The Alberta ROVER II On-road Vehicle Emissions Survey

Prepared for

Clean Air Strategic Alliance

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Table of Contents

1. INTRODUCTION 8

2. SURVEY DESIGN 9

2.1. EQUIPMENT DESCRIPTION 9
2.2. EQUIPMENT QA/QC AUDITS: 11
2.2.1. Factory Testing and Certification 11
2.2.2. Daily Set-Up and Calibration 12
2.2.3. Equipment Audits 12
2.3. SITES 12
2.4. DATA SCREENING 16
2.4.1. Screening of Exhaust Plumes 17
2.4.2. Screening of Hourly Observations 17
2.4.3. Screening of Day-to-Day Variations in Emissions Values 17
2.4.4. Effect of Engine Load on Measured Vehicle Emissions 20

3. PUBLIC AWARENESS 21

4. ANALYSIS OF DATA COLLECTED 24

4.1. STATISTICS AND RSD COVERAGE 24
4.1.1. Overall Program Statistics 24
4.2. LIGHT VEHICLE FLEET EMISSION RATES 27
4.2.1. Emission Rates Summary 27
4.2.2. Carbon Monoxide Emissions in 1998 and 2006 27
4.2.3. 2006 Emissions Distributions 28
4.2.4. Conversion to Gram per Liter 31
4.2.5. Municipality Comparison 32
4.2.6. Emissions by Fuel Type 34
4.2.7. Emissions Rates by Model Year Group 36
4.2.8. Emissions Contributions by Model Year 38

5. CHARACTERISTICS OF HIGH EMITTERS 41

6. VEHICLE OCCUPANCY 47

7. COMPARISON WITH EMISSIONS IN OTHER REGIONS 49

8. DISCUSSION 53

8.1. EMISSION CONCENTRATIONS VS. MASS 53
8.2. TRENDS IN CRITERIA AIR CONTAMINANTS 53
8.3. GREENHOUSE GASES 54
8.4. DEVELOPING AN EMISSIONS INVENTORY 54
8.5. POLICY IMPLICATIONS AND OPTIONS FOR ALBERTA 55
8.5.1. Voluntary Accelerated Retirement Programs 56
8.5.2. Anti-tampering and Maintenance Requirements 56
8.5.3. Greenhouse Gas Reduction 56

9. FINDINGS AND CONCLUSIONS 58

List of Tables

TABLE 2-1: SELECTED SITES 13
TABLE 4-1: NUMBER OF REMOTE SENSING RECORDS BY LICENSE PLATE 24
TABLE 4-3 RECORDS USED TO ESTIMATE EMISSION RATES 27
TABLE 4-4 2006 ON-ROAD EMISSIONS SUMMARY 27
TABLE 4-5 1998 AND 2006 CO EMISSIONS COMPARISON 28
TABLE 4-5: MEASUREMENTS BY FUEL 35
TABLE 4-6: MEASUREMENTS BY MODEL YEAR 36
TABLE 5-1: HIGH EMITTERS 41
TABLE 5-2 HIGHER EMITTERS BY POLLUTANT 41
TABLE 6-1 VEHICLE OCCUPANCY BY MUNICIPALITY 47
TABLE 6-2 VEHICLE OCCUPANCY BY HOUR 47
TABLE 6-3 VEHICLES SURVEYED FOR OCCUPANCY 48
TABLE 7-1 AVERAGE EMISSIONS 49
TABLE 7-2 HIGH EMITTERS 50
TABLE 7-3 HIGH EMITTER CONTRIBUTIONS TO TOTAL ON-ROAD EMISSIONS 50

List of Figures

FIGURE 2-1 ON-ROAD REMOTE SENSING SET-UP SCHEMATIC 10
FIGURE 2-2 ON-ROAD REMOTE SENSING EQUIPMENT PICTURE 10
FIGURE 2-2 SITE LOCATIONS 14
FIGURE 2-3 DAILY MEDIAN HC HEXANE FOR 2001 AND NEWER MODEL 18
FIGURE 2-4 DAILY MEDIAN CO FOR 2001 AND NEWER MODEL 19
FIGURE 2-5: DAILY MEDIAN NOX FOR 2001 AND NEWER MODELS 19
FIGURE 4-1 ON-ROAD VEHICLES MEASURED BY TYPE AND MODEL YEAR 25
TABLE 4-2 BODY STYLES OBSERVED FOR 1981-2005 MODELS 26
FIGURE 4-2 CO EMISSIONS DISTRIBUTION 29
FIGURE 4-3 HC EMISSIONS DISTRIBUTION 29
FIGURE 4-4 NO EMISSIONS DISTRIBUTION 30
FIGURE 4-5 UV-SMOKE EMISSIONS DISTRIBUTION 30
FIGURE 4-6: MEAN CO BY CITY 32
FIGURE 4-7: MEAN HC BY CITY 33
FIGURE 4-8: MEAN NOX BY CITY 33
FIGURE 4-9: SMOKE BY CITY 34
FIGURE 4-10: VSP BY CITY 34
FIGURE 4-11: EMISSION BY FUEL 35
FIGURE 4-12: MEAN CO BY MODEL YEAR 37
FIGURE 4-13: MEAN HC BY MODEL YEAR 37
FIGURE 4-14: MEAN NOX BY MODEL YEAR 38
FIGURE 4-15: MEAN SMOKE BY MODEL YEAR 38
FIGURE 4-16: COMPOSITION OF VEHICLES MEASURED ON-ROAD 39
FIGURE 4-17: APPROXIMATE EMISSIONS CONTRIBUTIONS 40
FIGURE 5-1: HIGH EMITTERS BY CITY 43
FIGURE 5-2: NUMBER OF HIGH EMITTERS BY MODEL YEAR 43
FIGURE 5-3: PERCENT OF HIGH EMITTERS BY MODEL YEAR 44
FIGURE 5-4: HIGH EMITTERS BY FUEL 44
FIGURE 5-5: HIGH EMITTERS BY WEIGHT CLASS (1981-2005 MODELS) 45
FIGURE 5-6: HIGH EMITTERS BY CYLINDERS AND AGE (1995 & OLDER, 1996 & NEWER) 45
FIGURE 5-7: HIGH EMITTERS BY MANUFACTURER ORIGIN 46
FIGURE 7-1 HIGH EMITTER RATES BY YEAR 50
FIGURE 7-2 HC HIGH EMITTER RATES BY YEAR 51
FIGURE 7-3 CO HIGH EMITTER RATES BY YEAR 51
FIGURE 7-4 NO HIGH EMITTER RATES BY YEAR 52

Glossary of Terms and Abbreviations

ADT	Average Daily Traffic
ASM	Acceleration Simulation Mode
Basic I/M	A set of vehicle I/M program inspection requirements defined by the U.S. EPA that may be used in areas not required to implement an Enhanced I/M program; the inspection procedure usually involves idle testing
CAC	Criteria Air Contaminants
CO	Carbon monoxide
CO2	Carbon dioxide
Cutpoint	An emissions level used to classify vehicles as having met an emissions inspection requirement
Enhanced I/M	A set of more rigorous vehicle I/M program inspection requirements defined by the U.S. EPA that usually involves IM240 testing
EPA	United States Environmental Protection Agency
Excess Emissions	Vehicle emissions that exceed an I/M cutpoint
FTP	Federal Test Procedure
g/mi	Grams per mile, the units of measurement for FTP and IM240 tests
GHG	Greenhouse Gases
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbons
High Emitter Identification	The on-road identification of vehicles with high emission levels
I/M	Inspection and maintenance program
Idle Test	A tailpipe emission test conducted when the vehicle is idling and the transmission is not engaged
IM240 Test	A loaded-mode transient tailpipe emission test conducted when the vehicle is driven for up to 240 seconds on a dynamometer, following a specific speed trace that simulates real world driving conditions
KW/t	Kilowatts per metric ton, the units of measurement for vehicle specific power
LDGV	Light-duty Gasoline-powered Vehicle
LDGT	Light-duty Gasoline-powered Truck
NO_X	Oxides of nitrogen, usually measured as nitric oxide (NO)

OBDII	On board diagnostic system to detect emissions related problems that is required on all 1998 and newer light–duty vehicles
PM	Particulate Matter
Repairable Emissions	The emission reductions that can be obtained by repairing a vehicle. The amount of repairable emissions is equal to or greater than the amount of excess emissions
RSD	Remote Sensing Device
SDM	Source Detector Module
VIN	Vehicle Identification Number
VDR	Vehicle On-road Record
VMT	Vehicle Miles Traveled
VSP	Vehicle Specific Power; estimated engine power divided by the mass of the vehicle
VTM	Vertical Transfer Mirror

Executive Summary

The Clean Air Strategic Alliance of Alberta (CASA) is a non-profit association composed of diverse stakeholders from government, industry and non-governmental organizations. Representatives from each of these three sectors are committed to developing and applying a comprehensive air quality management system for Alberta through a consensus-based approach.
The CASA Vehicle Emissions Team (VET) has a mandate to recommend initiatives that will reduce vehicle emissions in Alberta. Within this context, the VET undertook a survey in 1998 to assess actual in use vehicle emissions using remote sensing technology. The survey was called ROVER (Roadside Optical Vehicle Emission Reporter). A copy of the 1999 VET Rover Report can be found at:
http://www.casahome.org/uploads/VETrover_final_report_summary.pdf

Eight years later, this ROVER II survey repeated and expanded the previous survey to determine what progress has been made and what policies may be needed to control emissions in the future. The survey monitored vehicle emissions from September 21 to October 17, 2006. In total, 66,002 light duty vehicles were tested in four municipalities (Edmonton, Calgary, Red Deer and Canmore) and registration information was obtained on 91% of the vehicles. The first ROVER survey measured carbon monoxide emissions (CO). The ROVER II survey was performed using an ESP RSD4000 remote sensing van equipped to measure exhaust emissions of carbon dioxide (CO_2), hydrocarbon (HC), carbon monoxide (CO), nitrogen oxide (NO) and smoke also known as particulate matter (PM).

Findings

The key findings of the 2006 ROVER II survey include:

- On-road emissions per vehicle are lower than in the previous 1998 ROVER survey:
    - Median CO emissions of 0.02% in this 2006 survey were lower than in the 1998 survey when median CO was measured at 0.11%.
    - In the 1998 survey, 7% of vehicles were identified as gross CO emitters and they contributed 54% of the total CO emissions.
    - In this 2006 survey, 1.2% of vehicles were identified as gross CO emitters using the same standard.
    - In this 2006 survey 5% of vehicles were identified as gross emitters for one or more of the pollutants; HC, CO, NO or smoke.
    - These gross emitters contributed 60% of CO and 31%, 26% and 7% of HC, NO and particulate matter respectively.
- Median emission levels were similar in all four municipalities.
- 20% of light duty vehicles account for 80% of exhaust emissions of HC, CO, NO and PM.
- The characteristics of survey gross emitters are; older, heavier or fueled by propane.
- The gross emitter rate among 1996 and newer models is less than 2% vs. 20-40% for 1989 and older models. Asian vehicles had lower rates of gross emitters.

- Three quarters of LDVs observed had only one occupant. Single occupancy levels were highest in Edmonton and lowest in Canmore.
- Occupancy levels were similar to those observed in the 1988 survey with the exception of Canmore, where a greater number of vehicles with multiple occupants were observed in the 2006 survey.
- Public awareness and interest in vehicle emissions was evident. The ROVER II survey was very well received by the municipalities, the media, and the public.

It is important to recognize that the lower emission rates per vehicle are partly offset by increased numbers of vehicles.

The survey did not study Greenhouse gas emissions. Greenhouse gas emissions are primarily dependent on average fuel economy and the total miles driven.

1. INTRODUCTION

In 1996, the Clean Air Strategic Alliance (CASA), which has a mandate to develop Alberta strategies for solving air quality problems, established the Vehicle Emissions Working Group (VEWG) to address air quality issues related to vehicle emissions. The working group included stakeholders from government, industry, and non-government organizations (NGOs). In June 1998, the VEWG presented nine recommendations to the CASA board of directors addressing vehicle emissions. This submission included a recommendation to conduct vehicle emissions testing by remote sensing. The recommendations were approved.

The CASA Vehicle Emissions Team (VET) undertook a survey in 1998 to assess actual in use vehicle emissions using remote sensing technology. The survey was called ROVER (Roadside Optical Vehicle Emission Reporter). The survey measured CO and CO2 emissions and recorded vehicle occupancy.

In 2006, CASA contracted with ESPH to conduct the Rover II on-road remote sensing survey using their RSD 4000 equipment, which measures hydrocarbon (HC), carbon monoxide (CO), nitrogen oxide (NO) and particulate matter (PM).

ROVER II SURVEY OBJECTIVES

1. Repeat the remote testing of light duty vehicle emissions testing to assess changes in the vehicle emissions profile since 1998, including absolute emission levels and the impact of "gross emitters".
2. Generate model specific emissions profiles in an attempt to better understand which vehicles in Alberta are the 'gross emitters'.
3. Promote driver awareness through the use of real time flashboards to identify vehicle emission performance. The CASA Rover Survey Team will undertake a communication awareness program.
4. Assess vehicle occupancy and trends since1998.
5. Measure the vehicle emissions of PM, CO, CO2, HC and NOx and missions.
6. Based on the findings, comment on the future direction of in use vehicle emissions management.

The Rover II survey ran from September 21 to October 17, 2006. This summary report documents the results of the survey. Section 2 discusses the study design and equipment involved. Section 3 describes how the public was made aware of the survey. Section 4 reports the results of the survey including the emission levels measured. Section 5 characterizes high emitters and their frequency by municipality, model year, fuel and weight class. Section 6 gives the results of the vehicle occupancy survey.

Sections 7 and 8 give a comparison of the Alberta ROVER Survey and emissions of vehicles in other regions and discussion of the survey results. Section 9 summarizes the survey's findings.

2. SURVEY DESIGN

2.1. Equipment Description

The survey utilized the newest addition to ESP's line of products, the RSD4000, which is the fourth generation of ESP commercial remote sensing systems based on the ROVER technology developed by Professor Donald Stedman (University of Denver). The underlying technology is the same as the equipment used in the first ROVER survey. Over time, the equipment has been developed to measure more pollutants, be more durable, easier to operate and more accurate.

The RSD4000 detects vehicle emissions when a car drives through an invisible light beam the system projects across a roadway. Figure 2-1 illustrates the remote sensing equipment set-up. The process of measuring emissions remotely begins when the RSD4000 Source & Detector Module (SDM) sends an infrared (IR) and ultraviolet (UV) light beam across a single lane of road to a lateral transfer mirror. The mirror reflects the beam back across the street (creating a dual beam path) into a series of detectors in the SDM. Concentrations of HC, CO, CO2, NOx and smoke are measured in vehicle exhaust plumes based on their absorption of IR/UV light in the dual beam path[1,2,3]. In advance of the SDM, two low power laser beams spaced 6' apart are projected across the road and reflected back. As each vehicle passes, the equipment measures the interruption and resumption of the two beams and uses the time intervals to calculate the vehicle speed and acceleration.

During this process, a digital camera captures an image of the vehicle's rear license plate and stores it on a data-recording device. The License plate information is stored with the emissions measurement and subsequently matched to motor vehicle registrations to determine the characteristics of the vehicle that was measured.

The RSD units are housed in specially outfitted vans. These vans are equipped with heating/cooling, a generator, and adequate storage for all components. The vans carry a full complement of road safety equipment and are equipped with additional lighting for testing during pre-dawn and post dusk hours. The RSD4000 unit continuously measures ambient conditions and background CO2.

The smoke measurement uses a UV beam with a longer wavelength to measure PM10 and the finer PM2.5 particles that are invisible to traditional visible light opacity meters.

More information on remote sensing is available from ESP at www.rsd-remotesensing.com and from Denver University at http://www.feat.biochem.du.edu/.

Figure 2-1 On-Road Remote Sensing Set-Up Schematic

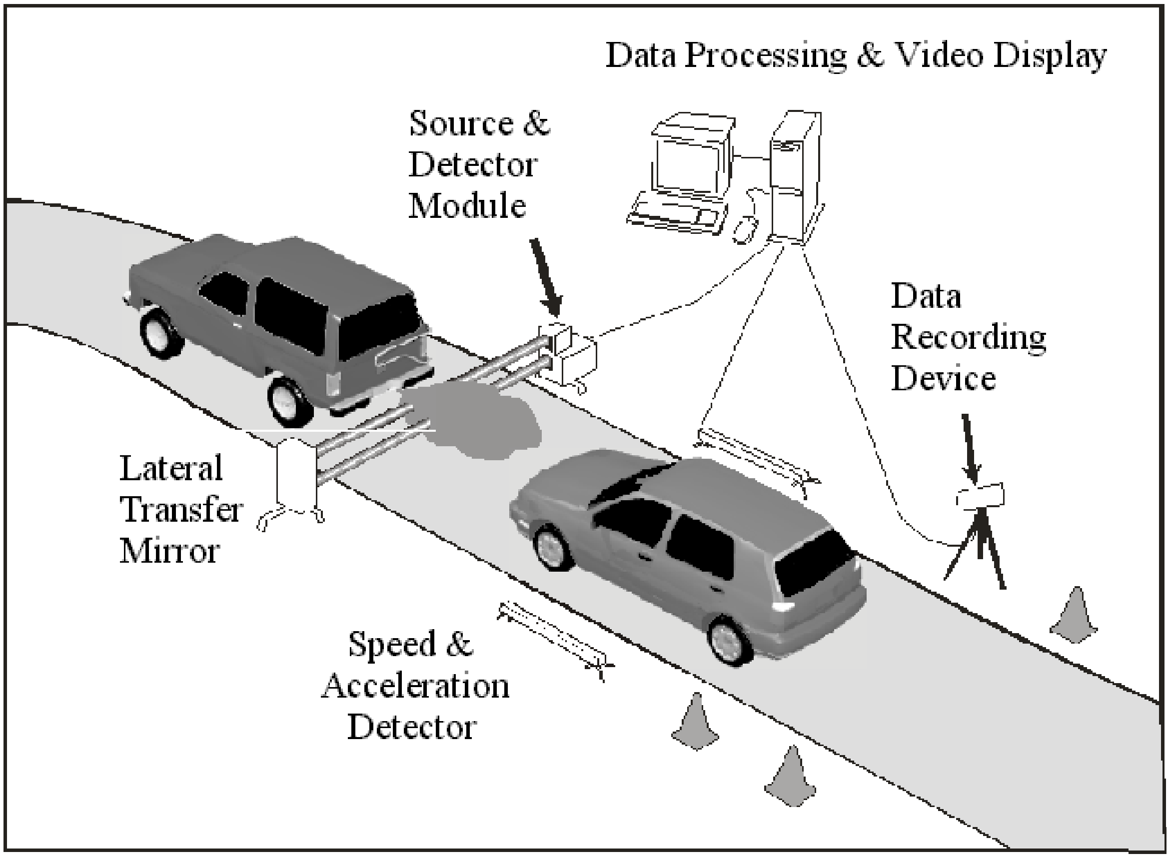


Figure 2-2 On-Road Remote Sensing Equipment Picture

2.2. *Equipment QA/QC Audits:*

2.2.1. Factory Testing and Certification

When an RSD system is built at the Tucson Technology Center, it undergoes several steps to ensure accuracy. First, the source detector module is bench calibrated. It is then audited using several blends of gas. When the system is fully calibrated and assembled, it is tested again in the parking lot using an audit truck. The unit tests are based on the California Bureau of Automotive Repair On-road Emissions Measurement System (OREMS) specification.

An audit truck is a modified vehicle that uses a long exhaust stack to direct the vehicle engine exhaust upwards and away from the roadway. Audit gases of known concentrations are dispensed through a simulated tailpipe routed to the rear of the audit truck. When the truck is driven past a roadside remote sensing SDM/VTM set of modules, the system measures the pollutant concentrations in the dispensed test gas instead of the vehicle engine exhaust.

The remote sensing unit is setup in a parking lot to avoid interference from other traffic. The auditor drives the audit truck through the remote sensing system 40 times for each gas blend during acceptance testing. ESP detector accuracy, including speed and acceleration, will meet the detector accuracy tolerances shown below for at least 97.5% (39/40) runs for each gas. Six different audit gas blends are used to verify the unit accuracy over a range of pollutant concentrations.

2.2.1.1 Detector Accuracy:

(1) The carbon monoxide (CO%) reading will be within ± 10% of the Certified Gas Sample, or an absolute value of ± 0.25% CO (whichever is greater), for a gas range less than or equal to 3.00% CO. Negative values shall be included and will not be rounded to zero. The CO% reading will be within ± 15% of the Certified Gas Sample for a gas range greater than 3.00% CO. Negative values will be included and will not be rounded to zero.

(2) The hydrocarbon reading (recorded in ppm propane) will be within ± 15% of the Certified Gas Sample, or an absolute value of ± 250 ppm HC, (whichever is greater). Negative values will be included and will not be rounded to zero.

(3) The nitric oxide reading (ppm) will be within ± 15% of the Certified Gas Sample, or an absolute value of ± 250 ppm NO, (whichever is greater). Negative values shall be included and will not be rounded to zero. NO is a surrogate for measuring NOx. We refer to NOx elsewhere in this document.

(4) Speed and Acceleration Accuracy:

(5) The vehicle speed measurement will be accurately recorded within ± 1.0 mile per hour.

(6) The vehicle acceleration measurement will be accurately recorded within ± 0.5 mile per hour / second.

2.2.2. Daily Set-Up and Calibration

Every scheduled work day, the operator drives to an existing or new test site. The operator's first duty is to provide themselves and passing motorists with a safe work area. The next step is to set up the source detector module and allow the electronic components within to warm up for a minimum of 30 minutes. Following the set up and alignment of the other components, the SDM is aligned and ready for Calibration.

A puff audit calibration is a method of testing the equipment without the need to drive an audit truck past the unit. During a gap in the passing traffic, a test gas with a known blend of HC, CO, CO2 and NOx, is puffed into the optical path of the remote sensing beam. If necessary, the instrument set-up is adjusted so that the pollutant values measured by the unit, match the known concentrations of pollutants in the test gas blend.

Calibration for the RSD4000 occurs once at the beginning day and at mid-day if conditions warrant.

2.2.3. Equipment Audits

After each daily calibration, the Operator is required to perform an audit to verify an optimal calibration. If the audit demonstrates that that the unit is operating within the detector accuracy tolerances described in Section 2.2.1.1 the operator is allowed to begin testing vehicles. If not, the operator is required to realign and recalibrate the system until it passes the audit process.

2.3. __Sites__

The site selection goal was to identify a network of sites suitable for RSD operation that would provide a representative sampling of the area fleet.

CASA VET identified the cities / towns and municipal contacts helped to identify the appropriate sites within each. The survey team logged the site locations and captured layouts and configurations using intersection layouts and digital camera images.

Sites needed to have a single lane of traffic, or be able to be coned down to create a single lane, with sufficient space to the side for the roadside van and equipment.

To provide the broadest fleet coverage the site visit strategy was to visit most sites for a single day.

The survey data collection phase lasted a total of 30 van days from 9/21/2006 through 10/17/2006 including two media events on 9/29 and 10/12. Two vans were used to accomplish the data collection. ESP worked some 12-hour days in order to reduce travel and set-up time and, hence, maximize on-road collection time.

