pscleanair.org
Puget Sound Clean Air Agency

1904 Third Avenue, Suite 105
Seattle, Washington 98101
www.pscleanair.org

Final Report

2013-14 Special Winter Intensive Monitoring Campaign

October 2014

Working Together for Clean Air

Background

Wintertime fine particle pollution levels pose a public health concern throughout the Puget Sound region and Pierce County. In 2009, western Pierce County was designated a nonattainment area for exceeding the daily PM2.5 National Ambient Air Quality Standard (NAAQS). Multiple fixed, temporary, and mobile monitors have been deployed in the nonattainment area (also called the Smoke Reduction Zone or SRZ) over the last decade. These measurements were directed at understanding the sources and spatial patterns of fine PM. While fine PM levels in the SRZ have been fairly well characterized, there is little monitoring information outside the SRZ.

The Agency calls air quality burn bans in the winter to reduce fine particle pollution during stagnation events. Because of the SRZ, Pierce County has a lower threshold for calling a Stage I burn ban than neighboring King County. The question has arisen: is it feasible to call wintertime air quality burn bans independently inside and outside of the SRZ, based on different criteria? In order to address this question, we first have to assess if 1) fine PM levels outside of the SRZ are different than those within and 2) if meteorological conditions outside the SRZ can be distinguished from conditions in the SRZ.

Approach

To address these questions, we conducted a Special Winter Intensive Monitoring campaign in Pierce County (SWIM-PC) during the 2013-14 heating season. Prior analysis of the wind patterns in the south Puget Sound and Pierce County suggested that stagnant conditions were fairly widespread, but not necessarily consistent, throughout the season and multiple burn ban episodes. See Figures 1 and 2.

Our primary measurement was total scattering (Radiance nephelometer), which is a proxy for PM2.5 mass. We established fixed sites in population centers outside the SRZ in the cities/towns of Orting, Bonney Lake, Carbonado, and Eatonville. See Figures 3 - 7 for a county scale map and zoomed-in maps of the four sites.

We also developed a mobile monitoring platform to fill in the spatial gaps between the fixed sites. The route connected south Graham to Orting, to Bonney Lake, and then to Carbonado. This route was completed twice per mobile sampling run. The mobile route map is shown in Figure 12 and mobile results are shown in Figure 13.

Results

We collected measurements at the fixed sites run from November 22, 2013, through February 28, 2014 – a duration of about 90 days. During this time, four mobile runs were conducted during inversion/elevated conditions and five were conducted during background/mixed conditions.

For the campaign average, Bonney Lake, Orting, and Carbonado behaved consistently with SRZ monitors and the nearby Kent monitor. Figure 8 shows the average concentration for the whole campaign at the permanent fixed sites and the SWIM-PC sites. Bonney Lake, Carbonado, and Orting looked similar to the permanent sites, while Eatonville was significantly lower.

The metric most relevant for burn bans and the nonattainment status of the Pierce County and potential for future violations, however, is the daily PM2.5 NAAQS. An examination of the highest 10% of daily values, shown in Figure 9, suggests a similar relationship as the campaign average. The highest values in Bonney Lake, Carbonado, and Orting look similar to the permanent sites. Eatonville, however, appears to be significantly lower. The estimated 98 percentile for the year (sixth highest in this case, colored red) showed the same pattern.

Figure 10 shows a time series of all fixed monitors in this campaign. All of the sites track closely except for Eatonville and Carbonado. Eatonville appears to be consistently lower, while Carbonado tracked well and was elevated for limited portions of the campaign. Pearson's correlations of the daily PM2.5 values support this conclusion with Bonney Lake and Orting having correlations > 0.8 with the monitors in the SRZ. Carbonado and Eatonville were more modestly correlated with the remaining sites.

The results of the mobile monitoring are shown in Figure 13. Data were aggregated into a regular hexagonal grid from elevated/burn ban runs. All data were collected in the 5-9 pm range with multiple values taken in each cell throughout each run and across multiple runs. A single value for each cell was calculated by fitting a trend line (in time) through all available data within that cell. The line was projected to 9 pm to compensate for varying observation times and to allow for a comparison to be made with the fixed sites. In any cell, if the slope of the trend line was negative, the average of all available values in that cell was used (i.e. the slope was 0). In some cells, the slope was very steep due to lack of data in early hours or an atypical spike at the end. To reduce the potential for bias, the trend line was also constrained to have an upper limit of twice the average slope of the trend of the fixed site monitors over the same hours.

The mobile monitoring data were also compared to the fixed sites. Figure 14 shows a transect of mobile route PM2.5 values (adjusted to 9 pm) along with the fixed-site values at 9 pm. See description in Figure 13 for details about how the adjustment to 9 pm was calculated. Note that the transect is not continuous because of branching of the route in south Graham and Bonney Lake. The fixed site values, however, are placed on the appropriate index that corresponds to the mobile monitoring cell.

The Appendix includes wind and pollution rose figures from Carbonado.

Conclusions

Fine PM levels are consistent with burn bans being warranted outside of the SRZ. During the study period, PM2.5 daily values reached or exceeded the burn ban threshold in the SRZ and were similar in Bonney Lake, Carbonado, and Orting. Levels at the Eatonville monitor, however, were significantly lower and exhibited different patterns than the other sites. This suggests that the poor air quality conditions observed in northern Pierce County were not present in at least some parts of southern Pierce County. We do not, however, have sufficient data to draw any further conclusions as to whether all of Eatonville, or the surrounding rural areas have similarly lower levels. Thus, we do not have sufficient information to conclude if the southern portion of Pierce County can be treated independently for calling burn bans.

