Seeley Lake Particulate Matter with an Aerodynamic Diameter of 2.5 Microns or less ($PM_{2.5}$) Saturation Study
Missoula City-County Health Department
October 2, 2012

I. INTRODUCTION

Missoula County has collected $PM_{2.5}$ data in the Missoula valley since the first $PM_{2.5}$ National Ambient Air Quality Standards (NAAQS) were adopted in 1997. Over time, $PM_{2.5}$ sampling was expanded into other areas, including Frenchtown, Milltown and Seeley Lake, to determine if those parts of the county were below the $PM_{2.5}$ NAAQS. Seeley Lake $PM_{2.5}$ sampling started in 2005. In 2005, the data collected in Missoula, Frenchtown, Milltown, and Seeley Lake indicated that all of Missoula County was in compliance with the 1997 $PM_{2.5}$ NAAQ daily standard of 65 micrograms per cubic meter ($\mu g/m^3$) and the annual $PM_{2.5}$ standard of 15 $\mu g/m^3$.

When the Environmental Protection Agency (EPA) revised the daily $PM_{2.5}$ NAAQS to 35 $\mu g/m^3$ in 2006, large parts of western Montana, including the mountain valleys of Missoula County, were close to exceeding the daily $PM_{2.5}$ NAAQS. $PM_{2.5}$ saturation studies conducted throughout western Montana show that smoke from residential wood combustion is the primary source of $PM_{2.5}$ air pollution in the winter.[1]

Seeley Lake is a small, mountain valley community located north of Missoula in Missoula County, Montana. As is common in rural, forested areas, many residents rely on woodstoves to heat their homes.[2] The Seeley Lake valley, like many areas in western Montana, is prone to frequent temperature inversions that have the potential to trap smoke from those stoves near the ground where it poses a threat to human health.

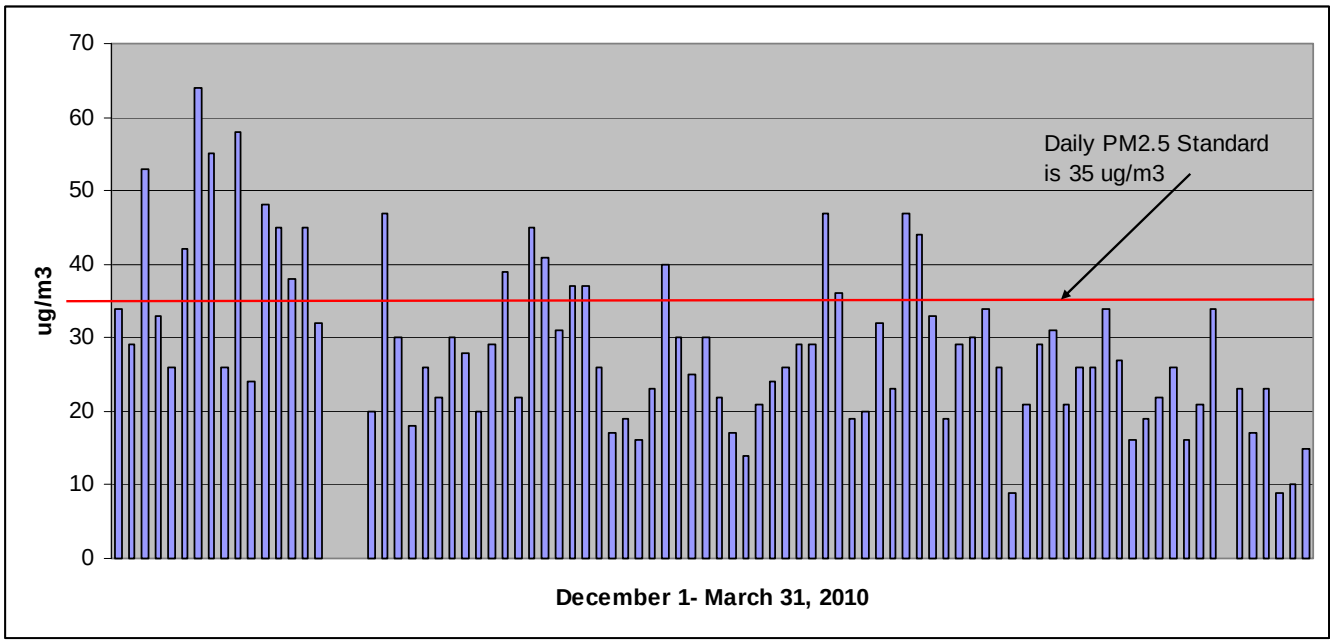
The Missoula City-County Health Department (Department) and Montana Department of Environmental Quality (DEQ) first started measuring fine particulate concentrations in Seeley Lake in 2005. During that initial study in 2005 and 2007, 24-hour $PM_{2.5}$ concentrations greater than the daily 2006 National Ambient Air Quality Standard (NAAQS) of 35 $\mu g/m^3$ were measured at the Seeley Lake Fire Hall. In 2009, based on the results of the 2005-2007 study, the Department and the DEQ installed a new continuous $PM_{2.5}$ monitor in Seeley Lake. This permanent $PM_{2.5}$ beta-attenuated monitor (BAM) was installed near the Seeley Lake Elementary School (School) at a location meeting all EPA siting criteria. The elementary school BAM $PM_{2.5}$ monitor is also centrally located in a residential area where many of the homes are heated with wood-burning appliances. The BAM reports hourly data on a near-real time basis and provides the Department and the local community near-real time information about Seeley Lake's air quality.

