2000-2002 Data Addendum
Quesnel Airshed Management Planning
Background Air Quality Report

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1.0 INTRODUCTION

This addendum is intended to supplement the meteorological and ambient air quality data that was analysed in the "Quesnel Airshed Management Planning Background Air Quality Report" (Plain July 2001). In the original report, there were 10 months of PM_{10} and $PM_{2.5}$ continuous monitoring data available, which limited the conclusions and the level of assessment that could be conducted. Now that there are at least three to four years of data available, the data can be more thoroughly analysed, compared with guidelines including the Canada Wide Standards for $PM_{2.5}$, and potential trends can be identified. In this addendum, the meteorological and ambient air quality data collected in the Quesnel Airshed was summarized and interpreted to the end of 2002 for the following parameters:

- Local meteorology
- Total Reduced Sulphur (TRS)
- Suspended particulate less than 10 microns in diameter (PM_{10}),
- Suspended particulate less than 2.5 microns in diameter ($PM_{2.5}$),
- Fine particulate sulphates

For the period of 2000-2002, the Quesnel ambient air monitoring network that was analysed consisted of four continuous air monitoring sites, one PM_{10} site operated on the National Air Pollution Surveillance (NAPS) schedule (1 in 6 day sampling), and two WLAP meteorological measurement sites. The MSC Quesnel Airport meteorological data was also analysed for comparison purposes. The stations that were analysed included:

- Quesnel Senior Secondary (QSS) – PM_{10}, $PM_{2.5}$, sulphate (Continuous and NAPS)
- Maple Drive – PM_{10} (Continuous)
- Pinecrest – PM_{10}, $PM_{2.5}$ (Continuous)
- Maple Drive – PM_{10}, $PM_{2.5}$ (Continuous)
- Quesnel Linden – wind speed, wind direction, temperature (Continuous)
- Cariboo Pulp and Paper (QCP) – wind speed, wind direction, temperature (Continuous)
- MSC Quesnel Airport – wind speed and direction, temperature, precipitation (Continuous)

Further details on these monitoring sites are provided in Table 1. Figures 1 through 4 show the locations of the sources and stations in the airshed. No changes to these Figures have been made from the main report.

2.0 Air Quality Meteorology

A summary of air quality meteorology was previously provided in Section 3.1 of the main report. Details on meteorological conditions and processes that could lead to poor dispersion or increased ambient concentrations were provided. This section focuses on the meteorological data measured from 2000-2002 and compares the meteorological data with the previous conclusions that were outlined in the main report. In some cases 1999 monitoring data was also used to establish trends.

2.1 Analysis of Winds (2000-2002)

For the period of 2000-2002 two Meteorological Information Stations (MIS) were operated by the Ministry of Water, Land And Air Protection (Figure 3) in the Quesnel Airshed. The Quesnel Airport station was operated by Meteorological Services of Canada (MSC) of Environment Canada (EC). The "Quesnel Linden" station is located at a similar elevation (545 m) to the MSC Quesnel Airport station on a local plateau just to the north of the Two-Mile Flat industrial area. The Quesnel CP station is located in the valley bottom to the north of the downtown core, at 500 metres in elevation. This station is representative of valley wind flow regimes, where as Quesnel Linden is generally representative of the regional winds.

Figures 5 through 8 shows the frequency of unit vector wind direction (degrees) and the average wind speed (m/s) at sixteen compass points for each year of data 1999-2002 collected at the Quesnel CP station. This type of plot is collectively known as a windrose. The direction of a "petal" on the rose indicates the direction "from" which the wind is blowing, while the length of the "petal" on the rose indicates its frequency. For example, winds blew from the south at the Quesnel CP meteorological station approximately 8% of the time in 2000. Similarly, Figures 9 through 12 show the frequency and speed distribution for the Quesnel Linden station. Lastly, Figures 13 through 15 show the windroses at the Quesnel Airport location for 2000-2002.

The windroses at the Quesnel CP station show the influence that the valley topography has on wind patterns. The stronger winds (synoptic flows) in each of the years exhibited a predominantly south-easterly and north-westerly flow. There was also a higher frequency of light winds from the south-west quadrant (up to 7 % of the time) at this station. This is mainly due to the Quesnel River valley configuration which deflects light winds blowing from the south and south-east, as they drop into the valley bottom, into a south-westerly direction. Figures 16 through 19 show the windroses for the Quesnel CP station by season for 2000-2002. Each of the seasons (winter, spring, summer, fall) were defined by three months of the year (e.g. Dec, Feb, Jan for winter). The figures show that the most frequent time of year for winds from the south-west are fall and winter. During these seasons the frequent presence of a trough over the Pacific ocean will bring south-westerly winds across the province. During the spring and summer, this situation is reversed, and the more predominant flows from the north-west prevail. When combined with topographic channelling, the frequency of the southwest conditions may be more predominant at this site.

The additional years (2000-2002) of data show that wind direction for the Quesnel Linden station is predominantly south-easterly with a secondary north-west flow, similar to 1999 (Figures 20 to 23). These direction patterns are similar to historical records recorded at the Quesnel Airport (Table 2, Figures 24 to 27). Wind speeds recorded at the Quesnel Linden site in 1999-2002 were generally stronger in all quadrants than indicated by the Climate Normals. This is not unexpected as the Quesnel Airport data is measured at a 10m height, while the Linden station winds are measured at a 20 m height. In the boundary layer, wind speeds commonly increase with increasing height, as the influence of friction and ground level effects lessen, therefore the difference in climate normals to the Linden site is not entirely unexpected. Calm winds were recorded roughly 6% to 7.8% of the time at the Linden site while the Normals indicate a frequency of 43.7% to 49.6% of the time from 2000-2002.

It should be noted that airport normals are based on a single observation (approximately 1-2 minutes in duration) for wind speed and direction near the end of each hour. The MIS measurements are made every 2 seconds and the data is retained electronically by a datalogger. Airport wind speed sensors also have a higher starting threshold (approx. 2 m/s) than MIS anemometers (0.5 m/s). The MIS measurements therefore provide a more accurate representation of meteorological conditions than do airport normals observations.

Figures 28 to 30 shows the average temperatures at each of the monitoring site from 2000-2002. The mean daily temperatures listed in these figures were calculated by averaging the daily mean temperature over the entire monitoring period for each month. The mean daily maximum and minimum temperatures were calculated by averaging daily maximum and minimum temperatures for the month. The extreme maximum and minimum temperatures are the maximum and minimum temperatures for the monthly period.

Monthly average scalar wind speeds for 1999 are presented in Figure 31 and are updated for 2000-2002 in Figure 32. The lowest mean wind speeds at all three stations occur in the months July, August and September. Highest mean monthly wind speeds at the sites generally occurred in April, November and December. Months with higher wind speeds may be expected to generate more dust from roads and other ground level sources (e.g. log yards). In general, mean wind speeds at both Ministry sites were higher than the airport normals average wind speed (1961-1990).

2.2 Meteorological Trends

Table 3 presents annual average mean wind speeds and the percent valid data for the two WLAP MIS sites in Quesnel from 1992 to 2002. Annual average mean wind speeds at the Quesnel Linden meteorological station ranged from a low of 2.31 m/s in 1995 to a high of 2.73 m/s in 1999. Annual average mean wind speeds at the Quesnel CP meteorological station ranged from a low of 2.09 m/s in 1995 to a high of 2.63 m/s in 1996. The additional 2000-2002 data was within these ranges and could be considered average years in terms of mean wind speeds. Based on the annual average wind speed data alone, during months and years with lower wind speeds (e.g. Jan 1995), one would expect higher concentrations of pollutants.

Table 4 presents monthly average mean wind speed information for the two Quesnel MIS sites from 1992 to 2002. At the Quesnel Linden site, the lowest monthly average wind speeds occur in January, August and September while the highest wind speeds are generally recorded during the spring months of March, April and May. Airport normals follow a similar pattern (Figure 32) except that average wind speeds in January are middle range values. At the valley bottom site, lowest monthly average wind speeds are recorded during September, January and August while the highest average wind speeds are recorded in April, May and March.

Figure 33 presents the percent of time that calm winds (wind speeds < 1 m/s) were experienced on an annual basis at the two MIS sites from 1992 to 2002. On average, in recent years (2000-2002) there has been a slightly higher frequency of calms reported at the Linden site, while the QCP site had lower calms in 2000 and 2002, with a higher frequency of calms in 2002. A high frequency of calms limits the dispersal of pollutants and promotes thermal stratification or inversion conditions, which trap pollutants near the ground where they can accumulate to high levels. In general, a higher frequency of calms is experienced at the valley bottom station (QCP) than on the local plateau.

