SOUTH COUNTY COMMUNITY MONITORING PROJECT

San Luis Obispo County Air Pollution Control District

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Glossary of Terms

beta source	A radioactive material (typically carbon 14) that emits beta particles. In air monitoring, it is used to measure mass of particulates deposited on a filter.
coarse fraction	Airborne particulates with an aerodynamic diameter between 2.5 and 10 microns.
dust event	
-Minor event	Only one permanent monitoring site has 24-hour PM10 average greater than 50 ug/m3
-Moderate event	Two permanent monitoring sites have 24-hour PM10 average greater than 50 ug/m3, but both less than 100 ug/m3
-Significant event	Two permanent monitoring sites have 24-hour PM10 average greater than 50 ug/m3 and at least one greater than 100 ug/m3
-Very Significant event	At least one permanent monitoring site has 24-hour PM10 average greater than 150 ug/m3
FEM	Federal Equivalent Method. US EPA designation indicating a monitoring method has been determined to be equivalent to the established federal reference method for measurement of a particular pollutant.
fine fraction	Airborne particulates with an aerodynamic diameter less than 2.5 micron.
FRM	Federal Reference Method. US EPA designation for the established measurement method for a particular pollutant.
histogram	A graphical representation showing a visual impression of the distribution of data.
hi-volume sampler	A particulate sampler designated as the federal reference method for PM_{10}. The hi-volume sampler is a manual method used to measure 24 hour average concentration of PM_{10}.
nephelometer	A nephelometer measures suspended particulates by employing a light beam (source beam) and a light detector set to one side (often 90°) of the source beam.
OHV	Off-highway vehicle
Plume	The spatial pattern of airborne pollutants resulting from an emission source.
PM_{10}	Airborne particles with an aerodynamic diameter less than 10 microns.
$PM_{2.5}$	Airborne particles with an aerodynamic diameter less than 2.5 microns.
ug/m3	micrograms per cubic meter. The unit of measure typically used for airborne particle pollution representing the mass weight of particles per cubic meter of air sampled.
wind blown dust	Crustal particles entrained in the atmosphere by wind blowing across open soil and/or sand areas

Executive Summary

The San Luis Obispo County Air Pollution Control District (APCD) has been investigating elevated particulate levels on the Nipomo Mesa for the past decade. Studies performed by the APCD in the area have shown the source of the elevated particulate matter (PM) pollution to be windblown dust from the open sand areas of the Oceano Dunes State Vehicular Recreation Area (SVRA), and that emissions are increased by off road vehicle activity. Additionally, previous studies have shown elevated airborne particulates are present near Pier Avenue in Oceano.

While working to reduce the particulate emissions at the source, the APCD also recognizes the need to provide the most accurate information available to residents of the area regarding the impacts of the windblown dust to their community. That was a primary impetus behind the design and implementation of the South County Community Monitoring Project. The goal of this project was to map the spatial extent and concentration gradient of the dust plume to better understand its impacts on Nipomo Mesa and Oceano neighborhoods. The data collected was ultimately intended to facilitate the preparation of more detailed air quality forecasts for those areas and enhance the ability of local residents to individually determine if or when protective actions might be needed on high PM days. Better knowledge of the plume path and downwind concentrations would also help inform the development of dust controls at the SVRA.

A saturation monitoring approach was utilized for this project with 23 semi-portable, real time beta attenuation (EBAM) PM_{10} monitors (many equipped with wind sensors), deployed across the Nipomo Mesa, as well as near the beach and adjacent to Pier Avenue and in Oceano. These monitors gathered data during the months of March through May, 2012 to capture the period known to have the highest winds and prevalence of dust episodes.

Nipomo Mesa Study Results

The data gathered from the Nipomo Mesa study area provides a detailed and comprehensive picture of the path, concentration gradient and influence of different wind conditions on the dust plume. Most dust episodes showed a remarkable similarity in plume extent and concentration gradient, with the main variable being the severity of the event. Figure E-1 below presents a visualization of the typical plume pattern observed on the Mesa.

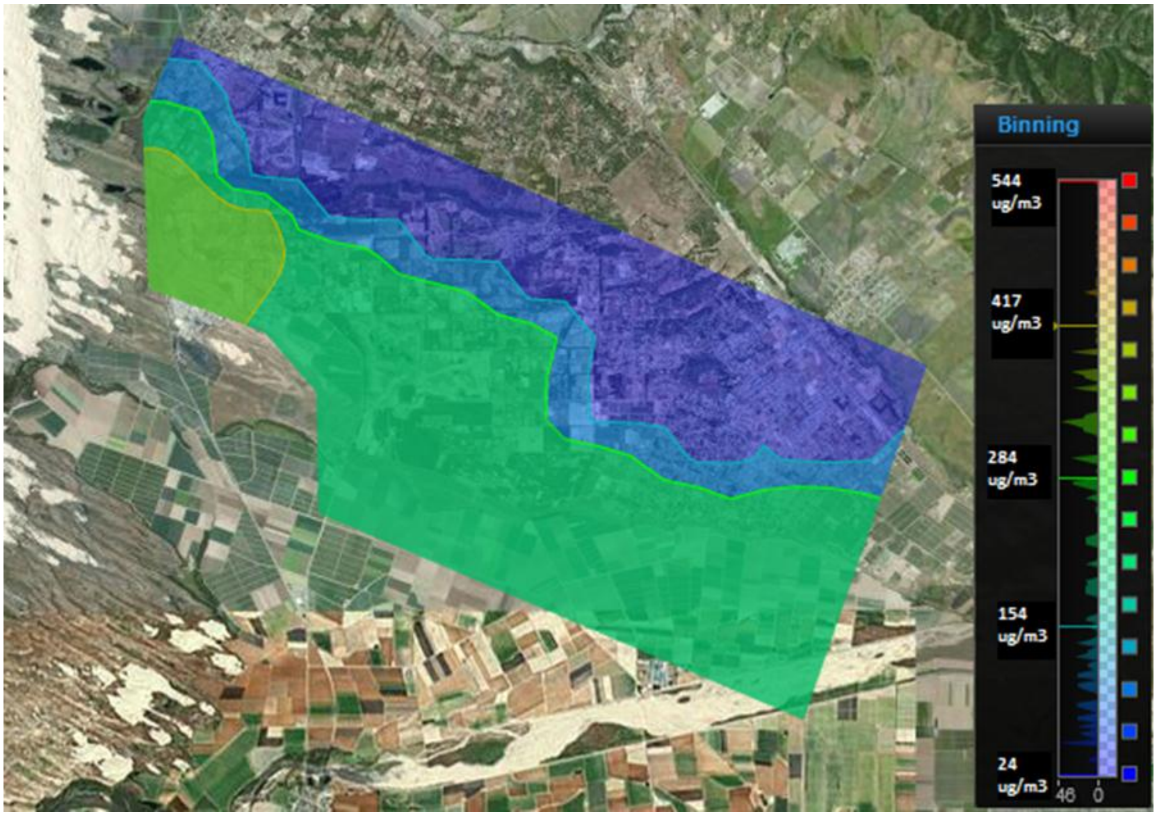

Figure E-1 – Typical Pattern of PM10 Distribution for Peak Hour of Dust Episode on the Nipomo Mesa

While the pattern of PM_{10} concentration depicted above is typical for most wind/dust events, some subtle differences were noted on specific episodes. The most significant variable in episodes appears to be changes in wind direction as the plume moves inland. Wind data shows that during the strong northwest winds when the dust events typically occur, the wind direction is quite constant near the coast, resulting in only small changes in the plume characteristics on the western portion of the Nipomo Mesa. However, the wind direction farther inland becomes much more variable, resulting in more variations in the plume path as one moves inland. For example, it is not uncommon for the wind direction five miles from the coast to shift more northerly, which results in a plume impact that is pushed in a more southerly direction with little to no impact in the northern portion of the Mesa. Conversely, particulate concentrations increase in the northerly portion of the study area when the wind direction inland is more westerly than on the coast. Analysis of the project data also demonstrated that the dust plume from the coastal dunes often extends inland to Santa Maria.

Oceano Area Study Results

Data gathered from the Oceano area showed elevated particulate concentrations are present during high northwesterly winds at monitors in close proximity to any area of disturbed open sand. These sand areas include the beach as well as Pier Avenue where sand commonly is tracked out of the SVRA by vehicles exiting the park. The project data showed the extent of the plume from these open sand areas to be quite small, with particulate concentrations diminishing quickly downwind. A 40% drop in PM_{10} concentration was observed just 0.1 mile downwind of the Pier Avenue monitoring site, while almost no plume presence was detectable at a site less than 0.4 miles downwind from the beach area.

<u>Implications for Air Quality Forecasting in the South County</u>

Detailed analysis of the study data and the particulate concentration relationships between each monitoring site under various meteorological conditions was used to generate more detailed forecast maps than previously possible for both the Nipomo Mesa and Oceano areas. Figures E-2 and E-3 below define the typical areal influence of the dust plume on each area during strong northwesterly winds. The APCD will use these maps to provide a numerical forecast of the Air Quality Index (AQI) for each forecast zone based on the approximate magnitude of the forecasted particulate concentrations. Each forecast zone is related to PM concentrations measured at the three permanent APCD monitoring stations on the Nipomo Mesa: CDF (Willow Road), Mesa2 (Guadalupe Road) and NRP (Nipomo Regional Park). Areas outside of the zones shown in these figures should use the San Luis Obispo monitoring station for particulate air quality guidance, unless otherwise noted.

