Modelling Proposal for an Air Quality Modelling Study in Prince George, British Columbia

Prince George Air Quality Implementation Committee, Research Working Group
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1 Introduction and Rationale

Prince George, a city of 80,000 located on the central interior plateau of British Columbia, has the highest ambient PM2.5 levels in the province (the only monitored location to exceed the Canada Wide Standard) and among the highest levels of other pollutants as well. Significant sources, combined with low wind speeds and stagnation episodes resulting in trapping of pollutants and cold air in the valley, contribute to the problem (BC MWLAP, 2004)

This proposes a dispersion modelling study to support decision making in an on-going air quality management program in Prince George, British Columbia. In Prince George, air quality is managed in a multi-stakeholder airshed approach. The first air quality management plan (phase I) was published in 1998 and went into effect in 1999 (Prince George Air Quality Technical Management Committee, 1998). As part of that plan, a Steering Committee, an Implementation Committee (Prince George Air Quality Implementation Committee – PGAQIC) a Research Working Group (PGAQIC-RWG), and a Monitoring Committee were established to enact the plan and develop phase II to continue improving air quality in the Prince George airshed.

Phase II of the air quality plan needs to identify specific targets for emission reduction that will have the greatest impact on improving ambient air quality. In order to do this, those sources need to be identified in a robust and defendable way, ideally using several lines of evidence and sources of information to strengthen confidence in the source identification. We envisage using three independent methods to provide evidence on emission sources. A wind sector analysis was undertaken by BC MWLAP staff, to identify correlations with ambient levels and wind directions. A source apportionment student is currently underway in Prince George, that will use receptor based approaches with speciated $PM_{2.5}$ and PM_{10} data. These two approaches will provide evidence and some validation for the dispersion modelling study proposed here. A dispersion modelling study offers a strong method for determining sources, and offers the best method for examining the impact on ambient air of various scenarios for source reduction. It is therefore an essential part needed to develop phase II of the air quality management plan.

1.1 Ambient Monitoring Results

PM_{10} has been monitored at various locations in Prince George since 1990, and the fine (PM2.5) fraction has been monitored at one central site since 1994 (MWLAP, 2004) (Figure 1). Continuous monitoring has been done since 1992 and 1997 for these two

particulate components, respectively, at the central (Plaza) site. Monitoring of continuous sulphur dioxide, ozone, nitrogen oxides, carbon monoxide and total reduced sulphur is also done at the same site.

Annual average levels of ambient $PM_{2.5}$ are the highest in the province, and average 98th percentile values exceeded the Canada Wide Standard over the most recent three-year period. Trends in various $PM_{2.5}$ statistics, based on non-continuous monitoring, are shown in Table 1 below.

Table 1 Annual Trend Summary of Non-Continuous $PM_{2.5}$ Data at Plaza

Year	Annual Average ($\mu g/m^3$)	No. (%) of Daily Values > 15 $\mu g/m^3$	No. (%) of Daily Values > 30 $\mu g/m^3$	Maximum Daily Value ($\mu g/m^3$)	Number of Samples
1994	-	4 (18.2%)	1 (4.5%)	52	22
1995	13.3	19 (31.1%)	3 (4.9%)	54	61
1996	12.7	17 (28.3%)	2 (3.3%)	40	60
1997	12.3	16 (26.2%)	5 (8.2%)	43	61
1998	11.3	18 (29.5%)	3 (4.9%)	52	61
1999	9.6	11 (18.3%)	2 (3.3%)	38	60
2000	11.5	12 (19.7%)	5 (8.2%)	52	61
2001	9.9	16 (26.2%)	4 (6.6%)	35	61
2002	11.2	14 (23.0%)	5 (8.2%)	34	61
2003	12.1	15 (24.6%)	3 (4.9%)	38	61

* Instrument installed August 1994

1.2 Source Identification under the Airshed Management Plan

The air quality management plan that went into effect in 1999 achieved reductions in the largest primary particulate emission sources, including sawmills, pulpmills, road dust, domestic woodburning and open burning (Prince George Airshed Technical Management Committee, 1998). Despite these actions, ambient $PM_{2.5}$ levels remain high in the downtown area, indicating the need for more precise identification of sources.

