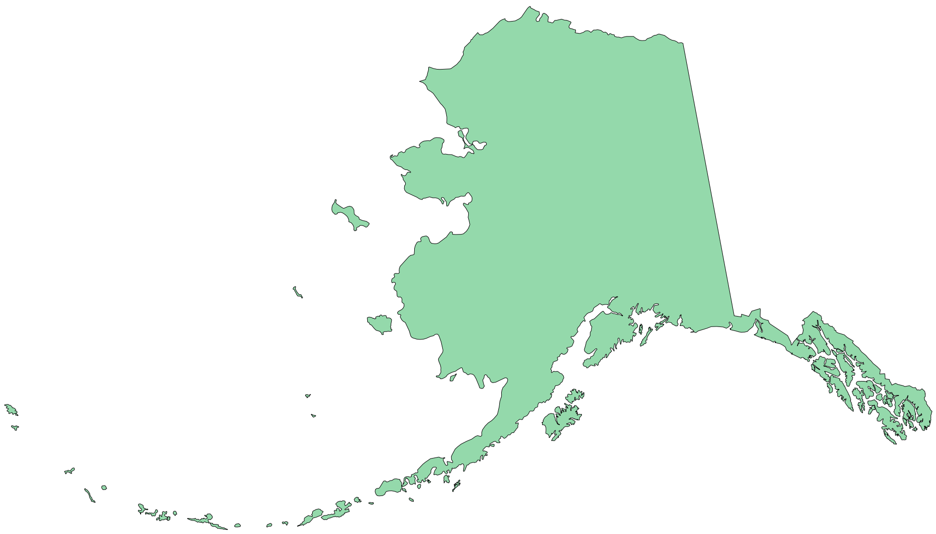
# DRAFT
# Regional Haze in Alaska



# Summary of Scientific Knowledge and its Implications for Alaska's State Implementation Plan

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# 1.0 INTRODUCTION

## 1.1 Overview and Purpose of Report

The Alaska Department of Environmental Conservation (ADEC) is working to develop a State Implementation Plan to meet EPA's regional haze requirements for four designated Class I areas within Alaska. The Regional Haze Rule requires states to develop long-term plans for reducing pollutant emissions that contribute to visibility degradation and to establish goals aimed at improving visibility in the Class I areas. The purpose of this report is to describe the information and data that currently exists with regard to regional haze impacts in Alaska. As ADEC moves forward in its planning efforts, additional technical information and data will be developed. This report will serve as a baseline from which ADEC can begin expanding its current understanding of visibility impairment within the state's Class I areas. The Alaskan Class I areas are Denali National Park, Tuxedni Wilderness Area, Simeonof Wilderness Area, and the Bering Sea Wilderness Area.

## 1.2 Report Organization

This report is organized into five main sections. This first section serves to provide background information on Alaska, the atmospheric processes that lead to haze formation, and on some of the general types of visibility impacts that have been documented in Alaska. Section 2 describes air-monitoring efforts related to visibility that have taken place within Alaska. Section 3 discusses trends in visibility and provides analysis and results related to haze impacts in Alaska. Section 4 discusses local sources that may impact visibility near the Class I areas. Section 5 provides some discussion of potential strategies and needs for future work.

### 1.3 Geography of Alaska

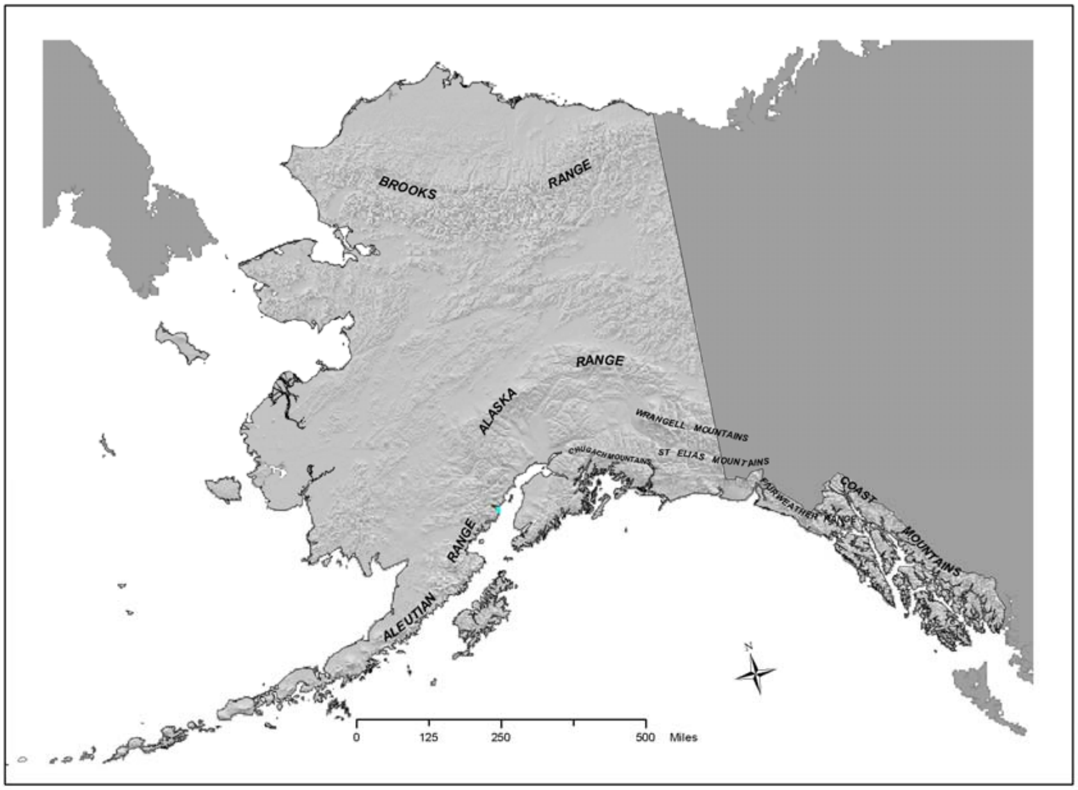
Alaska is the largest of the fifty United States, encompassing 656,424 square miles. It is 1,400 miles long and 2,700 miles wide. Its geographic features are quite diverse, with large mountain ranges, lakes, river systems, and glaciers. Glaciers cover 10% of the Alaskan landmass.

Many areas of Alaska are quite mountainous. There are approximately fifty mountain ranges within the state. Of the 20 highest peaks in the United States, 17 are located in Alaska, including Mt. McKinley (Denali), which is the highest point in North America. Some of the largest mountain ranges include (Figure 1):

- Alaska Range, which forms an arc between Cook Inlet and the Fairbanks area.
- Brooks Range, which runs East-West between the North Slope and the Yukon River
- Aleutian Range, which lies along the Alaska Peninsula
- Wrangell Mountains and St. Elias Mountains, which lie between Tok and the Gulf of Alaska on the Canadian border
- Chugach Mountains, which lie between Anchorage and the Canadian border
- Fairweather Range, which lies between Yakutat and Glacier Bay along the northern Southeast coast
- Coast Mountains, which run through the Southeast Alaska mainland along the Canadian border

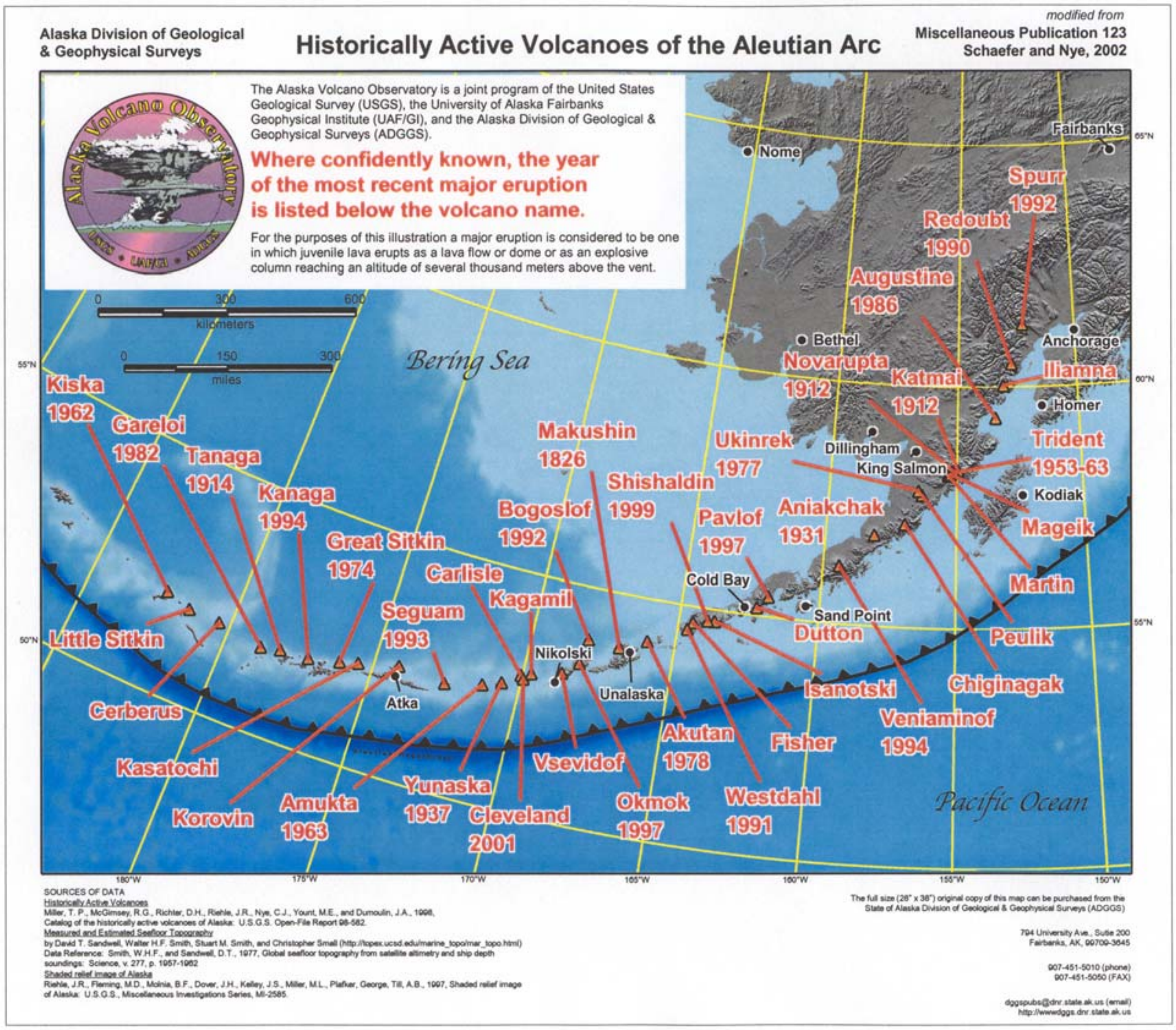
**Figure 1.**

**Mountain Ranges in Alaska**




In addition to the many mountains, Alaska lies on the Pacific "Ring of Fire" and is home to many active or dormant volcanoes. Volcanoes erupt fairly routinely within the Aleutian Islands and the Aleutian Range. Since 1990, eleven volcanoes have had major eruptions. Mt. Spurr (1992) and Mt. Redoubt (1990) were the most recent volcanoes to erupt in the Cook Inlet vicinity. Mt. Cleveland (2001) was the latest volcano to erupt within the Aleutian Islands. Figure 2[1] below shows the many volcanoes in the Aleutian Arc and the year of their last known major eruption.

**Figure 2.**




Alaska also has over 33,000 miles of shoreline including the islands and inlets[2]. The main portion of Alaska is bordered on the north by the Arctic Ocean and Beaufort Sea, on the west by the Bering and Chukchi Seas, and to the South by the Gulf of Alaska and Pacific Ocean. The Aleutian Islands lie between the Pacific Ocean and the Bering Sea. Cook Inlet and Prince William Sound are important water features in Southcentral Alaska. Southeast Alaska is bordered by the Pacific Ocean and includes the Inside Passage, a series of protected waterways connected to the Pacific Ocean.

Alaska has several major river systems including the Yukon-Kuskokwim, Matanuska-Susitna, and Copper River. Denali National Park is home to several rivers including the Teklanika, Toklat, and McKinley. Alaska's river systems are important for transportation and as sources for subsistence foods.

Although Alaska has several national parks, two national forests, and many wilderness areas and refuges, Alaska has only four designated Class I areas subject to the Regional Haze Rule. Alaska's Class I areas are Denali National Park, Tuxedni Wilderness Area, Simeonof Wilderness Area, and the Bering Sea Wilderness Area (Fig. 3).

**Figure 3.**


Denali National Park and Preserve lies approximately 100 miles north of Anchorage in the center of the Alaska Range. The park area totals more than 6 million acres. Denali, the highest mountain in North America standing 20,320-feet, is a prominent feature in the park and throughout Alaska. Denali is the only Class I site in Alaska that is easily accessible, connected to the road system and accommodates a wide variety of visitor uses.

Tuxedni Wilderness Area is located in southcentral Alaska, in western lower Cook Inlet at the mouth of Tuxedni Bay. Tuxedni is comprised of two Islands, Chisik and Duck, totaling 6,402 acres. Most of the wilderness area lies on Chisik. Duck is a small rocky island, only 6 acres, with little or no vegetation. Tuxedni Wilderness Area is only accessible by small boats and planes, weather permitting.

Simeonof Wilderness Area consists of 25,141 acres located in the Aleutian Chain 58 miles from the mainland. It is one of 30 islands that make up the Shumagin Group on the western edge of the Gulf of Alaska. Access to Simeonof is difficult due to its remoteness and the unpredictable weather.

The Bering Sea Wilderness Area is located off the western coast of Alaska approximately 350 miles southwest of Nome. The Class I area consists of 41,113 acres within the St. Matthew Island group (which totals approximately 81,340 acres). The Bering Sea Wilderness Area is one of the most isolated landmasses in America with few if any visitors.

## 1.4 Chemical and Physical Processes for Haze Formation

Regional haze is a result of the scattering and absorption of atmospheric particles and gases that are nearly the same size as the wavelength of light[3].  Haze impairs visibility in all directions over a large geographic area.  The distance that we can see is limited because of tiny particles in the air absorbing and scattering sunlight, which degrades the color, contrast, and clarity of the view.

Many sources produce the particulate matter and their precursors that cause haze.  Particulate matter is both manmade and naturally occurring.  Some natural sources of particulate matter include windblown dust, wildfires, “bioorganic” emissions from trees, volcanoes, and coastal emissions from the ocean.  Manmade sources include gas and diesel engines, electric utility and industrial fuel burning, manufacturing operations, prescribed burns, residential wood combustion, gas stations, and dust from unpaved roads, construction, and agriculture.  Additionally, particulate matter is formed when gaseous pollutants undergo chemical reactions with sunlight in the atmosphere.  Factors such as humidity further impact the formation of haze by increasing the size of the particles thereby increasing their light-scattering efficiency.  Particulate matter tends to remain suspended in the air for a long period of time and can travel to areas hundreds or even thousands of miles away from the pollution sources.

