

# **Identification, Quantification, and Control of PM-10 Sources In Anchorage**

**Prepared by the Midwest Research Institute  
for the Municipality of Anchorage  
Department of Health and Human Services  
Air Pollution Control Agency**

**MRI Project No. 4576**

**Approved by the AMATS Policy Committee  
April 15, 1999**

## Preface

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This report was prepared by Midwest Research Institute (MRI) for the Municipality of Anchorage. The work was performed under a MOA Professional Services Contract, Purchase Order No. 64139. Mr. Stephen S. Morris (Department of Health and Human Services, Air Quality Section) served as the MOA Project Officer for this study.

This report describes the results of MRI's testing and analysis to identify and quantify PM-10 emissions in the MOA and recommend PM-10 control measures that will lead to attainment of the National Ambient Air Quality Standards. Dr. Chatten Cowherd, Jr., was the MRI Project Leader for this research effort. Dr. Cowherd and Mrs. Mary Ann Grelinger were responsible for preparing this report. Mr. Ronald G. Draftz of the IIT Research Institute, who performed the microscopical analysis of filters and reference samples, prepared the corresponding segments of this report.

MRI gratefully acknowledges the assistance and information provided by Mr. Morris and Ms. Anne Schlapia of MOA in the conduct of this study. Their technical comments and suggestions contributed substantially to the success of this work. The contributions of Mr. Draftz of IIT Research Institute throughout the project are also acknowledged.

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# Contents

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Preface.....	ii
Figures.....	v
Tables.....	vi

## EXECUTIVE SUMMARY

1. Introduction.....	1
1.1 Background .....	1
1.2 Key Questions to be Answered .....	3
1.3 Project Tasks .....	4
1.4 Organization of Report.....	4
2. Historical Data Review .....	5
2.1 Source Apportionment Studies.....	5
2.2 Road Dust Entrainment Studies .....	8
2.3 Street Sediment Studies.....	10
2.4 Inferences Drawn from Previous Source Apportionment and Street Sediment Studies.....	13
3. Analysis of Anchorage PM-10 Data .....	14
3.1 Seasonal and Episodic Nature of the PM-10 Problem .....	14
3.2 Relationship between PM-10 Concentration and Proximity to Major Roadways .....	17
3.3 Meteorological Factors Associated with PM-10 Episodes in Anchorage ....	22
3.4 Inferences Drawn from the Analysis of Anchorage PM-10 Data.....	26
4. Analysis of Archived Filters .....	29
4.1 Archived Filters/Source Materials.....	29
4.2 Analytical Methods for Particle Composition.....	31
4.3 Analytical Results—Microscopy.....	32
4.4 Inferences Drawn from the Microscopical Analyses.....	34
5. Source Observation and Sample Collection .....	36
5.1 Mat-Su Valley Soils .....	36
5.2 Pretest Sampling.....	38
5.3 Track-on Observations .....	38
5.4 Other Localized Sources .....	39
5.5 Pavement Wear .....	41
5.6 Inferences Drawn from the Source Observations.....	42
6. Intensive Road Dust Study .....	43
6.1 Monitoring Equipment .....	43

6.2	Road Surface Dust Loading.....	44
6.3	Test Week Activities .....	45
6.4	Test Results .....	47
6.5	Particle Chemistry .....	51
6.6	Inferences from Test Week Results.....	54
7.	PM-10 Emission Inventory.....	56
7.1	Assumptions of Spring and Fall Emission Inventories .....	56
7.2	Spring Emissions from Paved and Unpaved Roads .....	59
7.3	Fall Emissions from Paved and Unpaved Roads.....	60
7.4	Microinventory of Gambell/Ingra Roadway Emissions .....	61
7.5	Inferences Drawn from Emission Inventories .....	67
8.	Emission Control Measures .....	68
8.1	Approaches to Control .....	68
8.2	Recently Implemented PM-10 Control Measures .....	69
8.3	Effect of New Controls on Ambient PM-10 Concentrations .....	72
8.4	Candidate PM-10 Control Measures .....	74
8.5	Recommended Control Methods.....	82
8.6	Control Cost Effectiveness.....	83
9.	Conclusions and Recommendations .....	85
9.1	Inferences Drawn from Previous Source Apportionment and Street Sediment Studies.....	86
9.2	Inferences Drawn from the Analysis of Anchorage PM-10 Data.....	86
9.3	Inferences Drawn from the Microscopical Analyses.....	88
9.4	Inferences Drawn from the Source Observations.....	89
9.5	Inferences from Test Week Results.....	89
	References.....	91

## Figures

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Figure 1. Aerial Photograph of Area Around Gambell Monitor.....	2
Figure 2. Median Spring Silt Loadings for Arterials (ADT>10,000) .....	11
Figure 3. Pre- and Post-Sweep Silt Loadings on Anchorage Roadways.....	12
Figure 4. Comparison of Upper 90 <sup>th</sup> Percentile PM-10 Concentrations* Gambell and Muldoon Sites—1995-1997 .....	15
Figure 5. Comparison of Upper 90 <sup>th</sup> Percentile PM-10 Concentrations at Gambell and Oceanview Sites 1995-1997 .....	16
Figure 6. Relationship between Roadway Setback and PM-10 Concentration at the Gambell Site Spring 1997.....	18
Figure 7. Relationship between Roadway Setback and PM-10 Concentration at the Gambell Site Fall 1997 .....	19
Figure 8. Comparison of PM-10 Concentrations Anchorage Monitoring Sites October 1996—December 1997 .....	21
Figure 9. Influence of Freezing and Melting on PM-10 Gambell Site— March 20, 1996.....	25
Figure 10. Mat-Su Valley Soils (1997 Version prepared by Mark Clark, USDA Soil Scientist).....	37
Figure 11. Early April Daytime Winds in Anchorage .....	44
Figure 12. Sampling Timeline and Results for Test Week .....	49
Figure 13. Immediate Impact of Limestone Application to Gambell/Ingra Roadway .....	52
Figure 14. PM-10 Concentrations Adjacent to Gambell Following Limestone Application .....	53
Figure 15. 1996 Silt Loadings on Anchorage Roadways .....	58
Figure 16. Measured Dust-Trak PM-10 vs. Modeled PM-10.....	66
Figure 17. Winter Traction Sand Use in Anchorage.....	70
Figure 18. Winter Use of Magnesium Chloride Deicing Solution in Anchorage .....	71
Figure 19. Trend in Average PM-10 Concentrations at Gambell (1990-98) .....	73

## Tables

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Table 1. Particle Size Multipliers for Paved Road Equation .....	9
Table 2. Early spring silt loadings on Anchorage roads .....	11
Table 3. PM-10 Episodes in Anchorage October 1988 - December 1997 .....	17
Table 4. Ratios of PM-2.5 to PM-10 at the Gambell Monitor .....	20
Table 5. PM-10 Monitoring Sites Operated in the Anchorage Bowl October 1996—December 1997 .....	20
Table 6. Historical PM-10 Samples Selected for Analysis .....	29
Table 7. List of Reference Samples .....	30
Table 8. Component Concentrations in Reference Samples .....	32
Table 9. Component Weight % Concentrations in Filter Samples .....	33
Table 10. Pre-test Surface Samples .....	38
Table 11. Test-Week Surface Samples (Other than Silt Loading) .....	46
Table 12. Hourly Traffic Counts During Test Week .....	49
Table 13. Paved Road Surface Silt Loadings During Test Week .....	49
Table 14. Integrated PM-10 Concentrations During Test Week .....	53
Table 15. Carbonate Analysis of Air Quality Samples Collected During Test Week (Analyzed by Huffman Laboratories) .....	54
Table 16. 1996 Paved Road Silt Loadings .....	58
Table 17. Roadway PM-10 Emission Inventory Anchorage Bowl Spring 1996 .....	59
Table 18. Roadway PM-10 Emission Inventory Anchorage Bowl Fall 1996 .....	60
Table 19. Test Week Emission Inventory for Gambell Street .....	63
Table 20. Test Week Emission Inventory for Ingra Street .....	63
Table 21. High Emitter Percentages as Determined from DustTRAK Measurements of PM-10 near Gambell Street .....	64
Table 22. DustTRAK PM-10 Concentrations West of Gambell Immediately Following Limestone Tracer Application .....	65
Table 23. Exceedances of the NAAQS at Gambell Site (1990 –1998) .....	74

# 1. Introduction

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The Municipality of Anchorage has experienced frequent violations of the 24-hour National Ambient Air Quality Standards (NAAQS) for PM-10 (particles equal to or smaller than 10 micrometers in aerodynamic diameter). A major source category is paved road dust resuspension, which emits anti-skid materials, pavement materials, rubber tire fragments, and dirt that is tracked from unpaved areas. This report presents the results of a study by Midwest Research Institute (MRI) for the Municipality of Anchorage to (a) characterize paved road dust emissions as a primary contributor to violations of the 24-hour NAAQS for PM-10 in Anchorage, (b) improve the PM-10 emission inventory for paved roads, and (c) develop appropriate PM-10 control strategies for paved roads.

The air quality standard for PM-10 is health-based and is intended to protect the health of the most sensitive individuals in the population. Elevated PM-10 concentrations have been associated with increases in asthma and upper respiratory illness in Anchorage. A study by Gordian et al showed a 3-6% increase in outpatient visits for asthma and a 1-3% increase in visits for upper respiratory illness associated with each  $10\mu\text{g}/\text{m}^3$  increase in PM-10.<sup>1</sup>

## 1.1 Background

All of the violations of the 24-hour PM-10 standard in Anchorage that are not attributable to volcanic activity have occurred at the Gambell monitoring site just west of the 8-lane divided Gambell/Ingra (Seward Highway) roadway system (Figure 1). The Gambell monitor is located in the Chester Creek valley, just to the north of Chester Creek, which runs east to west. The terrain slopes up to the intersections that lie to the north and south, at 15<sup>th</sup> Street and Fireweed Lane, respectively. Between these intersections the Gambell/Ingra roadway segment is 0.66 miles in length (as determined from the aerial photo reprinted in Figure 1). Eight lanes of traffic (4 southbound lanes on Gambell and 4 northbound lanes on Ingra) carry a traffic load that exceeds 50,000 ADT.

The air quality samplers at the Gambell site are installed on a roof of the Worthington Ford building, at a distance of approximately 15 m west of the nearest traveled portion of Gambell Street. The sampler intakes are located at a height of approximately 4 m above the Gambell roadway surface. Analysis of the filter deposits from exceedance days have shown a prevalence of crustal materials. In prior studies, the origins of these materials have been associated both with localized sources near the Gambell monitoring site and with remote sources to the north of the Anchorage area.

Wind erosion of exposed soils in the Matanuska-Susitna (Mat-Su) Valley has been suspected of contributing to enhanced PM-10 concentrations in Anchorage. The Gulf of Alaska, to the south of Anchorage, and the rugged terrain surrounding the Mat-Su Valley contribute to strong seasonal winds, especially in the farming areas of Palmer. “Knik”

winds blow down to Anchorage from the Knik River flood plain in spring and summer, but



**Figure 1. Aerial Photograph of Area Around Gambell Monitor**



only occasionally in winter. In the spring, blowing dust from Matanuska Valley loess has been observed up to an elevation of 3,000 feet.

Anchorage has been dusted with volcanic ash on at least four occasions since 1985. The most recent volcanic activity affected MOA in 1992 when Crater Peak on Mount Spurr erupted. Even though this volcano is located 75 miles west of Anchorage, 3 mm of ash fell on Anchorage during August 1992.

The preponderance of evidence, however, points to a dominance of localized sources on days with PM-10 violations at the Gambell site. The violations tend to occur under dry road conditions (a) in the early spring just after the snow melt and (b) in the fall periods when vegetation is scarce or has died. These periods are characterized by elevated surface silt loadings\* on the MOA roadway system. The loadings consist of residues from anti-skid material applications, and track-out from adjacent parking areas, occasionally supplemented by deposition of wind-advected materials.

During early April, the seasonal snow melt releases anti-skid abrasives previously applied to the roadways for snow/ice control and exposes bare soil along the roadway. Vehicle traffic carries (a) anti-skid abrasives from paved parking lots and (b) mud and dirt from unpaved areas onto paved roadways. Studded tires significantly abrade the pavement at rates well above those normally encountered. Prevailing northerly winds that blow along fetch lengths (the north-south Gambell roadway) also contribute to paved roadway surface loadings by atmospheric deposition.

Springtime exceedances of the PM-10 NAAQS in Anchorage can be expected until excessive surface material on and near the Gambell/Ingra roadway system is removed. Eventually the elevated road surface loadings are reduced by sweeping, resuspended by traffic, or washed off, and new vegetative cover holds the adjacent soil.

## **1.2 Key Questions to be Answered**

The research described in this report was performed to:

- Confirm the identity and characteristics of the dust sources that contribute to violations of the NAAQS for PM-10 and that could lead to the MOA being declared a PM-10 nonattainment area;
- Identify and quantify source contributions during episodes when the PM-10 standard has been exceeded in the past;

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\* Silt loading is a primary source attribute used in USEPA's PM-10 emission factor equation for paved roadways. Silt loading is defined as the mass per unit area consisting of loose, dry road surface particulate matter that passes through a 200-mesh screen (75  $\mu$ m openings).

- Develop information to support reliable control strategies for mitigating dust emissions that contribute to nonattainment of the PM-10 standard.

Specifically the investigation was structured to answer the following questions:

1. What is the relationship between PM-10 concentrations at the Gambell monitor and the surface conditions of the Gambell/Ingra roadway system?
2. What is the origin of the high surface loadings on Gambell and Ingra during PM-10 violation periods?
3. What methods are most suitable and cost effective for reducing paved road dust impacts on PM-10 violations at the Gambell monitor and at other locations adjacent to similar high-volume roadways?

### **1.3 Project Tasks**

To achieve the research objectives, two tasks were performed: Task 1—Historical Data Analysis and Task 2—Intensive Field Study. The historical data analysis reviewed past air quality measurements throughout the Anchorage bowl to characterize temporal and other factors influencing ambient levels of PM-10. The intensive field study was conducted to evaluate the impact of PM emissions from the Gambell/Ingra roadway system on PM-10 concentrations in the vicinity of the Gambell monitoring site. These two tasks and the study results are described in detail in this report.

### **1.4 Organization of Report**

This report is organized as follows. Section 2 describes the historical data review, including source appointment and street sediment studies in Anchorage. Section 3 presents an analysis of Anchorage PM-10 concentrations. Section 4 gives the results of microscopical analysis of archived PM-10 filters from Anchorage. Section 5 describes source observations of the areas around the PM-10 monitoring sites in Anchorage. Section 6 presents the results of the one-week intensive Road Dust Study conducted in Anchorage, including a limestone tracer component. Section 7 evaluates and updates the PM-10 emission inventory for Anchorage paved roads. Section 8 reviews potential paved road dust emission control measures and recommends cost-effective options. Finally, Section 9 presents the overall conclusions and recommendations derived from this research effort.

## 2. Historical Data Review

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### 2.1 Source Apportionment Studies

Source apportionment is one of the keys to identifying which activities are causing violations of the PM-10 standard in Anchorage. Source apportionment is a technique that infers source contributions by comparing the composition of particles collected on a filter with the signatures (compositions) of candidate source categories.

Three previous source apportionment studies of Anchorage and/or Eagle River all came to similar conclusions: minerals (a.k.a. crustal sources) are the cause of PM-10 violations.<sup>2-3</sup> The approaches were diverse, including elemental analyses by x-ray fluorescence, polarized light microscopy (PLM) with image analysis, and computer-controlled scanning electron microscopy with image analyses. Only x-ray diffraction was lacking to complete the range of methods commonly used for aerosol source apportionment.

These studies produced valuable information but were unable to explain the specific contributions from various activities involving crustal minerals that lead to PM-10 violations. The apportionment of the crustal materials is a common problem to all receptor modeling methods which use elemental analyses for sources that have co-linear signatures. Receptor modeling can be approached by any number of sophisticated statistical methods but is unable to differentiate sources whose elemental compositions do not vary significantly.

#### 2.1.1 NEA, Inc., Aerosol Characterization Study of Anchorage, 23 Jan 85<sup>1</sup>

In the mid-1980's, large amounts of slash from land clearing operations at the Point MacKenzie agricultural project north of Anchorage were burned. This resulted in occasional smoke incidents in Anchorage and Eagle River. The Aerosol Characterization study focused on quantifying the impacts of open burning and residential wood combustion on air quality in Anchorage and Eagle River. Another objective of the study was to characterize the brown haze that is sometimes observed in the Anchorage area in the March through May period.

The study showed a 1% or lower impact from wood burning and "little or no impact" from vegetative burns. However, the *crustal sources* accounted for 90% to 98% of the coarse fraction (2.5  $\mu\text{m}$  to 10  $\mu\text{m}$ ) and 64% to 85% of the fine fraction (< 2.5  $\mu\text{m}$ ). This study concluded that fugitive dust was the primary source of the PM-10 problem.

Although most of the PM-10 mass was identified as crustal in origin, the various sources of this crustal material could not be resolved in this study, because of lack of statistically distinguishable differences in source signatures. Roadway sources of crustal

particulate were not further investigated to determine the contribution of coarse fraction particles, including rubber tire particles, anti-skid material, and pavement material. The conclusion was reached that the tailpipe emissions component of PM-10 emissions occurs mainly in the fine fraction.

When developing control strategies, ducted emissions (tailpipe) must be distinguished from fugitive emissions (road dust entrainment). Roadway related materials such as rubber tire fragments, abraded pavement, brake pad wear products, underbody mud releases, and tire track-out particles should be identified as individual components that contribute to the exceedances. This process requires a method of particle characterization beyond information offered by elemental analyses.

### **2.1.2 NEA, Inc. Source Apportionment by Chemical Mass Balance Technique of PM-10 Sources in Eagle River and Juneau, Alaska, 23 May 88<sup>2</sup>**

A portion of this study focused on Eagle River, a community about 10 miles north of Anchorage. It showed an exceptionally high percentage (94.7%) contribution from crustal sources. Meteorology, primarily wind speed and direction, was used (but not statistically) in conjunction with receptor modeling to assign the cause the exceedances to road dust from traffic in Eagle River. One objective of the study was to determine whether wind-transported dust from glacial river valleys in the Mat-Su Valley were responsible for exceedances in Eagle River. The author noted that the highest PM-10 days occurred during calm wind episodes in October and inferred that local sources not transported dust, were the source of the particulate problem in Eagle River. This study could not separate whether the road dust was due to crushed pavement aggregate wind-deposited soils and glacial till, anti-skid abrasive residues, turbulent dust emissions from trucks of road-shoulder-dust, or carryout dust from traffic on unpaved roads and parking areas.

An assumption was made that winds of 10 to 15 mph would entrain riverbed and valley soils that lie more than 20 miles to the north of Anchorage. The commonly used 12 mph wind threshold for soils is based on surface creep. Wind speeds normally have to exceed 20 mph to produce particle lofting and a direct PM-10 impact or, to deposit significant quantities that subsequently become traffic-entrained road dust. However, wind speeds above 20 mph also dilute airborne concentrations minimizing wind-blown dust impacts, except when winds produce visible dust storms.

### **2.1.3 Microlab Northwest Source of Particles on PM-10 Filters: Gambell Street Locations, 17 Oct 94<sup>3</sup>**

This polarized light microscopy (PLM) study went further than the other Anchorage studies in concluding that crustal materials were the major sources. However, this study tended to focus on quantifying the impacts of volcanic eruptions of Mt. Redoubt in 1989 and Mt. Spurr 1992. Exceedances resulting from volcanic eruptions are normally treated

as exceptions by the EPA. Increased PM-10 surface road loadings in Anchorage that followed those two eruptions appeared to have significantly impacted the re-entrainment of volcanic ash by traffic, and wind erosion from nearby soils at wind speeds over the erosion threshold. Multiple exceedances of the national ambient air quality standard were observed for months following these eruptions. The main objective of this study was to quantify the significance and duration of these impacts on Anchorage PM-10 concentrations.

PLM analysis of the traffic debris (road dust) showed that impacts of volcanic ash deposited from the two eruptions persisted for long periods after the eruptions. The author concluded that volcanic ash accounted for approximately 20% of the PM-10 mass measured 18 months of the eruption of Mt. Spurr. He also noted that rubber tire particles may account for more than 40% of the traffic dust. An unresolved question was whether soils contaminated with volcanic ash through track-out or wind erosion are a significant component of the Anchorage road dust. Other studies have shown that fine particles tend to agglomerate to the surface of large, mineral grains which are usually too large to be entrained by wind or by car wake turbulence or are simply too large to enter the sampler.

Reference samples of volcanic ash collected immediately after the eruptions of Mt. Spurr and Redoubt, and traction sand samples from street maintenance stockpiles were obtained for the PLM analysis. No size discrimination was performed on these samples. The samples appeared to have been analyzed after they were ground to some unspecified size using a mortar and pestle. There was also no indication that the samples were riffled prior to grinding to obtain a representative sub-sample for analysis.

The concentrations of each component in the source samples were considered to be the same for any size range, whether PM-10 or TSP. Consistency of the size distribution for all components is probably not a valid assumption for minerals, glassy phases, presence of rubber tire fragments, etc. Size-segregated analysis could have been accomplished through the image analysis that was used, or through manual counting or size separation (by resuspension) to produce the PM-10 fraction of each component. Therefore, the results of quantitative source apportionment for the samples may be a bit doubtful for this study.

A final drawback of this study was the use of overly simple image analysis to quantitate “opaques,” crystalline minerals, and the balance (mainly glassy volcanic ash fragments). The source apportionment assumed that the areas of each optical group were proportional to mass. The densities of the particles are similar among the components, approximately 2 to 3 g/cm<sup>3</sup>, but the shapes may not be similar, leading to possible errors in total mass for each component or “assemblage.”

In spite of these uncertainties, PLM analysis was and is a clearly superior method for distinguishing source contribution to PM-10 in Anchorage compared to chemical mass balance methods.

## 2.2 Road Dust Entrainment Studies

The particle size distribution of the exposed soil or surface material determines its susceptibility to mechanical entrainment by vehicle traffic. The upper size limit for particles that can become “suspended” (i.e., having a drift potential exceeding about 100 m when released from a ground-level source) has been estimated at about 75  $\mu\text{m}$  in aerodynamic diameter (Cowherd et al., 1974). Conveniently, 75  $\mu\text{m}$  in physical diameter is also the smallest particle size for which size analysis by dry sieving is practical (ASTM, 1984). Below that particle size, wet sieving as a recommended method enhances particle disaggregation so that the texture of the material may be substantially modified in comparison with its “in place” condition. Particles passing a 200-mesh screen (74  $\mu\text{m}$  opening) on dry sieving are termed “silt” by highway officials. Note that for fugitive dust particles, the physical diameter, and aerodynamic diameter are roughly equivalent because of the offsetting effects of higher density and irregular shape.

Throughout Chapter 13 of the Emission Factor Handbook (AP-42) published by USEPA (1995), the silt content of an exposed dust-producing material has been used as a representative predictor of fine particle emissions. This applies not only to Total Suspended Particulate Matter (TSP, with a particle size cutpoint of approximately 30  $\mu\text{m}$  in aerodynamic diameter) but also to the fine fraction components (PM-10, PM-2.5, and PM-1.0).

The AP-42 predictive emission factor equation for paved roads is as follows:

$$E = k (sL/2)^{0.65} (W/3)^{1.5} \quad (1)$$

where:  $E$  = particulate emission factor

$k$  = base emission factor for particle size range and units of interest (see below)

$sL$  = road surface silt loading (grams per square meter) ( $\text{g}/\text{m}^2$ )

$W$  = average weight (tons) of the vehicles traveling the road.

This equation uses silt loading and average vehicle weight as predictors of the emission potential of a paved road surface.

It is important to note that Equation 1 calls for the average weight of all vehicles traveling the road. For example, if 99% of traffic on the road are 2-ton cars/trucks while the remaining 1% consists of 20-ton trucks, then the mean weight “ $W$ ” is 2.2 tons. More specifically, Equation 1 is not intended to be used to calculate a separate emission factor for each vehicle weight class. Instead, only one emission factor should be calculated to represent the “fleet” average weight of all vehicles traveling the road. The particle size multiplier ( $k$ ) above varies with aerodynamic size range as shown in Table 1.

**Table 1. Particle Size Multipliers for Paved Road Equation**

Size range <sup>a</sup>	Multiplier k <sup>b</sup>		
	g/VKT	g/VMT	lb/VMT
PM-2.5	2.1	3.3	0.0073
PM-10	4.6	7.3	0.016
PM-15	5.5	9.0	0.020
PM-30 <sup>c</sup>	24	38	0.082

<sup>a</sup> Refers to airborne particulate matter (PM-x) with an aerodynamic diameter equal to or less than x micrometers.

<sup>b</sup> Units shown are grams per vehicle kilometer traveled (g/VKT), grams per vehicle mile traveled (g/VMT), and pounds per vehicle mile traveled (lb/VMT).

<sup>c</sup> PM-30 is sometimes termed “suspendable particulate” (SP) and is often used as a surrogate for TSP.

To determine particulate emissions for a specific particle size range, use the appropriate value of k above.

Previous testing has shown that typically an “equilibrium silt loading” exists for a given road based on its traffic volume (ADT). Under this condition, the rate of emissions balances the rate of deposition. If the silt loading is higher than the equilibrium, because of the short-term addition of surface material (e.g., from anti-skid material application), the emissions will be temporarily elevated, so that the rate of emission exceeds the rate of deposition. The emissions will decay to the equilibrium value as the equilibrium loading is approached. On the other hand, if the silt loading is temporarily decreased by surface cleaning (e.g., road sweeping), the decreased emissions will gradually increase to the equilibrium value, as the silt loading returns to the equilibrium value. The equilibrium silt loading has been found to be inversely correlated with the average daily traffic (ADT) count (Cowherd and Englehart, 1984), as follows:

$$sL = 21.3/(V^{0.41}) \quad (2)$$

where:  $sL$  = surface silt loading ( $\text{g/m}^2$ )  
 $V$  = average daily traffic volume (vehicles/d)

The inverse relationship in Equation 2 is consistent with the fact that roadways designed for high-volume traffic flow also tend to convey traffic at high speed (so that volume and speed are directly correlated). In addition to the self-cleaning effect of high-speed traffic, such roads provide less opportunity for track-on from unpaved areas, because of the buffering effect of feeder roads.

As noted in the Introduction, most prior studies have found that non-dust components of particulate emissions (e.g., vehicle exhaust) from paved roads constitute only a minor fraction of the PM-10 emissions. Also, recognizing that the dirt from track-on and vehicle underbody release tends to be ubiquitous, chemical composition of road surface material has been a relatively unsatisfactory indicator of uniqueness for paved road dust.