At the QCP site, calm winds occurred from a low of 5.6% of the time in 1992 to a high of 20.4% of the time in 1998. High frequencies of calms at Quesnel CP also occurred in 1995 (13.5%) and in 1993 (15.7%). At the Quesnel Linden site, calms occurred from a low of 2.8% of the time in 1992 to a high of 9.2% of the time in 1995. The second highest % calms year occurred in 1998 (8.6% of the time). The 2000-2002 data did not affect this range of calm conditions, indicating that 1993, 1995 and 1998 had poorer than normal dispersion than the other years. 2002 indicated relatively higher frequencies of calms at both sites, which could be a contributing factor to reduced dispersion.

Table 5 is a summary of monthly and annual precipitation records from 1990 to 2002 as obtained from the Quesnel Airport recording station (courtesy of Environment Canada, Climatic Services). The 2000-2002 data can be considered average years, with above average precipitation in June and July of 2000 and 2001. Precipitation data was not available past March of 2002 from the MSC.

From 1990 to 2002 the driest year in terms of total precipitation was 1993 (442.3 mm), while the wettest year was 1999 with 675.5 mm. The 2000-2002 data did not affect the extremes. With the exception of 1993, February of 2000 and 2001 had a very little amount of precipitation amounting to only 4.4 and 4.5 mm respectively. The dry conditions would have been conducive to producing dust events.

3.0 Total Reduced Sulphur

The B.C. Ambient Air Quality Objectives for TRS were used to compare the measured ambient concentrations and are presented below:

		Level A	Level B
Total Reduced Sulphur (TRS)	One Hour	7 µg/m^3	28 µg/m^3
	24-Hour	3 µg/m^3	6 µg/m^3

Tables 6 through 9 present the mean monthly TRS concentrations for all of the Quesnel ambient air monitoring stations and their respective annual means (1999-2002). On a monthly basis at each of the stations averages are generally below 1 µg/m^3. In each of the years, maximum monthly averages generally occur in warmer weather in summer, while minimum averages occur in fall or winter.

At QSS, the maximum monthly average from 1999-2002 was recorded in August 1999 at 1.09 µg/m^3 while the lowest monthly average was recorded in March 1999 at 0.16 µg/m^3. Monthly average results ranged from 0.07 to 0.92 µg/m^3 at Maple Drive. At the West Fraser station, the maximum was recorded in April 1999 at 2.13 µg/m^3, while the minimum was recorded in December 2002 at 0.1 µg/m^3. TRS emissions from both pulp mills impact this site.

3.1 Total Reduced Sulphur Annual Trends

The Total Reduced Sulphur (TRS) data was examined at all three sites to identify potential trends. Tables 10, 11 and 12 show the maximum results for the individual monitoring stations; the Quesnel Senior Secondary (QSS), the Maple Drive Junior Secondary, and the West Fraser station. The first two represent residential areas, while the West Fraser is located in an industrial-type setting. The values in brackets indicate the % of time that the BC Ambient Air Quality Objectives were exceeded. The 24-hour concentrations are based on a rolling or moving 24-hour average. A valid 24-hour rolling average must contain at least 18 hours of valid data.

The QSS site indicates that annual average concentrations were lower from 1996 to 2002 than those recorded from 1990 to 1995. 2002 represents the lowest annual average at QSS at 0.35 µg/m^3 (Table 10), while the highest year was 1990. Much of this improvement can be linked to process changes at the area pulp mills in the early 1990's. Figure 34 shows the percent of calms along with the average TRS concentrations. In general, the years with peak TRS concentrations correspond with years exhibiting higher amounts of calm winds. However, in recent years this trend was not exhibited. Concentrations were average in 2000 and 2001, yet the amount of calm wind conditions were low, and in 2002, although the calms were more frequent, the lowest TRS concentrations in the past ten years were observed. This could be evidence of reduced emissions from TRS sources for 2002. A similar correlation is evident at the Maple Drive TRS monitoring location. Annual average TRS trends at the Maple Drive ambient monitoring location have fluctuated from 2000-2002 with a low of 0.30 µg/m^3 in 1997 and 2002 to a high of 0.69 $\mu g/m^3$ in 1995 (Table 11). Overall, the measured values are on average lower than at QSS, and a similar trend in data occurred from 2000-2002.

Annual average TRS concentrations have been fairly consistent at the West Fraser site since 1993 (Figure 35). Annual average TRS values declined from a high of 8.51 $\mu g/m^3$ in 1990 to a low of 0.94 $\mu g/m^3$ in 1995 (Table 12 and Figure 35). In the past four years, annual average TRS concentrations at West Fraser have shown a decreasing trend from 1.49 $\mu g/m^3$ in 1999 to the lowest ever, 0.61 $\mu g/m^3$, in 2002. Each year was lower than the previous. This likely represents the improvements that have been ongoing at each of the mills. Emission data was not included in the analysis for 2000-2002, and therefore Figure 36 remains unchanged.

Figures 37 through 40 are pollution roses for the 1999-2002 QSS TRS data, using meteorological data collected at the QCP site. For each year, the majority of TRS readings are detected at the QSS monitoring site when winds are out of the north and north-east sector. The winds from the north likely indicate the low level emission sources at the Cariboo Pulp and Paper facility. However, from 2000-2002 a much larger predominance of increased concentrations during south-west wind conditions occurred, although the highest concentrations still occurred from the north. This shift in direction of elevated concentrations could be due to the lower frequency of calm conditions and/or a greater frequency of night-time inversions during the 2000-2002 period. Specifically, the TRS readings from the southwest could be due in large part to atmospheric recirculation in the valley bottom during inversion breakup. The QCP seasonal windroses (Figures 16 through 19) suggest dominance of southwesterly winds in fall and winter, but the majority of these winds are light (1-2 m/s). This likely occurs as an inversion layer dissipates and up-valley flows begin. Emissions could accumulate during calm conditions, then impinge upon sensors when winds commence. In 2001, when elevated TRS concentrations occurred with the greatest frequency, TRS values less than 1 $\mu g/m^3$ were recorded only 63.04% of the time, compared to 76.48% of the time in 1999. Also, as sources of TRS are reduced, a shift in direction of measurement could also be expected depending on the location of the reduction.

The pollution roses (Figures 41 through 48) for the Maple Drive and the West Fraser TRS monitoring stations were generated using meteorological data from the Quesnel Linden. At Maple Drive, the majority of TRS readings were detected when winds were from the north and north-west sectors. This trend continued from 2000-2002. TRS values less than 1 $\mu g/m^3$ were observed at this site between 63% to 78% of the time from 1999-2002. At the West Fraser site, the highest TRS concentrations were recorded when winds were from the north-west sector (from Quesnel River Pulp) and the south-east sector (directed from Cariboo Pulp), although less frequently. Non-detectable concentrations of TRS (< 1 $\mu g/m^3$) occurred 41.6% of the time at the West Fraser Station in 1999 and up to 70.2% of the time in 2002.

From 1990-2002, concentrations that exceeded the British Columbia Level A 1-hour TRS Objective (7 $\mu g/m^3$) at QSS ranged from a low of 8 hours in 2002 to a high of 79 hours in 1991. It was noted that concentrations exceeded the Level A Objective closer to 1% of the time from 1990 to 1995 and have occurred 0.6% of the time or less since then, with 2002 exceeding only 0.1% (8 hours) of the time (Table 10, Figure 49). The hourly Level B Objective (28 $\mu g/m^3$) was exceeded once in 2001 and 2002. Table 10 also shows the number of times the 24-hour concentrations have been exceeded. From 1990 to 1995 there was an average of 197 occurrences whereas from 1996 to 1999 there was an average of 73 times. From 2000 to 2002 there has been an average of 63 occurrences over the Level B Objective. In 2001 the 24-hour Level B Objective was exceeded 16 times.

The number of occurrences above the 1-hour Level A Objective (7 $\mu g/m^3$) at the Maple Drive ambient monitoring site has varied from a high of 50 hours in 1995 to a low of 3 hours in 1996 and 2002 (Table 11, Figure 49). Since monitoring began at this site in 1992, the Level A hourly Objective has been exceeded less than 0.6% of the time. There have never been concentrations exceeding the 1-hour Level B Objective, and the 24-hour Level B Objective was exceeded only in 1995. There has been a significant reduction in the number of concentrations exceeding the 24-hour Level A Objective since 1995.

The number of occurrences exceeding the 1-hour Level A Objective at the West Fraser station ranged from a high of 1635 hours in 1990 to 62 hours in 2002 (Table 12). The number of times the Level B Objective has been exceeded has significantly declined from a high of 510 hours in 1990 (Table 12). From 2000-2002 there were only two occurrences, and in 2002, for the first time, there were no measured values exceeding the 1-hour Level B Objective. Figure 50 shows that the number of occurrences in the past few years has been lower than in the early 1990s. The number of values exceeding the 24-hour ambient TRS Objectives has continually declined since the early 1990s. The 24-hour Level A Objective of 3 $\mu g/m^3$ was exceeded 87.5% of the time (based on a rolling 24-hour average) in 1990. In 2002, concentrations exceeded the 24-hour Level A Objective 81 times (0.9%) and exceeded the 24-hour Level B Objective once. This is the lowest number of times on record, and represents a significant improvement.

