ALPINE GEOPHYSICS REGIONAL AIR QUALITY COUNCIL ENVIRON

EXECUTIVE SUMMARY

Due to violations of the 0.08 parts per million (ppm) 8-hour ozone National Ambient Air Quality Standard (NAAQS) based on 2005-2007 air quality data, in November 2007 the Denver Metropolitan Area (DMA) reverted to an 8-hour ozone nonattainment area. This requires the DMA to develop an 8-hour ozone State Implementation Plan (SIP) that demonstrates the area will achieve the 0.08 ppm 8-hour ozone NAAQS by 2010. The Denver Regional Air Quality Council (RAQC), in consultation with the Colorado Department of Health and Environment (CDPHE) Air Pollution Control Division (APCD), contracted with ENVIRON International Corporation and their subcontractor Alpine Geophysics, LLC to develop the photochemical modeling databases necessary to demonstrate that the DMA will achieve the 0.08 ppm 8-hour ozone NAAQS by 2010.

OVERVIEW OF APPROACH

The Comprehensive Air-quality Model with extensions (CAMx; www.camx.com) was set up for a June-July 2006 episode on a 36/12/4 km grid with the 4 km domain focused on Colorado. Meteorological inputs were prepared using the MM5 meteorological model whose results and evaluation are discussed by McNally and co-workers (2008). An initial emissions inventory was prepared using the SMOKE emissions modeling system and a preliminary 2006 base case was performed. A preliminary model performance evaluation was conducted and diagnostic sensitivity tests performed to identify an optimal model configuration for simulating ozone formation in the DMA (Morris et al., 2008b). A revised final CAMx 2006 base case (Run 17) simulation was performed and a comprehensive model performance evaluation was conducted (Morris et al., 2008c). Although there were some model performance issues on some of the modeling days during the June-July 2006 episode, usually due to an ozone underestimation bias, on a vast majority of the modeling days the ozone model performance achieved EPA's model performance goals that along with the other model performance metrics indicated that the model was simulating the observed ozone sufficiently well for use in making ozone projections. Furthermore, on most days the model reproduced the observed VOC/NOx ratios in Denver quite well suggesting that the model is simulating the same chemical regimes as observed as well.

2010 BASE CASE OZONE PROJECTIONS

The procedures given in EPA's 8-hour ozone modeling guidance were used to project current year 8-hour ozone Design Values (DVC) to obtain projected future year 2010 8-hour ozone Design Values (DVF) at each of the DMA monitoring sites (EPA, 2007). These procedures use the 2006 and 2010 base case modeling results in a relative fashion whereby modeled relative response factors (RRFs) are used to scale the current year 8-hour ozone Design Value (DVC) to obtain the projected future year 8-hour ozone Design Value (DVF):

$$DVF = DVC \times RRF$$

For the Denver 2010 ozone projections, with one exception, the DVCs were based on the 8-hour ozone Design Values from the 2005-2007 period (i.e., the three year average of the fourth highest daily maximum 8-hour ozone concentration at each monitor). The exception to this was for the Fort Collins West (FTCW) monitor that started monitoring in 2006 so that the two year average of the fourth highest daily maximum 8-hour ozone concentrations was used from 2006-2007 for FTCW.

Table ES-1 summarizes the projected 8-hour ozone Design Values (DVF) at the DMA monitoring sites for the 2010 base case simulation using the CAMx 2006 and 2010 base case modeling results and EPA recommended default ozone projection procedures described above. The maximum projected 8-hour ozone Design Value is 84 ppb and occurs at both the Rocky Flats North (RFNO) and Fort Collins West (FCTW) monitoring sites (see column 5 in Table ES-1). As this value is 84 ppb or lower, then the 2010 base case modeling results pass the modeled attainment demonstration test. However, because the maximum projected 8-hour ozone Design Values lie between 82 and 87 ppb, then a WOE analysis is required. Although the EPA 8-hour ozone projection procedure is to truncate the final projected DVF for comparisons with the NAAQS, in column 6 of Table ES-1 we present the DVFs to the nearest tenth of a ppb before truncation. In this case we see that the projected 2010 base case DVFs at RFNO and FTCW are both 84.9 ppb.

Also shown in Table ES-1 are the RRFs and the cut-off thresholds used in selecting days and number of days used in calculating the RRF. The EPA desire to use at least 10 modeled days is satisfied using the Denver June-July 2006 modeling period. In order to achieve that many modeled days, the cut-off threshold had to be reduced from 74 ppb to 78 ppb depending on the monitor, with the RFNO and FTCW monitors using a 78 and 76 ppb thresholds, respectively.