Of course, as roadways become cleaner, the resuspended dust component of the particulate emissions may lose its dominance over emissions from vehicle exhaust, from tire and brake wear, and from direct sloughing of particles from vehicle underbodies (tires, wheel wells, etc.). Therefore for such roads, silt loading may lose its effectiveness as a predictor of traffic-related particulate emissions from paved roadways.

## **2.3 Street Sediment Studies**

In 1994, MOA identified source control of the runoff of surface sediment from urban streets as a top water resources management priority. To develop a set of pollutant build-up and washoff models, MOA hired Montgomery Watson, Inc. to characterize the nature and distribution of street sediment in urban Anchorage.

The data collected were useful for characterizing “silt loading” on Anchorage roadways in developing a PM-10 emission inventory. Consequently the Air Quality Section (AQS) of the MOA Department of Health and Human Services worked jointly with the MOA Department of Public Works, Watershed Management Section, to design a street sediment loading assessment project.<sup>5-6</sup>

Investigators collected surface sediment samples from multiple transects across Anchorage roadways using a modified shop vacuum cleaner in three 1996 periods: March/April, April/May, and July/August. Field crews sampled a total of 34 intersection (within 61 m of an intersection) and track-out sites on four classes of roads:

- Local (< 2,000 ADT);
- Collector (2,000 to 10,000 ADT);
- Minor arterial (10,000 to 20,000 ADT); and
- Major arterial (> 20,000 ADT).

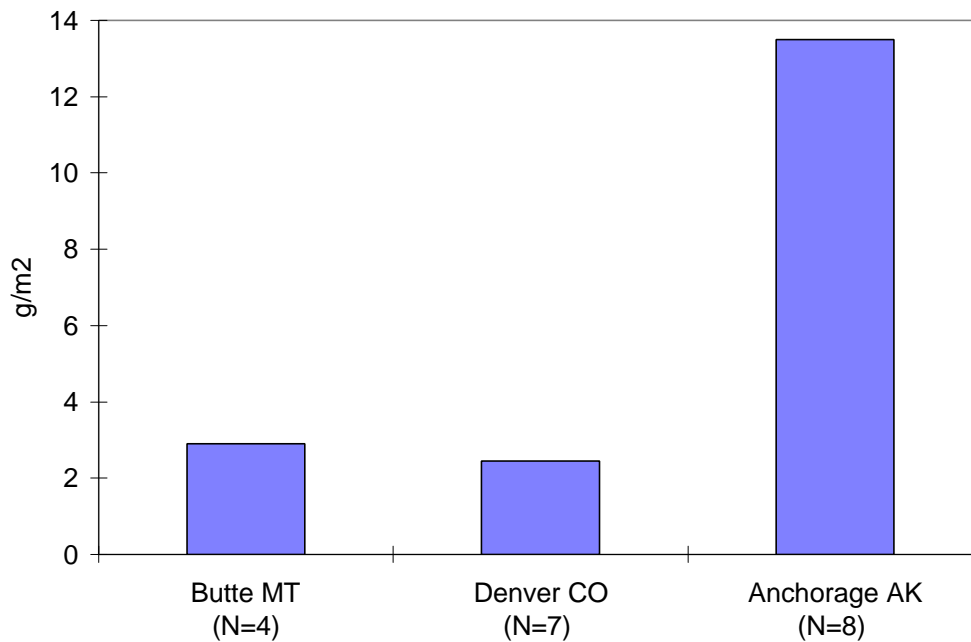
Early spring silt loading measurements for each roadway classification are summarized in Table 2. These measurements were made prior to the first street cleaning after the winter season.



**Table 2. Early spring silt loadings on Anchorage roads**

Road Type	N	Silt loading (g/m <sup>2</sup> )		
		Median	Lower Quartile	Upper Quartile
Local	7	18.4	10.7	24.3
Collector	5	9.4	8.1	17.3
Minor arterial	4	6.7	2.7	9.8
Major arterial	4	20.4	5.3	49.1

These measurements suggest that the spring silt loadings on Anchorage roads are substantially higher than other U.S. cities. Figure 2 shows that silt loadings in Anchorage are approximately five times higher than those measured in Butte and Denver, as reported by EPA.

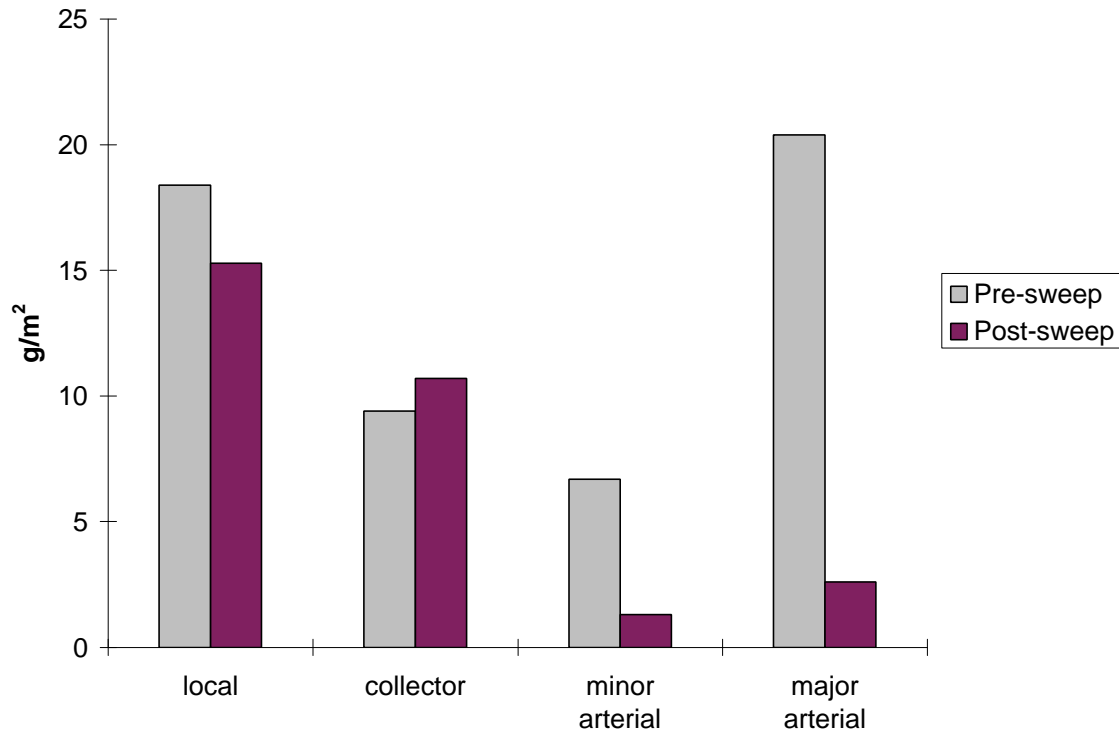


**Figure 2. Median Spring Silt Loadings for Arterials (ADT>10,000)**

Anchorage uses large amounts of traction sand during its long October-March “winter.” Although the amount of sand applied has been reduced in recent years, State and municipal road crews still apply 20,000 - 30,000 tons of sand to roads in the Anchorage bowl each winter. This dependence on traction sand and the lack of mid-winter thaw/washoff events contribute to heavy accumulations of roadway sand and silt in the late winter.

The study showed that street sediment fine fractions on low ADT roads may not be effectively reduced by spring street sweeping (see Figure 3). It should be noted that silt loading measurements were not taken immediately before and after sweeping and thus

were not a direct measure of street sweeping efficiency. The large observed reductions in silt loadings may be the result of removal by passing traffic. This may explain why silt loadings were reduced on arterials but not on the lower volume collectors and local roads. For all road types, sweeping efficiency decreased with decreasing particle size.



**Figure 3. Pre- and Post-Sweep Silt Loadings on Anchorage Roadways**

The Montgomery Watson study also provided information on sediment build-up rates for summer and winter conditions for the four types of roadways. The silt loading results from the sampling program were used to develop a preliminary PM-10 emission inventory for paved roads in Anchorage. This is discussed in Section 7.

## 2.4 Inferences Drawn from Previous Source Apportionment and Street Sediment Studies

1. *Crustal sources account for the vast majority of Anchorage's PM-10 mass loading.* All three previous source apportionment studies identified crustal sources as the primary source of PM-10. These three studies were not successful in resolving the contributions of various possible sources of crustal matter, however. The relative contributions of road sanding activity, road way abrasion, track-out from unpaved roads and parking lots, and dust from unvegetated lots were not quantified.
2. *Local sources are the most likely cause of PM-10 exceedances at the Gambell site.* The large amounts of rubber tire particles observed in PM-10 samples indicate that local traffic is responsible for most of the PM-10 mass. Most PM-10 exceedances have occurred on days with low wind speeds suggesting that long range transport from the Mat-Su Valley is unlikely.
3. *PM-10 emission rates from Anchorage roadways are probably significantly higher than most other cities in North America.* Although PM-10 emission rates were not measured directly, roadway PM-10 emission rates are strongly correlated with the amount of silt or fine particulate on the road. Silt loads measured on Anchorage roads appear to be several times higher than other cities. This suggests that PM-10 emission rates from Anchorage roadways are higher than most other cities.
4. *Current street sweeping practices in Anchorage may not be an effective means of controlling roadway PM-10 emissions.* Although sweeping has been shown to be an effective means of reducing large particle street sediment loads, pre- and post-sweep silt load measurements in Anchorage suggest that sweeping may have little impact fine particle loads. Similar observations have been made in other U.S. cities. In fact some studies have suggested that fine particle loads actually *increase* after sweeping. Intensive backflushing following sweeping may be necessary to achieve effective control.

### **3. Analysis of Anchorage PM-10 Data**

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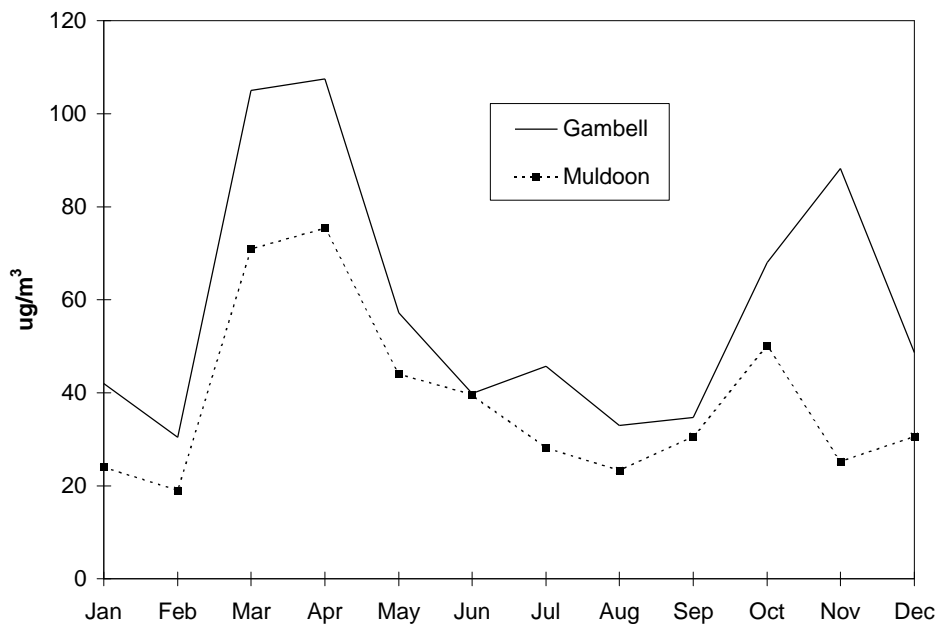
The Anchorage Air Pollution Control Agency has collected over 10,000 PM-10 samples in Anchorage and Eagle River since monitoring began in October 1985. Monitoring has been conducted in 18 different locations, twelve of which have been in the Anchorage bowl. Six sites have been in the Eagle River area.

A comprehensive analysis of PM-10 data collected in Anchorage from 1988 through 1997 was performed as part of this project. This analysis revealed insights into the nature of Anchorage's PM-10 problem. This section discusses this analysis and the deductions made about emissions sources, the spatial extent of the problem and the meteorological conditions associated with PM-10 episodes. Inferences about the mechanisms involved in PM-10 episodes are also discussed.

#### **3.1 Seasonal and Episodic Nature of the PM-10 Problem**

The Anchorage Air Pollution Control Agency currently operates three permanent PM-10 monitoring sites in the Anchorage bowl. The Gambell site is located about 15 meters west of the nearest traffic lane of a major roadway couplet (Gambell/Ingra) with an average daily traffic (ADT) of over 51,000. Gambell is classified as a "micro-scale" site due to its proximity to a major traffic arterial. The Muldoon site is also located near a major traffic arterial (Muldoon Road, ADT= 32,300), but is set further back (about 25 meters) from the nearest traffic lane. According to EPA criteria, it is classified as a "middle-scale" site. The Oceanview site is located in the midst of a residential area with no major roadways nearby and is classified as a "neighborhood-scale" site. Gambell is the only site that has violated the NAAQS.

Seasonal patterns in upper-90<sup>th</sup> percentile PM-10 concentrations measured at Gambell and Muldoon between 1995-1997 are plotted in Figure 4. The Gambell and Muldoon sites are both located near major roadways; reentrained dust generated by passing vehicles is presumed to be a major influence on both of these sites. Although the magnitude of the concentrations at these sites differ, seasonal patterns are similar. The highest PM-10 concentrations occur during "break-up" in late March and early April and during "freeze-up" in late October and early November. Spring break-up concentrations tend to be higher than those exhibited during fall freeze-up, perhaps because silt loadings on these roads are highest at this time of the year.

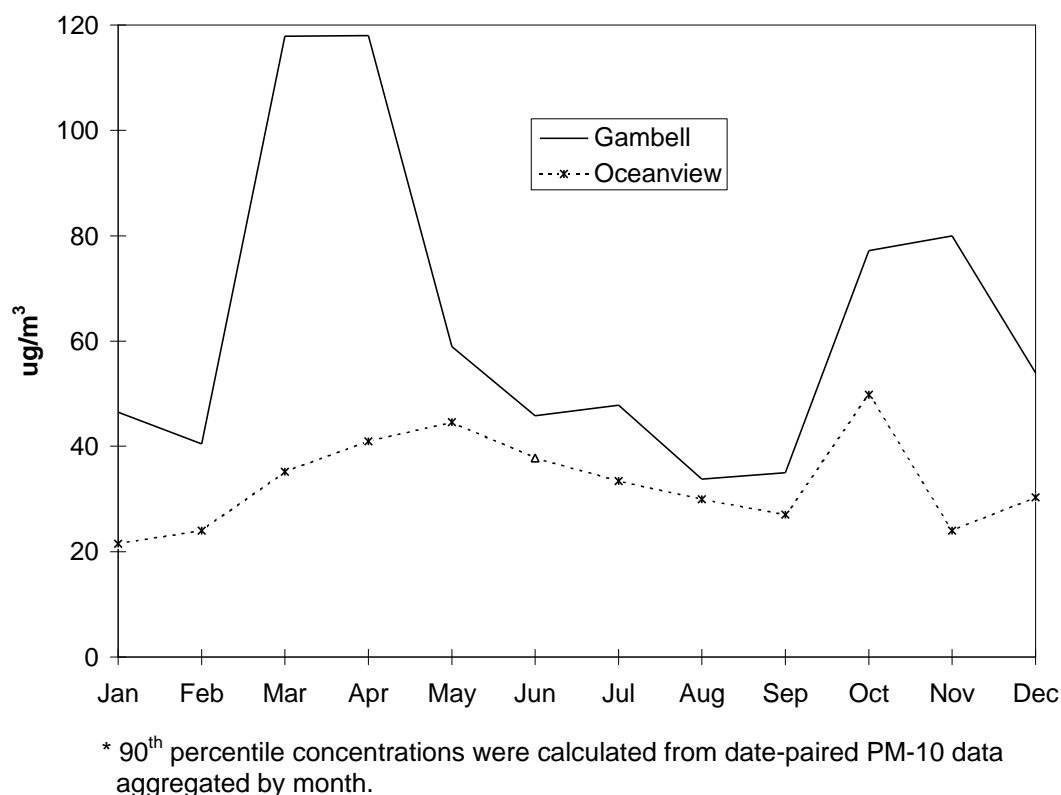


\* 90<sup>th</sup> percentile concentrations were calculated from date-paired PM-10 data aggregated by month.

**Figure 4. Comparison of Upper 90<sup>th</sup> Percentile PM-10 Concentrations\* Gambell and Muldoon Sites—1995-1997**

The seasonal pattern at the Oceanview site is somewhat different than those at either Gambell or Muldoon. The spring PM-10 peak is higher than the fall peak at both the Muldoon and Gambell sites. In contrast, the fall peak at the Oceanview neighborhood site is higher than the spring peak (Figure 5). This suggests that there may be a larger area-wide PM-10 component in the fall. Emissions from major roadways may not be as large an influence in the fall as they are in the spring. Possible reasons for this are discussed later in this section.

When PM-10 data from the Anchorage network are examined, it is apparent that the particulate problem is episodic in nature. During the past ten years, Anchorage has experienced 23 episodes when PM-10 levels approached or exceeded the 24-hour NAAQS (see Table 3). All but five of these episodes occurred during the spring break-up or fall freeze-up periods. Those episodes that occurred outside the usual spring and fall time periods were all associated with unusual circumstances (volcanic eruptions, unusual mid-winter thaws, and smoke from wildfires or high winds).



**Figure 5. Comparison of Upper 90<sup>th</sup> Percentile PM-10 Concentrations\*  
Gambell and Oceanview Sites  
1995-1997**

With the exception of an extended period of elevated PM-10 following the eruption of Mt. Spurr in 1992, these episodes varied in length from one day to three weeks. These episodes are summarized in the table below. A PM-10 episode is defined as any period with at least one day exceeding  $120 \mu\text{g}/\text{m}^3$ . Multi-day episodes are bounded at the beginning and end by a day exceeding  $120 \mu\text{g}/\text{m}^3$ .

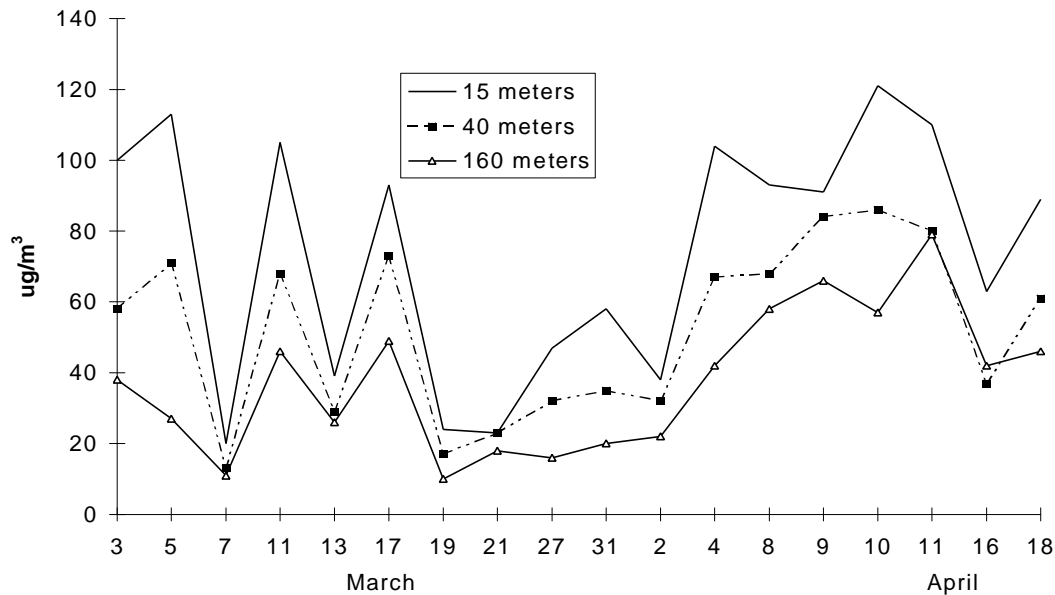
**Table 3. PM-10 Episodes in Anchorage October 1988 - December 1997**

Date	Max PM-10 ( $\mu\text{g}/\text{m}^3$ )	Duration of Episode (days)	Comments/Unusual Circumstances
Nov 3 - Nov 11, 1988	134	9	
Mar 31, 1989	137	1	
Apr 7 - Apr 17, 1990	260	11	
Nov 2 - Nov 16, 1990	152	15	
Apr 3 - Apr 9, 1991	134	7	
Oct 21 - Nov 7, 1991	144	18	
Mar 30 - Apr 10, 1992	152	12	
Aug 18 - Dec 5, 1992	565	109	aftermath of Mt. Spurr eruption
Mar 25 - Apr 19, 1993	185	26	lingering impacts of Mt. Spurr
Oct 22, 1993	126	1	
Nov 1 - Nov 4, 1993	161	4	
Nov 15, 1993	174	1	
Feb 10 - Feb 26, 1994	242	17	thaw in January, no snow cover
Apr 4, 1994	129	1	
Oct 20, 1994	145	1	
Mar 13, 1995	131	1	
Apr 7 - Apr 21, 1995	206	15	
Dec 1 - Dec 2, 1995	162	2	no snow cover, high winds
Mar 19 - Mar 30, 1996	138	12	
May 14, 1996	158	1	high winds, area-wide blowing dust
Jun 4, 1996	210	1	smoke from Big Lake fire
Mar 16 - Mar 18, 1997	128	3	
Apr 10, 1997	121	1	

### 3.2 Relationship between PM-10 Concentration and Proximity to Major Roadways

The influence of major roadways on PM-10 was alluded to in the previous subsection. Data from the permanent monitors at the Gambell, Muldoon and Oceanview sites suggest that proximity to high volume roadways has a major influence on PM-10. Gambell is subject to the greatest influence from roadway sources and is the only site in Anchorage that has violated the NAAQS. The influence of roadway PM-10 emissions appears to be particularly pronounced in the spring break-up period when silt loads are highest.

The relationship between roadway setback and PM-10 concentration was investigated during the spring and fall of 1997 at the Gambell site. The permanent monitoring station is located approximately 15 meters west of the nearest travel lane on Gambell Street. Two additional monitors were established 40 meters and 160 meters west of the travel lane to determine what influence roadway setback had on PM-10 concentration. Monitoring results from the spring of 1997 are shown in Figure 6.



Roadway Setback vs. PM-10 Concentration at Gambell  
Spring 1997

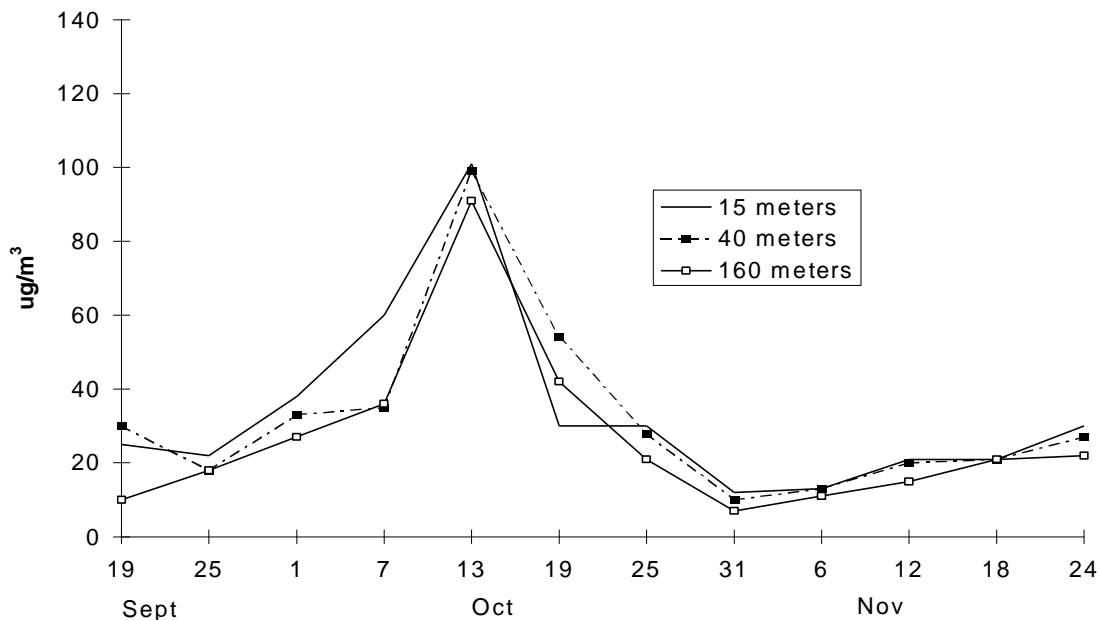
PM-10 Concentration	Setback from Roadway		
	15 meters	40 meters	160 meters
mean	74 $\mu\text{g}/\text{m}^3$	52 $\mu\text{g}/\text{m}^3$	37 $\mu\text{g}/\text{m}^3$
upper 90 <sup>th</sup> percentile	111 $\mu\text{g}/\text{m}^3$	81 $\mu\text{g}/\text{m}^3$	60 $\mu\text{g}/\text{m}^3$

**Figure 6. Relationship between Roadway Setback  
and PM-10 Concentration at the Gambell Site  
Spring 1997**

Figure 6 shows a clear and consistent decrease in spring PM-10 concentrations with respect to roadway setback distance. In comparison to the permanent monitor 15 meters from the roadway, average PM-10 concentrations decline by about 30% at 40 meters and by about 50% at 160 meters. Similar declines are observed in the 90<sup>th</sup> percentile concentration.



A different relationship between roadway setback and PM-10 was observed in the fall. Proximity to the roadway appeared to have less of an impact on concentrations. This again suggests that the fall PM-10 peak may be more of an area-wide phenomena than the spring peak. Fall and early winter PM-10 concentrations measured at 15, 40 and 160 meter setbacks from Gambell Street are shown in Figure 7.



Roadway Setback vs. PM-10 Concentration at Gambell  
Fall 1997

PM-10 Concentration	Setback from Roadway		
	15 meters	40 meters	160 meters
mean	34 $\mu\text{g}/\text{m}^3$	32 $\mu\text{g}/\text{m}^3$	27 $\mu\text{g}/\text{m}^3$
upper 90 <sup>th</sup> percentile	58 $\mu\text{g}/\text{m}^3$	52 $\mu\text{g}/\text{m}^3$	41 $\mu\text{g}/\text{m}^3$

**Figure 7. Relationship between Roadway Setback  
and PM-10 Concentration at the Gambell Site  
Fall 1997**

The Gambell site is believed to reflect “worst case” PM-10 concentrations in Anchorage. The Gambell site is located near a major high speed roadway. The roadway is oriented north-south which results in maximum fetch lengths during northerly winds

which predominate during the spring PM-10 season. Resultant concentrations would be highest under this wind direction regime. Topographic factors probably also contribute to localized increases in the PM-10 concentrations measured at this site. Gambell is located at the bottom of valley where PM-10 may concentrate, especially when drainage winds occur.

