Supplemental Information
Alaska Department of Environmental Conservation
$PM_{2.5}$ Designation and Boundary Recommendations

I. $PM_{2.5}$ Design Value Calculations

Below is a table showing the calculated 24-hour and annual $PM_{2.5}$ design values for locales represented by Alaska's $PM_{2.5}$ monitoring network.

	Anchorage	Matanuska Susitna Valley-Butte	Juneau – Mendenhall Valley	Fairbanks
24-hour $PM_{2.5}$ design value	**26**	**31**	**35**	**43**
annual $PM_{2.5}$ design value	**6.7**	**6.0**	**7.8**	**11.0**

The table below shows the number of days the new standard was exceeded each year at each location. The timeframe for this designation calculation is 2004-2006. The 24-hour values in bold font for each site were the 98th percentile values averaged for the 24-hour design values. The new $PM_{2.5}$ health standard went into effect on Dec. 18, 2006. Consequently, these locales were managed to less rigorous National Ambient Air Quality Standard (NAAQS) throughout 2004-2006.

	Anchorage			Matanuska Susitna Valley - Butte			Juneau – Mendenhall Valley			Fairbanks		
Calendar Year	**2004**	**2005**	**2006**	**2004**	**2005**	**2006**	**2004**	**2005**	**2006**	**2004**	**2005**	**2006**
Max. 24-hr Concentration, μg/m³	43.7	55.9	34.1	**27.5**	45	48.6	29.8	45.1	48.5	54.2	60	51.9
2nd Max. 24-hr Concentration, μg/m³	32	33.3	30.7	23.3	25.2	**40**	**27.5**	**39.9**	**36.7**	**46.2**	**40.6**	**42.2**
3rd Max. 24-hr Concentration, μg/m³	**31.9**	**17.9**	**26.9**	20.3	**25.2**	39.4	26.1	35.4	33	38.1	34	41.1
Days above new standard	**1**	**1**	**0**	**0**	**1**	**4**	**0**	**3**	**2**	**3**	**2**	**4**
24-hour design value, μg/m³	**26**			**31**			**35**			**43**		
annual design value, μg/m³	**6.7**			**6.0**			**7.8**			**11**		

The data for the Butte area in the Matanuska-Susitna Valley has two missing quarters in 2004. No data was collected during the second and third quarters due to staff turnover. Higher concentrations of $PM_{2.5}$ are typically measured during the winter months (i.e. the first and fourth quarters). Thus, the design value was calculated with the remaining data values for 2004.

II. Fairbanks $PM_{2.5}$ Non-Attainment Boundary Analysis

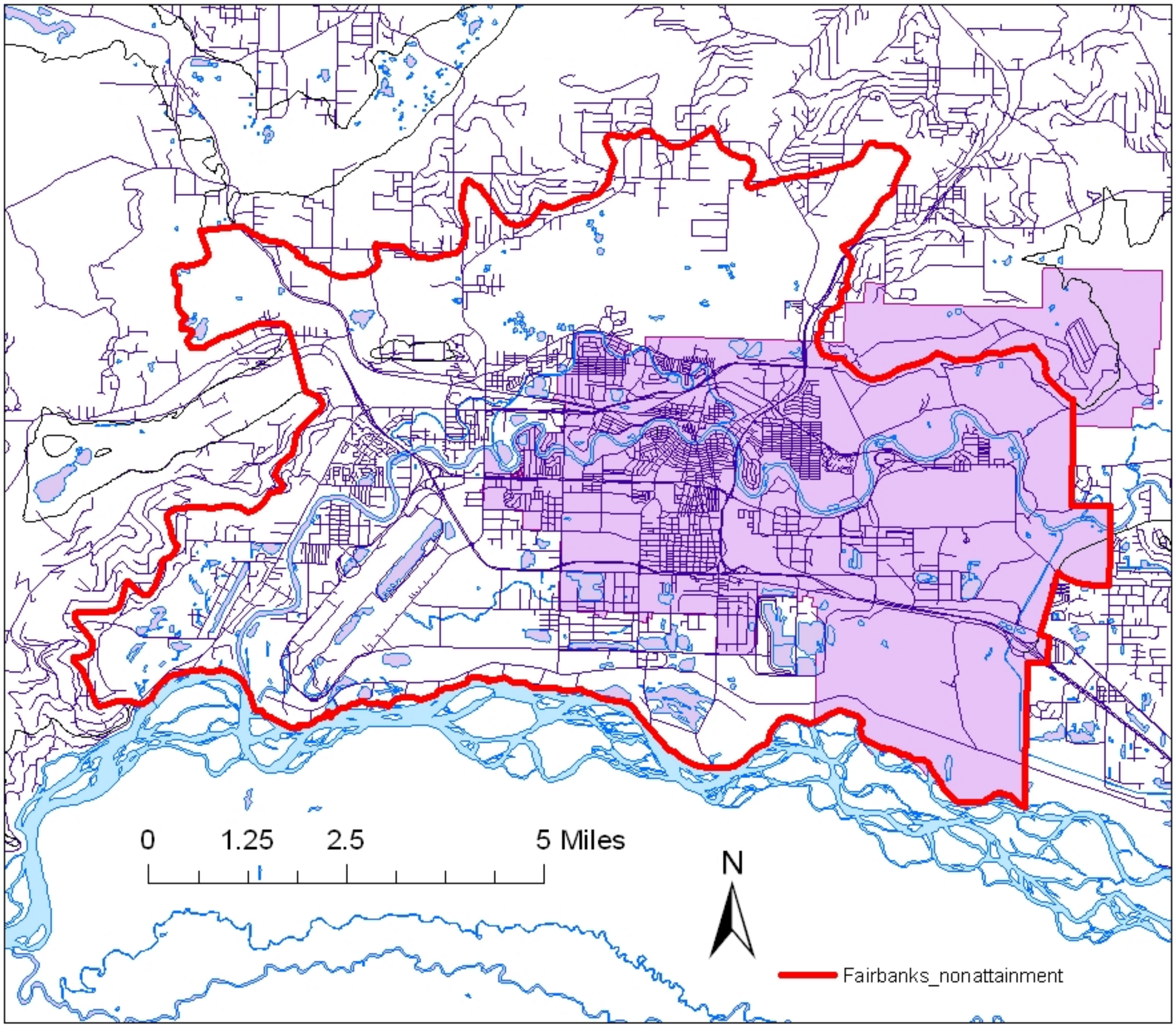
Ambient air monitoring has been conducted at one site in downtown Fairbanks since the $PM_{2.5}$ network was established in 1999. While this site does represent the level of fine particulates in the downtown area, there is nothing to confirm that $PM_{2.5}$ concentrations exceed state and federal fine particulate standards outside of the urban center. EPA recommends that states consider nine factors in making non-attainment boundary recommendations. These nine factors include:

- Emission data
- Air Quality data
- Population density and degree of urbanization (including commercial development)
- Traffic and commuting patterns
- Growth rates and patterns
- Meteorology (weather/transport patterns)
- Geography/topography (mountain ranges or other air basin boundaries)
- Jurisdictional boundaries (e.g. counties, air districts, reservations, metropolitan planning organizations (MPOs)
- Level of control of emission sources

Based on a number of these factors, the department, in consultation with the Fairbanks North Star Borough, has developed a recommended boundary for a $PM_{2.5}$ non-attainment area in Fairbanks. The proposed boundary, depicted in Figure 1, captures the airshed most likely to be in non-attainment of the health standard based on existing monitoring data and other factors listed above. As supplemental information and data is collected over the next several years, this boundary could be further refined.

The proposed Fairbanks non-attainment area would be bounded on the south by the Tanana River. The western and northern boundary would occur at the 600 foot elevation on the surrounding hills and ridges. The eastern boundary would also extend along at the 600 foot elevation level until it reaches the eastern edge of the Fairbanks city boundary (also the Fort Wainwright military reservation boundary). The eastern boundary would then continue to extend south along the city boundary until it meets the Tanana River. Figure 1 shows a map of the proposed boundary.

Figure 1
Proposed Fairbanks $PM_{2.5}$ Non-Attainment Area Boundary Map



$PM_{2.5}$ Air Quality in Fairbanks

In 1997, the national ambient air quality standard for $PM_{2.5}$ was 15µg/m^3 for an annual average and 65µg/m^3 for a 24-hour average. As of August 2007, the U.S. Environmental Protection Agency (EPA) had determined that Fairbanks was in attainment of the 65 µg/m^3 standard. In 2006, the 24-hour standard was tightened by EPA[1*] to 35µg/m^3. In each of the three winter periods (Oct-Mar) from 2004–2007 Fairbanks experienced 25-30 days when the daily average $PM_{2.5}$ exceeded 35µg/m^3 (based on measurements recorded on continuous analyzers), with yearly 24-hour average maxima ranging from 65 to 88µg/m^3 as measured by either federal reference monitors or continuous monitors. The 24-hour $PM_{2.5}$ design value calculated for Fairbanks during the period 2004-2006 is 43µg/m^3.