3.2 Comparison of TRS Concentrations with Other BC Communities

Figure 51 compares the 1999 TRS annual averages recorded in Quesnel, BC with those recorded at other selected monitoring sites in BC (only sites with > 75% data capture were included). Data for 2000-2002 was not analysed at all of the other stations in BC. However, for a first order comparison purpose, assuming that all other sites in BC had little change in ambient measurements, the West Fraser site would be more similar to the average communities across BC, but higher than the other residential areas of Quesnel.

4.0 Particulate Matter

$PM_{2.5}$ sampling was initiated in November of 1995 at the QSS site by using a non-continuous ACCU-System sampler attached to the bypass flow of the TEOM. Two continuous $PM_{2.5}$ samplers (TEOMs) were installed in Quesnel in the spring of 2000. These monitors are collocated with continuous PM_{10} monitors at QSS and Pinecrest Center. A third continuous $PM_{2.5}$ monitor was installed in the fall of 2000 at the Maple Drive monitoring location.

In 1999, there was a single Hivol PM_{10} monitor located in West Quesnel and 3 continuous PM_{10} monitors (TEOMs) located in downtown Quesnel, Red Bluff and the Two-Mile Flat area (Table 1). In the winter of 2000, a collocated continuous PM_{10} and $PM_{2.5}$ site was established in west Quesnel at Correlieu Secondary School.

Dustfall measurements were not updated for 2000-2002 data. Therefore, there are no changes for Tables 13 through 17. The analysis of particulate matter data for 2000 to 2002 included all of the measurements from the continuous stations. There is no change to Table 18.

4.1 Continuous PM_{10} Results

The PM_{10} results were compared to the British Columbia Air Quality Level B Objective for PM_{10} of 50 $\mu g/m^3$ and the CEPA health reference level for PM_{10}, 25 $\mu g/m^3$.

Tables 19 through 22 summarize the 1999-2002 continuous PM_{10} results as collected by TEOMs at QSS. The following was observed:

- The annual average PM_{10} concentration ranged from 20.2 to 22.6 $\mu g/m^3$ from 1999-2002
- The provincial 24-hour ambient Objective for PM_{10} was exceeded on average 376 times (4.3% of the time) from 1999-2002. 1999 and 2002 were slightly above the average while 2001 and 2002 were below the average. 2001 was the lowest year with 304 times.
- In each of the years, the most frequent occurrence happened during February, March and April and have been observed to be primarily associated with road dust episodes in combination with stagnant meteorological conditions.
- There were also concentrations exceeding in the summer months, during stable warm periods, most commonly in August, but also in June and July in 2002. November represented the other month of the year when concentrations exceeded the Level B Objective, although less frequently than during the other months.
- 24-hour concentrations were above 100 $\mu g/m^3$ in 1999 and 2000, but not in 2001 and 2002.
- On average QSS PM_{10} levels were above the health reference levels 24.3% to 31.7% of the time from 1999-2002.
- There has not been a single month of observations when a 25 $\mu g/m^3$ 24-hour level was not exceeded.

- On average the months of December and January had the fewest frequencies above the reference levels, and the odd month, for example July 2000, June 2001, and Septmber 2002 had reduced frequencies when compared to other months.

Tables 23 through 26 summarize the 1999-2002 continuous PM_{10} results as collected by TEOM at the commercial monitoring location of Pinecrest.

- The annual average PM_{10} concentration ranged from 20.9 to 24.4 μg/m^3 from 1999-2002.
- Concentrations were above 100 μg/m^3 in 2000 during March and April.
- PM_{10} has exceeded the Level B Objective each month of the year except January.
- The number of occurrences above the Level B Objective ranged from 356 times (4.1%) in 2001 to 790 times (9.1%) in 1999.
- The impacts of springtime road dust at this site are not as evident with the potential exception of the year 2000. Other sources are likely contributing a higher amount of the concentrations to this location throughout the year.
- The health effects level of 25 μg/m^3 was exceeded from 28.1% to 39.2% of the time from 1999-2002.

Tables 27 through 30 summarize the 1999-2002 continuous PM_{10} results as collected by TEOMs at Maple Drive. The following was observed:

- The annual average PM_{10} concentration ranged from 15.5 to 17.1 μg/m^3 from 1999-2002.
- In 1999, the 24-hour ambient Level B Objective for PM_{10} was exceeded a total of 35 times (0.4% of the time) based on a rolling 24-hour average (Table 27). They occurred in February and March.
- In 2000, the 24-hour ambient Level B Objective for PM_{10} was exceeded a total of 204 times (2.3% of the time) based on a rolling 24-hour average (Table 28). They occurred in February, March, and December.
- In 2001, the 24-hour ambient Level B Objective for PM_{10} was exceeded a total of 126 times (1.4% of the time) based on a rolling 24-hour average (Table 29). They occurred in January to March, with three in August.
- In 2002, the 24-hour ambient Level B Objective for PM_{10} was exceeded a total of 115 times (1.3% of the time) based on a rolling 24-hour average (Table 30). They occurred in March, April and November.
- The patterns indicate that road dust has an impact at this site.
- The health effects level of 25 μg/m^3 was exceeded from 12.4% to 17.8% of the time from 1999-2002 at Maple Drive.
- Some months (Feb, May, Dec) in 1999 and one month (June) in 2001 were below the reference levels at all times.

Tables 31 to 33 summarize the 2000-2002 continuous PM_{10} results as collected by TEOM at the Correlieu School. The following was observed:

- The annual average PM_{10} concentration ranged from 12.3 to 15.0 μg/m^3 from 2000-2002.

- The maximum rolling 24-hour average value occurred in November 2002 and was 70.8 $\mu g/m^3$. This month also frequently exceeded 25 $\mu g/m^3$ (37.6% of the time).
- The health effects level of 25 $\mu g/m^3$ was exceeded most frequently in the winter months and in early spring. It was exceeded 8.4% of the time in 2001, and 13.9% of the time in 2002.
- On a monthly basis, 25 $\mu g/m^3$ was exceeded from 0.0% to 37.6% of the time.

Each year in January the health effects level was exceeded more frequently at Maple Drive than at either QSS or at Pinecrest. This indicates that sources such as wood stoves or stack emissions from tall sources were contributing to the increased concentrations during this period. The lower annual average values observed at Correlieu, along with the increases in winter, indicate that the most likely influence is local sources, possibly wood burning. In early spring, particulate matter at Correlieu may be derived chiefly from road dust, some of which is pulverized traction material that remains from the winter. This material tends to produce finer particles than does other road dust. Poor dispersion meteorology exacerbates the situation. From 2000 to 2002, the average ratio of $PM_{2.5}$ to PM_{10} at Correlieu was 31.8% in March, and 21.5% in April. Traffic is typically light in the vicinity of the monitoring location and therefore the magnitude of the impacts is lower than at the other sites. The Pinecrest station has the highest annual averages when compared to the other sites, most likely due to the greater influence of the industrial sources.

Figures 52 to 54 show the percentage of the time that the PM_{10} Objective was exceeded at the QSS site from 1999-2002, and the monthly average total precipitation, combined with the percentage of the time that calm winds (less than 1 m/s) occurred. Wind data were obtained from the Quesnel CP meteorological station. The data show the following:

- Months with higher precipitation correspond with the lowest concentrations of PM_{10}.
- The months of March with more precipitation had fewer concentrations exceeding the Level B Objectives.
- Springtime road dust, and dust from other ground level sources (e.g. log yards) was likely the main cause of elevated PM_{10} during the months of February and March.
- Calm winds did not indicate any significant relationship with more frequent values above the Level B Objective, although in some instances, months with more calms tended to have more occurrences that exceeded.
- Ice and snow pack likely have a greater influence on concentrations than do calm wind conditions.

As was previously generated for 1999, pollution roses for the Pinecrest location were generated for 2000-2002 (Figures 55 to 58) using the same criteria. These pollution roses show a similar pattern to 1999. The highest frequency of elevated hourly PM_{10} values occurred when winds were out of the south-east sector from the Two-Mile Flat industrial sector and Cariboo Pulp. Other high values were experienced when winds were from the north and northwest sector where other industrial sources are located.

Pollution roses were constructed for the QSS and Maple Drive continuous PM_{10} monitoring sites and are shown in Figures 59 through 66. At QSS high hourly average PM_{10} levels were recorded from all compass directions. This is indicative of the large number of sources contributing to PM_{10} levels at this site (i.e. point, mobile and area sources). Maple Drive shows a slightly more distinct north-west and south-east pattern, but high hourly average concentrations were also recorded from all directions. The pattern is more indicative of the predominant meteorological directions rather than a particular source.