The effect of localized sources on the PM-10 concentrations is further supported by an analysis of the ratios of PM-2.5 to PM-10 obtained from dichotomous samplers at the Gambell site. Table 4 shows that as the 24-hour concentration increases, the ratio of PM-2.5/PM-10 decreases, indicating that for high PM-10 concentrations, the coarse fraction of PM-10 predominates. This size fraction is associated with the impacts of nearby dust sources.

**Table 4. Ratios of PM-2.5 to PM-10 at the Gambell Monitor**

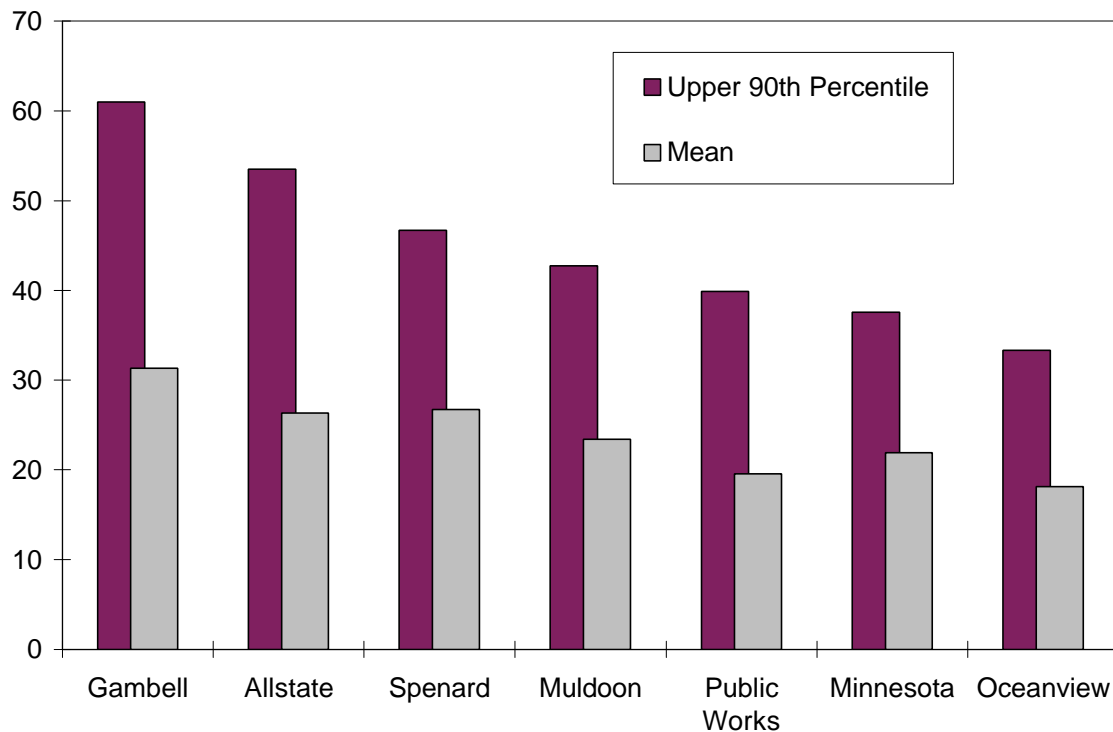
<b>PM-10 Concentration range</b>	<b>No. of 24-hour values</b>	<b>Ratio of PM-2.5/PM-10</b>
<25	108	0.38
25 to 50	24	0.21
>50	35	0.13

The AAPCA monitored at four additional sites in the Anchorage bowl from October 1996 through December 1997 to compare with the three permanent monitors. AAPCA was particularly interested in examining PM-10 data collected near other major roadways for comparison with Gambell. The site characteristics of the four “special purpose” sites are described along with the three permanent monitors at Gambell, Oceanview, and Muldoon in Table 5.

**Table 5. PM-10 Monitoring Sites Operated in the Anchorage Bowl  
October 1996—December 1997**

<b>Site</b>	<b>Spatial-scale Classification</b>	<b>Adjacent Roadway</b>	<b>Average Daily Traffic</b>	<b>Setback to Nearest Traffic Lane</b>
Gambell	Micro	Gambell / Ingra	51,260	15 meters
Oceanview	Neighborhood	Johns Road	3,420	90 meters
Muldoon	Middle	Muldoon Road	32,300	25 meters
Allstate	Micro	Tudor Road	43,810	15 meters
Public Works	Neighborhood	Tudor Road	43,810	130 meters
Spenard	Micro	Spenard Road	14,730	15 meters
Minnesota	Middle	Minnesota Blvd	36,800	30 meters

Data collected from the four special purpose monitoring sites suggest that Gambell is indeed representative of worst case particulate concentrations in Anchorage. Figure 8 shows that upper decile and mean concentrations at Gambell were 25% or more higher than all other sites.



**Figure 8. Comparison of PM-10 Concentrations  
Anchorage Monitoring Sites  
October 1996—December 1997**

Roadway setback appears to strongly influence PM-10. The Allstate site, which like Gambell is located very close to a major thoroughfare (Tudor Road, ADT=43,810), showed the second highest concentrations. PM-10 concentrations at the Spenard site were higher than at Minnesota or Public Works even though traffic volumes at Spenard were significantly lower. Again, roadway proximity appears to be responsible for the higher concentrations observed at Spenard. Like Gambell and Allstate, Spenard is located approximately 15 meters from the roadway.

Data from the Oceanview neighborhood site also suggest that most PM-10 episodes are localized rather than area-wide in nature. Oceanview had the lowest PM-10 concentrations of all sites. As a neighborhood site, Oceanview is furthest removed from roadway impacts. PM-10 concentrations at Oceanview rarely approach those at Gambell. On 90% of the days when PM-10 at Gambell exceeded  $120 \mu\text{g}/\text{m}^3$ , concentrations at Oceanview were at least one-third lower.

### 3.3 Meteorological Factors Associated with PM-10 Episodes in Anchorage

Meteorological conditions on days when the 24-hour concentration exceeded  $120 \mu\text{g}/\text{m}^3$  at Gambell were reviewed to determine whether these PM-10 episodes were associated with particular weather patterns. PM-10 data collected between 1988 and 1997 were examined along with local climatological data collected by the National Weather Service at the Point Campbell Weather Observatory at Anchorage International Airport. During this ten year period, 104 days exceeded the  $120 \mu\text{g}/\text{m}^3$  PM-10 episode criteria. The NAAQS is set at  $150 \mu\text{g}/\text{m}^3$ .

These 104 days were grouped into four categories based on the meteorological or environmental conditions in place while elevated PM-10 concentrations were observed. These four episode categories are described below.

1. *Days substantially affected by volcanic ash from the Mt. Spurr eruption.*  
N = 23 (22% of all days above  $120 \mu\text{g}/\text{m}^3$ )

Mt. Spurr erupted on August 18, 1992. Microscopic analysis of PM-10 samples collected after the eruption indicated that its effects persisted for at least a year. Impacts were particularly significant in the first few months following the eruption. For this reason, the elevated PM-10 concentrations measured between August 18 and December 5, 1992 were directly attributed to the volcanic eruption.

2. *Days affected by wind blown dust.*  
N = 15 (14% of all days above  $120 \mu\text{g}/\text{m}^3$ )

High winds (sustained wind speeds  $> 20$  mph) were recorded on 15 of the 104 days with elevated PM-10. These high winds were almost always combined with very low relative humidity. Appreciable snow cover was present on one-third of the days with high winds. Although unvegetated lots and gravel pits were covered in snow, some roadways and parking lots were likely exposed. On these days, high PM-10 concentrations occurred at Gambell but not at neighborhood sites. This suggests that the blowing dust probably originated from exposed snowless roadways and parking lots near the Gambell station. Area-wide blowing dust did not appear to be a problem when snow cover was present.

3. *Days affected by “freeze dry” conditions.*  
N = 18 (17% of all days above  $120 \mu\text{g}/\text{m}^3$ )

Elevated PM-10 concentrations also seem to be associated with cold, dry, low wind speed days without snow cover. This is particularly true in the fall. This category of elevated PM-10 days is defined by the following conditions:

Maximum temperature < 33 °F  
Minimum temperature < 25 °F  
Sustained winds < 20 mph  
No measurable snow cover at Point Campbell

Under these conditions, a “freeze dry” effect has been observed in Anchorage. Roadway silt accumulated in gutters and medians and the ground surface of unvegetated shoulders takes on a dry chalky appearance and is readily entrained by any disturbance. The wakes of large trucks and other aerodynamically blunt vehicles have been observed to generate considerable amounts of dust under these conditions. Even the dust on dry grass and other frozen vegetation is prone to entrainment. Relatively poor atmospheric mixing is commonly experienced during in these cold, dry, low wind speed days. This exacerbates the impact of the enhanced PM-10 emissions on ambient concentrations.

When temperatures are above freezing, fine-grained surface soils can be kept moist by a process known as capillary rise. These fine-grained soils “wick” moisture from wetter soils below to replenish surface soil moisture lost due to evaporation. When temperatures drop below freezing this capillary action is disrupted because soils freeze. The dry chalky appearance of surface soils during freeze dry conditions can be explained by this phenomena.

4. *Days affected by PM-10 mobilized through diurnal melting and subsequent freezing.*  
N = 37 (36% of all days above 120 µg/m<sup>3</sup>)

A substantial number of elevated PM-10 days occurred when snow melting and subsequent freezing may have mobilized fine roadway particulate for entrainment as PM-10. Although most of these days occurred during the spring breakup, some days in the late fall also met the criteria for inclusion in this category. Local climatological data records indicate that each of these 37 days had daytime temperatures warm enough to melt snow along roadway shoulders and nights that were cold enough to curtail melting and allow portions of the roads that were wet during the day to dry out. This category of episode days is defined as follows:

Maximum daytime temperature > 28 °F  
Minimum nighttime temperature < 35 °F  
Sustained winds < 20 mph  
One inch or more of snow cover on the ground at Pt. Campbell

Weather records suggest that daytime snow melting was significant on the 37 days that qualified for inclusion in this category. The average maximum temperature was 41°F and snow cover averaged 7 inches. Although a few days had daytime shade

temperatures a few degrees below freezing, temperatures in the sun were presumed to be warm enough to promote melting along sun-exposed roadways. During daylight hours, significant snow melting is often observed in Anchorage when temperatures are below freezing.

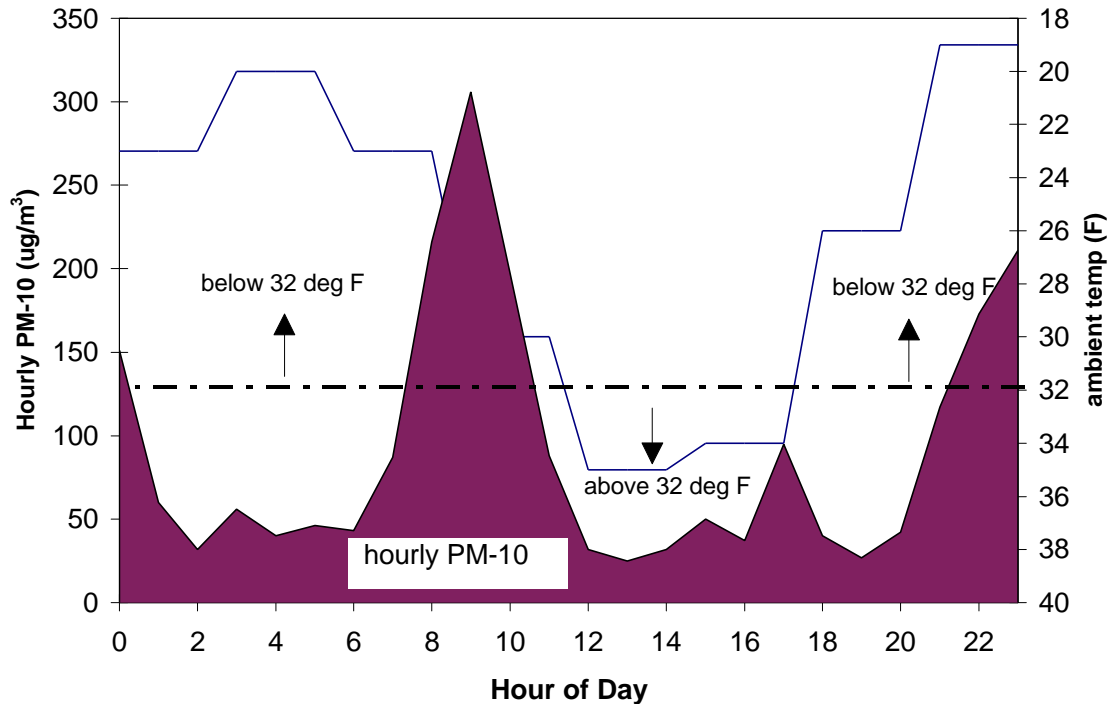
Nighttime minimum temperatures averaged 23 °F on these 37 days. At these temperatures snow melting would cease, and the low relative humidity typical of these days would promote drying of previously wet streets. A small number of days had night time temperatures a few degrees above freezing, but it was presumed that temperatures were cold enough to reduce melting to a trickle and allow large areas of previously wet pavement to dry out over the colder late night and early morning hours.

This diurnal pattern of daytime snow melting and night time drying is believed to be an important factor in producing elevated PM-10. This snow melting and subsequent freeze pattern is believed to mobilize PM-10 through several mechanisms. Some of these mechanisms are described below:

- a. Exposure of particulate matter previously covered with ice or snow along roadway shoulders and medians. This wet material can be tracked out on to the dry, traveled portion of the roadway by vehicles that make excursions to the shoulder and median. When this newly exposed material dries it can be reentrained by vehicle wakes or other disturbances.
- b. Transport of fine particulate from roadway shoulders and medians to the traveled portion of the roadway via melt water laden with suspended solids. Reentrainment occurs when the roadway dries.
- c. Water suspension of fine particulate previously lodged in roadway cracks and crevices. Melt water may “float” this fine particulate to coat exposed surfaces where it can be reentrained after drying.
- d. Vehicle track-out of fine material from unpaved roads and alleys, and from paved local streets and parking lots. Although major thoroughfares may dry early in the spring because of superior drainage and heavy traffic, many local streets and parking lots remain wet. The wetness of this material facilitates track on to major thoroughfares where it dries out and becomes reentrained as PM-10. Unpaved roads and alleys remain wet even longer and often remain as a source of track-out material into late spring.

Hourly average PM-10 data collected by the Beta attenuation monitor (BAM) at Gambell support the hypothesis that particulate mobilization through melt/freeze contributes to PM-10 episodes. On days when the melt/freeze phenomena appears to be a factor, PM-10 levels tend to be lowest during the daytime melt period when streets are wet, and highest when temperatures fall below freezing and streets dry out. This diurnal

pattern is displayed in Figure 9 where hourly PM-10 concentrations on March 20, 1996 are plotted against temperature. (Note the temperature scale on the second y-axis has been inverted for clarity.)



**Figure9. Influence of Freezing and Melting on PM-10  
Gambell Site—March 20, 1996**

On March 20, 1996, PM-10 levels were highest during the morning commute period when temperatures were below freezing and the road was dry. As temperatures warmed in the midday and snow melting began, PM-10 concentrations dropped and remained low through the afternoon and early evening. It is worth noting that PM-10 concentrations did not increase during the heavy traffic experienced during the evening commute period, presumably because the roadway was wet or moist from melt water. As ambient temperatures dropped during the late evening and roads began to dry, PM-10 levels increased again. This pattern is typical of many of the days when the melt/freeze pattern is thought to influence PM-10.

Other evidence also supports the notion that this melt/freeze pattern is important in generating elevated PM-10 levels. Anchorage often experiences long dry periods during the winter when maximum temperatures remain well below freezing. Even though there may be significant amounts of snow cover in most areas, traveled roadway surfaces, particularly those on major thoroughfares, are clear of snow and ice. PM-10 concentrations are almost always low despite the fact that roadway

surfaces are dry, and large amounts of traction sand have been previously applied to the roadways. This again suggests that fine particulate mobilization and subsequent reentrainment are related to the daytime melting process.

5. *Days that do not meet criteria for inclusion in any of the four previous categories.*  
N = 11 (11% of all days above 120  $\mu\text{g}/\text{m}^3$ )

Eleven days did not meet the meteorological criteria (wind, temperature, and/or snow cover) for inclusion in the four previously described categories (Mt. Spurr influence, wind-related, freeze dry effect, or melt/freeze mobilization).

Eight of these days fell on the tail end of the spring breakup or after fall season snowfalls when most of the snow cover had just recently melted. They were excluded because they did not have the requisite one inch of snow cover required for inclusion in the melt/freeze category. On almost all of these days, however, a trace of snow was still being observed at the Point Campbell Weather Observatory. This suggests that melting could still have been a factor in the mobilization of particulate. In particular, track-out of fine particulate from wet local roads, parking lots, and from unpaved roads and alleys on to major thoroughfares was probably enhanced on these eight days.

One of these eleven days occurred in late October (10/22/93) and perhaps should have been included in the “freeze dry” category. Although the maximum temperature (40°F) exceeded the 32°F criteria, the minimum temperature recorded was 21°F. Thus, the freeze dry effect may have been a factor may have contributed to the elevated PM-10 concentrations measured that day.

Two of the eleven days that did not fall into previously described four categories were very cold days that also had appreciable snow cover. Cold ambient temperatures and the presence of snow cover seem to rule out the freeze dry or melt/freeze mechanisms as an explanation for the high PM-10 concentrations observed on the two days. On both days average ambient temperatures were near 0°F and the relative humidity was very low.

### **3.4 Inferences Drawn from the Analysis of Anchorage PM-10 Data**

1. *In Anchorage, data strongly suggest that exceedances of the NAAQS only occur near major roadways.* Monitoring data suggest that the Gambell monitoring station is representative of the highest PM-10 concentrations experienced in the Anchorage. It is the only site that has violated the NAAQS. The high traffic volume on adjacent roadway (Gambell/Ingra) couplet, the north-south orientation of the roadway and



topographic factors all contribute to the high PM-10 concentrations observed at this site.

2. *High PM-10 days are usually confined to the spring break-up (March 15 - April 15) and fall freeze-up periods (October 15 - November 15).* Almost all of the days defined as PM-10 episode days ( $\text{PM-10} > 120 \mu\text{g}/\text{m}^3$ ) have occurred in these two periods. Most of the high PM-10 days occurring outside this period are attributed to the Mt. Spurr eruption in August 1992. One or more days with PM-10 concentrations above  $120 \mu\text{g}/\text{m}^3$  have occurred during almost every spring break-up and fall freeze-up period since 1988.
3. *PM-10 concentrations decrease rapidly as distance from the roadway increases.* During spring break-up, PM-10 concentrations at a monitor 40 meters from Gambell Street were about 30% lower than those 15 meters from the road. Concentrations 160 meters from the road were about 50% lower.

PM-10 concentrations appear to be less dependent on roadway setback distance during the fall freeze-up period. Although PM-10 concentrations dropped as distance from the roadway increased, the decline was less than that observed in the spring. This suggests that fall PM-10 episodes may be more of an area-wide phenomena than those in the spring.

4. *Local sources appear to be responsible for almost all of the PM-10 episodes in Anchorage.* Data from the Oceanview neighborhood site suggest that most PM-10 episodes are localized rather than area-wide in nature. PM-10 concentrations at Oceanview rarely approach those at Gambell. Of the 35 episode days when PM-10 measurements were made both at Gambell and Oceanview, concentrations at Gambell were at least twice as high as Oceanview on 29 days. Concentrations at Oceanview were comparable to those at Gambell on only 3 of the 35 episode days. Strong winds were recorded on two of those days.

This suggests that localized sources near Gambell account for almost all of the PM-10 episodes observed there. The data suggest that long range transport of PM-10 from the Mat-Su Valley rarely has a significant impact on PM-10 concentrations at Gambell.

5. *Mobilization of fine particulate through daytime melting and subsequent roadway drying during cooler nighttime and early morning hours appears to enhance reentrainment of roadway dust and contributes to PM-10 episodes.* Melting exposes large amounts of fine particulate on roadway shoulders and medians. This material can be mobilized on to the traveled portion of the roadway by melt water, track out, and if dry, by vehicle wakes. Particulate lodged in roadway cracks and crevices can also be mobilized by melt water and deposited on exposed roadway surfaces where it can be reentrained upon drying.

6. *Some fall PM-10 episodes appear to be associated with “freeze dry” conditions which contribute to increases in roadway PM-10 emissions.* Many fall PM-10 episodes occur on cold days without snow cover. Fine grained soils are more prone to entrainment because of moisture loss during these subfreezing periods. Poor atmospheric mixing on these days may also contribute to high PM-10 concentrations.

## 4. Analysis of Archived Filters

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### 4.1 Archived Filters/Source Materials

Archived filters from selected days with high PM-10 concentrations in Anchorage were analyzed microscopically for particle morphology, as the basis for source apportionment. In the selection process, consideration was given to the target number of filters that could be processed within the analytical budget.

The archived filters that were selected for microscopic analysis are listed in Table 6. The criteria for selection, which are summarized in the last column, focused on comparison of data matched samples from the Gambell site and a second “reference” monitoring site. Note that the last pair samples (not date-matched) was collected from the Gambell site during the intensive April 1997 field study described later in this report.

**Table 6. Historical PM-10 Samples Selected for Analysis**

Filter No.	Sampling site	Sampling Date	PM-10 ( $\mu\text{g}/\text{m}^3$ )	Selection Criteria
3549845	Gambell	10/22/93	126	Oceanview
3549846	Oceanview	10/22/93	123	Similar to Gambell
4594781	Gambell	02/19/94	166	Dry weather,
4594783	Oceanview	02/19/94	70	Snowmelt
4595410	Oceanview	10/20/94	82	Oceanview
4595419	Gambell	10/20/94	145	Similar to Gambell
5507573	Gambell	04/12/95	159	Possible
5507577	Oceanview	04/12/95	38	Track-out
5508279	Gambell	11/06/95	126	Possible
5508282	Oceanview	11/06/95	147	Track-out
5508293	Gambell	11/08/95	172	Persistent wind
5508296	Muldoon	11/08/95	116	From south
6546987	Gambell	05/14/96	147	Persistent wind
6546988	Caribou	05/14/96	57	From north
6169470	Gambell	04/08/97	93	Test week
6169498	Gambell	04/11/97	110	

Samples of the reference source materials were also obtained for microscopic analysis. These included:

- Volcanic ash from Mt. Spurr;
- Anti-skid aggregate applied to Alaska State roadways, including Gambell/Ingra;
- Limestone tracer material; and
- Agricultural soil from the Mat-Su Valley.

The morphological features of the reference materials were to be used in identifying the components of the collected PM-10 on the archived filters.

The list of reference samples is given in Table 7. The list includes vacuumed road surface dust samples collected during the April 1997 test week. Only samples of materials that were likely contributors to filter loadings were examined. The samples that had compositions similar to the pavement, road dust, and soils were examined by PLM but not analyzed because their compositions were so similar to the other reference samples.

**Table 7. List of Reference Samples**

Sample ID # (Sampling Date)	PLM Exam/ Analysis	Description (Location)
1 (4/6/97)	Yes/No	Roadside soil adjacent to farm (Matanuska Valley 45 miles from Anchorage)
3 (4/6/97)	Yes/No	Tilled potato field soil south of Palmer (~ 40 miles NE of Anchorage)
4 (4/6/97)	No/No	Sand from Knik River sand bar (~ 35 miles NE of Anchorage)
7 (4/7/97)	Yes/No	Soil from unpaved parking lot at ice rink (75 feet of Gambell monitors)
8 (4/7/97)	No/No	Mud from snow piles (~30 feet N of Gambell monitors)
9 (4/9/97)	No/No	Tidal mud from Ship Creek in the Knik Arm (1.5 miles N of downtown Anchorage)
13 (8/1/92)	Yes/No	Volcanic ash from Mt. Spurr eruption of August 1992 (road shoulder at Int. Airport)
14 (4/10/97)	Yes/Yes	Loess/"glacial flour" from Bodenbug Butte near Palmer (~ 35 miles NE of Anchorage)
P (4/8/97)	Yes/Yes	Pavement from far east lane of Gambell (directly east of the monitors)
Limestone Apr/97	Yes/Yes	Limestone (Doloimitic) used as the tracer for the road dust experiment
LTS97GAM-R1, silt (4/8/97)	Yes/Yes	Vacuumed road dust near Gambell monitors during tracer study, no added limestone
LTS97GAM-R2, silt (4/9/97)	Yes/Yes	Vacuumed road dust near Gambell monitors during tracer study, limestone added
LTS97GAM-R3, silt (4/10/97)	Yes/Yes	Vacuumed road dust near Gambell monitors during tracer study, limestone added
LTS97GAM-R4, silt (d4/11/97)	Yes/Yes	Vacuumed road dust near Gambell monitors during tracer study, limestone added
MOA-TC-W-93/94 & 94/95, silt	Yes/Yes	Silt fraction of anti-skid aggregate used in Anchorage during winters of 93/94 and 94/95
MOA-TC-W-95/96 & 96/97, silt	Yes/Yes	Silt fraction of anti-skid aggregate used in Anchorage during winters of 95/96 and 96/97

## **4.2 Analytical Methods for Particle Composition**

Three analytical methods were designated to determine the fine particle components in (a) the PM-10 deposits on the quartz filters from the air samplers and (b) the road surface material samples collected in vacuum bags. Polarized light microscopy (PLM) supplemented by low temperature ashing (LTA) was performed by IIT Research Institute of Chicago, Illinois. A separate method was used to analyze test week filters and vacuumed road dust samples for carbonate content. The carbonate analyses were performed by Huffman Laboratories of Denver, Colorado.

These three analytical methods are described briefly below. The results of particle analysis by PLA/LTA are reported in this section; however, the carbonate analyses are presented in the next section as part of the discussion of the limestone tracer study.

### **4.2.1 Polarized Light Microscopy (PLM)**

PLM, documented by photomicrography, was used to count known particles on quartz filters or to list specific morphological features of unknown trace particles. A hydrocarbon fluid mixture was applied to make each quartz filter nearly transparent, so that particles and agglomerates can be examined in situ. Powdered samples of reference source materials were transferred to glass slides, and drops of immersion oils of different refractive indices were added to prepare the samples for microscopic analysis.

Particles were identified by comparison to the reference samples and to published data on the morphological and crystallographic features of known materials (e.g., tire fragments, feldspar and quartz, spores, pollen, plant tissue).

