

Air Quality 101: What local politicians need to know to manage AQ in Prince George

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Air Quality Management

- Goal is to lower **ambient** levels of particular pollutants to a level sufficient to protect health, environment and quality of life
- Decision makers have to weigh information from various sources and experts, as well as potentially competing interests (e.g. health, environment, economy) on behalf of the public

Air Quality Considerations

Sources → Atmosphere → Receptors

All must be considered!

Most AQ issues are complex and solutions that work can be challenging

What we care about are impacts on Receptors (i.e. people)

Sources

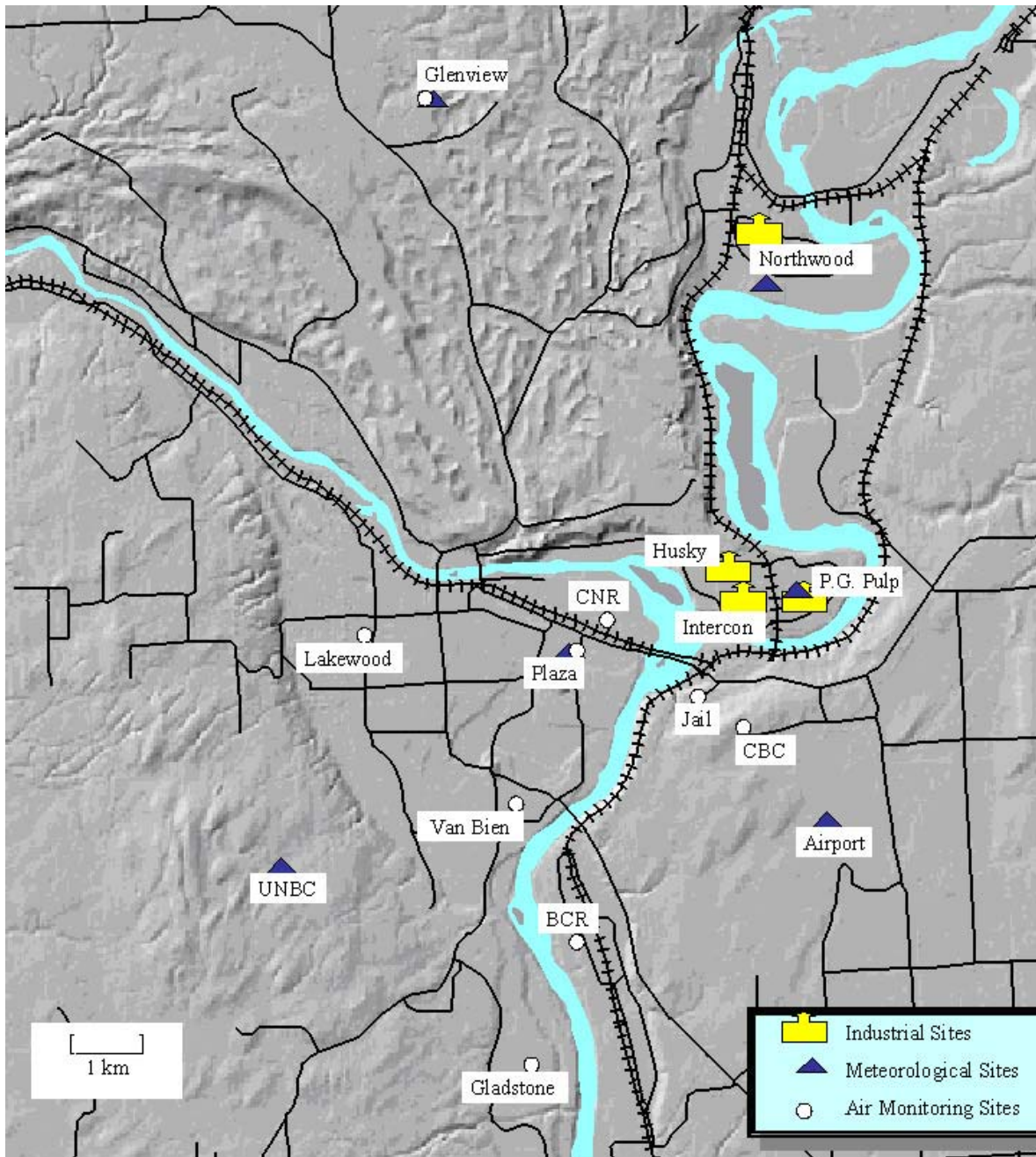
- No source = no pollution!
- Amount, configuration, characteristics all important
- Total discharge of a particular source may not be as important as other factors (e.g. elevation of emission, distance from population)

Atmosphere

- Acts to **dilute, disperse, transform, remove** pollutants, as well as **transporting** them between source and receptor
- Most AQ episodes are due to atmospheric conditions, **not** emission changes
 - **Inversions and light winds associated with High Pressure systems cause episodes in PG**

Receptors

- Where pollution is received and has impact (where people live and work)
- Different pollutants will have different impacts (e.g. PM vs TRS)
- Health issues, environmental degradation, visibility, nuisance / odor, etc.



PG Topography

- PG in a “bowl”
- “bowl” restricts free mixing of air and dilution of pollution
 - especially under inversion conditions and light winds



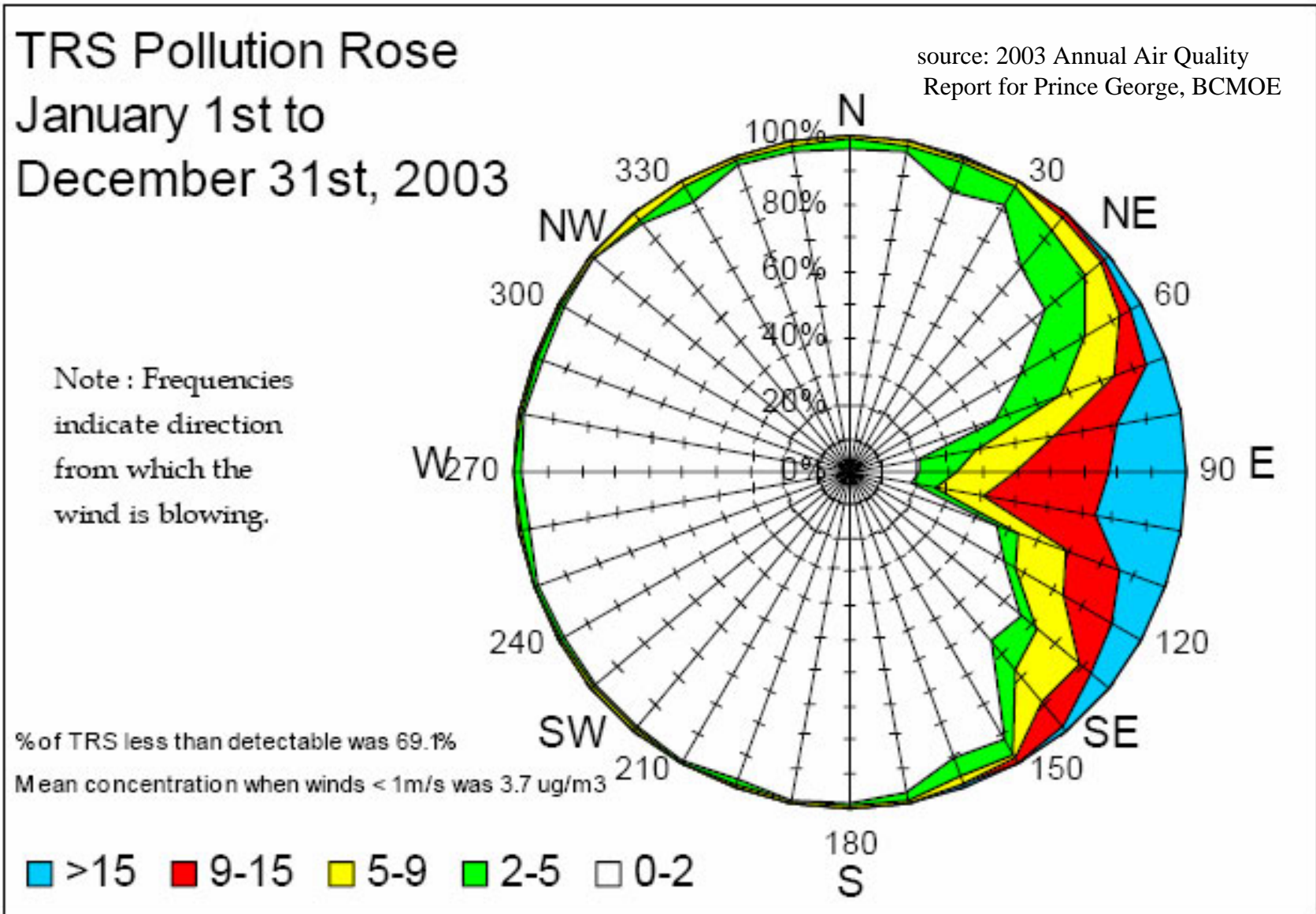
BC Ambient Air Quality Objectives

- Level A Maximum Desirable for the long-term goal for air quality and forms the basis for anti-degradation policy for the pristine parts of the country and for continuing development of control technology.
- Level B Maximum Acceptable is intended to provide adequate protection against the effects of pollution on soil, water, vegetation, materials animals, visibility, personal comfort and well being.
- Level C Maximum Tolerable denotes time based concentrations of air contaminants beyond which, due to diminishing margins of safety, appropriate action is required without delay to protect the health of the general population.

