Review of Historical Volatile Organic Compound Data Gathered from Studies Performed in 1996, 2003, and 2006 In the Colorado Front Range

COLORADO

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November 4, 2015

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1.0 Introduction

1.1 *Background Information*

Ozone (O_3) is an air pollutant of increasing concern in the State of Colorado, particularly due to the decreasing level of the National Ambient Air Quality Standard (NAAQS). Ozone in the troposphere is primarily a secondary formation pollutant, with precursor compounds including oxides of nitrogen (NOx) and hydrocarbons. Along with motor vehicles, a large portion of the precursor compounds in the Colorado North Front Range area has been attributed to the oil and gas development/production sector.

In order to better protect the health and safety of the citizens of Colorado, and to obtain a more accurate picture of air quality as it relates to ozone precursors, the Colorado Department of Public Health and Environment (CDPHE) performed several short term studies to determine ambient air concentrations of volatile organic compounds (VOCs) in the Denver/North Front Range area of Colorado. Three separate studies were performed over the course of ten years. The studies were designed to build on each other, as well as other VOC/non-methane organic compound (NMOC) /carbonyl studies that CDPHE conducted prior to 1996. Additional NMOC/carbonyl data is necessary to capture the emissions mix that could be used for future ozone modeling efforts, and to serve as a general qualitative check of the emission inventory that has been used for previous ozone modeling projects. The first study took place from July 10 through September 18, 1996, and sampled at three locations. The second study took place from August 8 to September 10, 2003, and sampled at five different locations, two of which were sampled at in the 1996 study. The third study took place between June 16, 2006 and August 3, 2006, at six different sites, four of which were sampled at during the previous 1996 or 2003 studies.

The two primary sites used in all three studies were the Denver – CAMP (CAMP) site, and the Denver – Welby (Welby) site. Several other locations were monitored during the course of the three studies to determine the extent of the oil/natural gas processing contributions to the air toxics inventory, as well the urban contribution to the local background concentrations. Further information regarding the sampling sites is presented in the next section.

1.2 *Site Information*

1.2.1. 1996 Monitoring Locations

Three locations were used for monitoring during the 1996 study. Their names, addresses, and the sampling dates are listed in Table 1. The CAMP and Welby sites took samples on an every second day basis, for a total of 33 and 35 sample dates, respectively, while the Rocky Flats site took samples on an every sixth day basis, for a total of 12 sample dates. The approximate site locations are shown in Figure 1. The primary sampling sites are indicated with a red star, while the secondary site is indicated with a blue star.

Table 1. 1996 Sample Site Names and Addresses

Site Name	Site Address	Sampling Time Period	# Sample Days
Denver - CAMP	2105 Broadway, Denver	10 Jul 1996 – 18 Sep 1996	33
Denver – Welby	78th Ave. & Steele St., Commerce City	10 Jul 1996 – 18 Sep 1996	35
Rocky Flats – North	16600 W. Hwy. 128, Broomfield	14 Jul 1996 – 18 Sep 1996	12

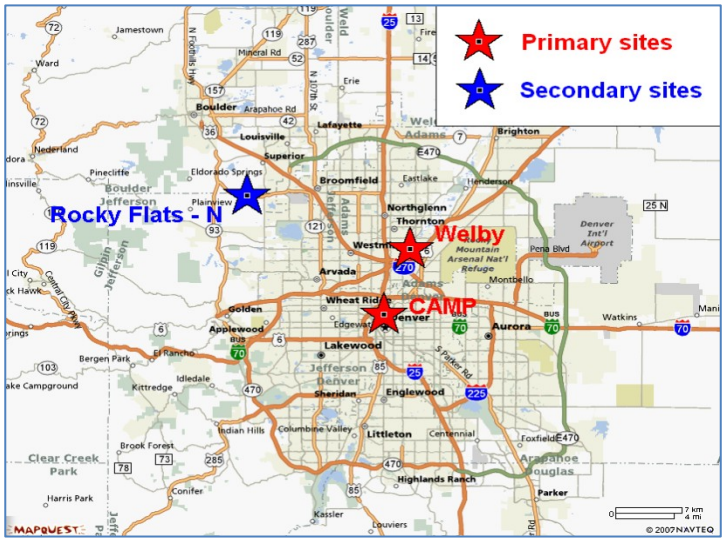

Figure 1. 1996 Monitoring Locations

1.2.2. 2003 Monitoring Locations

Five different locations were used for monitoring during the 2003 study. Their names, addresses, and the sampling dates are listed in Table 2. Sampling was performed on twelve days in August and September 2003, with samples being taken in the morning and afternoon. Some samples were either voided by the lab, or missed all together, meaning the sites had less than 24 or eight samples collected. Two sites were used for all twelve days: CAMP at 21st Street and Broadway in downtown Denver, and Welby at 78th Avenue and Steele Street, to the northeast. In addition, a third sampler moved around to three other sites, collecting four sample days at each. These sites were NREL (near Golden), Platteville (just south of Greeley), and Chatfield Reservoir (to the southwest). The approximate site locations are shown in Figure 2. The primary sampling sites are indicated with a red star, while the secondary sampling sites are indicated with a blue star.

Table 2. 2003 Sample Site Names and Addresses

Site Name	Site Address	Sampling Time Period	# Sample Days
Denver - CAMP	2105 Broadway, Denver	8 Aug 2003 – 9 Sep 2003	12
Denver – Welby	78th Ave. & Steele St., Commerce City	8 Aug 2003 – 9 Sep 2003	12
NREL	2054 Quaker St., Golden	8 Aug 2003 – 16 Aug 2003	4
Platteville	1004 Main St., Platteville	20 Aug 2003 – 28 Aug 2003	4
Chatfield Reservoir	11500 N. Roxborough Rd., Littleton	1 Sep 2003 – 9 Sep 2003	4

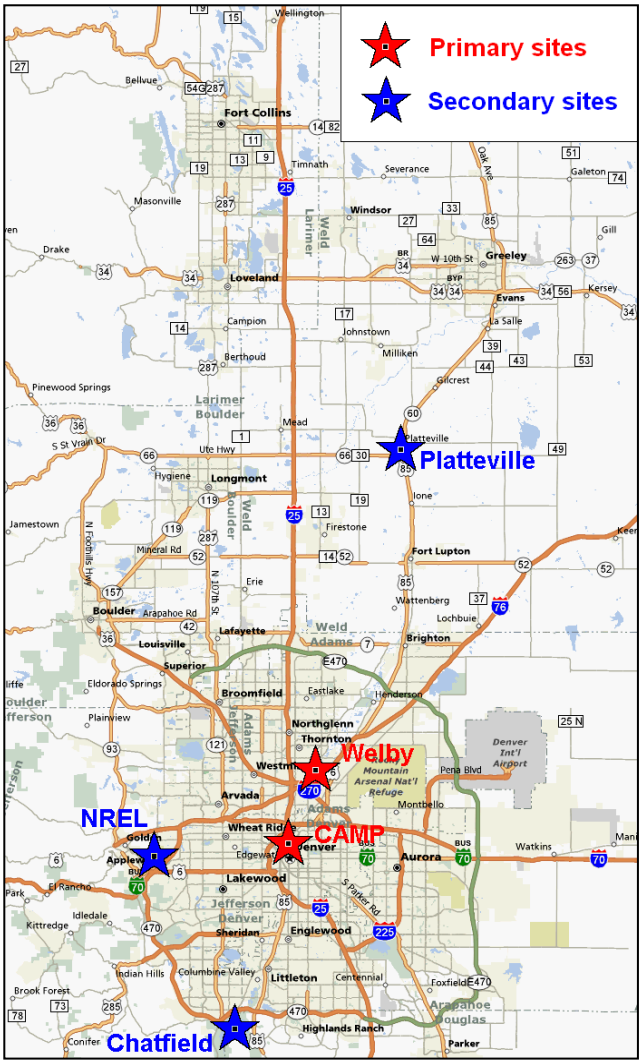

Figure 2. 2003 Monitoring Locations

1.2.3. 2006 Monitoring Locations

Six different locations were used for monitoring during the 2006 study. Their names, addresses, and the sampling dates are listed in Table 3. The CAMP, Welby, Fort Lupton, and Platteville sites were all primary sampling sites (indicated by a red star), and all collected samples on at least 15 days each, using a one in three day sample schedule. The Rocky Flats, and Fort Collins sites were secondary sampling sites (indicated by a blue star), and sampled for three days each, using the same one in three day schedule. The approximate locations of the sampling sites are shown in Figure 3.

Table 3. 2006 Sample Site Names and Addresses

Site Name	Site Address	Sampling Time Period	# Sample Days
Denver - CAMP	2105 Broadway, Denver	16 Jun 2006 – 3 Aug 2006	16
Denver – Welby	78th Ave. & Steele St., Commerce City	16 Jun 2006 – 3 Aug 2006	16
Fort Lupton	Kahil St. & Fulton Ave.	16 Jun 2006 – 3 Aug 2006	17
Platteville	1004 Main St., Platteville	16 Jun 2006 – 3 Aug 2006	15
Rocky Flats – North	16600W. Hwy. 128, Broomfield	28 Jun 2006 – 13 Jul 2006	3
Fort Collins – West	3416 Laporte Ave., Fort Collins	19 Jul 2006 – 28 Jul 2006	3

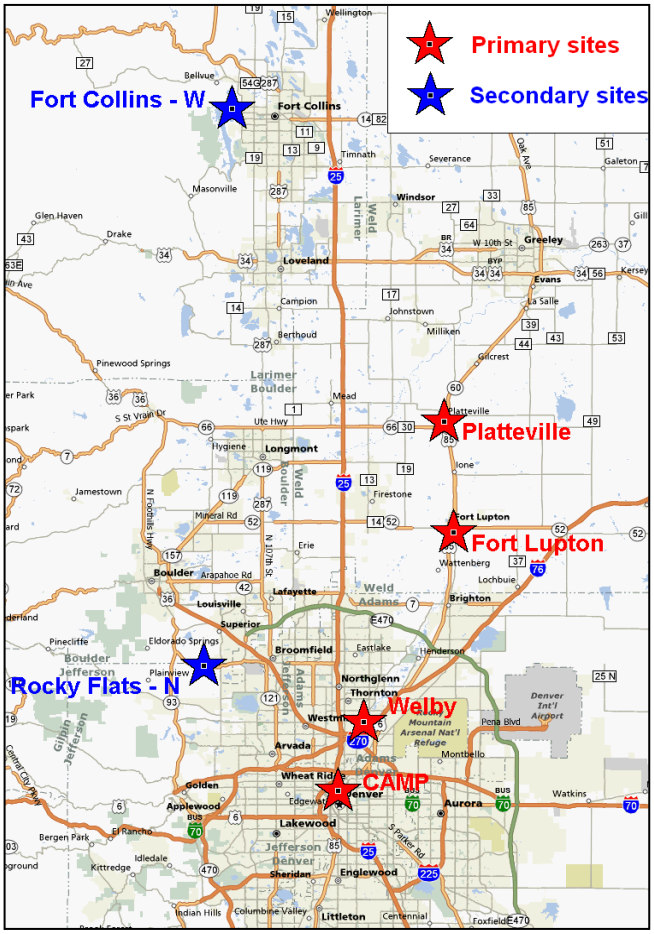

Figure 3. 2006 Monitoring Locations

1.3 *Sampling Information*

There are typically hundreds of compounds that make up urban air pollution. The U. S. Environmental Protection Agency (EPA) put together a list of 188 compounds considered to be Hazardous Air Pollutants (HAPs). These are pollutants that are known, or suspected, to cause cancer, or other major health issues. People who are exposed to these HAPs at sufficient concentration levels may have an increased chance of getting cancer, damaging their immune system, etc. Most air toxics originate from mobile sources, like cars, trucks, or buses, as well as stationary sources, such as factories, refineries, and power plants. Some air toxics also come from indoor sources as well, like cleaning solvents, and building materials. HAPs can be organic or inorganic compounds. The 187 HAPs can be split into several subsets. There is a subset of 97 that are considered volatile organic compounds (VOCs), a subset of 15 carbonyl compounds, and a subset of 80 Speciated Nonmethane Organic Compounds (SNMOCs). There are many compounds that are in both the SNMOC and VOC subsets. VOCs are defined as organic compounds with a vapor pressure that is greater than 10^{-1} Torr, at 25 °C and 760 millimeters of mercury (mm Hg). (1)

1.3.4. 1996 Sampling Information

In the 1996 study, 115 VOCs and NMOCs were measured via EPA Methods TO-12, TO-14, and TO-15. Thirteen carbonyl compounds were measured via EPA Method TO-11. The samples were taken over a three-hour period, from 06:00 to 09:00 on an every second day schedule. This was done in an effort to collect an air sample with an un-reacted set of pollutants, as the VOCs, SMNOCs, and carbonyls are highly controlled by photochemistry.

Table 4 and Table 5 list the carbonyl and NMOC/VOC compounds in the 1996 study. Also measured at all three sites were oxides of nitrogen (NOx), using a continuous air monitor.

Table 4. Carbonyl Compounds Measured in 1996

Carbonyl Compounds Measured in 1996	
2,5-Dimethylbenzaldehyde	**Formaldehyde**
Acetaldehyde	Hexanal
Acetone	Isovaleraldehyde
Acrolein	Propionaldehyde
Benzaldehyde	Tolualdehydes (o-,m-,p-)
Butyr/Isobutyraldehyde	Valeraldehyde
Crotonaldehyde	

Table 5. NMOC/VOC Compounds Measured in 1996

NMOC/VOC Compounds Measured in 1996			
1,1,1-Trichloroethane	2-Methyl-1-butene	Cyclohexane	n-Propylbenzene
1,1,2,2-Tetrachloroethane	2-Methyl-1-pentene	Cyclopentane	n-Tridecane
1,1,2-Trichloroethane	2-Methyl-2-Butene	Cyclopentene	n-Undecane
1,1-Dichloroethane	2-Methylheptane	Dibromochloromethane	o-Dichlorobenzene
1,1-Dichloroethene	2-Methylhexane	Dichlorodifluoromethane	o-Ethyltoluene
1,2,3-Trimethylbenzene	2-Methylpentane	Dichlorotetrafluoroethane	o-Xylene
1,2,4-Trichlorobenzene	3-Methyl-1-butene	Ethylbenzene	p-Dichlorobenzene
1,2,4-Trimethylbenzene	3-Methylheptane	Ethylene	p-Diethylbenzene
1,2-Dibromoethane	3-Methylhexane	Hexachloro-1,3-butadiene	p-Ethyltoluene
1,2-Dichloroethane	3-Methylpentane	Isobutane	Propane
1,2-Dichloropropane	4-Methyl-1-pentene	Isobutene / 1-Butene	Propylene
1,3,5-Trimethylbenzene	Acetylene / Ethane	Isopentane	Propyne
1,3-Butadiene	a-Pinene	Isoprene	Styrene
1-Decene	**Benzene**	Isopropylbenzene	tert-Amyl methyl ether
1-Dodecene	b-Pinene	m-Dichlorobenzene	**Tetrachloroethylene**
1-Heptene	Bromochloromethane	m-Diethylbenzene	Toluene
1-Hexene	Bromodichloromethane	Methyl tert-butyl ether	trans-1,2-Dichloroethylene
1-Nonene	Bromoform	Methylcyclohexane	trans-1,3-Dichloropropene
1-Octene	Bromomethane	Methylcyclopentane	trans-2-Butene
1-Pentene	**Carbon tetrachloride**	**Methylene chloride**	trans-2-Hexene
1-Tridecene	Chlorobenzene	m-Ethyltoluene	trans-2-Pentene
1-Undecene	Chloroethane	m-Xylene / p-Xylene	**Trichloroethylene**
2,2,3-Trimethylpentane	**Chloroform**	n-Butane	Trichlorofluoromethane
2,2,4-Trimethylpentane	Chloromethane	n-Decane	Trichlorotrifluoroethane
2,2-Dimethylbutane	Chloroprene	n-Dodecane	**Vinyl chloride**
2,3,4-Trimethylpentane	cis-1,2-Dichloroethylene	n-Heptane	
2,3-Dimethylbutane	cis-1,3-Dichloropropene	n-Hexane	
2,3-Dimethylpentane	cis-2-Butene	n-Nonane	
2,4-Dimethylpentane	cis-2-Hexene	n-Octane	
2-Ethyl-1-butene	cis-2-Pentene	n-Pentane	

1.3.5. 2003 Sampling Information

In the 2003 study, 78 SNMOCs were measured via EPA Method TO-15, and twelve carbonyl compounds were measured via EPA Method TO-11a. After a review of the 1996 study results, it was determined that monitoring for all 115 VOC/NMOC compounds was not necessary, and the list was then reduced to 78 compounds. For the carbonyl analyses, acrolein was dropped from the list. Table 6 and Table 7 list the compounds measured during the 2003 study. At CAMP and Welby, samples were taken over two three-hour periods, from 06:00 to 09:00, and 13:00 to 16:00 on an every third day schedule. The third sampler was rotated between three other sites, NREL, Platteville, and Chatfield, collecting on four sample dates at each site during the same time periods. This was done in an effort to collect an air sample with an un-reacted set of pollutants, and one where the sun's photochemistry had time to alter the compound concentrations throughout the day. In addition to the air toxics measurements, carbon monoxide (CO), and NOx were monitored at the Welby and CAMP sites. Ozone was also monitored at Welby and CAMP, as well as NREL and Chatfield.

Table 6. Carbonyl Compounds Measured in 2003

Carbonyl Compounds Measured in 2003	
2,5-Dimethylbenzaldehyde	**Formaldehyde**
Acetaldehyde	Hexaldehyde
Acetone	Isovaleraldehyde
Benzaldehyde	Propionaldehyde
Butyr/Isobutyraldehyde	Tolualdehydes (o-, m-, p-)
Crotonaldehyde	Valeraldehyde

Table 7. NMOC/VOC Compounds Measured in 2003

NMOC/VOC Compounds Measured in 2003			
1,2,3-Trimethylbenzene	2-Ethyl-1-butene	Cyclopentane	n-Nonane
1,2,4-Trimethylbenzene	2-Methyl-1-butene	Cyclopentene	n-Octane
1,3,5-Trimethylbenzene	2-Methyl-1-pentene	Ethane	n-Pentane
1,3-Butadiene	2-Methyl-2-butene	Ethylbenzene	n-Propylbenzene
1-Decene	2-Methylheptane	Ethylene	n-Tridecane
1-Dodecene	2-Methylhexane	Isobutane	n-Undecane
1-Heptene	2-Methylpentane	Isobutene / 1-Butene	o-Ethyltoluene
1-Hexene	3-Methyl-1-butene	Isopentane	o-Xylene
1-Nonene	3-Methylheptane	Isoprene	p-Diethylbenzene
1-Octene	3-Methylhexane	Isopropylbenzene	p-Ethyltoluene
1-Pentene	3-Methylpentane	m-Diethylbenzene	Propane
1-Tridecene	4-Methyl-1-pentene	Methylcyclohexane	Propylene
1-Undecene	Acetylene	Methylcyclopentane	Propyne
2,2,3-Trimethylpentane	a-Pinene	m-Ethyltoluene	Styrene
2,2,4-Trimethylpentane	**Benzene**	m-Xylene / p-Xylene	Toluene
2,2-Dimethylbutane	b-Pinene	n-Butane	trans-2-Butene
2,3,4-Trimethylpentane	cis-2-Butene	n-Decane	trans-2-Hexene
2,3-Dimethylbutane	cis-2-Hexene	n-Dodecane	trans-2-Pentene
2,3-Dimethylpentane	cis-2-Pentene	n-Heptane	
2,4-Dimethylpentane	Cyclohexane	n-Hexane	

1.3.6. 2006 Sampling Information

In the 2006 study, as in the 2003 study, 78 NMOC/VOC compounds, and twelve carbonyl compounds were measured. Table 8 and Table 9 summarize the compounds measured in 2006. Sampling was done over a two month period, nominally on an every other or every third day schedule, for the four primary sites, and took place from 06:00 to 09:00. Three samples were collected at the two secondary sites. Those samples were taken in the afternoon hours, from 13:00 to 16:00. In addition to the air toxics, NOx was also monitored at the CAMP and Welby sites.

Table 8. Carbonyl Compounds Measured in 2006

Carbonyl Compounds Measured in 2006	
2,5-Dimethylbenzaldehyde	**Formaldehyde**
Acetaldehyde	Hexaldehyde
Acetone	Isovaleraldehyde
Benzaldehyde	Propionaldehyde
Butyr/Isobutyraldehyde	Tolualdehydes (o-, m-, p-)
Crotonaldehyde	Valeraldehyde

Table 9. NMOC/VOC Compounds Measured in 2006

NMOC/VOC Compounds Measured in 2006			
1,2,3-Trimethylbenzene	2-Ethyl-1-butene	Cyclopentane	n-Nonane
1,2,4-Trimethylbenzene	2-Methyl-1-butene	Cyclopentene	n-Octane
1,3,5-Trimethylbenzene	2-Methyl-1-pentene	Ethane	n-Pentane
1,3-Butadiene	2-Methyl-2-butene	Ethylbenzene	n-Propylbenzene
1-Decene	2-Methylheptane	Ethylene	n-Tridecane
1-Dodecene	2-Methylhexane	Isobutane	n-Undecane
1-Heptene	2-Methylpentane	Isobutene / 1-Butene	o-Ethyltoluene
1-Hexene	3-Methyl-1-butene	Isopentane	o-Xylene
1-Nonene	3-Methylheptane	Isoprene	p-Diethylbenzene
1-Octene	3-Methylhexane	Isopropylbenzene	p-Ethyltoluene
1-Pentene	3-Methylpentane	m-Diethylbenzene	Propane
1-Tridecene	4-Methyl-1-pentene	Methylcyclohexane	Propylene
1-Undecene	Acetylene	Methylcyclopentane	Propyne
2,2,3-Trimethylpentane	a-Pinene	m-Ethyltoluene	Styrene
2,2,4-Trimethylpentane	**Benzene**	m-Xylene / p-Xylene	Toluene
2,2-Dimethylbutane	b-Pinene	n-Butane	trans-2-Butene
2,3,4-Trimethylpentane	cis-2-Butene	n-Decane	trans-2-Hexene
2,3-Dimethylbutane	cis-2-Hexene	n-Dodecane	trans-2-Pentene
2,3-Dimethylpentane	cis-2-Pentene	n-Heptane	
2,4-Dimethylpentane	Cyclohexane	n-Hexane	

2.0 Carbonyls

Three of the carbonyl compounds are considered to be significant health risk drivers at the nation-wide level.[1] Acetaldehyde, crotonaldehyde, and formaldehyde are the three main compounds of interest with the carbonyls. Acetaldehyde can be released to the environment as a product of incomplete combustion in fireplaces and wood stoves, forest and wild fires, pulp and paper production, stationary internal combustion engines and turbines, vehicle

1 US EPA. "Health Effects Notebook Online." http://www.epa.gov/ttn/atw/hlthef/hapindex.html

exhaust, petroleum refineries, and wastewater processing. It should be noted that the two largest sources are from residential fireplaces and woodstoves, followed by various industrial emissions.

Crotonaldehyde is a colorless liquid with a pungent, suffocating odor. It can be emitted to the environment from the combustion of gasoline, the burning of wood, paper, cotton, plastics and tobacco. It can also be released through industrial use. It is found naturally in emissions of some vegetables, and volcanoes. It is a skin irritant, and can cause eye irritation and damage to the cornea.

Formaldehyde exists in the atmosphere as a colorless gas with a pungent odor. The major sources of formaldehyde emissions to the ambient air include power plants, manufacturing facilities, incinerators, forest and wild fires, stationary internal combustion engines and turbines, pulp and paper plants, petroleum refineries and automobile traffic. In urban areas, combustion of automotive fuel is the dominant source for much of the year. However, formaldehyde can also form photochemically in the air, as other hydrocarbons and oxides of nitrogen from automobile traffic break down to form ozone.

Carbonyl data is presented in the following subsections.

2.1 *1996 Carbonyl Data*

Table 10 lists the average concentrations recorded at CAMP over the study period in 1996. Also listed are the number of samples taken, and the number of samples that the compound was not detected in. Values in italics indicate that the compound was not found in greater than 85% of the samples taken. Bolded values indicate that the compounds are on the EPA's list of 19 priority compounds targeted for further study. Carbonyl sampling did not begin until well after the NMOC sampling started, thus the difference in the number of samples between the two. Acetaldehyde, acetone, and formaldehyde had the highest averages, with values of 21.03 ppbv, 4.51 ppbv, and 4.21 ppbv, respectively. All three of those compounds were detected in all seven samples taken. Hexanal was the only other compound detected in all the samples at CAMP. One compound, isovaleraldehyde, was not detected in any of the samples. For compounds that were not detected in greater than 85% of the samples taken, one-half of the method detection limit (MDL) was substituted as a conservative concentration value. This makes averages for the samples with several non-detects highly dependent on their respective MDLs, and not indicative of what the actual concentrations may be.

Table 10. CAMP Average Carbonyl Concentrations

Compound	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-Detects
2,5-Dimethylbenzaldehyde	*0.15*	*0.34*	*7*	*4*
Acetaldehyde	**21.03**	**40.52**	**7**	**0**
Acetone	4.51	8.28	7	0
Acrolein	*0.23*	*0.56*	*7*	*5*
Benzaldehyde	*0.12*	*0.24*	*7*	*3*
Butyr/Isobutyraldehyde	0.49	0.72	7	1
Crotonaldehyde	0.74	2.01	7	1
Formaldehyde	**4.21**	**5.56**	**7**	**0**
Hexanal	0.32	0.43	7	0
Isovaleraldehyde	*0.07*	*0.07*	*7*	*7*
Propionaldehyde	*0.33*	*0.57*	*7*	*2*
Tolualdehydes (o-,m-,p-)	*0.40*	*0.87*	*7*	*3*
Valeraldehyde	*0.13*	*0.29*	*7*	*5*

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

Table 11 lists the average carbonyl concentrations at the Welby sampling site. Also listed are the number of samples taken, and the number of samples that the compound was not detected in. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and bolded values indicate the compound is a priority compound as determined by the EPA. Carbonyl sampling was started several weeks after the NMOC

sampling began, which is why the sample numbers are different. As was seen at the CAMP site, acetaldehyde, acetone, and formaldehyde had the highest average concentrations, with values of 22.33 ppbv, 12.49 ppbv, and 6.46 ppbv, respectively. Those three compounds, as well as crotonaldehyde, hexanal, and propionaldehyde were detected in all seven samples taken. The remaining compounds all had at least one non-detect sample. As with the CAMP data, one-half of the compound's respective MDLs was substituted as a conservative estimation of the compound's ambient concentration. Figure 4 and Figure 5 graphically illustrate a comparison of the average and maximum carbonyl concentrations at the CAMP and Welby sampling sites. In general, the Welby site saw larger values than the CAMP site did.

Table 11. Welby Average Carbonyl Concentrations

Compound	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-Detects
2,5-Dimethylbenzaldehyde	*0.09*	*0.16*	*7*	*6*
Acetaldehyde	**22.33**	**36.07**	**7**	**0**
Acetone	12.49	54.93	7	0
Acrolein	*0.31*	*1.13*	*7*	*5*
Benzaldehyde	*0.14*	*0.41*	*7*	*3*
Butyr/Isobutyraldehyde	1.13	4.24	7	1
Crotonaldehyde	0.94	1.71	7	0
Formaldehyde	**6.46**	**14.28**	**7**	**0**
Hexanal	0.55	0.87	7	0
Isovaleraldehyde	*0.09*	*0.21*	*7*	*6*
Propionaldehyde	0.58	1.54	7	0
Tolualdehydes (o-,m-,p-)	*0.43*	*0.99*	*7*	*2*
Valeraldehyde	*0.14*	*0.45*	*7*	*5*

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

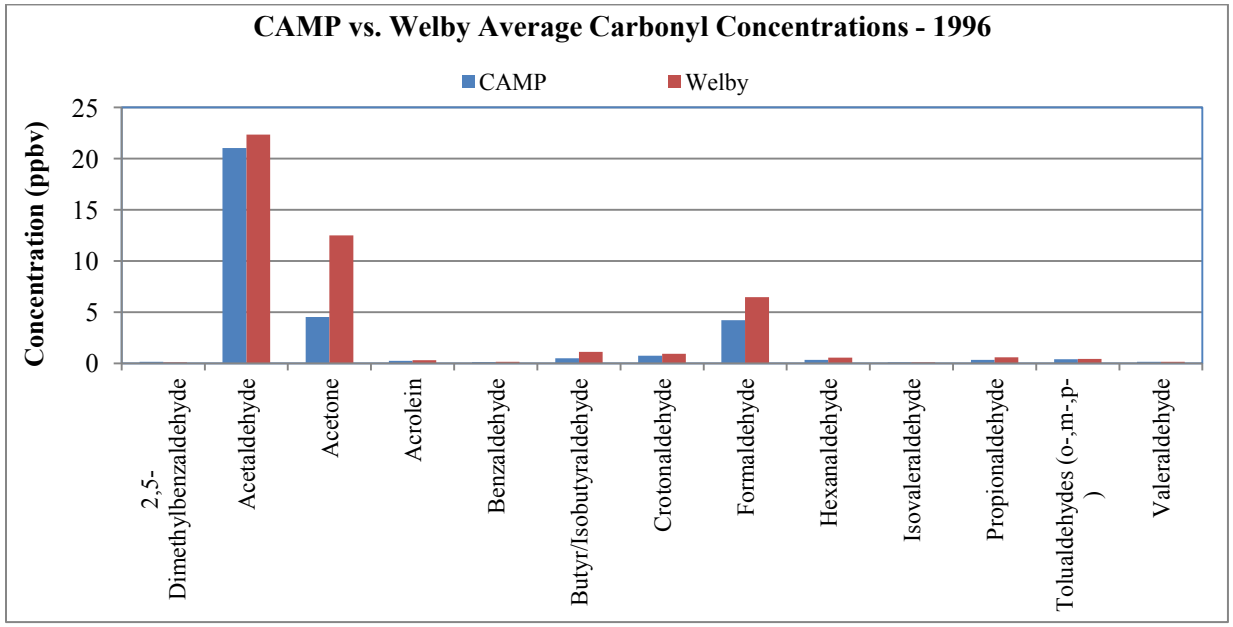

Figure 4. CAMP vs. Welby Average Carbonyl Concentrations, 1996

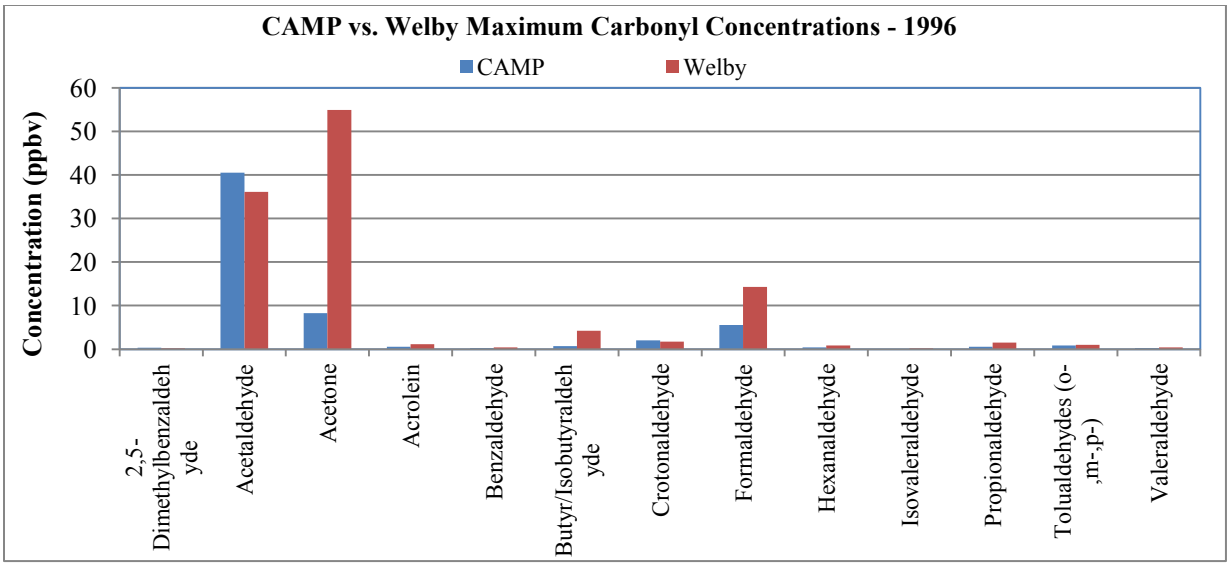

Figure 5. CAMP vs. Welby Maximum Carbonyl Concentrations, 1996

2.2 *2003 Carbonyl Data*

During the 2003 study, both morning and afternoon samples were taken in an effort to determine the amount of photochemistry taking place during the daylight hours. Table 12 lists the average and maximum carbonyl concentrations recorded at the CAMP site. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and bolded values indicate that the compound is on the EPA's priority list of target compounds. With the exception of the tolualdehydes, all the compounds had lower concentrations in the afternoon samples than in the morning samples. Only one compound was never detected, which was 2,5-dimethylbenzaldehyde. Isovaleraldehyde was not detected in 16 of the 24 samples taken. The averages for those two compounds are dependent on their respective MDLs, as one half of that value was substituted in place of the non-detect values. Figure 6 graphically illustrates the differences between the morning and afternoon averages at CAMP.

Table 12. AM and PM Carbonyl Average and Maximum Concentrations at CAMP, 2003

	CAMP					
	Morning		Afternoon		Total	
Compound	Average (ppbv)	Maximum (ppbv)	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.00*	*0.00*	*0.00*	*0.00*	*24*	*24*
Acetaldehyde	**8.70**	**17.28**	**5.94**	**8.06**	**24**	**0**
Acetone	9.62	36.52	6.52	8.89	24	0
Benzaldehyde	0.17	0.26	0.15	0.23	24	0
Butyr/Isobutyraldehyde	0.94	2.84	0.89	1.15	24	0
Crotonaldehyde	0.28	0.39	0.26	0.51	24	0
Formaldehyde	**10.61**	**21.84**	**8.41**	**12.69**	**24**	**0**
Hexaldehyde	0.16	0.30	0.15	0.22	24	0
Isovaleraldehyde	*0.02*	*0.11*	*0.01*	*0.06*	*24*	*16*
Propionaldehyde	0.30	0.95	0.26	0.47	24	0
Tolualdehydes (o-, m-, p-)	0.10	0.17	0.14	0.40	24	0
Valeraldehyde	0.16	0.69	0.11	0.19	24	0

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

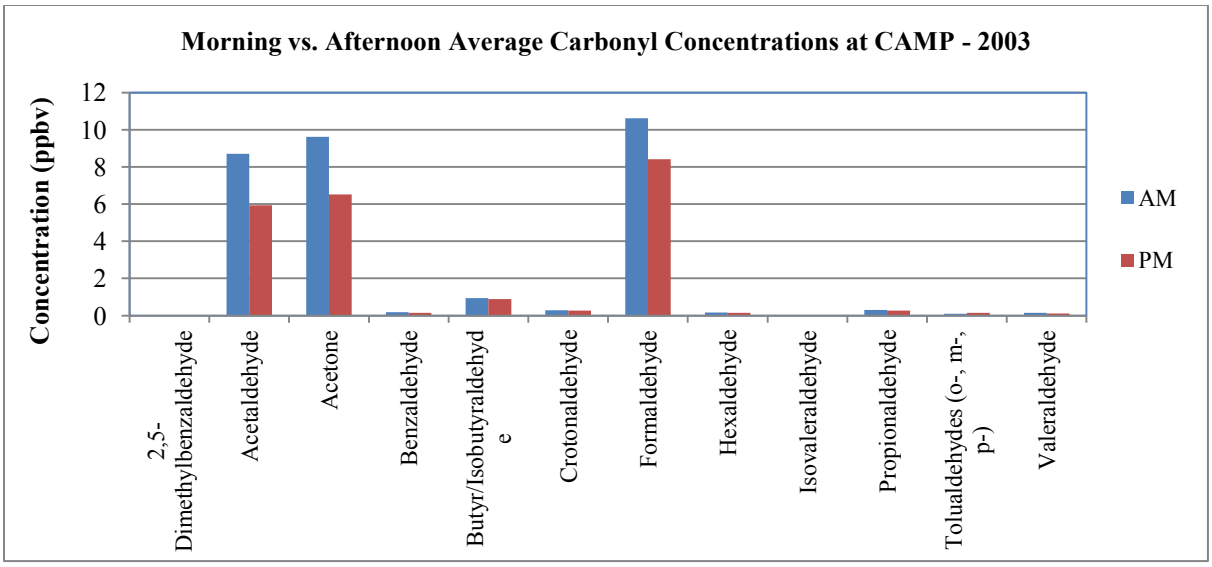

Figure 6. Morning vs. Afternoon Average Carbonyl Concentrations at CAMP, 2003

Table 13 lists the morning and afternoon average and maximum carbonyl concentrations at the Welby site. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, while bolded values indicate the compound is on the EPA's priority list of target compounds. As was the case at the CAMP site, all the afternoon averages were lower than the morning averages. There were three compounds that had non-detect values on some of the sample days. As was the case at CAMP, 2,5-dimethylbenzaldehyde was not detected in greater than 85% of the samples taken. Crotonaldehyde and isovaleraldehyde also had non-detect values at Welby. Figure 7 graphically illustrates the differences between the morning and afternoon samples at Welby.