Visibility impairment is primarily caused by the emissions into the atmosphere of sulfur dioxide ($SO_2$), nitrogen oxides (NOx), and fine particulate matter (PM) (e.g., sulfates, nitrates, organic carbon, elemental carbon, and soil dust).  Meteorological factors such as wind, cloud cover, rain, and temperature affect pollution, and in turn, these weather conditions are affected by pollution[4]. The presence and absence of clouds and the amount of sunlight determine the rate at which pollutants are converted to other pollutants, for example, sulfur dioxide gas to sulfate particles[5]. Wind is an important process for mixing the earth’s atmosphere and dispersing pollutants. Pollutants produced under stagnant conditions can become trapped and produce a layered haze, whereas pollutants produced under windy conditions are well mixed and dispersed and appear as a uniform haze[6]. Particles that absorb water molecules become highly responsible for visibility impairment under conditions of high relative humidity, due to their increase in size when compared to dry conditions.

## 1.5 Haze Impacts in Alaska

In the past, the focus of regional haze research in Alaska has not centered on Alaska's Class I areas. Research has been conducted to look at visibility degradation within the Arctic region. These studies identified international transport of pollutants into Alaska as important to the creation of observed haze. The two primary areas of concern have been Arctic Haze and Asian dust events.

*Arctic Haze*

Arctic Haze can be defined as diffuse bands of tropospheric aerosol occurring northward of about 70° latitude and at altitudes of up to 9,000 meters[7]. These layers are hundreds to thousands of kilometers wide and 1-3 km thick. Arctic Haze specifically refers to the presence of anthropogenic aerosol from midlatitudinal sources[8]. Aerosols can be either liquid or solid particles suspended in a gas, such as air. Aerosols with liquid particles include clouds and mist, and aerosols with solid particles include smoke and dust.

Although scientific observations of Arctic Haze were first recorded in the 1950's, extensive research did not begin until the early 1970's. Pollutants contributing to Arctic Haze reach their maximum in March/April due to increased airflow from central Eurasia and increased gas to particle conversion. This enhanced conversion is attributable to an increase in solar radiation and liquid water in early spring[9]. The haze is mostly comprised of acidic sulfate aerosols, which make up approximately 90% of the haze's mass, and soot[10]. Other elemental components include lead, arsenic, nitrate, sodium, magnesium and chloride[11]. Haze particles are no larger than 2 µm in diameter. Aerosols between 0.1 µm and 1 µm are capable of remaining suspended in the atmosphere for weeks and therefore able to travel into the Arctic, which has few locally generated aerosols[12]. The size of Arctic Haze aerosols is roughly the same as the wavelength of visible light (0.39-0.76 µm) allowing the aerosol particles to scatter light and therefore diminish visibility very effectively. Coal burning and metal smelting appear to be the primary contributors to Arctic Haze, based on both its composition and the source regions[13].

Evidence from meteorological studies indicates that the pollution comprising Arctic Haze originates in industrial regions of the world, mainly Europe and Russia. The presence of strong source regions in Eurasia, the occurrence of the Arctic air mass over much of this source, the occurrence of a poleward circulation over the source area, and the lack of precipitation, clouds, and vertical mixing along the transport trajectory all show evidence that Eurasia is a major source region for the Arctic[14].

Sources in North America and the Orient only contribute a minor amount of pollution to the Arctic[15]. This is a consequence of their position relative to the oceans. Pollution from China and Japan follows a northeastern track towards the Arctic and encounters the Aleutian Low, which scavenges pollutants from the air. Similarly, pollution from eastern North America is scavenged when it encounters the Icelandic Low in the North Atlantic. Pollution from Europe and Russia can move over land, avoiding an encounter with a strong scavenging system. Furthermore, the major industrial centers of Europe lie approximately 10° north of those in the US and the Orient; Russian industry lies yet farther north[16]. One important pollution source to note is the large polymetallic ore mining-smelting complex at Nor'ilsk, Russia[17]. Two large plumes can be traced for up to 40 km and originate from smelters processing sulfide rich nickel-copper ores[18].

Denali National Park and Preserve is in the sub-Arctic and not as severely impacted as the Arctic; sulfate aerosol mixing ratios in Denali are 30-50% of those in the Arctic. Nevertheless, Arctic Haze appears to have a substantial impact on visibility in the Park. For seven months out of the year (November-May), sulfates are the dominant aerosol species in Denali National Park and Preserve, of which Arctic Haze aerosol appears to make up a sizeable portion[19].

The most severe Arctic Haze episodes in Denali National Park and Preserve limit visibility to 120 km at low humidity[20]. This underestimates the impact of the haze though, because Denali NPP's humidity in the early spring is quite high, averaging between 70 and 80%. Considering that the light-scattering efficiency of sulfate aerosols increases by 2-3 times when one introduces them into an environment with approximately 80% humidity[21], a more realistic estimate is around 40-60 km.

*Asian Dust*

One of the first attempts to characterize the origin of Arctic Haze found that a large haze incident in early May 1976 was caused by desert dust[22]. This conclusion was based on the morphology of the aerosols and their chemical composition, along with consideration of the meteorological situation preceding the appearance of the haze. The dust was almost certainly transported from the Gobi and Taklimakan deserts in Mongolia and northern China. Nearly every spring, high winds loft so much dust that it falls on Japan and Korea like yellow snow.

Rahn *et al.*[23] estimated that such a wind event could carry an enormous amount of soil into the Arctic. Given that a large plume recently tracked across the Pacific moved at an average velocity of 43 km/hr[24], a plume of the intensity observed in 1976 would deliver approximately 250,000 tons of soil during a five-day episode.

Since Rhan *et al.*[25], the transport of Asian desert dust into the North Pacific atmosphere has been the subject of extensive study[26]. These investigations have established that Asian dust events occur in the springtime, usually April and May, and can reach as far south as Mexico, or as far north as the Arctic. Even the arctic research station at Alert in Canada, at 82˚N latitude, sees a sharp seasonal elevation of soil dust in April/May[27].

Spring is not only the most active period for dust storms in the Gobi and Taklimakan, but also the period of most active atmospheric transport between the Orient and the Arctic[28]. Generally, long-range transport must occur at high altitudes (above 5 km) over an ocean in order to avoid scavenging[29]. Therefore, while the Pacific Ocean usually serves as a barrier to pollution transport, pollution can undergo long-range transport over it if lofted high enough. The transport of desert dust from the Orient is a well-documented phenomenon[30], and so, increasingly, is the transport of anthropogenic pollution.

Rhan *et al.*[31] detected little pollution in the 1976-dust plume, but Chinese sulfur dioxide emissions have since tripled. Unsurprisingly, more recent studies have shown an increase in anthropogenic pollution concurrent with the transport of Asian air during the spring over the Pacific Ocean[32] and North America[33]. The concentration of sulfate, nitrate, soot, and heavy metal aerosols accompanying these dust plumes will almost certainly increase as China's coal-fired economy rapidly expands over the coming decades.

Aside from the probable increase in obviously anthropogenic pollution, the amount of dust may also be increasing. The dust storms should be considered at least partially anthropogenic, because human activities are contributing to an expansion of the Gobi desert, which has in turn produced more dust storms[34]. Beijing lies directly in the path of these storms, and therefore the Chinese have anxiously noted their more frequent occurrence. Chinese records describe fierce dust storms occurring in Beijing once every seven or eight years in the 1950s. By the 1970's they occurred every two or three years, and by the early 1990s they had become an annual problem. By 2000, the problem had become acute; the worst storm in memory continued for many days, blotting out the sun, halting air travel and filling emergency rooms[35].

Evidence suggests that global scale transport of Asian dust has been a long-running natural phenomenon[36]. Chemical analysis of Greenlandic ice cores[37] and Hawaiian soil studies[38] have shown that the chemical and radiological fingerprints of deposited dust were consistent with the composition of the Asian dust sources.

Cahill[39] found that elemental ratios in dust from recent events were similar in Denali National Park and Preserve and Crater Lake National Park, Oregon. Both experience peaks in soil aerosol concentrations during the spring, indicating that the dust had a common origin. Cahill et al.[40] also showed Asian dust reaching Adak Island, Alaska, and the Poker Flat Research Range, north of Fairbanks, Alaska. These measurements were taken as a part of the Aerosol Characterization Experiment-Asia (ACE-Asia), a multi-national experiment designed to quantify the emissions of dust and other aerosols from the Asian continent into the North Pacific. During this study, large segments of dust clouds moving east over the Pacific from Asia were observed to peel off and transport northward into the Arctic and western United States[41]. Model simulations also predict this phenomenon[42,43].

The IMPROVE monitoring site in Denali National Park and Preserve actually saw a slight decrease in the severity of dust events reaching Alaska between 1988 and 2000. Perhaps this could be due to changes in transport patterns, but barring a fundamental shift in the seasonal transport pattern between the Gobi and Alaska, the Gobi desert's accelerating expansion ought to eventually cause an increase in the amount of dust entering the Arctic.

## 2.0 REGIONAL HAZE MONITORING

Several $PM_{2.5}$ and IMPROVE samplers are in operation in Alaska. Maintaining the $PM_{2.5}$ and IMPROVE monitors currently collecting data are of primary concern in the visibility monitoring strategy for the state of Alaska. This has taken a great deal of consideration due to the remote location of the sites. Currently the National Park Service (NPS) and Fish and Wildlife Service (FWS) are responsible for the funding and operation of Alaska's IMPROVE network.

### 2.1 Class I Area Monitoring

As Denali is the only Alaskan Class I area with any analysis of data, it is consequently the one with which the most detail has been given in terms of a site description. Each of the other sites has a cursory description, which serves to give an overview of its proportions and location.

*Simeonof Wilderness Area*
The Fish and Wildlife Service placed an IMPROVE monitor in the community of Sand Point, a more accessible island which is being used to characterize Simeonof Wilderness Area. The monitor, which is approximately 60 miles north west of the Wilderness Area, went on line on September 10, 2001. A DELTA-DRUM sampler (described in section 2.2) was also placed near the IMPROVE monitor for approximately 6 weeks and another one actually on Simeonof for 1 week during the summer of 2002.

*Tuxedni Wilderness Area*
The Fish and Wildlife Service installed an IMPROVE monitor near Lake Clark National Park. This site is on the west side of Cook Inlet, approximately 5 miles from the Tuxedni Wilderness Area. The site was operational as of December 18, 2001.

*The Bering Sea Wilderness Area*
The Bering Sea Wilderness Area had a DELTA-DRUM sampler placed on it during a field visit this past summer (2002). Difficulties were encountered with the power for the sampler and at this time it is not clear how much data was captured. No IMPROVE monitoring is currently planned in this area as a result of its inaccessibility and prohibition against human presence.

*Denali National Park*
Denali National Park and Preserve is a park of 6,075,030 acres, approximately the size of the state of Vermont (Fig. 4). There is one road in the park that extends 89 miles into the park at the northeastern corner, and is paved for only the first 15 miles. Along this road are the Visitor Center (mile 0.7), the Alaska Railroad depot (mile 1.5), the park Headquarters (mile 3.4), and several campgrounds. Denali National Park currently has two monitors up and running, one near the park's headquarters and the second just south of the park boundary at Trapper Creek. The IMPROVE monitor near the park's headquarters was originally the IMPROVE site, but due to topographical boundaries, such as the Alaska Range, it was determined that this was not adequately representative of the entire Class I area. Therefore, Trapper Creek, just outside of the park's southern boundary, was chosen as a second site for an IMPROVE monitor and is the official Denali IMPROVE site as of September 10, 2001. The headquarters site is now the protocol site. It is hoped this will characterize any transport from the Anchorage area, the most densely populated region in the state.

IMPROVE monitoring data has been recorded at the Denali Headquarters IMPROVE site from March of 1988 to present but data has only been analyzed up to February of 2000. In addition, a DELTA-DRUM sampler was installed at the Poker Flat research range north of Fairbanks the September 1 – 29, 2000, March 25 – April 22, 2001, and July 26 – September 7, 2001. The Denali National Park headquarters site also had a DELTA-DRUM sampler installed July 30 – September 7, 2001. There has also been a CASTNet (Clean Air Status and Trends Network) style monitor located near the Trapper Creek IMPROVE site. Another CASTNet style monitor is located at Poker Flat Research Range, and a third is co-located with the Denali National Park headquarters IMPROVE monitor.

During the park season, mid-September to mid-May, 70 buses and approximately 560 private vehicles per day traverse the road loaded with park visitors. During the off season, approximately 100 passenger and maintenance vehicles pass within 0.3 miles of the monitoring site[44]. Private vehicles are only allowed on the first 14.8 miles of the Park Road. The Denali Headquarters monitoring site is located across the Park Road from the park headquarters, approximately 250 yards from the buildings there. It is up a hill at an elevation of 2,125 feet above sea level, and the road is at 2,088 feet. The side road winds up the hill for 130 yards, and provides access to not only the monitoring site, but also a single-family residential staff cabin. The hill is moderately wooded, but the monitoring site is in a clearing with the dimensions of 0.54 acres. In addition to the IMPROVE network, many other monitoring networks have sites in this clearing, including the National Atmospheric Deposition Program, State of Alaska Federal Reference Method $PM_{2.5}$ partisol monitors, NPS's meteorological monitoring equipment, along with several research projects from the University of Alaska, Fairbanks. The site is 9.1 miles from the coal-fired power plant in the town of Healy, and 3.2 miles south of the Healy Ridge, which rises to 6,000 feet at its highest point, 2 miles west of the Nenana River. It is located in an east-west valley, between the Healy Ridge and the main Alaska Range, that is about two miles wide at the monitoring station and gets wider to the west towards the Sanctuary and Savage Rivers. The monitoring site is located just to the west of Windy Pass, which runs north-south along the Nenana River. The major flow influence for this site is likely to be the north-south Windy Pass.

The Trapper Creek IMPROVE monitoring site is located 100 yards east of the Trapper Creek Elementary School (latitude 62 18' 57" longitude 150 18' 42", elevation 150 meters). The site is located west of Trapper Creek, Alaska and a quarter of a mile south of the Petersville Road. The site is considered the official site for Denali National Park and Preserve and was established in September 2001 to evaluate the long-range transport of pollution into the Park from the south. The school experiences relatively little traffic during the day, 3-4 buses and 50 automobiles (20 of those staff). The school is closed June through August. This site was selected because it had access to power, was relatively wide open and was not directly impacted by local sources.