Quantitative analysis of the selected particle size range was derived from counting and sizing each particle by type (tire particle, pavement fragment, etc.) to produce a mass per unit area of particles on each filter. Particle mass was computed from the size and density of particles (published rather than measured densities). Scanned filter areas were defined by a calibrated counting graticule in the microscope.

### **4.2.2 Low Temperature Ashing (LTA)**

Ambient filter samples were burned at low temperatures to quantitatively distinguish between ashable and non-ashable components. Reference source samples were not ashed because the bulk samples did not contain much ashable content and were of a much larger particle size range ( $< 75 \mu\text{m}$  diameter).

LTA is a quantitative combustion technique to measure the mass of all organics and elemental carbon particles that react with monatomic oxygen. This basically divides the

aerosols into “organics + elemental carbon + volatiles” vs. “inorganics and a few very high molecular weight organics that do not ash (e.g., pollens and spores).”

#### 4.2.3 Carbonate Content

Carbonates in ambient aerosols were measured by acidification of filters with phosphoric acid ( $\text{H}_3\text{PO}_4$ ) to produce carbon dioxide  $\text{CO}_2$ .<sup>7</sup> The  $\text{CO}_2$  was reduced to methane ( $\text{CH}_4$ ) which was measured in a flame ionization detector.

### 4.3 Analytical Results<sup>3/4</sup>Microscopy

Table 8 shows the component concentrations of the nine reference source samples as a percentage of each sample mass. The plagioclase/quartz component ranged from approximately 85% (Gambell pavement) to 99% (loess glacial flour). The road surface dust samples and anti-skid material samples had intermediate values. The only other components appearing in greater than 1% concentrations were limestone (from the tracer study), mica (in the anti-skid samples) and asphalt (in the road vacuuming and pavement samples).

**Table 8. Component Concentrations in Reference Samples**

Material	Date	Average Abundance			
		Tire Fragments	Asphalt Aggregates	Plagioclase Feldspars + Quartz	Limestone
Gambell pavement	4/8/97	< 0.01%	5.5%	86.1%	< 0.01%
Anti-skid 93/95	Not given	< 0.01%	< 0.01%	98.8%	< 0.01%
Anti-skid 95/97	4/8/97	< 0.01%	< 0.01%	96.65	< 0.01%
Loess Glacial Flour	4/10/97	< 0.1%	< 0.01%	99.8%	< 0.01%
Road Dust Tracer	4/97	< 0.01%	< 0.01%	1.5%	98.4%
Vacuumed Road Dust	4/8/97	< 0.01%	3.00%	95.8%	< 0.01%
Vacuumed Road Dust	4/9/97	< 0.01%	3.00%	95.3%	1.5%
Vacuumed Road Dust	4/10/97	< 0.06%	3.00%	94.0%	2.0%
Vacuumed Road Dust	4/11/97	< 0.01%	1.50%	97.3%	0.55%

Limestone was detected in all the samples except for the pavement and loess glacial flour. Its concentrations were < 0.01% in all samples except the road dust samples on the days following the addition of limestone tracer. Hornblende, a distinctive green mineral, was present in the pavement and road surface samples but was at trace levels or not detected in the other samples. Mica fragments and slivers were detected in all reference samples except in the limestone tracer.

As shown in Table 9, the LTA-residue PM-10 aerosol compositions on the filters closely mimic the components in the reference samples (e.g., pavement, vacuumed road

dust (including anti-skid abrasives), the soil (loess glacial flour). The major distinction is that the filters had rubber tire fragments as the primary component of the LTA-loss fraction.

**Table 9. Component Weight % Concentrations in Filter Samples**

Date	PM-10 Concentration ( $\mu\text{g}/\text{m}^3$ )	LTA Loss (%)	Average Abundance (%)			
			Tire Fragments	Asphalt Aggregates	Plagioclase Feldspars & Quartz	Limestone
10/22/93	126	32.1	31.0%	< 0.01%	64.3%	0.04%
10/22/93	123	23.7	22.6%	< 0.01%	73.5%	0.04%
2/19/94	166	16.1	14.8%	0.8%	81.9%	0.5%
2/19/94	70	25.2	24.6%	< 0.01%	71.8%	0.4%
10/20/94	82	19.1	17.7%	< 0.01%	77.4%	1.6%
10/20/94	145	18.7	18.1%	< 0.01%	76.9%	2.4%
4/12/95	159	18.2	17.7%	< 0.01%	79.7%	0.2%
4/12/95	38	33.5	31.0%	< 0.01%	63.2%	0.2%
11/6/95	126	16.6	15.7%	< 0.01%	81.1%	0.2%
11/6/95	147	14.7	14.0%	< 0.01%	83.6%	0.2%
11/8/95	172	22.9	22.2%	< 0.01%	74.4%	0.4%
11/8/95	116	22.1	21.2%	< 0.01%	75.7%	0.09%
4/8/97	93	37.1	36.1%	0.03%	53.1%	6.2%
4/11/97	110	39.3	38.3%	0.03%	56.5%	0.3%
5/14/96	147	20.9	20.1%	< 0.01%	76.8%	0.2%
5/14/96	57	34.5	33.7%	0.03%	62.1%	0.04%

On the archived filters, the mass of mineral fragments from anti-skid and/or road dust and/or soils combined with rubber tire fragments exceeded 95% in all of the samples. The PM-10 filters collected at the Gambell site during the road dust tracer experiments had rubber tire concentrations of 36% and 38% that corresponded to ambient concentrations of 34 and 42  $\mu\text{g}/\text{m}^3$ , respectively.

Asphalt agglomerate particles were found in much greater proportion in the roadway silt samples than in the PM-10 samples. (Asphalt agglomerate particles are defined as particles composed of mineral particles coated or partially coated with bituminous organic asphalt.) Particles with this "asphalt signature" comprised 1.5% to 3.0% of roadway silt vacuumed from Gambell/Ingra but were absent or found in very low quantities in the PM-10 samples. The absence of PM-10 particles with this asphalt signature might lead one to hypothesize that particles produced by roadway abrasion contribute little to the airborne particulate mass.

Although this initial hypothesis seems to be supported by laboratory evidence, most of the small, PM-10 sized particles created from the relatively large gravel and sand grains in the asphalt aggregate would not be expected to have any traces of asphalt coating. If sand-sized grains (1 -mm diameter) were crushed to form 10 micron-sized

cubes more than 940,000 mineral fragments without traces of asphalt and approximately 58,000 mineral fragments with a partial asphalt coating would be produced. Thus, the likelihood of sampling discrete 10 micron-sized mineral fragments with a partial coating of bituminous asphalt is less than 6%. As the size of the mineral fragments decrease the proportion of uncoated particles increases. Therefore, it is entirely possible that asphalt pavement-origin particles are a significant contributor to the PM-10 at the Gambell site even though very few asphalt signature particles were present in the PM-10 samples themselves.

One additional finding in this study may have important consequences for road dust control strategies. The rubber tire fragments are directly emitted into the air after release from the tire tread and are not emitted as re-entrained road dust.

This observation is based on the analysis of the road surface dust samples that were collected for the road dust tracer study. These vacuumed samples contained very low tire fragment concentrations (most at 0.01% with just one of the four samples at 0.06%). The particle size of these tire fragments were mostly greater than 50  $\mu\text{m}$  (equivalent spherical diameter) which should not be collected (and were not) on the PM-10 filters.

#### **4.4 Inferences Drawn from the Microscopical Analyses**

1. *On days with moderate to high PM-10 concentrations, the major source contributions are road dust minerals and rubber tire fragments, accounting for more than 95% of the PM-10 burden.* For filters representing concentrations that exceed 100  $\mu\text{g}/\text{m}^3$ , 56% to 83% of the minerals impact is due to plagioclase feldspars and quartz minerals. Rubber tire fragments range from 15% to 42% of the PM-10 mass among these samples.
2. *It appears that windblown soils are not a typical or usual cause of high PM-10 concentrations in Anchorage.* If windblown dust were typically a major contributor to high PM-10 concentrations at the Gambell site, such concentrations would tend to occur on days with high wind speeds, and PM-10 concentrations at other monitors would also be elevated on those days. Only for one pair of archived filters did the average wind speed exceed 12 mph.
3. *The principal sources of minerals contributing to 24-hour PM-10 violations are anti-skid materials and pulverized roadway aggregate abraded from the roadway wearing course by studded and unstudded tires on major thoroughfares.* The composition of the principal minerals in the anti-skid material are identical to those in the asphalt road aggregate minerals. The PM-10 minerals collected on the filters are also identical to predominantly the same as the anti-skid and road aggregate minerals. This clearly points to both mineral sources as major causes of PM-10 violations.



4. *Rubber tire fragments are a significant contributor to PM-10 concentrations that may not be eliminated by road cleaning.* The impact of anti-skid materials would be reduced by road cleaning because they are entrained from the roads, but not rubber tire fragments. The tire fragments are directly emitted from the tire treads with apparently little accumulation in road surface dust.
5. *Removing the anti-skid accumulations might reduce direct tire wear and emissions by limiting impregnation of the tire treads with mineral fragments.* Most tire fragments seen in PM-10 samples (and also in the surface of tire treads) are found impregnated with road dust minerals that undoubtedly contribute to cohesive failure and release of tire fragments.

## 5. Source Observation and Sample Collection

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The Study Design developed for the Anchorage field study was divided into two parts: on-site source characterization and the intensive road dust study. It took into account MOA's Conceptual Design as well as findings from the historical data review and the hot spot analysis. The Study Design emphasized localized PM-10 emission sources at the Gambell site, as distinct from distant sources. However, sources near three other PM-10 monitoring sites (Tudor-Allstate, Muldoon, and Oceanview) were also observed. In addition, the Study Design specified on-site observations of potential source areas in the Eagle River and Mat-Su Valleys north of Anchorage.

Source observation included surface inspection and surface sample collection and analysis for wind erodibility. Photographs documented special interest areas around the PM-10 monitoring sites, especially the adjacent roadways and parking lots where traffic-related dust resuspension would be likely. Also included in source characterization were traffic conditions (speed, volume, and vehicle mix) and meteorology.

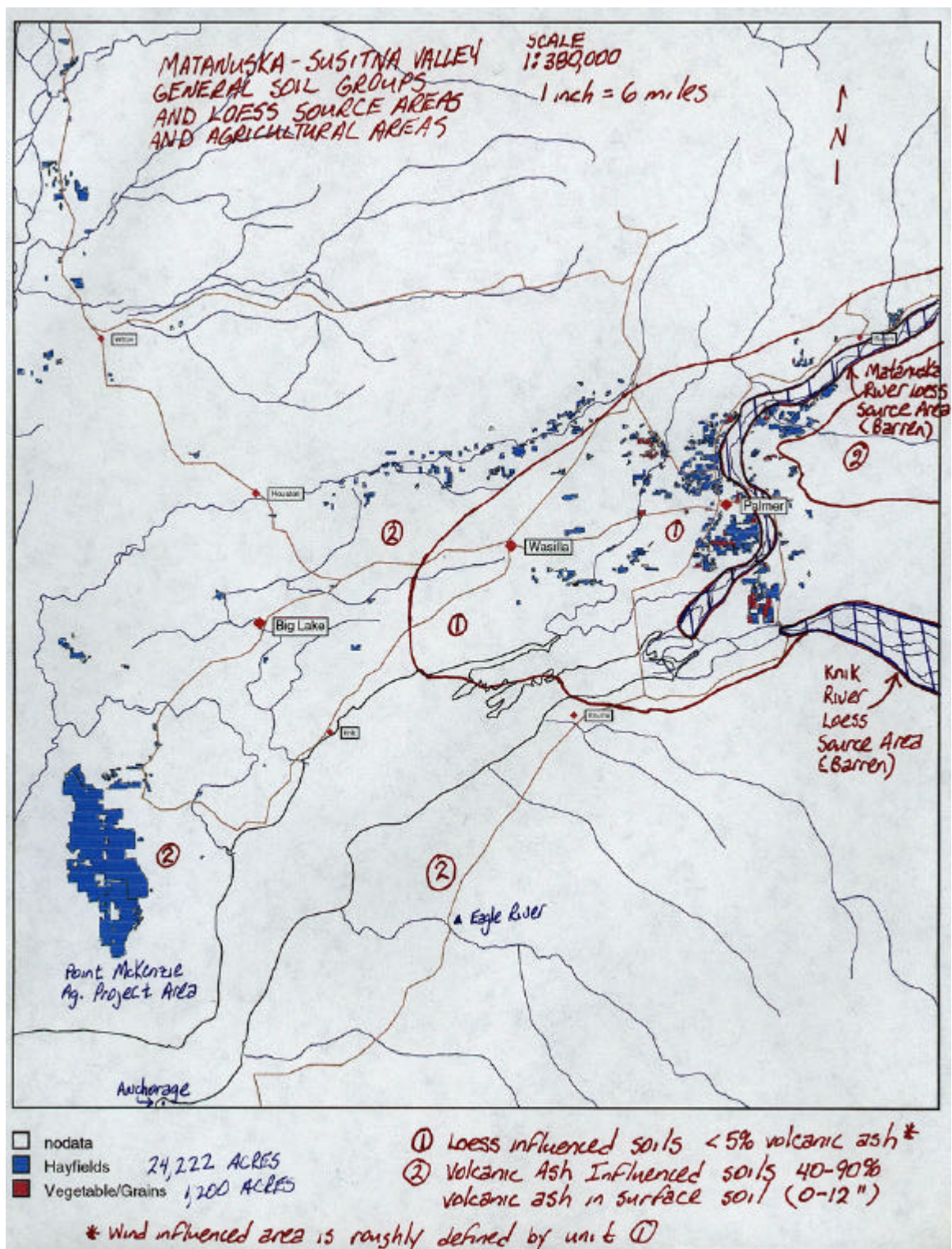
### 5.1 Mat-Su Valley Soils

Prior to the field study information on Mat-Su soils was collected and analyzed. The USDA has completed a soil survey of the soils that lie to the north of Anchorage, and the soil characteristics are summarized in this section for PM-10 source apportionment purposes.<sup>8</sup> Figure 10 is a map illustrated by Mark Clark, USDA NCRS Soil Scientist in Wasilla, Alaska that shows the distribution of soil types, wind corridors, and agricultural areas in the area to the north of Anchorage.

The largest contiguous area of agricultural lands near Anchorage is the Point MacKenzie agricultural area on the north side of the Cook Inlet from Anchorage. However, this area is not a significant wind erosion source because it is mostly under permanent cover of hay or is being revegetated to natural plant species.

Clark explains that Zone 1 soils consist of approximately 1 to 25 feet of silty material that originates from the barren flood plain areas of the Matanuska and Knik Rivers (blue hatched areas on the map). This good agricultural soil is primarily loess intermixed with a small percentage of volcanic ash (estimated at less than 15% by volume). However, the silty loess is highly porous (50% to 60% air volume), and thus can be easily transported by the wind.

Northern winds in the Zone 1 corridor drop rapidly in speed outside the corridor fringe. The primary exception is when southeast winds blow across the Chugach Mountains, when wind can affect zone 1 as well as the toeslopes of the Chugach Mountains from Eklutna to Anchorage.



**Figure 10. Mat-Su Valley Soils (1997 Version  
prepared by Mark Clark, USDA Soil Scientist)**

Zone 2 soils (Figure 10) consist of 1 to 2 feet of volcanic ash from volcanoes in the lower Alaska Range and Aleutian Range to the west and southwest of Anchorage. Ash content in Zone 2 soils generally increases from east to west, ranging from about 10% to 90%. Ash particles are highly porous, and when dry, the soil texture feels sandy.

## 5.2 Pretest Sampling

The pretest sampling began on Sunday, April 6, with a drive to Eagle River and the Mat-Su Valleys to (a) check mud flats, farmlands, and other open areas for crusts and vegetation, and (b) collect and hand sieve selected surface samples for determination of threshold velocities for wind erosion. The pretest surface samples are listed in Table 10. During the visit, current, prior, and forecast weather was documented. Likely remote and local source surface materials were photographed.

**Table 10. Pre-test Surface Samples**

Sample ID	Sample Date	Sample Description
1-4/6/97	April 6, 1997	Soil from the edge of a farm field in the Matanuska Valley. Approximately 45 miles NNE of Anchorage.
3-4/6/97	April 6, 1997	Soil from a tilled potato field. Just to the south of Palmer. Approximately 40 miles NE of Anchorage.
4-4/6/97	April 6, 1997	Sand from a sand bar on the Knik River. Approximately 35 miles NE of Anchorage.
14-4/10/97	April 10, 1997	Loess, "glacial flour," from Bodenburg Butte, near Palmer. Approximately 35 miles NE of Anchorage.

After returning to Anchorage, PM monitoring sites, and possible local sources (including traffic) near Gambell and up/down Chester Creek were photographed and documented. Surface material from parking lots and road shoulders were described and selectively sampled. Unpaved roads and open areas near the Gambell site (and other PM-10 monitors in Anchorage) were located and characterized, especially those locations where dirt was tracked onto major thoroughfares.

## 5.3 Track-on Observations

During the test week, the areas adjacent to Gambell and Ingra were carefully observed for visible sources of track-on to Gambell moving from north to south. The track-on sources included:

- Small amount of dry material track-on from the Crazy Horse parking lot.
- Small amount of dry track-on from East 16th Street onto Gambell.

- Track-on of wet and dry material from the Arena and ice rink parking lots. [The worst situation occurred following a sold-out Anchorage Aces game.]
- Track-on of wet black “slurry” from large, very dirty, melting snowpiles adjacent to the parking area for the Gambell monitors. [Traffic to support monitor operation was greater than usual in this area during the test week. During the week of the tracer study, the runoff from the melting snowpiles was not observed to directly be deposited on Gambell.]
- Track-on of a small amount of dry material from the Westchester parking lot of the First National Bank of Anchorage. [Vehicles routinely use the semi-circle driveway through the lot to change from northbound Ingra to southbound Gambell.]
- Track-on of dry material from the south exit of Worthington Ford.
- Track-on of wet and dry material from the Hillside Motel and RV Park.

In contrast, no large sources of track-on were observed on Ingra between Fireweed Lane and 15th Street. A small amount of dry track-on from the First National Bank parking lot onto Ingra was observed.

## 5.4 Other Localized Sources

In addition to the track-on sources identified above, other potential sources of airborne particulate in the Gambell monitor area were observed during the test week and are discussed below. Prevailing winds were from the north during the test period, and potential sources to the north of the Gambell monitor were carefully scrutinized.

South of the businesses along 15th Street and between Ingra and Gambell lies a rough hillside with cut trees, tall weeds, and bare earth. The area was wet during the test week and was not observed to be a dust source. The buildings and hill to the north of the hillside serve as a protection against strong north winds. When north winds change to south winds in the summer, the hillside area is likely protected by vegetative cover.

The Crazy Horse parking lot was a source of direct emissions, as determined by observing one vehicle emit visible dust while crossing the unoccupied lot. Because the Crazy Horse opens at 4:00 p.m. for business through the evening and night, the parking lot was empty during most of the day. A strong south wind could stir up dust, but the lot was somewhat protected from the prevailing northerly winds by a hillside and buildings to the north.

Between Gambell and Ingra, the First National Bank was constructing a new building to the north of the current structure. The area around this new structure was in a pit, was

fenced in, and was muddy, thus leading to the conclusion that it was not a source of airborne particulate.

A parking lot to the south of the new bank structure is somewhat protected from north winds. This lot, like almost all in the vicinity, was covered with sand from winter application for snow and ice control.

The Arena parking lot and ice rink parking lot (paved portion) appeared to have less particulate residue than many other parking lots in Anchorage. However, a portion of the ice rink parking lot was unpaved and under dry conditions could be an important source of PM-10. The unpaved lot was wet during Monday and Tuesday of the test week, but had begun to dry in spots by Thursday. Drying produced a protective crust against wind erosion that was not disturbed by traffic, except for about 5 to 8 vehicles that were observed to park daily in this lot against the south fence. The Anchorage Aces game mentioned earlier took place during the time when the unpaved lot was wet.

A sidewalk on the east side of the bank building had a high loading of surface silt. While the sample was being collected, wakes (drafts) from trucks could be felt and dust was thrown into the eyes.

The parking lot of the First National Bank of Anchorage, which was paved in 1996, had a very high surface loading due to winter sanding of the lot. However, almost no cars were observed to travel through it, except for vehicles related to the tracer study.

The sidewalk on the west side of Ingra across from the Hillside Motel and RV Park was observed to have significantly less surface loading than the sidewalk near the Gambell monitors on the east side of Gambell Street. This may have been due to the even more intense wake felt at this location.

The Hillside Motel and RV Park to the south of the Gambell monitors had a mixture of paved (but loaded with sand) and unpaved surfaces. All unpaved surfaces were wet or muddy and did not appear to be direct sources that could impact the Gambell monitors during the test week, especially with a prevailing northerly wind.

Other areas north of the Gambell monitors did not appear to be sources because of protection by vegetation, pavement, or snow cover. These included paved parking lots to the west of the ice rink and sports arena that were observed to be covered with only a small amount of sand, with loadings visibly similar to the east paved arena parking lot. The parking lots were observed to be heavily used on the evening of Tuesday, April 8, when a major ice hockey game was played, and the arena was sold out. DustTRAK readings were taken at four general locations downwind of the parking lots (and surrounding the arena) on that evening, Wednesday, and are reported separately.

Sports fields to the west of the arena included a soccer/football field, two tennis courts, baseball diamond, and other grassy areas (at least partially covered with snow).

None of these areas was observed to be a significant source of airborne particulate matter during the test week.

## 5.5 Pavement Wear

Quantifying the impact of studded tires on PM-10 was one of the objectives of this study. Significant pavement rutting has been observed on many Anchorage roads. The Alaska Department of Transportation and Public Facilities (ADOT&PF) attributes most this rutting to studded tire wear. Presumably, some of the material abraded from the roadway contributes to PM-10. A Japanese study concluded that a decline in studded tire use resulted in significant reductions in particulate matter.<sup>9</sup> The number of days exceeding the local visibility standard dropped from 40 per year when 90% of vehicles were equipped with studded tires to 3 days per year when studded tire usage was cut to 50%.

During the winter, 50% to 60 % of Anchorage vehicles operate with studded tires. Studded tires are allowed from September 16 through April 30. A 1996 ADOT&PF report estimated pavement wear from studded tires at 0.13 inches per million tire passes.<sup>10</sup> This equates to 22 tons of road material per mile per million vehicle passes. Ten to 15 thousand tons of material would be abraded during the course of a winter. The quantity of roadway material generated by studded tire wear approaches the amount of traction sand that is applied each winter in the Anchorage bowl (20 to 30 thousand tons).

Although these studded tire wear estimates are somewhat speculative, they seem to be corroborated by other evidence. An average of 2.6% of the mineral particles (average of four samples) in road silt samples taken from Gambell/Ingra had partial asphalt coatings serving as road aggregate signatures. A pavement sample from Gambell Street was ground and sieved to silt size and 5.5% of the particles carried the asphalt signature. This suggests that almost half (48%) of the roadway silt was comprised of particles abraded from the roadway itself. However, this estimate is based on a very limited sample size and the validity of this estimation technique for determining roadway wear impacts on PM-10 has not been assessed.

It should also be acknowledged that the pavement wear rates referenced here are disputed by some who assert that much of what is considered as studded tire wear is actually roadway deformation resulting from vehicles loads, especially from heavy trucks. If this is the case, wear rates would be lower than assumed here, but this would not contradict the ratio of asphalt-coated to uncoated minerals in road dust that is the primary basis for assigning road wear as a significant contributor to PM-10.

Although there is a great deal of uncertainty associated with these estimates, they suggest that pavement wear is a very significant contributor to PM-10 and that up half of the mineral portion of the PM-10 mass (i.e. the portion exclusive of rubber tire particles) may

originate from pavement wear. It appears that studded tires could be the cause of much of this wear.

## 5.6 Inferences Drawn from the Source Observations

1. *A large reservoir of anti-skid abrasives and soil is available for track-on to Gambell during the spring snowmelt.* On-site observations prior to and during the April 1997 intensive road dust study indicated visual evidence of track-on from heavily loaded parking lots adjacent to Gambell near the monitoring site. The heavy loadings in the source areas resulted from directly applied anti-skid abrasives with additional accumulations in the melting snowbanks. Track-out from wet areas was more evident than from dry areas.
2. *The effectiveness of surface cleaning of Gambell and Ingra would be reduced by immediate buildup of surface silt loading from the track-out sources.* As the active Gambell/Ingra roadway surfaces dry, they tend to be silt cleaned by traffic. Additional street cleaning, by vacuuming, assuming that efficient methods are available, would deal with a relatively small portion of the silt reservoir that is available to feed suspendable particles to the road surface. Most of the reservoir lies in the heavily loaded adjacent parking lots, from which track-on would continue to occur.
3. *Although asphalt pavement particles appear to make-up a significant portion of the PM-10 at Gambell, direct quantification of the impact of studded tires was not possible.* There were no chemical or morphological characteristics that could distinguish asphalt pavement particles produced by studded tires from other pavement wearing mechanisms (e.g. abrasion by rubber tires in concert with traction sand, or weathering processes). The impact of studded tires on PM-10 was estimated from roadway wearing rates determined by ADOT&PF. Using these wearing rates to estimate the impact on PM-10 is a crude method of assessing studded tire impacts on PM-10. The uncertainties in these estimates should be weighed when considering control strategies aimed at reducing studded tire impacts on PM-10.



## 6. Intensive Road Dust Study

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The Study Design called for a 1-week Intensive Road Dust Study to determine the relationship between the Gambell/Ingra road surface condition and the PM-10 concentrations in and around the Gambell monitoring site. This study was conducted from April 6 through April 11, 1998.

The Intensive Road Dust Study included application of a crushed limestone tracer to the divided roadway, after it had been cleaned. Crushed dolomite limestone, which does not occur naturally in the Anchorage area, was transported from a source near Cantwell, Alaska.

The primary purpose of the intensive study was the determination of the contribution of resuspended dust from the Gambell/Ingra roadway to PM-10 concentrations in the vicinity of the Gambell monitoring site. This was to be accomplished by relating measured ambient impacts to (a) variations of road surface silt loading and (b) road surface “spiking” with the limestone tracer. Included in the intensive road dust study was the characterization of site conditions, meteorology, traffic flow and other source activity near the Gambell site.

### 6.1 Monitoring Equipment

The primary air samplers for the intensive road dust study were the permanent Gambell monitors, which were located on a roof of the Ford dealership building west of Gambell Street at a setback distance of 15 m from Gambell Street (Figure 1). The ambient air monitors included four Andersen high-volume PM-10 monitors, two dichotomous PM-10/PM-2.5 samplers, and a beta gauge continuous PM-10 monitor.

