Appendix A:
BAAQMD's 2015 five year network assessment

BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

Air Monitoring Five-Year Assessment

July 1, 2015

Prepared by
Meteorology, Measurement & Rules Division

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Executive Summary

This Network Assessment for the Bay Area Air Quality Management District (Air District) follows a top-down methodology to determine whether the existing air monitoring network meets the needs of seven million Bay Area residents. It assesses whether the existing network meets all State and national air monitoring requirements, as well as all local air monitoring priorities (such as SO_2 monitoring near oil refineries far beyond EPA mandated requirements), and suggests locations where monitoring should be initiated or terminated.

The requirement to submit an assessment of the air quality surveillance system to the EPA Regional Administrator is provided for in 40 CFR, Part 58 which states:

> *"The State, or where applicable local, agency shall perform and submit to the EPA Regional Administrator an assessment of the air quality surveillance system every 5 years to determine, at a minimum, if the network meets the monitoring objectives defined in appendix D to this part, whether new sites are needed, whether existing sites are no longer needed and can be terminated, and where new technologies are appropriate for incorporation in the ambient air monitoring network. The network assessment must consider the ability of existing and proposed sites to support air quality characterization for areas with relatively high populations of susceptible individuals (e.g., children with asthma), and, for any sites that are being proposed for discontinuance, the effect on data users other than the agency itself, such as nearby States and Tribes or health effects studies. For $PM_{2.5}$, the assessment also must identify needed changes to population-oriented sites. The State, or where applicable local, agency must submit a copy of this 5-year assessment, along with a revised annual network plan to the Regional Administrator. The first assessment is due July 1, 2010."*

The Air District's Executive Management requires that every criteria pollutant be measured in each of the nine Bay Area counties unless a criteria pollutant is in attainment. In that case, lesser monitoring may be approved. When less extensive monitoring is approved, the freed resources may be directed at other, more locally valuable air monitoring efforts (such as temporary source-oriented multi-pollutant monitoring at Cupertino, Berkeley, and Benicia in the recent past). Therefore, knowledge of the attainment status for each criteria pollutant is critical for this network assessment.

The Air District is in attainment for three of the six criteria pollutants: carbon monoxide, sulfur dioxide, and lead. The Air District is in non-attainment for ozone and fine particulate matter ($PM_{2.5}$), and is unclassified for nitrogen dioxide and PM_{10}. Therefore, by Air District policy, ozone and $PM_{2.5}$ must be monitored in each county but some flexibility is allowed in monitoring the other pollutants (but still meeting EPA minimum requirements). Finally, it is Air District policy that within each of the nine Bay Area counties, monitoring priority is given to the city with the largest population unless compelling reasons dictate otherwise. This is the basic framework for this assessment.

To achieve tangible cost-savings, and to maximize the resources available to conduct a multi-county air monitoring network, it is important to eliminate entire monitoring sites rather than curtailing the measurement of one pollutant at a site. In short, there is little savings curtailing carbon monoxide monitoring at a site if ozone monitoring at that site must continue.

Another way to improve efficiency in the network is to combine two or more sites. As pollutant levels have decreased over time, it is reasonable to suspect that some sites once deemed of high importance are no longer critical in defining a county or regions air quality. In practice, this is already occurring through written agreements with the Monterey Bay Unified Air Pollution Control District to share monitoring responsibilities in Santa Clara and San Benito Counties. These counties are part of a single Core Based Statistical Area with EPA minimum monitoring requirements applicable to both agencies in the absence of such written agreements. Below are the major recommendations from this assessment.

Actions for Consideration:

- Close the Fairfield site. Ozone is the only pollutant measured at this site and the data show ozone to be well below the NAAQS. The nearby site, Vacaville, can adequately describe ozone levels in the Fairfield-Vacaville area.

- Combine monitoring sites at San Martin and Gilroy into one site. Because San Martin has a much higher design value for ozone, it should continue operating. Therefore, move $PM_{2.5}$ monitoring at Gilroy five miles to the north and discontinue ozone monitoring at Gilroy. There have been no NAAQS violations for ozone in four years at Gilroy. The $PM_{2.5}$ annual design value is 7.6µg/m3 and the daily design value is 18µg/m3, both well below the annual and daily NAAQS respectively.

- Close the Oakland site. This site measures a wide array of pollutants. However, the first year of CO, NO_2, and $PM_{2.5}$ data at the newly opened Laney College site shows that concentrations at Laney College are representative of measurements at Oakland. There is no need to operate two sites in the same area. Additionally, the source-oriented Oakland West site, in combination with the Laney College site, more than adequately characterizes source-oriented and population oriented air pollution in and around Oakland.

- Discontinue monitoring CO at all sites except at EPA required near-road sites and at San Jose Jackson for the NCore program. If data users wish CO monitoring to continue, then change to trace-level analyzers because CO levels are very low in the Bay Area.

- Discontinue SO_2 monitoring at Bethel Island. This monitor is identified as being needed to assess background and transport of SO_2. However, San Jose Jackson (an NCore site) has a similar design value and is far from most SO_2 sources. Therefore, at this time, the San Jose Jackson trace-level monitor could be considered a background monitor. SO_2 levels are so low in the Bay Area that a transport site at Bethel Island is of limited value. However, because the site is important for other pollutant measurements (ozone), little savings would result from this action.

Overview of 5-Year Network Assessment

Background

The Bay Area Air Quality Management District (Air District) is the public agency responsible for air quality management in nine Bay Area counties: Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, southwestern Solano, and southern Sonoma. The Air District operates air monitoring stations in each of these nine counties. The Air District has been measuring air quality in the San Francisco Bay Area since 1957. At the close of 2014 there were 30 sites in the air monitoring network measuring criteria air pollutants, two sites measuring only H_2S (a non-criteria pollutant), and one site measuring Black Carbon (another non-criteria pollutant) in a wood smoke prone site in Marin County.

For most pollutants, EPA requires a minimum number of monitors based on the population in Core Based Statistical Areas (CBSAs). In the Bay Area, there are five CBSAs. The San Jose – Santa Clara – Sunnyvale CBSA is shared with Monterey Bay APCD because this CBSA includes San Benito County which is part of Monterey Bay APCD. Monitoring agreements between the two Air Districts are in place to meet EPA minimum monitoring requirements. The Vallejo – Fairfield CBSA is shared with Yolo-Solano APCD and the Santa Rosa – Petaluma CBSA is shared with Northern Sonoma APCD. However, the Bay Area Air District meets all minimum monitoring requirements within its own network. Therefore, no monitoring agreements are needed to meet EPA minimum monitoring requirements in these CBSAs. The other two CBSAs are fully within the Air District jurisdiction. In the Bay Area, CBSAs are identical to Metropolitan Statistical Areas (MSA) found in some EPA monitoring requirements.

Purpose of Monitoring

The purpose of the Air District monitoring network is:

- To provide air pollution data to the general public in a timely manner.
- To support compliance with California and national ambient air quality standards (NAAQS). When sites do not meet the standards, attainment plans are developed to attain the standards.
- To support air pollution research studies.

To meet its monitoring objectives the Air District monitoring network collects ambient air data at locations with a variety of site types which, as defined in 40 CFR Part 58 Appendix D, Table D-1, are intended to characterize air pollution levels in areas of high pollution, high population, transported air pollution, and air pollution near specific sources. Figure 1 shows the current Air District monitoring network superimposed on a map showing population density. Most air monitoring stations are located in the populated areas of the Bay Area.

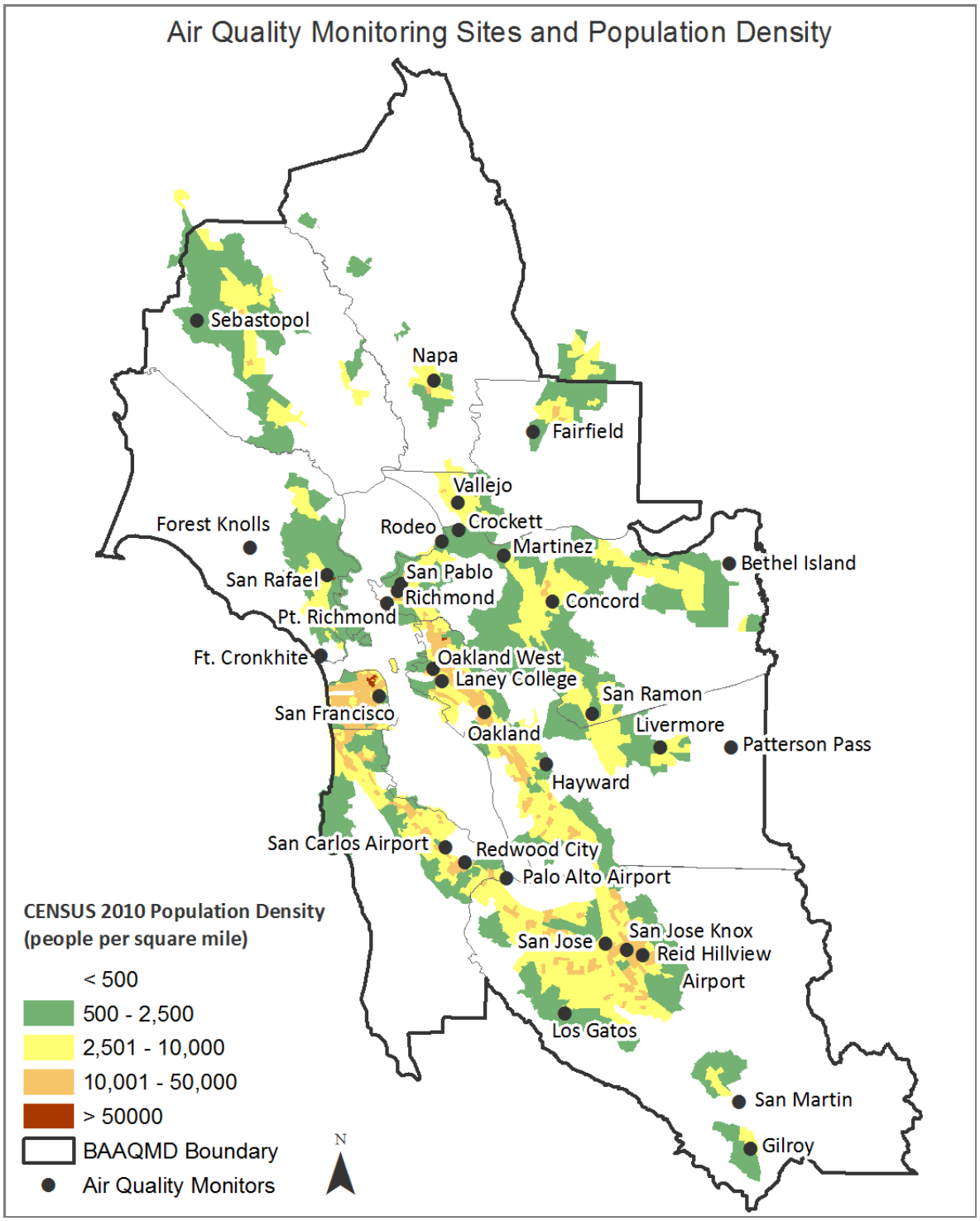


Figure 1. Air quality monitoring sites and population density (2010 CENSUS)

Ambient air monitoring at Air District stations is intended to meet one or more of the following monitoring objectives:

- A determination of typical concentrations in areas of high population density.
- A determination of the highest concentrations expected to occur in the area covered by the network.
- A determination of impacts from significant sources.
- A determination of general background concentration levels.
- A determination of the extent of regional pollutant transport.

To meet its monitoring objectives the Air District collects ambient air data at locations with a variety of monitoring site types. These site types, as defined in 40 CFR Part 58, Appendix D Table D-1 are listed below:

Extreme downwind: Sites established to characterize the extreme downwind transported ozone and its precursor concentrations, located in the predominant afternoon downwind direction from the local area of maximum precursor emissions. This site type is only used at sites designated as PAMS or unofficial PAMS.

Highest concentration: Sites expected to have the highest concentration, even if populations are sparse in that area. High concentrations may be found close to major sources, or further downwind if pollutants are emitted from tall stacks. High concentrations may also be found at distant downwind locations when the pollutants such as ozone or secondary particulate matter are a result of chemical reactions in the atmosphere.

Maximum ozone concentration: Sites intended to monitor maximum ozone concentrations occurring downwind from the area of maximum precursor emissions. Locations should be chosen so that urban scale measurements are obtained. Typically, these sites are located 10 to 30 miles from the fringe of the urban area. This site type is only used at sites designated as PAMS or unofficial PAMS.

Maximum precursor impact: Sites established to monitor the magnitude and type of precursor emissions in the area where maximum precursor emissions are representative of the CBSA are expected to impact and are suited for the monitoring of urban air toxic pollutants. This site type is only used at sites designated as PAMS or unofficial PAMS.

Population exposure: Sites in areas with high population density to evaluate exposure to air pollution. In most cases, stations are located within the largest cities in each county. Because people spend more time at home than at work, air monitoring sites are generally located in residential areas rather than at downtown locations.

Source oriented: Sites in areas downwind of potential major sources of pollutants. In the Bay Area, there are five refineries that are potential pollutant sources: Chevron, Shell, Tesoro, Phillips 66, and Valero. The Port of Oakland also can be a significant source of particulates, CO, and toxics. General aviation airports can be sources of lead because piston engine aircraft continue to use leaded fuel.

Upwind background: Sites in areas that have no significant emissions from mobile, area, or industrial sources. At these sites, the measured concentrations reflect the transported air quality levels from upwind areas. This site type is only used at sites designated as PAMS or unofficial PAMS.

General Background: Where there are no significant emission sources upwind of a site, then the site is considered to be a general background site.

Regional Transport: The Air District shares a common boundary with six other air districts: Monterey Bay Unified APCD, San Joaquin Valley APCD, Sacramento Metropolitan AQMD, Yolo-Solano AQMD, Lake County AQMD, and Northern Sonoma County APCD. When upwind areas have significant air pollution sources, pollutants may be transported into the Bay Area Air District and result in overall higher air pollution levels in the Bay Area.

Welfare-related impacts: Sites located to measure impacts on visibility, vegetative damage, or other welfare-based impacts.

Quality Assurance: Sites where dual or collocated instruments are maintained to confirm that the primary instruments are providing accurate data.

Criteria for Assessment

This assessment will rate the importance of all criteria-pollutant monitors operated by the Air District. Criteria pollutants monitored are carbon monoxide, ozone, nitrogen dioxide, sulfur dioxide, PM_{10}, and $PM_{2.5}$, and lead. Monitors will be designated as high, medium, or low in importance. These evaluations will be based on how well the monitor helps meet the monitoring objectives defined in 40 CFR Part 58 Appendix D, and how well the monitor meets the monitoring objectives of the Air District. The assessment will also determine whether new monitoring sites are needed. Specific criteria used to assess the need for monitoring will be based on the following:

- Meeting the minimum number of monitors within each Core Based Statistical Area as required by EPA.
- Monitoring non-attainment criteria pollutants in each of the nine Bay Area counties.
- Locating a monitor at the expected maximum concentration for each pollutant.
- Locating monitors to determine background or transported pollutant levels.
- Operating fewer monitors for pollutants in attainment of the NAAQS.
- Operating more monitors for non-attainment criteria pollutants.

To meet EPA monitoring objectives, only monitors which are designated State and Local Air Monitoring Stations(SLAMS) are counted toward meeting EPA minimum monitoring requirements. SLAMS monitoring has specific requirements which vary by pollutant and are based on siting factors such as the distance from roadways and obstructions to air flow.

In addition to SLAMS, the Air District operates Special Purpose Monitors (SPMs) at some sites for special needs or shorter term studies. These monitors cannot be counted toward meeting EPA minimum monitoring requirements according to 40 CFR Part 58. However, these monitors are needed to meet Air District objectives (such as monitoring ozone in each County – a more stringent requirement than that of EPA). All SPM monitoring is held to the same calibration and audit requirements as SLAMS monitors.

Criteria Pollutant Assessment

Carbon Monoxide

The Air District currently operates 14 carbon monoxide (CO) monitors in its network, two of which are at near-road sites. Carbon monoxide had been a problem in the past before lower tailpipe emission standards were enacted by California and national governmental agencies. The Air District has not exceeded the 1-hr CO standard since 1967, and has not exceeded the 8-hour national carbon monoxide standard since 1991. Carbon monoxide levels have continued to decrease since then to levels that are now less than 1/3 of the national standard at all locations in the Bay Area.

Figure 2 shows the current locations of SLAMs carbon monoxide monitors. The stations are superimposed on a gridded carbon monoxide emission map. It shows that the stations are generally located in areas of significant CO emissions. Bethel Island, a background concentration site, can be seen in an area of low CO emissions. Additionally, the Air District plans to start monitoring CO at a new near-road site in Dublin starting in late 2015. This site is not needed to meet EPA minimum monitoring requirements. This site is being installed at the request of the Air District's Board of Directors and is not shown in Figure 2 or Table 1.

EPA requires CO monitoring at one near-road site in each CBSA that has a required near-road site. In the Air District, this would amount to a minimum of two sites because two CBSAs are required to operate near-road sites. There are no CO monitors required for Air District SIP or Maintenance Plans. The Air District was selected to operate an NCore site (effective January 1, 2011) and EPA approved NCore operations at the San Jose Jackson site. The NCore program began in January 2011. The requirement is for the Air District to operate a trace-level CO monitor at this site. In summary, there are three sites that require CO monitoring (San Jose Jackson and at two near-road sites).

Table 1 lists the stations currently measuring carbon monoxide in the Bay Area by County. It also lists the site type and the design values. The last column rates the importance of the data measured at the site in meeting the Air District's monitoring objectives. There are no SPMs in the network.

Alameda County has three CO monitoring sites – Oakland, Oakland West, and Laney College (an EPA required near-road monitoring site). Oakland is rated low because although Oakland is a major city in the Bay Area there are two other monitoring sites in Oakland measuring CO (Laney near-road and Oakland West). Oakland West is rated high because it is a source-oriented site downwind of the Port of Oakland and Interstate 880. The Laney College site is rated high because it is required by EPA for near-road CO monitoring.

Contra Costa County has three CO monitoring sites – Bethel Island, Concord, and San Pablo. Bethel Island is a background site and was rated high in the assessment of 2010. However, a background site is not of high priority any longer because the design values are so low for CO in the Bay Area. The other two sites, Concord and San Pablo are rated low because their design values are low and similar to other sites.

In Santa Clara County there are two CO monitors, both rated high. The San Jose Jackson CO is required because it is part of the EPA's NCore program. San Jose Knox Avenue is rated high because it is a near-road monitoring site and is required by EPA regulations.

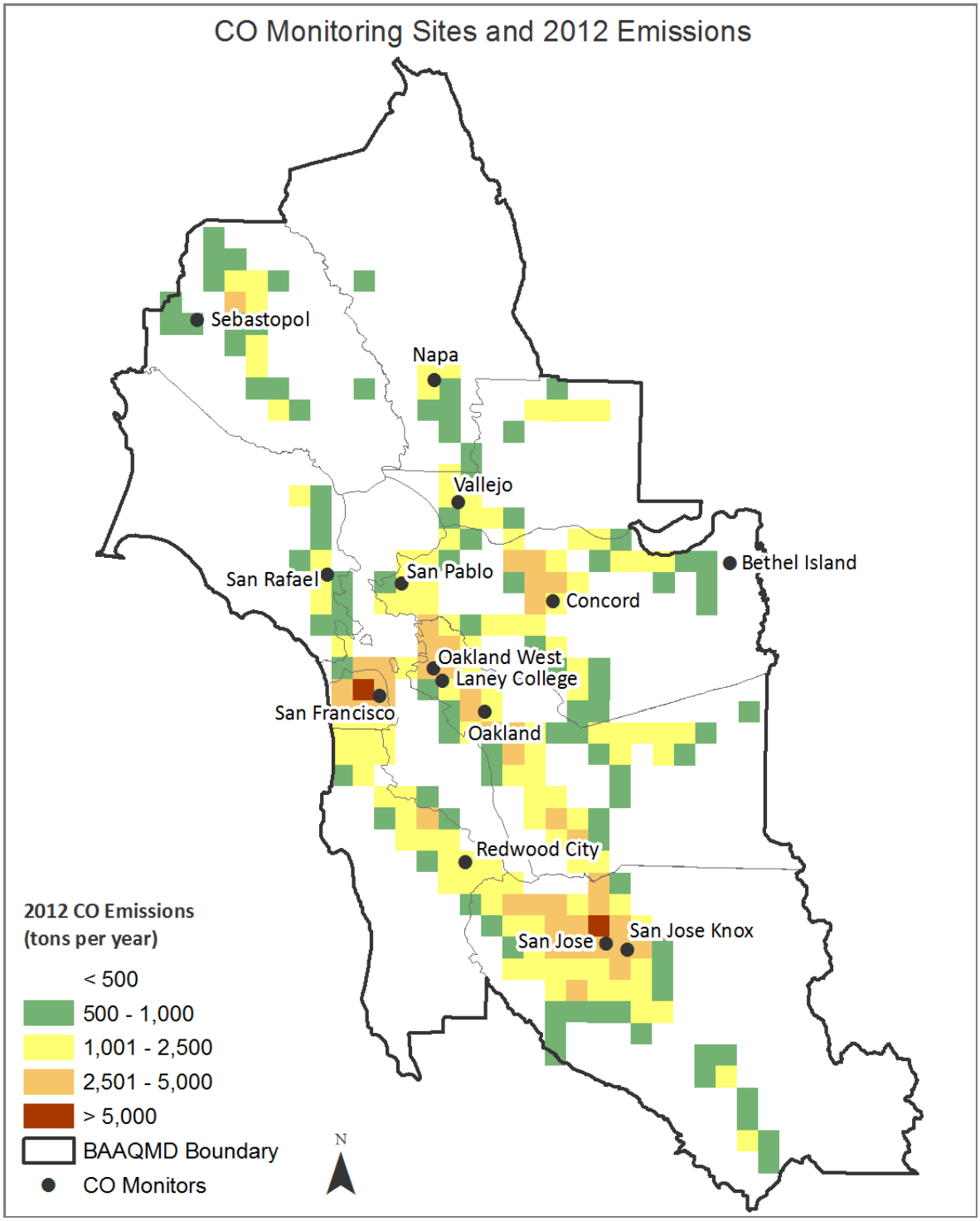


Figure 2. Carbon monoxide monitoring sites and 2012 emissions

All other sites are rated low because their design values are quite low and similar to the sites that are rated high or medium. Overall, the Air District is over-monitoring CO. Monitoring of CO at low value sites is recommended to be discontinued. However, if a low value site will continue monitoring another pollutant, then the cost-savings is minimal. Alternatively, if CO monitoring is continued at all low value sites, then trace-level monitors may need to be considered employed because CO levels across the Bay Area are now roughly as low as they are at San Jose where NCore program requirements are already using trace-level analyzers.

