

**BRITISH  
COLUMBIA  
CLEAN AIR  
RESEARCH FUND**

**Final Report  
November 2008**

## 1. Introduction

Since the inception of the British Columbia Clean Air Research Fund (CAR Fund) at the end of 1995, the fund has been utilized for two programs, BC Scrap-It and Clean Air Research. From the outset half of the fund has been used to start the BC Scrap-It pilot program for retirement of old high-polluting motor vehicles. Since 1997 contributions have been made from the fund to a number of research projects on air quality in the Lower Fraser Valley and other areas of British Columbia.

All Clean Air Research Fund Status Reports are currently being made available at the following web site:

<http://www.bcairquality.ca>

From 1995 to the end of 2008 thirty-five projects have been co-funded by the CAR Fund for a total of more than \$575,000. The total value of these projects, including funds from other partners exceeded \$3.5 million. CAR Fund has contributed in excess of \$1.5 million to the BC Scrap-It program. In addition CAR Fund has provided moneys for several special projects including:

- Canadian Synthetic Diesel Fuel Testing Project - \$75,000 (overall value of this project was more than \$1.1 million)
- Ethanol BC - \$100,000 (overall value of this project was \$7.4 million)
- Pacific 2001 - \$62,500 (overall value of this project was \$1.4 million)
- Bob Caton Scholarship Fund \$33,361.

This report summarizes the activities of the CAR Fund from 1995 until its termination in 2008.

## 2. Clean Air Research Fund History

In December 1995, the Canadian Petroleum Products Institute (CPPI) and BC MOE signed an agreement funding two specific programs. While the BC Scrap-It Program is an old, high-polluting motor vehicle scrapping program, the Clean Air Research Program is for research projects on air quality issues in the Province with a particular focus on transportation and fuels. Under the agreement, CPPI was committed to contribute up to a maximum of \$500,000 per year for a total of \$2.5 million over the 5-year period (1996-2001), and the total annual amount was to be split between the two programs. The agreement was amended in December 1997 to include the Greater Vancouver Regional District (GVRD) as another party to the agreement. The current CPPI funding members are Chevron Canada, Husky Oil, Imperial Oil, Petro-Canada and Shell Canada. The Clean Air Research Fund is being managed by a Steering Committee consisting of one representative from each of CPPI, MOE and GVRD.

The original CAR Fund Agreement was due to expire at the end of 2001, however, the Parties agreed in March 2001, to continue the Agreement until “... *the full commitment of \$2.5 million has been expended or committed.*” Hence the Fund was used for air quality research projects and the BC Scrap-It Program beyond the year 2001.

The CAR Fund Steering Committee usually meets several times a year. Environment Canada and the Fraser Valley Regional District representatives attend the meetings as observers.

### 3. Project Summaries

#### 1. *Evaluation of the Scrap-It Pilot Program*

In May 1997, the Scrap-It Steering Committee initiated a project to have an independent assessment of the pilot program in terms of emission reduction benefits of scrapping old high-polluting vehicles and its cost-effectiveness. A contract for the study was awarded to InnovaTech Energy Systems Inc., in association with Alchemy Consultants Inc. and Constable Associates Consulting Inc. The entire project cost of \$20,022 was funded from the CAR Fund. The project was completed in August 1997.

#### 2. *Mass Flow Leakage Rate from Faulty Gas Caps – Evaporative Emissions and Their Impact on AirCare Program Effectiveness*

In November 1997, the AirCare Administration Office submitted a proposal for testing motor vehicle fuel tank caps to determine the leakage of gasoline vapour. The project is a part of a five-part investigation on AirCare program effectiveness in reducing fuel loss and emissions of evaporative volatile organic compounds from in-use vehicles. It was to be conducted at the AirCare Research Centre at a total cost of \$45,000. In September 1998, the Steering Committee approved the request for funding the entire cost from the CAR Fund. The final report on the project was submitted in June 1999.

#### 3. *Development of a Fine Particulates Model for the Lower Fraser Valley - Phase I*

In February 1998, the Atmospheric Environment Services of Environment Canada, Pacific and Yukon Region submitted a proposal to the Steering Committee for partial funding of a two-phase project on the development of an air quality model for fine particulates in the Lower Fraser Valley. The goal of the project was to incorporate a particulate matter module into one of the two existing air quality models for ground level ozone. During Phase I of the project an assessment of these models was undertaken to determine their applicability to fine particulates modelling.

The estimated total budget for the two-phase project was \$150,000. A sum of \$50,000 was approved by the CAR Fund (payment of \$45,000 provided), as the remaining \$100,000 were to be funded equally by GVRD and Environment Canada. A contract was issued to ICF Consulting Inc. of San Rafael, California for both phases of the project. Phase I was completed in mid-1998 and a report submitted later in the year. The work on Phase II commenced immediately afterwards but was not completed.

#### 4. *Further Development and Application of a Tool for Analysing Policies for Reducing Greenhouse Gas Emissions in the Transportation Sector of British Columbia*

The proposal from the Energy Research Group (ERU) of the Simon Fraser University was received by the Steering Committee in March 1998 through British Columbia Environment. ERU proposed to enhance its analytical model for evaluation of a variety of policies for reducing emissions of greenhouse gases in British Columbia's transportation sector. The total cost of the project was estimated at \$30,000. Funding of \$10,000 was requested from the CAR Fund, as the British Columbia Ministry of Environment and Environment Canada had committed to fund the

rest. Upon approval of the requested funding by the Steering Committee, the enhanced model was developed and a final report was submitted in July 1999.