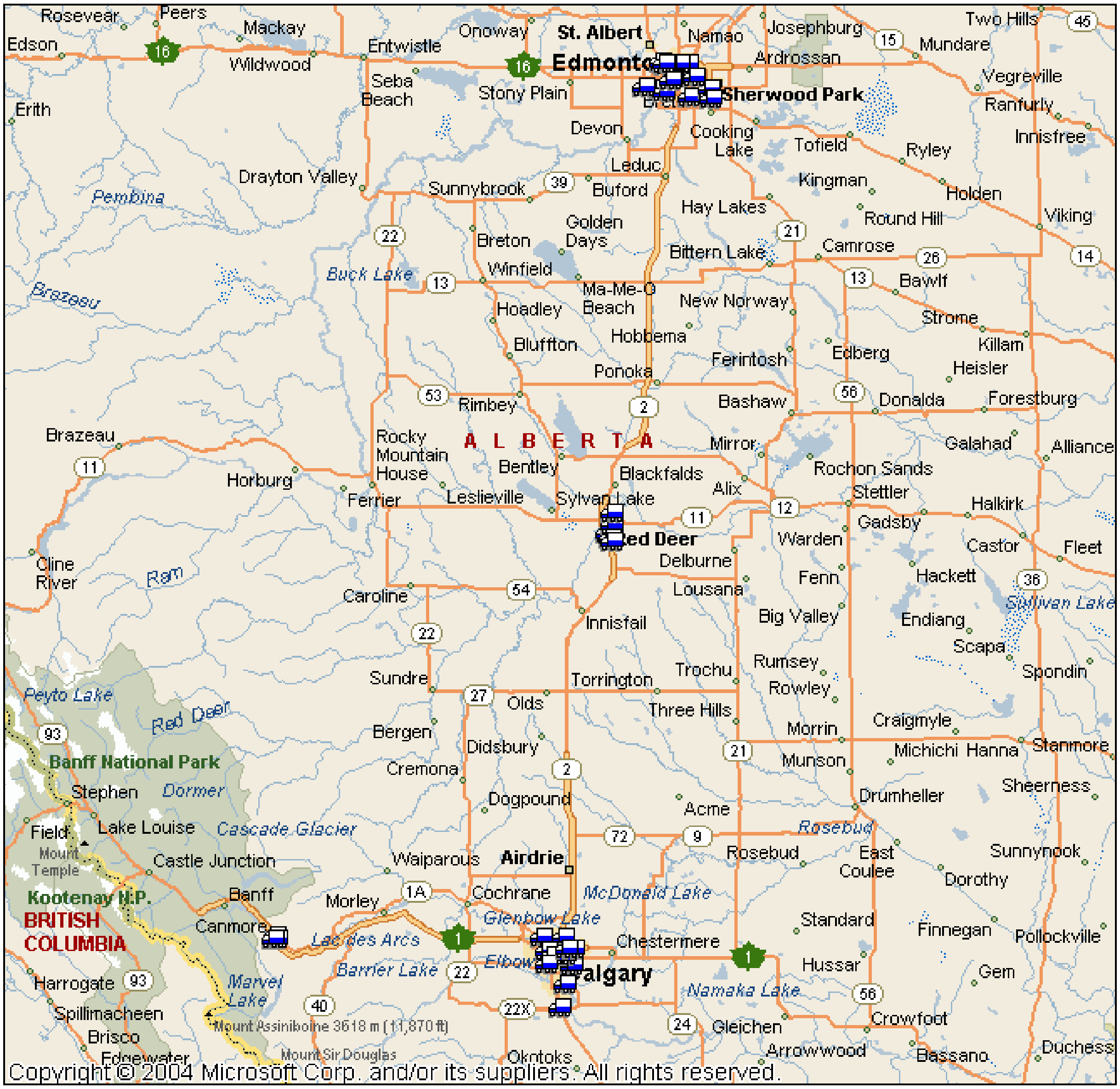
The twenty-six sites listed in Table 2-1 were identified and used in the survey. Figure 2-2 displays the distribution of the sites in the region and in each city.

Table 2-1: Selected Sites

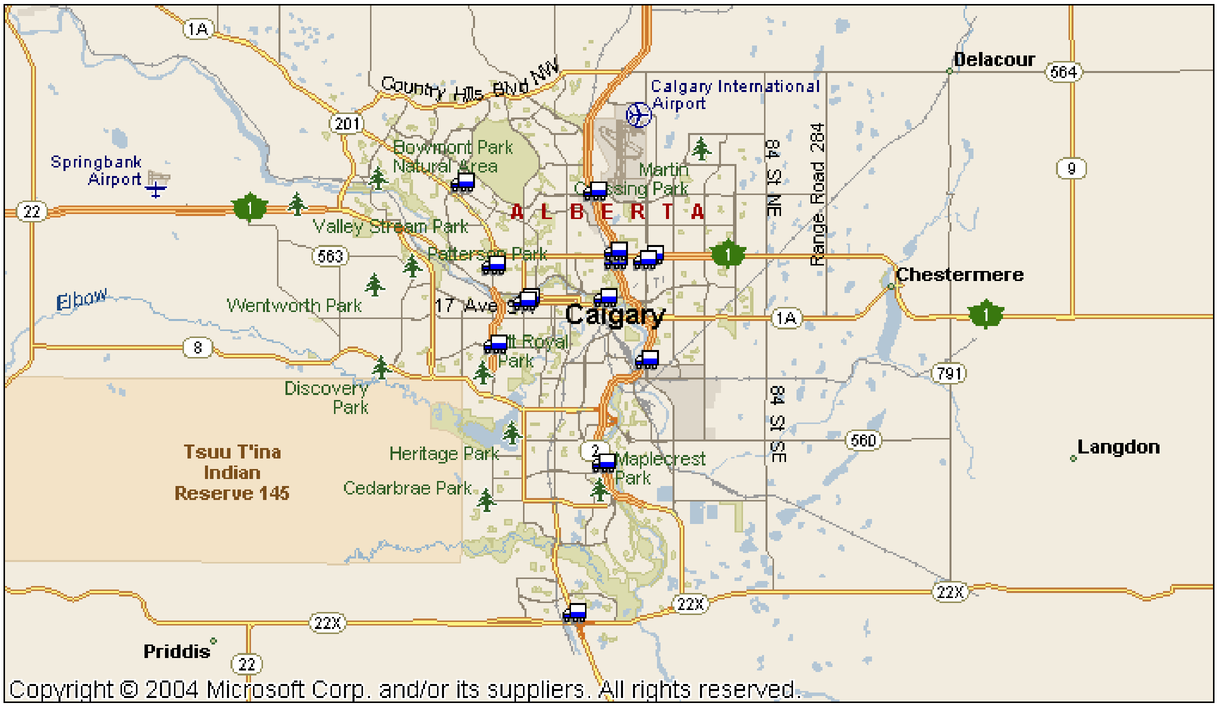
Site ID	Location	City	Grade (degrees)	Days
CAL02	SB Deerfoot Trail to Southland Drive.	Calgary	0.2	1
CAL03	Hwy 22X onto NB Macleod Trail.	Calgary	0.8	1
CAL05	14th Street SB to 9th Ave EB.	Calgary	2.2	2
CAL06	Bow Trail EB To 5th Ave EB. 4th Ave To Bow Trail WB.	Calgary	0.2	1
CAL08	Northland Drive NB On To NB Shaganappi Trail.	Calgary	2.4	1
CAL09	Mcknight Blvd To NB Deerfoot Trail.	Calgary	-2.2	1
CAL10	16Th Ave EB onto Barlow Trail SB.	Calgary	0.4	1
CAL11	Barlow Trail NB to 16th Ave WB.	Calgary	1.6	1
CAL12	Barlow Trail NB to NB Deerfoot Trail.	Calgary	-0.3	1
CAL13	16th Ave onto Deerfoot Tr North (Towards Edmonton).	Calgary	-0.2	1
CAL14	16th Ave onto Deerfoot Trail (Hwy 2) SB.	Calgary	-0.1	1
CAN02	Benchlands Trail onto Trans Canada Hwy 1 EB.	Canmore	2.2	2
EDM01	Onramp WB from St Alberts Trail onto WB Yellowhead Trail.	Edmonton	-0.5	1
EDM03	Whitemud WB onto Anthony Henday NB.	Edmonton	0.6	1
EDM04	Fox Drive WB onto Whitemud WB.	Edmonton	2.2	1
EDM05	149th Street SB Merging Onto EB Whitemud.	Edmonton	-0.4	1
EDM06	EB Whitemud to NB Hwy 14.	Edmonton	0.6	1
EDM07	66th Street onto Whitemud WB.	Calgary	-1.1	1
EDM09	EB River Road Across From Victoria Golf Course Entrance.	Edmonton	0.2	1
EDM13	EB Onramp To Yellowhead Hwy from St Elbert Trail NB.	Edmonton	-0.3	1
EDM15	Hwy 16 WB Onramp from Fort Road.	Edmonton	0.3	1
EDM16	SB Hwy 14 from Sherwood Parkway WB.	Edmonton	-0.1	1
RED01	19th Street onto Hwy 2NB.	Red Deer	0.2	1
RED04	Taylor Drive EB onto Taylor Drive SB.	Red Deer	0.8	1
RED05	32 Street WB onto Hwy 2 NB..	Red Deer	0.0	2
MEDIA		Calgary	0.0	2

Figure 2-2 Site Locations

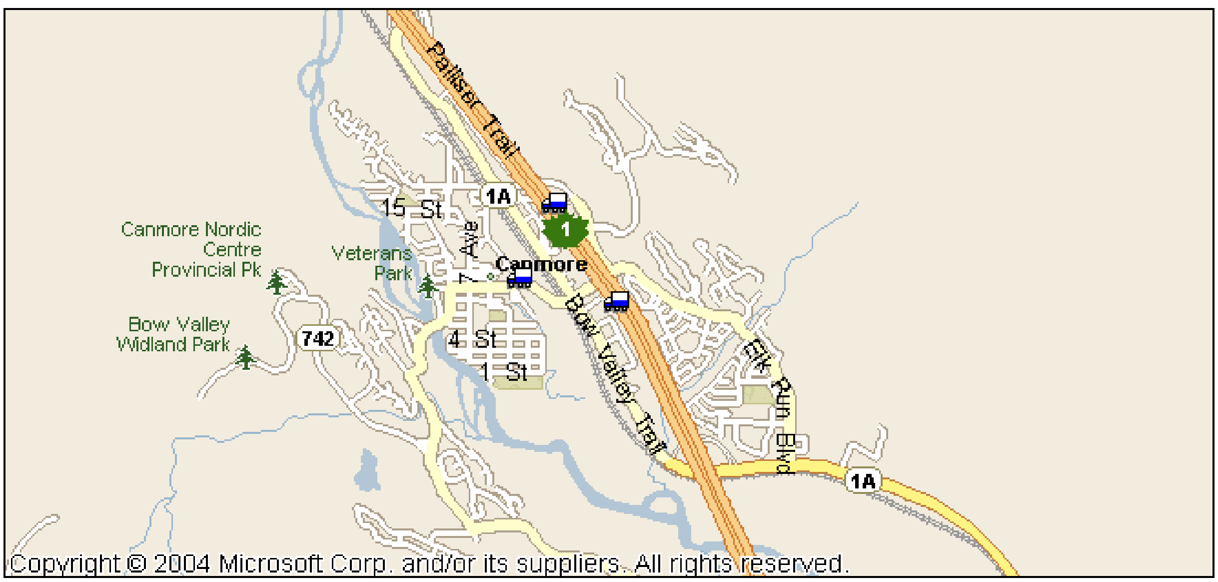
Regional Map



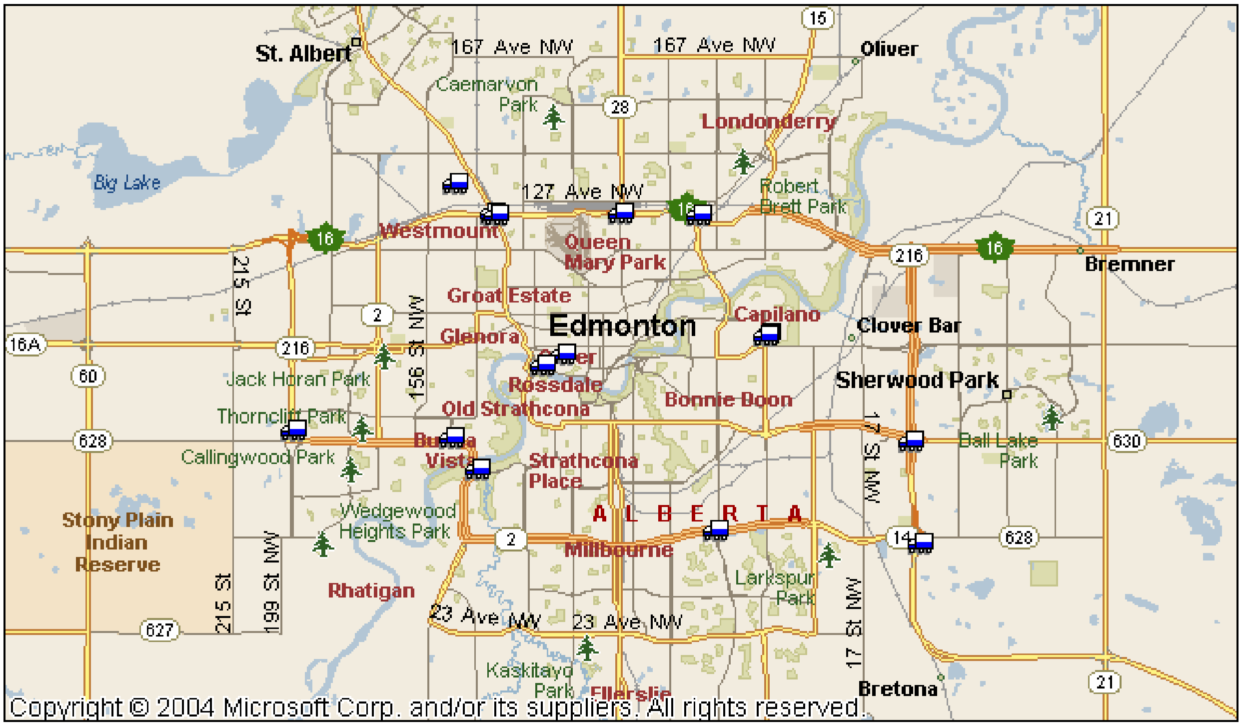
Calgary Sites



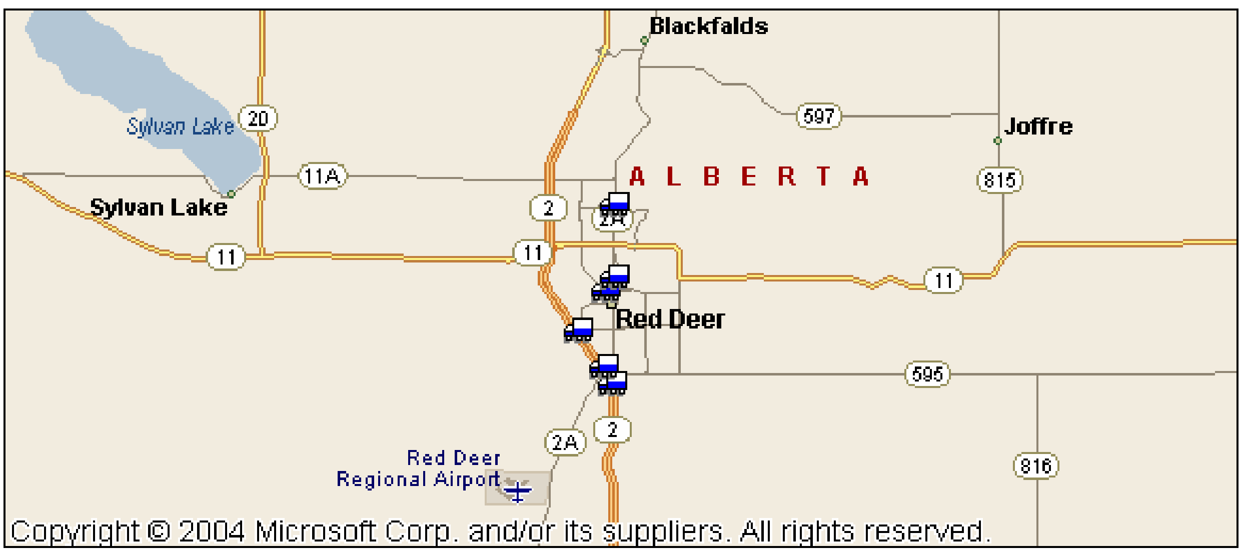
Canmore Sites



Edmonton Sites



Red Deer Sites



2.4. Data Screening

ESP applied screening checks to the RSD measurements to ensure the data used for fleet evaluation and fleet comparisons are reasonable and consistent:

- Screening of exhaust plumes
- Screening of hourly observations to check for cold starts

Screening of day-to-day variations in emissions values
Screening for Vehicle Specific Power (VSP) range

The screening procedures are described briefly in the following paragraphs. Additional tables and charts relating to data screening are provided in Appendix A.

2.4.1. Screening of Exhaust Plumes

The RSD4000 unit samples each exhaust plume approximately every 10 milliseconds during the one half second after each vehicle passes the equipment. The basic gas record validity criteria applied are:

- A gas record is valid if there are at least 5 plume measurements where the sum of the amount of CO2 and CO gas exceed 10%-cm[i]; or
- A gas record is valid if there are at least 5 plume measurements where the sum of the amount of CO2 and CO gas exceed 5%-cm and the background gas values are very stable (not changing faster than a specified rate) at the time the front of the vehicle breaks the measurement beam.

2.4.2. Screening of Hourly Observations

Vehicles operating in cold start mode or under conditions when exhaust plumes condense to steam may appear to have high emissions without any emission system problems. Vehicles produce high emissions in the first minutes after being started when the fuel mixture is enriched and the catalytic converter is not hot enough to function effectively. Exhaust steam plumes can interfere with accurate measurements because the UV and I/R beam path is partly obscured.

To investigate this possibility, ESP tabulated for each site and hour the percentage of 2000 and newer vehicles that exceeded 250 ppm HC. To avoid these measurements ESP removed observations made during hours when more than 10% of 2000 and newer vehicles exceeded 250 ppm HC or when the temperature was below zero centigrade.

2.4.3. Screening of Day-to-Day Variations in Emissions Values

Day-to-day decile values were compared for 2001 and newer vehicles. Only a small percentage of these vehicles are expected to have high emissions. For this group of vehicles, we expect the intermediate decile emission values should not vary significantly from day-to-day, from site-to-site or between RSD units.

The daily median values of emissions of 2001 and newer vehicles were compared to the median values for all days. The daily median values for all 2001 and newer vehicles are shown in Figures 2-3, 2-4 and 2-5. In each of these charts the y-axis range is set to the detector accuracy specification. Each point represents the median emissions of 2001 and newer models measured by the RSD unit on the date shown. In total, three separate RSD units were used during the survey but only two were used on any single day. It is evident that the daily median differences are small compared to the claimed detector accuracy but they are not insignificant compared to typical emission levels of new vehicles.

For CO and NO there appear to be only small differences between the RSD units. The HC results, however, showed significant variation for unit 4619, which had emissions shifted high on some days compared to other units. Therefore, an adjusted set of HC values was created by direct addition or

[i] The unit of measurement 10%-cm is a measurement of the amount of a gas in the optical path. In this case, if all the molecules of the gas in the path were collected together into just one centimeter of the path then the concentration of the gas in the one-centimeter would be 10%.

subtraction of a daily offset to the daily median values with the median value for all the results from the other units.

The emissions analyses shown in this report use the adjusted values. In a Virginia survey[4] that used a similar methodology, many statistics were run two ways, 1) using the RSD results as measured and 2) using the adjusted values. The differences between the results were small but the adjusted values resulted in slightly lower average emissions for the newest vehicles and slightly smaller standard deviations from mean values.