Table 1. Carbon monoxide SLAMS monitoring sites

Station	County	Site Type	1-hr CO Design Value[1] (ppm) 2013-14	8-hr CO Design Value[1] (ppm) 2013-14	Assigned Value from Assessment
Laney College	Alameda	Source Oriented Population Exposure (Near-road)	Insufficient Data[2]	Insufficient Data[2]	High
Oakland	Alameda	Population Exposure	3.6	1.9	Low
Oakland West	Alameda	Source Oriented	3.6	2.6	High
Bethel Island	Contra Costa	Background	1.0	0.8	Low
Concord	Contra Costa	Population Exposure	1.3	1.0	Low
San Pablo	Contra Costa	Population Exposure	1.7	1.0	Low
San Rafael	Marin	Population Exposure	2.1	1.0	Low
Napa	Napa	Population Exposure	2.8	1.5	Low
San Francisco	San Francisco	Population Exposure	1.8	1.3	Low
Redwood City	San Mateo	Population Exposure	3.3	1.6	Low
San Jose Jackson	Santa Clara	Population Exposure (NCore)	2.8	2.1	High
San Jose Knox Avenue	Santa Clara	Source Oriented Population Exposure (Near-road)	Insufficient Data[2]	Insufficient Data[2]	High
Vallejo	Solano	Population Exposure	2.6	2.0	Low
Sebastopol	Sonoma	Population Exposure	Insufficient Data[2]	Insufficient Data[2]	Low

1. CO design values are the higher of the 2nd highest concentration from each of the past two years.
2. Laney College, San Jose Knox Avenue, and Sebastopol sites opened in 2014. Two years of data are needed to assess a design value.

Ozone

At the close of 2014, the Air District operated 15 SLAMS and 4 SPM ozone (O_3) monitors in its network. The number of EPA-required SLAMS ozone monitors is based on the CBSA population and design value; as specified in Table D-2 of 40 CFR Part 58, Appendix D – SLAMS Minimum O_3 Monitoring Requirements. SPM monitors are not counted toward meeting the minimum requirements. The Bay Area meets all minimum monitoring requirements for ozone with its own network. No additional monitors are required in the SIP or Maintenance Plan for ozone. No monitoring agreements are needed with other Air

Districts to meet minimum requirements. The Annual Network Plan for 2014 has more specific details about minimum monitoring requirements, which are also listed in Table 2.

Ozone levels have dropped significantly in the Bay Area since the 1960s (see Figure 3). At the close of 2014, every ozone monitor in the Bay Area has a design value below the national standard. The highest design value is 72 ppb at Livermore. The second highest is 70 ppb at San Martin. Both of these sites are downwind of the major metropolitan area where ozone levels rise appreciably during hot summer days. A map of the 2014 8-hour ozone design values is shown in Figure 4. About ⅔ of the Air District adjacent to the Pacific Ocean enjoys relatively low ozone levels with design values of 65 ppb or below. Less than ⅓ of the Air District is between 70 to 75 ppb. The map also suggests there is a small portion of western Alameda County that is above 75 ppb range but this is an artifact of the spatial interpolation technique used to create the contours. In Sonoma County, no values are shown but the Santa Rosa site (closed in December 2013) had a 2013 DV of 47 ppb.

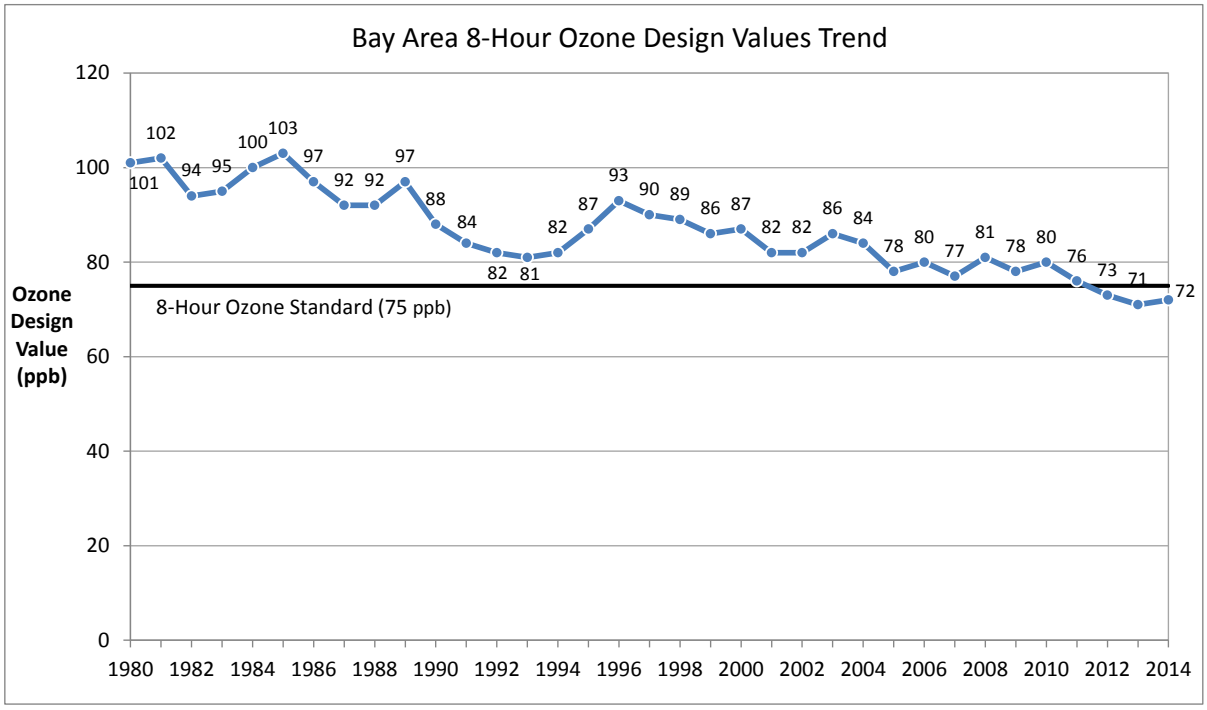
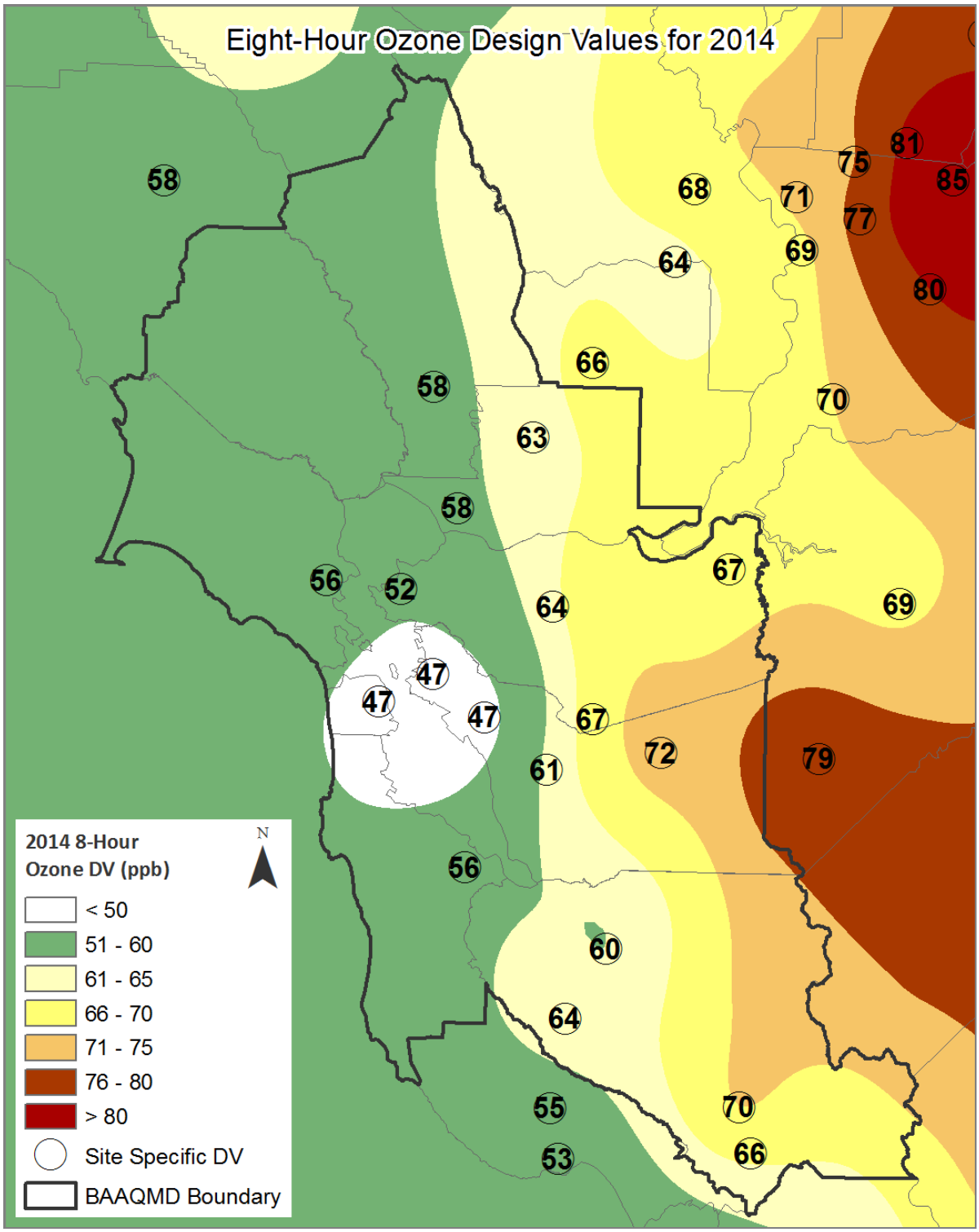


Figure 3. Bay Area 8-hour ozone design value trend (1980 through 2014)



Note: Spatial interpolation technique is adopted from the Maryland Department of the Environment (http://www.mde.state.md.us/programs/Air/AirQualityMonitoring/Pages/OzonePlumeHelp.aspx).

Figure 4. Spatial pattern for the 2014 8-hour ozone design values

Figure 5 shows the current Bay Area ozone monitoring stations. The stations are superimposed on a color-coded exceedance probability map. There are a number of wind patterns on hot days which can produce high ozone levels. The most common summertime wind pattern in the Bay Area is a delayed afternoon sea breeze that carries precursor pollutants to the eastern and southern portions of the Air District, as is depicted in Figure 5. Ozone monitors have been placed at Bethel Island, Livermore, Concord, and Fairfield to measure these high levels. Occasionally a very light wind pattern occurs, which results in high ozone concentrations close to source areas near the bay, generally at San Jose, Los Gatos, Napa, and Hayward.

Table 2. Minimum monitoring requirements for ozone SLAMS sites

CBSA	County	Population in millions 2010	8-hour Design Value[1] (ppb) 2012-14	Number of SLAMS Monitors Required	Number of SLAMS Monitors Operated by the Bay Area Air District	Number of SLAMS Monitors Operated by the Bay Area and other Air Districts
San Francisco-Oakland-Fremont	SF, Marin, Alameda, San Mateo, Contra Costa	4.34	72	3	7	7
San Jose-Sunnyvale-Santa Clara	Santa Clara, San Benito	1.84	70	2	4	6[2]
Santa Rosa-Petaluma	Sonoma	0.48	58	1	1	2[3]
Vallejo-Fairfield	Solano	0.41	66	2	2	3[4]
Napa	Napa	0.14	58	0	1	1

[1] Design values are calculated at each monitoring site by taking the 3-year mean of the 4th highest 8-hour concentration. Design values at or below the 0.075 ppm National Ambient Air Quality 8-hour Ozone Standard meet the standard.

[2] One monitor is in Hollister and another is in Pinnacles National Monument. Both are in San Benito County within the Monterey Bay Unified Air Pollution Control District.

[3] One monitor is in Healdsburg in Sonoma County and is within the Northern Sonoma Air Pollution Control District.

[4] One monitor is in Vacaville in Solano County and is within the Yolo-Solano Air Pollution Control District.

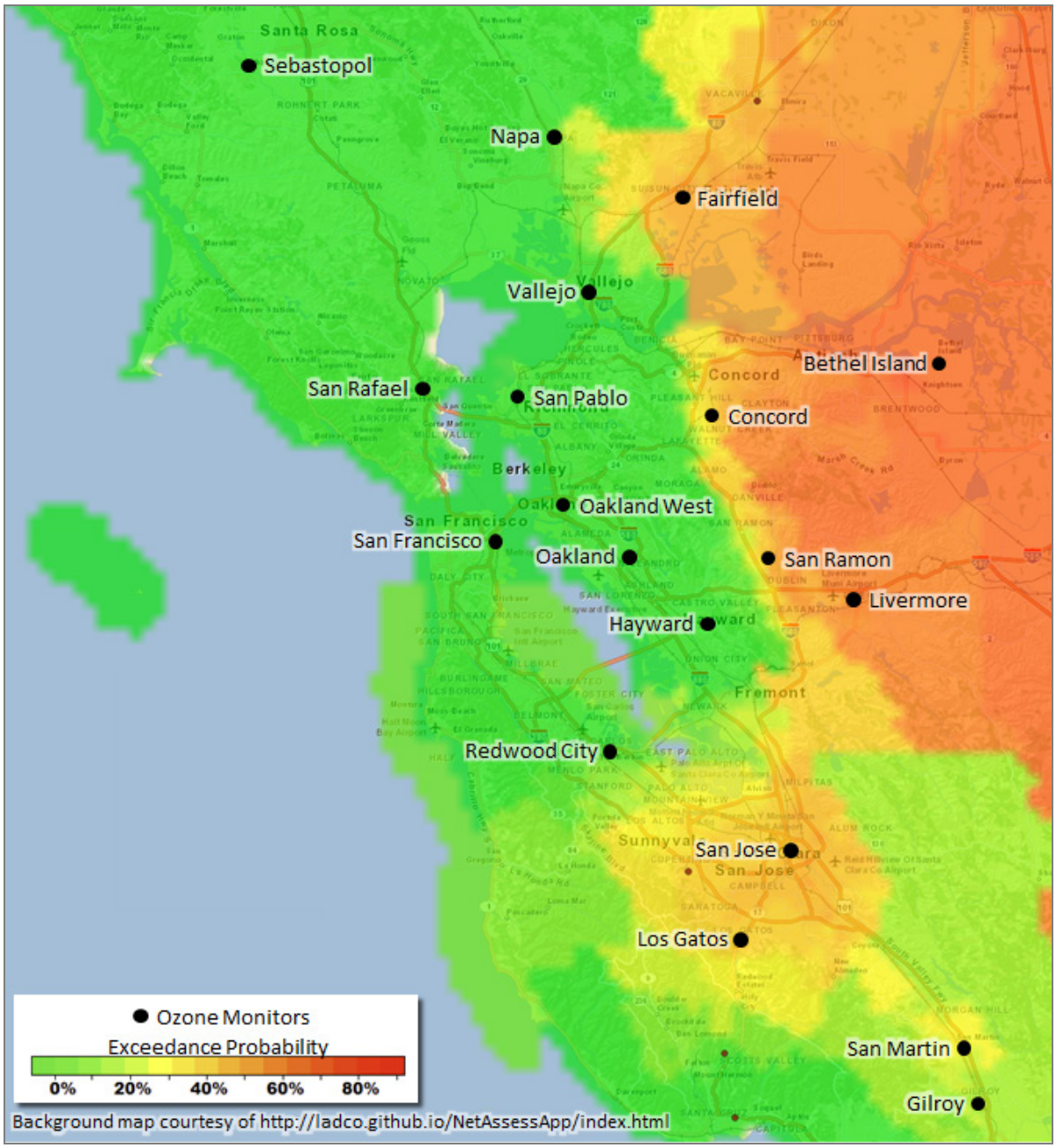


Figure 5. Ozone monitoring sites and ozone exceedance probability

Table 3 lists sites measuring ozone in the Bay Area by county. It also lists the monitor type, site type and the ozone design values. The last column rates the importance of the data measured at the site in meeting monitoring objectives.

Table 3. Ozone monitoring (SLAMS and SPM) sites

Station	County	Monitor Type	Site Type	8-hour Design Value (ppb) 2012-14	Assigned Value from Assessment
Hayward	Alameda	SLAMS	Population Exposure	61	Low
Livermore	Alameda	SLAMS	Population Exposure & Highest Concentration	72	High
Oakland	Alameda	SPM	Population Exposure	47	Low
Oakland West	Alameda	SLAMS	Population Exposure	47	Low
Bethel Island	Contra Costa	SLAMS	Regional Transport Highest Concentration	67	High
Concord	Contra Costa	SLAMS	Population Exposure	64	High
San Pablo	Contra Costa	SPM	Population Exposure	52	Low
San Ramon	Contra Costa	SPM	Population Exposure Upwind Background (unofficial PAMS)	67	Low
San Rafael	Marin	SPM	Population Exposure	56	High
Napa	Napa	SLAMS	Population Exposure & Highest Concentration	58	High
San Francisco	San Francisco	SLAMS	Population Exposure	47	High
Redwood City	San Mateo	SLAMS	Population Exposure	56	High
Gilroy	Santa Clara	SLAMS	Population Exposure	66	Low
Los Gatos	Santa Clara	SLAMS	Population Exposure	64	Medium
San Jose Jackson	Santa Clara	SLAMS	Population Exposure (NCore)	60	High
San Martin	Santa Clara	SLAMS	Population Exposure & Highest Concentration	70	High
Fairfield	Solano	SLAMS	Population Exposure & Highest Concentration & Regional Transport	63	Low
Vallejo	Solano	SLAMS	Population Exposure	58	High
Sebastopol	Sonoma	SLAMS	Population Exposure & Highest Concentration	Insufficient Data	High

The importance of each ozone monitor is related to

- EPA minimum monitoring requirements.
- Demonstration of attainment of air quality standards.
- Proximity of the site to other sites.
- The monitoring purpose.
- The number of monitors in a county.
- The size of the population in the surrounding area.

The Air District desires to operate at least one ozone monitor in each of the nine Bay Area counties. There are five counties where the Air District operates only one monitor: San Francisco, San Mateo, Marin, Napa, and Sonoma (there is another monitor in Healdsburg which is in Northern Sonoma Air District). These monitors are rated high because they are the only ozone measurements done by the Air District in those counties.

Alameda County has four ozone monitors. Livermore is rated high because it has the highest design value in the Air District. Livermore is located downwind of the major metropolitan area and experiences hot summers compared to the more ocean-sourced cooler air near the coast and bay. All other Oakland sites are rated low because although they are in a major population center, their design values are very low and NAAQS violations almost never occur.

Figure 6 shows an ozone correlation matrix for the San Francisco – Oakland – Fremont CBSA. The correlation matrix was created using the NetAssess software developed by the Lake Michigan Air Directors Consortium (LADCO). The matrix displays the correlation, relative difference, and distance between pairs of sites within the CBSA. The purpose of the matrix is to identify possible redundant sites that could be removed. Possible redundant sites would exhibit fairly high correlations and would have low average relative difference despite the distance. The shape of the ellipses represents the Pearson correlation between sites (http://en.wikipedia.org/wiki/Pearson_product-moment_correlation_coefficient). Circles represent zero correlation and straight diagonal lines represent a perfect correlation. The correlation may indicate whether a pair of sites is related. However, it does not indicate if one site consistently measures pollutant concentrations at levels substantially higher or lower than the other. For this purpose, the average relative difference between the two sites is calculated. The average relative difference between the two sites is an indicator of the overall measurement similarity between the two sites. Site pairs with a lower average relative difference are more similar to each other than pairs with a larger difference.

The matrix in Figure 6 shows that the Oakland – Oakland West site pairing has a high Pearson correlation and a low average relative difference. Since Oakland West is similar to Oakland, it is recommended that ozone monitoring be discontinued at Oakland.