Table 13. AM and PM Carbonyl Average and Maximum Concentrations at Welby, 2003

	Welby					
	Morning		Afternoon		Total	
Compound	Average (ppbv)	Maximum (ppbv)	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.01*	*0.04*	*0.01*	*0.04*	*23*	*17*
Acetaldehyde	**3.80**	**5.63**	**2.81**	**4.78**	**23**	**0**
Acetone	5.70	8.57	4.42	6.63	23	0
Benzaldehyde	0.15	0.23	0.09	0.19	23	0
Butyr/Isobutyraldehyde	0.63	0.86	0.56	0.80	23	0
Crotonaldehyde	0.27	0.40	0.18	0.30	23	1
Formaldehyde	**5.64**	**8.38**	**5.51**	**7.91**	**23**	**0**
Hexaldehyde	0.20	0.29	0.14	0.32	23	0
Isovaleraldehyde	0.06	0.11	0.03	0.07	23	2
Propionaldehyde	0.39	0.70	0.30	0.61	23	0
Tolualdehydes (o-, m-, p-)	0.13	0.22	0.08	0.10	23	0
Valeraldehyde	0.14	0.26	0.12	0.31	23	0

Italics = Detected in < 85% of samples take; **Bold = Priority Compound**

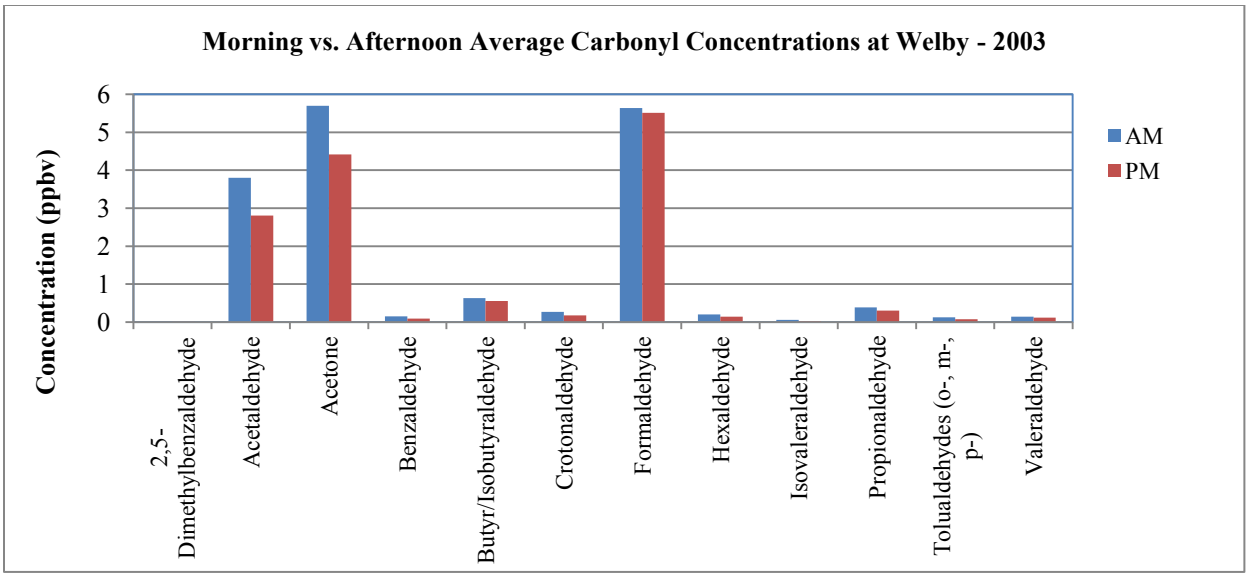

Figure 7. Morning vs. Afternoon Average Carbonyl Concentrations at Welby, 2003

Table 14 lists the morning and afternoon average and maximum concentrations at the NREL site. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and values in bold indicate the compound is on the EPA's priority list. Unlike the CAMP and Welby sites, the NREL site had slightly higher afternoon than morning averages for many of the compounds. This is likely due to the location of the site. It is not in an area that has heavy motor vehicle traffic, as the CAMP and Welby sites do. As was the case with the other sites, 2,5-Dimethylbenzaldehyde was not detected in any of the samples taken. All other compounds were present in each of the seven samples taken. Figure 8 shows a graphic comparison of the morning and afternoon average concentrations.

Table 14. AM and PM Carbonyl Average and Maximum Concentrations at NREL, 2003

	NREL					
	Morning		Afternoon		Total	
Compound	Average (ppbv)	Maximum (ppbv)	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.00*	*0.00*	*0.00*	*0.00*	*7*	*7*
Acetaldehyde	**2.95**	**2.97**	**3.28**	**3.87**	**7**	**0**
Acetone	4.92	5.35	5.40	6.12	7	0
Benzaldehyde	0.09	0.11	0.09	0.18	7	0
Butyr/Isobutyraldehyde	0.44	0.52	0.43	0.57	7	0
Crotonaldehyde	0.19	0.23	0.34	0.39	7	0
Formaldehyde	**4.49**	**4.73**	**6.02**	**6.95**	**7**	**0**
Hexaldehyde	0.08	0.09	0.10	0.15	7	0
Isovaleraldehyde	0.04	0.06	0.02	0.04	7	0
Propionaldehyde	0.25	0.26	0.33	0.46	7	0
Tolualdehydes (o-, m-, p-)	0.07	0.09	0.13	0.24	7	0
Valeraldehyde	0.08	0.10	0.07	0.12	7	0

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

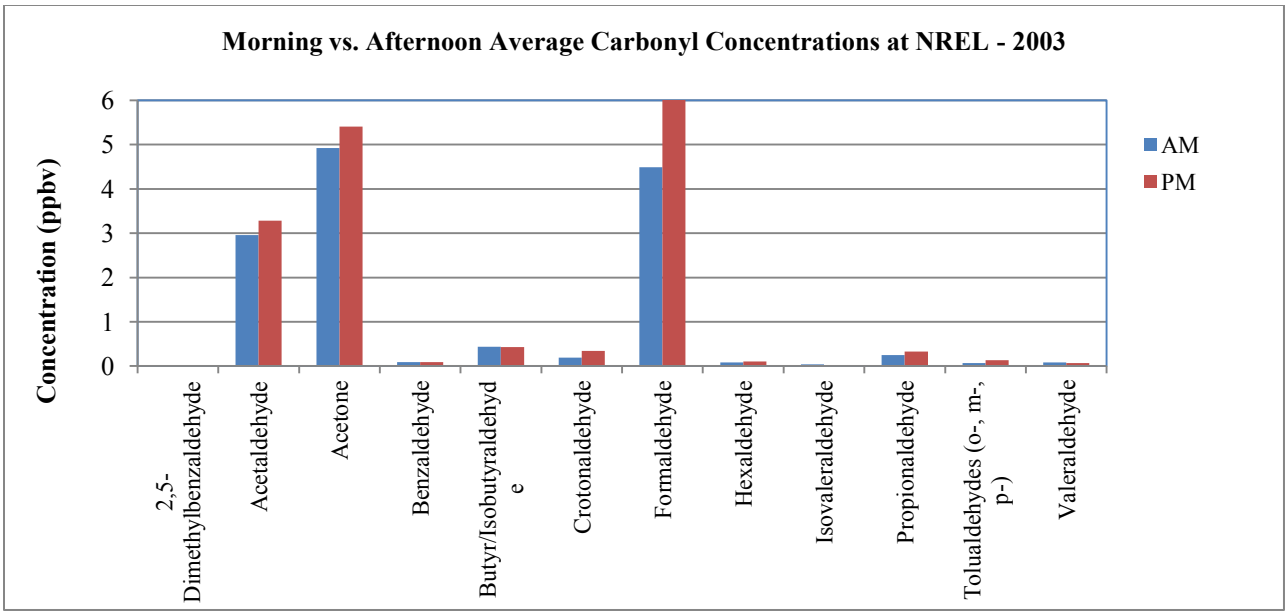

Figure 8. Morning vs. Afternoon Average Carbonyl Concentrations at NREL, 2003

Table 15 lists the morning and afternoon average and maximum carbonyl concentrations for the Platteville site. Values in italics indicate that the compound was not found in greater than 85% of the samples taken. Bolded values indicate that the compound is a priority compound on the EPA's target monitoring list. The Platteville site is located in the midst of an oil and gas development area to the north and slightly east of the Denver area. Only two compounds had larger afternoon than morning concentrations. Formaldehyde had a morning average of 4.73 ppbv, and an afternoon average of 5.14 ppbv. Butyr/isobutyraldehyde had a morning average of 0.43 ppbv, and an afternoon average of 0.57 ppbv. In seven of the eight samples taken, 2,5-Dimethylbenzaldehyde was not detected. Isovaleraldehyde was not detected in one of the eight samples. Figure 9 gives a clearer picture of how the morning and afternoon averages compared.

Table 15. AM and PM Carbonyl Average and Maximum Concentrations at Platteville, 2003

	Platteville					
	Morning		Afternoon		Total	
Compound	Average (ppbv)	Maximum (ppbv)	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.00*	*0.00*	*0.00*	*0.01*	*8*	*7*
Acetaldehyde	**3.52**	**4.17**	**3.29**	**4.73**	**8**	**0**
Acetone	5.62	6.92	5.20	6.62	8	0
Benzaldehyde	0.12	0.16	0.07	0.11	8	0
Butyr/Isobutyraldehyde	0.43	0.50	0.57	0.81	8	0
Crotonaldehyde	0.28	0.44	0.14	0.19	8	0
Formaldehyde	**4.73**	**5.27**	**5.14**	**6.46**	**8**	**0**
Hexaldehyde	0.16	0.24	0.11	0.16	8	0
Isovaleraldehyde	0.06	0.09	0.02	0.04	8	1
Propionaldehyde	0.33	0.38	0.32	0.49	8	0
Tolualdehydes (o-, m-, p-)	0.08	0.13	0.06	0.07	8	0
Valeraldehyde	0.15	0.25	0.09	0.12	8	0

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

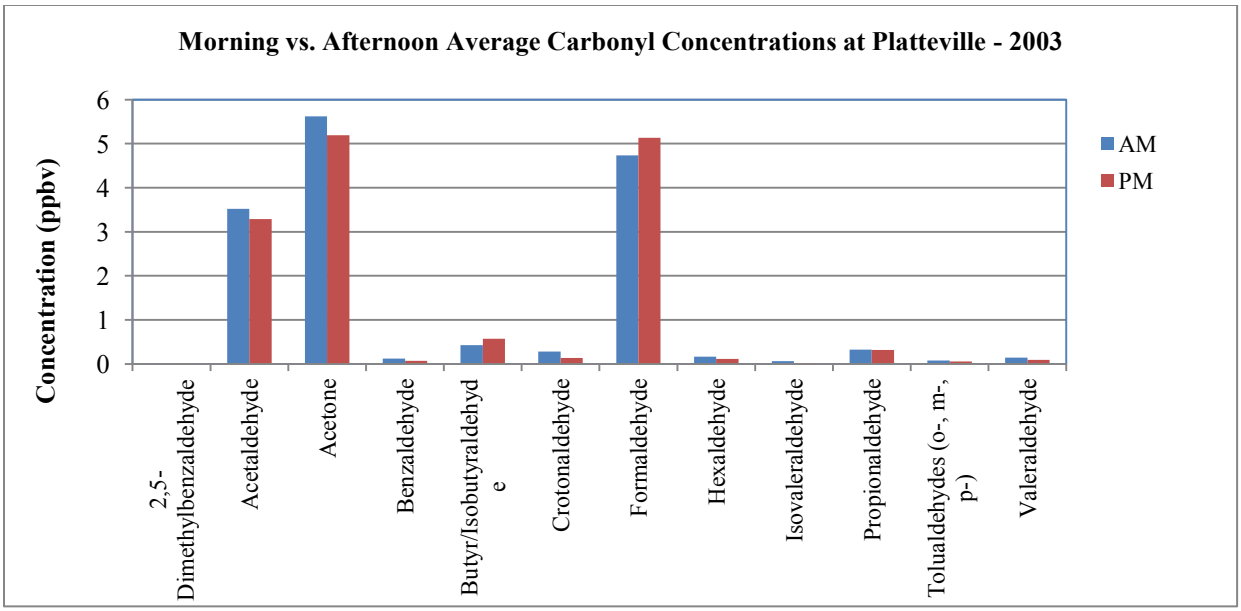

Figure 9. Morning vs. Afternoon Average Carbonyl Concentrations at Platteville, 2003

Table 16 lists the morning and afternoon average and maximum carbonyl concentrations at the Chatfield site. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and bolded values indicate the compound is on the EPA's priority target list. The Chatfield site is located in close proximity to a large reservoir. Several of the compounds had larger afternoon than morning concentrations. Acetaldehyde, acetone, crotonaldehyde, and formaldehyde all had larger afternoon values. The 2,5-dimethylbenzaldehyde compound was not detected in any of the eight samples taken, while isovaleraldehyde was not detected in five of the eight samples taken.

Table 16. AM and PM Carbonyl Average and Maximum Concentrations at Chatfield, 2003

	Chatfield					
	Morning		Afternoon		Total	
Compound	Average (ppbv)	Maximum (ppbv)	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.00*	*0.00*	*0.00*	*0.00*	*8*	*8*
Acetaldehyde	**1.72**	**2.50**	**2.03**	**2.47**	**8**	**0**
Acetone	2.98	3.55	3.82	4.38	8	0
Benzaldehyde	0.11	0.12	0.09	0.10	8	0
Butyr/Isobutyraldehyde	0.67	0.78	0.66	0.90	8	0
Crotonaldehyde	0.11	0.14	0.16	0.23	8	0
Formaldehyde	**2.88**	**3.32**	**4.53**	**6.22**	**8**	**0**
Hexaldehyde	0.20	0.24	0.14	0.18	8	0
Isovaleraldehyde	*0.01*	*0.02*	*0.00*	*0.00*	*8*	*5*
Propionaldehyde	0.15	0.24	0.13	0.16	8	0
Tolualdehydes (o-, m-, p-)	0.07	0.08	0.06	0.07	8	0
Valeraldehyde	0.09	0.13	0.06	0.08	8	0

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

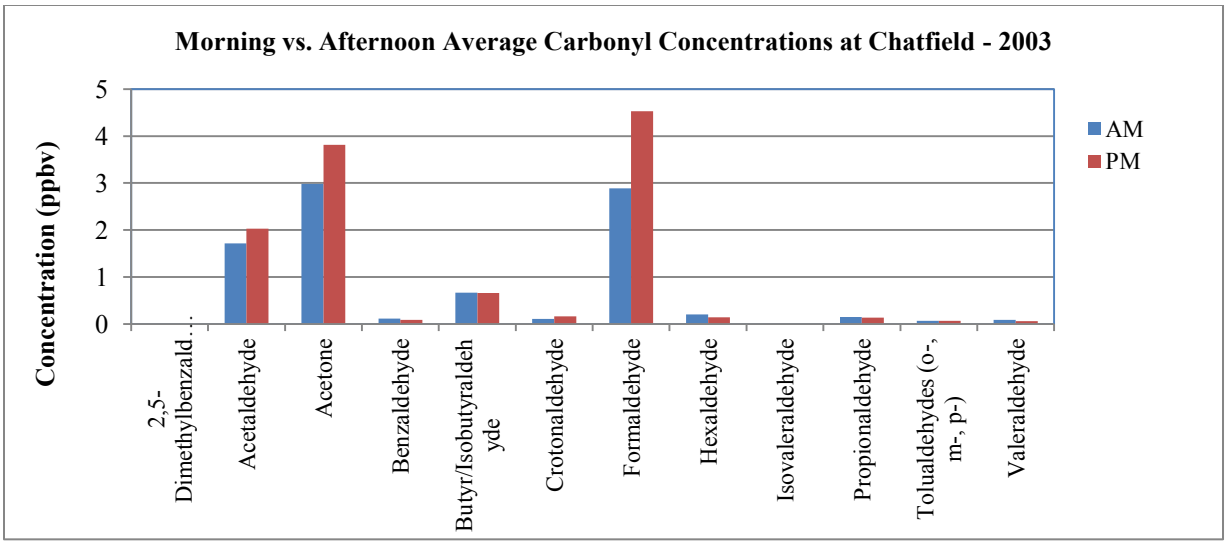

Figure 10. Morning vs. Afternoon Average Carbonyl Concentrations at Chatfield, 2003

2.3 *2006 Carbonyl Data*

The 2006 air toxics study took samples from four sites during the morning hours and from two other sites during the afternoon hours. The CAMP, Welby, Fort Lupton, and Platteville sites all took morning samples, while the Rocky Flats – North, and Fort Collins – West sites took afternoon samples. Table 17 through Table 22 list the morning average and maximum concentrations measured at CAMP, Welby, Fort Lupton, and Platteville, as well as the afternoon concentrations at Rocky Flats – North, and Fort Collins – West. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, while values in bold indicate the compound is on the EPA's priority list.

2,5-dimethylbenzaldehyde was not detected in any samples, at any of the sites, during the morning or afternoon hours. At the CAMP site, isovaleraldehyde was detected only once, while at the Welby, Fort Lupton, Platteville, Rocky Flats – North, and Fort Collins – West sites it was detected one, thirteen, two, zero, and one times, respectively. At Welby, the tolualdehydes were not detected at all. All the remaining compounds were detected at least once at all the other sites.

Table 17. AM Carbonyl Concentrations at CAMP, 2006

	CAMP			
	Morning		Total	
Compound	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.00*	*0.01*	*16*	*16*
Acetaldehyde	**8.90**	**11.60**	**16**	**0**
Acetone	8.00	14.30	16	0
Benzaldehyde	0.18	0.27	16	0
Butyraldehyde	0.35	0.56	16	0
Crotonaldehyde	0.20	0.35	16	0
Formaldehyde	**5.65**	**9.09**	**16**	**0**
Hexaldehyde	0.13	0.23	16	0
Isovaleraldehyde	*0.01*	*0.07*	*16*	*15*
Propionaldehyde	0.18	0.26	16	0
Tolualdehydes	*0.08*	*0.19*	*16*	*7*
Valeraldehyde	0.10	0.16	16	0

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

Table 18. AM Carbonyl Concentrations at Welby, 2006

Compound	Welby			
	Morning		Total	
	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.01*	*0.01*	*15*	*15*
Acetaldehyde	**6.28**	**9.77**	**15**	**0**
Acetone	6.32	9.75	15	0
Benzaldehyde	*0.06*	*0.12*	*15*	*6*
Butyraldehyde	0.18	0.49	15	1
Crotonaldehyde	0.15	0.38	15	2
Formaldehyde	**3.16**	**4.81**	**15**	**0**
Hexaldehyde	*0.06*	*0.15*	*15*	*7*
Isovaleraldehyde	*0.01*	*0.08*	*15*	*14*
Propionaldehyde	0.18	0.35	15	1
Tolualdehydes	*0.02*	*0.02*	*15*	*15*
Valeraldehyde	*0.03*	*0.10*	*15*	*11*

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

Table 19. AM Carbonyl Concentrations at Fort Lupton, 2006

Compound	Fort Lupton			
	Morning		Total	
	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.00*	*0.00*	*16*	*16*
Acetaldehyde	**2.61**	**3.49**	**16**	**0**
Acetone	4.78	6.21	16	0
Benzaldehyde	0.12	0.22	16	0
Butyraldehyde	0.22	0.36	16	0
Crotonaldehyde	0.15	0.23	16	0
Formaldehyde	**2.70**	**3.24**	**16**	**0**
Hexaldehyde	0.07	0.12	16	1
Isovaleraldehyde	*0.06*	*0.11*	*16*	*3*
Propionaldehyde	0.28	0.45	16	0
Tolualdehydes	0.08	0.14	16	2
Valeraldehyde	0.09	0.12	16	0

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

Table 20. AM Carbonyl Concentrations at Platteville, 2006

Compound	Platteville			
	Morning		Total	
	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.00*	*0.00*	*14*	*14*
Acetaldehyde	**4.22**	**8.47**	**14**	**0**
Acetone	5.54	8.67	14	0
Benzaldehyde	0.06	0.11	14	1
Butyraldehyde	0.12	0.19	14	1
Crotonaldehyde	0.13	0.22	14	0
Formaldehyde	**1.33**	**2.83**	**14**	**0**
Hexaldehyde	0.08	0.12	14	2
Isovaleraldehyde	*0.01*	*0.07*	*14*	*12*
Propionaldehyde	0.11	0.21	14	0

Compound	Platteville			
	Morning		Total	
	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
Tolualdehydes	*0.03*	*0.12*	*14*	*10*
Valeraldehyde	*0.03*	*0.07*	*14*	*7*

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

Table 21. PM Carbonyl Concentrations at Rocky Flats – North, 2006

Compound	Rocky Flats - North			
	Afternoon		Total	
	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.01*	*0.01*	*3*	*3*
Acetaldehyde	**5.47**	**7.29**	**3**	**0**
Acetone	7.12	7.49	3	0
Benzaldehyde	0.08	0.10	3	0
Butyraldehyde	0.34	0.38	3	0
Crotonaldehyde	0.17	0.19	3	0
Formaldehyde	**4.55**	**5.65**	**3**	**0**
Hexaldehyde	0.09	0.09	3	0
Isovaleraldehyde	*0.01*	*0.01*	*3*	*3*
Propionaldehyde	0.42	0.51	3	0
Tolualdehydes	*0.05*	*0.11*	*3*	*2*
Valeraldehyde	0.12	0.14	3	0

Italics = Detected in < 85% of samples taken; Bold = Priority Compound

Table 22. PM Carbonyl Concentrations at Fort Collins – West, 2006

Compound	Fort Collins - West			
	Afternoon		Total	
	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-detects
2,5-Dimethylbenzaldehyde	*0.00*	*0.01*	*3*	*3*
Acetaldehyde	**2.72**	**3.02**	**3**	**0**
Acetone	5.91	6.50	3	0
Benzaldehyde	0.11	0.15	3	0
Butyraldehyde	0.22	0.26	3	0
Crotonaldehyde	0.16	0.21	3	0
Formaldehyde	**3.53**	**4.09**	**3**	**0**
Hexaldehyde	0.08	0.09	3	0
Isovaleraldehyde	*0.03*	*0.07*	*3*	*2*
Propionaldehyde	0.23	0.28	3	0
Tolualdehydes	*0.07*	*0.12*	*3*	*1*
Valeraldehyde	0.07	0.08	3	0

Italics = Detected in < 85% of samples taken; **Bold = Priority Compound**

Figure 11 and Figure 12 show the morning and afternoon average carbonyl concentrations by site. In general, CAMP had the largest concentrations for the sites sampling in the morning. Given the site's location in downtown Denver, this is not unexpected. For the afternoon samples, Rocky Flats – North generally had the larger concentrations.

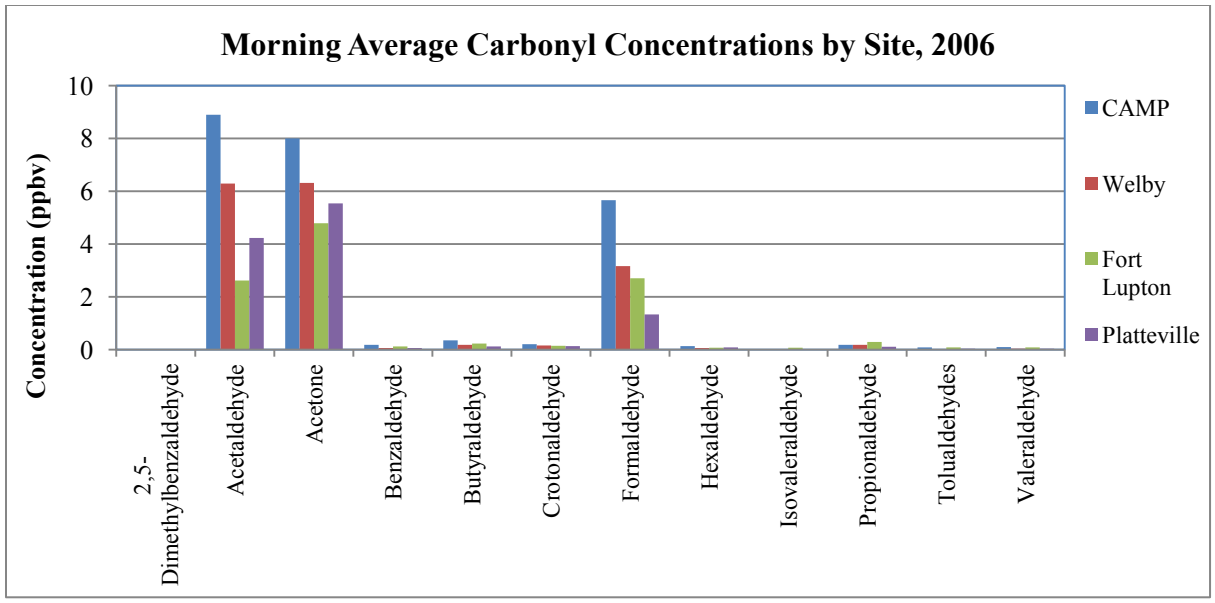

Figure 11. Morning Average Carbonyl Concentrations by Site, 2006

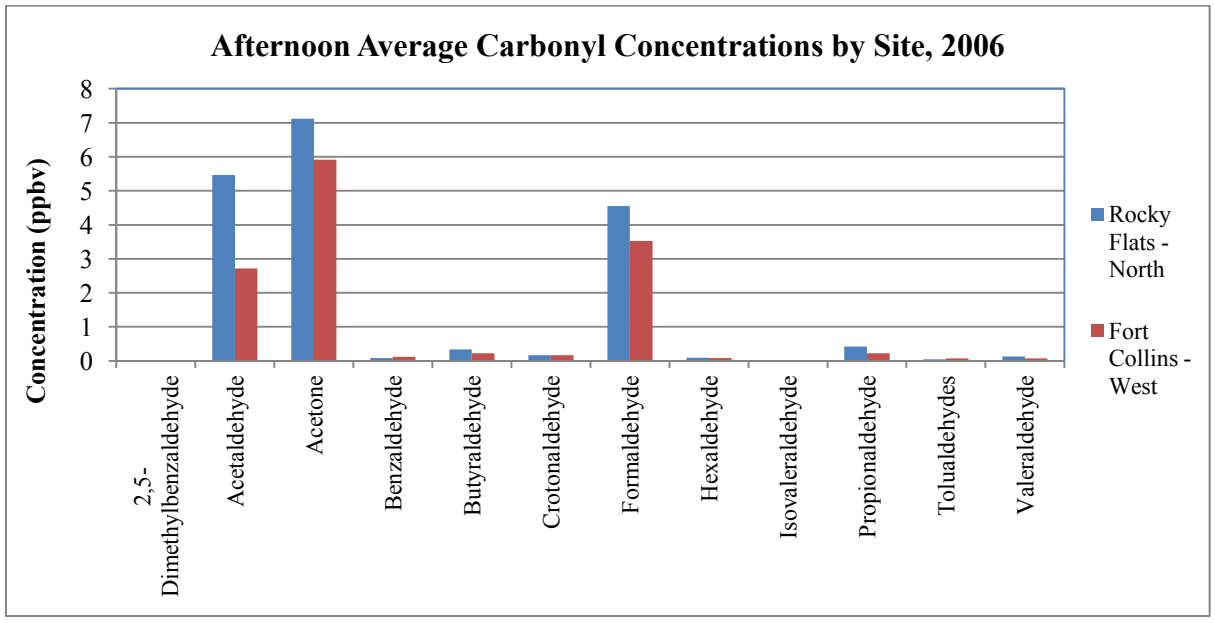

Figure 12. Afternoon Average Carbonyl Concentrations by Site, 2006

2.4 *Carbonyl Data Comparisons*

2.4.1. Site Comparisons

Only two sites collected air toxics samples in each of the three campaigns. These were the CAMP and Welby sites. The Platteville site sampled in the 2003 and 2006 studies, but not in the 1996 study. The Rocky Flats – North site sampled in both the 1996 and 2006 studies, however, only NMOC/VOC samples were taken there in 1996. It should be noted here that all comparisons are made using the data from the samples gathered in the morning hours, between 06:00 and 09:00. No comparisons are made using the afternoon sampling data. Values in italics indicate that the compound was not found in greater than 85% of the samples taken. Bolded values indicate compounds that

are on the EPA's priority list.

Table 23. CAMP Carbonyl Averages 1996 - 2006

CAMP Averages			
Compound	**1996**	**2003**	**2006**
2,5-Dimethylbenzaldehyde	*0.15*	*0.00*	*0.00*
Acetaldehyde	**21.03**	**8.70**	**8.90**
Acetone	4.51	9.62	8.00
Benzaldehyde	*0.12*	0.17	0.18
Butyr/Isobutyraldehyde	0.49	0.94	0.35
Crotonaldehyde	0.74	0.28	0.20
Formaldehyde	**4.21**	**10.61**	**5.65**
Hexanal	0.32	0.16	0.13
Isovaleraldehyde	*0.07*	*0.02*	*0.01*
Propionaldehyde	*0.33*	0.30	0.18
Tolualdehydes (o-,m-,p-)	*0.40*	0.10	*0.08*
Valeraldehyde	*0.13*	0.16	0.10

** Italics = Detected in < 85% of samples taken*
Bold = Priority Compound

Table 24. Welby Carbonyl Averages 1996 - 2006

Welby Averages			
Compound	**1996**	**2003**	**2006**
2,5-Dimethylbenzaldehyde	*0.09*	*0.01*	*0.01*
Acetaldehyde	**22.33**	**3.80**	**6.28**
Acetone	12.49	5.70	6.32
Benzaldehyde	*0.14*	0.15	*0.06*
Butyr/Isobutyraldehyde	1.13	0.63	0.18
Crotonaldehyde	0.94	0.27	0.15
Formaldehyde	**6.46**	**5.64**	**3.16**
Hexanal	0.55	0.20	*0.06*
Isovaleraldehyde	*0.09*	0.06	*0.01*
Propionaldehyde	0.58	0.39	0.18
Tolualdehydes (o-,m-,p-)	*0.43*	0.13	*0.02*
Valeraldehyde	*0.14*	0.14	*0.03*

** Italics = Detected in < 85% of samples taken*
Bold = Priority Compound

Table 25. Platteville Carbonyl Averages 2003 - 2006

Platteville Averages		
Compound	**2003**	**2006**
2,5-Dimethylbenzaldehyde	*0.00*	*0.00*
Acetaldehyde	**3.52**	**4.22**
Acetone	5.62	5.54
Benzaldehyde	0.12	0.06
Butyr/Isobutyraldehyde	0.43	0.12
Crotonaldehyde	0.28	0.13
Formaldehyde	**4.73**	**1.33**
Hexanal	0.16	0.08
Isovaleraldehyde	0.06	*0.01*
Propionaldehyde	0.33	0.11
Tolualdehydes (o-,m-,p-)	0.08	*0.03*
Valeraldehyde	0.15	*0.03*

** Italics = Detected in < 85% of samples taken*
Bold = Priority Compound

Table 23, Table 24, and Table 25 list the average concentrations obtained over the respective durations of each study period at the CAMP, Welby, and Platteville sites. The compounds with italicized results indicate that they were not detected in greater than 85% of the samples taken during the respective study periods. 2,5-dimethylbenzaldehyde was not detected at any of the three sites shown above during any of the studies. Of the six compounds detected in all three studies at CAMP, only crotonaldehyde and hexanal show a downward trend in concentrations. At Welby, there were six compounds detected in all three studies, and four of them show downward concentration trends. These compounds are butyr/isobutyraldehyde, crotonaldehyde, formaldehyde, and propionaldehyde. Of the eight compounds detected in both studies at Platteville, seven showed downward concentration trends, while the acetaldehyde concentration increased from 2003 to 2006. These trends can be seen more easily in Figure 13, Figure 14, and Figure 15. These figures graphically illustrate the year to year differences for the compounds that were detected in greater than 85% of the samples taken at the three sites.

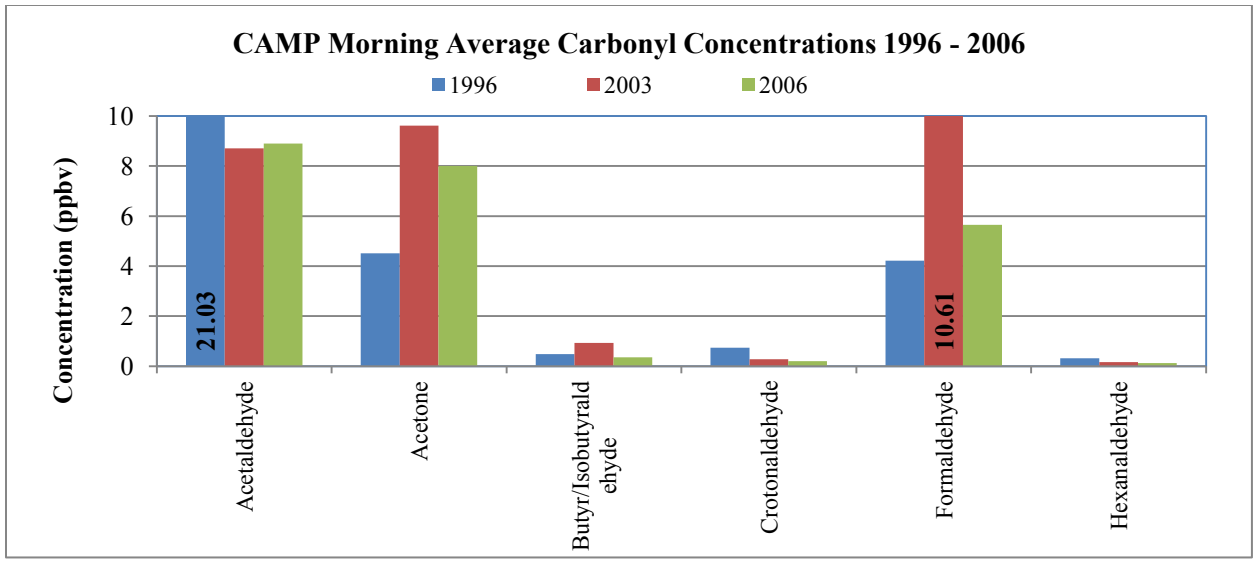

Figure 13. CAMP Morning Average Carbonyl Concentrations 1996 - 2006

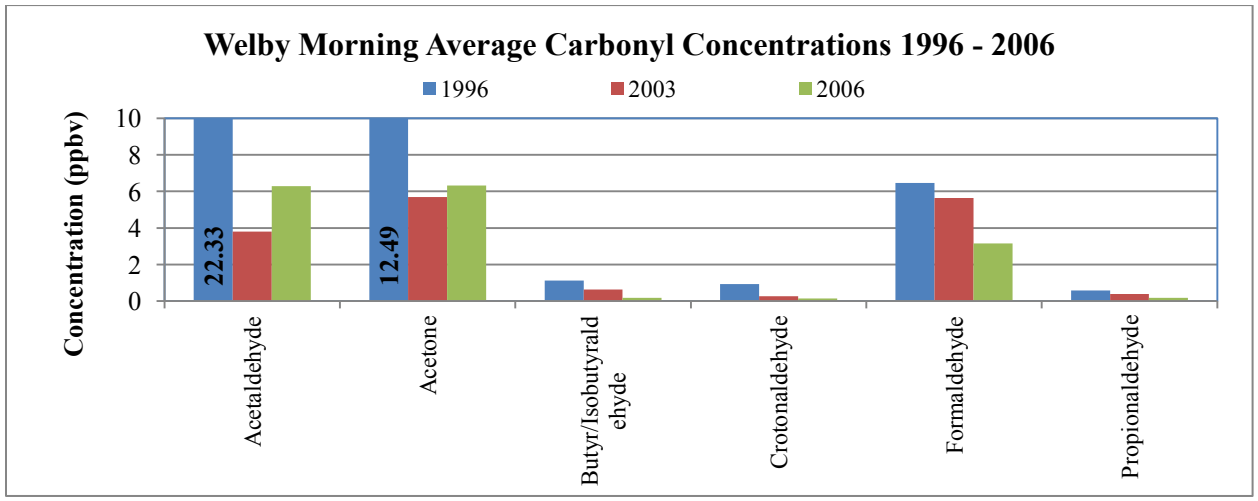

Figure 14. Welby Morning Average Carbonyl Concentrations 1996 – 2006

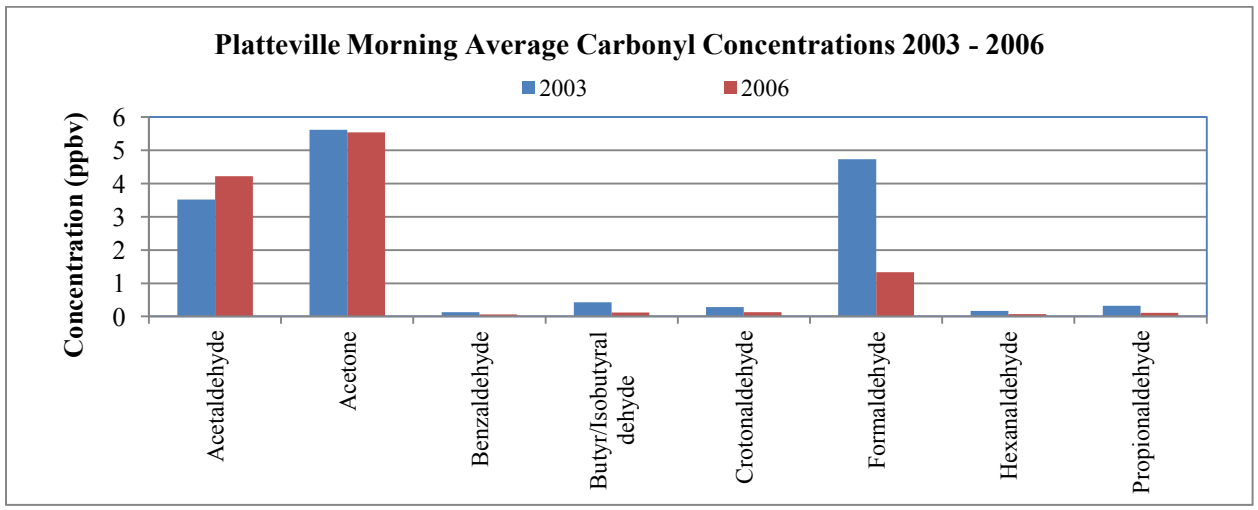

Figure 15. Platteville Morning Average Carbonyl Concentrations 2003 – 2006

The first thing to note about the figures is the scale associated with each. The CAMP and Welby sites both have scales ranging from zero to 10 parts per billion volume (ppbv). However, the scale for the Platteville site is from zero to six ppbv. The acetaldehyde values from 1996 inflate the scales for the CAMP and Welby sites, while there is no data for the Platteville site from 1996. The Welby site had the highest acetone, and acetaldehyde concentrations in the 1996 study.

