozone greater than 85 ppb.

Source Region	APCA Attributions (ppb) *	Zero-Out Differences (Base - Zero-Out; ppb)
Four Core Counties Combined	35.2	28.3
Johnson Co.	0.5	0.3
Ellis Co.	1.6	0.6
Kaufman Co.	0.7	0.4
9 Remaining Non-core Counties Combined	1.4	0.8
Central Texas	3.1	2.3
Northeast Texas	3.5	2.5
Houston-Galveston/Beaumont-Port Arthur 11 Counties	2.4	2.1
Arkansas	1.9	0.9
Louisiana	4.5	3.0
All Other Areas	4.6	2.1
Boundary condition and top concentration	31.3	18.5
TOTAL:	90.6	61.5[3]

* Note: These values differ from those in Table 4-1 because they do not include contributions from biogenic sources.

The total number of grid cell hours in the four core counties greater than 85 ppb for the 15 – 22 August 1999 period is 6,690. In addition to the average APCA attributions and zero-out differences over all these grid cell hours that were presented in Table 4-2 above, we also tabulated the percentage of all such grid cell hours for which the APCA source attribution or the zero-out run differences exceeded 2 ppb (**Table 4-3**). A threshold of 2 ppb was chosen for this analysis because EPA and other parties have suggested that this threshold value could be used as a benchmark in the determination of what constitutes a "significant" impact. These results generally mirror those for the average ozone contributions discussed above: percentages for the zero-out differences are less than for the APCA attributions but the rank ordering of source regions is the same between the two methods. In terms of grid cell hours with values above 2 ppb, large source regions such as other parts of Texas and surrounding states contribute a minimum of 2 ppb to a large percentage of grid cell hours. Of the DFW CMSA counties surrounding the four core counties, the maximum percentage is computed for Ellis County: for the APCA source attribution estimates, anthropogenic emission in Ellis contribute at least 2 ppb of ozone in over a quarter of the grid cell hours with ozone exceeding 85 ppb.

Finally, we also calculated the maximum attributions and zero-out differences for all grid cell hours in the 4 core counties exceeding 85 ppb (**Table 4-4**). While some of the maximum attributions are quite large, it is important to remember that these values are for a single grid cell hour out of many thousands and by themselves convey very little information about the overall impact of a source region. Because they are single grid cell results, these maximum values may also be subject to more modeling uncertainty than would be the case, for example, for the average values listed in Table 4-2. Nevertheless, the rank ordering of source regions by maximum values is generally consistent between the attributions and zero-out differences and closely follows the rank ordering of the averages.

[3] Simple sum of values for each source region. This number does *not* represent the average difference in ozone which would have been calculated using a zero-out run in which anthropogenic emissions from all of the listed source regions were set to zero.

Table 4-3. Percent of grid cell hours in the four core DFW counties with 8-hour average ozone greater than 85 ppb for which the APCA anthropogenic ozone attributions and zero-out ozone differences exceed 2 ppb during the 15 – 22 August 1999 episode.

Source Region	APCA Attributions (ppb)	Zero-Out Differences (Base - Zero-Out; ppb)
Four Core Counties Combined	100%	100%
Johnson Co.	8%	3%
Ellis Co.	26%	9%
Kaufman Co.	7%	2%
9 Remaining Non-core Counties Combined	18%	5%
Central Texas	80%	65%
Northeast Texas	77%	57%
Houston-Galveston/Beaumont-Port Arthur 11 Counties	55%	46%
Arkansas	31%	13%
Louisiana	78%	69%
All Other Areas	100%	44%
Boundary condition and top concentration	100%	100%

Table 4-4. Maximum APCA anthropogenic attributions and zero-out differences for all grid cell hours in the 4 core DFW counties with 8-hour average ozone greater than 85 ppb (15 – 22 August 1999).

Source Region	APCA Attributions (ppb)	Zero-Out Differences (Base - Zero-Out; ppb)
Four Core Counties Combined	66.0	57.7
Johnson Co.	7.3	5.5
Ellis Co.	20.2	16.3
Kaufman Co.	6.7	4.5
9 Remaining Non-core Counties Combined	9.1	9.9
Central Texas	11.6	9.9
Northeast Texas	14.2	12.4
Houston-Galveston/Beaumont-Port Arthur 11 Counties	8.8	9.0
Arkansas	9.1	5.6
Louisiana	9.6	7.7
All Other Areas	10.5	8.1
Boundary condition and top concentration	39.5	33.1

5. NEW SOURCE SENSITIVITY ANALYSIS

Construction of new sources in the DFW area may lead to higher ozone levels in the absence of offsetting emission reductions. New sources constructed outside of whatever boundaries are ultimately established for the 8-hour DFW ozone nonattainment area will generally be subject to less stringent limitations than will apply to new sources inside the boundary. For example, new sources in nonattainment areas may be subject to emission offset requirements. This raises the question of what impact on ozone levels can be expected from new sources built in the region surrounding the four core DFW counties. To address this question, we performed a model sensitivity analysis in which we computed the changes in ozone levels resulting from the addition of several new point sources which have been built in the region since 1999. *For this sensitivity analysis, the new sources were simply added to the existing 1999 inventory, no other changes were made to the inventory. Thus results from this simulation merely indicate the sensitivity of ozone to addition of the new sources, they are not intended to represent the ozone levels which would actually occur under an actual post-1999 emissions scenario as any such scenario would include other emission changes, including but not limited to reductions in on-road mobile sources and reduced emissions from some existing point sources. It should be noted that other new sources not yet permitted may also be built.*