The first step in improving source identification was taken by doing a wind sector analysis of the continuous $PM_{2.5}$ data, using annually averaged levels at the Plaza site. The distribution of $PM_{2.5}$ concentrations by wind direction, from 1998 through 2002, shows the highest concentrations consistently concentrated in the northeast to southeast sector (Figure 2). The product of the annual average concentration, and the duration of winds, in hours per year, from each sector was calculated to assess the effect of wind direction on overall $PM_{2.5}$ contributions. The resulting distribution of cumulative contributions shows a pattern similar to that for $PM_{2.5}$ concentration alone. (Figure 3).

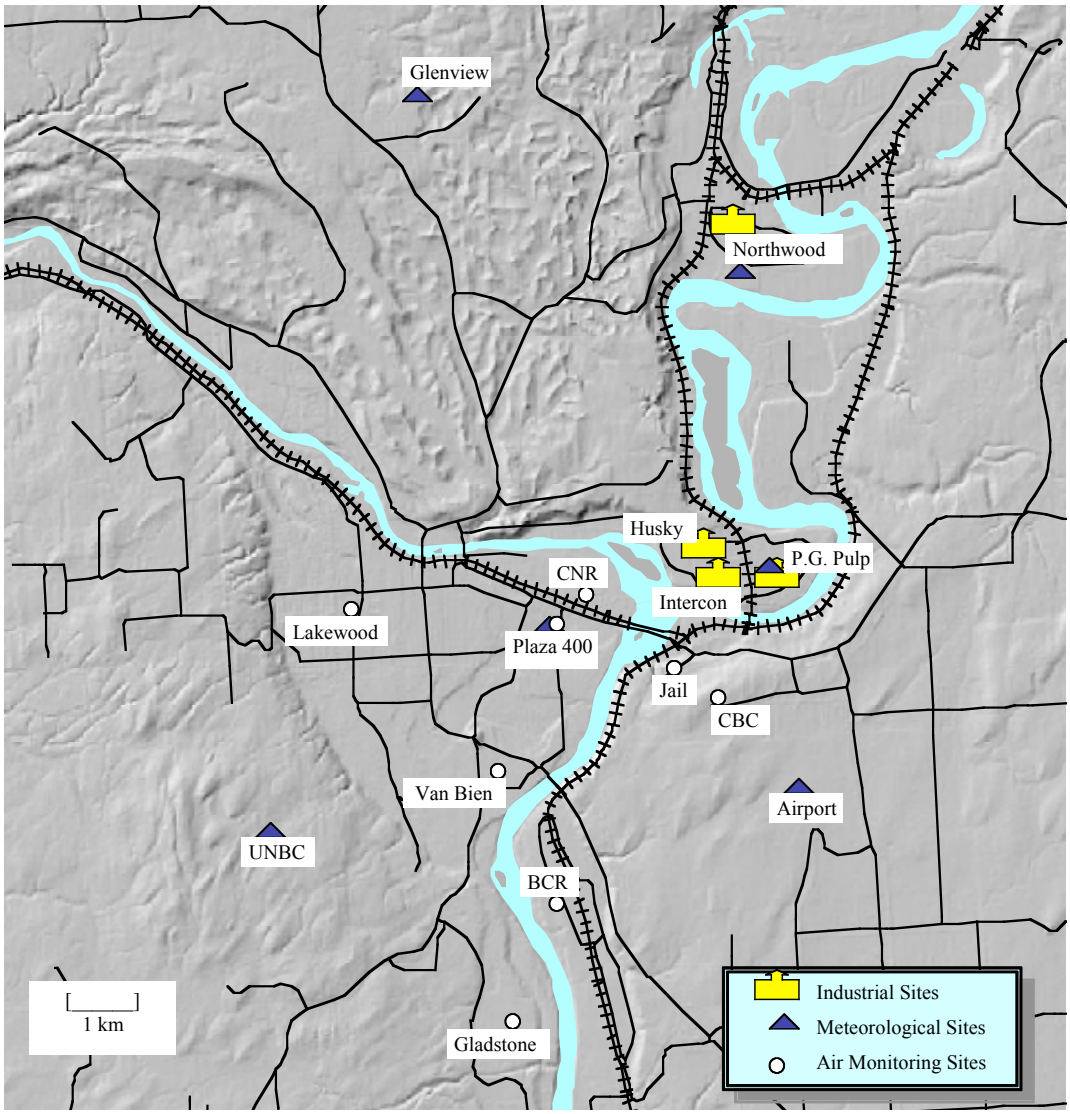

Figure 1. Location of meteorological and air monitoring sites in Prince George, BC.