Contaminant	Averaging Period	Level A	Level B	Level C
1. Total Reduced Sulphur	1 hour	7.5	28	42
	24 hour	4	6	7.5
2. Sulphur Dioxide	1 hour	450	900	1300
	24 hour	160	260	360
	Annual	25	50	80
Nitrogen Dioxide	1 hour		400	1000
	24 hour		200	300
	Annual	60	100	
Total Suspended Particulate (TSP)	24 hour	150	200	260
	Annual	60	70	75
3. Particulate Matter (PM ₁₀)	24 hour		50	
Formaldehyde (HCHO)	1 hour	60		
Lead in TSP	24 hour	4	4	6
	Annual	2	2	3
Ozone	1 hour	100	160	300
	24 hour	30	50	
	Annual		30	
Carbon Monoxide	1 hour	14,300	28,000	35,000
	8 hour	5500	11,000	14,300

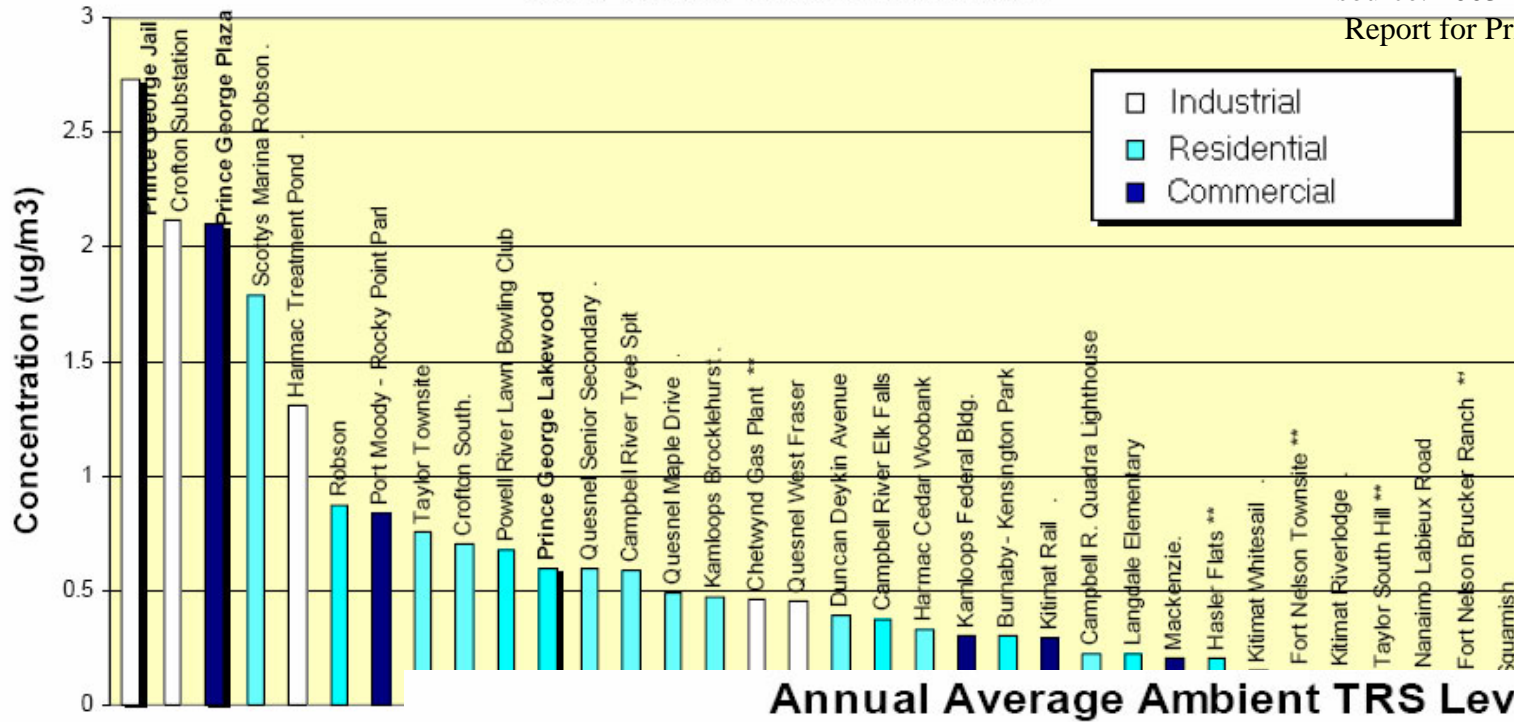
4. Also – for PM_{2.5} Canada Wide Standard in 2010 will be 98th percentile of 30 µg / m³ averaged over 3 years (can exceed 30 only 2% of the time = 7 days / year)

Figure 4.1.2: TRS Pollution Rose at Plaza for 2003



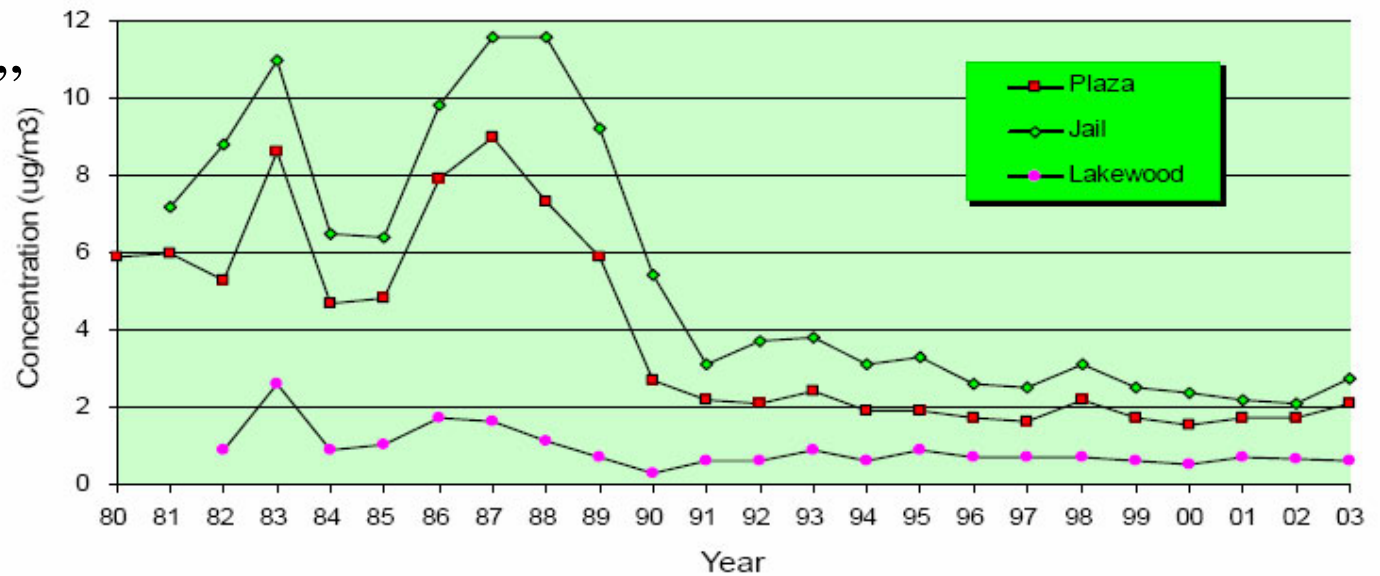
Comparison of 2003 Annual Average TRS Levels with Other B.C. Locations

source: 2003 Annual Air Quality Report for Prince George, BC MOE



** Only monitors H2S

Annual Average Ambient TRS Levels



- TRS = “the smell”
- Dominant source
- is pulp mills

Source: BC Ministry of Environment
Wind sector analysis

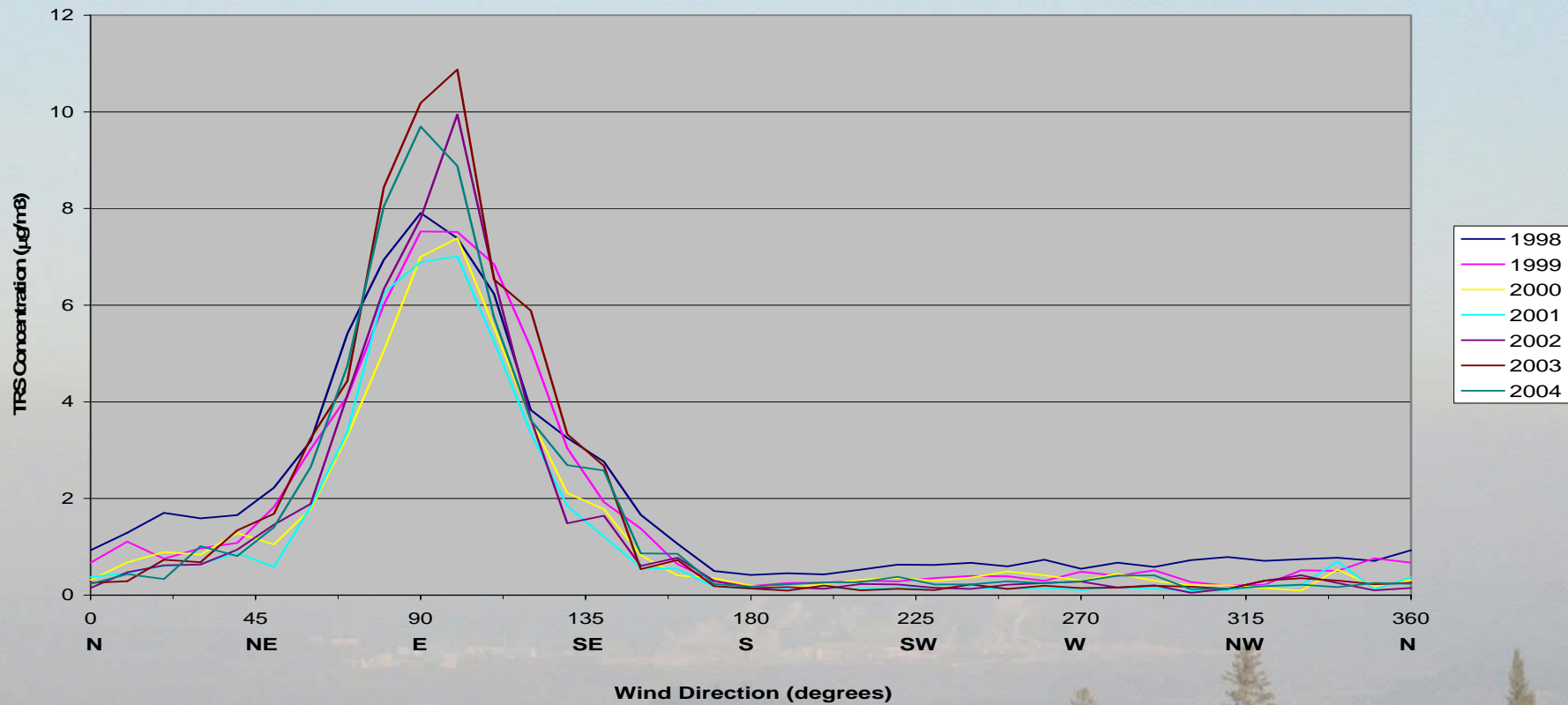


Figure 5: Variation in annual distributions of Prince George Plaza 400 TRS concentrations ($\mu\text{g}/\text{m}^3$) by wind direction (degrees), from 1998 to 2004.