Figures

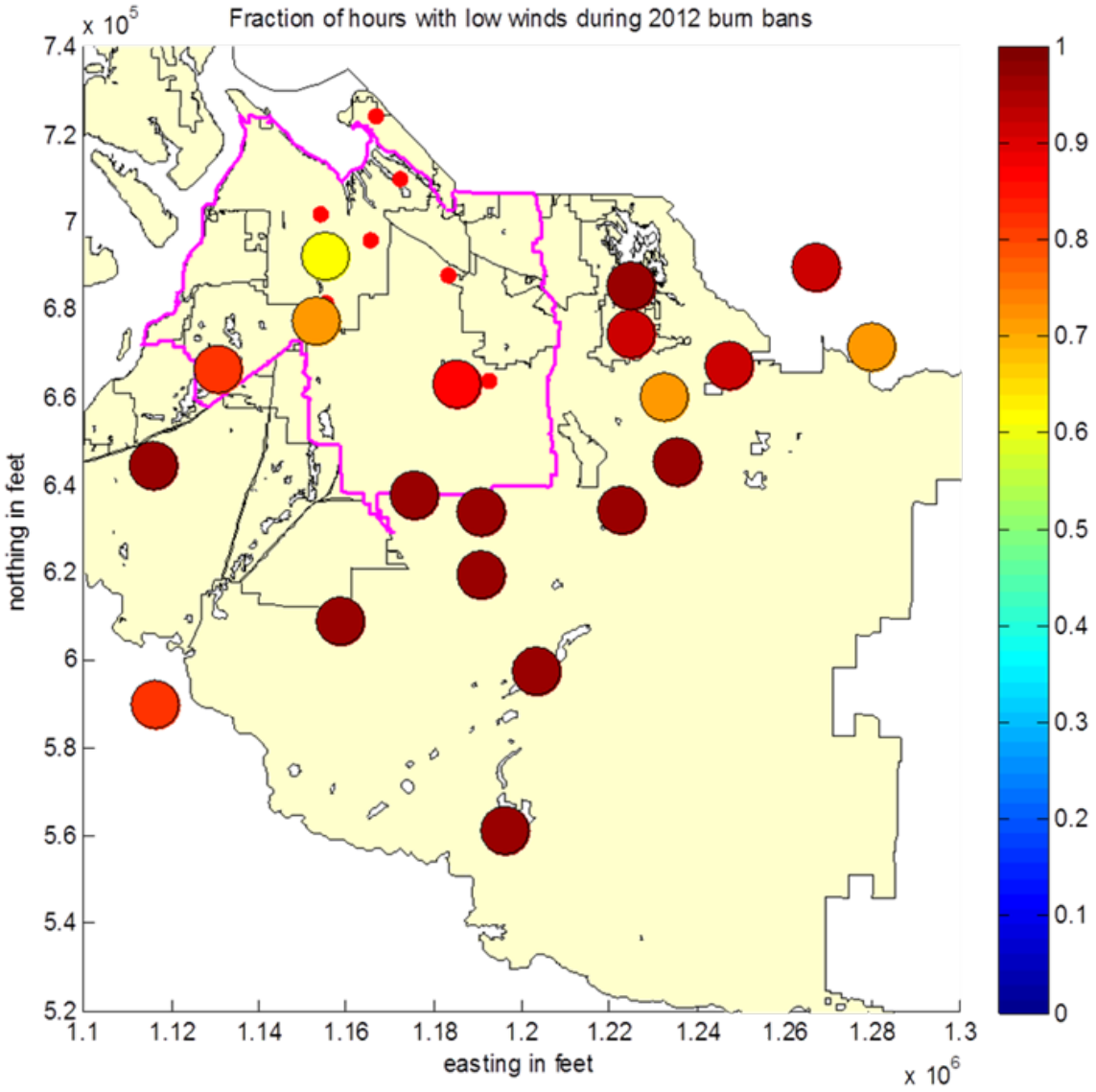

Figure 1. Locations of Weather Underground sites in and near Pierce County used in a prior analysis of countywide meteorology. The color of the circle indicates the fraction of nighttime hours that the site had stagnant winds during the burn bans of the 2012-13 heating season. Stagnant winds were defined as having a reported hourly average below a threshold. The threshold was varied from about 1-2 mph; the same pattern occurred in all cases.