Uncertainties in Air Monitoring Data

While the state believes winter monitoring results have shown a 24 hour $PM_{2.5}$ problem in Fairbanks, the data has some limitations that could possibly invalidate most of the winter data. First, the federal reference method samplers frequently operated at temperatures below the design range of the instruments making flow readings, particle movement, and general low-temperature operation uncertain. Problems with calibrator operations at extreme cold temperatures further impacts monitoring results. In addition, it is known that the Federal Reference Method filter-based sampling does not properly adjust for changing sample flow rates at the lower temperatures experienced in Fairbanks in winter.

At the same time, the Fairbanks North Star Borough operated a Met One Beta Attenuation Monitor to provide a more robust assessment of fine particle concentrations. Because these samplers are not federal reference methods or federal equivalent methods, they were operated to collect co-located measurements with the federal reference method samplers. During the evaluation period, the continuous sampler design was undergoing modifications and upgrade. A heater was installed in 2007 to help control humidity which may have caused readings to be subject to a positive artifact,[2] and measurements made after that time may be subject to a negative artifact due to loss of nitrate (which has been observed in other samplers when an in-line heater was used).[3]

Geography/Topography

The state's proposed $PM_{2.5}$ nonattainment area boundary centers on the city of Fairbanks which is located in interior Alaska at 64.837780° North Latitude, -147.71639° West Longitude. The city lies on the winding Chena River near its confluence with the Tanana River, which occurs just south of town. The city is surrounded by ridges on the northeast, north, and west. The Chatinika, Chena, and Salcha River drainages define the area surrounded by rolling hills to the north, east and west of the urban centers. The Tanana River Valley flats border the city to the south and southeast.

[*] Superscripts denote references provided at the end of this document.

The elevation of Fairbanks on the valley floor is approximately 440 feet above sea level (ASL) with the immediate surrounding ridges rising to about 600 feet ASL and other ridges close by that reach as much as 2500 feet ASL. The low elevation of the city center with respect to the surrounding ridges causes air pollution build up within the bowl during stagnant air conditions.

The nearby city of North Pole lies to the southeast of Fairbanks on the valley floor in a less topographically confined region, with the closest hills lying to the east at a greater distance from the North Pole city center than the hills surrounding downtown Fairbanks.

Meteorology

Fairbanks winters are dominated by a pattern of cold, stable air that supports the buildup of air pollutants.[4,5] Temperatures typically range between -20° and +20° F, with several periods of -40° F each winter. Occasionally, temperatures can extend to much colder temperatures (e.g. -66° F). A combination of high albedo and the low solar elevation that occurs in northern latitudes during the winter months, creates little heating of the ground and weak vertical mixing between the surface an overlying air. Fairbanks frequently experiences ground-based inversions of considerable strength (40° F/100m) topped by weaker inversion zones such that the layer of inverted lapse rate often reaches as high as 1-2 kilometers. This condition together with local emissions of $PM_{2.5}$ and its precursors (especially sulfur dioxide) can cause episodes of elevated $PM_{2.5}$ concentrations.

Location and Jurisdictional Boundaries

The Fairbanks North Star Borough is located in the heart of Interior Alaska at approximately 64.833330° North Latitude and -147.716670° West Longitude. The area encompasses 7,361.0 sq. miles of land and 77.8 sq. miles of water. The Borough seat is located in the city of Fairbanks. A less densely urbanized area extends from Fairbanks along the Richardson Highway corridor through the city of North Pole to the southeast. The Borough also contains other smaller outlying residential areas (i.e., Ester, Fox, etc.) as well as two military bases (Fort Wainwright and Eielson Air Force Base). Fairbanks has a metropolitan planning organization, FMATS, whose boundary includes both Fairbanks and North Pole and extends further into population areas within the vicinity of both communities.

Figures 2 through 4 are maps of the borough, cities, and FMATS boundaries.