## 2.2 Pollutants Analyzed

*IMPROVE Monitoring*

The IMPROVE monitor sample filters are analyzed for 47 different compounds including fine mass ($PM_{2.5}$), total mass ($PM_{10}$), optical absorption, elements (table 1), ions (chloride, nitrate, nitrite, sulfate), and organics (table 2).

**Table 1. Elements analyzed in IMPROVE program**

| | |
|---|---|
| Aluminum | Nickel |
| Arsenic | Phosphorus |
| Bromine | Potassium |
| Calcium | Rubidium |
| Chlorine | Selenium |
| Chromium | Silicon |
| Copper | Sodium |
| Hydrogen | Strontium |
| Iron | Sulfur |
| Lead | Titanium |
| Magnesium | Vanadium |
| Manganese | Zinc |
| Molybdenum | Zirconium |

**Table 2. Organics analyzed in IMPROVE program**

| Analyte | Description |
|---|---|
| OCLT | Organic Carbon, low temperature of volatilization from filter (25-120˚C) |
| OCHT | Organic carbon, High temperature of volatilization from filter (120-550˚C) |
| ECLT | Elemental Carbon, Low temperature of volatilization from filter (550-700˚C) |
| ECHT | Elemental Carbon, high temperature of volatilization from filter (above 700˚C) |
| O1 | Organic carbon, ambient-120°C |
| O2 | Organic carbon, 120°C-250°C |
| O3 | Organic carbon, 250°C-450°C |
| O4 | Organic carbon, 450°C-550°C |
| OP | Pyrolized carbon |
| E1 | Elemental carbon remains at 550°C |
| E2 | Elemental carbon remains at 550°C-700°C |
| E3 | Elemental carbon remains at 700°C-800°C |

*CASTNet Monitoring*

The CASTNet style monitors collect data on sulfur dioxide ($SO_2$), sulfate ($SO_4$), nitrate ($NO_3$), nitric acid ($HNO_3$), and ammonium ($NH_4$). This sampler consists of three filters, one Teflon®, one nylon, and one Whatman. The Teflon® filter collects the $SO_4$, $NO_3$, and $NH_4$. The nylon filter has two functions; it collects $HNO_3$ and reacts with sulfur dioxide gas to form $SO_4$. The Whatman filter collects $SO_2$ gas. The three filters collect samples for a one-week period from a height of 10 meters above ground level[45]. Three CASTNet sites have operated in Alaska. The sites are useful because they directly collect and measure criteria visibility-related pollutants which must be extrapolated under the IMPROVE protocol.

*DELTA-DRUM Sampler*
The DELTA-DRUM sampler, officially known as the three-stage drum impactors, were designed by the University of California-Davis, and built by Integrity Manufacturing. They collect three fractions of particulate matter, 2.5-1.1 µm, 1.1-0.34 µm, and 0.34-0.069 µm. These can be subjected to various analyses as needed, such as organic and elemental composition. Since they run on either batteries or battery back up for wind or solar power, they require neither power to be run to the site nor a generator that creates local emissions. This is the type of monitor that was used at the Bering Sea Wilderness Area. Table 3 lists the elements analyzed with DELTA-DRUM samplers.

**Table 3. Elements Analyzed in DELTA-DRUM Sampler**

| | |
|---|---|
| Aluminum | Nickel |
| Arsenic | Phosphorus |
| Bromine | Potassium |
| Calcium | Rubidium |
| Chlorine | Selenium |
| Chromium | Silicon |
| Copper | Sodium |
| Cobalt | Strontium |
| Iron | Sulfur |
| Lead | Titanium |
| Magnesium | Vanadium |
| Manganese | Zinc |
| Molybdenum | Zirconium |
| Barium | Gallium |
| Mercury | Scandium |
| Chromium | Germanium |

**2.3 Alaska Ambient Air Monitoring Network Summary**

The state ambient air-monitoring network has been in operation for many years. The network has primarily focused on Alaska's larger communities and non-attainment areas[i]. The state and local agencies operate particulate monitors ($PM_{2.5}$ and/or $PM_{10}$) in Anchorage, Fairbanks, Juneau, the Matanuska-Susitna Valley, and on the Kenai Peninsula. An additional $PM_{2.5}$ monitor has recently been placed at the Denali National Park Headquarter Site. Carbon monoxide monitoring is conducted in the Anchorage and Fairbanks non-attainment areas. In addition to monitoring in these areas, monitoring in Sitka and Ketchikan has been conducted in the past.

The purpose of the state ambient air-monitoring network has been focused on determining whether levels of pollutants are exceeding the national ambient air quality standards. For this reason, sites have typically been placed to observe impacts from local emission sources, such as motor vehicles, wood-burning stoves, unpaved roads, wind blown dust, and industrial facilities.

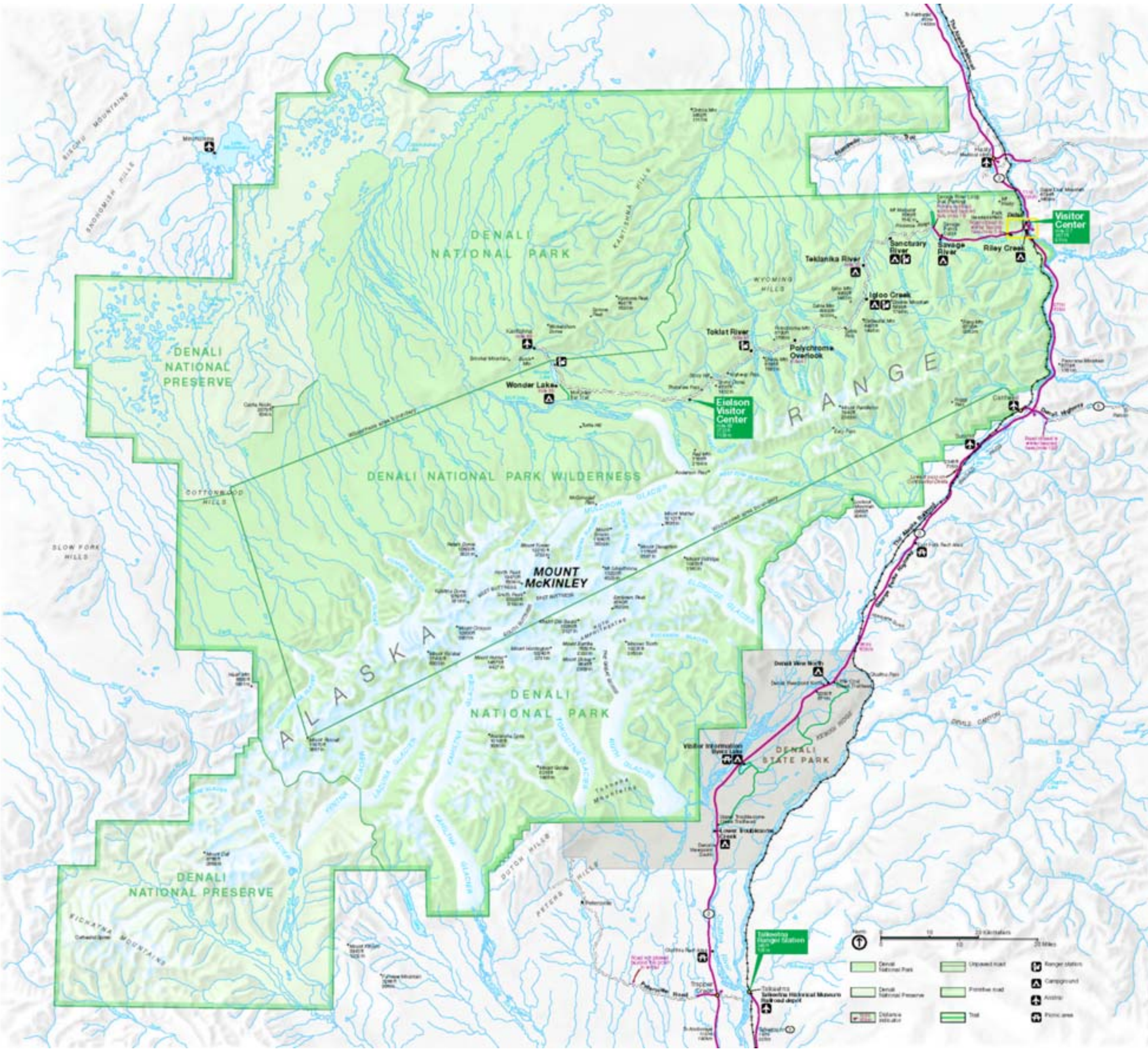
[i] Alaska has four non-attainment areas. For CO: Anchorage and Fairbanks. For PM-10: Anchorage-Eagle River and Juneau-Mendenhall Valley.

Because of this, the data is not representative of impacts within Alaska's Class I areas and may not be relevant for analysis of regional haze pollutants within Alaska's Class I areas.
The Anchorage and Fairbanks monitoring data provide some information on the levels of pollutants within the major communities of Anchorage and Fairbanks. The pollutants measured within these communities could be potentially transported to the Denali and/or Tuxedni Class I areas. In addition, monitoring data from Kenai Peninsula sites would provide information on pollutant levels that could potentially transport to the Tuxedni Class I area.

The Denali $PM_{2.5}$ monitoring site provides federal-reference method $PM_{2.5}$ monitoring data within one Alaska Class I area. This $PM_{2.5}$ site could be used to look at fine particulate data correlation with the IMPROVE monitoring site. Developing a correlation between the federal-reference method and the IMPROVE method could allow for better integration of $PM_{2.5}$ data from other sites into the regional haze analyses.

The primary monitoring data available within Alaska's Class I areas is from the IMPROVE network and the correlation between this method and the federal reference method under Alaskan conditions is not yet clear. Therefore, this report focuses on the monitoring research related specifically to haze and the historical IMPROVE data and does not include any analyses of the data from the state ambient air monitoring network.

**Figure 4. Denali National Park and Preserve**



# 3.0 RESULTS/ANALYSIS

## 3.1 Chemical composition

All of the Class I areas in Alaska are remotely located.  Because of this, the sources of visibility-degrading pollution are generally either transported from a distance, naturally occurring, or both, as in the case of Asian dust.  Since Denali is the only Class I area in Alaska for which data has been analyzed, it is the only site for which one can back up a discussion on composition with actual analyzed air samples.  The IMPROVE monitors analyze four different filters for 47 compounds, although some changes in sample analysis resulted in changes in the species which were reported.  As one example, the organic and elemental carbon analysis changed at the end of 1993.  The first three filters collect fine particulate matter of 2.5 micron diameter or less, and the fourth collects coarse particulate matter with a diameter of 10 microns or less.

The analyses that the State of Alaska performed on the IMPROVE data utilized several simplifying assumptions.  First, when looking at a particular event such as fire (Fig. 5), it was assumed that all of the components being assessed have no other source than fire.  Secondly, the sources considered were based solely upon previous research conducted over the last few decades in Alaska; this would inhibit any original findings.

Each of the component sources of regional haze can be fingerprinted using the elements or compounds that are its primary features.  Fire events, for instance, increase the levels of soluble potassium (K) and organic components (OCHT, OCLT, OC1, OC2, OC3, OC4, OP) in the air and, consequently, in the samples collected by the IMPROVE monitors.  Similarly, when an Arctic Haze event takes place (Fig. 6), the levels of copper (Cu), nickel (Ni), vanadium (V), zinc (Zn), sulfur dioxide (SO2), and sulfate[ii] ($SO_4$) increase.  The third of the largest contributors to regional haze is Asian dust or, in a broader sense, soil.  During high soil events, the levels of silicon (Si), calcium (Ca), iron (Fe), strontium (Sr) and titanium (Ti) will increase (Fig. 7).

One of the ways to identify a soil event from an international source is to fingerprint the exact elemental and isotopic ratios found in a sample to a particular region of the world.  This can then be corroborated with transport trajectory data to see if the air mass that transported the particulates moved over the suspected source region.  A more simplistic approach at certain times of year is to note that due to snow cover and frozen ground, it is nearly impossible for Alaska to be the origination point of any measurable amount of soil in the late autumn, winter, and early spring.

[ii] Due to an overlap with other sources sulfate was not graphed.