A list of sources constructed within the DFW CMSA and its immediate vicinity since 1999 was obtained from the TCEQ (Thomas, 2004). These include 9 new electric generating units (EGUs) and one new cement kiln as listed in **Table 5-1**; source locations are plotted in **Figure 5-1**. Although a new kiln has also been permitted at the TXI facility in Midlothian, the permit conditions limit operation of older sources at this facility whenever the new kiln is running. Information supplied by TCEQ indicates that, as a result of this permit conditions, maximum allowable emissions are lower under operating scenarios that include the new kiln (Thomas, 2004). We therefore chose not to include this kiln as a new source for our sensitivity analysis. Where available, actual emission data were used for the new sources; permit allowable emissions were used where actual reported emissions were not available. In particular, the permit allowable limit of 6.5 tons/day was used to represent the new kiln at the Holcim facility. This approach is suitable for our purposes in a sensitivity run but the reader must recognize that we are not attempting to represent actual emissions in this analysis.

Table 5-1. New sources in the DFW area included in the CAMx 1999 new source sensitivity run.

Company	Business	County	City	NOx (tons/day)
Mirant Texas, Lp (Formerly SEI)	EGU	Bosque	Whitney	2.3
Midlothian Energy	EGU	Ellis	Midlothian	2.4
Ennis-Tractebel Power Co., Inc.	EGU	Ellis	Ennis	2.6
AES Aurora	EGU	Hood	Granbury	2.2
Cobisa-Forney Limited Partnership	EGU	Kaufman	Forney	7.6
Mirant Parker LLC (Formerly SEI)	EGU	Parker	Weatherford	2.4
City of Garland	EGU	Collin	Nevada	0.4
Duke Energy Jack, LP	EGU	Jack	Jacksboro	1.1
Wise County Power Co LLC	EGU	Wise	Bridgeport	2.7
Holcim	Cement Production		Midlothian	6.5
			TOTAL:	30.2

NOx emissions from the new sources total 30.2 tons/day which amounts to approximately 60% of the total point source NOx in the four core DFW counties or, equivalently, 5% of total NOx from all sources in the four core counties (based on 1999 emissions).

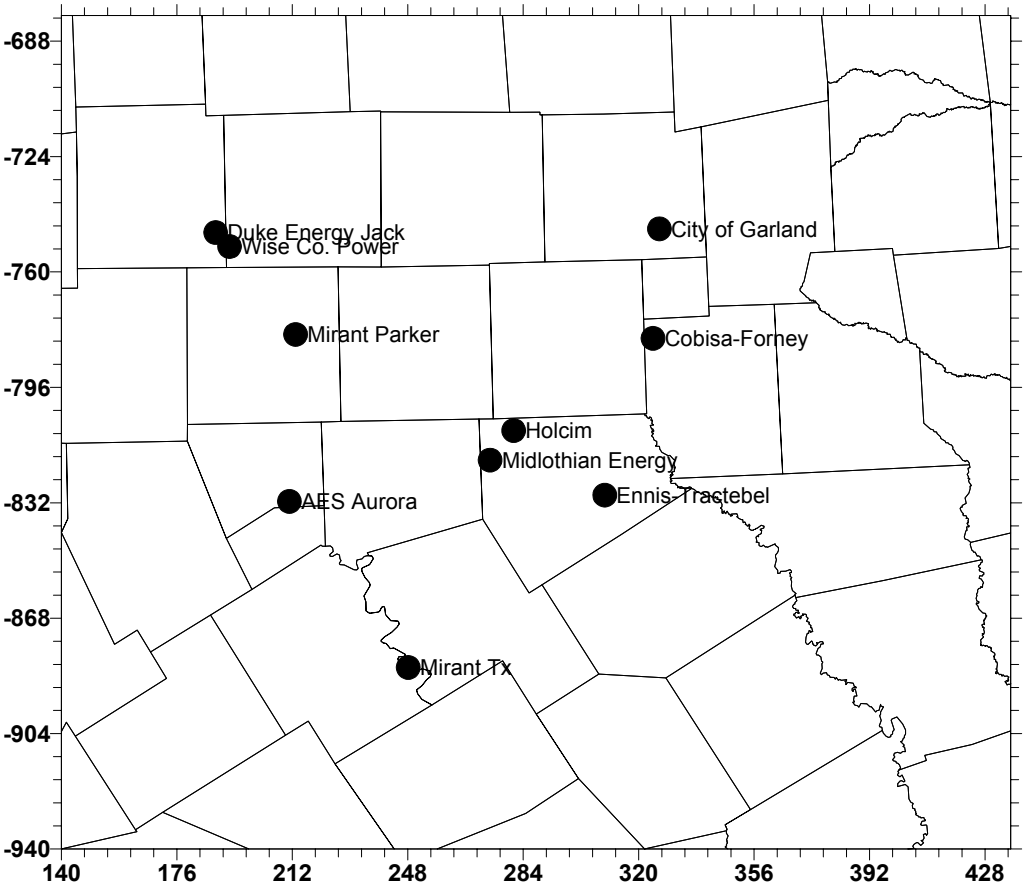


Figure 5-1. New point sources used in 1999 sensitivity run (see Figure 1-1 for place names).