Figure 2 - Fairbanks North Star Borough

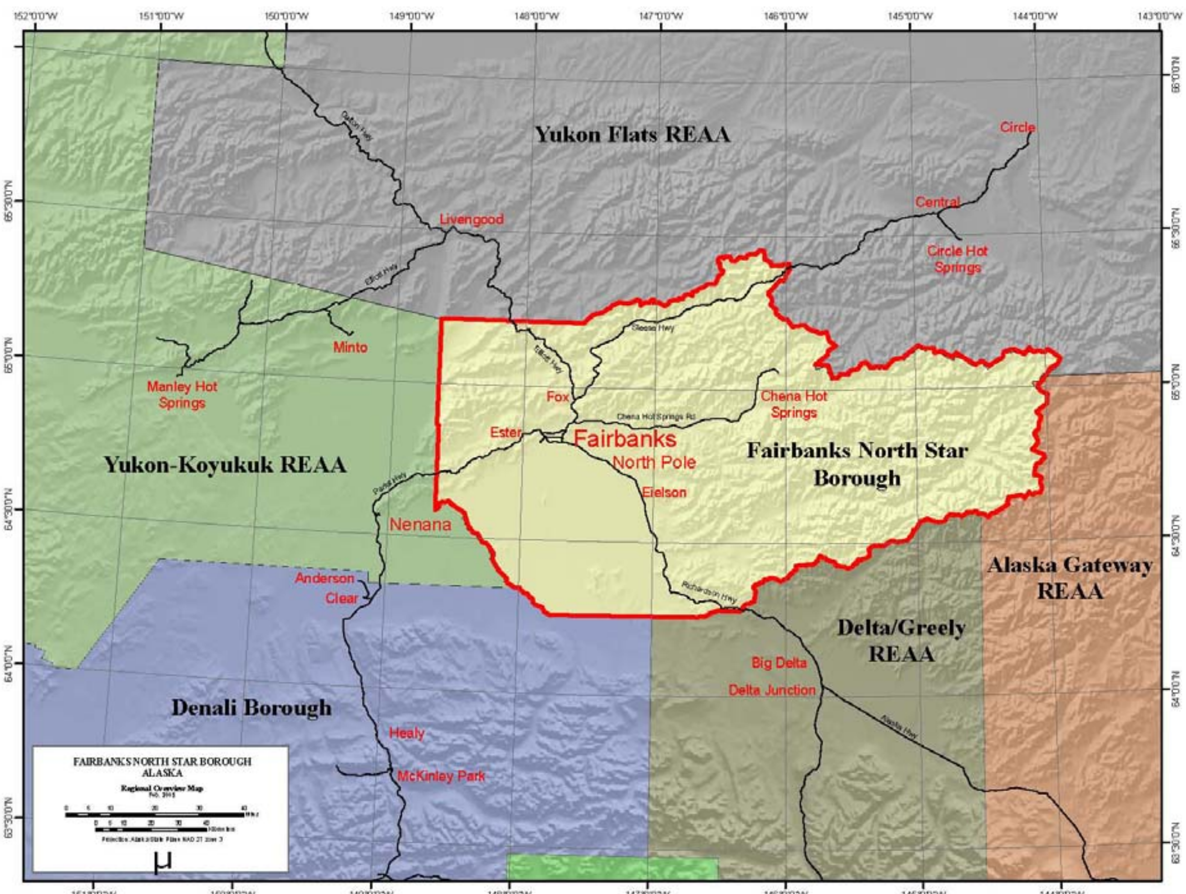


Figure 3 - City Boundaries within the Fairbanks North Star Borough

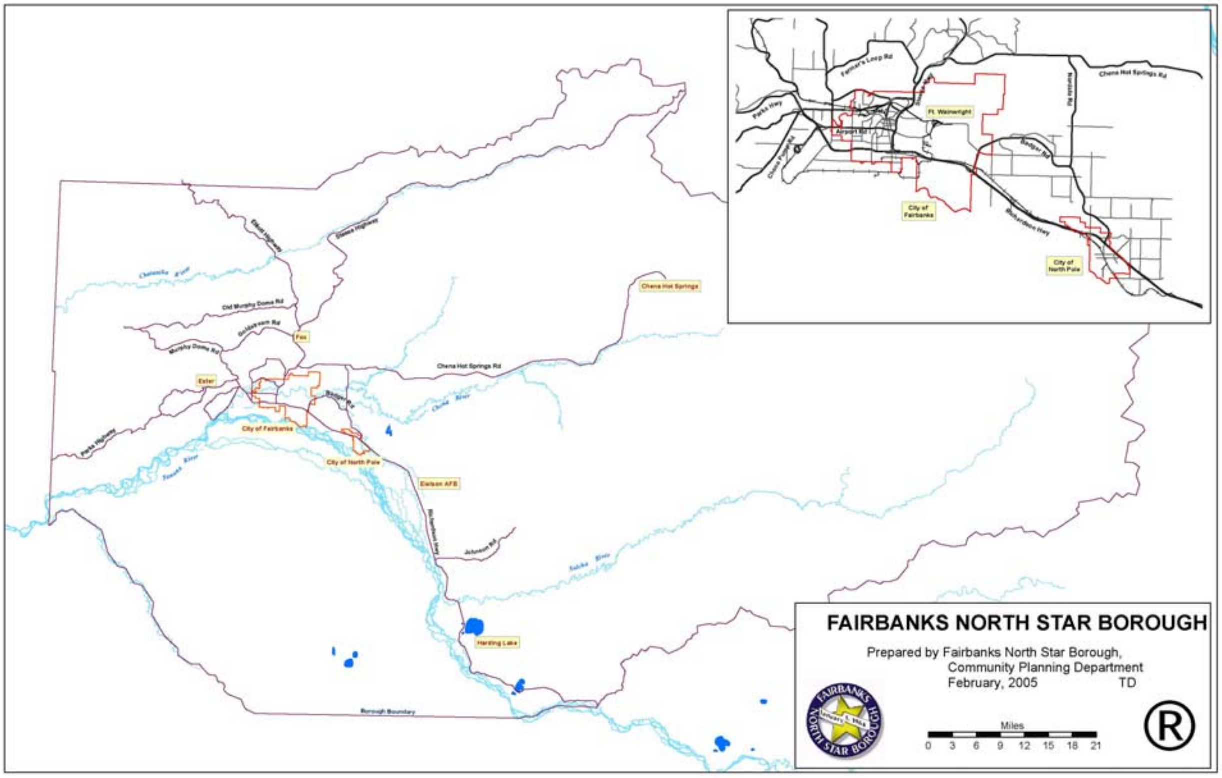
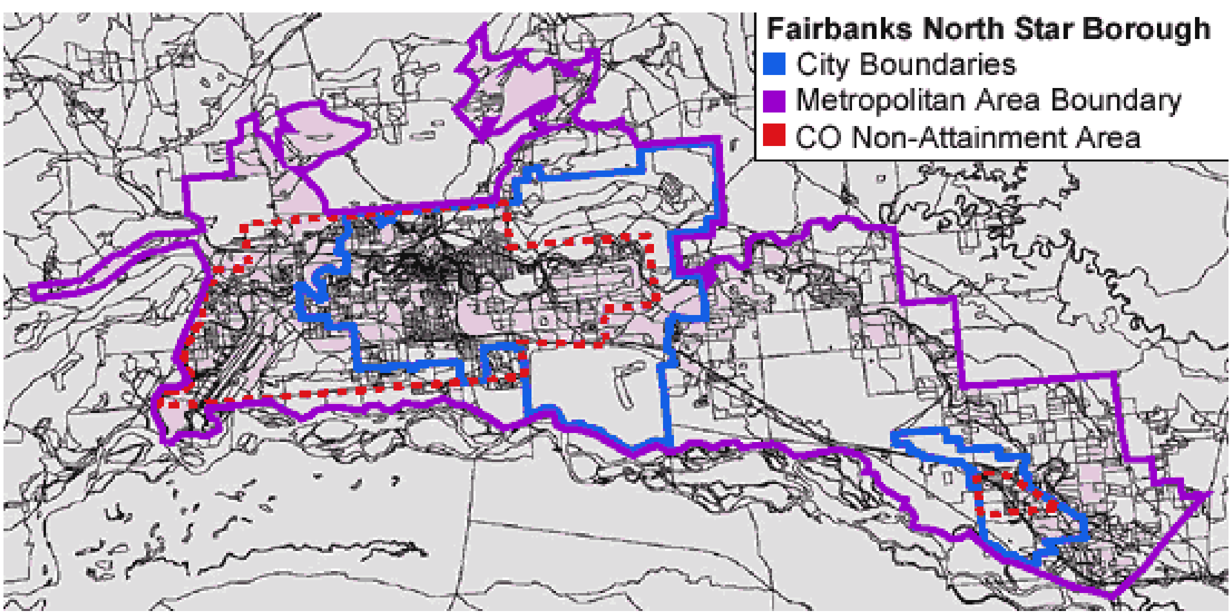


Figure 4 – FMATS Boundary



Population Density and Degree of Urbanization

The Fairbanks North Star Borough 2006 population as certified by the U.S. Census Bureau was 94,803 people and it is the second largest community in the state. Much of the Borough's population is concentrated in the urban area in and around the city of Fairbanks. A less densely urbanized area extends along the Richardson Highway corridor through the city of North Pole to the southeast. The Borough also contains other smaller outlying residential areas (i.e., Ester, Fox, etc.) as well as two military bases (Fort Wainwright and Eielson Air Force Base).

Air Quality and Sources of $PM_{2.5}$ Emissions

Ambient air monitoring conducted in downtown Fairbanks coupled with efforts by the department and the Fairbanks North Star Borough to characterize possible sources of $PM_{2.5}$ have identified a number of potential causes of high concentrations within the community. Much work remains to more fully understand the extent of the problem area and the sources of concern. The information provided in this section serves as a starting point for further efforts on source characterization.

In a recent study by the Fairbanks North Star Borough's contractor, Sierra Research, positive matrix factorization (PMF[6,7]) was used to analyze the co-variance in air quality measurements in Fairbanks in an attempt to discern the number and types of contributing sources.[8] PMF is a tool for looking at speciated air quality data to attribute source categories; however, its accuracy and effectiveness at attributing data under Fairbanks winter conditions is not fully known. Nonetheless, it can provide some initial insight into sources contributing to $PM_{2.5}$ concentrations at the Fairbanks downtown monitoring site.

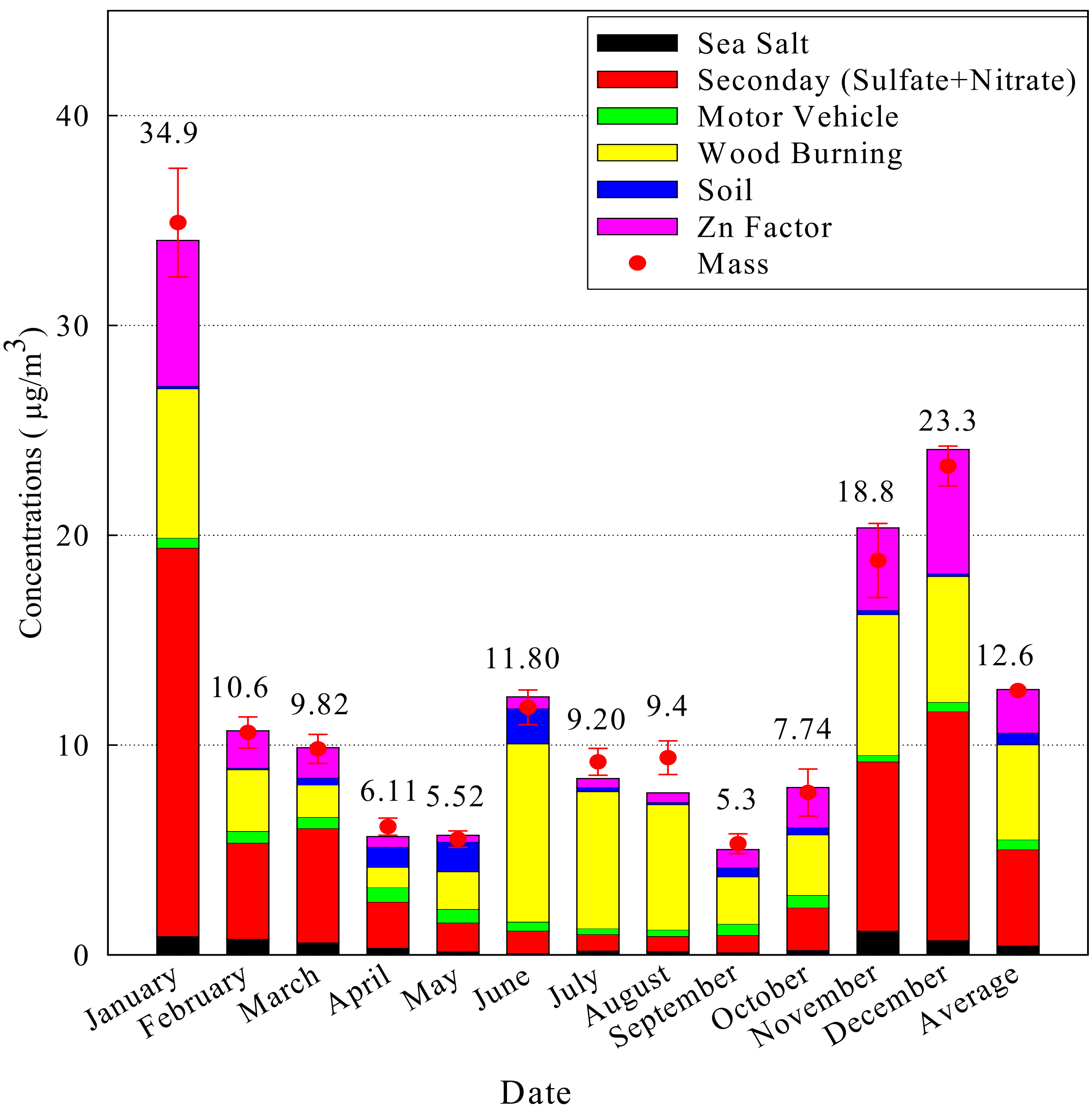
The study found that in winter months, secondary aerosol, which is primarily sulfate and nitrate, makes up about 40-55% of the monthly average mass concentrations of $PM_{2.5}$, with the highest percentage in January (the coldest month, with an average temperature of about -10ºF). Most of the remaining aerosol mass, by this accounting, is contributed about equally by wood burning and an unknown zinc-related factor, with smaller contributions found for sea salt, motor vehicles, and soil (in that order). These results are summarized in Figure 5 (see reference 11 for additional details).