The concentrations for acetaldehyde in 2003 are comparable at the Welby and Platteville sites, with values of 4.22 ppbv, and 3.80 ppbv, respectively. The acetaldehyde value at the CAMP site was 8.70 ppbv, more than the other two sites combined. Formaldehyde was highest at the CAMP site in 2003, followed by Welby, and Platteville, with values of 10.61, 5.64, and 4.73 ppbv, respectively. The 2003 acetone concentrations at the Platteville and Welby sites were quite similar, with values of just over 5 ppbv. In 2003, the CAMP site had the largest concentration for this compound as well, with a value of 9.62 ppbv.

In 2006, CAMP had the highest acetaldehyde values, followed by Welby, and then Platteville, with concentrations of 8.90, 6.28, and 4.22 ppbv, respectively. The same was true for acetone, with values of 8.00, 6.32, and 5.54 ppbv, at the CAMP, Welby, and Platteville sites, respectively. Formaldehyde exhibited the same trend with the highest values seen at CAMP, followed by Welby, and Platteville, with concentrations of 5.65, 3.16, and 1.33 ppbv, respectively.

2.4.2. NO/NO_2 Comparisons

2.4.2.1. 1996

In 1996, at CAMP and Welby, NOx monitors were in operation at the same time the air toxics sampling was taking place. The data used was gathered from hourly averages obtained from the monitors on site. A correlation between carbonyl concentrations detected in each of the samples taken, and the 3-hour average NO/NO_2 values, from 06:00 to 09:00, was performed. The three-hour average NO/NO_2 concentrations were calculated by taking the hourly mean concentrations from the 06:00, 07:00, and 08:00 hours, and averaging them over the three hour period. This was done for each of the days that the carbonyl samplers were in operation at both sites. In addition, a correlation between the carbonyl concentrations and the daily maximum NO/NO_2 concentrations at each of the sites was performed.

Table 26 shows the correlation values (r) for selected carbonyl compounds with NO/NO_2 values obtained during the 1996 study at the CAMP and Welby sites. Only compounds that were detected in all of the samples taken were used for the correlations. The highlighted cells indicate r values that are larger than 0.7, and smaller than -0.7. At CAMP, acetaldehyde showed a reasonable correlation with the three-hour NO and NO_2 concentrations, with r-values of 0.58, and 0.73. All other compounds showed either no correlation, or negative correlations with the three-hour NOx data. The correlation with the daily maximum NO/NO_2 values showed that formaldehyde had an intermediate correlation with NO, and acetaldehyde had a strong correlation with the NO_2 values. The only other strong correlation seen between the carbonyls and daily maximum NO/NO_2 data was with acetone and NO_2. There was a strong negative correlation between those two compounds, with an r-value of -0.81.

At Welby, only hexanal showed any correlation with the three-hour NO/NO_2 values. It had an r-value of 0.42 with the NO_2 data. In addition, hexanal showed a positive correlation with the NO data, though it was very low, with a value of 0.34. Two of the compounds showed a negative correlation with the three-hour NO_2 data at Welby, acetaldehyde and crotonaldehyde. There were no strong positive or negative correlations with the daily max NO/NO_2 data at Welby.

Table 26. Carbonyl/NO/NO_2 Correlation Values at CAMP and Welby, 1996

	CAMP R-values				Welby R-Values			
	3-hour average		Daily Max		3-hour average		Daily Max	
Compound	NO	NO_2	NO	NO_2	NO	NO_2	NO	NO_2
Acetaldehyde	0.58	0.73	0.06	0.89	-0.13	-0.60	0.17	-0.04
Acetone	-0.61	-0.68	-0.03	-0.81	-0.01	0.23	-0.17	-0.01
Crotonaldehyde	*	*	*	*	-0.34	-0.76	-0.12	-0.44
Formaldehyde	-0.21	-0.19	0.53	-0.26	0.04	0.29	-0.13	0.02
Hexanal	0.03	0.26	-0.02	0.08	0.34	0.42	0.28	0.44
Propionaldehyde	*	*	*	*	0.01	0.15	-0.10	0.03

* = Detected in < 85% of samples taken

2.4.2.2. 2003

In 2003, as in 1996, air toxics sampling was done at two sites where a NOx monitor was in operation, CAMP, and Welby. Table 27 lists the correlation values of the carbonyls with the 3-hour average and daily maximum NO/NO_2 concentrations at the CAMP and Welby sites in 2003. Correlation values that were greater than 0.7, or less than -0.7 are highlighted in the table. The NO/NO_2 values used for the correlation were the three-hour averages from the same time period the air toxics samplers were in operation, 06:00 to 09:00, on the same sample days, and the daily maximum concentration values from the same sample days. At CAMP, acetaldehyde, acetone, and valeraldehyde all correlated well with the three-hour NO concentrations, having r-values of 0.58, 0.60, and 0.63, respectively. With the exceptions of crotonaldehyde, benzaldehyde and the tolualdehydes, the remaining carbonyl compounds showed an intermediate correlation with the three hour averages of NO. This was not the case with the three hour NO_2 average concentrations. None of the carbonyls showed any type of correlation with the three hour average NO_2, with all correlation values being negative. For the daily maximum NO concentration correlations, valeraldehyde, acetaldehyde, and acetone all correlated well. All the carbonyls showed some sort of positive correlation with the daily maximum NO concentrations at CAMP. The daily max NO_2 only had one carbonyl compound that correlated well, which was crotonaldehyde, with an r-value of 0.62.

At Welby, isobutyraldehyde, acetone, and benzaldehyde all showed intermediate to strong correlations with the three hour NO averages, having r-values of 0.58, 0.65, and 0.53. Formaldehyde had a low to intermediate correlation with NO, with a correlation value of 0.49. Isovaleraldehyde showed a slight negative correlation with the gas, while all the other carbonyls had little to no correlation with NO. Unlike the CAMP site, many of the carbonyls at Welby exhibited a strong correlation with the three hour average NO_2 concentrations. Benzaldehyde had the strongest correlation, with an r-value of 0.88. Acetaldehyde and formaldehyde also showed strong correlations, with their r-values of 0.84, and 0.82, respectively. Acetone, crotonaldehyde, hexaldehyde, and propionaldehyde all had intermediate to strong correlations with r-values ranging from 0.54 to 0.71. Isovaleraldehyde showed a slight negative correlation with NO_2, while isobutyraldehyde and the tolualdehydes showed no correlation with the gas. There was little to no correlation between the carbonyls and the daily maximum NO concentrations. The strongest correlation for the daily maximum NO_2 concentrations was with hexaldehyde, having an r-value of 0.72.

Table 27. Carbonyl/NO/NO_2 Correlation Values at CAMP and Welby, 2003

	CAMP				Welby			
	3-Hr. Avgs.		Daily Max		3-Hr. Avgs.		Daily Max	
Compound	NO	NO_2	NO	NO_2	NO	NO_2	NO	NO_2
Acetaldehyde	0.58	-0.64	0.73	0.02	0.43	0.84	0.08	0.70
Acetone	0.60	-0.44	0.76	0.07	0.65	0.71	0.34	0.60
Benzaldehyde	0.16	-0.20	0.10	0.33	0.53	0.88	0.13	0.68
Crotonaldehyde	0.22	-0.15	0.26	0.62	0.16	0.66	-0.22	0.71
Formaldehyde	0.56	-0.35	0.66	0.34	0.49	0.82	0.20	0.69
Hexaldehyde	0.51	-0.36	0.56	0.18	0.19	0.54	-0.19	0.72
Isobutyraldehyde	0.50	-0.62	0.66	0.00	0.58	0.19	0.28	0.19
Isovaleraldehyde	*	*	*	*	-0.24	-0.09	-0.43	0.35
Propionaldehyde	0.49	-0.46	0.61	0.03	0.10	0.55	-0.14	0.61
Tolualdehydes	0.24	-0.26	0.28	-0.50	0.00	0.02	-0.29	0.19
Valeraldehyde	0.63	-0.47	0.76	-0.02	0.10	0.56	-0.03	0.59

* = Detected in < 85% of samples taken

2.4.2.3. 2006

In 2006, only two of the sampling sites had continuous gaseous monitors in operation during the air toxics sampling study. These were the CAMP and Welby sites, and both had NO/NO_2 monitors in operation. Table 28 lists the correlation values for the carbonyls with both the three hour average NO/NO_2 concentrations, and the daily maximum NO/NO_2 concentrations observed at the sites on the same days the air toxics were being sampled.

At CAMP, there were no strong correlations between either the NO, or NO_2 data, and the carbonyl data, for either the 3-hour averages, or the daily maximum concentrations. The highest correlation for the three-hour average data fell with acetaldehyde, having an r-value of 0.47. For the daily maximum NO/NO_2 data at CAMP, valeraldehyde

correlated the best with both NO and NO_2, with r-values of 0.52, and 0.51, respectively.

At Welby, only three compounds were detected in all the samples taken during the study. These were acetaldehyde, acetone, and formaldehyde. None of the compounds exhibited any correlation with either the three-hour average, or daily maximum NO/NO_2 data.

Table 28. Carbonyl/NO/NO_2 Correlation Values at CAMP and Welby, 2006

	CAMP Correlation Values				Welby Correlation Values			
	3-hour Average		Daily Maximum		3-hour Average		Daily Maximum	
Compound	NO	NO_2	NO	NO_2	NO	NO_2	NO	NO_2
Acetaldehyde	0.35	0.47	0.24	0.43	0.15	0.22	0.20	0.24
Acetone	0.25	0.29	0.00	0.07	-0.11	0.09	0.00	0.21
Benzaldehyde	-0.15	-0.15	0.25	0.27	*	*	*	*
Butyraldehyde	-0.27	-0.38	0.03	-0.14	*	*	*	*
Crotonaldehyde	0.02	0.16	-0.02	0.05	*	*	*	*
Formaldehyde	-0.09	-0.12	0.23	0.20	0.22	0.35	0.32	0.32
Hexaldehyde	0.10	0.11	0.40	0.42	*	*	*	*
Propionaldehyde	-0.18	-0.19	0.06	0.04	*	*	*	*
Valeraldehyde	0.29	0.21	0.52	0.51	*	*	*	*

* = Detected in < 85% of samples taken

3.0 NMOCs/VOCs

During the three studies, NMOC/VOC samples were taken at various sites around the Denver Metro area. This group of compounds is much larger than the twelve carbonyl compounds. During the 1996 study, a total of 115 compounds were measured. In 2003 and 2006, that list was pared down to 77, based on the number of compounds not detected in the 1996 study. In comparison, the EPA's National Air Toxics Trends Station (NATTS) network monitors for 58 compounds. Of those 58 compounds, eight are considered to be "priority compounds" because they are major health risk drivers, based on a relative ranking performed by the EPA.[2] They are 1,3-butadiene, acrolein, benzene, carbon tetrachloride, chloroform, tetrachloroethylene, trichloroethylene, and vinyl chloride.

1,3-Butadiene is a hydrocarbon compound with the formula C_4H_6. It exists in the atmosphere as a colorless gas with an odor similar to gasoline. Most emissions of 1,3-butadiene come from combustion of fuels in diesel and gas-powered motor vehicles. Other sources include petroleum refining, tire wear, residential wood heating, and forest fires. Rubber and chemical production plants also have emissions.

Acrolein is a hydrocarbon compound with the formula C_3H_4O. It is a colorless or yellow liquid with a disagreeable odor. It dissolved in water very easily, and quickly changes to a vapor when heated. Small amounts of acrolein can be formed, and can enter the air when trees, tobacco, other plants, gasoline, and oil are burned. Acrolein is used as a pesticide to control algae, weeds, bacteria, and mollusks. It breaks down rapidly in air by reacting with other chemicals and sunlight.

Benzene is a hydrocarbon compound with the formula C_6H_6. It exists in the atmosphere as a colorless gas with a sweet odor. The largest sources of benzene in ambient air are automobiles, gasoline service stations, refineries, and chemical plants. Burning of vegetative matter in forest fires and woodstoves is also a source. In ambient air, benzene readily reacts with hydroxyl (OH^-) radicals within a few hours. Since hydroxyl radicals are common in outdoor air, this chemical transformation prevents the build-up of large concentrations of benzene.

Carbon tetrachloride, also known as tetrachloromethane or methane tetrachloride, is a chlorinated hydrocarbon with the formula CCl_4. It exists in the atmosphere as a gas. It has a sweet odor. The primary uses of carbon tetrachloride were as a dry cleaning solvent, a grain fumigant, as a refrigerant, and as an aerosol propellant. Carbon tetrachloride has a long atmospheric half-life, so it can travel to the higher reaches of the atmosphere and damage the

[2] Technical Assistance Document for the National Air Toxics Trends Stations Program." US Environmental Protection Agency. April 1, 2009. http://www.epa.gov/ttnamti1/files/ambient/airtox/nattsTADRevision2_508Compliant.pdf

earth's ozone layer. Due to its toxicity and ozone-damaging qualities, most uses of carbon tetrachloride have been banned. It is still in use in industrial settings for producing refrigerants.

Chloroform is also known as trichloromethane, or methyltrichloride. It is a colorless liquid with a pleasant, nonirritating odor, and a slightly sweet taste. Most of the chloroform found in the environment comes from industry. It will only burn at very high temperatures. It enters the environment from chemical companies and paper mills. It is also found in waste water from sewage treatment plants, and drinking water to which chlorine has been added.

Tetrachloroethylene, also known as perchloroethylene, is a chlorinated hydrocarbon with the formula C_2Cl_4. It exists in the atmosphere as a gas. It has a sweet, "chloroform-like" odor. The primary uses of tetrachloroethylene are as a dry cleaning solvent, metal cleaning solvent, or for chemical production. Tetrachloroethylene is used in paints, inks, aerosols, glues, polishes, silicones and rubber products. Most emissions of tetrachloroethylene come from degreasing, dry cleaning, or chemical production facilities.

Trichloroethylene is a nonflammable, colorless liquid at room temperature, with a somewhat sweet odor, and a sweet, burning taste. It is mainly used as a solvent to remove grease from metal parts. It is also used as a solvent in other ways, and is used to make other chemicals. It can also be found in some household products, including paint removers, adhesives, and spot removers.

Vinyl chloride is also known as chloroethene, or chloroethylene. At room temperature, it is a colorless gas, it burns easily, and it is not stable at high temperatures. Vinyl chloride exists in liquid form if kept under high pressure or at low temperatures. It has a mild, sweet odor. It is a manufactured substance that does not occur naturally. It is mainly used in the production of polyvinyl chloride (PVC) polymers.

3.1 *1996 Data*

For the NMOC/VOC part of the 1996 study, two different analytical methods were used. Federal Method TO-12 was used for the analysis of 77 compounds on all sample days, and Method TO-14 was used for the analysis of 38 compounds on five of the sample days. Ten of the 115 compounds were able to be analyzed via both methods. The compounds were 1,3-butadiene, acetylene, benzene, Ethylbenzene, m-xylene/p-xylene, n-octane, o-xylene, propylene, styrene, and toluene. Both analytical methods were used in an effort to fully characterize the Front Range air mass.

Table 29 lists the average and maximum NMOC concentrations measured via EPA Method TO-12 at CAMP in 1996. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in 85% or more of the samples taken, and therefore the average is dependent upon the respective compound's MDL. Compounds that were not detected in 85% or more of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority compounds are bolded in the table below. Seventeen of the 77 compounds were not detected in at least one of the samples taken.

Table 29. Method TO-12 Average and Maximum NMOC/VOC Concentrations at CAMP, 1996

Analyte	1996 Avg. (ppbv)	1996 Max. (ppbv)	# of Samples	# of Non-Detects	Analyte	1996 Avg. (ppbv)	1996 Max. (ppbv)	# of Samples	# of Non-Detects
1,2,3-Trimethylbenzene	0.20	0.51	33	0	Cyclohexane	0.40	0.75	33	0
1,2,4-Trimethylbenzene	0.94	2.25	33	0	Cyclopentane	0.35	0.72	31	0
1,3,5-Trimethylbenzene	0.35	0.94	33	0	Cyclopentene	0.09	0.22	31	1
1,3-Butadiene	***0.33***	***3.93***	***33***	***8***	Ethylbenzene	0.68	1.34	33	0
1-Decene	0.25	1.15	33	3	Ethylene	7.95	18.09	33	0
1-Dodecene	0.18	0.70	33	0	Isobutane	1.81	5.28	33	0
1-Heptene	0.22	0.44	32	1	Isobutene/1-Butene	1.08	5.39	33	0
1-Hexene	*0.14*	*0.32*	*31*	*12*	Isopentane	7.55	19.25	29	0
1-Nonene	0.06	0.26	33	1	Isoprene	0.20	0.56	32	1
1-Octene	0.10	0.21	33	0	Isopropylbenzene	0.04	0.26	33	1
1-Pentene	0.21	0.46	31	0	m-Diethylbenzene	0.17	0.35	33	0
1-Tridecene	0.52	1.04	32	5	Methylcyclohexane	0.52	1.03	33	0
1-Undecene	0.36	2.13	33	0	Methylcyclopentane	0.87	1.65	32	0
2,2,3-Trimethylpentane	0.21	0.44	33	0	m-Ethyltoluene	0.65	1.88	33	0
2,2,4-Trimethylpentane	0.85	1.69	32	0	m-Xylene/p-Xylene	2.43	4.74	33	0

Analyte	1996 Avg. (ppbv)	1996 Max. (ppbv)	# of Samples	# of Non-Detects	Analyte	1996 Avg. (ppbv)	1996 Max. (ppbv)	# of Samples	# of Non-Detects
2,2-Dimethylbutane	0.27	0.60	32	0	n-Butane	4.04	9.77	33	1
2,3,4-Trimethylpentane	0.28	0.62	33	0	n-Decane	0.20	0.51	33	0
2,3-Dimethylbutane	0.52	1.03	32	0	n-Dodecane	0.10	0.22	33	0
2,3-Dimethylpentane	0.47	0.94	33	0	n-Heptane	0.67	1.40	33	0
2,4-Dimethylpentane	0.32	0.65	33	0	n-Hexane	1.84	3.48	33	0
2-Ethyl-1-butene	*0.18*	*0.18*	*33*	*33*	n-Nonane	0.14	0.29	33	0
2-Methyl-1-butene	0.32	0.90	31	0	n-Octane	0.27	0.50	33	0
2-Methyl-1-pentene	0.12	0.38	31	0	n-Pentane	4.59	10.06	31	0
2-Methyl-2-Butene	0.52	1.47	32	0	n-Propylbenzene	0.19	0.58	33	0
2-Methylheptane	0.27	0.75	33	0	n-Tridecane	1.76	3.87	31	0
2-Methylhexane	0.73	1.62	33	0	n-Undecane	0.25	0.55	33	0
2-Methylpentane	2.23	4.77	31	0	o-Ethyltoluene	0.26	0.76	33	0
3-Methyl-1-butene	0.07	0.31	32	1	o-Xylene	0.87	1.66	33	0
3-Methylheptane	0.28	0.64	33	0	p-Diethylbenzene	0.28	0.56	33	0
3-Methylhexane	0.91	1.70	33	0	p-Ethyltoluene	0.28	0.88	33	0
3-Methylpentane	1.37	2.88	32	0	Propane	4.84	14.19	33	0
4-Methyl-1-pentene	0.09	0.21	31	1	Propylene	2.52	5.46	33	0
Acetylene / Ethane	14.04	29.95	33	0	*Propyne*	*0.06*	*0.16*	*33*	*30*
a-Pinene	0.16	0.56	33	0	Styrene	0.26	0.84	33	0
Benzene	**2.20**	**4.09**	**33**	**0**	Toluene	4.72	8.79	33	0
b-Pinene	0.18	1.44	33	4	trans-2-Butene	0.31	0.73	31	1
cis-2-Butene	0.24	0.50	31	1	trans-2-Hexene	0.11	0.34	33	0
cis-2-Hexene	0.07	0.18	33	0	trans-2-Pentene	0.42	1.16	32	0
cis-2-Pentene	0.24	0.73	31	0	**Bold = Priority Compound,** *Italic = Detected in <85% of samples*				

Table 30 lists the average and maximum NMOC concentrations measured via EPA Method TO-14 at CAMP in 1996. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and therefore the average is dependent upon the respective compound's MDL. Compounds that were not detected in greater than 85% of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority compounds are bolded in the table below. Twenty-three of the 38 compounds were not detected in at least one of the samples taken.

Table 30. Method TO-14 Average and Maximum VOC/NMOC Concentrations at CAMP, 1996

Compound	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-Detects
1,1,1-Trichloroethane	0.20	0.30	5	0
1,1,2,2-Tetrachloroethane	*0.08*	*0.08*	*5*	*5*
1,1,2-Trichloroethane	*0.03*	*0.03*	*5*	*5*
1,1-Dichloroethane	*0.03*	*0.03*	*5*	*5*
1,1-Dichloroethene	*0.05*	*0.05*	*5*	*5*
1,2-Dichloroethane	*0.13*	*0.13*	*5*	*5*
1,2-Dichloropropane	*0.02*	*0.02*	*5*	*5*
1,3-Butadiene	***0.34***	***0.61***	***5***	***1***
Acetylene	8.87	16.63	5	0
Benzene	**2.05**	**3.57**	**5**	**0**
Bromochloromethane	*0.04*	*0.04*	*5*	*5*
Bromodichloromethane	*0.05*	*0.05*	*5*	*5*
Bromoform	*0.04*	*0.04*	*5*	*4*
Bromomethane	*0.09*	*0.09*	*5*	*4*
Carbon tetrachloride	**0.10**	**0.10**	**5**	**0**

Compound	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-Detects
Chlorobenzene	*0.03*	*0.03*	*5*	*5*
Chloroethane	*0.09*	*0.09*	*5*	*5*
Chloroform	**0.06**	**0.10**	**5**	**0**
Chloromethane	0.53	0.60	5	0
Chloroprene	*0.03*	*0.03*	*5*	*5*
cis-1,3-Dichloropropene	*0.03*	*0.03*	*5*	*5*
Dibromochloromethane	*0.03*	*0.03*	*5*	*5*
Ethylbenzene	0.60	1.05	5	0
m-Dichlorobenzene	*0.03*	*0.04*	*5*	*4*
Methylene chloride	0.35	0.47	5	0
m-Xylene / p-Xylene	2.25	3.85	5	0
n-Octane	0.26	0.42	5	0
o-Dichlorobenzene	*0.03*	*0.04*	*5*	*3*
o-Xylene	0.79	1.32	5	0
p-Dichlorobenzene	*0.06*	*0.10*	*5*	*1*
Propylene	2.56	4.66	5	0
Styrene	1.00	1.79	5	0
Tetrachloroethylene	**0.19**	**0.40**	**5**	**0**
Toluene	4.52	7.67	5	0
trans-1,2-Dichloroethylene	*0.11*	*0.11*	*5*	*5*
trans-1,3-Dichloropropene	*0.04*	*0.04*	*5*	*5*
Trichloroethylene	***0.04***	***0.06***	***5***	***1***
Vinyl chloride	***0.06***	***0.06***	***5***	***5***

Bold = Priority Compound
Italic = Detected in <85% of samples taken

A comparison of nine of the ten compounds found in both analyses is shown in the figure below. The tenth compound, acetylene, was not used in the comparison because it co-eluted with ethane in the TO-12 analytical method, but did not in the TO-14 method. The results are similar for all compounds. It should be noted here that 1,3-butadiene was not detected in all the samples for both of the analytical methods, while the rest of the compounds were detected in all samples.

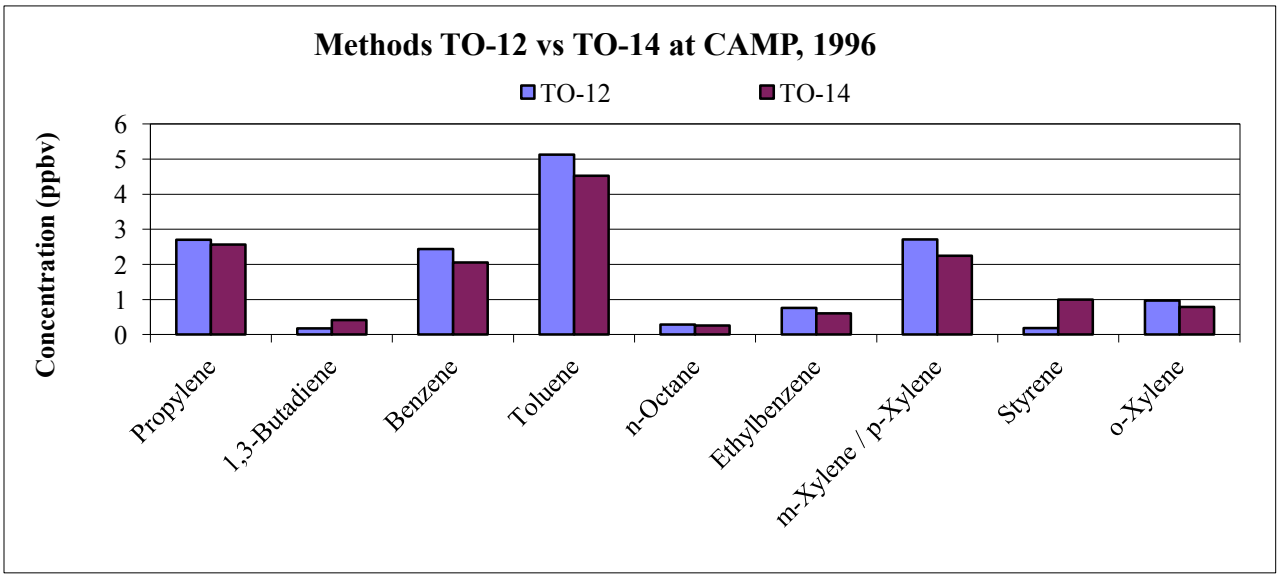

Figure 16. TO-12 vs. TO-14 at CAMP, 1996

Table 31 lists the average and maximum NMOC concentrations measured via EPA Method TO-12 at Welby in 1996. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in 85% or more of the samples taken, and therefore the average is largely dependent upon the respective compound's MDL. Compounds that were not detected in 85% or more of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority compounds are bolded in the table below. Twenty-four of the 77 compounds were not detected in at least one of the samples taken.

Table 31. TO-12 NMOC/VOC Average and Maximum Concentrations at Welby, 1996

Analyte	Avg. (ppbv)	Max. (ppbv)	# of Samples	# of Non-Detects	Analyte	Avg. (ppbv)	Max (ppbv)	# of Samples	# of Non-Detects
1,2,3-Trimethylbenzene	0.22	0.59	35	0	Cyclohexane	0.41	1.12	35	0
1,2,4-Trimethylbenzene	0.67	2.31	35	0	Cyclopentane	0.33	0.99	33	1
1,3,5-Trimethylbenzene	0.24	0.78	35	1	Cyclopentene	0.07	0.25	33	4
1,3-Butadiene	***0.15***	***0.80***	***35***	***15***	Ethylbenzene	0.52	1.70	35	0
1-Decene	0.25	0.79	35	4	Ethylene	5.67	15.39	34	0
1-Dodecene	0.19	0.66	35	0	Isobutane	2.33	5.87	35	1
1-Heptene	0.17	0.58	35	0	Isobutene / 1-Butene	1.32	3.03	35	0
1-Hexene	*0.15*	*0.31*	*34*	*17*	Isopentane	8.72	23.68	32	0
1-Nonene	0.04	0.15	35	0	Isoprene	0.23	0.53	31	1
1-Octene	0.08	0.33	34	0	Isopropylbenzene	0.05	0.26	35	3
1-Pentene	0.43	1.52	32	1	m-Diethylbenzene	0.14	0.45	35	1
1-Tridecene	0.05	0.18	35	3	Methylcyclohexane	0.41	1.20	35	0
1-Undecene	0.42	2.28	35	0	Methylcyclopentane	1.25	6.63	35	0
2,2,3-Trimethylpentane	0.16	0.48	35	0	m-Ethyltoluene	0.44	1.46	35	0
2,2,4-Trimethylpentane	0.71	2.28	35	0	m-Xylene / p-Xylene	1.79	6.28	35	0
2,2-Dimethylbutane	0.23	0.71	32	0	n-Butane	5.39	12.65	35	0
2,3,4-Trimethylpentane	0.20	0.69	35	0	n-Decane	0.18	0.47	35	0
2,3-Dimethylbutane	0.47	1.56	32	0	n-Dodecane	0.29	1.34	35	0
2,3-Dimethylpentane	0.36	0.96	35	0	n-Heptane	0.53	1.57	35	0
2,4-Dimethylpentane	0.27	0.90	34	0	n-Hexane	5.00	45.28	34	0
2-Ethyl-1-butene	*0.17*	*0.18*	*34*	*33*	n-Nonane	0.12	0.35	35	0
2-Methyl-1-butene	0.31	0.94	32	0	n-Octane	0.22	0.76	35	0
2-Methyl-1-pentene	0.09	0.28	34	1	n-Pentane	4.73	11.96	31	0
2-Methyl-2-Butene	0.43	1.57	32	0	n-Propylbenzene	0.14	0.41	35	1
2-Methylheptane	0.21	0.68	35	0	n-Tridecane	0.15	0.34	35	0
2-Methylhexane	0.59	1.86	35	0	n-Undecane	0.33	1.16	35	0
2-Methylpentane	2.03	6.34	32	0	o-Ethyltoluene	0.18	0.62	35	0
3-Methyl-1-butene	*0.07*	*0.22*	*33*	*6*	o-Xylene	0.68	2.15	35	0
3-Methylheptane	0.22	0.73	35	0	p-Diethylbenzene	0.21	0.52	35	0
3-Methylhexane	0.81	2.02	35	0	p-Ethyltoluene	0.19	0.55	35	0
3-Methylpentane	1.39	3.98	34	0	Propane	6.89	17.25	34	0
4-Methyl-1-pentene	0.10	0.28	33	4	Propylene	2.48	8.44	34	0
Acetylene / Ethane	14.82	29.62	34	0	*Propyne*	*0.06*	*0.15*	*34*	*32*
a-Pinene	0.16	0.38	35	0	Styrene	0.25	0.83	35	0
Benzene	**1.63**	**5.61**	**35**	**0**	Toluene	3.64	11.57	35	0
b-Pinene	0.21	1.33	35	1	trans-2-Butene	0.31	1.04	35	2
cis-2-Butene	0.23	0.70	35	2	trans-2-Hexene	0.10	0.27	34	2
cis-2-Hexene	0.07	0.25	35	3	trans-2-Pentene	0.42	1.47	33	1
cis-2-Pentene	0.22	0.70	32	0	**Bold = Priority Compound,** *Italic = Detected in <85% of samples*				

Table 32 lists the average and maximum NMOC concentrations measured via EPA Method TO-14 at Welby in 1996. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and therefore the average is dependent upon the respective compound's MDL. Compounds that were not detected in greater than 85% of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority

compounds are bolded in the table below. Twenty-one of the 38 compounds were not detected in at least one of the samples taken.

Table 32. TO-14 NMOC/VOC Average and Maximum Concentrations at Welby, 1996

Compound	Average (ppbv)	Maximum (ppbv)	# of Samples	# of Non-Detects
1,1,1-Trichloroethane	0.81	0.96	5	0
1,1,2,2-Tetrachloroethane	*0.08*	*0.08*	*5*	*5*
1,1,2-Trichloroethane	*0.03*	*0.03*	*5*	*5*
1,1-Dichloroethane	*0.03*	*0.03*	*5*	*5*
1,1-Dichloroethene	*0.05*	*0.05*	*5*	*5*
1,2-Dichloroethane	*0.13*	*0.13*	*5*	*5*
1,2-Dichloropropane	*0.02*	*0.02*	*5*	*5*
1,3-Butadiene	**0.36**	**0.76**	**5**	**0**
Acetylene	9.28	19.59	5	0
Benzene	**2.43**	**4.73**	**5**	**0**
Bromochloromethane	*0.05*	*0.11*	*5*	*4*
Bromodichloromethane	*0.07*	*0.16*	*5*	*4*
Bromoform	*0.04*	*0.04*	*5*	*4*
Bromomethane	*0.09*	*0.09*	*5*	*5*
Carbon tetrachloride	**0.10**	**0.10**	**5**	**0**
Chlorobenzene	*0.03*	*0.03*	*5*	*5*
Chloroethane	*0.09*	*0.09*	*5*	*5*
Chloroform	**0.09**	**0.14**	**5**	**0**
Chloromethane	0.59	0.63	5	0
Chloroprene	*0.03*	*0.03*	*5*	*5*
cis-1,3-Dichloropropene	*0.03*	*0.03*	*5*	*5*
Dibromochloromethane	*0.03*	*0.06*	*5*	*4*
Ethylbenzene	0.71	1.44	5	0
m-Dichlorobenzene	*0.04*	*0.04*	*5*	*5*
Methylene chloride	0.52	0.73	5	0
m-Xylene / p-Xylene	2.60	5.27	5	0
n-Octane	0.28	0.56	5	0
o-Dichlorobenzene	*0.04*	*0.04*	*5*	*5*
o-Xylene	0.99	1.79	5	0
p-Dichlorobenzene	0.09	0.21	5	0
Propylene	3.07	5.87	5	0
Styrene	1.73	2.71	5	0
Tetrachloroethylene	**0.11**	**0.17**	**5**	**0**
Toluene	5.38	10.11	5	0
trans-1,2-Dichloroethylene	*0.11*	*0.11*	*5*	*5*
trans-1,3-Dichloropropene	*0.04*	*0.04*	*5*	*5*
Trichloroethylene	***0.04***	***0.06***	***5***	***1***
Vinyl chloride	***0.06***	***0.06***	***5***	***5***

Bold = Priority Compound
Italic = Detected in <85% of samples taken

A comparison of nine of the ten compounds found in both analyses is shown in the figure below. The tenth compound, acetylene, was not used in the comparison because it co-eluted with ethane in the TO-12 analytical method, but did not in the TO-14 method. The results are similar for all compounds.