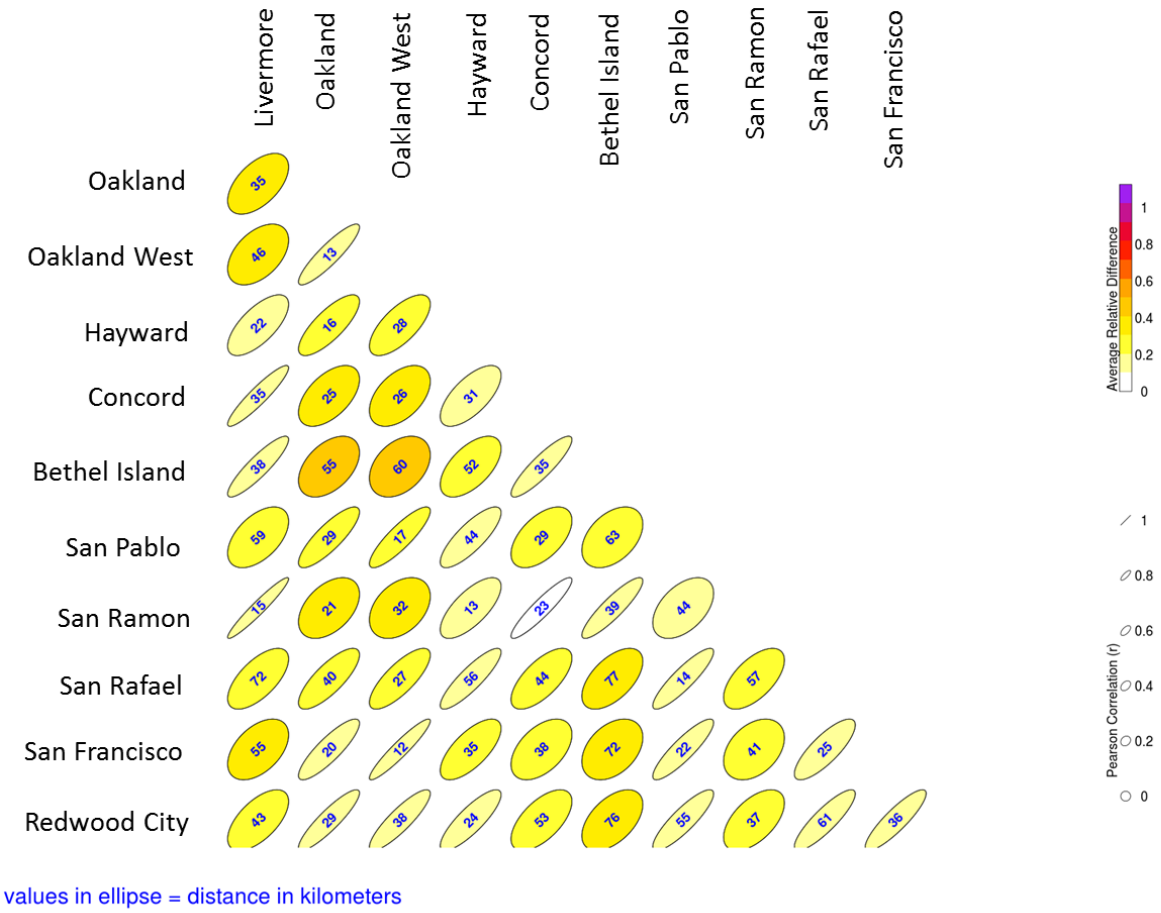


Figure 6. Eight-hour daily maximum ozone correlation matric for the San Francisco – Oakland – Fremont CBSA.

Contra Costa County has four ozone monitoring sites. Bethel Island is rated high because it has the highest design value in the county. Concord is also rated high because its design value is elevated and the site is in the most populated city in the county. San Pablo is rated low because the site is near the cooler waters of San Francisco Bay and, therefore, has a low design value. San Ramon is rated low because this SPM is being operated to support an unofficial PAMS study being done by the Air District. Data has been collected for this study since 2012, and may soon be terminated depending on the results of the study (which are unknown at this time). San Ramon is also rated low because it is highly correlated with the Concord site, as shown in Figure 6.

Santa Clara County has four ozone monitoring sites. San Jose is rated high because it is required for NCore and is the most populated city in the Bay Area. San Martin is rated high because it has the highest design value in Santa Clara County (and the CBSA which is shared with San Benito County in the Monterey Bay Air District). Los Gatos is rated medium because it is located on the west side of Silicon Valley and near the hills that border with Santa Cruz County. The other site, Gilroy, is rated low. Gilroy is rated low because it is very close to San Martin (only 5.5 miles separate the two sites), and has not recorded an

exceedance of the NAAQS in the past four years. At Gilroy, only ozone and $PM_{2.5}$ are measured and $PM_{2.5}$ levels are well below the national standard and $PM_{2.5}$ may be moved to San Martin. Therefore, if ozone monitoring is discontinued, then the entire Gilroy site may be closed.

Figure 7 shows an ozone correlation matrix for the San Jose – Sunnyvale – Santa Clara CBSA. The matrix in Figure 7 shows that the San Martin – Gilroy site pairing has a high Pearson correlation and a low average relative difference. Since San Martin has the highest design value in the CBSA, and Gilroy is similar to San Martin, it is recommended that ozone monitoring be discontinued at Gilroy.

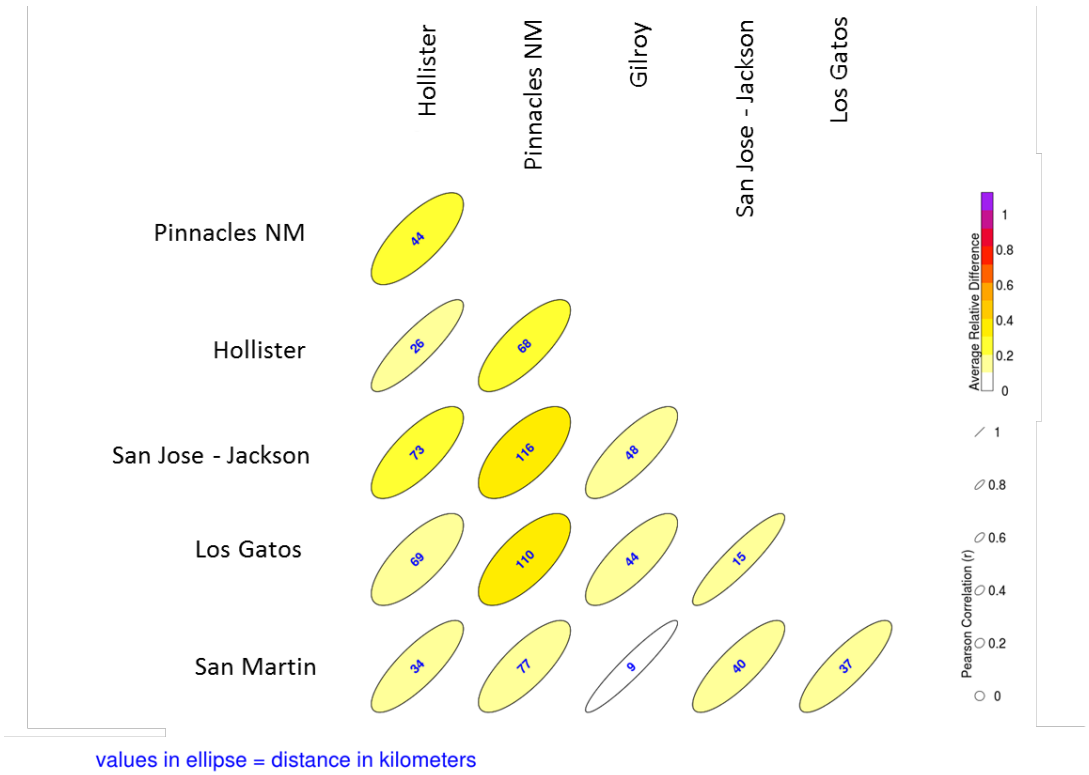


Figure 7. Eight-hour daily maximum ozone correlation matric for the San Jose – Sunnyvale – Santa Clara CBSA.

Solano County is in the Vallejo-Fairfield CBSA and is required to operate two ozone monitors to meet EPA minimum monitoring requirements. The Air District operates two ozone monitoring sites in Solano County at Vallejo and Fairfield. Additionally, the Yolo-Solano Air District operates a third monitor at Vacaville.

Ozone monitoring in Vallejo is rated high because it is a good trend site, having monitored ozone since 1976 and is in the most populated city in Solano County. Fairfield is rated low because it is just 11 miles southwest of the Vacaville ozone monitoring site (in the Yolo-Solano Air District) and has a lower design value. Both sites can be considered transport

sites (Fairfield measuring transport out of the Bay Area and Vacaville measuring transport into the Sacramento Valley).

The ozone design value at Vacaville is 66 ppb while at Fairfield it is 64 ppb. Both sites have been monitoring ozone since 2005 and the DV has been higher at Vacaville in 8 of the 10 years as summarized in Table 4 below.

Table 4. Vacaville vs Fairfield ozone design value comparison

Year	Vacaville (Ulatis Drive) DV (ppb)	Fairfield (Chadbourne Rd) DV (ppb)
2005	71	68
2006	73	69
2007	74	66
2008	75	68
2009	72	67
2010	71	69
2011	68	69
2012	69	68
2013	65	67
2014	66	63

Figure 8 shows an ozone correlation matrix for the Vallejo – Fairfield, CA CBSA. The Fairfield – Vacaville site pairing has a high Pearson correlation and a low average relative difference. Therefore, the two sites are similar. Because two sites are not needed to characterize transport between the Bay Area and the Sacramento Valley, it is reasonable to consider closing the Fairfield site. Closure would require a monitoring agreement with the Yolo-Solano Air District to meet EPA required minimum monitoring requirements for ozone in the CBSA.

Vallejo – Fairfield, CA CBSA

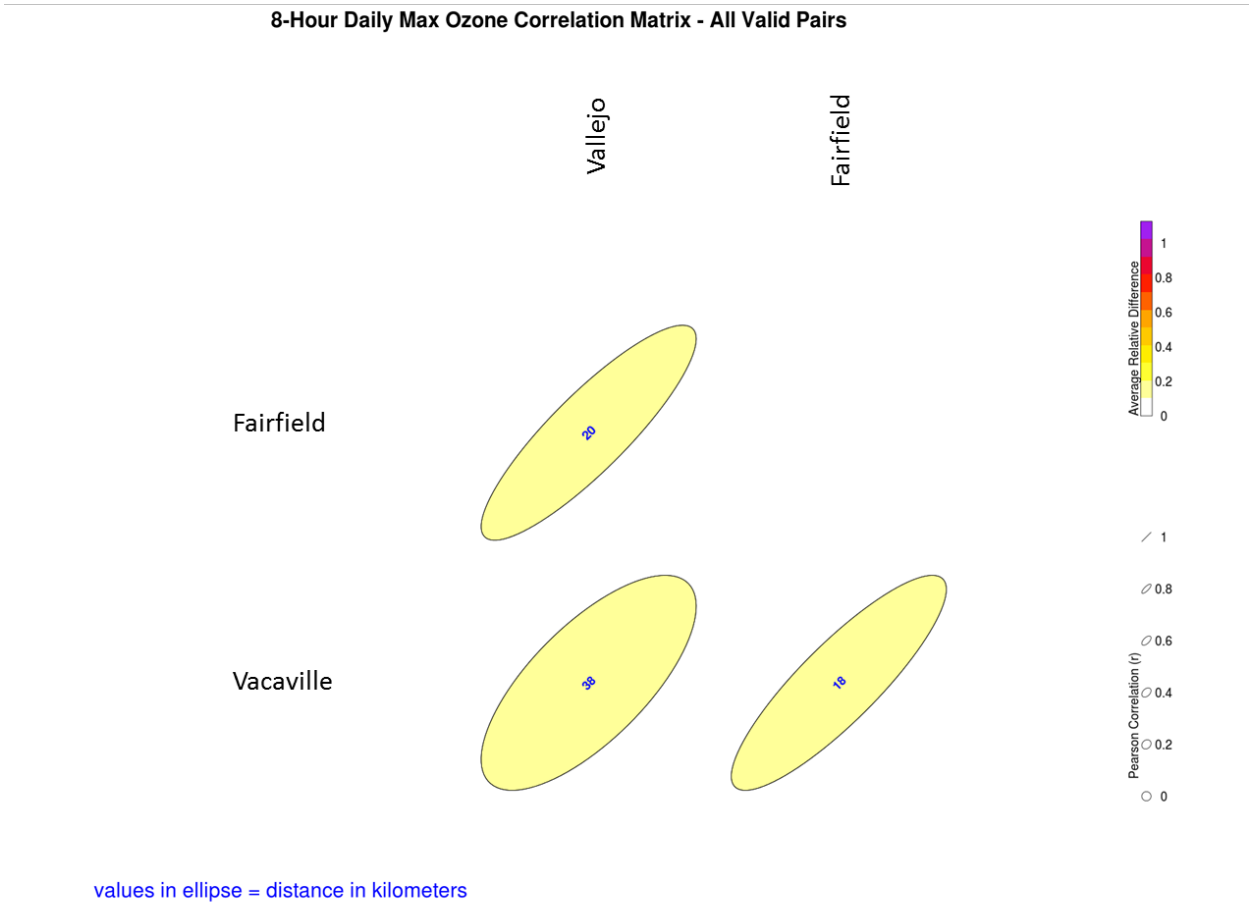


Figure 8. Eight-hour daily maximum ozone correlation matric for the Vallejo – Fairfield CBSA.

Nitrogen Dioxide

At the close of 2014, the Air District operated 17 nitrogen dioxide (NO_2) monitors in its network. Within the network two monitors (San Ramon and Patterson Pass) are SPM and are not counted toward meeting minimum monitoring requirements. Two additional monitors (Laney College and San Jose Knox) are for EPA required near-road monitoring and are not contributing toward area-wide monitoring (but are counted in meeting near-road monitoring requirements). Of the remaining 13 monitors, four (Napa, Oakland, San Rafael, and San Pablo) are classified as middle scale because their probes are too close to nearby busy roadways and not counted toward meeting monitoring requirements. The remaining nine sites are counted for area-wide monitoring and exceed EPA minimum monitoring requirements.

EPA also requires 40 sites across the United States to measure NO_2 near susceptible and vulnerable populations. The Oakland West site was selected to be one of the sites for this program. It is loosely termed Regional Administrator monitoring or RA-40 monitoring.

NO_2 monitors also measure nitrogen oxide (NO), and the sum of NO_2 and NO, is called NO_x. NO_2 measurements have been made in the Bay Area since the 1960s. NO_2 levels have only exceeded the national 1-hour standard once in the past five years. NO_2 is formed from vehicle, power plant and other industrial emissions, and contribute to the formation of ozone and fine particulate matter.

Figure 9 shows the current locations of NO_2 monitors. The stations are superimposed on a gridded NO_x emission map. NO_x is used in place of NO_2 because the amount of NO_x is better quantifiable and because NO and NO_2 concentrations change throughout the day depending upon the amount of sunlight, the ambient temperature, and the concentration of oxidizing pollutants available in the air. The map shows that the stations are generally located in areas of high NO_x emissions. Bethel Island, a site located to measure transported pollutants, is in an area of low NO_x emissions. Additionally, the Air District plans to start monitoring NO_x at a new near-road site in Dublin starting in late 2015. This site is not needed to meet EPA minimum monitoring requirements. This site is being installed at the request of the Air District's Board of Directors and is not shown in Figure 9 or Table 5.

EPA minimum area-wide monitoring requirements are based on CBSA population. EPA near-road minimum monitoring requirements are based on CBSA and maximum highway traffic counts in the CBSA. Monitoring requirement details are listed in Table 5. No additional monitors are required for the SIP or Maintenance Plans because the Air District has never been designated as non-attainment for NO_2. The Air District is not presently meeting the near-road minimum requirement because the Berkeley Aquatic Park site has been held up in local permits. It is now planned to open early in the 2nd half of 2015.

For planning purposes, it should be noted that presently only one near-road site is required in the San Jose – Sunnyvale – Santa Clara CBSA. However, the maximum traffic count in the CBSA is 245,000 (2013 data, the latest available). Should it reach 250,000, EPA requires an additional near-road NO_2 site in this CBSA.

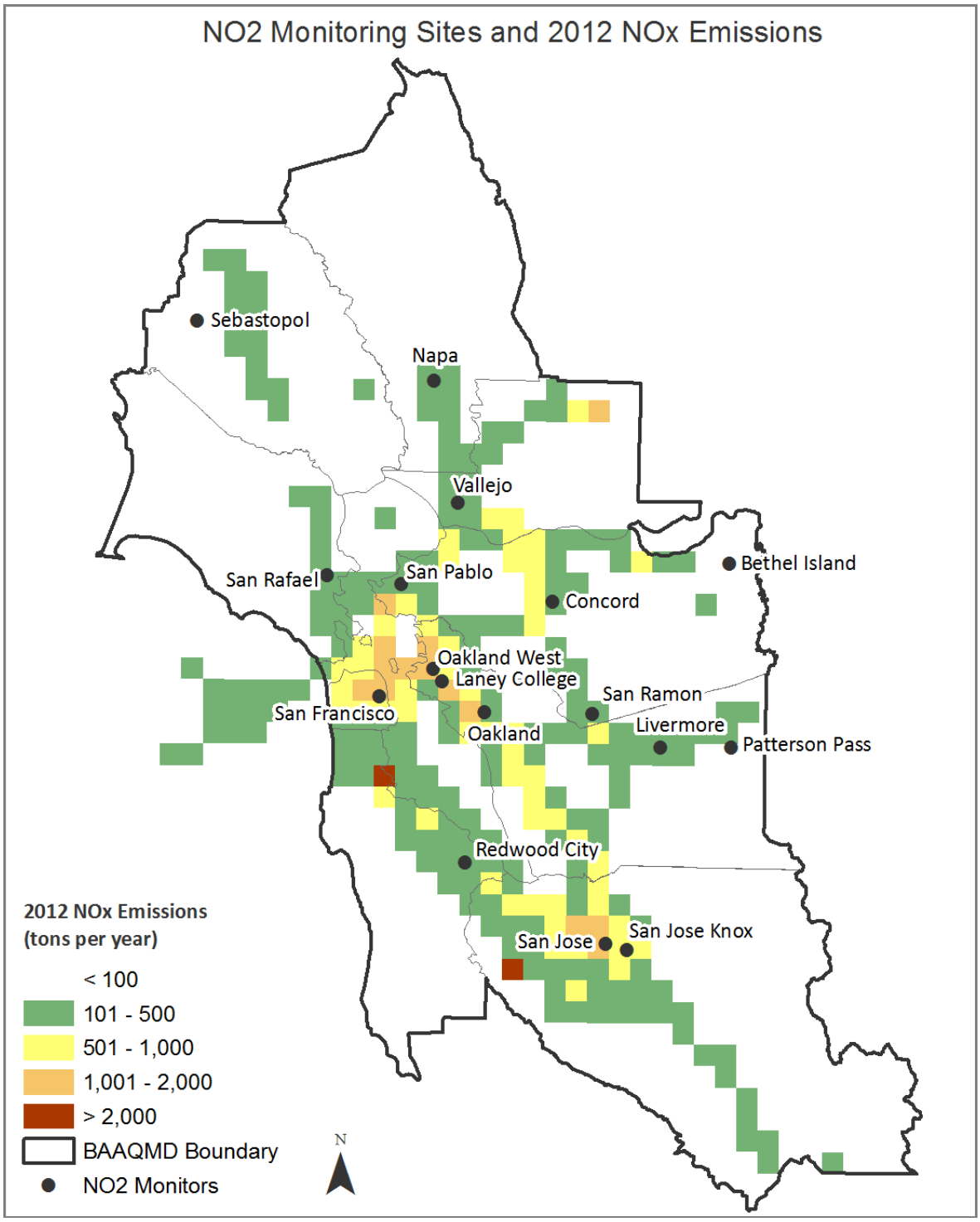


Figure 9. Nitrogen dioxide monitoring sites and 2012 NOx emissions

Table 5. Minimum monitoring requirements for NO_2 SLAMS sites

			Near-road Monitoring			Area-wide Monitoring		
CBSA	Pop. 2010 Census	Max Traffic Count (2013)	Required Monitors	Active Monitors	Additional Monitors Needed	Required Monitors	Active Monitors	Additional Monitors Needed
San Francisco-Oakland-Fremont	4,335,391	270,000	2	1	1[a]	1[b]	6	0
San Jose-Sunnyvale-Santa Clara	1,836,911	245,000	1	1	0	1	1	0
Santa Rosa-Petaluma	483,878	146,000	0	0	0	0	1	0
Vallejo-Fairfield	413,344	202,000	0	0	0	0	1	0
Napa	136,484	119,000	0	0	0	0	0	0

a One near-road monitor is expected to open at Berkeley Aquatic Park by mid-2015, and another in late 2015 or early 2016 in Dublin. While only one additional monitor is required to be opened, the Air District will be opening 2 within the next year.

b One area-wide monitor is required however the Oakland West monitoring site was selected as one of the 40 nationwide sites for monitoring near susceptible and vulnerable populations. Therefore, there are two required for this CSBA (one based on population and one for Regional Administrator Required Monitoring).

Table 6 lists the stations currently measuring nitrogen dioxide in the Bay Area in each county. It also lists the site and monitor type, and the NO_2 design values for each site. The last column rates the importance of the data measured at the site in meeting Air District and EPA monitoring objectives.

The Air District desires at least one NO_2 monitor in each of the nine Bay Area counties. There are six counties with only one monitor: San Francisco, San Mateo, Marin, Sonoma, Solano, and Napa. They are rated medium in importance because NO_2 levels are only about one half of the 1-hour national standard, and less than a quarter of the national annual standard but they are the only monitor in their respective counties.

In Santa Clara County, there are two NO_2 monitors. Both are rated of high importance. The San Jose Knox monitor is required for near-road NO_2 monitoring. The San Jose Jackson monitor is rated high because San Jose is the most populated city in the Bay Area.