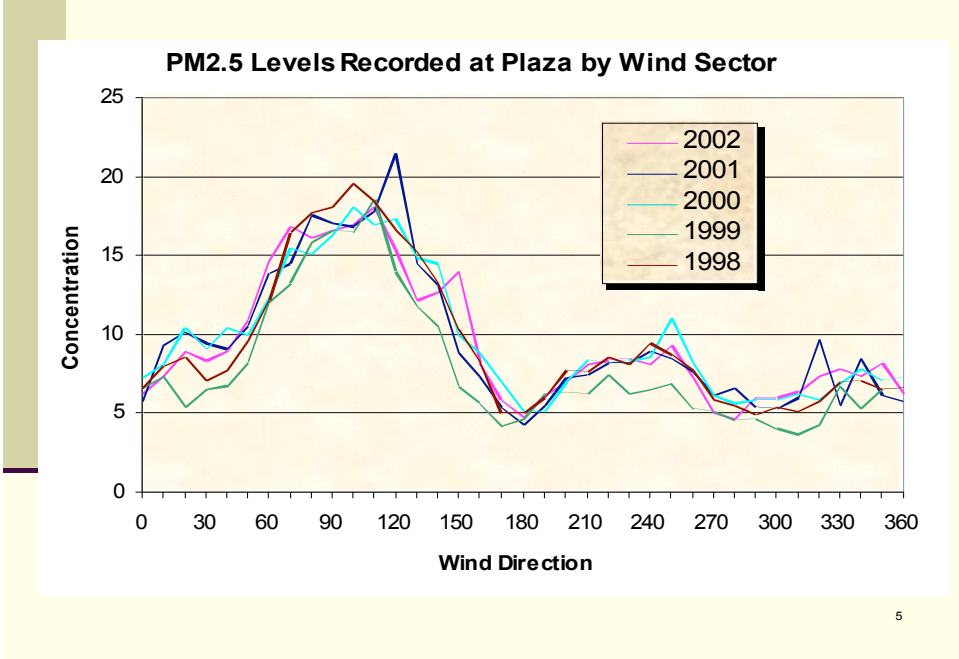

Figure 2: Prince George Plaza $PM_{2.5}$ Levels by Wind Sector (1998-2002)

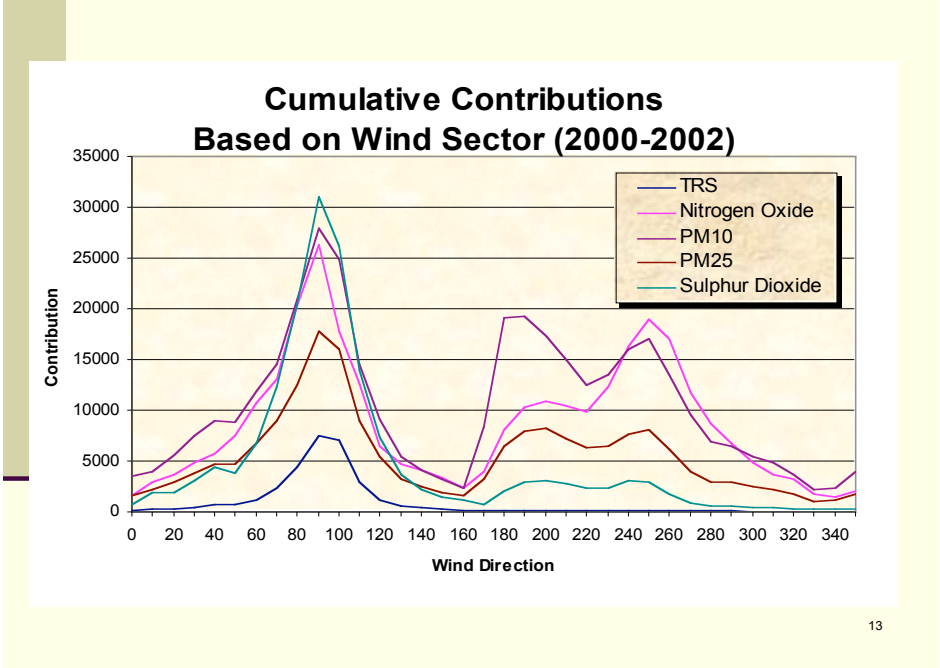

Figure 3: Prince George Plaza Cumulative $PM_{2.5}$ Contributions (2000-2002)