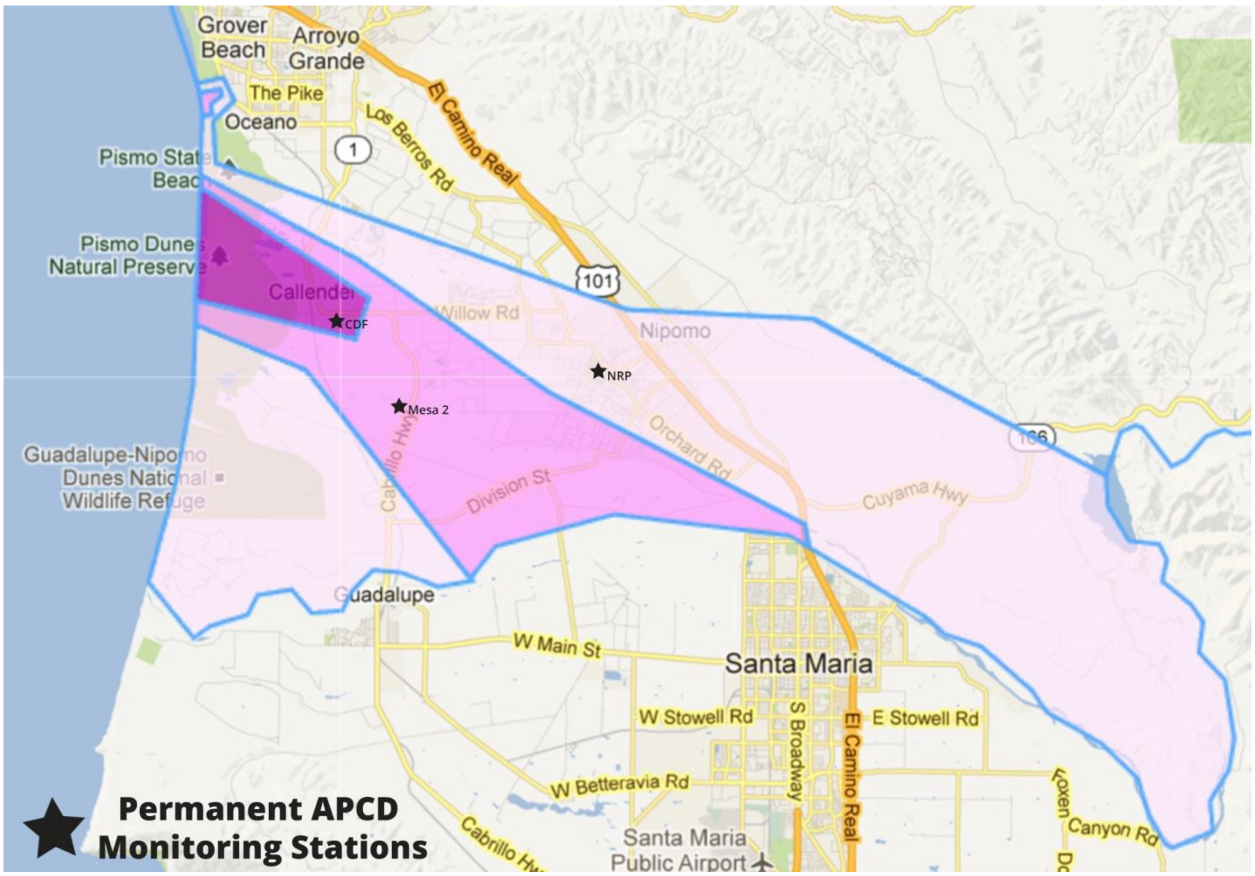

Figure E-2 - Nipomo Area Forecast Map. Forecast zones: Dark Pink = CDF, Medium Pink = Mesa2, Light Pink = NRP

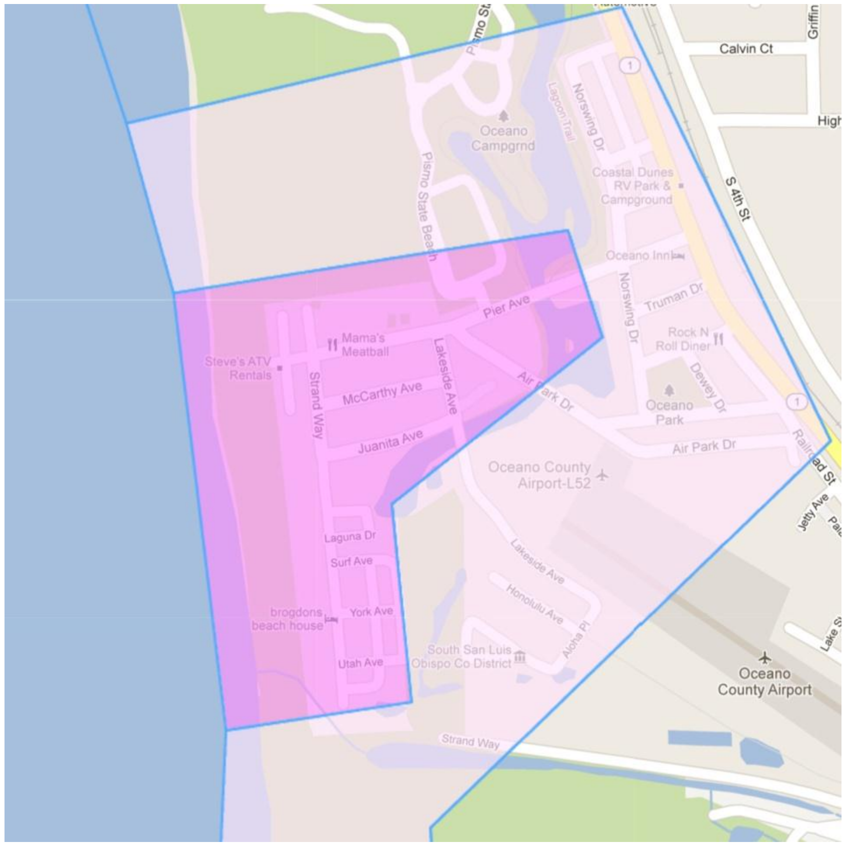

Figure E-3 – Oceano Area Forecast Map. Forecast zones: Medium Pink = Mesa2, Light Pink = NRP

It is important to note that each wind-blown dust event can have different wind and particulate concentration characteristics, so the forecast zones on these maps are based on the estimated average magnitude of the particulate concentrations observed in each area. The borders of each zone are approximate and not meant to be a rigid boundary; the plume path can vary with changes in wind direction and speed, and particulate concentrations on either side of a forecast zone border are likely to be similar. Thus, the public should use the air quality forecasts as a guide to help plan their outdoor activities and protect their health during blowing dust episodes, understanding that the forecast is our best estimate of potential maximum PM levels in each zone on a given day. The San Luis Obispo County forecast zones end at the Santa Barbara County border; however, as previously discussed, data from this study indicates impacts of the plume continue into Santa Barbara County during the more significant blowing dust events.

Introduction and Background

This report describes a special air monitoring study conducted by the San Luis Obispo County Air Pollution Control District (SLO APCD or District) to better define the spatial distribution and neighborhood impacts of the windblown dust plume that originates from the Oceano Dunes during high northwest wind conditions. The study focused on two primary impact areas in the South County: the Nipomo Mesa neighborhoods directly downwind of the dunes, and the Oceano neighborhoods adjacent to Pier Ave and the beach. The results of this study will be used to increase the accuracy of our South County air quality forecasting and the information available to affected residents and the media.

Historical ambient air monitoring conducted by the SLO APCD has recorded high airborne particulate matter (PM) concentrations in southwestern San Luis Obispo County that are much higher than those observed at other coastal areas of San Luis Obispo County and California as a whole (1). Ambient PM levels of on the Nipomo Mesa exceed State air quality standards about 60 to 70 days per year and occasionally exceed the considerably more stringent Federal standards. Of particular concern are the very high hourly PM levels that typically occur in the active hours of the day during these episodes.

To better understand the extent and source(s) of this particulate pollution, the SLO APCD has previously performed other air monitoring studies in and around the Nipomo Mesa and Oceano areas, including what are now commonly referred to as the Phase 1 and Phase 2 South County Particulate Studies (2,3). These comprehensive research efforts have documented the severity of the problem and confirmed that the high particulate levels impacting the Nipomo Mesa are associated with high winds, and that the main source area is the open sand sheets of the Oceano Dunes State Vehicular Recreation Area (SVRA). The Phase 2 study concluded that all open sand areas exposed to high winds have the potential to emit PM, but that off-highway vehicle (OHV) activity in the SVRA increases the magnitude of these emissions. Considerable analyses of airborne particulate samples collected during these studies has shown that, on high concentration days, the majority of the particle mass consists of earth crustal elements, along with 5 to 10 % sea salt, about 5% ammonium sulfate and less than 1% ammonium nitrate (2, 3).

High particulate concentrations were also measured in Oceano near Pier Avenue in the Phase 2 study during high wind events, but the source area was not clearly defined (2). While there is a small open sand area (beach) upwind from Oceano, other nearby areas with similar upwind beaches have not measured high concentrations of windblown dust (e.g., Grover Beach). Wind entrainment of sand tracked out onto the south side of Pier Avenue as vehicles exit the beach was suggested in the study as a possible source.

Figure 1 below shows the study area and air monitoring locations utilized in the Phase 2 study.

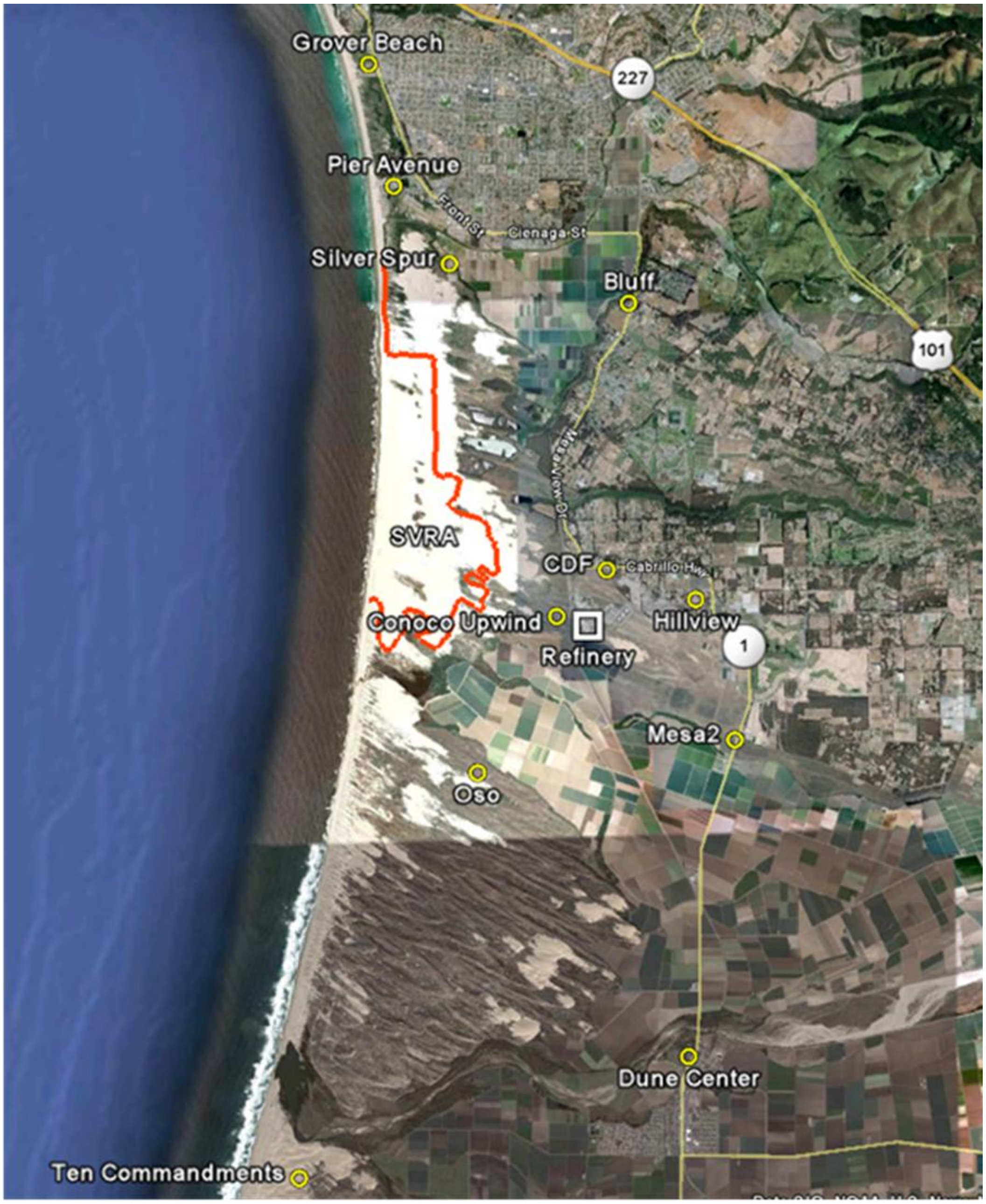

Figure 1 – South County Phase 2 Particulate Study Air Monitoring Locations

Concern over potential health impacts from these high PM levels led the District to perform short-term PM_{10} monitoring at the four public schools in the area (Figure 2, below) to better understand the PM exposure levels for local school children. The monitoring was performed sequentially from April through October 2011, one school at a time, with the goal of measuring PM levels at each location during at least 6 to 8 high northwest wind days before moving to the next school. Data from this limited monitoring project showed the following:

1. No windblown dust impacts were measured at Oceano Elementary School, indicating the extent of the dust plume affecting that community was likely confined to the area near Pier Avenue where PM was measured during the Phase 2 study.