Table 6. Nitrogen Dioxide Monitoring Sites

Station	County	Monitor Type	Site Type	1-hour Design Value[1] (ppb)	Annual Design Value[2] (ppb)	Assigned Value from Assessment
Laney College	Alameda	SLAMS	Population Exposure Source Oriented (Near-road)	Insufficient Data[3]	17	High
Livermore	Alameda	SLAMS	Population Exposure	44	10	High
Oakland	Alameda	SLAMS	Population Exposure	50	12	Low
Oakland West	Alameda	SLAMS	Population Exposure Source Oriented (RA-40 site)	51	14	High
Patterson Pass	Alameda	SPM	Extreme Downwind (unofficial PAMS)	Insufficient Data[3]	Insufficient Data[3]	Low
Bethel Island	Contra Costa	SLAMS	Transport	30	5	High
Concord	Contra Costa	SLAMS	Population Exposure	37	8	High
San Pablo	Contra Costa	SLAMS	Population Exposure	40	9	Low
San Ramon	Contra Costa	SPM	Upwind background (unofficial PAMS)	Insufficient Data[3]	Insufficient Data[3]	Low
San Rafael	Marin	SLAMS	Population Exposure	47	11	Medium
Napa	Napa	SLAMS	Population Exposure	39	8	Medium
San Francisco	San Francisco	SLAMS	Population Exposure	61	12	Medium
Redwood City	San Mateo	SLAMS	Population Exposure	46	11	Medium
San Jose Jackson	Santa Clara	SLAMS	Population Exposure	53	13	High
San Jose Knox	Santa Clara	SLAMS	Population Exposure Source Oriented (Near-road)	Insufficient Data[3]	Insufficient Data[3]	High
Vallejo	Solano	SLAMS	Population Exposure	42	8	Medium
Sebastopol	Sonoma	SLAMS	Population Exposure	Insufficient Data[3]	4	Medium

[1] The 1-hour design value is the 8th highest daily maximum hourly value at a site per year, averaged over the past three years. Design values at or below the national NO_2 1-hour standard of 100 ppb meet the standard.

[2] The annual design value is the average of all hourly NO_2 measurements during the most recent year. Design values at or below the national NO_2 annual standard of 53 ppb meet the standard.

[3] Laney College, San Jose Knox, and Sebastopol sites opened in 2014. There is not enough data to calculate design values. Patterson Pass and San Ramon do not monitor NO_2 during winter. There is not enough data to calculate design values.

Alameda County has five NO_2 monitors. Livermore is rated high because ozone exceedances frequently occur and NO/NO_2 data are needed for modeling and analysis as ozone precursors. Oakland West is rated high because it is a source-oriented site as well. Laney College is also rated high as it is a near-road monitor. Oakland is rated low because Laney College and Oakland West already characterize the pollution in the Oakland area. Patterson Pass is also

rated low because it is in an SPM operating in an unpopulated area as part of an Air District ozone study. The site may be closed when the results of the study are known.

Contra Costa County has four NO_2 monitoring sites. Bethel Island and Concord are rated high because NO/NO_2 data are needed for modeling and analysis of ozone exceedances. Bethel Island is also important for measuring NO_x transport to and from neighboring air districts. San Pablo is rated low because there is no specific need for the data, and NO_2 design values are low. San Ramon is rated low because it is an SPM as part of an Air District ozone study. The site may be closed when the results of the study are known.

Sulfur Dioxide

At the close of 2014, the Air District operated nine sulfur dioxide monitors (SO_2) in its network. Eight of the monitors are SLAMS and one (at Crockett) is an SPM because it does not meet SLAMS siting requirements. SO_2 measurements have been made in the Bay Area since 1969. Today the network is primarily source-oriented with most monitoring done near oil refineries and at Oakland West downwind of the Port of Oakland. Unlike other pollutants, SO_2 concentrations are normally measured near sources. Counties without sources usually have concentrations near background levels.

Figure 10 shows the locations of sulfur dioxide monitors. The stations are superimposed on a gridded SO_2 emission map. The map shows areas off the coast and on the San Francisco Bay with SO_2 emissions. These emissions are from ships. The Oakland West SO_2 monitor is located downwind of the Port of Oakland to measure SO_2 from shipping. The other major source of SO_2 emissions are Bay Area refineries owned by Chevron, Shell, Tesoro, Valero, and ConocoPhillips. Most of the remaining monitors are located near these refineries. One other SO_2 monitor is located at the San Jose NCore site, a requirement of 40 CFR Part 58. Bethel Island also has an SO_2 monitor to measure transport and background levels.

The Air District meets the minimum number of SO_2 monitors as shown in Table 7. The number of required SO_2 monitors in each CBSA is proportional to the product of the total amount of SO_2 emissions in the CBSA and its population as specified in 40 CFR Part 58, Appendix D Section 4.4. The resulting value is defined as the Population Weighted Emissions Index (PWEI). SO_2 emissions shown in Table 7 are from the 2011 National Emissions Inventory (NEI). No additional monitors are required for SIP or Maintenance Plans, because the Air District has never been designated as non-attainment for SO_2, and no SIP or Maintenance Plans have been prepared for SO_2.

Table 8 lists the stations currently measuring sulfur dioxide in the Bay Area in each county. It also lists the site and monitoring types along with the SO_2 design values. It shows that design values are significantly below the 75 ppb 1-hour SO_2 national standard. The last column rates the importance of the data measured at the site in meeting both the Air District's and EPA's monitoring objectives.

In Contra Costa County there are six monitors. All are rated high except Bethel Island which is rated low. Bethel Island is rated low because it was originally designed to measure transport and background levels. However, the design value is similar to San Jose Jackson (an NCore monitor) and both of these sites could be considered background today. With SO_2 levels so low and well below the NAAQS, the need for a transport site at Bethel Island is somewhat questionable. The other monitors are near the oil refineries and are rated high.

In Alameda County there is one monitor. This is at Oakland West to measure emissions from shipping and is therefore rated high. In Santa Clara County there is one monitor. This is for the EPA NCore program at San Jose Jackson and is therefore rated high. In Solano County there is one monitor at Vallejo which is downwind of the refineries and is the only SO_2 monitor in Solano County, so it is rated high.

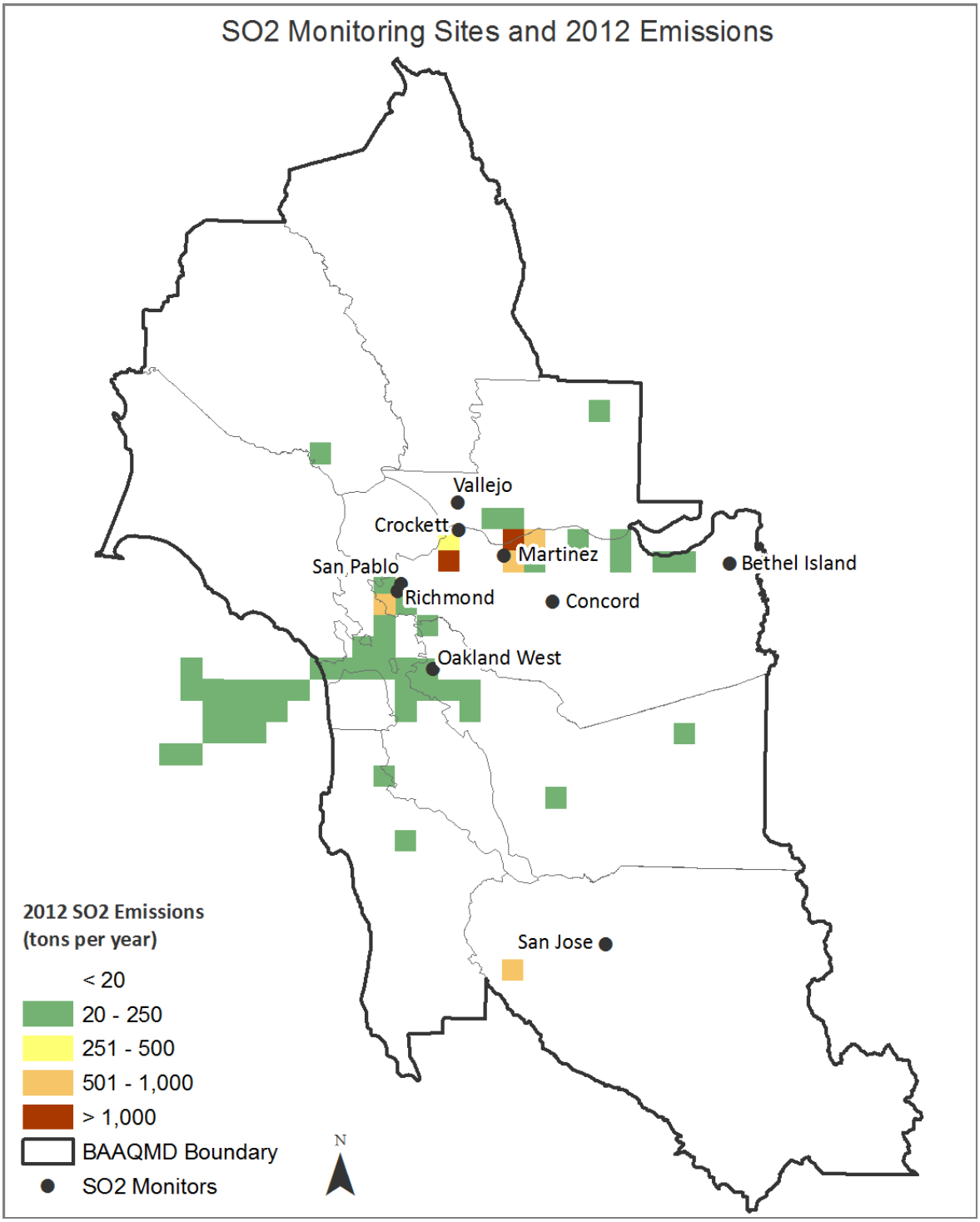


Figure 10. Sulfur dioxide monitoring sites and 2012 emissions

Table 7. Minimum monitoring requirements for SO_2 SLAMS sites

CBSA	County or Counties	Pop. 2010 Census	Total SO_2 (tons/yr) 2011 NEI	PWEI (million -person-tons/yr)	Required SLAMS Monitors	Active SLAMS Monitors	Additional SLAMS Monitors Needed
San Francisco-Oakland-Fremont	SF, San Mateo, Alameda, Marin, Contra Costa	4,335,391	5318	23056	1	6[1]	0
San Jose-Sunnyvale-Santa Clara	Santa Clara, San Benito	1,836,911	608	1117	1 (NCore)	1	0
Santa Rosa-Petaluma	Sonoma	483,878	20	10	0	0	0
Vallejo-Fairfield	Solano	413,344	4080	1686	0	1	0
Napa	Napa	136,484	6	1	0	0	0

1 The Crockett monitor does not meet SLAMS siting criteria and is designated as an SPM monitor. Therefore, it is not counted in the Table above.

Table 8. Sulfur dioxide monitoring sites

Station	County	Monitor Type	Site Type	1-hour Design Value[1] (ppb) 2012-14	Assigned Value from Assessment
Oakland West	Alameda	SLAMS	Population Exposure & Source Oriented	14	High
Bethel Island	Contra Costa	SLAMS	Transport & Background	4	Low
Concord	Contra Costa	SLAMS	Population Exposure & Source Oriented	8	High
Crockett	Contra Costa	SPM	Population Exposure & Source Oriented	12	High
Martinez	Contra Costa	SLAMS	Population Exposure & Source Oriented	14	High
Richmond 7th	Contra Costa	SLAMS	Population Exposure & Source Oriented	11	High
San Pablo	Contra Costa	SLAMS	Population Exposure & Source Oriented	8	High
San Jose Jackson	Santa Clara	SLAMS	Population Exposure (NCore)	3	High
Vallejo	Solano	SLAMS	Population Exposure & Source Oriented	5	High

[1] For SO_2, the design value is the average of the 4th highest daily hourly maximum value from the past 3 years, 2012-2014

PM_{10}

At the close of 2014, the Air District operated four SLAMS and three SPM PM_{10} samplers in its network. The three SPM samplers operate every 12th day and do not meet the SLAMS requirement to operate every 6th day. These SPMs would have been discontinued completely but some data was desired for research purposes. Therefore, the Air District continues to operate the three sites, but on a reduced schedule.

The last year when exceedances of the 24-hour national standard were recorded in the Bay Area was 1991 (at Livermore and San Jose). Figure 11 shows the current Bay Area PM_{10} monitoring stations. The stations are superimposed on a gridded PM_{10} emission map. It shows that the stations are generally located in areas of high PM_{10} emissions.

Because PM_{10} levels are one-half or less of the national standard, there is no need to measure PM_{10} in every county. Instead, monitoring resources have been put into sampling for fine particulate ($PM_{2.5}$) because the Bay Area is not in attainment of the 24-hour $PM_{2.5}$ national standard and because the fine particles have more serious health impacts.

The number of required PM_{10} monitors in each CBSA is determined by population and design value, as specified in Table D-4 of Appendix D to 40 CFR Part 58 – PM_{10} Minimum Monitoring Requirements. PM_{10} design values are a calculated concentration (see footnote no.1 below in Table 9) which are used to determine the PM_{10} attainment status of an area.

Table 9 shows that the Air District monitoring network meets or exceeds the PM_{10} minimum monitoring requirements. No additional monitors are required for the SIP or Maintenance Plan because the Bay Area has never been designated as non-attainment for PM_{10}, and no SIP or Maintenance Plans have been prepared for PM_{10}. Note that the Bay Area Air District has a monitoring agreement with Monterey Bay Air District to share PM10 monitoring responsibilities in the San Jose – Sunnyvale – Santa Clara CBSA. No other monitoring agreements are needed to meet minimum requirements.

Table 9. Minimum monitoring requirements for PM_{10} SLAMS sites

CBSA	County or Counties	Pop. 2010 Census	Highest 24-hr conc. ($\mu g/m^3$)	Highest 24-hr conc. site & AQS ID	Required SLAMS Sites[a]	Active SLAMS Sites	Additional SLAMS Sites Needed
San Francisco-Oakland-Fremont	SF, San Mateo, Alameda, Marin, Contra Costa	4,335,391	57	Bethel Island 060131002	2-4	2	0
San Jose-Sunnyvale-Santa Clara	Santa Clara, San Benito	1,836,911	56	San Jose 06085005	2-4	2[b]	0
Santa Rosa-Petaluma	Sonoma	483,878	42	Healdsburg 060970002	0-1	3[c]	0
Vallejo-Fairfield	Solano	413,344	28	Vacaville 060953001	0-1	1[d]	0
Napa	Napa	136,484	37	Napa 060550003	0-1	1	0

a For PM_{10} in the Bay Area, the number of monitors required depends on the population of the CBSA and whether the ambient concentration of PM_{10} exceed 80% of the 150 $\mu g/m^3$ NAAQS. No stations in the CBSAs listed exceed the 80% threshold. Therefore, the minimum monitoring requirement is determined from Table D-4 of Appendix D, Part 58 of 40 CFR under the "low concentration" category.

b One of the two monitors is in Hollister which is in the Monterey Bay Unified Air Pollution Control District.

c Monitors are in Healdsburg, Guerneville, and Cloverdale. All are in the Northern Sonoma Air Pollution Control District.

d This monitor is in Vacaville which is in the Yolo-Solano Air Quality Management District.

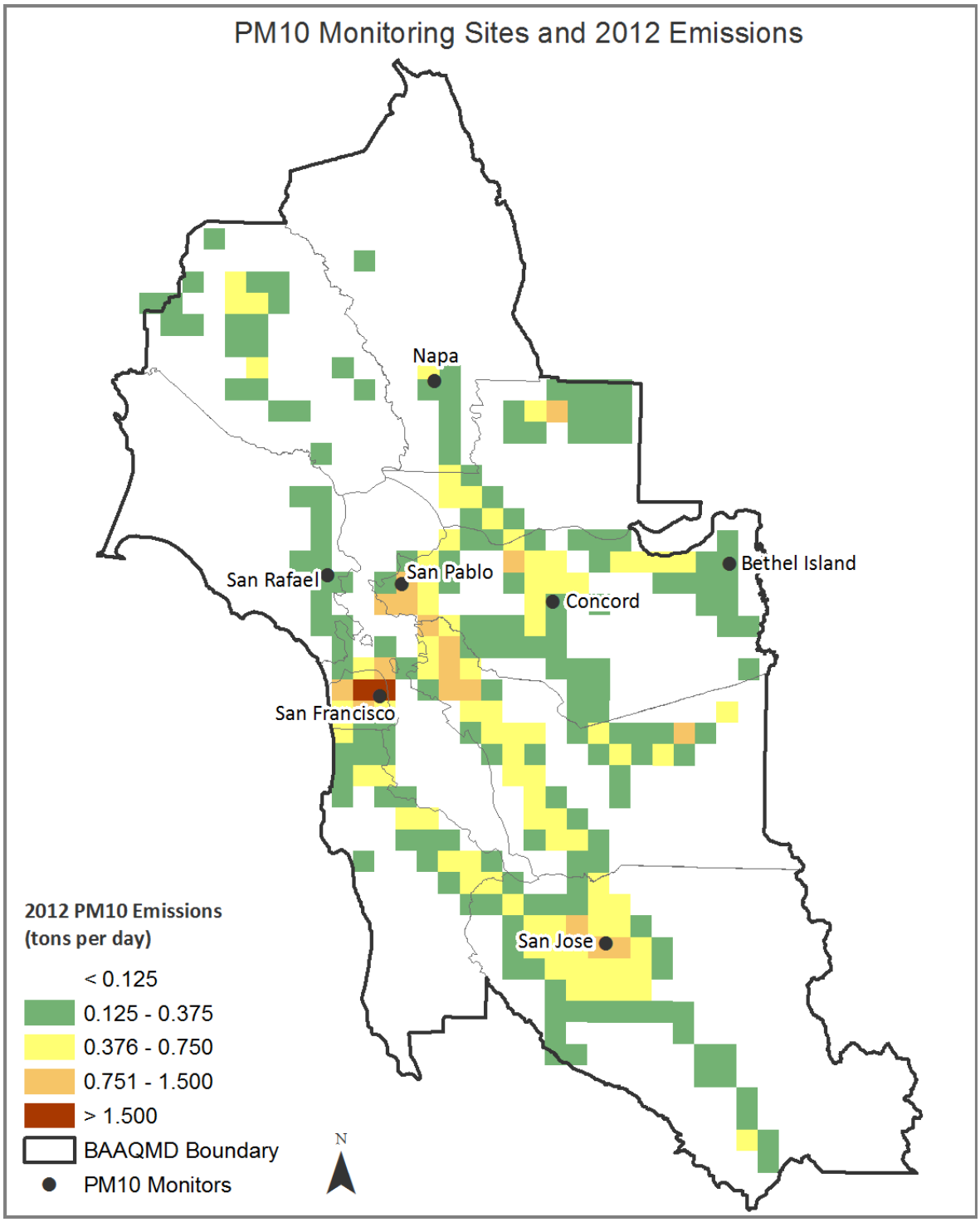


Figure 11. PM_{10} monitoring sites and 2012 emissions

Table 10 lists the stations currently measuring PM_{10} in the Bay Area along with monitoring and site types, and the maximum 24-hour value ($\mu g/m^3$) from 2012-14 for each site. The last column rates the importance of the data measured at the site in meeting the Air District and EPA monitoring objectives.

The Air District operates one PM_{10} monitor in Napa County. There is no requirement for PM_{10} monitoring in Napa County, and the concentrations are not particularly high, so it is rated as medium. Napa is rated medium (rather than low) because it is the only sampler operated by the Air District in Sonoma, Napa, and Solano Counties which generally have more emissions from agricultural burning. Additionally, the Napa Valley has extensive vineyards which are periodically pruned and then burned in piles. This site also has a collocated PM_{10} sampler for Quality Assurance purposes, but with PM_{10} levels so low, the collocated sampler may be located at any SLAMS site.

Two PM_{10} monitors are required for the San Jose-Sunnyvale-Santa Clara CBSA. One monitor is operated by the Monterey Bay Unified APCD in San Benito County. The second is at the San Jose Jackson site. It is used to derive PM coarse measurements, which can be calculated by subtracting $PM_{2.5}$ concentrations from PM_{10} concentrations and is required by the NCore program. Consequently, the San Jose Jackson PM_{10} monitor is rated high.

PM_{10} air monitoring was reassessed by the Air District in 2013 with low value placed on monitors at Bethel Island, Concord, and San Francisco because their maximum values were quite low. PM_{10} monitoring at these sites was being considered for total discontinuation to free up resources for airport lead and near-road monitoring programs but in the end the sites were maintained but sample frequency reduced. This assessment finds no reason to adjust previous assessments for these low value sites.

San Pablo is rated high because it is downwind of major emission areas near San Francisco and Oakland, and is also near the Chevron oil refinery where a 2012 explosion and fire stirred strong public interest in PM_{10} monitoring and the related filter analysis for multiple compounds.

Table 10. PM_{10} monitoring sites (SLAMS and SPM)

Station	County	Monitor Type	Site Type	Max 24 hour Value ($\mu g/m^3$) 2014	Assigned Value from Assessment
Bethel Island	Contra Costa	SPM	Background & Transport	57	Low
Concord	Contra Costa	SPM	Population Exposure	40	Low
San Pablo	Contra Costa	SLAMS	Population Exposure	44	High
San Rafael	Marin	SLAMS	Population Exposure	39	Low
Napa	Napa	SLAMS	Population Exposure Quality Assurance	37	Medium
San Francisco	San Francisco	SPM	Population Exposure	34	Low
San Jose Jackson	Santa Clara	SLAMS	Population Exposure (NCore)	56	High

$PM_{2.5}$

At the close of 2014, the Air District operated SLAMS $PM_{2.5}$ monitors at 15 sites in the Bay Area. There were no SPM monitors in the $PM_{2.5}$ network. All primary $PM_{2.5}$ monitors are continuous FEM-BAMs which record an hourly reading. The Air District operates a FRM $PM_{2.5}$ sampler at San Jose Jackson for quality assurance and support of the NCore program. This is a collocated monitor and it does not provide hourly readings. It is not counted toward meeting EPA minimum monitoring requirements for primary monitors but it is counted in meeting the EPA collocated monitoring requirements for quality assurance. A more complete discussion of collocation requirements is in the 2014 Air District Annual Network Plan.