One major uncertainty in the aforementioned Fairbanks PMF analysis is that the source of the zinc factor is unknown. Possible sources include burning of waste lubricating oil in and around Fairbanks, burning of lubricating oil by motor vehicles, other local trace sources, or distant sources of zinc mining and ore handling.[9,10] Zinc is widely used as an additive in lubricating oils for Diesel engines and, in lower concentrations, for gasoline-powered engines in motor vehicles and other machines.[11] Cahill has shown[12] that "Diesels and smoking cars have robust metallic tracers (Zn, P) in the very fine, ultra fine, and nano-particle modes from burned lubricating oil." If, in fact, the zinc-related factor is due to motor vehicles, the motor vehicle contribution to $PM_{2.5}$ would be much greater than shown above from the PMF analysis.

Another uncertainty about the aforementioned analysis is whether the monthly average accurately reflects conditions during the worst-case 24-hour period that may correspond to a

$PM_{2.5}$ design day. For example, the inventory of space heating sources, including both the burning of both wood and of sulfur-bearing fuel oil, is expected to be significantly higher on the coldest day(s) compared to average winter days or even to average January days. Furthermore, atmospheric conditions may be quite different on the coldest days, which are likely to include episodes of "ice fog,"[5] very restricted vertical mixing, and little or no wind.

Figure 5
Source Contributions to Total $PM_{2.5}$ in Fairbanks
(03/17/2005~01/15/2007)



Sulfates

In winter, levels of $PM_{2.5}$ in Fairbanks are correlated inversely with temperature, as shown in Figure 6. The correlation, while statistically significant, is rather weak ($r^2 = 0.28$) and is complicated by the fact that at least two factors are confounded. First, a likely source of the sulfur dioxide emissions and atmospheric sulfate is fuel burning for space heating, which increases as temperature decreases. But in addition, atmospheric dispersion decreases with temperature due to lower wind speeds, lower mixing depths, and more extreme lapse rates (which further retard vertical mixing). Ice fog may present an additional complication. The net effect of all these factors, as shown in Figure 6, is that the daily average $PM_{2.5}$ concentration increases by about 4μg/m^3 for each 10 degree drop in temperature. Furthermore, as shown in Figure 7, $PM_{2.5}$ and sulfate concentrations are highly correlated ($r^2 = 0.85$). In contrast to sulfates, nitrates are much more weakly correlated with $PM_{2.5}$ ($r^2 = 0.38$, as shown in Figure 8).

Figure 6
$PM_{2.5}$ vs Temperature

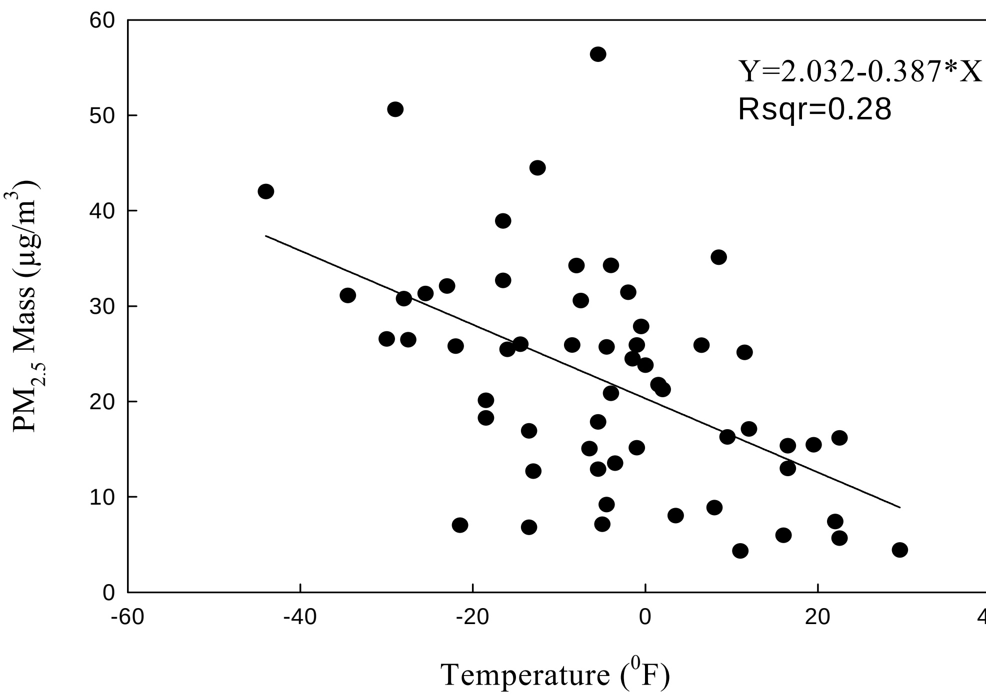


Figure 7
$PM_{2.5}$ Mass vs Sulfate Mass

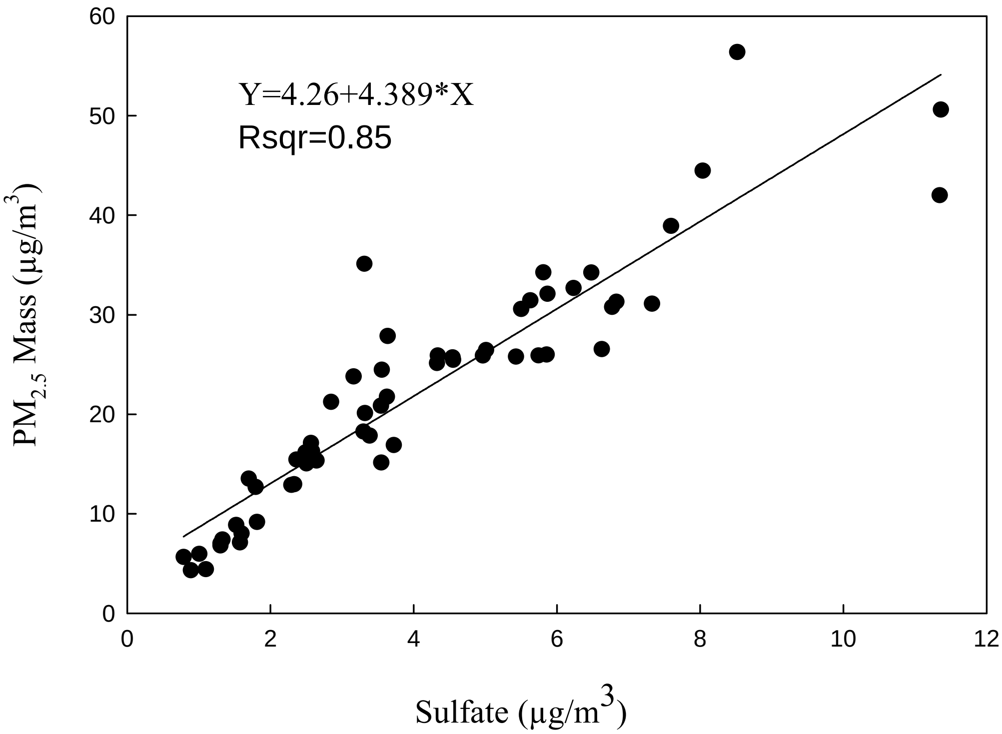
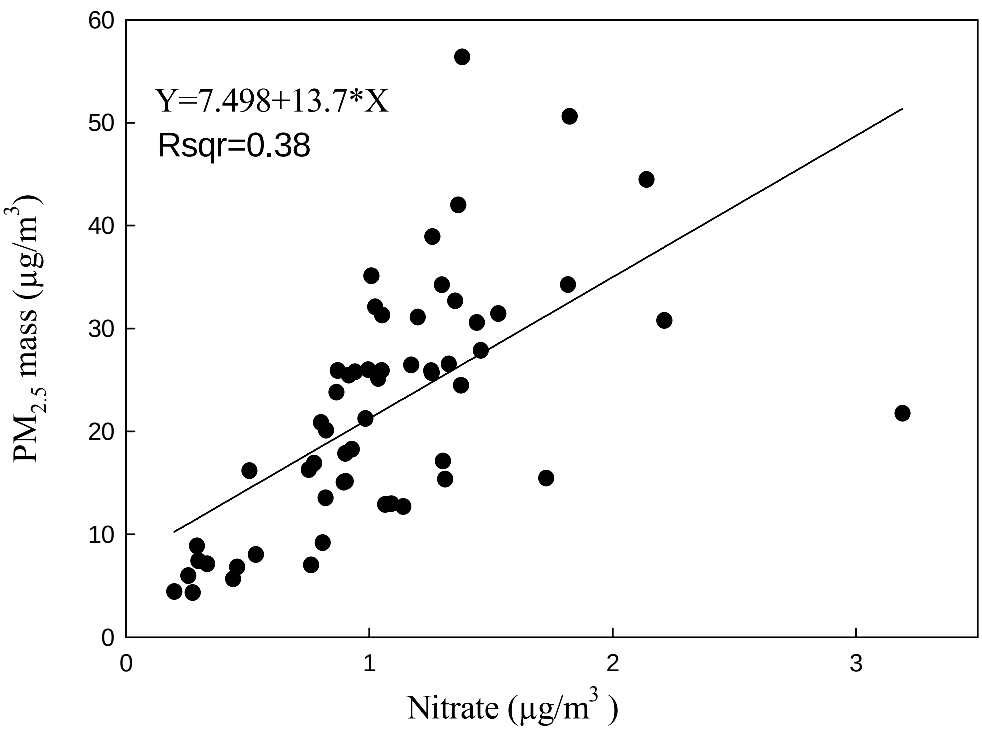


Figure 8
$PM_{2.5}$ Mass vs Nitrate Mass



Fuel Burning

Although there is a multiplicity of sources in Fairbanks that burn fuel containing sulfur, it is possible that the distillate fuel used in space heating could be a dominant source of sulfur oxide emissions and atmospheric sulfates in Fairbanks in the winter. This conclusion follows from consideration of the inventory of fuel used, which is summarized for a recent year in Table 1 (attached)*, and knowledge of the fuel sulfur contents.