2. There also was no significant windblown dust impacts measured at Mesa Middle School, indicating this school was likely situated to the north of the dust plume.
3. Windblown dust impacts were measured at Lopez High School, but were lower than those concurrently measured at the District's CDF monitoring site about a mile to the south. It is important to note that only one significant dust event occurred during the monitoring period for this school, so the dataset is quite limited. The wind speeds measured at this site were also considerably lower than any other wind speed measurements in the area, likely due to the thick eucalyptus groves directly upwind of the school.
4. Dust impacts were also measured at Dorothea Lange Elementary School on the south eastern portion of the Nipomo Mesa. PM levels observed there were less than measured on the western edge of the Mesa, and closely followed the PM levels concurrently measured at the District's nearby NRP monitoring station. (4)

Figure 2 – Location of District Permanent Monitors and Short Term School Monitors

In analyzing the data collected during the short-term schools monitoring projects it became clear a much better understanding was needed of the spatial extent and concentration gradients of the dust plume impacting the Nipomo Mesa, as well as the source and extent of the dust impacting the community of Oceano. Such information would enhance our air quality forecasting capabilities and enable area residents in affected areas to better determine if protective actions were needed on high PM days. Better knowledge of the plume path and downwind concentrations would also help inform the development of dust controls at the SVRA. Thus, in late 2011 the SLOAPCD initiated this Community Monitoring Project.

Community Monitoring Project

The Community Monitoring Project was designed and developed in late 2011 to provide a detailed understanding of the spatial extent and concentration gradient of the dust plume originating at the Oceano Dunes SVRA. March through May 2012 was selected as the desired timeframe for data collection to capture the period that historically has the most wind-blown dust events. The project focused on two areas of study, Oceano and the Nipomo Mesa, as depicted in Figure 3.

Figure 3 – Community Monitoring Project Study Areas

Study Design

The primary goal of the Community Monitoring Project was to better define the downwind path and concentration gradient of the dust plume originating from the Coastal Dunes. The monitoring plan developed for this study is included in Appendix B. Historical measurements in the study area show that most wind/dust events occur in the spring months from March through May, so the project was designed to have monitors deployed in the field during this period.

Saturation monitoring is a well-established method for analyzing spatial differences in concentrations and was implemented for this study using semi-portable PM_{10} monitors saturating the area downwind from the source area. Two challenges in any saturation monitoring project are:

1. To identify a measurement method that is technically and logistically feasible to apply, is semi-portable, has the necessary time resolution and operational characteristics needed to provide reliable data, and is affordable to acquire and implement.
2. To establish a sufficient density of monitors, in representative locations, to provide sufficient resolution of the plume path and concentration levels.

If these challenges can be overcome in the design of the project, the result is a very clear description of plume path and concentration gradients. One important advantage of the saturation approach is the entire pattern of data is considered, rather than placing all emphasis on a single point of measurement. Looking at the pattern of data across the study area allows data outliers to be discounted as the focus is on the common pattern of data. In essence, when similar values are measured from adjacent monitors, the adjacent monitors provide additional validation to each other's data value. Systematic bias in measurement would not be detected by comparison to adjacent monitors, but can be addressed by a robust QA/QC program that includes comparison to different monitoring methods.

<u>Selection of the Monitoring Method</u>

Because windblown dust typically has more mass in the coarse fraction (2.5-10 micron) than the fine fraction (<2.5 micron), PM_{10} was the obvious parameter to measure for this project. Including measurement of meteorological parameters across the study area provides added insight into the plume behavior.

Hourly data resolution was considered essential to understanding the short term movement of the plume; thus, traditional manual filter methods that only provide 24-hour average readings were eliminated as candidate methods. A number of PM_{10} measurement methods that provide hourly (or less) resolution were evaluated for use in this project (5). Project staff weighed the benefits and drawbacks of each method and ultimately selected the MetOne EBAM as the best available method for this study. Important considerations included the following:

- EBAMS are often configured with meteorological sensors, so in addition to gathering PM_{10} data, wind speed and direction data could also be gathered across the study area.
- Project staff is already very familiar with operation of the EBAM.
- The large number of EBAM samplers needed for this project was available on loan from other government agencies.

The MetOne EBAM is a portable PM_{10} monitor that uses beta attenuation as the sampling method. One important operational characteristic of the EBAM to be mindful about is its known tendency to respond low to PM_{10} samples when most of the mass consists of particle sizes in the coarse range above 7 microns. This characteristic was first discovered by the SLO APCD in Quality Assurance (QA) tests associated with the Phase 2 study. After investigation by the sampler manufacturer, the issue was confirmed and determined to be caused by the partial obstruction of the sample path by the beta source (6), located just above the sample filter tape (see Figure 4). EPA-approved Federal Equivalent Method (FEM) monitors with more advanced beta attenuation systems (such as the MetOne BAM 1020 used at APCD permanent monitoring sites) do not have the beta source in the sample path; instead, they have a complex shuttle mechanism that moves the filter tape between the sample path and the beta source and detector.

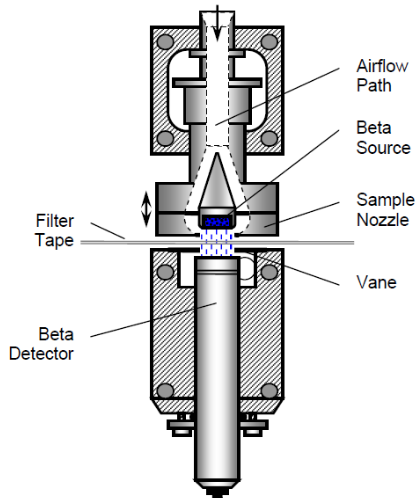

Figure 4 – EBAM Source, Detector, and Sample Path

Through extensive QA testing during the Phase 2 study, the District was able to successfully apply a correction factor developed by running side-by-side tests comparing the EBAM measurements to FEM monitors (2). The corrected EBAM data ensures PM_{10} measurements are accurately reported even when the majority of the sample mass consists of particles greater than 7 microns. In selecting the EBAM for use in this study, project staff acknowledged that extensive QA testing would be needed to ensure valid and high quality data was collected.

Quality Assurance Program

Independent quality assurance oversight for this project was performed by Mr. Karl Tupper of the San Luis Obispo County APCD. He was not involved in performing any calibrations, QC checks, maintenance or other aspects of sampler operation for this program to allow for independent oversight of QA issues. Mr. Tupper was responsible for reviewing all Quality Control (QC) check documentation for accuracy, reviewing all site selection surveys, and assuring the procedures utilized followed those outlined in the monitoring plan and the EBAM Standard Operating Procedures (SOP) manual (Appendix B). In addition, He was also responsible for review and analysis of the methods inter-comparison tests between the EBAM samplers and the federally approved monitoring method performed at the District's Mesa2 and Nipomo Regional Park (NRP) monitoring stations prior to the saturation sampling, including approval of all correction factors to the data. Finally, Mr. Tupper approved the validation of all data utilized in the analysis of data for this project.

All EBAM samplers utilized for this project were operated adjacent (collocated) to the Districts Mesa2 or NRP monitoring stations, both of which are equipped with FEM PM_{10} monitors. The FEMs are subjected to bi-annual performance audits by the California Air Resources Board (CARB) and successfully passed all audits; the last audit was in April 2012. Most of the samplers were collocated with the District's FEM

PM_{10} monitors for the approximate period of February 7, 2012 through March 7, 2012. Some samplers that needed additional repair work prior to deployment, or were received from the loaning agency at a later date, were collocated during alternative time periods.

This period of collocation of all EBAM samplers with the BAM 1020 FEMs was used to establish the relationship between each EBAM sampler and the FEM, focusing on comparisons between the two sampling methods during wind-blown dust events. The results of these comparison tests were used to calculate correction factors for the EBAM data to make it comparable to the federally equivalent PM_{10} method. Throughout most of the project measurement period at least one EBAM was collocated at both the NRP and Mesa2 sites. Cycling of EBAM samplers between the Mesa 2 site and the NRP site was performed to establish a consistent relationship between the EBAM monitors and the FEM monitors at both the Mesa2 and NRP monitoring locations.

In addition to collocation of the EBAM samplers with FEMs, the project followed a strict Quality Control protocol to ensure only valid representative data was used in analyzing the monitoring results. Details of the QC protocol, QC results, and a detailed description of the collocation tests and correction factor calculations can be found in Appendix A and Appendix B.

Nipomo Mesa Monitor Locations

A common approach in saturation monitoring is to divide the study area into a grid, siting one monitor in each grid area; this results in an almost even distribution of monitors across the study area. To achieve the project goal of describing the plume path and concentration gradient on the Nipomo Mesa, while ensuring measurements captured sensitive receptors and more populated areas, a modified grid approach was used. In this approach, a grid was used as a starting point for monitor siting, followed by a detailed examination of each grid area to identify sensitive receptors, relative population density, our current understanding of micro-meteorological patterns, and any previous monitoring performed in the area. This analysis was used to determine if, and approximately where, a monitor should be sited in each grid.

Figure 5 shows the study area downwind from the coastal dunes with an approximately 1 square mile grid aligned to the prevailing winds that occur during dust events. A resolution of 1 square mile provides an adequate description of the plume, even with the obvious topographic and other obstructions to airflow that will result in micro-meteorological conditions in some areas. The northern grid boundary was determined based on previous monitoring projects in the area that indicated this was likely the northern extent of the plume under most conditions. The southern grid boundary was set at the edge of the Nipomo Mesa, which also is the edge of the most populated areas. In addition to siting monitors based on analysis and investigation of each grid, it was determined that siting a few additional monitors outside of the populated grid area would be of value in enhancing our knowledge of the plume extent.