Figure 2-3 Daily Median HC hexane for 2001 and Newer Model

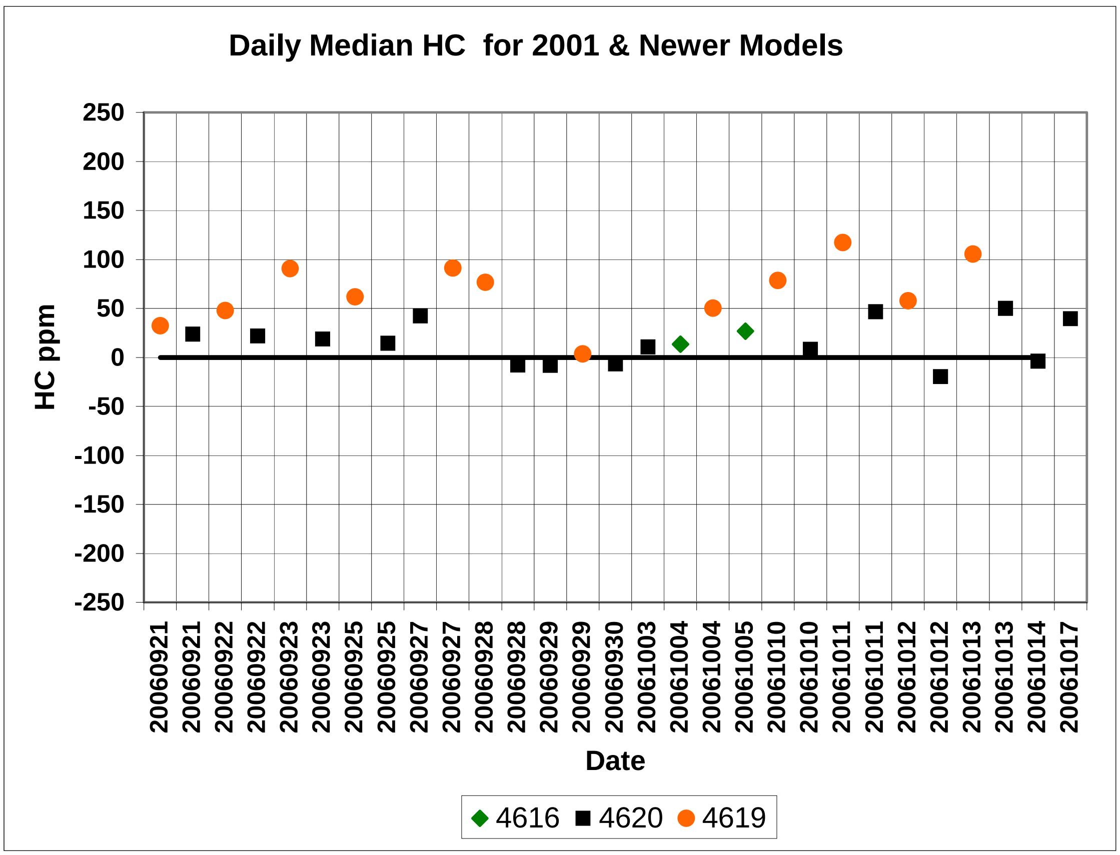


Figure 2-4 Daily Median CO for 2001 and Newer Model

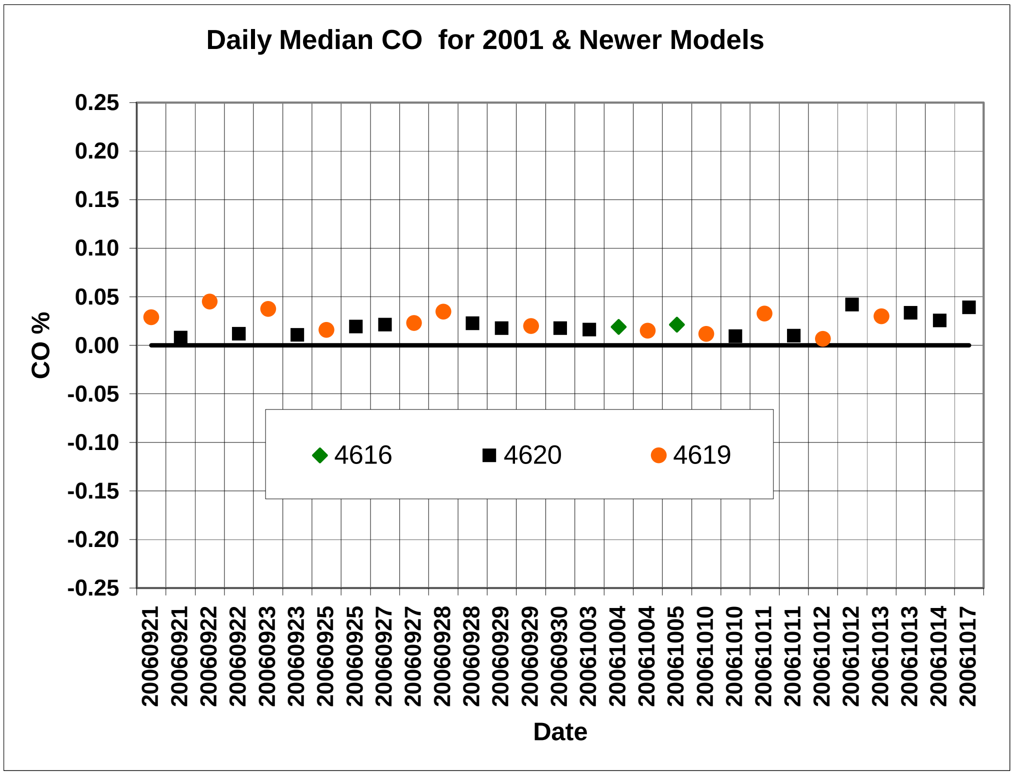
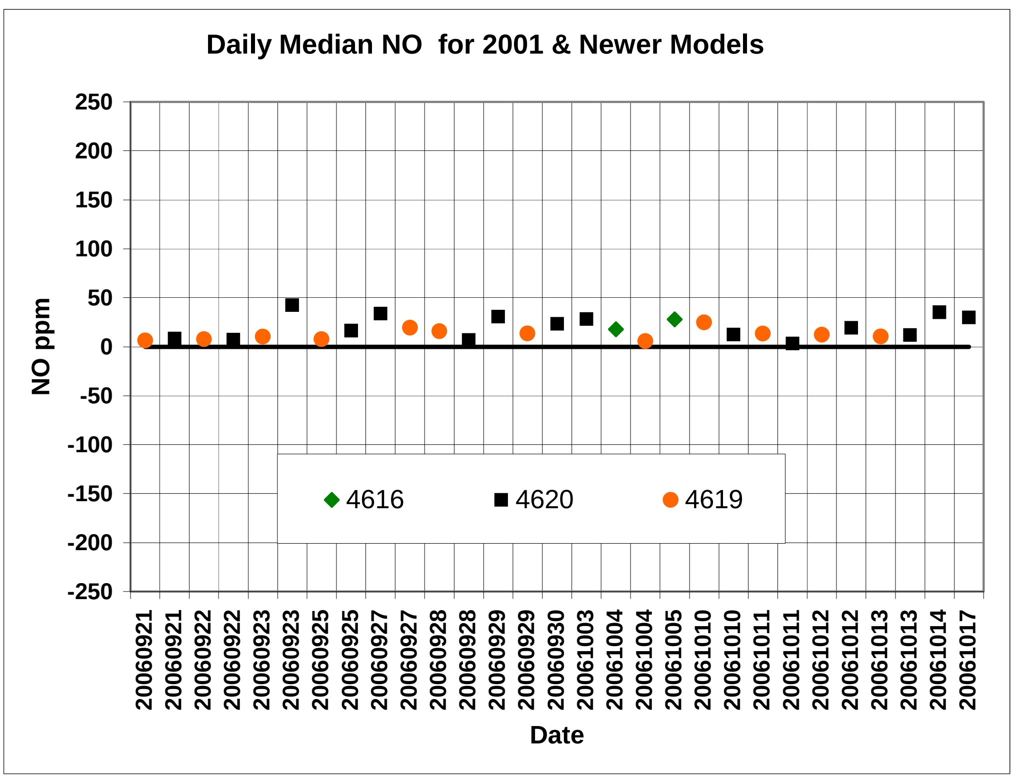


Figure 2-5: Daily Median NOx for 2001 and Newer Models



2.4.4. Effect of Engine Load on Measured Vehicle Emissions

The operating mode of vehicles, e.g. idle, cruise, acceleration, travel uphill and travel downhill, affects engine power output. The mass of pollutants emitted per gallon of fuel can vary significantly at low power and at high power – especially for older vehicles that have less well-controlled emissions.

Vehicle Specific Power (VSP) is the estimated engine power output divided by the vehicle weight. VSP is proportional to the rate of fuel consumption[5]. ESP used the speed/acceleration and site grade data to estimate Vehicle Specific Power (VSP), which for light vehicles is approximated by the following equation:

VSP kw/t = 4.364*sin(Grade in Deg/57.3)*Speed + 0.22*Speed*Accel + 0.0657*Speed + 0.000027*Speed*Speed*Speed

Where speed is in mph and acceleration is mph/s.

Newer vehicles have much lower emissions and their emissions concentrations are stable across a wide range of VSP. For older vehicles HC emissions can be quite unstable when VSP is close to zero or negative. Older vehicles also tend to go into enrichment mode when the VSP is above 22 kw/t, which is the highest load in the federal test procedure (FTP) used to certify new vehicles.

ESP used observations where VSP is between 3 and 22 kW/t in the analysis in section 4. This is broader than the 5 and 20 kW/t range recommended by EPA[6] but retains about 15% more of the measurements and we have used the 3-22kw/t range elsewhere[7].

3. Public Awareness

Increasing public awareness was one of the main objectives of the survey. This was accomplished in a number of ways. Prior to the commencement of the survey, CASA provided media releases and established a web site for the public. This web site included a driver checklist for the proper maintenance and operation of vehicles. In addition, each municipality hosted a launch on the first day of testing which involved government officials, the media, and the public. CASA continued to post preliminary results on its web site as testing was completed in each municipality. Copies of the ARP report will be made publicly available. A sampling of media coverage is contained in Appendix B of this report.

ROVER Communications Sub-Committee

A sub-committee was formed and met five times to organize the communications aspect of the project. Members included the following Vehicle Emissions Team members and communicators from stakeholder organizations:

- Scott Wilson (Chair), Alberta Motor Association
- Gerry Ertel, Shell Canada Ltd. and Canadian Petroleum Products Institute (CPPI)
- Alan Brownlee, City of Edmonton
- Kelly Vail, City of Edmonton
- Josepha Vanderstoop, City of Calgary
- Kim McLeod, Alberta Environment
- Denise Poirier, City of Red Deer
- Sally Caudill, Town of Canmore
- Jean-Luc Matteau, Environment Canada
- Tony Hudson, The Lung Association – Alberta & NWT
- Kevin Boothroyd, Environmental Systems Products
- Sharon Hawrelak, CASA

CASA is most appreciative of the time and effort the sub-committee members expended in planning the events. CASA also thanks the following stakeholders who were spokespersons at the events:

- Myles Kitagawa, Toxics Watch Society of Alberta
- Gerry Ertel, Shell Canada Ltd. and CPPI
- Tony Hudson, The Lung Association – Alberta and NWT
- Ted Stoner, CPPI
- Leonore Harris, Parkland Airshed Management Zone
- Jay Litke, Alberta Environment
- Ernie Hui, Alberta Environment
- Barry Erskine, City of Calgary
- David Thiele, City of Edmonton
- Corinna Dootjes, Town of Canmore
- Mike Western, Town of Canmore
- Sally Caudill, Town of Canmore
- Ed Theobold, ESP
- Donna Tingley, CASA
- Sharon Hawrelak, CASA

Communications Plan

The sub-committee approved and implemented a communications plan which included the following objectives:

1. Increase public awareness of vehicle emissions and impact on air quality.
2. Increase vehicle owner awareness of how much their vehicle is emitting and what they can do to lower the amount of emissions.
3. Increase public awareness of what can be done to lower the impact of vehicle emissions on air quality.

Key Messages

1. Reduce vehicle emissions and we'll all breathe easier.
2. Certain types and conditions of vehicles emit more.
3. Vehicle owners are encouraged to make choices and take actions that limit the amount that their vehicles emit.

COMMUNICATIONS STRATEGIES

Media Relations

The ROVER Communications Sub-Committee organized four media events, one in each of the four municipalities of the study. The events were:
September 26, 2006 - News conference at Stampede Park in Calgary
September 29, 2006 – Photo and interview opportunity at testing site in Canmore
October 3, 2006 – Photo and interview opportunity at testing site in Red Deer
October 12, 2006 – News conference in Wm. Hawrelak Park in Edmonton

The Edmonton media event was wildly successful with 15 media personnel representing all 5 TV stations, 2 daily newspapers and one radio station. Twenty stakeholders and one MLA also attended the event.

The Red Deer and Canmore events, which were informal interview and photo opportunities at the testing sites, also netted impressive coverage. In Red Deer, the only TV, only daily newspaper and 3 radio stations provided coverage, including a spin-off news story on Global TV in Edmonton. In Canmore, both weekly papers and one radio station ran news stories. In Calgary, the media event was well-attended by stakeholders. One television station and the daily newspaper covered the testing in that city.

Website

Over 300 visitors visited the ROVER study webpage on the CASA website during the six week period of the study. The webpage contained:

- A project overview
- A brochure for motorists on the study and related information
- The news releases
- A backgrounder with Information on the issue and how to reduce vehicle emissions
- Links to stakeholder websites with information on vehicle emissions

Print Materials

- A *sponsorship banner* was produced for display at the media events.
- A *brochure* was distributed to motorists stopping by the testing sites which included information on the project, helpful hints on reducing vehicle emissions and contact information.
- Thirty-two *media kits* were distributed, which included:
  - News release
  - Backgrounder
  - “Welcome to the CASA ROVER vehicle emissions study” brochure
  - “use less…save move” brochure from the Alberta Motor Association

- “Fuel Stretch” brochure from Shell Canada Ltd.
- “Facts at your fingertips” brochure from Alberta Environment
- “The CASA way” brochure
- “Vehicle Inspection and Maintenance Programs” brochure from Envirotest Canada
- In Calgary – information on City of Calgary environmental programs
- In Edmonton – information on City of Edmonton environmental programs

Promotional Item

Four hundred tire pressure gauge key chains, with an imprinted reminder to check tire pressure on the first day of each month, were distributed at media events and to city/town councillors in the four communities of the study.

Advertising

Province-wide television public service announcements were planned to coincide with the testing phase of the project but were deferred to support team recommendations at the end of the project.

RESULTS

The media relations phase of this project resulted in at least 37 news stories on television, radio, daily and weekly newspapers. Spokesman Gerry Ertel was interviewed by at least 19 different media outlets in Alberta over the three weeks of the media relations phase of the communications plan. Thirty-two media kits were distributed, two-thirds of them in Edmonton.

The rest of the coverage was extremely positive, resulting in an overall approval rating of 92% for the media relations phase, positive tone of 4.57 out of 5, a cost of less than 1/4 cent per contact and a total reach of 2,350,000 contacts. Despite traffic problems in Calgary and Edmonton, the media coverage in Calgary was positive and focussed mainly on the study. The top of the news hour story on CBC TV in Calgary was among the best positioned coverage. Only two media outlets reported negatively on the traffic tie-up in Edmonton and even then, Gerry Ertel was able to refocus them onto the study by mid-story, so the report ended on a positive note. Also, positive coverage extended past the events as an in-depth follow-up story on reducing vehicle emissions was filmed by SHAW TV a week after the Edmonton media event.

4. ANALYSIS OF DATA COLLECTED

4.1. Statistics and RSD Coverage

4.1.1. Overall Program Statistics

Table 4.1 summarizes the records collected during the survey. Two RSD vans were used and three RSD units. One RSD unit developed a problem during the survey and was replaced. The vans were stationed at 26 sites mostly for one day. Over 120,000 vehicles were observed passing the RSD vans and 71% of their exhaust plumes were satisfactorily measured by the RSD systems. Plates were readable and tag edited on 76%. Alberta vehicle registry information was obtained for 91% of the license plates result in almost 60,000 emission measurements associated with a known vehicle. Some vehicles, less than 10%, were measured more than once. In total, 55,000 unique vehicles were measured.

Table 4-1: Number of Remote Sensing Records by License Plate

Data Collection Summary	Number	%
Number of RSD Vans	2	
Number of RSD Units	3	
Number of Sites	26	
Number of Van Days	31	
Total raw records (includes system check records)	122,333	
Valid emissions	87,326	71%
Valid Emissions and Tag Edited Plate	66,002	76%
Measurements with Plates Matched	59,876	91%
Unique vehicles matched	55,364	

ESP decoded the vehicle identification number (VIN) to yield additional information on virtually all 1981-2005 models. Figure 4.1 shows the distribution of the vehicles observed by age and the type of vehicle. Four fifths of vehicles were ten years old or newer (MY: 1997-2007).

Since the RSD units were set-up to measure light-duty vehicles, heavy-duty trucks and motorcycles are not fully represented in the RSD data.

Table 4-2 shows the numbers of 1981-2005 models by the body style reported by the Vehicle Registry and the weight range decoded from the VIN.

Figure 4-1 On-road Vehicles Measured by Type and Model Year

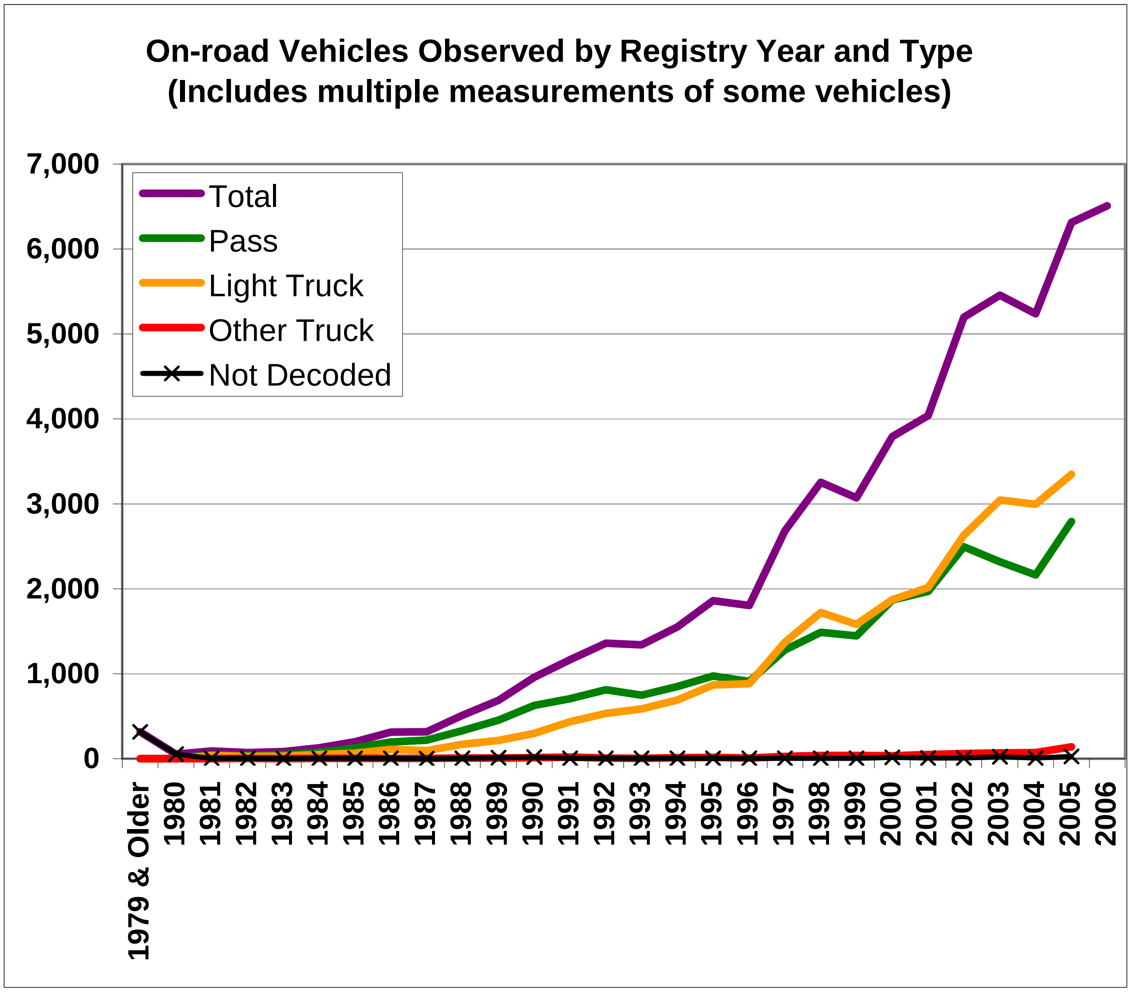


Table 4-2 Body Styles Observed for 1981-2005 Models

Vehicle Registry Body	Model Years 1981-2005 VIN Decode Result						Total
	M/C	Passenger	Light Truck	Medium-Heavy Truck	Other Trucks	Unknown	
2 door	-	3,721	5	1	1	17	3,745
2h	-	1,035	-	-	-	1	1,036
3 door	-	83	-	-	-	-	83
4 door	2	18,141	81	-	2	20	18,246
4drcoupe	-	50	-	-	-	-	50
5 door	-	58	1	-	-	-	59
ambulanc	-	-	-	1	-	-	1
atvwheel	6	-	-	-	-	6	12
boat tlr	-	-	-	-	-	1	1
bus	-	-	44	52	-	62	158
comm tlr	-	-	-	-	-	4	4
convert	-	317	7	-	-	2	326
hatch	-	153	11	-	-	-	164
in	-	1	-	-	-	-	1
limo	-	1	-	-	-	-	1
mtrcycle	10	-	-	-	-	-	10
mtrhome	-	-	3	18	-	-	21
my	-	-	1	17	-	-	18
other	-	1	-	-	-	-	1
psv tlr	-	-	-	-	-	1	1
rd	-	24	-	-	-	-	24
snow veh	-	-	-	-	-	4	4
sportcar	-	4	-	-	-	-	4
stnwagon	-	1,102	1,056	-	-	1	2,159
trailer	-	-	-	-	-	1	1
trav tlr	-	-	-	-	-	4	4
trk tlr	-	-	106	27	-	1	134
truck	-	43	8,156	344	19	18	8,580
util tlr	-	-	-	-	-	11	11
utility	-	207	7,186	1	51	4	7,449
van	-	28	9,013	101	1	17	9,160
Total	18	24,969	25,670	562	74	175	51,468

4.2. *Light Vehicle Fleet Emission Rates*

ESP applied the data screening described in section 2 to produce a subset of 35,224 measurements that represent typical emissions from vehicles operating on-road. These records were used to estimate emission rates and identify high emitters.

For summary emissions, independent of vehicle fuel or model year, the additional measurements of vehicles with unmatched plates were also included.

Table 4-3 Records Used to Estimate Emission Rates

Data Analyis Records Summary	Number	
1. Measurements with Plates Matched	59,876	
2. Subset of 1 - operating in acceptable Power Range	36,148	60%
3. Subset of 2 - after screening for quality and ambient temperature	35,223	97%

4.2.1. Emission Rates Summary

Average on road emissions were 49ppm hexane, 0.18% CO, 244ppm NO and 0.03 RSD smoke factor. The vast majority of vehicles were relatively clean while 5% of vehicles exceeded high emitter cutpoints. Results are summarized in Tables 4-4 and emissions distributions are shown in Figures 4-2 through 4-5.

The 5% vehicles identified as high emitters contributed 31%, 60%, 26% and 7% of HC, CO, NO and particulate matter respectively. Estimates of emissions contributions are based on exhaust pollutant concentration data only. The mass of pollutant emissions is dependent on vehicle fuel economy and miles driven in addition to the pollutant concentration. This is discussed further in section 8.

Table 4-4 2006 On-road Emissions Summary

Pollutant	Median Emissions	Average Emissions	High Emitter Cutpoint	% High Emitters	High Emitter % of Emissions	Normal Emitter Cutpoint	% Normal Emitters
HC ppm hex	15	49	500	1.3%	31%	150	92.9%
CO %	0.02	0.18	3.00	1.2%	60%	1.00	96.1%
NO ppm	22	244	2000	2.4%	26%	750	88.0%
Smoke	0.009	0.028	0.750	0.2%	7%	0.250	98.0%

4.2.2. Carbon Monoxide Emissions in 1998 and 2006

In the 1998 Rover survey, 7% gross CO emitters were estimated to contribute 54% of the total CO emissions. Table 4-4 and Figures in section 4.2.5 show that new model vehicles have become much cleaner. Table 4-4 compares carbon monoxide emissions in 1998 and 2006 and shows that emissions concentrations have been substantially reduced over the eight years.

Table 4-5 1998 and 2006 CO Emissions Comparison

	1998	*2006*
Average CO concentration	0.69%	0.18%
Median CO Concentration	0.11%	0.02%
Vehicle with less than 1% CO	81%	96%
Vehicles with greater than 3% CO	7%	1.2%

In reality the overall improvement is not as great as suggested by Table 4-5. RSD measures running exhaust emissions from warmed-up vehicles. There are in addition, cold start emissions and evaporative emissions from gas cap leaks, fuel seepage, etc., which are not measured directly by RSD. Although cold start and evaporative emissions are also lower in newer models the reductions are probably not as great as the reduction in running emissions.

4.2.3. 2006 Emissions Distributions

The following series of charts shows the distribution of emissions in 2006. The colored lines plot the emissions of vehicles when ordered from dirtiest to cleanest. The emissions values are on the left y-axes.

The black lines plot the cumulative percentage of emissions (right y-axes) vs. the percentage of vehicles when ordered from dirtiest to cleanest. This makes it easy to determine the emissions contributed by the dirtiest 10 or 20% of vehicles. For example, in Figure 4.3, 20% of vehicles contribute 80% of the exhaust HC.

Over 30% of vehicles have no measurable exhaust emissions. Therefore, 100% of exhaust emissions are emitted by fewer than 100% of vehicles.