Emissions of NOx, CO, and VOCs from each of the new sources were added to the 13 – 22 August 1999 model ready inventory using emissions, stack parameters and temporal profiles provided by TCEQ (Thomas, 2004). CAMx was run with the new inventory and results compared with the base case run. **Figure 5-2** shows the base case episode maximum 1-hour (top left panel) and 8-hour (bottom left panel) ozone concentrations along with the differences (sensitivity run – base case run) in episode maximum 1-hour (top right panel) and 8-hour (bottom right panel) ozone. Addition of the new sources results in increased ozone levels at various locations, depending on wind direction, location of the new source, and the degree to which (if any) addition of NOx from the new source delays formation of the downwind ozone peak. The largest change within the 4 km domain in the episode maximum 1-hour ozone is 4.4 ppb; the largest change in the 8-hour maximum is 4.2 ppb. Some negative differences can be seen in Figure 5-2, most noticeably near Midlothian in northwestern Ellis County where three of the new sources are located. These values reflect ozone reductions resulting from the addition of NOx in a small VOC limited area found within the immediate vicinity of a cluster of existing and new NOx sources.

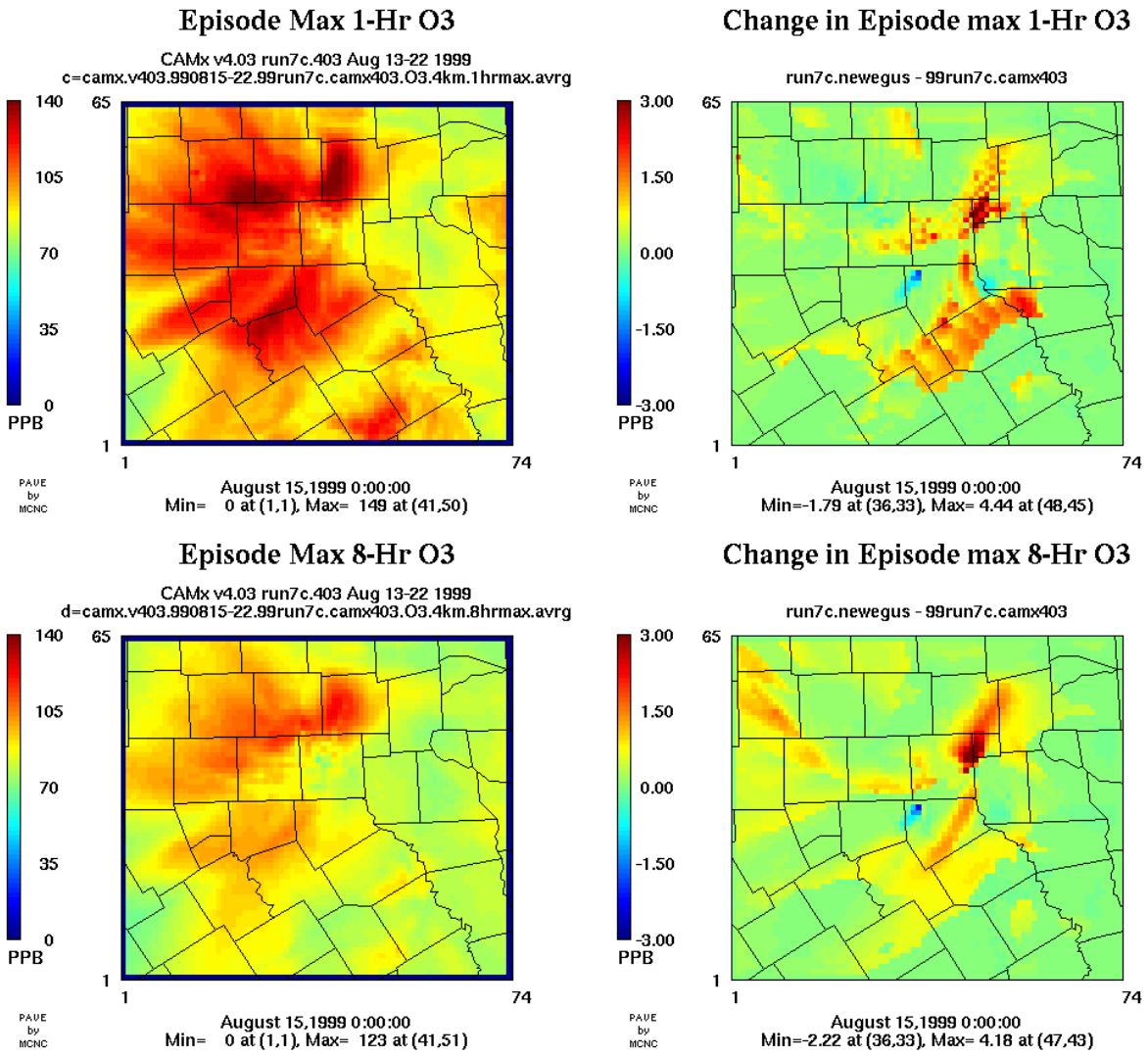


Figure 5-2. Episode maximum 1-hour (top) and 8-hour (bottom) ozone concentrations (left panel) and changes in ozone concentrations (right panel) under the new source sensitivity scenario.