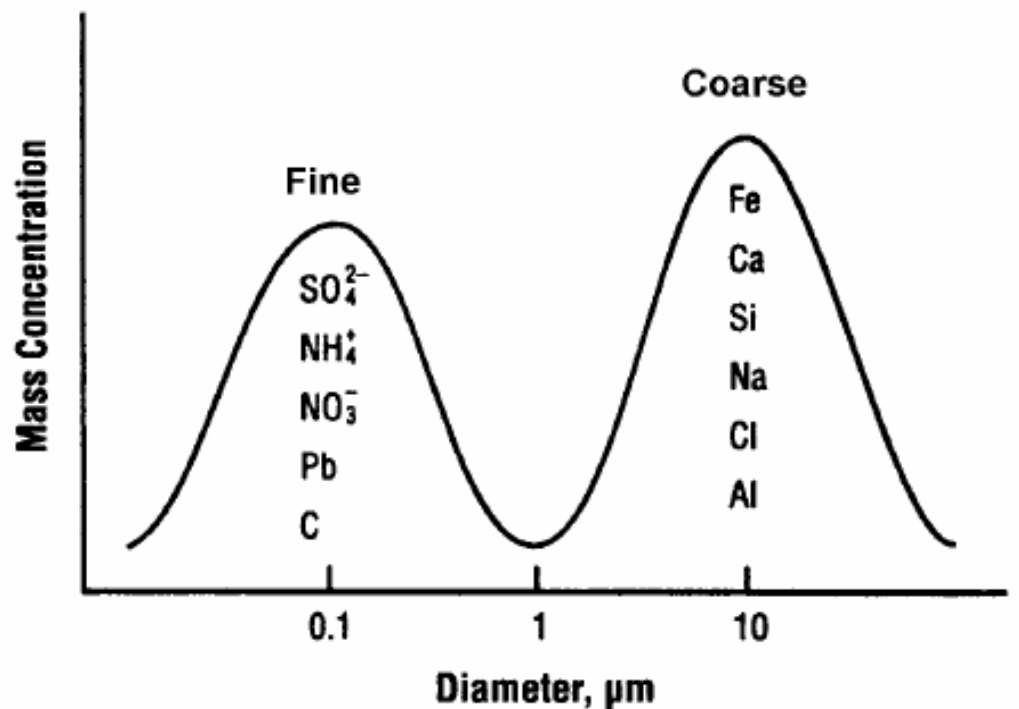
Particulate Matter – What is it?

- An airborne atmospheric particle
- PM10 - a particle of 10 microns, about 1/5th the width of a human hair.
- PM2.5 - a particle of 2.5 microns, about 1/20th the width of a human hair
- BC Ministry of Health has called PM **“single greatest air pollution problem in BC”**
- PM10 – travels into the lungs and cause a variety of respiratory problems
- PM2.5- penetrates the respiratory system deeper and is therefore more of a problem than the sizes > 2.5 microns

- PM size distribution is bi-modal.

- coarse mode generally results from mechanical breakdown of larger particles

- fine mode generally results from combustion processes and secondary particulates



Source: Seinfeld (1986)

- PM_{2.5} is about 15% dust and the rest from combustion – it can be used as a measure of ambient conditions due to combustion sources

- The coarse fraction (PM₁₀ – PM_{2.5}) comprises 85% of the dust

Typical PM_{2.5} Components

- **Geological Material** – suspended dust consists mainly of oxides of Al, Si, Ca, Ti, Fe, and other metal oxides.
- **NaCl** – salt is found in PM near sea coasts, and after de-icing materials are applied.
- **Sulfate** – secondary particulate resulting from conversion of SO₂ gas to sulfate-containing particles.
- **Nitrate** – secondary particulate resulting from a reversible gas/particle equilibrium between NH₃, HNO₃, and particulate ammonium nitrate.
- **Ammonium** – ammonium bisulfate, sulfate, and nitrate most common.
- **Water (liquid)** – soluble nitrates, sulfates, ammonium, sodium, other inorganic ions, and some organic material absorb water vapor from the atmosphere.
- **Organic Carbon (OC)** – consists of hundreds of separate compounds containing mainly carbon, hydrogen and oxygen.
- **Elemental Carbon (EC)** – composed of carbon without much hydrocarbon or oxygen. EC is black, often called soot.

Chow and Watson, 1997

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Sources of PM

- Industrial processes
- Dust
- Locomotive engines
- Heating
- On-road mobile
- Burning
- Chemical transformations of gases (e.g. SO₂) to sulfate (secondary particulates)
- **Many** others

Diversity of Sources Makes PM difficult to manage!

Sources

Table 7.13.1: Summary of PM source emissions (g/sec), assumed valid for year 2005.

Sec No	PGAQ (2005)	Peak emission rates (g/sec)				Average emission rates (g/sec)			
		NOx	SOx	PM10	PM2.5	NOx	SOx	PM10	PM2.5
2	Permitted	38.5	39.7	65.7	43.8	36.8	37.0	62.3	41.9
3	On-road dust			270.0	27.0			45.9	4.6
4	Railway	510.0	2.8	11.1	10.5	461.0	2.4	10.1	9.6
5	On-road mobile	67.7	1.1	2.4	1.7	11.5	0.2	0.4	0.3
6	Res Heating	12.1	0.2	7.1	7.1	3.4	0.1	2.0	2.0
7	Burning			4.0	3.8			2.7	2.5
8	Com Heating	8.4	0.1	0.6	0.6	2.4	0.0	0.2	0.2
9	Res Sources			9.0	9.0			4.5	4.5
10	Com Sources	88.0	9.0	109.6	29.2	32.0	32.0	82.2	21.9
11	Wind-blown PM			2000.0	200.0			250.0	25.0
12	Secondary formations			60.5	60.5			60.5	60.5
	Sum	725	53	2540	394	547	72	520	173

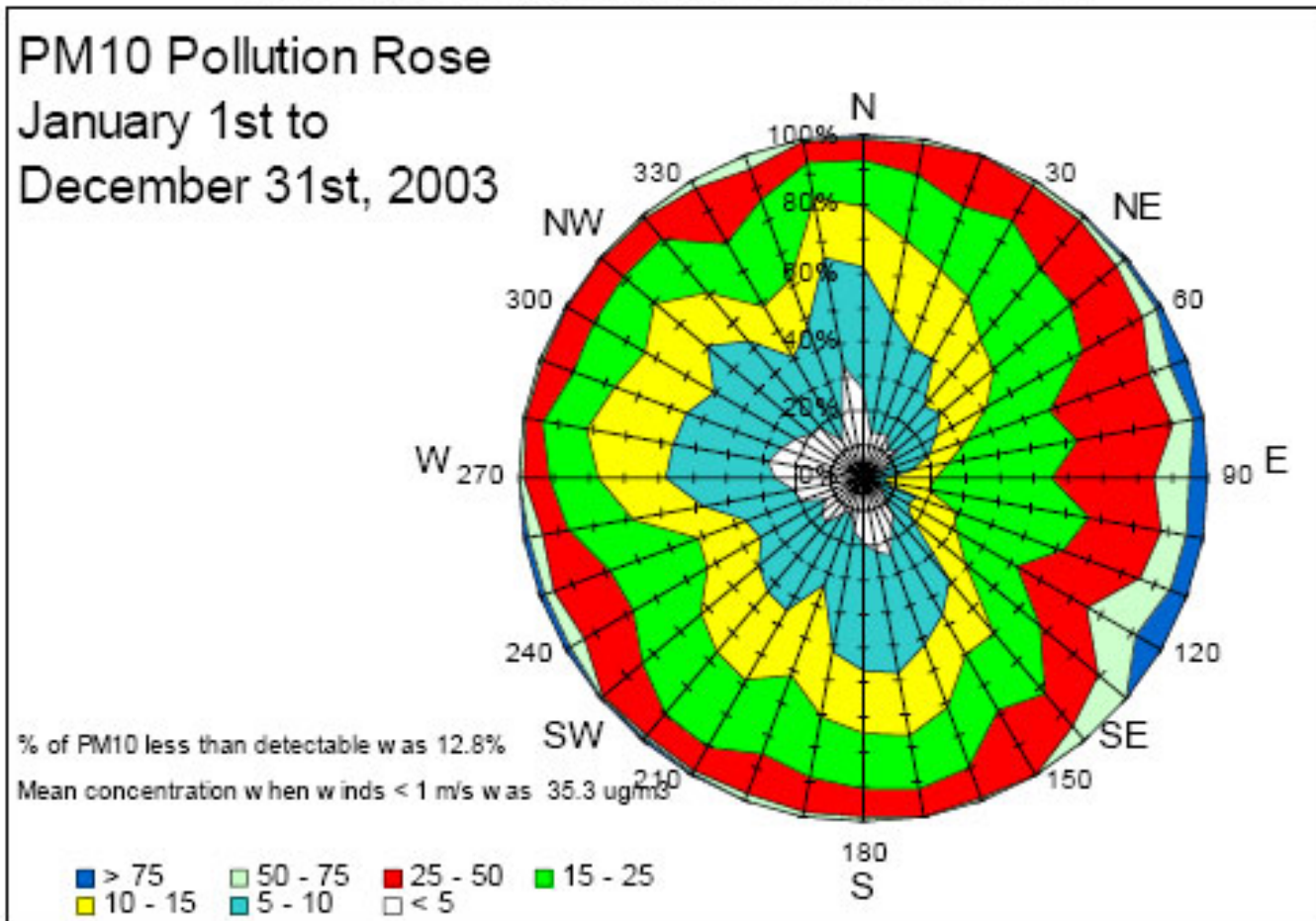
Permitted sources are a combination of stack testing and permit levels; road dust source estimates and locomotive estimates are uncertain.