Figure 5 – Approximately 1 square mile Grids over Populated Area Downwind from the SVRA and Permanent District Monitoring Stations

<u>Oceano Monitoring Locations</u>

The situation in the Oceano study area is different due to the much smaller spatial scale being investigated (most of the community fits into a single half square mile area) and the added goal of providing a more definitive determination of the source of particulate matter impacting the community. Additionally, State Parks, in conjunction with the County of San Luis Obispo, has instituted a street cleaning program designed to minimize the accumulation of sand being tracked out of the SVRA onto Pier Avenue; thus, it was hoped that measurements in this area might also be able to determine how much reduction in ambient particulate matter has occurred due to this mitigation effort. The study design for Oceano incorporated a similar saturation approach, with one monitor located at approximately the same location where the Phase 2 study measured high particulate concentrations.

For both study areas, land owners in desirable monitoring site locations were approached to host samplers. Each potential sampler location was investigated by project staff and a formal evaluation of the suitability of the site was performed. The Project Monitoring Plan, attached as Appendix B, details the specific siting criteria and the forms and procedures used to evaluate potential site locations. In general, the sites were evaluated for:

- Minimal obstructions to air flow, particularly from the NW direction as that is the path for most windblown dust events.
- Proximity to other potential local particulate sources.
- Availability of electrical power.
- Ease of access to the site.
- Security for staff and equipment.

Following an exhaustive search and onsite evaluations for appropriate monitor locations, a set of suitable locations on the Mesa and in Oceano was finalized and formal agreements with the hosting land owners were established. One important study zone where staff was unable to secure a monitoring site was the agricultural area south of the Nipomo Mesa in the northern portion of the Santa Maria Valley (site ID S-E). As an alternative, staff utilized a sampler mounted on the bed of a truck parked on the side of the roadway from approximately 10am through 5pm on 6 days that were forecast to be episode events, and one day forecast to be a non-event day for comparison.

Figure 6 below presents the approximate location of each monitoring site in the Nipomo Mesa study area along with its assigned site ID. Note that not all sites were operational for the entire monitoring period.

Figure 6 – Nipomo Mesa Project Site Locations. Permanent SLO APCD/State Parks monitoring stations are shown with yellow pins, temporary EBAM locations with purple circles.

In the Oceano study area, a sampler (O-C) was sited across the street from a monitoring location previously used in the Phase 2 Study (the original Phase 2 location was unavailable) that had measured high PM_{10} concentrations. A second site (O-A) was selected further inland from O-C along the northwestern prevailing wind direction. A third site (O-B) was also selected approximately the same distance inland (along prevailing wind direction) as O-A, but farther south and well away from any influence of Pier Avenue. After review of preliminary data from these three sites in early May, a fourth Oceano site (O-D) was selected on the beach. Figure 7, below, shows the approximate location of these sites as well as the location of Oceano Elementary School, where monitoring in the Spring of 2011 detected no dust plume or elevated PM_{10} readings. (4) Note that for the Community Monitoring Project, no new monitoring was performed at Oceano Elementary School.

Figure 7 – Oceano Study Area Sampling Locations in Relation to Oceano Elementary School

Results and Analysis

Overall, the data from the saturation monitoring provide exceptional detail on plume extent, concentration gradient, and wind patterns across the study area. The density of monitors was more than sufficient to meet the goals of the project, even with sporadic data loss from some sampling locations.

For the Community Monitoring Project, the EBAM samplers operated quite well; occasional monitor failures did occur, as expected, both for PM_{10} and wind sensors. Some PM_{10} data loss occurred due to hardware failures (mostly pumps), out of tolerance quality control checks (mostly due to occasional nozzle leaks), and tape failures. Data loss for wind parameters was almost entirely due to failure of the internal reed relay on wind speed sensors in certain samplers; the reed relay has a finite life, and as most the EBAM samplers were used units, their age contributed to the failure rate of these sensors. During the saturation monitoring period after all monitors were installed (3/10/12 to 5/31/12) the average data recovery for PM_{10} from the EBAM saturation monitors was a respectable 81%, and the wind data recovery rate exceeded the PM_{10} data recovery. A more complete breakdown of data recovery is provided in Appendix A.

Nipomo Mesa Study Area

Plume Path and Concentration Gradient

The data gathered from the Nipomo Mesa study area provide a detailed and comprehensive picture of the dust plume path, concentration gradient, and how wind conditions influence the dust plume. Most dust episodes show a remarkable similarity in plume extent and concentration gradient, with the main variable being the severity of the dust event. Figure 8 below presents a visualization of the typical plume pattern observed on the Mesa. The colored isopleths were produced using Groundswell Technologies Waiora software.

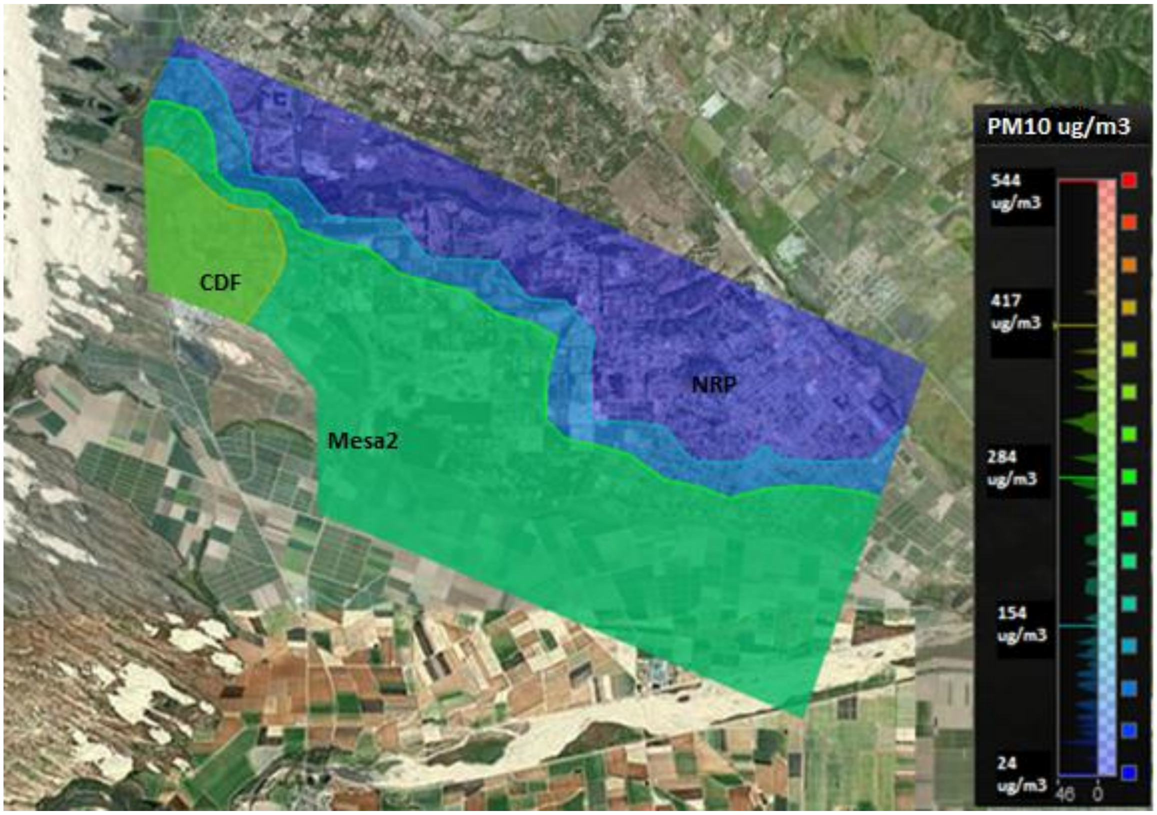

Figure 8 - Typical Pattern of PM10 Distribution for Typical Peak Hour of Dust Episode on the Nipomo Mesa

Note in Figure 8, above, that the concentrations are quite low along the entire northern and northeastern study domain. This confirms previous measurements which showed that under most wind-blown dust event conditions, the northern/northeastern edge of the plume path generally follows the northern boundary of the study domain where PM concentrations tend to be least influenced by the plume. There are some exceptions, and under extreme dust events, the concentrations along the northern study extent can be significantly higher than typical background levels; however in general, the Community Monitoring Project data confirms the study domain captured the northern extent of dust plumes from the SVRA.

Figure 8 also demonstrates the highest concentration areas are along the western and southern boundaries of the study domain. The very highest concentration areas are consistently in the vicinity of the District's permanent CDF monitoring station, with slightly lower concentrations to the north and south. PM_{10} concentrations similar to those observed at the APCD Mesa2 site occur along the southern edge of the Nipomo Mesa and the northern portion of the Santa Maria Valley, as measured by the temporary site SE. The Community Monitoring Project study domain does not extend farther south than the temporary site SE in the northern portion of the Santa Maria Valley. Thus, the southerly extent of the dust plume was estimated using the data from this study and historical data from a monitoring station previously located in Guadalupe.

A PM_{10} monitor was located in downtown Guadalupe in March 2009 as part of the Phase 2 study; the Guadalupe site was a similar distance from the coast as Mesa2, but about 3.5 miles south of Mesa2. PM_{10} concentrations at Guadalupe barely exceeded normal background levels, even during hours when Mesa2 measured 200 to 300 ug/m3. Based on this historical data, it appears the southern extent of the dust plume is somewhere between Mesa2 and Guadalupe when the winds are from the northwest.

The average 24-hour PM_{10} concentrations at all temporary sites on days with dust events compared to average concentrations at the permanent District sites on those same days provide a good gauge of typical plume impacts in areas without a permanent site. Figure 9 below shows the name and location of each temporary and permanent site, while Table 1 presents the data comparisons as a ratio of the average concentration observed at each temporary site versus each permanent site. Multiplying the ratio listed times the 24 hour average concentration from the specified permanent site provides the approximate 24-hour average concentration one would expect at the location of the temporary site. These factors can be utilized in future dust episodes to estimate the impacts at one or more temporary site location. Note that there is no 24 hour data for site S-E, but comparing the hourly concentrations gathered from S-E show that the concentrations during dust episodes at S-E are very similar to Mesa2.