Data collection at the School site started in mid-November 2009. Within a month and half, 19 days had daily $PM_{2.5}$ averages greater than the 24-hour NAAQS of 35 $\mu g/m^3$. Between January 1 and March 18, 2010, 21 days exceeded the $PM_{2.5}$ 24-hour NAAQS (Graph 1). For the 2010-2011 winter (November-February), 50 days with $PM_{2.5}$ concentrations greater than 35 $\mu g/m^3$ were measured and for the 2011-2012 winter, 54 days with $PM_{2.5}$ concentrations greater than 35 $\mu g/m^3$ were measured.

1 Ward, T.J., Lange, T., 2010. The impact of wood smoke on ambient PM2.5 in northern Rocky Mountain valley communities. Environmental Pollution 158 (2010) 723–729.

2 2010 Census reported 45.5% of Seeley Lake homes heat with wood. Propane was the second most commonly used fuel at 30.7%.

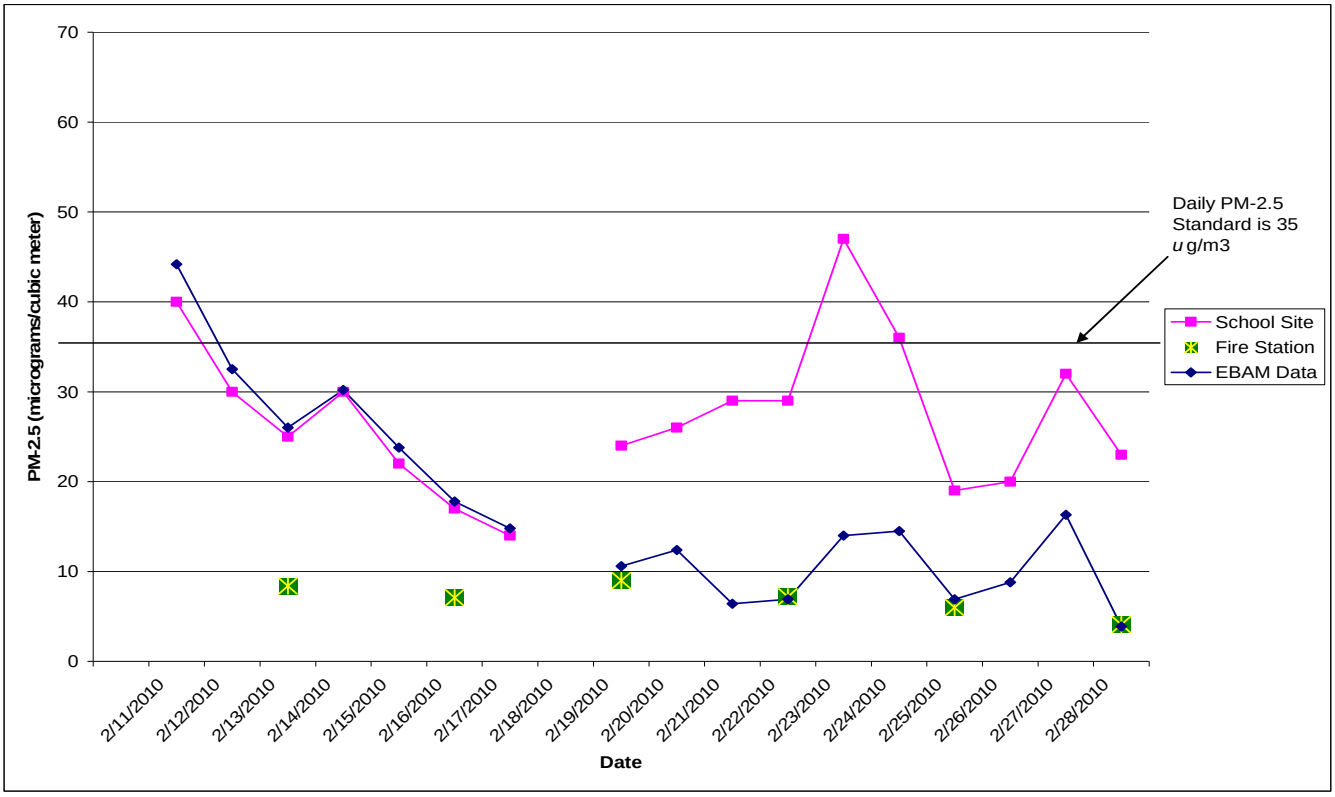
Graph 1. Daily $PM_{2.5}$ Concentrations at Seeley Lake Elementary School
December 1 – March 31, 2010



However, data collected concurrently at the Fire Station site 0.5 miles away showed $PM_{2.5}$ concentrations roughly half those measured at the School site (Graph 2). The samples at the Fire Station were collected once every three days by Federal Reference Method (FRM) filter-based BGI samplers. The School site, in contrast, uses a continuous monitor.

In order to verify the accuracy of the monitoring stations, the DEQ first co-located an eBAM with the BAM at the School site, and then later co-located the eBAM with the BGI sampler at the Fire Station site. The eBAM is a mobile non-reference method continuous particulate sampler that operates on the same principles as a BAM. The results of those co-located comparisons are presented in Graph 2. The eBAM values were in agreement with the $PM_{2.5}$ values from both sites, confirming that the data collected at both the School and Fire Station sites were accurate.