PM Bottom Line

- Smaller particles (PM_{2.5}) are worse than larger particles (coarse part of PM₁₀)
- Particles from combustion more harmful than particles from dust
- Many sources of PM are hard to quantify

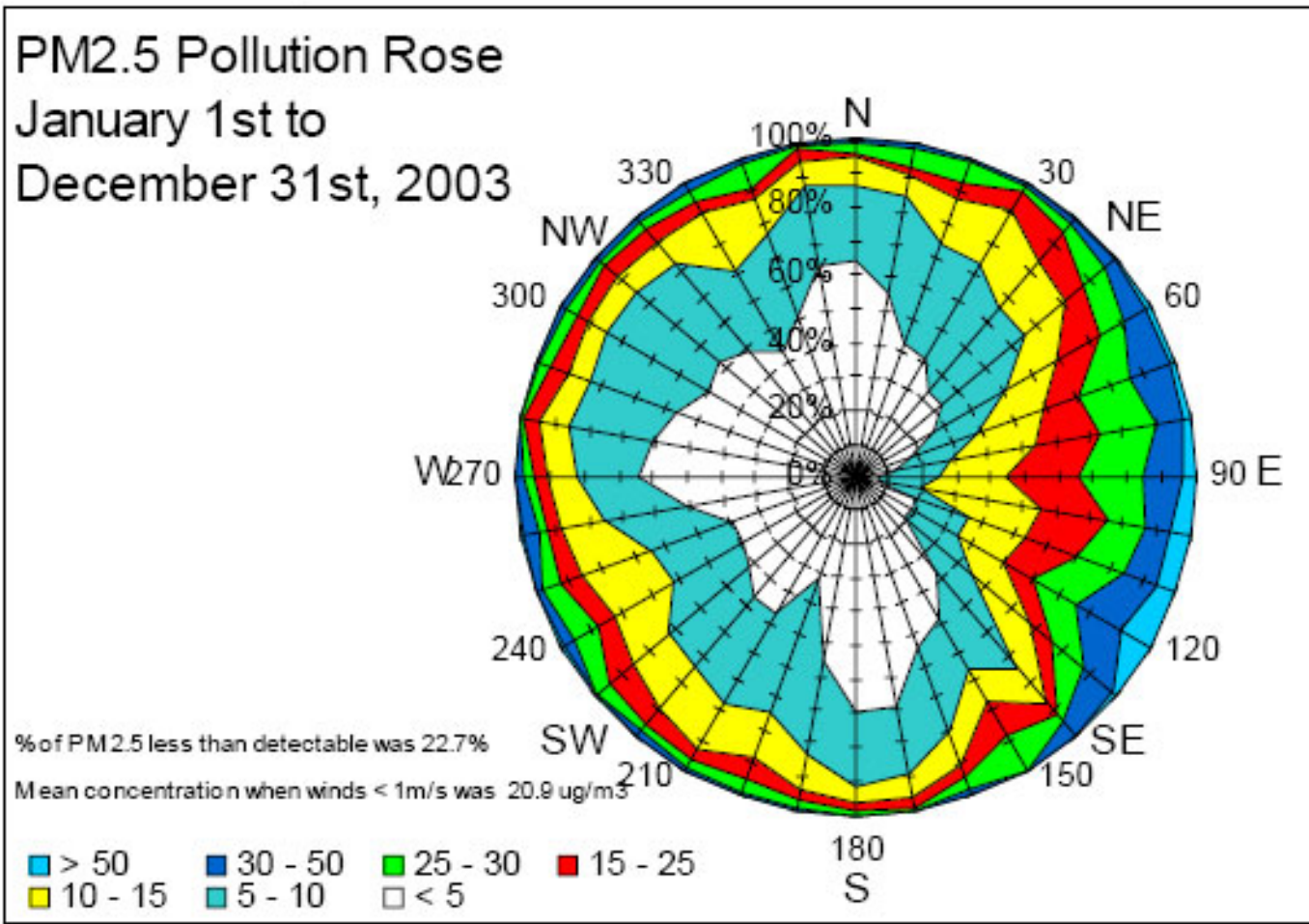
PM10

Figure 4.5.7 PM₁₀ Pollution Rose at Plaza for 2003

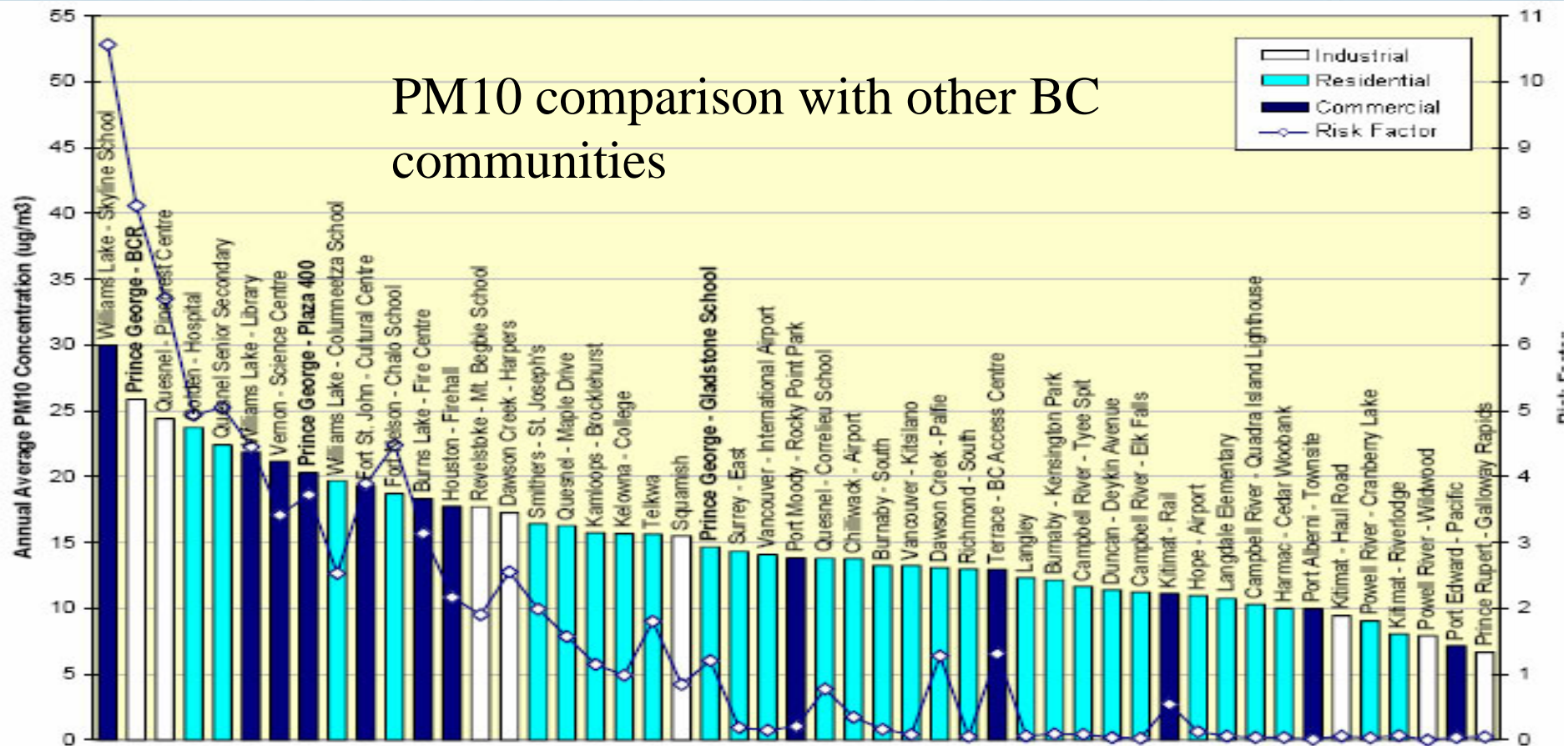


PM2.5

Figure 4.5.14 PM_{2.5} Pollution Rose at Plaza for 2003

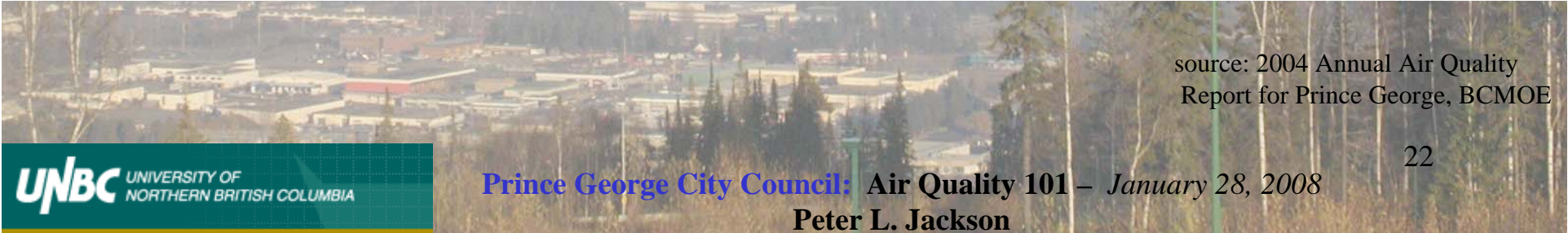
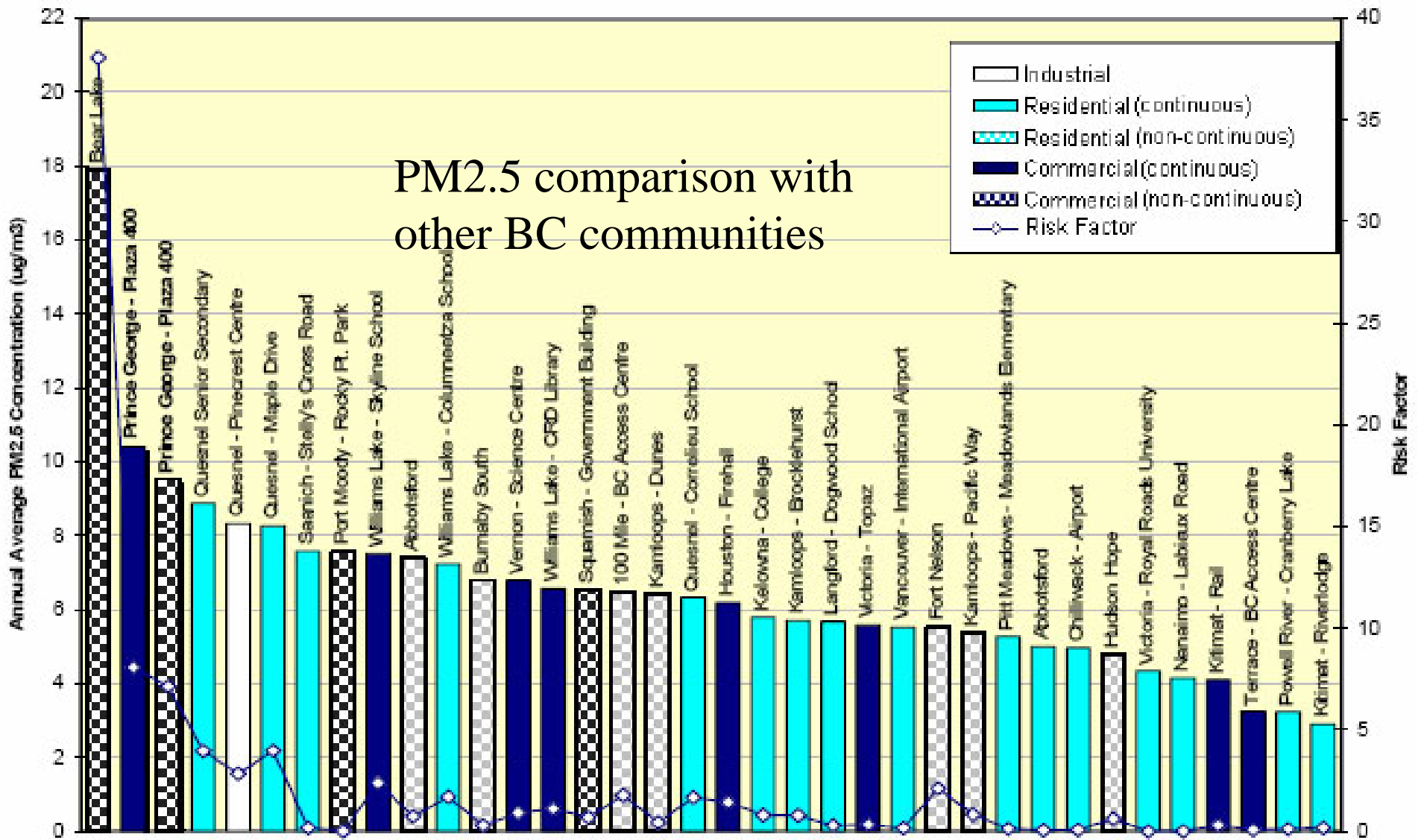