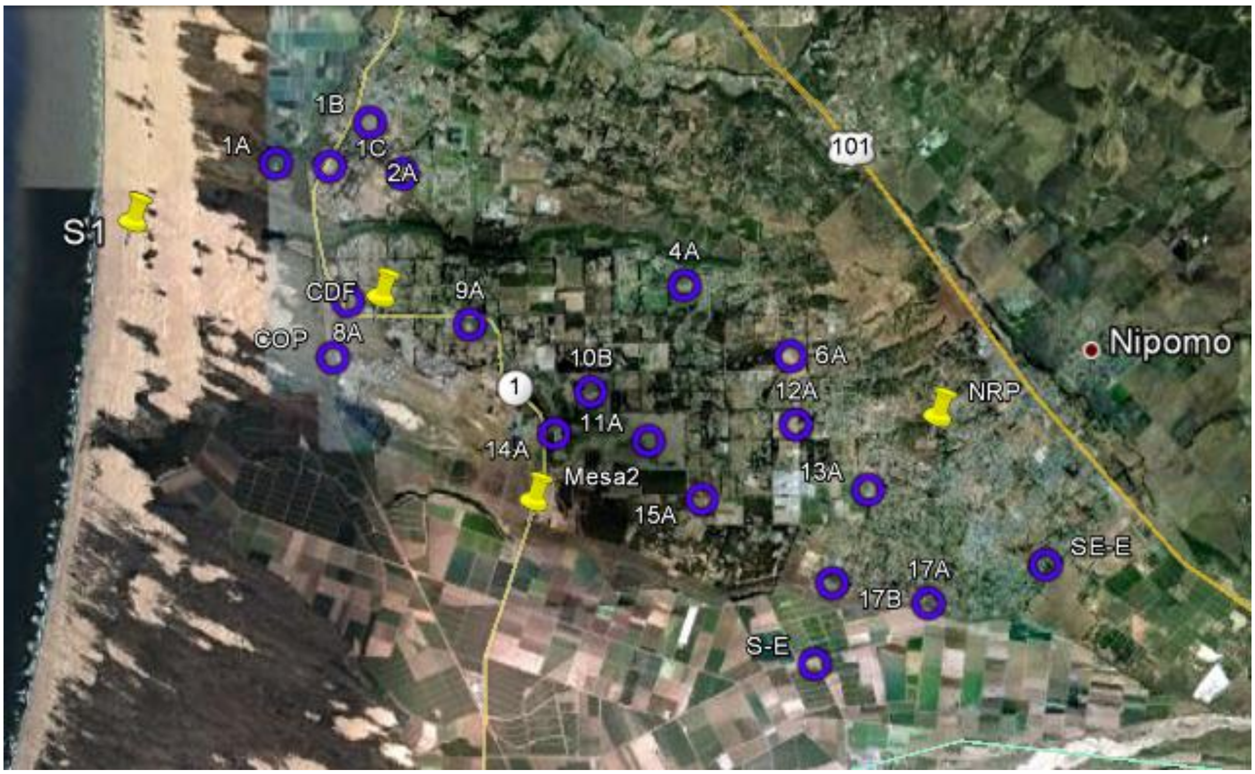

Figure 9–Temporary sites and Permanent Sites Used in Study

Table 1 – Comparison of average 24-hour PM_{10} concentrations at temporary and permanent monitoring sites on episode days during the study period

Temporary Sites	Most Comparable District Site	Ratio of Average 24-hr PM_{10} Concentration to District Site			# Episode Days Analyzed	Statistical Correlation of Episode Data to District Site		
		NRP	CDF	Mesa2		NRP	CDF	Mesa2
1A	Mesa2	1.34	0.55	0.75	26	0.41	0.82	0.80
1B	NRP	0.74	0.24	0.33	9	0.63	0.47	0.80
1C	Mesa2	1.20	0.58	0.75	14	0.46	0.89	0.88
2A	NRP	0.76	0.29	0.39	23	0.39	0.51	0.47
4A	NRP	1.08	0.49	0.64	20	0.88	0.29	0.27
6A	NRP	0.76	0.29	0.39	29	0.95	0.49	0.49
8A	CDF	2.12	0.85	1.12	23	0.36	0.93	0.93
9A	Mesa2	1.43	0.52	0.70	23	0.62	0.84	0.81
10B	Mesa2	1.59	0.62	0.82	29	0.72	0.87	0.87
11A	Mesa2	1.45	0.53	0.72	23	0.55	0.83	0.76
12A	NRP	1.19	0.46	0.63	19	0.87	0.53	0.56
13A	NRP	1.14	0.45	0.58	23	0.78	0.48	0.53
14A	Mesa2	1.75	0.72	0.98	20	0.13	0.79	0.84
15A	Mesa2	1.83	0.68	0.88	20	0.61	0.82	0.87
17B	Mesa2	1.40	0.55	0.73	26	0.68	0.87	0.85
17A	Mesa2	1.43	0.55	0.73	29	0.76	0.88	0.85
SE-E	NRP	1.10	0.43	0.56	26	0.94	0.58	0.60
COP	Mesa2	1.65	0.66	0.84	6	0.51	0.91	0.99

Based on the project data, in most cases the centerline of the dust plume follows the prevailing northwesterly wind direction centered on the CDF monitoring station and extending inland. As the plume moves inland, the wind direction may vary, resulting in subtle shifts in the plume centerline. Data analysis from the Santa Maria monitoring station and numerous visual observations indicate that the plume reaches Santa Maria during the more significant events when the inland wind direction directs the plume to this monitor.

<u>Variations in Dust Events</u>

While the pattern of PM_{10} concentration depicted in Figure 8 above is typical for most wind/dust events, some subtle differences were noted on specific episodes. The most significant variable in episodes appears to be changes in wind direction as the plume moves inland. At the S1 meteorological site located on the dunes, there is very little variability in wind direction during significant dust episodes, as shown in Figure 10. This figure presents a histogram depicting the distribution of wind direction at S1 for the peak PM_{10} hour (measured at CDF) of each day during the monitoring phase of this project when the CDF site exceeded the state 24-hour PM_{10} health standard of 50 ug/m3.

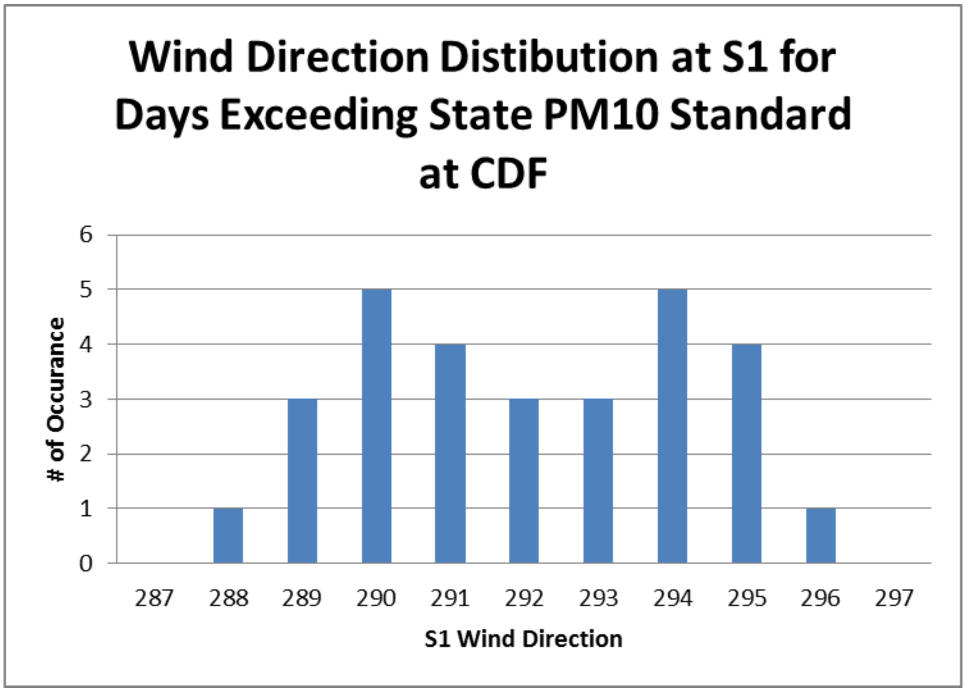

Figure 10 –S1 Wind Direction Distribution at Peak Hour of Significant Dust Events

In contrast, wind direction variability increases as you move inland as represented in Figures 11 and 12 below. Figures 11 and 12 present the same wind direction histogram as Figure 10 from monitoring stations farther inland.

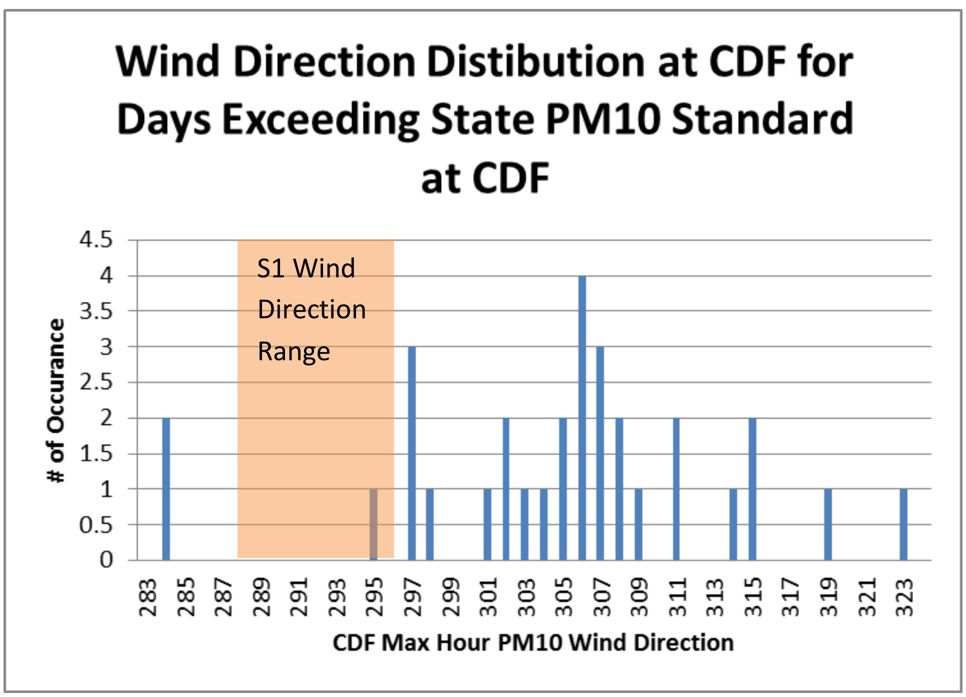

Figure 11 –CDF Wind Direction Distribution at Max Hour of Significant Dust Events

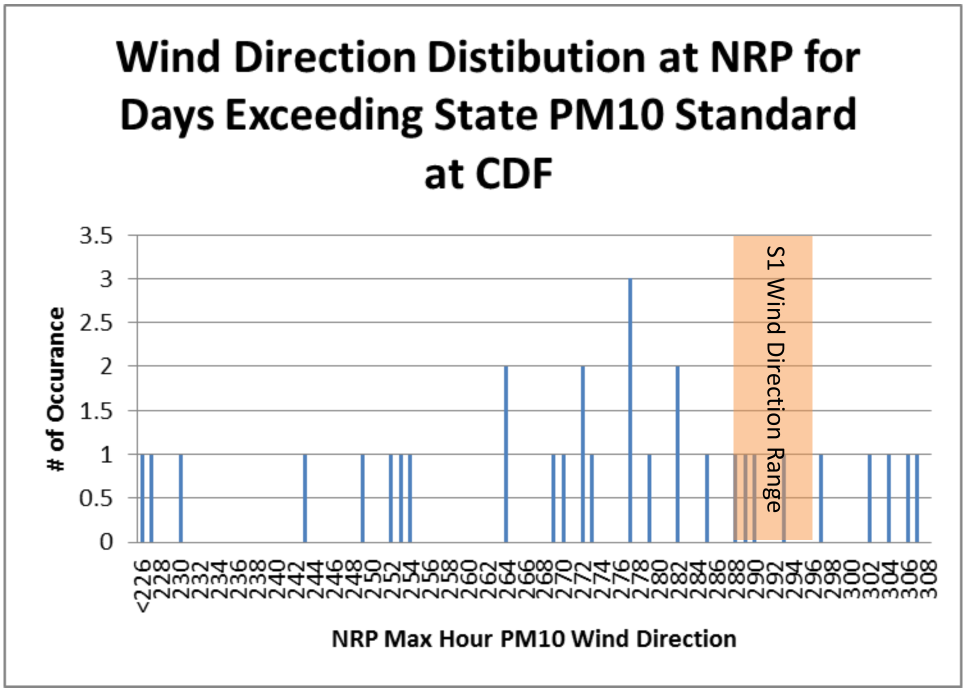

Figure 12 –NRP Wind Direction Distribution at Peak Hour of Significant Dust Events

These shifts in wind direction inland result in clear movement of the dust plume. The Community Monitoring Project wind sensors captured these shifts, showing the interaction between wind conditions and plume path. For example, Figures 13 to 15 present data from the Nipomo Study Area for hours 12 to 14 on April 19, 2012. On this day there was a moderate wind event, with wind speeds at S1 ranging from 19.6 to 23 mph for these hours. The figures show the data as interpolated by the Groundswell software, with wind direction arrows manually added for sites reporting wind conditions (arrows indicate direction only, not speed). It is important to note that wind data from the EBAM wind sensors will be more influenced by surrounding terrain due to their lower sensor height (~ 2 meters) than the permanent monitoring sites with sensors at 10 meters. It is also important to note that the only locations where PM_{10} concentrations are actually known are the monitoring sites. Elsewhere on the map concentrations are interpolations between these known points, and do not take into account local topography, surface features, meteorological data, or other complexities.