Significant amounts of gasoline and Diesel fuel are burned in mobile sources in Fairbanks, but the sulfur content of both of these fuels has been reduced dramatically in recent years, due to strict environmental regulation, to respective levels of about 0.007% and 0.08% sulfur by weight. The sulfur content of distillate oil that is used for home heating has not been so regulated, and remains at about 0.22 weight percent sulfur, resulting in about 600 tons per year of sulfur dioxide emissions. The vast majority of these emissions occur during the winter months, and the annual level is roughly six times greater than the summed SO_2 emissions contribution from the combustion of gasoline and Diesel fuel used in the mobiles source sector (estimated at 95 tons for calendar year 2002). By comparison, point sources in the Borough (some of which are elevated well above typical ground-based mixing heights) emit about 2500 tons of SO_2 per year. Of this 2500 tons, the coal-fired power plants in Fairbanks emit an estimated 828 tons per year and the Golden Valley Electric Association (GVEA) power plant in North Pole is estimated to emit about 1578 tons per year.

The contribution to SO_2 emissions from coal-burning in and around Fairbanks and from the combustion of distillate fuel oil for reasons other than space heating in North Pole and elsewhere is significant. However, emissions from the Aurora Energy Chena and Fort Wainwright coal-fired power plants are generally expected to have an effective plume height that is well above the surface-based mixed layer under conditions of cold temperature. The other distillate fuel sources are generally much more distant from the downtown air monitoring site (the GVEA power plant in North Pole is about 14 miles SE of the downtown Fairbanks air monitor). While both of these sources could potentially be important contributors to regional sulfate, the most likely local source appears to be the very large amount of fuel that is burned to heat individual homes and buildings in and around Fairbanks. These local space heating emissions as well as those from diesel vehicles are released into or very close to the boundary of the semi-permanent surface-based mixed layer. An important countervailing consideration is that many commercial buildings in the downtown area (generally to the north of the monitoring site) are heated by hot water from the Aurora Energy power plant.

Refinement of several of these assumptions will require updated fuel use information and a detailed calculation of temperature-dependent SOx emissions. Ideally, it would also include dispersion modeling predictions for the major point sources in the region and a detailed measurement survey of $PM_{2.5}$ concentrations both within and well outside of Fairbanks during the winter.

---

* The fuel use estimates are partly based on assumptions and should be considered rough estimates only.

Wood Burning

A recent investigation into possible increases in wood-burning in and around Fairbanks in recent years found the following[13]:

> *Residential heating oil prices in Alaska increased significantly in each of the last four years, and data from DEC-sponsored home heating surveys in 2006 and 2007 show that more households have installed wood-burning appliances. The same two-year survey data do not show a statistically significant change in the amount of wood burned per household (the average cords burned per household actually decreased in the respective surveys from 3.22 to 2.82). However, there is suggestive evidence that wood burning may have increased between 2004 and 2005, and then stabilized in 2006.*

Another important source of wood burning emissions in and around Fairbanks is external or outdoor wood boilers (OWBs). Such OWBs are believed to be relatively few (but increasing) in number in Fairbanks and are believed to have rather severe but generally localized impacts, as suggested by a recent NESCAUM assessment[14,15] (mostly in the lower 48 states) and confirmed by a recent pilot $PM_{2.5}$ survey in Fairbanks.[16]

If a major effort were to be made in the future to restrict the installation or use of wood-burning appliances in Fairbanks in order to improve air quality, much more information would first be needed to quantify their contribution to emissions and $PM_{2.5}$ concentrations on critical high-$PM_{2.5}$ days. Investigators have used a variety of methods to measure and try to distinguish wood combustion $PM_{2.5}$ from that caused by other sources. Ionic (water soluble) potassium is one chemical marker used for wood smoke, and another is elemental potassium[17]. More recently, several investigators have used or are currently testing the use of a two-wavelength aethalometer to distinguish wood smoke in Rutland, Vermont,[18,19] Connecticut,[20] and in Seattle, Washington[21]; results have been promising but further confirmatory work is reportedly needed. The use of levoglucosan, a pyrolysis product of cellulose has been tested as a tracer of wood smoke, but results have been uncertain.[22]

Mobile Sources

A recent review of source contributions for Fairbanks[11] provided some initial insights regarding the significance of motor vehicle $PM_{2.5}$ and precursor emissions as outlined below. As with other source categories, there remains a need to further characterize contributions from gasoline and diesel on-road and non-road mobile sources.

- Diurnal Trends – These trends show that the a.m., p.m., and midday travel peaks are not discernable in the hourly trends in concentrations observed on days when the standard was exceeded. Particularly surprising is that the impact of the morning traffic peak is barely discernable in the PM data.

- Correlation Analysis – This analysis does not directly address motor vehicles, but suggests that nitrate and therefore NOx precursor emissions (of which motor vehicles are a significant source) are not significant. It also shows that organic carbon (OC) is highly correlated with $PM_{2.5}$ mass, but provides no insight into the contribution of motor vehicles to OC.* CO is shown to have a relatively high correlation (r^2=0.51) with $PM_{2.5}$, which suggests that motor vehicles, which are a significant source of CO, could be a contributor to $PM_{2.5}$. An alternate interpretation could be that as temperature declines, the production of $PM_{2.5}$ from other sources is increased in such a manner that it is roughly proportional to the increase in CO production from motor vehicles.† In other words, the same meteorological conditions that cause an increase in $PM_{2.5}$ concentrations can cause an increase in CO concentrations, even though the primary sources of these pollutants may be different.

- PMF Analysis – The interpretation of PMF factors is somewhat subjective, however, motor vehicles as a source are shown to have a very limited contribution to $PM_{2.5}$ mass and exhibit little seasonal variation‡. The motor vehicle contribution to secondary particulate, which is shown to be the most significant source, is unclear. While the contribution to sulfate appears to be limited,§ the contribution to OC could be significant. A review of the relative amount of gallons of fuel consumed on a typical winter day shows that space heating consumes roughly 104,500 gallons of fuel oil. Motor vehicles are estimated to consume 18,650 gallons of Diesel fuel and 104,600 gallons of gasoline on an average winter day, and are suspected to be a significant contributor to OC.

- Emission Inventory – Motor vehicles are responsible for 56% of the corrected inventory of directly emitted $PM_{2.5}$ emissions in 2005 and 26% in 2018. Their share of the inventory in 2005 is almost double the level emitted by wood burning stoves, which PMF has identified as the second most significant source after secondary pollutants. Their share of NOx emissions is high, but nitrates are not a significant contributor to $PM_{2.5}$. Their share of SOx emissions is low in 2005 and essentially disappears after 2006.

Overall, the available data are not conclusive with regard to the significance of motor vehicles' contribution to $PM_{2.5}$ concentrations measured in downtown Fairbanks. Several of the data

---

* A review of MOBILE6.2 national average PM emission estimates for calendar year 2005 shows that the model does not differentiate exhaust species for light-duty vehicles, but does for heavy-duty vehicles. Total exhaust for light-duty vehicles is estimated to be 0.0056 g/mi. Heavy-duty vehicles are estimated to produce 0.0163 g/mi elemental carbon (EC) and 0.0083 g/mi organic carbon (OC). A review of the literature shows that over 50% of gasoline exhaust is OC and 24% is EC. When weighted for travel (82% gasoline, 18% Diesel), gasoline vehicles are estimated to be responsible for roughly 60% of the directly emitted OC.

† The interpretation of correlations in air pollutant concentrations, including the correlations cited herein, entails some risk. In general, correlation does not prove causality and, for the case at hand, correlations in pollutant concentrations could be caused in large part by emissions from several types of unrelated sources all being affected in a substantially similar way by changes in meteorology.

‡ An important caution here is that the interpretation of PMF factors is somewhat subjective. The factor that is described as "motor vehicle" may be most representative of gasoline-powered motor vehicles while at the same time including some elements from other sources. Similarly, the "Zn factor" may contain some contribution from Diesel-powered motor vehicles and other sources (although the large contribution to Zinc variance is unexplained).

§ It is possible to rule out motor vehicles as a significant source of sulfate, because of the recent phase-in of low sulfur Diesel fuel (last October) and low sulfur gasoline (last January). Since the actual phase-in of both fuels occurred well before the mandated implementation date, it is clear that motor vehicles were not a significant contributor to sulfate levels produced during this past winter. Nevertheless, high concentrations of $PM_{2.5}$ were recorded this past winter.

sources suggest that directly emitted and precursor emissions from motor vehicles may not be significant, including those explained below.

- PMF analysis (if correct) shows motor vehicles to be a consistently low contributor in both summer and winter months.