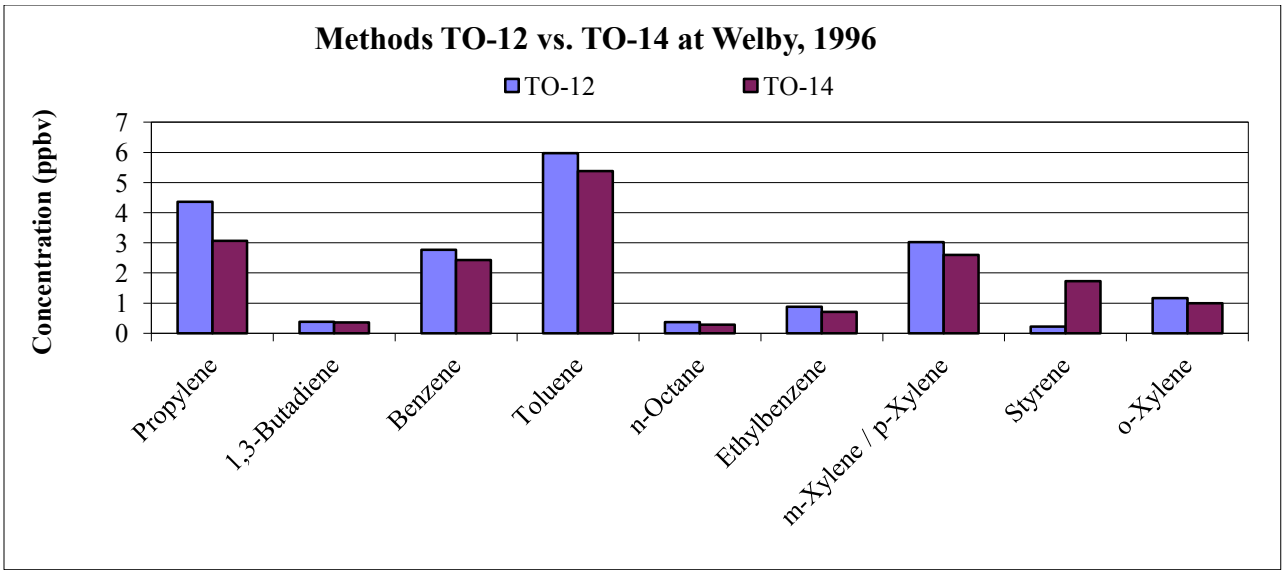

Figure 17. TO-12 vs. TO-14 Concentration Comparison at Welby, 1996

Table 33 lists the average and maximum NMOC concentrations measured via EPA Method TO-12 at Rocky Flats - North in 1996. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and therefore the average is largely dependent upon the respective compound's MDL. Compounds that were not detected in greater than 85% of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Those compounds are bolded in the table below. Thirty-four of the 77 compounds were not detected in at least one of the samples taken. TO-12 and TO-14 comparison sampling was not performed at the Rocky Flats – North sites, only at the CAMP and Welby sites.

Table 33. TO-12 NMOC/VOC Concentrations at Rocky Flats – North, 1996

Analyte	Avg. (ppbv)	Max. (ppbv)	# of Samples	# of Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# of Samples	# of Non-Detects
1,2,3-Trimethylbenzene	0.16	0.71	12	0	Cyclohexane	0.07	0.32	12	0
1,2,4-Trimethylbenzene	0.37	1.14	12	0	Cyclopentane	0.06	0.17	12	1
1,3,5-Trimethylbenzene	0.02	0.04	12	0	*Cyclopentene*	*0.05*	*0.12*	*12*	*2*
1,3-Butadiene	***0.03***	***0.03***	***12***	***12***	Ethylbenzene	0.07	0.13	12	0
1-Decene	0.08	0.24	12	0	Ethylene	0.65	1.76	12	0
1-Dodecene	0.13	0.29	12	0	Isobutane	0.70	3.60	12	0
1-Heptene	*0.09*	*0.27*	*12*	*3*	Isobutene / 1-Butene	0.51	1.00	12	0
1-Hexene	*0.16*	*0.18*	*12*	*11*	Isopentane	1.53	4.65	12	0
1-Nonene	*0.08*	*0.26*	*12*	*3*	*Isoprene*	*0.07*	*0.36*	*12*	*5*
1-Octene	0.02	0.03	12	0	*Isopropylbenzene*	*0.09*	*0.26*	*12*	*3*
1-Pentene	*0.03*	*0.04*	*12*	*6*	m-Diethylbenzene	0.06	0.23	12	1
1-Tridecene	0.05	0.18	12	1	Methylcyclohexane	0.11	0.34	12	0
1-Undecene	0.29	0.95	12	0	Methylcyclopentane	0.15	0.56	12	0
2,2,3-Trimethylpentane	0.03	0.09	12	0	m-Ethyltoluene	0.05	0.09	12	0
2,2,4-Trimethylpentane	0.11	0.30	12	1	m-Xylene / p-Xylene	0.15	0.31	12	0
2,2-Dimethylbutane	*0.07*	*0.18*	*12*	*2*	n-Butane	1.62	8.13	12	1
2,3,4-Trimethylpentane	*0.08*	*0.30*	*12*	*2*	n-Decane	0.07	0.20	12	0
2,3-Dimethylbutane	0.10	0.22	12	0	n-Dodecane	0.26	0.82	12	0
2,3-Dimethylpentane	0.05	0.13	12	0	n-Heptane	0.09	0.35	12	0
2,4-Dimethylpentane	0.06	0.14	12	0	n-Hexane	0.29	1.11	12	0
2-Ethyl-1-butene	*0.18*	*0.18*	*12*	*12*	*n-Nonane*	*0.08*	*0.26*	*12*	*2*
2-Methyl-1-butene	*0.03*	*0.04*	*12*	*5*	n-Octane	0.06	0.22	12	0

Analyte	Avg. (ppbv)	Max. (ppbv)	# of Samples	# of Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# of Samples	# of Non-Detects
2-Methyl-1-pentene	*0.06*	*0.18*	*12*	*3*	n-Pentane	0.83	3.24	12	0
2-Methyl-2-Butene	*0.04*	*0.10*	*12*	*4*	n-Propylbenzene	0.04	0.26	12	1
2-Methylheptane	0.04	0.10	12	0	n-Tridecane	0.10	0.25	12	0
2-Methylhexane	0.09	0.22	12	0	n-Undecane	0.27	0.87	12	0
2-Methylpentane	0.51	0.92	12	0	o-Ethyltoluene	0.03	0.06	12	0
3-Methyl-1-butene	*0.11*	*0.81*	*12*	*9*	o-Xylene	0.07	0.12	12	0
3-Methylheptane	0.06	0.30	12	1	p-Diethylbenzene	0.09	0.23	12	1
3-Methylhexane	0.23	0.67	12	0	p-Ethyltoluene	0.03	0.09	12	0
3-Methylpentane	0.19	0.56	12	0	Propane	2.94	14.04	12	0
4-Methyl-1-pentene	*0.14*	*0.18*	*12*	*8*	*Propylene*	*0.41*	*2.52*	*12*	*2*
Acetylene / Ethane	4.68	18.22	12	0	*Propyne*	*0.05*	*0.05*	*12*	*12*
a-Pinene	0.14	0.21	12	0	Styrene	0.13	0.31	12	0
Benzene	**0.25**	**0.51**	**12**	**0**	Toluene	0.43	1.19	12	0
b-Pinene	*0.22*	*0.84*	*12*	*2*	*trans-2-Butene*	*0.04*	*0.19*	*12*	*10*
cis-2-Butene	*0.02*	*0.03*	*12*	*10*	*trans-2-Hexene*	*0.11*	*0.18*	*12*	*7*
cis-2-Hexene	*0.14*	*0.18*	*12*	*9*	*trans-2-Pentene*	*0.04*	*0.07*	*12*	*5*
cis-2-Pentene	*0.03*	*0.04*	*12*	*6*	**Bold = Priority Compound**, *Italic = Detected in <85% of samples*				

The final table in this section lists the average and maximum concentrations of speciated NMOCs (SNMOCs), total NMOCs (TNMOCs), and unknowns. The unknown concentration is obtained by subtracting the concentration of SNMOCs from the TNMOC concentration. The SNMOC concentration is obtained by summing the concentrations of each of the speciated compound concentrations. The TNMOC concentration is obtained via lab analysis. The percentages in red indicate the percent contribution of the unknown and SNMOC concentrations to the overall TNMOC concentration. The CAMP and Welby sites show much larger maximums and averages for the TNMOC and SNMOC concentrations than the Rocky Flats – North site.

Table 34. Average and Maximum Total NMOC Concentrations at All Sites, 1996

	CAMP			Welby			Rocky Flats - North		
	TNMOC	SNMOC	UNKNOWN	TNMOC	SNMOC	UNKNOWN	TNMOC	SNMOC	UNKNOWN
Averages (ppbC)	498	388 (78%)	110 (22%)	518	388 (75%)	130 (25%)	169	92 (54%)	77 (46%)
Maximums (ppbC)	984	798 (81%)	185 (19%)	1164	998 (86%)	166 (14%)	358	276 (77%)	147 (41%)

3.2 *2003 Data*

The 2003study was conducted from August 8, 2003 through September 9, 2003. Three hour samples were taken during both the morning and afternoon hours for this study. The morning samples ran from 06:00 to 09:00, and the afternoon samples ran from 13:00 to 16:00. A total of five sites were used during the sampling period. The CAMP and Welby sites were used throughout the duration of the study, while the Platteville, Chatfield, and NREL sites had a sampler rotated between them. Each of those three sites had the sampler for a total of eight days, with samples being taken approximately every two days.

At CAMP, a total of 24 samples were taken overall. At Welby, only 22 samples were taken overall, as two samples were missed. At the remaining three sites, NREL, Platteville, and Chatfield, seven, eight, and eight samples were taken, respectively. One sample was missed at NREL. Table 35 lists the average and maximum NMOC concentrations measured at CAMP in 2003. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and therefore the average is largely dependent upon the respective compound's MDL. Compounds that were not detected in greater than 85% of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority compounds are bolded in the table below. Twenty-two of the 78 compounds were not detected in at least one of the samples taken. In the 1996 analyses, ethane and acetylene co-eluted from the gas

chromatograph column, meaning that they could not be detected as separate compounds. Thus, the concentrations listed in 1996 are unable to be separated out. For the 2003 analyses, the analysis technology improved, and ethane and acetylene have separate concentrations listed.

Both of the priority compounds, benzene and 1,3-butadiene, were detected in all samples taken. Fifty of the 62 compounds that were detected in greater than 85% of the samples taken had average concentrations that were higher in the morning hours than in the afternoon hours. The highest concentrations were detected among the alkane compounds.

Table 35. AM and PM NMOC/VOC Concentrations at CAMP, 2003

	AM		PM			
Compound	**Avg. (ppbv)**	**Max. (ppbv)**	**Avg. (ppbv)**	**Max. (ppbv)**	**# Samples**	**# Non-Detects**
1,2,3-Trimethylbenzene	0.08	0.13	0.07	0.14	24	0
1,2,4-Trimethylbenzene	0.48	0.75	0.30	0.46	24	0
1,3,5-Trimethylbenzene	0.16	0.24	0.10	0.16	24	0
1,3-Butadiene	**0.20**	**0.30**	**0.10**	**0.17**	**24**	**0**
1-Decene	*0.01*	*0.01*	*0.01*	*0.01*	*24*	*24*
1-Dodecene	0.05	0.13	0.03	0.05	24	2
1-Heptene	*0.06*	*0.11*	*0.04*	*0.06*	*24*	*6*
1-Hexene	0.10	0.14	0.08	0.11	24	0
1-Nonene	*0.02*	*0.05*	*0.01*	*0.02*	*24*	*10*
1-Octene	*0.01*	*0.02*	*0.01*	*0.01*	*24*	*23*
1-Pentene	0.17	0.25	0.18	0.32	24	0
1-Tridecene	*0.02*	*0.02*	*0.02*	*0.02*	*24*	*24*
1-Undecene	*0.01*	*0.01*	*0.01*	*0.01*	*24*	*24*
2,2,3-Trimethylpentane	0.11	0.17	0.06	0.08	24	0
2,2,4-Trimethylpentane	0.47	0.67	0.32	0.48	24	0
2,2-Dimethylbutane	0.29	0.44	0.28	0.46	24	0
2,3,4-Trimethylpentane	0.14	0.20	0.09	0.11	24	0
2,3-Dimethylbutane	0.43	0.55	0.37	0.60	24	0
2,3-Dimethylpentane	0.34	0.48	0.23	0.32	24	0
2,4-Dimethylpentane	0.24	0.34	0.17	0.26	24	0
2-Ethyl-1-butene	*0.02*	*0.02*	*0.02*	*0.02*	*24*	*24*
2-Methyl-1-butene	0.25	0.41	0.30	0.59	24	0
2-Methyl-1-pentene	*0.04*	*0.06*	*0.03*	*0.07*	*24*	*5*
2-Methyl-2-butene	0.28	0.40	0.32	0.62	24	0
2-Methylheptane	0.12	0.18	0.07	0.10	24	0
2-Methylhexane	0.45	0.69	0.30	0.45	24	0
2-Methylpentane	1.61	2.20	1.39	2.40	24	0
3-Methyl-1-butene	*0.02*	*0.02*	*0.02*	*0.02*	*24*	*24*
3-Methylheptane	0.13	0.18	0.08	0.11	24	0
3-Methylhexane	0.50	0.76	0.35	0.59	24	0
3-Methylpentane	0.91	1.24	0.72	1.26	24	0
4-Methyl-1-pentene	*0.02*	*0.03*	*0.02*	*0.03*	*24*	*16*
Acetylene	4.57	7.64	2.22	3.61	24	0
a-Pinene	0.10	0.21	0.08	0.19	24	0
Benzene	**2.41**	**3.94**	**2.04**	**3.55**	**24**	**0**
b-Pinene	*0.02*	*0.06*	*0.02*	*0.14*	*24*	*20*
cis-2-Butene	0.25	0.33	0.29	0.56	24	0
cis-2-Hexene	*0.03*	*0.07*	*0.03*	*0.05*	*24*	*8*
cis-2-Pentene	0.16	0.22	0.17	0.29	24	0
Cyclohexane	0.38	0.64	0.25	0.58	24	0
Cyclopentane	0.27	0.36	0.26	0.43	24	0
Cyclopentene	*0.06*	*0.09*	*0.06*	*0.13*	*24*	*5*

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
Ethane	13.05	28.65	5.13	9.50	24	0
Ethylbenzene	0.27	0.49	0.18	0.30	24	0
Ethylene	5.04	7.19	2.53	3.91	24	0
Isobutane	62.00	249.76	98.18	315.53	24	0
Isobutene / 1-Butene	0.81	1.11	0.64	1.52	24	0
Isopentane	6.56	9.65	6.77	14.60	24	1
Isoprene	0.19	0.23	0.25	0.92	24	0
Isopropylbenzene	0.03	0.06	0.03	0.03	24	1
m-Diethylbenzene	0.03	0.05	0.04	0.11	24	1
Methylcyclohexane	0.37	0.54	0.20	0.31	24	0
Methylcyclopentane	0.59	0.83	0.40	0.67	24	0
m-Ethyltoluene	0.20	0.36	0.13	0.23	24	0
m-Xylene / p-Xylene	0.84	1.44	0.54	0.87	24	0
n-Butane	4.58	6.68	5.22	21.95	24	0
n-Decane	0.14	0.30	0.09	0.14	24	0
n-Dodecane	0.04	0.06	0.03	0.07	24	2
n-Heptane	0.40	0.60	0.25	0.45	24	0
n-Hexane	1.35	1.96	0.92	1.61	24	0
n-Nonane	0.09	0.20	0.06	0.11	24	0
n-Octane	0.15	0.24	0.09	0.15	24	0
n-Pentane	3.10	4.46	3.46	6.86	24	0
n-Propylbenzene	0.07	0.14	0.05	0.08	24	0
n-Tridecane	*0.02*	*0.02*	*0.02*	*0.02*	*24*	*23*
n-Undecane	0.08	0.18	0.07	0.17	24	0
o-Ethyltoluene	0.13	0.21	0.10	0.15	24	0
o-Xylene	0.35	0.56	0.22	0.35	24	0
p-Diethylbenzene	0.02	0.05	0.02	0.02	24	2
p-Ethyltoluene	0.11	0.20	0.08	0.14	24	0
Propane	7.57	12.93	3.86	10.22	24	0
Propylene	1.42	2.10	0.72	1.17	24	0
Propyne	*0.03*	*0.03*	*0.03*	*0.03*	*24*	*24*
Styrene	0.13	0.60	0.06	0.10	24	0
Toluene	2.20	4.51	1.33	2.48	24	0
trans-2-Butene	0.23	0.33	0.25	0.47	24	0
trans-2-Hexene	*0.05*	*0.08*	*0.04*	*0.07*	*24*	*5*
trans-2-Pentene	0.26	0.37	0.28	0.53	24	0

Bold = Priority Compound *Italic = Detected in <85% of samples taken*

Table 36 lists the average and maximum NMOC concentrations measured at Welby in 2003. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and therefore the average is dependent upon the respective compound's MDL. Compounds that were not detected in greater than 85% of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority compounds are bolded in the table below. Forty of the 78 compounds were not detected in at least one of the samples taken.

Benzene was detected in all samples taken, while 1,3-butadiene was detected in less than half of the samples taken. All of the 52 compounds that were detected in greater than 85% of the samples taken had average concentrations that were higher in the morning hours than in the afternoon hours. As at CAMP, the highest concentrations were detected among the alkane compounds.

Table 36. AM and PM NMOC/VOC Concentrations at Welby, 2003

Compound	AM		PM		Sample Data	
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
1,2,3-Trimethylbenzene	0.06	0.12	0.04	0.11	22	3
1,2,4-Trimethylbenzene	0.38	0.69	0.10	0.25	22	0
1,3,5-Trimethylbenzene	0.12	0.22	0.03	0.05	22	3
1,3-Butadiene	***0.21***	***0.40***	***0.02***	***0.04***	***22***	***12***
1-Decene	*0.01*	*0.01*	*0.01*	*0.01*	*22*	*22*
1-Dodecene	*0.03*	*0.06*	*0.03*	*0.13*	*22*	*5*
1-Heptene	0.07	0.11	0.03	0.06	22	3
1-Hexene	0.13	0.19	0.07	0.11	22	1
1-Nonene	*0.03*	*0.05*	*0.01*	*0.01*	*22*	*15*
1-Octene	*0.02*	*0.03*	*0.01*	*0.01*	*22*	*19*
1-Pentene	0.24	0.38	0.06	0.11	22	1
1-Tridecene	*0.02*	*0.02*	*0.02*	*0.02*	*22*	*22*
1-Undecene	*0.01*	*0.01*	*0.01*	*0.01*	*22*	*19*
2,2,3-Trimethylpentane	*0.12*	*0.18*	*0.02*	*0.02*	*22*	*11*
2,2,4-Trimethylpentane	0.55	0.94	0.09	0.17	22	0
2,2-Dimethylbutane	0.33	0.47	0.11	0.16	22	0
2,3,4-Trimethylpentane	0.16	0.25	0.03	0.06	22	0
2,3-Dimethylbutane	0.53	0.73	0.13	0.31	22	0
2,3-Dimethylpentane	0.39	0.64	0.09	0.15	22	0
2,4-Dimethylpentane	0.28	0.42	0.07	0.10	22	0
2-Ethyl-1-butene	*0.02*	*0.02*	*0.02*	*0.02*	*22*	*22*
2-Methyl-1-butene	*0.30*	*0.49*	*0.06*	*0.15*	*22*	*4*
2-Methyl-1-pentene	*0.05*	*0.08*	*0.02*	*0.02*	*22*	*15*
2-Methyl-2-butene	*0.34*	*0.57*	*0.04*	*0.13*	*22*	*5*
2-Methylheptane	0.15	0.25	0.03	0.05	22	0
2-Methylhexane	0.51	0.78	0.10	0.15	22	0
2-Methylpentane	2.03	2.85	0.49	1.11	22	0
3-Methyl-1-butene	*0.02*	*0.02*	*0.02*	*0.02*	*22*	*22*
3-Methylheptane	0.16	0.26	0.03	0.05	22	0
3-Methylhexane	0.60	1.03	0.11	0.22	22	0
3-Methylpentane	1.13	1.59	0.20	0.53	22	0
4-Methyl-1-pentene	*0.02*	*0.04*	*0.02*	*0.04*	*22*	*17*
Acetylene	5.39	13.26	0.80	1.54	22	0
a-Pinene	*0.11*	*0.20*	*0.04*	*0.21*	*22*	*9*
Benzene	**3.90**	**5.58**	**2.47**	**3.21**	**22**	**0**
b-Pinene	*0.02*	*0.06*	*0.01*	*0.01*	*22*	*20*
cis-2-Butene	0.31	0.51	0.09	0.20	22	1
cis-2-Hexene	*0.04*	*0.06*	*0.02*	*0.02*	*22*	*15*
cis-2-Pentene	0.21	0.34	0.06	0.12	22	1
Cyclohexane	0.46	0.70	0.10	0.15	22	0
Cyclopentane	0.37	0.50	0.11	0.21	22	0
Cyclopentene	*0.06*	*0.11*	*0.03*	*0.04*	*22*	*10*
Ethane	17.26	27.95	5.63	14.10	22	0
Ethylbenzene	0.31	0.61	0.07	0.10	22	0
Ethylene	5.27	9.09	0.66	1.42	22	0
Isobutane	2.71	5.94	2.35	18.90	22	0
Isobutene / 1-Butene	0.73	1.17	0.22	0.56	22	0
Isopentane	9.29	14.68	2.85	6.28	22	0
Isoprene	0.35	0.48	0.41	0.55	22	0
Isopropylbenzene	*0.03*	*0.06*	*0.02*	*0.04*	*22*	*5*

Compound	AM		PM		Sample Data	
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
m-Diethylbenzene	*0.03*	*0.06*	*0.02*	*0.03*	*22*	*5*
Methylcyclohexane	0.43	0.73	0.09	0.16	22	0
Methylcyclopentane	0.69	1.02	0.12	0.24	22	0
m-Ethyltoluene	0.18	0.35	0.03	0.06	22	2
m-Xylene / p-Xylene	0.96	1.86	0.19	0.29	22	0
n-Butane	5.52	7.04	1.51	3.30	22	0
n-Decane	0.13	0.21	0.05	0.08	22	0
n-Dodecane	0.03	0.04	0.02	0.05	22	3
n-Heptane	0.51	0.88	0.09	0.15	22	0
n-Hexane	1.55	2.15	0.25	0.43	22	0
n-Nonane	0.10	0.17	0.03	0.05	22	2
n-Octane	0.20	0.40	0.05	0.07	22	0
n-Pentane	4.27	5.71	0.79	1.35	22	0
n-Propylbenzene	*0.06*	*0.13*	*0.02*	*0.03*	*22*	*5*
n-Tridecane	*0.02*	*0.02*	*0.02*	*0.02*	*22*	*22*
n-Undecane	0.07	0.11	0.03	0.06	22	0
o-Ethyltoluene	0.11	0.18	0.03	0.04	22	2
o-Xylene	0.37	0.68	0.07	0.11	22	0
p-Diethylbenzene	*0.03*	*0.04*	*0.01*	*0.02*	*22*	*9*
p-Ethyltoluene	*0.09*	*0.20*	*0.02*	*0.04*	*22*	*4*
Propane	10.74	15.66	3.59	8.10	22	0
Propylene	1.51	2.74	0.23	0.56	22	0
Propyne	*0.03*	*0.03*	*0.03*	*0.03*	*22*	*22*
Styrene	0.07	0.14	0.04	0.12	22	1
Toluene	2.55	4.26	0.47	0.77	22	0
trans-2-Butene	0.29	0.50	0.07	0.18	22	1
trans-2-Hexene	*0.06*	*0.12*	*0.02*	*0.02*	*22*	*14*
trans-2-Pentene	0.36	0.57	0.06	0.18	22	1

Bold = Priority Compound *Italic = Detected in <85% of samples taken*

Table 37 lists the average and maximum NMOC concentrations measured at NREL in 2003. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and therefore the average is largely dependent upon the respective compound's MDL. Compounds that were not detected in greater than 85% of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority compounds are bolded in the table below. Twenty-four of the 78 compounds were not detected in at least one of the samples taken.

Benzene was detected in all samples taken, while 1,3-butadiene was detected in less than half of the samples taken. Forty-six of the 58 compounds that were detected in greater than 85% of the samples taken had average concentrations that were higher in the morning hours than in the afternoon hours. As was seen at CAMP and Welby, the highest concentrations were detected among the alkane compounds.

Table 37. AM and PM NMOC/VOC Concentrations at NREL, 2003

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
1,2,3-Trimethylbenzene	0.05	0.09	0.04	0.11	7	0
1,2,4-Trimethylbenzene	0.18	0.24	0.17	0.34	7	0
1,3,5-Trimethylbenzene	0.04	0.04	0.03	0.06	7	0
1,3-Butadiene	***0.06***	***0.10***	***0.02***	***0.02***	***7***	***4***
1-Decene	*0.01*	*0.01*	*0.01*	*0.01*	*7*	*7*

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
1-Dodecene	0.07	0.13	0.05	0.14	7	1
1-Heptene	0.06	0.13	0.02	0.04	7	1
1-Hexene	0.06	0.06	0.06	0.08	7	0
1-Nonene	*0.01*	*0.01*	*0.01*	*0.01*	*7*	*7*
1-Octene	*0.02*	*0.03*	*0.01*	*0.01*	*7*	*6*
1-Pentene	0.08	0.13	0.06	0.07	7	0
1-Tridecene	*0.02*	*0.02*	*0.02*	*0.02*	*7*	*7*
1-Undecene	*0.01*	*0.01*	*0.01*	*0.01*	*7*	*7*
2,2,3-Trimethylpentane	*0.04*	*0.05*	*0.03*	*0.04*	*7*	*2*
2,2,4-Trimethylpentane	0.18	0.30	0.12	0.17	7	0
2,2-Dimethylbutane	0.14	0.19	0.14	0.18	7	0
2,3,4-Trimethylpentane	0.07	0.11	0.04	0.06	7	0
2,3-Dimethylbutane	0.22	0.36	0.17	0.21	7	0
2,3-Dimethylpentane	0.16	0.21	0.11	0.17	7	0
2,4-Dimethylpentane	0.10	0.13	0.09	0.12	7	0
2-Ethyl-1-butene	*0.02*	*0.02*	*0.02*	*0.02*	*7*	*7*
2-Methyl-1-butene	0.11	0.19	0.06	0.12	7	1
2-Methyl-1-pentene	*0.02*	*0.02*	*0.02*	*0.02*	*7*	*7*
2-Methyl-2-butene	*0.10*	*0.21*	*0.02*	*0.03*	*7*	*2*
2-Methylheptane	0.04	0.05	0.03	0.06	7	0
2-Methylhexane	0.24	0.32	0.17	0.27	7	0
2-Methylpentane	0.66	1.01	1.08	2.68	7	0
3-Methyl-1-butene	*0.03*	*0.06*	*0.02*	*0.02*	*7*	*6*
3-Methylheptane	0.05	0.06	0.04	0.06	7	0
3-Methylhexane	0.23	0.34	0.14	0.24	7	0
3-Methylpentane	0.40	0.67	0.30	0.44	7	0
4-Methyl-1-pentene	*0.02*	*0.02*	*0.02*	*0.02*	*7*	*7*
Acetylene	1.10	1.35	1.08	1.64	7	0
a-Pinene	*0.35*	*0.99*	*0.01*	*0.01*	*7*	*4*
Benzene	**1.32**	**1.89**	**1.42**	**2.38**	**7**	**0**
b-Pinene	*0.11*	*0.28*	*0.04*	*0.11*	*7*	*3*
cis-2-Butene	0.12	0.16	0.10	0.11	7	0
cis-2-Hexene	*0.02*	*0.03*	*0.02*	*0.02*	*7*	*6*
cis-2-Pentene	0.08	0.13	0.05	0.06	7	0
Cyclohexane	0.17	0.22	0.26	0.65	7	0
Cyclopentane	0.13	0.17	0.13	0.17	7	0
Cyclopentene	*0.03*	*0.04*	*0.03*	*0.04*	*7*	*2*
Ethane	6.93	9.13	6.69	8.02	7	0
Ethylbenzene	0.15	0.17	0.10	0.13	7	0
Ethylene	1.57	2.41	0.89	1.24	7	0
Isobutane	1.42	2.42	0.97	1.44	7	0
Isobutene / 1-Butene	0.41	0.45	0.32	0.48	7	0
Isopentane	2.94	3.57	3.11	4.14	7	0
Isoprene	0.46	0.85	0.25	0.30	7	0
Isopropylbenzene	0.02	0.03	0.02	0.02	7	1
m-Diethylbenzene	0.03	0.04	0.03	0.04	7	0
Methylcyclohexane	0.15	0.23	0.11	0.17	7	0
Methylcyclopentane	0.23	0.30	0.17	0.28	7	0
m-Ethyltoluene	0.06	0.11	0.04	0.07	7	0
m-Xylene / p-Xylene	0.41	0.48	0.25	0.38	7	0
n-Butane	2.30	2.99	2.20	3.30	7	0

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
n-Decane	0.07	0.09	0.05	0.10	7	0
n-Dodecane	0.03	0.04	0.04	0.06	7	0
n-Heptane	0.16	0.24	0.11	0.21	7	0
n-Hexane	0.49	0.60	0.39	0.68	7	0
n-Nonane	0.03	0.03	0.03	0.05	7	0
n-Octane	0.07	0.09	0.05	0.08	7	0
n-Pentane	1.21	1.49	1.28	1.99	7	0
n-Propylbenzene	0.02	0.02	0.02	0.03	7	0
n-Tridecane	*0.02*	*0.02*	*0.02*	*0.02*	*7*	*7*
n-Undecane	0.04	0.04	0.06	0.13	7	0
o-Ethyltoluene	0.04	0.06	0.03	0.06	7	0
o-Xylene	0.15	0.19	0.10	0.14	7	0
p-Diethylbenzene	*0.01*	*0.01*	*0.01*	*0.01*	*7*	*4*
p-Ethyltoluene	0.03	0.03	0.03	0.05	7	0
Propane	4.29	5.76	4.49	6.71	7	0
Propylene	0.47	0.76	0.23	0.28	7	0
Propyne	*0.03*	*0.03*	*0.03*	*0.03*	*7*	*7*
Styrene	0.06	0.09	0.02	0.03	7	0
Toluene	1.12	2.01	0.62	1.32	7	0
trans-2-Butene	0.08	0.13	0.05	0.06	7	0
trans-2-Hexene	*0.02*	*0.02*	*0.02*	*0.02*	*7*	*7*
trans-2-Pentene	0.12	0.22	0.05	0.06	7	0

Bold = Priority Compound *Italic = Detected in <85% of samples taken*

Table 38 lists the average and maximum NMOC concentrations measured at Chatfield in 2003. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and therefore the average is largely dependent upon the respective compound's MDL. Compounds that were not detected in greater than 85% of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority compounds are bolded in the table below. Twenty-five of the 78 compounds were not detected in at least one of the samples taken.

Benzene was detected in all samples taken, while 1,3-butadiene was not detected in any of the samples taken. Twenty-nine of the 57 compounds that were detected in greater than 85% of the samples taken had average concentrations that were higher in the morning hours than in the afternoon hours. As was seen at the previous sites, the highest concentrations were detected among the alkane compounds.

Table 38. AM and PM NMOC/VOC Concentrations at Chatfield, 2003

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
1,2,3-Trimethylbenzene	0.02	0.02	0.02	0.02	8	1
1,2,4-Trimethylbenzene	0.11	0.15	0.07	0.11	8	0
1,3,5-Trimethylbenzene	0.03	0.04	0.03	0.03	8	0
1,3-Butadiene	***0.02***	***0.02***	***0.02***	***0.02***	***8***	***8***
1-Decene	*0.01*	*0.01*	*0.01*	*0.01*	*8*	*8*
1-Dodecene	0.03	0.04	0.02	0.02	8	1
1-Heptene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*4*
1-Hexene	0.07	0.08	0.07	0.09	8	0
1-Nonene	*0.01*	*0.01*	*0.01*	*0.01*	*8*	*8*
1-Octene	*0.01*	*0.01*	*0.01*	*0.01*	*8*	*8*
1-Pentene	0.06	0.07	0.05	0.08	8	0

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
1-Tridecene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
1-Undecene	*0.01*	*0.01*	*0.01*	*0.01*	*8*	*8*
2,2,3-Trimethylpentane	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*7*
2,2,4-Trimethylpentane	0.08	0.09	0.12	0.18	8	0
2,2-Dimethylbutane	0.10	0.12	0.14	0.27	8	0
2,3,4-Trimethylpentane	0.03	0.04	0.04	0.06	8	0
2,3-Dimethylbutane	0.10	0.11	0.11	0.17	8	0
2,3-Dimethylpentane	0.12	0.14	0.11	0.17	8	0
2,4-Dimethylpentane	0.07	0.08	0.07	0.11	8	0
2-Ethyl-1-butene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
2-Methyl-1-butene	*0.02*	*0.02*	*0.03*	*0.05*	*8*	*5*
2-Methyl-1-pentene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
2-Methyl-2-butene	*0.02*	*0.03*	*0.04*	*0.07*	*8*	*5*
2-Methylheptane	0.03	0.04	0.04	0.05	8	0
2-Methylhexane	0.11	0.18	0.09	0.16	8	0
2-Methylpentane	0.29	0.37	0.39	0.54	8	0
3-Methyl-1-butene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
3-Methylheptane	0.03	0.04	0.03	0.05	8	0
3-Methylhexane	0.16	0.18	0.15	0.23	8	0
3-Methylpentane	0.12	0.14	0.16	0.26	8	0
4-Methyl-1-pentene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
Acetylene	0.69	0.79	0.78	1.14	8	0
a-Pinene	0.05	0.09	0.03	0.04	8	0
Benzene	**0.30**	**0.38**	**0.27**	**0.41**	**8**	**0**
b-Pinene	*0.01*	*0.01*	*0.01*	*0.01*	*8*	*8*
cis-2-Butene	0.08	0.09	0.09	0.12	8	0
cis-2-Hexene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
cis-2-Pentene	0.06	0.06	0.06	0.08	8	0
Cyclohexane	0.13	0.28	0.08	0.11	8	0
Cyclopentane	0.08	0.12	0.08	0.12	8	0
Cyclopentene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
Ethane	2.18	2.87	1.96	3.25	8	0
Ethylbenzene	0.07	0.11	0.07	0.09	8	0
Ethylene	0.67	0.78	0.60	0.76	8	0
Isobutane	0.30	0.37	0.38	0.48	8	0
Isobutene / 1-Butene	0.27	0.39	0.19	0.25	8	0
Isopentane	0.59	0.69	1.04	1.62	8	0
Isoprene	0.16	0.28	0.32	0.38	8	0
Isopropylbenzene	0.02	0.02	0.02	0.03	8	0
m-Diethylbenzene	0.02	0.03	0.02	0.03	8	1
Methylcyclohexane	0.08	0.12	0.08	0.10	8	0
Methylcyclopentane	0.08	0.09	0.11	0.15	8	0
m-Ethyltoluene	0.05	0.07	0.03	0.04	8	0
m-Xylene / p-Xylene	0.21	0.32	0.17	0.25	8	0
n-Butane	0.48	0.61	0.71	1.07	8	0
n-Decane	0.03	0.04	0.03	0.04	8	0
n-Dodecane	0.02	0.02	0.02	0.03	8	0
n-Heptane	0.09	0.14	0.07	0.12	8	0
n-Hexane	0.16	0.20	0.20	0.31	8	0
n-Nonane	0.02	0.03	0.02	0.03	8	0
n-Octane	0.05	0.05	0.04	0.06	8	0

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
n-Pentane	0.35	0.42	0.57	0.89	8	0
n-Propylbenzene	0.02	0.02	0.02	0.02	8	0
n-Tridecane	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
n-Undecane	0.03	0.04	0.03	0.04	8	0
o-Ethyltoluene	0.04	0.05	0.04	0.06	8	0
o-Xylene	0.09	0.12	0.07	0.10	8	0
p-Diethylbenzene	*0.01*	*0.02*	*0.01*	*0.02*	*8*	*5*
p-Ethyltoluene	0.03	0.03	0.03	0.03	8	0
Propane	1.72	2.16	0.91	1.55	8	0
Propylene	0.24	0.28	0.22	0.33	8	0
Propyne	*0.03*	*0.03*	*0.03*	*0.03*	*8*	*8*
Styrene	0.02	0.03	0.02	0.02	8	1
Toluene	0.33	0.45	0.36	0.65	8	0
trans-2-Butene	0.06	0.07	0.07	0.09	8	0
trans-2-Hexene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
trans-2-Pentene	0.06	0.07	0.07	0.09	8	0

Bold = Priority Compound *Italic = Detected in <85% of samples taken*

Table 39 lists the average and maximum NMOC concentrations measured at Platteville in 2003. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and therefore the average is dependent upon the respective compound's MDL. Compounds that were not detected in greater than 85% of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority compounds are bolded in the table below. Thirty-five of the 78 compounds were not detected in at least one of the samples taken.