On April 8, the day that the limestone tracer was applied, the Gambell monitors collected four 6-hour samples and one 24-hour sample of PM-10. On each of the three days following tracer application, two 12-hour samples and one 24-hour sample of PM-10 were collected. Daily 24-hour sampling resumed on April 12.

Two additional PM-10 monitors were also located west of Gambell Street at a distance of approximately 1/3 mile south of the Gambell monitor. The “Best East” monitor was 40 m west of the Gambell/Ingra roadway, and the “Best West” PM-10 monitor was located 160 m west of the roadway. At these sites 24-hour PM-10 samples were collected daily during the road dust study.

Separate monitoring tests were also conducted using two TSI DustTRAKs to record short-term PM-10 and PM-3.5 concentrations at and in the vicinity of the Gambell site. DustTRAK monitoring locations upwind and downwind from the major thoroughfare and

at other points in the vicinity were traversed in sequence several times to record 5- to 30-min average PM concentrations.

An R.M. Young meteorological station was established by the MOA at the Gambell site to record actual wind direction and speed, and horizontal wind fluctuation during the limestone tracer study. Other meteorological data were collected from Merrill Field (hourly observations), and the weather station at Anchorage International Airport (hourly observations and radiosonde measurements). The historical distribution of Anchorage winds in early April is shown in Figure 11.

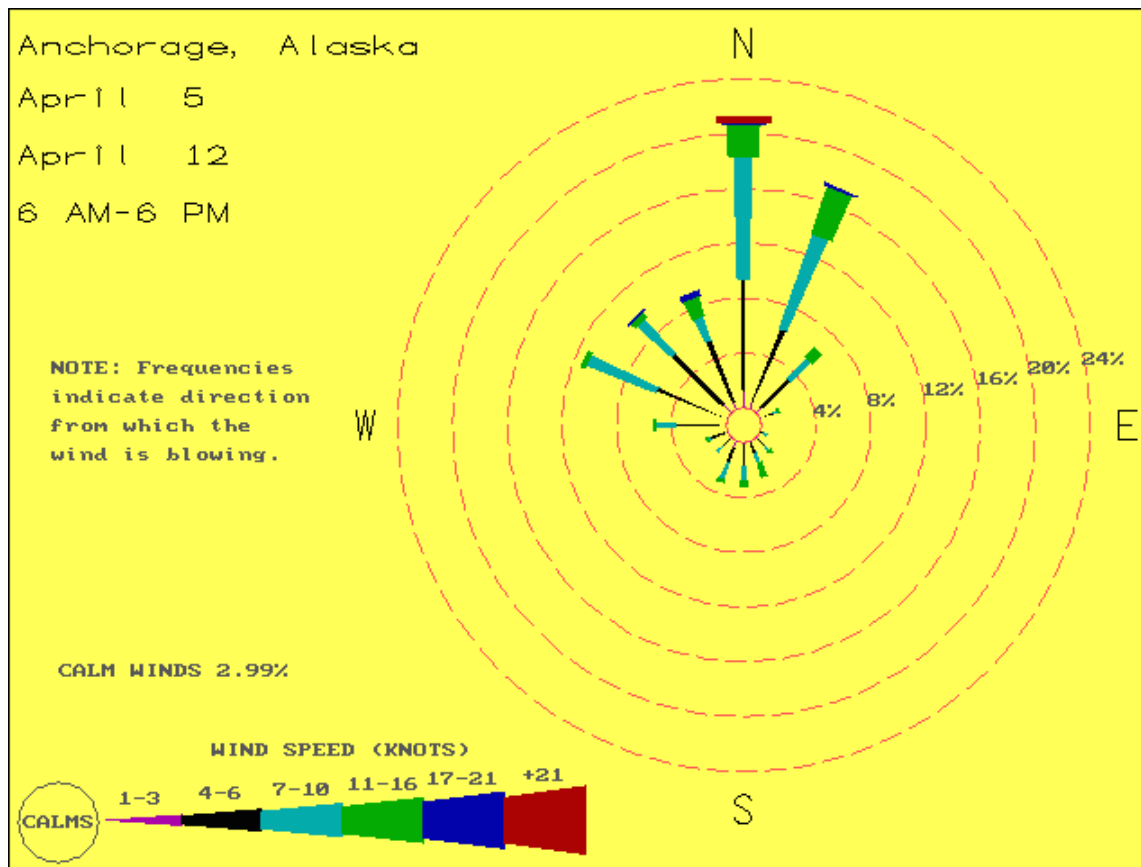


Figure 11. Early April Daytime Winds in Anchorage

## 6.2 Road Surface Dust Loading

Variation of the loading and type of surface material on the Gambell/Ingra roadway system was a key part of the intensive road dust study. After the roads were cleaned with a high-efficiency vacuum sweeper, crushed limestone obtained from Cantwell, Alaska was applied as a road dust tracer to Gambell and Ingra Streets between 15th Street and Fireweed Lane. Limestone is a distinctive white carbonate material not occurring in the natural environment within 100 miles of Anchorage. The tracer study was designed to

corroborate the contribution of localized surface dust loading to PM-10 concentrations measured at the Gambell monitoring site.

Montgomery Watson personnel collected road surface samples from Gambell and Ingra throughout the test week, with an emphasis on the period before and after limestone tracer application. A Craftsman 6 HP, 16-gal wet/dry vacuum with large dust collection bags, and a 10 in. wide brush was used for the road surface sampling.

Road surface samples from transects across the four traveled lanes were composited from the four Gambell sampling locations and also from the two Ingra locations. Gutter samples were composited for the eight samples taken on Gambell (4 locations x 2 gutters), and the four samples taken on Ingra (2 locations x 2 gutters). Gutter samples were usually of a 24 in. width from the roadway edge, unless a clear boundary between the traveled portion of the roadway and the gutter area extended further toward the center of the roadway.

### **6.3 Test Week Activities**

The weather during the test week was mild with partly cloudy skies and high temperatures in the 40's (°F) on Monday, April 7, and 50's (°F) by the end of the week. Winds were mostly light (less than 15 mph) with a northerly component. The test week was characterized by melting snow from large snowbanks and wet ground, although Gambell/Ingra streets remained mostly dry throughout the period. Paved parking lots were usually dry except for track-on areas. Road gutter deposits were mostly wet at the beginning of the test week.

On Monday, April 7, both the Gambell and Ingra roadway surfaces were cleaned using an EnviroWhirl sweeper/vacuum truck. Although a large quantity of surface material was removed from the road, "pockets" of material remained in the depressions and cracks of the road surface. A film of fine particles was visible on the road surface after sweeping. Relatively high PM concentrations were measured at the roadside using a portable TSI DustTRAK monitor as roadway traffic resumed on the lanes that had been swept. This indicated that sweeping/ vacuuming might not have been very effective in the immediate reduction of particulate emissions from vehicle traffic, because of the residual silt layer that was left behind.

Background roadway surface samples were collected by Montgomery Watson personnel very early Tuesday morning, April 8. Samples were obtained from the gutters and travel lanes of Gambell and Ingra after the Monday sweeping/vacuuming and before planned application of the limestone tracer. The road surface loadings were sampled along transects across Gambell, 75 m apart (with small exceptions due to drains and on/off lanes). Only two locations were sampled on Ingra because of interference by increasing early morning traffic and because Ingra Street was further away from the Gambell monitor.

After vacuuming the road for surface sample collection, the vacuumed area “glistened” under the street lamp, as contrasted with the duller, dusty roadway surface adjacent to the vacuumed path. This indicated that the roadway surface silt loading early Tuesday morning was substantial, in spite of cleaning the two roadways with the EnviroWhirl Sweeper on Monday.

At approximately 13:00, on Tuesday afternoon, April 8, 3,900 lb of limestone was applied to the 8 lanes of the Gambell/Ingra roadways (0.66 mi length). The tracer application was delayed almost 10 hours because of material discharge problems. The damp limestone that had “set” in the truck for over a week. Limestone was applied at a rate of 740 lb/lane mile to dry roadway surfaces. A sieving analysis of the bulk limestone applied to the roadway showed a silt content of 9.3%.

Immediately after limestone application to the dry roadway surface, traffic began to disperse the small limestone particles, resulting in visible sheets of dust being blown from the roadway. After an hour, white particles of deposited limestone were observed in roadway cracks, on the sidewalk to the east of Gambell, in the gutter area, and in the unvegetated and dry grass areas adjacent to the two roadways. At that point in time, little if any limestone was visible on the traveled portion of the roadway surface.

To measure the effect on PM-10 increasing the roadway surface loading, 6-hour ambient PM-10 samples were collected at the Gambell site on Tuesday, April 8, the day of limestone application. On the following three days, PM-10 samples were collected at the Gambell site and at other nearby locations.

The roadways were not cleaned after tracer application, leading to a visible buildup of particulate in the gutters, especially on the west side of Gambell closest to the permanent monitors. Additional samples from the roadway surface were collected very early in the morning on Wednesday, Thursday, and Friday (April 9-11).

During the period immediately prior to and during the intensive road dust study, a number of surface material samples were collected from sources other than the Gambell Ingra roadway system. These are listed below in Table 11.

**Table 11. Test-Week Surface Samples (Other than Silt Loading)**

Sample ID	Sample Date	Sample Description
7-4/7/97	April 7, 1997	Soil from the unpaved parking lot at the Dave Baumeister ice rink. Approximately 75 ft north of the Gambell monitors.
8-4/7/97	April 7, 1997	Mud from the snowpiles, 30' to the north of the Gambell monitors.
9-4/9/97	April 9, 1997	Tidal mud from Ship Creek in the Knik Arm. Approximately 1.5 miles north of downtown Anchorage.
13-8/19/92	August 19, 1992	Ash from the August 1992 eruption of Mt. Spurr. Samples taken near the International Airport in Anchorage.
P-4/8/97	April 8, 1997	Pavement from the far east lane of Gambell. East of the Gambell monitors.

## **6.4 Test Results**

This section presents the results of monitoring data and the analyses of samples collected during the intensive field study. Figure 12 shows the sampling timeline and selected key results for the test week.

### **6.4.1 Traffic**

The hourly traffic counts during the test week, as obtained from the MOA, are given in Table 12. The diurnal traffic count increased sharply during the hour ending at 0800 and remained heavy until the hour ending at 2000 (8:00 p.m.) except on Friday when it extended until about 2200.

### **6.4.2 Road Surface Loadings**

The paved road samples collected by Montgomery Watson during the test week are listed in Table 13, along with the results of the silt analyses. The roadway silt loadings on Gambell and Ingraham during this period were in the lowest quartile of the values measured in 1996 at other major arterial locations in Anchorage. (The 1996 data were summarized earlier in Section 2 of this report). The differences between the test week silt loadings and the 1996 data reflected in part the intense street sweeping that occurred on April 7, prior to tracer application. Silt loadings in gutter areas and on parking lots were one or two orders of magnitude higher than on the traveled portions of the roadways.

**Table 12. Hourly Traffic Counts During Test Week**

Traffic Count for Southbound Direction						Traffic Count for Northbound Direction					
Date	4/7/97	4/8/97	4/9/97	4/10/97	4/11/97	Date	4/7/97	4/8/97	4/9/97	4/10/97	4/11/97
D.O.W.	Mon.	Tues.	Wed.	Thurs.	Fri.	D.O.W.	Mon.	Tues.	Wed.	Thurs.	Fri.
100	217	256	283	293	303	100	208	274	253	257	273
200	121	143	133	145	183	200	184	128	180	159	193
300	113	103	130	109	157	300	120	102	118	128	134
400	76	89	87	77	84	400	81	91	85	86	79
500	83	99	96	83	100	500	79	125	115	88	102
600	166	188	191	174	164	600	213	254	241	273	213
700	488	512	506	512	482	700	872	944	951	937	859
800	1300	1304	1287	1302	1308	800	2203	2280	2170	2185	2167
900	1257	1422	1433	1333	1400	900	2050	2142	2004	1969	2002
1000	1369	1355	1287	1388	1361	1000	1526	1552	1547	1548	1522
1100	1422	1412	1429	1421	1514	1100	1420	1469	1382	1440	1621
1200	1818	1763	1712	1771	1896	1200	1673	1691	1642	1698	1927
1300	2116	2032	2028	2075	2097	1300	1967	1967	1935	1975	2093
1400	1926	2013	1919	2041	2209	1400	2008	1982	1995	2077	2251
1500	1874	1938	1895	1965	2113	1500	2048	2028	1975	1965	2249
1600	2242	2200	2098	2175	2350	1600	2128	2027	2067	2104	2276
1700	2490	2418	2459	2350	2568	1700	2228	2098	2131	2128	2285
1800	2389	2394	2412	2265	2406	1800	2149	2319	2274	2134	2280
1900	1603	1565	1683	1757	1771	1900	1624	2121	1824	1880	1981
2000	1144	1216	1115	1301	1367	2000	1171	1344	1341	1389	1456
2100	975	992	1035	1091	1094	2100	898	969	1062	1016	1147
2200	734	1148	1014	982	1204	2200	817	890	954	964	1101
2300	517	1755	580	695	813	2300	550	854	658	673	925
2400	335	435	398	436	687	2400	401	388	405	391	625
Total	26775	28752	27210	27741	29631	Total	28618	30039	29309	29464	31761

**Table 13. Paved Road Surface Silt Loadings During Test Week**

Sample I.D.	Location	Sample Data	Silt Content (%)	Silt Loading (g/m <sup>2</sup> )
LTS97BEN-P1	Arena parking lot	April 9, 1997	39.3%	65.5
LTS97BEN-P2	Arena parking lot	April 10, 1997	41.8%	55.3
LTS97BEN-P3	Arena parking lot	April 11, 1997	45.6%	70.4
LTS97BNK-P1	Bank parking lot	April 9, 1997	4.6%	87.1
LTS97BNK-P2	Bank parking lot	April 10, 1997	4.6%	94.5
LTS97BNK-P3	Bank parking lot	April 11, 1997	8.3%	82.8
LTS97GAM-G1	Gambell gutter	April 8, 1997	7.2%	84.7
LTS97GAM-G2	Gambell gutter	April 9, 1997	5.6%	205.6
LTS97GAM-G3	Gambell gutter	April 10, 1997	7.6%	299.9
LTS97GAM-G4	Gambell gutter	April 11, 1997	6.3%	314.8
LTS97GAM-G5	Gambell gutter	April 11, 1997	7.4%	685.8
LTS97GAM-G65	Gambell gutter	April 11, 1997	7.6%	647.1
LTS97GAM-R1	Gambell roadway	April 8, 1997	8.4%	0.9
LTS97GAM-R2	Gambell roadway	April 9, 1997	7.1%	1.9
LTS97GAM-R3	Gambell roadway	April 10, 1997	7.9%	1.9
LTS97GAM-R4	Gambell roadway	April 11, 1997	8.0%	3.3
LTS97GAM-R5	Gambell roadway	April 11, 1997	9.2%	1.3
LTS97GAM-R65	Gambell roadway	April 11, 1997	12.6%	3.8

Sample I.D.	Location	Sample Data	Silt Content (%)	Silt Loading (g/m <sup>2</sup> )
LTS97GAM-S1	Gambell sidewalk	April 10, 1997	12.1%	143.4
LTS97ING-G1	Ingra gutter	April 8, 1997	5.9%	39.7
LTS97ING-G2	Ingra gutter	April 9, 1997	8.8%	65.6
LTS97ING-G3	Ingra gutter	April 10, 1997	8.2%	72.4
LTS97ING-G63	Ingra gutter	April 10, 1997	13.5%	63.0
LTS97ING-G4	Ingra gutter	April 11, 1997	10.4%	118.9
LTS97ING-G5	Ingra gutter	April 11, 1997	9.0%	94.9
LTS97ING-R1	Ingra roadway	April 8, 1997	7.9%	0.5
LTS97ING-R2	Ingra roadway	April 9, 1997	7.9%	1.4
LTS97ING-R3	Ingra roadway	April 10, 1997	5.4%	0.7
LTS97ING-R63	Ingra roadway	April 10, 1997	2.7%	0.8
LTS97ING-R4	Ingra roadway	April 11, 1997	7.9%	1.3
LTS97ING-R5	Ingra roadway	April 11, 1997	5.7%	1.2

After application of the limestone tracer, the silt loadings on the active roadways increased sharply. Then the loadings remained relatively stable on Ingra but increased on Gambell. The observed rapid removal of the tracer after application apparently was offset by additional road surface material deposition, primarily due to track-on.

#### 6.4.3 PM-10 Concentrations

Figure 13 shows the decrease of PM-10 concentrations with distance from Gambell Street during the first hour after tracer application, as measured by two portable DustTRAK monitors. The DustTRAK measurements began immediately after passage of the limestone tracer application truck on Gambell at approximately 13:00 on April 8. Corresponding with high levels of visible dust that were immediately stirred up by roadway traffic, the DustTRAK monitors recorded the highest PM-10 concentration at 3 to 5 m from Gambell, and decreasing concentrations as one moved further west from the roadway during the next half-hour period. Because winds were mostly from the northeast at 5 to 7 mph, dust was transported from the roadway to both the permanent and portable monitors. Figure 14 is a graph of DustTRAK-recorded 6-sec PM-10 concentrations which produced the 469  $\mu\text{g}/\text{m}^3$  at a distance of 5 m west of the Gambell roadway immediately after application of the limestone tracer. Table 14 presents the test results from the high-volume PM-10 samplers operated during the test week. The PM-10 concentrations were charted earlier in Figure 12. The concentrations measured by the Andersen samplers.

Table 14 presents the test results from the high-volume PM-10 samplers operated during the test week, as charted earlier in Figure 13. The concentrations measured by the Andersen samplers, which should be regarded as the most reliable, generally increased during the test week. A sharp increase in the 24-hour PM-10 concentration occurred between Monday (44  $\mu\text{g}/\text{m}^3$ ) when the street was cleaned to Tuesday (93  $\mu\text{g}/\text{m}^3$ ). On

Tuesday, the 6-hour PM-10 concentrations increased  $79 \mu\text{g}/\text{m}^3$  to  $156 \mu\text{g}/\text{m}^3$  immediately after application of the limestone tracer. As the week progressed, the 24-hour PM-10 concentration at the Gambell monitor gradually increased from  $93 \mu\text{g}/\text{m}^3$  on Tuesday to  $121 \mu\text{g}/\text{m}^3$  on Thursday and  $110 \mu\text{g}/\text{m}^3$  on Friday. A slight drop in the PM-10 concentrations on Wednesday, as compared to Tuesday, reflected the occurrence of northwest winds during much of the high volume traffic period.

The increasing PM-10 concentrations during the test week effectively tracked the surface silt loading on Gambell as shown in Figure 13. The silt loading on Gambell Street increased from  $0.9 \text{ g}/\text{m}^2$  on Monday (before limestone application and after thorough street cleaning) to  $3.3 \text{ g}/\text{m}^2$  on Friday. Track-on of anti-skid abrasives was the apparent cause of the increasing silt loading on the Gambell roadway surface during the test week. In addition, the roadway shoulders had begun to dry as warmer temperatures were encountered at the end of the test week, and vehicle wake effects were visible.

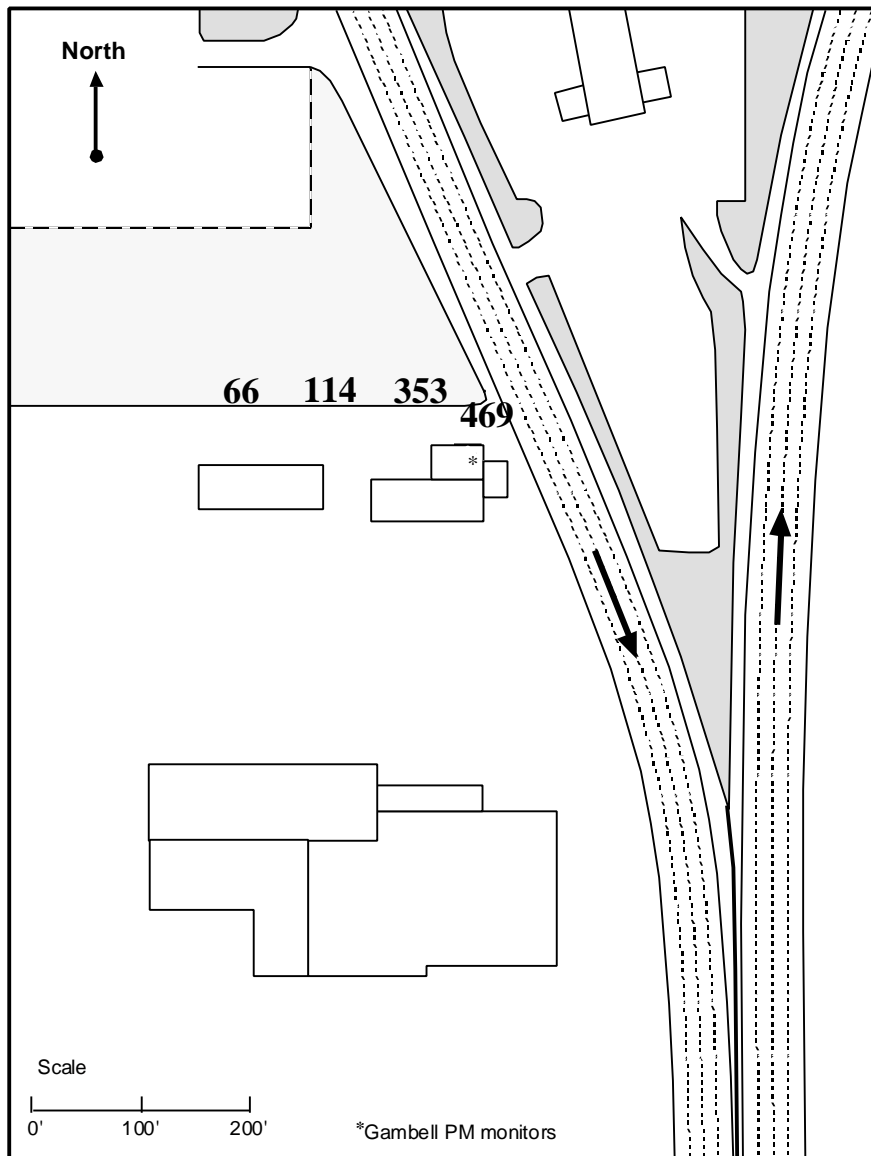
The trend of 24-hour PM-10 concentrations at the three local monitoring sites during the test week is also shown in Figure 13. Because the road was cleaned prior to tracer application and the tracer was relatively quickly removed by traffic flow, the 24-hour PM-10 concentration at the Gambell monitor showed only a slight maximum on Tuesday. Later in the week, as the silt loading returned to more typical levels for this time of year, the PM-10 concentration at Gambell increased.

## 6.5 Particle Chemistry

The limestone mass percentages in the ambient air samples were quantified to determine the impact of the limestone tracer material applied to Gambell Street during the test week. The results of the carbonate analyses of air samples are shown in Table 15. The carbonate contents were adjusted to equivalent limestone based on an 11.4% carbon carbonate content in limestone.

The highest limestone value of 15.2% occurred in the 6-hour PM-concentration immediately following application of the tracer to the Gambell/Ingra Roadway. Even though most of the limestone was thrown off the roadway within 1 hour of application,  $23.7 \mu\text{g}/\text{m}^3$  of the 6-hour PM-10 concentration was limestone. This represented 31% of the increase in the 6-hour PM-10 concentration from  $79 \mu\text{g}/\text{m}^3$  to  $156 \mu\text{g}/\text{m}^3$  immediately after application of the limestone tracer.





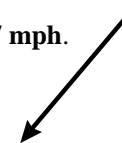
DUSTTRAK MEASUREMENTS						
4/8/97 (2)						
PARTICLES <3.5um						
Test No.	Date	Start Time	Stop Time	Wind Direction	Wind Speed	Average (ug/m <sup>3</sup> )
N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
PARTICLES <10um						
Test No.	Date	Start Time	Stop Time	Wind Direction	Wind Speed	Average (ug/m <sup>3</sup> )
1-6	4/8/97	12:56	13:02	N-NE	<7	66
2-23	4/8/97	12:56	13:02	N-NE	<7	114
1-7	4/8/97	13:05	13:19	E-NE	~5	469
2-24	4/8/97	13:05	13:19	E-NE	~5	353

**Notes:**

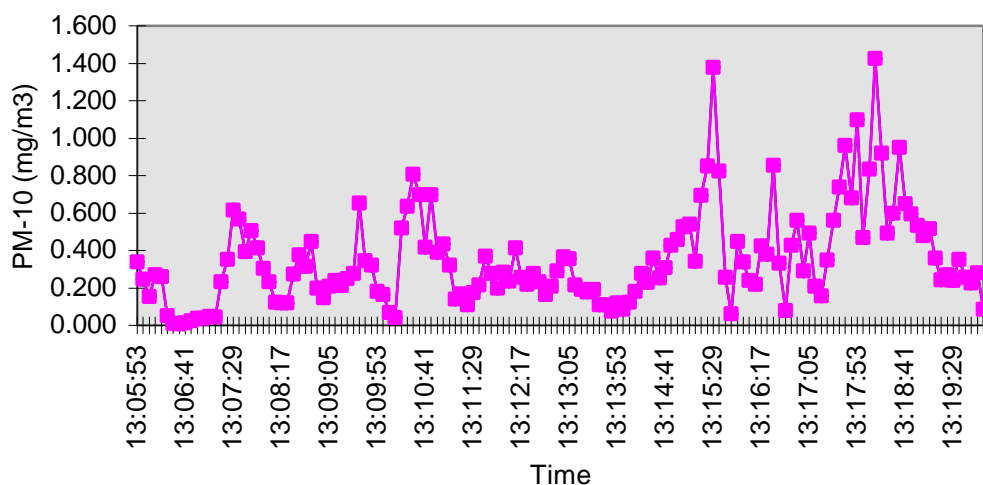
Truck began to spread limestone on Gambell at approximately 12:58. The truck continued to spread limestone on Gambell and Ingra until approximately 13:30.

**Wind:**

E to N, mostly NE @ 5-7 mph.