Figure 4-2 CO Emissions Distribution

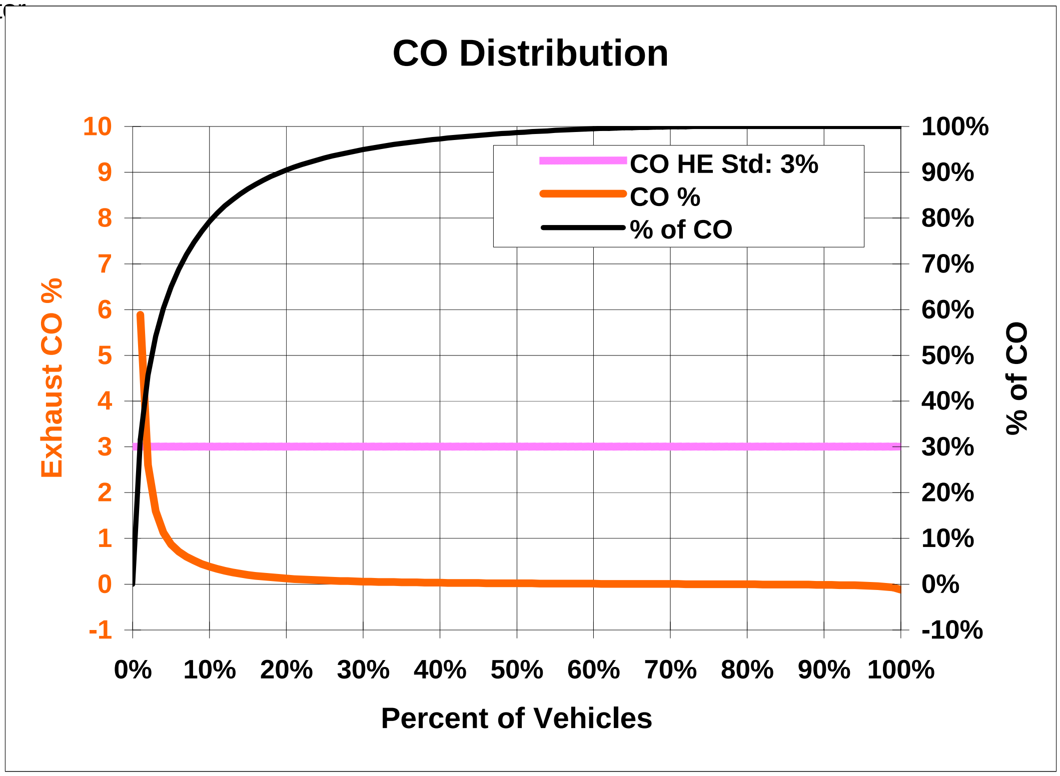


Figure 4-3 HC Emissions Distribution

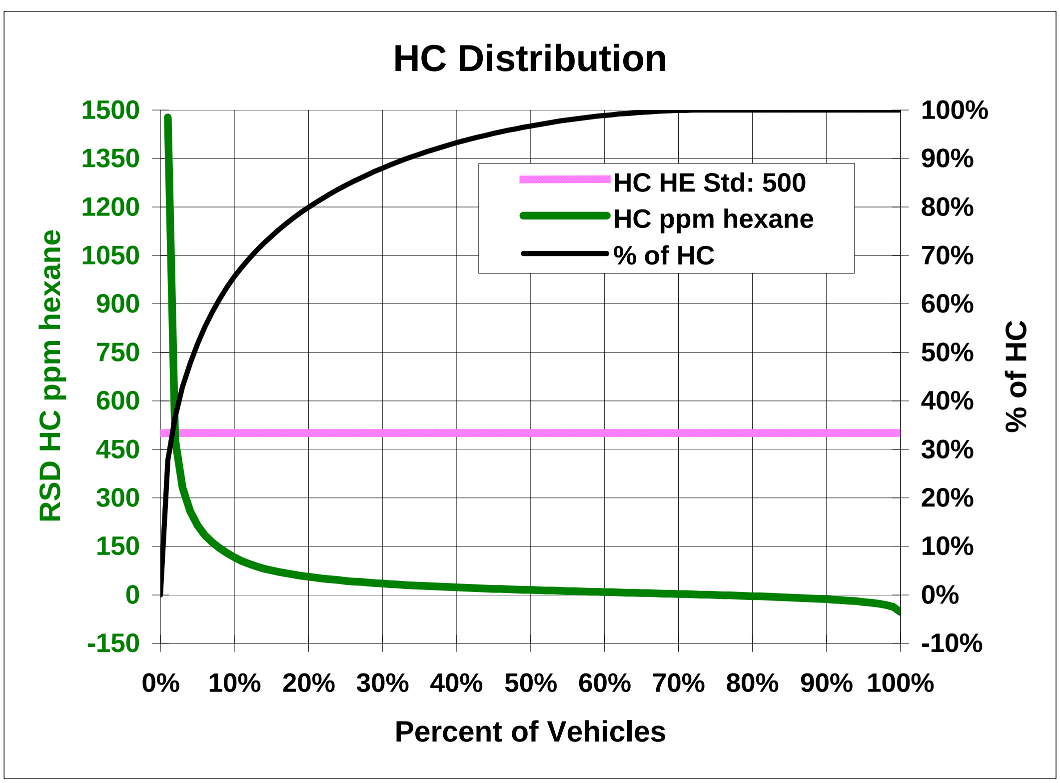


Figure 4-4 NO Emissions Distribution

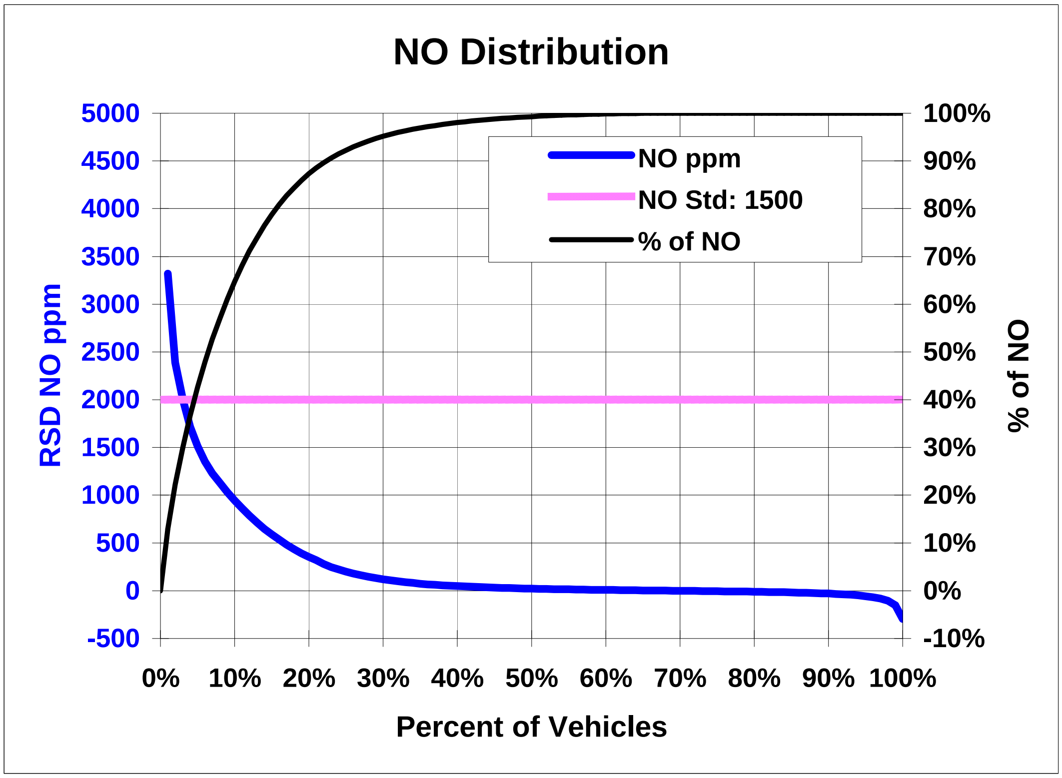
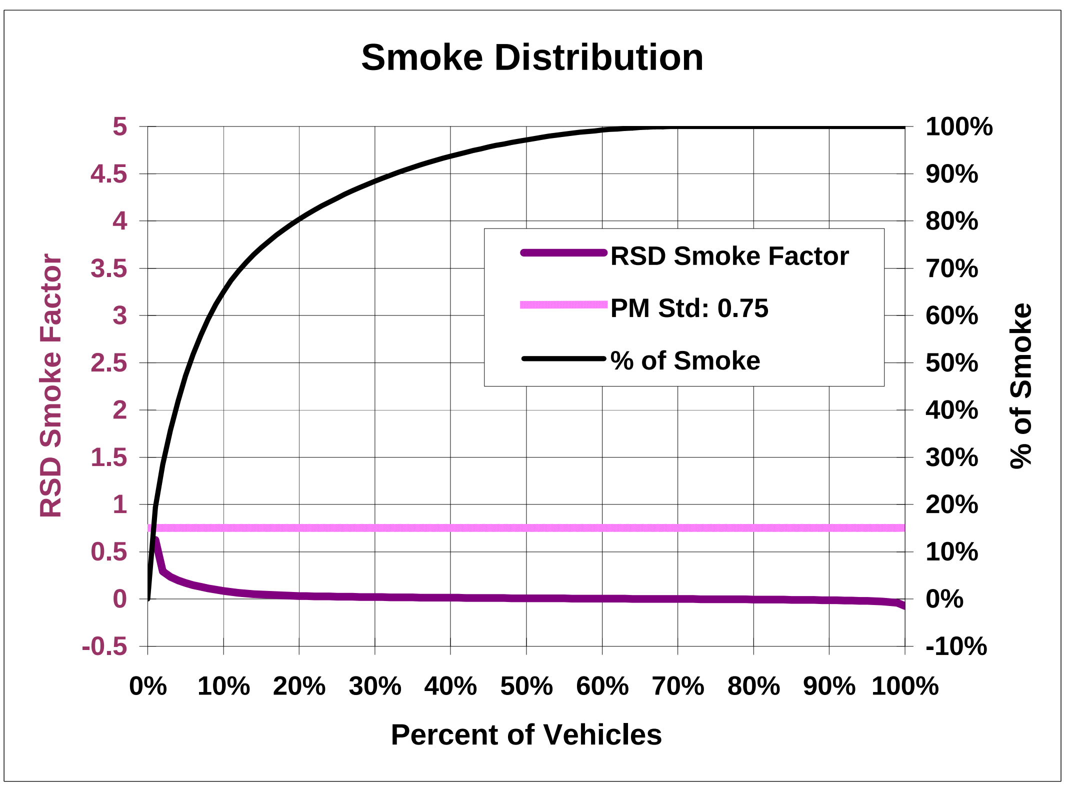


Figure 4-5 UV-Smoke Emissions Distribution



4.2.4. Conversion to Gram per Liter

ESP calculated average emission rates by City (Figures 4-6 to 4-10). Exhaust emissions concentrations are often reported in HC ppm hexane, NO ppm and CO %. Test results are typically reported in these units in vehicle inspection programs that use Idle and ASM test procedures. Therefore, the units are useful for considering whether a vehicle is a high emitter.

Emissions concentrations can be converted from ppm and % to grams per liter of fuel consumed. Mass emissions of pollutants in kilograms per year or tons per day can then be approximated from fuel usage or fuel economy and miles driven. This is discussed further in section 8.

The following equations provided by Bishop[8] were used to first convert from concentration percentages to grams per kilogram:

$$\text{gm CO/kg} = (28 \times \%CO/\%CO_2 / (\%CO/\%CO_2 + 1 + 3 \times \%HC / \%CO_2)) / 0.014$$

$$\text{gm HC/kg} = (48 \times \%HC/\%CO_2 / (\%CO/\%CO_2 + 1 + 3 \times \%HC / \%CO_2)) / 0.014$$

$$\text{gm NO/kg} = (30 \times \%NO/\%CO_2 / (\%CO/\%CO_2 + 1 + 3 \times \%HC / \%CO_2)) / 0.014$$

Where the 28, 48 and 30 are grams/mole for CO, HC (as propane) and NO respectively and 0.014 is the kg of fuel per mole of carbon assuming gasoline is stoichiometrically CH2. HC values in ppm hexane were multiplied by two to convert to the propane equivalent.

In a comparison of Non-dispersive Infra-red (NDIR) analyzers vs. Flame ionization detectors (FIDs), Singer and Harley[9] noted that NDIR analyzers are not sensitive to all species of exhaust hydrocarbons. Their results indicate that hydrocarbon concentrations measured by remote sensors with 3.4 micron filters should be multiplied by a factor of 2.0 for light duty vehicles using US reformulated gasoline blends and by 2.2 when conventional gasoline is used. An additional factor of 2.2 was used to estimate g/kg HC.

In many countries, including Canada, government NOx emission standards are written as mass of NO_2, even though NO is the molecule emitted. NO is oxidized to NO_2 in the atmosphere. NO results were multiplied by 46/30 to convert to NO_2 mass units.

Fuel densities for gasoline and diesel of 0.73 kg/l and 0.81 kg/l respectively were used to convert to grams per liter.

The RSD smoke channel is calibrated such that a value of 1 corresponds approximately (depending on an average size distribution and assuming black smoke) to a diesel particle mass of 1% of fuel by weight. A vehicle with a reading of 1 is a “Black Smoker”.

Approximate conversions from concentrations to grams per liter for gasoline vehicles are then:

- 1% CO ~ 91.25 g/l
- 100 ppm HC hexane ~ 7.34 g/l
- 100 ppm NO ~ 1.60 g/l NOx

- 1 RSD smoke factor ~ 3.7 g/l smoke

The conversion for gasoline smoke is very approximate. There are several different types of gasoline smoke including black smoke (carbon), blue smoke (oil) and white smoke (coolant). Since the mass of particulate matter will vary dependent on the type of smoke, a crude assumption is used of 50% of black smoke.

For diesel vehicles:

- 1% CO ~ 101.25 g/l
- 100 ppm HC hexane ~ 8.14 g/l
- 100 ppm NO ~ 1.77 g/l NOx
- 1 RSD smoke factor ~ 8.1 g/l black smoke

4.2.5. Municipality Comparison

Average emissions for each city and for the region are shown in Figures 4-6 to 4-10. Although there are variations between sites, average emissions in each city are similar. Red Deer may have lower NOX and higher HC, CO and smoke. Figure 4-10 shows the mean VSP by city. Although there is some variation, no obvious relationship between site VSP and emissions was observed.

Figure 4-6: Mean CO by City

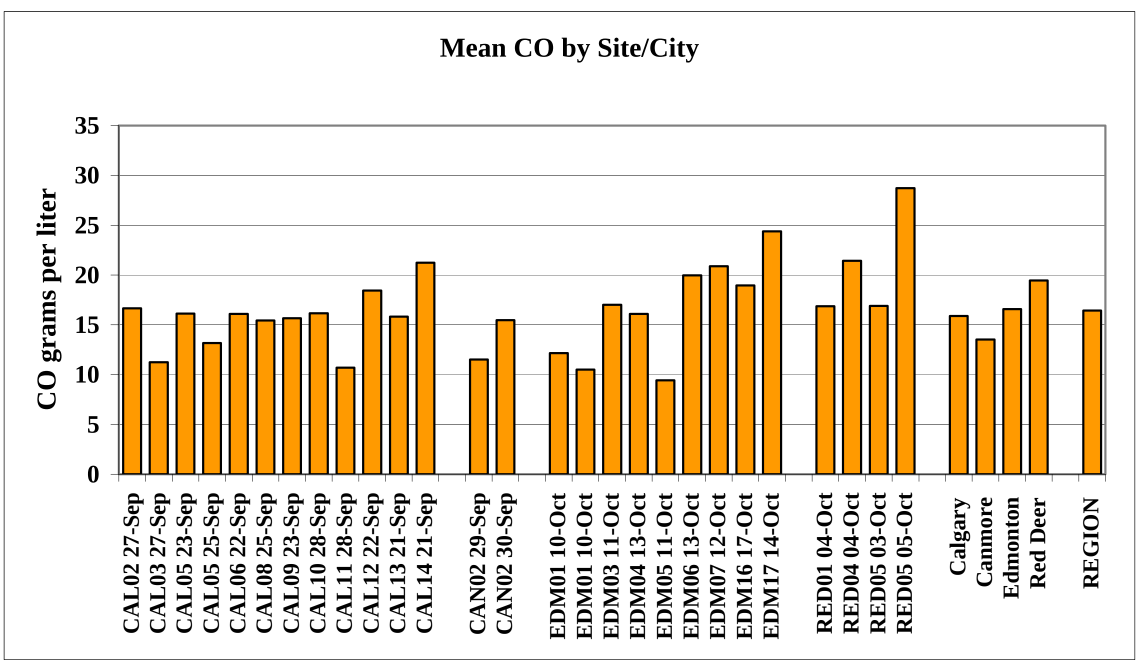


Figure 4-7: Mean HC by City

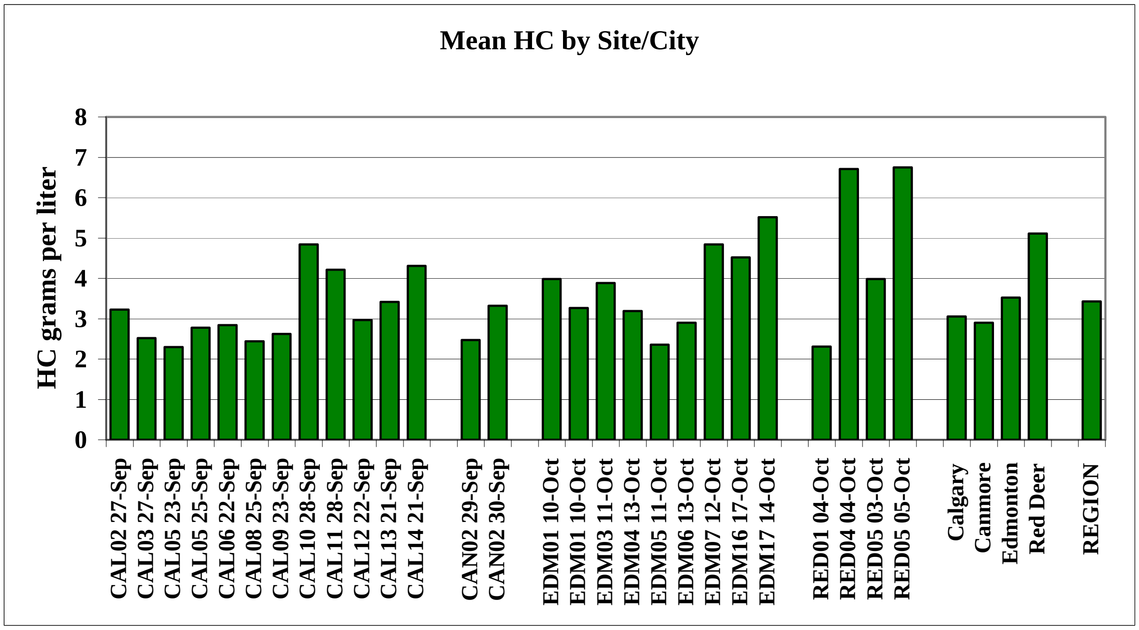


Figure 4-8: Mean NOx by City

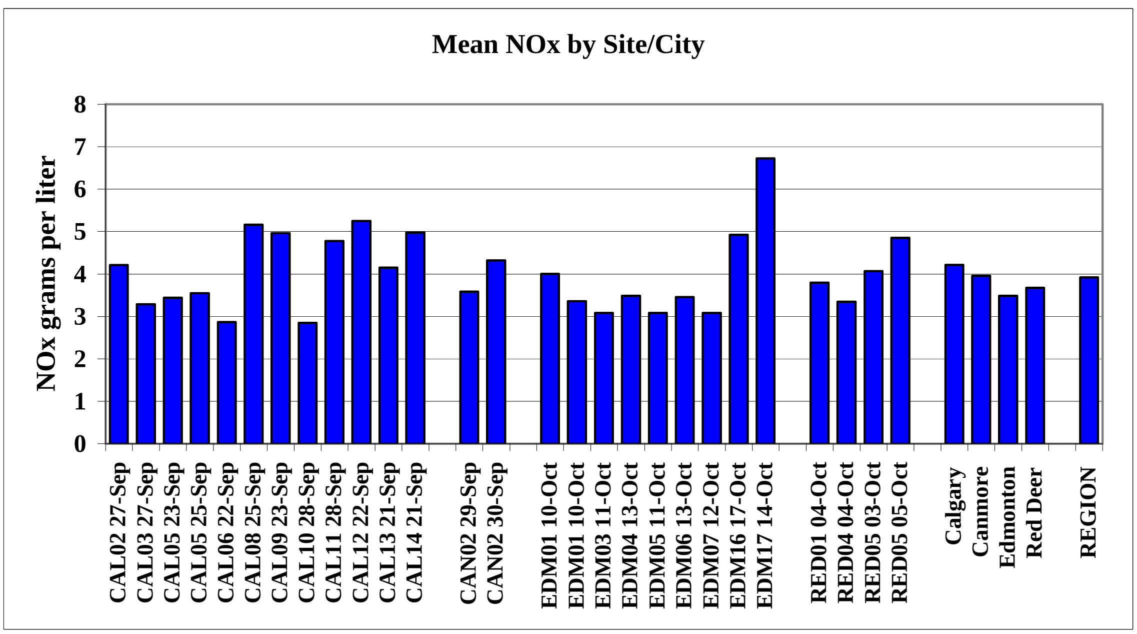


Figure 4-9: Smoke by City

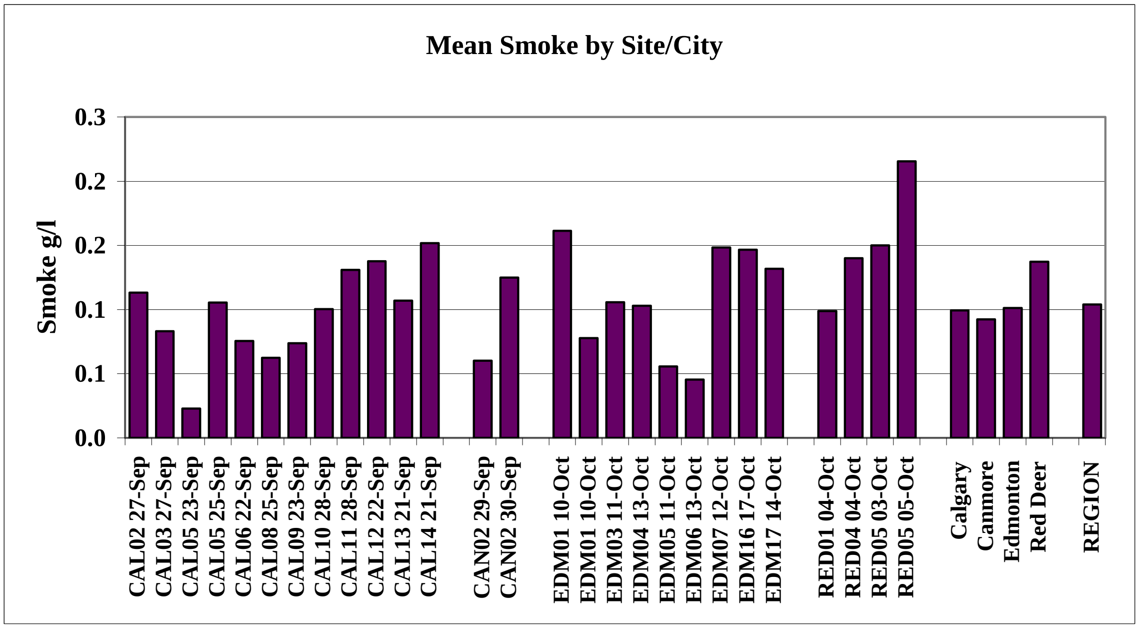
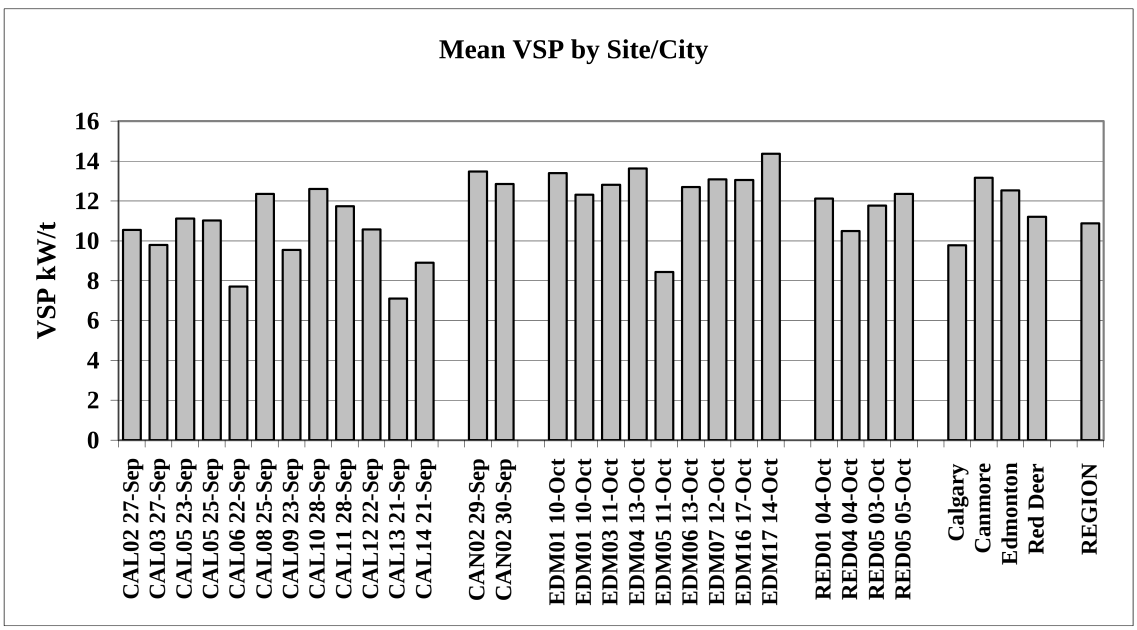