The level of ozone reductions in the projected Design Values appears to be greater the further away from central Denver the monitor resides. In fact, ozone is estimated to increase very slightly at the monitors in or immediately downwind of the urban core. This is due to the reductions in on-road mobile sources NOx emissions that increase ozone in the urban core. The ozone increases are due to less ozone titration due to reduction in the primary emitted NOx emissions and/or less inhibition effect that high NOx concentrations have on ozone formation. As one moves away from the Denver urban core, the ozone increases between 2006 and 2010 turn into no change and then to ozone decreases. The distance from the Denver urban core when the ozone increases change to ozone decreases varies by day due to changes in emissions (e.g., weekday versus weekend day) and changes in meteorology. The RFNO monitor lies near the modeled ozone increase-to-decrease cross over distance, which explains why the model projected 2010 Design Value is relative insensitive to the changes in emissions from 2006 to 2010 at this site (85.0 to 84.9 ppb, a 0.1 ppb reduction); of the 10 days used to construct the RRF for RFNO there are some days of ozone increases and some with ozone decreases. At the FTCW monitoring site, on the other hand, the model is more responsive (1.1 ppb ozone reduction) as it is an area where the modeled ozone changes either stay the same or are reduced between 2006 and 2010.

Figure ES-1 display the results of EPA's unmonitored area analysis for the 2010 base case. DVCs in excess of 80 ppb are estimated to the south, west and northwest of Denver stretching to Fort Collins and then west of Fort Collins (Figure ES-1, left). In fact, the unmonitored area procedure estimates that there are current-year DVCs in excess of the 85 ppb NAAQS occurring in 12 grid cells to the west of the Fort Collins monitoring sites. The projected DVFs for the 2010 base case (Figure ES-1, right) have greatly reduced the spatial extent of the DVFs in excess of 80 ppb occurring to the south, west and northwest of Denver and the 12 cells with DVCs exceeding the 85 ppb NAAQS have been reduced by half to 6 grid cells in the 2010 base case emissions scenario. EPA stresses that the unmonitored area analysis is much more uncertain than the modeled attainment test at the monitors. And whereas additional emissions controls would likely be needed to eliminate continued violations at the monitor, such actions may not be appropriate for the unmonitored area analysis.

Table ES-1. Current-year (DVC) and projected future-year (DVF) 8-hour ozone Design Values using the CAMx 2006 and 2010 base case modeling results.

			2005-07	2010 Base Case				
Site ID	**Monitor Name**	**County**	**DVC**	**DVF**	**DVF**	**RRF**	**Cutoff**	**#days**
80013001	Welby	Adams	70.0	70	70.2	1.0042	77.0	11
80050002	Highland	Arapahoe	78.0	77	77.3	0.9916	78.0	14
80130011	S. Boulder Creek	Boulder	81.0	80	80.8	0.9976	78.0	10
80310002	Denver - CAMP	Denver	56.0	56	56.0	1.0017	78.0	10
80310014	Carriage	Denver	74.0	74	74.1	1.0022	78.0	10
80350004	Chatfield State Park	Douglas	84.0	83	83.4	0.9934	78.0	11
80410013	USAF Academy	El Paso	73.0	72	72.0	0.9873	75.0	10
80410016	Manitou Springs	El Paso	74.0	73	73.7	0.9966	74.0	10
80590002	Arvada	Jefferson	79.0	79	79.2	1.0026	78.0	10
80590005	Welch	Jefferson	75.0	75	75.0	1.0004	78.0	10
80590006	Rocky Flats North	Jefferson	85.0	84	84.9	0.9994	78.0	10
80590011	NREL	Jefferson	82.0	82	82.3	1.0039	78.0	11
80690011	Fort Collins - West	Larimer	86.0	84	84.9	0.9874	76.0	10
80691004	Fort Collins	Larimer	74.0	73	73.0	0.9878	76.0	12
81230009	Greeley - Weld Tower	Weld	78.0	77	77.7	0.9964	75.0	10
GTH161	Gunnison	Gunnison	68.0	67	67.8	0.9984	74.0	10
ROM206	Larimer	Larimer	76.0	75	75.2	0.9903	77.0	10
ROM406	Larimer	Larimer	76.0	75	75.2	0.9903	77.0	10