Figure 67 presents the 1999 annual average PM_{10} concentrations from all BC communities where continuous PM_{10} monitoring is performed. This analysis was not updated for 2000-2002.

4.2 Annual Continuous PM_{10} Monitoring Trends

Tables 34 through 37 present annual average statistics for the residential monitoring sites since continuous PM_{10} monitoring began at the respective sites.

Figure 68 shows the annual average concentrations, 24-hour maximum concentrations and the 24-hour 75^{th} and 95^{th} percentiles for the QSS location from 1995-1999, and is updated in Figure 69 for 2000-2002. The peak annual average PM_{10} concentrations at QSS occurred in 1995 and 1998. This was consistent with the poor dispersion meteorology for those years. 2001 and 2002 showed the lowest maxima, likely reflecting improvement to industrial operations. The 95^{th} and 75^{th} percentiles were not significantly different from previous years. Table 34 shows that overall, annual averages have remained fairly constant. Tables 38 and 39 present statistical trend analysis for each monitoring location. Trends in the annual mean, 75^{th}, 95^{th} and 99^{th} percentile 24-hour average values were calculated and then tested for significance. The trend at QSS shows slight improvement for all averaging periods (negative slope) with no statistical significance.

Figure 70 shows the annual average concentrations, 24-hour maximum concentrations and the 24-hour 75^{th} and 95^{th} percentiles for the Pinecrest location from 1995-1999, and is updated in Figure 71 for 2000-2002. The peak 24-hour average PM_{10} concentration at Pinecrest occurred in 2000, while 2001 and 2002 showed similar values to previous years. The peak in 2000 resulted from the combination of industry sources and a springtime road dust event. The 95^{th} and 75^{th} percentiles were not significantly different from previous years. Table 39 shows that overall, annual averages have had a slight increasing trend that is not statistically significant.

Figure 72 shows the annual average concentrations, 24-hour maximum concentrations and the 24-hour 75^{th} and 99^{th} percentiles for the Maple Drive location from 1995-1999, and is updated in Figure 73 for 2000-2002. The 2000-2002 data showed similar values to previous years. Maximum 24-hour rolling values have been lower since 1998. The 99^{th} and 75^{th} percentiles were not significantly different from previous years. Table 39 shows that overall annual averages have a slight decreasing trend. Although for the 1995-1999 data there is a statistical significance to the 99^{th} percentile trend (Table 38), this is not exhibited when the 2000-2002 are added. This is likely due to the slight increase in slope on the latter portion of the data set, and the relatively small number of values that are used in the calculation.

Figure 74 shows the annual average concentrations, 24-hour maximum concentrations and the 24-hour 75th and 99th percentiles for the Correlieu location for 2001 and 2002. There is insufficient data collected at this time to determine potential annual trends or statistical significance.

4.3 Monthly Variations in Continuous PM_{10} Data

The seasonal trends that were identified for 1995-1999 in the main report were updated for 2000-2002 data. For Figures 75 through 81, the 1995-1999 monthly average data is presented for each location, directly followed by the monthly average data for the 2000-2002 period.

As was summarised in the main report, seasonal trends are apparent at QSS, Maple Drive and Pinecrest. The highest concentrations typically occurred in the late winter/early springs months while the lowest concentrations were measured in December or January. For 2000-2002 the Pinecrest data indicated a secondary peak in November that was not as noticeable in previous years. The two years of data at the Correlieu site did not indicate the same trends as other stations, as it is not likely influenced by road dust or downtown sources to the same extent.

4.4 Diurnal Variations of Continuous PM_{10} Data

The hourly data from 1995 to 1999 that was used to examine diurnal variability in PM_{10} concentrations at QSS, Maple Drive and Pinecrest was updated in subsequent figures to reflect the 2000-2002 data. Figures 82 through 87 show the diurnal variations for the data.

Overall, the diurnal variation at the three sites was very similar in 2000-2002 to patterns of previous years with very minor differences in peak hour maximum concentrations. As the main report summarises, inversions (presence or break-ups), meteorological patterns, and variation in traffic volumes are likely all contributing factors to the variations.

The diurnal variation at the Correlieu site is presented for 2000-2002 in Figure 88. Although there are peak periods from 7 to 9 am, and 3 to 6pm, indicating a potential influence from vehicle traffic, there is much less variation than the other sites. Based on the location and meteorology of the area, the extent to which sources influence this site is greatly reduced when compared to the others.

Seasonal diurnal patterns for average hourly PM_{10} concentrations are presented for QSS, Pinecrest, and Maple Drive monitoring sites in Figures 89 through 94. For each station, the Figure represents 1995 to 1999 data, while the second represents 2000-2002. All of the data from 2000-2002 exhibits a similar pattern of seasonal variation as the 1995-1999 data.

Figure 95 shows the diurnal seasonal variation for 2000-2002 data at the Correlieu monitoring site. The seasonal variation shows that the maximum concentrations occur during the peak traffic hours, particularly in the summertime. The presence of this variation indicates that concentrations are less influenced by the downtown or industrial sources. The effect of valley inversions is also evident at this site, as illustrated by the morning peak (present at all three valley sites: Correlieu, QSS, and Pinecrest), which is most prominent in summer and is caused by fumigation following the dispersion of the nocturnal inversion. At Maple Drive, which is located on the local plateau to the South of the city, the morning peak is much less apparent than at the three valley sites. This suggests that not all the emissions are localized in nature, but that the sources affecting the downtown core have a relatively diminished impact in west Quesnel.

4.5 Hebdomadal Analysis of Continuous PM_{10} Data

PM_{10} data from 1995-1999 for QSS, Pinecrest, and Maple Drive monitoring sites are presented on a hebdomadal basis, and updated for 2000-2002 data in Figures 96 through 101. Tables 40 and 41 show the data values. All of the hebdomadal analysis for 2000-2002 show a similar pattern to the analysis that was conducted for 1995-1999.

Figure 102 shows the hebdomadal analysis for the Correlieu station. At this station, there are no significant variations on each day of the week. A slight peak is evident on Thursdays and Fridays from the maximum to mean concentrations. Although there is little variation, the minimums occur on weekends, with a gradual build-up to the maximum on Thursday or Friday. Therefore anthropogenic activities affect this site, but not as significantly as they do the other sites.

The difference between the midweek maximum PM_{10} concentration and the weekend minimum PM_{10} concentration at each site is presented in Tables 40 and 41. Similar differences were observed with 2000-2002 data when compared to the 1995-1999 data. The differences at the Correlieu station for the 75th, 95th and 98th percentile were 40%, 31.5% and 29% respectively.

4.6 Episode Analysis of Continuous PM_{10} Data

As was conducted previously for 1995 to 1999 data, an episode analysis was conducted for the 2000-2002 data. The episodes were defined in the same manner as the 1995 to 1999 episodes, and are defined as a period of at least twenty-four hours where the rolling average PM_{10} concentration is above 50 $\mu g/m^3$ (the Ambient Air Quality Objective for PM_{10} in BC). A Type 1 episode is defined as a period of time where levels above 50 $\mu g/m^3$ occur for at least 24 hours but less than 48 hours in duration. A Type 2 episode lasts 48 hours or more.

The 1995 to 1999 episode analysis is presented in Tables 42, 44, and 46 for QSS, Pinecrest and Maple Drive. While the PM_{10} data from all the continuous ambient PM_{10} monitoring sites between 2000 and 2002 was examined in Tables 43, 45, 47 and 48 for the Correlieu monitor.

At the Quesnel Senior Secondary School monitoring location, From 2000-2002 Type 1 episodes occurred 3.69%, 2.37% and 2.37% of the time each year. There were fewer Type 2 episodes from 2000 to 2002 compared to previous years with three in 2000 and one each in 2001 and 2002. The longest continuous period of high concentrations occurred in 2001 when the rolling 24-hour average was greater than 50 $\mu g/m^3$ for 130 hours. Type 1 Episodes occurred in March of each year from 1995 to 2002 while they occurred in February seven out of the eight years analyzed. From 2000 to 2002 two episodes occurred in April and one in August. One of the Type 2 episodes occurred in April of 2000. Episode days from 2000 to 2002 accounted for a significant fraction of the total number of times concentrations were above the Level B Objective and ranged from 58.23 to 77.8% of the year.

At the Pinecrest ambient monitoring location, Type 1 episodes occurred 2.81%, 2.32%, and 3.63% of the year from 2000 to 2002 respectively. There were no Type 2 episodes in 2000, two in 2001 and one in 2002. The longest continuous period occurred in November 2002 when the rolling 24-hour average was greater than 50 $\mu g/m^3$ for 91 hours. Episode periods accounted for between 56.03% and 65.86% of the total exceeding PM_{10} levels experienced at this site. Over the period, episodes occurred in November each year, and at individual years in February, March, April, June, and October. This further demonstrates from the 1995 to 1999 data the potential influence that industrial activities have on the area.