- Sulfate was found to be highly correlated with $PM_{2.5}$ mass. Implementation of low sulfur gasoline (January 2006) and Diesel fuels (October 2006) essentially eliminated on-road motor vehicle sulfate production during 2007. Nevertheless, Fairbanks continued to exceed the ambient $PM_{2.5}$ standard after the introduction of these low sulfur fuels. ,

- The impact of motor vehicle peak travel activity is not directly observable in the diurnal measurements of $PM_{2.5}$ concentrations.

In contrast, several findings suggest motor vehicles may be a significant contributor to $PM_{2.5}$ concentrations:

- The emission inventory estimate suggests that motor vehicles are responsible for roughly double the level of $PM_{2.5}$ emitted by wood burning and the PMF analysis identified wood burning as the second largest $PM_{2.5}$ source.

- Analysis of winter fuel consumption suggests that motor vehicles are a significant source of organic carbon (OC) emissions and OC is found to be highly correlated with $PM_{2.5}$ mass.

- A recent PMF study in the Midwest found that mobile as well as industrial sources were important to organic compound concentrations, and this was true with respect to all nine sites examined.[23]

These results tend to be consistent, at least qualitatively, with those reported earlier from dynamometer-based emissions study in Fairbanks.[24]

Because several of the above points could be debated, the most prudent conclusion is that additional data are needed to assess whether motor vehicles are a significant contributor to winter $PM_{2.5}$ concentrations in Fairbanks.

Critical Knowledge Gaps

There remain some key questions and knowledge gaps in understanding the magnitude, causes, and potential solutions to the problem of elevated $PM_{2.5}$ concentrations in and around Fairbanks. Further data and information would be helpful in better defining the spatial extent of the $PM_{2.5}$ problem area as well as in understanding the relative source contributions. Areas that need to be addressed include determining:

- the spatial extent of the high $PM_{2.5}$ concentrations in the vicinity of Fairbanks. With air quality measurements at only one multi-year monitoring site, it is difficult to verify the

actual size of the problem area. Additional monitoring could help to verify the proposed boundary for the non-attainment area.
- the principle source of SO_2 emissions and elevated secondary sulfate concentration during poor air episodes (space heating, aircraft, industrial facilities).
- the principal source(s) of the PMF zinc-factor (lube oil emitted from motor vehicles, waste oil burning, distant mining and zinc-handling operations, other).
- whether local or regional coal-burning is a significant contributor to $PM_{2.5}$ at the downtown monitoring site or elsewhere in the Fairbanks area.
- whether motor vehicles are important contributors to $PM_{2.5}$ during episodes.
- the impact from outside wood boilers.
- how cold temperatures interact with emissions from space heating, motor vehicles (Diesel and gas), and residential wood burning.
- at what rate sulfates are formed and removed from the atmosphere under conditions found in Fairbanks.
- how well the $PM_{2.5}$ sampling apparatus perform in cold temperatures.

Over time, as more information about the air quality and sources in the vicinity of Fairbanks is developed, a more refined understanding of the spatial distribution and contributing source impacts will be acquired.

Air Quality and Emission Source Summary

Fairbanks winters are dominated by a pattern of cold, stable air that is conducive to the buildup of air pollutants.[25,26] This condition, together with local emissions of $PM_{2.5}$ and its precursors (especially sulfur dioxide), causes episodes of elevated $PM_{2.5}$ concentrations as monitored in downtown Fairbanks.

Based upon a positive matrix factorization (PMF) analysis of $PM_{2.5}$ speciation data collected at a site in downtown Fairbanks, the principal factors responsible for the elevated concentrations appear to be secondary aerosol (sulfate and nitrate), wood burning, and an unidentified zinc-related source profile. Motor vehicles seem to be less significant, but that conclusion somewhat contradicts information from other sources that show, for other locations, sharply increasing PM emissions from motor vehicles at lower temperatures. Consequently, the department is currently unable to reach any definitive conclusion about the relative contribution from various source categories.

Sulfate is much more important than nitrate in the secondary aerosol, and the presumed principal source is the combustion of sulfur-bearing fuel for space heating, which results in sulfur dioxide emissions. The secondary sulfate is assumed to be formed primarily in aqueous particles* into which the sulfur dioxide dissolves.[27] A small fraction (less than five percent) of the combustion-

* Under all but the coldest conditions (below about -22º F) in Fairbanks winters, most aerosol water, including the water generated by the combustion of all hydrocarbon fuels, is expected to be present as a liquid or supercooled liquid rather than being frozen and, as a result, is available to serve as a sink for atmospheric sulfur dioxide and as a site for the heterogeneous chemical reactions that produce sulfate. Below this temperature, ice fog begins to form, and at temperatures below about -40ºF, essentially no liquid water will be present stably in the atmosphere.

generated sulfur oxides emitted from fuel burning sources may also be directly emitted as sulfate.

Sources of wood burning emissions in Fairbanks include residential wood stoves and other appliances, and external wood boilers. Survey data and other evidence suggest that wood burning has increased in recent years. External wood boilers are a relatively new and substantially uncontrolled $PM_{2.5}$ source that has the potential to cause high localized concentrations of $PM_{2.5}$ and thereby be a significant air pollution nuisance as well as a potential health threat to nearby neighbors. There are a variety of methods for measuring $PM_{2.5}$ emissions from wood burning, including new methods that have a degree of selectivity for wood smoke.

Population and Traffic Growth Rates and Patterns

Fairbanks was established in the early 1900s as a trading post serving gold prospectors in the area. During the first part of the century, the population peaked and waned according to the price and availability of gold. Completion of the Alaska Highway in the 1940s, plus increased military activity in the area due to World War II, combined to cause considerable growth. By 1950, the population of the Fairbanks Census District (an area somewhat larger than the current boundaries of the Fairbanks North Star Borough) had grown to 19,409.

Continued military spending and increased governmental growth resulted in renewed economic activity and growth in population during the 1950s. By 1960, the population of the Fairbanks Census District had risen to 43,412. In the 1960s, military influence in the area leveled off, while increased oil exploration on the North Slope accounted for a 15% increase in population during the decade. The Fairbanks North Star Borough was formed in the mid-1960s. The 1970 Census District population of 50,043 can be compared to a Borough population for the same year of 45,864.

Construction of the Trans-Alaska Oil Pipeline during the 1970s resulted in a large population influx into the area. Fairbanks North Star Borough population peaked at 72,037 in 1976. With completion of the pipeline, the population fell dramatically to 51,659 in 1981. However, increased state and local governmental spending due to state oil revenues led to a resurgence in local economic activity and another growth spurt in population, resulting in a 1985 Borough population of 75,079.

Since 1985, population levels in the Fairbanks area have remained relatively unchanged. Increase in military activity due to the addition of a light infantry division to Fort Wainwright acted to offset a reduction in state and local governmental spending due to declining oil revenues. These factors resulted in a 1990 Borough population of 77,720. According to the Census,[28] the Borough population experienced little change between 1990 and 2000, with an overall growth rate of 0.6% per year. During that same time period, the Census data indicate that the population within the cities of Fairbanks and North Pole actually declined from 39,858 to 39,231, a reduction of 0.16% per year. The decline in population during the 1990s is displayed in Figure 9. It shows that while there was a small net reduction in population, the year-to-year change was very modest.

Population forecasts for the 2005-2015 period show an increase of about 3% between 2005 and 2006 then a steady increase of about 1% each year to 2015. The population forecast for the carbon monoxide nonattainment area as projected in the 2025 Fairbanks Metropolitan Area Transportation System (FMATS) Long Range Transportation Plan (LRTP)[29] is shown in Table 2. The vehicle travel-specific forecasts for the period are described in more detail below.

Growth in Vehicle Travel

Despite the slight reduction in population recorded between 1990 and 2000, Fairbanks and North Pole still experienced a modest increase in travel during this decade. The increase is based on traffic counts recorded at Highway Performance Monitoring System (HPMS) and other sites located throughout the Borough.[30] Figure 10 shows that travel activity, measured by average daily traffic counts, increased from 665,398 miles per day in 1990 to 752,992 miles per day in 2001, a growth rate of 1.1% per year.