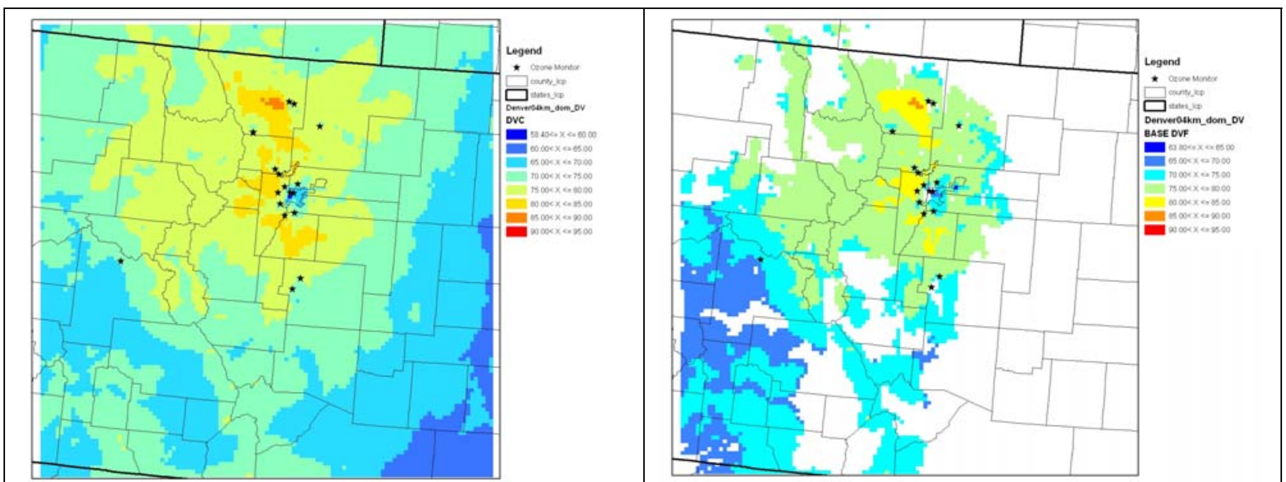

Figure ES-1. Current-year interpolated 8-hour ozone Design Values (DVC; left) and projected future-year 8-hour ozone Design Values (DVF; right) for the 2010 base case simulation.

2010 SENSITIVITY TEST RESULTS

Sixteen (16) 2010 emissions reductions sensitivity tests were conducted with the CAMx modeling system. Most of these emission reduction sensitivity tests reduced VOC and/or NOx emissions from a specific source category either just within the Denver nonattainment area (NAA) or within the entire state of Colorado. Ozone projections were made at each of the monitoring sites for each of the 2010 sensitivity tests. We also performed the unmonitored area analysis for each sensitivity test to better understand the spatial extent of any ozone benefits or adverse effects. All sensitivity tests modified emissions from the 2010 base case emissions scenario.

Table ES-2 displays the results of the 2010 sensitivity tests in terms of VOC, NOx and CO emission reductions from the 2010 base case, changes in projected 8-hour ozone Design Values at the key RFNO and FTCW monitoring sites, maximum difference in 2010 8-hour ozone Design Values anywhere in the DMA and maximum difference in daily maximum 8-hour ozone concentrations anywhere in the DMA and on any of the modeling days.

Mobile Source Emissions: The first three sensitivity tests examined the sensitivity of 2010 ozone projections to on-road mobile source emissions. Reducing on-road mobile sources VOC emissions 20% in the DMA reduces the projected DVFs at RFNO and FTCW by 0.2 and 0.1 ppb, respectively. The 7 psi RVP gasoline in on-road mobile source gasoline vehicles reduces the DVFs by 0.1 ppb at both monitors. And the zero percent ethanol penetration scenario in the on-road and non-road mobile source gasoline engines increases the DVF at RFNO by 0.1 ppb, and has no effect at FTCW.

Oil and Gas VOC Emissions: VOC emissions from O&G sources in the NAA were reduced by 20% (b1-sens04) and 40% (b1-sens04d) in two of the 2010 emissions sensitivity tests. The O&G VOC emission reductions had little effect at the RFNO monitor, but reduced the projected DVF at the FTCW monitor by 0.1 and 0.2 ppb, respectively. The spatial maps of differences in the DVFs show a large area of ozone benefits due to the O&G VOC reductions centered on the O&G production area in Weld County. The RFNO monitor is right at the edge of this benefits area. Note that the Denver EAC SIP modeling of the June-July 2002 episode saw more transport from the Weld County O&G production area down to the RFNO monitor, so these results are partly an artifact of the meteorological conditions of the June-July 2006 modeling period. The O&G VOC emissions clearly have an effect on ozone formation in the Fort Collins area. In fact, the 6 grid cells west of Fort Collins that are projected to still violate the 0.08 ppm 8-hour ozone NAAQS in the 2010 base case (Figure ES-1, right) are reduced to 4 and 3 grid cells in the 20% and 40% O&G VOC emission reduction sensitivity scenarios. Clearly VOC emission reductions from O&G sources in Weld County would benefit ozone attainment in the Fort Collins area and likely elsewhere in the Denver NAA under other meteorological conditions.