PM10 comparison with other BC communities

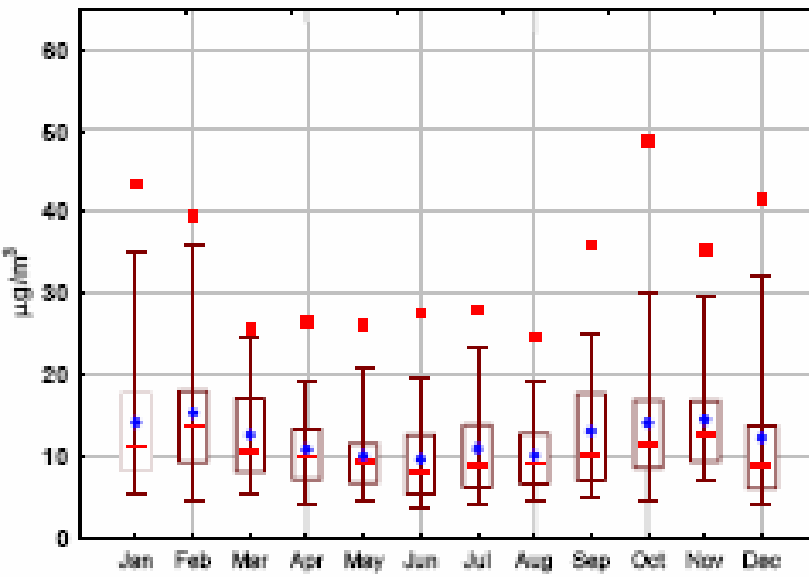
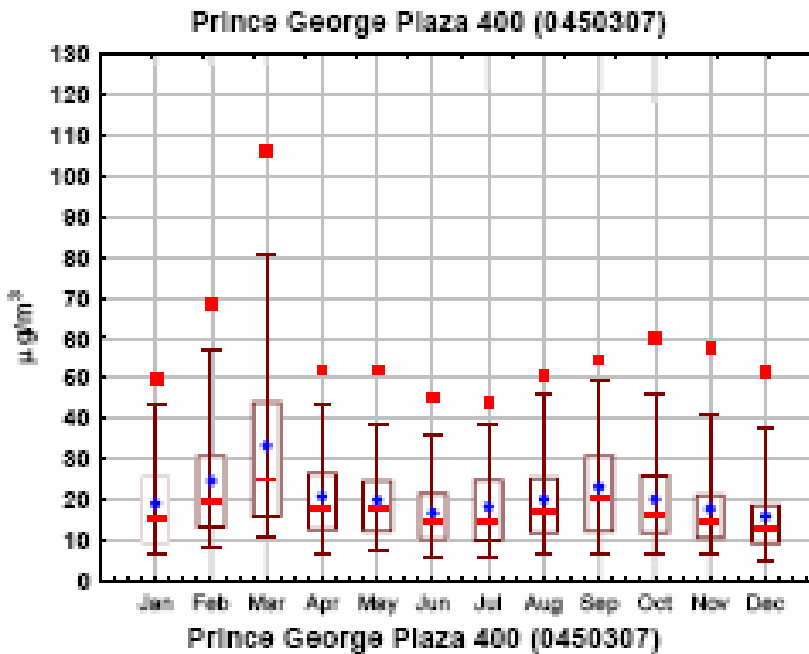
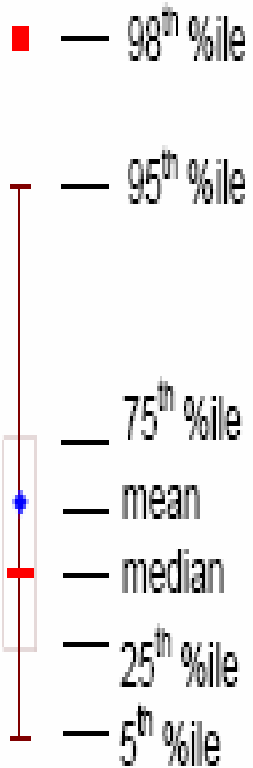


Risk factor is a relative health index normalized to 2000 average values based on increments > 25 ug/m³

source: 2004 Annual Air Quality Report for Prince George, BC MOE



source: 2004 Annual Air Quality Report for Prince George, BCMOE

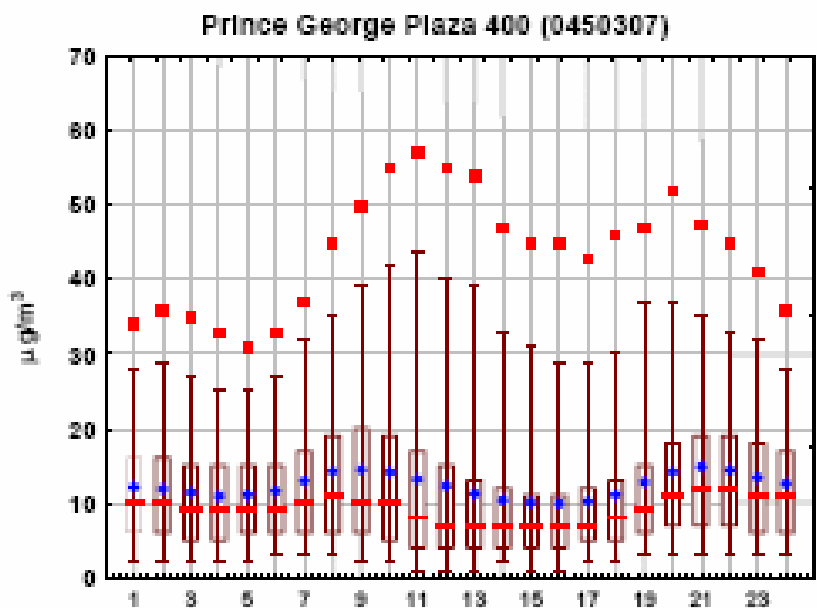
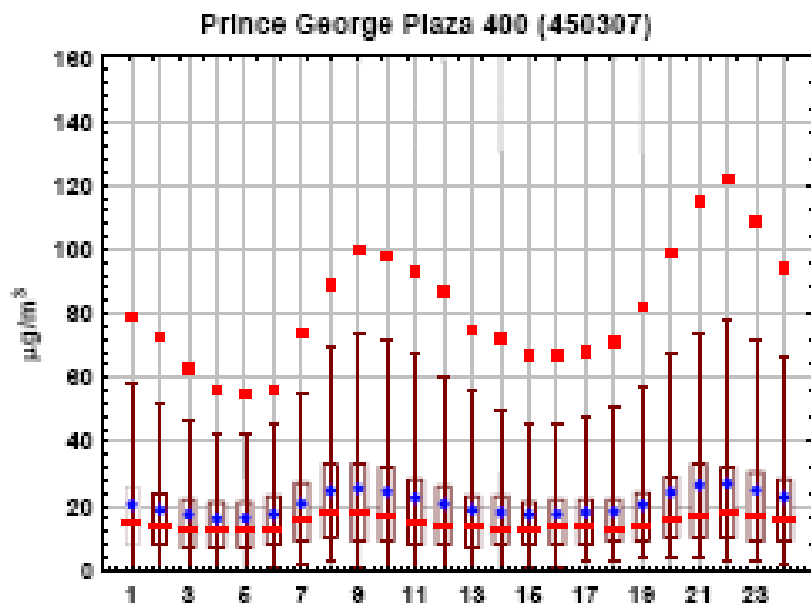


- annual variation in PM10 shows influence of dust episodes in late winter / early spring as roads dry out

- PM2.5 levels are highest in fall and winter due to combustion combined with stagnation events

source: Suzuki and Taylor, 2003.