The number of required $PM_{2.5}$ monitors for each CBSA in the Bay Area is determined by its population and design value, as specified in Table D-5 of Appendix D to 40 CFR Part 58. $PM_{2.5}$ design values are calculated concentrations (see footnotes in Table 11) used to determine the $PM_{2.5}$ attainment status of an area. Table 11 shows that the Air District monitoring network meets or exceeds the $PM_{2.5}$ minimum monitoring requirements.

Table 11. Minimum monitoring requirements for $PM_{2.5}$ SLAMS sites

CBSA	County	Pop. in millions 2010	Annual Design Value[1] (µg/m^3) 2012-14	24-hour Design Value[2] (µg/m^3) 2012-14	Monitors Required	Active Monitors
San Francisco-Oakland-Fremont	SF, San Mateo, Alameda, Marin, Contra Costa	4.32	9.8	27	2	9
San Jose-Sunnyvale-Santa Clara	Santa Clara, San Benito	1.84	10.0	30	3	4[3]
Santa Rosa-Petaluma	Sonoma	0.47	N/A[4]	N/A[4]	0	1
Vallejo-Fairfield	Solano	0.41	9.6	26	0	1
Napa	Napa	0.13	N/A[5]	N/A[5]	0	1

[1] Annual design values are calculated at each site by taking the 3-year mean (2012-2014) of the annual averages for each site. Design values at or below the national $PM_{2.5}$ annual standard of 12.0µg/m^3 indicate the area meets the standard.

[2] Daily design values are calculated by taking the 3-year mean (2012-2014) of the 98th percentiles for each site. Design values at or below the national $PM_{2.5}$ 24-hour standard of 35µg/m^3 meet the standard.

[3] One of the monitors is located in Hollister in San Benito County and is operated by the Monterey Bay Unified Air Pollution Control District.

[4] The Sebastopol site opened in January 2014, therefore design values cannot be calculated. However, Santa Rosa operated from 2009 to 2013 and met completeness requirements. The daily and annual design values for Santa Rosa were 22µg/m3 and 8.4µg/m3 respectively for 2011-13.

[5] There were no FRM or FEM $PM_{2.5}$ monitors in Napa County until December 2012. Therefore there are no annual or daily design values because three full years of data have yet to be completed. The two year average 98th percentile for daily values at Napa is 26µg/m3 and the two year annual average is 11.9µg/m3.

There are no monitoring agreements with the Monterey Bay Air Pollution Control Agency for $PM_{2.5}$ because the Bay Area meets the requirements with its own network. This is a recent change. In 2014, the San Jose Knox Avenue monitoring became operational, making the past monitoring agreement with Monterey Bay unneeded. Additionally, there are no monitoring agreements with the Northern Sonoma Air District because the Santa Rosa – Petaluma CBSA is not required to have any $PM_{2.5}$ monitors. There are no monitoring agreements with the Yolo-Solano Air District because the Vallejo – Fairfield CBSA is not required to have any $PM_{2.5}$ monitors. No additional monitors are required for the State Implementation Plan or Maintenance Plans.

Figure 12 shows the current Bay Area $PM_{2.5}$ monitoring stations. The stations are superimposed on a gridded $PM_{2.5}$ emission map. It shows that the stations are located in areas of high $PM_{2.5}$ emissions. All of the stations are population oriented, in addition to meeting other monitoring objectives. Additionally, the Air District plans to start monitoring $PM_{2.5}$ at a new near-road site in Dublin starting in late 2015. This site is not needed to meet EPA minimum monitoring requirements. This site is being installed at the request of the Air District's Board of Directors and is not shown in Figure 12 or Table 12.

Particulate concentrations have dropped significantly in the Bay Area since $PM_{2.5}$ monitoring began in 1999. The daily and annual $PM_{2.5}$ design value trend graphs are shown in Figure 13 and Figure 14. At the end of 2014, every $PM_{2.5}$ monitor in the Bay Area has design values below the national standards. The highest daily design value is 30 µg/m3 at the San Jose Jackson Street station which is located in the largest city in the Bay Area, with a population of 945,942 according to the 2010 census. Additionally, San Jose is located in the Santa Clara Valley, which tends to trap emissions and transported pollutants during winter particulate episodes. The second highest daily design value is 27 µg/m3 at Livermore, followed by Vallejo at 26 µg/m3. Vallejo and Livermore $PM_{2.5}$ air monitoring sites are located in areas that are subject to regional transport. Due to geography and seasonal weather patterns, both of these sites are frequently downwind of the Sacramento and San Joaquin Valleys, which are often heavily laden with particulates during winter months (November-February). A map of the Bay Area's daily $PM_{2.5}$ design value is shown in Figure 15.

The highest annual design value is 10.0 µg/m3 at San Jose Jackson, due to high population and its complex geography. The second highest annual design value is San Rafael at 9.8 µg/m3, which is primarily caused by light winds combined with wood burning, vehicular traffic, and surfaced-based inversions during winter. The third highest is 9.6 µg/m3 at Vallejo, which is related to regional transport. A map of the Bay Area's annual $PM_{2.5}$ design values is shown in Figure 16.

Table 12 lists the stations where $PM_{2.5}$ concentrations are measured in the Bay Area along with the monitoring objective and the $PM_{2.5}$ design value for each site. The last column rates the importance of the data measured at the site in meeting both the Air District's and EPA's monitoring objectives.

The Air District desires to operate at least one $PM_{2.5}$ monitor in each of the nine Bay Area counties. There are six counties with only one monitor: Napa, Marin, San Francisco, San

Mateo, Solano, and Sonoma. All monitors in those counties are rated high because they are the only monitors in those counties.

Alameda County has four monitoring sites. Livermore is rated high because the site is impacted by transport from the San Joaquin Valley and is one of the first sites to detect this transport for the Bay Area. Oakland West is rated high because it is near the Port of Oakland and is a source oriented site. Laney College is rated high because it is an EPA required near-road monitoring site. Oakland is rated low because Laney College and the Oakland West site adequate characterize the pollutant levels in the Oakland area.

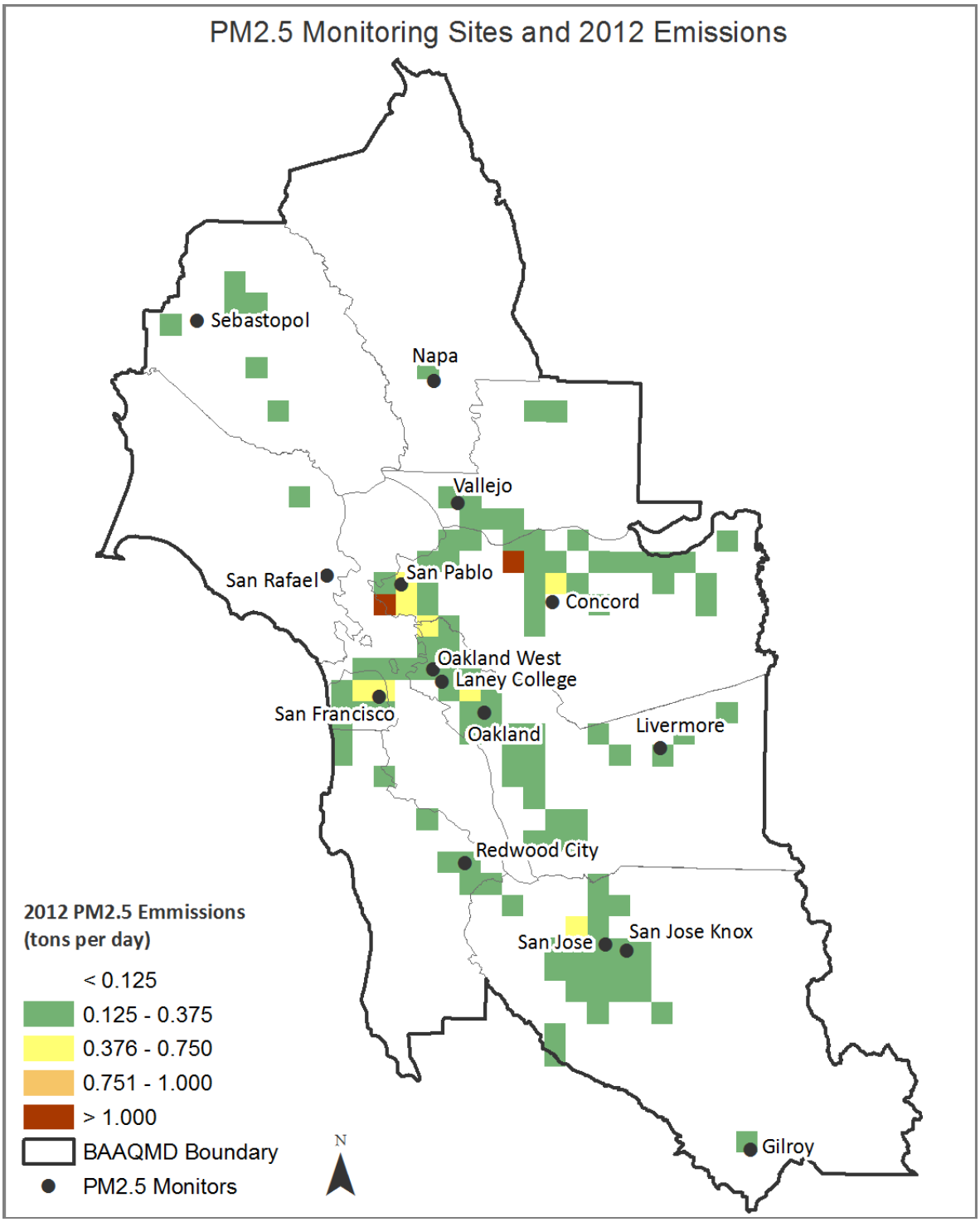


Figure 12. $PM_{2.5}$ monitoring sites and 2012 emissions

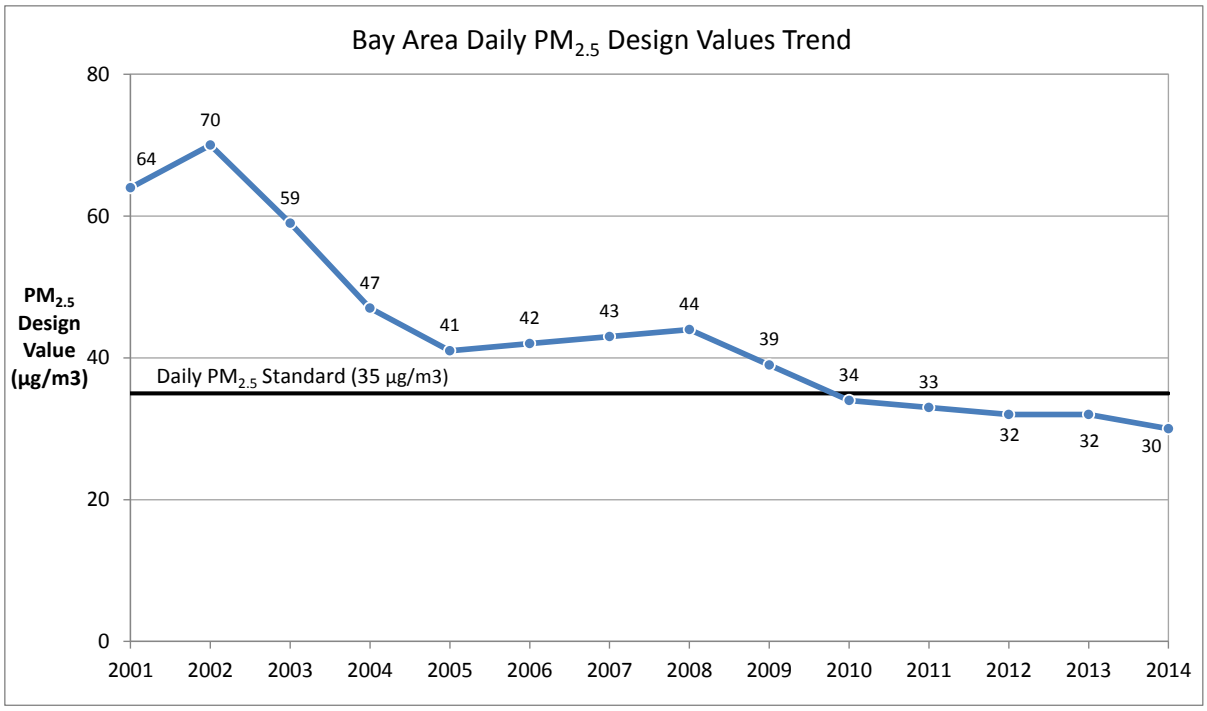


Figure 13. Bay Area daily $PM_{2.5}$ design values trend (2001 through 2014)

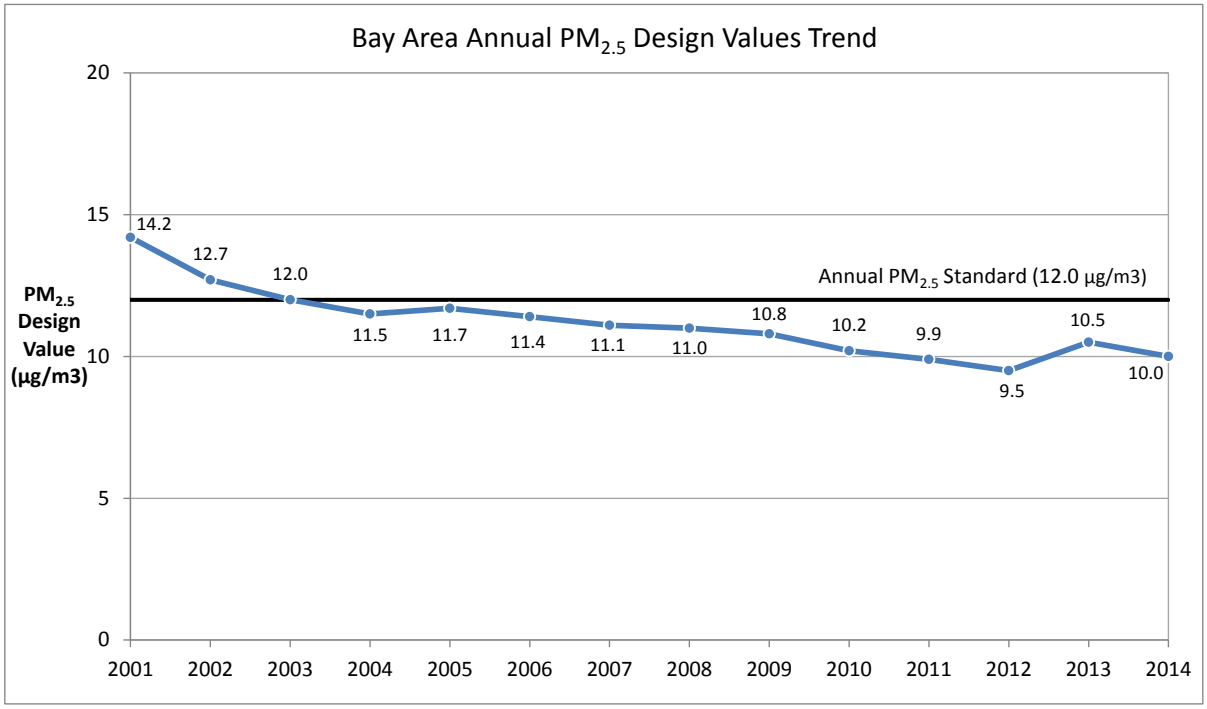
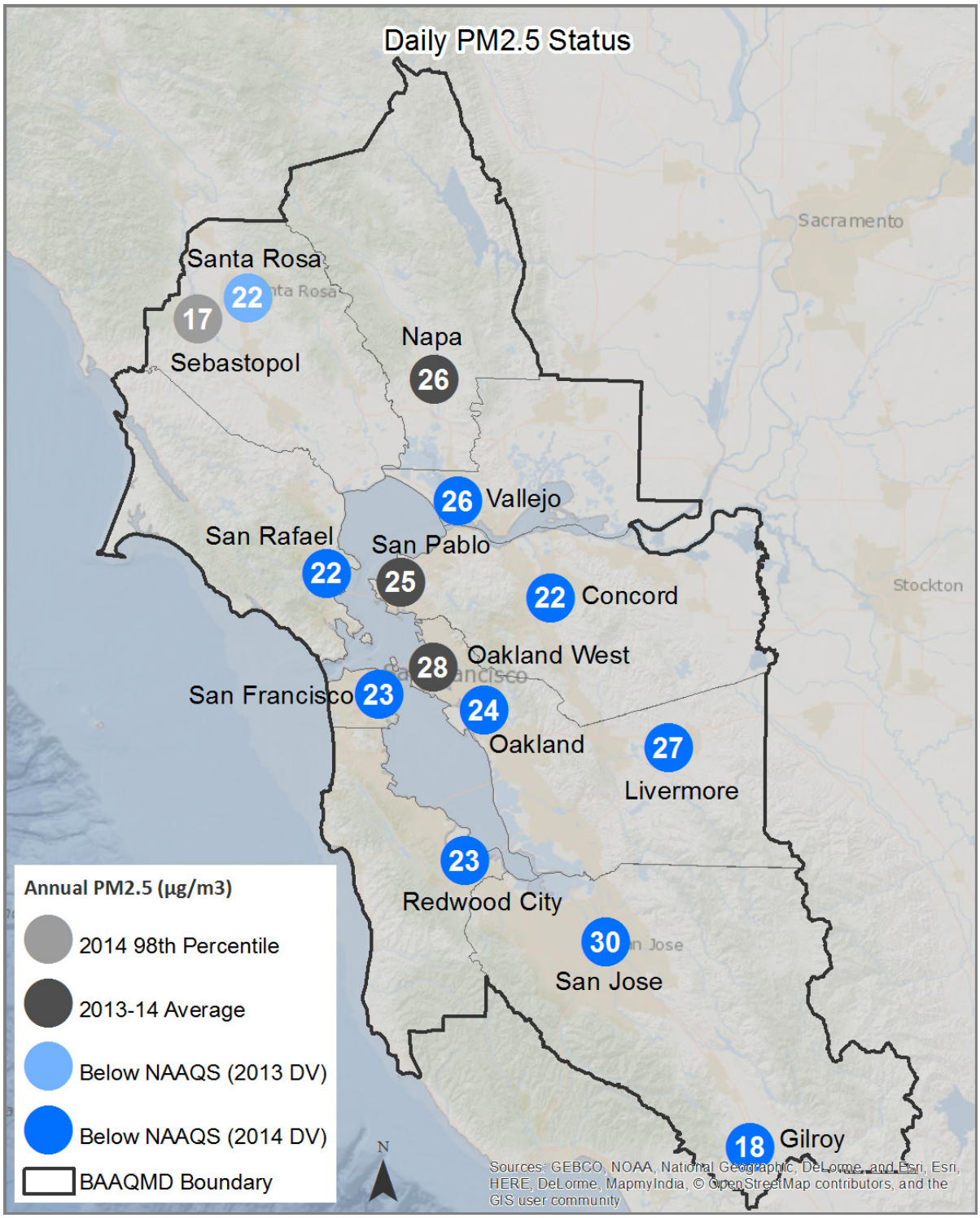
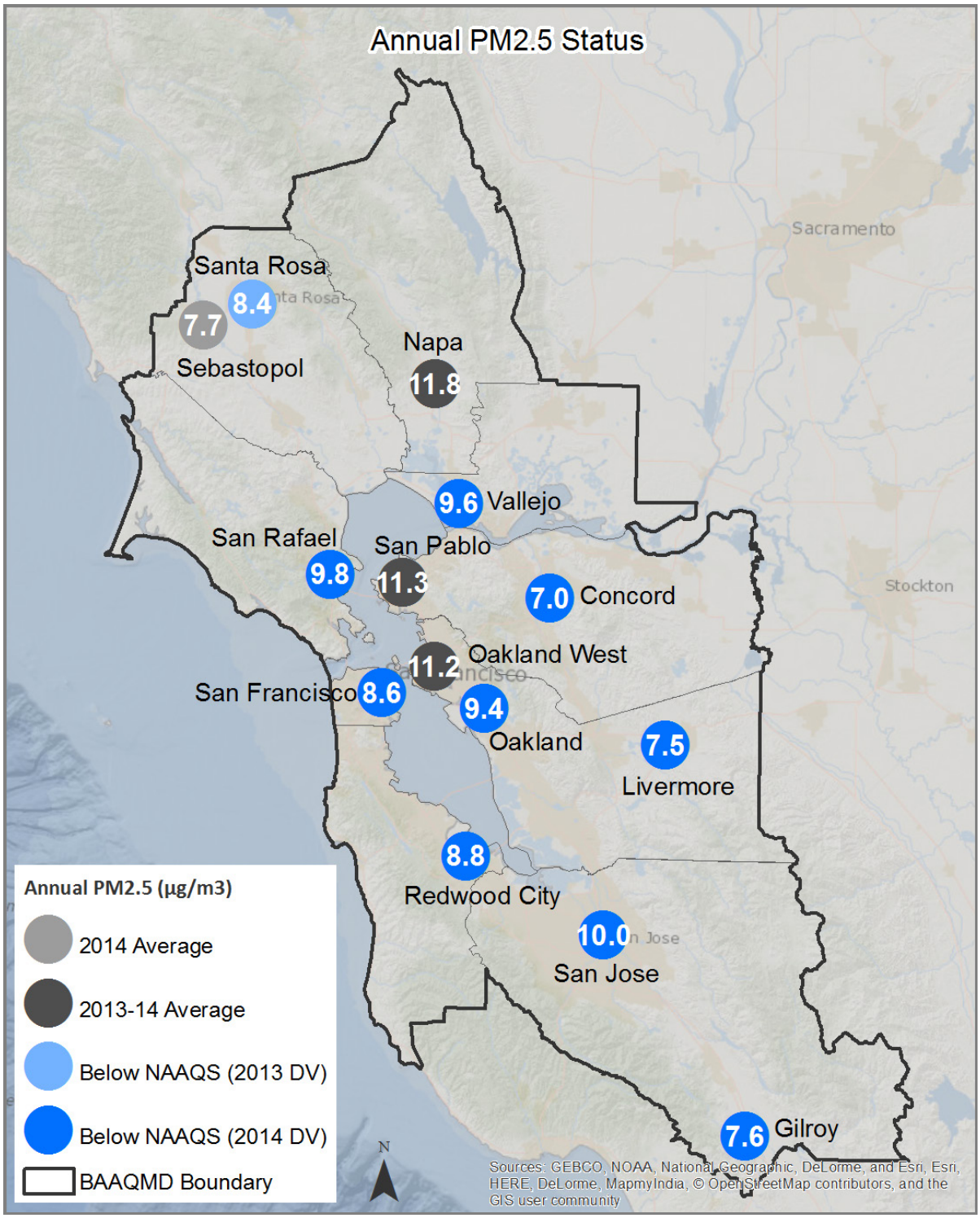


Figure 14. Bay Area annual $PM_{2.5}$ design values trend (2001 through 2014)



Note: (a) The Santa Rosa site was closed in December 2013 and its 2013 design value is shown to provide a reference for particulate concentration in Sonoma County. (b) The Sebastopol site was opened in January 2014 and replaced the Santa Rosa site. Therefore, only the 2014 98th percentile can be provided. (c) FEM $PM_{2.5}$ monitoring began at Napa, Oakland West and San Pablo in December 2012. Therefore, only 2013-2014 average of the 98th percentiles is provided.