Combined VOC & NOx Sensitivity Simulations: Sensitivity simulations b1-sens04b and b1-sens04c looked at combined VOC and NOx emissions reductions from area, non-road point and O&G emissions in the NAA. Although both simulations reduced VOC emissions by 20%, NOx emissions were reduced by 20% in sens04b and by 30% in sens04c allowing us to isolate the effects of the NOx controls. Several of the other sensitivity tests also allow us to isolate the effects of the VOC and NOx controls in these two sensitivity tests for each source category. The b1-sens04b 20% VOC/NOx emissions reduction scenario reduces the DVF at RFNO by 0.5 ppb. This is due to reductions in the RFNO ozone DVF of approximately 0.1 ppb from area source

VOC (b1-sens07), 0.1 ppb from O&G VOC (b1-sens04), 0.2 ppb from non-road VOC (b1-sens06) and 0.2 ppb from point and O&G source NOx (b1-sens05). An additional 0.2 ppb ozone reduction in the RFNO DVF is obtained when the NOx reduction is increased from 20% to 30%. At the FTCW monitor, the effects of the NOx emission reductions alone are even greater. The 20% VOC/NOx reduction gives a 1.1 ppb reduction in the ozone DVF at the FTCW monitor; increasing the NOx reduction by another 10% increases the ozone reduction at the FTCW monitor by another 0.5 ppb (total 1.6 ppb reduction). This suggests that a majority of the ozone benefits at FTCW are due to the NOx emission reductions. Although as noted above, VOC emission reductions from O&G sources in the NAA are also beneficial for reducing ozone in the Forth Collins area. With the exception of a couple grid cells of isolated ozone increases, the effects of the combined VOC/NOx controls are wide-spread reductions in ozone throughout the DMA.

State-Wide Sensitivity: The state-wide sensitivity tests produce nearly the same ozone benefits at DMA monitors as the controls in the NAA alone. This is seen most clearly by comparing b1-sens05 with b1-sens08 that examine a 20% reduction in NOx emissions from point and O&G sources in, respectively, the NAA and Colorado. They produce the same ozone reduction at RFNO (0.2 ppb) and the state-wide reduction produces slightly more ozone reduction at FTCW (0.6 ppb) than the NAA controls alone (0.5 ppb). At this time we have only evaluated the effects of the state-wide emission reduction sensitivity tests within the DMA. There are likely more ozone benefits due to the Colorado state-wide emission reductions outside of the DMA that may be important given the new lower (March 2008) ozone NAAQS.

Bark Beetle Sensitivity: The effects of accounting for the Bark Beetle infestation on biogenic emissions have small effects on the DVFs in the DMA (0.1 ppb reduction). Thus, the 2010 Denver ozone projections are not affected by the Bark Beetle infestation.

The 2010 emissions sensitivity tests show higher ozone sensitivity to reducing NOx emissions than reducing VOC emissions. Although there are small areas of ozone increases due to NOx emissions reductions in the Denver urban core, and at the locations (grid cells) of some point sources, the overall ozone reduction benefits of the NOx controls outweigh the ozone increases. Furthermore, the locations of the highest ozone increases due to NOx reductions are monitoring sites with low ozone concentrations. Although the ozone benefits of VOC reductions do not seem as great as those from NOx reductions, VOC emissions reductions do reduce ozone somewhat and do not exhibit any ozone increases as seen with the NOx emissions reductions. In particular, the VOC emissions reductions from O&G sources have ozone benefits in the Fort Collins area and particular the key FTCW ozone monitor.

Table ES-2. Results of the Denver 2010 emission sensitivity tests.