#### *5. Okanagan Airshed Management Plan – 1998 Work*

In order to develop an air quality management plan for the Okanagan Airshed, in 1998 the Okanagan Air Quality Technical Steering Committee (OAQTSC) prepared a 5-year project to gather necessary regional air quality related information. In June 1998, the OAQTSC submitted a proposal for the 1998 work plan to collect local air quality and meteorology data. The total monetary budget for the 1998 work was estimated to be \$20,000, towards which funding of \$9,050 from Okanagan University College and the City of Kelowna was confirmed. A sum of \$10,950 from the CAR Fund was requested and approved by the Steering Committee. Upon completion of the 1998 work, the OAQTSC submitted a final report and requested only \$9,108 from the CAR Fund, because of the additional financial support received from the other partners.

#### *6. Estimation of Road Dust Emission from Vehicular Traffic on Paved and Unpaved Roads.*

Preliminary estimates of road dust emissions in the Lower Fraser Valley and the rest of British Columbia for the year 1995 indicated that airborne road dust due to motor vehicles could be a significant source of PM<sub>10</sub> and PM<sub>2.5</sub>. There were uncertainties about the methods used to estimate the road dust emission, and the GVRD and British Columbia Environment proposed a two-phase study to determine appropriate emission estimation methods, and to re-estimate the 1995 road dust emissions in the Lower Fraser Valley (Phase 1) and the rest Province (Phase 2). The total cost of the project was estimated at \$30,000, and \$10,000 was requested from the CAR Fund. The GVRD, Environment Canada and British Columbia Environment contributed \$11,302, \$10,000 and \$963 respectively. Upon approval of the requested amount by the Steering Committee, Levelton Engineering Ltd. was awarded the contract in July 1998. The contractor submitted final reports for both phases of work by April 1999. CAR Fund provided \$9,346.

#### *7. To Develop an Expert Diagnostic Computer Software to Assist the AirCare Repair Industry by Recommending Efficient Repair Strategies for Failed Vehicles*

This request for CAR funding was submitted in September 1998. The proposal was to develop an 'intelligent computer software system' using AirCare data for assisting the vehicle repair industry to repair failed vehicles appropriately. The project would be undertaken by the Statistical Consulting and Research Laboratory (SCARL) at the University of British Columbia. The total cost of the project was estimated to be \$47,500. The Steering Committee approved a contribution of \$16,000. Other funding partners were Environment Canada, Ontario Ministry of Energy and Environment, and the University of British Columbia, Statistics Department. The final project report was submitted in December 1999.

#### *8. Meteorology, Emissions and Ambient Air Quality During Two Ozone Episodes in the Lower Fraser Valley, B. C.*

In October 1998, the Atmospheric Science Program, Department of Geography, The University of British Columbia submitted a research proposal to the Steering Committee for funding. The objective of the project was to examine the meteorology, emissions and air quality data for the Lower Fraser Valley during the summer months in 1988 and 1998, when dissimilar ground level

ozone concentrations were observed. At the suggestion of the Steering Committee, a revised proposal was submitted in March 1999 for a total budget of \$7,700 (the final budget was \$7,635). Regular progress reports and the final report were submitted to the Steering Committee in 1999.

### *9. Clean Transportation Analysis*

The project was awarded by the GVRD in June 1999 in cooperation with five other partners to assess both direct and indirect air quality benefits of several recent initiatives related to transportation in the Lower Fraser Valley. A primary objective of the study was to assess the cost-effectiveness of the US Environmental Protection Agency's Tier 2 and California Low Emission Vehicle II emission standards for motor vehicles in order to support the impending Provincial Government decision on the appropriate British Columbia emission standards for motor vehicles for the 2004 – 2020 period. The scope of the study included customization of the MOBILE 5B-Tier 2 evaporative emission model to Canadian conditions, analysis of the impacts of the heavy-duty vehicle smoke testing program (ACORP), and additional evaluation of the cost-effectiveness of the proposed US Federal and California motor vehicle emissions standards for the period 2004-2020. The original study budget of \$50,000 was later increased to \$90,000. The Steering Committee had approved the original request for \$10,000 from the CAR Fund, and subsequently increased it to \$15,000 due to expanded scope of the project. Additional funding was contributed by two new partners. Altogether eight funding partners contributed to the project as follows: (i) GVRD - \$20,000, (ii) British Columbia Environment - \$10,000, (iii) Environment Canada - \$10,000, (iv) CAR Fund - \$15,000, (v) Canadian Vehicle Manufacturers' Association - \$10,000, (vi) Association of International Automobile Manufacturers of Canada - \$10,000, (vii) Translink - \$10,000, and (viii) Fraser Valley Regional District - \$5,000. The project was completed in January 2000.

Note: The CAR Fund was not used in “estimating health and other benefits associated with the air quality improvements”, and CPPI's position on the cost-benefit estimates has been recognized in the Disclaimer and in an Appendix to the final report issued in January 2000.