As shown in the figures, on hour 12 (Fig 13), the inland sites 6A, 13A, NRP, and SE-E all measured wind direction out of the NE to east, and at these locations, PM_{10} concentrations were near baseline values. Then on hour 13 (Fig 16), the wind direction shifted at sites 6A, 13A and NRP to a westerly wind, and PM_{10} impacts were then measured at these locations. Then on hour 14 (Fig 14) the winds shifted northerly at 6A, 13A, and NRP and PM_{10} concentrations at these sites dropped dramatically. On the next hour, sites 17A and 17B also shift northerly and the PM_{10} levels in this entire region drop to near background levels.

In addition to the displays presented below, hourly data from the spatial display is available as a video at Video link for spatial display of 4/19/12 data It is recommended that the video display be set to full screen.

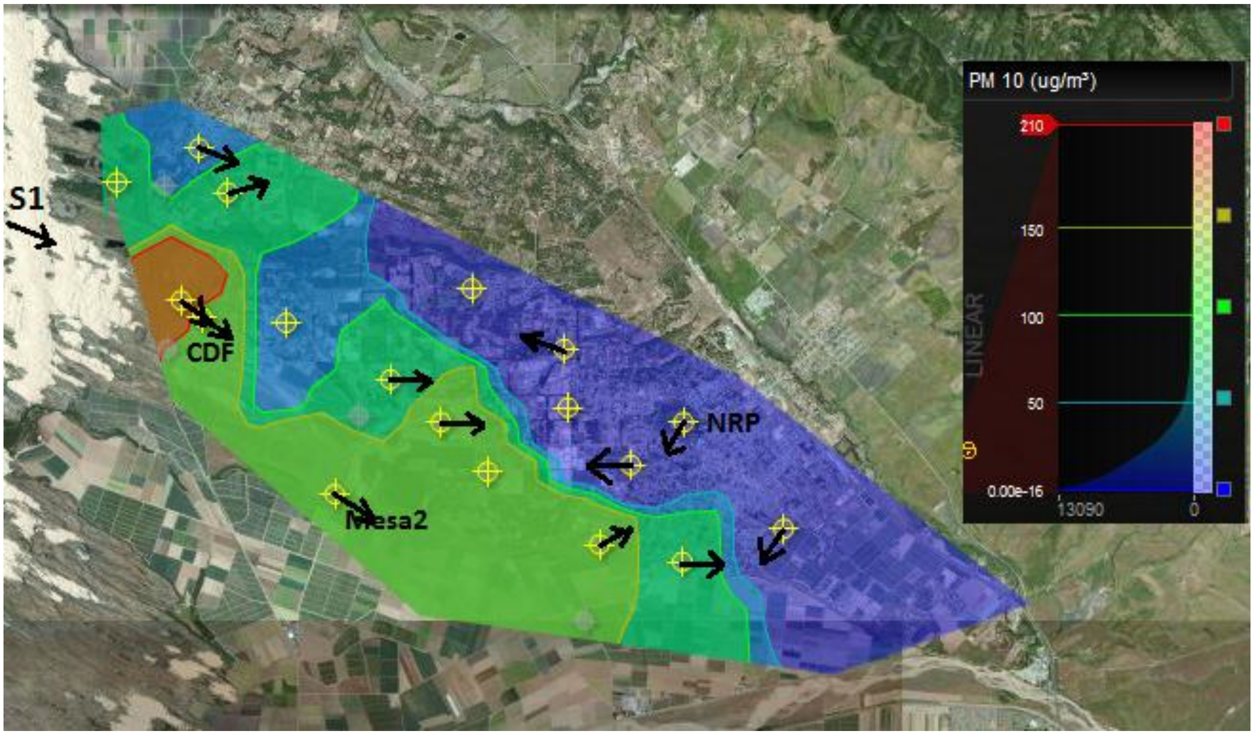

Figure 13 – PM10 and Winds for the Nipomo Study Area 4/19/12 at 12:00

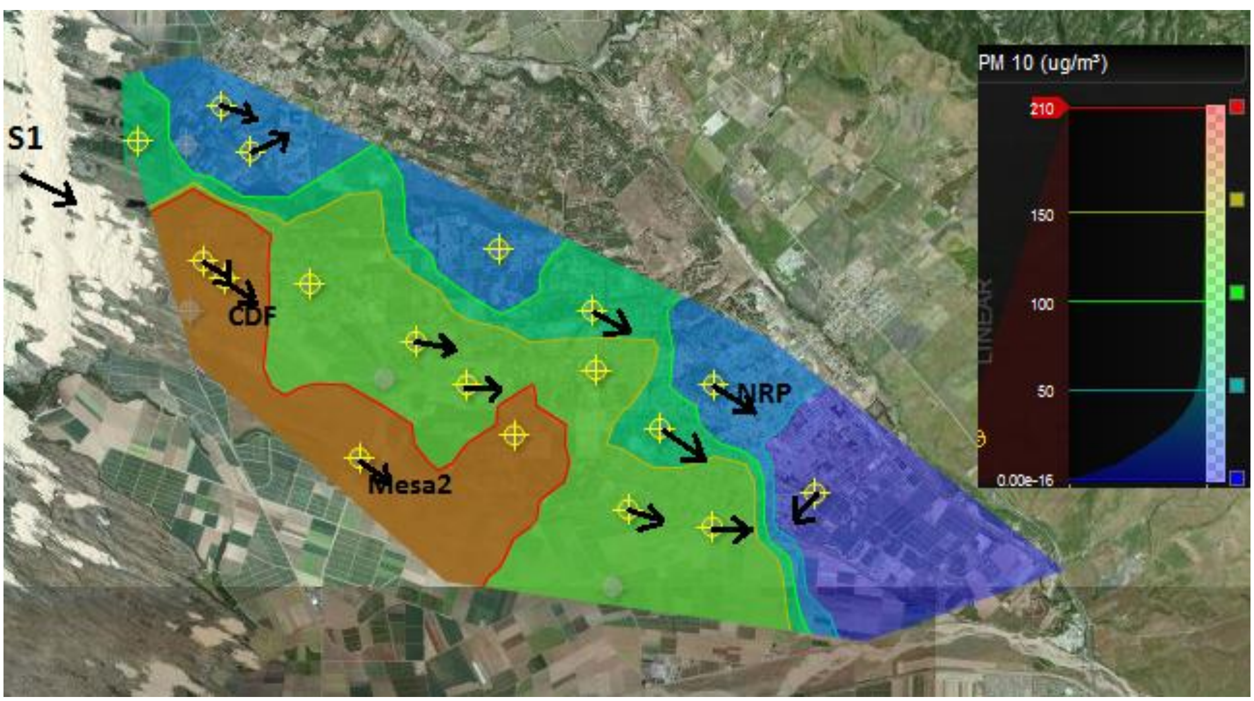

Figure 14 – PM10 and Winds for the Nipomo Study Area 4/19/12 at 13:00

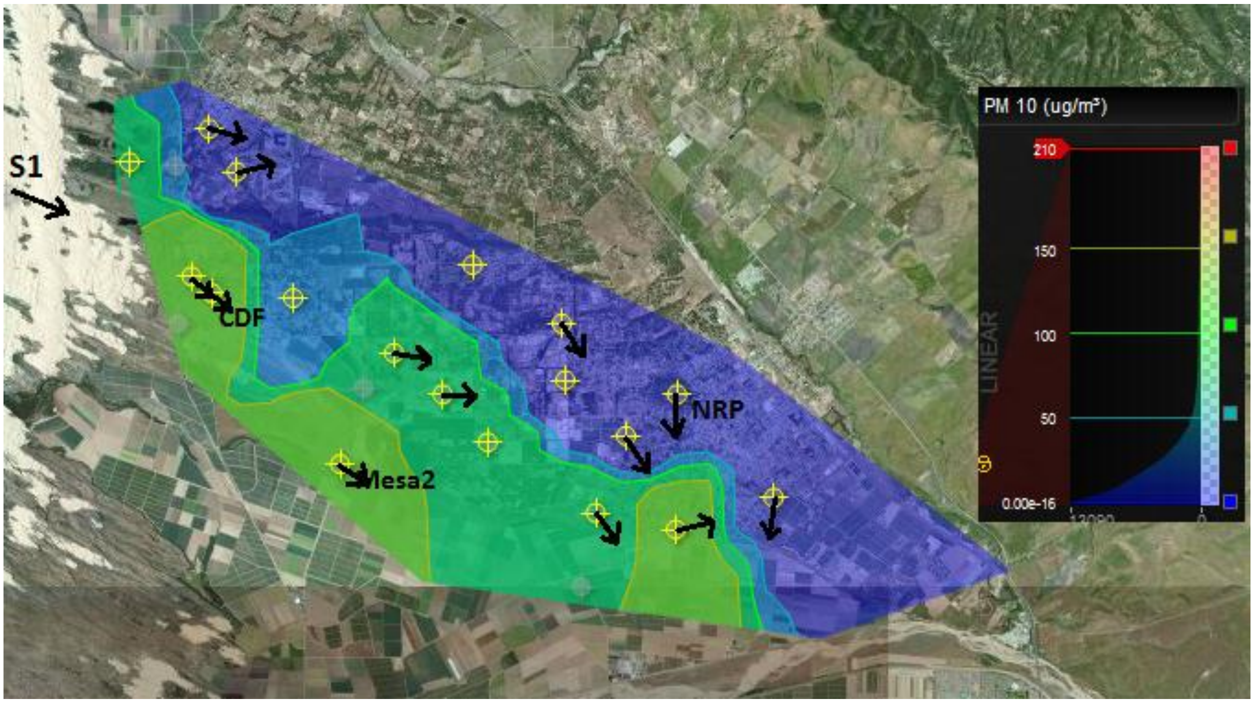

Figure 15 – PM10 and Winds for the Nipomo Study Area 4/19/12 at 14:00

Differences in inland wind direction from episode to episode also can result in downwind plume impacts. Review of the study data shows that episodes with a consistent northerly component in inland wind directions result in very little PM_{10} impacts in the vicinity of NRP (See Appendix C, day 4/4/12 for an example), but higher PM_{10} levels are often seen in Santa Maria on those days. On episodes with a consistent westerly inland wind direction, the plume appears to have little to no impact at the Santa Maria monitoring station but higher concentrations are usually measured in the vicinity of NRP (See Appendix C, day 5/17/12 for an example).