The most significant sources lie in the northeast-southeast, and south-southwest sectors relative to the central Plaza monitor. Contributions are particularly significant from the northeast-southeast sector, because of the prevalence of low-speed winds and wind channeling in that sector. The strong co-varying relationship between the sulphur gases, which originate almost exclusively from sources in that sector, and PM2.5, corroborates the results of this analysis.

The worst fine particulate episodes in the airshed also have significant contributions from up-valley sources (Sutherland and Fudge, 2002). Over the past 10 years, episodes for which public advisories were issued average about 10 days per year, with individual episodes ranging from 1 day to 7 days in length. Maximum twenty-four PM_{10} levels during these episodes ranged from 53 $\mu g/m^3$ to 155 $\mu g/m^3$, and $PM_{2.5}$ levels from about 50% to 90^+% of the PM_{10} levels. Cold season episodes are mainly dominated by $PM_{2.5}$ and spring episodes are more evenly split between $PM_{2.5}$ and the coarser ($PM_{10} - PM_{2.5}$) fraction.

The wind sector analysis provides basic information about the most significant potential $PM_{2.5}$ source types. While individual sources are not identified by this analysis, comparison of contributions from the two dominant sectors indicates the following:

1. The distribution of $PM_{2.5}$ contributions in the northeast-southeast sector mirrored that of SO_2, NO_2 and TRS, all of which originate from the industrial operations in that sector.
2. The combination of commercial and residential sources to the west-southwest of the Plaza site contributed significantly less $PM_{2.5}$ than all combined sources to the northeast-southeast, which indicates that commercial and residential sources are not the main contributors in this latter sector.

The overall conclusion from this analysis is that any future source identification studies must be able to distinguish between the northeast industrial sources and the commercial and residential sources that surround the Plaza monitoring site.

An attempt was made in 1997 to use the CALPUFF dispersion model to apportion PM_{10} sources for selected episodes (Jacques Whitford, 1999). Substantial over-prediction of the emissions from road dust, and uncertainty in sawmill beehive burner emissions limited the usefulness of this source modelling study for identifying sources. Subsequently, the Prince George Air Quality Implementation Committee – Research Working Group (PGAQIC-RWG) contracted with RWDI West to identify deficiencies in the emission inventory and suggest ways of improving it to a level suitable for dispersion modelling (RWDI, 2004).

2 Objectives

The overall objectives of this proposal are to i) identify the relative contribution of each major source in the Prince George airshed, to ambient air quality, especially particulate matter; and ii) examine scenarios for source reduction to maximize the reduction in ambient levels, especially of particulate matter.

3 Methods and Work Plan

In order to achieve the objectives of the study, the following steps, outlined below, will be undertaken: input data (emission and meteorological) for modelling prepared, air quality modelling conducted, model verification undertaken, and source assessment based on the model results, completed and assessed. The work will be undertaken by the Air Quality Project Manager (AQPM) and other staff hired for this project at UNBC and will be supervised by Dr. Peter L. Jackson, UNBC Environmental Science and Engineering Program. The AQPM will report to the PGAQIC-RWG and also work closely with BCMOE staff (especially Dave Sutherland and Dennis Fudge).

3.1 Model input data preparation

Emission factors for dispersion modelling of PM_{10}, $PM_{2.5}$, NO_x and SO_2 sources will be prepared by:

- Compiling emission data and emission factors that are appropriate for use in the selected dispersion models;
- Conducting or supervising surveys of emission sources such as domestic wood use, locomotive activities, etc. as needed;
- Assessing the suitability of each emission inventory source for modelling average annual and short-term (24-hour) ambient predictions; and
- Preparing an emission inventory report suitable for model input.

The work will be guided by the emission inventory assessment (RWDI, 2004) and will continue the PGAQIC-RWG efforts at addressing emission inventory issues described in Appendix A.