**Figure 5. Fire Components by Month**

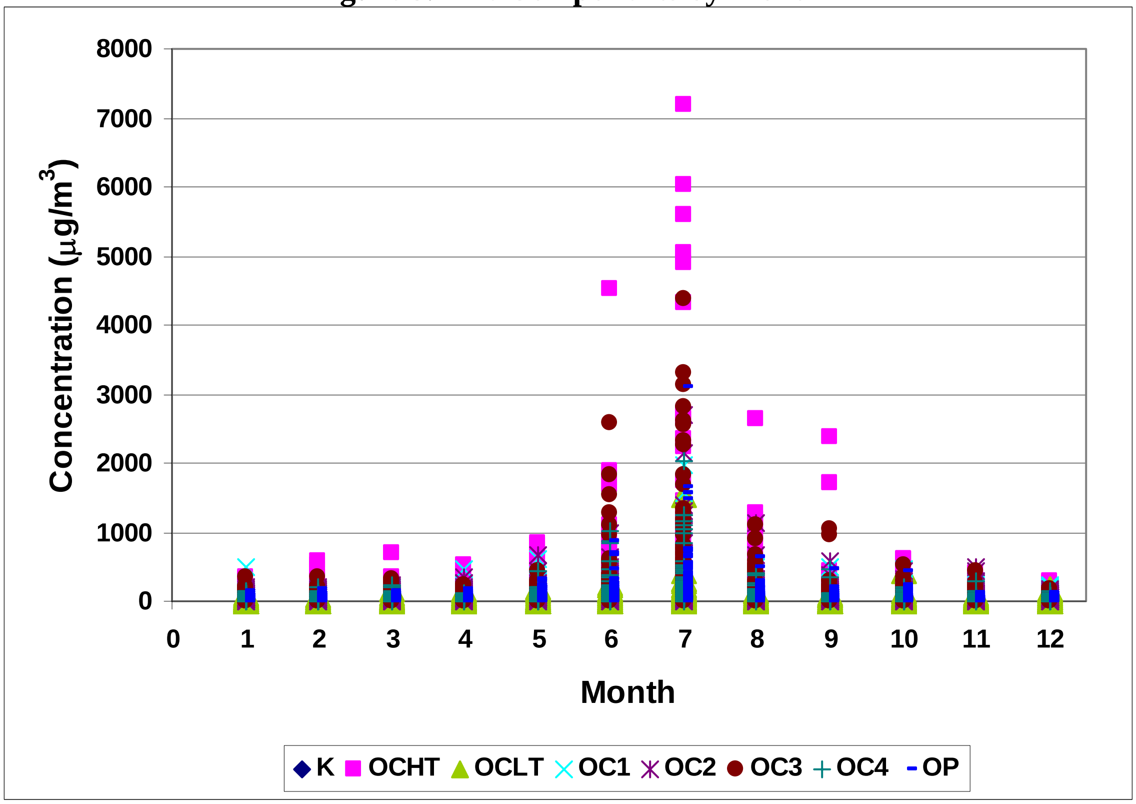



**Figure 6. Arctic Haze Components by Month**

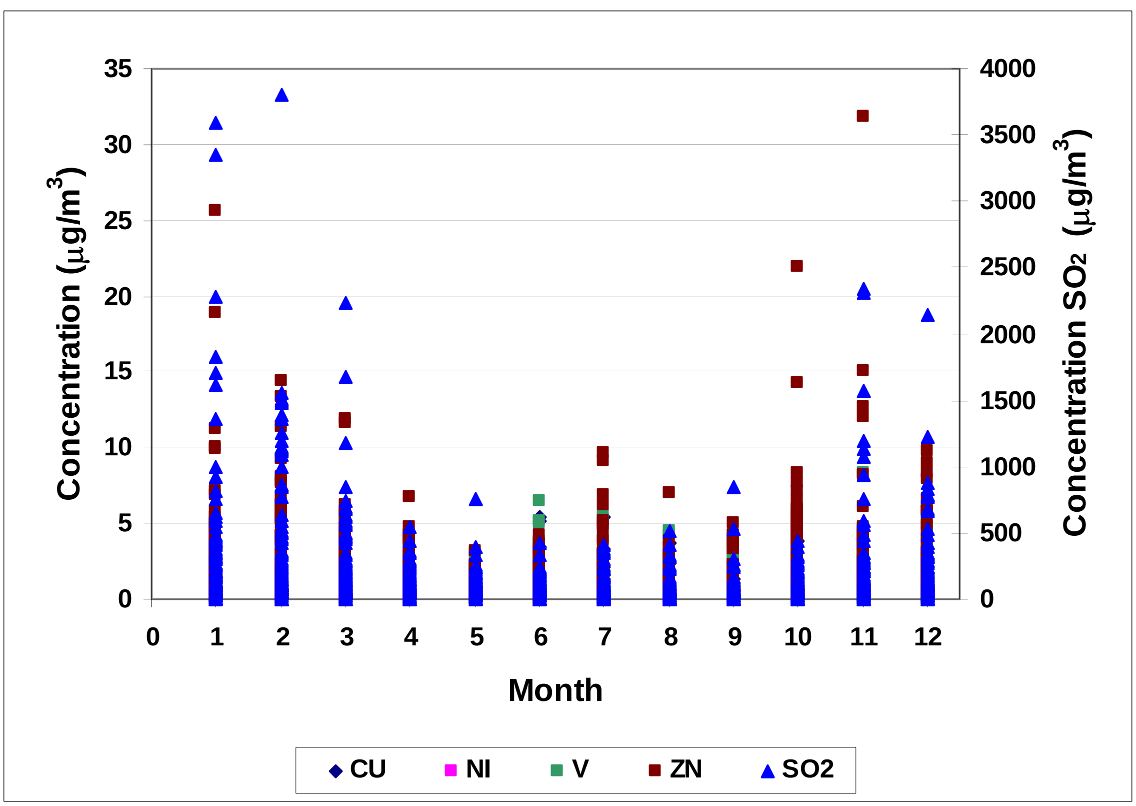
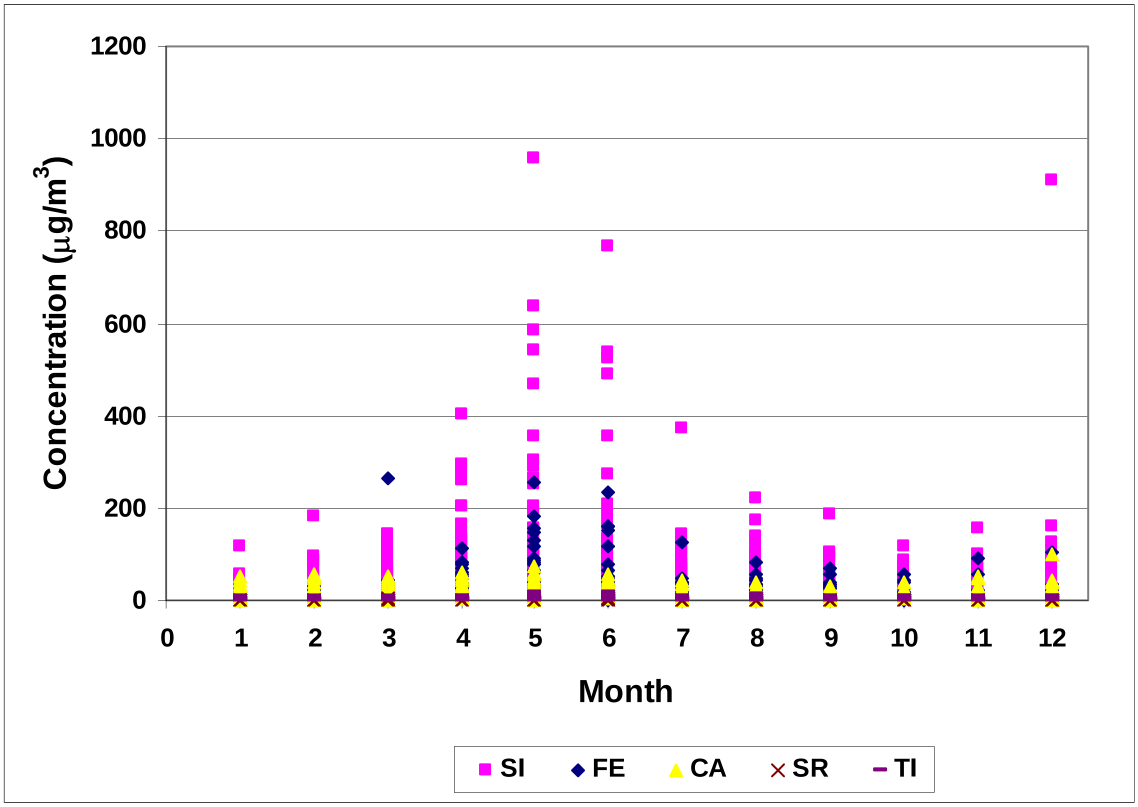


**Figure 7. Soil Components by Month**




### 3.2 Seasonality

There are strong seasonal trends to the visibility degradation in the state of Alaska. From March through May, dust originating in Asia blows across the Pacific Ocean. This trend comes at the tail end of the Arctic Haze time period, which runs from October through March. The fire season in the area starts when the snow melts, usually in April, and continues until mid August. These trends lead to a bimodal trend of low visibility days, which peaks once in summer and once in winter. Another component to the spring upswing in visibility degradation is meteorological. In the spring, relative humidity increases, which increases the light-scattering efficiency of sulfate. Also, the sun, which has been nearly absent in the winter months, returns quickly in the spring, increasing daylight by as much as seven minutes a day, this in turn increases photochemical oxidation of components such as sulfur dioxide.

The Alaska Department of Environmental Conservation attempted to look at the effect of meteorology at the monitoring site on the concentrations and types of pollutants found on the filters. The meteorological data used came from the NPS met monitoring site located only a few feet from the IMPROVE monitors at Denali National Park Headquarters site. The analysis of this data showed nothing other than simple seasonal trends, i.e. when the temperatures were warm, we had high instances of fire components, and it is already known that the fire season is in the summer when temperatures are warm (Figs. 8 and 9). The factors involved in this assessment included temperature, wind speed and direction, rainfall, amount of solar radiation, and relative humidity, all of which involve strong seasonal variations.

**Figure 8. IMPROVE Visibility Data per Month from 3/2/1988 to 2/26/2000**

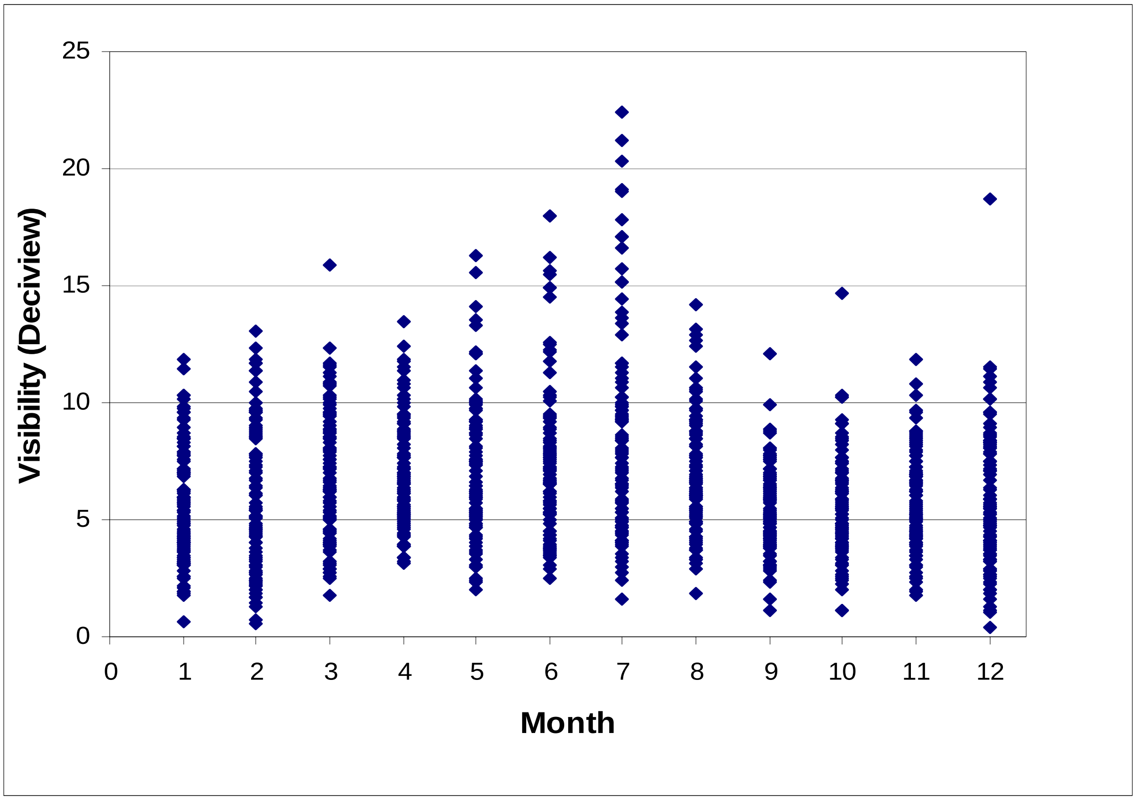
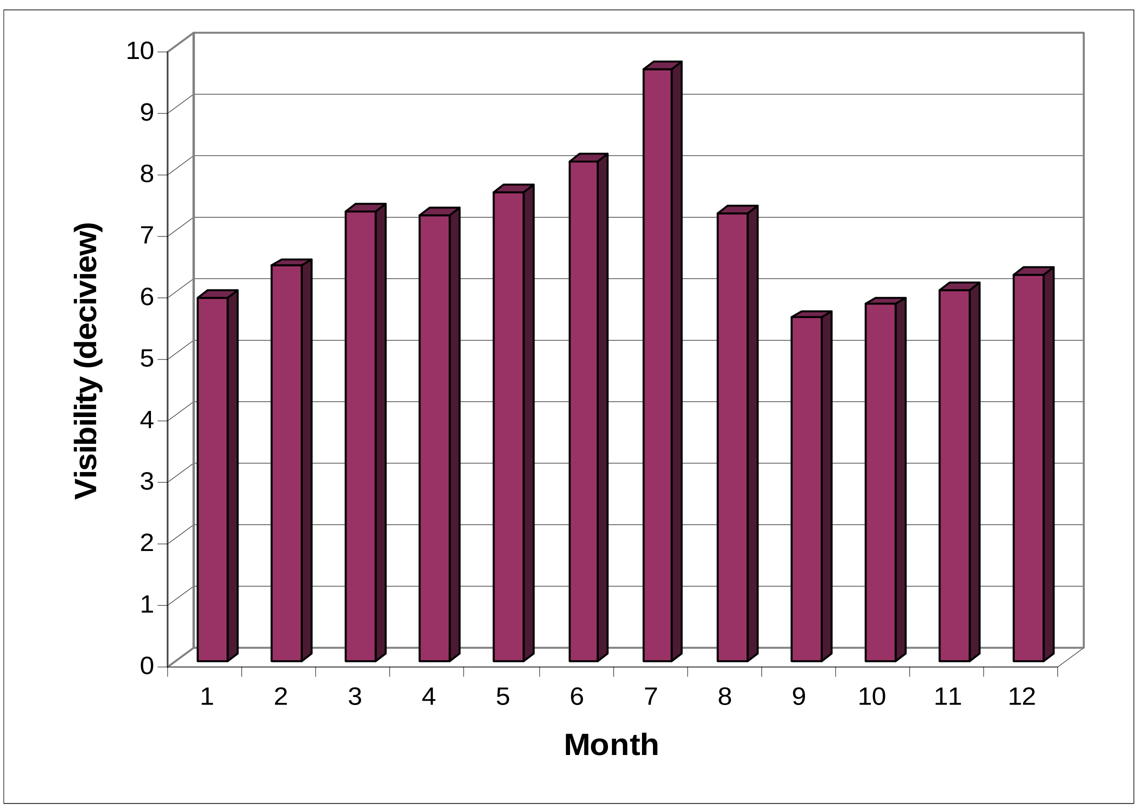


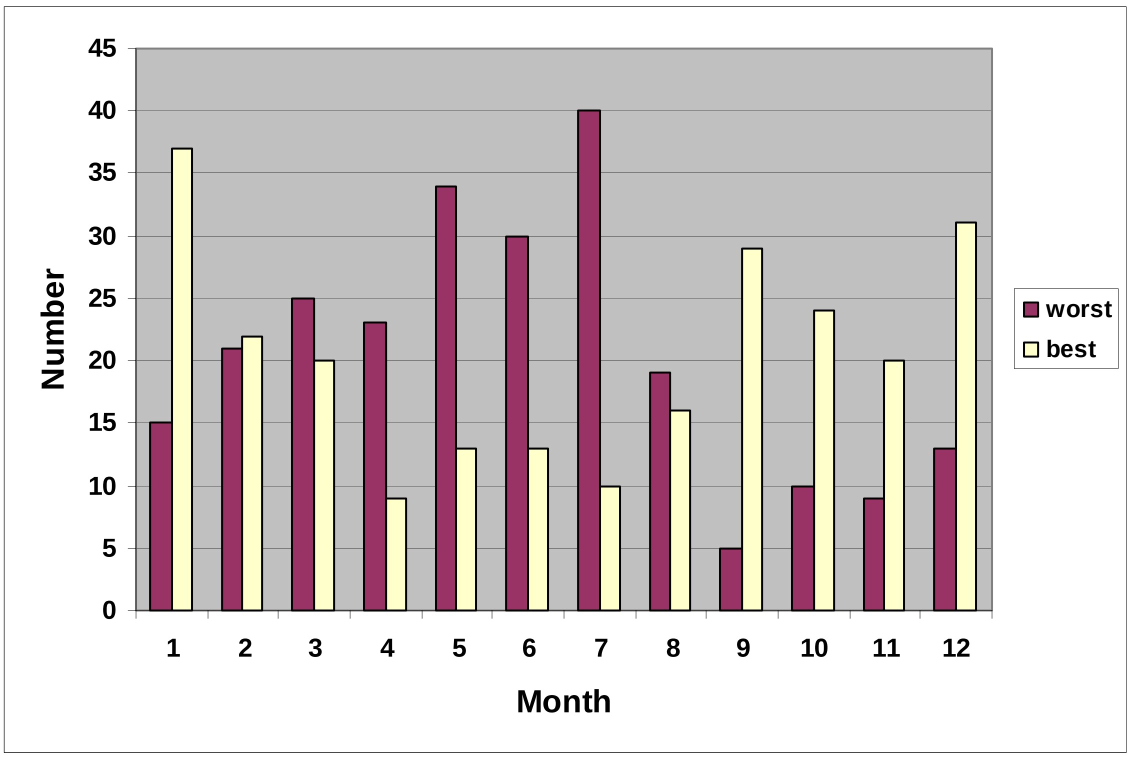

**Figure 9. Average Deciview per Month for IMPROVE Data from 3/2/1988 to 2/26/2000**



### 3.3 Best and Worst Days

The Regional Haze Rule bases progress off of trends in the days with the highest 20% deciview reductions in visibility (worst) and the days with the 20% lowest deciview reduction. These have been calculated for each full year of analyzed data, and were used to compare everything from transport patterns to meteorology. In Alaska, the worst days are most frequently seen in the summer when fire appears to be the most significant source. The best days tend to occur in the autumn and winter (Fig.10). A statistical test, called a t-test, was used to compare the average values for each component on the best days with the average values for each component on the worst days. The worst days were found to be higher in every case to a very high degree of statistical confidence.