An additional observation of the Nipomo data set is that on a few occasions, some monitors appeared to be impacted by local PM_{10} sources. These rare occurrences are easily identified by looking at the overall pattern of PM_{10} measurement in the region and clearly are very localized in impact. While such anomalies are interesting to investigate and understand, they do not change the overall pattern observed in the study data, which was very consistent. A more detailed discussion of possible local source impacts is presented in Appendix A.

<u>Visual Observations of Dust Plume</u>

The particulate measurements and plume analysis performed for this project also match visual observations of the dust plume. APCD staff has observed the plume both from the ground and an aerial perspective. Figures 16-18 were taken on April 28, 2011 during a significant dust event. The 24-hour average PM_{10} level at CDF on this day was 135 ug/m3, with a peak hour concentration of 442 ug/m3. The winds were quite strong on this day, with Mesa2 recording wind speeds over 20 mph during the peak of the event. The wind direction inland at Nipomo Regional Park monitoring station was around 295 degrees during the event. As seen in the project data as well as these images, when the inland wind direction has a northerly component as seen at NRP, it appears to push the main portion of the plume more to the south, reducing its impact in the northern portion of the study area. Additionally, these images show that the plume does extend inland to Santa Maria and likely beyond. Figure 17 also shows a smaller dust plume originating from the dunes west of Guadalupe.

Figure 16 – 4/28/11 Aerial Image from above Santa Maria River and HWY101 looking to the Northwest

Figure 17 – 4/28/11 Aerial Image from above Willow Road and HWY101 looking to the Southwest

Figure 18 – 4/28/11 Aerial Image from above Arroyo Grande looking to the Southeast

Summary of Nipomo Mesa Monitoring Results

In summary, the dust plume originating in the coastal dunes most often has a centerline of highest concentration passing through the CDF site along a trajectory of the prevailing NW winds. However, variations in the wind direction can cause the plume to shift to the north or south. Spatial displays of 24 hour averaged data of each day where at least one monitor exceeded the state 24 hour PM_{10} standard of 50 ug/m3 are presented in Appendix C. Additionally, a summary of PM and wind data from all permanent monitors in the area is provided, as well as a brief description of significant conditions of each event. Links to videos of the hourly data are also provided in the data summaries for some of the more interesting days. These plots and videos are useful in understanding the areas impacted by blowing dust and will be used by District staff in forecasting the air quality and levels of PM_{10} impact on the Nipomo Mesa.

Oceano Study Area

Saturation monitoring in the Oceano study area started on March 19, 2012; initially 3 sites were installed. As depicted in Figure 19 below, site O-C was located within feet of the previous Phase2 Pier Avenue monitoring site to facilitate comparisons to that data, which showed significant PM_{10} impacts at that site. Site O-A was located about 0.1 mile downwind from O-C. Site O-B was located a similar distance inland as Site O-A, but about 0.3 mile to the south. On May 10, 2012 site O-D was installed upwind from site O-B directly on the edge of the beach (on the roof of a beachfront house).

Figure 19 – Oceano Study Area Monitoring Locations

The sampler at site O-C experienced a number of problems that resulted in the invalidation of data from installation until April 12, 2012. Additionally, there were a number of wind speed sensor failures on the Oceano samplers due to failed reed relays. While the loss of O-C PM_{10} data is unfortunate, the close proximity of these samplers allows lost wind speed data to be dealt with by referring to adjacent site values in most cases.

An additional complication in analyzing PM_{10} impacts in the Oceano area is the added influence of sea salt due to its close proximity to the ocean. To evaluate this, approximately 50 hourly particulate samples collected under a variety of conditions were selected from the Oceano sites for salt analysis. These analyses showed that samples taken during wind events typically contain between 5% and 10% salt (very similar to the salt content measured during episode days on the Nipomo Mesa during the Phase 1 and Phase 2 studies). This consistency in the data allows comparisons of PM_{10} measurements during wind events without much consideration of salt content. However, the analysis did show high salt concentrations can occur during calm periods in this area, so salt impacts during these periods must be taken into consideration in evaluating 24-hour average PM_{10} concentrations. Additional discussion of the salt analysis conducted for Oceano is provided in Appendix D.

Observations of Plume Impacts

The pattern of PM_{10} concentrations observed during wind events from April 12 through May 10, prior to the installation of site O-D, was quite consistent: O-C was always the high site, with O-A next lowest and O-B near background levels. Figure 20 below depicts the typical concentration pattern seen during this period from the three initial Oceano sites, as interpolated by the Groundswell software.

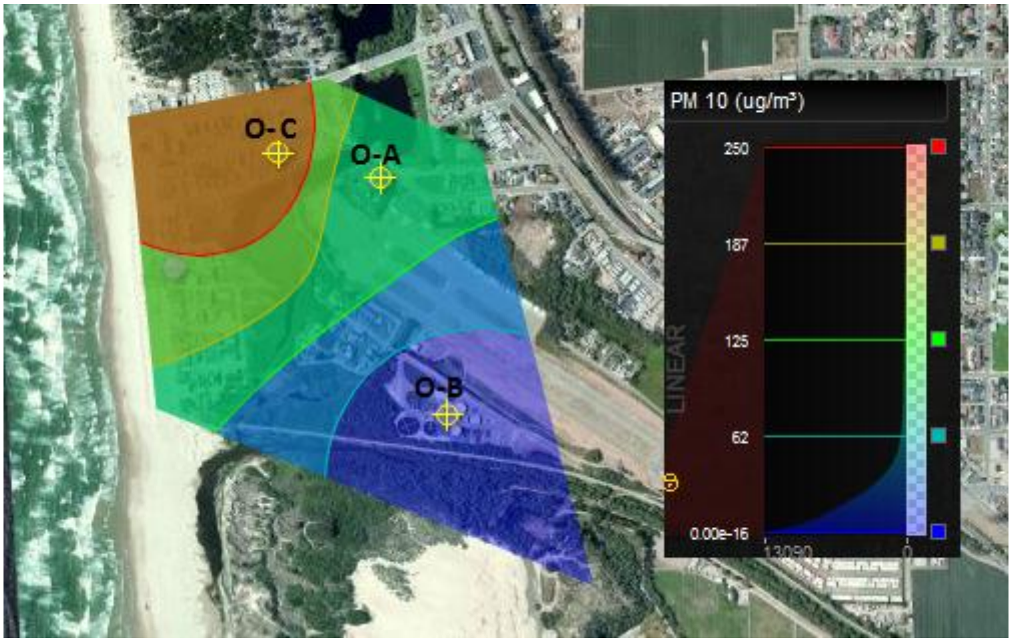

Figure 20 – Oceano Typical PM10 Concentrations Prior to Install of O-D

Review of this preliminary data showed the plume measured at O-C to be relatively small, dropping off significantly just 0.1 mile downwind at site O-A. Additionally, this data was consistent with the theory of Pier Avenue as the source, as was suggested in the Phase2 data analysis. However, this data pattern could also point to the beach itself as the source responsible for the high readings at O-C, as this site is closest to the beach of the three locations. This question was the impetus for installing the fourth monitor, O-D, directly at the beach sand edge on the roof of a home.

Review of the data set from May 10, 2012 through May 31, 2012 when all four monitors were operational showed a typical average pattern during wind events: PM_{10} levels at O-D were slightly higher (~10%) than O-C, O-A levels were significantly lower than O-C, and O-B measuring near background levels. Figure 21 below presents this typical pattern.

The first observation from analysis of the Oceano data set is that PM_{10} impacts in Oceano are much different than in Grover Beach, just one mile to the north. Phase2 PM_{10} measurements at Grover Beach showed virtually no significant PM_{10} impacts during strong (>15 mph) NW wind event hours. Yet in Oceano, significant hourly PM_{10} impacts are measured at O-A under those conditions; site O-A is a similar distance downwind from the open beach sand as Grover Beach. This indicates one or a combination of factors influencing windblown PM emissions in Oceano, such as sand track out onto Pier Avenue, OHV disturbance to the beach sand surface or other unidentified differences between the two areas is responsible for the difference in measured PM_{10} levels.

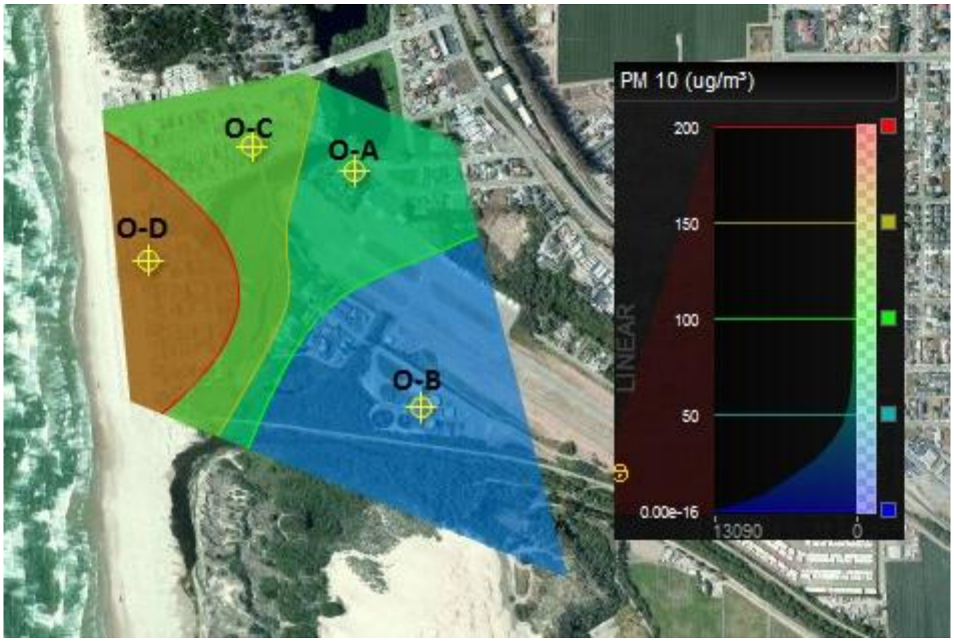

Figure 21 – Oceano Typical PM10 Concentrations with site O-D

Comparison of the average PM_{10} levels during wind/dust events between sites O-C and O-D show that on average, both sites measure similar PM_{10} concentrations, with site O-D about 10% higher. Site O-C is approximately 0.2 miles downwind from the edge of the beach sand, while O-D is just a few feet from the edge of the sand (with about 100 feet of sparse vegetation before open sand is encountered upwind). If the emission source for the Oceano area was predominately the beach sand, O-C PM_{10} measurements should be significantly lower compared to O-D because it is located further downwind from the beach sand. While the data from O-D demonstrates the beach itself is a localized source, the data from O-C suggests an additional source is impacting that site, and strongly points to the sand that accumulates on Pier Avenue as the source. The fact that site O-B rarely measured any impacts from windblown dust during the project provides additional evidence that site O-C is impacted by a source other than the beach.