Emission and meteorological model inputs will be prepared by:

- Allocating the emission inventory data to spatial and temporal scales
- Preparing three years of meteorological data, including local surface and upper atmosphere wind measurements, for modelling

3.2 Modelling

Carrying out the modelling for long and short-term prediction of ambient levels of the selected priority pollutants by:

- Selecting the appropriate models;
- Running the models;

- Adding the dust contributions and comparing the model predictions to ambient levels;
- Assessing the effect of varying emission levels and other model parameters on model outputs (sensitivity analysis); and
- Preparing a source apportionment report.

This will be done both for the full three-year period as well as for specific episodes of high ambient levels in order to assess the contributors to both long term (chronic) exposure, and short term (acute) exposure. It is likely that different models will be used for the short term and long term modelling, due to computational constraints and the availability of data needed to drive the short term models.

3.3 Model Verification

The credibility of the model predictions will be assessed by:

- Comparing the model meteorology with observations available in the Prince George airshed
- Comparing the modelling ambient air quality results with the results of other airshed source identification studies, including:
    - a wind sector analysis (BCMWLAP, 2004)
    - past studies conducted in Prince George (e.g. Breed, 1999; Noullett, 2005)
    - ongoing $PM_{2.5}$ and PM_{10} coarse fraction speciation studies

3.4 Reporting

Deliverables for the project will include reports and possibly peer-reviewed papers documenting the findings in all phases of the study. The main deliverable will be a weight of evidence assessment of the relative significance of each contributor to ambient PM_{10} and $PM_{2.5}$ levels in the Prince George Airshed.

Results will be presented to, and feedback sought from:

- PGAQIC and PGAQIC-RWG on a regular basis
- The public (in conjunction with PGAQIC)
- Third party reviewers
- Funding agencies

Results will be made freely and publicly available on the project website at http://cirrus.unbc.ca/pgarwg.

At the conclusion of the project, a financial accounting of all expenditures will be made to the funding agencies.

3.5 Timeline

Milestone	Description	Start Date	End Date
1	Hire AQPM	2005-09-01	2005-10-31
2	Emission Inventory suitable for modelling	2005-01-01	2006-08-31
3	Meteorological data suitable for modelling	2006-01-01	2006-06-30
4	Model selection	2005-11-01	2006-01-31
5	Baseline modelling – long term models	2006-07-01	2006-10-31
6	Sensitivity testing – long term models	2006-11-01	2007-04-30
7	Short term modelling of episodes	2006-09-01	2007-08-31
8	Model validation	2006-09-30	2007-08-31
9	Consultations and feedback	ongoing	
10	Final report and recommendations	2007-04-01	2007-10-31

4 Budget

4.1 Expenditures

Item	Year 1	Year 2	Total
Air Quality Project Manager salary (including benefits)	$67000	$67000	$134000
Co-op and summer student salary (including benefits)	$20000	$15000	$35000
Equipment and supplies	$3000	$2000	$5000
Travel, training, meetings	$2000	$2000	$4000
Subtotal	$92000	$86000	$178000
UNBC overhead (15%)	$13800	$12900	$26700
Total	**$105800**	**$98900**	**$204700**

Note: equipment and supplies includes a computer. Benefits are at 21% for full-time employees. Normal UNBC overhead is 25%, 15% was negotiated for this project.

4.2 Revenues

Organization	Year 1	Year 2	Total
City of Prince George	$30000	$30000	$60000
Canfor	$15000	$15000	$30000
*Environment Canada	$25000*	?	$25000
Other partners			
Total	**$70000**	**$45000**	**$115000**

Note: *indicates the amount is not yet confirmed.

We intend to seek funds from other sources, such as the Clean Air Research Fund, the BC Ministry of Environment, Fraser-Fort George Regional District, and the BC Ministry of Health, to make up the deficit.

5 Intellectual Property

The motivation for this study is to provide the best possible information for managing air quality in Prince George. The results and any deliverables and intellectual property that arise from the study will remain vested with the creators at UNBC who will make all information freely available to the PGAQIC and its member partners, as well as the funding agencies, as soon as it is available.

6 References

BC MWLAP, 2005: *2003 Annual Air Quality Report for Prince George*, BC Ministry of Water, Land and Air Protection, 157pp. (available online at: http://wlapwww.gov.bc.ca/nor/pollution/environmental/air/index.html)

Jacques Whitford, 1999: *Prince George Airshed PM10 Study*. Report prepared for Northwood Inc.,

Prince George Airshed Technical Management Committee, 1998: *Prince George Air Quality Management Plan - Phase One - Final Draft*.