Graph 2. School and Fire Station Site Comparison with eBAM Collocation
February 11 - February 28, 2010



In addition to monitoring $PM_{2.5}$ concentrations, Department staff performed several visual smoke assessments in Seeley Lake during the winter of 2009-2010. They observed the thickest smoke near the elementary school and in the neighborhoods immediately south and north of the elementary school site. Visual observations by Missoula City-County Health Department staff in Seeley Lake frequently identified opacity readings of 90-100% from woodstoves. Smoke levels appeared less dense in other parts of the community, including the high school, golf course, intersection of Boy Scout Road and Hwy 83 and the intersection of Morrell Creek Road and Hwy 83 north of the elementary school site.

On April 7, 2010, the Department conducted a visual woodstove/fireplace/pellet stove chimney survey in the residential neighborhood just south of the elementary school. In an approximately 16 square block area or a ½ square mile, the survey found 50 residences with chimneys and five residences with a second chimney for a total of up to 55 woodstove/fireplace/pellet stove chimneys in the survey area.

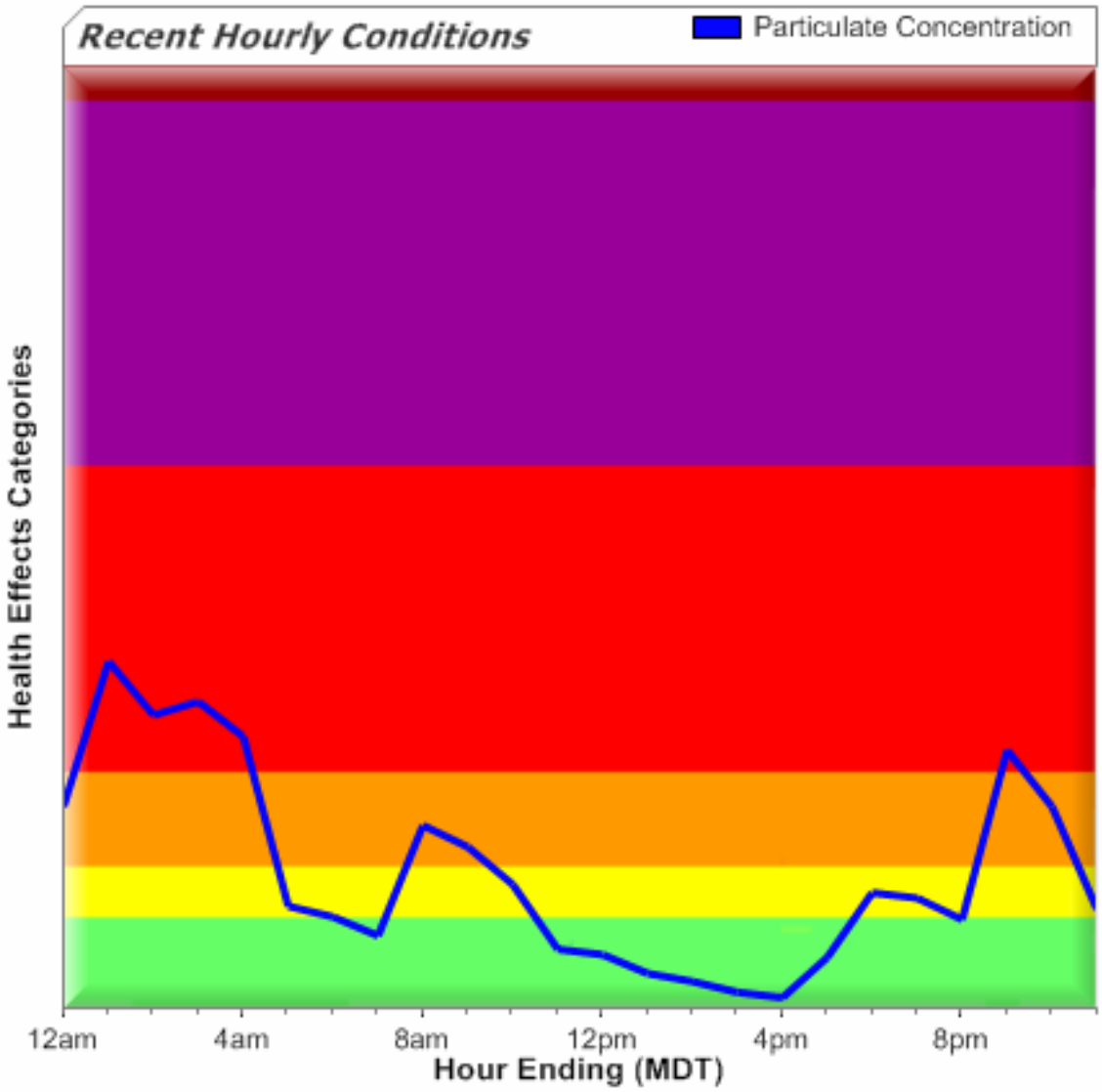
Chemical mass balance studies in western Montana have shown that woodstoves are the primary source of winter $PM_{2.5}$ air pollution[3]. Based on these chemical mass balance studies and visual observations, wood stove smoke is the primary source of $PM_{2.5}$ in Seeley Lake.