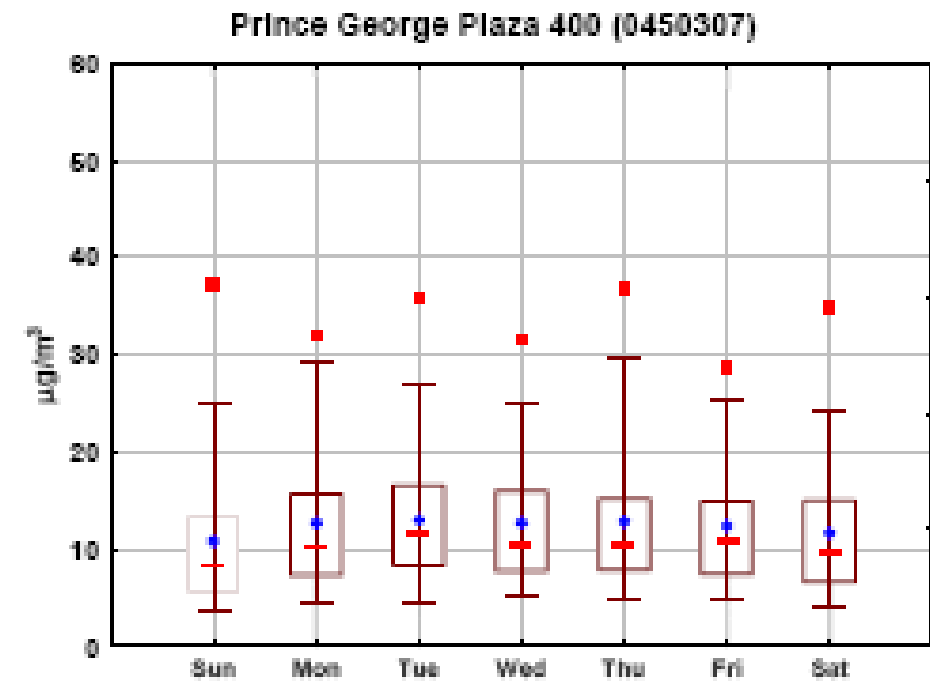
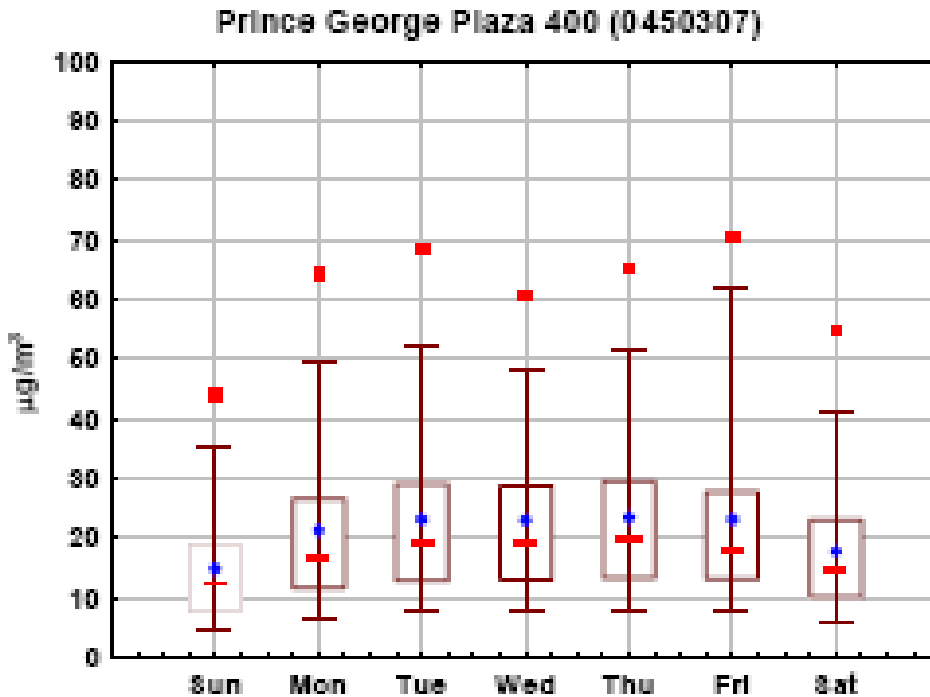




- PM10 – diurnal variation responds to traffic (dust)

- PM2.5 – can see the influence of fumigation events (late morning) on the 95th and 98th percentiles

source: Suzuki and Taylor, 2003.



- hebdomodal variability shows higher levels of PM_{10} during the week reflecting traffic and work patterns that generate dust (episodes caused by dust sources)

- $PM_{2.5}$ have somewhat lower median and mean values during weekends, but 95 and 98th percentile values show no weekly trend (episodes caused by combustion sources which operate 24/7)

source: Suzuki and Taylor, 2003.

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Information / Research Needs for Management of PM

- Goal of PM management is to reduce both average and episodic PM levels in airshed
- This requires knowing which **sources** are contributing to average and episodic levels
- Characterization of PM sources from routine ambient data is useful but may not provide strong enough evidence
- Several methods for evaluating source contributions exist, each giving different sorts of answers: **none are perfect!**
- Methods can be highly complementary
- If results from different studies point to same results (triangulation), then they increase confidence and strengthen management actions that result

Research Studies

- Past studies done by Industry, BCMOE, UNBC, etc.
- Some sources are very poorly characterized – especially non-industrial sources
- Current studies have the goal of improving understanding of contribution of all PM sources to ambient AQ and inform phase III AQ Mgmt plan

Types of Source ID Studies

1. Receptor Modelling

- based on **ambient AQ data**
- wind sector analysis (Fudge et al, BCMOE)
- chemical mass balance (CMB) – associates source chemical source profiles to ambient data (EC/BCMOE/STI study)
- PCA / PMF (EC/BCMOE/STI study) - lets the ambient data “speak for themselves” and infers source profile

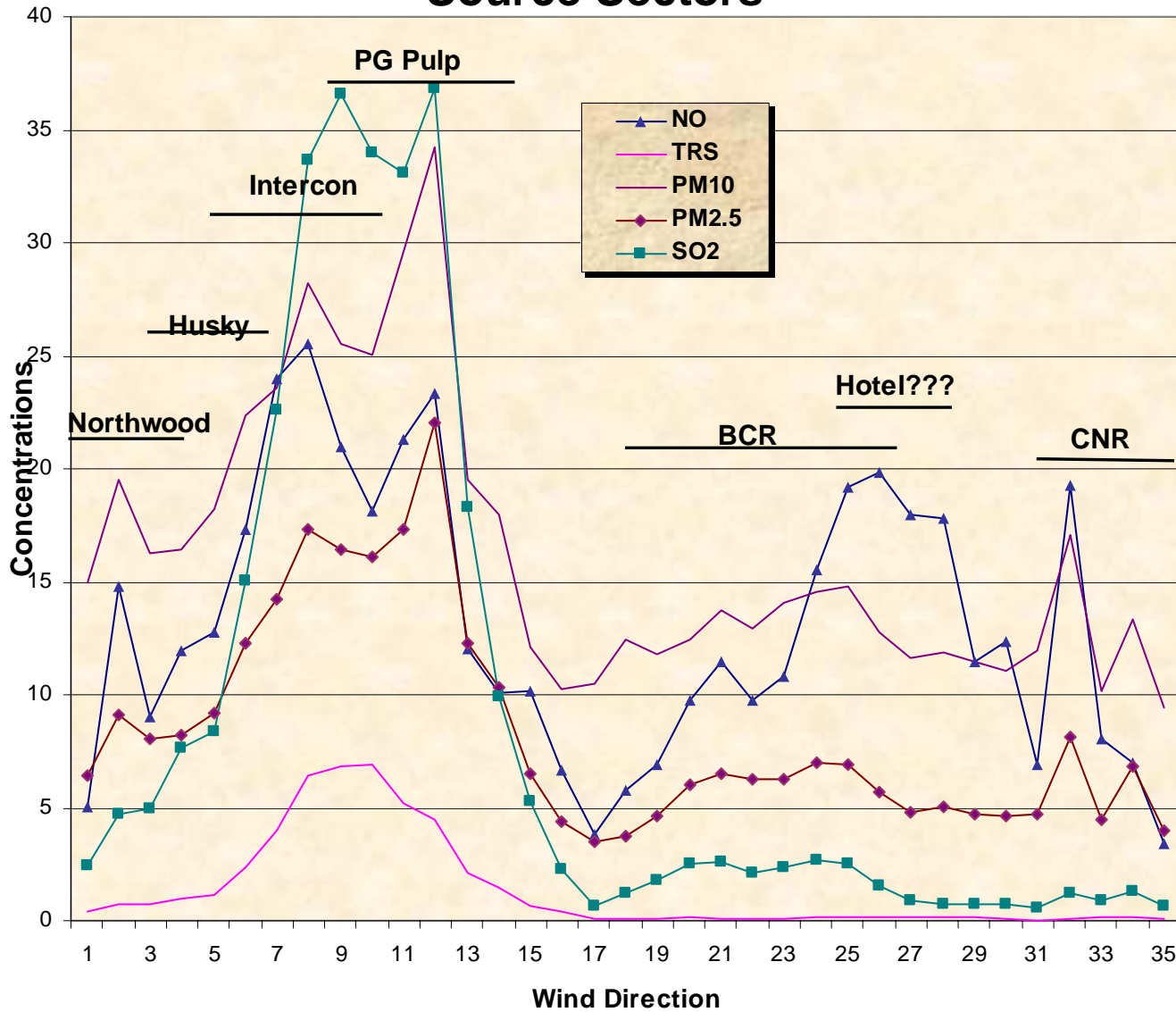
2. Dispersion Modelling

- based on **source emission inventory**, meteorological data
- validated by ambient data and can determine contributions of individual sources at any receptor in the airshed
- Many “levels” of modelling
- Several past studies by gov’t / industry
- Current comprehensive study using Calpuff (Spagnol et al, UNBC – PGAQIC – Research Working Group)