Benzene was detected in all samples taken, while 1,3-butadiene was detected in less than half of the samples taken. Fifty-five of the 56 compounds that were detected in greater than 85% of the samples taken had average concentrations that were higher in the morning hours than in the afternoon hours. As was seen at the previous sites, the highest concentrations were detected among the alkane compounds.

Table 39. AM and PM NMOC/VOC Concentrations at Platteville, 2003

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
1,2,3-Trimethylbenzene	0.06	0.10	0.03	0.04	8	0
1,2,4-Trimethylbenzene	0.29	0.51	0.15	0.21	8	0
1,3,5-Trimethylbenzene	0.11	0.17	0.03	0.04	8	0
1,3-Butadiene	***0.10***	***0.14***	***0.02***	***0.02***	***8***	***5***
1-Decene	*0.01*	*0.01*	*0.01*	*0.01*	*8*	*8*
1-Dodecene	0.03	0.04	0.03	0.04	8	3
1-Heptene	0.76	1.16	0.04	0.06	8	0
1-Hexene	0.10	0.13	0.07	0.10	8	1
1-Nonene	*0.03*	*0.04*	*0.01*	*0.01*	*8*	*5*
1-Octene	*0.02*	*0.03*	*0.01*	*0.01*	*8*	*5*
1-Pentene	0.12	0.17	0.05	0.07	8	1
1-Tridecene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
1-Undecene	*0.01*	*0.01*	*0.01*	*0.01*	*8*	*8*
2,2,3-Trimethylpentane	*0.23*	*0.33*	*0.02*	*0.02*	*8*	*4*
2,2,4-Trimethylpentane	0.18	0.32	0.05	0.07	8	0
2,2-Dimethylbutane	0.83	1.23	0.11	0.16	8	0
2,3,4-Trimethylpentane	0.09	0.11	0.03	0.04	8	1

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
2,3-Dimethylbutane	1.92	2.98	0.14	0.25	8	0
2,3-Dimethylpentane	0.68	0.98	0.09	0.11	8	0
2,4-Dimethylpentane	0.63	0.86	0.08	0.12	8	0
2-Ethyl-1-butene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
2-Methyl-1-butene	*0.09*	*0.12*	*0.02*	*0.03*	*8*	*2*
2-Methyl-1-pentene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*7*
2-Methyl-2-butene	0.09	0.12	0.04	0.05	8	1
2-Methylheptane	0.59	0.81	0.05	0.10	8	0
2-Methylhexane	2.07	3.03	0.18	0.20	8	0
2-Methylpentane	8.94	14.05	0.61	1.00	8	0
3-Methyl-1-butene	*0.02*	*0.05*	*0.02*	*0.02*	*8*	*7*
3-Methylheptane	0.46	0.62	0.04	0.07	8	0
3-Methylhexane	2.01	2.89	0.14	0.27	8	0
3-Methylpentane	4.95	7.71	0.28	0.54	8	0
4-Methyl-1-pentene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
Acetylene	3.08	4.31	0.53	0.68	8	0
a-Pinene	*0.13*	*0.20*	*0.01*	*0.02*	*8*	*4*
Benzene	**3.98**	**5.20**	**1.32**	**2.05**	**8**	**0**
b-Pinene	*0.01*	*0.01*	*0.01*	*0.01*	*8*	*8*
cis-2-Butene	0.14	0.19	0.08	0.12	8	1
cis-2-Hexene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*7*
cis-2-Pentene	0.09	0.13	0.05	0.06	8	1
Cyclohexane	3.32	5.01	0.18	0.35	8	0
Cyclopentane	1.73	2.73	0.12	0.23	8	0
Cyclopentene	*0.05*	*0.06*	*0.04*	*0.06*	*8*	*3*
Ethane	327.24	548.40	15.87	31.18	8	0
Ethylbenzene	0.26	0.43	0.10	0.13	8	0
Ethylene	3.34	4.15	0.48	0.55	8	0
Isobutane	40.76	66.64	1.99	4.23	8	0
Isobutene / 1-Butene	0.49	0.62	0.22	0.30	8	0
Isopentane	36.12	56.54	1.47	2.11	8	0
Isoprene	0.27	0.38	0.29	0.41	8	0
Isopropylbenzene	*0.03*	*0.05*	*0.02*	*0.03*	*8*	*2*
m-Diethylbenzene	0.03	0.05	0.03	0.04	8	1
Methylcyclohexane	3.89	5.96	0.18	0.34	8	0
Methylcyclopentane	4.11	6.27	0.20	0.40	8	0
m-Ethyltoluene	0.13	0.21	0.03	0.04	8	0
m-Xylene / p-Xylene	1.11	1.61	0.30	0.43	8	0
n-Butane	84.06	137.90	4.31	9.32	8	0
n-Decane	0.13	0.19	0.06	0.09	8	0
n-Dodecane	*0.02*	*0.03*	*0.03*	*0.04*	*8*	*2*
n-Heptane	3.13	4.51	0.18	0.33	8	0
n-Hexane	10.17	15.55	0.55	1.09	8	0
n-Nonane	0.22	0.30	0.03	0.04	8	0
n-Octane	0.94	1.31	0.07	0.12	8	0
n-Pentane	30.57	49.07	1.67	3.44	8	0
n-Propylbenzene	0.06	0.09	0.02	0.03	8	1
n-Tridecane	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
n-Undecane	0.06	0.10	0.03	0.04	8	0
o-Ethyltoluene	0.09	0.13	0.03	0.04	8	1
o-Xylene	0.33	0.50	0.11	0.15	8	0

Compound	AM		PM		# Samples	# Non-Detects
	Avg. (ppbv)	Max. (ppbv)	Avg. (ppbv)	Max. (ppbv)		
p-Diethylbenzene	0.02	0.04	0.02	0.02	8	1
p-Ethyltoluene	0.09	0.13	0.03	0.05	8	1
Propane	198.87	331.74	9.71	20.35	8	0
Propylene	0.83	1.15	0.17	0.20	8	0
Propyne	*0.03*	*0.03*	*0.03*	*0.03*	*8*	*8*
Styrene	0.06	0.08	0.04	0.06	8	0
Toluene	3.40	4.80	0.44	0.66	8	0
trans-2-Butene	0.17	0.33	0.05	0.07	8	1
trans-2-Hexene	*0.02*	*0.02*	*0.02*	*0.02*	*8*	*8*
trans-2-Pentene	0.17	0.22	0.06	0.09	8	1

Bold = Priority Compound *Italic = Detected in <85% of samples taken*

Table 40 and Table 41 list the average and maximum concentrations of speciated NMOCs (SNMOCs), total NMOCs (TNMOCs), and unknowns. The unknown concentration is obtained by subtracting the concentration of SNMOCs from the TNMOC concentration. The SNMOC concentration is obtained by summing the concentrations of each of the speciated compound concentrations. The TNMOC concentration is obtained via lab analysis. The percentages in red indicate the percent contribution of the SNMOC and unknown concentrations to the makeup of the TNMOC concentration. It is interesting to note that at the Welby and Chatfield sites the concentration of unknown compounds made up a larger percentage of the TNMOC concentration than the SNMOCs did. This was true for both the morning and afternoon samples. At Welby, the percentage of unknown concentrations increased in the afternoon samples. At Chatfield, the percentages were nearly identical. These concentrations are indicative of background concentrations for the area. As was previously mentioned the Welby site is near a large refinery, which could contribute to the different compositional makeup of the TNMOCs. The Platteville site shows the largest average and maximum concentrations, which is to be expected, as the site is in the middle of a large oil/natural gas development area.

Table 40. Average SNMOC, TNMOC, and Unknown Concentrations at All Sites, 2003

	CAMP		Welby		NREL		Chatfield		Platteville	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
	Avg. (ppbC)	Avg. (ppbC)	Avg. (ppbC)	Avg. (ppbC)	Avg. (ppbC)	Avg. (ppbC)	Avg. (ppbC)	Avg. (ppbC)	Avg. (ppbC)	Avg. (ppbC)
SNMOCs	522 (72%)	599 (81%)	354 (38%)	106 (20%)	138 (73%)	119 (65%)	51 (38%)	54 (36%)	2512 (94%)	151 (59%)
Unknowns	204 (28%)	138 (19%)	588 (62%)	415 (80%)	51 (27%)	62 (35%)	84 (62%)	95 (64%)	167 (6%)	104 (41%)
TNMOCs	726	737	942	521	189	182	135	149	2679	255

Table 41. Maximum SNMOC, TNMOC, and Unknown Concentrations at All Sites, 2003

	CAMP		Welby		NREL		Chatfield		Platteville	
	AM	PM	AM	PM	AM	PM	AM	PM	AM	PM
	Max. (ppbC)	Max. (ppbC)	Max. (ppbC)	Max. (ppbC)	Max. (ppbC)	Max. (ppbC)	Max. (ppbC)	Max. (ppbC)	Max. (ppbC)	Max. (ppbC)
SNMOCs	1203 (69%)	1532 (92%)	499 (39%)	207 (10%)	178 (85%)	161 (69%)	61 (37%)	79 (45%)	4025 (95%)	283 (72%)
Unknowns	533 (31%)	128 (8%)	766 (61%)	1768 (90%)	32 (15%)	70 (31%)	103 (63%)	96 (55%)	232 (5%)	110 (28%)
TNMOCs	1736	1660	1264	1974	210	232	164	176	4257	393

3.3 *2006 Data*

The 2006 study was conducted from June 16, 2006 through August 3, 2006. Three hour samples were taken during the morning hours for this study. The samples ran from 06:00 to 09:00. A total of six sites were used during

the sampling period. The CAMP, Welby, Ft. Lupton, and Platteville sites were used throughout the duration of the study, while the Rocky Flats - North, and Ft. Collins – West sites had a sampler rotated between them. Each of those two sites had the sampler for roughly two weeks, with three samples being taken at each site. As with the 2003 study, in addition to the TNMOC concentrations, 78 speciated compounds were looked at.

At CAMP, a total of 16 samples were taken overall. At Welby, 16 samples were taken overall, while 17 were taken at Ft. Lupton, and 15 at Platteville. At the remaining two sites, Rocky Flats – North, and Ft. Collins - West, three samples were taken. Table 42 lists the average and maximum NMOC concentrations measured at CAMP in 2006. Also listed are the total number of samples taken, and the number of times each compound was not detected in a sample during the study. Values in italics indicate that the compound was not found in greater than 85% of the samples taken, and therefore the average is dependent upon the respective compound's MDL. Compounds that were not detected in greater than 85% of the samples are listed here, but not used in the data correlations, or the concentration graphs, unless they are one of the "priority compounds" mentioned in the previous section. Priority compounds are bolded in the table below.

Twenty-five of the 78 compounds were not detected in at least one of the samples taken. Of the priority compounds, only benzene was detected in all samples taken. 1,3-butadiene was found in only six of the sixteen samples taken. A total of 59 of the 78 compounds were present in at least 85% of the samples taken. The highest concentrations were detected among the alkane compounds.

Table 42. Average and Maximum SNMOC Concentrations at CAMP, 2006

Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
1,2,3-Trimethylbenzene	0.051	0.090	16	0	Cyclohexane	0.197	0.358	16	0
1,2,4-Trimethylbenzene	0.364	0.540	16	0	Cyclopentane	0.164	0.276	16	0
1,3,5-Trimethylbenzene	0.098	0.158	16	0	*Cyclopentene*	*0.086*	*0.882*	*16*	*6*
1,3-Butadiene	***0.153***	***1.788***	***16***	***10***	Ethane	10.999	27.750	16	0
1-Decene	*0.060*	*0.563*	*16*	*15*	Ethylbenzene	0.163	0.265	16	0
1-Dodecene	*0.099*	*0.702*	*16*	*12*	Ethylene	2.954	5.000	16	0
1-Heptene	0.051	0.119	16	1	Isobutane	1.288	3.775	16	0
1-Hexene	0.024	0.042	16	0	Isobutene/1-Butene	0.489	0.765	16	0
1-Nonene	0.016	0.042	16	1	Isopentane	3.068	6.200	16	0
1-Octene	*0.020*	*0.059*	*16*	*5*	Isoprene	0.148	0.294	16	0
1-Pentene	0.099	0.164	16	0	Isopropylbenzene	0.015	0.030	16	0
1-Tridecene	*0.029*	*0.055*	*16*	*16*	*m-Diethylbenzene*	*0.015*	*0.025*	*16*	*6*
1-Undecene	*0.014*	*0.029*	*16*	*13*	Methylcyclohexane	0.180	0.389	16	0
2,2,3-Trimethylpentane	0.036	0.070	16	1	Methylcyclopentane	0.350	0.555	16	0
2,2,4-Trimethylpentane	0.140	0.241	16	0	m-Ethyltoluene	0.169	0.293	16	0
2,2-Dimethylbutane	0.132	0.177	16	0	m-Xylene/p-Xylene	0.545	0.870	16	0
2,3,4-Trimethylpentane	0.046	0.088	16	0	n-Butane	2.736	9.600	16	0
2,3-Dimethylbutane	0.201	0.290	16	0	n-Decane	0.077	0.156	16	0
2,3-Dimethylpentane	0.110	0.163	16	0	*n-Dodecane*	*0.037*	*0.081*	*16*	*3*
2,4-Dimethylpentane	0.113	0.260	16	0	n-Heptane	0.212	0.397	16	0
2-Ethyl-1-butene	*0.109*	*1.138*	*16*	*15*	n-Hexane	0.596	1.138	16	0
2-Methyl-1-butene	0.129	0.286	16	0	n-Nonane	0.062	0.103	16	0
2-Methyl-1-pentene	*0.022*	*0.038*	*16*	*3*	n-Octane	0.081	0.117	16	0
2-Methyl-2-butene	0.138	0.226	16	0	n-Pentane	2.331	6.460	16	0
2-Methylheptane	0.066	0.088	16	0	n-Propylbenzene	0.055	0.099	16	0
2-Methylhexane	0.220	0.413	16	0	*n-Tridecane*	*0.027*	*0.055*	*16*	*13*
2-Methylpentane	0.948	1.367	16	0	*n-Undecane*	*0.032*	*0.126*	*16*	*3*
3-Methyl-1-butene	*0.036*	*0.064*	*16*	*15*	o-Ethyltoluene	0.099	0.160	16	1
3-Methylheptane	0.059	0.083	16	0	o-Xylene	0.216	0.339	16	0
3-Methylhexane	0.341	0.484	16	0	*p-Diethylbenzene*	*0.016*	*0.025*	*16*	*6*
3-Methylpentane	0.498	0.772	16	0	p-Ethyltoluene	0.084	0.147	16	0
4-Methyl-1-pentene	*0.043*	*0.077*	*16*	*15*	Propane	6.155	18.800	16	0
Acetylene	3.434	27.750	16	0	Propylene	0.836	1.293	16	0
a-Pinene	0.097	0.271	16	1	*Propyne*	*0.020*	*0.040*	*16*	*15*
Benzene	**0.746**	**1.083**	**16**	**0**	Styrene	0.072	0.186	16	0
b-Pinene	*0.028*	*0.073*	*16*	*11*	Toluene	1.313	2.200	16	0

Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
cis-2-Butene	0.073	0.134	16	0	trans-2-Butene	0.078	0.142	16	0
cis-2-Hexene	*0.027*	*0.077*	*16*	*6*	trans-2-Hexene	0.042	0.182	16	2
cis-2-Pentene	0.058	0.084	16	0	trans-2-Pentene	0.124	0.186	16	0

Bold = priority compound *Italics = Detected in < 85% of samples taken*

Table 43 lists the average and maximum NMOC concentrations measured at Welby in 2006. Twenty-three of the 78 compounds were not detected in at least one of the samples taken. Of the priority compounds, only benzene was detected in all samples taken. 1,3-butadiene was found in only seven of the sixteen samples taken. A total of 55 of the 78 compounds were present in at least 85% of the samples taken. The highest concentrations were detected among the alkane compounds.

Table 43. Average and Maximum SNMOC Concentrations at Welby, 2006

Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
1,2,3-Trimethylbenzene	0.052	0.108	16	0	Cyclohexane	0.266	0.823	16	0
1,2,4-Trimethylbenzene	0.254	0.587	16	0	Cyclopentane	0.220	0.458	16	0
1,3,5-Trimethylbenzene	0.074	0.138	16	0	*Cyclopentene*	*0.044*	*0.137*	*16*	*8*
1,3-Butadiene	***0.038***	***0.095***	***16***	***9***	Ethane	11.481	27.400	16	0
1-Decene	*0.025*	*0.025*	*16*	*16*	Ethylbenzene	0.196	0.380	16	0
1-Dodecene	*0.124*	*0.422*	*16*	*7*	Ethylene	3.301	6.900	16	0
1-Heptene	0.067	0.130	16	0	Isobutane	1.711	3.725	16	0
1-Hexene	0.043	0.130	16	0	Isobutene/1-Butene	0.384	0.755	16	0
1-Nonene	*0.021*	*0.041*	*16*	*4*	Isopentane	3.966	6.640	16	0
1-Octene	*0.028*	*0.046*	*16*	*6*	Isoprene	0.250	0.600	16	0
1-Pentene	0.133	0.290	16	0	*Isopropylbenzene*	*0.014*	*0.020*	*16*	*3*
1-Tridecene	*0.027*	*0.027*	*16*	*16*	*m-Diethylbenzene*	*0.040*	*0.128*	*16*	*5*
1-Undecene	*0.014*	*0.016*	*16*	*11*	Methylcyclohexane	0.227	0.347	16	0
2,2,3-Trimethylpentane	0.041	0.100	16	1	Methylcyclopentane	0.453	0.835	16	0
2,2,4-Trimethylpentane	0.145	0.338	16	0	m-Ethyltoluene	0.139	0.276	16	0
2,2-Dimethylbutane	0.159	0.307	16	0	m-Xylene/p-Xylene	0.622	1.185	16	0
2,3,4-Trimethylpentane	0.054	0.099	16	0	n-Butane	3.761	9.175	16	0
2,3-Dimethylbutane	0.250	0.462	16	0	n-Decane	0.076	0.152	16	0
2,3-Dimethylpentane	0.151	0.307	16	0	*n-Dodecane*	*0.048*	*0.118*	*16*	*6*
2,4-Dimethylpentane	0.099	0.164	16	0	n-Heptane	0.259	0.513	16	0
2-Ethyl-1-butene	*0.038*	*0.038*	*16*	*16*	n-Hexane	0.820	1.477	16	0
2-Methyl-1-butene	0.169	0.432	16	0	n-Nonane	0.066	0.160	16	0
2-Methyl-1-pentene	*0.027*	*0.047*	*16*	*3*	n-Octane	0.101	0.213	16	0
2-Methyl-2-butene	0.185	0.554	16	0	n-Pentane	2.903	5.860	16	0
2-Methylheptane	0.084	0.173	16	0	n-Propylbenzene	0.047	0.120	16	0
2-Methylhexane	0.239	0.446	16	0	*n-Tridecane*	*0.028*	*0.042*	*16*	*11*
2-Methylpentane	1.198	2.333	16	0	*n-Undecane*	*0.064*	*0.178*	*16*	*3*
3-Methyl-1-butene	*0.032*	*0.032*	*16*	*16*	o-Ethyltoluene	0.074	0.167	16	0
3-Methylheptane	0.070	0.138	16	0	o-Xylene	0.225	0.434	16	0
3-Methylhexane	0.435	1.067	16	0	*p-Diethylbenzene*	*0.023*	*0.051*	*16*	*5*
3-Methylpentane	0.637	1.213	16	0	p-Ethyltoluene	0.072	0.136	16	0
4-Methyl-1-pentene	*0.038*	*0.038*	*16*	*16*	Propane	7.819	19.033	16	0
Acetylene	2.120	4.635	16	0	Propylene	0.972	2.207	16	0
a-Pinene	0.080	0.150	16	0	*Propyne*	*0.020*	*0.020*	*16*	*16*
Benzene	**1.623**	**2.950**	**16**	**0**	*Styrene*	*0.039*	*0.146*	*16*	*8*
b-Pinene	*0.028*	*0.089*	*16*	*13*	Toluene	1.417	2.829	16	0
cis-2-Butene	0.089	0.270	16	0	trans-2-Butene	0.102	0.250	16	0
cis-2-Hexene	*0.031*	*0.038*	*16*	*9*	*trans-2-Hexene*	*0.035*	*0.078*	*16*	*6*
cis-2-Pentene	0.075	0.198	16	0	trans-2-Pentene	0.162	0.408	16	0

Bold = priority compound *Italics = Detected in < 85% of samples taken*

Table 44 lists the average and maximum NMOC concentrations measured at Ft. Lupton in 2006. Thirty-four of the 78 compounds were not detected in at least one of the samples taken. Of the priority compounds, only benzene was detected in all samples taken. 1,3-butadiene was found in only two of the seventeen samples taken. A total of 52 of the 78 compounds were present in at least 85% of the samples taken. The highest concentrations were detected among the alkane compounds.

Table 44. Average and Maximum SNMOC Concentrations at Ft. Lupton, 2006

Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
1,2,3-Trimethylbenzene	0.027	0.084	17	2	Cyclohexane	0.882	1.733	17	0
1,2,4-Trimethylbenzene	0.319	0.984	17	0	Cyclopentane	0.500	0.920	17	0
1,3,5-Trimethylbenzene	0.048	0.099	17	0	*Cyclopentene*	*0.039*	*0.147*	*17*	*13*
1,3-Butadiene	***0.030***	***0.070***	***17***	***15***	Ethane	62.271	120.000	17	0
1-Decene	*0.025*	*0.025*	*17*	*17*	Ethylbenzene	0.116	0.193	17	0
1-Dodecene	*0.175*	*1.383*	*17*	*8*	Ethylene	1.752	2.890	17	0
1-Heptene	*0.065*	*0.256*	*17*	*10*	Isobutane	8.055	17.500	17	0
1-Hexene	0.030	0.066	17	1	Isobutene/1-Butene	0.240	0.368	17	0
1-Nonene	0.017	0.037	17	1	Isopentane	8.172	15.720	17	0
1-Octene	*0.035*	*0.065*	*17*	*5*	Isoprene	0.240	0.558	17	0
1-Pentene	0.069	0.159	17	1	*Isopropylbenzene*	*0.010*	*0.019*	*17*	*3*
1-Tridecene	*0.027*	*0.027*	*17*	*17*	*m-Diethylbenzene*	*0.019*	*0.054*	*17*	*8*
1-Undecene	*0.013*	*0.015*	*17*	*14*	Methylcyclohexane	0.958	1.943	17	0
2,2,3-Trimethylpentane	0.057	0.095	17	2	Methylcyclopentane	1.110	2.117	17	0
2,2,4-Trimethylpentane	0.205	0.418	17	0	m-Ethyltoluene	0.072	0.167	17	0
2,2-Dimethylbutane	0.173	0.292	17	0	m-Xylene/p-Xylene	0.434	0.758	17	0
2,3,4-Trimethylpentane	0.031	0.067	17	1	n-Butane	18.250	41.000	17	0
2,3-Dimethylbutane	0.406	0.755	17	0	n-Decane	0.072	0.113	17	0
2,3-Dimethylpentane	0.174	0.310	17	0	n-Dodecane	0.034	0.135	17	1
2,4-Dimethylpentane	0.140	0.243	17	0	n-Heptane	0.749	1.486	17	0
2-Ethyl-1-butene	*0.038*	*0.038*	*17*	*17*	n-Hexane	2.337	4.500	17	0
2-Methyl-1-butene	0.070	0.212	17	0	n-Nonane	0.080	0.139	17	0
2-Methyl-1-pentene	*0.028*	*0.038*	*17*	*11*	n-Octane	0.254	0.518	17	0
2-Methyl-2-butene	0.062	0.170	17	1	n-Pentane	7.183	14.300	17	0
2-Methylheptane	0.155	0.314	17	0	n-Propylbenzene	0.030	0.056	17	0
2-Methylhexane	0.445	0.840	17	0	*n-Tridecane*	*0.026*	*0.033*	*17*	*13*
2-Methylpentane	2.245	4.000	17	0	n-Undecane	0.048	0.164	17	0
3-Methyl-1-butene	*0.032*	*0.032*	*17*	*17*	*o-Ethyltoluene*	*0.039*	*0.102*	*17*	*3*
3-Methylheptane	0.109	0.213	17	0	o-Xylene	0.144	0.249	17	0
3-Methylhexane	0.599	0.974	17	0	*p-Diethylbenzene*	*0.019*	*0.025*	*17*	*8*
3-Methylpentane	1.179	2.200	17	0	p-Ethyltoluene	0.044	0.085	17	0
4-Methyl-1-pentene	*0.038*	*0.038*	*17*	*17*	Propane	42.247	87.000	17	0
Acetylene	0.982	1.685	17	0	Propylene	0.466	0.797	17	0
a-Pinene	*0.068*	*0.626*	*17*	*12*	*Propyne*	*0.020*	*0.020*	*17*	*17*
Benzene	**0.593**	**1.032**	**17**	**0**	*Styrene*	*0.028*	*0.035*	*17*	*9*
b-Pinene	*0.023*	*0.025*	*17*	*16*	Toluene	1.064	1.886	17	0
cis-2-Butene	*0.032*	*0.080*	*17*	*4*	*trans-2-Butene*	*0.036*	*0.090*	*17*	*4*
cis-2-Hexene	*0.034*	*0.054*	*17*	*12*	*trans-2-Hexene*	*0.041*	*0.134*	*17*	*12*
cis-2-Pentene	*0.027*	*0.062*	*17*	*3*	trans-2-Pentene	0.093	0.186	17	0

Bold = priority compound *Italics = Detected in < 85% of samples taken*

Table 45 lists the average and maximum NMOC concentrations measured at Platteville in 2006. Thirty-four of the 78 compounds were not detected in at least one of the samples taken. Of the priority compounds, only benzene was detected in all samples taken. 1,3-butadiene was found in only 8 of the fifteen samples taken. A total of 51 of the 78 compounds were present in at least 85% of the samples taken. The highest concentrations were detected among the alkane compounds.

Table 45. Average and Maximum SNMOC Concentrations at Platteville, 2006

Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
1,2,3-Trimethylbenzene	0.018	0.043	15	1	Cyclohexane	1.635	3.617	15	0
1,2,4-Trimethylbenzene	0.197	0.341	15	0	Cyclopentane	0.960	2.100	15	0
1,3,5-Trimethylbenzene	0.052	0.104	15	0	*Cyclopentene*	*0.040*	*0.107*	*15*	*12*
1,3-Butadiene	***0.039***	***0.077***	***15***	*7*	Ethane	137.563	301.500	15	0
1-Decene	*0.025*	*0.025*	*15*	*15*	Ethylbenzene	0.107	0.221	15	0
1-Dodecene	*0.103*	*0.445*	*15*	*8*	Ethylene	1.675	2.770	15	0
1-Heptene	*0.026*	*0.027*	*15*	*14*	Isobutane	20.370	46.500	15	0
1-Hexene	0.023	0.056	15	1	Isobutene/1-Butene	0.319	0.535	15	0
1-Nonene	0.021	0.037	15	2	Isopentane	17.377	40.800	15	0
1-Octene	*0.038*	*0.107*	*15*	*4*	Isoprene	0.202	0.482	15	0
1-Pentene	0.060	0.136	15	1	Isopropylbenzene	0.011	0.019	15	2
1-Tridecene	*0.027*	*0.027*	*15*	*15*	*m-Diethylbenzene*	*0.027*	*0.078*	*15*	*5*
1-Undecene	*0.023*	*0.165*	*15*	*11*	Methylcyclohexane	1.756	4.014	15	0
2,2,3-Trimethylpentane	0.099	0.200	15	1	Methylcyclopentane	2.065	4.333	15	0
2,2,4-Trimethylpentane	0.348	0.744	15	0	m-Ethyltoluene	0.061	0.157	15	0
2,2-Dimethylbutane	0.296	0.653	15	0	m-Xylene/p-Xylene	0.499	0.869	15	0
2,3,4-Trimethylpentane	0.029	0.054	15	0	n-Butane	47.862	110.000	15	0
2,3-Dimethylbutane	0.788	1.800	15	0	n-Decane	0.073	0.133	15	0
2,3-Dimethylpentane	0.271	0.601	15	0	*n-Dodecane*	*0.034*	*0.070*	*15*	*3*
2,4-Dimethylpentane	0.235	0.546	15	0	n-Heptane	1.331	2.743	15	0
2-Ethyl-1-butene	*0.038*	*0.038*	*15*	*15*	n-Hexane	4.527	9.333	15	0
2-Methyl-1-butene	0.095	0.240	15	0	n-Nonane	0.126	0.317	15	0
2-Methyl-1-pentene	*0.030*	*0.038*	*15*	*11*	n-Octane	0.443	1.000	15	0
2-Methyl-2-butene	*0.064*	*0.180*	*15*	*4*	n-Pentane	16.309	38.800	15	0
2-Methylheptane	0.269	0.583	15	0	n-Propylbenzene	0.025	0.057	15	0
2-Methylhexane	0.778	1.700	15	0	*n-Tridecane*	*0.023*	*0.027*	*15*	*11*
2-Methylpentane	4.231	9.000	15	0	n-Undecane	0.040	0.096	15	1
3-Methyl-1-butene	*0.034*	*0.058*	*15*	*14*	*o-Ethyltoluene*	*0.028*	*0.072*	*15*	*8*
3-Methylheptane	0.182	0.401	15	0	o-Xylene	0.142	0.226	15	0
3-Methylhexane	0.881	1.771	15	0	*p-Diethylbenzene*	*0.015*	*0.025*	*15*	*5*
3-Methylpentane	2.257	4.900	15	0	p-Ethyltoluene	0.053	0.223	15	0
4-Methyl-1-pentene	*0.038*	*0.038*	*15*	*15*	Propane	99.322	219.333	15	0
Acetylene	1.176	2.975	15	0	Propylene	0.413	0.697	15	0
a-Pinene	*0.081*	*0.341*	*15*	*5*	*Propyne*	*0.020*	*0.020*	*15*	*15*
Benzene	**2.134**	**4.383**	**15**	**0**	*Styrene*	*0.022*	*0.029*	*15*	*9*
b-Pinene	*0.022*	*0.026*	*15*	*10*	Toluene	1.376	2.371	15	0
cis-2-Butene	*0.038*	*0.098*	*15*	*3*	*trans-2-Butene*	*0.047*	*0.223*	*15*	*3*
cis-2-Hexene	*0.040*	*0.066*	*15*	*11*	*trans-2-Hexene*	*0.046*	*0.177*	*15*	*13*
cis-2-Pentene	*0.027*	*0.048*	*15*	*4*	trans-2-Pentene	0.081	0.139	15	0

Bold = priority compound *Italics = Detected in < 85% of samples taken*

Table 46 lists the average and maximum NMOC concentrations measured at Rocky Flats – North in 2006. Thirty-six of the 78 compounds were not detected in at least one of the samples taken. Of the priority compounds, only benzene was detected in all samples taken. 1,3-butadiene was not found in any of the three samples taken. A total of 42 of the 78 compounds were present in at least 85% of the samples taken. The highest concentrations were detected among the alkane compounds.

Table 46. Average and Maximum SNMOC Concentrations at Rocky Flats – North, 2006

Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
1,2,3-Trimethylbenzene	*0.013*	*0.019*	*3*	*1*	Cyclohexane	0.023	0.047	3	0
1,2,4-Trimethylbenzene	0.107	0.136	3	0	Cyclopentane	0.039	0.058	3	0
1,3,5-Trimethylbenzene	*0.011*	*0.017*	*3*	*1*	*Cyclopentene*	*0.032*	*0.032*	*3*	*3*
1,3-Butadiene	***0.028***	***0.028***	***3***	***3***	Ethane	3.863	7.500	3	0
1-Decene	*0.025*	*0.025*	*3*	*3*	Ethylbenzene	0.043	0.050	3	0
1-Dodecene	*0.023*	*0.030*	*3*	*2*	Ethylene	0.292	0.370	3	0

Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
1-Heptene	0.022	0.022	3	0	Isobutane	0.399	0.890	3	0
1-Hexene	0.011	0.012	3	0	Isobutene/1-Butene	0.101	0.117	3	0
1-Nonene	*0.020*	*0.027*	*3*	*2*	Isopentane	3.245	6.020	3	0
1-Octene	*0.025*	*0.029*	*3*	*1*	Isoprene	0.105	0.123	3	0
1-Pentene	0.024	0.026	3	0	*Isopropylbenzene*	*0.014*	*0.019*	*3*	*1*
1-Tridecene	*0.027*	*0.027*	*3*	*3*	*m-Diethylbenzene*	*0.015*	*0.025*	*3*	*1*
1-Undecene	*0.012*	*0.015*	*3*	*2*	Methylcyclohexane	0.052	0.065	3	0
2,2,3-Trimethylpentane	*0.023*	*0.029*	*3*	*2*	Methylcyclopentane	0.048	0.061	3	0
2,2,4-Trimethylpentane	0.015	0.026	3	0	m-Ethyltoluene	0.012	0.014	3	0
2,2-Dimethylbutane	0.016	0.023	3	0	m-Xylene/p-Xylene	0.114	0.141	3	0
2,3,4-Trimethylpentane	*0.017*	*0.019*	*3*	*1*	n-Butane	0.892	2.133	3	0
2,3-Dimethylbutane	0.014	0.029	3	0	n-Decane	0.019	0.031	3	0
2,3-Dimethylpentane	*0.013*	*0.027*	*3*	*1*	n-Dodecane	0.016	0.023	3	0
2,4-Dimethylpentane	*0.015*	*0.021*	*3*	*1*	n-Heptane	0.033	0.055	3	0
2-Ethyl-1-butene	*0.038*	*0.038*	*3*	*3*	n-Hexane	0.080	0.167	3	0
2-Methyl-1-butene	*0.016*	*0.032*	*3*	*1*	n-Nonane	0.010	0.012	3	0
2-Methyl-1-pentene	*0.038*	*0.038*	*3*	*3*	n-Octane	0.019	0.024	3	0
2-Methyl-2-butene	0.016	0.019	3	0	n-Pentane	0.537	0.794	3	0
2-Methylheptane	0.015	0.019	3	0	*n-Propylbenzene*	*0.018*	*0.022*	*3*	*2*
2-Methylhexane	0.051	0.076	3	0	*n-Tridecane*	*0.027*	*0.027*	*3*	*3*
2-Methylpentane	0.064	0.076	3	0	n-Undecane	0.020	0.026	3	0
3-Methyl-1-butene	*0.032*	*0.032*	*3*	*3*	*o-Ethyltoluene*	*0.019*	*0.019*	*3*	*3*
3-Methylheptane	*0.007*	*0.011*	*3*	*1*	o-Xylene	0.056	0.075	3	0
3-Methylhexane	0.122	0.183	3	0	*p-Diethylbenzene*	*0.018*	*0.025*	*3*	*2*
3-Methylpentane	0.048	0.090	3	0	*p-Ethyltoluene*	*0.015*	*0.024*	*3*	*1*
4-Methyl-1-pentene	*0.037*	*0.038*	*3*	*2*	Propane	2.184	4.933	3	0
Acetylene	0.242	0.281	3	0	Propylene	0.116	0.170	3	0
a-Pinene	*0.025*	*0.025*	*3*	*3*	*Propyne*	*0.020*	*0.020*	*3*	*3*
Benzene	**0.091**	**0.109**	**3**	**0**	*Styrene*	*0.029*	*0.029*	*3*	*3*
b-Pinene	*0.025*	*0.025*	*3*	*3*	Toluene	0.129	0.142	3	0
cis-2-Butene	*0.021*	*0.028*	*3*	*1*	*trans-2-Butene*	*0.019*	*0.024*	*3*	*2*
cis-2-Hexene	*0.028*	*0.038*	*3*	*2*	*trans-2-Hexene*	*0.031*	*0.038*	*3*	*1*
cis-2-Pentene	*0.032*	*0.032*	*3*	*3*	trans-2-Pentene	0.015	0.021	3	0

Bold = priority compound *Italics = Detected in < 85% of samples taken*

Table 47 lists the average and maximum NMOC concentrations measured at Ft. Collins – West in 2006. Forty of the 78 compounds were not detected in at least one of the samples taken. Of the priority compounds, only benzene was detected in all samples taken. 1,3-butadiene was not found in any of the three samples taken. A total of 38 of the 78 compounds were present in at least 85% of the samples taken. The highest concentrations were detected among the alkane compounds.