6. SUMMARY AND CONCLUSIONS

Using a variety of data analysis and modeling techniques, we have evaluated the impact of transport from both nearby and more distant source regions on ozone concentrations in DFW. Our analyses included:

- Examination of ozone precursor emission budgets and ozone monitoring data in counties that are part of the DFW CMSA.
- Comparisons of historical trends in emissions and ambient ozone levels in DFW.
- Comparison of the frequencies of ozone exceedances by day of week.
- Examination of aircraft data from flights over DFW and vicinity and other portions of East Texas.
- Examination of back trajectories indicating the paths taken by air parcels arriving at DFW on the afternoons of high and low ozone days during the ozone season.
- Application of the Trajectory Mass Balance (TrMB) method to selected receptor sites in DFW.
- Examination of animated point source plume trajectories for selected days.
- Source apportionment modeling of the 15 – 22 August 1999 episode with CAMx using the OSAT and APCA methodologies.
- Zero-out modeling of selected source regions for comparison with the source apportionment results.
- Sensitivity modeling study of the impact of new industrial NOx sources on DFW ozone levels.

Our results clearly indicate the important contribution to peak 1-hour and 8-hour ozone levels of NOx emissions from sources located upwind of the four core DFW counties (Dallas, Denton, Collin, and Tarrant). Given prevailing wind directions during high ozone events, upwind sources lie to the east, southeast, and south of the core urban area, consistent with the spatial pattern of measured ozone design values.

Trajectory analyses show that high ozone events in DFW are associated with slow moving air parcels originating primarily from east, southeast and south of the metropolitan area. This is in contrast to low ozone days which are typically characterized by stronger southerly flow. Quantitative estimates of the relative contributions of different source regions within and outside of Texas to ozone concentrations in DFW obtained from the TrMB method are difficult to interpret because of technical limitations of the technique. Animated plume trajectories show plumes from sources just upwind of the four core DFW counties traveling over the urban area during high ozone episodes but provide no quantitative estimates of the contribution of a source to observed ozone levels.

Comparisons of trends in ambient ozone concentrations with trends in VOC and NOx emissions, comparisons of weekday versus weekend ozone levels, and a CAMx sensitivity run all indicate that ozone levels in DFW are sensitive to changes in NOx emissions and relatively insensitive to changes in anthropogenic VOC emissions. Data from aircraft measurement programs show that conditions in East Texas are favorable for formation of ozone in NOx source plumes. The aircraft data also show that transport of elevated regional background ozone into the DFW CMSA is significant, approaching 80 - 90 ppb under certain conditions and typically amounting to about 50% of the ozone measured in the center of the urban plume downwind of the city.

Examination of emission budgets for counties in the DFW CMSA reveals that large NOx point sources are present in several outlying counties. Dallas and Tarrant counties have the highest total NO_x emissions with Ellis Co. having the third highest. In addition, Ellis Co. has the highest point source NOx of any CMSA county. Of course, high emissions do not necessarily produce high ozone impacts: the emissions must be upwind of the ozone impact area of concern and the emissions, when mixed with those from other sources, must have the right mix of precursors (VOC and NOx) to form ozone. As discussed above, Ellis Co. is frequently upwind of DFW on high ozone days, and aircraft data show that point source NOx emissions can produce ozone in eastern Texas because VOCs are typically available from biogenic sources. Large biogenic VOC source regions are upwind of Ellis Co. and DFW under southeasterly winds.

A survey of new sources which have begun or are planned to begin operation between 1999 and 2007 in the DFW CMSA and surrounding counties indicates that these sources are estimated to emit approximately 30 tons/day of NOx. This amount of NO_x is equivalent to approximately 60% of the total point source NOx in the four core counties or, equivalently, 5% of total NOx from all sources in the four core counties in 1999. Results from a CAMx sensitivity run in which these new sources were added to the 1999 inventory show that ozone in the CMSA is sensitive to the additional NOx, with episode maximum 8-hour ozone increasing by as much as 4 ppb in some locations.

We used several different modeling approaches in CAMx (OSAT, APCA and zero-out) to evaluate the contributions of different source regions to ozone concentrations above 85 ppb in the DFW area. Each method has its own interpretation and associated strengths and weaknesses. Taken together, these results provide a variety of quantitative data on anthropogenic source contributions that can be used by policy-makers to inform decisions on nonattainment area boundaries and control strategy development. In interpreting these results, it is important to keep in mind that there is no unique way to assess the contribution to ozone exceedances of different sources of precursor emissions due to nonlinearities in ozone chemistry. For the same reason, ozone source contributions do not provide quantitative predictions of the impact of any specific emission control strategies. However, the APCA and zero-out modeling do reveal consistent patterns in the relative contributions of anthropogenic emissions between source areas thus supporting the reliability of these results as a guide for control strategy development.

OSAT results identify biogenic emissions as a major contributor to ozone formation, reflecting the high contribution of biogenics to total VOC emissions. APCA reduces the apportionment of ozone to biogenic emissions to near zero and increases the apportionments to anthropogenic (NOx) emissions to compensate.

The APCA and zero-out results for anthropogenic emissions are consistent with one another in terms of rank ordering of source regions and the locations of maximum impacts and areas of influence). APCA results indicate that emissions within the 4 core counties are the largest anthropogenic emissions contributor and are responsible for about one third of elevated ozone levels in DFW. The continental ozone background (i.e., model boundary contributions) and transport from upwind areas each also contribute about one third of elevated ozone levels in DFW. The zero-out differences are always smaller in magnitude than the corresponding APCA apportionments because zero-out does not account for the non-controllable nature of biogenic emissions, among other reasons. The zero-out results generally suggest slightly greater importance for local emissions (4 core counties) and lesser importance for distant sources (continental ozone background). APCA and zero-out both show that transport from upwind

source areas is an important contributor to elevated ozone in DFW, and so reductions in ozone transport will likely be necessary for DFW to demonstrate attainment of the ozone standard. The APCA and zero-out results both indicate that Ellis Co. is the largest contributor of the 12 counties surrounding the 4 core DFW counties. Outside of this 16 county region, Northeast Texas and Central Texas are the next most important source regions within Texas, followed by the Houston/Galveston/Beaumont/Port Arthur nonattainment area. Of the three neighboring states most frequently upwind on high ozone days (LA, AR, OK), Louisiana provides the largest contribution.