Figure 15. Spatial pattern for the 2014 daily $PM_{2.5}$ design values



Note: (a) The Santa Rosa site was closed in December 2013 and its 2013 design value is shown to provide a reference for particulate concentration in Sonoma County. (b) The Sebastopol site was opened in January 2014 and replaced the Santa Rosa site. Therefore, only the 2014 98th percentile can be provided. (c) FEM $PM_{2.5}$ monitoring began at Napa, Oakland West and San Pablo in December 2012. Therefore, only 2013-2014 average of the 98th percentiles are provided.

Figure 16. Spatial pattern for the 2014 annual $PM_{2.5}$ design values

Contra Costa County has two $PM_{2.5}$ monitors and both are rated high. Concord is rated high because it is geographically separated from all other monitors and is a major population area. San Pablo is rated high because of public concern of pollution from nearby oil refineries.

Santa Clara County is part of the San Jose-Sunnyvale-San Benito CBSA which is required to operate three monitors. The Air District operates three $PM_{2.5}$ monitors in Santa Clara County and Monterey Bay Air District operates one in San Benito County. The San Jose Jackson monitor is in the largest city in the Bay Area and is needed to support the NCore program, so it is rated high. The monitor at San Jose Knox Avenue is part of the EPA near-road monitoring program and is therefore rated high. The monitor in Gilroy is rated low because measurements show this location to be well below national standards and the lowest in the entire Bay Area. Some redirecting of resources is possible by discontinuing monitoring in Gilroy and moving $PM_{2.5}$ monitoring five miles north to San Martin to see if it is more of a hot-spot.

Table 12. SLAMS $PM_{2.5}$ monitoring sites

Station	County	Site Type	24-hour Design Value[1] (µg/m3)	Annual Design Value[2] (µg/m3)	Assigned Value from Assessment
Laney College	Alameda	Population Exposure Source Oriented (near-road)	N/A[3]	N/A[3]	High
Livermore	Alameda	Population Exposure	27	7.5	High
Oakland	Alameda	Population Exposure	24	9.4	Low
Oakland West	Alameda	Population Exposure Source Oriented	N/A[3]	N/A[3]	High
Concord	Contra Costa	Population Exposure	22	7.0	High
San Pablo	Contra Costa	Population Exposure	N/A[3]	N/A[3]	High
San Rafael	Marin	Population Exposure	22	9.8	High
Napa	Napa	Population Exposure	N/A[3]	N/A[3]	High
San Francisco	San Francisco	Population Exposure	23	8.6	High
Redwood City	San Mateo	Population Exposure	23	8.8	High
Gilroy	Santa Clara	Population Exposure	18	7.6	Low
San Jose Jackson	Santa Clara	Population Exposure (NCore)	30	10.0	High
San Jose Knox	Santa Clara	Population Exposure Source Oriented (near-road)	N/A[3]	N/A[3]	High
Vallejo	Solano	Population Exposure	26	9.6	High
Sebastopol	Sonoma	Population Exposure	N/A[3]	N/A[3]	High

[1] Design values at or below the national $PM_{2.5}$ standard of 35µg/m^3 meet the standard.
[2] Design values at or below the national $PM_{2.5}$ annual standard of 12.0µg/m^3 indicate the area meets the standard.
[3] The $PM_{2.5}$ monitors with N/A for design values have less than three years of data, which is inadequate to calculate design values.

Location of maximum concentration in the San Francisco – Oakland – Fremont CBSA

The Air District operates nine $PM_{2.5}$ FEM BAM monitors in the San Francisco – Oakland – Fremont CBSA and eight of the monitors are population oriented while representing area-wide concentrations. One additional monitor operates at Laney College measuring microscale near-road concentrations. The Laney College monitoring data appears to be representative of area-wide concentrations found in the Oakland area (see Appendix A). While the EPA only requires three monitors in the CBSA (two area-wide monitors and one near-road monitor for 2015) the Air District operates nine monitors (eight at neighborhood or greater scale and one near-road monitor). EPA Region 9 is not satisfied that the nine active monitors are capturing the maximum concentration in the CBSA due to the predominance of wood smoke in the Marin County portion of the CBSA during the winter as many of the homes in Western Marin County do not have gas or electricity service, and rely on wood burning as their sole source of heat.

Marin County is somewhat unique in the San Francisco Bay Area because of its relatively high coastal mountains and complex terrain. The county is bounded by the Pacific Ocean to the west and San Pablo Bay to the east. The county has high steep terrain along its central spine, generally running south to north. It is within the hilly and complex terrain away from the coast and bay that wood smoke is prone to become trapped during winter because vertical mixing depths are frequently low in winter and many of the populated regions are in wind sheltered valleys. Further complicating the air pollution issue is that many homes in the sheltered valleys of Marin County do not have natural gas service and wood burning is the sole source of heat for these homes.

In order to meet EPA requirements to monitor within the CBSA at the location of maximum $PM_{2.5}$ concentration, the Air District relies extensively on public smoke complaints as well as visual observations from its Compliance and Enforcement (C&E) staff. Because it is monetarily not practical to deploy the estimated twenty to *thirty* $PM_{2.5}$ monitors to cover every part of the CBSA which *may* have the maximum concentration on any given day, the Air District has had to rely on human monitoring information to narrow down this ill-defined location (that is, the sole location with the maximum concentration where monitoring is required by EPA guidance and regulations).

Part of the issue with EPA guidance is in defining what is meant by maximum concentration. It could mean the highest one-hour average for a year, or perhaps the location with the highest daily average for a year, or the location with the highest design value (either annual or daily). Nonetheless, based on the Air District's internal observations and records, Forest Knolls was identified as potentially having the highest concentration within the complex terrain regions of Marin County (and the San Francisco – Oakland – Fremont CBSA), or if it is not the location with the highest concentration, it would be representative of many locations with similar complex mountain/valley terrain in the county and CBSA during the winter.

Forest Knolls is not significantly impacted by car or truck emissions (see Appendix B). Therefore, this area was chosen to be monitored so the Air District could measure wood smoke without having other source categories interfere with the measurements.

Additionally, the Air District concluded that the San Rafael monitoring site would continue to monitor $PM_{2.5}$ to measure the sum total of all other source categories, in addition to wood smoke. San Rafael has been a monitoring site for $PM_{2.5}$ since 2009, and a trend site in Marin County was desired, so there was no consideration given to closing the $PM_{2.5}$ monitor at San Rafael and moving it to Forest Knolls. Monitoring for wood smoke (Black Carbon) began in 2013 using an Aethalometer in Forest Knolls.

As an illustration of the variability in $PM_{2.5}$ concentrations in the complex terrain of Marin County, Sonoma Technology, Inc. (STI) monitored $PM_{2.5}$ at two locations in Marin County between November 2010 and February 2011. STI then compared the $PM_{2.5}$ daily averaged data with those from the Air District monitoring site in San Rafael. A summary of the study is included in Appendix C.

The results of the STI study showed that $PM_{2.5}$ concentrations in San Anselmo were lower than those at San Rafael. However, $PM_{2.5}$ was higher in Woodacre than in San Rafael or in San Anselmo and no station was well correlated with another station. This is exactly the problem with identifying the location of maximum concentration – there is no day to day, week to week, or year to year consistency in making such a determination using stationary measurement methods. Because the study was only conducted for one winter, there is some question about whether the results of the study would be similar in subsequent years or whether they were unique to that year insofar as assessing which of the three sites has the "maximum concentration" as required by EPA regulations. As is well known, wood smoke concentrations are significantly impacted by just a single neighborhood "burner" moving out ofan area, or a new "burner" moving into an area.

Another study was conducted jointly by the Air District and STI in Sonoma County between November 22, 2013 and February 7, 2014. Sonoma County is adjacent to Marin County but has much less complex terrain. In this study, five $PM_{2.5}$ monitors were deployed in and around Santa Rosa, the most populated city in Sonoma County, as shown in Figure 17 and Figure 18, below.

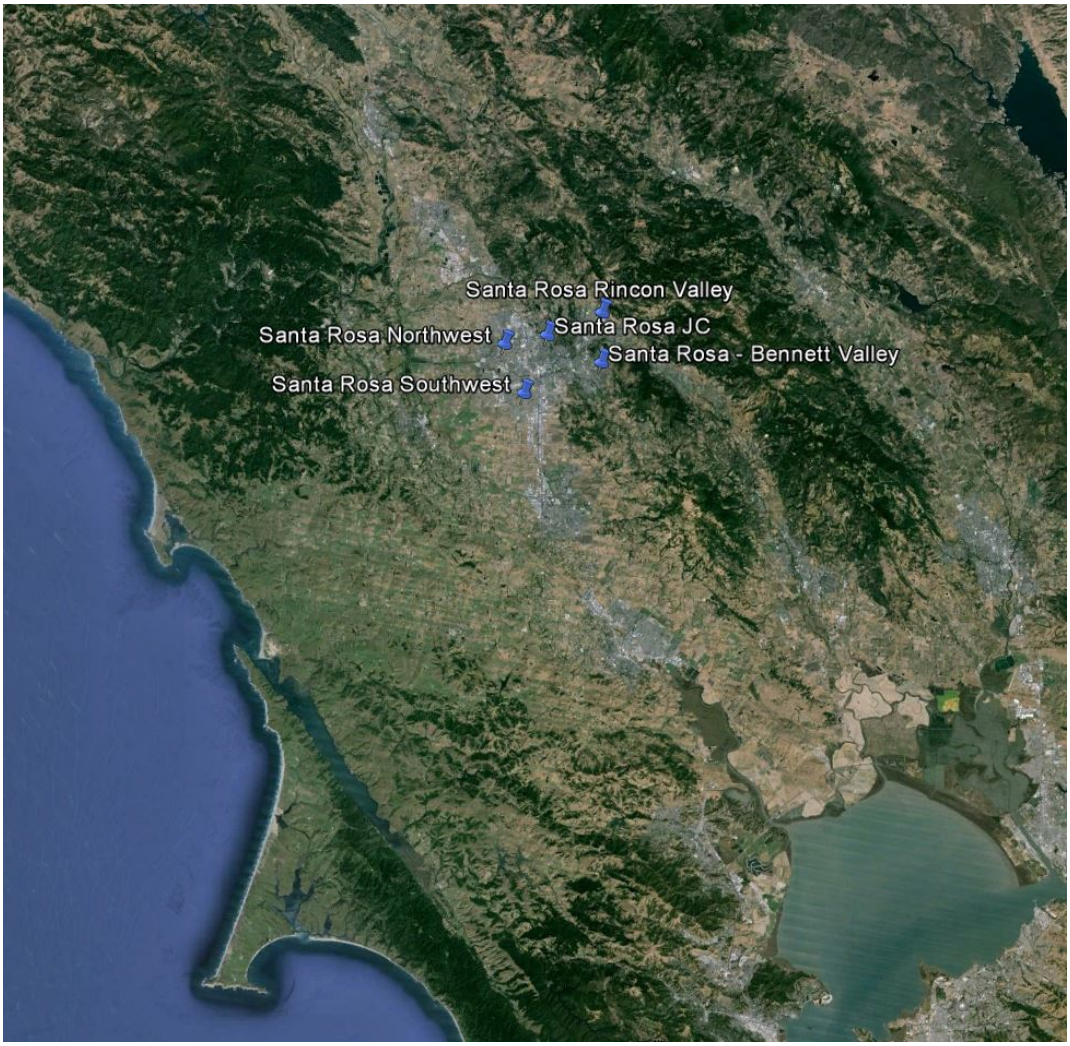


Figure 17. Locations of PM2.5 monitors during Air District/STI study.

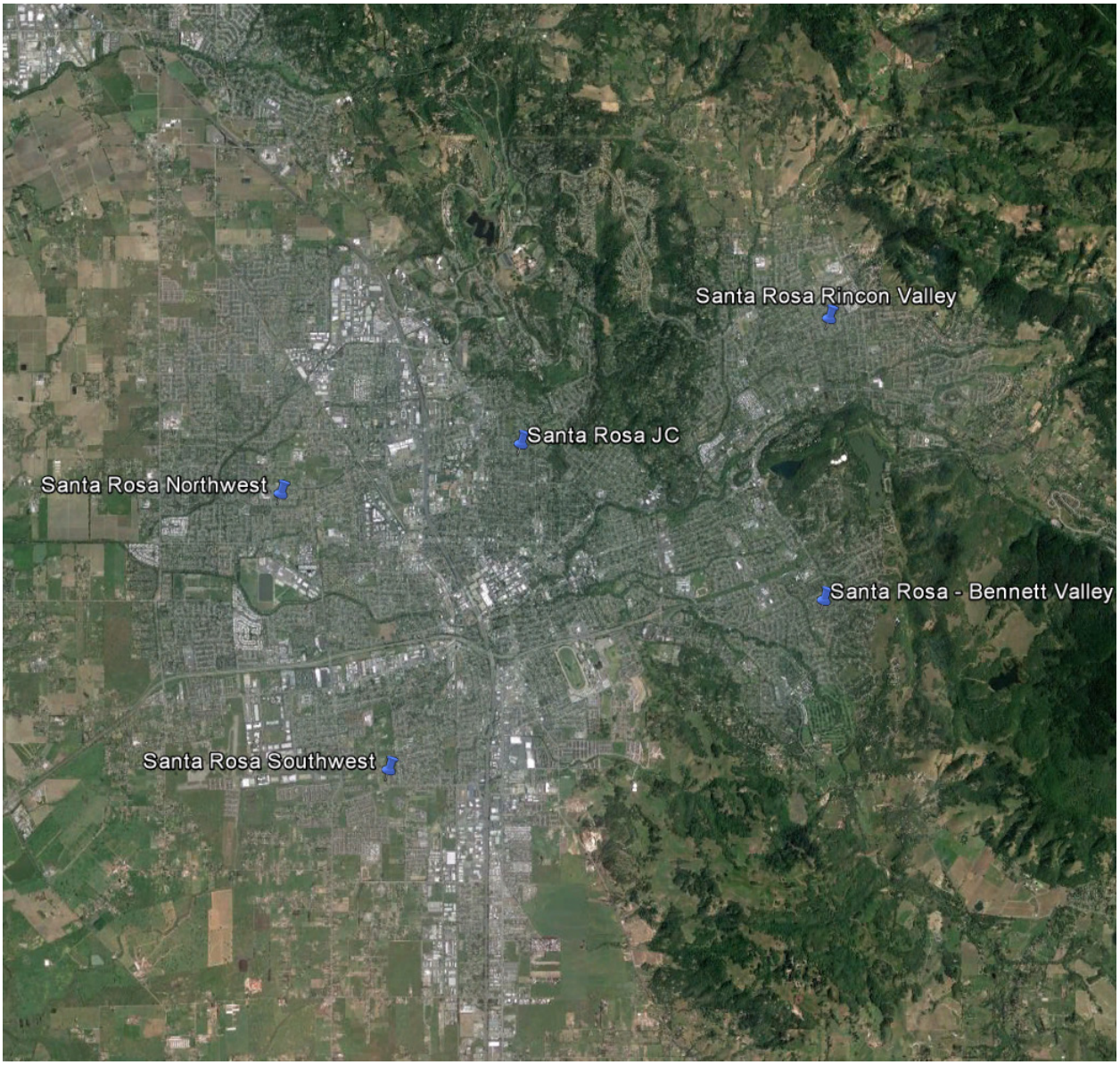


Figure 18. Locations of PM2.5 monitors during Air District/STI study.

The results of this study showed two sites in the west side of the city to have consistently higher values than sites to the east of the core. What is not known is whether the small sample size is representative of what longer term observations would show or if the primary source of the wood smoke was just several "heavy" wood burners.

The Air District recognizes the need to protect public health in the wind sheltered regions of Marin County and in all regions of the Bay Area. While the Air District acknowledges that winter time wood smoke is a major health concern, we do not feel that more monitoring is the solution. Instead, the Air District has been seeking a broad range of solutions to address the impacts from wood smoke during winter.

Spare the Air (20% risk)
To protect public health and reduce the adverse impacts from wood smoke during winter, the Air District makes wood burning illegal when meteorological conditions suggest that $PM_{2.5}$ may reach the Unhealthy for Sensitive Groups (USG) AQI category. Recognizing that $PM_{2.5}$ accumulates in different areas from day to day, and is highly variable within complex mountain /valley terrain, burn bans are issued when there is a 20% risk of reaching the USG AQI category anywhere in the Bay Area, including remote areas where monitoring is not occurring. This highly conservative approach has been implemented since the winter of 2012-13 to account for the spatial variability in $PM_{2.5}$ concentrations from hour to hour and from day to day. The location of maximum concentration is not a fixed and steady location, but varies from day to day throughout the Bay Area, so the 20% risk threshold was implemented to ensure an adequate margin of safety keeping in mind the actual $PM_{2.5}$ level will vary by the number of burners in a neighborhood as well as the duration of their burning. In a perfect world, there would be no burners when a burn ban is in effect, by the reality is otherwise. Additionally, there are provisions in Air District regulations to allow burning when the sole source of heat is from wood burning.

Wood Smoke Burn Ban Enforcement
To ensure burn ban restrictions are enforced the Air District fines individuals who are confirmed to be burning while a burn ban is in effect. First-time violators are encouraged to take a Wood Smoke Awareness course to learn more about the health impacts from wood smoke. Those who choose not to take the course receive a $100 ticket. Second-time violators receive a $500 ticket, with tickets amounts increasing for subsequent violations.

During the winter of 2014-15 (defined as November 1 through February 28) the Air District received a total of 3,739 wood smoke complaints from residents, and most were from Marin County. A total of 155 tickets were issued to residents who were observed to be in violation of the Wood Burning Rule. Preliminary survey data indicates that the Wood Burning Rule is an effective instrument for reducing particulates from wood smoke. Despite 23 burn ban days, 30% of Bay Area residents indicated they are burning less wood even on days when an alert has not been issued. Surveys also indicated that 75 percent of Bay Area residents support the Air District's Wood Burning Rule.

Winter 2014-15 (Total # complaints = 3739)

Complaints by County
Alameda – 499
Contra Costa – 576
Marin – **865 (most of all counties)**
Napa – 123
San Francisco – 85
San Mateo – 423
Santa Clara – 521
Solano – 94
Sonoma – 521
No county indicated – 32

Complaints by CBSA
San Francisco – Oakland – Fremont – **2448 (most of all CBSAs)**
San Jose – Sunnyvale – Santa Clara – 521
Vallejo – Fairfield – 94
Napa – 123
Santa Rosa – Petaluma – 521
No CBSA indicated – 32

Lead

At the close of 2014, the Air District operated three lead samplers. The San Jose Jackson site samples lead from the PM_{10} filter as required for the NCore program. The EPA has additional requirements which are stated in 40 CFR Part 58, Appendix D Section 4.5. In short, EPA requires lead monitoring near sources expected to contribute to a maximum lead concentration in ambient air in excess of the NAAQS. In the Bay Area there are no sources meeting this criteria according to the latest National Emissions Inventory (NEI). However, additional sections of 40 CFR do require source oriented monitoring near three airports in the Bay Area (Palo Alto, San Carlos, and Reid-Hillview) because emissions from piston engine aircraft using leaded fuel may approach 0.50 tons per year (one half of the NAAQS).

The San Carlos Airport I site operated from March 2012 to September 2013, but had to be closed due to expiration of the lease and the owner would not renew it. A new San Carlos Airport lead monitoring site (San Carlos Airport II) opened on March 25, 2015 and is about 120 meters southeast of the old site.

The Palo Alto Airport site operated from February 3, 2012 through December 19, 2014. This site had to be closed because of an FAA review of the airport operations found the sampler was not properly located to comply with FAA regulations. The review was triggered by an ownership transfer from Santa Clara County to the City of Palo Alto.

As of late June 2015, a new site has not been determined for Palo Alto airport, and it is possible that one will never be located on the airport property.

All airport lead monitors are rated high value because these airports are specifically named for lead monitoring in the regulations. Lead monitoring at San Jose Jackson is also rated high because it is required for the NCore program.