3 Ward, T.J., Lange, T., 2010. The impact of wood smoke on ambient PM2.5 in northern Rocky Mountain valley communities. Environmental Pollution 158 (2010) 723–729.

II. $PM_{2.5}$ SATURATION STUDY DESIGN

$PM_{2.5}$ is generally considered a regional pollutant with a uniform widespread distribution. However, the data from Seeley Lake shows very different $PM_{2.5}$ concentrations at two sites which are only a half mile apart. In addition, the $PM_{2.5}$ values at the School site fluctuate rapidly. The highest $PM_{2.5}$ concentrations frequently occur at night and often clear out to some extent in the afternoon when the inversions break. Graph 3 below shows how particulate levels can clear our on many afternoons and how spikes can occur when people reload their stoves in the morning. What appears to be a large number of woodstoves in a few blocks produces enough pollution to generate high $PM_{2.5}$ concentrations over the short-term. Plus, the stagnant atmospheric conditions do not appear to last long enough in Seeley Lake to produce the more uniform distribution of elevated $PM_{2.5}$ concentrations commonly seen at other areas of western Montana. Therefore, the high $PM_{2.5}$ values measured at the School site appear to be a neighborhood effect and likely do not accurately represent regional air quality.

Graph 3. Seeley Lake Elementary School Hourly $PM_{2.5}$ Values
January 11, 2011



To analyze the distribution of $PM_{2.5}$ throughout the Seeley Lake Community, a $PM_{2.5}$ saturation study was performed from October 1, 2010, through March 31, 2011.

Some factors considered when designing this study:

1. When compared to the Fire Station site, $PM_{2.5}$ levels are clearly higher at the School site. While $PM_{2.5}$ values at the two sites rise and fall together during the winter months, the School site values are always higher.
2. The hourly $PM_{2.5}$ data collected at the School site improves dramatically on most days. This decrease in the $PM_{2.5}$ concentrations usually occurs by early afternoon and indicates that atmospheric inversions typically break up daily in Seeley Lake (Graph 3).
3. On April 7, 2010, a visual survey of woodstove/fireplace chimneys showed high numbers of wood burning devices in the residential neighborhood just south of the School site.
4. Wind data collected at the School site indicates high $PM_{2.5}$ levels occur when there are very slight breezes from the south
5. Several visual assessments of smoke plumes during the winter of 2009-2010 seem to indicate thicker smoke in the vicinity of the School site and the neighborhoods immediately south and north of the school, as compared to other locations in Seeley Lake. While high emitting woodstoves (as indicated by the amount of smoke) were found scattered throughout the Seeley Lake community, the greatest concentration of high emitting woodstoves was observed in the neighborhood immediately south of the School site.
6. The study timeframe included the last part of the outdoor burning season which ends each year on November 30th. During the study, major outdoor burning activities were tracked by the Department through the Montana Idaho Smoke Management Unit web page. The data collected just before and after December 1 was analyzed in an attempt to quantify the effects from outdoor burning on ambient $PM_{2.5}$ concentrations. Since exceedances of the daily $PM_{2.5}$ NAAQS are uncommon after mid March, the "high $PM_{2.5}$ season" was covered.

Six sampling sites, in addition to the School site, were chosen to characterize $PM_{2.5}$ distribution and determine which Seeley Lake neighborhoods have high $PM_{2.5}$ concentrations:

1. The U.S. Forest Service Ranger Station at the northern end of Seeley Lake - a location 1.5 miles north of the School site to cover the north side of the community.
2. The Barn south of Seeley Lake – near the Double Arrow Ranch and golf course.
3. Just west of the airport on County land- several houses in this area may produce enough home heating emissions to generate high $PM_{2.5}$ concentrations in the neighborhood. In addition, the airport is located above the valley floor at a higher elevation and this location covers the east side of town.
4. The corner of Juniper & Alder by the wood waste landfill – in Seeley Lake just north of the wood waste landfill and south of the chimney survey area.
5. A private parcel on Boy Scout Road – a location between Boy Scout Road and the lake.
6. "DogTown" – a neighborhood south of Pyramid Mountain Lumber that potentially contains a significant number of houses with wood stoves.

Monitor locations are shown on the attached map (Appendix A).

III. MONITORING METHODS

Portable eBAM samplers were installed at the monitoring sites. These eBAMs produce $PM_{2.5}$ data as an hourly average. Even though the eBAM samplers were not federal reference (FRM) or equivalence (FEM) rated, DEQ has operated eBAMs alongside FRM/FEM rated monitors in studies at Butte, Libby, Belgrade and the Bitterroot

Valley and found that the eBAMs accurately measure $PM_{2.5}$.

IV. DATA HANDLING

The eBAMs were outfitted with cellular modems and the data was polled from DEQ's main office in Helena using MetOne® software. $PM_{2.5}$ data from the existing School site was processed according to standard DEQ quality assurance and quality control (QA/QC) protocols.

V. AGENCY INVOLVEMENT

The Department contacted homeowners and businesses and arranged for the specific monitor locations and for electric service to power each monitor and assisted with monitor maintenance.

DEQ installed, operated, maintained, and removed the monitoring equipment. DEQ downloaded the data and conducted the appropriate QA/QC checks. Both the Department and DEQ analyzed the data.