Table 47. Average and Maximum SNMOC Concentrations at Ft. Collins – West, 2006

Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
1,2,3-Trimethylbenzene	*0.015*	*0.019*	*3*	*2*	Cyclohexane	0.027	0.056	3	0
1,2,4-Trimethylbenzene	0.090	0.101	3	0	Cyclopentane	0.028	0.052	3	0
1,3,5-Trimethylbenzene	*0.013*	*0.017*	*3*	*2*	*Cyclopentene*	*0.032*	*0.032*	*3*	*3*
1,3-Butadiene	***0.028***	***0.028***	***3***	***3***	Ethane	3.382	5.750	3	0
1-Decene	*0.025*	*0.025*	*3*	*3*	Ethylbenzene	0.026	0.031	3	0
1-Dodecene	*0.057*	*0.112*	*3*	*2*	Ethylene	0.350	0.560	3	0
1-Heptene	*0.018*	*0.027*	*3*	*1*	Isobutane	0.410	0.810	3	0
1-Hexene	0.017	0.030	3	0	Isobutene/1-Butene	0.105	0.148	3	0
1-Nonene	*0.026*	*0.027*	*3*	*2*	Isopentane	0.481	0.918	3	0
1-Octene	*0.022*	*0.029*	*3*	*2*	Isoprene	0.239	0.448	3	0
1-Pentene	0.028	0.037	3	0	*Isopropylbenzene*	*0.019*	*0.019*	*3*	*3*
1-Tridecene	*0.027*	*0.027*	*3*	*3*	*m-Diethylbenzene*	*0.025*	*0.025*	*3*	*3*
1-Undecene	*0.015*	*0.015*	*3*	*3*	Methylcyclohexane	0.028	0.032	3	0

Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects	Analyte	Avg. (ppbv)	Max. (ppbv)	# Samples	# Non-Detects
2,2,3-Trimethylpentane	*0.021*	*0.029*	*3*	*2*	Methylcyclopentane	0.046	0.095	3	0
2,2,4-Trimethylpentane	0.016	0.022	3	0	m-Ethyltoluene	0.010	0.011	3	0
2,2-Dimethylbutane	0.025	0.046	3	0	m-Xylene/p-Xylene	0.086	0.091	3	0
2,3,4-Trimethylpentane	*0.017*	*0.024*	*3*	*2*	n-Butane	1.084	2.273	3	0
2,3-Dimethylbutane	0.026	0.055	3	0	*n-Decane*	*0.013*	*0.020*	*3*	*1*
2,3-Dimethylpentane	*0.024*	*0.027*	*3*	*2*	*n-Dodecane*	*0.023*	*0.030*	*3*	*1*
2,4-Dimethylpentane	0.020	0.040	3	0	n-Heptane	0.027	0.038	3	0
2-Ethyl-1-butene	*0.038*	*0.038*	*3*	*3*	n-Hexane	0.087	0.160	3	0
2-Methyl-1-butene	*0.059*	*0.138*	*3*	*1*	n-Nonane	0.008	0.010	3	0
2-Methyl-1-pentene	*0.038*	*0.038*	*3*	*3*	n-Octane	0.014	0.019	3	0
2-Methyl-2-butene	*0.048*	*0.079*	*3*	*2*	n-Pentane	0.360	0.648	3	0
2-Methylheptane	0.015	0.024	3	0	*n-Propylbenzene*	*0.017*	*0.022*	*3*	*2*
2-Methylhexane	0.035	0.053	3	0	*n-Tridecane*	*0.027*	*0.027*	*3*	*3*
2-Methylpentane	0.287	0.773	3	0	*n-Undecane*	*0.019*	*0.034*	*3*	*1*
3-Methyl-1-butene	*0.032*	*0.032*	*3*	*3*	*o-Ethyltoluene*	*0.019*	*0.019*	*3*	*3*
3-Methylheptane	*0.011*	*0.011*	*3*	*3*	o-Xylene	0.040	0.044	3	0
3-Methylhexane	0.108	0.146	3	0	*p-Diethylbenzene*	*0.025*	*0.025*	*3*	*3*
3-Methylpentane	0.062	0.107	3	0	p-Ethyltoluene	0.006	0.008	3	0
4-Methyl-1-pentene	*0.038*	*0.038*	*3*	*3*	Propane	1.944	3.467	3	0
Acetylene	0.228	0.313	3	0	Propylene	0.101	0.146	3	0
a-Pinene	*0.073*	*0.152*	*3*	*1*	*Propyne*	*0.020*	*0.020*	*3*	*3*
Benzene	**0.085**	**0.116**	**3**	**0**	*Styrene*	*0.014*	*0.029*	*3*	*1*
b-Pinene	*0.018*	*0.025*	*3*	*2*	Toluene	0.118	0.144	3	0
cis-2-Butene	*0.045*	*0.080*	*3*	*2*	*trans-2-Butene*	*0.057*	*0.124*	*3*	*2*
cis-2-Hexene	*0.038*	*0.038*	*3*	*3*	*trans-2-Hexene*	*0.038*	*0.038*	*3*	*3*
cis-2-Pentene	*0.027*	*0.032*	*3*	*2*	*trans-2-Pentene*	*0.019*	*0.036*	*3*	*1*

Bold = priority compound *Italics = Detected in < 85% of samples taken*

The final table in this section lists the average and maximum concentrations of speciated NMOCs (SNMOCs), total NMOCs (TNMOCs), and unknowns. The unknown concentration is obtained by subtracting the concentration of SNMOCs from the TNMOC concentration. The SNMOC concentration is obtained by summing the concentrations of each of the speciated compound concentrations. The TNMOC concentration is obtained via lab analysis. The red percentages indicate the percent contribution of the unknown and SNMOC concentrations to the TNMOC concentration. The Platteville and Rocky Flats – North sites show much larger averages than the other sites, with values that are nearly double those of the other sites. The maximums for CAMP, Rocky Flats – North, and Platteville were close in value, with a range of 240 ppbC between them. A look at the percentage contributions shows that CAMP, Rocky Flats – North, and Ft. Collins – West all had very large concentrations of unknown compounds. The Platteville site had larger SNMOC concentrations than unknown concentrations. Because the suite of compounds being analyzed for was intended to look at oil and gas activity, it makes sense that the Platteville site would be the best characterized by this particular group of compounds as it sits in the middle of a large oil and gas development area. The Rocky Flats – North, and Ft. Collins – West sites were intended as background sites, and are well out of the oil and gas development area. The large concentrations of unknowns at those two sites indicate that the compounds that are present in that area may not be linked to oil and gas development activity, but are more representative of compounds generated through the ozone photolytic process.

Table 48. Average and Maximum Total NMOC Concentrations for All Sites, 2006

	CAMP		Welby		Ft. Lupton		Platteville		Rocky Flats - North		Ft. Collins - West	
	Avg. (ppbC)	Max. (ppbC)	Avg. (ppbC)	Max. (ppbC)	Avg. (ppbC)	Max. (ppbC)	Avg. (ppbC)	Max. (ppbC)	Avg. (ppbC)	Max. (ppbC)	Avg. (ppbC)	Max. (ppbC)
SNMOCs	172 (28%)	117 (4%)	203 (62%)	291 (53%)	552 (71%)	852 (60%)	1210 (80%)	2670 (92%)	51 (3%)	62 (2%)	38 (9%)	69 (11%)
Unknowns	441 (72%)	2740 (96%)	127 (38%)	255 (47%)	225 (29%)	561 (40%)	305 (20%)	234 (8%)	1756 (97%)	3040 (98%)	398 (91%)	534 (89%)
TNMOCs	613	2860	330	547	778	1410	1516	2900	1806	3100	435	603

3.4 *NMOC/VOC Comparisons*

3.4.1. Site Comparisons

Two sites collected NMOC/VOC samples in each of the three campaigns. These were the CAMP and Welby sites. The Platteville site sampled in the 2003 and 2006 studies, but not in the 1996 study. The Rocky Flats – North site sampled in both the 1996 and 2006 studies. It should be noted here that all comparisons are made using the data from the samples gathered in the morning hours, between 06:00 and 09:00. No comparisons are made using the afternoon sampling data. The compounds used for comparisons are those which were detected in greater than 85% of the samples taken, or are priority compounds, as designated by the EPA.

Figure 18 through Figure 22 depict the average SNMOC concentrations at CAMP from the 1996 study through the 2006 study. The compounds are grouped by their classifications as alkanes, alkenes, alkynes, or aromatics. They are further ordered from the largest concentration to the smallest concentration for ease of viewing. The graphs indicate that the average concentrations for the majority of compounds decreased from 1996 to 2006. Ethane, propane, n-butane, isobutane, 2,2-dimethylbutane, *cis*-2-butene, and benzene showed initial increases in their average concentrations from 1996 to 2003, before decreasing in 2006. Isobutane showed the largest increase, jumping from an average of just under 2 ppbv in 1996 to 62 ppbv in 2003, then back down to just over 1 ppbv in 2006. It is unclear why there was such a large change in the average concentrations for this compound.

Aside from the isobutane anomaly, the largest concentrations over the three studies are found in the lighter end alkanes like ethane, propane, butane and pentane. Acetylene had a large average in 1996, but decreased significantly in 2003 and 2006. In the 1996 TO-12 analyses, this alkyne compound was co-eluting with ethane. In the TO-14 and TO-15 analyses, however, singular acetylene concentrations were obtained. Taking the average of the acetylene concentration values from these two different analyses, and subtracting it from the value from the TO-12 analysis gives more representative values for the ethane and acetylene concentrations. In 2003, due to advances in technology, these compounds were able to be adequately separated to give two distinct concentrations.

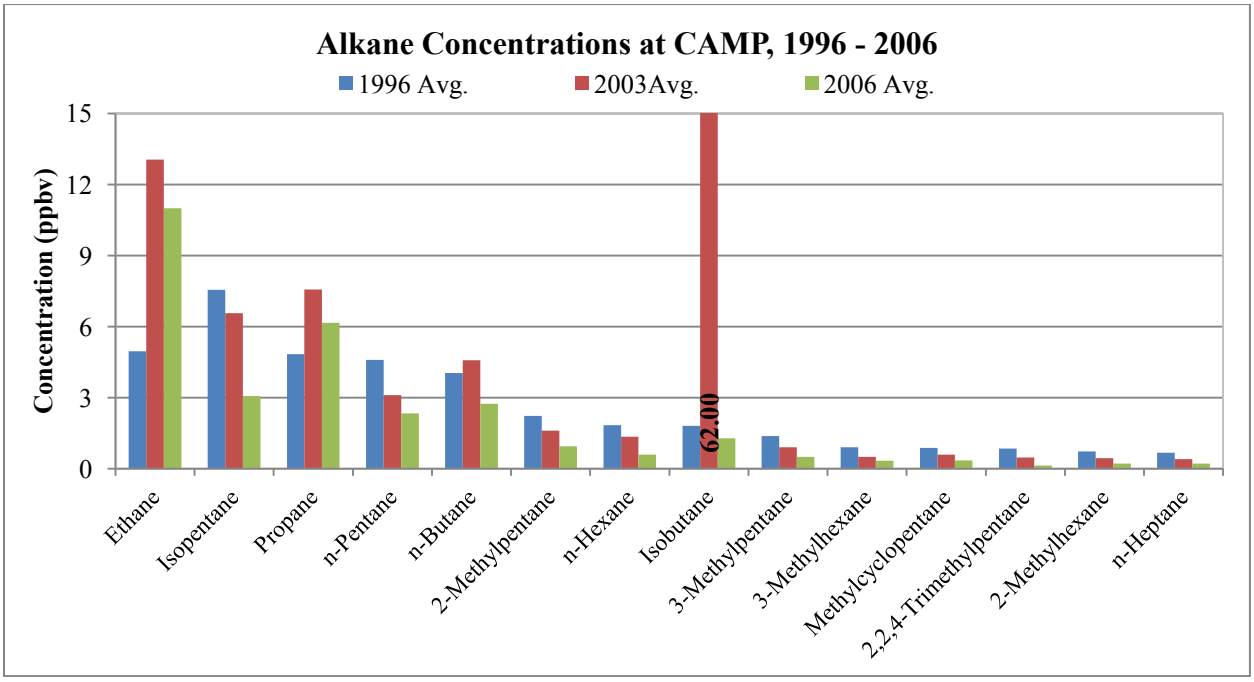

Figure 18. Alkane Concentrations at CAMP, 1996 – 2006

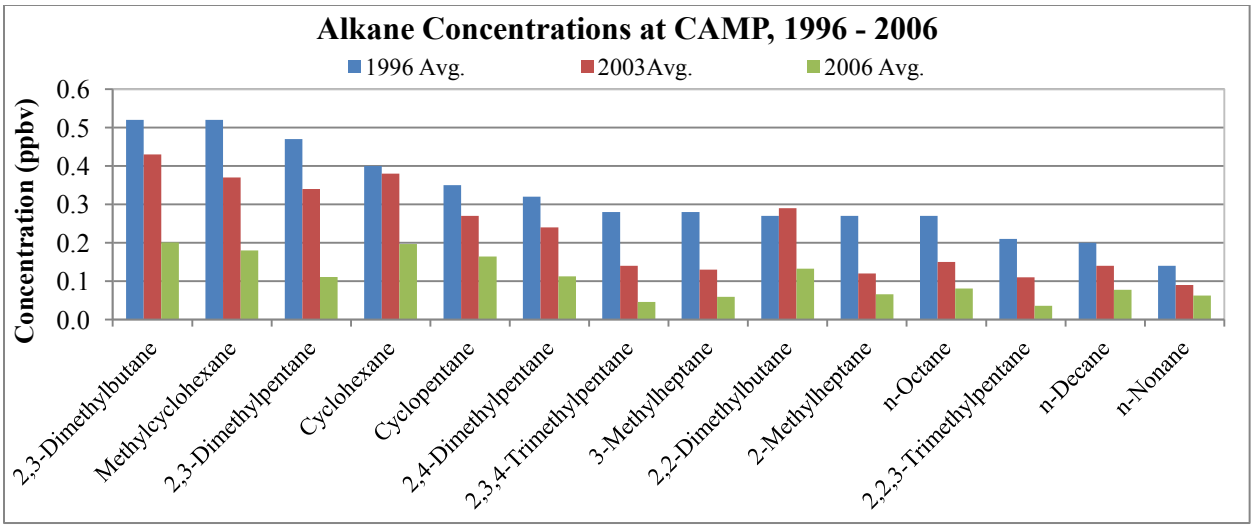

Figure 19. Alkane Concentrations at CAMP, 1996 – 2006

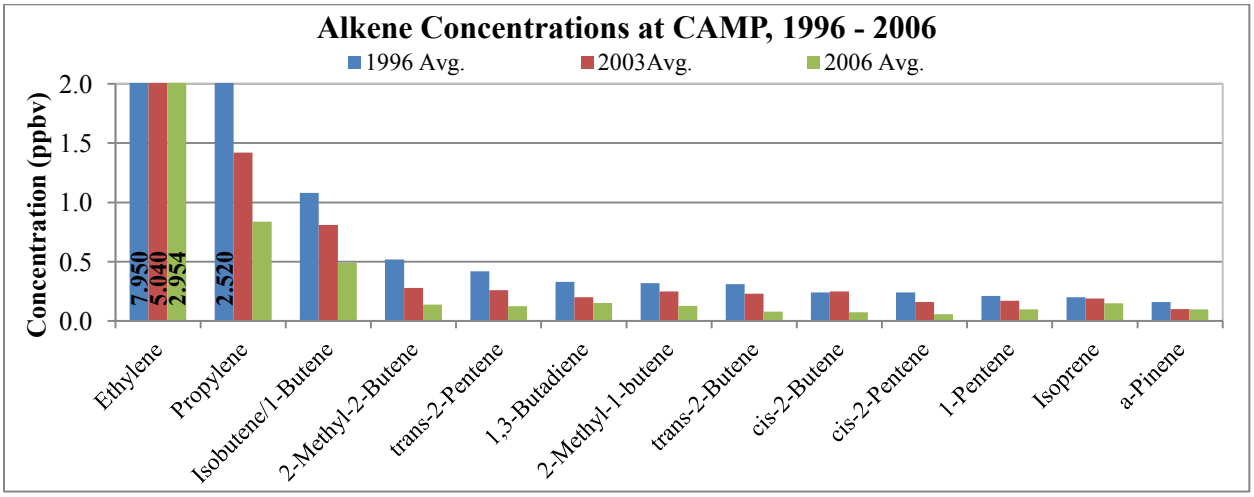

Figure 20. Alkene Concentrations at CAMP, 1996 - 2006

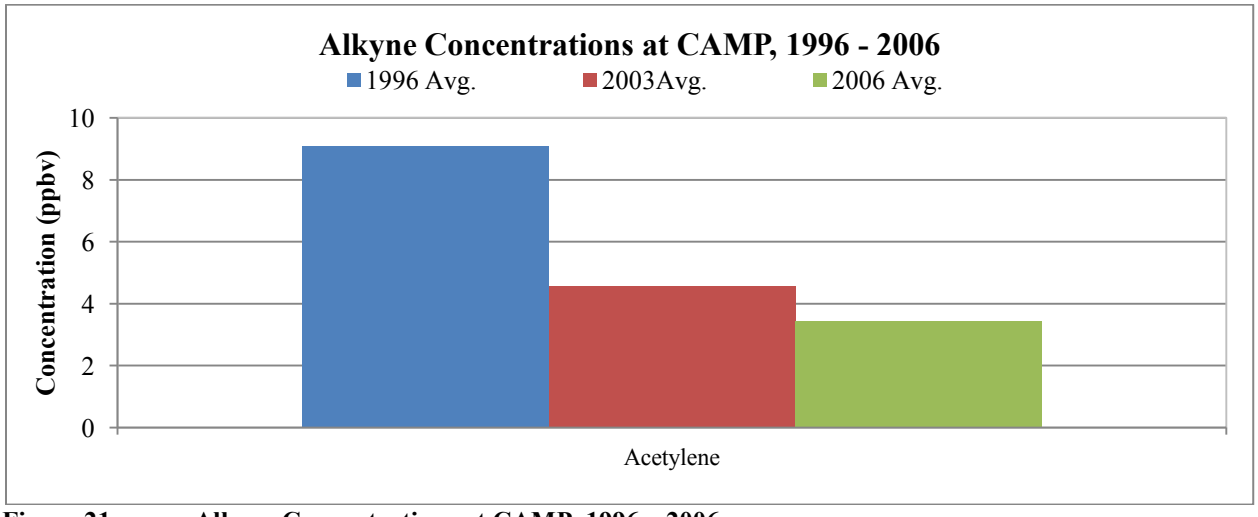

Figure 21. Alkyne Concentrations at CAMP, 1996 – 2006

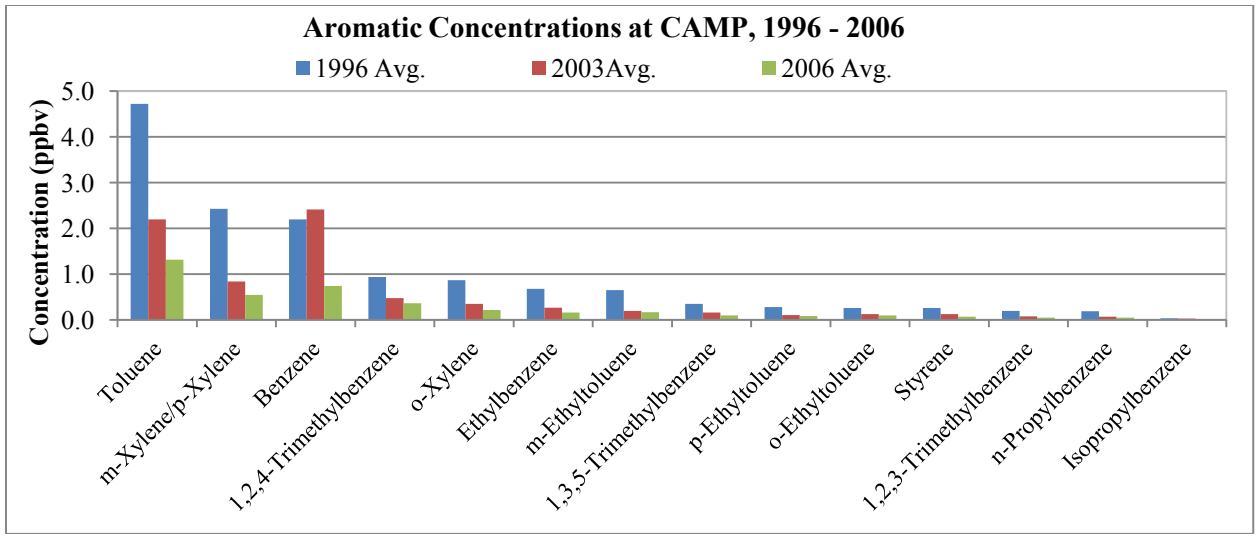

Figure 22. Aromatic Concentrations at CAMP, 1996 - 2006

Figure 23 through Figure 27 depict the average SNMOC concentrations at Welby from the 1996 study through the 2006 study. The compounds are again grouped by their classifications as alkanes, alkenes, alkynes, or aromatics, and are further ordered from the largest concentration to the smallest concentration for ease of viewing. The graphs indicate that the average concentrations for the majority of compounds decreased from 1996 to 2006. Twelve of the 28 alkane compounds showed initial increases in their average concentrations from 1996 to 2003, before decreasing in 2006. Unlike the isobutane concentrations at CAMP, no compounds showed very large concentration increases. Benzene, however, did have a 2003 average that was twice as large as the 1996 and 2006 averages. It is unclear why the concentrations of so many compounds increased from 1996 to 2003, but the site's close proximity to several industrial sources could be a contributing factor.

Similar to the values seen at CAMP, the largest concentrations over the three studies were found in the lighter end alkanes like ethane, propane, and pentane. Acetylene had a large average in 1996, but decreased significantly in 2003 and 2006. In the 1996 TO-12 analyses, this alkyne compound was co-eluting with ethane. In the TO-14 and TO-15 analyses, however, singular acetylene concentrations were obtained. Taking the average of the acetylene concentration values from these two different analyses, and subtracting it from the value from the TO-12 analysis gives more representative values for the ethane and acetylene concentrations.

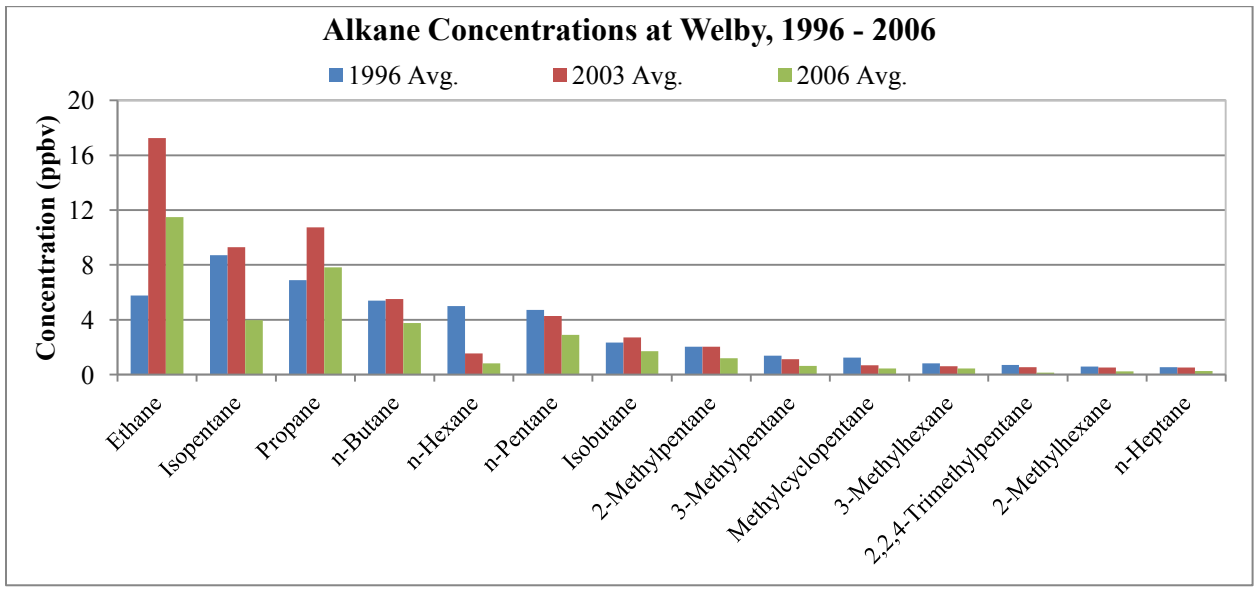

Figure 23. Alkane Concentrations at Welby, 1996 – 2006

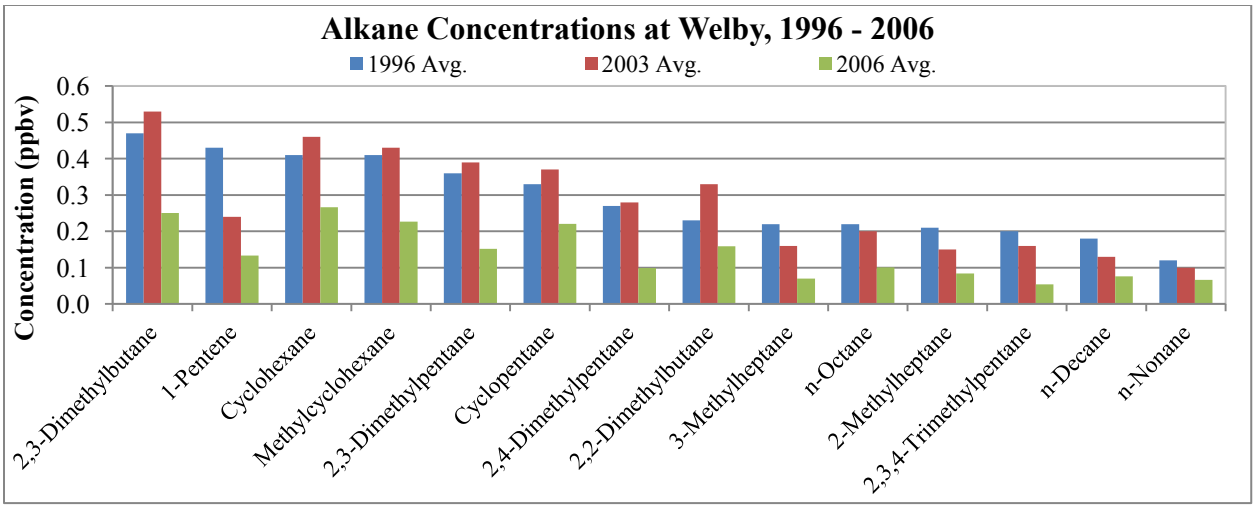

Figure 24. Alkane Concentrations at Welby, 1996 - 2006

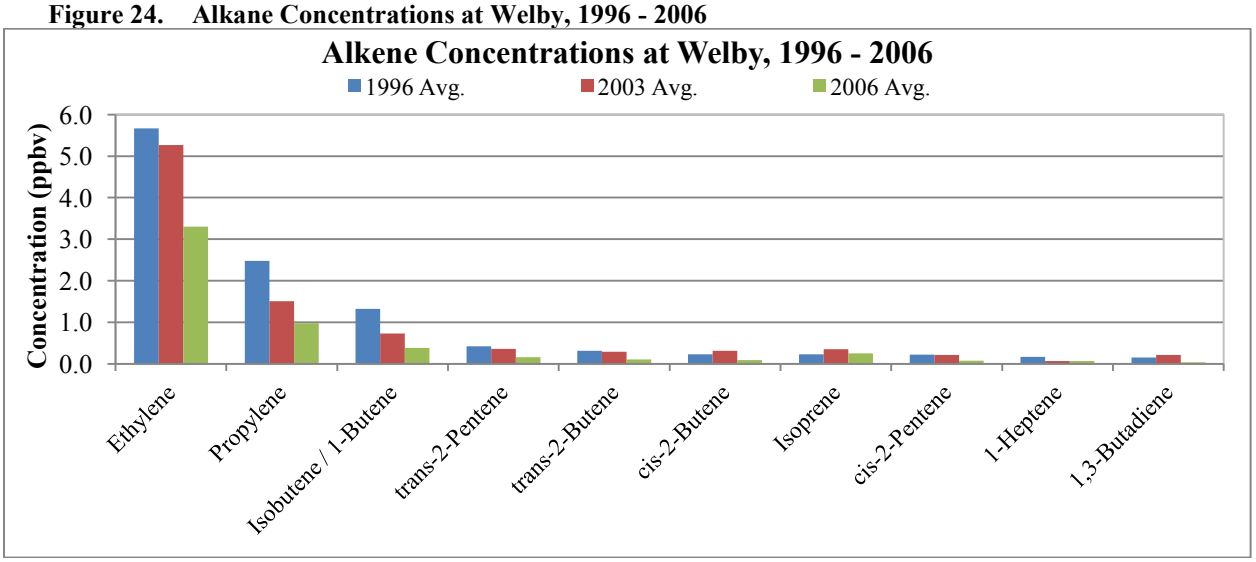

Figure 25. Alkene Concentrations at Welby, 1996 – 2006

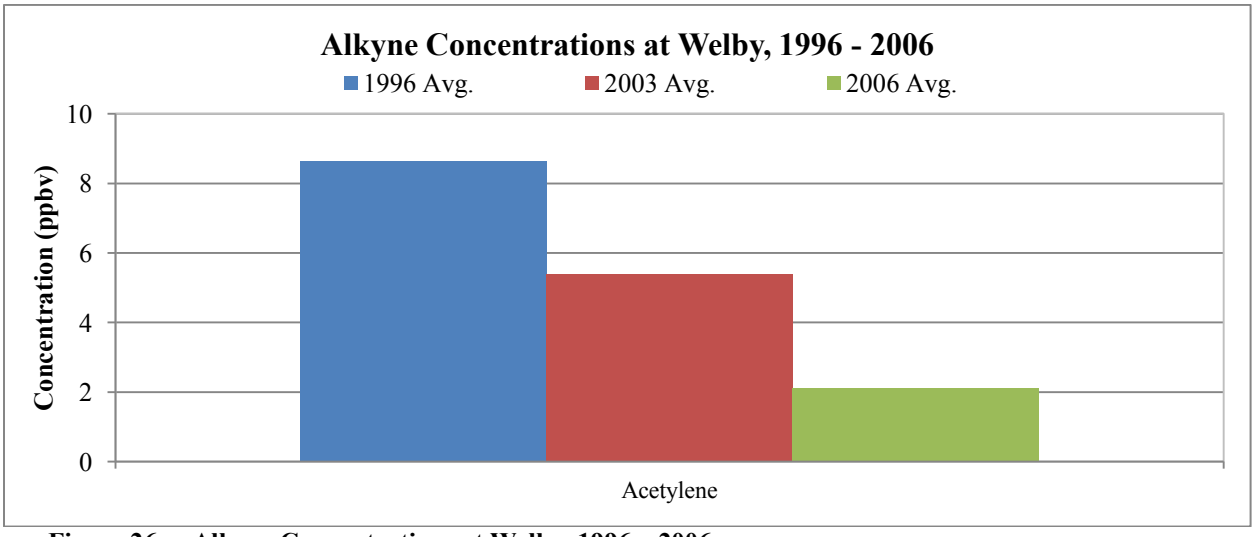

Figure 26. Alkyne Concentrations at Welby, 1996 – 2006

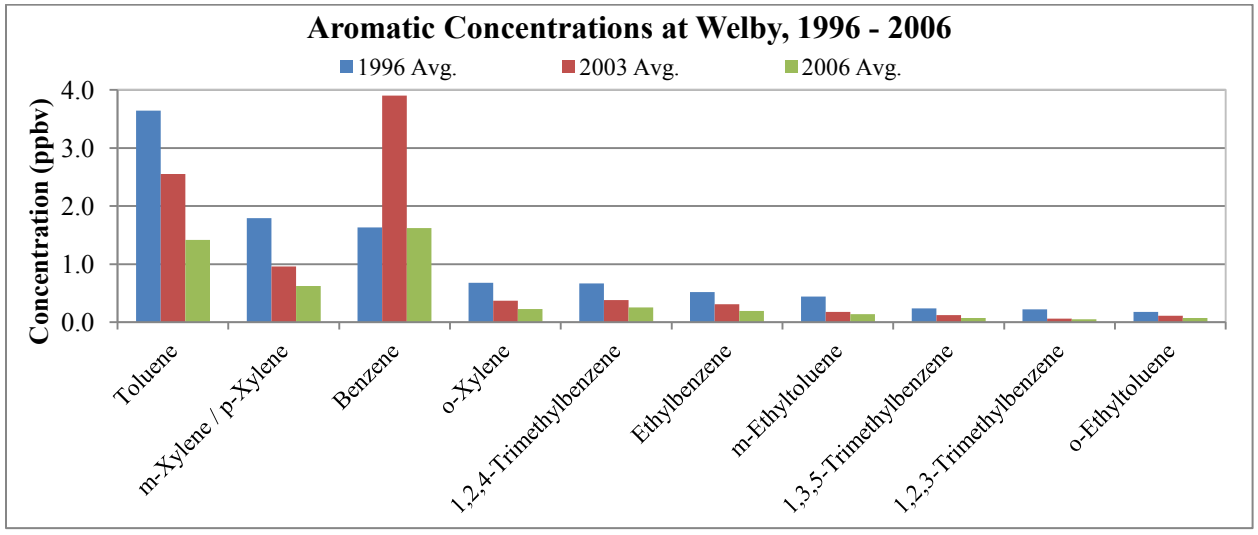

Figure 27. Aromatic Concentrations at Welby, 1996 - 2006

Figure 28 through Figure 32 depict the average SNMOC concentrations at Rocky Flats - North from the 1996 study and the 2006 study. The compounds are again grouped by their classifications as alkanes, alkenes, alkynes, or aromatics, and are further ordered from the largest concentration to the smallest concentration for ease of viewing. The graphs indicate that the average concentrations for all but one of the compounds decreased from 1996 to 2006. The average isopentane concentration more than doubled from 1996 to 2006. It is unclear why this compound's concentration average increased from 1996 to 2006.

Similar to the values seen at CAMP, the largest concentrations over the three studies were found in the lighter end alkanes like ethane, propane, butane, and isopentane. The average concentration values at Rocky Flats – North were much less than those obtained at the CAMP and Welby sites, however. This is due to the fact that the site was purposely located in an area so as to obtain background NMOC concentrations away from major sources. This Acetylene had a large average in 1996, but decreased significantly in 2006. In the 1996 TO-12 analyses, this alkyne compound was co-eluting with ethane. As such, the concentrations shown for these two compounds are the same for that year. Because no method testing between TO-12 and TO-14 was done at Rocky Flats – North, there is no separate concentration for acetylene in 1996 as there was at the CAMP and Welby sites, and the ethane/acetylene concentrations cannot be separated.