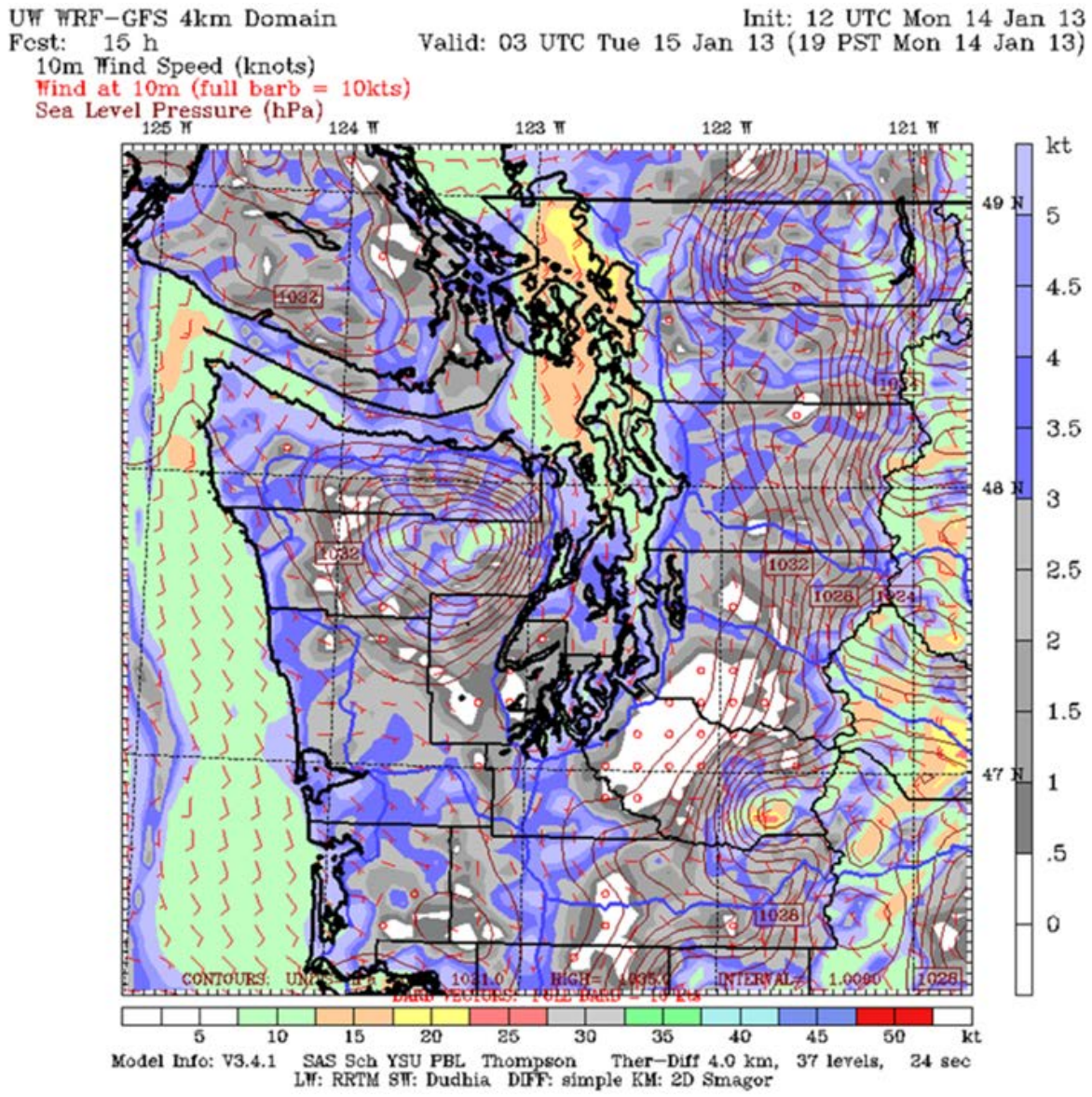

Figure 2. An example map of surface winds forecast by the UW-WRF system during a wintertime impaired air quality episode. The white region indicates that winds were stagnant over much of Pierce County and portions of southern King County.

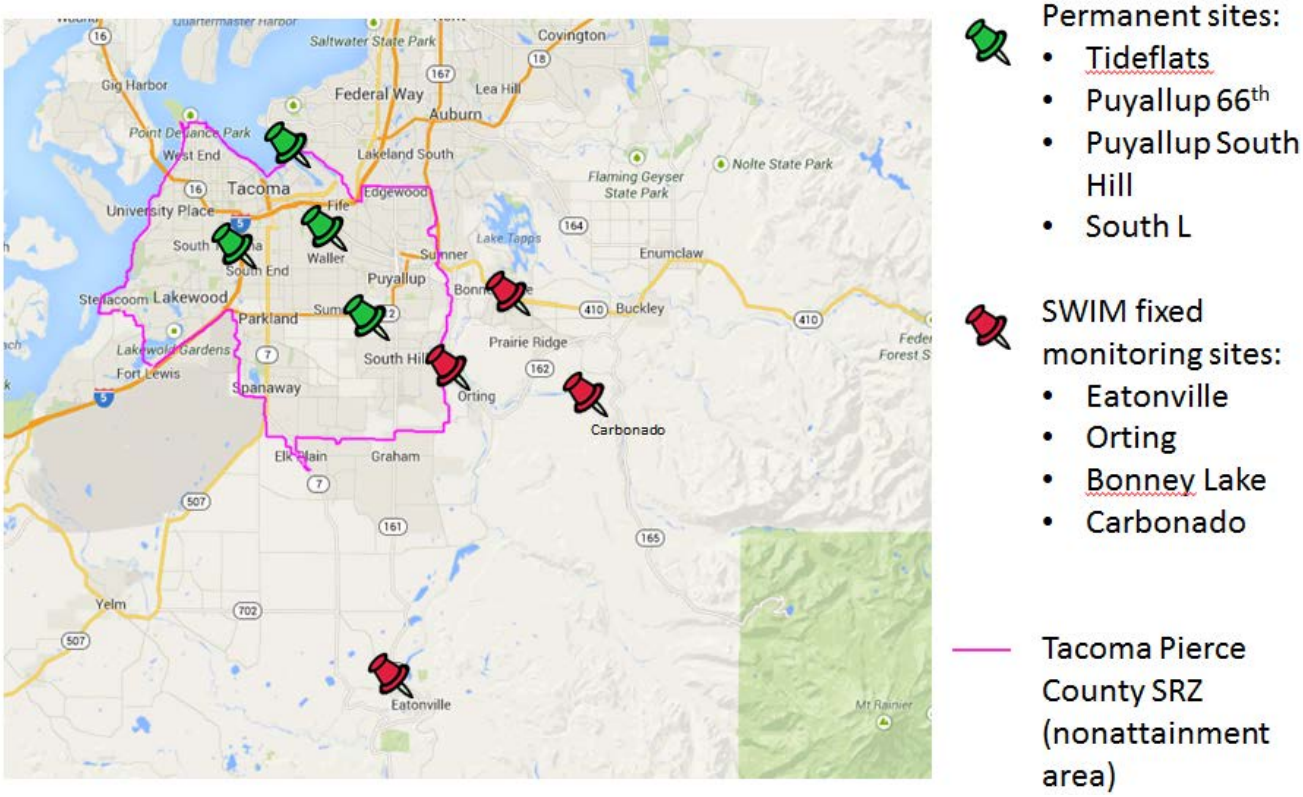

Figure 3. Locations of the existing permanent monitoring sites and the SWIM-PC fixed sites.

Figure 4. The location of the Eatonville monitor on the south side of the high school property.

Figure 5 shows the location of the Orting fixed monitor near the intersection at the center of town.

Figure 6 shows the location of the Carbonado fixed site monitor on the southwest outskirts of town.

Figure 7 shows the location of the Bonney Lake monitor. The site is suburban and surrounded by numerous housing developments.