VI. WOOD SMOKE STUDY RESULTS

Table 1 shows the number of days woodstove smoke caused fine particulate concentrations to exceed the $PM_{2.5}$ 24-hour NAAQS of 35 µg/m^3 at each monitoring site. The permanent monitor at the School exceeded the 24-hour $PM_{2.5}$ standard 48 times, more than any other location. The outlying areas such as the Forest Service, Barn and Airport had no days over the standard.

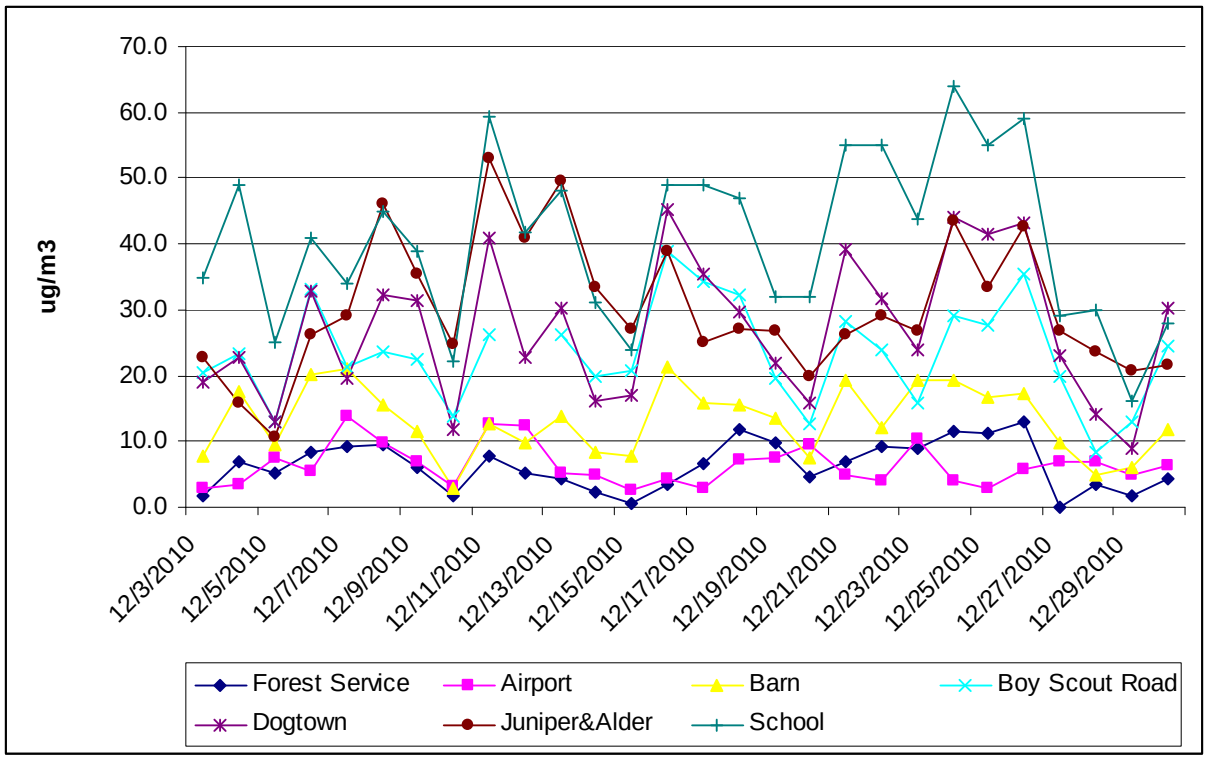
Table 1. Study Days with 24-Hour $PM_{2.5}$ Values > 35 µg/m^3 by Site Caused by Wood Stoves

	Forest Service	Barn	Airport	Boy Scout Rd.	Dogtown	Juniper & Alder	School (permanent)
October	0	0	0	0	No Data*	0	0
November	0	0	0	2	4	7	7
December	0	0	0	2	6	8	18
January	0	0	0	1	1	9	13
February	0	0	0	0	2	6	7
March	0	0	0	0	0	2	3
Total	**0**	**0**	**0**	**5**	**13**	**32**	**48**

* There is no data for Dogtown in October because the monitor was not set up until November.