### *10. Sustainable Transportation Planning at Simon Fraser University: Analysis, Design and Recommendations*

In view of the anticipated growth in the proposed Burnaby Mountain Community Development, it appeared that commuting to and from the Simon Fraser University campus would be primarily by single occupant vehicles. The subject project was proposed by Robert MacDonald, a student of the Simon Fraser University, as the topic for his Master's thesis. In February 1999, a request for partial funding of an amount between \$15,000 and \$20,000 was submitted to the Steering Committee. The total cost of the project was estimated to be approximately \$34,000. Subsequently, the proponent received commitments from the following six other funding partners: (i) Transport Canada - \$5,000, (ii) British Columbia Ministry of Municipal Affairs - \$6,000, (iii) Simon Fraser University - \$5,000, (iv) Transport Association of Canada - \$4,000, (v) Burnaby Mountain Community Corp., and (vi) BC Hydro - \$1,000. In view of these commitments, the CAR Fund Steering Committee approved \$5,000 in March 1999.

The study results indicate that a minimum of 20% reduction in single-occupant vehicle trips to and from Simon Fraser University is achievable through implementation of the recommended policies and strategies. The Master Sustainable Transportation and Land Use Planning

Framework can also be used as a template for other communities and local governments for similar purposes.

### *11. Light Duty Vehicle Fine Particulate Matter Emission*

The CAR funding for this project was approved in August 1999 to the amount of \$10,000 for sampling and analysis of emissions and \$2,005 in gasoline coupons to procure test vehicles. Other cash contributions of \$100,000 and \$65,000 were received from the Program of Energy Research and Development (PERD) and Atmospheric Environment Services, Pacific and Yukon Region respectively.

The final report was submitted in June 2000. The test results showed that PM<sub>2.5</sub> (particulate matter of diameter 2.5 micron and smaller) emission varied from 0.25 to 100 mg/mile. On average about two-thirds of the PM<sub>2.5</sub> consisted of carbon and the remainder was composed of ammonium sulphate and metals, mainly iron and manganese. Nearly half of the manganese was soluble in water. The emissions of ammonia and sulphur dioxide were similar in magnitude, and ranged from 1 to 300 mg/mile. Emissions of non-methane hydrocarbons and vapour phase organic acids were of similar magnitude. Emissions of non-carbon dioxide greenhouse gases, namely nitrous oxide and methane, were also of similar magnitude and ranged from 1 to 300 mg/mile.

### *12. Okanagan Air Quality Management – Transportation Initiatives for 2000*

CAR funding of \$5,000 towards two initiatives, Transportation Use Survey and a Statistical Study of Traffic Volumes and Air Quality Monitoring Data, proposed by the City of Kelowna and Central Okanagan Regional District was approved-in-principle by the Steering Committee in April 2000. Only the project on Transportation Use Survey was completed, and an invoice of \$2,900 has been submitted with the final report in September 2000.

The survey of the local residents' travel pattern was conducted by a consultant, and the results were analyzed by the City of Kelowna staff. Four hundred randomly selected residents were surveyed by telephone (150) and personal interviews (250). The survey results are considered to be representative of the area's total population within at least +/- 5%, 19 times out of 20.

The survey provided information on:

- (1) motor vehicle and bicycle ownership per household,
- (2) average vehicle kilometres travelled per year,
- (3) number of trips per week by different mode of travel,
- (4) trip origin and destination,
- (5) walking, car, bicycling and transit use pattern, and
- (6) respondents' concern about the effects of motor vehicle use on air pollution and health effects, traffic congestions, and accidents.

The respondents also provided their opinions on willingness to change their travel mode and behaviour, their preferences to alternative travel modes, and extent of support of action on transportation demand management by local government.

*13. Assessment of the Impact of 'Cold Transient' Vehicle Operations and Driving Pattern on GHG Emissions from In-use Personal Vehicles*

In January 2000, the Steering Committee approved CAR funding of \$17,000 towards the total cost of \$47,000 for a project proposed by Instrumental Solutions of Woodlawn, Ontario and AirCare. The scope of the study was to develop a commuter driving behaviour pattern in the Lower Fraser Valley and to determine the effects of cold transient operations of vehicles on fuel use and emissions. The work on the project started in January 2000, and the final report was submitted in November 2000. The key findings of the study were as follows:

- (i) limited number of tests indicate that the driving behaviour in the Lower Fraser Valley is different from that considered in the US Federal Test Procedure and consequently the mass emissions of air pollutants are also different;
- (ii) the average commute pattern shows higher speeds, more aggressive acceleration and more frequent stop and go traffic than is represented by the EPA 75 test, and
- (iii) the energy use of the vehicles during "cold start" is about 19% higher than average fuel consumption and approximately of the same order of magnitude as was observed in earlier studies.

*14. Improving Behavioural Parameters in Transportation Modelling in British Columbia and Canada*

The School of Resource and Environmental Management, Simon Fraser University sponsored this research project for graduate thesis work. The primary goal of the project was to identify the mode choice response of single-occupant vehicle drivers in the Lower Mainland of British Columbia to certain transportation demand management (TDM) measures. A quantitative survey was used to address the key data gaps and to use the results as an aid in policy makers' abilities to evaluate TDM measures for air pollution reduction.

CAR Fund provided \$8,069 and other partners included Environment Canada - \$8,000, and MoE - \$8,000. Original completion date of May 2001 was extended and a final report was delivered in July 2001.

Commuters from Ladner and Tsawwassen were selected for the study, and a telephone pre-survey was used for a follow-up mail survey of 650 qualified respondents. The experiment was used to measure preferences of commuters among three modes of travel, namely driving alone, carpooling and riding a 'hypothetical' express bus to and from work. The survey responses were analyzed statistically to determine 'elasticities of probability' of different responses for fuel, parking and road charges. The results appear to under represent 'the true elasticities of demand for driving alone in response to road and parking charges in the region' The results may be biased due to several possible reasons. Further study using a 'mode choice simulator' to determine market shares of the travel modes has been recommended.