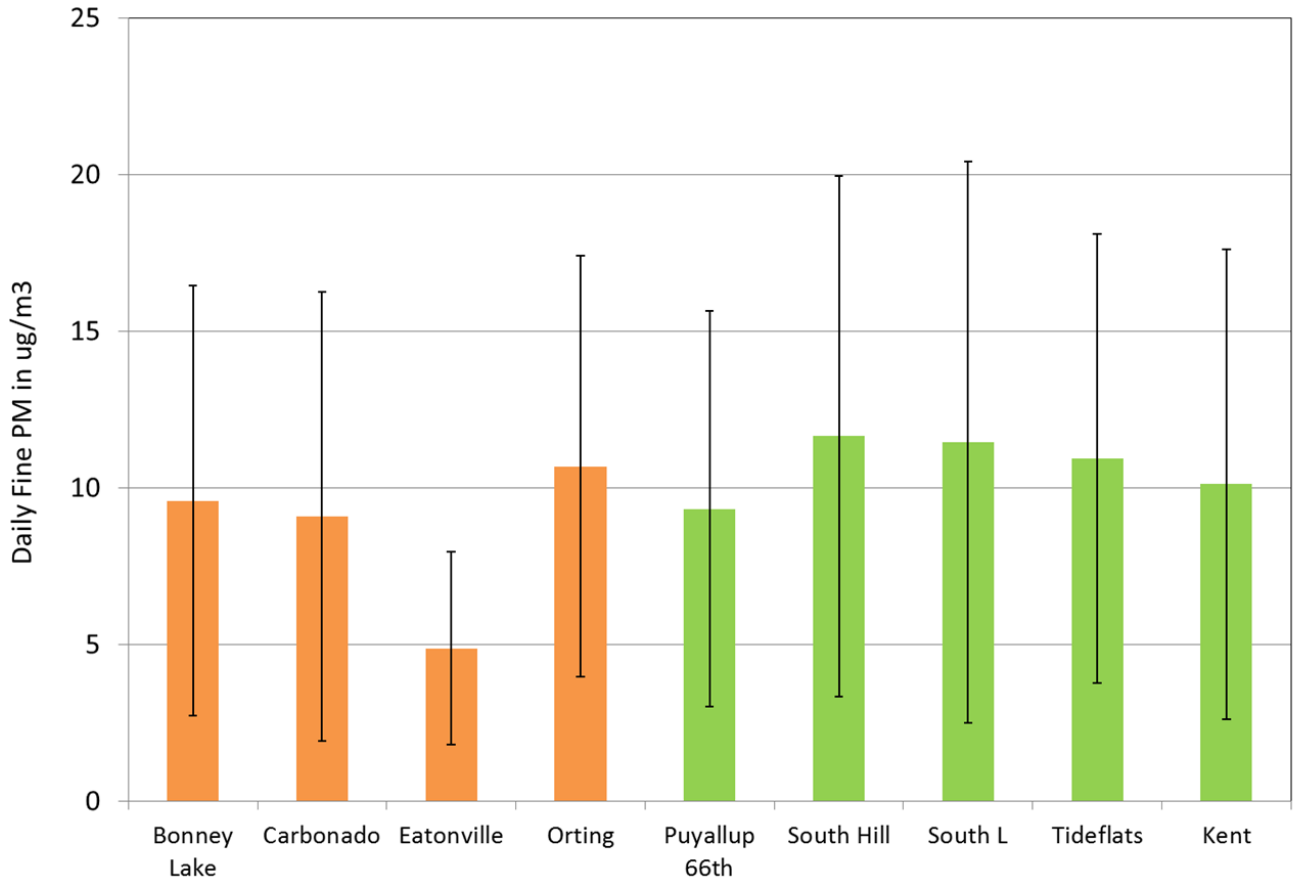

Figure 8. The bars show the average concentration for the whole campaign at the permanent fixed sites (green) and the SWIM-PC sites (orange) along with their respective standard deviation. The error bars indicate one standard deviation of the daily averages. Bonney Lake, Carbonado, and Orting looked similar to the permanent sites, while Eatonville was significantly lower.

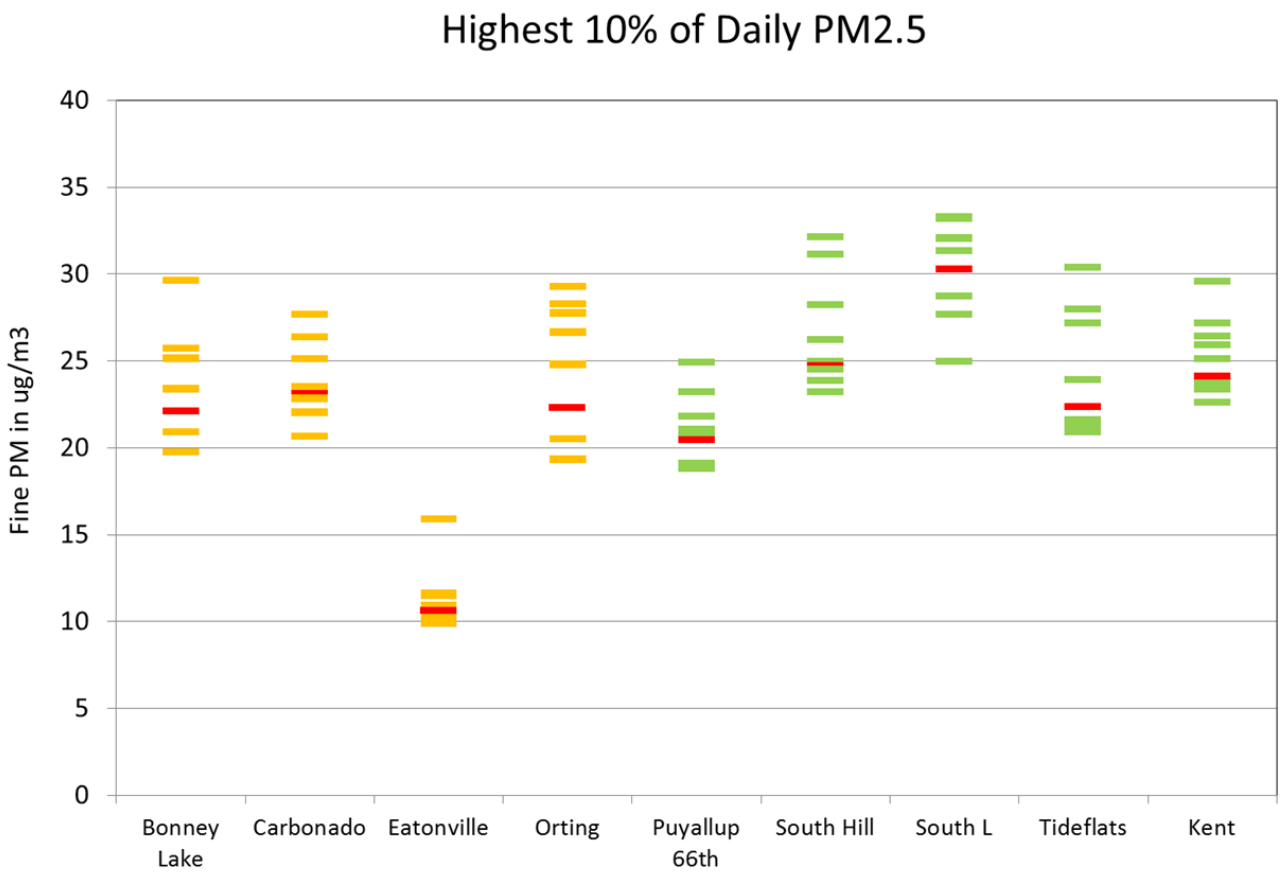

Figure 9. Bars indicate the highest 10% of daily PM2.5 values (9 highest days) over the campaign. The red bar approximates the yearly percentile. Eatonville was significantly lower than all other monitors.