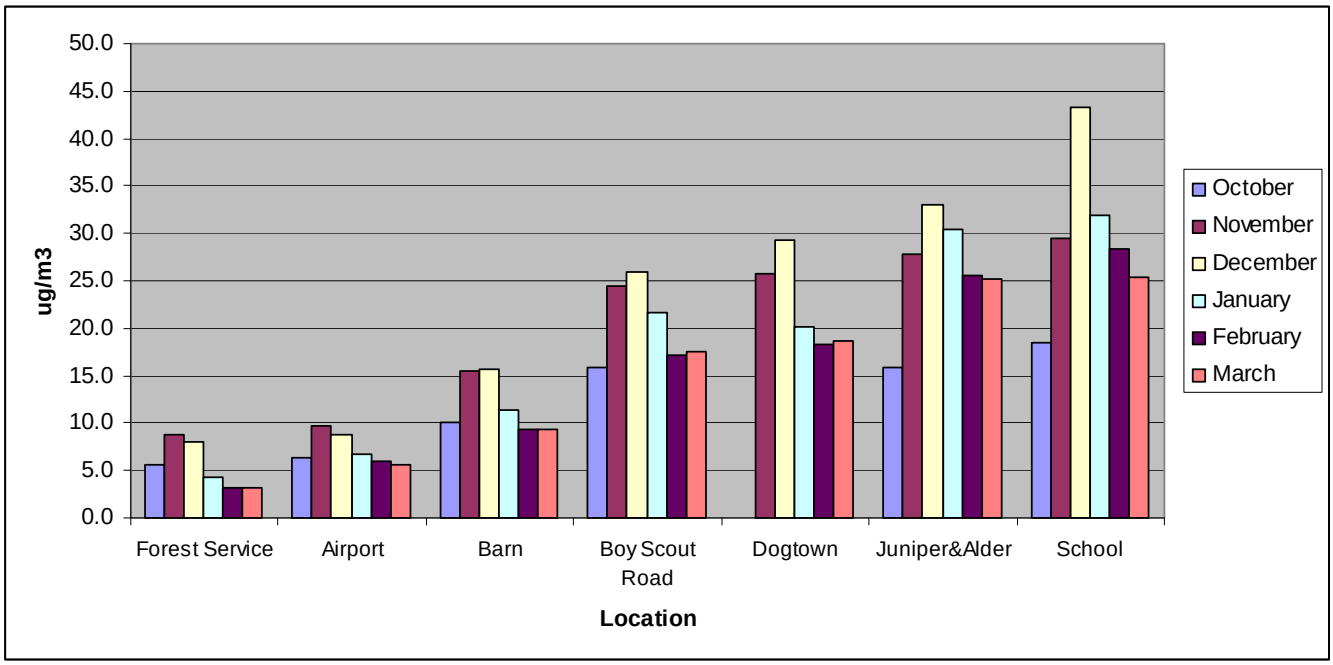
All the residential sites on the valley floor (Boy Scout Road, DogTown, Juniper & Alder and the School) had multiple days with 24-hour $PM_{2.5}$ averages greater than 35 µg/m^3. While $PM_{2.5}$ values rose and fell together throughout the study area, the residential sites had consistently greater $PM_{2.5}$ concentrations (Graph 4). . Similar results were recorded for the duration of the study.

Graph 4. Daily $PM_{2.5}$ Averages for December 3-30, 2010



Another way to compare the $PM_{2.5}$ intensities between all the sites is to look at the monthly average (Graph 4). This method smooths out daily variations and the differences between sites can be clearly illustrated.

Graph 5. Monthly Average $PM_{2.5}$ Concentrations



All the monthly averages in Graph 5 are less than 16 µg/m^3 for the three non-residential sites, and each of the residential sites had at least one monthly average greater than 25 µg/m^3. The residential neighborhoods with the most woodstoves per block (Juniper & Alder and the School), have the highest daily and monthly average $PM_{2.5}$ concentrations. For December, the monthly average for the School site was 43.2 µg/m^3, which is well over the daily standard of 35 µg/m^3.

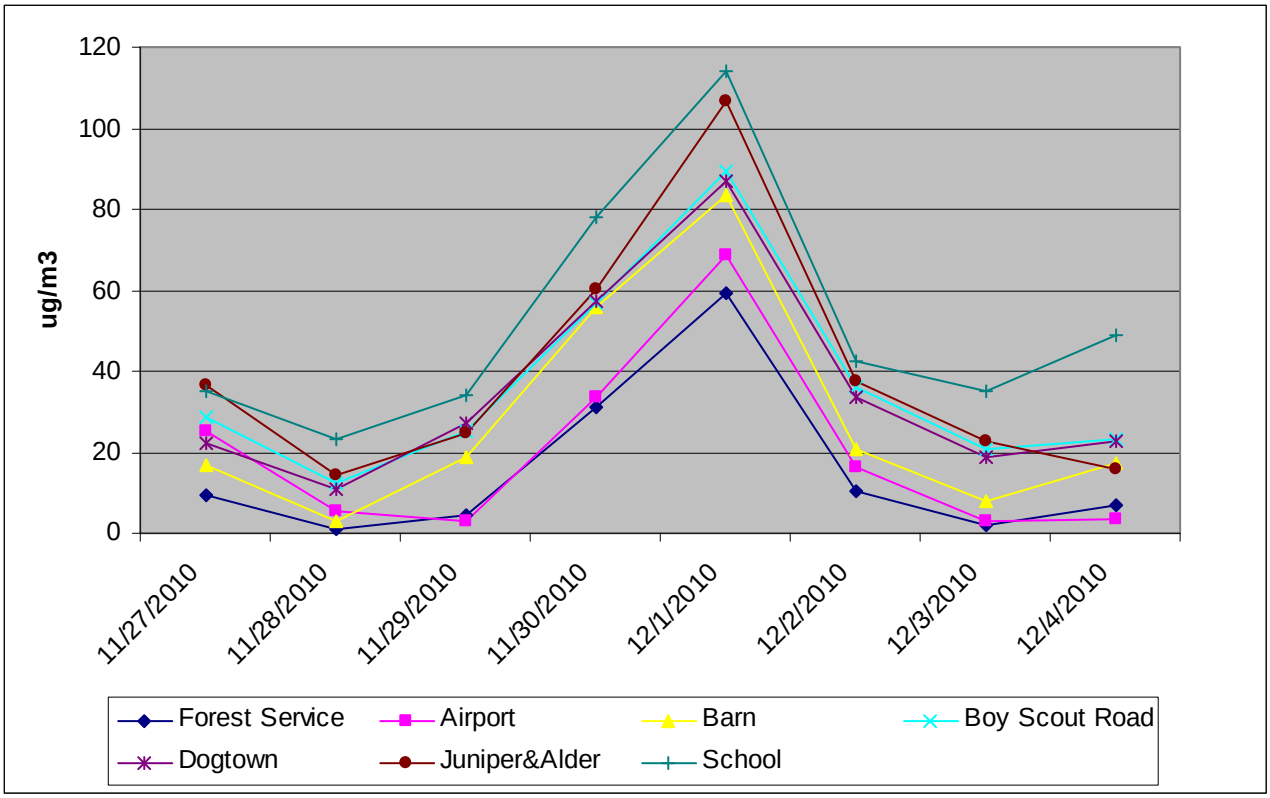
The study results show that high $PM_{2.5}$ concentrations in the winter are the result of a neighborhood affect and the regional air quality is typically good. In fact, the north and south sites at the Forest Service and the Barn, respectively, had no daily $PM_{2.5}$ concentrations over the 24-hour NAAQS from residential wood stove burning.