*15. Ambient and Personal Exposure Levels of Fine Particulate Matter (PM<sub>2.5</sub>) Throughout the Prince George Airshed*

The project was undertaken by a graduate student from the Faculty of Natural Resources and Environmental Studies, University of Northern British Columbia, as her thesis research work.

The total budget for the work was \$55,000 from several government and private agencies, and the CAR funding amounted to \$10,000. The objective of the project was to develop a detailed understanding of the relationship between ambient PM<sub>2.5</sub> concentrations and actual personal exposure levels and to determine the spatial variation of these parameters within the Prince George airshed during a 6-week period in the winter of 2001. Personal exposures of 15 children and ambient levels on their respective school roofs were collected. In addition, PM<sub>2.5</sub> mass, sulphate and absorption coefficient (as a surrogate for elemental carbon) were measured in both samples. The total PM<sub>2.5</sub> personal exposure was contributed almost equally by ambient and non-ambient sources, and a strong association between ambient concentration and ambient generated exposure was found. The final thesis was successfully defended in May 2004.

#### *16. Review of British Columbia AirCare On-Road Program (ACORP)*

The goal of the project was to review of the effectiveness of the 2-year operation of the mandatory AirCare On-Road Program (ACORP), the heavy-duty vehicle emission testing program in British Columbia. The primary objectives of the study were to determine the cost-effectiveness and benefits of the ACORP, to review the options for program enhancement, enforcement and recovery of program costs, and to provide a critique on potential impediments to the program efficiency in reducing vehicle emissions.

Total funding for this project was \$75,000 and CAR Fund approved \$25,000. Other partner contributions: Environment Canada - \$25,000, British Columbia agencies - \$25,000 (Insurance Corporation of B. C. - \$5,000, Ministry of WLAP - \$5,000, Fraser Valley Regional District - \$5,000, Greater Vancouver Regional District - \$5,000, and Pacific Vehicle Testing Technologies/TransLink - \$5,000).

The project started in December, 2001 and was completed in May 2002. The major findings were:

- the ACORP had a consistent pre-screening efficiency and testing of vehicle activities,
- ACORP had reduced an estimated 85 tonnes/year of total PM in a cost-effective manner (\$312/tonne),
- the health and welfare benefits of PM<sub>10</sub> and PM<sub>2.5</sub> reductions are significant in terms of the program costs,
- its contribution to reducing regional PM<sub>10</sub> or PM<sub>2.5</sub> levels appears to be comparable to that of the potential impacts of the new Tier 2 emission standards for new light-duty vehicles, and
- the report has also made a number of recommendations for program enhancement.

#### *17. Potential Road Dust Emissions Mitigative Measures*

Road dust has been identified as a source of particulate matter (PM<sub>10</sub> and PM<sub>2.5</sub>) in the Lower Fraser Valley (LFV). In the past two years, GVRD conducted a program to collect and analyze road dust samples from LFV roads to determine temporal and spatial variations in road dust emissions. The objectives of the proposed study were to determine the fate of emitted road dust and evaluate potential control measures to reduce emissions. The study was conducted through a review of available information and by interviewing staff in regional governments and municipalities involved in road cleaning. The estimated cost of the study was \$45,000, of which

\$15,000 was provided from the CAR Fund. GeoViro Engineering Ltd. of Vancouver was awarded the contract at the end of December 2001.

The project started in January, 2002, and the final report was submitted in June 2002. The major conclusions of the study include:

- (i) the present knowledge about the fate of entrained road dust, its deposition mechanisms and the factors which influence deposition of airborne dust is incomplete,
- (ii) ambient air monitoring data and source apportionment studies indicate significantly lower levels of road dust constituents than expected from emission inventory estimates,
- (iii) as a result of (i) and (ii), the US EPA's AP-42 and other methodologies for estimating road dust emission are in question,
- (iv) identification of potential mitigation measures for road dust, and the costs of such measures, in the LFV could not be done at present,
- (v) street sweeping is only able to remove particles larger than PM<sub>10</sub>, and
- (vi) vehicular road dust can be contributors to regional stormwater pollution.

#### *18. Special Project - MOBILE6 Training*

At the October 2001 meeting, the CAR Fund Steering Committee approved funding of \$6,500 requested by GVRD to organize a training session on the recently released MOBILE6 model by the US EPA for estimating on-road motor vehicle emissions (actual CAR Funds provided were \$5,374). The training on MOBILE6 was held at GVRD from January 8-10, 2002, and it was offered by Mr. Phil Heirigs of Sierra Research of Sacramento, California. The total cost for the training, including in-kind contribution, was approximately \$27,000, which was shared by Environment Canada (maximum \$15,000), CAR Fund and GVRD (\$5,000 in-kind). The training was attended by 19 persons (15 attended for 3 days and another 4 attended the first day only) representing Environment Canada, BC MoE, GVRD, TransLink, CPPI, Levelton Engineering Ltd., RWDI West and TSi Consultants. The first day was a lecture session providing an overview of the MOBILE6 model and the next 2 days were hands-on computer training for the model users.