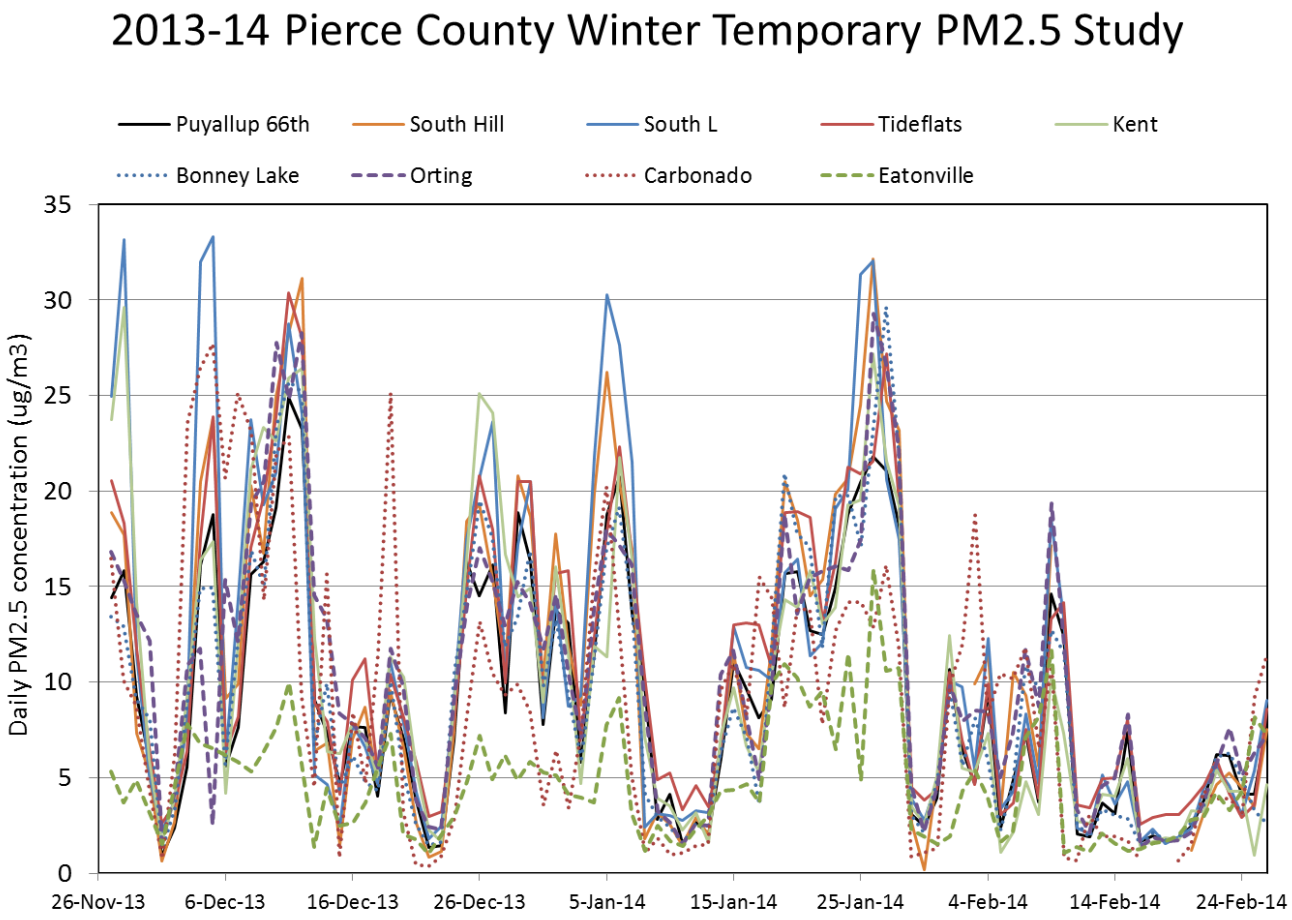

Figure 10. The plot shows a time series of daily averages for all monitors compared in this campaign. SWIM-PC sites are plotted with dashed lines, existing permanent sites are shown with solid lines.

	Bonney Lake	*Carbonado*	*Eatonville*	*Orting*	*Puyallup 66th*	*South Hill*	*SL FEM*	*Tideflats*
Carbonado	0.60	1						
Eatonville	0.75	0.62	1					
Orting	0.91	0.68	0.71	1				
Puyallup	0.93	0.58	0.66	0.91	1			
South Hill	0.88	0.53	0.59	0.87	0.92	1		
SL FEM	0.83	0.65	0.60	0.86	0.91	0.87	1	
Tideflats	0.92	0.57	0.63	0.89	0.98	0.89	0.89	1
Kent	0.88	0.54	0.59	0.87	0.90	0.80	0.88	0.91

Figure 11. The table shows the Pearson's correlations of the daily average PM2.5. Correlations ≥ 0.8 are highlighted in pink. Bonney Lake and Orting are well correlated with the existing permanent sites. Carbonado and Orting are modestly correlated.