Table 13. Source-oriented airport lead monitoring sites in July 2015

Source Name	Monitors Required	Monitors Active	Monitors Needed
San Carlos Airport	1	1	0
Palo Alto Airport	1	0	1
Reid-Hillview Airport	1	1	0

Table 13. Source-oriented NCore lead monitoring site in July 2015

NCore Site	CBSA	Pop. 2010 Census	Monitors Required	Monitors Active	Monitors Needed
San Jose Jackson	San Jose-Sunnyvale-Santa Clara	1,836,911	1	1	0

Summary

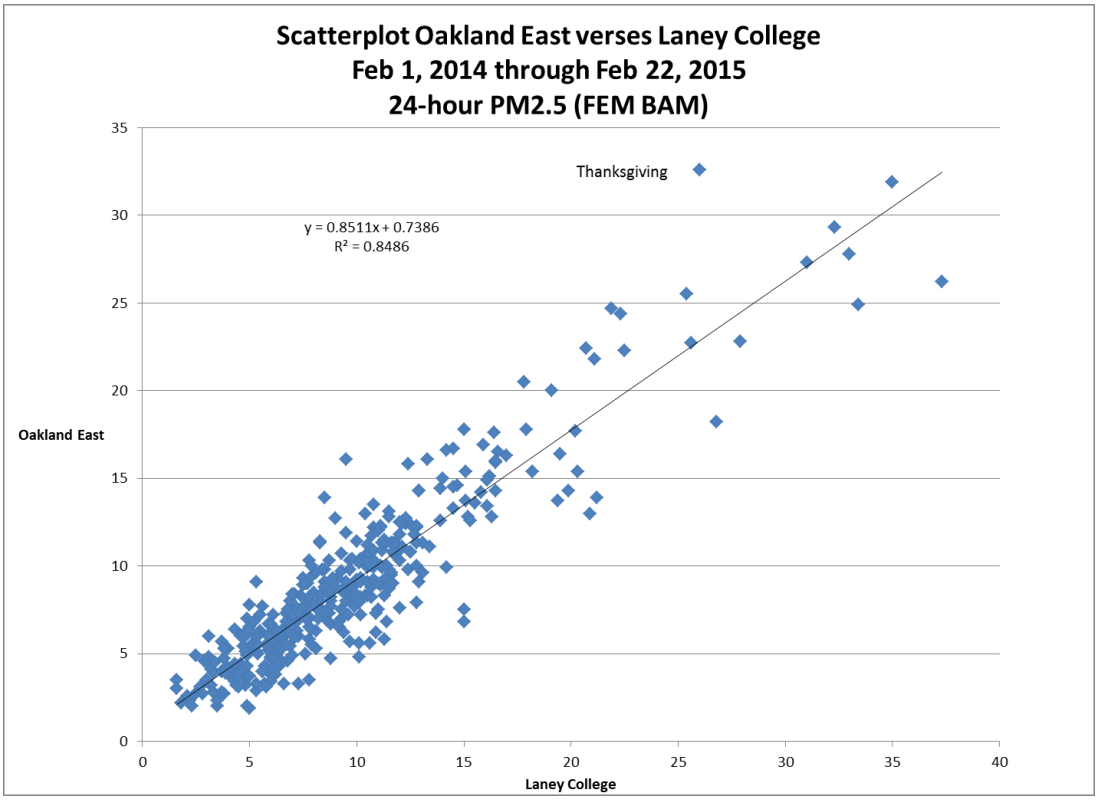
The purpose of this assessment is to rate the effectiveness of each monitor in the Bay Area Air Quality Management District's air monitoring network in meeting the monitoring objectives defined in 40 CFR, Part 58 Appendix D, and the local objectives of the Bay Area Air Quality Management District. This assessment also determines whether new monitors or sites are needed and if monitors or sites may be discontinued to free up resources for alternative monitoring efforts, and to assess if new technologies for monitoring should be deployed.

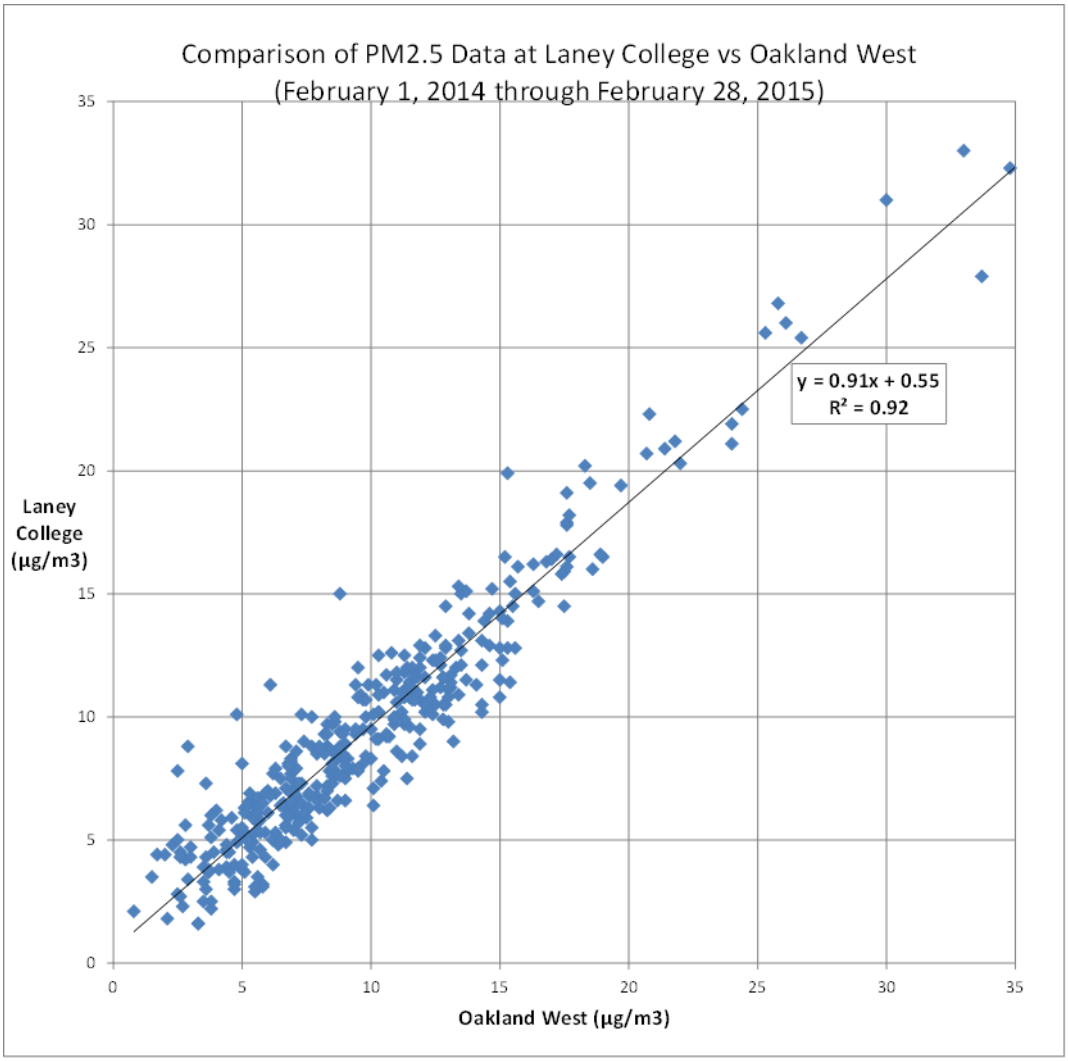
Table 14. Assessment ratings of monitors

Station	CO	Ozone	NO_2	SO_2	PM_{10}	$PM_{2.5}$
Bethel Island	Low	High		Low	Low	
Hayward		Low				
Livermore		High	High			High
Oakland	Low	Low	Low			Low
Oakland West	High	Low	High	High		High
Laney College	Low		High			High
Concord	Low	High		High	Low	High
Patterson Pass			Low			
Crockett				High		
Martinez				High		
Richmond 7th				High		
San Pablo	Low	Low	Low	High	High	High
San Ramon		Low	Low			
San Rafael	Low	High	Medium		Low	High
Napa	Low	High	Medium		Medium	High
San Francisco	Low	High	Medium		Low	High
Redwood City	Low	High	Medium			High
Gilroy		Low				Low
Los Gatos		Medium				
San Jose Jackson	High	High	High	High	High	High
San Jose Knox	High		High			High
San Martin		High				
Fairfield		Low				
Vallejo	Low	High	Medium	High		High
Sebastopol	Low	High	Medium			High

Appendices A through C

Appendix A. Laney College monitoring data.




Comparison of PM2.5 Data at Laney College vs Oakland West
(February 1, 2014 through February 28, 2015)
y = 0.91x + 0.55
R² = 0.92
Laney College (µg/m3)
Oakland West (µg/m3)
0
5
10
15
20
25
30
35

Appendix B. Forest Knolls aethalometer study.

Analysis of Forest Knolls aethalometer data

There are concerns that wintertime wood burning leads to unhealthy PM levels in the San Geronimo Valley. In response to these concerns, the District has operated an aethalometer at Forest Knolls since January, 2013.

An Aethalometer measures the absorption of a wavelength of light that is particularly sensitive to carbon particles. Thus, although the measurements don't provide a measurement of the total fine particle concentration, they do provide information on carbonaceous particles. Both woodsmoke and tailpipe emissions are largely carbon, and largely in the fine fraction (mostly < 2.5 microns in diameter), so that it is possible to estimate the contribution to $PM_{2.5}$ concentrations from these sources.

This analysis:

1. Establishes that a very high fraction of the Forest Knolls aethalometer readings derive from wood burning rather than other sources, and

2. Develops a function that relates the aethalometer readings to woodsmoke concentrations, and apply this function for Forest Knolls.

We conclude that woodsmoke does significantly impact this area, raising wintertime mean $PM_{2.5}$ concentrations as high or higher than urban sites, and causing $PM_{2.5}$ to exceed the national 24-hour standard on some days.

Data

The District has operated aethalometers at several sites, with measurements on an hourly basis. Besides Forest Knolls, the sites with a substantial data record are San Jose, Livermore, and West Oakland. Other measurements are made at these same sites that allow us to estimate woodsmoke, diesel and gasoline PM concentrations. More specifically, 24-hour filter samples are collected at these sites on a regular basis. A range of species is measured, including elements with atomic weights of aluminum and higher, certain ions, and elemental and organic carbon. Table 1 presents information about the measurements available at each site.

Table 1.

	Aethalometer			Speciated Filters		
Site	Start	Most Recent	# of obs'ns.	Start	Most Recent	# of obs'ns*
Forest Knolls	2013-07-30	present	817			
Livermore	2011-04-	present	1,722	2008-09-	2013-06-	130

	22			03	27	
Oakland West	2009-02-27	present	1,018	2009-02-12	2013-06-27	227
San Jose	2009-01-01	2011-04-04	373	2009-01-01	2013-09-10	172

* # of observations with corresponding aethalometer measurements on same day.

In addition to aethalometer measurements, the District has conducted wintertime wood burning surveys of Bay Area residents, with approximately 13,000 responses between the winters of 2005-06 and 2012-13. Respondents' zip code of residence is known, and they are asked if they'd burned the day before and how many hours they typically burn.

Also available are Census data on households and the fraction of households using wood for fuel. These were obtained down to the block group level from the 5-year aggregated American Community Survey 2008-2012 (Census 2014). The fuel use data were combined with the latitude & longitude interior points for each Census block group.

Estimated wood burning in neighborhood of site

Table 2 presents information on wood burning in the neighborhood of the four sites. Forest Knolls has only one tenth as many households as the other sites. But the fraction of those households using wood for fuel is much higher because the Forest Knolls area does not have natural gas service. A much higher percentage of Forest Knolls residents burn on a given winter night and they tend to burn much longer, again because they are generally burning to heat rather than for ambiance.

The last column combines the information on the number of households and the amount burned. It provides a rough measure of the amount of woodsmoke that may be present in the air around the sites. The take-away is that the air around the Forest Knolls site may have a substantial amount of woodsmoke even though the population density is low.

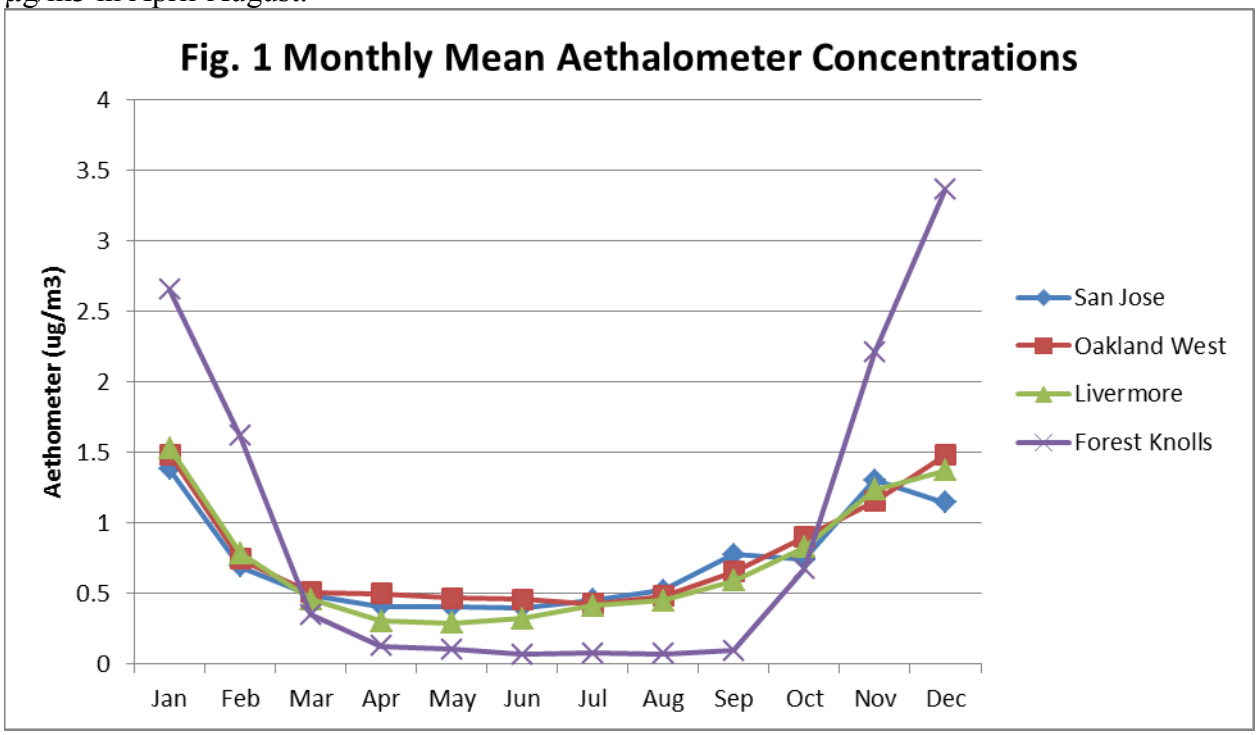
Table 2.

Site	# households within 1 mile	% using wood for fuel	% burning per winter night	Average hours burned	Wood burning hours/night*
San Jose	9,787	0.2%	3.1%	0.8	226
Livermore	6,593	1.3%	12.4%	1.9	1,524
Oakland West	13,414	0.6%	2.9%	0.8	291
Forest Knolls	786	18.6%	30.0%	5.2	1,233

* Estimated number of household-wood burning hours = hhs x fraction burning x Ave. hrs burned.

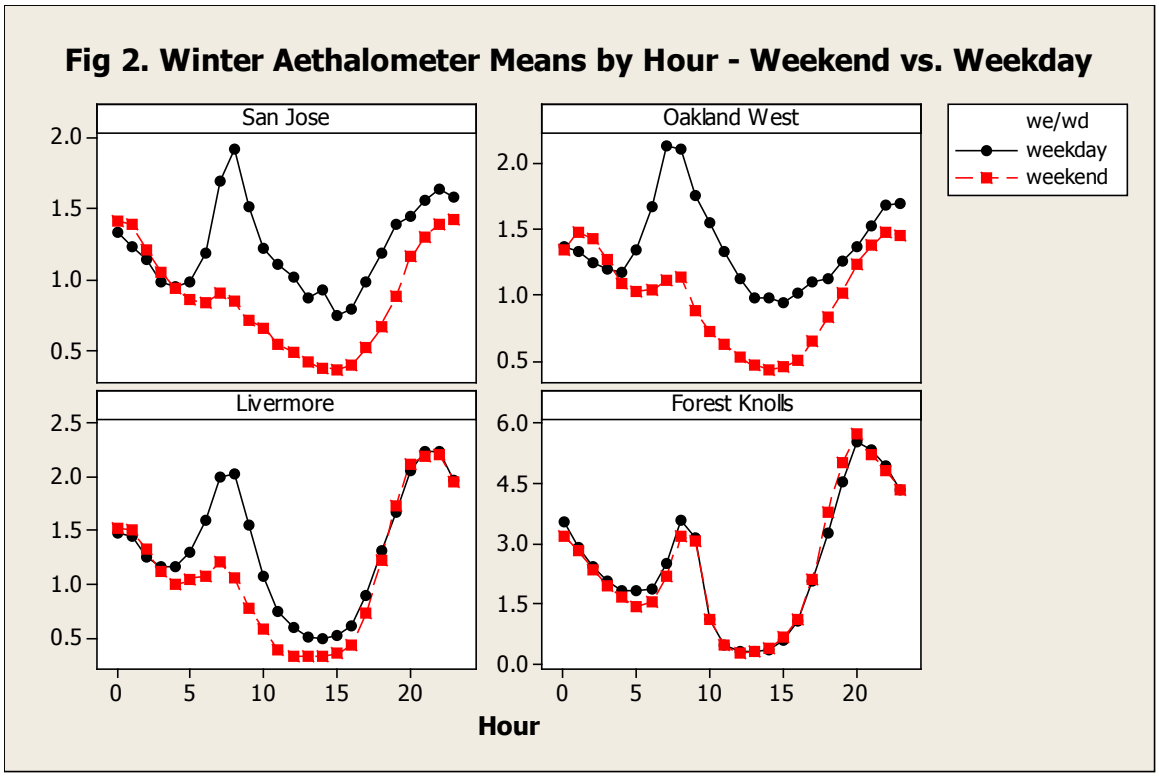
Sources of aethalometer readings

The main sources of carbonaceous particles in the Bay Area are wood smoke, diesel exhaust, gasoline exhaust, and cooking (Fairley 2012). These sources vary by time of day, day of week, and season. Figure 1 shows mean aethalometer concentrations at the four sites by month. The three urban sites show a very similar pattern, with means between 1.0 and 1.5 µg/m3 in January, November and December and 0.3 to 0.5 µg/m3 in April through August. Forest Knolls shows a quite different pattern – much higher in the winter, and close to 0 µg/m3 in April-August.



The three urban sites are surrounded by busy city streets and are within a mile of major freeways. Forest Knolls, in contrast, is near roads with much less traffic and has no freeway nearby.

Figure 2 shows winter (Jan, Feb, Nov, and Dec) weekday and weekend mean aethalometer concentrations by hour for each of the four sites. All sites show an evening peak and a secondary peak around 8 am.



For the urban sites, the 8 am peak is high on weekdays and barely noticeable on weekends. In contrast, the Forest Knolls 8 am peak is almost as high on weekends and weekdays. Also, its weekday 8 am peak is considerably lower than its evening peak, unlike the other sites.

Forest Knolls sits in the San Geronimo Valley, which is distinctive in having no natural gas service; a large fraction of homes use wood for heating. It seems reasonable that its 8 am peak derives mainly from residents stoking up their woodstoves rather than from commuting.

Estimated wood burning contribution to Forest Knolls $PM_{2.5}$

The urban sites above have all had speciated samples that overlap with aethalometer readings, as shown in Table 1. Chemical Mass Balance (CMB) analysis was performed for some of these data (Fairley 2012), and was augmented for the present study using the same software to include more recently collected measurements. The CMB analysis provides estimates of the contributions of woodsmoke and motor vehicle exhaust to 24-hour $PM_{2.5}$. Figure 3 shows the relation of these estimated woodsmoke values to 24-hour averaged aethalometer measurements for the winter months.