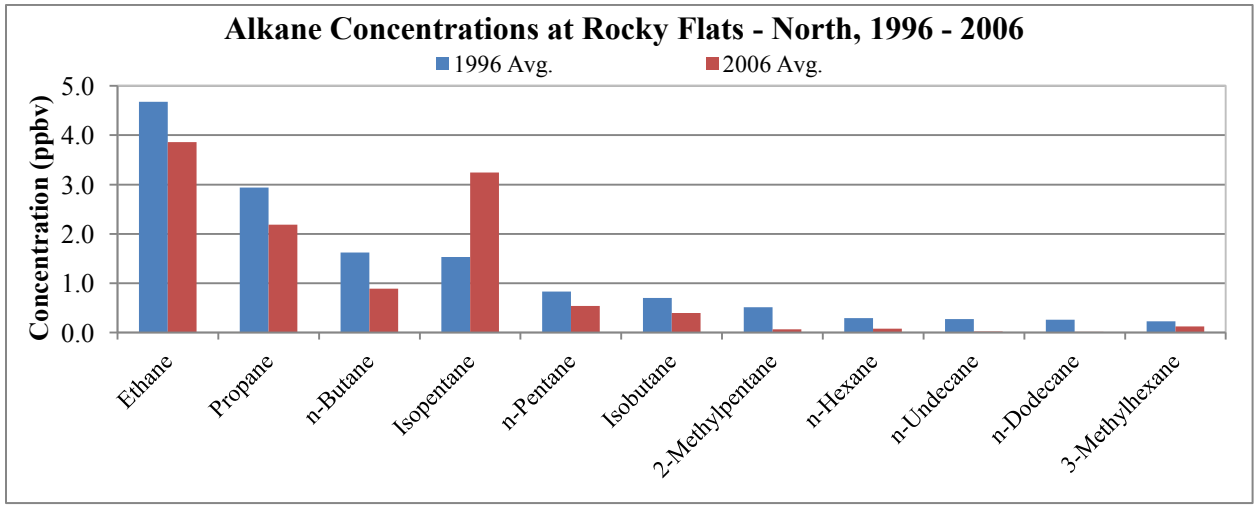

Figure 28. Alkane Concentrations at Rocky Flats – North, 1996 - 2006

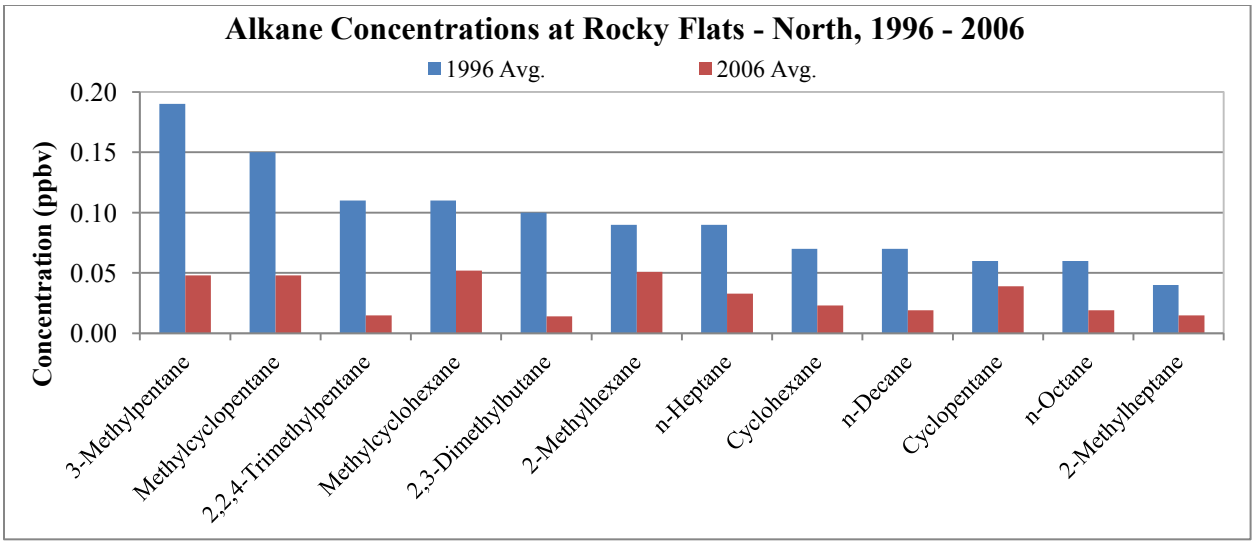

Figure 29. Alkane Concentrations at Rocky Flats – North, 1996 – 2006

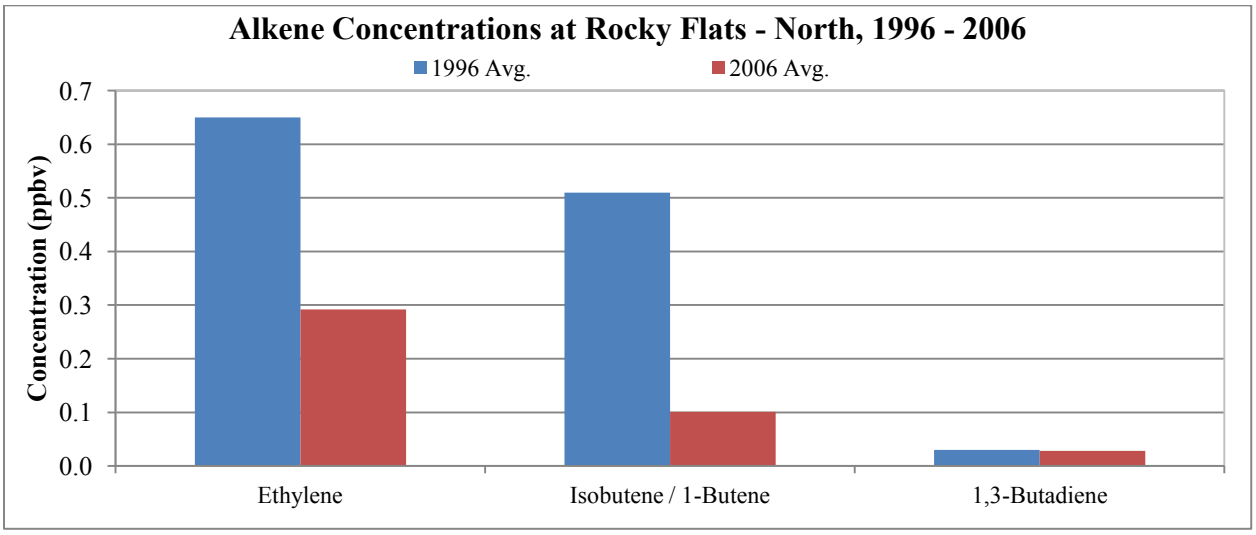

Figure 30. Alkene Concentrations at Rocky Flats – North, 1996 – 2006

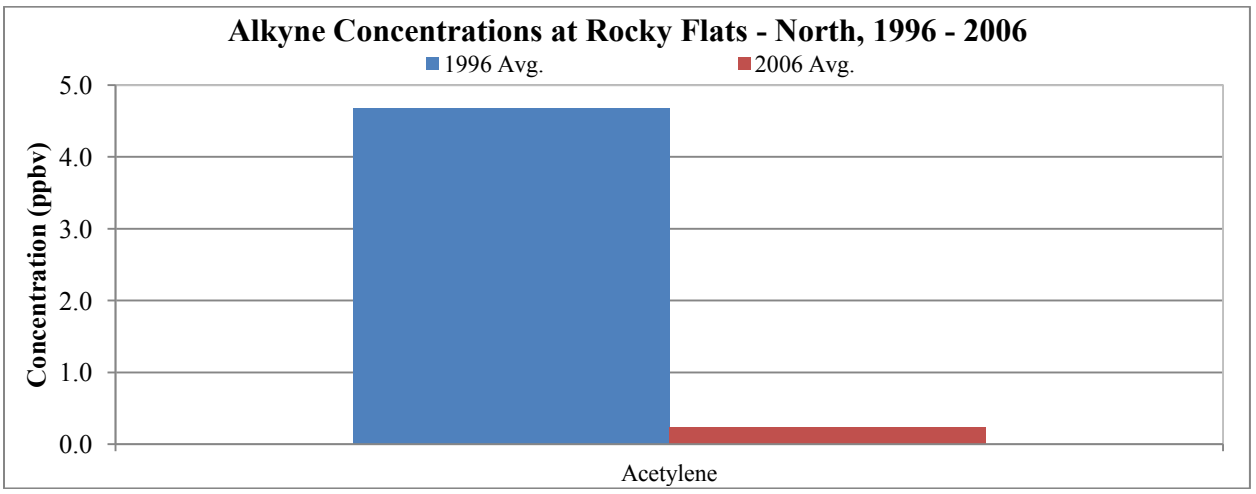

Figure 31. Alkyne Concentrations at Rocky Flats – North, 1996 – 2006

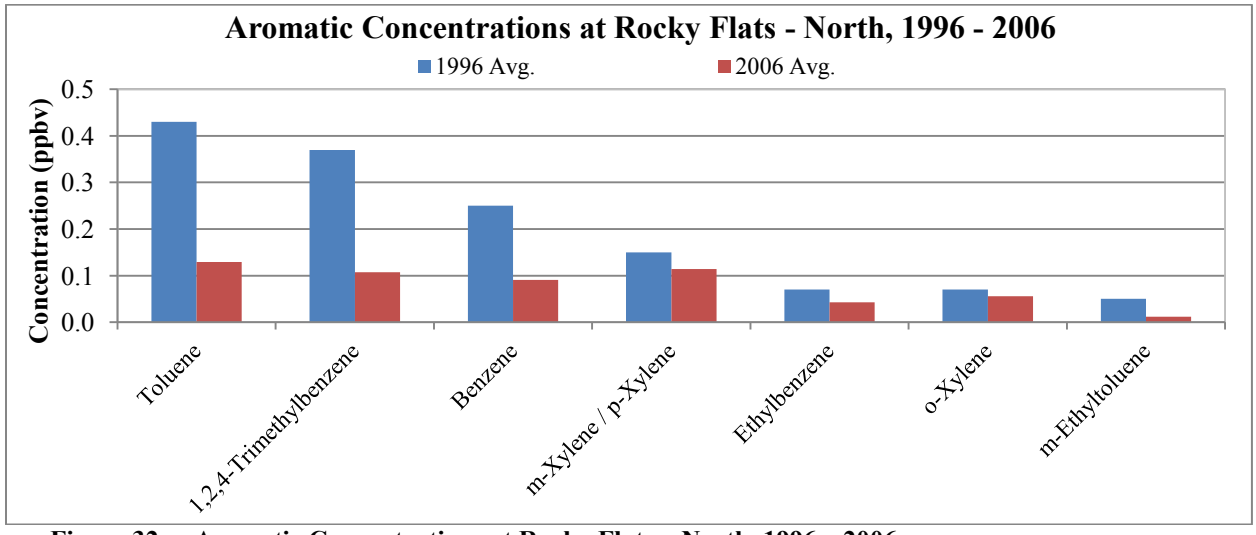

Figure 32. Aromatic Concentrations at Rocky Flats – North, 1996 – 2006

Figure 33 through Figure 37 depict the average SNMOC concentrations at Platteville from the 2003 and 2006 studies. The compounds are again grouped by their classifications as alkanes, alkenes, alkynes, or aromatics, and are further ordered from the largest concentration to the smallest concentration for ease of viewing. The graphs indicate that the average concentrations for all but one of the compounds decreased from 2003 to 2006. The average 2,2,4-trimethylpentane concentration nearly doubled from 2003 to 2006, but the concentration values themselves are still quite low.

Similar to the pattern seen at CAMP, Welby, and Rocky Flats - North, the largest concentrations over the three studies were found in the lighter end alkanes like ethane, propane, the butanes, and isopentane. The average concentration values at Platteville were much larger than those obtained at the CAMP, Welby, and Rocky Flats - North sites. This is due to the fact that the site was purposely located in an area where it is surrounded by oil/natural gas drilling and development sites. Benzene had the largest concentration among the aromatic compounds.

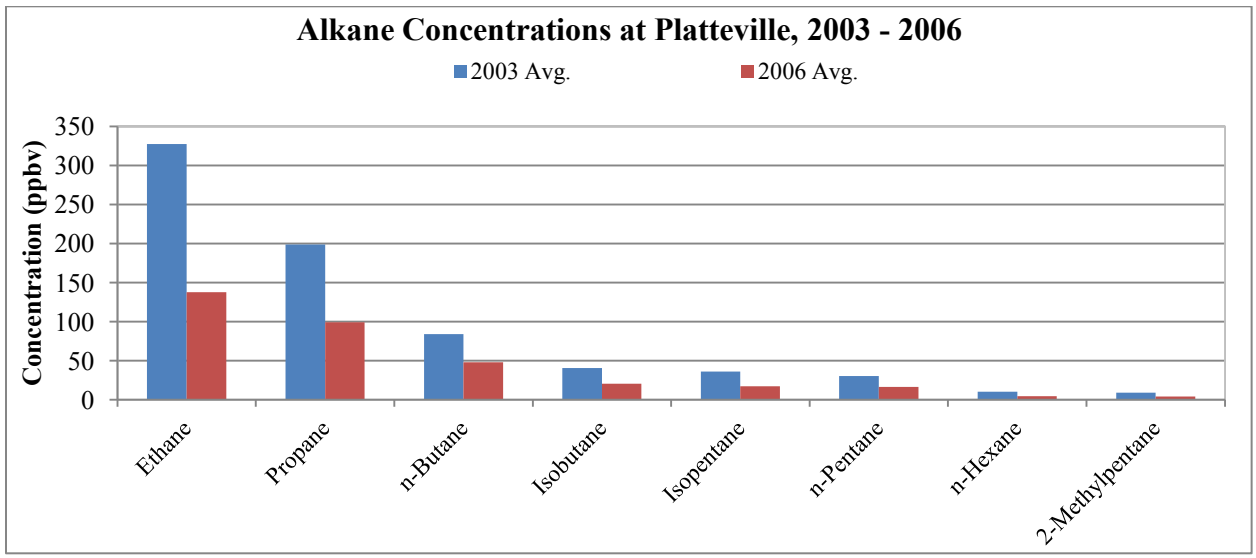

Figure 33. Alkane Concentrations at Platteville, 2003 - 2006

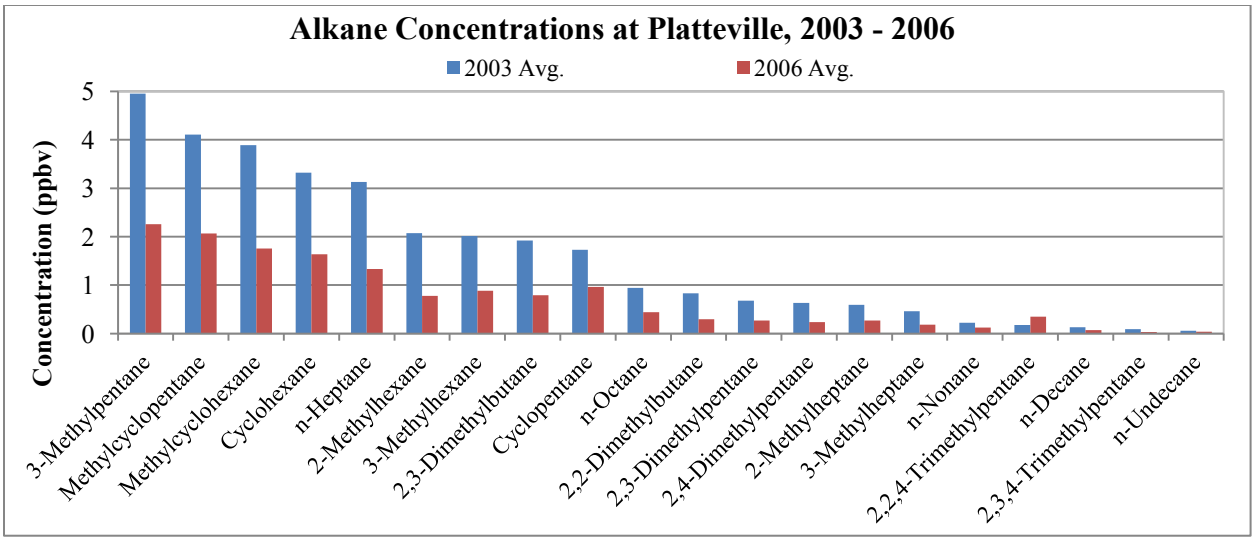

Figure 34. Alkane Concentrations at Platteville, 2003 – 2006

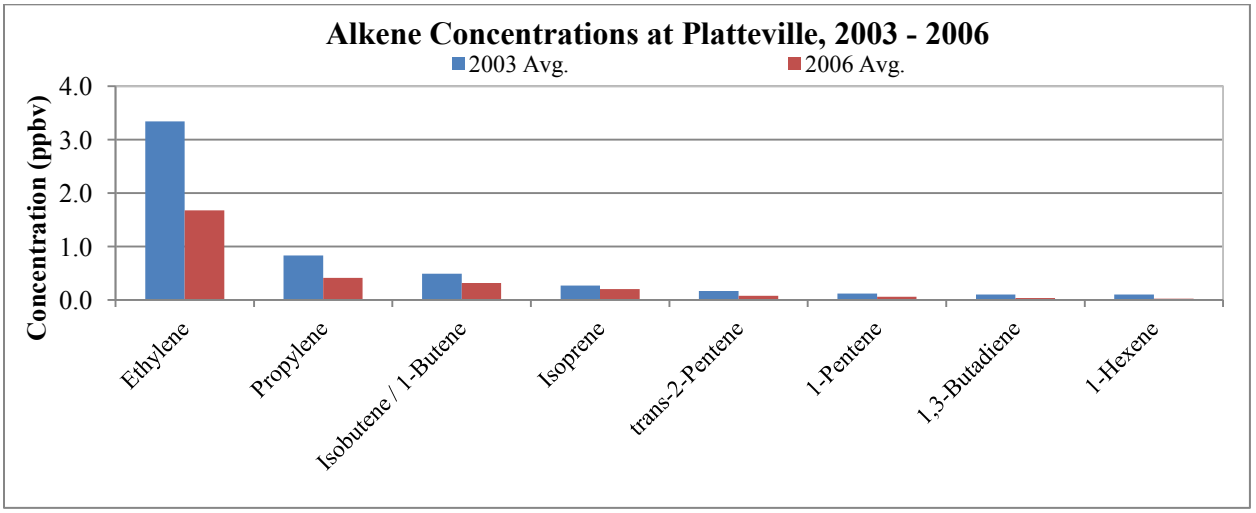

Figure 35. Alkene Concentrations at Platteville, 2003 – 2006

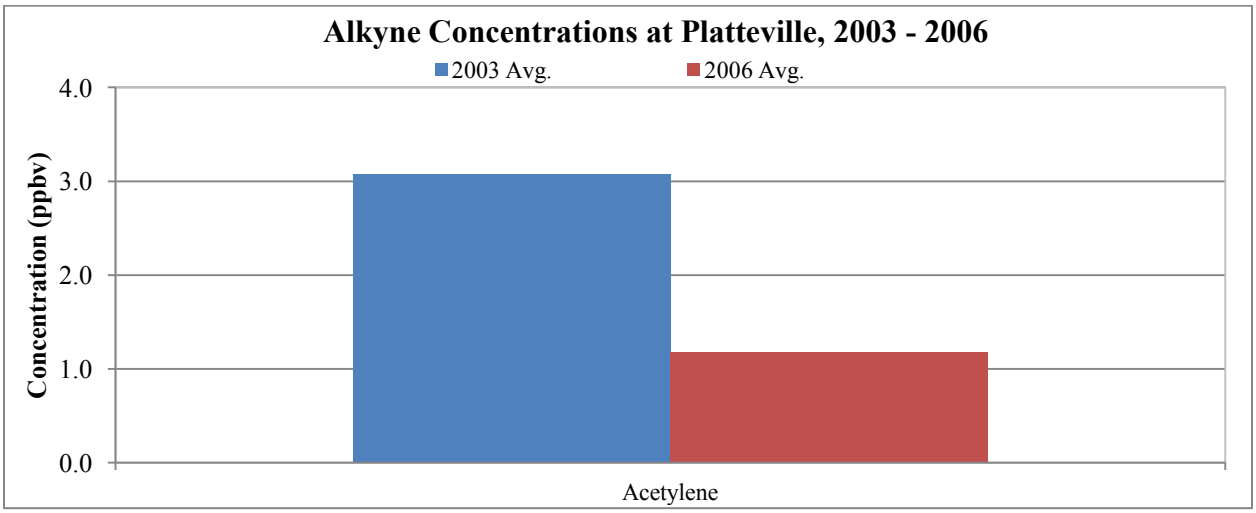

Figure 36. Alkyne Concentrations at Platteville, 2003 - 2006

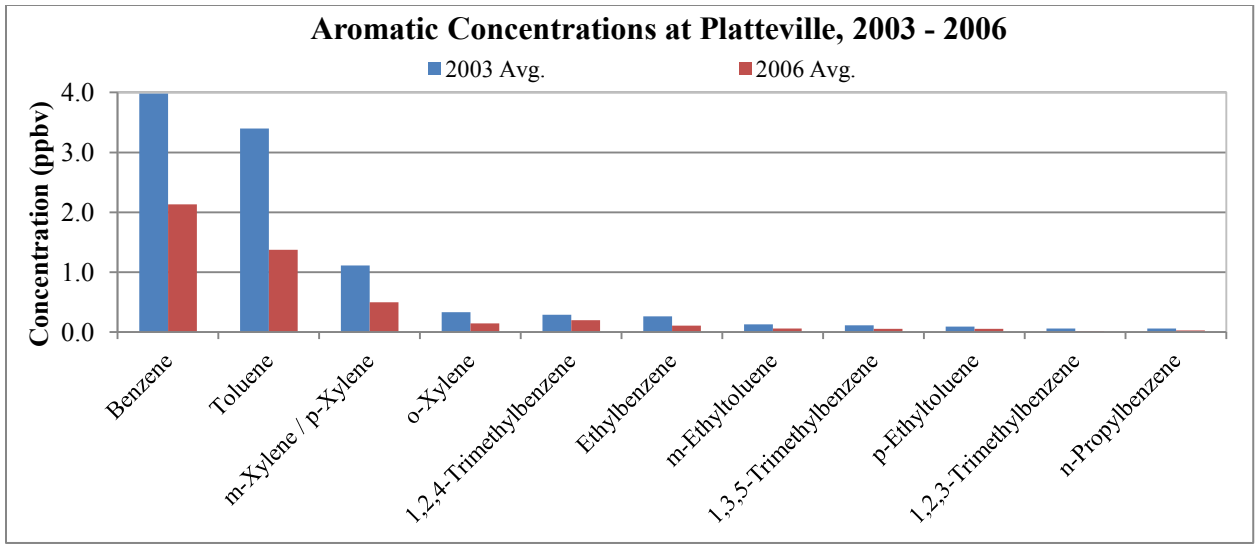

Figure 37. Aromatic Concentrations at Platteville, 2003 – 2006

Figure 38 through Figure 43 show how the average concentrations of certain compounds varied from site to site during each study year. The compounds shown are those that were detected in greater than 85% of the samples taken at each of the sites, and that are common to all four sites. There were 32 such compounds comprising this list. Each graph shows the average SNMOC concentrations for that study year, in order of largest to smallest concentration.

In 1996, the CAMP and Welby sites had concentrations that were much larger than those at the Rocky Flats – North background site. For 10 of the 32 compounds, Welby had slightly larger average concentrations. For the remaining 22 compounds, CAMP had the larger averages, though the values are quite similar between the sites. As was mentioned in earlier sections, the CAMP site is located in downtown Denver, and subject to significant mobile sources throughout the day. The Welby site is located in north Denver, and is in close proximity to an oil/natural gas refinery.

In 2003, the Platteville site had significantly larger concentrations for most of the 32 compounds. For some compounds, Platteville had concentrations that were 20 times larger than those seen at CAMP and Welby. This was true for acetylene, ethane, and ethylene. The Platteville site is located amidst significant oil and natural gas development activities. Although the Platteville site dominated the concentrations, CAMP did have several compounds with averages that were higher. The isopentane average is significantly larger, with the average concentrations being 62 and 41 at CAMP and Platteville, respectively.

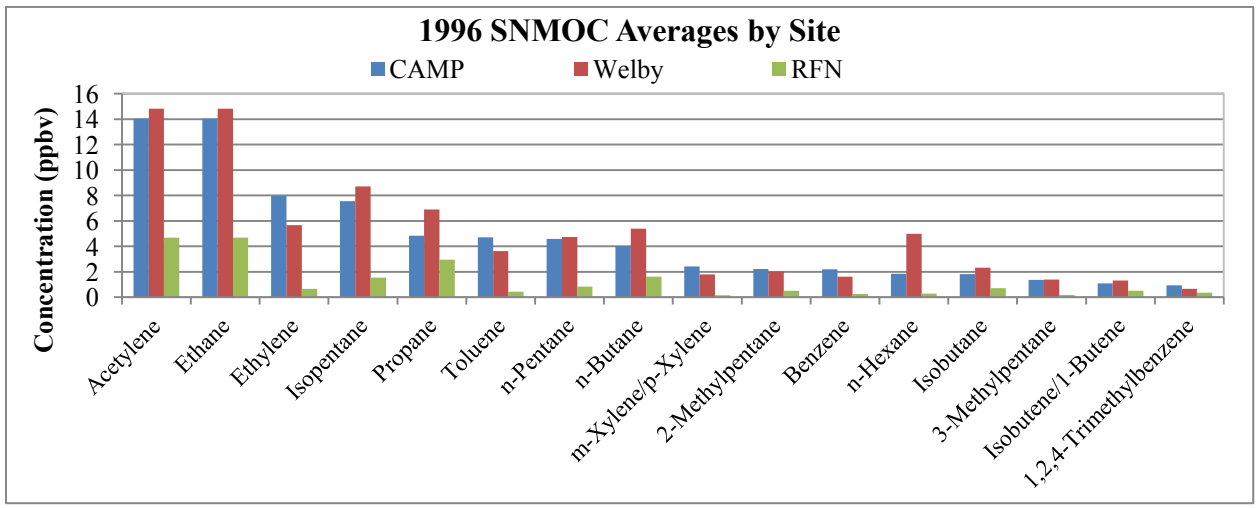

Figure 38. SNMOC Averages by Site, 1996

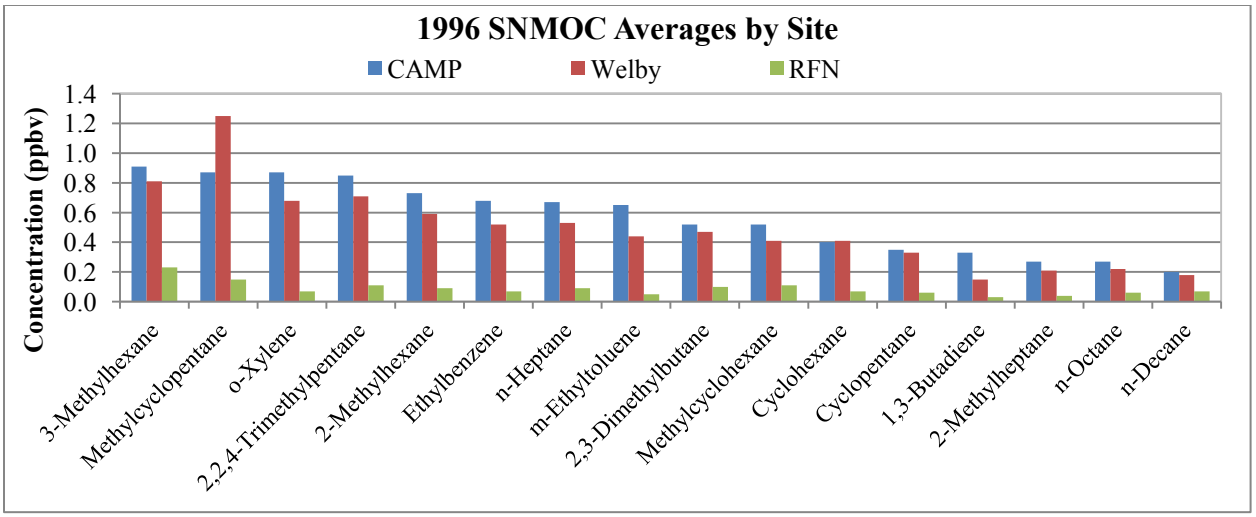

Figure 39. SNMOC Averages by Site, 1996

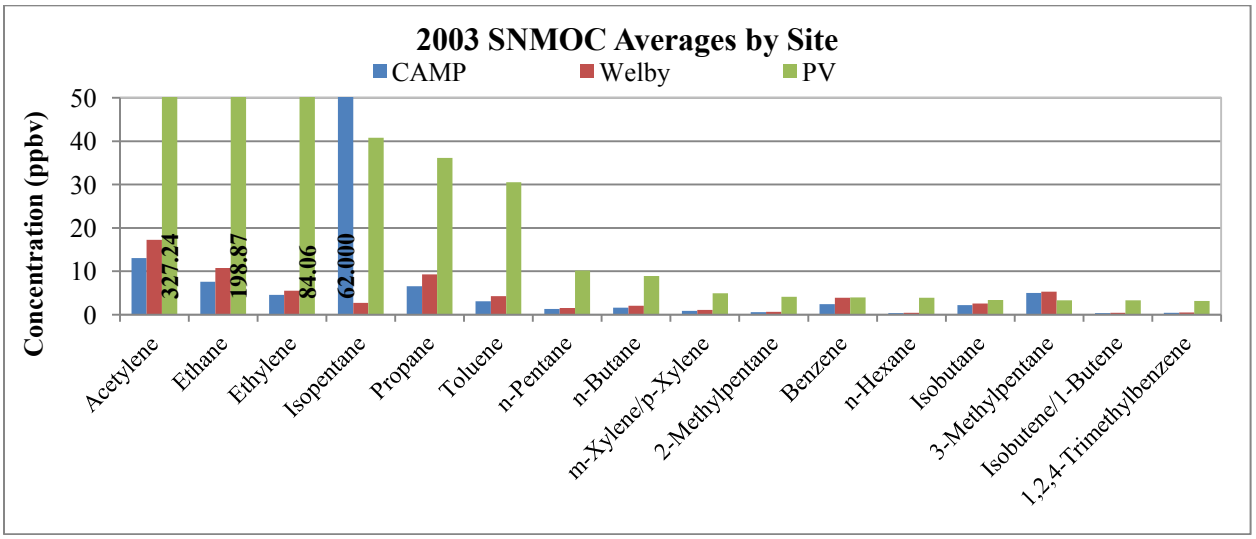

Figure 40. SNMOC Averages by Site, 2003

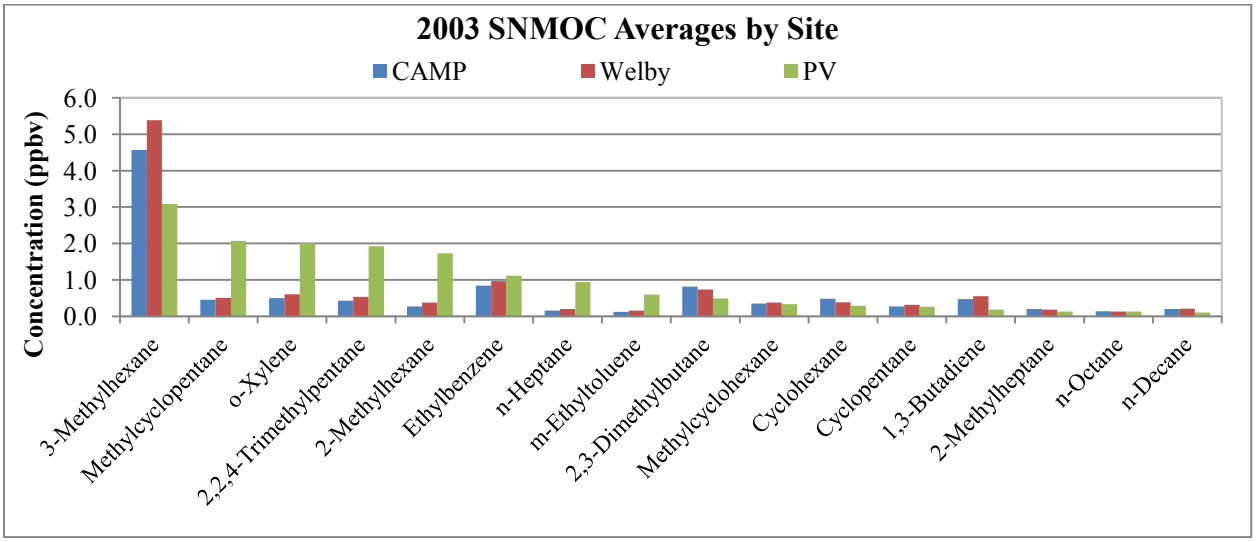

Figure 41. SNMOC Averages by Site, 2003

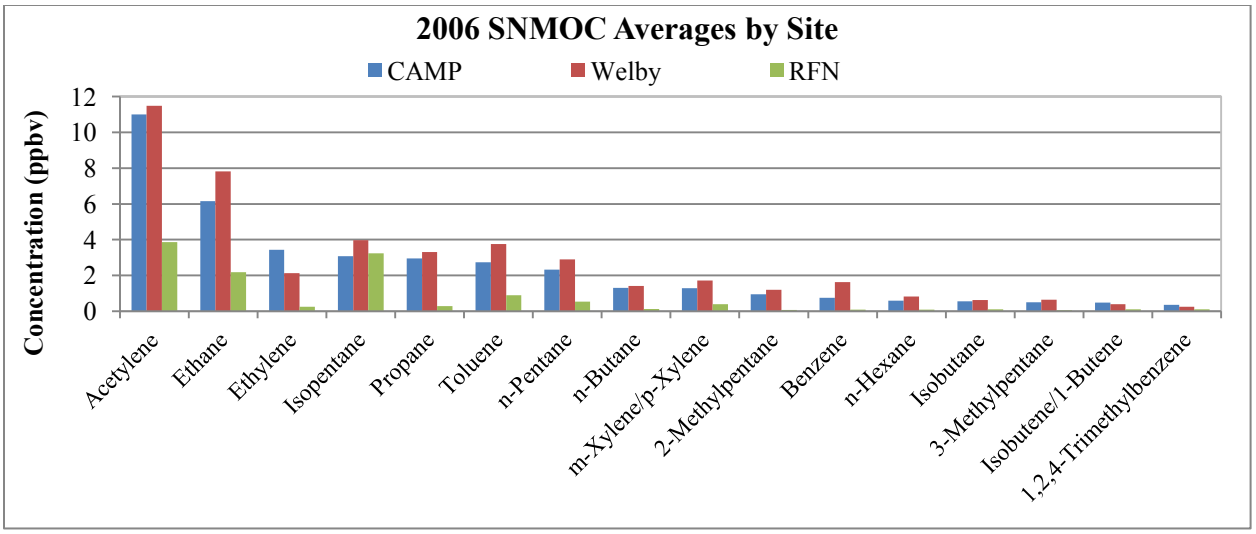

Figure 42. SNMOC Averages by Site, 2006

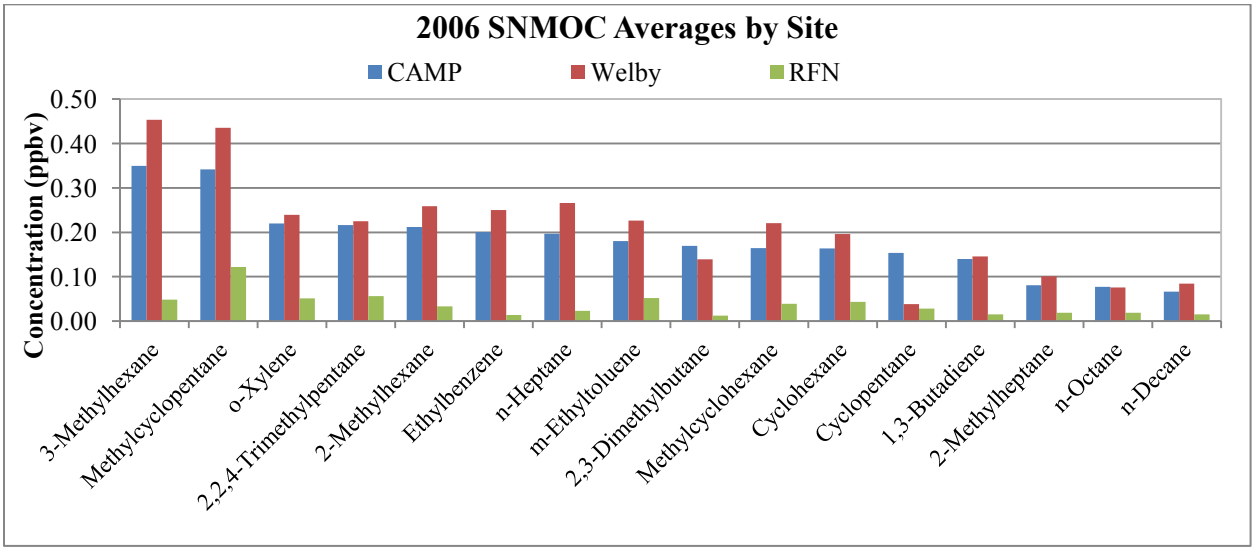

Figure 43. SNMOC Averages by Site 2006

In 2006, CAMP and Welby again showed much larger SNMOC concentrations than the Rocky Flats – North site did; though the difference was not as large as the difference seen between the Platteville, CAMP, and Welby sites in 2003. The important thing to take away from all this data is the fact that SNMOC concentrations along the Front Range decreased for the 1996 to 2006 time period.