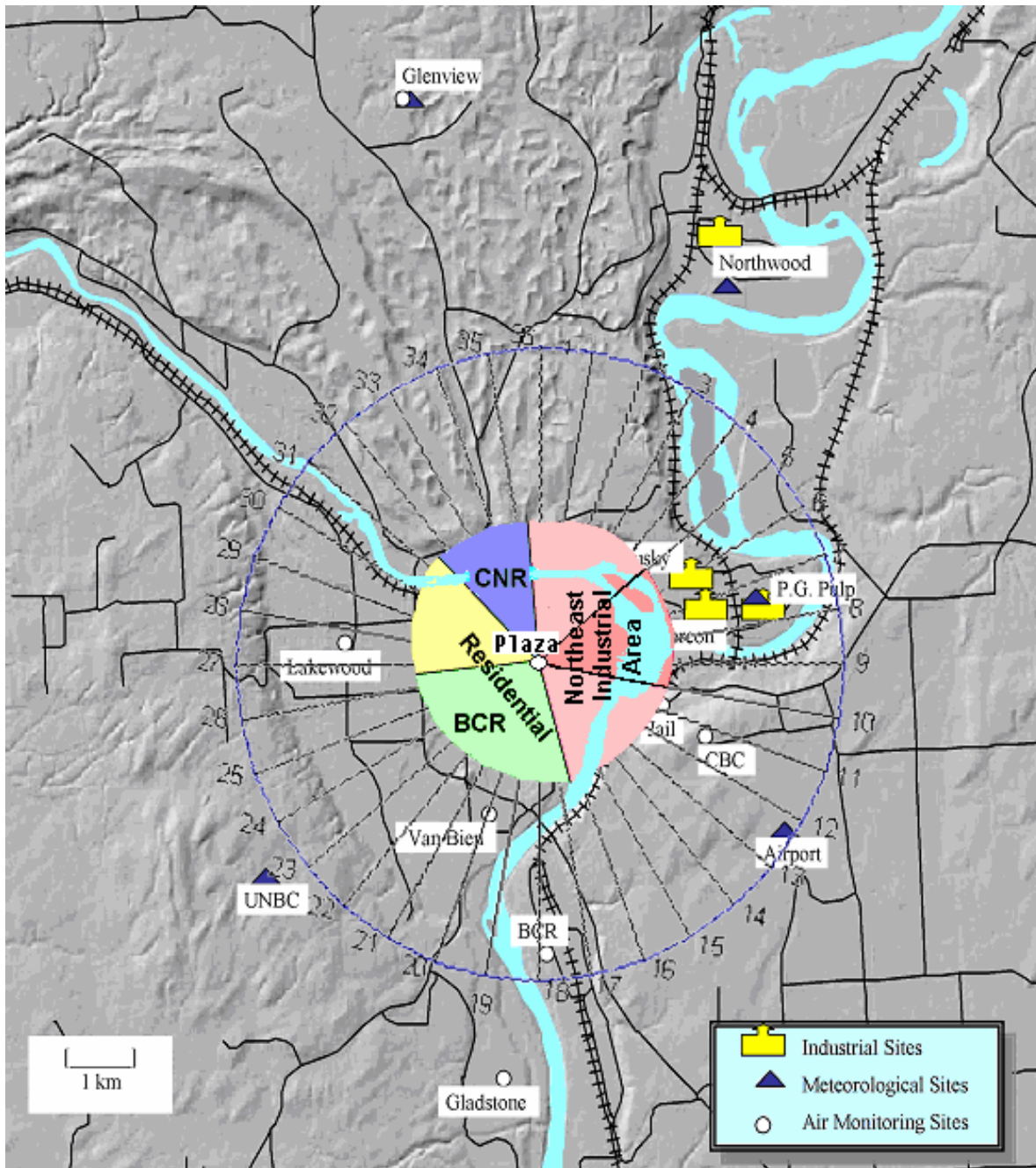
Recent PM_{2.5} Studies

- wind sector analysis by BCMOE used ambient AQ levels and winds at Plaza 400 to characterize direction of likely sources from Plaza 400 monitoring site
 - Take-home message from this study is that for PM_{2.5}: probably about **40 % are from the direction of the heavy industrial area** NE of town, about **40% are public/commercial/industrial** from other directions, and about **20% are “background”**
 - Needs confirmation and refinement from other studies (not possible to identify or quantify specific sources)
- Another study of PM_{2.5} monitored school children and neighborhoods in PG, by MSc student, Melanie Noullett

Pollutant Levels Relative to Potential Source Sectors



Fudge and Sutherland, 2002



Fudge and Sutherland, 2002

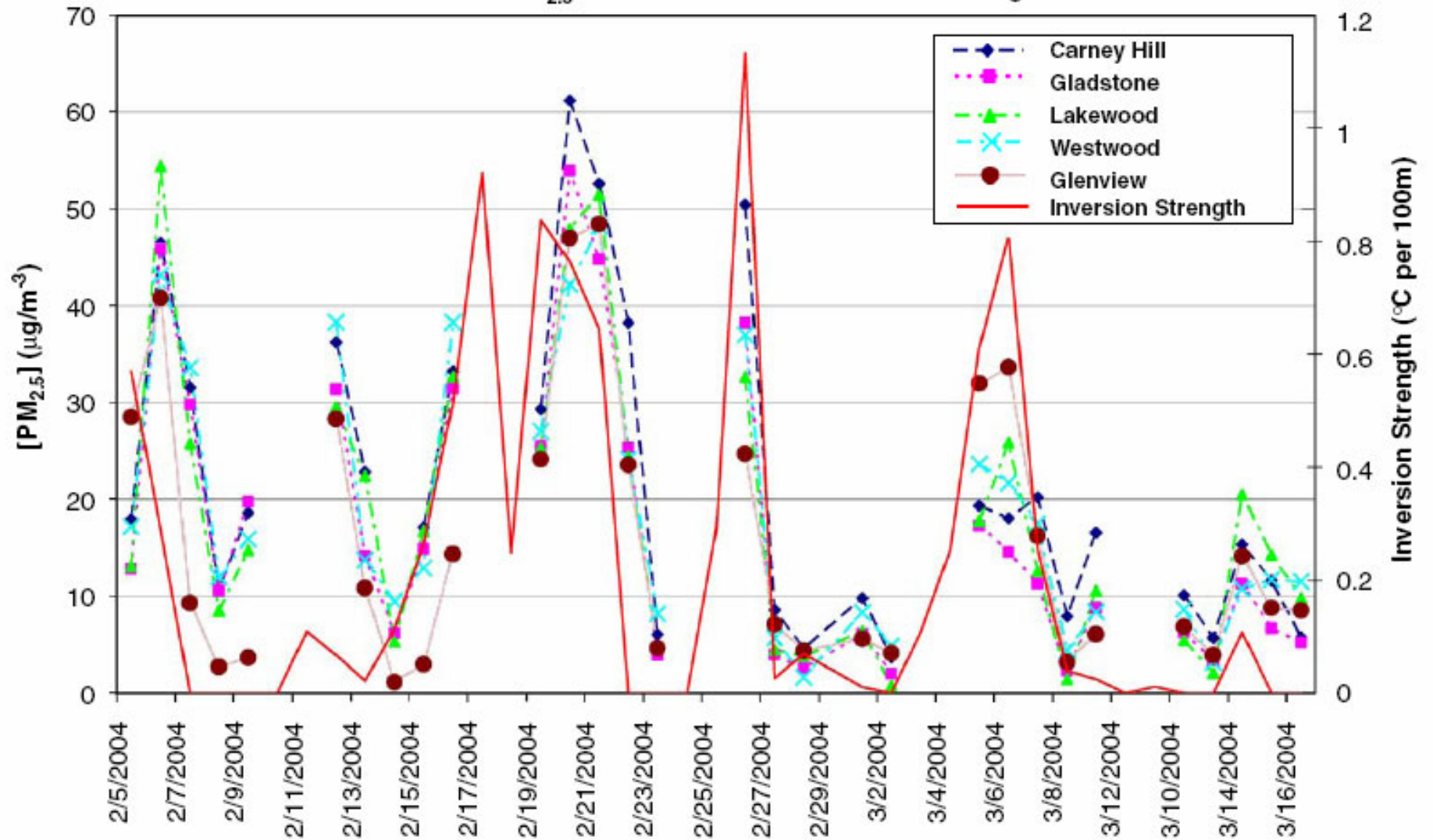
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Average Percent Contributions to the Plaza Site (2000 - 2002)

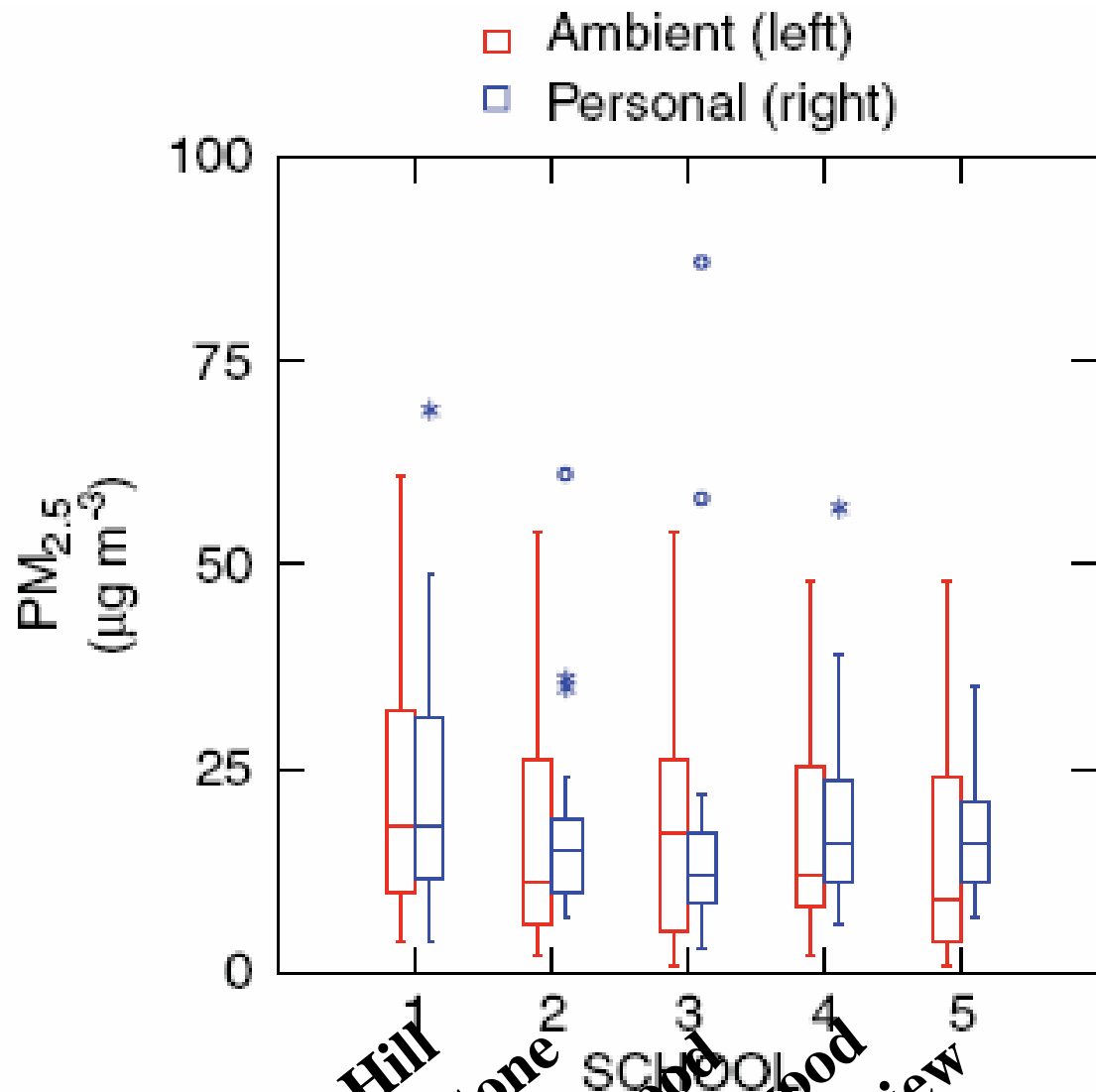
Sector	SO ₂	PM _{2.5}	PM ₁₀	TRS	NO	NO ₂
Northeast Industrial Areas	77.2%	43.6%	31.9%	82.9%	39.8%	31.8%
Residential Area	8.3%	16.5%	14.0%	4.0%	24.9%	24.7%
BCR Industrial Area	5.2%	6.3%	4.6%	0.7%	6.3%	7.1%
CNR/Commercial Area	0.6%	1.6%	1.2%	0.3%	1.7%	1.8%
Unknown	8.7%	12.0%	9.7%	11.3%	19.0%	10.2%
Background	0.0%	19.9%	38.7%	0.8%	8.3%	24.4%

Fudge and Sutherland, 2004

Ambient PM_{2.5} Concentration and Inversion Strength



Source: Noullett, Jackson and Brauer, 2006 (note dates are actually in 2001)



Source: Noullett, Jackson and Brauer, 2006

* 2 personal extreme values at school 1 are outside of the scale.