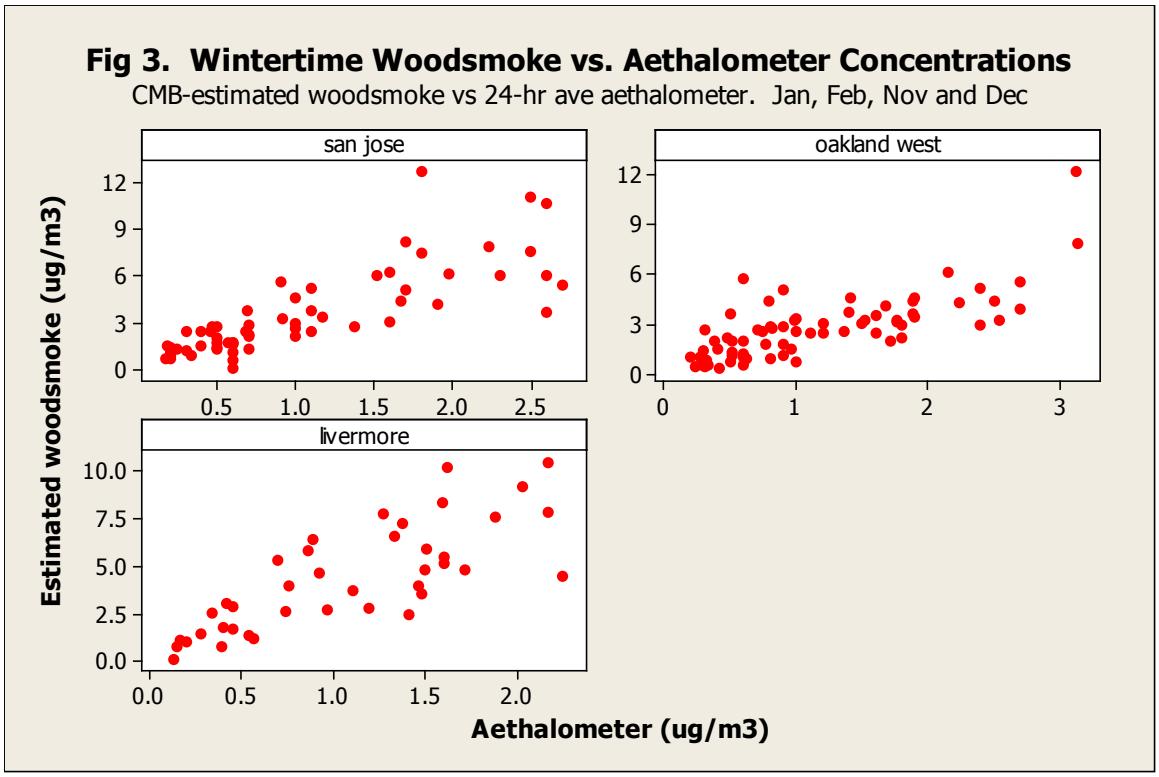
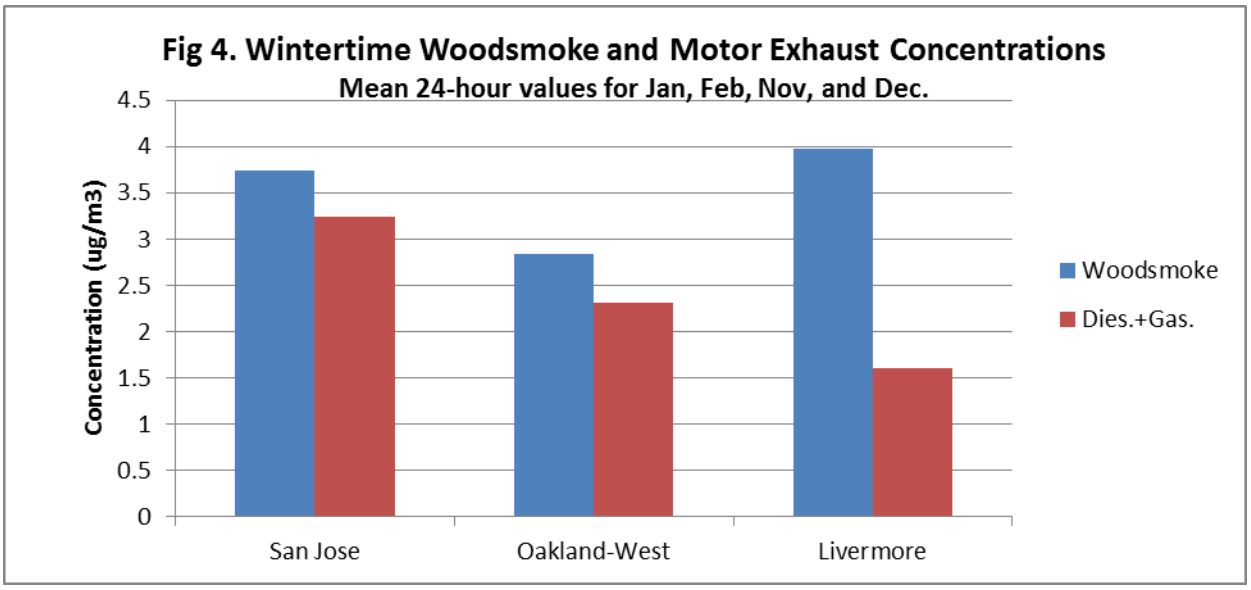


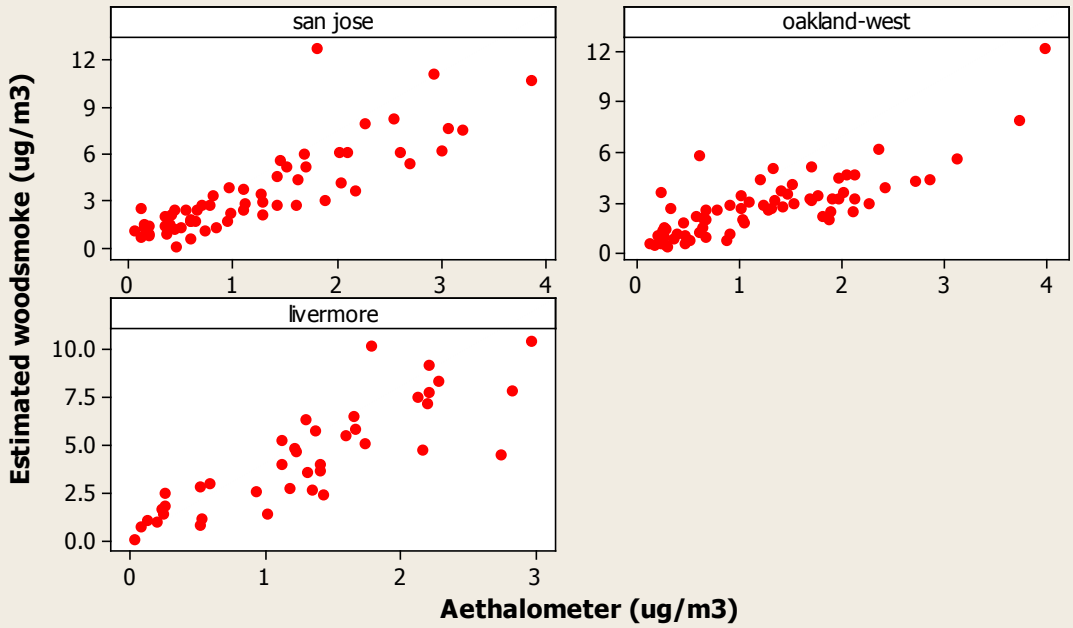
Figure 4 shows that the wintertime contributions from motor exhaust are still relatively large relative to woodsmoke at the urban sites. This implies that the aethalometer measurements from these sites will be substantially greater than from woodsmoke alone. Thus, using the relationship of woodsmoke to 24-hour aethalometer measurements from these sites to predict Forest Knolls woodsmoke concentrations would likely lead to substantial underestimation.



An alternative is to consider the average aethalometer values during the hours where woodsmoke predominates. Figure 5 is like Figure 3, except using the aethalometer measurements averaged over the hours 0-6 am and 8-12 pm.

Fig 5. Wintertime Woodsmoke vs. Nighttime Aethalometer Concentrations

CMB-estimated woodsmoke vs 0-6am+8-12pm ave aethalometer. Jan, Feb, Nov and Dec



Even during the nighttime, a substantial fraction of winter $PM_{2.5}$ may derive from motor vehicle exhaust as $PM_{2.5}$ often remains suspended for long periods. Figure 4 shows that Livermore has substantially less mv exhaust relative to woodsmoke than do San Jose or Oakland-West, and Figure 2 shows that Livermore's nighttime $PM_{2.5}$ on weekends is similar to its weekday concentrations, unlike SJ or OW, but like Forest Knolls. Therefore, we use the relationship of woodsmoke to nighttime average aethalometer from Livermore only. The regression relation[1] is woodsmoke = 3.27*(nighttime average aethalometer), where the units are both $\mu g/m^3$.

From Table 1, the period of burning is longer at Forest Knolls than at the other sites. And it apparently includes a morning spurt around 7-9 am as discussed above. Thus, to estimate the 24-hour contribution of woodsmoke we take the average aethalometer measurements from 0-10 am plus 8-12 pm, and scale this value upward by the ratio of the number of hours: (10+4)/(6+4) = 14/10.

Applying the 3.27 factor and the ratio correction, we estimate that the mean woodsmoke contribution to winter $PM_{2.5}$ in the Forest Knolls area was 14.9 $\mu g/m^3$. Over the same winter days, the mean total $PM_{2.5}$ from San Jose, Oakland-West and Livermore was 19.2 $\mu g/m^3$, 16.6 $\mu g/m^3$, and 15.7 $\mu g/m^3$ respectively. Thus, at Forest Knolls, woodsmoke alone may

[1] The intercept was non-significant, so the regression was run through the origin.

have resulted in mean $PM_{2.5}$ concentrations almost as high as $PM_{2.5}$ concentrations at urban sites from all sources.

The maximum estimated woodsmoke concentration for Forest Knolls was 39 $\mu g/m^3$, exceeding the national 24-hour $PM_{2.5}$ standard of 35 $\mu g/m^3$. Note that the actual $PM_{2.5}$ concentrations must have been a several $\mu g/m^3$ higher, at least. Secondary $PM_{2.5}$, including ammonium nitrate and sulfate, accounts for about 40% of Bay Area $PM_{2.5}$ at its urban sites.

Conclusions

The District's aethalometer monitoring reinforces the evidence that woodsmoke is a significant factor in the air quality in San Geronimo Valley. There can be little doubt that woodsmoke raises $PM_{2.5}$ concentrations to unhealthy levels, occasionally exceeding the national air quality standards. As with any monitoring location, this site provides data for one specific location; there will be other areas with higher woodsmoke concentrations, perhaps substantially higher.

The San Geronimo Valley is unusual for the Bay Area in not being serviced by natural gas. Thus, measures to reduce $PM_{2.5}$ in the Bay Area, such as cleaner diesel engines, may have limited benefit in improving the air quality in San Geronimo Valley.

Extending natural gas service to this area would certainly improve its air quality locally. But it is valuable to step back and consider the wider and longer-term picture, namely that natural gas is a fossil fuel that contributes to global warming, producing CO_2 when it's burned, and emitting methane – which is about 30 times more potent greenhouse forcer than CO_2 – when it leaks. Wood, on the other hand, is renewable, at least in theory. Newer wood stoves and pellet stoves emit considerably less $PM_{2.5}$. On the other hand, these stoves may well produce black carbon, a greenhouse forcer 900 times more potent than CO_2.

What is incontestable would be measures to make residences snugger – like weather-stripping and double-glazed windows – that would reduce the need for heating and very likely improve air quality. This also points to the importance of considering the climate implications of District initiatives.

Reference

Census. American Community Survey 5-year summary 2008-2012 http://www2.census.gov/acs2012_5yr/summaryfile/2008-2012_ACSSF_By_State_All_Tables/, Accessed 2/8/14.

D. Fairley. "Sources of Bay Area Fine Particles: 2010 Update and Trends." December 2012.

Appendix C. Winter PM2.5 monitoring study in Marin County.

Sonoma Technology, Inc.
Air Quality Research and Innovative Solutions

MEMORANDUM

March 14, 2011 Reference: 911010

To: Susan Goldsborough (Families for Clean Air)

From: Fred Lurmann, Manager of Exposure assessment Studies

CC: Eric Stevenson (Bay Area Air Quality Management District)
Jack Broadbent (Bay Area Air Quality Management District)

Re: Winter $PM_{2.5}$ Monitoring Study in Marin County

The purpose of this memorandum is to summarize our findings from the $PM_{2.5}$ monitoring conducted this winter in Marin County. The monitoring was conducted to objectively quantify air pollution levels in communities commonly impacted by wood smoke. The impetus for this monitoring effort was a concern that the Bay Area Air Quality Management District's San Rafael monitoring was not adequately capturing the range of $PM_{2.5}$ concentrations commonly occurring in residential areas of Marin County. The San Rafael monitoring location is well suited for capturing the urban and motor-vehicle contributions to PM; however, the extent to which the station captures the impacts of wood smoke emissions is uncertain.

To address this concern, we installed $PM_{2.5}$ BAM monitors in Woodacre and the Sleepy Hollow area of San Anselmo. The monitors were operated from mid November (2010) through February (2011) in accordance with our standard operating procedures. The monitors were installed on the roof tops of residences at 49 Castle Rock Ave. in Woodacre and 6 Crane Drive in San Anselmo (see Figure 1). The monitoring inlets were located high enough (about 5 meters above ground) and far enough away from obstructions to capture free following air in the communities (see Figures 2 and 3). The locations were selected for convenience (Goldsborough and Lurmann residences) rather than expected location of highest concentrations. The hourly data, including instrument operating parameters, were carefully reviewed and validated. Daily average concentrations (midnight-to-midnight) were calculate from hourly data that exceeded the 75% completeness criteria. Real-time data (not quality assured) from the San Rafael monitor were downloaded from AIRNow Tech for comparison purposes.

Daily $PM_{2.5}$ concentrations from the San Anselmo and San Rafael monitoring location are shown in Figure 4. With only one exception, they show that the concentrations in San Anselmo were lower than those observed in San Rafael. Concentrations during this

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period[1] did not exceed the level of the National Ambient Air Quality Standard (NAAQS) for daily $PM_{2.5}$ (35 μg/m^3) at either location.

Daily $PM_{2.5}$ concentrations from the Woodacre monitoring location are compared to those in San Rafael in Figure 5[2]. $PM_{2.5}$ levels in Woodacre were consistently higher (30% on average) than those in San Rafael. The maximum daily concentration (42.5 μg/m^3) in Woodacre was 49% higher than that at San Rafael (28.5 μg/m^3). The level of the $PM_{2.5}$ daily NAAQS was exceeded on five days in Woodacre, compared to zero days in San Rafael. Not only was the frequency of exceedance high, but also the severity was high, as indicated below:

Date	Daily PM2.5
Nov. 25, 2010	39.3 μg/m^3
Nov. 26, 2010	42.5 μg/m^3
Nov. 30, 2010	41.0 μg/m^3
Dec. 1, 2010	40.0 μg/m^3
Jan. 5, 2011	40.3 μg/m^3

Air quality conditions on the evening of Nov. 30th were particularly adverse. The daily average concentration from noon on Nov. 30th to noon on Dec. 1st was 49 μg/m^3, or 40% above the level of the NAAQS. Furthermore, these conditions occurred in a winter with meteorological conditions that were less adverse for air pollution than most winters in the Bay Area.

Four of the days with $PM_{2.5}$ exceeding the level of the NAAQS occurred in one week. Figure 6 shows the hourly and daily concentrations in Woodacre during the Nov. 25 – Dec. 2 period. The hourly concentrations reach a peak of 111 μg/m^3 at 11 pm on Nov. 30th. The hourly data indicate concentrations are much higher at night, often in the middle of the night, than in the daytime which is consistent with other areas where wood smoke is the main source of $PM_{2.5}$. Lastly, a scatter plot of Woodacre and San Rafael daily $PM_{2.5}$ data, shown in Figure 7, indicates the concentrations at the two locations are not well correlated (r^2=0.37). The measurements in San Rafael are not only lower than in Woodacre, but they are only able to explain 37% of the variance in concentrations at Woodacre.

As you are aware, the NAAQS is not a 'never to exceed' standard but rather a statistical standard that states the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 μg/m^3. The form of the PM2.5 daily standard effectively allows up to 22 days over the 35 μg/m^3 level standard in a 3-year period in an air basin such as the SF Bay Area. The data from the Woodacre site this winter alone would provide 5 of those allowable days out of the average of 7.3 per year.

[1] Nov. 21, 2010 to Feb. 7, 2011 excluding days with missing data: Dec. 28-31, Jan. 1-3, 7, and 23-25.
[2] Nov. 21, 2010 to Mar. 5, 2011 excluding days with missing data: Jan. 7, 9-15, and 20-23, and Feb 1-2.

In conclusion, while conditions in San Anselmo were cleaner than those in San Rafael, the $PM_{2.5}$ levels in Woodacre were consistently higher than and not well correlated with those in San Rafael. The diurnal patterns of concentrations in Woodacre matched the conceptual model of wood smoke impacted areas (i.e., high nighttime levels). We observed 5 days above the level of the daily $PM_{2.5}$ NAAQS in Woodacre this winter. The frequency of high $PM_{2.5}$ observations in this pilot study would contribute significantly (5 of 7.3 days per year) to the pool of allowable days above the level of the NAAQS in the Bay Area. These results suggest the need for additional monitoring in subregions of Marin County impacted by wood smoke for purposes of compliance with the NAAQS and protection of public health.

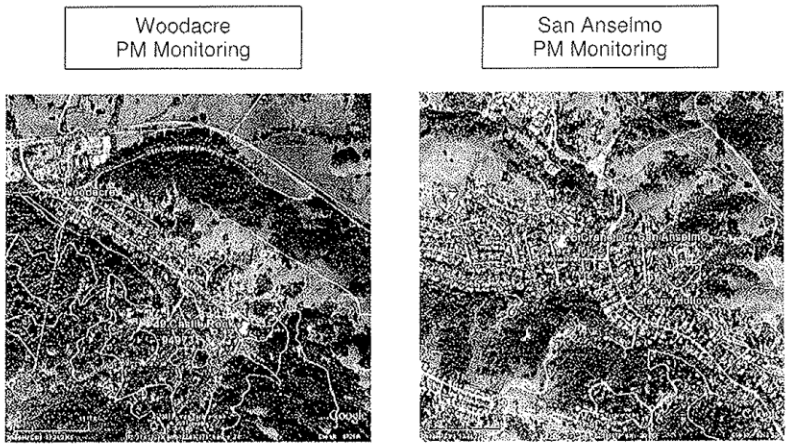

Figure 1. PM monitoring locations in Woodacre and San Anselmo.

Figure 2. Photographs of monitoring shelter installed in Woodacre.

Figure 3. Photographs of monitoring shelter installed in San Anselmo.

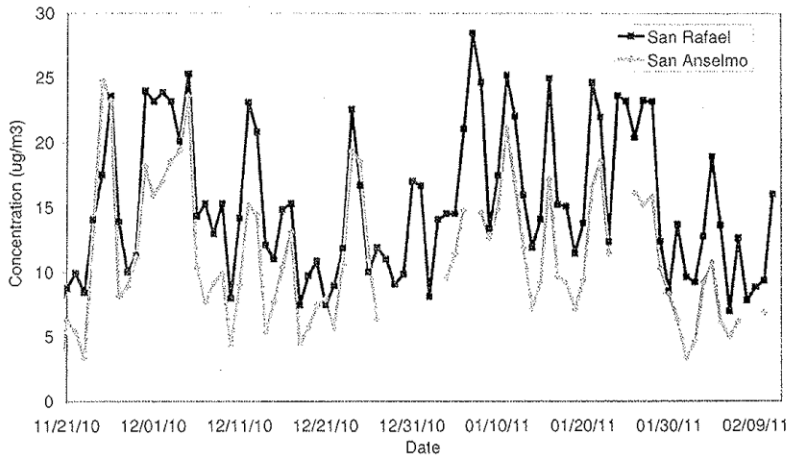

Figure 4. Comparison of Daily PM2.5 concentrations in San Anselmo and San Rafael (Marin County) in winter 2010/2011

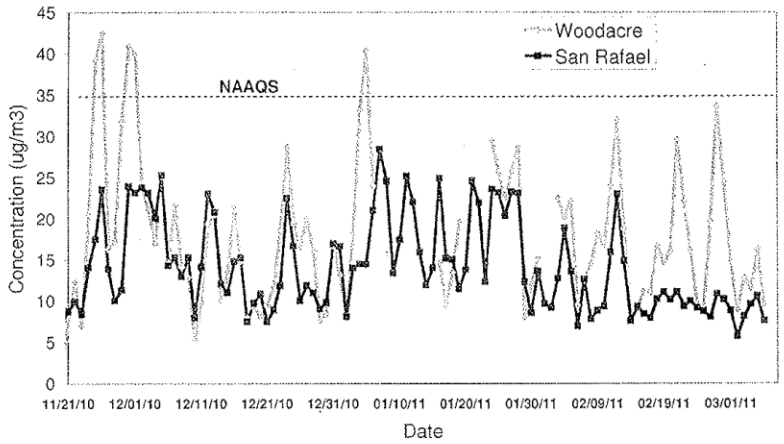

Figure 5. Comparison of Daily $PM_{2.5}$ concentrations in Woodacre and San Rafael (Marin County) in winter 2010/2011.

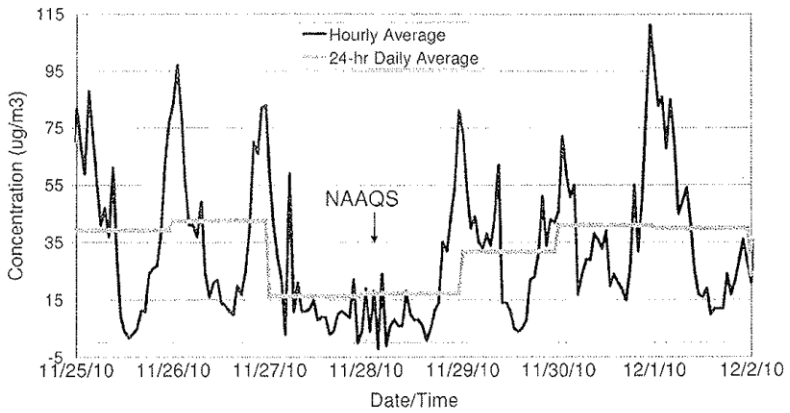

Figure 6. PM2.5 in Woodacre Nov 25 - Dec 2, 2010, indicating 4 NAAQS Exceedances.

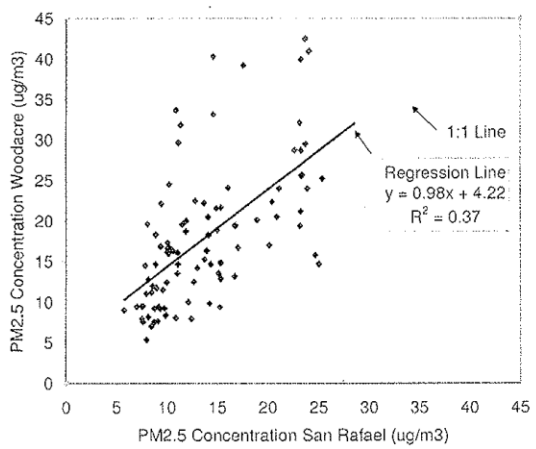

Figure 7. Scatterplot of Woodacre vs San Rafael $PM_{2.5}$ data indicating poor correlation (r^2=0.37). The San Rafael data only explain 37% of the variance in the Woodacre data for this period.