RWDI, 2004: *Prince George Emission Inventory Improvement Strategy*, Final Report, 27pp. (available online at http://cirrus.unbc.ca/pgarwg/docs/RWDI-PG-EI-Scoping-Final-Report-2004-05-27.pdf)

Appendix A

Research Implementation Plan – October 2004 to

PGAQIC – Research Working Group (RWG)

Latest table updates (in blue) showing input from January 18,2005 RWG meeting at City Hall. In attendance were:

- Del Reinheimer
- Dennis Fudge
- Dave Sutherland
- Gina Layte Liston
- Peter Jackson
- Glenda Waddell (Scribe)

Dec 2, 2004 RWG meeting at MWLAP Offices. In attendance were:

- Dave Sutherland
- Dennis Fudge
- Del Reinheimer
- Gina Layte Liston
- Ron Fujino
- Glenda Waddell (Scribe)

	Target	Action	Due Date	$ Estimate
1.	Estimate road dust contributions by speciation of ambient samples	**MWLAP to provide proposal for PM10 and PM2.5 dust speciation**. Observed values will be matched with dispersion model estimates to generate local adjustment factors to be applied to the EPA empirical equations for calculation of dust emissions.	Dec 10, 2004	

	Target	Action	Due Date	$ Estimate
		❑ Per Committee discussions Oct 19, 2004, focus should be on PM2.5 component of road dust including metals, carbon, diesel emission particles, rubber, crustal. Considerations for location of background site: • Ease of access • Should it be most representative of impacts i.e. upstream of prevailing wind or in a location away from prevailing winds so that reverse flows don't disable its function as a background monitor? • Are we trying to assess natural background or incoming airstreams that most impact the airshed? Should we avoid peaks like Pilot Mtn as they will show less PM from vegetation? 13/01/2005 - Sampling for speciation due to start at end of January. Potential background monitor location - Western Acres Wetlands at City well. City staff attend the site daily. **MWLAP to visit site to determine acceptability.** **Site has been selected and monitors are being set up week of April 11th.** **Gina to supply a map showing all well/reservoir locations.**		
2.	Update and improve mobile source emission estimates	**City to incorporate this target with their initiative to inventory GHG emissions**. ❑ Traffic Survey to include: i. Vehicle type and age ii. miles traveled iii. level of vehicle maintenance iv. fuel types (gas, diesel, propane) • **MWLAP to determine method used by Quesnel to survey traffic** • **Gina to discuss survey criteria with consultant to ensure we are asking the right questions.**	City GHG inventory Report to be completed March 31, 2005	Paid for as part of Partners for Climate Protection Milestone One.

	Target	Action	Due Date	$ Estimate
		• 13/01/2005 – MOT will share traffic studies and supply any additional studies required. • Fuel purchase info available for all city pumps back to 1981 from Market database firm – doesn't include fleet fuel usage. • ICBC supplying vehicle inventory by end of Jan. Inventory includes types including car, truck, # axles. Breakdown by 4 postal code areas in PG.		
3.	Determine Traffic patterns	Traffic studies on major roadways to determine local travel and vehicle fleet characteristics. • **Gina to contact MOT to determine:** ▫ **what traffic counts have been done on major routes (i.e. 1st Ave, Hwy 16, Hwy 97, Victoria St.), and** ▫ **what enforcement capabilities MOT has for emissions testing.**		
4.	Estimate impact from vehicle emissions	Upon completion of Traffic Survey, **RWG to commission use of Mobile 6.2C** to estimate vehicle emission impacts using more location-specific information as inputs. • **Dennis to:** ▫ **determine whether 6.2C gives PM2.5** ▫ **supply Gina with 6.2C model criteria** 13/01/2005 – PM2.5 is included Gina has 6.2 model criteria but limited use to GHG survey consultants		$5,000 to $7,000 (RWDI)
5.	Update and improve wood stove source emission estimates	**City to commission a fuel use survey** including items such as: ▫ stove types ▫ temporal/seasonal distribution of wood burning ▫ species burned (e.g. softwood vs Birch)		$15,000 to $25,000 (RWDI)