Figure 4-10: VSP by City



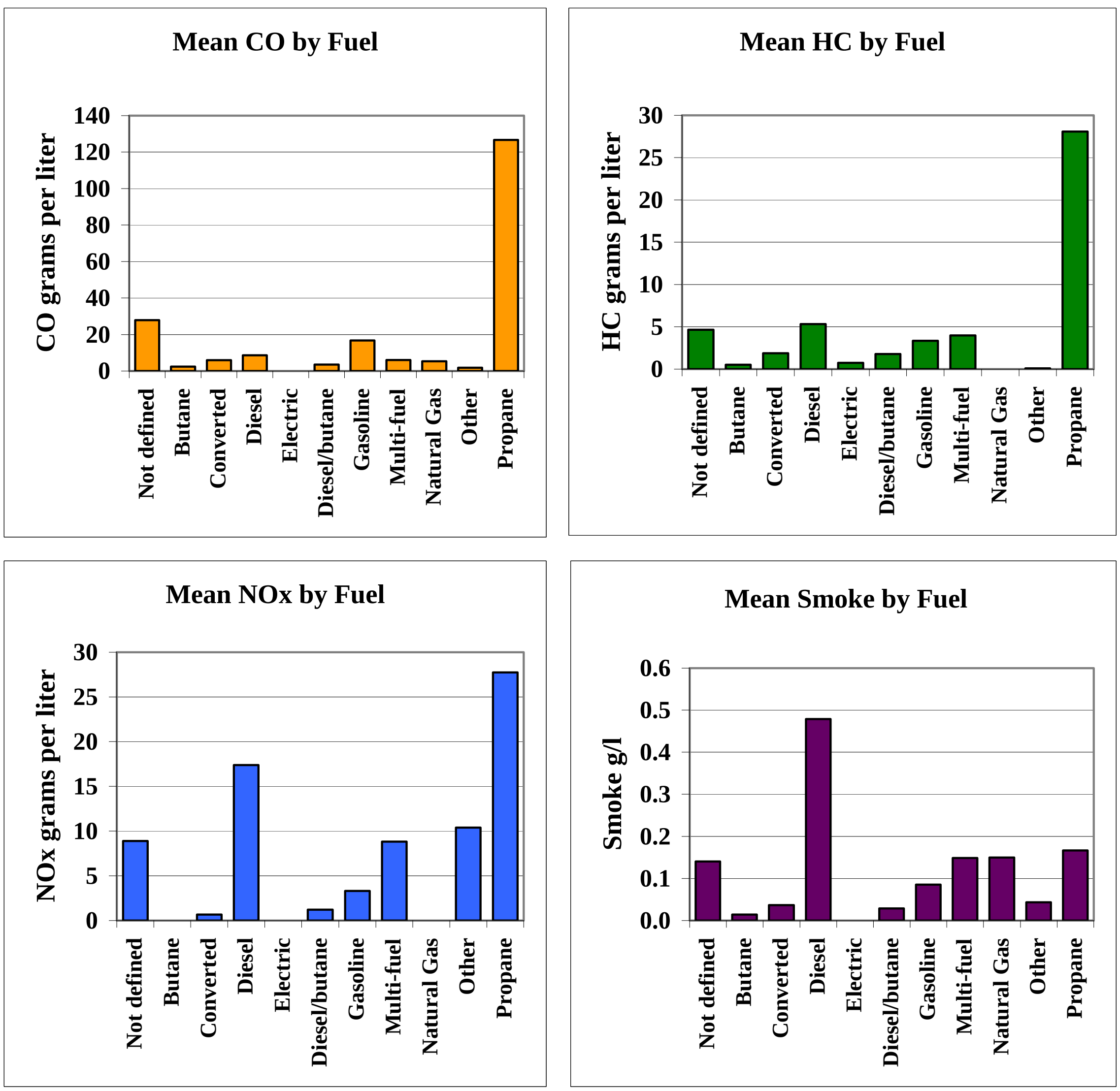
4.2.6. Emissions by Fuel Type

Results by fuel are shown in Figure 4-11. Propane vehicles stand out as having high emissions of HC, CO and NOx. Diesel vehicles have high NOx and high smoke emissions.

Table 4-5: Measurements by Fuel

Fuel	N
Not defined	21
Butane	31
Converted	79
Diesel	1,465
Electric	1
Diesel/butane	143
Gasoline	33,422
Multi-fuel	14
Natural Gas	1
Other	1
Propane	45
Total	35,223

Figure 4-11: Emission by Fuel



4.2.7. Emissions Rates by Model Year Group

Emission rates were compared by model year group for gasoline vehicles and diesel vehicles. The few alternative fuel vehicles were included in the gasoline group.

Table 4-6: Measurements by Model Year

Model Years	Diesel	Gasoline & Other
1980-	7	204
1981-1990	47	1,943
1991-1995	91	4,285
1996-2000	181	8,444
2001-2005	759	14,577
2006+	380	4,305
Total	1,465	33,758

Figures 4-12 to 4-15 show the results of this analysis. It is no surprise that the dirtiest vehicles were the oldest models. 1996 and newer gasoline vehicles were the cleanest and these make up a large majority of the fleet. Even the newest Diesel vehicles had dramatically higher NOx and smoke emissions. New Diesel vehicles also had higher HC than new gasoline vehicles.

The apparent high CO in 1980 and older diesels is due to a small sample of six vehicles including a 1978 model that has emissions characteristics more consistent with a dirty gasoline vehicle than a diesel. It was a high emitter for HC (537 ppm) and CO (6.7%) with low NO. This vehicle also skewed the 1980 and older diesel results for HC and NO. It is interesting that newer diesel vehicles not only have high NO, which is expected, but also have high HC emissions than modern gasoline vehicles. The diesel sample contains a greater proportion of medium- and heavy-duty vehicles that have less emissions control.

Figure 4-12: Mean CO by Model Year

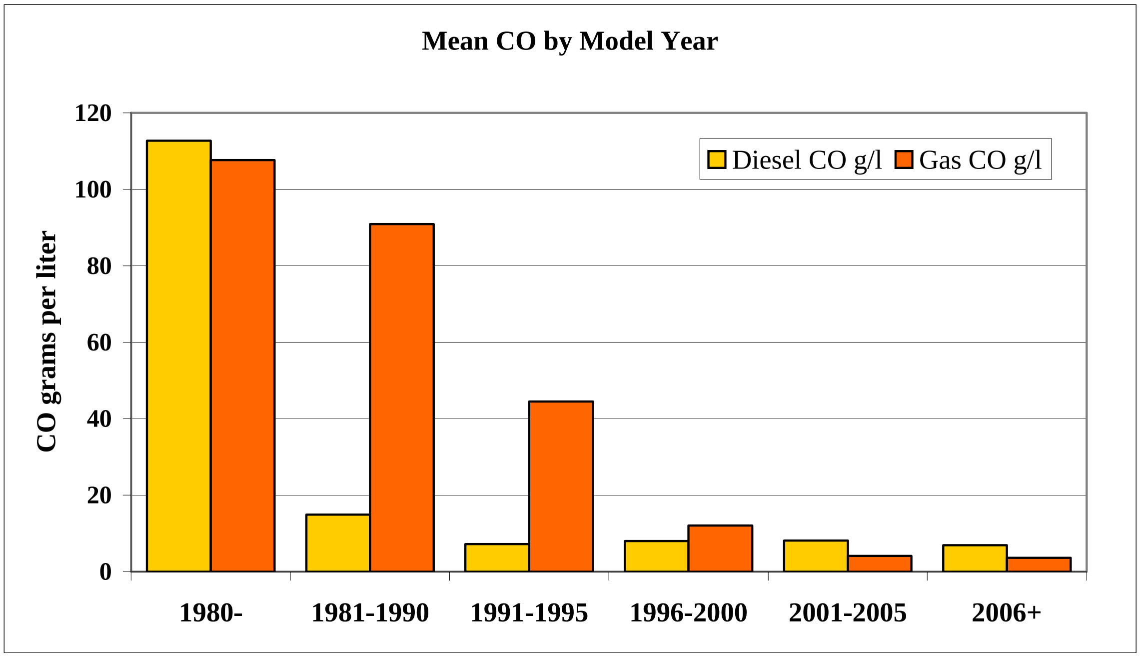


Figure 4-13: Mean HC by Model Year

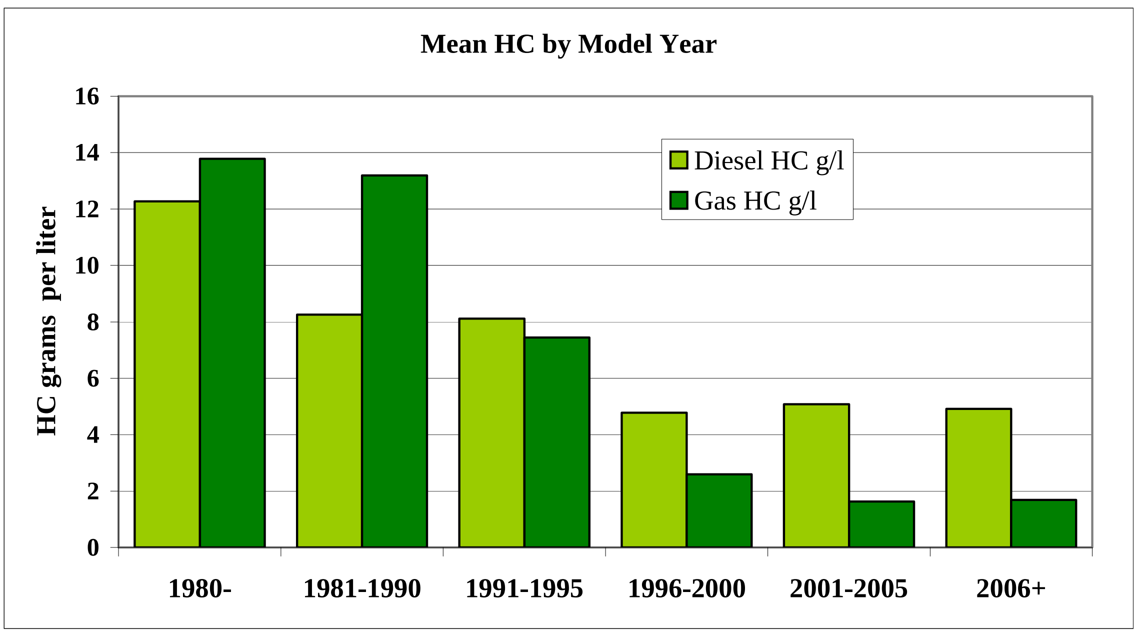


Figure 4-14: Mean NOx by Model Year

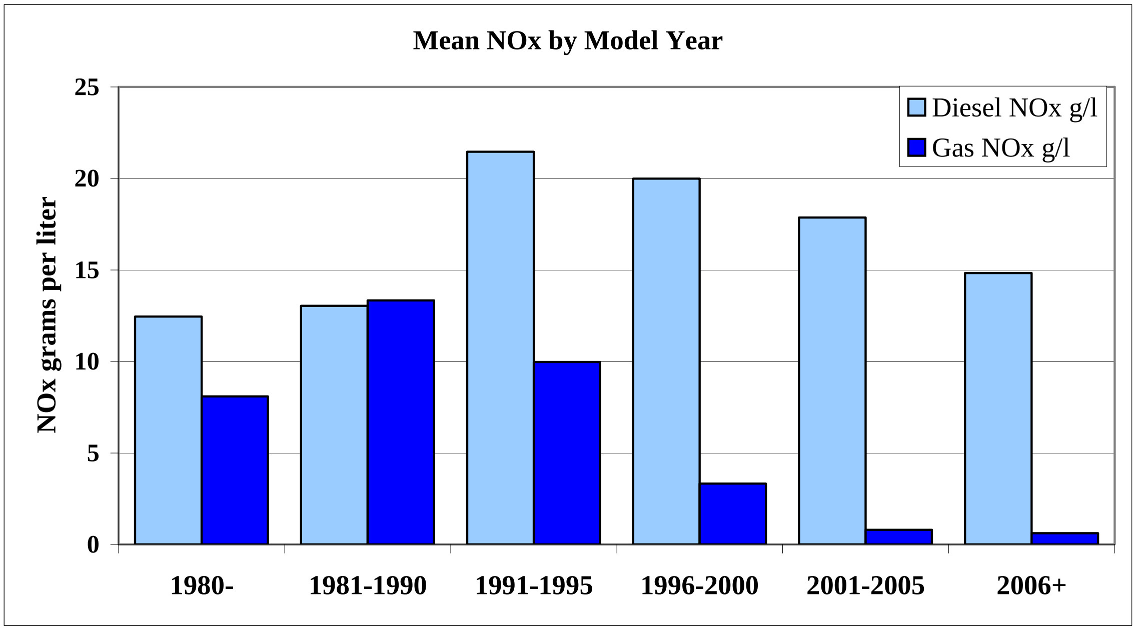
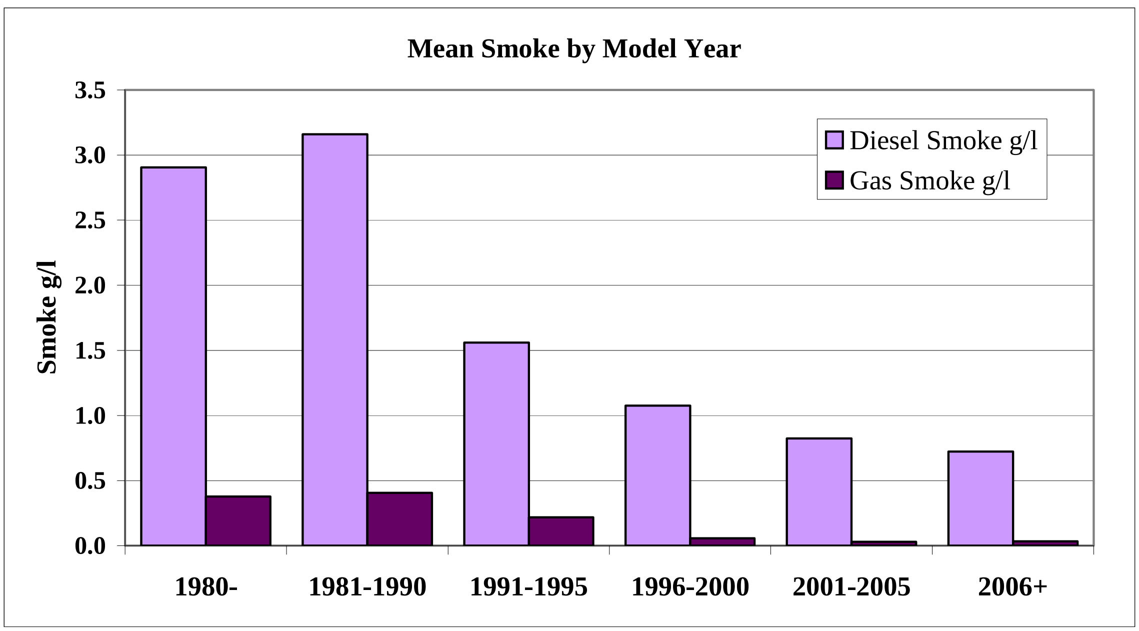


Figure 4-15: Mean Smoke by Model Year



4.2.8. Emissions Contributions by Model Year

Figures 4-16 shows the distribution of vehicles by fuel and model year group and Figure 4-17 shows the corresponding emissions contributions.

As noted earlier, the contribution charts make the assumption that fuel economy is the same across model years and fuel type. The average fuel economy of each new model year of vehicles has remained approximately the same over the past twenty years. Therefore, to a first approximation, the assumption is reasonable.

Note, however, that the RSD configuration used in the survey was not designed to measure heavy vehicles and the contributions shown are for light vehicles only.

1995 and older models are 19% of the on-road fleet but contribute more than half of running emissions; 51% of HC, 68% of CO, 53% of NO and 49% of smoke.

The 1996-2000 gasoline models have significantly lower per vehicle emissions than 1991-1995 models (Figures 4-12 to 15). Therefore, despite their greater number, total emissions for 1996-2000 gasoline models were lower than for 1991-1995 models. Per vehicle CO and NO emissions were again substantially lower for 2001-2005 models vs. 1996-2000 but less so for HC and smoke. This resulted in a bi-modal distribution for total HC and smoke (Figure 4-17).

Figure 4-16: Composition of Vehicles Measured On-Road

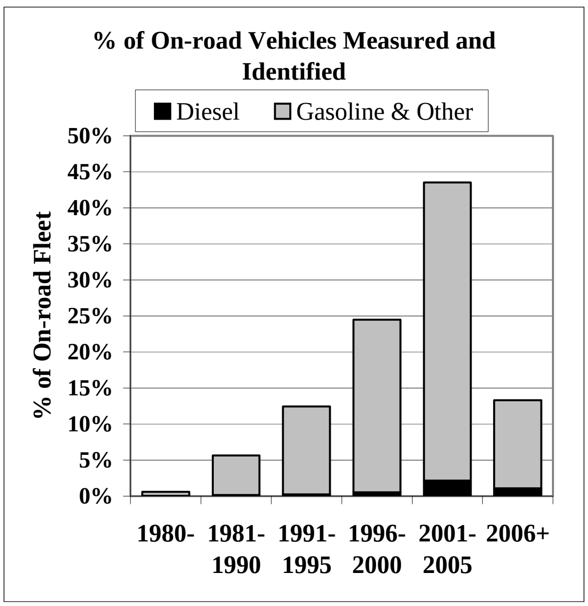
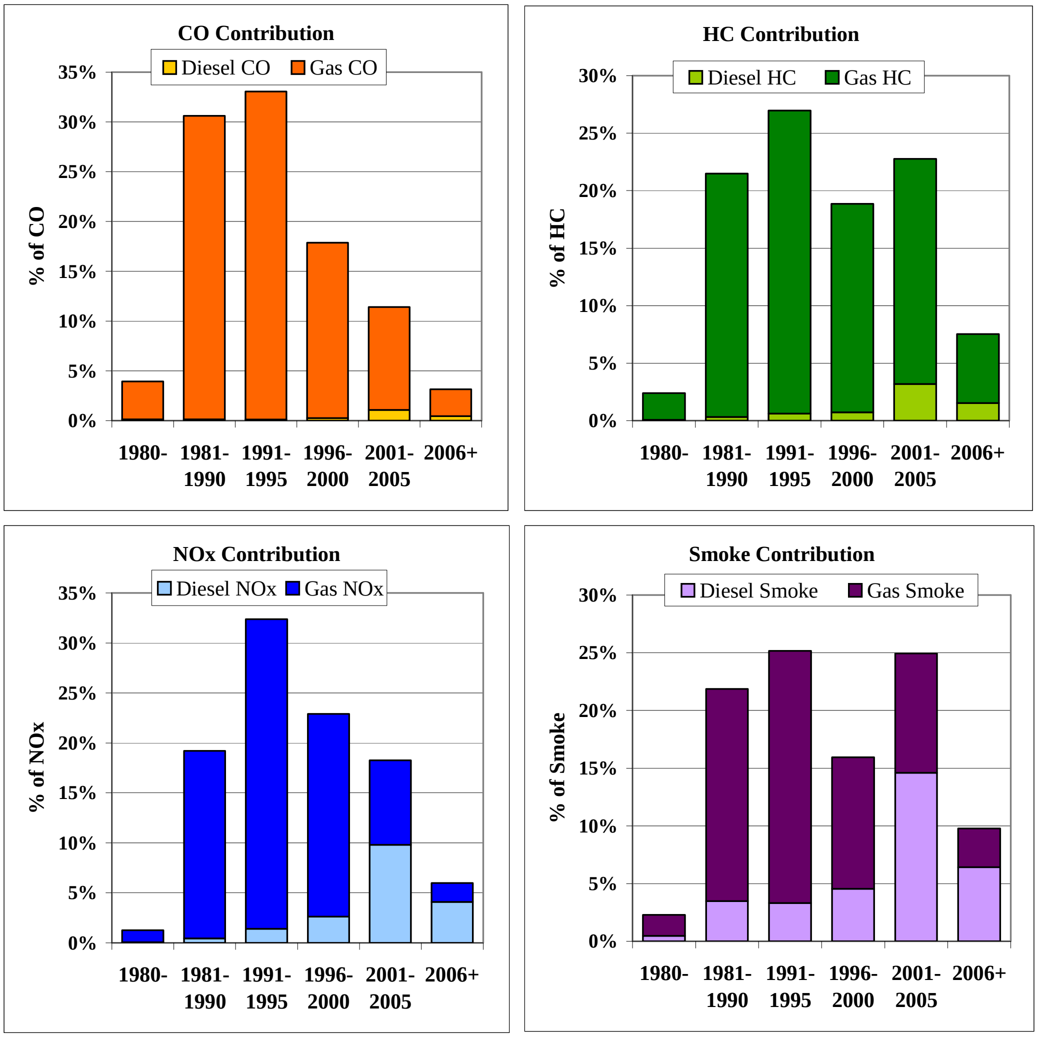


Figure 4-17: Approximate Emissions Contributions



5. Characteristics of High Emitters

As noted earlier, cutpoints of 500ppm HC, 3% CO, 2,000ppm NO and 0.75 RSD smoke factor were selected to identify high emitters. Of the 35,223 vehicles measured on-road that were identified by plate and matched to a registration, 1,631 exceeded one or more of the pollutant cutpoints (Table 5-1).

Table 5-2 shows the combinations of cutpoints that were exceeded. About one quarter of vehicles with high HC had high CO and vice-versa. Few vehicles that failed for NO had high HC or CO. Almost half the smoking vehicles also failed for HC.

Table 5-1: High Emitters

	Count
RSD measurements exceeding one or more cutpoints	1,631
Emissions cutpoints exceeded:	
HC 500 ppm hexane	472
CO 3%	436
NO 2000ppm	857
UV Smoke Factor 0.75	59
Total Cutpoints Exceeded	1,824

Table 5-2 Higher Emitters by Pollutant

HE Cutpoint Exceedance Combination	Count
Single pollutant:	
HC Only	310
CO Only	311
NOx Only	817
Smoke Only	21
Two Pollutants:	
HC & CO Only	105
HC & NO Only	23
CO & NO Only	4
HC & Smoke Only	16
CO & Smoke Only	-
NO & Smoke Only	6
Three Pollutants:	
HC & CO & NOx	2
HC, CO & Smoke	11
HC, NOx & Smoke	2
CO, NOx & Smoke	-
Jackpot:	
HC, CO, NOx & Smoke	3
Total	1,631

The fraction of high emitters was similar across the municipalities with Red Deer having the highest rate (Figure 5-1).