Test	Description	Emissions (TPD)			% Anthro (%)			DV Ozone (PPB)		Grid DV Ozone(ppb)*		Grid Diff. Ozone (ppb)**	
		CO	VOC	NOx	CO	VOC	NOx	RFNO	FTCW	Max.	Min.	Max.	Min.
2006.a3	Current Year 8-Hour Ozone Design Value							85	86				
b1	2010 Base Case	-386.0	-42.2	-50.1	-10.2%	-5.3%	-5.6%	84.9	84.9				
b1-sns01	20% VOC On-Road NAA	0.0	-22.8	0.0	0.0%	-3.0%	0.0%	-0.2	-0.1	0.1	-0.2	0.1	-0.6
b1-sns02	Evap VOC On-Road in NAA (7 psi RVP)	-46.9	-9.8	-0.3	-1.4%	-1.3%	0.0%	-0.1	-0.1	0.1	-0.1	-0.2	-0.3
b1-sns03	0% Ethanol in NAA	323.3	-3.8	-2.0	9.5%	-0.5%	-0.2%	0.1	0.0	0.4	0.0	1.3	-0.2
b1-sns04	20% VOC O&G in NAA	0.0	-48.2	0.0	0.0%	-6.4%	0.0%	0.0	-0.1	0.0	-0.4	0.0	-0.8
b1-sns04b	20% VOC & NOx Ar, Pnt, Non-Rd and O&G in NAA	0.0	-72.5	-41.3	0.0%	-9.6%	-4.9%	-0.5	-1.1	1.8	-1.4	3.2	-3.3
b1-sns04c	20% VOC & 30% NOx Ar, Pnt, Non-Rd, O&G in NAA	0.0	-72.5	-62.0	0.0%	-9.6%	-7.4%	-0.7	-1.6	2.8	-2.0	5.1	-4.7
b1-sns04d	40% VOC O&G in NAA	0.0	-96.3	0.0	0.0%	-12.7%	0.0%	-0.1	-0.2	0.1	-0.7	0.1	-1.7
b1-sns05	20% NOx Pnt & O&G NAA	0.0	0.0	-20.6	0.0%	0.0%	-2.5%	-0.2	-0.5	0.3	-0.8	1.7	-2.0
b1-sns06	20% VOC Non-Rd in NAA	0.0	-12.7	0.0	0.0%	-1.7%	0.0%	-0.2	-0.1	0.0	-0.2	0.0	-0.8
b1-sns07	20% VOC Area in NAA	0.0	-7.5	0.0	0.0%	-1.0%	0.0%	-0.1	-0.1	0.0	-0.1	0.0	-0.2
b1-sns08	20% NOx Pnt & O&G CO	0.0	0.0	-78.0	0.0%	0.0%	-9.3%	-0.2	-0.6	1.1	-1.0	2.2	-2.2
b1-sns09	20% VOC O&G in CO	0.0	-67.2	0.0	0.0%	-8.9%	0.0%	0.0	-0.1	0.1	-0.3	0.1	-0.8
b1-sns10	20% VOC & NOx Point & O&G in CO	0.0	-77.5	-78.0	0.0%	-10.2%	-9.3%	-0.3	-0.6	0.9	-1.2	2.1	-2.7
b1-sns11	20% NOx Point & O&G in NAA + 20% NOx Pawnee	0.0	0.0	-23.0	0.0%	0.0%	-2.7%	-0.2	-0.5	0.3	-0.8	1.7	-2.0
b1-sns12a	Effects of increase in Bark Beetle 2006 to 2010	-8.4	-87.8	-0.3	-0.2%	-11.6%	0.0%	0.0	-0.1	0.1	-0.1	0.1	-0.1
b1-sns12b	Effects of 2010 Bark Beetle infestation	-21.1	-233.5	-0.8	-0.6%	-30.8%	-0.1%	-0.1	-0.1	0.1	-0.1	0.3	-0.3

2010 OZONE SOURCE APPORTIONMENT MODELING

The Anthropogenic Precursor Culpability Assessment (APCA) version of the CAMx ozone source apportionment was applied using the 2010 base case inventory with the emissions segregated into 8 source categories and 11 source regions. The source categories are presented in Table ES-3 and the geographic source regions are given in Table ES-4. Ozone source apportionment is obtained for each source group, which consist of a source region and source category (e.g., on-road mobile sources from the 7-County Denver Metro area). As the contributions of ozone from initial concentrations (IC) and boundary conditions (BC) are always obtained, this results in ozone source apportionment to 90 separate source groups in the Denver ozone source apportionment modeling (90 = 8 x 11 + 2).

The CAMx ozone source apportionment uses reactive tracers that operate in parallel to the host model. For each source group, there are four tracers corresponding to the source group's VOC and NOx concentrations (V_i and N_i) and ozone formed that is attributable to the source groups VOC concentrations ($O3V_i$) or NOx concentrations ($O3N_i$). In the original Ozone Source Apportionment Technology (OSAT) ozone source apportionment approach implemented in CAMx, when ozone is formed in a grid cell it is attributable to a source group based on the relative contributions of the source groups VOC or NOx concentration to the total VOC or NOx concentration in that grid cell based on a determination of whether the ozone formed was under VOC-limited or NOx-limited conditions. Thus, in OSAT the O3V and O3N reactive tracers indicate how much of the ozone is formed under VOC-limited versus NOx-limited conditions. This results in OSAT assigning ozone to biogenic VOCs, which is not necessarily control strategy relevant information as they are uncontrollable. The APCA version of source apportionment only assigns ozone formed to biogenic (uncontrollable) sources when it is due to the interaction of biogenic VOC with biogenic NOx. When ozone is formed under VOC-limited conditions due to the interaction of biogenic VOC with anthropogenic NOx, a case where OSAT would assign it to the biogenic VOC (O3V) source group, APCA redirects the assignment to the anthropogenic NOx (O3N) source group. Thus, with APCA the O3V and O3N tracers no longer represent ozone formed under VOC-limited and NOx-limited conditions.