#### *19. Marine Vessels Air Emissions in the Georgia Coast Cascade Air basin and Coastal Areas for the Year 2000*

The Greater Vancouver Regional District (GVRD) retained Levelton Engineering Ltd. to prepare an emission inventory of marine vessels for the Georgia Coast Cascade Air Basin for the year 2000, and to do forecasts of emissions from marine vessels in the Air Basin to the year 2025. The project was a multi-partner effort at a total cost of \$94,000, and the funding requested from CAR Fund was \$13,600 (actual funds provided \$8,411). The 3-Phase project was initiated in October 2001 starting with Phase 1 (marine vessels emission inventory for the Core Area [GVRD and Fraser Valley Regional District] for 2000) and Phase 2 (marine vessels emission inventory for the Expanded Area [British Columbia outside LFV and Washington Coast, including Whatcom County and Puget Sound] for 2000). The Phase 3 work consists of backcasts and forecasts of marine vessels emissions for both Core and Expanded Areas. The year 2000 emission inventory was used as the baseline for backcasting emission estimates to 1985 and forecasting future emissions to the year 2025.

## *20. FIX-IT Program Pilot Project 1*

Pacific Vehicle Testing Technologies Ltd. (PVTT), administrator of the AirCare Program, conducted this project at a total cost of \$76,000. The contribution approved by the CAR Fund was \$16,000 (actual funds provided \$11,889) and the rest was borne by PVTT in cash and kind. The goal of the project is to develop a new initiative to reduce vehicle exhaust emissions of pre-1992 light-duty vehicles. A working model of the proposed FIX-IT program has been designed, and the objective of this project was to evaluate the operational procedures and potential benefits of the FIX-IT program. A total of 15 vehicles, of an average age of 17 years and with an average odometer reading of 231,000 km, were assessed for repair effectiveness from before and after repair mass emission testing. The vehicles were repaired at certified repair shops, and the repair costs ranged from \$334 to \$1,342 with an average cost of about \$800. It has been determined that repair shops with good track records can be relied upon to perform good diagnoses and repairs, and the emissions from even old, high mileage vehicles can be brought back into compliance with original emission standards. The cost-effectiveness of repair was estimated to be: \$390/tonne of CO, \$1,141/tonne of HC and \$1,259/tonne of NO<sub>x</sub>. However, the public response and participation in the study was found to be slow.

## *21. M. A. Turbo – Water Injection Emission Reduction System (testing at US Navy)*

Environment Canada sponsored this project on behalf of M. A. Turbo/Engine Ltd. to test the effectiveness of water injection in marine vessel diesel engines in reducing nitrogen oxides emission. An amount of \$3,500 was contributed from the CAR fund towards the total project cost of \$18,700.

M. A. Turbo/Engine Ltd. conducted tests with its water injection system at the US Navy engine testing facility in Philadelphia. The regular base fuel and biofuel were tested in an engine, and reductions in NO<sub>x</sub> emissions by as much as 22% due to water injection were observed at a wide range of engine power. There were significant reductions in emission of total hydrocarbons for all range of engine operations; however, there was no effect of water injection on specific fuel consumption.

## *22. Emissions Reduction Options Study for Heavy-Duty Vehicles/Fleet in the Lower Fraser Valley*

A contract for this project in the amount of \$149,000 was awarded to B.H. Levelton Consultants Ltd. and Others. The CAR Fund provided \$49,500.

The study was undertaken to assess reduction options for heavy-duty diesel vehicle emissions in the Lower Fraser Valley airshed. Various options, ranging from engine and emission control technology, diesel fuel quality, alternative and renewable fuels, were assessed and their effectiveness evaluated. The report contains a Disclaimer from the CPPI, prepared by an epidemiologist retained by the CPPI. The CPPI Disclaimer is concerned with the analytical and cost-effectiveness methodologies used by the study consultants to estimate the potential health effects of air quality improvements.

*23. Reduction of Non-road Diesel Emissions in the Lower Fraser Valley and the Rest of British Columbia*

The project, awarded to Genesis Engineering Inc., was initiated to identify cost-effective methods for reducing smog-forming emissions from non-road diesel engine emissions in the Lower Fraser Valley and the rest of the Province of British Columbia. Total cost of the project was \$40,000 and CAR Fund provided \$13,300. Non-road heavy-duty diesel fuel engines, railway locomotives and small passenger ferries were investigated. Eleven potential emission reduction options, including engine technology and cleaner and alternative fuels, were investigated. The study indicates that there are options available to reduce emissions from non-road diesel fuel combustion sources, and recommended that additional studies could be undertaken to refine the “broad brush” methodology used in this investigation to identify economic instruments and regulatory methods for implementing some of these options. The report was issued with a Disclaimer from the CPPI, prepared by an epidemiologist retained by the CPPI. The Disclaimer is concerned the methodology used to evaluate cost-effectiveness of health impacts due to potential improvement in the air quality.

*24. Vehicle Emissions Inspections and Maintenance – Effects on CO<sub>2</sub> Emissions and Fuel Consumption*

Pacific Vehicle Testing Technologies Ltd. (PVTT), administrator of the AirCare Program, completed this project in 2003 with funding from Environment Canada. The CAR funding of \$3,532 was used for presentation of the study findings at the 14<sup>th</sup> Coordinating Research Council (CRC) On-Road Emissions Workshop held in March 2004 in San Diego, California and to publish the results in the May 2004 issue of the Journal of the Air and Waste Management Association. The project developed a methodology to project full-duration fuel consumption and carbon dioxide emission from IM240 tests conducted during AirCare inspection.