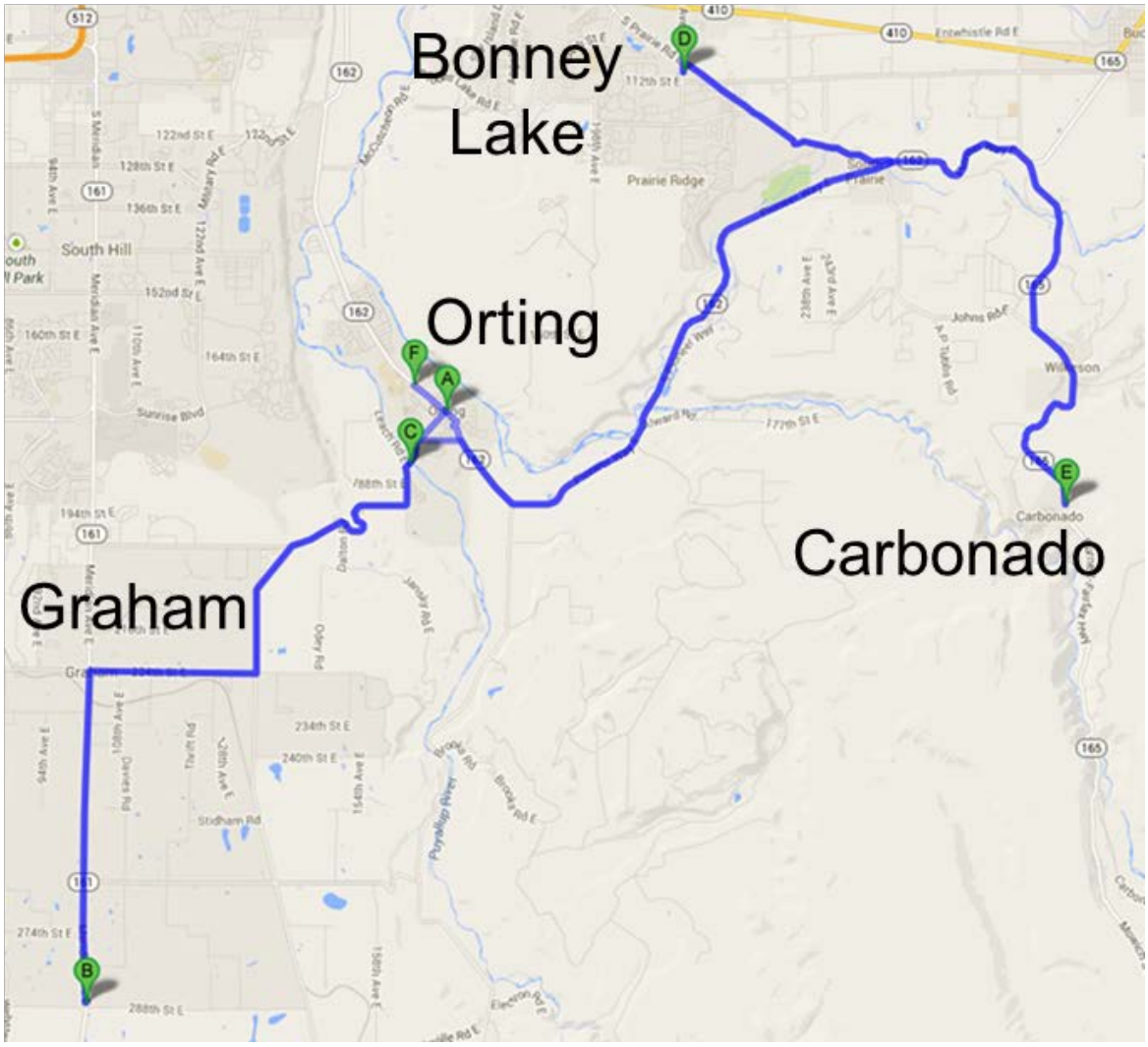

Figure 12. Map showing the mobile monitoring route. Nominally, it begins at **A** in Orting and proceeds to south Graham, turns around at **B**, goes back through Orting to Bonney Lake, turns around at **D**, goes to Carbonado, turns around at **E**, and returns to Orting.