**Figure 10. Number of Best and Worst Days by Month**



### 3.4 Trajectories

Using the IMPROVE data from Denali National Park and Preserve and an Excel spreadsheet[iii] that calculated visibility reduction in deciviews, the ADEC calculated the 20% best and 20% worst days for each of the years from 1988 to 1999. With the aid of the National Oceanic and Atmospheric Administration (NOAA) HYSPLIT[iv] model, ADEC obtained back trajectories for each of the best and worst days at five terminating altitudes. The five altitudes are 10, 100, 500, 1000, and 3000 meters above ground level, and the trajectories traced the air back for 315 hours from 0h GMT[v] on the date measured at Denali. A portion of these trajectories was organized by the originating country (tables 4 and 5) and the point at which they crossed the border into the state of Alaska (Figures 11 & 12, and Appendix A). Due to time constraints, ADEC has not inventoried all trajectories in this manner at this time. These particular trajectories were selected in order to show changes over time (oldest and newest analyzed data sets) and because of a below or above average standard deviation in that particular year's data.

For the 20% of the days with the best visibility (best days) the trajectories mainly came from over the Pacific Ocean (30.06 %) and Russia (24.25 %), as well as over the Arctic Ocean (14.63 %). The trajectories with marine origins seem to have come from Russia or other parts of Asia before moving over water. On the 20% of the days with the worst visibility (worst days) the predominant origins were also the Pacific Ocean (28.14 %), Russia (20.24 %), and the Arctic Ocean (17.00 %). The Bering Sea was a relatively close fourth most frequent origin on the worst days (13.97 %). Again, the trajectories with origins over the water seem to come from Russia or other parts of Asia. As a result of the similarities in the origins of the best and worst days, it seems the trajectory inventory suggests mainly the predominant weather patterns, rather than a difference between the origination of the best and worst days.

With regards to the points of entrance, the south and southeast dominate. On the best days, roughly 60 percent of the trajectories entered Alaska from one of those directions. However, on the worst days more trajectories had non-southern entrance points. Approximately 40 percent of the worst day trajectories entered Alaska from the south or southeast. Because this is only a very simplified approach, there is no way to rule out most areas as being potential sources for transport of pollution into the Denali Class I area on the worst visibility days. The use of a more complex and accurate model on which to base the idea of transport pollution origins appears warranted. More refined analyses are needed and comparisons of back trajectories to known events need to be made. This would help to provide some confidence that the back trajectory model is performing adequately.

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[iii] designed by Bret Schichtel from the Cooperative Institute for Research in the Atmosphere (CIRA) at the University of Colorado

[iv] HYbrid Single-Particle Lagrangian Integrated Trajectory

[v] 3pm Alaska Standard Time, or 4pm during Daylight Savings

**Table 4. Tally of Points of Origin of Air Masses for the Cleanest 20% of Days for the Years 1988, 1993, 1995, 1998, 1999 at Five Ending Altitudes**

| | # at 10 meters | # at 100 meters | # at 500 meters | # at 1000 meters | # at 3000 meters |
|---|---|---|---|---|---|
| **Alaska** | 10 | 4 | 10 | 7 | 2 |
| **Arctic Ocean** | 22 | 20 | 12 | 9 | 10 |
| **Atlantic Ocean** | 0 | 0 | 1 | 0 | 5 |
| **Bering Sea** | 1 | 5 | 8 | 7 | 6 |
| **Canada** | 11 | 14 | 12 | 4 | 1 |
| **China** | 0 | 0 | 0 | 0 | 3 |
| **Europe** | 0 | 0 | 0 | 0 | 5 |
| **Greenland** | 1 | 0 | 0 | 1 | 2 |
| **Iran** | 0 | 0 | 0 | 0 | 2 |
| **Iraq** | 0 | 0 | 0 | 0 | 1 |
| **Japan** | 0 | 0 | 1 | 0 | 1 |
| **Kazakhstan** | 0 | 0 | 0 | 0 | 7 |
| **Kyrgyzstan** | 0 | 0 | 0 | 0 | 1 |
| **Mongolia** | 0 | 0 | 0 | 0 | 2 |
| **North Korea** | 0 | 0 | 0 | 0 | 1 |
| **Pacific Ocean** | 38 | 36 | 24 | 33 | 19 |
| **Russia** | 15 | 16 | 27 | 35 | 28 |
| **Sea of Okhotsk** | 1 | 1 | 2 | 2 | 3 |
| **South Korea** | 0 | 0 | 0 | 0 | 1 |
| **United States** | 1 | 4 | 3 | 1 | 0 |

**Table 5. Tally of Points of Origin of Air Masses for the 20% of Days with Worst Visibility for the Years 1988-1991, 1999 at Five Ending Altitudes**

| Points of origin | # at 10 meters | # at 100 meters | # at 500 meters | # at 1000 meters | # at 3000 meters |
|---|---|---|---|---|---|
| **Alaska** | 5 | 5 | 6 | 7 | 5 |
| **Arctic Ocean** | 29 | 21 | 15 | 11 | 8 |
| **Bering Sea** | 15 | 17 | 14 | 13 | 10 |
| **Canada** | 6 | 9 | 11 | 12 | 3 |
| **China** | 0 | 0 | 1 | 2 | 2 |
| **Europe** | 0 | 2 | 3 | 2 | 2 |
| **Greenland** | 1 | 1 | 1 | 1 | 1 |
| **Kazakhstan** | 0 | 0 | 0 | 0 | 1 |
| **Mongolia** | 0 | 0 | 0 | 0 | 1 |
| **Norway** | 0 | 0 | 0 | 0 | 1 |
| **Pacific Ocean** | 29 | 23 | 30 | 31 | 26 |
| **Russia** | 12 | 17 | 17 | 18 | 36 |
| **Sea of Okhotsk** | 1 | 2 | 0 | 0 | 1 |
| **United States** | 1 | 2 | 1 | 1 | 2 |

**Figure 11. Best Days' Points of Entrance into Alaska**

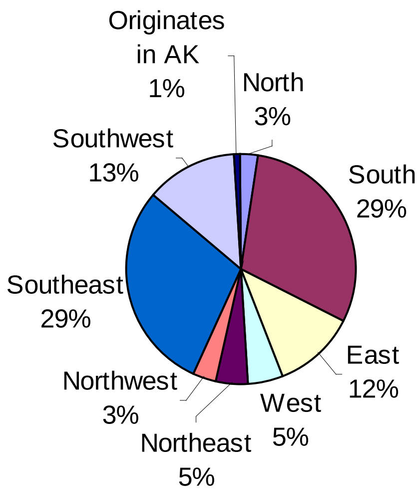
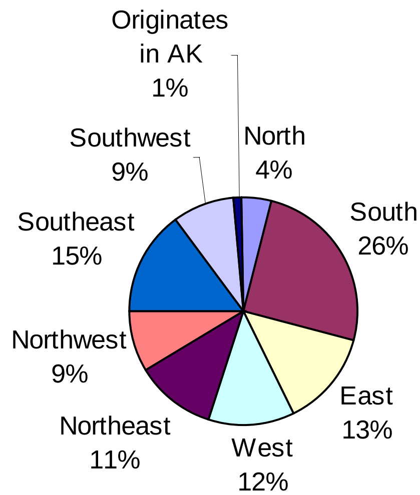



**Figure 12. Worst Days' Points of Entrance into Alaska**



### 3.5 Natural and Baseline Conditions

The goal of the regional haze program is to improve visibility and prevent future visibility impairment in all of the mandatory Class I areas. The Regional Haze Rule requires that states develop plans that include reasonable progress goals for improving visibility in Class I areas to natural conditions by 2064. Natural visibility conditions are meant to represent the long-term visibility in Class I areas without man-made impairment. Based on a calculation of the natural condition in deciviews, baseline conditions can be compared to natural allowing for a rate of progress to be established for tracking progress toward meeting the goal of natural conditions. Based on the draft Environmental Protection Agency guidance documents,[46,47] natural conditions and baseline conditions were calculated for Denali National Park and Preserve. Since no monitoring data was available until very recently for the other three Alaskan Class I areas, a comparison of baseline conditions to natural conditions cannot be made for them at this time. However, EPA’s draft default process for calculating natural conditions can be used to estimate natural conditions in Simeonof and Tuxedni.

The default approach provided in the guidance was followed for the calculation of the natural conditions at the three monitored Alaskan Class I areas (see calculation B-1 in Appendix B). The same guidance document states that the average best and worst natural visibility days can be estimated by performing 10$^{th}$ and 90$^{th}$ percentile calculations on the above calculation for average natural conditions. The estimate of annual average natural conditions in deciview units, as well as estimations for the average 20% best and worst average days for Denali, Simeonof, and Tuxedni can be found in Table 6 below.

**Table 6. Calculated Values for Estimating Natural Visibility in Deciviews**

| | Average | 10$^{th}$ percentile (20% best) | 90$^{th}$ percentile (20% worst) |
|---|---|---|---|
| **Denali** | 4.68 | 2.12 | 7.24 |
| **Tuxedni** | 5.00 | 2.44 | 7.56 |
| **Simeonof** | 5.34 | 2.78 | 7.90 |

Baseline and current conditions for Denali National Park and Preserve were obtained from the Visibility Information Exchange Web System (VIEWS). The EPA and five Regional Planning Organizations established VIEWS to facilitate the exchange of data and ideas related to the improvement of visibility and air quality. This is the site that contains all of the IMPROVE monitoring data and summary information. Since monitoring data is not yet available for the entire baseline period of 2000-2004, the most recent five-year period of analyzed data, 1995-1999, was used. The baseline and current condition for the 20% most impaired days at Denali was 9.7 deciviews. The baseline and current condition for the 20% least impaired days at Denali was 3.5 deciviews.

Based on the baseline/current conditions and the estimate of natural conditions (for the 20% worst days), the preliminary rate of progress for the period 2004 to 2018 would be 0.04 deciview per year or 0.57 deciview for the entire, 14-year, planning period (See Appendix B calculation B-2). This rate will need to be re-calculated for the rule’s baseline period of 2000-2004, but should provide some indication of the relative level of progress that will be required for Denali National

Park and Preserve in the Alaska SIP. Calculations of baseline conditions and rates of progress will also need to be made for the Simeonof and Tuxedni Wilderness Areas.
Clearly, the Denali National Park and Preserve data indicates that visibility in the area is close to the natural condition goal. Given the low level of impact observed in the Denali Class I area, estimation errors in technical analyses could become more important. For this reason, it may be prudent to consider an alternative approach for determining natural conditions; this would require further analysis and study. More widespread monitoring is needed, particularly to characterize fire emissions and international transport. Once these sources are more completely understood, they can be removed from current monitoring and the natural background, as well as the baseline and the progress, will be more precise.

Another detail that is clouding the knowledge base is the misrepresentation of relative humidity in cold climates. It is not an adequate measure of the levels of moisture in the air due to the lack of water that air is capable of holding at extremely low temperatures. Because of the nature of the relative humidity calculation, which is a ratio of water in the air to the maximum amount of water the air can hold at that temperature, amount of water in the air is misrepresented. Even if the meteorology shows 90% humidity on a given day at –40°F/°C, there is actually very little water, and almost all of it is frozen. One possible way to address this would be to modify the calculations for light extinction to utilize absolute humidity instead.

## 4.0 LOCAL REGIONS/SOURCES

### 4.1 BART

Alaska has an estimated twenty-one BART eligible sources located throughout the state. These sources are listed in table 7 and in the following map (Fig. 13). Fifteen of the twenty-one facilities are fossil fuel fired plants with the remainder being petroleum refineries and storage and transfer facilities, a sulfur recovery plant and a chemical processing plant. All of the potential BART sources are located near the two largest cities in Alaska, Anchorage and Fairbanks. Denali National Park and Preserve and Tuxedni Wilderness Area are in the closest vicinity of the BART sources. Tuxedni is situated less than seventy-five miles from the closest source and Denali is less than 5 miles. The Bering Sea Wilderness Area is over three hundred miles from any of the BART-eligible sources and Simeonof Wilderness Area is almost two hundred miles from the nearest BART-eligible source.