*25. Vehicle Emissions Inspection and Maintenance – Effects on CO<sub>2</sub> Emissions and Fuel Consumption – Phase 2*

In continuation of the earlier phase of the project, described above, the University of British Columbia led this phase of the project. The goal of the project was to develop a statistical model, using the test data from the first phase of the work, to project full duration fuel consumption rate and CO<sub>2</sub> emission from IM240 tests for vehicles which are fast-passed as early as 30 seconds from starting the test. Another part of the project was to test the model with other test data not used to develop the model. The total budget for the project was \$12,000 and the CAR funding was \$4,000.

A statistical analysis of over 3,044 records of IM240 inspection test data from November 2002 – May 2003 and November 2003 was used to find a prediction algorithm. After removing 14 outliers, the final model was developed by using 2,038 test records, and it was tested by using a separate set of 992 test records. The model is an improved one for projecting full-duration carbon emissions and fuel consumption from a fast-pass test. The original Phase 1 method was found to be accurate to within 12% 9 times out of 10 for fast-pass after 30 seconds. The new model has reduced this error to less than 8%. It also uses additional information which is already available within each inspection record.

*26. Testing of Continuous Water Injection System on one of the two Main Engines onboard the MV Queen of New Westminster*

This project was undertaken by British Columbia Ferry Services Inc. and had a total value of \$55,500. The CAR Fund provided \$18,500.

The ferry ship's No. 2 main engine cylinders were used to install the continuous water injection (CWI) system after some modifications. The engine was operated for a total of 4,826 hours. The results showed that with water injection NO<sub>x</sub> emissions were reduced by 22-24%, and fuel consumption was improved by 1.5-1.9%. There was no excessive engine cylinder wear and both scavenging air and exhaust gas temperatures were reduced with water injection. Overall, it is estimated that the payback period of a CWI system for the Queen of New Westminster's all four main engines would be about 15 months.

*27. ISOPART Model Application to the Lower Fraser Valley*

A contract for this project was awarded to Dr. S. Pryor, Indiana University at a total cost of \$84,809. The CAR Fund provided \$22,000.

The primary objectives of the project were to run a modified ISOPART model using output from meteorological model simulations for receptors at three locations within the Lower Fraser Valley. In addition, this project determined the roles of nitric acid-ammonia vs. nitric acid-sea spray, as well as the impact of anthropogenic marine sulphur emissions on the atmospheric particle concentrations. The meteorological, air quality, emissions and other data were obtained from the Pacific 2001 intensive monitoring study. The study findings indicate that:

- (i) the model simulations are generally in agreement with the observations, except for primary species near sources,
- (ii) the partitioning of total particle NO<sub>3</sub><sup>-</sup> between sea spray and NH<sub>4</sub>NO<sub>3</sub> was highly sensitive to the amount of sea spray present;
- (iii) the contribution of sea spray to the total PM was strongly dependent on the emission strength and wind speed and hence showed spatial variability;
- (iv) reactions on/in sea spray influenced the entire PM ensemble and gas-phase concentrations;
- (v) anthropogenic sulphur emissions in marine areas played a minor role in determining particle concentrations in the cases studied;
- (vi) substantial free ammonia was available at the receptor locations and the ammonia emission scenario simulations indicated that increased ammonia emissions were associated with enhanced NH<sub>4</sub>NO<sub>3</sub> concentrations; and the modelling of visibility was found to be more challenging than that of PM ensemble.

*28. FIX-IT Program 2<sup>nd</sup> Pilot Project*

Pacific Vehicle Testing Technologies (PVTT) sponsored this \$46,000 project. CAR Fund originally approved \$16,000 for this project. However, because of poor response the project was scaled back and the final CAR Fund contribution was \$5,324.

The goal of the project was to continue development and verification of the model developed during the 1<sup>st</sup> pilot program. The model was refined to determine potential effectiveness and administrative process that can be implemented to provide repair cost assistance for vehicles which would otherwise use the cost waiver and conditional pass provisions of the AirCare program.

The project was started in May 2004 and anticipated to be complete in six months. Ten AirCare-certified repair shops were selected and solicited for their participation in the project. These shops consist of the seven which had participated in the first pilot program plus three additional shops in North Vancouver and Abbotsford to improve geographic coverage. The project objectives, guidelines and vehicle eligibility criteria have been discussed with each participating repair shop. The total number of participating repair shops has been limited to ten because it is anticipated that about 20 vehicles will be targeted in the study. Various means of active promotion of the project have been implemented to seek response and participation by vehicle owners. However, because of poor response, the promotion of the project was temporarily suspended. A re-launch of the project occurred and the project was completed in 2008.

#### *29. Data Collection for Non-certified Emission Repairs*

Pacific Vehicle Testing Technologies (PVTT) is the sponsor/leader of this \$19,000 project. CAR Funding for the project was \$3,352.

More than half of vehicles failing the AirCare emission inspection are performed by non-certified repair shops. No data on the types of repair done and costs are available. The goal of the project was to collect repair information from a sample of these vehicles by offering a small incentive (\$2) to vehicle owners. The information was analyzed to determine the cost-effectiveness of non-certified emission-related repairs.

#### *30. AirCare Program Review - Phase 2*

Sierra Research Inc. undertook this contract with a total value of \$160,000. CAR Fund provided \$50,000.