The source apportionment results were analyzed at each of the ozone monitor sites in the DMA. At each monitor location, for each day, the 8-hour average ozone results for each period over 70 ppb were averaged to develop a composite contribution.

Example displays for a high ozone day (July 29th) at the Rocky Flats North monitor are presented in Figure ES-2. APCA ozone source apportionment modeling results for other days and other monitors are presented in Appendix C. The results show significant day-to-day and monitor-to-monitor variations. Figure ES-2a presents the ozone results including the boundary conditions, that is, the contribution from sources outside the 12 km domain. Of the 76.1 ppb of ozone estimated at the monitor, ~48 ppb (two-thirds) was transported into the 12 km domain and ~18 ppb (one-third) was attributed to sources in the seven-county Denver Metro area. Figure ES-2b presents the same results as ES-2a, but without the boundary conditions plotted and the vertical scale expanded to better resolve the source region contributions. This figure shows that of the ~18 ppb from Metropolitan Denver sources, ~10 ppb was from motor vehicles, ~5 ppb was from non-road mobile sources with the balance from other sources. Figure ES-2c presents the ozone formed that is attributable to anthropogenic NOx concentrations, whereas Figure ES-2d presents the ozone formed attributable to anthropogenic and biogenic VOC concentrations. These two figures suggest that emission reductions from anthropogenic NOx sources will be more effective at reducing ozone in the model than reductions from anthropogenic VOC sources, although both VOC and NOx controls will reduce ozone. The Fort Collins West monitor shows similar contributions as the Rocky Flats North monitor except the highest contributions are from sources in the Larimer/Weld County source region and oil and gas sources from Larimer/Weld county have a large contribution.

The source apportionment results vary by day and by location. However, several overall trends emerge, namely:

- Regional ozone transport into the 12 km domain is the largest contributor, often accounting for more than two-thirds of the total ozone;

- At the Denver Metropolitan monitors the largest contributors are Denver Metropolitan metro area motor vehicle and non-road sources;

- At the Fort Collins and Greeley monitors, the largest contributors tend to be Larimer and Weld County motor vehicles, non-road sources and oil and gas sources, and Denver Metropolitan sources;

- The majority of the ozone formed is attributable to anthropogenic NOx emissions.

In interpreting these results it is important to keep in mind that these source apportionment results are based on the Denver SIP 2006 modeling episode and are meteorologically dependent. For instance, the source apportionment modeling in support of the Denver Early Action Compact using a 2002 ozone episode showed more impact of sources in Northern Colorado into the Denver Metropolitan area.

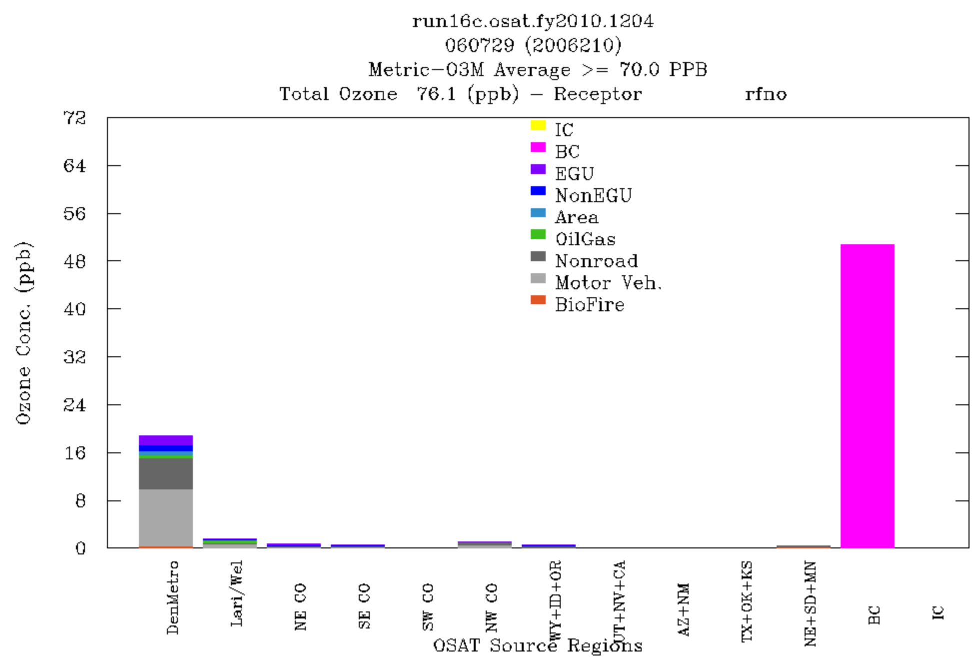

Figure ES-2a. Rocky Flats North source apportionment for 29 July including boundary conditions.