Similar to the 1995 to 1999 data, a low number of episode days occurred at the Maple Drive site. Two Type 1 episodes were recorded in 2000, one in 2001 and three episodes in 2002. There was two Type 2 episodes in 2000 and none in 2001 or 2002. With the exception of November 2002, all episodes at Maple Drive occurred during the spring months of February or March. Episode periods accounted for between 33% and 82.35% of the total PM_{10} above the Level B Objective at this site.

The Correlieu monitoring location recorded one Type 1 episode in November 2002 which lasted for 40 hours. The pattern at each of the sites shows that November 2002 was an extended period of poor air quality at all monitoring locations in the airshed. High wind speeds indicate that dust may have been transported across town during this period. Precipitation data was not available, and poor dispersion conditions for an extended period contributed to this airshed episode.

5.0 Fine Fraction Particulate Matter Results – $PM_{2.5}$

In 2000, continuous $PM_{2.5}$ samplers (TEOMs) were installed at two existing continuous PM_{10} monitoring locations in Quesnel, one at QSS and one at Pinecrest. In addition, a third collocated site was established at West Quesnel Correlieu School. The continuous data from these stations are analysed and discussed in this section. $PM_{2.5}$ concentrations are compared against the 24-hour average health reference level of 15 $\mu g/m^3$ (CEPA/FPAC, 1999) even though this value has not been formally adopted nationally or by the province of BC. $PM_{2.5}$ concentrations are also compared to the Canada-wide Standard (CWS) for $PM_{2.5}$ (30 $\mu g/m^3$, 24-hour averaging time) which was adopted in June of 2000. Achievement with this standard is based on the 98^{th} percentile ambient measurement annually, averaged over 3 consecutive years.

5.1 Non-Continuous $PM_{2.5}$

Table 49 presents the previous summary information for non-continuous $PM_{2.5}$ data collected from the Quesnel Senior Secondary site from 1996-2000. Figure 103 shows seasonal concentrations for $PM_{2.5}$ and PM_{10} at the Quesnel Senior Secondary School monitoring location using the non-continuous data winter of 1995/96 to the winter of 1999/00 and the continuous data subsequently. Seasons were defined as follows: Winter – December, January, February; Spring – March, April, May; Summer – June, July, August; Fall – September, October, November. All concentrations are based on paired data with the daily PM_{10} data coming from a TEOM and the $PM_{2.5}$ data coming from the ACCU system. In most years the peak $PM_{2.5}$ concentration occurred during the winter months and is likely associated with increases in home heating emissions (particularly wood stoves) and mobile emissions (running longer) combined with poor dispersion meteorology that traps industrial emissions. Also, in most years, fall $PM_{2.5}$ concentrations were the same or higher than summertime concentrations.

Figure 104 presents the percentage of PM_{10} that is $PM_{2.5}$ on a seasonal basis at the QSS site from 1996-2000, and updated for 2001 and 2002. These calculations are based on paired $PM_{2.5}$ and daily TEOM PM_{10} values. $PM_{2.5}$ accounted for roughly 30-40% of the PM_{10} mass during the spring months but up to 85% of the mass in the winter.

5.2 Continuous $PM_{2.5}$

Tables 50 through 54 present the summary information for the continuous $PM_{2.5}$ data from 2000-2002. The maximum 24-hour concentrations at QSS were above 30 $\mu g/m^3$ in each of the years (Table 50), however the Canada Wide Standard was not exceeded on the 3-year metric (2-years available), and was 24 $\mu g/m^3$. Figure 105 shows the 3-year average 98^{th} percentile concentration of $PM_{2.5}$ from 1998-2002. (Note: In 1998 1-year of data was used, 1999 – 2-years, 2000 onward – 3-years). The data shows that $PM_{2.5}$ was above the CWS in 1998 (this may not constitute an exceeding value without the full 3-years of data), and has been below the CWS in subsequent years near 25 $\mu g/m^3$ since that time.

Although Pinecrest had the highest rolling 24-hour average values ranging from 30.5 to 59.0 µg/m^3, the CWS value was lower at 21 µg/m^3(2-year average) than at Maple Drive which was 26 µg/m^3. This could in part be due to the number of samples collected in 2001 at the Maple Drive site. All stations in Quesnel were below the Canada Wide Standard from 2000 to 2002.

At QSS, Pinecrest and Maple Drive, the annual average $PM_{2.5}$ concentrations were similar and ranged from 6.25 to 8.83 µg/m^3 from 2000-2002. The annual average concentrations at Correlieu were lower and ranged from 4.87 to 7.46 µg/m^3.

5.3 Monthly, Diurnal and Hebdomadal Variations of Continuous $PM_{2.5}$

Continuous $PM_{2.5}$ analyzers are currently in place at four locations in Quesnel and were analysed for 2000 to 2002. It was previously noted that data in 2000 at the stations does not necessarily include the entire year of data (depending on when the station was installed).

Figures 106 through 109 show the monthly variation in $PM_{2.5}$ results measured at QSS, Pinecrest, Maple Drive, and Correlieu stations. The highest mean monthly values were as follows: 14.75 µg/m^3 at QSS in November 2002, 13.00 µg/m^3 at Pinecrest in November 2002, 13.36 µg/m^3 at Maple Drive in November 2002, 9.25 µg/m^3 at Correlieu in February 2002 (Tables 55 to 63). These peaks correspond with the continuous PM_{10} episodes that occurred during that period. The variations show higher peaks in winter when home heating becomes a factor.

Figures 110 to 113 present hour of the day (diurnal) variations in $PM_{2.5}$ concentrations at the at QSS, Pinecrest, Maple Drive, and Correlieu sites averaged over the 2000-2002 record. Figures 114 to 117 examine diurnal trends on a seasonal basis.

The diurnal patterns show a morning peak in mean through 99^{th} percentile concentrations at all sites except Maple Drive between 0700 and 1000 hours. The highest maximum hourly concentrations at all sites generally occur during the morning to mid-afternoon, while a slightly larger distribution occurs throughout the day at the Pinecrest site. A number of factors could contribute to the maximums at these times, and most likely include the break-up of the morning inversion, as well as the increase in particulate matter emissions from vehicles mobile sources and road dust during the day. Although the maximums at Maple Drive exhibit a similar variation, the percentiles and means indicate an inverse relationship. This could be due to the decreased emissions from mobile sources present during the day close to this site.

The seasonal analysis of diurnal mean average $PM_{2.5}$ concentrations (Figures 114 to 117) show some interesting similarities and differences between sites. The following was noted:

- All sites exhibited a elevated summer peak average concentrations in the morning.
- The summer morning peaks (e.g. 8am), occur slightly before the spring and fall peaks (e.g. 9am), which occurs before the winter peaks (e.g. 10am). This strongly indicates that the seasonal peak morning concentrations are occurring subsequent to the inversion

break-up. In wintertime, the break up happens later than summer (The time of sunrise will affect when heating and subsequent break up occurs.)

- Conversely evening peak concentrations occur in fall and winter when the sun sets early and the inversion forms, while summer and spring peaks do not happen until much later; also, home heating emissions (particularly from wood stoves) are greater in fall and winter evenings than in summer and spring.
- The low non-morning values at all stations during spring and summer could in part be due to the higher mixing depths that occur in the late afternoon, allowing for greater dispersion.
- During the evening hours, springtime values are higher than summertime values, likely due in part to summertime reductions in residential emissions; home heating requirements are minimal in summer, but heating is still necessary during night time hours in the spring.
- The QSS and Maple Drive Locations exhibit a maximum in the afternoon around 6pm-7pm; also, the evening peaks are higher than the morning peaks, especially in winter and fall.
- At Pinecrest, the afternoon peak is not as significant.
- The Correlieu site has a more similar pattern to the Pinecrest station, and does not exhibit the variation to the same extent as the other stations; concentrations at Pinecrest are generally higher than at Correlieu, because there are more sources in the vicinity of Pinecrest.
- The overall patterns indicate that ground level sources such as traffic likely contribute to the variations. Home heating and open burning also emit noteworthy amounts of particulate matter during certain seasons. In addition, industrial emissions are held aloft by nocturnal inversions (and can be a large source of fumigation material in the morning hours), so that during subsidence a wide variety of sources can impact particulate matter concentrations. Permitted sources emit a substantial amount of $PM_{2.5}$ to the Airshed.

Weekday (hebdomadal) variations in $PM_{2.5}$ are shown in Figures 118 through 121 for each of the continuous $PM_{2.5}$ monitoring stations. The results are summarized in Table 64. $PM_{2.5}$ concentrations at each of the monitoring stations do not exhibit the same weekly variation that PM_{10} exhibits. The maximum, and 99th percentile and maximum daily $PM_{2.5}$ concentrations occur on Saturdays at all of the stations. Overall, Thursday, Friday, and Saturday $PM_{2.5}$ concentrations are higher at the 95th percentile or above. In part, this is because certain mobile sources, including non-road sources like lawn mowers and snowmobiles, are likely to operate more frequently on a weekend than during the week. The weekend maxima could also be due to residential activities (i.e. wood burning) that are short in duration, and do not have a large effect on the mean values; residential wood burning is less likely to occur in summer. Without the more significant presence of other $PM_{2.5}$ sources on weekends, the $PM_{2.5}$ concentration would more likely exhibit a midweek maximum.