The Phase 2 of the AirCare Program Review was initiated to develop the design details of a new program scope, economic feasibility, delivery models, transitional approaches, vehicle test fees, customer acceptability, and other technical aspects. The study recommended a new program with several design changes to the current (2005) AirCare program, while retaining the other existing features, to provide cost-effective benefits to the motorists as well as to reduce air pollutant emissions in the Lower Fraser Valley.

#### *31. Dispersion Modelling During Episode Events in Golden, B. C.*

Dr. Peter Jackson of the Faculty of Natural Resources and Environmental Studies, University of Northern British Columbia led the project and Tyler Abel, a graduate student, was the other member of the project team.

The objectives of the project were to investigate the dispersion of air pollutants from the source to receptor in the Golden airshed, to characterize the boundary layer properties which influence the mixing and movement of air pollutants, and to assess the relative contributions of various sources to the observed and modelled ambient air pollutant levels. Recently collected meteorological and

particulate measurements data under the Source Apportionment Study in Golden, as well as the emission inventory, were used in this study. The research was the basis of the thesis for an M. Sc. Degree in Environmental Studies at the University of Northern British Columbia.

The project budget was estimated to be \$44,000 of which \$11,000 is approved from the CAR Fund. The remaining funds were made available from MOE and UNBC.

### *32. Holland America Sea Water Scrubber*

The project was designed to demonstrate the feasibility of using sea water to “scrub,” engine emissions on oceangoing vessels. The scrubber system uses seawater to remove virtually all sulphur oxides (SO<sub>x</sub>) as well as significantly reduce particulate matter emissions. The sea water is then treated to remove harmful components while the calcium carbonate (CaCO<sub>3</sub>) in seawater renders the sulphur oxides harmless by conversions to sulphates and neutral salts. Additional sponsors include the Port of Seattle, the Port of Vancouver, and Environment Canada.

The project budget is estimated to be \$1.5 million (US) of which \$25,000 (US) was approved from the CAR Fund (\$29,518 CAN).

### *33. Development of Source Receptor Tool for the Lower Fraser Valley, Victoria and Okanagan*

This project was Approved-in-Principle in May 2006. (The CAR Fund Steering Committee has been considering the proposals “*Updating the Lower Fraser Valley Source-Receptor Air Quality Model*” submitted by RWDI Air in December 2004 and Levelton Engineering Ltd.’s “*An Improved Health Benefit Assessment Model for the GVRD*” submitted in November 2005. The Committee had initially approved-in-principle the first one; however, after a further review of these proposals it was decided to replace these proposals with a new one and to invite the consultants to submit bids.) The contract for this work was awarded to RWDI.

The total budget for the project was estimated at \$55,000 and CAR Fund provided \$20,350.

### *34. Characterizing Marine Emissions in the Capital Regional District*

Dr. C. Peter Keller of the Geography Department at the University of Victoria is the project leader. The project undertook screening level and comprehensive dispersion modelling associated with marine vessels using the CALPUFF modeling system. In addition, field monitoring was used to aid in the evaluation of model results.

The project budget was estimated at \$50,000 of which \$23,810 was contributed from the CAR Fund. The remaining funds were provided by MOE and Victoria Harbour Authority.

### *35. AirCare CO<sub>2</sub>*

Reporting a vehicle’s individual annual CO<sub>2</sub> tonnage contribution as part of the AirCare Vehicle Inspection Report provides pertinent and personalised information that an individual may use in their own lifestyle choices, and to reduce their environmental footprint. The information and data needed to provide this information already existed within the AirCare databases. This project developed the algorithms and software necessary to create the CO<sub>2</sub> report, and developed a suitable report design and messaging to optimise use of the communication opportunity.

The project budget was estimated to be \$61,000 of which \$20,000 was approved from the CAR Fund.

#### **4. Special Projects**

##### *Ethanol BC*

The University of British Columbia (UBC) leads this multi-stakeholder sponsored project under a stakeholder Steering Committee. The primary goals of the project are to promote development and demonstration of technologies for production of ethanol, electricity and other products from softwood residues, and a commercial ethanol facility in British Columbia. The ethanol project has three major objectives – process development demonstration, development of policy recommendations and preparation of a business plan for commercialization of the process.

CAR Fund provided \$100,000 over a 5-year period with an annual contribution of \$20,000. Other partners included the Province of British Columbia (\$300,000), and various amounts of cash and in-kind contributions from Federal Government Agencies, University of British Columbia and the private sector. By the end of 2001, Environment Canada contributed \$20,000 from its Georgia Basin Ecosystems Initiative – Clean Air Action Plan, and \$120,000 from the forest products industry (Canfor, West Fraser, Weldwood and Slocan) by taking advantage of the provincial beehive burner fee rebate program. Total estimated cost of this project was \$7.4 million for the 5-year duration.

##### *Tunnel Study Pacific 2001 – Effects of Fuel and Lubricant Quality on Vehicle Emissions Fuel Analysis.*

Environment Canada was the leader and sponsor of this project, which was a part of the Pacific 2001 intensive air quality monitoring program during August-September 2001 in the Lower Fraser Valley. The objective of the project was to characterize gasoline and diesel fuels and lubricants used in vehicles, as well as to assess their potential impacts on motor vehicle emissions during the Cassiar Tunnel Testing during August 9-15, 2001. The project was a collaborative work undertaken by Environment Canada, CPPI, GVRD, AirCare and other partners.