The APCA and zero-out results reveal plumes of ozone contributions from large industrial combustion sources in Ellis Co. that are shown to overlap regions of maximum ozone on more than one occasion during the 15 – 22 August 1999 episode. The zero-out differences are smaller than APCA apportionments and do not sum to total ozone, thus emphasizing that zero-out run differences do not represent source apportionments. The APCA and zero-out results were analyzed to see how frequently source areas contributed more than 2 ppb to 8-hour ozone above 85 ppb in the 4 core counties. Ellis Co. was the most frequent contributor above 2 ppb of the surrounding counties, contributing more than 2 ppb 26% of the time in the APCA results and 9% of the time in the zero-out results. Central Texas, Northeast Texas, and the Houston-Galveston/Beaumont-Port Arthur areas each contribute more than 2 ppb over 55% of the time in the APCA results and more than 46% of the time in the zero-out results.

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Appendix A

Detailed Source Contribution Results

Table A-1. APCA attributions and zero-out differences averaged over all grid cell hours in the four core county region and the 12 county DFW CMSA with 8-hour average ozone greater than 85 ppb (15 – 22 August 1999).

	APCA Contribution Est.				Zero-Out Differences			
			Sub Totals				Sub Totals	
Source Region	**4 County**	**12 County**	**4 County**	**12 County**	**4 County**	**12 County**	**4 County**	**12 County**
Four Core Counties Combined	35.2	32.1			28.3	26.9		
Johnson Co.	0.5	0.9			0.3	0.4		
Ellis Co.	1.6	1.7			0.6	0.7		
Kaufman Co.	0.7	0.7			0.4	0.4		
9 Remaining Non-core Counties Combined	1.4	2.7	39.3	38.1	0.8	1.4	30.3	29.8
Central Texas	3.1	2.8			2.3	2.0		
Northeast Texas	3.5	3.8			2.5	2.4		
Houston-Galveston/Beaumont-Port Arthur 11 Counties	2.4	1.8	9.0	8.4	2.1	1.4	6.9	5.8
Arkansas	1.9	2.2			0.9	1.1		
Louisiana	4.5	3.7			3.0	2.3		
All Other Areas	4.6	5.1	10.9	10.9	2.1	2.7	5.9	6.1
zero boundary condition and top concentration	31.3	32.2			18.5	19.6		
TOTAL:	90.6	89.6			61.5	61.2		

Table A-2. Maximum APCA attributions and zero-out differences over all grid cell hours in the four core county region and the 12 county DFW CMSA with 8-hour average ozone greater than 85 ppb (15 – 22 August 1999).

8-hr O3 > 85 ppb; ANTHRO ONLY	APCA Contribution Est.		Zero-Out Differences	
Episode Max (ppb)				
Source Region	4 County	12 County	4 County	12 County
Four Core Counties Combined	66.0	66.0	57.7	57.7
Johnson Co.	7.3	9.4	5.5	7.4
Ellis Co.	20.2	20.2	16.3	16.3
Kaufman Co.	6.7	6.7	4.5	4.5
9 Remaining Non-core Counties Combined	9.1	14.3	9.9	10.2
Central Texas	11.6	30.3	9.9	32.1
East Texas	14.2	38.5	12.4	43.8
Houston-Galveston/Beaumont-Port Arthur 11 Counties	8.8	8.9	9.0	38.0
Arkansas	9.1	9.1	5.6	5.6
Louisiana	9.6	10.1	7.7	48.7
All Other Areas	10.5	13.6	8.1	50.9
Boundary condition and top concentration	39.5	40.5	33.1	38.3

Table A-3. Percentage of grid cell hours in the four core county region and the 12 county DFW CMSA with 8-hour average ozone greater than 85 ppb (15 – 22 August 1999) for which APCA attributions and zero-out differences are greater than 2 ppb.

8-hr O3 > 85 ppb; ANTHRO ONLY	**APCA Contribution Est.**		**Zero-Out Differences**	
% Cell-Hrs > 2 ppb				
Source Region	**4 County**	**12 County**	**4 County**	**12 County**
Four Core Counties Combined	100%	98%	100%	100%
Johnson Co.	8%	16%	3%	6%
Ellis Co.	26%	30%	9%	12%
Kaufman Co.	7%	7%	2%	2%
9 Remaining Non-core Counties Combined	18%	45%	5%	22%
Central Texas	80%	71%	65%	52%
East Texas	77%	73%	57%	54%
Houston-Galveston/Beaumont-Port Arthur 11 Counties	55%	39%	46%	27%
Arkansas	31%	39%	13%	20%
Louisiana	78%	69%	69%	44%
All Other Areas	100%	100%	44%	53%
Boundary condition and top concentration	100%	100%	100%	100%

Appendix B

Response to April 1, 2004 Comments from Ellis County

Background

Judge Chad Adams of Ellis County requested a meeting with TERC to discuss HARC project H-27 "Evaluation of the Role of Local and Regional Transport in Ozone Nonattainment for the Dallas - Ft. Worth Area." The meeting took place in the offices of Mr. Laboon, TERC Chairman, on March 25, 2004. Present at the meeting were:

Mr. Chad Adams, Ellis County Judge
Mr. Weiping Dai, Trinity Consultants
Ms. Sue Sung, Trinity Consultants
Mr. Ron Wright, office of Congressman Barton for the 6th District of Texas
Mr. R. Bruce Laboon, TERC
Mr.John Hall, HARC
Mr. Eduardo (Jay) Olaguer, HARC (by phone)
Mr. Greg Yarwood, ENVIRON

The purpose of the H-27 study is to assess the role of transport in ozone nonattainment for the Dallas - Ft. Worth (DFW) area. The report considers transport over distances ranging from neighboring counties to other parts of Texas to surrounding States, and beyond. Ellis County is part of this analysis, but the report is not about Ellis County. The Study was directed by the Texas Environmental Research Consortium (TERC) and funded through the Houston Advanced Research Center (HARC).

At the time of the March 25, 2004 meeting this report was in draft form and was being reviewed within the HARC Scientific Advisory Committee. The discussions at the meeting covered the background to the project, the roles of TERC, HARC and ENVIRON, the project objectives, the technical approach, the study findings, and questions raised by Ellis County. On April 1, 2004, Judge Adams wrote to Mr. Laboon documenting Ellis County's initial questions and concerns and stating the County's disagreement with some of the study findings. Judge Adams' letter of April 1, 2004 is included below.

The following are ENVIRON's responses to the comments from Ellis County. They follow the same order and headings as Judge Adams' letter.

Problematic Meteorological Data

At the March 25, 2004 meeting Ellis County asked about the significance of problems with meteorological data for the August 17, 1999 day included in the ozone modeling. The development and evaluation of the August 15-22, 1999 ozone modeling databases for DFW was described in an earlier ENVIRON report by Mansell et al. (2003). The model performance for ozone is poorer on August 17th than other modeling days and this may be due to problems with the representation of the meteorology on this day. ENVIRON disagrees with Ellis County's conclusion that model performance issues for August 17th invalidate any and all conclusions based on ozone modeling results for

August 17th and subsequent days. Modeling results for August 17th are questionable, but due to the effects of winds and transport, ozone produced by DFW area emissions on August 17th has moved downwind by the next day and will have little or no impact on DFW ozone results for subsequent days (August 18-22, 1999). Consequently, the transport assessments based on ozone modeling retain considerable value in evaluating the role of ozone transport for August 15-22, 1999.

Inaccurate Scientific Analysis

The ENVIRON H-27 report finds that back trajectory analyses are inconclusive for showing cause and effect relationships between specific sources and specific high ozone levels, however back trajectories do provide useful information on typical wind directions and transport patterns for high ozone conditions. We also conclude that analyses of many trajectories tend to be more reliable than analyses of single trajectories. Back trajectories are useful for building a general understanding of potential relationships between emissions sources and high ozone areas and should be part of a "weight of evidence" approach to understanding how ozone transport affects the DFW area.

There are situations where ozone can be traced back to specific sources of ozone precursors with a high degree of certainty. Aircraft studies have identified plumes of high ozone that trace back to a specific source of ozone precursors. The H-27 report shows an example of an aircraft study in Northeast Texas where emissions from NOx point source interact with natural (biogenic) VOCs causing plumes with high ozone. In this type of situation it is reasonable to conclude that the NOx point source is responsible for causing high ozone levels, and the amount of excess ozone can be quantified from the difference in ozone levels inside and outside the plume.

When many ozone precursor sources are in close proximity it is difficult to trace ozone formation back to specific sources in the real world. Mathematical ozone models provide additional techniques for quantifying the ozone contributions from interacting sources. Because ozone is a secondary pollutant formed by non-linear chemical reactions, there is no *unique* way to quantify how much ozone is attributable to emissions from a specific source. For this reason we used several methods (APCA source apportionment, OSAT source apportionment and zero-out modeling) to calculate source contributions to ozone and ozone transport. We also calculated several different valuations of the ozone impacts from the APCA and zero-out methods (maximum impact, average impact when total ozone was above 85 ppb, number of impacts greater than a 2 ppb threshold when total ozone was above 85 ppb). As noted by Ellis County, it is important to understand what each of these valuations means when forming conclusions. We recommend looking at all of the modeling results and seeking consistent patterns in the relative magnitudes of contributions from different sources. However, the H-27 report does not attempt to specify any specific threshold value for what constitutes a significant contributions since this is a decision for policy makers when deciding issues such as nonattainment area boundaries.

Inaccurate Emission Inventory and Failure to Recognize Voluntary Emission Reductions in Ellis County

Most of the modeling and emission inventory analyses in this report are based on the 1999 emission inventory described in the report by Mansell et al., (2003). The year 1999 is used extensively because the ozone modeling is for this year and consequently emissions data are relatively complete, reviewed and quality assured for 1999.

The only ozone modeling analysis that includes emissions data more recent than1999 is a single sensitivity test that asks the *hypothetical* question "what is the ozone impact of including newly permitted stationary sources in the DFW area on top of 1999 emissions?" This analysis is carefully described as a sensitivity test because it is not for any specific year since 1999 and does not account for emissions reductions since 1999. The sensitivity test is intended to provide a simple estimate of the impact of the new sources without the confounding effect of emissions reductions.