To help gauge the impacts of Pyramid Mountain Lumber mill on the air shed, a monitor was located north of the mill just off Boy Scout Road and another monitor was located south of the mill in Dogtown. These two locations were in residential neighborhoods with a much lower density of wood stoves than the Juniper & Alder and School sites. When compared to the residential sites at Juniper & Alder and the School, $PM_{2.5}$ levels were consistently and substantially lower at the two study sites located north and south of Pyramid Mountain Lumber. These study results, in addition to visual observations that found most of smoke in Seeley Lake was generated by residential woodstoves, indicate that proximity to Pyramid Mountain Lumber has minimal impact on $PM_{2.5}$ concentrations.Residential wood stoves are by far the primary source of $PM_{2.5}$ in Seeley Lake.

VII. OUTDOOR BURNING HIGH $PM_{2.5}$ VALUES

On November 30, 2010, outdoor burning was closed below 4800 feet in the Seeley Lake area because of poor dispersion conditions. Even with the outdoor burning closure, several people in the Seeley Lake Valley floor chose to burn on November 30, the last day of the outdoor burning season. Graph 6 below shows that the illegal burns caused elevated levels of $PM_{2.5}$ at every study monitoring site for November 30 and December 1. Smoke ($PM_{2.5}$) from the fires was trapped in the valley through December 1. All the values over 35 µg/m^3 at the Forest Service, Airport and Barn sites, except for the November 20 reading at the Forest Service, were caused by the illegal November 30 outdoor burning.

Graph 6. Illegal Outdoor Burn Impacts
November 30, 2012



With outdoor burning closed, the Forest Service, Airport and Barn sites had levels of $PM_{2.5}$ air pollution below 35 µg/m^3 throughout the winter, while the sites in the residential zones frequently had $PM_{2.5}$ concentrations over 35 µg/m^3. Based on the $PM_{2.5}$ data and outdoor burning information, it is clear that the November 30 and December 1 high $PM_{2.5}$ concentrations were primarily caused by outdoor burning.

Table 2 shows the number of days over 35 µg/m^3 by month at each monitoring site. The table includes impacts from outdoor burning at the end of November and beginning of December

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Table 2. Study Days with 24-Hour $PM_{2.5}$ Values > 35 µg/m^3 by Site

	Forest Service	Barn	Airport	Boy Scout Rd.	DogTown	Juniper & Alder	School
October	0	0	0	0	No Data	0	0
November	1	1	0	3	5	8	8
December	1	1	1	3	7	9	19
January	0	0	0	1	1	9	13
February	0	0	0	0	2	6	7
March	0	0	0	0	0	2	3
Total	**2**	**2**	**1**	**7**	**15**	**34**	**50**

VIII. CONCLUSIONS AND RECOMMENDATIONS

High daily $PM_{2.5}$ readings in Seeley Lake are caused by wildfires, outdoor burning and residential wood smoke. Since western Montana has a naturally occurring wildfire regime, it would be impossible to totally eliminate smoke events from wildfires. The November 30th, 2010, outdoor burning smoke episode shows that an active outdoor burn program, with an education and enforcement component on appropriate burn times, will need to continue if severe impacts from outdoor burning are to be eliminated.