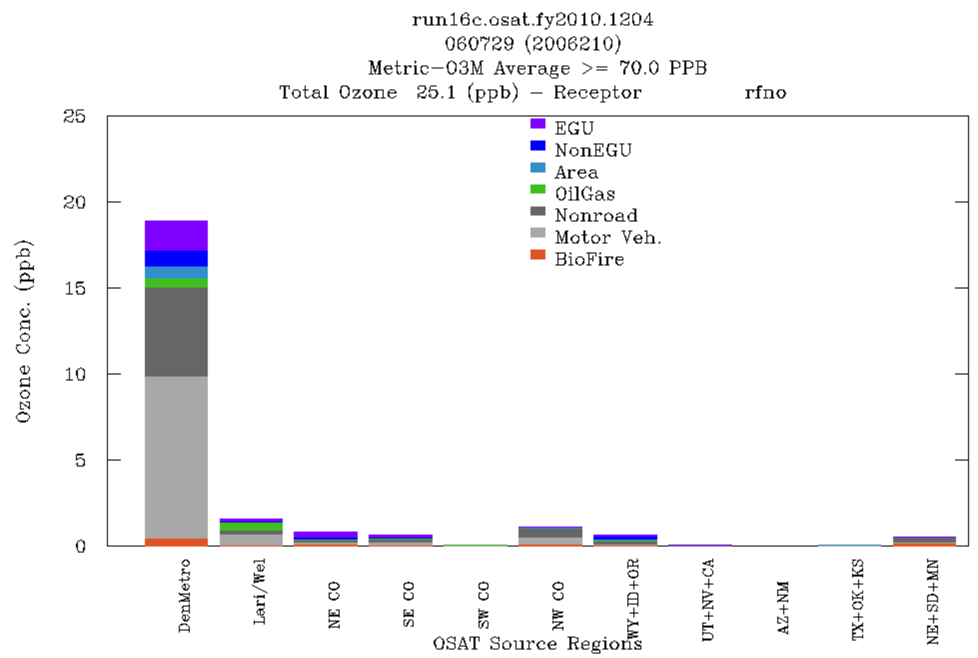

Figure ES-2b. Rocky Flats North source apportionment for 29 July excluding boundary conditions.

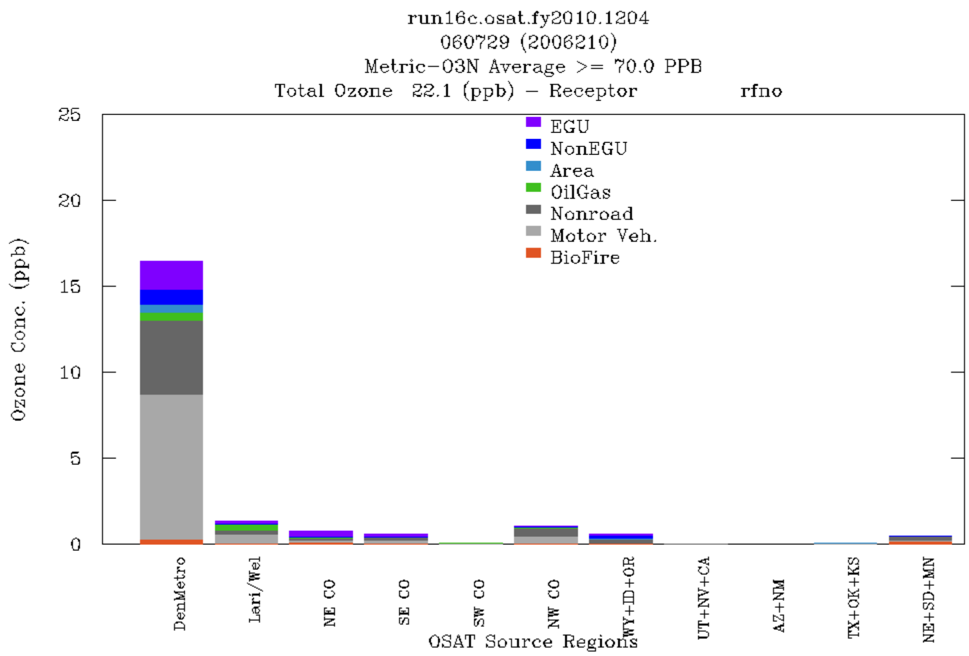

Figure ES-2c. Rocky Flats North source apportionment for 29 July attributable to anthropogenic NOx emissions.