While it was beyond the scope of the H-27 project to quantify emissions reductions that may have taken place since 1999 due to mandatory and voluntary measures, the TCEQ will be considering emissions reductions in future year ozone modeling for the forthcoming SIP revision. Emissions increases and decreases from 1999 levels will be accounted for if new emissions reduction strategies are developed for the DFW area.

The TCEQ has provided us with data on emissions from cement kilns in Ellis County for years from 1999 to 2002 (see table below). These data show no downward trend for the Ellis County cement kiln emissions in recent years.

Summary of NOx emissions (tons/day) for Ellis County cement kilns in 1999 to 2002.

	TXI	Holcim	NTCC	Total
1999	12.6	8.7	8.4	29.7
2000	12.4	11.5	8.5	32.4
2001	12.2	8.4	8.0	28.6
2002	11.6	11.5	7.0	30.1

Closing

Individual studies and analyses have uncertainties and limitations, therefore we recommend considering all relevant sources of information and evaluating the "weight of evidence" about the role played by transport in ozone nonattainment for the DFW area. It is the intent of the H-27 report to contribute objective data analyses to the decision-making processes for the DFW State Implementation Plan. Other data certainly should be considered as well as they become available.

ELLIS COUNTY JUDGE
CHAD ADAMS

April 1, 2004

Mr. R. Bruce Laboon, P.C.
Locke Liddell & Sapp LLP
Texas Environmental Research Consortium
3400 Chase Tower
600 Travis Street
Houston, TX 77002-3095

Reference: ***March 25, 2004 meeting***

Dear Mr. Laboon:

Thank you for your continued leadership in the realm of environmental research. Your reputation for diligence and commitment precedes you. It was gracious of you to allow me to discuss the Photochemical Modeling Analysis report prepared by ENVIRON prior to its public release.

As you may be aware, the Ellis County Commissioners' Court has retained Trinity Consultants to provide technical advice and interpretation of complex air quality reports and associated issues. After discussions covering our meeting of March 25, 2004, I would like to bring up certain technical objections to the conclusions drawn by ENVIRON.

Problematic meteorological data

ENVIRON Consultant Greg Yarwood is highly articulate and brings with him a wealth of knowledge on the subject of air quality. In our discussions, he himself noted various hesitancies with regard to his report. Specifically, Mr. Yarwood alluded to technical concerns with meteorological data from August 17, 1999 and its potential to corrupt pollutant-modeling results from that date forward. This voids the validity of any study using that data. Certainly, public policy should not be based on this questionable data.

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Inaccurate scientific analysis

Mr. Yarwood noted that his assessments from back-trajectory analysis were inconclusive, and we are in agreement with that statement.

Additionally, because of the many complex variables involved in ozone formation, there is currently no accurate and conclusive scientific method to trace ozone concentration back to specific points of NOx and VOC emissions.

A 1999 base case study performed by ENVIRON (which included the questionable meteorological data discussed above) utilized Anthropogenic Precursor Culpability Assessment (APCA) to evaluate the average contributions from various regions, including Ellis County, to the 8-hour ozone in the DFW area. Trinity reports (and I am certain ENVIRON would agree) that contributions estimated with the APCA technique are not exact. However, ENVIRON's August 31, 2003 report utilizing this technique confirmed that Ellis County's contribution is extremely small.

According to ENVIRON, their most recent study utilizes both the APCA technique and the "zero-out" technique to evaluate the contributions from Ellis County. Although the exact value of the alleged contribution from the study is not available to Ellis County or our consultants at this time, as discussed above, any contribution value should be considered to be approximate and inconclusive.

Another misunderstanding of the Ellis County contributions comes from a presentation slide developed by ENVIRON and dated 1/28/2004. This slide shows two plots for the Ellis County 8-hour contributions to the DFW area. Based on these plots, some have publicly stated that Ellis County contributes more than 20 ppb to the DFW ozone problem. This conclusion is incorrect and is not scientifically validated because it ignores the fact that the two plotted values occur at locations that are separated by a distance of 26 miles and may be in an area where ozone concentrations are below the 8-hour standard.

Inaccurate emission inventory

Lastly, the emission inventory in ENVIRON's most recent study is incomplete. The report begins with the emission inventory for 1999, adds certain new sources, but fails to consider emission reductions. Ellis County has been aggressive in its implementation of voluntary emission controls, particularly through our initiation of the inspection and maintenance program for auto emissions, as well as voluntary speed limit reductions. Additionally, the current State Implementation Plan includes stringent requirements relating to the reduction of NOx emissions from cement plants located in Ellis County.

Failure to recognize voluntary emission reductions in Ellis County

Adding new sources to the equation without subtracting the emission reductions or considering the significant impact of voluntary regulation negates the accuracy of ENVIRON's conclusions regarding Ellis County's contribution to the DFW area's ozone problems. Mr. Yarwood noted this anomaly during the March 25 meeting as well, but indicated that some necessary updates to the emission inventory were outside the scope of the current study.

In a regular meeting on April 12, the Commissioners' Court will consider additional voluntary air quality measures, which, if passed, will mean that Ellis County has voluntarily put in place every environmental control mandated for the four counties under non-attainment sanctions. This continued proactive approach to improving air quality, a high priority for both the citizens and the leaders of Ellis County, allows for planned economic growth in tandem with environmental conservation.

Conclusion

Based upon our discussion of March 25, 2004, until the foregoing issues have been adequately addressed, I must remain in disagreement with the conclusions in the ENVIRON study.