In terms of mean and 75th percentile concentrations, $PM_{2.5}$ minima occurred on either Sunday, Monday or Tuesday, with corresponding maximum values on either Thursday or Friday. This could indicate a gradual accumulation through the week due to continued activity from all sectors. Most commercial activity ceases on Sundays, but the pulp mills and the majority of the sawmills run continuously. Thus it is possible that the lowest mean value represents industrial activity and minimal mobile source activity, while the highest mean value represents impacts from all sectors.

The difference between the midweek maximum $PM_{2.5}$ concentration and the weekend minimum $PM_{2.5}$ concentration at each site is presented in Table 64. On average at the monitoring stations, mean and 75th percentile $PM_{2.5}$ concentrations during the midweek maximum are 29% higher respectively.

5.4 Ratios of PM_{10} to $PM_{2.5}$ from Continuous Data

Figures 122 to 125 show the percentage of PM_{10} that is $PM_{2.5}$ on a monthly basis from the QSS, Pinecrest, Maple Drive and Correlieu continuous sampling sites between 2000 and 2002. At each of the sites, the data show that $PM_{2.5}$ accounts for a more significant portion of the PM_{10} data in winter. For example, in December, $PM_{2.5}$ data accounts for 52.4%, 48.6%, 47.7%, and 47.7% of the PM_{10} in December at QSS, Pinecrest, Maple Drive and Correlieu, respectively. The winter highs could again indicate that wood burning, which is attributable to a larger portion of $PM_{2.5}$ is the main contribution to elevated $PM_{2.5}$ concentrations. It is notable that during the spring, and particularly during March when PM_{10} episodes are more frequent, $PM_{2.5}$ only accounts for 31.3%, 32.0%, 36.6%, and 31.8% percent of the PM_{10} at the respective stations. The coarse component in the early spring is largely attributable to road dust. In winter, much of the coarse fraction of PM_{10} in the form of road dust can be bound to the surface by ice and snow, depending on snowfall amounts and temperature, thus much of the winter PM_{10} mass is represented by fine fraction particles.

5.5 Sulphate Results from Continuous $PM_{2.5}$ Samples

The $PM_{2.5}$ filters were analyzed for sulphate from January 1999 (Non-continuous) and 2000 to 2002 (Continuous). Table 65 summarizes the sulphate data collected from the QSS site. The annual average values (arithmetic/geometric) may be biased high in 1999 due to the number of samples collected (no data available for June, July or August). The annual average sulphate concentration was 1.95 $\mu g/m^3$ in 1999, 0.92 $\mu g/m^3$ in 2000, 0.35 $\mu g/m^3$ in 2001, and 1.20 $\mu g/m^3$ in 2002. The maximum observed daily values were lower (less than half) in 2001 and 2002 than in 1999 or 2000. Sulphate concentrations accounted for between 1.3% and 70.3% (30.2% excluding Summer 1999) of the $PM_{2.5}$ mass (Figure 126). Figures 127 to 130 present the annual percentages of concentrations of $PM_{2.5}$ and sulphate data.

Table 66 shows Formaldehyde results that were not updated within this addendum.

6.0 AIR QUALITY INDEX

The Air Quality Index (AQI) that was presented for 1994/95 to 1999 was updated for the 2000 to 2002 data. All AQIs in Canada are calculated using the same federal guidelines and are therefore directly comparable between communities.

The Air Quality Index numbers are interpreted according to the following scale: 0 to 25 is GOOD, 26 to 50 is FAIR, 51 to 100 is POOR, and 100+ is VERY POOR. Table 67 compares the percent of time that the Air Quality Index values fell into each AQI category for all three continuous PM_{10} sites from 1994 to 1999 and the four sites from 2000 to 2002.

From 2000 to 2002 the AQI was more frequently in the GOOD range when compared with 1997 to 1999. The AQI was rated GOOD from 72.19 to 75.51% of the time. Conversely, the AQI was rated VERY POOR from 0.93 to 1.36% of the time. On average, this is a higher average than the averages of previous years. The ratings of FAIR and POOR conditions were similar to what has been observed in previous years. The drier years in 2000 and 2002 and the poor air quality that was observed in the springtime in 2001 and 2002, as well as in November of 2002 contributed to the increased frequency of VERY POOR air quality in recent years. The Correlieu site was never rated VERY POOR and POOR only 0.55% of the time in 2002.

7.0 SUMMARY OF RESULTS

This section summarizes the results of the data analysis by topic and parameter.

7.1 Meteorology

a) Data gathered at the Quesnel Cariboo Pulp (QCP) and Linden meteorological stations indicate wind speeds and directions that were similar to all of the previous years when data were collected. Wind speeds, wind directions, and temperature can be considered to be average when compared with other months. The years of 1993, 1995 and 1998 remain the worst-case meteorological years for their poor dispersive capabilities.

b) The record of precipitation collected from the Quesnel Airport showed a wetter than normal June and July in 2000 and 2001, and particularly dry conditions in February of 2000 and 2001. Precipitation records were not available past the spring of 2002. This could be further examined to determine whether precipitation was a factor in the elevated PM concentrations in November of 2002.

7.2 Ambient Air Quality – Total Reduced Sulphur (TRS)

a) Trend analysis indicates relatively little change in annual average TRS values at the residential monitoring locations of Maple Drive and Quesnel Senior Secondary (QSS), although 2002 was a lower than normal year at these sites. No discernable trend is evident at either residential monitoring site.

   The QSS site indicates that annual average concentrations were lower from 1996 to 2002 than those recorded from 1990 to 1995. 2002 represents the lowest annual average at QSS at 0.35 $\mu g/m^3$, while the highest year was 1990. From 2000-2002 a much larger predominance of increased concentrations during south-west wind conditions occurred, although the highest concentrations still occurred from the north. This shift in direction of elevated concentrations could be due to the lower frequency of calm conditions and/or a greater frequency of night-time inversions and associated up-valley flows during the 2000-2002 period.

   Concentrations were average in 2000 and 2001, yet the amount of calm wind conditions were low, and in 2002, although the calms were more frequent, the lowest TRS concentrations in the past ten years were observed. This could be evidence of reduced emissions from TRS sources for 2002. A similar correlation is evident at the Maple Drive TRS monitoring location. Annual average TRS trends at the Maple Drive ambient monitoring location have fluctuated from 2000-2002 with a low of 0.30 $\mu g/m^3$ in 1997 and 2002 to a high of 0.69 $\mu g/m^3$ in 1995. Overall, the measured values are on average lower than at QSS, and a similar trend in data occurred from 2000-2002. At Maple Drive, the majority of TRS readings were detected when winds were from the north and north-west sectors. This trend continued from 2000-2002. TRS values less than 1 $\mu g/m^3$ were observed at this site between 63% to

78% of the time from 1999-2002. Figures 131 and 132 show that TRS concentrations at QSS tend to be higher during PM_{10} episodes.

b) In the past four years, annual average TRS concentrations at West Fraser have shown a decreasing trend from 1.49 $\mu g/m^3$ in 1999 to the lower ever 0.61 $\mu g/m^3$ in 2002. Each year was lower than the previous. This likely represents the improvements that have been ongoing at each of the mills.

The number of occurrences exceeding the 1-hour Level A Objective at the West Fraser station ranged from a high of 1635 hours in 1990 to 62 hours in 2002. Exceedances of the one-hour Level A Objective at the West Fraser station, occurred over 21% of the time in 1990 but have since come down to 4% of the time or better since 1994. The number of times the Level B Objective has been exceeded has significantly declined from a high of 510 hours in 1990. From 2000-2002 only there were only two occurrences, and in 2002, for the first times, there were no measured values exceeding the 1-hour Level B Objective. Hourly Level A and B Objective exceedance patterns have remained fairly consistent since 1993 following significant process changes at both pulp mills.

c) Based on the number of exceedances of provincial Ambient Air Quality Objectives for TRS in 2000 to 2002, Maple Drive continues to experience the best air quality out of the three ambient TRS monitoring sites and West Fraser experiences the worst, although improvements have been made. This is to be expected given the respective monitoring site locations in relation to the main sources of TRS.