The greatest numbers of high emitters, 64%, were 1988-1995 models (Figure 5-2). 1996 and newer models accounted for 81% of the vehicles measured and 29% of the high emitters.

High emitter rates vary dramatically by model year, with the oldest models having rates of 30-40% and the newest models have rates of 0.2% (Figure 5-3). Fortunately, relatively few of the oldest models remain in operation. On a positive note, high emitter rates among 1996 and newer models remain low – an average of 1.6%. This coincides with the introduction of OBD-II emission control systems. Manufacturers improved component quality considerably to meet OBD-II requirements. This improvement, combined with the engine warning light that alerts owners to emissions problems, is responsible for the lower rate of high emitters even in vehicles ten years old at the time of the survey. The high emitter rate among 1995 models was 10% vs. 4% for 1996 models.

The few Propane fueled vehicles measured had a very high rate of high emitters - more than 60% (Figure 5-4). The propane vehicles were all larger model North American makes and evenly split between 1980s and 1990s models. Most were vans or trucks. The high emitter rates were independent of age. Out of the twenty 1990-1997 propane fueled vehicles surveyed, 65% were high emitters. Some very high NO values were observed. A few propane vehicles had very high HC and very high NO.

NREL states that in early experience[10:] “CNG conversions generally showed a significant reduction in NMHC emissions, but an increase in either CO, NOx, or both. The three LPG conversions tested showed increased emissions on gasoline after conversion, in addition to showing mixed results on LPG.”

CNG is predominantly methane (CH_4). Propane (C_3H_8) contains three times as many carbon atoms per molecule. The appropriate propane/air mixture would therefore require a smaller percentage of propane than the appropriate CNG/air mixture. Further investigation might reveal whether the propane vehicle conversions are adequately controlling fuel-air mixture.

Heavier vehicles were more likely to be high emitter than light cars and light pick-ups. Medium-duty vehicle have substantially greater rates of high NO emitters and high smoke emitters. The heaviest classes of vehicles had higher rates of high NO emitters but few, if any, HC high emitters (Figure 5-5).

Passenger vehicles and light trucks with eight cylinder engines were more likely to be high emitters than 4- or 6-cylinder vehicles (Figure 5-6). Six-cylinder engine vehicles had the lowest rates.

Asian vehicles had the lowest rate of high emitters (Figure 5-7). High emitter rates for 1980 and older models were 28%, 22% and 29% for Asian, European and North American models respectively. For 1990s models the rates were 6%, 8% and 9%. For 2000 and newer models the rates were 0.8%, 0.7% and 1.3%.

Figure 5-1: High Emitters by City

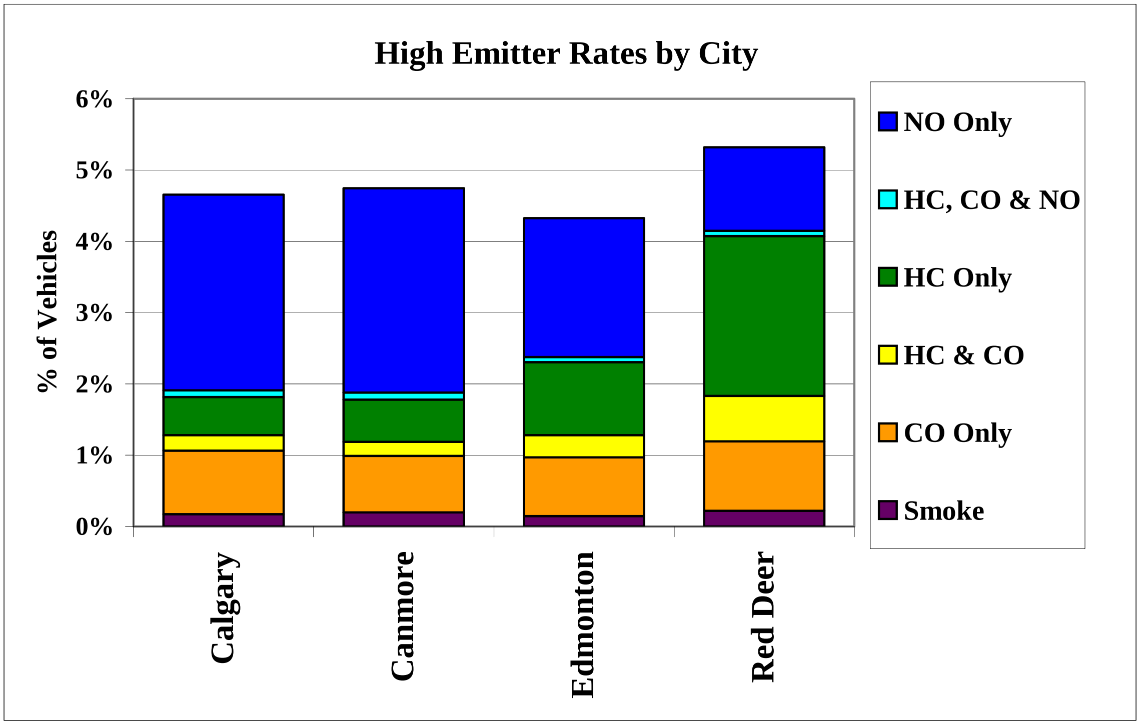


Figure 5-2: Number of High Emitters by Model Year

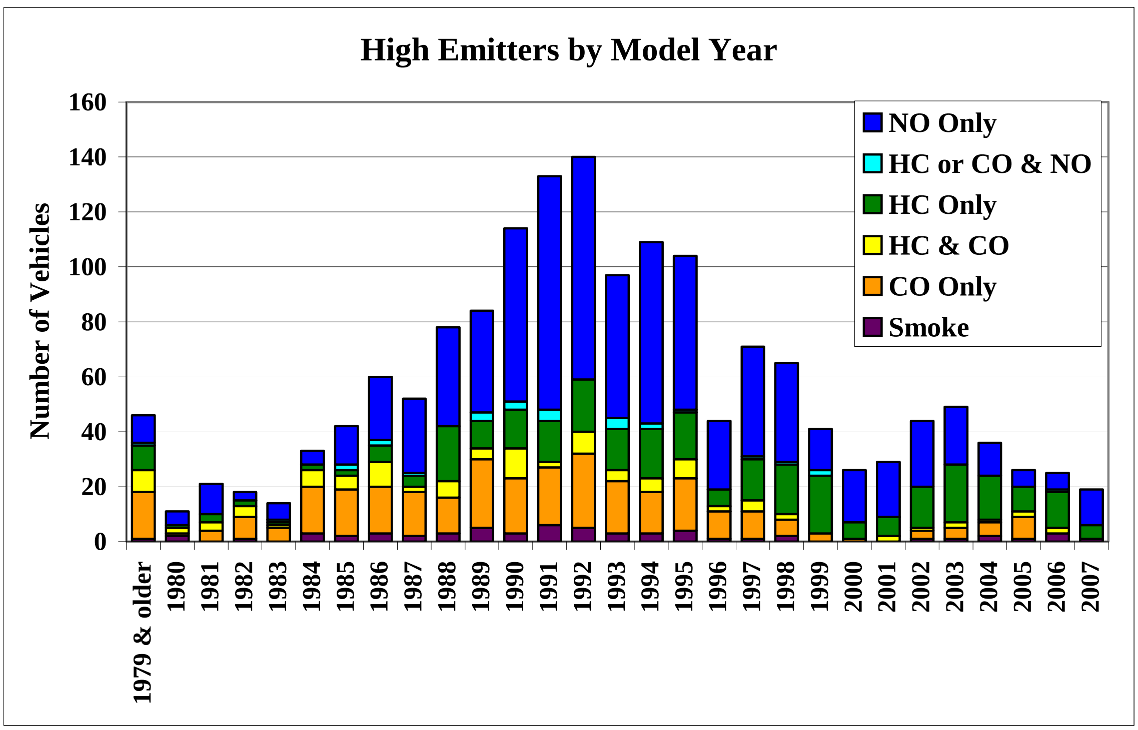


Figure 5-3: Percent of High Emitters by Model Year

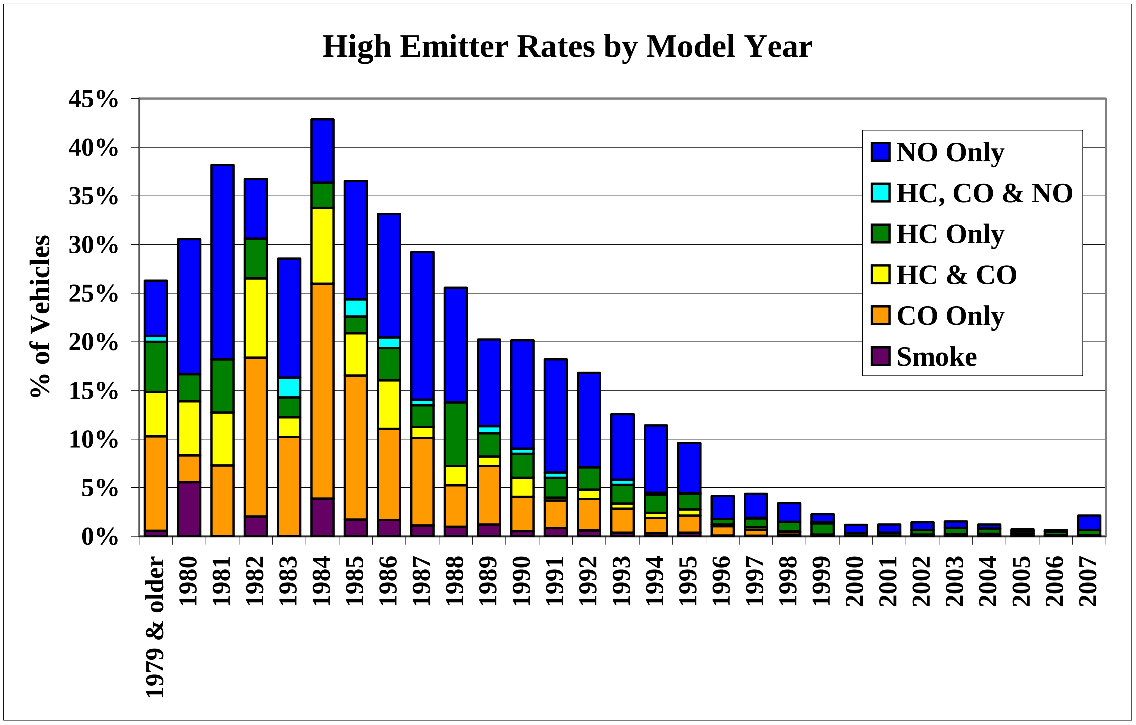


Figure 5-4: High Emitters by Fuel

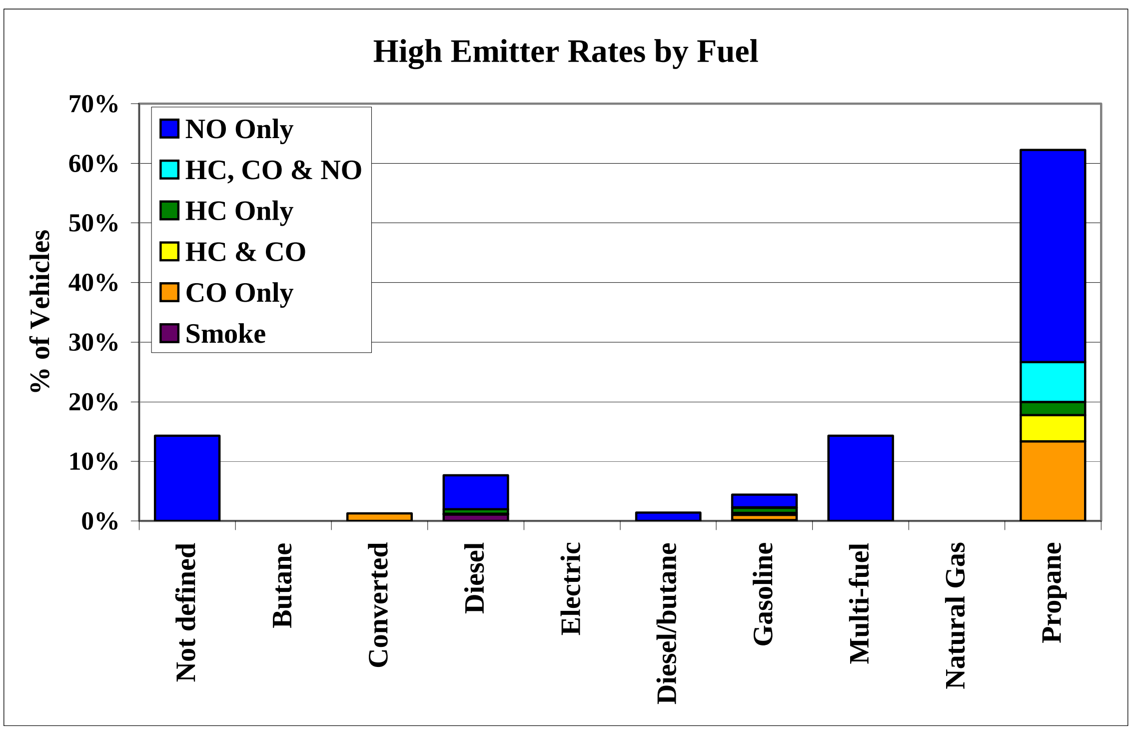
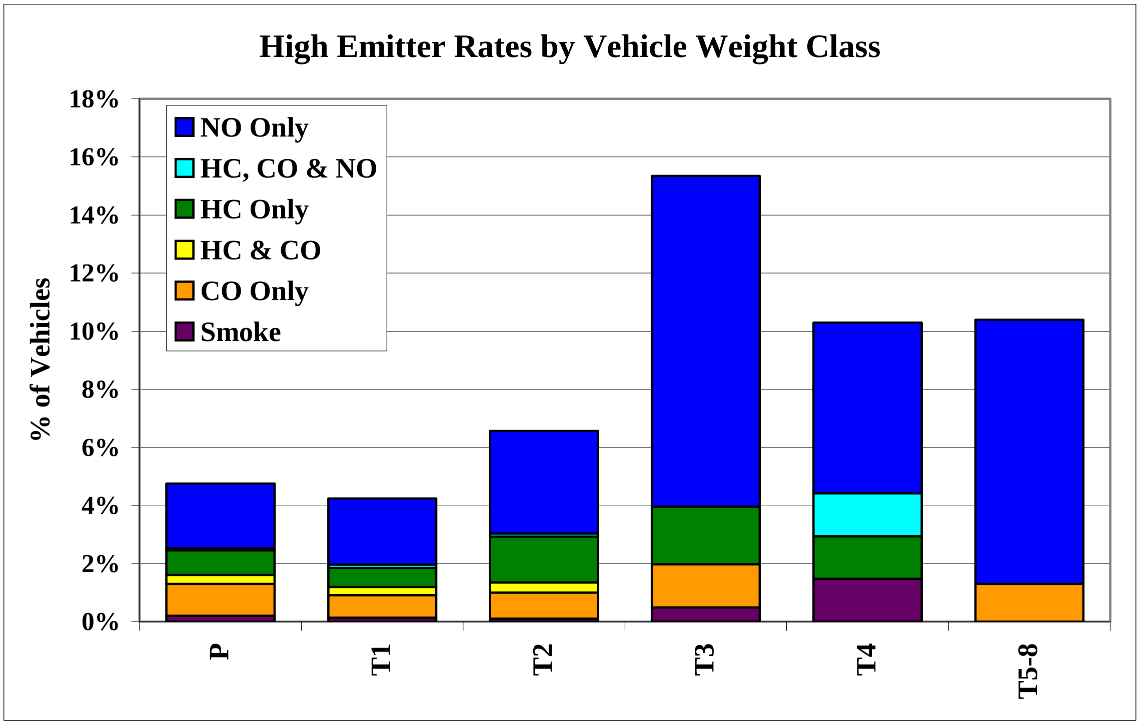


Figure 5-5: High Emitters by Weight Class (1981-2005 models)



* P - passenger vehicle, T - truck. Max. laden weight classes; 1: <6,000lbs, 2: 6-10,000lbs, 3:10-14,000lbs, 4: 14-16,000lbs, 5-8: 16,000lbs and higher.

Figure 5-6: High Emitters by Cylinders and Age (1995 & older, 1996 & newer)

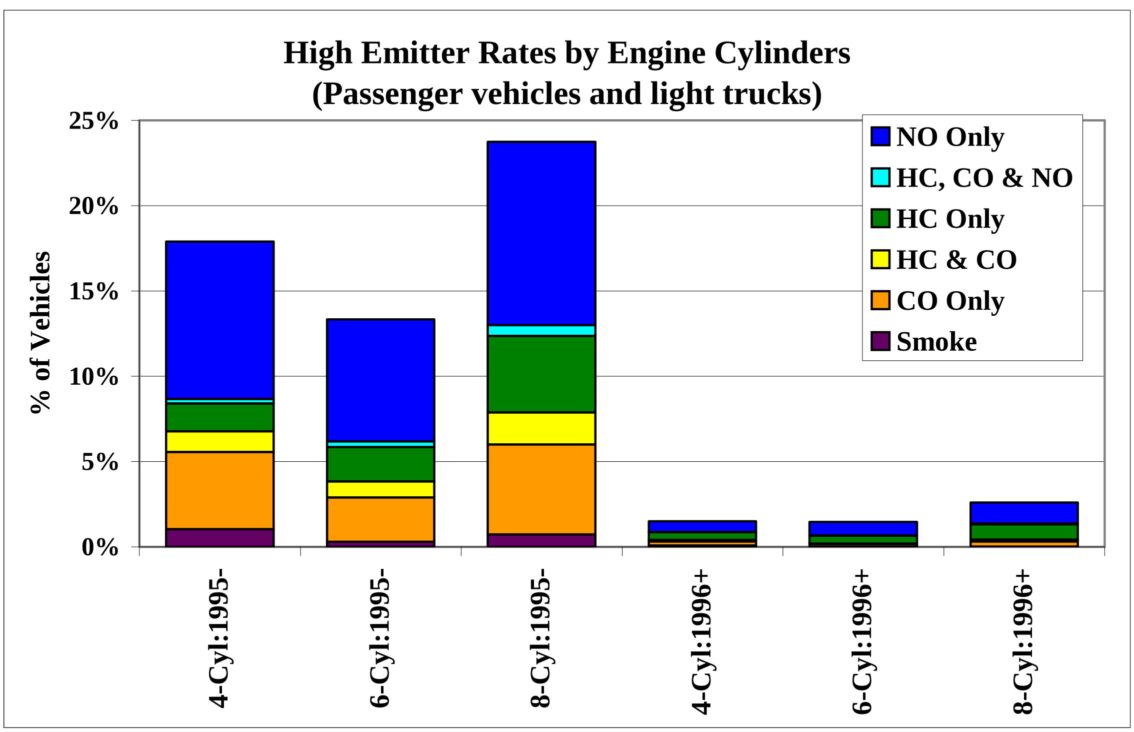
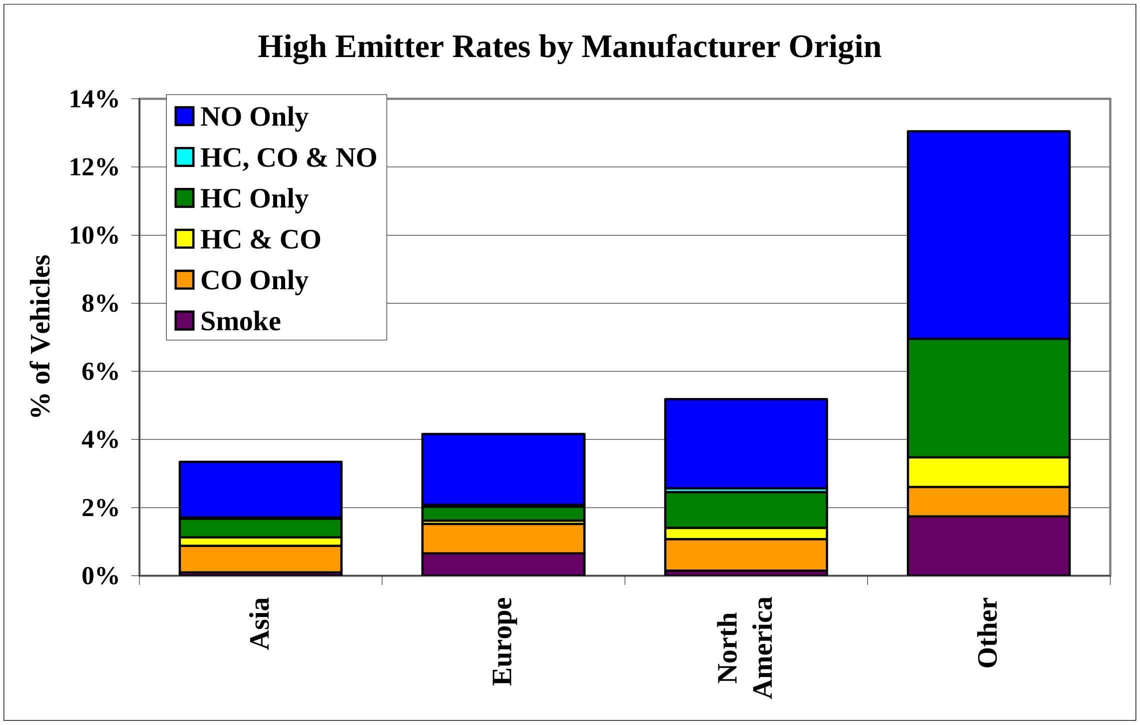


Figure 5-7: High Emitters by Manufacturer Origin



6. Vehicle Occupancy

Table 6-1 gives average LDV occupancy results obtained for each municipality. The vehicle occupancy rates observed in each municipality are generally similar to those found in the ROVER I surveys

The City of Edmonton continues to have lower vehicle occupancies compared to the other municipalities. As noted in the Rover I report, this may partly result from the more diverse location of employment opportunities in Edmonton, with less opportunity for work-related trip car-pooling.

The low rate of single occupant vehicles in Canmore stands out. Table 6-3 lists the number of vehicles surveyed in each period. In most periods close to 100 or more vehicles were surveyed. The result for Canmore 8:00-9:00 AM should be discounted as it is based on only six vehicles.

Table 6-2 shows little variation in the single occupant vehicle rate through the day. Slightly higher single occupant rates are evident in the morning commute period.