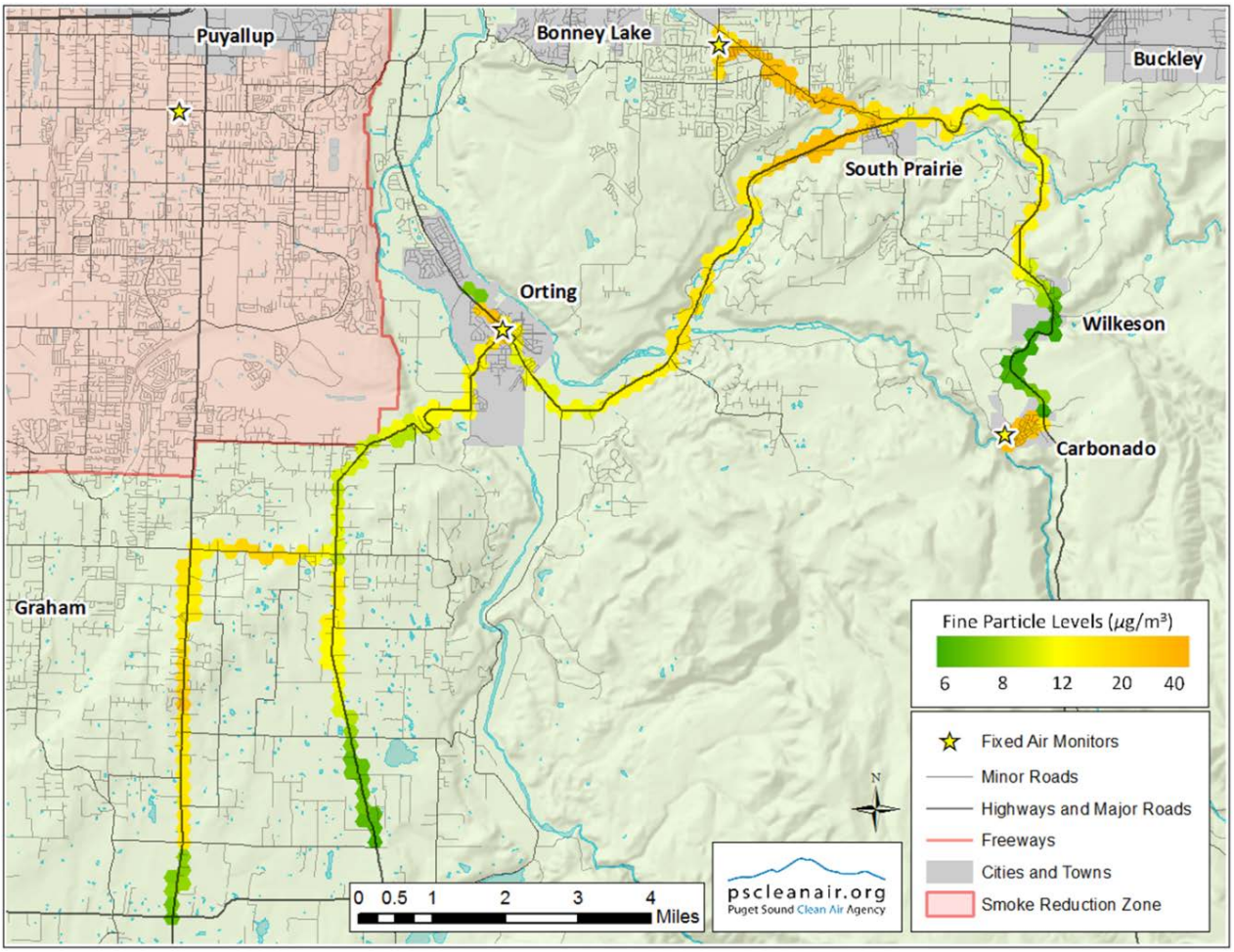

Figure 13. Map showing the fine particle levels during elevated/burn ban runs. All data were collected in the 5-9 pm range with multiple values taken in each cell throughout each run and across multiple runs. A single value for each cell was calculated by fitting a line through all available data within each respective cell. The line was projected to 9 pm to compensate for varying observation times. If the slope of the line for a cell was negative, the average of all available data was used (i.e. the slope was 0). The slope was constrained to have an upper limit of twice the average slope of the fixed site monitors over the same hours.

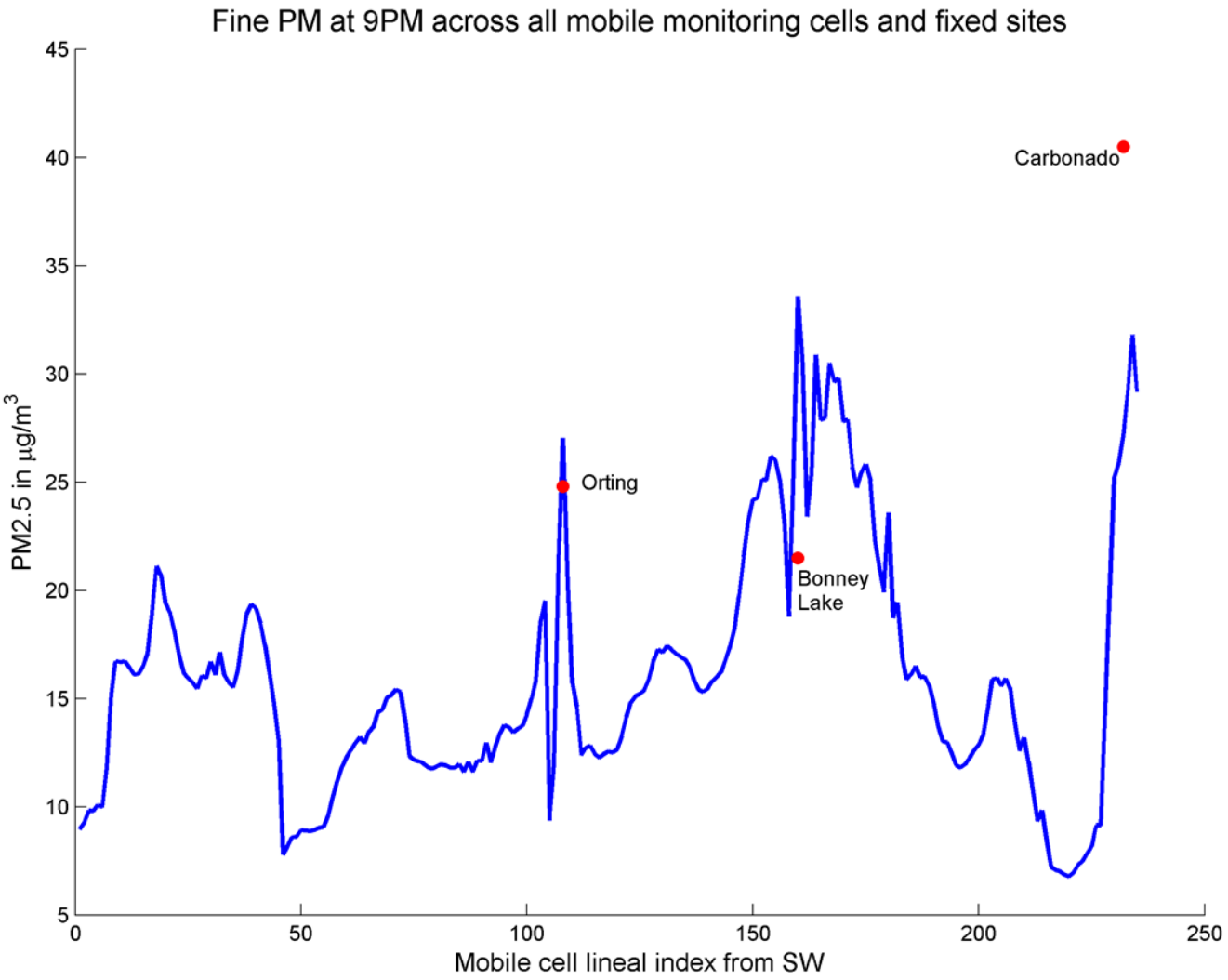

Figure 14. Transect of mobile route PM2.5 values (adjusted to 9 pm) and the fixed site values at 9 pm. See description in Figure 13 for details about how the adjustment to 9 pm was calculated. Note that the transect is not continuous because of branching of the route in south Graham and Bonney Lake. The fixed site values, however, are placed on the appropriate index that corresponds to the mobile monitoring cell.