3.4.2. NO/NO_2 Comparisons

3.4.2.1. 1996

In 1996, at CAMP, Welby, and Rocky Flats – North, NOx monitors were in operation at the same time the air toxics sampling was taking place. The data used was gathered from hourly averages obtained from the monitors on site. A correlation between SNMOC concentrations in samples with greater than an 85% detection rate, and the 3-hour average NO and NO_2 values from 06:00 to 09:00 was performed for each site. The results of these correlations can be seen in the following tables.

In general, the SNMOC concentrations at CAMP correlated rather well with the NO concentrations, with ethylene

having the largest r-value at 0.85. Twenty of the 55 compounds had r-values that were 0.70 or larger. These values are highlighted in the table. The correlations were less favorable between the SNMOCs and NO_2. Toluene showed the best correlation with NO_2, having an r-value of 0.77. There were only five compounds with r-values larger than 0.70.

Table 49. NO/NO_2/SNMOC 3-Hr. Average Correlations at CAMP, 1996

Analyte	CAMP Correlations NO	CAMP Correlations NO_2	Analyte	CAMP Correlations NO	CAMP Correlations NO_2
1,2,3-Trimethylbenzene	0.32	0.38	Ethylene	0.85	0.67
1,2,4-Trimethylbenzene	0.62	0.63	Isobutane	0.47	0.25
1,3,5-Trimethylbenzene	0.56	0.59	Isobutene/1-Butene	0.39	0.28
1,3-Butadiene	0.18	0.06	Isopentane	0.69	0.62
1-Pentene	0.57	0.61	Isoprene	0.71	0.69
2,2,3-Trimethylpentane	0.69	0.64	Isopropylbenzene	0.26	0.35
2,2,4-Trimethylpentane	0.73	0.67	Methylcyclohexane	0.66	0.59
2,2-Dimethylbutane	0.64	0.61	Methylcyclopentane	0.71	0.56
2,3,4-Trimethylpentane	0.58	0.53	m-Ethyltoluene	0.52	0.58
2,3-Dimethylbutane	0.60	0.49	m-Xylene/p-Xylene	0.78	0.71
2,3-Dimethylpentane	0.70	0.67	n-Butane	0.40	0.26
2,4-Dimethylpentane	0.73	0.67	n-Decane	0.42	0.43
2-Methyl-1-butene	0.70	0.67	n-Heptane	0.62	0.54
2-Methyl-2-Butene	0.72	0.65	n-Hexane	0.72	0.63
2-Methylheptane	0.73	0.63	n-Nonane	0.44	0.46
2-Methylhexane	0.71	0.63	n-Octane	0.60	0.49
2-Methylpentane	0.70	0.60	n-Pentane	0.69	0.61
3-Methylheptane	0.76	0.68	n-Propylbenzene	0.50	0.56
3-Methylhexane	0.57	0.58	o-Ethyltoluene	0.35	0.36
3-Methylpentane	0.69	0.60	o-Xylene	0.75	0.68
Acetylene	0.57	0.31	p-Ethyltoluene	0.45	0.51
a-Pinene	-0.27	-0.28	Propane	0.22	-0.08
Benzene	0.79	0.71	Propylene	0.70	0.56
cis-2-Butene	0.49	0.54	Styrene	0.35	0.36
cis-2-Pentene	0.68	0.62	Toluene	0.78	0.77
Cyclohexane	0.68	0.54	trans-2-Butene	0.67	0.72
Cyclopentane	0.72	0.58	trans-2-Pentene	0.72	0.66
Ethylbenzene	0.77	0.71			

Bold = Priority Compound, *Italics = <85% detection rate*

Table 50. 3- Hr. Avg. Correlations of NO/NO_2 and TNMOCs/SNMOCs at CAMP, 1996

	Correlations		
	TNMOC	**SNMOC**	**Unknowns**
NO	0.71	0.72	0.54
NO_2	0.62	0.61	0.54

Table 50 shows the r-values for the correlations between the TNMOCs, the total SNMOCs, and the unknown concentrations with the 3-hour average NO and NO_2 concentrations at CAMP. The TNMOC and SNMOC concentrations correlated fairly well with the NO concentrations, having r-squared values of 0.71 and 0.72, respectively. The TNMOC and SNMOC comparisons with NO_2 showed less correlation than those with NO. The unknown NMOC concentrations did not correlate very well with either NO or NO_2.

In general, the SNMOC concentrations at Welby in 1996 correlated quite well with the NO concentrations, with toluene having the largest r-value at 0.88. Thirty-one of the 48 compounds had r-values that were 0.70 or larger. Those compounds are highlighted in the table. The correlations were also favorable between the SNMOCs and NO_2. Toluene also showed the best correlation with NO_2, having an r-value of 0.79. There were thirty compounds with r-values larger than 0.70. The correlations at Welby are stronger than those observed at CAMP in 1996, though there are fewer SNMOC compounds that were detected in greater than 85% of the samples taken at Welby (55 versus 48).

Table 51. NO/NO_2/SNMOC 3-Hr. Average Correlations at Welby, 1996

Analyte	Welby Correlations NO	Welby Correlations NO_2	Analyte	Welby Correlations NO	Welby Correlations NO_2
1,2,3-Trimethylbenzene	0.45	0.39	Ethylbenzene	0.85	0.77
1,2,4-Trimethylbenzene	0.80	0.67	Ethylene	0.85	0.73
1,3,5-Trimethylbenzene	0.84	0.71	Isobutane	0.37	0.43
1,3-Butadiene	0.87	0.70	Isobutene / 1-Butene	0.77	0.74
1-Heptene	0.85	0.74	Isopentane	0.68	0.75
1-Pentene	0.45	0.33	Isoprene	0.53	0.66
2,2,4-Trimethylpentane	0.83	0.74	Methylcyclohexane	0.78	0.69
2,2-Dimethylbutane	0.72	0.65	Methylcyclopentane	0.21	0.28
2,3,4-Trimethylpentane	0.85	0.76	m-Ethyltoluene	0.84	0.72
2,3-Dimethylbutane	0.81	0.77	m-Xylene / p-Xylene	0.85	0.74
2,3-Dimethylpentane	0.86	0.79	n-Butane	0.41	0.38
2,4-Dimethylpentane	0.85	0.73	n-Decane	0.68	0.73
2-Methylheptane	0.74	0.59	n-Heptane	0.85	0.77
2-Methylhexane	0.82	0.76	n-Hexane	0.00	0.08
2-Methylpentane	0.81	0.77	n-Nonane	0.83	0.78
3-Methylheptane	0.65	0.48	n-Octane	0.85	0.72
3-Methylhexane	0.77	0.71	n-Pentane	0.63	0.72
3-Methylpentane	0.74	0.73	o-Ethyltoluene	0.82	0.68
Acetylene	0.49	0.39	o-Xylene	0.83	0.74
Benzene	0.87	0.76	Propane	-0.01	-0.04
cis-2-Butene	0.41	0.51	Propylene	0.56	0.51
cis-2-Pentene	0.79	0.74	Toluene	0.88	0.79
Cyclohexane	0.75	0.71	trans-2-Butene	0.64	0.71
Cyclopentane	0.54	0.61	trans-2-Pentene	0.81	0.76
Bold = Priority Compound, *Italics = <85% detection rate*					

Table 52 shows the r-values for the correlations between NO/NO_2, the TNMOCs, and the total of the SNMOCs. The TNMOC concentrations showed slight correlation with NO and NO_2, having r-values that were 0.65, and 0.67, respectively. The total SNMOC concentrations correlated better than the TNMOC concentrations did, with r-values of 0.74, and 0.76, respectively.

Table 52. 3- Hr. Avg. Correlations of NO/NO_2 and TNMOCs/SNMOCs at Welby, 1996

	Correlations		
	TNMOC	**SNMOC**	**Unknowns**
NO	0.65	0.74	0.06
NO_2	0.67	0.76	0.08

In general, the SNMOC concentrations at Rocky Flats – North in 1996 did not correlate as well with the NO/NO_2 concentrations. There were only 12 NMOC samples taken at the sites, as opposed to the 30 plus samples at the other two sites. The highest r-value obtained for the NO correlation was 0.53 for n-pentane. Only two of the 33 compounds had r-values that were 0.50 or larger. The correlations were slightly more favorable between the SNMOCs and NO_2. m-Ethyltoluene showed the best correlation with NO_2, having an r-value of 0.80. There were three compounds with r-values larger than 0.70. Correlation values of 0.70 or larger are highlighted in the table. The correlations at Rocky Flats - North are not as strong as those observed at Welby or CAMP in 1996, though there are fewer SNMOC compounds that were detected in greater than 85% of the samples taken at Rocky Flats - North (48 versus 33).

Table 53. NO/NO_2/SNMOC 3-Hr. Average Correlations at Rocky Flats - North, 1996

Analyte	RFN Correlations NO	RFN Correlations NO_2	Analyte	RFN Correlations NO	RFN Correlations NO_2
1,2,4-Trimethylbenzene	-0.29	-0.45	Isopentane	0.14	0.56
1,3-Butadiene	*0.00*	*0.00*	Methylcyclohexane	0.34	0.39
2,2,4-Trimethylpentane	-0.23	0.00	Methylcyclopentane	0.34	0.43
2,3-Dimethylbutane	0.06	-0.21	m-Ethyltoluene	0.48	0.80
2-Methylheptane	0.30	0.39	m-Xylene / p-Xylene	0.38	0.71

Analyte	RFN Correlations NO	RFN Correlations NO_2	Analyte	RFN Correlations NO	RFN Correlations NO_2
2-Methylhexane	0.23	0.41	n-Butane	0.30	0.49
2-Methylpentane	0.15	0.08	n-Decane	-0.27	-0.13
3-Methylhexane	0.22	0.13	n-Dodecane	-0.30	-0.27
3-Methylpentane	0.52	0.67	n-Heptane	0.43	0.60
Acetylene	0.38	0.51	n-Hexane	0.41	0.59
Benzene	0.35	0.69	n-Octane	0.29	0.27
Cyclohexane	0.34	0.47	n-Pentane	0.53	0.59
Cyclopentane	0.30	0.46	n-Undecane	-0.30	-0.21
Ethylbenzene	0.16	0.22	o-Xylene	-0.01	0.37
Ethylene	0.46	0.70	Propane	0.37	0.48
Isobutane	0.30	0.44	Toluene	0.44	0.65
Isobutene / 1-Butene	0.03	0.21			

Bold = Priority Compound, *Italics = <85% detection rate*

Table 54. 3- Hr. Avg. Correlations of NO/NO_2 and TNMOCs/SNMOCs at Rocky Flats - North, 1996

	Correlations		
	TNMOC	**SNMOC**	**Unknowns**
NO	0.33	0.30	0.24
NO_2	0.41	0.44	0.15

Table 54 shows the r-values for the correlations between NO/NO_2, the TNMOCs, and the total of the SNMOCs. The TNMOC concentrations showed no correlation with NO and NO_2, having r-values that were 0.33, and 0.41, respectively. The total SNMOC concentrations also correlated poorly, with r-values of 0.30, and 0.44, respectively.

In summary, Welby showed the best correlation between the NO/NO_2 concentrations and many of the SNMOC concentrations, having several compounds with r-values above 0.80. The Rocky Flats – North site had the least amount of correlation between the data sets, exhibiting r-values that were all less than 0.45. The SNMOC and TNMOC concentrations tended to correlate better with the NO concentrations than with the NO_2 concentrations.

3.4.2.2. 2003

In 2003, at CAMP, and Welby, NOx monitors were in operation at the same time the air toxics sampling was taking place. The data used was gathered from hourly averages obtained from the monitors on site. During this study samples were taken in both the morning and afternoon hours, from 06:00 to 09:00, and 13:00 to 16:00. A correlation between the SNMOC compounds with detection rates greater than 85%, and the 3-hour average NO/NO_2 values was performed for each site for the morning and afternoon samples. The results of these correlations can be seen in the following tables.

Table 55 lists the correlation r-values for each NMOC compound detected in greater than 85% of samples taken at the CAMP site during the morning hours. Many of the SNMOC concentrations at CAMP correlated rather well with the NO concentrations, with 2,2,4-trimethylpentane having the largest r-value at 0.85. Twelve of the 62 compounds had r-values that were 0.70 or larger. Those values are highlighted in the table. The correlations were less favorable between the SNMOCs and NO_2, with many compounds exhibiting negative correlation values. *m*-Diethylbenzene showed the best correlation with NO_2, having an r-value of 0.55. There were no compounds with r-values larger than 0.70 in this correlation, however, ethane showed a strong negative correlation with NO_2, having an r value of -0.79.

Table 55. NO/NO_2/SNMOC 3-Hr. Morning Average Correlations at CAMP, 2003

Analyte	CAMP Correlations NO	CAMP Correlations NO_2	Analyte	CAMP Correlations NO	CAMP Correlations NO_2
1,2,3-Trimethylbenzene	0.22	0.39	Ethylene	0.77	-0.29
1,2,4-Trimethylbenzene	0.08	0.48	Isobutane	-0.24	0.24
1,3,5-Trimethylbenzene	0.43	0.14	Isobutene / 1-Butene	0.46	-0.14
1,3-Butadiene	0.76	-0.41	Isopentane	-0.31	0.08
1-Dodecene	-0.31	0.19	Isoprene	0.17	-0.09
1-Hexene	0.74	0.23	Isopropylbenzene	0.39	0.08
1-Pentene	0.55	-0.07	m-Diethylbenzene	0.30	0.55

Analyte	CAMP Correlations		Analyte	CAMP Correlations	
	NO	NO_2		NO	NO_2
2,2,3-Trimethylpentane	0.45	-0.23	Methylcyclohexane	0.53	-0.45
2,2,4-Trimethylpentane	0.85	-0.27	Methylcyclopentane	0.48	-0.44
2,2-Dimethylbutane	0.66	-0.37	m-Ethyltoluene	0.44	0.15
2,3,4-Trimethylpentane	0.79	-0.21	m-Xylene / p-Xylene	0.44	0.17
2,3-Dimethylbutane	0.62	-0.34	n-Butane	-0.36	-0.48
2,3-Dimethylpentane	0.73	-0.40	n-Decane	0.17	0.24
2,4-Dimethylpentane	0.72	-0.29	n-Dodecane	-0.11	0.35
2-Methyl-1-butene	0.00	-0.34	n-Heptane	0.36	-0.21
2-Methyl-2-butene	0.62	-0.40	n-Hexane	0.51	-0.36
2-Methylheptane	0.75	-0.27	n-Nonane	0.39	0.13
2-Methylhexane	0.29	-0.17	n-Octane	0.52	0.00
2-Methylpentane	0.33	-0.49	n-Pentane	-0.03	-0.68
3-Methylheptane	0.69	-0.11	n-Propylbenzene	0.34	0.32
3-Methylhexane	0.64	-0.25	n-Undecane	0.24	0.44
3-Methylpentane	0.54	-0.47	o-Ethyltoluene	0.39	0.13
Acetylene	0.82	-0.34	o-Xylene	0.52	0.12
a-Pinene	0.26	-0.67	p-Diethylbenzene	0.19	0.39
Benzene	0.26	-0.28	p-Ethyltoluene	0.37	0.24
cis-2-Butene	0.52	-0.34	Propane	-0.48	-0.66
cis-2-Pentene	0.80	-0.28	Propylene	0.81	-0.33
Cyclohexane	-0.24	-0.39	Styrene	0.02	0.40
Cyclopentane	0.33	-0.62	Toluene	0.50	0.08
Ethane	-0.40	-0.79	trans-2-Butene	0.71	-0.36
Ethylbenzene	0.45	0.15	trans-2-Pentene	0.65	-0.38
Bold = Priority Compound					

Table 56 lists the correlation values for each SNMOC compound with detection rates that are greater than 85% in the afternoon samples. The SNMOC concentrations did not correlate well with the NO concentrations, with propylene having the largest r-value at 0.65. None of the 62 compounds had r-values that were 0.70 or larger for the correlation with NO. The correlations between the SNMOCs and NO_2 were also not very good, with several compounds exhibiting negative correlation values. 2,2,3-trimethylpentane showed the best correlation with NO_2, having an r-value of 0.75. There were two compounds with r-values larger than 0.70 in this correlation. Their values are highlighted in the table.

Table 56. NO/NO_2/SNMOC 3-Hr. Afternoon Average Correlations at CAMP, 2003

Analyte	CAMP Correlations		Analyte	CAMP Correlations	
	NO	NO_2		NO	NO_2
1,2,3-Trimethylbenzene	0.32	0.25	Ethylene	0.65	0.67
1,2,4-Trimethylbenzene	-0.35	-0.05	Isobutane	-0.43	0.19
1,3,5-Trimethylbenzene	-0.04	0.03	Isobutene / 1-Butene	0.01	0.11
1,3-Butadiene	0.65	0.64	Isopentane	-0.29	0.37
1-Dodecene	-0.51	-0.27	Isoprene	0.30	0.21
1-Hexene	-0.34	-0.25	Isopropylbenzene	-0.27	-0.26
1-Pentene	-0.15	0.48	m-Diethylbenzene	0.07	0.18
2,2,3-Trimethylpentane	0.43	0.75	Methylcyclohexane	0.36	0.50
2,2,4-Trimethylpentane	0.34	0.58	Methylcyclopentane	0.01	0.60
2,2-Dimethylbutane	-0.25	0.41	m-Ethyltoluene	-0.08	0.04
2,3,4-Trimethylpentane	0.26	0.59	m-Xylene / p-Xylene	-0.08	0.00
2,3-Dimethylbutane	-0.08	0.57	n-Butane	0.01	0.46
2,3-Dimethylpentane	0.09	0.65	n-Decane	-0.21	-0.01
2,4-Dimethylpentane	0.00	0.54	n-Dodecane	-0.33	0.08
2-Methyl-1-butene	-0.10	0.55	n-Heptane	0.09	0.47
2-Methyl-2-butene	-0.04	0.56	n-Hexane	0.02	0.61
2-Methylheptane	0.26	0.32	n-Nonane	-0.02	0.08
2-Methylhexane	0.14	0.72	n-Octane	0.13	0.22
2-Methylpentane	-0.05	0.60	n-Pentane	-0.16	0.52
3-Methylheptane	0.29	0.46	n-Propylbenzene	-0.21	-0.12

Analyte	CAMP Correlations NO	CAMP Correlations NO_2	Analyte	CAMP Correlations NO	CAMP Correlations NO_2
3-Methylhexane	0.32	0.64	n-Undecane	-0.07	0.08
3-Methylpentane	-0.05	0.58	o-Ethyltoluene	-0.02	0.06
Acetylene	0.57	0.56	o-Xylene	-0.06	0.03
a-Pinene	0.21	0.13	p-Diethylbenzene	0.06	0.16
Benzene	-0.44	-0.46	p-Ethyltoluene	-0.11	-0.01
cis-2-Butene	-0.08	0.52	Propane	-0.22	0.30
cis-2-Pentene	-0.09	0.49	Propylene	0.68	0.64
Cyclohexane	-0.22	0.25	Styrene	-0.48	-0.32
Cyclopentane	-0.14	0.53	Toluene	0.10	0.28
Ethane	-0.29	0.06	trans-2-Butene	-0.01	0.57
Ethylbenzene	-0.12	0.00	trans-2-Pentene	-0.04	0.57
Bold = Priority Compound					

Table 57 shows the r-values for the TNMOC, SNMOC, NO, and NO_2 correlations between the morning and afternoon datasets. There is no correlation between any of the NMOC concentrations and NO/NO_2, as is evidenced by the low values. During the 1996 sampling campaign, there were better correlations between the data sets at this location. This may be due to the fact that there were not as many samples taken during this study, as there were in the previous study.

Table 57. 3-Hr. NMOC/NO/NO_2 Concentration Correlation at CAMP, 2003

	3-Hr. Correlations - AM Samples			3-Hr. Correlations - PM Samples		
	TNMOC	SNMOC	Unknowns	TNMOC	SNMOC	Unknowns
NO	-0.13	-0.23	0.11	-0.41	-0.40	0.07
NO_2	0.13	0.15	0.08	0.28	0.27	0.00

Table 58 lists the correlation values for each SNMOC compound having a detection rate greater than 85% at the Welby site during the morning samples. Many of the SNMOC concentrations at Welby correlated rather well with the NO concentrations, with n-heptane having the largest r-value at 0.92. Forty of the 53 compounds had r-values that were 0.70 or larger, with seven of the compounds having values of 0.90 or larger. The correlations were also favorable between the SNMOCs and NO_2, with many compounds exhibiting r-values above 0.70. Benzene showed the best correlation with NO_2, having an r-value of 0.91. There were seventeen compounds with r-values larger than 0.70 in this correlation. As was previously mentioned, the Welby site is located approximately two miles to the north of a large refinery. Compounds with r-values greater than 0.70 are highlighted in the table.

Table 58. NO/NO_2/SNMOC 3-Hr. Morning Average Correlations at Welby, 2003

Analyte	Welby AM Correlations NO	Welby AM Correlations NO_2	Analyte	Welby AM Correlations NO	Welby AM Correlations NO_2
1,2,3-Trimethylbenzene	0.77	0.67	Ethylene	0.89	0.74
1,2,4-Trimethylbenzene	0.62	0.60	Isobutane	-0.24	-0.32
1,3,5-Trimethylbenzene	0.80	0.64	Isobutene / 1-Butene	0.88	0.76
1,3-Butadiene	*0.89*	*0.64*	Isopentane	0.38	0.48
1-Heptene	0.05	-0.12	Isoprene	0.10	-0.06
1-Hexene	0.73	0.54	Methylcyclohexane	0.88	0.59
1-Pentene	0.75	0.77	Methylcyclopentane	0.83	0.69
2,2,4-Trimethylpentane	0.87	0.70	m-Ethyltoluene	0.79	0.71
2,2-Dimethylbutane	0.78	0.69	m-Xylene / p-Xylene	0.72	0.72
2,3,4-Trimethylpentane	0.90	0.67	n-Butane	0.20	0.24
2,3-Dimethylbutane	0.75	0.66	n-Decane	0.83	0.64
2,3-Dimethylpentane	0.90	0.66	n-Dodecane	0.59	0.16
2,4-Dimethylpentane	0.87	0.69	n-Heptane	0.92	0.75
2-Methylheptane	0.74	0.52	n-Hexane	0.78	0.70
2-Methylhexane	0.90	0.68	n-Nonane	0.89	0.62
2-Methylpentane	0.62	0.64	n-Octane	0.44	0.19
3-Methylheptane	0.77	0.47	n-Pentane	0.81	0.75
3-Methylhexane	0.91	0.73	n-Undecane	0.83	0.54
3-Methylpentane	0.76	0.67	o-Ethyltoluene	0.86	0.70

Analyte	Welby AM Correlations		Analyte	Welby AM Correlations	
	NO	NO_2		NO	NO_2
Acetylene	0.90	0.76	o-Xylene	0.78	0.72
Benzene	0.67	0.91	Propane	0.35	0.30
cis-2-Butene	0.73	0.67	Propylene	0.91	0.73
cis-2-Pentene	0.82	0.68	Styrene	0.53	0.60
Cyclohexane	0.84	0.62	Toluene	0.85	0.69
Cyclopentane	0.79	0.57	trans-2-Butene	0.72	0.80
Ethane	0.55	0.43	trans-2-Pentene	0.83	0.68
Ethylbenzene	0.72	0.72	**Bold = Priority Compound,** *Italics = <85% detection rate*		

Table 59 lists the correlation coefficients for the afternoon NMOC samples and NO/NO_2 concentration 3-hour averages. There was very little correlation between the SNMOC and NO concentrations, with the largest r-value being 0.46 for acetylene. The NO_2 concentrations, however, showed a much better correlation with the SNMOC concentrations. m-Ethyltoluene had the largest r-value at 0.93. There were 23 of the 53 compounds that had coefficients of 0.70 or larger. Those values are highlighted in the table.

Table 60 shows the correlations between the total NMOC compounds and NO/NO_2. While the TNMOCs did not correlate well with the 3-hour average NO concentrations, they did correlate better with the NO_2 concentrations for the morning hours. There was no correlation in the afternoon samples. The total SNMOCs correlated well with both NO and NO_2 in the morning hours, but showed less of a correlation in the afternoon samples. Compounds with r-values greater than 0.70, or less than -0.70 are highlighted in the table.

Table 59. NO/NO_2/SNMOC 3-Hr. Afternoon Average Correlations at Welby, 2003

Analyte	Welby PM Correlations		Analyte	Welby PM Correlations	
	NO	NO_2		NO	NO_2
1,2,3-Trimethylbenzene	-0.30	-0.09	Ethylene	0.28	0.87
1,2,4-Trimethylbenzene	-0.26	0.66	Isobutane	-0.25	0.32
1,3,5-Trimethylbenzene	0.27	0.77	Isobutene / 1-Butene	-0.21	0.17
1,3-Butadiene	-0.07	0.80	Isopentane	0.09	-0.29
1-Heptene	-0.25	0.10	Isoprene	-0.42	0.08
1-Hexene	0.00	0.23	Methylcyclohexane	-0.24	0.84
1-Pentene	0.15	0.59	Methylcyclopentane	-0.08	0.87
2,2,4-Trimethylpentane	0.38	0.85	m-Ethyltoluene	0.33	0.93
2,2-Dimethylbutane	0.11	0.66	m-Xylene / p-Xylene	-0.19	0.71
2,3,4-Trimethylpentane	0.02	0.65	n-Butane	-0.36	0.77
2,3-Dimethylbutane	-0.14	0.62	n-Decane	0.03	0.62
2,3-Dimethylpentane	0.32	0.23	n-Dodecane	-0.16	0.07
2,4-Dimethylpentane	0.11	0.58	n-Heptane	-0.30	0.74
2-Methylheptane	0.26	0.68	n-Hexane	-0.16	0.83
2-Methylhexane	-0.57	-0.28	n-Nonane	0.18	0.67
2-Methylpentane	-0.33	0.48	n-Octane	0.00	0.71
3-Methylheptane	0.05	0.71	n-Pentane	-0.11	0.79
3-Methylhexane	0.45	0.45	n-Undecane	0.02	0.39
3-Methylpentane	-0.22	0.79	o-Ethyltoluene	0.21	0.57
Acetylene	0.46	0.56	o-Xylene	-0.04	0.77
Benzene	-0.09	-0.33	Propane	-0.25	0.55
cis-2-Butene	-0.08	0.72	Propylene	0.20	0.85
cis-2-Pentene	0.04	0.78	Styrene	-0.33	-0.19
Cyclohexane	-0.37	0.50	Toluene	-0.15	0.79
Cyclopentane	-0.10	0.49	trans-2-Butene	0.09	0.81
Ethane	-0.49	-0.23	trans-2-Pentene	0.04	0.82
Ethylbenzene	-0.12	0.70	**Bold = Priority Compound,** *Italics = <85% detection rate*		

Table 60. 3-Hr. NMOC/NO/NO_2 Concentration Correlation at Welby, 2003

	3-Hr. Correlations - AM Samples			3-Hr. Correlations - PM Samples		
	TNMOC	SNMOC	Unknowns	TNMOC	SNMOC	Unknowns
NO	0.49	0.83	0.13	0.34	0.76	0.30
NO_2	0.72	0.72	0.38	0.25	0.56	0.20

In summary, the samples taken at Welby in 2003 tended to have better correlations between the NMOC concentrations and the NO/NO_2 concentrations than those taken at the CAMP site. This is likely due to the locations of both sites. CAMP is in the downtown Denver area, surrounded by large buildings that restrict the flow of air around the site, while the Welby site is in a much more open, agricultural area, and is located to the north of a large refinery.

3.4.2.3. 2006

In 2006, at CAMP and Welby, NOx monitors were in operation at the same time the air toxics sampling was taking place. The data used was gathered from hourly averages obtained from the monitors on site. A correlation between SNMOC concentrations detected in greater than 85% of the samples taken, and the 3-hour average NO/NO_2 concentrations, from 06:00 to 09:00, was performed for each site. The results of these correlations can be seen in the following tables.

In general, the SNMOC concentrations at CAMP correlated rather well with the NO concentrations, with propylene having the largest r-value at 0.96. Sixteen of the 60 compounds had r-values that were 0.70 or larger. Their values are highlighted in the table. The correlations were also favorable between the SNMOCs and NO_2. Trans-2-pentene showed the best correlation with NO_2, having an r-value of 0.90. There were nine compounds with r-values larger than 0.70. Their values are highlighted in the table.

Table 61. NO/NO_2/SNMOC 3-Hr. Average Correlations at CAMP, 2006

	CAMP Correlations			CAMP Correlations	
Analyte	NO	NO_2	Analyte	NO	NO_2
1,2,3-Trimethylbenzene	0.39	0.55	Ethane	0.02	-0.11
1,2,4-Trimethylbenzene	0.41	0.38	Ethylbenzene	0.69	0.61
1,3,5-Trimethylbenzene	0.44	0.47	Ethylene	0.73	0.50
1,3-Butadiene	-0.11	-0.17	Isobutane	0.12	0.01
1-Heptene	0.04	-0.01	Isobutene/1-Butene	0.85	0.75
1-Hexene	0.49	0.50	Isopentane	0.54	0.51
1-Nonene	0.38	0.18	Isoprene	0.37	0.58
1-Pentene	0.70	0.78	Isopropylbenzene	0.21	0.01
2,2,3-Trimethylpentane	0.70	0.50	Methylcyclohexane	0.30	0.28
2,2,4-Trimethylpentane	0.70	0.62	Methylcyclopentane	0.66	0.63
2,2-Dimethylbutane	0.78	0.76	m-Ethyltoluene	0.47	0.38
2,3,4-Trimethylpentane	0.74	0.52	m-Xylene/p-Xylene	0.63	0.53
2,3-Dimethylbutane	0.76	0.71	n-Butane	0.08	-0.02
2,3-Dimethylpentane	0.70	0.64	n-Decane	0.34	0.51
2,4-Dimethylpentane	0.18	0.04	n-Heptane	0.48	0.45
2-Methyl-1-butene	0.55	0.52	n-Hexane	0.47	0.42
2-Methyl-2-butene	0.65	0.67	n-Nonane	0.49	0.54
2-Methylheptane	0.65	0.58	n-Octane	0.56	0.46
2-Methylhexane	0.52	0.50	n-Pentane	0.32	0.35
2-Methylpentane	0.68	0.62	n-Propylbenzene	0.48	0.37
3-Methylheptane	0.66	0.59	o-Ethyltoluene	0.42	0.45
3-Methylhexane	0.63	0.69	o-Xylene	0.63	0.53
3-Methylpentane	0.71	0.68	p-Ethyltoluene	0.44	0.38
Acetylene	-0.06	-0.13	Propane	0.08	-0.05
a-Pinene	0.15	0.12	Propylene	0.96	0.81
Benzene	0.78	0.70	Styrene	0.22	0.13
cis-2-Butene	0.77	0.58	Toluene	0.64	0.66
cis-2-Pentene	0.85	0.89	trans-2-Butene	0.82	0.70
Cyclohexane	0.52	0.48	trans-2-Hexene	-0.08	-0.21
Cyclopentane	0.53	0.49	trans-2-Pentene	0.85	0.90

Table 62. 3- Hr. Avg. Correlations of NO/NO_2 and TNMOCs/SNMOCs at CAMP, 2006

	3-Hr. Correlations		
	TNMOC	**SNMOC**	**Unknowns**
NO	-0.13	-0.16	0.33
NO_2	-0.14	-0.17	0.23

Table 62 shows the correlation coefficient values for the total NMOC compounds with NO and NO_2. While there was a good deal of correlation between the 3-hour average gaseous concentrations and some individual SNMOC compounds, there was not any correlation with the TNMOCs, the total SNMOCs, or the unknowns.

4.0 Summary

During the summers of 1996, 2003, and 2006 air toxics studies along the Front Range were performed. In general, the concentration levels of all pollutants analyzed for dropped from the first study in 1996 to the last study in 2006. There were exceptions to this, however. At CAMP, the concentrations of acetone and formaldehyde increased from 1996 to 2003, but then decreased to levels lower than those seen initially in 1996. At Welby, acetaldehyde and acetone had concentrations in 2006 that were higher than those recorded in 2003, but less than those in 1996. In Platteville, samples were taken in 2003 and 2006 only. While all other carbonyl compounds had decreasing concentrations from 2003 to 2006, acetaldehyde concentrations increased. There was little to no correlation between the NO and NO_2 compounds and the TNMOC/SNMOC compounds in any of the studies performed at any of the sites.

At CAMP, the NMOC concentrations from alkane compounds decreased from 1996 to 2006, with the exception of the isobutane, propane, and 2,2-dimethylbutane spikes in 2003. All alkene concentrations decreased for that same time period except cis-2-butene. The only alkyne analyzed for (acetylene) showed decreases in concentrations with each study performed. The aromatic concentrations all decreased for the same time period, except for benzene, which spiked in 2003. The average percentage that the unknown compounds contribute to the TNMOC concentrations at CAMP increased from 22% in 1996, to 28% in 2003, to 72% in 2006. The reason for this may be due to the fact that the list of NMOC compounds being analyzed for went from 115 in 1996 to 78 in 2003 and 2006. This shift would cause a larger percentage of previously known compounds to fall under the "unknown" category as they were not being specifically looked for. This does not account for the large jump going from 2003 to 2006, however. The cause is unclear at this time.

At Welby, the NMOC concentrations from alkane compounds decreased from 1996 to 2006, in general, with the following exceptions: ethane, Isopentane, propane, n-butane, isobutane, 2,3-dimethylbutane, cyclohexane, methylcyclohexane, 2,3-dimethylpentane,cyclopentene, 2,4-dimethylpentane, and 2,2-dimethylbutane. The concentrations of those compounds all increased in 2003 before decreasing in 2006. All alkene concentrations decreased for the same time period, with the exceptions of cis-2-butene, isoprene, and 1,3-butadiene. The only alkyne analyzed for (acetylene) showed decreases in concentrations with each study performed. All aromatic concentrations decreased for the 1996 to 2006 time period, except benzene, which increased in 2003 before decreasing in 2006. In 1996, Welby had the highest SNMOC concentrations, over CAMP and Rocky Flats – North, though some individual compounds had concentrations that were higher at CAMP than at Welby. In 2006, Welby again had some of the highest NMOC concentrations over CAMP and Rocky Flats – North. The average percentage that the unknown compounds contribute to the TNMOC concentrations at Welby increased from 25% in 1996, to 62% in 2003, then decreased to 38% in 2006. The increase from 1996 to 2003 is likely due to the fact that the list of NMOC compounds being analyzed for went from 115 to 78. This shift would cause a larger percentage of previously known compounds to fall under the "unknown" category as they were not being specifically looked for. The subsequent drop in percentages seen in going from the 2003 to 2006 study indicates that the air around Welby was better characterized by the list of compounds being analyzed for.

At Rocky Flats – North, the concentrations of all aromatic, alkyne, alkene, and alkane compounds decreased from 1996 to 2006, with the exception of isopentane, which increased. Studies were performed at this site only in 1996 and 2006. This site had some of the lowest NMOC concentrations of any of the sites in 1996 and 2006. The percentage contributions of the unknown concentrations to the TNMOC concentrations more than doubled from 1996 (46%) to 2006 (97%). Again, this is likely due to the drop in the total number of compounds being looked for.

At the Platteville site, the concentrations of all NMOC compounds decreased from 2003 to 2006, except for 2,2,4-

trimethylpentane. Studies were performed at this site in 2003 and 2006 only. In 2003, Platteville dominated the NMOC concentrations with the exceptions of Isopentane at CAMP, and 3-methylpentane and 3-methylhexane at both the CAMP and Welby sites. The list of compounds being analyzed for seems to best characterize the air at the Platteville site. The site had very low percentages of unknown NMOC concentrations in 2003 (6%) and 2006 (20%). In fact, they were the lowest percentages of any of the sites in any of the studies. This is likely because the suite of compounds being looked at was designed to characterize contributions to air toxics concentrations from oil and gas development, and the site sits in the middle of a large development area.