**Figure 13.**

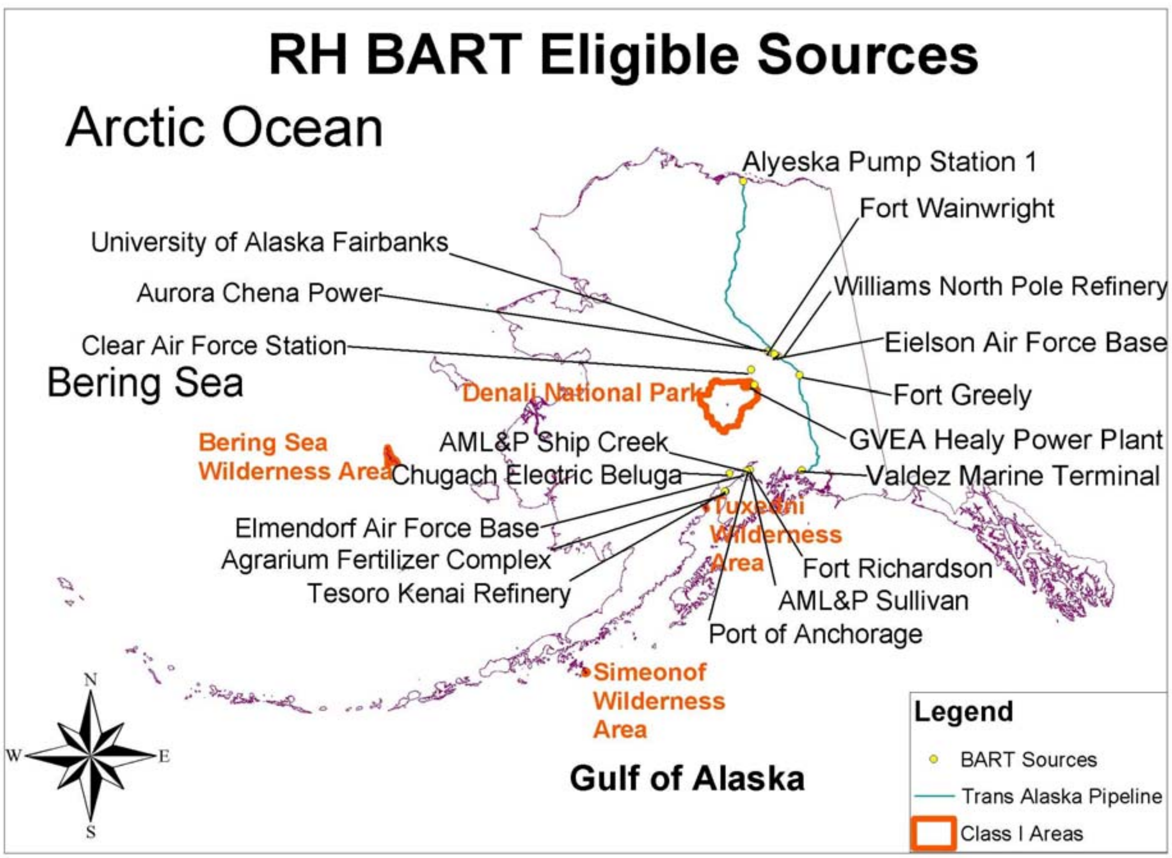


**Table 7. Potential BART Eligible Sources**

| |
|---|
| **Fossil-fuel fired steam electric plants of more than 250 million BTU per hour heat input** |
| Aurora Energy Chena Power Plant |
| Anchorage Municipal Light and Power Plant 2 |
| US Army Ft. Richardson (Scheduled for shutdown 2003) |
| US Army Ft. Wainwright |
| US Army Ft. Greely (Inadequate records, may be under 250 MMBtu/hr) |
| USAF Elmendorf AFB |
| USAF Eielson AFB |
| USAF Clear Air Station |
| Anchorage Municipal Light and Power Sullivan |
| Chugach Electric Beluga (combined cycle waste heat recovery combustion turbine) |
| University of Alaska Fairbanks |
| Ship Creek Power LLC., Knik Arm Power Plant (currently shut down and not permitted, but plans are to repower the unit) |
| Golden Valley Electric Cooperative Healy Power Plant (Note: Unit 2 HCCP went through PSD in 1994) |
| **Petroleum Refineries** |
| Tesoro Kenai Refinery (went through subsequent NSR/PSD permitting for facility modifications) |
| Williams Alaska North Pole Refinery (went through subsequent NSR/PSD permitting for facility modifications) |
| **Sulfur recovery plants** |
| Tesoro Kenai Refinery |
| **Chemical processing plants** |
| Agrium Nikiski Fertilizer Complex |
| **Fossil-fuel fired boilers of more than 250 million BTU per hour heat input** |
| Agrium Nikiski Fertilizer Complex |
| (Aggregate) Alyeska Pipeline Service Company Valdez Marine Terminal |
| **Petroleum storage and transfer facilities with a capacity exceeding 300,000 barrels** |
| APSC Pump Station 1 |
| Williams Alaska Petroleum Port of Anchorage |
| Tesoro Alaska Port of Anchorage (Inadequate records, may be under 300,000 barrels) |
| Defense Fuels Port of Anchorage (Inadequate records, may be under 300,000 barrels) |
| Alyeska Pipeline Service Company Valdez Marine Terminal |

### 4.2 Communities near the Class I Areas

The communities that are in close proximity of the Class I areas, with the exception of Anchorage and Fairbanks, are small communities, many not on the road system, with populations ranging anywhere from 22 to 7,000. The population of Anchorage and Fairbanks are 260,000 and 29,000 respectively (population of Fairbanks North Star Borough is 83,000). The tables below show the populations[48] of the communities within 100 miles of each of the Class I areas (Appendix C). There are no communities within 200 miles of the Bering Sea Wilderness Area; the closest mid-size communities are Nome and Bethel each approximately 350 miles to the northeast. With few major point sources in the rural areas, the majority of emissions in these small communities come from non-road, area, and mobile sources.

**Table 8.**

| **Communities within 100 Miles of Denali and their Population** | | | | |
|---|---|---|---|---|
| Anchorage | 260,283 | | McGrath | 401 |
| Fairbanks | 30,224 | | Eklutna | 394 |
| Wasilla | 5,469 | | Tanana | 308 |
| Palmer | 4,533 | | Fox | 300 |
| Big Lake | 2,635 | | Minto | 258 |
| Ester | 1,680 | | Cantwell | 222 |
| Willow | 1,658 | | Chickaloon | 213 |
| North Pole | 1,570 | | Tyonek | 193 |
| Houston | 1,202 | | McKinley Park | 142 |
| Sutton-Alpine | 1,080 | | Skwentna | 111 |
| Healy | 1,000 | | Nikolai | 104 |
| Delta Junction | 840 | | Manley Hot Springs | 72 |
| Talkeetna | 772 | | Susitna | 37 |
| Big Delta | 749 | | Lake Minchumina | 32 |
| Knik | 582 | | Petersville | 27 |
| Anderson | 513 | | Medfra | 0 |
| Nenana | 486 | | Poorman | 0 |

**Table 9.**

| **Communities within 100 Miles of Tuxedni and their Population** | | | | |
|---|---|---|---|---|
| Kenai | 6,942 | | Nondalton | 221 |
| Nikiski | 4,327 | | Tyonek | 193 |
| Homer | 3,946 | | Nanwalek | 177 |
| Soldotna | 3,759 | | Kokhanok | 174 |
| Anchor Point | 1,845 | | Clam Gulch | 173 |
| Salamatof | 954 | | Port Graham | 171 |
| Ninilchik | 772 | | Newhalen | 160 |
| Kasilof | 471 | | Port Alsworth | 104 |
| Kachemak | 431 | | Iliamna | 102 |
| Cooper Landing | 369 | | Pedro Bay | 50 |
| Nikolaevsk | 345 | | Portlock | 0 |
| Seldovia | 286 | | | |

**Table 10.**

| Communities within 100 Miles of Simeonof and their Population | | | | |
|---|---|---|---|---|
| Sand Point | 952 | | Ivanof Bay | 22 |
| Chignik Lake | 145 | | Port Moller | 0 |
| Perryville | 107 | | Squaw Harbor | 0 |
| Chignik | 79 | | Unga | 0 |

### 4.3 Fire

Fire is a large source of emissions in Alaska averaging anywhere between 350-800 fires per year. The 10-year average for the 90's was 630 fires per year for 978,000 acres burned[49]. Forest fires generally occur between March and October each year with the major cause of fires being lightning in Interior Alaska and the typical "human-caused" in more populated parts of Alaska[50]. There are numerous factors that affect wildfire intensity including weather and fuel conditions, such as moisture content in vegetation or depth of vegetative mat[51]. Table 11 shows the number of fires and the acres burned from 1990 though 2001[52].

**Table 11. Number of Fires and Acres Burned 1990-2001**

| Year | # of Fires | Acres Burned |
|---|---|---|
| 1990 | 802 | 3,189,427.4 |
| 1991 | 760 | 1,750,653.2 |
| 1992 | 474 | 135,360.3 |
| 1993 | 869 | 713.116.7 |
| 1994 | 643 | 265,721.6 |
| 1995 | 421 | 43,965.8 |
| 1996 | 724 | 599,267.1 |
| 1997 | 773 | 2,026,899.3 |
| 1998 | 413 | 120,751.8 |
| 1999 | 486 | 1,005,428.0 |
| 2000 | 369 | 756,296.2 |
| 2001 | 351 | 218,113.9 |

# 5.0 FUTURE WORK

This report provides information on the current research, air monitoring, local sources, and haze analyses for Alaska. The research and analyses are useful in guiding the development of the technical information needed for development of a regional haze plan. Additional technical analyses are needed to answer many questions about haze in Alaska and the need for controlling air pollution. The future work identified and included in this section relates to emission inventory, monitoring, modeling, analysis of control strategies, and refined analysis of natural conditions. This additional technical work is an important component of developing a reasonable, rational approach to mitigating regional haze impacts in Alaska.

## 5.1 Emission Inventory

The emission inventory is a key component of the Regional Haze Rule that will help to determine the goals and strategies needed for the rule's implementation. A statewide inventory of emissions is required for pollutants that are reasonably anticipated to cause or contribute to visibility impairment in any Class I area. Currently Alaska does not possess a coordinated statewide inventory of source specific emission estimates. Instead, emission inventories have been developed as needed to support the development of state implementation plans (SIP's) and related maintenance plans for communities designated as non-attainment for specific criteria pollutants.

Due to Alaska's large area of 656,424 square miles, the development of a statewide emission database is a complex and difficult task. Alaska is approximately one-fifth the size of the lower 48 states. There is currently little information compiled regarding air-polluting activities in Alaska. Because of a lack of readily available data and information, significant effort and cost would be incurred in developing a statewide inventory.

•

The pollutants that need to be inventoried in order to comply with the Regional Haze Rule include volatile organic compounds, nitrogen oxides ($NO_x$), elemental carbon, organic carbon, fine particulate ($PM_{2.5}$), coarse particulate ($PM_{10}$), sulfur oxides ($SO_x$), and carbon monoxide (CO). An emission inventory preparation plan has been developed to serve as a guide for development of the emission inventory. Due to resource constraints, Alaska will likely need to phase its inventory efforts.

Regardless of the approach taken, the aforementioned lack of available resources will have an impact on the final inventory that is developed. Decisions will need to be made as to whether activity data collection is warranted for various source categories, or whether other "top-down" approaches will suffice. In addition, decisions may be needed regarding which emission factors to use if no specific factor is available. Despite the many concessions and assumptions that will need to be made, it is important that we have a reasonable emission inventory for use in technical analyses. A lack of reasonable data to use in modeling could lead to erroneous conclusions related to controlling emission sources.

Alaska will need to collect data on emission-generating activities and emission factors. Specific sources that will be inventoried include mobile sources; stationary sources; area sources, such as road dust, construction activities, fire emissions; and biogenic sources that include natural windblown dust, wild fire smoke, and vegetative emissions. Studies may need to be designed and funded to refine emission factors for certain sources (such as biogenic sources) that have not been inventoried in the past and for which no emission factors exist.

Trans-boundary emissions also need to be inventoried to determine the emissions from other countries that impair visibility in Alaska's Class I areas. We anticipate that Canada will be the only nation providing Alaska with emissions information. Therefore, Alaska desires to establish monitoring sites placed strategically on the Alaskan perimeter to capture the contributions from any international sources.

Once the emission inventory and calculations are complete, staff will continue to track emissions to demonstrate that reasonable progress goals are being met for Class I areas. This emission data will be used in a modeling demonstration to show there will be improvement on the worst days and no degradation on the best days.

### 5.2 Monitoring

*Trans-boundary monitoring*
Unlike the states in the contiguous U.S., Alaska borders no other states. Instead, we have direct impacts from Russia, other parts of Asia, Europe, and Canada. Due to the winter conditions at high latitudes (like Denali), namely a lack of sunlight and liquid water, expected atmospheric chemical reactions do not occur. This causes emissions which have been transported hundreds or thousands of miles to appear in analyses as though from a local source. Since foreign emissions are out of Alaska's control, the effect of these emissions must be isolated and essentially considered background. This can be accomplished by monitoring the boundary areas to determine what is transported into the state.

In consideration of Alaska's international boundaries, there has been some preliminary discussion regarding placement of monitors on the Canadian border and in western Alaska near the Russian border. Modeling will be used to show locations on each border that can provide the most useful information in terms of international emissions transport. Concern has been expressed over the ability to discern what portion of the emissions that cross into Alaska's borders will actually reach a Class I area. One option that has been proposed is to place monitors on the periphery of the parks, but this will do little to distinguish international sources from those within Alaska or the other states in the US. It seems that a combination of border monitoring and modeling will provide the most information into this issue.

Alaska's four Class I areas are separated by hundreds of miles and represent different ecosystems. Because of these vast distances and complicated logistics for such remote areas, simultaneous monitoring of all four regions would present a significant strain on personnel and funds. The State of Alaska therefore proposed to EPA a phased approach where we would focus our monitoring efforts on characterizing one Class I area at a time and sequentially move the instruments to the next area after completion of each field season. The first phase of this approach would be the assessment of the Denali National Park and Preserve Class I area.

*Transport*
Given the potential for Arctic Haze and Asian dust events to impact Alaska's Class I areas, Alaska needs to evaluate the impacts of internationally transported pollutants in the regional haze planning process. Data from the Denali Class I area indicates that the visibility conditions in the

park are close to natural. Because the concentrations of pollutants are generally low, internationally transported pollution becomes a more important component to consider in determining what controls will be effective for improving visibility in the Class I areas and the rate of improvement that can be expected at each area.

Since foreign emissions are out of Alaska's control, the effect of these emissions must be isolated and essentially considered separately from controllable emissions within the Regional Haze SIP. The two primary ways to evaluate these pollutants are through monitored data or through the use of emissions information and modeling. At this time, it is unlikely that Alaska will obtain emission inventory information from other countries to use in regional haze analyses. However, Alaska could isolate and address international transport of pollution by monitoring for visibility impairing pollutants being transported across international boundaries into Alaska's Class I areas.

*Remote monitoring*
Resources at UAF have a monitor, the DELTA-DRUM sampler, suitable for remote locations that the ADEC is considering for use at the less accessible areas. This sampler has successfully been used in several remote locations in Alaska and will prove to be a valuable resource for capturing trans-boundary emissions. Their benefits are that they are small, portable, and can operate at low temperatures; Alaska's interior winter temperatures frequently dip below –40˚F to –50˚F. Additionally, they are able to be run off of battery, solar, or wind power, none of which would bias the sample with its own emissions.