Table 6-1 Vehicle Occupancy by Municipality

City	Vehicles Surveyed	Single Occupant Vehicles Rover II	Single Occupant Vehicles Rover I
Calgary	5,330	75%	73%
Canmore	883	43%	70%
Edmonton	5,152	86%	82%
Red Deer	1,877	71%	76%

Table 6-2 Vehicle Occupancy by Hour

	Single Occupant Vehicles			
Hour	**Calgary**	**Canmore**	**Edmonton**	**Red Deer**
7:00 - 8:00 AM	79%			
8:00 - 9:00	67%	100%	92%	68%
9:00 - 10:00	75%	54%	90%	78%
10:00 - 11:00	75%	35%	86%	68%
11:00 - 12:00	75%	45%	89%	71%
12:00 - 1:00 PM	76%	39%	84%	75%
1:00 - 2:00	78%	39%	83%	70%
2:00 - 3:00	79%	52%	79%	67%
3:00 - 4:00	63%	43%	81%	67%
4:00 - 5:00	76%	36%	86%	70%

Table 6-3 Vehicles Surveyed for Occupancy

	Vehicles Surveyed for Occupancy			
Hour	**Calgary**	**Canmore**	**Edmonton**	**Red Deer**
7:00 - 8:00 AM	191			
8:00 - 9:00	405	6	198	145
9:00 - 10:00	706	76	934	209
10:00 - 11:00	710	97	685	137
11:00 - 12:00	751	154	728	242
12:00 - 1:00 PM	713	134	758	269
1:00 - 2:00	785	133	820	287
2:00 - 3:00	609	126	609	167
3:00 - 4:00	366	93	204	233
4:00 - 5:00	94	64	216	188

7. Comparison with Emissions in Other Regions

Ideally several conditions should be met in order to compare the emissions of vehicles measured in one region with those in another:

- Measurements should be contemporary;
- Made with the same type of equipment
- Under similar operating conditions
- Using similar screening techniques.

ESP operates ongoing remote sensing programs using RSD4000 units in Colorado, Virginia and, more recently, southern California. Therefore, measurements meeting the first three criteria listed are available from these locations.

Virginia is unique in that remote sensing data is collected in areas subject to an inspection and maintenance program and in areas not subject to the I/M program. Virginia, therefore, provides two points of comparison. In addition, the Virginia 2006 remote sensing data was recently processed to prepare a 2006 report using similar screening techniques

ESP compared the Alberta results to those from Virginia. Table 7-1 shows Alberta average emissions over the 3-22kw/t VSP range and the 5-20kw/t VSP range used in a Virginia report. The Alberta results are similar for both VSP ranges so comparisons are possible with the Virginia emissions.

The Virginia I/M area is the in northern Virginia south of Washington DC. The Virginia non-I/M area results include measurements from Fredericksburg, Richmond and Tidewater. Both Virginia I/M and non-I/M areas had lower HC, CO and smoke averages than Alberta. Virginia I/M and non-I/M area NO bracketed Alberta average NO.

Table 7-2 compares the number of high emitters where high emitters are defined as HC greater than 500 ppm hexane, CO greater than 3%, NO greater than 2000 ppm or RSD smoke factor greater than 0.75. These definitions of high emitters are, admittedly, somewhat arbitrary. They do not reflect any particular standards such as might be used in an inspection and maintenance program. Nevertheless, the results illustrate the importance of high emitters in the overall light vehicle emissions inventory.

The fraction of high emitters in Alberta is similar to the Virginia non-I/M area for NO and smoke and a little higher for HC and CO. The Virginia I/M area had a lower rate of high emitters.

Table 7-3 shows the estimated fraction of total on-road emissions contributed by high emitters – 31% of HC, 50-60% of CO and 26% of NOx. The high emitter contributions to total emissions in Alberta are again similar to those in the Virginia non-I/M area.

The lower rates of high emitters in Virginia, especially in the Virginia I/M area, suggest that the number of high emitters in Alberta could be reduced by encouraging or requiring better vehicle maintenance.

Table 7-1 Average Emissions

	Alberta VSP 3-22	Alberta VSP 5-20	Virginia Non-I/M	Virginia I/M
Average HC ppm	49	48	27	20
Average CO %	0.18	0.18	0.15	0.12
Average NO ppm	244	250	262	208
Smoke > 0.75 RSD	0.028	0.027	0.015	0.010

Table 7-2 High Emitters

	Alberta	Virginia Non-I/M	Virginia I/M
HC > 500ppm	1.3%	0.7%	0.4%
CO > 3%	1.2%	0.9%	0.6%
NO > 2000ppm	2.5%	2.6%	1.6%
Smoke > 0.75 RSD	0.1%	0.1%	0.1%
Combined	4.6%	3.9%	2.5%

Table 7-3 High Emitter Contributions to Total On-road Emissions

	Alberta	Virginia Non-I/M	Virginia I/M
High Emitter % of total HC	31%	30%	20%
High Emitter % of total CO	60%	51%	44%
High Emitter % of total NO	26%	25%	19%
High Emitter % of total Smoke	7%	7%	4%

Figures 7-1 – 7-4 illustrate the high emitter rates by model year. The newest models are far more numerous and the newest models have very low rates of high emitters ~ 0.2%.

Figure 7-1 High Emitter Rates by Year

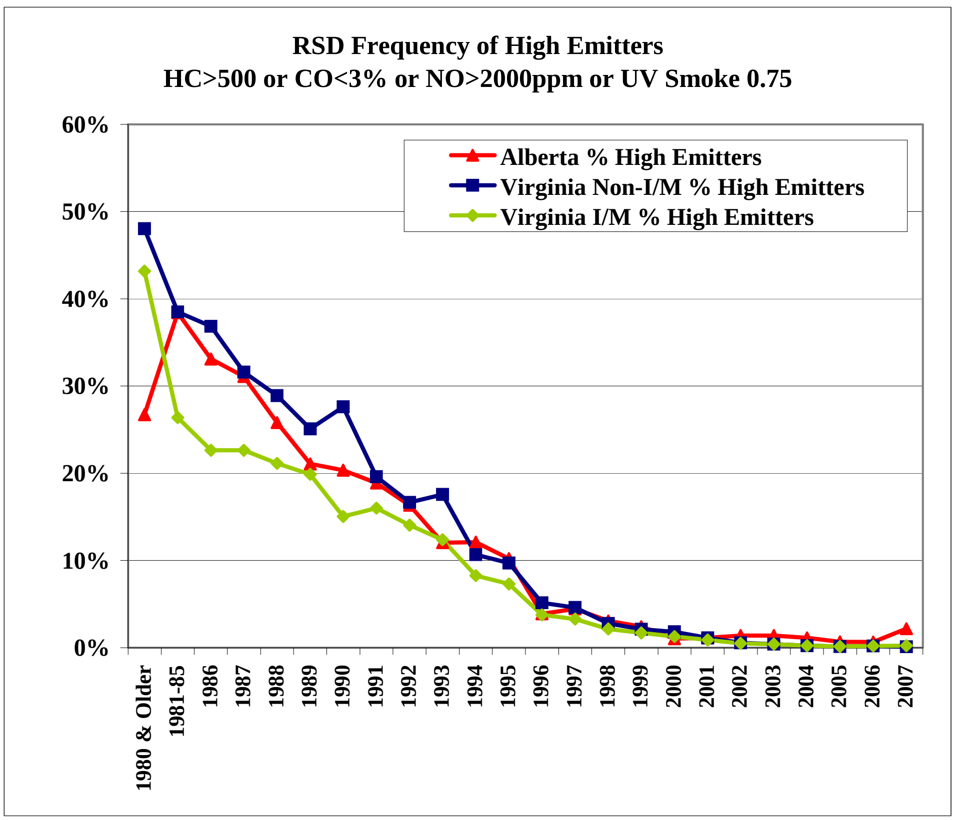


Figure 7-2 HC High Emitter Rates by Year

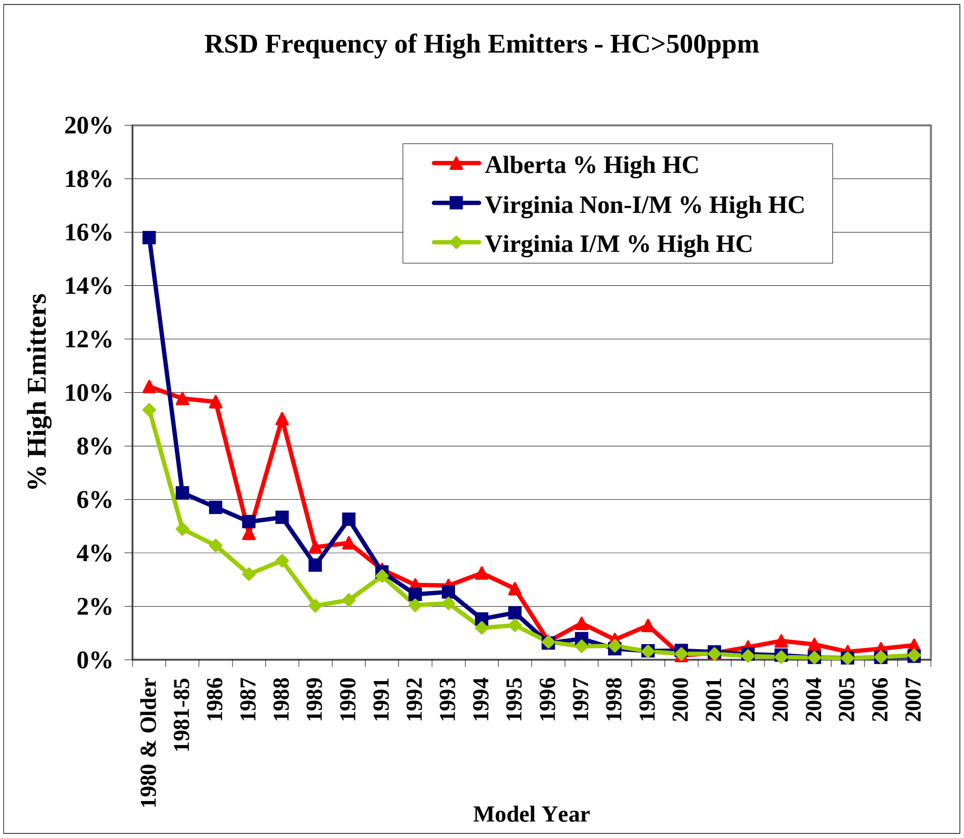


Figure 7-3 CO High Emitter Rates by Year

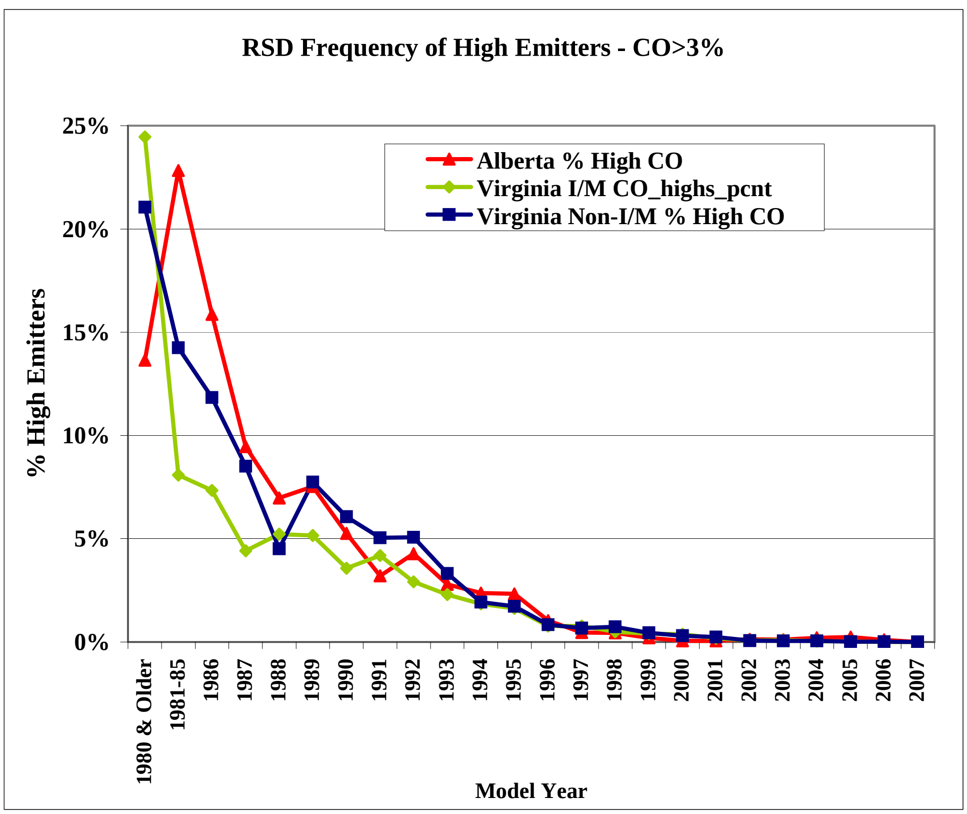
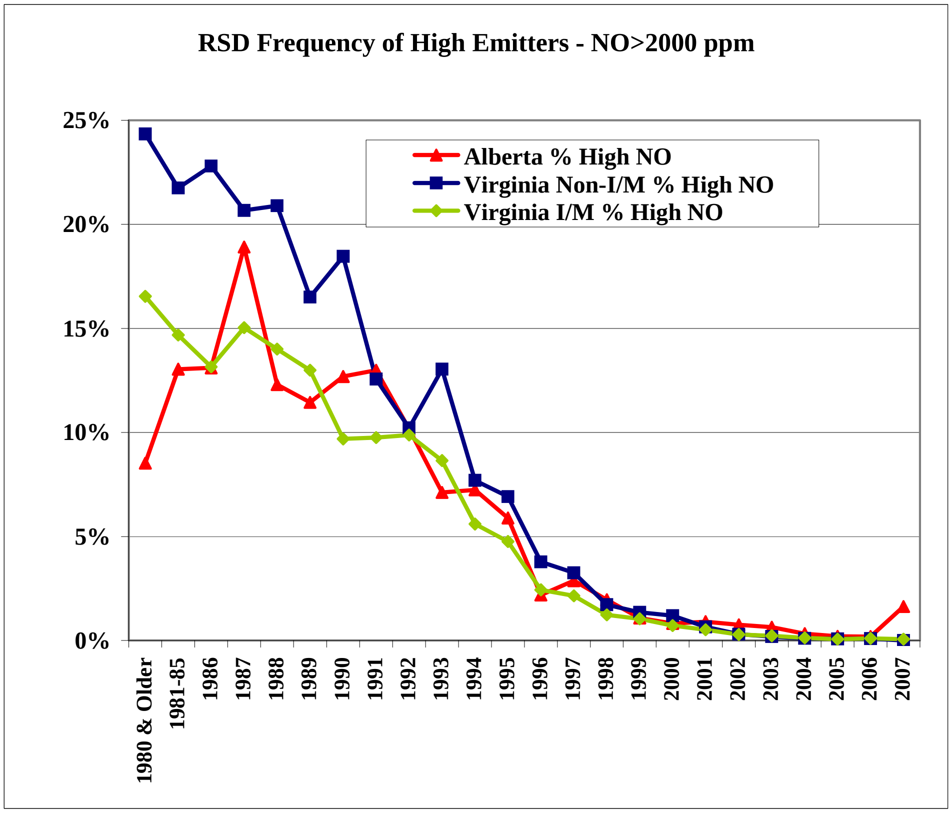


Figure 7-4 NO High Emitter Rates by Year



8. Discussion

This section discusses several issues that are relevant to emissions that are not directly observable from the survey data alone. These include:

- The difference between vehicle emission concentrations vs. mass emissions.
- Trends in Criteria Air Contaminants
- Greenhouse Gases
- Developing an Emissions Inventory
- Policy Implications and Options for Alberta

8.1. Emission Concentrations vs. Mass

The estimates of the emissions contributions in the previous sections are based on exhaust pollutant concentration data only, which were expressed in ppm, percent or grams per liter. In addition to the pollutant concentration, the mass of pollutant emissions is dependent on the kilometers driven and vehicle fuel economy, i.e.:

Emissions grams = emissions grams per liter x kilometers driven / kilometers per liter

Therefore, two vehicles could emit the same concentration of pollutants but the one consuming more fuel or driven more miles would emit a proportionately larger mass of exhaust gases. Section 5 of the report showed that high emitters are typically older, heavier and have larger engines. Therefore, they typically have worse fuel economy than clean vehicles and their emissions contribution is actually a greater fraction of total mass emissions than described in section 4.

8.2. Trends in Criteria Air Contaminants

Transportation is a major emitter of pollutants —known as 'criteria air contaminants' (CAC)— that contribute to poor air quality in and around urban areas. The Human Activity and the Environment: Annual Statistics 2006 report by Statistics Canada (http://www.statcan.ca/english/freepub/16-201-XIE/16-201-XIE2006000.pdf) assesses the impact of transportation on the environment. Transportation activities generated more than one-quarter of Canada's greenhouse gas (GHG) emissions in 2004 and accounted for 28% of their growth from 1990 to 2004. More than one-half of all nitrogen oxides, a quarter of volatile organic compounds and upwards of 17% of fine particulate matter reportedly came from transportation activities in 2004.

The good news is that, over time, transportation's output of CAC has declined. The introduction of catalytic converters, cleaner burning fuels and higher fuel efficiency standards have all contributed to the decrease. Statistics Canada reports NOx emissions from transportation were

19% lower in 2004 than in 1990. In the same period, CO and VOC emissions each dropped 37%. The ROVER II survey suggests this decline is continuing as a result of the introduction of OBD-II equipped vehicles and continued tightening of new vehicle standards.

The ROVER II survey found that average vehicle emissions concentrations are lower in 2006 than in 1998. This is due to the increased fraction of improved technology vehicles in the fleet. Other factors are less favorable in terms of overall mobile source emissions. There are more vehicles on the road and, as cities expand, they are driving further. A further issue is increasing congestion. Vehicle efficiency is poor at low speeds and braking wastes energy. Idling and slow-moving vehicles caught in stop-and-go traffic have worse fuel economy and, as a result, release more emissions.

Although the trend is believed to have been lower criteria pollutant emissions in recent years, these emissions continue to be a concern because of their potential environmental and human health impacts. For example, NOx and VOC are precursors to the formation of ground level ozone—a key component of smog. NOx is also a major contributor to acid rain. Small amounts of CO can slow human response and perception, and prolonged exposure to low levels—or brief exposure to high concentrations—can cause unconsciousness and death. Recent California Air Resources Board studies link smog and particulate emissions to respiratory conditions and increased rates of cancer.

8.3. Greenhouse Gases

Transportation is a major source of Greenhouse Gas emissions. Greenhouse gases emitted by transportation include carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O).

Greenhouse gases are primarily a function of total fuel consumption, which is not the measured by ROVER II survey. The ROVER II survey results can however be used to estimate the effective fuel economy of the on-road fleet from the vehicle models observed. Previous studies in Virginia4,[11] have found that the frequency of observation of light vehicles by RSD corresponds well with Mobile[12] estimates of annual mileage by model year. The distributions of observations by vehicle type and model year approximate the actual travel fractions.

Statistics Canada reported that from 1990 to 2004, GHG emissions from transportation rose 30%, or almost 45 megatonnes. Eighty-six percent of the increase in transportation’s emissions came from road vehicles, in particular light trucks and heavy-duty vehicles. SUVs, pickups and vans have grown in popularity. From 2000 to 2005, the fleet of light automobiles fell 1%, while the number of light trucks rose 26%, according to the Canadian Vehicle Survey. Generally, light trucks are heavier and have greater horsepower than cars. In 2005, the average fuel efficiency for cars in the Canadian vehicle fleet was 9.1 L/100 km; for pickups, 14.0 L/100 km; and for vans, 11.5 L/100 km. Therefore, while criteria air contaminants are declining, Greenhouse gas emissions continue to increase.

8.4. Developing an Emissions Inventory

The results of the ROVER II study can be combined with data from other sources to develop regional inventories of light vehicle Criteria Air contaminants and Greenhouse gases. The

University of Denver developed an inventory for Denver[13] based on fuel consumption and remote sensing emissions.

For a simple fuel based estimate the vehicles measured on road are assumed to be a representative sample of the total vehicle miles traveled for gasoline vehicles. For a first approximation one can use the measured average emissions/liter x regional fuel consumption. Estimates need to be adjusted for cold start emissions – the elevated emissions that occur when cold vehicles are first started - and for evaporative emissions, i.e. fuel and vapor leaks.

A fuel-based inventory described above can be compared to the inventory estimated using models, e.g. the US EPA Mobile6 model. The Mobile6 model requires additional inputs including registration counts by vehicle type and model year, estimates of vehicle miles traveled, roadway types and speeds. Mobile6 contains default values (intended to represent the typical US values) for registration distributions, VMT by age and type, and driving conditions. The Alberta fleet and highway network is likely to have some different characteristics, e.g. a greater fraction of trucks and a different mix of roadway types and speeds.

Vehicle miles traveled would be difficult to assess independently unless some research has been done within the region or in similar regions. It might be best to conform the two analyses (Mobile6 and fuel based) by estimating VMT from the fuel sales and the estimated fleet average fuel economy. The latter can be estimated from the ROVER II survey distribution of vehicle model observations and specific vehicle model fuel economies. For simplicity, vehicle trips, including the mixture of speeds and accelerations, could be assumed to be similar to default Mobile6 values.

Typical daily temperature ranges for the area and gasoline characteristics are also inputs for Mobile6. With the large seasonal differences in Alberta, it may be appropriate to run Mobile6 for each season and weight the results together using quarterly gasoline sales.

8.5. *Policy Implications and Options for Alberta*

The ROVER II survey highlights that a small percentage of vehicles are creating a large fraction of the Criteria Air Contaminants. Dirty vehicles have poorer fuel economy and emit more HC, CO, NOx and particulates in addition to CO2. The primary concern is the health effects from these pollutants. Greenhouse effects are also increased through higher emissions of hydrocarbons. Even when regional levels meet national air quality standards, health effects are often a local concern for residential areas and schools close to heavily traveled highways. Efforts to encourage vehicle owners to properly maintain vehicles are therefore important.

The Virginia results show that vehicle inspection and maintenance programs can reduce the frequency of high emitters and average Criteria Air Contaminants. Short of requiring mandatory inspection of all vehicles, however, there are a number of less intrusive measures that could be implemented to help reduce the impact of vehicle emissions.

Some level of ongoing remote sensing monitoring can help reinforce public recognition of the need for prompt maintenance and identify groups of vehicles with high emissions

Further investigation of the large fraction of gross emitters among propane conversions is warranted. Frost & Sullivan (automotive.frost.com), “Evaluation of Global Market Potential for LPG and CNG Vehicles and Alternative Fuel Conversion Equipment in the OE and Aftermarket”, estimates that the number of LPG/CNG kits sold globally was 2.9 million in 2006 and will reach 8.0 million by 2012. Other models with known emissions systems weaknesses could also be identified and notified.

8.5.1. Voluntary Accelerated Retirement Programs

Calgary implemented the Breathe-Easy Calgary Vehicle Scrappage Program from March to November 2002. The goal of the program was to remove 600 pre-1988 vehicles from Calgary streets. The Breathe Easy technical evaluation found that, conservatively, over a three-year period, the program would reduce smog-forming compounds (hydrocarbons, carbon monoxide, and nitrogen oxides) by 803 tonnes or 1.5 tonnes per vehicle. The program also reduced carbon dioxide emissions by 2,889 tonnes or 5.39 tonnes per vehicle.

British Columbia (Scrap-it), Manitoba (Bye Bye Beaters), New Brunswick (Fredericton Vehicle Scrappage Program), Ontario (Green Mobility Pilot Project) and Quebec (Faites de l'air!) have all implemented voluntary scrap programs with various monetary and transport pass incentives. California also runs incentive based Voluntary Accelerated Retirement and Voluntary Repair programs.

Voluntary retirement programs typically target 1987 and older models, which are the dirtiest. However, as Figure 7.1 showed, roughly 10% of 1995 models and 20% of 1991 models are also gross emitters and these percentages will rise as models age further.

In 2007, the California South Coast AQMD started a pilot program using remote sensing to better target the worst polluters for voluntary accelerated retirement and repair. This allows newer models to be targeted effectively.