7.3 Ambient Air Quality – PM_{10}

a) The 2000 to 2002 PM_{10} annual averages at the Correlieu ambient monitoring station (West Quesnel) were much lower than the downtown area. Maple Drive was the next lowest, followed by QSS and Pinecrest.

b) Each year in January the health effects level was exceeded more frequently at Maple Drive than at either QSS or at Pinecrest. This indicates that sources such as wood stoves or tall stacks were contributing to the increased concentrations during this period. The lower annual average values observed at Correlieu, along with the increases in winter, indicate that the most likely influence is local sources, possibly wood burning. The Pinecrest station has the highest annual averages when compared to the other sites, most likely due to the greater influence of the industrial sources.

c) Months with higher precipitation correspond with lower concentrations of PM_{10}. The months of March with more precipitation had fewer concentrations exceeding the Level B Objective. Springtime road dust, and dust from other ground level sources (e.g. log yards) was likely the main cause during the months of February and March. Calm winds did not indicate any significant relationship with more frequent levels exceeding, although in some instances, months with more calms tended to have more elevated values. Ice and snow pack likely have more of an influence on concentrations than calm wind conditions.

d) The provincial 24-hour ambient Objective for PM_{10} was exceeded on average 376 times (4.3% of the time) from 1999-2002 at QSS. 1999 and 2002 were slightly above the average while 2001 and 2002 were below the average. In each of the years, occurrences were most frequent during February, March and April and have been observed to be primarily associated with road dust episodes in combination with stagnant meteorological conditions. Concentrations also exceeded the Objective in the summer months, during stable warm periods, most commonly in August, but also in June and July in 2002. November represents the other month of the year when concentrations exceed the Level B Objective, although less frequently than the other months. At QSS high hourly average PM_{10} levels were recorded from all compass directions. This is indicative of the large number of sources contributing to the PM_{10} levels experienced at this site (i.e. point, mobile and area sources).

e) At the residential continuous monitoring site of Maple Drive, the annual average PM_{10} concentration ranged from 15.5 to 17.1 $\mu g/m^3$ from 1999-2002. The patterns indicated that road dust had an impact at this site. The health effects level of 25 $\mu g/m^3$ was exceeded from 12.4% to 17.8% of the time from 1999-2002 at Maple Drive. Some months (Feb, May, Dec) in 1999 and one month in June 2001 were below the reference levels at all times. This indicated that sources in addition to spring road dust episodes had a significant impact at this location.

f) At Pinecrest, the annual average PM_{10} concentration ranged from 20.9 to 24.4 $\mu g/m^3$ from 1999-2002. Concentrations were above 100 $\mu g/m^3$ in 2000 during March and April. PM_{10} has exceeded the 24-hour Level B Objective each month of the year except January. The number of occurrences above the 24-hour Level B Objective ranged from 356 (4.1%) in 2001 to 790 (9.1%) in 1999. The impacts of springtime road dust at this site are not as evident with the potential exception of the year 2000. Other sources are likely contributing a higher amount of particulate matter to this location throughout the year. The health effects level of 25 $\mu g/m^3$ was exceeded from 28.1% to 39.2% of the time from 1999-2002.

g) At Correlieu site represents the best air quality of all of the sites. The annual average PM_{10} concentration ranged from 12.3 to 15.0 $\mu g/m^3$ from 2000-2002. 24-hour Concentrations were only above the 24-hour Level B Objective during one month: November 2002. The health effects level of 25 $\mu g/m^3$ was exceeded most frequently in the winter months and in early spring. It was exceeded 8.4% of the time in 2001, and 13.9% of the time in 2002.

Trends in Continuous PM_{10} Results

h) No statistically significant trends are evident for all averaging periods at any of the ambient PM_{10} monitoring sites although there appears to be a slight increasing trend at the Pinecrest location since 1996. The 75th Percentile trend at this site showed a slight decreasing trend. All of the other sites have exhibited a slight decreasing trend, however, none of the trends are statistically significant at $p<0.05$.

i) Seasonal trends are apparent at QSS, Maple Drive and Pinecrest. The highest concentrations typically occur in the late winter/early spring months, while the lowest concentrations are measured in December or January. For 2000-2002 the Pinecrest data indicated a secondary peak in November that was not as noticeable in previous years. The two years of data at the Correlieu site did not indicate the same trends, as it is not likely influenced by road dust or downtown to the same extent as the other sites.

j) An analysis of the 2000-2002 average diurnal (hour of the day) PM_{10} patterns demonstrates that the diurnal variation at all three sites was very similar in 2000-2002 as it was in previous years with very minor difference in peak hour maximum concentrations. Inversions (presence or break-ups), meteorological patterns, and variation in traffic volumes are likely all contributing factors to the variations.

k) The diurnal variation at the Correlieu site for 2000-2002 showed that there are peak periods from 7 to 9 am, and 3 to 6pm, indicating a potential influence from vehicle traffic, however, there is much less variation than at the other sites. Based on the location and meteorology of the area, the extent to which sources influence this site is greatly reduced when compared to the others.

l) All of the data from 2000-2002 exhibits a similar pattern of seasonal variation as the 1995-1999 data. The diurnal seasonal variation for 2000-2002 data at the Correlieu monitoring site shows that the maximum concentrations occur during the peak traffic hours, particularly in the summertime.

Episode Analysis

m) An air quality episode analysis was conducted on continuous PM_{10} data from 2000-2002. At the Quesnel Senior Secondary School monitoring location, From 2000-2002 Type 1 episodes occurred 3.69%, 2.37% and 2.37% of the time each year. There were fewer Type 2 episodes from 2000 to 2002 compared to previous years. The longest continuous period of high concentrations occurred in 2001 when the rolling 24-hour average was greater than 50 $\mu g/m^3$ for 130 hours. Type 1 Episodes occurred in March of each year from 1995 to 2002 while they occurred in February seven out of the eight years analyzed. From 2000 to 2002 two episodes occurred in April and one in August. One of the Type 2 episodes occurred in April of 2000. Episode days from 2000 to 2002 accounted for a significant fraction of the total number of times concentrations were above the Level B Objective and ranged from 58.2% to 77.8% of the year.

n) At the Pinecrest Center ambient monitoring location, Type 1 episodes occurred 2.81%, 2.32%, and 3.63% of the year from 2000 to 2002 respectively. There were no Type 2 episodes in 2000, two in 2001 and one in 2002. The longest continuous period occurred in November 2002 when the rolling 24-hour average was greater than 50 $\mu g/m^3$ for 91 hours. Episode periods accounted for between 56.03% and 65.86% of the total PM_{10} exceedances experienced at this site. Over the period, episodes occurred in November each year, and at individual years in February, March, April, June, and October. This further demonstrates from the 1995 to 1999 data the potential influence that industrial activities have on the area.

o) Similar to the 1995 to 1999 data, a low number of episode days occurred at the Maple Drive site. Two Type 1 episodes were recorded in 2000, one in 2001 and three episodes in 2002. There was two Type 2 episodes in 2000 and none in 2001 or 2002. With the exception of November 2002, all episodes at Maple Drive occurred during the spring months of February or March. Episode periods accounted for between 33% and 82.35% of the total PM_{10} exceedances at this site.

p) The Correlieu monitoring location recorded one Type 1 episode in November 2002 which lasted for 40 hours. The pattern at each of the sites shows that November 2002 was an extended period of poor air quality at all monitoring locations in the airshed. The dry period coupled with poor dispersion conditions for an extended period contributed to this airshed episode.

q) A significant portion of PM_{10} Objective exceedances occur during air quality episodes. It was noted that the November 2002 episode occurred at all sites. This episode would be worthy of further examination when more data is available (e.g. precipitation, emissions). Management efforts targeted at those sources that contribute most significantly to episodes should reduce the overall number of exceedances, reduce the annual average PM_{10} value and result in improved air quality. Management efforts aimed at reducing the total loading of fine particulate to the airshed is necessary to control episodes during stagnant condition.

7.4 Ambient Air Quality – $PM_{2.5}$

a) Continuous $PM_{2.5}$ data is only available for analysis from March to December 2000 at the Pinecrest and QSS monitoring sites. The highest mean monthly values of 11.38 $\mu g/m^3$ at QSS and 11.63 $\mu g/m^3$ at Pinecrest occurred during October and November respectively. Both peaks correspond well with the beginning of the winter burning season indicating that this source of fine particulate may be significant for this period. Home heating also becomes a factor at this time of the year and dispersion is poor. At QSS, monthly mean $PM_{2.5}$ concentrations remain elevated through December while they fall to levels similar to summertime concentrations at Pinecrest. Even though this is a short-term record, the data infers that the downtown area may act as a collection area for $PM_{2.5}$ emissions from other parts of the city.

b) Annual diurnal patterns show a morning peak in mean through 99th percentile $PM_{2.5}$ concentrations at both sites between 0700 and 1000 hours. The highest maximum hourly concentrations generally occur during the morning to mid-afternoon at QSS (under the influence of the nocturnal inversion and subsequent break-up) while they are well distributed throughout the day at the Pinecrest site. The additional industrial sources of $PM_{2.5}$ near the Pinecrest site likely account for the wide distribution of maximums throughout the day.