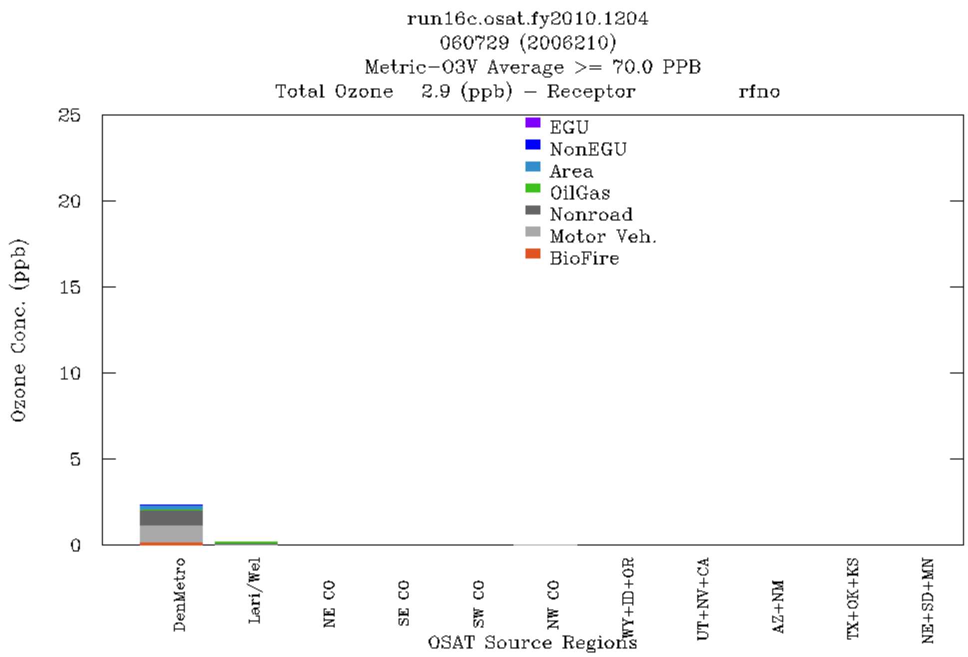

Figure ES-2d. Rocky Flats North source apportionment for 29 July attributable to anthropogenic and biogenic VOC emissions.

CONCLUSIONS OF 2010 OZONE PROJECTIONS AND EMISSIONS SENSITIVITY TESTS

The 2010 emissions reduction sensitivity tests and 2010 ozone source apportionment modeling provide consistent results. The source apportionment modeling estimates that when daily maximum 8-hour ozone concentrations are greater than 70 ppb then approximately two-thirds of the ozone in the DMA is coming from outside of the Denver 12 km modeling domain (roughly outside of Colorado and adjacent states). Most of the remainder one-third of the ozone comes from sources within the Denver 9-county NAA. For the Rocky Flats North monitoring site on July 29, 2006, the 2010 ozone source apportionment results suggest that half of the locally generated ozone comes from on-road mobile sources, with ~1/4 from non-road mobile source, 1/8 from EGU point sources and the remainder 1/8 from area, non-EGU and oil and gas (O&G) sources from the 7-County Denver area. For the Forth Collins West monitoring sites a similar breakdown in source categories is seen only sources from Larimer/Weld Counties contribute more than sources from the 7-County DMA and O&G emissions from Larimer/Weld Counties are major contributors as well.

The APCA ozone source apportionment attributes most of the ozone formed to anthropogenic NOx emissions rather than anthropogenic and biogenic VOC emissions. This suggests that anthropogenic NOx control may be a viable path toward reducing ozone concentrations. The 2010 sensitivity modeling also suggests that NOx emissions reductions are effective at reducing ozone concentrations. However, the 2010 emissions sensitivity tests also saw areas where the NOx emission reductions resulted in ozone increases. These areas include isolated grid cells at the locations of some point sources and within the Denver urban core. The extent of the ozone increases due to the NOx controls in the Denver urban core varied day-to-day due to changes in emissions (e.g., weekday versus weekend day) and meteorology. However, the overall benefits for reducing ozone from the NOx controls out weigh the adverse effects of the ozone increases, although care should be taken in the level and types of NOx emissions controlled to limit the adverse effects. Although the VOC emission reductions do not produce as large ozone reduction as the NOx controls at some key sites (e.g., Fort Collins West), they always reduce ozone or have no effect and no adverse effects of VOC emissions reductions are seen.

Thus, an ozone reduction path using either NOx and/or VOC emission reductions appear to be a viable paths in the Denver area. The VOC emission reductions always reduce ozone or have no or very little effect. Although the ozone reductions due to the NOx controls are larger and more widespread, there are also local ozone increases due to the NOx controls that need to be considered.