*CASTNet*
A CASTNet style monitor is currently co-located with the Denali IMPROVE monitor at the Trapper Creek site. It will be useful to see how the data from these two monitors compare to one another and if the CASTNet can be used as a surrogate for the IMPROVE monitor. Another CASTNet style monitor is located at Poker Flat research range, north of Fairbanks. This is the only monitor collecting samples in this region and can be used as an additional source of data identifying pollutants approaching Denali from the north.

*Fire*
Another issue that Alaska must address is forest fire emissions. The fires are predominantly from natural sources, occur randomly, and are in remote locations; consequently, they are beyond reasonable human control. Since fire emissions are such a large contributor to regional haze in Alaska, a thorough emissions inventory in combination with modeling and monitoring is necessary to make discerning natural background possible. The random nature of fire events in modeling will be an important issue. The rate of progress will not be determinable until natural background can be established.

Although some research has been done on the emissions from forest fires in Alaska through a July 1999 research project called FrostFire, the burn was not as extensive as was originally planned. While 2,200 acres were expected to burn only 800 were actually burned. The amount of emissions was insufficient to conduct a reliably informative study. One possible new opportunity to characterize the emissions has presented itself. The Geophysical Institute of the University of Alaska, Fairbanks has been building a portable LIDAR (Laser RADAR) which will be field tested by December 2002 in the Fairbanks area. It is possible that the LIDAR may be able to characterize fire emissions. If the LIDAR can be used to track fire emissions, and if funding becomes available, it would be desirable to take this LIDAR to an Alaskan forest fire and look at not only the composition, but also the transport of the emissions.

*North Side of Denali*
Although there are two monitors keeping track of pollutant contributions at Denali National Park and Preserve, the terrain and climactic differences of the vast park warrant consideration of more sites. Natural boundaries such as the Alaska Range cause meteorological and pollutant composition differences all over the park. A boundary such as this can be enough of a barrier that it is unlikely that the composition and extent of the haze on either side is similar, and therefore one or two air samplers are inadequate to monitor the entire Class I area. A site on the north side of the park would assist in characterizing pollutants impacting visibility on the north side of the Alaska Range. If funding is found, it would be important to consider installation and operation of a northern site.

## 5.3 Modeling

While modeling is only explicitly referenced in two sections of the Regional Haze Rule (308(c)(ii) and 308 (d)(3)(iii)), it is a critical technical step in meeting many of the planning requirements under the rule. Models will be needed for control strategy development and optimization, analysis of incremental impacts of individual source categories, and analysis of cumulative impacts. In order for modeling analysis to be relevant to Alaskan planning, it is important that the models used are capable of adequately characterizing the unusual conditions found in Alaska, such as a lack of light and low humidity at Denali National Park in the winter months. There are several key data inputs needed to complete regional haze modeling, including meteorological information and emissions information.

In addition to the need for developing meteorological and emissions information, a suitable modeling approach is needed to assist in development of the Alaskan SIP. It is not clear at this time, what modeling approach will be reasonable and approvable by EPA. Options include:

- Simple stationary source modeling
- Modeling back trajectories
- Regional scale modeling

Alaska poses some unique challenges for regional modeling. It is geographically large, but has relatively sparse sources in much of the state. The meteorology of Alaska is also unique. International transport of air pollutants into Alaska from Eurasia is a significant issue. The two largest Alaskan cities, Anchorage and Fairbanks, are in relatively close proximity to two of Alaska's Class I areas. The other two Class I areas are relatively isolated from the major source regions in Alaska. These issues may drive the types of models used in Alaska's regional haze planning.

A brief discussion of the various modeling options and the work associated with them are presented as follows:

<u>Meteorological Modeling:</u> It is not clear if the current MM5 meteorological model will adequately represent meteorological conditions in Alaska. Work is needed to run the model and determine

whether it generates meteorological information that is usable for Alaska's SIP planning. The meteorological field development will be complex and must handle flows in complex terrain combined with marine influences. The terrain in the area from Tuxedni to Denali varies from sea level to 20,000 feet. The development of meteorological information is a key first step in allowing any other modeling to move forward.

Simple Stationary Source Modeling: While Alaska continues to work toward development of the capability for full-scale, complex regional modeling, more simplistic modeling could be initiated for many of the more important sources near the Class I areas. This modeling could be accomplished using established models such as ISC and CalPuff. This could provide some information on the potential impacts of certain sources to specific Class I areas.

Modeling Back-Trajectories: In order to assist in a basic understanding of where haze generating pollutants are originating, back trajectory modeling could be undertaken for selected pollutant events monitored at the Class I areas. Back trajectory modeling could allow for a better understanding of the sources and areas that generate pollution coming into the Class I areas. Standard models, such as HYSPLIT, could be used for this analysis. MM5 can also be used in generating back trajectories.

Full-Scale Regional Modeling: Initially, work would need to be completed to select a suitable regional model for use in Alaska, most likely EPA's Community Multi-Scale Air Quality (CMAQ) model. Some initial work would be needed to look at whether or not the model is capable of handling typical conditions found in Alaska. These conditions could include lack of sunlight in the winter, abundance of sunlight in the summer, dry climate areas, terrain, international transport of pollutants, etc. If the model has deficiencies, a decision would need to be made whether to proceed with the analysis or to conduct work to improve the models to correct the problems. Any revisions needed to the model would need to be addressed collaboratively with EPA.

Once the initial model inputs are developed and an appropriate model is selected, an initial run of the selected regional model would be made using the meteorological and emission information developed previously. This initial run would be used to look for important emission sources and to ground truth the reasonability of the model under Alaskan conditions. The model would need to undergo calibration and verification. Following any refinements, a base case would be run for each of Alaska's Class I areas. Once the base cases have been completed, the model would be run to project the impacts of controls over the required time period. This will provide the information needed to demonstrate how the Alaska control plan meets the progress goals. There will likely be several iterations of these modeling runs as control strategies are considered and assessed.

### 5.4 Potential Control Strategies

At this time, it is unclear what sources will be most important in Tuxedni, Simeonof, and Bering Sea. This makes it impossible to determine the most important strategies to consider in improving visibility in these areas. Given the data for the Denali site, however, two strategies may prove important in developing a regional haze plan for the Class I area. The first strategy that should be considered is smoke management and the second is control of stationary sources. Both of these control programs are currently required measures under the Regional Haze Rule, but each will require further analysis to determine whether the specific details of the programs under consideration are appropriate and warranted in achieving regional haze goals in Denali. It is not yet clear whether other control strategies will be necessary to achieve visibility goals within the Class I areas. Any additional strategies will need to be analyzed to determine their benefits and feasibility for implementation in Alaska.

*Smoke Management*

Fire appears to play an important role in visibility impairment on the worst 20% visibility days in Denali, particularly in the summer months. A smoke management plan will likely be an important component of the regional haze plan. Developing appropriate methods for minimizing and managing emissions from fire will be critical to achieving improvement on the worst visibility days.

A Smoke Management Plan (SMP) is currently being drafted by ADEC to assist Alaska with smoke and burning issues. The SMP will help determine how to manage smoke-related issues that impact Class I areas, as well as the rest of the state, and what control measures are feasible to manage fire emissions. The SMP will be developed in coordination with the Alaska WildLand Fire Coordinating Work Group (AWFCWG) and FLM fire coordination personnel. The AWFCWG consists of state and federal agencies that work on fire-related issues in Alaska. It is anticipated that, once finalized, this plan will become an integral part of the first Regional Haze SIP submittal.

*Stationary Source Control*

In the winter when Arctic Haze impacts are more prevalent, there is also the potential that emissions from stationary sources within Alaska are impacting the Denali Class I area. It is difficult to distinguish between the pollution that is being transported from international industrial sources and similar sources within Alaska. Analysis is needed to determine the contribution of Alaskan stationary sources to visibility impacts and whether controls are needed to achieve visibility improvement on the 20% most impaired days and maintain visibility on the 20% least impaired days.

In the summer 2002 court decision on the American Corn Growers case against EPA[53], the regional haze provisions that address Best Available Retrofit Technology (BART) for certain stationary sources were struck down and remanded back to EPA. While the status of the final BART provisions are not clear at this time, Alaska may need to assess the impacts of certain stationary sources on Class I areas within the state. As discussed previously, twenty-one sources have been preliminarily identified as potentially subject to BART provisions of the rule. These sources would need to be analyzed and controlled in accordance with any final rules promulgated by EPA.

## 5.5 Calculation Modifications

Because Alaska's current levels of visibility reduction are so low, every approximation in monitoring or calculation presents an opportunity for a gross misrepresentation of conditions here. The EPA allows for a refined approach to the calculations for natural background and tracking progress[54,55]. This may be something that the state of Alaska should pursue, since an approach more specific to Alaska's needs and conditions would more precisely characterize the conditions in the state.  One specific problem that it would help to address is the distortion of the relative humidity calculation in cold climates due to the lack of water that air is capable of holding at extremely low temperatures.  Because of the nature of the relative humidity calculation, which is a ratio of water in the air to the maximum amount of water the air can hold at that temperature, amount of water in the air is deceptive.  Even if the meteorology shows 90% humidity on a given day at –40°F/°C, there is actually very little water, and almost all of it is frozen.  One possible way to address this would be to modify the calculations for light extinction to utilize absolute humidity instead.

# Appendix A

**Table A-1: Tally of Entrance Points of Air Masses for the Cleanest 20% of Days for the Years 1988, 1993, 1995.**

**Table A-2: Tally of Entrance Points of Air masses for the 20% of Days with Worst Visibility for the years 1988-1991, 1999 at Five Ending Altitudes.**

**Table A-1. Tally of Entrance Points of Air Masses for the Cleanest 20% of Days for the Years 1988, 1993, 1995, 1998, 1999 at Five Ending Altitudes**

| | # at 10 meters | # at 100 meters | # at 500 meters | # at 1000 meters | # at 3000 meters |
|---|---|---|---|---|---|
| **North** | 2 | 2 | 4 | 3 | 2 |
| **South** | 24 | 24 | 27 | 32 | 42 |
| **East** | 18 | 22 | 9 | 6 | 3 |
| **West** | 2 | 5 | 1 | 6 | 10 |
| **Northeast** | 11 | 5 | 5 | 2 | 0 |
| **Northwest** | 4 | 2 | 4 | 2 | 4 |
| **Southeast** | 27 | 27 | 38 | 34 | 21 |
| **Southwest** | 11 | 11 | 12 | 14 | 18 |
| **Originates in AK** | 1 | 2 | 0 | 1 | 0 |

**Table A-2. Tally of Entrance Points of Air Masses for the 20% of Days with Worst Visibility for the Years 1988-1991, 1999 at Five Ending Altitudes**

| | # at 10 meters | # at 100 meters | # at 500 meters | # at 1000 meters | # at 3000 meters |
|---|---|---|---|---|---|
| **North** | 6 | 4 | 3 | 3 | 6 |
| **South** | 28 | 25 | 22 | 22 | 25 |
| **East** | 9 | 12 | 16 | 17 | 10 |
| **West** | 10 | 8 | 16 | 13 | 13 |
| **Northeast** | 18 | 19 | 8 | 6 | 4 |
| **Northwest** | 4 | 6 | 9 | 11 | 13 |
| **Southeast** | 13 | 13 | 15 | 16 | 17 |
| **Southwest** | 8 | 10 | 7 | 9 | 10 |
| **Originates in AK** | 1 | 1 | 2 | 1 | 0 |

# Appendix B

**B-1: Calculations for Estimating Default Natural Background at Alaskan Class I Areas**

**B-2: Preliminary Calculation for Estimating Rate of Progress for Denali National Park SIP**

## B-1: Calculations for Estimating Default Natural Background at Alaskan Class I Areas

**<u>EQUATIONS</u>**

### Default Natural Light Extinction

$$b_{ext} = (3)\,fRH[Sulfate] + (3)\,fRH[Nitrate] + (4)[OMC] + (10)[LAC] + (1)[Soil] + (0.6)[CM] + 10$$

where:

$b_{ext}$ = reconstructed light extinction in inverse megameters
f(RH) = annual average site specific relative humidity correction factors
OMC = Organic carbon mass
LAC = Light absorbing carbon (elemental carbon)
CM = Coarse Mass

Conversion of Natural Light Extinction into Deciview Units

$$dv = 10\ln(b_{ext}/10)$$

where:

dv = deciview
$b_{ext}$ = reconstructed light extinction in inverse megameters

### Relative Humidity Correction Factors for Alaskan Class I Areas

Correction Factors obtained from Appendix A of EPA's Draft Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program

Bering Sea Wilderness – Not provided in EPA Guidance
Denali National Park – f(RH) = 2.52 (annual average)
Simeonof Wilderness – f(RH) = 4.25 (annual average)
Tuxedni Wilderness – f(RH) = 3.34 (annual average)

### Average Natural Levels of Aerosol Components

From Table 2-1 of EPA's Draft Guidance for Estimating Natural Visibility Conditions Under the Regional Haze Program

| Aerosol Component | Average Natural Concentration for West ($ug/m^3$) |
|---|---|
| Ammonium sulfate | 0.11 |
| Ammonium nitrate | 0.10 |
| Organic carbon | 0.47 |
| Elemental carbon (LAC) | 0.02 |
| Soil | 0.50 |

| | |
|---|---|
| Coarse Mass | 3.0 |

**Average daily deciview values for 20% best and worst visibility days**

**20% best days**

$$p10 = dv - 1.28sd$$

where:

$p10$ = 10th percentile deciview value
$dv$ = annual average natural deciview value
$sd$ = standard deviation of the daily deciview values for that area
best estimate for natural visibility $sd$ for the west is 2

**20% worst days**

$$p90 = dv + 1.28sd$$

where:

$p90$ = 90th percentile deciview value
$dv$ = annual average natural deciview value
$sd$ = standard deviation of the daily deciview values for that area
best estimate for natural visibility $sd$ for the west is 2

# CALCULATIONS

## Denali National Park

### Annual average natural light extinction –

$$b_{ext} = (3)\,fRH[Sulfate] + (3)\,fRH[Nitrate] + (4)[OMC] + (10)[LAC] + (1)[Soil] + (0.6)[CM] + 10$$
$$b_{ext} = (3)(2.52)(0.11) + (3)(2.52)(0.10) + (4)(0.47) + (10)(0.02) + (1)(0.50) + (0.6)(3.0) + 10$$
$$b_{ext} = 15.9676 \text{ Mm}^{-1}$$