If funds are available from industry or other sources, vehicle retirement programs provide an effective method of getting some of the worst polluters off the road.

8.5.2. Anti-tampering and Maintenance Requirements

Modern vehicles depend on complex, very effective emissions control systems to reduce engine emissions. A modern vehicle on which emission controls have been disabled will emit many times more pollutants than the design standard.

It would be beneficial to establish anti-tampering regulation to ensure vehicles maintain their intended vehicle emission reduction capabilities.

A further step to be considered in the case of OBD-II equipped vehicles (1998 and newer light vehicles) is to require their emissions control systems be maintained. Malfunction Illumination Lights (MIL) should be functional and not illuminated. At a minimum, requirements could be introduced for high mileage commercial vehicles, e.g. taxis, shuttles and utility vehicles. Police could issue ‘Fix-it’ tickets.

If not already implemented, an OBD-II functional inspection should be added to existing Alberta vehicle safety inspection procedures.

Legislation could allow for the identification of suspect vehicles with very high on-road emissions.

8.5.3. Greenhouse Gas Reduction

Transportation Demand Measures (TDM) to encourage tele-commuting, use of public transport, car-pooling or vanpools can directly reduce vehicle miles traveled, fuel consumption, greenhouse gas emissions and criteria pollutant emissions.

All such measures should be encouraged and they also have the benefit of reducing congestion. Congestion by itself increases fuel consumption, criteria pollutant emissions and greenhouse gas emissions.

9. FINDINGS and CONCLUSIONS

Findings:

Following are the key findings of the survey:

- *The survey met its data collection goal*s.

  Over 66,000 vehicles were measured and 59,876 were identified via their license plate.

- *The Light Vehicle Fleet has lower emissions in 2006 than in 1998.*

  CO emission values were lower in 2006 than in the 1998 survey. Median CO emissions in 2006 were 0.02% vs. 0.11% in 1998 and average CO emissions were 0.2% vs. 0.7%.

  The lower average CO is the result of many newer technology vehicles entering the fleet. OBD-II equipped vehicles, which are most 1996 and newer models, have lower emissions and lower rates of high emitters than older models.

- *High Emitters contribute a disproportionate fraction of total emissions.*

  - The 5% of vehicles identified as high emitters contributed 31%, 60%, 26% and 7% of HC, CO, NO and particulate matter respectively. In the Rover I study, 7% gross CO emitters were estimated to contribute 54% of the total CO emissions.
    - 64% of the high emitters were model years 1988-1995.
    - 29% of the high emitters were 1996 and newer.

- *Diesel Vehicles*

  Diesel vehicles had higher rates of smokers and high NO emitters than gasoline vehicles. Vehicles in higher weight classes also had higher rates of high emitters. In addition, larger vehicles carrying loads will emit a greater mass of pollutants as they consume more fuel.

- *Propane Fueled Vehicles.*

  Propane fueled vehicles had exceptionally high rates of high emitters for HC, CO and NO.

Conclusions:

- *A high emitter program using RSD technology could be implemented to assist in maintaining lower light vehicle emissions.*

  A stand-alone high emitter program could identify the small percentage of dirty high emitters and encourage owners to obtain repairs or scrap the vehicle. A voluntary repair assistance/scrap program would make this more palatable to vehicle owners.

  In addition, the presence of on-road monitors could encourage vehicle owners of OBD-II equipped vehicles to respond promptly to malfunction indicator lights.

Appendix A Data Screening Charts

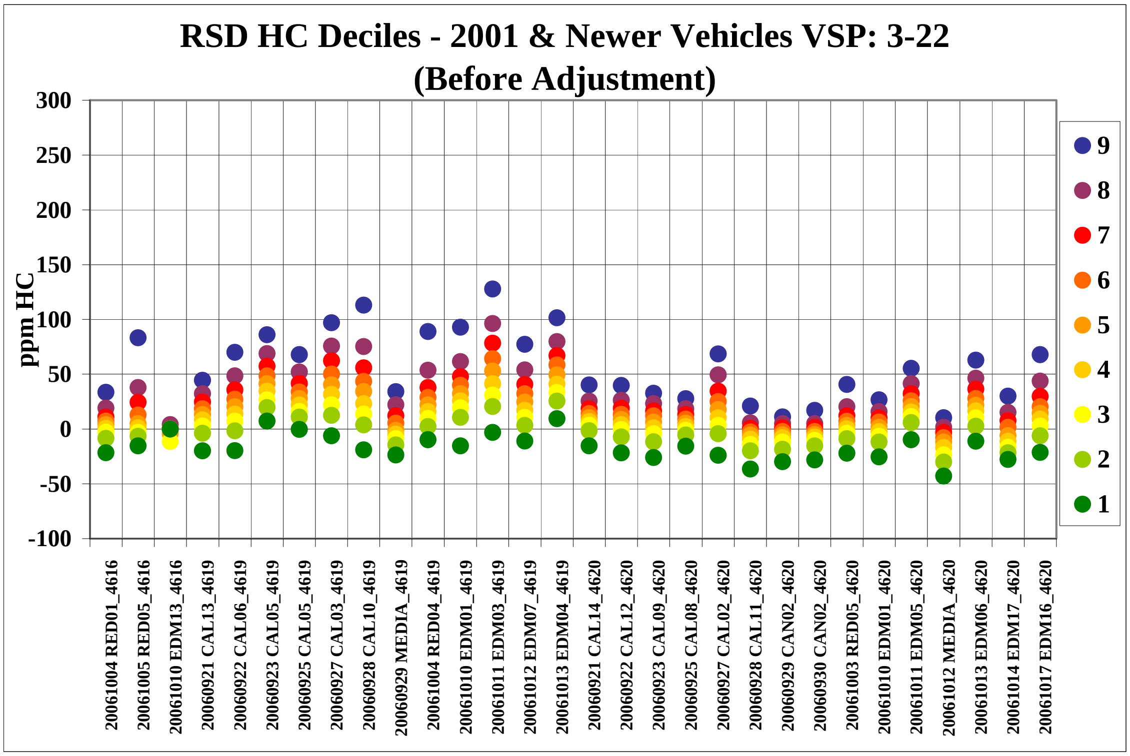
Hourly Temperatures

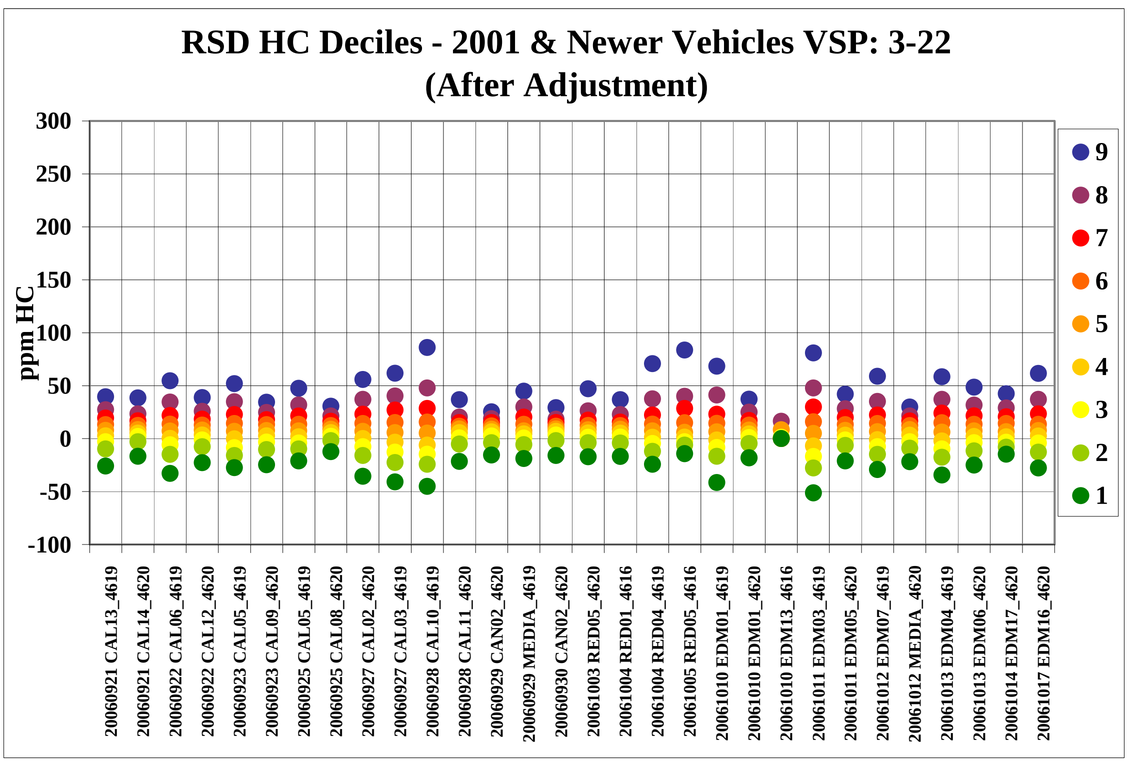
Day	Unit	Session	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
21-Sep-06	__07064619	4	#N/A	#N/A	8.2	8.0	7.9	8.2	9.5	9.8	8.9	9.9	10.1	9.6	9.6	8.8	8.2
21-Sep-06	__07064620	5	#N/A	7.1	7.7	7.7	8.4	10.0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
22-Sep-06	__07064619	6	8.7	#N/A	#N/A	#N/A	10.8	11.6	13.8	18.6	17.8	22.5	24.1	#N/A	#N/A	#N/A	#N/A
22-Sep-06	__07064620	7	7.0	7.2	8.0	8.5	9.1	9.5	9.9	10.7	11.5	12.4	16.1	#N/A	#N/A	#N/A	#N/A
23-Sep-06	__07064619	9	2.0	4.8	4.1	5.6	8.5	11.0	12.9	15.9	17.7	18.3	19.0	#N/A	#N/A	#N/A	#N/A
23-Sep-06	__07064620	8	2.7	3.9	4.6	5.6	7.8	10.0	11.5	12.6	14.1	15.8	17.4	#N/A	#N/A	#N/A	#N/A
25-Sep-06	__07064619	11	6.6	7.2	8.2	9.8	12.3	14.3	16.4	20.5	21.2	21.2	22.5	23.1	#N/A	#N/A	#N/A
25-Sep-06	__07064620	10	9.3	9.7	10.0	10.4	10.5	12.0	15.9	20.2	20.1	21.5	26.1	23.8	#N/A	#N/A	#N/A
27-Sep-06	__07064619	18	6.3	4.9	5.5	8.2	10.9	13.4	15.0	17.6	20.3	23.8	#N/A	#N/A	#N/A	#N/A	#N/A
27-Sep-06	__07064620	19	8.2	7.4	7.5	11.0	13.8	16.6	17.3	17.0	17.3	17.8	18.1	#N/A	#N/A	#N/A	#N/A
28-Sep-06	__07064619	16	12.8	12.2	12.4	15.9	17.9	19.0	20.0	20.2	20.3	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
28-Sep-06	__07064620	17	#N/A	13.4	13.3	14.0	14.8	16.6	18.1	19.1	20.0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
29-Sep-06	__07064619	15	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	19.6	21.0	21.2	#N/A	#N/A	#N/A	#N/A	#N/A
29-Sep-06	__07064620	14	#N/A	#N/A	#N/A	10.0	11.9	14.8	17.0	18.6	19.7	20.3	20.9	21.6	22.1	22.1	#N/A
30-Sep-06	__07064620	12	#N/A	#N/A	8.5	9.0	11.2	14.1	16.2	18.1	19.1	19.6	20.0	20.4	#N/A	#N/A	#N/A
3-Oct-06	__07064620	22	0.0	0.0	4.2	5.7	7.0	8.4	9.8	10.8	11.6	12.4	12.8	12.4	#N/A	#N/A	#N/A
4-Oct-06	__06064616	21	#N/A	0.0	0.0	0.0	0.0	4.8	9.8	21.1	24.2	27.0	21.6	18.6	17.5	#N/A	#N/A
4-Oct-06	__07064619	23	8.3	9.7	10.5	15.1	12.8	11.9	14.7	15.4	17.0	17.7	16.9	16.1	15.8	#N/A	#N/A
5-Oct-06	__06064616	20	2.5	2.6	2.1	1.7	3.6	5.1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
10-Oct-06	__06064616	30	7.8	6.9	6.4	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
10-Oct-06	__07064619	29	10.5	10.8	11.1	10.1	11.0	11.5	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
10-Oct-06	__07064620	29	#N/A	#N/A	#N/A	6.2	6.1	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
11-Oct-06	__07064619	24	#N/A	6.1	5.3	5.6	6.9	6.6	6.9	7.6	8.2	10.3	13.5	#N/A	#N/A	#N/A	#N/A
11-Oct-06	__07064620	25	#N/A	4.3	5.4	6.8	7.1	5.8	5.7	5.5	6.0	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
12-Oct-06	__07064619	26	2.9	3.2	4.3	4.5	5.8	6.1	8.0	8.3	10.1	12.6	11.9	#N/A	#N/A	#N/A	#N/A
12-Oct-06	__07064620	28	#N/A	#N/A	#N/A	4.4	6.0	6.9	7.3	7.3	8.1	9.6	11.3	12.0	12.4	#N/A	#N/A
13-Oct-06	__07064619	32	7.4	9.1	8.7	9.7	10.5	9.4	11.1	10.9	10.7	12.6	13.9	13.3	12.3	#N/A	#N/A
13-Oct-06	__07064620	31	6.6	8.7	11.3	13.7	15.9	16.5	16.3	15.6	15.6	16.0	16.0	16.2	16.5	#N/A	#N/A
14-Oct-06	__07064620	33	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	9.8	10.1	11.2	10.8	10.2	#N/A	#N/A
17-Oct-06	__07064620	35	#N/A	2.9	6.4	7.9	10.0	11.3	11.5	11.8	11.5	11.1	10.6	11.0	11.4	#N/A	#N/A

% Hourly Measurements of New Models with High HC

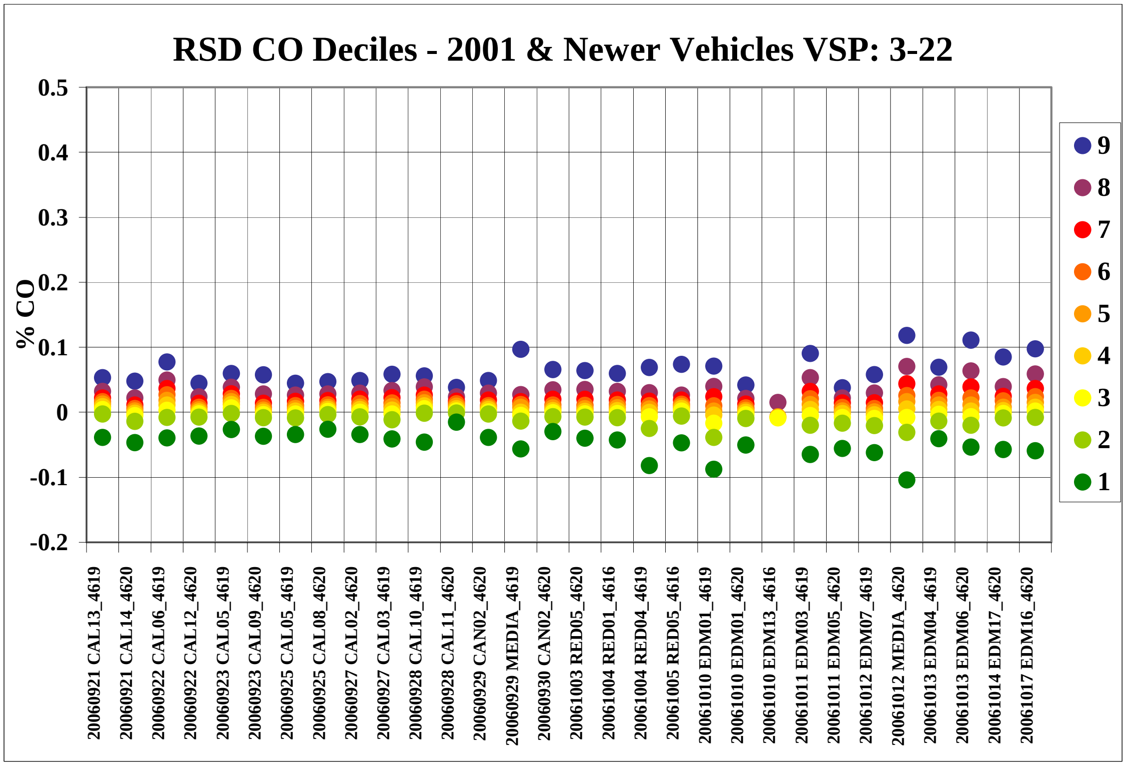
Day	RSD Unit	Session	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
21-Sep-06	__07064619	4	#N/A	#N/A	0%	2%	1%	0%	0%	1%	0%	1%	1%	0%	0%	3%	3%
21-Sep-06	__07064620	5	#N/A	1%	2%	1%	1%	1%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
22-Sep-06	__07064619	6	#N/A	#N/A	#N/A	#N/A	4%	0%	3%	1%	0%	1%	0%	#N/A	#N/A	#N/A	#N/A
22-Sep-06	__07064620	7	#N/A	0%	1%	1%	0%	0%	1%	0%	0%	1%	2%	#N/A	#N/A	#N/A	#N/A
23-Sep-06	__07064619	9	#N/A	#N/A	#N/A	#N/A	#N/A	0%	0%	0%	0%	0%	0%	#N/A	#N/A	#N/A	#N/A
23-Sep-06	__07064620	8	#N/A	#N/A	0%	0%	0%	0%	0%	0%	0%	0%	0%	#N/A	#N/A	#N/A	#N/A
25-Sep-06	__07064619	11	#N/A	3%	1%	1%	1%	0%	1%	1%	1%	0%	2%	0%	#N/A	#N/A	#N/A
25-Sep-06	__07064620	10	#N/A	0%	1%	1%	0%	0%	0%	0%	0%	0%	0%	0%	#N/A	#N/A	#N/A
27-Sep-06	__07064619	18	#N/A	0%	2%	2%	1%	0%	2%	5%	1%	1%	#N/A	#N/A	#N/A	#N/A	#N/A
27-Sep-06	__07064620	19	#N/A	#N/A	0%	0%	0%	0%	3%	0%	0%	1%	0%	#N/A	#N/A	#N/A	#N/A
28-Sep-06	__07064619	16	#N/A	#N/A	2%	4%	4%	0%	4%	11%	7%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
28-Sep-06	__07064620	17	#N/A	#N/A	0%	0%	0%	4%	0%	0%	0%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
29-Sep-06	__07064619	15	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0%	0%	#N/A	#N/A	#N/A	#N/A	#N/A
29-Sep-06	__07064620	14	#N/A	#N/A	#N/A	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	#N/A
30-Sep-06	__07064620	12	#N/A	#N/A	#N/A	0%	3%	0%	0%	0%	0%	0%	0%	0%	#N/A	#N/A	#N/A
3-Oct-06	__07064620	22	#N/A	12%	6%	0%	5%	4%	2%	4%	0%	4%	0%	0%	#N/A	#N/A	#N/A
4-Oct-06	__06064616	21	#N/A	#N/A	1%	0%	#N/A	0%	9%	0%	1%	1%	0%	0%	0%	#N/A	#N/A
4-Oct-06	__07064619	23	#N/A	6%	10%	9%	11%	5%	3%	5%	1%	3%	4%	3%	4%	#N/A	#N/A
5-Oct-06	__06064616	20	#N/A	#N/A	10%	4%	5%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
10-Oct-06	__06064616	30	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
10-Oct-06	__07064619	29	#N/A	#N/A	2%	2%	10%	14%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
10-Oct-06	__07064620	29	#N/A	#N/A	#N/A	3%	4%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
11-Oct-06	__07064619	24	#N/A	3%	4%	4%	3%	4%	4%	6%	5%	0%	0%	#N/A	#N/A	#N/A	#N/A
11-Oct-06	__07064620	25	#N/A	0%	0%	0%	1%	0%	0%	2%	0%	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A
12-Oct-06	__07064619	26	#N/A	6%	1%	2%	7%	3%	4%	4%	2%	2%	0%	#N/A	#N/A	#N/A	#N/A
12-Oct-06	__07064620	28	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	#N/A	0%	0%	0%	0%	#N/A	#N/A	#N/A
13-Oct-06	__07064619	32	#N/A	0%	2%	1%	3%	3%	2%	3%	2%	3%	1%	2%	3%	#N/A	#N/A
13-Oct-06	__07064620	31	#N/A	3%	2%	0%	0%	0%	3%	0%	0%	0%	1%	2%	0%	#N/A	#N/A

Daily HC Emissions Distribution for New Models

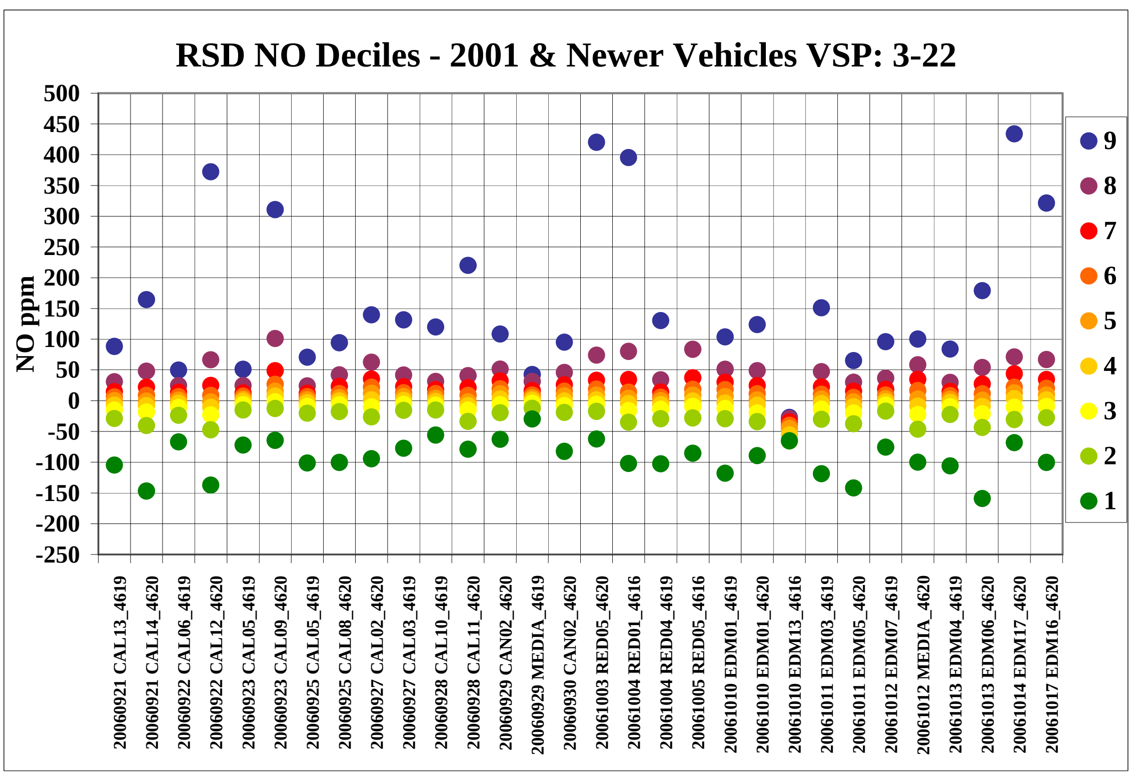




Daily CO Emissions Distribution for New Models



Daily NO Emissions Distribution for New Models



Appendix B Communications Package

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