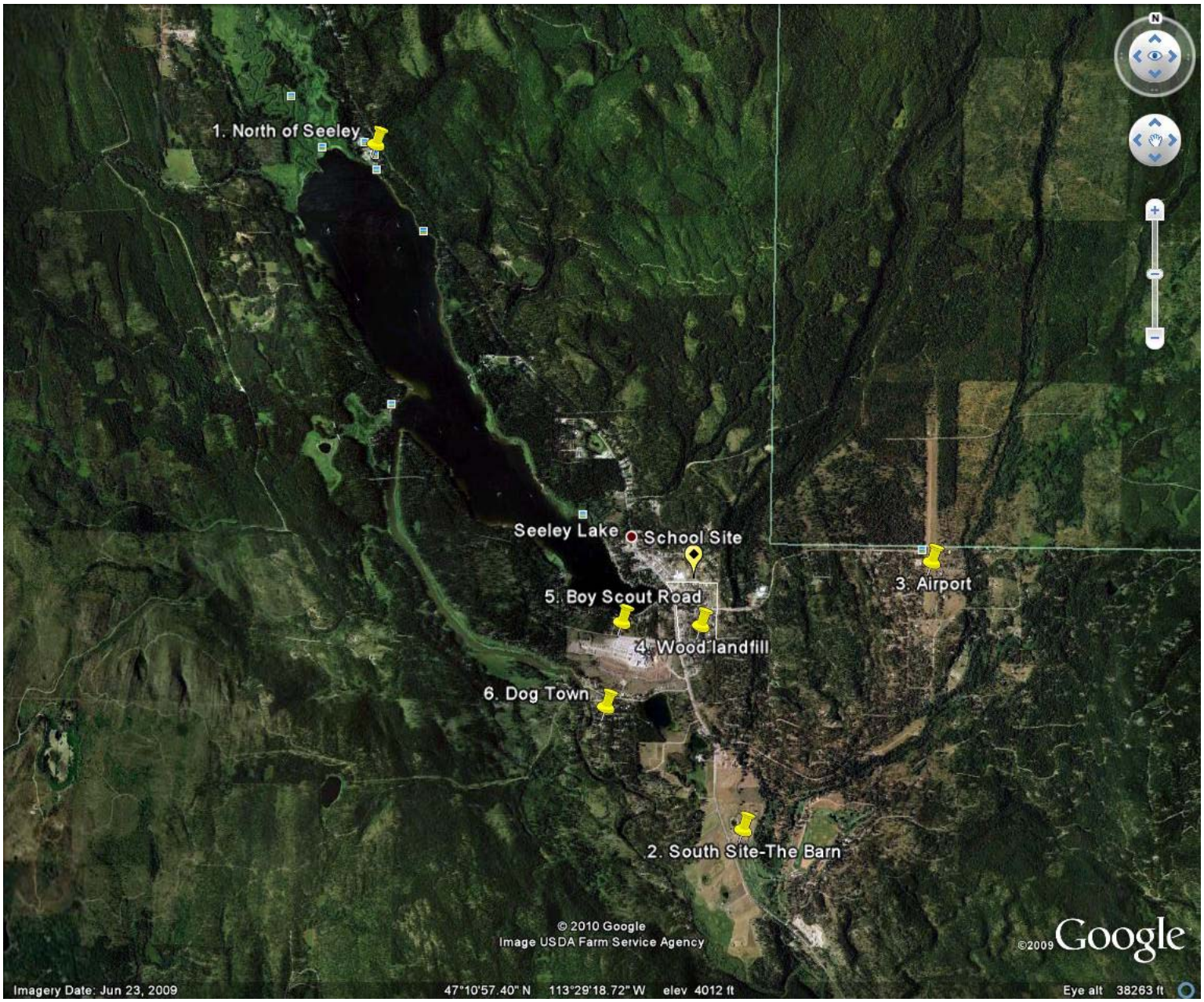
For air pollution, smoke from residential wood stoves has the most persistent negative impact on public health in Seeley Lake. Because the mountain valley topography and temperature inversions will always trap pollution to the valley floor in the winter months, smoke emissions from residential wood stoves will need to be addressed. To reduce smoke emissions from wood stoves, solutions will need to take into account some basic facts.

1. Natural gas is not available for home heating in the Seeley Lake area. More expensive sources of fuel for heat, such as propane and electricity, are available.
2. Wood is readily available in this forested area and often the cheapest choice of fuel for space heating.
3. Many Seeley Lake residents would have a financially difficult time changing from wood to a different heating fuel or different heating appliance. Outside financial help will frequently be required to change residents' current heating systems.
4. While a switch to all pellet stove heat would solve the winter air quality pollution, there is widespread resistance in Seeley Lake to using a manufactured fuel that costs money when wood is cheap and readily available. Many people prefer using wood stoves, which they are familiar with. They also feel wood stoves are less complicated and more reliable than pellet stoves and that a wood stove will work even during a power outage.
5. Replacing all the old wood stoves with cleaner and more efficient wood stoves would only be part of the solution. To reduce smoke pollution below the daily $PM_{2.5}$ standard, an on-going educational effort on how to burn cleanly and the use of dry fuel would also be needed.

To get Seeley Lake smoke pollution levels in compliance with the daily $PM_{2.5}$ national ambient air quality standard, wood stove appliances will need to be changed out and wood burning methods will need to change. Eventually, the community will need to have expectations that wood chimney emissions should be barely visible and 100% opacity is not acceptable.

Appendix A

Map of $PM_{2.5}$ Monitoring Sites



Appendix B

Photos of $PM_{2.5}$ Monitoring Sites

1. North end of Seeley Lake, Forest Service Ranger Station - a location 1.5 miles north of the School site to cover the north side of the community.

2. The Barn south of Seeley – near Double Arrow Ranch and Golf Course.

3. Just west of Airport on County Land- several houses in this area may use wood for heating. The airport is located above the valley floor at a higher elevation and this location covers the east side of town.

4. Juniper and Alder intersection by wood waste landfill – in Seeley just north of the wood waste landfill and south of the chimney survey.

5. Haines property by Boy Scout Road – a location between Boy Scout Road and the Lake just north of Pyramid Mountain Lumber, Inc.

6. “Dogtown” – a site south of Pyramid Mountain Lumber in a neighborhood that contains many houses with wood stoves.

7. Permanent Seeley Lake Elementary School Site. Photo taken from School Lane looking north.