**Figure 13. Immediate Impact of Limestone Application to Gambell/Ingra Roadway**



**Figure 14. PM-10 Concentrations Adjacent to Gambell Following Limestone Application**

**Table 14. Integrated PM-10 Concentrations During Test Week**

Date	Site	Start/Stop	Filter No.	PM-10 ( $\mu\text{g}/\text{m}^3$ )
4/7/97	Gambell A	0/2400	6169463	44
4/8/97	Best East A	12/1200	6169475	8 <sup>a</sup>
4/8/97	Best East A	0/1200	6169473	48
4/8/97	Best West A	mid/1200	6169474	27
4/8/97	Best West A	noon/noon	6169476	58
4/8/97	Gambell A	18/2400	6169479	56
4/8/97	Gambell B	0/2400	6169470	93
4/8/97	Gambell C	0/0600	6169471	37
4/8/97	Gambell C	12/600	6169477	156
4/8/97	Gambell D	6/1200	6169472	79
4/8/97	Gambell D	0/2400	6169478	91 <sup>a</sup>
4/9/97	Best East A	12/1200	6169495	84
4/9/97	Best West A	noon/noon	6169496	66
4/9/97	Gambell A	12/2400	6169492	113
4/9/97	Gambell C	0/1200	6169491	75
4/10/97	Best East A	12/1200	6169500	86
4/10/97	Best West A	noon/noon	6169501	57
4/10/97	Gambell A	12/2400	6169497	127
4/10/97	Gambell B	0/2400	6169493	121
4/10/97	Gambell C	0/1200	6169494	98 <sup>a</sup>
4/11/97	Best East A	12/1200	6169509	80
4/11/97	Best West A	noon/noon	6169510	79
4/11/97	Gambell A	12/2400	6169504	107
4/11/97	Gambell C	0/1200	6169499	116
4/12/97	Gambell B	0/2400	6169502	83
4/13/97	Gambell C	0/2400	6169503	30

<sup>a</sup> Duplicates for these samples showed identical concentrations

**Table 15. Carbonate Analysis of Air Quality Samples Collected During Test Week  
(Analyzed by Huffman Laboratories)**

Date	Site	Start/Stop	Filter No.	PM-10 ( $\mu\text{g}/\text{m}^3$ )	Limestone in PM-10	
					(%)	( $\mu\text{g}/\text{m}^3$ )
4/7/97	Gambell A	0/2400	6169463	44		
4/8/97	Best East A	12/1200	DUP	8	0.88%	0.1
4/8/97	Best East A	12/1200	6169475	8	0.88%	0.1
4/8/97	Best East A	0/1200	6169473	48	< 1.06%	
4/8/97	Best West A	mid/1200	6169474	27	<1.83%	
4/8/97	Best West A	noon/noon	6169476	58	0.86%	0.5
4/8/97	Gambell A	18/2400	6169479	56	2.17%	1.2
4/8/97	Gambell B	0/2400	6169470	93	7.14%	6.6
4/8/97	Gambell C	0/0600	6169471	37	0.39%	0.1
4/8/97	Gambell C	12/0600	6169477	156	15.17%	23.7
4/8/97	Gambell D	6/1200	6169472	79	1.76%	1.4
4/8/97	Gambell D	0/2400	6169478	91	1.39%	1.3
4/8/97	Gambell D	0/2400	DUP	91	1.50%	1.4
4/9/97	Best East A	12/1200	6169495	84	1.04%	0.9
4/9/97	Best West A	noon/noon	6169496	66	0.69%	0.5
4/9/97	Gambell A	12/2400	6169492	113	1.36%	1.5
4/9/97	Gambell C	0/1200	6169491	75	1.31%	1.0
4/10/97	Best East A	12/1200	6169500	86	2.14%	1.8
4/10/97	Best West A	noon/noon	6169501	57	1.08%	0.6
4/10/97	Gambell A	12/2400	6169497	127	1.36%	1.7
4/10/97	Gambell B	0/2400	6169493	121	1.31%	1.6
4/10/97	Gambell C	0/1200	6169494	98	0.94%	0.9
4/10/97	Gambell C	0/1200	DUP	98	1.25%	1.2
4/11/97	Best East A	12/1200	6169509	80	0.87%	0.7
4/11/97	Best West A	noon/noon	6169510	79	1.04%	0.8
4/11/97	Gambell A	12/2400	6169504	107	0.68%	0.7
4/11/97	Gambell C	0/1200	6169499	116	1.18%	1.4
4/12/97	Gambell B	0/2400	6169502	83	0.915	0.8
4/13/97	Gambell C	0/2400	6169503	30	<0.795	<0.2

## 6.6 Inferences from Test Week Results

1. *During the test week, PM-10 concentrations at the Gambell Site tracked the surface silt loading on Gambell Street. Some adjustments were necessary to discount for occasional periods of westerly winds which produced little, if any, impact of Gambell Street emissions on the Gambell monitor. After the Gambell-Ingra roadways were cleaned (prior to application of the limestone tracer), the silt loading and the PM-10 concentrations increased and then stabilized later in the week.*
2. *The application of the limestone tracer caused a definite impact on the PM-10 concentration in the area of the Gambell monitoring site. Although short-lived, the silt loading of approximately  $5.8 \text{ g}/\text{m}^2$  created by the limestone application (plus background), caused PM-10 concentrations exceeding  $400 \mu\text{g}/\text{m}^3$  at the Gambell monitoring site during the half-hour period immediately following*

application of the tracer. Even though the traffic removed most of the tracer from the travel Gambell lanes within one hour of application, the 6-hour PM-10 concentration at Gambell was elevated to  $156 \mu\text{g}/\text{m}^3$ , an increase of  $77 \mu\text{g}/\text{m}^3$  above the concentration for the previous 6-hour period.

3. *The impact of the tracer application was confirmed by limestone analysis of ambient PM-10 filters from the Gambell site.* The limestone analysis of the 6-hour PM-10 sample ( $156 \mu\text{g}/\text{m}^3$ ) collected immediately after tracer application showed that limestone accounted for 31% of the increase in PM-10 concentration above the previous 6-hour period. This result also is consistent with the fact that most of the limestone impact disappeared within about one hour after limestone application.
4. *A large silt loading reservoir was represented by the gutters and paved parking lots adjacent to Gambell Street.* Although the silt loadings on Gambell and Ingra during the test week were in the lowest quartile of 1996 values measured on other arterial roadways in Anchorage, the loadings in gutter areas and parking lots were one or two orders of magnitude higher. These surface loading accumulations had the track-out potential sufficient to provide several PM-10 exceedance days at the Gambell monitor.

## 7. PM-10 Emission Inventory

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A fundamental requirement in the effort to control pollution is to quantify the emissions being released. An emission inventory helps explain relationships between various sources (i.e. which sources are important contributors to the problem at particular time). Three emission inventories are presented in this section. The first two inventories are aimed at quantifying area-wide sources of the PM-10 problem during peak PM-10 periods in the spring (March 15 - April 15) and fall (October 15 -November 15).

The third inventory is a “microinventory” of the Gambell/Ingra roadway section near the Gambell monitoring site. The purpose of this inventory is to quantify the local sources of PM-10 that contribute to exceedances at the Gambell monitoring site. As the only site in Anchorage to violate NAAQS, it serves to characterize a “worst-case” site. This information can then be used to design controls for other high-volume roads.

### 7.1 Assumptions of the Spring and Fall Emission Inventories

Efforts for these two area-wide inventories were focused on quantifying emissions from paved and unpaved roads. Other possible PM-10 emission sources (i.e. motor vehicle exhaust, brake wear, wind blown dust, fireplaces and wood stoves, open burning, space heating, electrical power generation and industrial emissions) were not quantified because they were considered insignificant sources. The rationale for presuming these other sources insignificant is detailed below:

- the microscopical analysis performed as part of this study and previous source apportionment studies indicate that motor vehicle exhaust emissions, wood burning and other combustion sources were insignificant in relation to crustal / geological minerals found in PM-10 samples.
- preliminary AP-42 estimates were prepared and they confirm that these various other sources make-up an insignificant portion of the PM-10 inventory (i.e. fireplace and wood stove emissions make less than 2% of the total area-wide spring and fall PM-10 inventories, other possible sources made up an even smaller proportion). The combined contribution of these various sources is believed to be less than 3% of the total area-wide inventory in both the spring and fall.
- Although wind blown dust may be a significant contributor to the PM-10 problem on some windy days, the large majority of PM-10 exceedances in Anchorage have occurred when wind speeds were insufficient for particle lofting. Moreover, almost half of the exceedances in Anchorage occur when there was at least an inch of snow cover at the National Weather Service Observatory at Point Campbell in west Anchorage. This suggests that unvegetated areas were probably covered in snow and were unlikely sources of PM-10 during these exceedances.

Because these “other” sources appeared to be negligible in relation to road dust emissions, no additional effort was expended in developing precise estimates of their contribution to the problem.

The PM-10 emission rates for paved roads were estimated from AP-42 emission factor equations that require input data for surface silt loading and average vehicle weight. Resultant emission factors were multiplied by roadway activity levels (VMT or vehicle miles traveled) to obtain daily PM-10 emissions from each class of roadway.

AP-42 provides a different equation for estimating emissions from unpaved roads. It uses silt content of road surface material as well as mean vehicle weight, speed, and number of wheels to estimate an emission factor (lbs/VMT). A composite factor, specific to the spring and the fall equation, accounts for the dust control efficiency of water (surface moisture by season) and treatment of the roads with asphalt emulsion or calcium chloride.

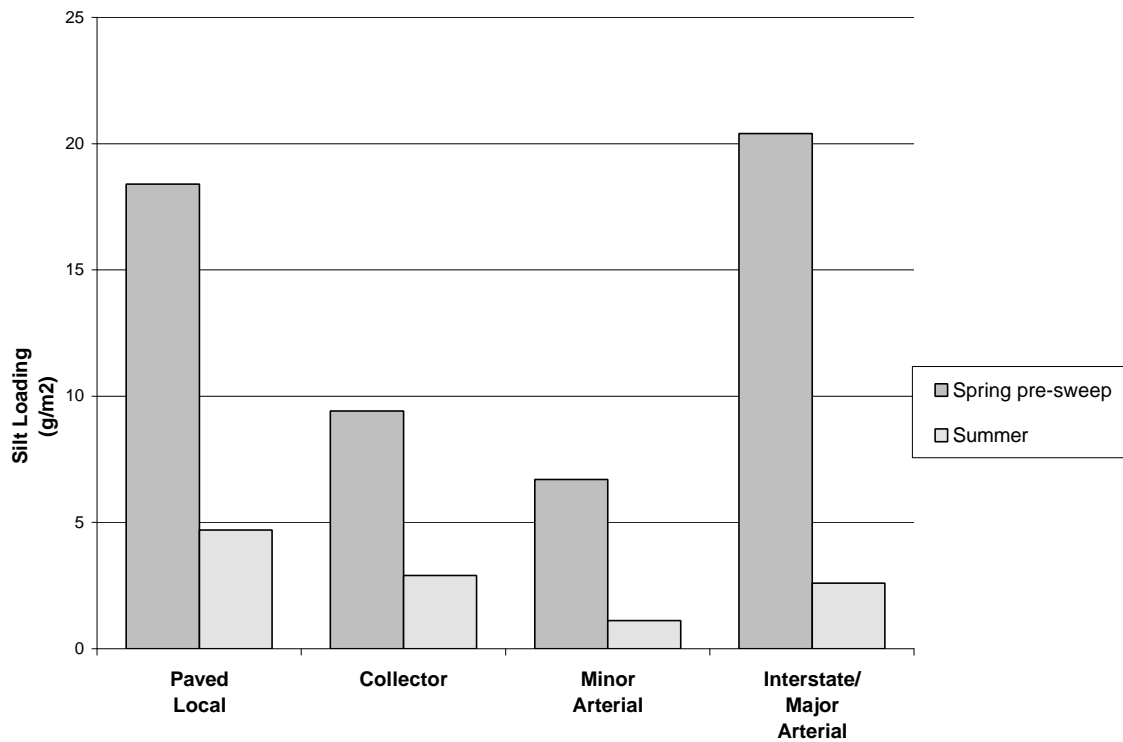
The 1996 emission inventories for MOA paved roads were prepared using the silt loading values collected by Montgomery Watson in the early spring and late summer of 1996. This sampling was conducted from March through August in order to track silt loadings on paved roads. Road mileage by class was obtained from the MOA. Based on vehicle miles traveled (VMT) the roads were divided into 4 classes: local; collector, minor arterial; and major arterial/freeway.

Special issues considered for the development of the emission inventories included:

- The silt loading on the traveled portion of the roadways, as measured by Montgomery Watson (and shown in Table 16 and Figure 15), is used in the AP-42 paved road emission factor equation to predict PM-10 emissions from both intersections and free-flow portions of roadways. The measured silt loadings at intersections were not considered applicable. Previous MRI tests at a similar road site in the Denver Metropolitan Area in February/March 1997 revealed that PM-10 concentrations near an intersection were similar to the PM-10 concentrations at the free-flowing mid-block location, after adjustment for the increased volume of traffic that passed through the intersection.
- The gutter silt loadings are considered as sources of track-on and also affect wake emissions from large aerodynamically blunt vehicles and vehicle clusters, but are not directly used in the AP-42 emission factor equation. The AP-42 equation predicts combined emissions from both normal and high emitters (vehicle or vehicles whose aerodynamic characteristics enhance emissions) on a time averaged basis.
- The average vehicle weight is assumed at 1.8 tons.
- The silt content for unpaved roads is assumed at 8%.

**Table 16 1996 Paved Road Silt Loadings (g/m<sup>2</sup>)**

Roadway type (ADT)	Spring pre-sweep 3/20 to 4/10	Summer 7/9 to 8/8
Paved Local ( $\leq 2,000$ )	18.4	4.7
Collector (2,000 to 10,000)	9.4	2.9
Minor Arterial (10,000 to 20,000)	6.7	1.1
Interstate/ Major Arterial ( $\geq 20,000$ )	20.4	2.6



**Figure 15. 1996 Silt Loadings on Anchorage Roadways**

## 7.2 Spring Emissions from Paved and Unpaved Roads

This section presents PM-10 emission inventories for paved and unpaved Anchorage roads during the spring break-up period. Silt loadings on paved roads are the highest for the year at this time as sweeping may not have begun or is limited in effectiveness due to the presence of ice in the gutters. Diurnal freezing and thawing of this ice exposes reserves of accumulated particulate and this wet particulate near the curb is easily tracked out onto the traveled portion of the roadway.

Unpaved roads are frequently saturated from snow melt well past the spring episode period. While snow is periodically removed near high-volume roads, it is often allowed to accumulate near low-volume dirt roads where it melts and provides thorough particulate control.

Table 17 illustrates the small relative contributions unpaved roads make to emissions from the total Anchorage roadway network during the spring. Unpaved roads, however, contribute indirectly to paved road emissions through track-out, especially if they connect directly with a major paved road. In addition, dirt collects on the undercarriage of vehicles traveling on these wet, unpaved roads and may be deposited later on paved roads, perhaps miles from where the dirt was originally collected.

**Table 17. Roadway PM-10 Emission Inventory  
Anchorage Bowl, Spring 1996**

<b>Roadway Type</b>	<b>Roadway Miles</b>	<b>VMТ per day (10<sup>3</sup> miles)</b>	<b>Median Silt Load (g/m<sup>2</sup>)</b>	<b>Estimated PM-10 Emissions (tons)</b>	<b>% of Total Roadway Emissions</b>
<b>Interstate and Major Arterial</b>	45	1199	20.4	20.2	51.2
<b>Minor Arterial</b>	79	1245	6.7	10.2	25.8
<b>Collector Road</b>	99	315	9.4	3.2	8.1
<b>Paved Local</b>	705	342	18.4	5.4	13.7
<b>Unpaved Local</b>	93	45	8%*	0.46	1.2
<b>TOTAL</b>	1021	3146		39.4	100

\* The AP-42 emission factor calculation for unpaved roads uses the silt content of the surface dirt rather than the silt loading (see AP-42, Section 13.2.2)

Paved arterials are responsible for an estimated 77% of roadway emissions in the spring although they comprise only 12% of the miles in the Anchorage road network. Seventy-eight percent of the vehicle miles traveled occurs on these roads, and to ensure safe traction at higher speeds they receive the greater portion of road treatment, including sanding, throughout the winter. The high-speed arterials are the most heavily laden with



silt at the time of spring break-up but, as a class, silt removal by sweeping and traffic is most effective on arterials through the spring and summer period.

PM-10 concentrations at micro-scale and middle-scale monitoring sights, perhaps due to their proximity to arterials, are much higher relative to neighborhood-scale sights in the spring than in the fall period.

### 7.3 Fall Emissions from Paved and Unpaved Roads

PM-10 concentrations are typically low during the summer months. Changing environmental conditions, however, result in a predictable pattern of increasing concentrations from late September through November.

Section 3.3 discusses several of the meteorological conditions which may be associated with fall PM-10 episodes. What has been described as “freeze-dry” conditions are typical of episode days during the fall period. Very dry silt is easily entrained by vehicle disturbances, and winds are low with poor atmospheric mixing. The unpaved roads are also very dry and vehicle traffic generates significant amounts of dust. These days prone to violations are often hazy in appearance, particularly near the mountains where most of the unpaved roads are located. The decreased significance of roadway setback (see Section 3.2) during the fall suggests that the fall peak is more of an area-wide phenomenon than the spring.

**Table 18. Roadway PM-10 Emission Inventory  
Anchorage Bowl, Fall 1996**

<b>Roadway Type</b>	<b>Roadway Miles</b>	<b>VMТ per day (10<sup>3</sup> miles)</b>	<b>Median Silt Loading (g/m<sup>2</sup>)</b>	<b>Estimated PM-10 Emissions (tons)</b>	<b>% of Total Roadway Emissions</b>
<b>Interstate and Major Arterial</b>	45	1199	2.6	5.3	24.7
<b>Minor Arterial</b>	79	1245	1.1	3.1	14.7
<b>Collector Road</b>	99	315	2.9	1.5	7.0
<b>Paved Local</b>	705	342	4.7	2.2	10.3
<b>Unpaved Local</b>	93	45	8%*	9.3	43.4
<b>TOTAL</b>	1021	3146		21.4	100.0

The AP-42 emission factor calculation for unpaved roads uses the silt content of the surface dirt rather than the silt loading (see AP-42, Section 13.2.2)

Silt loading measurements indicate that Anchorage roads become progressively cleaner through summer (Figure 15). Although fall measurements have not been made, this inventory assumes that the fall loadings can be approximated by late-summer silt

loading measurements. Consequently, late summer silt loadings are used to determine paved road emissions in Table 18. Most fall PM-10 episodes have occurred prior to a major snowfall, and before the application of significant amounts of traction sand.

Unpaved road emissions appear to be a more significant source of PM-10 in the fall than in the spring. Unpaved roads receive only 1.5% of the VMT yet account for an estimated 43% of area-wide PM-10 emissions in the fall. Because fall PM-10 episodes are usually associated with cold and snowless conditions, unpaved roads are dry and much more prone to emit than in the spring.

In 1987, a portion of the community of Eagle River was designated a PM-10 nonattainment area as a result of unpaved road emissions. Eagle River is located approximately 10 miles north of Anchorage. Concentrations measured near unpaved roads in the area exceeded  $300 \mu\text{g}/\text{m}^3$  on occasion. The highest concentrations were observed in late October and early November before snow arrived and the weather was cold and dry. An ambitious road paving and surfacing program has eliminated violations of the PM-10 standard in Eagle River.

In recognition of the contribution of unpaved roads to PM-10 concentrations many of the 93 miles of unpaved road in Anchorage with significant traffic have been treated with asphalt emulsion. Furthermore, in 1997 the MOA embarked on a program of surfacing unpaved roads with recycled asphalt. Plans are to surface nearly all the unpaved roads in the Anchorage bowl by the summer of 2002. Recycled asphalt surfacing reduces PM-10 emissions by an estimated 80%.

## **7.4 Microinventory of Gambell/Ingra Roadway Emissions**

The Gambell/Ingra roadway between Fireweed Lane and 15<sup>th</sup> Avenue is 0.66 mile in length and carries 4 lanes of traffic in each direction at a speed of approximately 45 to 50 mph. Each roadway is approximately 50 feet wide, except for turnon/turnoff areas where the roadways are slightly wider. The posted speed limit on both Gambell and Ingra Streets near the Gambell permanent PM-10 monitoring site is 45 mph.

The Gambell/Ingra roadway couplet carried well over 50,000 vehicles during each day of the test week (see Tables 19 and 20). During Monday through Thursday of the test week, Gambell carried an average daily traffic volume of 27,620, and Ingra carried an average volume of 29,358 vehicles. On Friday of the test week, the traffic volume increased by 7% to 8% over the previous weekday values.

Silt loadings on Anchorage paved roadways were measured by Montgomery Watson in the early spring and early summer of 1996 to determine seasonal and roadway type variations. Although the Gambell/Ingra roadway was not one of the selected sampling locations for the 1996 silt loading study, an intensive silt sampling program was

conducted on both Ingra and Gambell near the Gambell PM-10 monitors during the test week of April 7-11, 1997.

The silt loadings on both Gambell and Ingra during the test week were lowest immediately after thorough road vacuuming on Monday, April 7 (0.9 and 0.5 g/m<sup>2</sup>, respectively). On Tuesday after application of the limestone, the measured silt loadings rose to 1.8 and 1.4 g/m<sup>2</sup>.

Relatively consistent stabilization of road surface loadings were observed after limestone application, ranging from an average silt loading value of 2.1 g/m<sup>2</sup> on Gambell to 1.1 g/m<sup>2</sup> on Ingra. The higher value on Gambell can be explained by the larger number of track-out sources as compared to Ingra. Little trend in silt loadings was observed from Tuesday through Friday on both Gambell and Ingra, indicating that the roadways quickly reached "equilibrium," i.e., the rate of emissions equaled the rate of deposition/track-out.

Because Gambell and Ingra are classified as major arterial roadways, it is useful to compare the April 1997 post-cleaning silt loadings with the Spring 1996 value measured by Montgomery Watson. The April 1997 Gambell and Ingra average silt loadings are lower at 2.1 g/m<sup>2</sup> and 1.1 g/m<sup>2</sup>, respectively, than the average silt loading of 4.3 g/m<sup>2</sup> determined in 1996 for major arterial roadways. Montgomery Watson's samples may not have been collected in all locations as soon after sweeping as those on Gambell. Sweeping of the Gambell/ Ingra couplet was also particularly scrupulous as it preceded the application of the limestone tracer. The higher traffic speed on Gambell and Ingra (as compared to other Class 4 roadways in Anchorage) may also be responsible for the smaller loading.

Table 19 presents the Gambell Street microinventory for each day of the test week, using the AP-42 emission factor equation together with the measured silt loading values, daily traffic volume, and an estimated average vehicle weight of 1.8 tons. The microinventory for Ingra Street is given in Table 20.

**Table 19. Test Week Emission Inventory for Gambell Street**

Date	Day	Gambell roadway length (mi)	Daily traffic volume <sup>a</sup>	Daily VMT <sup>b</sup>	sL (g/m <sup>2</sup> ) <sup>c</sup>	Average vehicle weight (tons)	AP-42 PM-10 EF <sup>d</sup> (g/VMT)	PM-10 emissions (lb/day) <sup>e</sup>
4/7/97	Mon	0.66	26775	17672	0.9	1.8	10.49	409
4/8/97	Tue	0.66	28752	18976	1.8	1.8	17.05	713
4/9/97	Wed	0.66	27210	17959	1.9	1.8	17.05	675
4/10/97	Thu	0.66	27741	18309	3.1	1.8	24.41	985
4/11/97	Fri	0.66	29631	19556	1.6	1.8	15.25	657

<sup>a</sup> Measured traffic count data  
<sup>b</sup> VMT = ADT \* roadway length  
<sup>c</sup> Road surface travel lanes) loading samples were taken at approximately 3:00 a.m. each day and were calculated using a weighted average.

**Table 20. Test Week Emission Inventory for Ingra Street**

Date	Day	Ingra roadway length (mi)	Daily traffic volume <sup>a</sup>	Daily VMT <sup>b</sup>	sL (g/m <sup>2</sup> ) <sup>c</sup>	Average vehicle weight (tons)	AP-42 \PM-10 EF <sup>d</sup> (g/VMT)	PM-10 emissions (lb/day) <sup>e</sup>
4/7/97	Mon	0.66	28618	18888	0.5	1.8	7.16	298
4/8/97	Tue	0.66	30039	19826	1.4	1.8	13.98	611
4/9/97	Wed	0.66	29309	19344	0.7	1.8	8.91	380
4/10/97	Th	0.66	29464	19446	1.3	1.8	13.32	571
4/11/97	Fri	0.66	31761	20962	—	1.8	—	—

<sup>a</sup> Measured traffic count data  
<sup>b</sup> VMT = ADT \* roadway length  
<sup>c</sup> Road surface loading samples were taken at approximately 3:00 a.m. each day and were calculated using a weighted average.

While the AP-42 equation accounts for the composite effect of traffic, the effect of specific vehicle types was explored further prior to and immediately following application of the limestone tracer. Enhanced emissions result from vehicles that travel on shoulders or in gutters creating visible clouds of dust. In addition, long vehicles, particularly large trucks with trailers of extended lengths, generate increased emissions because of wakes that entrain loose particulate matter from gutters, sidewalks, and other surfaces adjacent to the roadway. Finally, clusters of smaller vehicles create a relatively intense wind flow along their path and entrain dust from areas adjacent to the traveled portion of the roadway.

Near the Gambell/Ingra roadway during the test week, sidewalks and dry grass were covered with considerable amounts of dry particulate. Wakes from large or extended length vehicles frequently stirred up visible dust from these areas. For example, when collecting a surface sample from a sidewalk across Gambell from the monitors, dust was blown into the sampler's eyes by several large aerodynamically blunt vehicles. All of these emissions are included, but not specifically quantified, in the AP-42 emission factors.

The effect of high emitters was evident from DustTRAK test measurements adjacent to the roadway. The graph of a DustTRAK test in Figure 14 shows the PM-10 concentration variation at a distance of 5 m west of Gambell during consecutive 6-sec periods.

In order to characterize the number and consequence of high emitters on Gambell Street, an analysis of the 6-sec PM-10 concentrations recorded by the DustTRAK monitor at a distance of 3-5 m from the roadway was performed. Table 8-6 presents the results of this analysis. In Table 21, a "high emitter" period is defined as a 6-sec interval during the test period when the PM-10 concentration is greater than 2 times the average concentration.