### Annual average deciview –

$$dv = 10\ln(b_{ext}/10)$$
$$dv = 10\ln(15.9676/10)$$
$$dv = 4.68$$

### 20% best day deciview –

$$p10 = dv - 1.28sd$$
$$p10 = 4.68 - 1.28(2)$$
$$p10 = 2.12$$

### 20% worst day deciview –

$$p90 = dv + 1.28sd$$
$$p90 = 4.68 + 1.28(2)$$
$$p90 = 7.24$$

**<u>Simeonof Wilderness Area</u>**

**Annual average natural light extinction –**

$$b_{ext} = (3)\,fRH[Sulfate] + (3)\,fRH[Nitrate] + (4)[OMC] + (10)[LAC] + (1)[Soil] + (0.6)[CM] + 10$$
$$b_{ext} = (3)(4.25)(0.11) + (3)(4.25)(0.10) + (4)(0.47) + (10)(0.02) + (1)(0.50) + (0.6)(3.0) + 10$$
$$b_{ext} = 17.0575 \text{ Mm}^{-1}$$

**Annual average deciview –**

$$dv = 10\ln(b_{ext}/10)$$
$$dv = 10\ln(17.0575/10)$$
$$dv = 5.34$$

**20% best day deciview –**

$$p10 = dv - 1.28sd$$
$$p10 = 5.34 - 1.28(2)$$
$$p10 = 2.78$$

**20% worst day deciview –**

$$p90 = dv + 1.28sd$$
$$p90 = 5.34 + 1.28(2)$$
$$p90 = 7.90$$

## Tuxedni Wilderness Area

**Annual average natural light extinction –**

$$b_{ext} = (3)\, fRH[Sulfate] + (3)\, fRH[Nitrate] + (4)[OMC] + (10)[LAC] + (1)[Soil] + (0.6)[CM] + 10$$
$$b_{ext} = (3)(3.34)(0.11) + (3)(3.34)(0.10) + (4)(0.47) + (10)(0.02) + (1)(0.50) + (0.6)(3.0) + 10$$
$$b_{ext} = 16.4842 \text{ Mm}^{-1}$$

**Annual average deciview –**

$$dv = 10\ln(b_{ext}/10)$$
$$dv = 10\ln(16.4842/10)$$
$$dv = 5.00$$

**20% best day deciview –**

$$p10 = dv - 1.28sd$$
$$p10 = 5.00 - 1.28(2)$$
$$p10 = 2.44$$

**20% worst day deciview –**

$$p90 = dv + 1.28sd$$
$$p90 = 5.00 + 1.28(2)$$
$$p90 = 7.56$$

**B-2: Preliminary Calculation for Estimating Rate of Progress for Denali National Park SIP**

Baseline Condition for 20% Worst Days (1995-1999) = 9.7 deciviews
Natural Condition for 20% Worst Days = 7.24 deciviews

Annual Rate of Progress =

(current worst day conditions – estimated natural conditions)/(2064-current year)

Annual Rate of Progress = (9.7-7.24)/(2064-2004)
Annual Rate of Progress = 2.46 deciviews/60 years = 0.04 deciviews

Preliminary 2004-2018 Progress Goal = 0.04 deciviews/year x 14 years = 0.574 deciviews

# Appendix C

**Figure C-1: Communities within 100 Miles of Denali National Park & Preserve**

**Figure C-2: Communities within 100 Miles of Tuxedni Wilderness Area**

**Figure C-3: Communities within 100 Miles of Simeonof Wilderness Area**

**Figure C-1.**

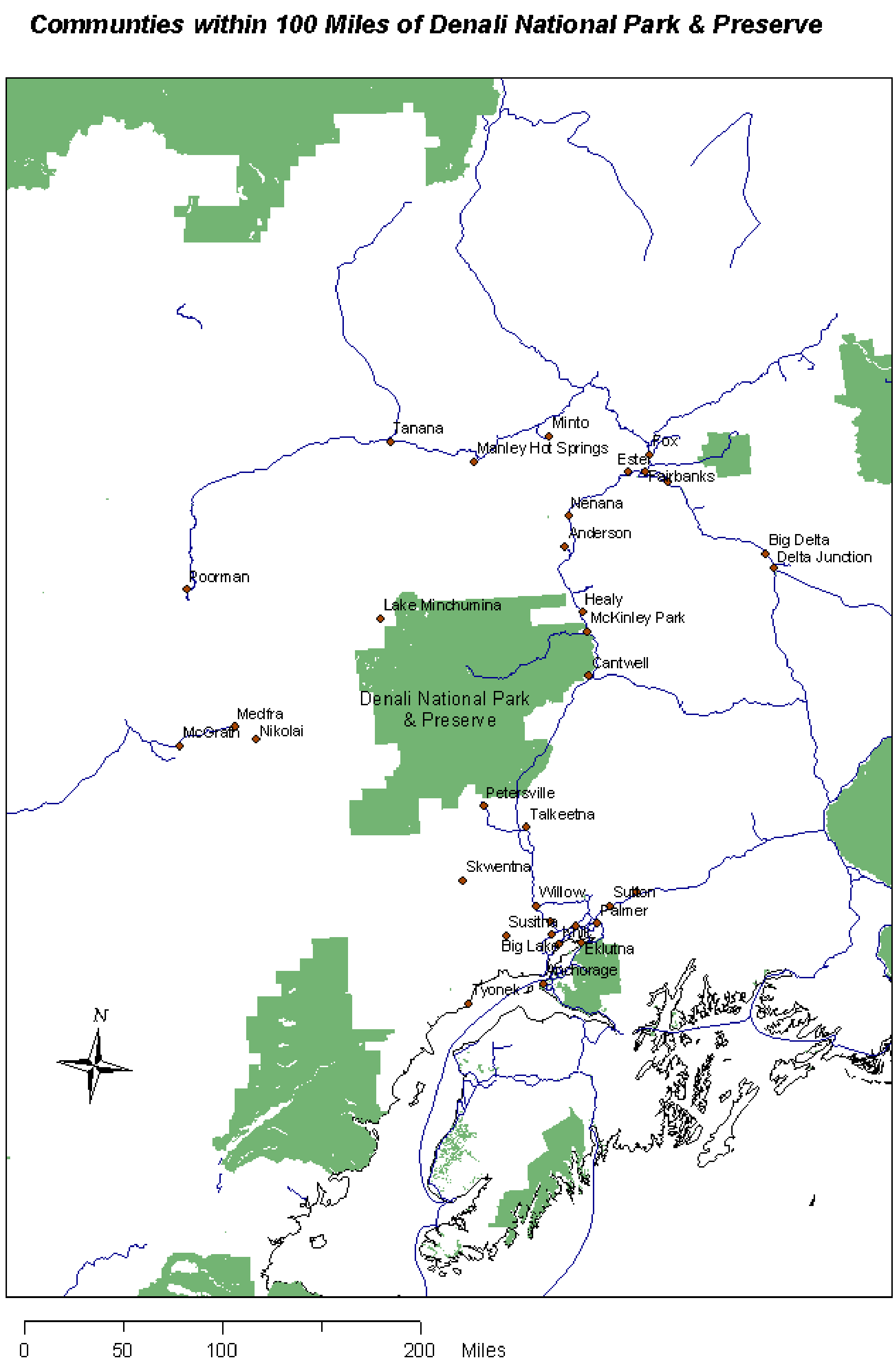





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**Figure C-2.**

***Communties within 100 Miles of Tuxedni Wilderness Area***

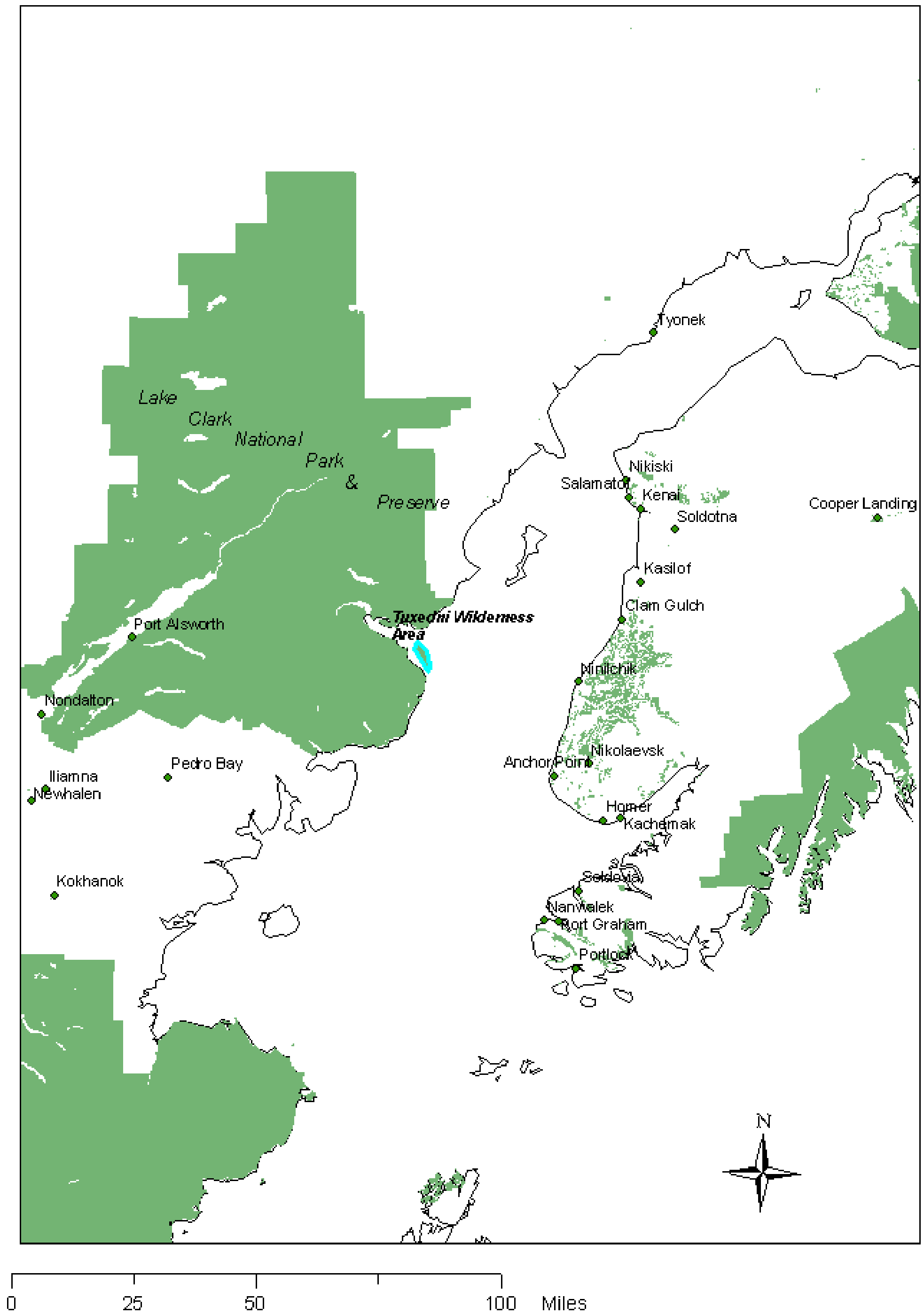
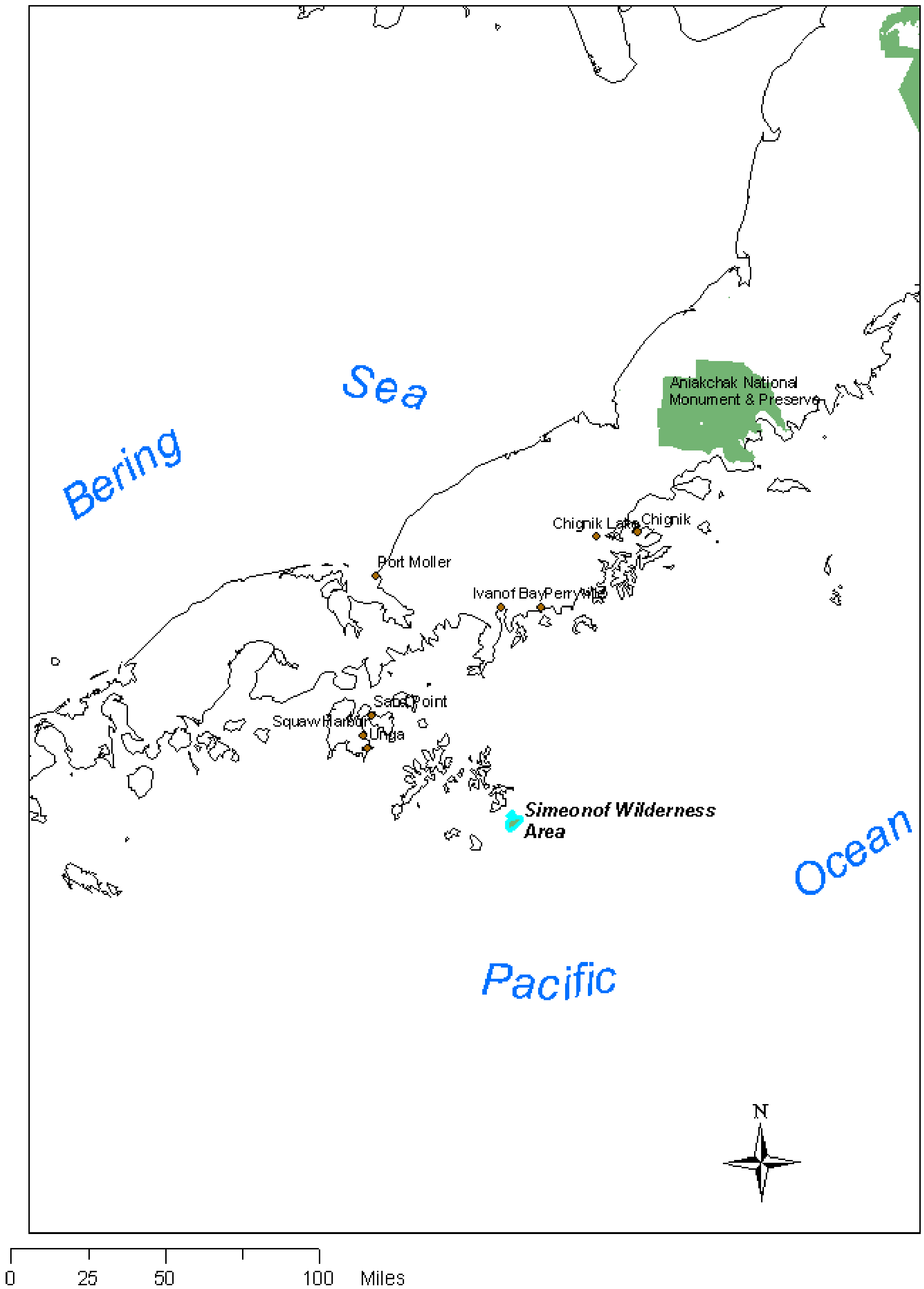


**Figure C-3.**

**Communties within 100 Miles of Simeonof Wilderness Area**



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