c) All sites exhibited a elevated summer peak average concentrations in the morning. The summer morning peaks (e.g. 0800), occur slightly before the spring and fall peaks (e.g.0900), which occurs before the winter peaks (e.g. 1000). This strongly indicates that the seasonal peak morning concentrations are occurring subsequent to the inversion break-up. In wintertime, the break up happens later than summer (the time of sunrise will affect when heating and subsequent break up occurs). Conversely evening peak concentrations occur in fall and winter when the sun sets early and the inversion forms, while summer and spring peaks do not happen until much later. The low values at all stations during spring in summer could in part be due to the higher mixing depths that occur in the late afternoon, allowing for greater dispersion. The QSS and Maple Drive locations exhibit a maximum in the afternoon around 1700. At Pinecrest, the afternoon peak is not as significant. The Correlieu site has a more similar pattern to the Pinecrest station, and does not exhibit the variation to the same extent as the other stations. The overall patterns indicate that ground level sources such as traffic likely contribute to the variations.

d) $PM_{2.5}$ concentrations at each of the monitoring stations do not exhibit the same weekly variation that PM_{10} exhibits. Overall, Thursday, Friday, and Saturday $PM_{2.5}$ concentrations are higher at the 95th percentile or above. In part, this is because certain mobile sources, including non-road sources like lawn mowers and snowmobiles, are likely to operate more frequently on a weekend than during the week. The weekend maxima could also be due to residential activities (i.e. wood burning) that are short in duration, and do not have a large effect on the mean values; residential wood burning is less likely to occur in summer. Without the more significant presence of other $PM_{2.5}$ sources on weekends, the $PM_{2.5}$ concentration would more likely exhibit a midweek maximum. In terms of mean and 75th percentile concentrations, $PM_{2.5}$ minima occurred on either Sunday, Monday or Tuesday, with corresponding maximum values on either Thursday or Friday. Most commercial activity ceases on Sundays, but the pulp mills and the majority of the sawmills run continuously. Thus it is possible that the lowest mean value represents industrial activity and minimal mobile source activity, while the highest mean value represents impacts from all sectors.

e) On average at the monitoring stations, the mean and 75th percentile $PM_{2.5}$ concentrations during the midweek maximum are 29% higher than the corresponding weekend concentrations. This likely corresponds with regular traffic patterns.

f) The percentage of PM_{10} that is $PM_{2.5}$ on a monthly basis from the QSS, Pinecrest, Maple Drive and Correlieu continuous sampling sites between 2000 and 2002 was analysed. At each of the sites, the data show that $PM_{2.5}$ accounts for a more significant portion of the PM_{10} data in winter. The winter highs could indicate that wood burning, which produces a relatively large portion of $PM_{2.5}$, is the main contributor to elevated $PM_{2.5}$ concentrations. In winter, much of the coarse fraction of PM_{10} in the form of road dust can be bound to the surface by ice and snow, depending on snowfall amounts and temperature, which is another reason for the higher wintertime ratio of fine fraction particles.

g) It is notable that during the spring, and particularly during March when PM_{10} espisodes are more frequent, $PM_{2.5}$ accounts for a smaller portion of the PM_{10} than in winter, at all stations. The coarse component in the early spring is largely attributable to road dust.

7.5 Ambient Air Quality – $PM_{2.5}$ Sulphate

a) The annual average sulphate concentration was 1.95 $\mu g/m^3$ in 1999, 0.92 $\mu g/m^3$ in 2000, 0.35 $\mu g/m^3$ in 2001, and 1.20 $\mu g/m^3$ in 2002. The maximum observed daily values were lower (less than half) in 2001 and 2002 than in 1999 or 2000. Sulphate concentrations accounted for between 1.3% and 70.3% of the $PM_{2.5}$ mass. These values highlight the importance of sulphate contributions to the fine particle concentrations in the airshed.

7.6 Air Quality Index

a) From 2000 to 2002 the AQI was more frequently in the GOOD range when compared with 1997 to 1999. The AQI was rated GOOD from 72.19 to 75.51% of the time. Conversely, the AQI was rated VERY POOR from 0.93 to 1.36% of the time. On average, this is a higher average than the averages of previous years. The ratings of FAIR and POOR conditions were similar to what has been observed in previous years. The drier years in 2000 and 2002 and the poor air quality that was observed in the springtime in 2001 and 2002, as well as in November of 2002 contributed to the increased frequency of VERY POOR air quality in recent years. This data is another indicator that management of the episodes and very poor air quality periods are important to improving overall air quality in the airshed.

8.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are provided to supplement, or reinforce conclusions that were provided in the original report.

1. Meteorology plays an important role in air pollution in the Quesnel airshed. Knowledge of precipitation patterns and calm wind conditions should be used to assist in developing management plans to reduce PM_{10} episodes and times when road-dust can contribute to POOR air quality periods. The 2002 precipitation data should be examined against the November 2002 air quality episode, when they are available.

2. Reductions in TRS concentrations have occurred in the airshed over the last decade. Further management and improvements (e.g. reduction in sources) are required to reduce the potential for exceeding the air quality Objectives.

3. PM_{10} concentrations can be above the Level B air quality Objectives at all monitors in the airshed. Road-dust and industrial sources are the main contributors to the poor air quality events.

4. There are no statistically significant trends evident at any of the continuous ambient PM_{10} monitoring sites. There appears to be a slight increasing trend in annual averages at the Pinecrest location since 1996, while the remaining sites appear to have a slight decreasing trend.

5. PM_{10} diurnal and seasonal patterns at each station show that peaks and low periods generally correspond with traffic patterns (road dust and direct emissions) as well as the night-time inversion development and break-up. Concentrations at the Pinecrest monitoring site depart somewhat from this pattern, indicating that industrial emissions likely influence this site.

6. Anthropogenic activities have a large influence on PM_{10} levels in Quesnel. This is reflected in the hebdomadal analysis (day of the week) by the fact that all monitoring sites show a weekend minimum vs. a weekday maximum.

7. A significant portion of concentrations exceeding the PM_{10} 24-hour Level B Objective occurs during air quality episodes. Management efforts targeted at sources that contribute most significantly to episodes should reduce the overall number of times above the 24-hour Level B Objective and reduce the annual average PM_{10} value as a result.

8. The coarse component of PM_{10} in the early spring is largely attributable to road dust being re-entrained by passing vehicles.

9. Sulphate can be an important component of $PM_{2.5}$

10. At QSS, Pinecrest and Maple Drive, the annual average $PM_{2.5}$ concentrations were similar and ranged from 6.25 to 8.83 $\mu g/m^3$ from 2000-2002. The annual average concentrations at Correlieu were lower and ranged from 4.87 to 7.46 $\mu g/m^3$. Although the maximum 24-hour concentrations at each of the stations were above 30 $\mu g/m^3$ in each of the years. All stations in Quesnel were below the Canada Wide Standard from 2000 to 2002.

11. $PM_{2.5}$ concentrations at each of the monitoring stations do not exhibit the same weekly variation that PM_{10} exhibits. Overall, Thursday, Friday, and Saturday $PM_{2.5}$ concentrations are higher at the 95th percentile or above. Although the source can not be absolutely determined, in part, this is because certain mobile sources, including non-road sources like lawn mowers and snowmobiles, are likely to operate more frequently on a weekend than during the week. The weekend maxima could also be due to residential activities (i.e. wood burning) that are short in duration, and do not have a large effect on the mean values; residential wood burning is less likely to occur in summer. Without the more significant presence of other $PM_{2.5}$ sources on weekends, the $PM_{2.5}$ concentration would more likely exhibit a midweek maximum. In terms of mean and 75th percentile concentrations, $PM_{2.5}$ minima occurred on either Sunday, Monday or Tuesday, with corresponding maximum values on either Thursday or Friday. Most commercial activity ceases on Sundays, but the pulp mills and the majority of the sawmills run continuously. Thus it is possible that the lowest mean value represents industrial activity and minimal mobile source activity, while the highest mean value represents impacts from all sectors.

12. The percentage of PM_{10} that is $PM_{2.5}$ on a monthly basis shows that $PM_{2.5}$ accounts for a more significant portion of PM_{10} in winter. The winter highs could indicate that wood burning, which produces a relatively large portion of $PM_{2.5}$, is the main contributor. In winter, much of the coarse fraction of PM_{10} in the form of road dust can be bound to the surface by ice and snow, depending on snowfall amounts and temperature, which is another reason for the higher wintertime ratio of fine fraction particles.It is notable that during the spring, and particularly during March when PM_{10} episodes are more frequent, $PM_{2.5}$ accounts for a smaller portion of the PM_{10} than in winter, at all stations. The coarse component in the early spring is largely attributable to road dust.

13. The Air Quality Index is a good indicator that management of the episodes and very poor air quality periods are important to improving overall air quality in the airshed. Dispersion modelling that has been conducted can assist in the future in identifying the highest contributors to poor air quality and assist in management plans.

10.0 REFERENCES

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