**Table 21 High Emitter Percentages as Determined from DustTRAK  
Measurements of PM-10 near Gambell Street**

DustTRAK test No.	Date	Day	No. of 6-sec gross emitters *	Total No. of 6-sec emitters	Fraction of gross emitters	Average PM-10 Concentration (mg/m <sup>3</sup> ) All emitters	Non-gross emitters	Gross emitters	Gross emitter PM-10 production (%)
2-13	4/7/97	Mon	34	307	0.111	0.032	0.015	0.176	0.61
2-14	4/7/97	Mon	10	162	0.062	0.194	0.159	0.718	0.23
2-15	4/7/97	Mon	7	114	0.061	0.176	0.159	0.429	0.15
2-17	4/7/97	Mon	4	102	0.039	0.070	0.060	0.316	0.18
1-1	4/8/97	Tue	6	59	0.102	0.088	0.075	0.209	0.24
1-7	4/8/97	Tue	15	147	0.102	0.458	0.389	1.057	0.24
1-9	4/8/97	Tue	13	145	0.090	0.116	0.078	0.500	0.39
1-21	4/8/97	Tue	8	231	0.035	0.101	0.097	0.239	0.08
2-25	4/8/97	Tue	6	177	0.034	0.107	0.098	0.350	0.11
2-35	4/8/97	Tue	4	82	0.049	0.036	0.034	0.084	0.11
2-36	4/8/97	Tue	7	81	0.086	0.031	0.027	0.075	0.21
2-37	4/8/97	Tue	13	202	0.064	0.071	0.061	0.220	0.20
1-25	4/10/97	Thu	6	75	0.080	0.083	0.070	0.233	0.22
1-27	4/10/97	Thu	6	70	0.086	0.078	0.067	0.202	0.22

Consider for example, Test No. 1-7 which was conducted on early Tuesday afternoon (April 8) adjacent to Gambell Street immediately after application of the limestone tracer. The DustTRAK results show that 10.2% of the 6-sec PM-10 concentrations exceeded the average PM-10 concentration of 0.458 mg/m<sup>3</sup> by more than a factor of two. The average concentration for high emitter periods (1.057 mg/m<sup>3</sup>) was almost 14 times higher than the average PM-10 concentration for other periods during that test (0.078 mg/m<sup>3</sup>). In that test, 10% of the roadway source activity caused 24% of the total PM-10.

Table 21 can be used to calculate a weighted average of the frequency of high emitter periods during all the tests. Although the average frequency is 7%, these periods account for over 25% of the PM-10 measured at the Gambell monitor.

An analysis of the PM-10 emission inventory for the Gambell/Ingra roadway immediately after application of the limestone tracer provides a unique look at how after limestone application traffic can quickly disperse dry road surface silt loadings. The initial silt loading after limestone application can be calculated from the roadway length of 0.66 mile, the roadway width of approximately 50 ft each for Gambell and Ingra, the application of 3,900 lb of limestone to the roadway, and a measured 9.3% silt content for the limestone. The results of this calculation show that the roadway had a silt loading of 5.1 g/m<sup>2</sup> from the limestone plus 0.7 g/m<sup>2</sup> as measured on the roadway earlier in the morning (after street cleaning), for a total silt loading of approximately 5.8 g/m<sup>2</sup> immediately after application of the limestone tracer.

$$(3900 \text{ lb} \times 0.093 \times 454.3 \text{ g/lb}) / [(0.66 \text{ mi} \times 5280 \text{ ft/mi} \times 2 \times 50 \text{ ft}) * \\ 0.0929 \text{ m}^2/\text{ft}^2 = 5.1 \text{ g/m}^2$$

Using the AP-42 emission factor equation for paved roads, this silt loading value produces an emission factor for the Gambell roadway.

$$E_{10} = 7.3 (5.8/2)^{0.65} (1.83)^{1.5} = 6.78 \text{ g/VMT}$$

As shown in Tables 19 and 20, the measured silt loadings from Tuesday through Friday of the test week ranged from 1.6-3.1 g/m<sup>2</sup> (Gambell) and 0.7-1.4 g/m<sup>2</sup> (Ingra) with no trend observed. The calculated silt loading on Gambell on early Tuesday afternoon of 5.8 g/m<sup>2</sup> is over 3 times the values from early Wednesday and Thursday mornings (1.8 and 1.9 g/m<sup>2</sup>). Approximately 4 g/m<sup>2</sup> of silt loading was dispersed from the Gambell roadway in the 14-hour period following limestone application and most of this lost silt loading is believed to have been emitted as visible dust in the 1-hour period immediately following limestone application.

During the period from 1300 to 1400 on April 8, 1997, (immediately following application of the limestone), the measured traffic volume on Gambell was 2,032 vehicles. To calculate a PM-10 emission rate for a 200 m length of roadway,

$$\begin{aligned} \text{PM-10 Emissions (g/sec)} &= 6.78 \text{ g/VMT} * 2032 \text{ vehicles/3600 sec} * \\ &200 \text{ m/1609m} = 0.47 \text{ g/sec} \end{aligned}$$

An emission rate of 0.47 g/sec for a volume source was entered into the SCREEN3 air dispersion model. This EPA screening model is useful for estimating maximum downwind concentrations of PM-10 at various distances from a source. No background concentrations was included. Input data included a volume of 200 m in length with a source height of 1 m and an initial vertical dimension of 1.4 m. The 200 m length was estimated to extend beyond the actual segment of the roadway that affected the PM-10 monitors. The initial lateral dimension was 23.3 m (200 m/4.3, as recommended in the SCREEN3 Users Guide).

DustTRAK measurements of PM-10 concentrations were obtained during the time period on April 8 when visible clouds of dust were emitted from the roadway by the traffic, immediately after the limestone was applied. PM-10 concentrations were measured adjacent to the permanent Gambell monitors and at three points further west from the roadway under northeasterly winds of 5 to 7 mph. These short-term PM-10 measurements using the DustTRAK were conducted for approximately 20 min following application of the limestone tracer, during which period PM-10 emissions were at a maximum because of the artificial road surface silt loading.

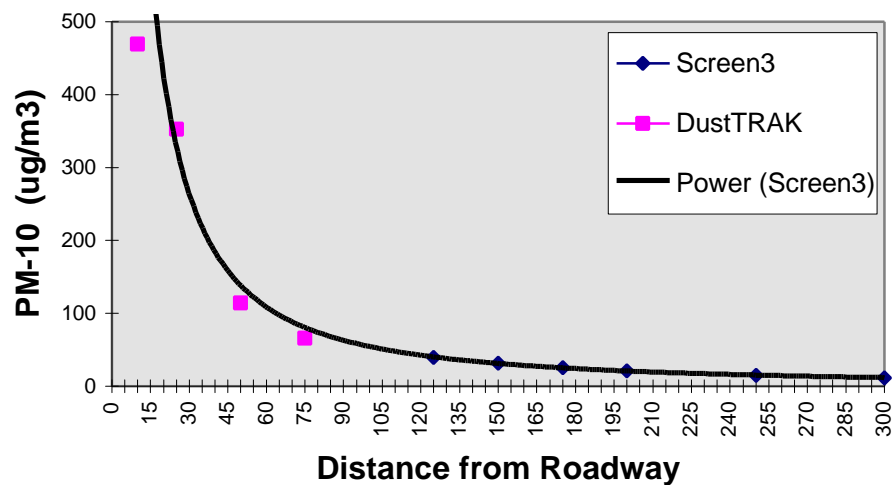
Table 22 presents the results of the DustTRAK tests, which are also shown in Figure 16 for downwind distance from the roadway.

**Table 22. DustTRAK PM-10 Concentrations West of Gambell Immediately Following Limestone Tracer Application**

DustTRAK Test No.	Distance from Gambell (m)	Sampling time (Start—Stop)	Average PM-10 Concentration* ( $\mu\text{g}/\text{m}^3$ )
1-6	75	12:56 to 13:02	66
2-23	50	12:56 to 13:02	114
2-24	25	13:05 to 13:19	353
1-7	10	13:05 to 13:19	469

\* Includes impacts of high emitters.

The PM-10 concentrations in Table 22 measured at four distances west of the Gambell roadway can be compared with the output of the SCREEN3 model, as extrapolated using the power law relationship. As shown in Figure 16, there is good comparability between the modeled AP-42 emission estimate (assuming a Gambell roadway length of 200 m is the primary contributor to PM-10 concentrations at the monitors) and the measured PM-10 concentrations at various distances downwind from the roadway source. This supports the applicability of the AP-42 equation for paved road emissions on Gambell Street near the Gambell PM-10 monitor during heavy road surface loadings, including the impact of high emitters.



**Figure 16 Measured DustTRAK PM-10 vs. Modeled PM-10**

## 7.5 Inferences Drawn from Emission Inventories

1. *The spring inventory identifies major paved roadways as the primary contributor to PM-10.* Although these roads comprise only 12% of roadway miles in the Anchorage bowl they carry a large proportion of the total traffic and 77% of spring time PM-10 emissions are generated from them.
2. *Unpaved roads may contribute significantly to PM-10 concentrations during fall PM-10 episodes.* Emission rates from dry, unpaved roads are very high. Although unpaved roads accounts for less than 2% of all vehicle miles traveled in the Anchorage bowl, they may account for 43% of area-wide emissions during dry fall periods. The direct impact of unpaved roads in the spring is insignificat in the spring because they are wet with snow melt. Emission rates are low when these roads are wet. Unpaved roads may have an indirect impact, however, through track-out of dirt on to paved roads.



## 8. Emission Control Measures

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Exceedances of the 24-hour NAAQS for PM-10 at monitoring sites in urban areas are frequently caused by localized, as compared to long distance, sources. For example, the quantitative impact of a heavily traveled roadway or intersection on the PM-10 levels at a microscale air sampling site can be more than double the levels simultaneously observed at nearby neighborhood sites, especially on days with exceedances at the microscale site.

The selection of the most appropriate additional control measures for MOA necessarily involves an understanding of 24-hour PM-10 episodes and the major sources that cause violations of the PM-10 NAAQS in Anchorage. Of particular concern is the control effectiveness of methods applicable to paved roads, which constitute the major source of PM-10 emissions that impact the Gambell monitoring site.

The MOA and State have already implemented a number of changes to road sanding, deicing and sweeping practices. This section of the report will evaluate the effectiveness of these changes and will propose additional control strategies designed to address the PM-10 problem in Anchorage.

### 8.1 Approaches to Control

Typically, there are several options for control of fugitive dust from any given source. This is clear from the mathematical equation used to calculate the emission rate:

$$R = M e (1 - c)$$

where:

R = estimated mass emission rate

M = source extent

e = uncontrolled emission factor, i.e., mass of uncontrolled emissions per unit of source extent

c = fractional efficiency of control

The uncontrolled emission rate is the product of the source extent and uncontrolled emission factor, a reduction in either of these two variables produces a proportional reduction in the uncontrolled emission rate.

Although the reduction of source extent results in a highly predictable reduction in the emission rate, such an approach usually requires a redistribution of source activity. Frequently, a reduction in the extent of one source may necessitate the increase in the extent of another, as in the shifting of vehicle traffic from an unpaved road to a paved road.

The reduction in the uncontrolled emission factor may be achieved by reducing either the amount of the emitting surface material or the degree of mechanical disturbance to the emitting surface material. The degree of the reduction of the uncontrolled emission factor can be estimated from the known dependence of the factor on source conditions that are subject to alteration. For fugitive dust sources, this information is embodied in the predictive emission factor equations presented in Section 13 of EPA's "Compilation of Air Pollutant Emission Factors" (AP-42). For example, the control of resuspended paved road dust is accomplished by reducing the silt loading on the traveled portion of the roadway. The predictive emission factor equation for paved roads was described earlier, in Section 2 of this report.

The reduction of source extent and the reduction of the uncontrolled emission factor are **preventive measures** for control of fugitive particulate emissions. Furthermore, any other measures which reduce the surface loading of exposed dust-producing material are also considered preventive techniques. This would include, for example, the elimination of mud/dirt carryout onto paved roads from muddy unpaved parking lots.

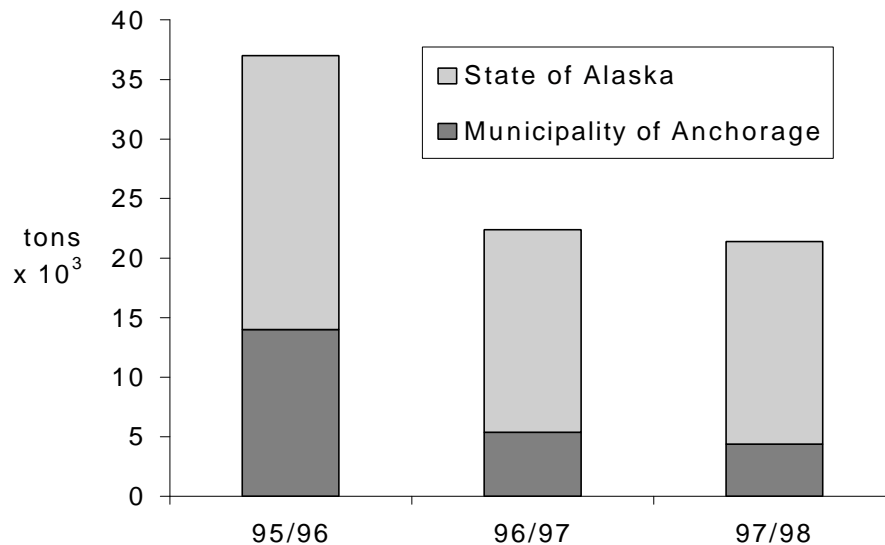
On the other hand, **mitigative measures** entail the periodic removal of dust-producing material. Examples of mitigative measures include: cleanup of paved travel surfaces and cleanup of paved parking lots, especially adjacent to major roadways. In prior studies, preventive measures have been shown to be much more cost-effective than mitigative measures.

## 8.2 Recently Implemented PM-10 Control Measures

The ADOT&PF and MOA street maintenance programs have made a number of significant changes to road sanding and maintenance practices in Anchorage in the past several years. These changes were prompted in part by commitments by the State and MOA to the EPA in a memorandum of understanding (MOU) signed in December of 1996. A number of "common sense" changes were implemented by the ADOT&PF and MOA street maintenance programs in an effort to reduce PM-10 emissions along roadways. The changes are described below.

### Reductions in Winter Traction Sand Application

The amount of traction sand being applied to State and Municipal roads in Anchorage during the past two winters has been reduced by one-third to one-half, as illustrated in Figure 17.



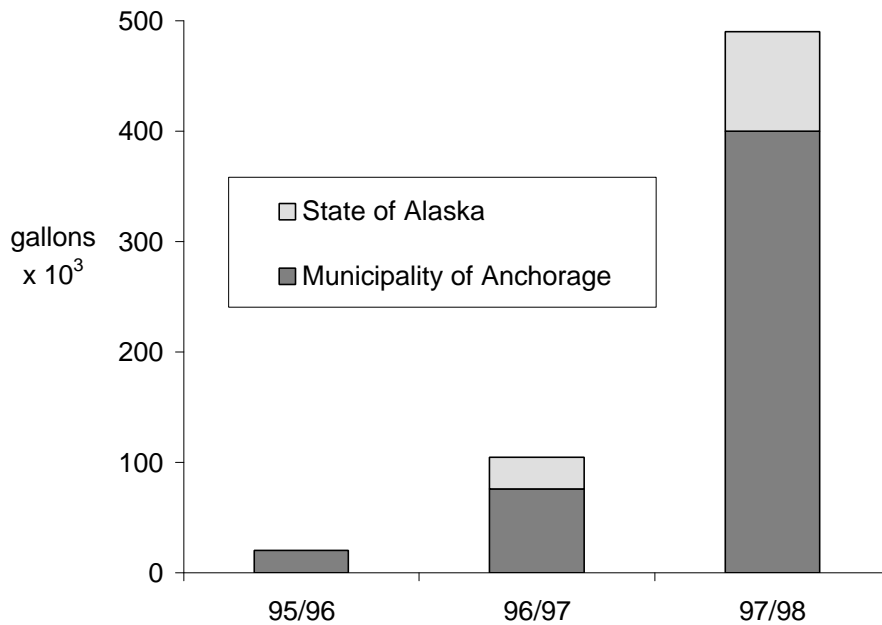
**Figure 17. Winter Traction Sand Use in Anchorage**

#### Changes in Winter Traction Sand Specifications

The MOA and ADOT&PF are also using a cleaner winter traction sand. The allowable silt content in traction sand has been cut to less than 2%. In the early 1990's contract specifications for sand suppliers allowed up to 7% silt.

#### Increased Use of Deicing Compounds in Lieu of Sand

Over the past three years ADOT&PF and MOA have increased the use of winter deicing compounds to reduce the amount of traction sand applied to roads (see Figure 18). In Anchorage's central business district, the application of traction sand has been completely eliminated through the use of magnesium chloride deicer. Liquid magnesium chloride solution is also being used as for anti-icing and deicing on major intersections when conditions allow.



**Figure 18. Winter Use of Magnesium Chloride Deicing Solution in Anchorage**

Magnesium chloride is also now being used to pre-wet traction sand. Municipal and State street maintenance personnel believe this increases the efficiency of the traction sand because the deicing compound has a tendency to “set” the traction sand into snow and roadway ice through melting action. As a consequence, the traction sand is less prone to being blown off the road and less frequent sanding is necessary.

#### Changes in Street Sweeping Practices

New technologies and innovative methods have allowed ADOT&PF and the MOA Street Maintenance Division to begin sweeping in the late-winter before the spring break-up PM-10 period. Most sweeping equipment requires the road to be pre-wetted to reduce dust emissions during sweeping. In the past, traffic safety concerns precluded pre-wetting with water when temperatures were below freezing. Typically, this delayed sweeping until mid-April. During the past two years, however, the MOA has been able to sweep in below-freezing weather in February and March by pre-wetting with liquid magnesium chloride solution. Six new regenerative air sweepers purchased in 1995 have been added to the MOA’s fleet of sweepers. In 1996, ADOT&PF purchased a dry vacuum sweeper with on-board particulate control equipment that allows sweeping without pre-wetting. This sweeper can be used in sub-freezing weather. It works best when road surfaces are dry.

Despite these innovations, the practicality and effectiveness of sweeping as a spring season PM-10 control measure is limited. Although some late-winter sweeping in Anchorage is being performed, it is effective only in the ice-free portions of the roadway. Most roadway silt is locked under inches of ice and snow along shoulders and medians until April 1 or later. Thorough sweeping of the entire roadway usually cannot be accomplished until then. For this reason, sweeping is only marginally effective in controlling the PM-10 episodes that commonly occur during late-March and early-April.

#### Studded Tires- Conversion to Light-weight Studs to Reduce Roadway Wear

ADOT&PF has promoted legislation that would require the use of light-weight studs to reduce roadway wear. Although this legislation has failed in the past two legislative sessions, most studded tire suppliers have voluntarily moved to light-weight studs with the encouragement of ADOT&PF. Presumably, this move to light-weight studs has reduced the amount of fine particulate generated through roadway wear. Some reduction in PM-10 emissions may have also occurred, but there is no direct evidence of this.

#### Surfacing of Unpaved Roads

Finally, the MOA is currently in the midst of a major effort to surface unpaved roads with recycled asphalt product (RAP). Plans are to RAP surface nearly all 93 miles of unpaved road within the Anchorage bowl by 2003. Roads unsuited for RAP surfacing may be treated with other dust palliatives.

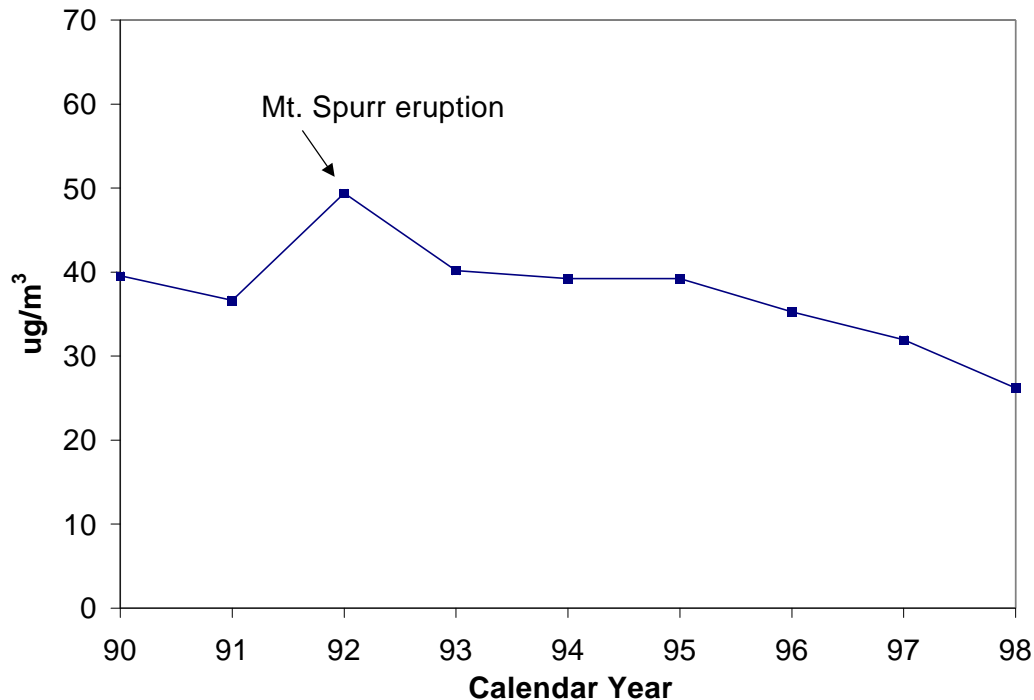
### **8.3 Effect of New PM-10 Controls on Ambient PM-10 Concentrations**

Anchorage has experienced a substantial decline in PM-10 concentrations from peak levels in 1992. Figure 19 shows that annual average PM-10 concentrations at the Gambell site dropped by 46% between 1992 and 1998. Concentrations in 1998 were the lowest on record.

The data suggest that road maintenance changes have had a positive impact on PM-10 air quality. New winter sanding and clean-up practices were implemented in 1996 and these changes correspond to observed improvements in air quality. PM-10 concentrations have dropped by over 30% since these changes were implemented.

The effect of natural events like volcanic eruptions, however, make it difficult to precisely quantify the impact these changes have had on air quality. The eruptions of Mt. Redoubt in 1989 and Mt. Spurr in 1992 both deposited ash in the Anchorage area. The August 1992 Mt. Spurr eruption, which deposited approximately 3 mm of ash on Anchorage, appears to have had a particularly significant impact on PM-10 concentrations. Figure 19 suggests that lingering ash may have affected ambient PM-10 concentrations for a number of years after the eruption. “Natural” improvements

resulting from diminishing influences from the Mt. Spurr eruption almost certainly account for much of the decline observed between 1992 and 1993 when ambient PM-10 concentrations dropped by nearly 20%. It is unclear whether diminishing impacts of the ash account for some of the improvements observed beyond 1993.



**Figure 19. Trend in Annual Average PM-10 Concentrations at Gambell (1990-98)**

Other environmental influences, like year-to-year weather variations, could also account for some of the reductions in annual average concentrations observed over the past several years. Early snowfalls in the fall of 1996 and 1997 almost certainly explain why PM-10 concentrations were low during the freeze-up periods for those two years. PM-10 levels during the March 15 – April 15, 1998 spring break-up period were the lowest on record. Although this period in 1998 was not extraordinarily wet, precipitation was more frequent than previous years. Thus, favorable weather was probably at least partially responsible for the good air quality experienced during this period. Year-to-year weather variations like these make it difficult to assess the effectiveness of newly implemented changes in street practices.

Despite these confounding influences, the evidence that these road maintenance changes have had a positive impact on PM-10 concentrations is fairly strong. The spring break-up of 1997 was very dry, with extended periods without precipitation. Despite these dry conditions, PM-10 concentrations remained below the NAAQS. In contrast, three exceedances were recorded in the spring of 1995 when precipitation patterns were

similar to those in 1997. This suggests that changes in street maintenance practices between 1995 and 1997 contributed to air quality improvements.

The number of exceedances of the NAAQS has declined over the past several years as well. Table 23 shows that exceedances dropped from a peak of eleven during 1992 (when Mt. Spurr erupted) to zero in 1997 and 1998. The two exceedances recorded in 1996 were both associated with natural events (the first resulted from dust from a wind storm, the second from smoke from the Houston-Big Lake fire). Thus, since street maintenance changes were implemented in 1996, Anchorage has experienced three consecutive years without a violation of the NAAQS.

**Table 23. Exceedances of the NAAQS at Gambell Site (1990 –1998)**

	Exceedances attributed to volcanic ash	Exceedance attributed to wind or wild fires	Exceedances attributed to human activity	TOTAL
1990	2	0	0	2
1991	0	0	0	0
1992	11	0	0	11
1993	0	0	6	6
1994	0	1	4	5
1995	0	2	3	5
1996	0	2	0	2
1997	0	0	0	0
1998	0	0	0	0

## 8.4 Candidate PM-10 Control Measures

Assuming that reduction in traffic volume is not feasible, control of emissions from paved arterial roadways in Anchorage must focus on reduction in road surface silt loading. There are two components of silt loading on the Gambell-Ingra roadway system that can be controlled: the amount of traction sand applied to the roadways and the amount of track-on and wash-on from adjacent areas.

In Anchorage, silt loadings on paved travel surfaces are highest during the spring snow melt in late-March and early-April. Large amounts of sand and fine particulate trapped under ice and snow in the late winter and early spring are released. Traction sand and dirt are also released from shoulders and medians during melting. Sand and dirt are transported from shoulders and medians by melt water and vehicle track-out to the traveled portion of the roadway where it is entrained by passing vehicles. As melting progresses during break-up, more sand and dirt are made available on a daily basis.

The loose surface material on parking lots adjacent to Gambell or Ingra, is also an appreciable source for track-on. It may consist of:

- Traction sand applied directly to the parking lot surface.
- Traction sand originally applied to the Gambell-Ingra roadway system and then thrown or tracked by traffic to the adjacent areas acting as reservoirs.
- Materials carried on the underbodies of vehicles from other areas and then sloughed onto the parking lot (or other reservoir surface).

The contribution of tire wear particles to PM-10 levels may not be controllable because this study has shown that the tire wear particles are directly emitted. The resultant inability to control tire fragment emissions will place an even greater emphasis and need for efficiency in limiting the accumulations of traction sand and dirt as sources of resuspended dust emissions.

Candidate control measures that have the potential to reduce the silt loading on the Gambell-Ingra roadway system (and other major arterials in Anchorage) are discussed in the subsections that follow. Included are controls directed to parking lots that are accessed from arterial roadways.

#### **8.4.1 Preventive Measures**

The following ten candidate preventive measures are designed to limit the initial accumulation of silt loading reservoirs. The measures are listed in approximate order of anticipated cost-effectiveness.

##### **P1. Reduce the amounts of traction sand applied to roadways.**

- a. In most areas of the country where traction sand is used, the rate of application to roadways is usually several times higher than the ideal rate for optimum anti-skid control.
- b. Engineering studies have shown that the excess traction sand is ineffective in anti-skid control.
- c. Reduction in the use of abrasives would effect an approximately proportional reduction in roadway silt loading as well as in subsequent wash-on and track-on of sand from melting snowbanks along the roadways.