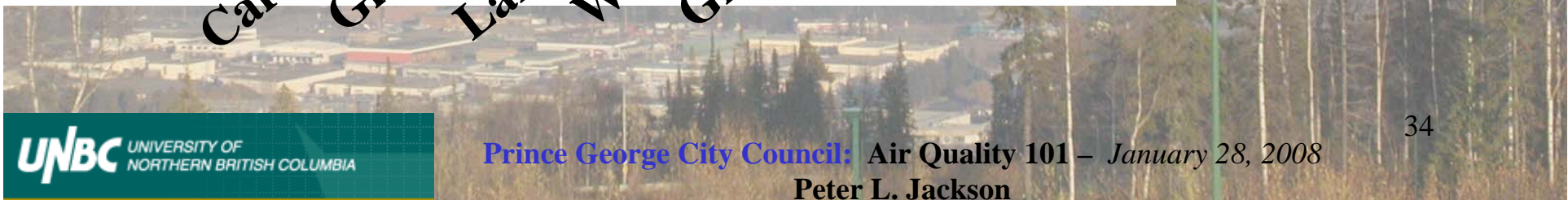


Table 5
Comparison of children's personal exposure, ambient concentration and the personal-ambient correlation from various locations where multiple samples were collected

Location	Subject health and age	Study period (season)	# of subjects	# of samples personal (ambient)	Personal exposures				Ambient concentrations			
					Avg (SD)	Median	GM (GSD)	Range	Avg (SD)	Median	GM (GSD)	Range
Prince George, BC	Healthy 10-12 years	2001 (Winter)	15	142 (149)	21 (22)	16	16 (2)	3-179	18 (15)	14	13 (3)	1-61
CAN				140 ^a	18 (13) ^a	16 ^a	16 (2) ^a	3-87 ^a				
Wageningen, Netherlands (Janssen et al., 1999)	Healthy 10-12 years	1995 (Spring)	9	55	24 (5)	—	—	19-33	17 (3)	—	—	15-22
Santiago, Chili (Rojas-Bracho et al., 2002)	Healthy 10-12 years	1998/99 (Winter)	18	87	70 (25)	58	—	20-202	68 (28)	61	—	17-190
Seattle, WA USA (Liu et al., 2003)	Asthmatic 6-13 years	1999/01 (All)	19	263 (272)	13 (8)	—	11 (2)	1-49	11 (6)	—	10 (2)	3-40
Alpine, CA USA (Wu et al., 2005; Delfino et al., 2004)	Asthmatic 9-17 years	1999/00 (Fall and spring)	20	202 (170)	24	—	20 (2)	2-72	13	—	12 (2)	4-32

All units are $\mu\text{g m}^{-3}$.

^aResults are reported with two extreme outliers (149 and 179 $\mu\text{g m}^{-3}$) removed from the analysis.

^bArticle does not report whether this longitudinal correlation is a median or mean value.

Source: Noullett, Jackson and Brauer, 2006

Current PM2.5 Studies

Need more info on PM2.5 sources affecting ambient AQ before phase III of AQ Mgmt plan can be made. Current studies will provide this info:

1. BC MOE / EC /STI PM2.5 receptor modelling / speciation study. Data collection complete, draft reports being reviewed
2. UNBC / City of PG / BCMOE / EC/ Northern Health / Canfor modelling study (PGAQIC – Research Working Group). Comprehensive study started February 2006, draft reports ready for review April 2008

Speciation Studies

- speciation / receptor modelling studies use chemical info on PM filters to infer sources – data-based approaches
- There are two broad types of speciation studies:
 - CMB (Chemical Mass Balance)
 - PCA / PMF (Principal Component Analysis or Positive Matrix Factorization)

Chemical Mass Balance (CMB)

- Need to know the major sources and what chemicals (and how much of each) they emit
- The approach then takes the observed chemical composition on ambient monitoring filters, and makes it equal to the sum of all the sources in the airshed
- In this way the relative contribution of each source can be estimated
- For this to be successful, each source has to have some unique “tracer”

Positive Matrix Factorization

- Also uses speciation data (information on the chemicals making up particulate matter on ambient air filters)
- No source profiles are needed, factors consisting of chemicals that are associated with each other are found – these factors must then be associated with sources

PG AQ Modelling Study

- Comprehensive AQ study **models** all sources in the airshed to find ambient AQ levels. By John Spagnol, postdoctoral fellow at UNBC.
 - First step is to specify the emissions (this could take as much time as we can give it)
 - Next step is to model the AQ (already done, being fine tuned)
 - Plan to model 2000 – 2005 – validate by comparing model with observed ambient levels for 2005
 - Will be able to see the relative contributions of all sources modelled and therefore inform Phase III

Prince George Airshed data accumulation - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://fist.gis.unbc.ca/fist4/plmMain.php?site=pg_airshed

WxV UNBC Atmos Sci Google

PG AQ
Modelling System

About Legend Layers Refresh Map Exit

Map Layers

- City of PG Layers
 - Layer 8 data
 - Residential Heating Sources
 - Layer 1 Data
 - Permitted Point sources
 - Layer 2a Data
 - Paved Road Sources

Refresh map

The screenshot shows a web-based GIS application. The main map area displays a geographical area with a river and various land use patterns. A red box highlights a specific area on the map. An 'Identify Results' window is open, showing the following data:

Identify Results	
Layer: layer1a	
Displaying records: 1 - 1 of 1	
gid	89
filename	p2761
unid	0
sitecode	B2
permitno	2761
sictext	Pulp&Paper Industry
sitesource	Co-generation Power Boiler
equipment	#2 Power stack
nox	
co	
voc	
so2	
trs	0
pm	95.09
pm10	70.36
pm2_5	61.81
toc	
x1	520722
y1	5974836
elev	588
stackht	60.7
stackdia	2.85
exitvel	15.81
tempk	459.15

Active Tool: **Identify**

Active Layer: **Permitted Point sources**

Map Scale: **1 : 111,132** (Change scale)

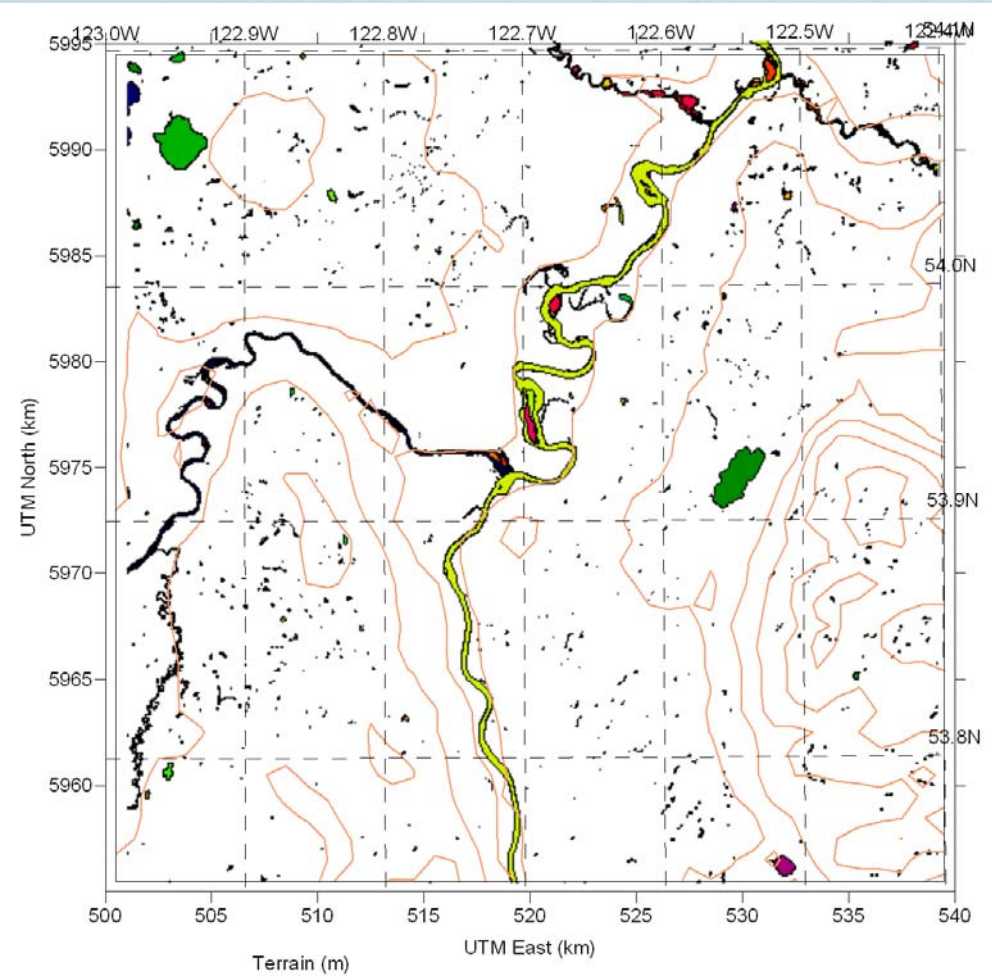
Done

start

11:50 PM

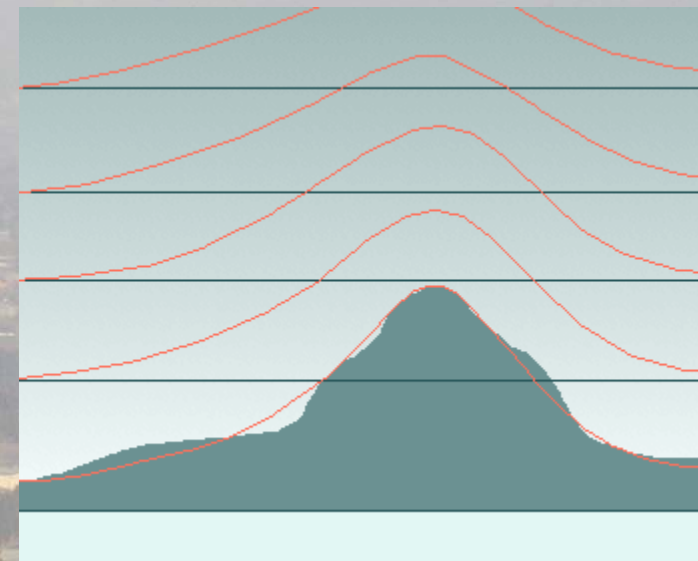
- Micro-emission inventory with a web based tool

Modeling Domain



11 levels (10 layers)
(metres)

0, 20, 50, 80, 100,
200, 400, 800, 1400,
2000, 3000



40 km x 40 km @ 1 km resolution



The End!