At this time, neither the Commissioners' Court nor our consultants have seen ENVIRON's report. The comments contained in this letter are based only on the verbal dialogue in our meeting of March 25, 2004. I feel it is important to reserve the right to make further comments on the report **if** it is publicly released.

Again, I thank you for your dedication to the people of Texas. I look forward to working with you in the future.

Sincerely,

Chad Adams

cc: Congressman Joe Barton

Appendix C

Response to April 2, 2004 Comments from Collin, Dallas, Denton and Tarrant Counties

Background

On April 2, 2004 the County Judges for Collin, Dallas, Denton and Tarrant Counties provided written comments to TERC on HARC project H-27 "Evaluation of the Role of Local and Regional Transport in Ozone Nonattainment for the Dallas - Ft. Worth Area." The following are ENVIRON's responses to three questions raised in April 2, 2004 letter. The original letter follows these responses.

1. What is the range of maximum ozone contributions from Ellis County sources?

The maximum contribution of Ellis County sources to 8-hour ozone using the APCA method was 20.12 ppb (Figure 4-5) whereas the minimum contribution was zero. Therefore the range of Ellis County contributions to 8-hour ozone is zero to 20.9 ppb using APCA. The corresponding range with the zero out method is 0 to 16.3. The ozone impacts of Ellis County sources vary with time and location depending upon meteorological factors such as wind speed and direction and the impacts of other emissions sources. Since the maximum Ellis County impacts may not coincide with the maximum ozone, these two numbers should not be compared as if they are related.

The H-27 report presents two metrics that are calculated specifically for conditions when 8-hour ozone exceeded 85 ppb in the 4 core DFW counties, namely:

- Average ozone contribution (ppb) when total ozone exceeded 85 ppb.
- Percent of time that Ellis County contribution was greater than 2 ppb when total ozone exceeded 85 ppb.

These two measures are more representative than the maximum impact and can be directly compared with the same measures calculated for other counties, regions and states. These results are shown in Tables 4-3 and 4-4.

2. Could these maximum values have a similar impact upon an actual monitor?

We have not analyzed the modeling results to determine maximum impacts at monitor locations. Given the sparsity of the monitoring network, it is unlikely that the maximum impacts referred to in answering the first question coincided with a monitor location. However, the maximum impacts of Ellis County sources were modeled to occur in the vicinity of monitors and so it is possible that under slightly different meteorological conditions of another episode the maximum modeled impacts could coincide with a monitor.

3. Therefore, to reach modeled attainment of the 8-hour standard, would we have to take measures to reduce these high ozone values in order to reach attainment?

Control strategies were not considered in the H-27 report. However, the H-27 report does provide information on what sources contribute to ozone nonattainment in the DFW area through ozone transport. Control strategy modeling is needed to determine which feasible control strategies are the most effective, and most cost-effective for attaining the 8-hour ozone standard in the DFW area.

April 2, 2004

Mr. R. Bruce Laboon
Locke Lidd & Sapp LLP
Texas Environmental Research Consortium
3400 Chase Tower
600 Travis Street
Houston, TX 77002-3095

Re: Clarifications of data contained in the Draft DFW Ozone Transport Report (H-27)

Dear Bruce:

Thank you for the opportunity to ask a few clarifying questions regarding the data presented in the draft final report of H-27. We are impressed with the completeness and diligence with which this report was prepared. When the report is finalized next week, we have no doubt that the report will represent the best evaluation of the impacts of NOx sources in the DFW airshed that has been prepared to date. The report also underlines the need for future research projects by the Texas Environmental Research Consortium ("TERC"), especially with regard to interstate impacts.

As elected officials we also face the daunting task of explaining the results of this project to our constituents. As a result, we would appreciate if ENVIRON could help us understand a few issues regarding the range and contribution of Ellis Co. point sources to high ozone events in the DFW non-attainment area.

I. The draft report contains the following analysis:

1. Figure 4-3 of the draft report is entitled "Episode maximum 8-hour average ozone and Ellis Co. source contribution to 8-hour ozone for 15-22 August, 1999." This figure documents a maximum Ellis Co. impact of 13.620 ppb on a maximum high ozone value of 125.366ppb for August 15 -22, 1999.

2. Similarly, figure 4-4 examines Ellis County contributions on August 22, 1999. As indicated on page 4-9 of the report, this figure documents a maximum source contribution of 8.4ppb, and documents "...contributions on the order of 3 ppb extend into the region of high total ozone in northern Tarrant and southern Wise Co."

3. A previous power point presentation that preceded the draft final report contained an analysis of maximum Ellis Co. source contributions for August 18, 1999 at 13:00, which documents a maximum Ellis Co. contribution of 20.887ppb on a maximum value of 125.481ppb.

Based upon these facts, what is the range of maximum ozone contributions from Ellis Co. sources, e.g., 8.4ppb to 20.887ppb?

II. We understand the difficulty in translating the maximum modeled value referred to in the previous question to the impact at an actual monitor on the ground. However, do we understand that these maximum values may have a similar impact upon an actual monitor? Therefore, to reach modeled attainment of the 8-hour standard, would we have to take measures to reduce these high ozone values in order to reach attainment?

Thank you for your attention to these questions.

Sincerely,

Ron Harris **Collin County** **Judge**	**Margaret Keliher** **Dallas County** **Judge**	**Mary Horn** **Denton County** **Judge**	**Tom Vandergriff** **Tarrant County** **Judge**

cc: John Hall