The total budget for the Pacific 2001 project was approximately \$1.4 million. The CAR Fund provided \$12,574 for the sampling and analysis of fuels and lubricants done by the CPPI and Alberta Research Council. Field experiments, collection of fuel samples, and extensive sampling and monitoring of various contaminants and gases emitted from motor vehicles were done during the Pacific 2001 monitoring period in August-September 2001. Samples were collected during 20 sampling intervals to capture emissions from vehicles traveling through the Cassiar Tunnel in Burnaby, British Columbia during weekdays and weekends. Samples of road dusts from the tunnel were also collected and analyzed. The fleet characterization information from AirCare and ICBC was used to estimate vehicle emission rates. The gaseous and PM samples collected were analyzed for a wide-range of chemical

species. Fleet average profiles of particle phase organic compounds were derived from source apportionment studies. Various data were used to estimate emission factors for light-duty and heavy-duty vehicles. In general, the estimated emission factors are consistent with those obtained in other tunnel studies in the U. S. A. and Europe, with the exception of the CO<sub>2</sub> emission factors which were unusually low.

#### *Ammonia Measurements – Pacific 2001 Field Study*

The objective of this project was to undertake ammonia sampling and measurement at different gradients at three locations in the Lower Fraser Valley during ‘Pacific 2001’ intensive air quality measurement program conducted for August-September 2001.

Total funds needed for this project were \$55,000 in cash and in-kind. CAR Fund contributed \$50,000, recognizing that it would form a part of all Pacific 2001 research projects costing approximately \$1.4 million.

The key findings are as follows. Continuous high resolution near surface ammonia measurements made at Slocan Park (Vancouver), Langley and Sumas Mountain (at an altitude of 300 m) indicated median hourly mean ammonia concentrations of 0.27, 0.82 and 0.73 µg/m<sup>3</sup> respectively. The Langley data indicated a diurnal cycle with highest concentrations during the morning hours. Those for Sumas Mountain varied and indicated a stronger dependence on temperature. Measurements at Slocan Park indicated occasional high ammonia concentrations during the night-time and during August 26-31, 2001. Nitric acid fluxes measured at Sumas Mountain exhibited considerable uncertainties because of the characteristics of the site with respect to ‘inhomogeneity’ of the micro-meteorology. Particle size distributions were in the size range 0.537 – 19.81µm, with the highest number concentrations at Slocan Park for aerodynamic particle diameters of 0.7 µm and a mean equivalent PM<sub>10</sub> mass of approximately 9 µg/m<sup>3</sup>. Chemical analysis of the size and chemically resolved particles collected at Langley and Sumas Mountain indicated that while the majority of the particle nitrate at both sites was present in the coarse mode (associated with heterogeneous reactions on/in sea spray drops), in the sub-micron size range ammonium sulphate dominated the inorganic species.

#### *Synthetic Diesel Fuel Emissions Testing*

The overall objectives of the project were to compare: (i) emissions from diesel fuels derived from synthetic crude stock with those from conventional diesel, and (ii) emissions from engines tested by Natural Resources Canada (NRCAN) and Environment Canada and those from a prototype advanced design engine to test diesel fuels produced from oil-sands and conventional crude oil.

The estimated cost of this 4 phase project was approximately \$1,185,000. CAR Fund contributed \$75,000 to the project. Other partners include: National Research Council, Syncrude, CPPI, Suncor, Imperial Oil, Shell, Natural Resources Canada, Environment Canada, and US Dept. of Energy.

## 5. Robert Caton Scholarship

The Robert Caton Scholarship was established in 2004 to honour the memory of Dr. Robert Brent Caton, a scholar, entrepreneur and expert in the field of air quality, atmospheric emissions, environmental management and policy. Bob led several projects funded under the CAR Fund, including the Clean Transportation Analysis, which involved careful balancing of a range of industry and agency points of view.

These scholarships are intended to support graduate-level students with high ideals, demonstrated interest in studies relating to atmospheric sciences, air quality and policy, and specific goals leading to future work in that field. In 2004 CAR Fund contributed an amount of \$12,500 towards Robert Caton Memorial Scholarship Fund.

Funds remaining in the CAR Fund after the completion of all major projects were contributed to the Robert Caton Scholarship<sup>1</sup>.

## 6. Summary

The Clean Air Research Fund, since its inception, has seen the removal of 5,263 older high-polluting vehicles from the street through the SCRAP-it program, and provided funding for 35 research projects with a return of almost six dollars for every dollar invested. In addition, the CAR Fund has partnered with others to help fund several major air quality projects in British Columbia and has contributed more than \$32,000 to a scholarship fund supporting air quality research.

All \$2.5 million in the British Columbia Clean Air Research Fund have now been distributed. A summary of the distribution of funds is given below in Table 1.

Project Type	Total Project Cost	CAR Fund Expenditure	
<b>Initial Fund Total</b>			\$2,500,000
Projects 1 to 35	\$3,405,296	\$575,445	
Special Projects			
Ethanol BC	\$7,400,000	\$100,000	
Pacific 2001	\$1,400,000	\$62,584	
Canadian Synthetic Diesel Testing	\$1,185,000	\$75,000	
Scrap-It		\$1,588,550	
Scholarships <sup>1</sup>		\$33,361	
Administration		\$65,060	
<b>Total</b>		2,500,000	

**Table 1:** CAR Fund Expenditures

<sup>1</sup>NOTE: Scholarships includes the original \$12,500 plus the remaining funds in the CAR Fund as of November 2008 (\$20,861).