Figure 9

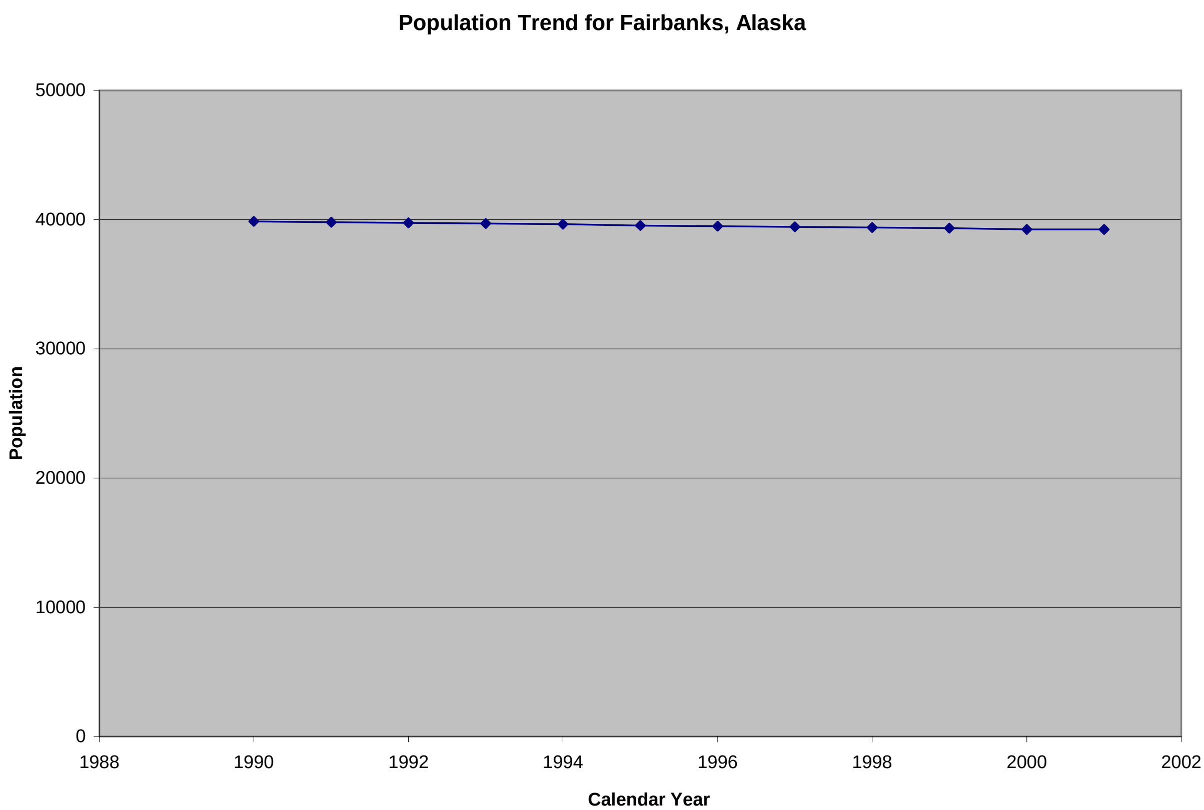


Figure 10

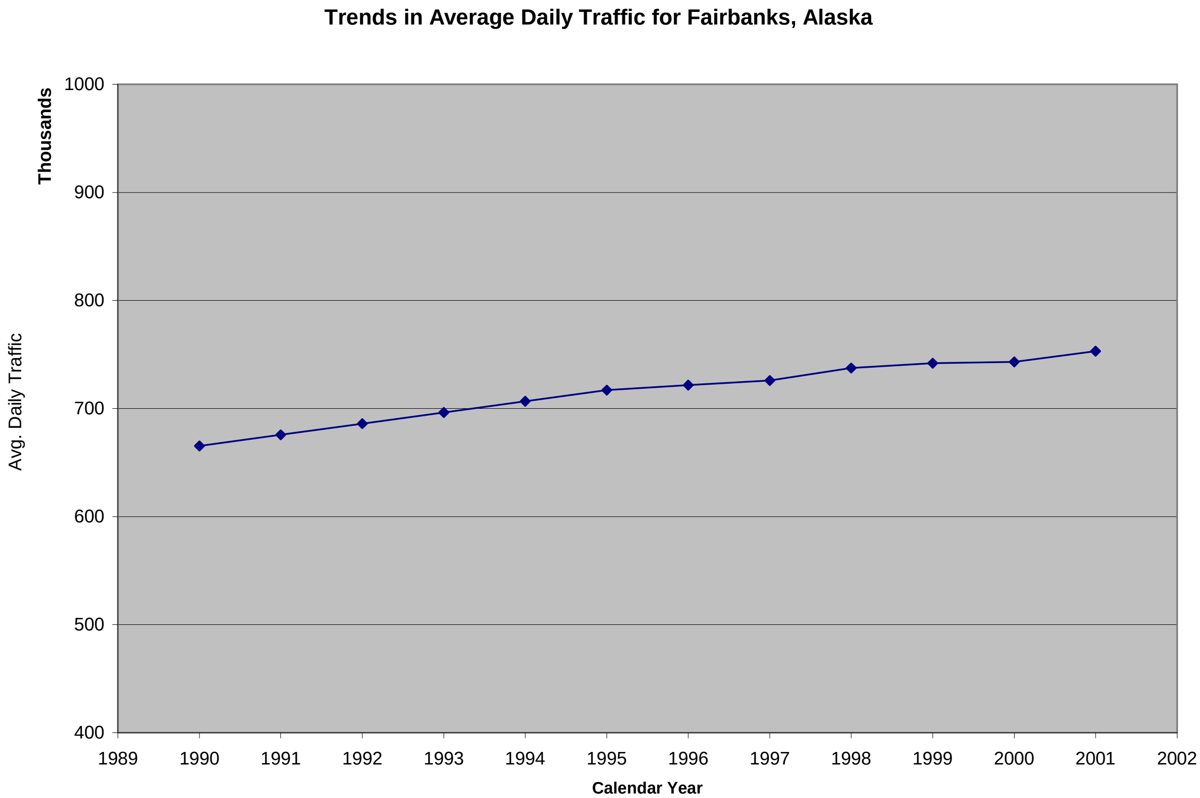


Table 2
Projected Fairbanks & North Pole Population

Calendar Year	LRTP Population Forecast
2005	41,183
2006	42,445
2007	42,809
2008	43,178
2009	43,553
2010	43,933
2011	44,320
2012	44,712
2013	45,111
2014	45,516
2015	45,926

From 2002 through 2004, ADOT&PF reported an annual VMT growth rate of 1.2% for Fairbanks and North Pole. Starting in 2005, the projected growth in vehicle travel reported in the area's current CO Maintenance Plan was updated using the VMT projections reported in the FMATS LRTP. The resulting annual VMT projections for the area during the 2005-2015 CO maintenance planning period are shown in Table 3. While the Fairbanks CO maintenance area boundary differs from that of the proposed $PM_{2.5}$ non-attainment area, these projections provide a basis for the VMT growth anticipated in the Fairbanks area.

Table 3
Projected Vehicle Travel in the Fairbanks CO Maintenance Area
(2005-2015)

Year	Vehicle Miles Traveled (per winter day)
2005	816,616
2006	862,743
2007	876,029
2008	889,519
2009	903,217
2010	917,126
2011	931,249
2012	945,590
2013	960,151
2014	974,937
2015	989,950

With a relatively stable population and slow growth in VMT, the FMATS transportation network has relatively low levels of congestion and excess transportation capacity. FMATS routinely considers and implements projects that will assist in reducing congestion such as signalization improvements at intersections. The Fairbanks North Star Borough also has a transit system that provides a good level of service for a relatively spread out community.

Existing Control of Emission Sources

While no Fairbanks area sources have been specifically targeted for control of fine particulates at this time, there are some existing controls in place:

- Major stationary sources are controlled through the Alaska Department of Environmental Conservation's permitting program. With regard to particulate matter, it should be noted that the coal-fired power plants in Fairbanks are controlled with bag houses.
- Mobile sources are controlled by federal fuel and emission rules that limit particulate matter and pre-cursor pollutants. It is not known how effective these controls are at the extreme cold temperatures found in Fairbanks, but improvements should continue to be made as the vehicle fleet turns over.
- Fairbanks has an extensive network of electrical plug-ins powered at 20° F that allow citizens to use engine block heaters to keep their motor vehicle engines warm during cold temperatures. This program significantly reduces CO emissions from cold starting vehicles, but it is not known how much benefit may exist for fine particulate emissions from the use of engine pre-heating.

- The Fairbanks North Star Borough operates a transit program that provides some benefits through reduced VMT from mobile sources.
- A local wood burning control program exists under the carbon monoxide maintenance plan. To the extent that high $PM_{2.5}$ days occur on days with high CO concentrations, this control program could provide some benefit. It is more likely that a different program will be needed to fully address $PM_{2.5}$ emissions from wood-burning stoves.
- Open burning is prohibited from November 1 through the end of February within the areas of the Borough designated as Urban, Urban preferred commercial, Light or Heavy Industrial, or Perimeter area, with camp fires being an exception.
- Prescribed fire for burns over 40 acres is managed by the Alaska Department of Environmental Conservation through a permitting process and a smoke management plan.

Conclusion

The non-attainment boundary proposed by the State of Alaska encompasses the portion of the Fairbanks North Star Borough airshed likely to be violating the fine particulate matter health standard. The air quality speciation data suggest a number of potential contributing sources all tied to population activities in the urban area. The boundary is based primarily on the topography of the airshed coupled with insight from the existing monitoring data from downtown Fairbanks on sources and chemical indicator species of concern. Because there is only one monitoring site in Fairbanks, the monitoring data and source characterization work derived from that site is most likely not representative of the source contributions thoughout the entire area.

It is possible that this boundary will need to be altered based on new data. At this time, no monitoring data exists for the city of North Pole or other residential areas in the outlying valleys to the north of Fairbanks. New monitoring data and better understanding of emission sources could lead to a larger or smaller non-attainment area boundary. If new monitoring data shows concentrations in excess of the standard in North Pole, or other outlying populated areas, or sources from North Pole are implicated in violations in Fairbanks, a revision to the proposed boundary would certainly be warranted. At this time, there is insufficient information to suggest that North Pole or these other outlying populated areas have an air quality problem or are significantly contributing to the air quality violations occurring in downtown Fairbanks. For this reason, they have been excluded from the proposed boundary.