Appendix

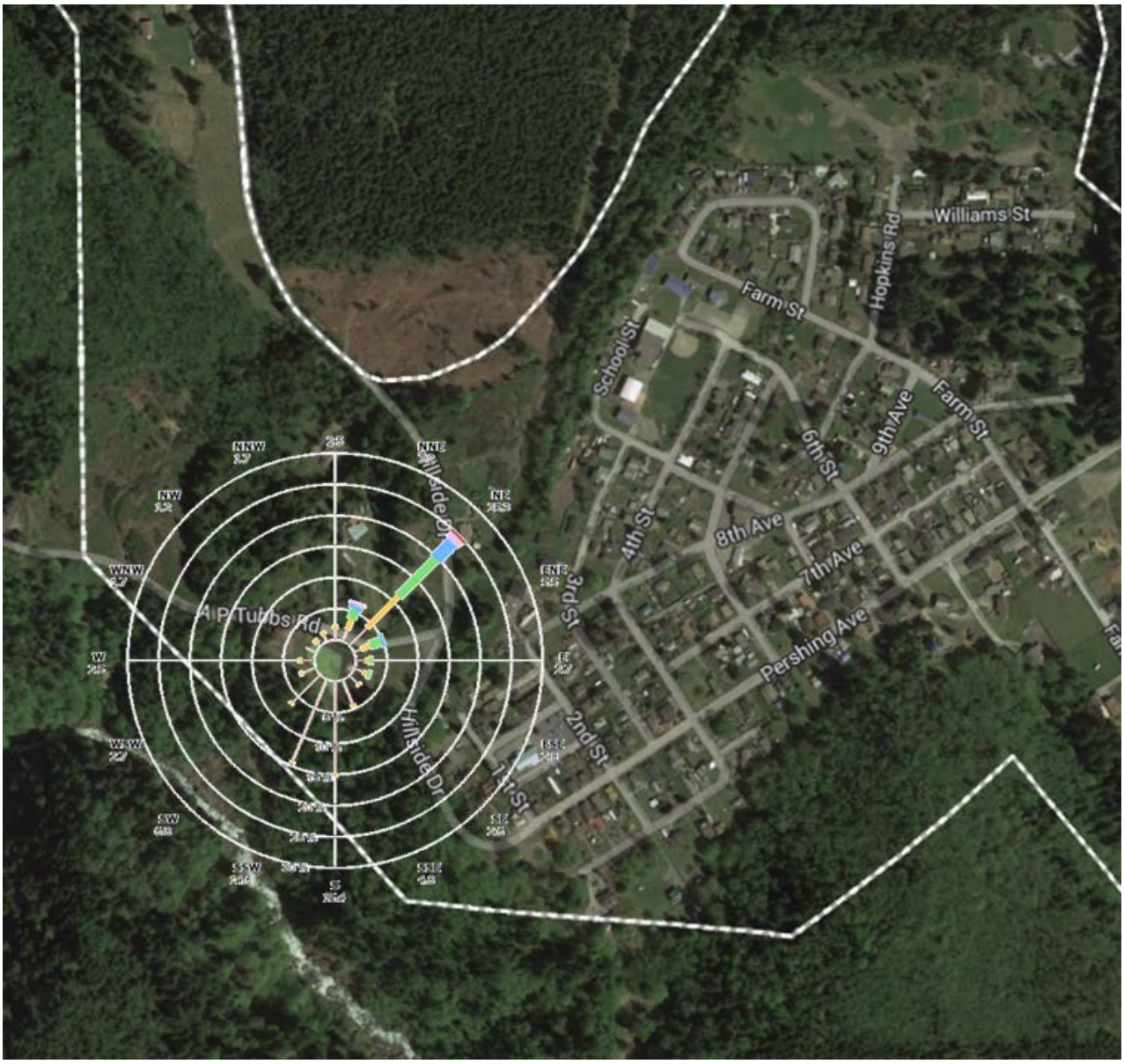

Figure A-1. Map of Carbonado with a pollution rose overlaid. This shows that fine PM levels were only elevated when the wind was from the northeast. Separate wind roses are shown in Figure 16.

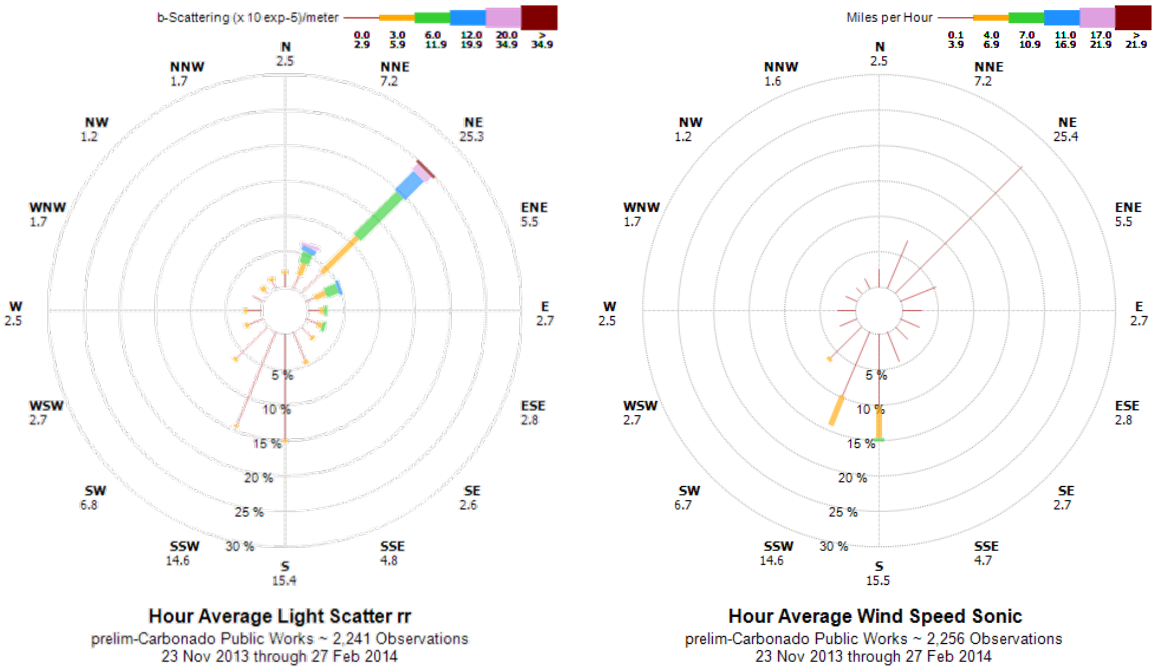

Figure A-2. PM 2.5 and wind speed roses from the Carbonado site. These show that the highest pollution was observed when the winds were from the northeast. But, this was also the predominant direction for light to stagnant winds. Winds were much less frequently directly from Carbonado (straight east). It is possible there was an isolated residence, outside of town, to the north-northeast or northeast of the site that was influencing the monitor.