	Target	Action	Due Date	$ Estimate
		▫ wood burned per yr ▫ factors that influence wood stove use (e.g. fuel prices) Survey results to be presented on a format that can be updated as new wood burning licenses are issued. Options for getting this information include: • Insurance agencies will give numbers of wood burners in PG – **Gina to request this information** • Online homeowner's grant application – could expand to include survey questions • Could insert post card surveys in utility bills or taxes – reaches 22,000 homes • **Gina to get costs for business reply mail to avoid cost of 22,000 stamps** **1/13/2005 - Business reply costs $500 plus postage for all returned** **Difficult to get info from insurance companies.** **Considering post card surveys sent with tax bills in May. One question should identify subdivision.** **Alot $ for processing of surveys.**	Dec 10, 2004	
6.	Determine significance of soot blowing from pulpmills	Canfor presentation to RWG of Oct 5, 2004 (on PGAQIC private research website) described the emissions testing program. Stacks are routinely sampled at mill run rates that are significantly above average. Periods (minimum 2 hrs per day) when power boilers are not burning wood fuel are not taken into account in reporting total emissions. While emissions from individual stacks can vary, total mill emissions as recorded by quarterly tests are consistent over several years of testing. Soot blowing occurs 2 hrs/day at the 2 power boilers at Northwood and at 1 power boiler at PGSPP. Given that pulpmill sources are, by far, the best characterized in the airshed, and that quarterly stack results represent the highest rates of operation, **RWG will model based on these data to determine magnitude of impact and therefore the need for additional information on emissions.**		

	Target	Action	Due Date	$ Estimate
7.	Improve data on temporal variability of pulpmill sources.	A correlation between continuous opacity measurements and test results has been discussed. The operation of this instrument was outlined at the Oct 5 presentation. Reliability issues include drift over time, spikes due to larger particles and fog and the absence of corresponding flow data. While emissions from individual stacks can vary, with the exception of step changes, total mill emissions as recorded by quarterly tests are consistent over several years of testing. However, the effect of emission variability from all major sources should be assessed in the modeling project (per D. Sutherland Dec 3, 2004 e-mail). The RWG will need to consider whether the benefits of such a correlation warrant the necessary resources. The mean value of all stack measurements made in the past 2 years – or since the last major modification at a facility – will be used to estimate emission rates. **Del to consider whether quarterly stack tests on recovery boilers and power boilers should be conducted at operating rates other than the current target of 90%ile.**		
8.	Improve untested Permitted source emission estimates	**MWLAP to tabulate untested Permitted emissions to determine common processes (e.g. cyclones, bag houses). From this inventory, determine next steps** which might include: ❑ Estimation of particle size ❑ Representative stack samples ❑ Survey Permittees to determine temporal and seasonal emissions variability **MWLAP is working to hire a temporary person (Q1, 2005) who might complete the tasks outlined here. MWLAP will provide input as required to Research Project Manager.**		$15,000 to $20,000 (RWDI)

	Target	Action	Due Date	$ Estimate
		MWLAP to determine method used by Quesnel to assess sawmill emissions.		
9.	Update and improve rail source emission estimates	**MWLAP (TW) to obtain railway data for PG** which includes: ❑ additional activity associated with rail yards in the airshed ❑ number of locomotives ❑ operating hours of rail yards ❑ operation cycles (i.e. idle, throttle speeds) **MWLAP is working to hire a temporary person (Q1, 2005) who might complete the tasks outlined here. MWLAP will provide input as required to Research Project Manager.** **MWLAP to determine method used by Quesnel to estimate railway emissions.**		$5,000 to $7,000 (RWDI)
10	Improve emissions estimate from open burning.	**MWLAP (DS) to determine how the open burning emission inventory was handled in Bulkley Valley Airshed**. Improved spatial and temporal data is required for modeling. RWG to determine need for CONSUME model. **MWLAP is working to hire a temporary person (Q1, 2005) who might complete the tasks outlined here. MWLAP will provide input as required to Research Project Manager.**		
11	Resources	**13/01/2005 - Peter to discuss project management role with Research Associate at UNBC** 6.1.1.1.1.1.1 Dave to develop job description/cost estimate including cost of personal computer.	Next wk before steering committee	
12	Next Meeting	**1st week in January? Jan 4, 1pm?**		