*Recommendation: Investigate current MOA roadway application criteria and rates for traction sand. Determine whether further reductions can be made without significantly reducing anti-skid performance.*

##### **P2. Reduce the amounts of traction sand applied to public parking lots.**



- a. In most areas of the country where traction sand is used, the rate of application to parking lots is usually several times higher than the ideal rate for optimum anti-skid control.
- b. Engineering studies have shown that the excess traction sand is ineffective in anti-skid control.
- c. Reduction in the use of traction sand would effect approximately proportional reduction in parking lot silt loading as well as in subsequent wash-on and track-on of sand from melting snowbanks in parking areas.

*Recommendation: Investigate current MOA parking lot application criteria and rates for traction sand. Determine whether reductions can be made without significantly reducing anti-skid performance.*

**P3. Use chemical deicers like magnesium chloride in lieu of traction sand application on arterial roadways.**

- a.  $MgCl_2$  has been used by both the MOA and ADOT during the past two winters.
- b.  $MgCl_2$  appears to be a cost effective substitute for traction sand application.
- c. The PM-10 control effectiveness of using chemical deicers in lieu of traction sand in Anchorage has not been established, but relevant work in Denver is nearing completion.
- d. Water quality impacts of deicer use need to be determined.

*Recommendation: Continue deicer program at existing level of effort. Begin two-year evaluation to quantify air quality benefits and determine water quality impacts. Transfer Denver study results as appropriate to Anchorage. If net environmental impact is positive, expand deicer program as appropriate.*

**P4. Set specifications for traction sand (or chemical deicers) applied to private parking lots accessible to arterial roadways.**

- a. Many private paved parking lots that are sanded act as track-on sources for arterial roadway silt loadings.
- b. Such parking lots may use low quality, inexpensive traction sand.

- c. In most areas of the country where traction sand is used, the rate of application to parking lots is usually several times higher than the ideal rate for optimum anti-skid control.
- d. Chemical deicers may be cost-effective as a substitute for traction sand in small parking lots.

*Recommendation: Evaluate the effectiveness of setting traction sand specifications for parking lots as a measure to reduce parking lot silt loadings and potential for track-on to arterial roadways.*

**P5. Enforce speed limits.**

- a. A critical issue for control of paved road emissions is the speed of the traffic, especially near the permanent monitors where PM-10 violations are most frequently recorded. Speed limits are typically exceeded by appreciable amounts.
- b. Based on MRI tests using short-term PM-10 monitoring devices (6-sec average concentrations), blunt aerodynamic vehicles (particularly extended length trucks) and clusters of vehicles are PM-10 “high emitters,” especially when traveling at high speeds that create intense wakes.
- c. Large trucks and vehicle clusters suspend road dust not only from the roadway surface, but from adjacent roadway gutters, shoulder areas, and sidewalks.
- d. When the variable for mean vehicle speed on unpaved roads during the fall PM-10 period is increased from 25 to 40mph in the Anchorage inventory emissions from this source are predicted to increase 60%.

*Recommendation: Enforce speed limits on arterial roadways and unpaved roads. The significant wake-related impacts of vehicles that are “high emitters” increase in proportion to their kinetic energy. Because kinetic energy is proportional to the square of the velocity, a moderate percentage reduction in velocity produces a much larger percentage reduction in PM-10 emissions.*

**P6. Apply dust palliatives to sand and dirt accumulations on the on the shoulders and medians of high volume roadways to reduce seasonal episodes of dust entrainment by vehicles.**

- a. The effectiveness of this measure in controlling PM-10 has not been determined.

- b. Repeated application of stabilizing compounds may be necessary because of evaporation.
- c. High volume roadways can be targeted, limiting the amount of lane miles that need to be treated.
- d. Dust episodes usually occur in late fall (Oct 15 - Nov 15) and early spring (March 15 - April 15), at the beginning and end of Anchorage's snow season.
- e. The use of chemical deicers as dust palliatives should be explored. Because the MOA and ADOT&PF may already be mobilized to use the deicer in response to snow storms, this same equipment could be used for dust abatement if needed.
- f. Special modifications of spray bars and other application equipment may be necessary to apply deicers to roadway shoulders and medians.

*Recommendation: Anchorage's late fall and early spring PM-10 problems seem to lend themselves to episodic controls like the above. The Municipality and State should evaluate the effectiveness of this control strategy. Federal CMAQ funds are available to test this control strategy. Limited, preliminary testing of  $MgCl_2$  could occur as early as this fall (without CMAQ funds). Full scale testing could be done with CMAQ funds during anticipated spring 1999 PM-10 episodes.*

**P7. Pave access areas that connect unpaved roadways, parking lots, and alleys to arterial roadways.**

- a. Track-out from unpaved parking lots and alleys may contribute significantly to PM-10 violations at the Gambell PM-10 site, as evidenced by higher silt loadings at access points.
- b. Localized, high PM-10 concentrations have been measured along untreated unpaved roads with moderate traffic levels.
- c. Although track-out from unpaved roads may not contribute significantly to PM-10 violations at the Gambell site, it probably contributes to PM-10 problems in other areas.
- d. Air quality impacts from track-out have not been quantified. Monitoring data may be necessary to acquire public funds necessary to pave city-owned alleys or regulations necessary to require paving of private-sector parking lots.

*Recommendation: Identify areas of track-out on to major roadways. Although track-out probably contributes to PM-10 problems along some major roads, impacts need to be better quantified thorough air monitoring. Mitigate track-out by paving aprons to major*

*roads or increasing clean-up activity in these areas. Accelerate recycled asphalt program in Anchorage with priority based on traffic volume. Increase level-of-effort for road oiling program in the interim.*

**P8. Use cleaner and/or more durable traction sand on roadways and public parking lots.**

- a. MOA and DOT have already reduced amount of fines in traction sand. In 1994, traction sand specs reduced fines from 5% to 1%. The effect of this change on PM-10 appears to be insignificant.
- b. The air quality impact of switching to a more durable (harder) traction sand is unclear.
- c. Use of more durable (harder) sand could result in increased roadway abrasion and increase particulate generation.
- d. Sources of more durable (i.e., harder) traction are scarce and probably expensive.

*Recommendation: There should be no major change in ADOT or MOA road sanding programs. Continue to use clean traction sand and limit usage as appropriate.*

**P9. Restrict studded tire usage (e.g. requirement to use light-weight studs, limiting studded tire season)**

- a. A blanket prohibition on the use of studded tires would be met with a great deal of opposition. At this time there is no compelling air quality justification for prohibiting the use of studded tires.
- b. Although requiring the use of light-weight studs may reduce roadway wear, air quality benefits are speculative.
- c. A further limitation on the current (October 1—May 1) studded tire season is probably impractical. Studded tire use would have to be prohibited in the late fall (October 1—November 15) and early spring (March 15—April 30) to affect the PM-10 episodes that typically occur in those periods. This would probably be unacceptable because wet snow falls and icy conditions are common in these periods.

*Recommendation: Support efforts of ADOT&PF to require light-weight studs to reduce roadway wear. The air quality impacts of studded tires are not well understood. Any effort to restrict studded tire use should be based primarily on roadway wear effects. Air quality is a secondary consideration.*

**P10. Adopt a covered load law to minimize spillage of dirt from truck hauling. Investigate methods to minimize track-on at construction sites.**

- a. Although spillage and track-on of dirt on roadways may not be a primary cause of PM-10 violations in the March 15- April 15 PM-10 season, spillage is the cause localized nuisance dust problems in the summer construction season, and may contribute to violations in the fall.
- b. A covered load law may reduce costs to the Municipality and State because road clean-up costs could be reduced.

*Recommendation: A covered load law would probably have little impact on the overall PM-10 problem in Anchorage. It would help prevent local nuisance dust problems and reduce clean-up costs for the municipality and state and allow street maintenance funds to be redirected to more effective particulate controls.*

#### **8.4.2 Mitigative Measures**

The following four mitigative measures are designed to remove silt accumulations by cleanup activities.

**M1. Remove snowbanks adjacent to roadways and parking lot access areas.**

- a. Snowbanks contain a substantial buildup of traction sand and dirt. Mobilization of particulate already on the roadway surface is thought to be enhanced due to melting and re-freezing of melt water (see Section 3.3). Likewise, melting snowbanks enhance track-on of wet materials on roadway shoulders.
- b. Control of wash-on of the residual sand in melting snow piles could be accomplished by periodically removing the snow piles prior to the spring melt.
- c. The piles could be transported to adjacent off-road areas or more remote locations where melting would not contribute to active roadway wash-on.

*Recommendation: Investigate the quantities of traction sand and dirt accumulations in snowbanks that could be eliminated as a source of track-on and wash-on. Evaluate the cost-effectiveness of this measure in comparison with other candidate measures.*

**M2. Control track-on from paved parking lots thorough surface cleaning and traffic rerouting.**

- a. Paved parking lots adjacent to arterial roadways act as substantial silt loading “reservoir” surfaces for track-on.
- b. Such materials can be eliminated as a subsequent source of material that could be tracked onto arterial roadways by: (a) removing the material from the parking lot (or other area), especially near the points of roadway access, or (b) rerouting the exiting traffic via side roadways that feed the arterial roadways.

*Recommendation: Investigate the feasibility of rerouting exiting traffic during spring and fall PM-10 problem periods. Exiting traffic should pass over regularly cleaned access aprons or side roads that feed arterials.*

**M3. Sweep roadways during snow melt periods.**

- a. Street sweeping must begin well before the early spring period to successfully control the PM-10 emissions that occur later. Ice and snow hinder the effectiveness of street sweeping in the winter and early spring. Sweeping costs increase because of special sub-freezing weather considerations.
- b. For sweeping to be effective as a PM-10 control, repeated (even daily) sweeps of roadways may be necessary when road surfaces are dry. This may not be practical.
- c. Current sweeping practices may not effectively control PM-10 emissions. Studies have shown that most street sweeping practices are ineffective at removing the very small particles that make up PM-10. Some street sweeping practices may actually increase PM-10 emissions in the short term by pulling sand and dirt from relatively inaccessible gutters and shoulders.
- d. The effectiveness of dry sweeping for PM-10 control in Anchorage has not yet been determined. Although this may prove to be an efficient sweeping method, effectiveness may be hindered because of ice and snow on roadway shoulders and medians or because of wet conditions.
- e. Because roads must be swept in February or early March to effectively control PM-10 emissions during break-up, traction sand may have to be applied to previously swept roads because of early spring snow or ice storms. Repeated sweeps of the same road will be necessary. Costs will increase.
- f. A study of street sweeping practices is planned for the year 2000 by the Water Quality Section of the Department of Public Works. Federal CMAQ funds may be used to incorporate an air quality component to the study.

*Recommendation: Street sweeping has significant limitations as a PM-10 control strategy because of weather factors and the time of the year that PM-10 episodes occur in Anchorage. Other strategies for PM-10 control should be evaluated before significant additional investments are made. The effectiveness of current street sweeping practices need to be evaluated and alternative methods considered. Best sweeping practices for local conditions, as identified by the proposed study, should be employed by municipal and state agencies and their contractors.*

#### **M4. Implement street flushing program.**

- a. Back-flushing and/or other intensive street sweeping methods are necessary to remove small particles from the street surface.
- b. Although street flushing has been shown to be an effective means of controlling PM-10, its suitability in Anchorage is questionable from the standpoints of safety and practicality, because of subfreezing temperatures common in the late winter and early spring.
- c. The water quality impacts of this measure on Anchorage streams and lakes need to be considered.

*Recommendation: Street flushing is probably not acceptable during the early spring and late fall PM-10 periods because of sub-freezing temperatures. In many instances, street flushing is necessary as a follow-up to street sweeping for effective PM-10 control. The limitations of street flushing in Anchorage's cold climate need to be considered before adopting street sweeping/street flushing as a PM-10 control strategy.*

## **8.5 Recommended Control Methods**

The most cost-effective control methods for reducing silt loadings on arterial roadways in Anchorage are those of a preventive nature. Mitigative measures generally are much more costly in terms of labor and capital investment. The control measures discussed above were presented in approximate order of anticipated cost-effectiveness. The most promising **preventive measures** are the following.

First, the application of traction sand directly to arterial roadways should be held to a minimum. Use of chemical deicers as a cost-effective alternative to traction sand should also be given priority consideration. Chemical deicers are currently being evaluated in several cities across the country.

Second, the application of traction sand to public and private parking lots that border arterial roadways should also be evaluated. The goal should be to reduce the amounts of traction sand and to set specifications as necessary to assure that the quality of sand meets acceptable standards, especially on private parking lots.

Third, speed limits of arterial roadways should be enforced. This will reduce the PM-10 impacts of “high emitter” vehicles and vehicle clusters. The impacts are related to wake effects that resuspend dust from shoulders and medians. The wake effects increase with the square of the vehicle speed, so even modest speed reductions produce larger reductions in PM-10 emissions.

Fourth, use of dust palliatives as an episodic measure to control resuspension emissions from shoulders and medians should be evaluated. In particular, it is recommended that the chemical deicers already used in Anchorage be explored for effectiveness as emergency dust palliatives because of the cost savings in using available application equipment.

Finally, paving of any unpaved parking lots or alleys adjacent to arterial roadways should be investigated as a potentially cost-effective measure for reducing track-out. As a minimum, paving of access aprons that can be periodically cleaned should be evaluated.

Regarding the candidate **mitigative measures**, it is recommended that the first three candidate measures be investigated further, in the event that the implemented preventive measures do not sufficiently reduce silt loadings on arterial roadways.

The most widely used mitigative measure for paved roads is surface cleaning. Periodic cleaning of the surface loading on the traveled portions of Gambell and Ingra may be feasible but undoubtedly are less cost-effective than the preventive measures. Even under the optimum dry surface conditions, effective removal of heavy layers of surface loading requires multiple passes of slow-moving sweepers. This was evident during cleaning of the roadway surfaces prior to the application of the limestone tracer material. Even after intense cleaning, a film of fine particles remained on the roadway surface. Moreover, if nearby track-on or wash-on reservoirs of silt are present (or if underbody accumulations of silt deposits areas are carried in by vehicle traffic from more distant areas), the silt loading quickly returns (e.g., in a matter of about two or three days) to an equilibrium level<sup>1</sup> that requires additional cleaning.

## 8.6 Control Cost Effectiveness

Control cost-effectiveness must be evaluated for any candidate control measure being considered, as the basis for final prioritization. Cost-effectiveness is defined as the ratio

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<sup>1</sup> At equilibrium, the rate of removal of silt-sized material during the resuspension/emission process is balanced by the rate of deposition of new material by track-on, wash-on, and underbody sloughing.



of the annualized cost of emission control to the amount of emission reduction achieved by the control measure. Control costs are normally annualized and are comprised of capital, operating, overhead, and enforcement/compliance costs.

Capital costs are incurred in purchase and installation of equipment, development of support facilities, and associated labor. Operating costs are associated with repeated applications of control measures or maintenance requirements, including utilities, materials, labor, and fuel. Overhead represents the costs associated with worker compensation (such as fringe benefits), and worker support. Enforcement/Compliance costs are a real expenditure associated with insuring that control measures are being implemented. These costs are likely to be incurred by any government agency responsible for permitting and monitoring programs. Annualized cost for an individual control measure is likely to vary because of geographic and environmental conditions.

## 9. Conclusions and Recommendations

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This study demonstrates that heavy surface loadings of mineral dusts on the Gambell roadway caused most, if not all, of the PM-10 violations of the NAAQS at the Gambell monitor in Anchorage. The north-south 8-lane Gambell-Ingra system roadway constitutes a dominant localized source of dust emissions when surface loadings are high. Evidence from a number of studies and associated data analyses support these conclusions, beginning with the Anchorage source apportionment and street sediments studies completed prior to the subject research effort. Additional supporting evidence is provided by (a) analysis of the seasonal and spatial characteristics of Anchorage PM-10 concentrations, (b) microscopical analysis of archived ambient PM-10 samples, representing a mix of conditions leading to elevated concentrations, and (c) on-site observations of the heavy dust loadings on the road surface and parking lots near the Gambell monitoring site during the spring snow melt period.

The dominance of roadway emissions is also strongly supported by the April 1997 one-week Intensive Road Dust Study. During the limestone tracer component of that study, a 30-min PM-10 concentration exceeding  $400 \mu\text{g}/\text{m}^3$  and a 6-hour PM-10 concentration of over  $150 \mu\text{g}/\text{m}^3$  were recorded at the Gambell monitoring site in the period immediately following limestone application.

After road dust minerals, the next largest source contribution to high PM-10 concentrations at the Gambell monitor consists of tire particles. This component appears to be directly injected into the air from vehicle traffic rather than resuspended from road surface accumulations. Under such a condition, roadway surface cleaning will serve as only a partial control measure. Also, tire and roadway pavement emissions may be enhanced by studded tires, but no strong evidence of that finding was uncovered.

The most cost-effective control methods for reducing silt loadings on arterial roadways in Anchorage are those of a preventive nature. Mitigative measures generally are much more costly in terms of labor and capital investment. The most promising preventive measures include (a) minimizing the use of traction sand, (b) enforcing speed limits on arterial roadways, (c) using dust palliatives as an episodic measure, and (d) paving access aprons for unpaved parking lots adjacent to arterial roadways. Mitigative measures should also be investigated further, in the event that feasible preventive measures do not achieve desired levels of emission reduction.

The inferences drawn from each data collection/analysis portion of this study are given below.

## 9.1 Inferences Drawn from Previous Source Apportionment and Street Sediment Studies

1. *Crustal sources account for the vast majority of Anchorage's PM-10 mass loading.* All three previous source apportionment studies identified crustal sources as the primary source of PM-10. These three studies were not successful in resolving the contributions of various possible sources of crustal matter, however, the relative contributions of road sanding activity, road way abrasion, track-out from unpaved roads and parking lots, and dust from unvegetated lots were not quantified.
2. *Local sources are the most likely cause of PM-10 exceedances at the Gambell site.* The large amounts of rubber tire particles observed in PM-10 samples indicate that local traffic is responsible for most of the PM-10 mass. Most PM-10 exceedances have occurred on days with low wind speeds suggesting that long range transport from the Mat-Su Valley is unlikely.
3. *PM-10 emission rates from Anchorage roadways are probably significantly higher than most other cities in North America.* Although PM-10 emission rates were not measured directly, roadway PM-10 emission rates are strongly correlated with the amount of silt or fine particulate on the road. Silt loads measured on Anchorage roads appear to be several times higher than other cities. This suggests that PM-10 emission rates from Anchorage roadways are higher than most other cities.
4. *Current street sweeping practices in Anchorage may not be an effective means of controlling roadway PM-10 emissions.* Although sweeping has been shown to be an effective means of reducing large particle street sediment loads, pre- and post-sweep silt load measurements in Anchorage suggest that sweeping may have little impact fine particle loads. Similar observations have been made in other U.S. cities. In fact some studies have suggested that fine particle loads actually *increase* after sweeping. Intensive backflushing following sweeping may be necessary to achieve effective control.

## 9.2 Inferences Drawn from the Analysis of Anchorage PM-10 Data

1. *In Anchorage, data strongly suggest that exceedances of the NAAQS only occur near major roadways.* Monitoring data suggest that the Gambell monitoring station is representative of the highest PM-10 concentrations experienced in the Anchorage. It is the only site that has violated the NAAQS. The high traffic volume on adjacent roadway (Gambell/Ingra) couplet, the north-south orientation of the roadway and topographic factors all contribute to the high PM-10 concentrations observed at this site.

2. *High PM-10 days are usually confined to the spring break-up (March 15 - April 15) and fall freeze-up periods (October 15 - November 15).* Almost all of the days defined as PM-10 episode days ( $\text{PM-10} > 120 \mu\text{g}/\text{m}^3$ ) have occurred in these two periods. Most of the high PM-10 days occurring outside this period are attributed to the Mt. Spurr eruption in August 1992. One or more days with PM-10 concentrations above  $120 \mu\text{g}/\text{m}^3$  have occurred during almost every spring break-up and fall freeze-up period since 1988.
3. *PM-10 concentrations decrease rapidly as distance from the roadway increases.* During spring break-up, PM-10 concentrations at a monitor 40 meters from Gambell Street were about 30% lower than those 15 meters from the road. Concentrations 160 meters from the road were about 50% lower.

PM-10 concentrations appear to be less dependent on roadway setback distance during the fall freeze-up period. Although PM-10 concentrations dropped as distance from the roadway increased, the decline was less than that observed in the spring. This suggests that fall PM-10 episodes may be more of an area-wide phenomena than those in the spring.

4. *Local sources appear to be responsible for almost all of the PM-10 episodes in Anchorage.* Data from the Oceanview neighborhood site suggest that most PM-10 episodes are localized rather than area-wide in nature. PM-10 concentrations at Oceanview rarely approach those at Gambell. Of the 35 episode days when PM-10 measurements were made both at Gambell and Oceanview, concentrations at Gambell were at least twice as high as Oceanview on 29 days. Concentrations at Oceanview were comparable to those at Gambell on only 3 of the 35 episode days. Strong winds were recorded on two of those days.

This suggests that localized sources near Gambell account for almost all of the PM-10 episodes observed there. The data suggest that long range transport of PM-10 from the Mat-Su Valley rarely has a significant impact on PM-10 concentrations at Gambell.

5. *Mobilization of fine particulate through daytime melting and subsequent roadway drying during cooler nighttime and early morning hours appears to enhance reentrainment of roadway dust and contributes to PM-10 episodes.* Melting exposes large amounts of fine particulate on roadway shoulders and medians. This material can be mobilized on to the traveled portion of the roadway by melt water, track out, and if dry, by vehicle wakes. Particulate lodged in roadway cracks and crevices can also be mobilized by melt water and deposited on exposed roadway surfaces where it can be reentrained upon drying.
6. *Some fall PM-10 episodes appear to be associated with “freeze dry” conditions which contribute to increases in roadway PM-10 emissions.* Many fall PM-10 episodes occur on cold days without snow cover. Fine grained soils are more prone to

entrainment because of moisture loss during these subfreezing periods. Poor atmospheric mixing on these days may also contribute to high PM-10 concentrations.

### 9.3 Inferences Drawn from the Microscopical Analyses

1. *On days with moderate to high PM-10 concentrations, the major source contributions are road dust minerals and rubber tire fragments, accounting for more than 95% of the PM-10 burden.* For filters representing concentrations that exceed  $100 \mu\text{g}/\text{m}^3$ , 56% to 83% of the minerals impact is due to plagioclase feldspars and quartz minerals. Rubber tire fragments range from 15% to 42% of the PM-10 mass among these samples.
2. *It appears that windblown soils are not a typical or usual cause of high PM-10 concentrations in Anchorage.* If windblown dust were typically a major contributor to high PM-10 concentrations at the Gambell site, such concentrations would tend to occur on days with high wind speeds, and PM-10 concentrations at other monitors would also be elevated on those days. Only for one pair of archived filters did the average wind speed exceed 12 mph.
3. *The principal sources of minerals contributing to 24-hour PM-10 violations are anti-skid materials and pulverized roadway aggregate abraded from the roadway wearing course by studded and unstudded tires on major thoroughfares.* The composition of the principal minerals in the anti-skid material are identical to those in the asphalt road aggregate minerals. The PM-10 minerals collected on the filters are also identical to predominantly the same as the anti-skid and road aggregate minerals. This clearly points to both mineral sources as major causes of PM-10 violations
4. *Rubber tire fragments are a significant contributor to PM-10 concentrations that may not be eliminated by road cleaning.* The impact of anti-skid materials would be reduced by road cleaning because they are entrained from the roads, but not rubber tire fragments. The tire fragments are directly emitted from the tire treads with apparently little accumulation in road surface dust.

5. *Removing the anti-skid accumulations might reduce direct tire wear and emissions by limiting impregnation of the tire treads with mineral fragments.* Most tire fragments seen in PM-10 samples (and also in the surface of tire treads) are found impregnated with road dust minerals that undoubtedly contribute to cohesive failure and release of tire fragments.

## 9.4 Inferences Drawn from the Source Observations

1. *A large reservoir of anti-skid abrasives and soil is available for track-on to Gambell during the spring snowmelt.* On-site observations prior to and during the April 1997 intensive road dust study indicated visual evidence of track-on from heavily loaded parking lots adjacent to Gambell near the monitoring site. The heavy loadings in the source areas resulted from directly applied anti-skid abrasives with additional accumulations in the melting snowbanks. Track-out from wet areas was more evident than from dry areas.
2. *The effectiveness of surface cleaning of Gambell and Ingra would be reduced by immediate buildup of surface silt loading from the track-out sources.* As the active Gambell/Ingra roadway surfaces dry, they tend to be silt cleaned by traffic. Additional street cleaning, by vacuuming, assuming that efficient methods are available, would deal with a relatively small portion of the silt reservoir that is available to feed suspendable particles to the road surface. Most of the reservoir lies in the heavily loaded adjacent parking lots, from which track-on would continue to occur.

## 9.5 Inferences from Test Week Results

1. *During the test week, PM-10 concentrations at the Gambell Site tracked the surface silt loading on Gambell Site tracked the surface silt loading on Gambell Street.* Some adjustments were necessary to discount for occasional periods of westerly winds which produced little, if any, impact of Gambell Street emissions on the Gambell monitor. After the Gambell-Ingra roadways were cleaned (prior to application of the limestone tracer), the silt loading and the PM-10 concentrations increased and then stabilized later in the week.
2. *The application of the limestone tracer caused a definite impact on the PM-10 concentration in the area of the Gambell monitoring site.* Although short-lived, the silt loading of approximately  $5.8 \text{ g/m}^2$  created by the limestone application (plus background), caused PM-10 concentrations exceeding  $400 \text{ } \mu\text{g/m}^3$  at the Gambell monitoring site during the half-hour period immediately following application of the tracer. Even though the traffic removed most of the tracer from the travel Gambell lanes within one hour of application, the 6-hour PM-10

concentration at Gambell was elevated to  $156 \mu\text{g}/\text{m}^3$ , an increase of  $77 \mu\text{g}/\text{m}^3$  above the concentration for the previous 6-hour period.

3. *The impact of the tracer application was confirmed by limestone analysis of ambient PM-10 filters from the Gambell site.* The limestone analysis of the 6-hour PM-10 sample ( $156 \mu\text{g}/\text{m}^3$ ) collected immediately after tracer application showed that limestone accounted for 31% of the increase in PM-10 concentration above the previous 6-hour period. This result also is consistent with the fact that most of the limestone impact disappeared within about one hour after limestone application.
4. *A large silt loading reservoir was represented by the gutters and paved parking lots adjacent to Gambell Street.* Although the silt loadings on Gambell and Ingra during the test week were in the lowest quartile of 1996 values measured on other arterial roadways in Anchorage, the loadings in gutter areas and parking lots were one or two orders of magnitude higher. These surface loading accumulations had the track-out potential sufficient to provide several PM-10 exceedance days at the Gambell monitor.

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