Table 1

Annual Fuel Use in Fairbanks by Source Category in 2002

(not the nonattainment area)

Source	Subcategory	Gasoline (gallons)	Diesel (gallons)	Distillate (gallons)	Process Gas (gallons)	Process Gas (feet3)	JP4 (gallons)	Aviation Gasoline (gallons)	LPG/ Propane (gallons)	Natural Gas (feet3)	CNG (gallons)	Coal (tons)	Wood (cords)	Daily Trips (trips/day)	Daily VMT (miles/day)
On-Road		**40,345,310**	**3,185,156**											**508,504**	**1,745,291**
Non-Road		**495,248**	**2,942,861**	**0**	**0**	**0**	**4,167,000**	**70,500**	**66,461**	**0**	**0**	**0**	**0**		
	Equipment	495,248	1,960,521						66,461		6,792,258				
	Rail		982,340												
	Aircraft						4,167,000	70,500							
Area				**19,311,033**						**300,000,000**			**2,737**		
Point		**0**	**80,603**	**43,446,679**	**42,410,066**	**173,000,000**	**0**	**0**	**67,926**	**0**	**0**	**438,887**			
	Flint Hills		80,603		42,410,066										
	Wainwright			113,000			78,000,000		67,926			207,465			
	Univ. of AK			1,407,811								54,783			
	GVEA NP			39,872,868											
	AK RR											2,918			
	Aurora											173,721			
	PetroStar			1,210,000		173,000,000									
	GVEA Zn			843,000											
TOTAL		**40,840,558**	**6,208,620**	**62,757,712**	**42,410,066**	**173,000,000**	**4,167,000**	**70,500**	**134,387**	**300,000,000**	**0**	**438,887**	**2,737**	**508,504**	**1,745,291**

Notes:

On-Road Diesel and Gasoline fuel use is conservatively estimated by assuming a VMT split of 95%/5% and a wintertime mpg of 15 for gasoline vehicles and 10 for Diesels x 365 days/year

Rail fuel use reported for 1999 (962,000 gallons) was adjusted at annualized growth rate of 0.7%/year to get the 2002 value

The aircraft fuel use values are based on estimates for representative aircraft during landing and take off operations at Fairbanks International and Fort Wainwright.

The point source values are based on information reported by each facility to the State.

Only a small portion of the 78 million gallons of JP4 listed by Fort Wainwright was consumed within Fairbanks.

An estimate of the actual fuel used within the Borough is listed in the Aircraft consumption estimate.

References

[1]. 40CFR Part 51, Clean Air Fine Particle Implementation Rule; Final Rule, April 25, 2007.

[2]. Met One, the manufacturer of the BAM 1020 Particulate Monitor, specifies an operating temperature range of the instrument down to 0ºC (32ºF) and an ambient temperature range (for the air sample) down to -30ºC (-22ºF). ("BAM 1020 Particulate Monitor Operation Manual", BAM-1020-9800 Rev F, Met One Instruments, Inc.) Instrument and sample ambient sample temperatures were at times lower than both of these limits for sampling prior to 2007 when Borough staff installed an environmental enclosure and an inline sample heater. Any measurements that were made under such conditions, absent the use of the environmental enclosure and in-line heater are subject to question. Measurements made after the installation of the in-line heater may, however, be subject to a negative artifact due to loss of VOC caused by the in-line heater (as described in the Met One operating manual) or by loss of volatile nitrate.

[3]. See, for example: "$PM_{2.5}$ in the Upper Midwest", Lake Michigan Air Director's Consortium, June 2, 2003: http://www.ladco.org/reports/PM25doc2xx-1_small.pdf

[4]. B.Hartman and G.Wendler, "Climatology of the Winter Surface Temperature Inversion in Fairbanks, Alaska," http://ams.confex.com/ams/pdfpapers/84504.pdf.

[5]. C.S. Benson, "Ice Fog, Low Temperature Air Pollution," Cold Regions Research and Engineering Laboratory, June 1970.

[6]. P. Hopke, "A Guide to Positive Matrix Factorization" (undated).

[7]. A. Reff et al, "Receptor Modeling of Ambient Particulate Matter Data Using Positive Matrix Factorization: Review of Existing Methods," Journal of the Air and Waste Management Association, 57:146-154, February 2007.

[8]. "Review and Source Contributions to Ambient $PM_{2.5}$ Concentrations," Sierra Research, 2007 (unpublished).

[9]. Zinc mining, refining and transport at the Red Dog Mine in western Alaska is a source of zinc dust (see for example: J.L. Clark , "Fugitive Dust Accumulation in Drifted Snow at the Red Dog Mine, Winter 2004- 2005, July 2005, teckcominco).

[10]. Other PMF analysis has shown factors that contain Zn (and other species) to be present at all sites in Alaska but concluded, due to lack of strong seasonal variations, that "local sources must be more important than distant sources" (A. Polissar *et al*, "Atmospheric Aerosol over Alaska, 2. Elemental Composition and Sources," Journal of Geophysical Research, 103, 19,045-19,057, 1998.)

[11]. See, for example, Wikipedia "Zinc dialkyldithiophosphate": "The main use of ZDDP is in anti-wear additives to lubricants (e.g. greases, motor oils). To date it is the dominant anti-wear agent, present in most machine and motor oils in amounts of about 1%. However for gasoline engine oil applications the amount of ZDDP has to be minimized; there is concern that zinc and phosphorus emissions could damage catalytic converters.")

[12]. T. Cahill, "Persistence of Very-fine, Ultra-fine, and Nano-particles in the Ambient Atmospheric Environment," University of California, Davis, available from: *http://www.cce.umn.edu/pdfs/cpe/conferences/nano/Thomas_Cahill.pdf*

[13]. Memorandum to Alice Edwards, ADEC, from R. Dulla et al, "Fairbanks Home Heating Survey Update," May 2, 2007.

[14]. "Assessment of Outdoor Wood-fired Boilers," prepared by NESCAUM (the Northeast States for Coordinated Air Use Management), March, 2006.

[15]. P.R.S. Johnson, "In-Field Ambient Fine Particle Monitoring of an Outdoor Wood Boiler: Public Health Concerns," Journal of Human and Ecological Risk Assessment, (in-press), February 21, 2006.

[16]. F. Di Genova, *et al*, "Tier 2 Gasoline Benefits in Alaska; Phase 2: Preliminary Investigation of Particulate Matter Emission Sources in Fairbanks, Alaska with In-use Tier 2 Gasoline and Ultra Low Sulfur Diesel," Sierra Report No. SR2007-08-01, prepared for ADEC, August 2007.

[17]. J. Watson *et al*, "$PM_{2.5}$ Chemical Source Profiles for Vehicle Exhaust, Vegetative Burning, Geological Material, and Coal Burning in Northwestern Colorado During 1995", Chemosphere, 43 (2001) 1141-1151.

[18]. G. Allen, "Update on the Met One BAM: Cold, Warm, and Filter Media Issues," Air Quality Monitoring & Data Analysis National Conference (aka SAMWG), Point Clear, AL, May 13, 2004.

[19]. G. Allen, "Evaluation of a New Approach for Real Time Assessment of Wood Smoke PM": *www.nescaum.org/documents/2004-10-25-allen-realtime_woodsmoke_indicator_awma.pdf*

[20]. See: ***http://www.dieselmidatlantic.org/calendar/events/presentations/ 2007_07MVRWC/ BabichMVRWC07.pdf***

[21]. M. Gilroy *et al*, "Urban Air Monitoring Strategy – Preliminary Results Using Aethalometer™ Carbon Measurements for the Seattle Metropolitan Area," Puget Sound Clean Air Agency, see: http://www.pscleanair.org/airq/Aeth-Final.pdf

[22]. E. Hedberg, "Is Levoglucosan a Suitable Quantitative Tracer for Wood Burning? Comparison with Receptor Modeling on Trace Elements in Lycksele, Seden," Journal of the Air and Waste Management Association, 56: 1669-1678, December 2006.

[23]. B. Buzcu-Guven, *et al* "Analysis and Apportionment of Organic Carbon and Fine Particulate Matter Sources at Multiple Sites in the Midwestern United States," Journal of the Air and Waste Management Association, 57:606-619, May 2007.

[24]. P. Mulawa, "Effect of Ambient Temperature and E-10 Fuel on Primary Exhaust Particulate Matter Emissions from Light Duty Vehicles," Environmental Science and Technology, 31:1302-1307, 1997.

[25]. B.Hartman and G.Wendler, "Climatology of the Winter Surface Temperature Inversion in Fairbanks, Alaska," http://ams.confex.com/ams/pdfpapers/84504.pdf.

[26]. C.S. Benson, "Ice Fog, Low Temperature Air Pollution," Cold Regions Research and Engineering Laboratory, June 1970.

[27]. See, for example: J. H. Seinfeld, Atmospheric Chemistry and Physics, John Wiley and Sons, Inc., NY, 1998.

[28]. Census data supplied by the Alaska Department of Transportation and Public Facilities (ADOT&PF).

[29]. LRTP report

[30]. "1997 – 1998 – 1999 Annual Traffic Volume Report," State of Alaska, Department of Transportation & Public Facilities.