Summary of Oceano Area Study Results

Data gathered from the Oceano area showed elevated particulate concentrations are present during high northwesterly winds at monitors in close proximity to any area of disturbed open sand. These sand areas include the beach as well as Pier Avenue where sand commonly is tracked out of the SVRA by vehicles exiting the park. The project data showed the extent of the plume from these open sand areas to be quite small, with particulate concentrations diminishing quickly downwind. A 40% drop in PM_{10} concentration was observed just 0.1 mile downwind of the Pier Avenue monitoring site, while almost no plume presence was detectable at a site less than 0.4 miles downwind from the beach area.

Conclusions and Recommendations

Study data from the South County Community Monitoring Project shows a relatively consistent pattern for the path of the dust plume from the Oceano Dunes that impacts the Nipomo Mesa area on high wind days. The approximate centerline of the plume typically follows a path along a line drawn through the CDF site inland following the prevailing northwesterly winds. The highest concentrations along the plume centerline occur closest to the dune source and slowly diminish inland, with lower but still significant PM_{10} levels appearing to impact the Santa Maria valley. In the Oceano area, elevated particulate concentrations are present during high northwesterly winds at monitors in close proximity to any area of disturbed open sand, but diminish very quickly a short distance downwind.

<u>Implications for Air Quality Forecasting in the Nipomo Mesa Study Area</u>

One of the primary reasons for determining the spatial extent and concentration gradients of the dust plume impacting the Nipomo Mesa was to provide more detailed air quality forecasts in that region and enable area residents to determine if protective actions are needed in their neighborhood on high PM days. Better knowledge of the plume path and downwind concentrations would also help inform the development of dust controls at the SVRA. Table 1 presented previously showed the relationship between average 24-hour PM_{10} concentrations measured at the temporary project sites compared to the permanent District sites, which can be used to approximate the plume impact in an area of the Mesa without a permanent site. The factors displayed in Table 1 were used to develop Figure 22 below, which presents recommendations on appropriate airborne particulate grid zones for the Nipomo Area. The name in each grid or adjacent to the grid represents the permanent monitoring station that most often is the best fit for approximating the maximum PM_{10} concentrations likely to occur in that grid square (or adjacent to the grid area) on a given day.

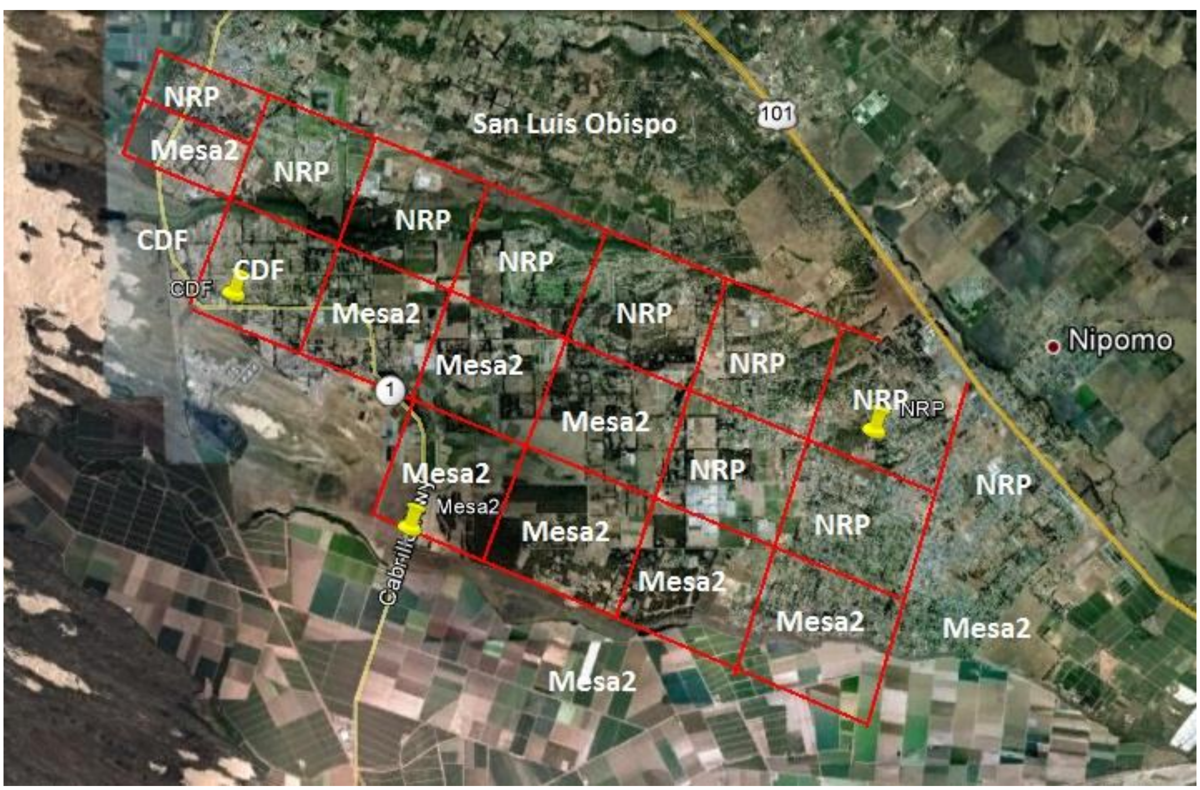

Figure 22– Forecasting Recommendations for the Nipomo Area

Study data and the inter-site relationships identified in Table 1 were used to generate the more detailed forecast map shown in Figure 25, below. This forecast map defines the typical areal influence of the dust plume during strong northwesterly winds. The APCD will use these maps to provide a numerical forecast of the Air Quality Index (AQI) for each forecast zone based on the approximate magnitude of the forecasted particulate concentrations. Each forecast zone is related to PM concentrations measured at the three permanent APCD particulate monitoring stations on the Nipomo Mesa - CDF (Willow Road), Mesa2 (Guadalupe Road) and NRP (Nipomo Regional Park). Areas outside of the zones shown in Figure 23 should use the San Luis Obispo monitoring station for particulate air quality guidance unless otherwise noted.

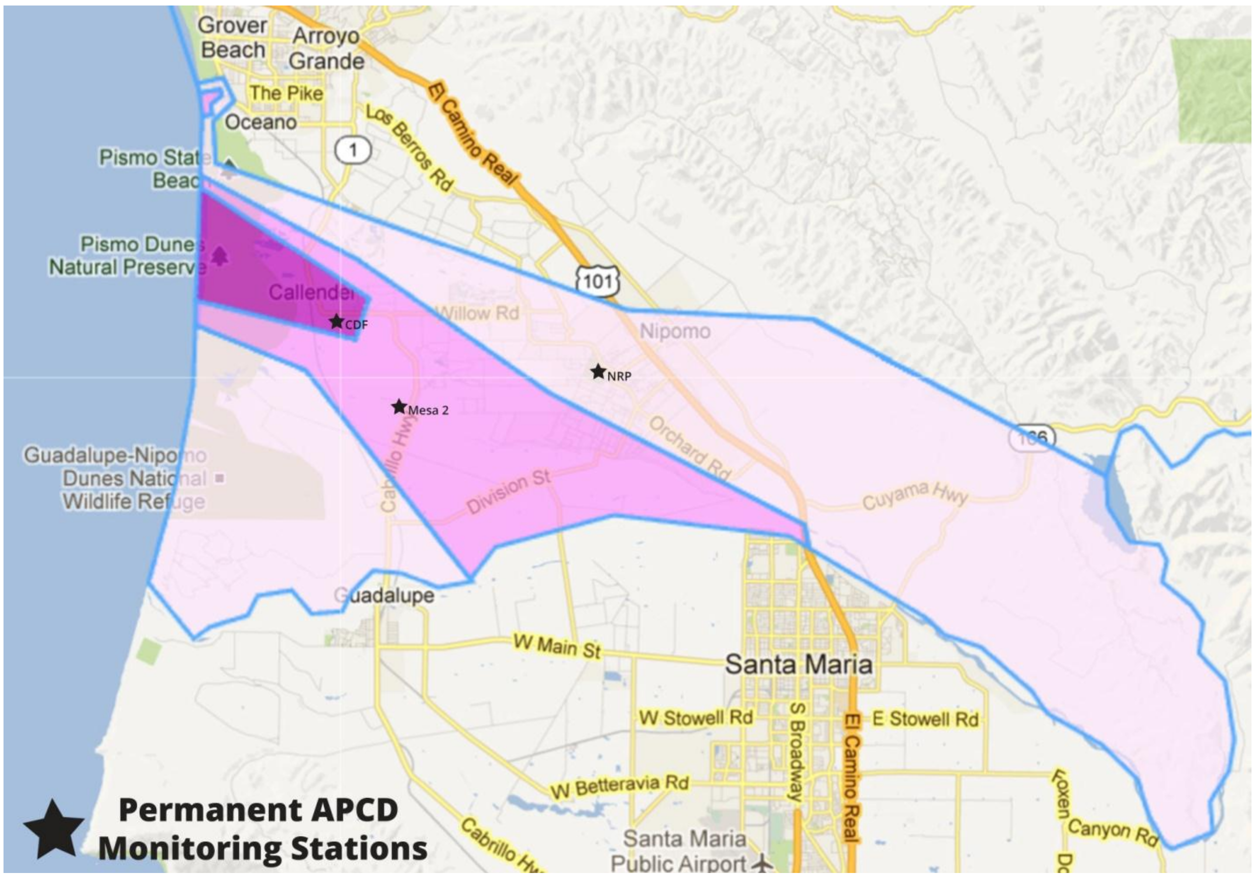

Figure 23 - Forecast map for Nipomo area. Forecast zones: Dark Pink = CDF, Medium Pink = Mesa2, Link Pink = NRP

Each wind-blown dust event can have different wind and particulate concentration characteristics, so it is important to note that the forecast zones are based on the estimated average magnitude of the particulate concentrations. The borders of each zone area are approximate and are not meant to be a rigid boundary; the plume path can vary with changes in wind direction and speed, and particulate concentrations on either side of a forecast zone border are likely to be similar. Thus, the public can use the air quality forecasts as a guide to help plan their outdoor activities and protect their health during blowing dust episodes, understanding that the forecast is our best estimate of potential maximum PM levels in each zone on a given day. The San Luis Obispo County forecast zones end at the Santa Barbara County border; however, as previously discussed, data from this study and the Santa Maria monitoring station indicate plume impacts continue into Santa Barbara County during the more significant blowing dust events.

Implications for Air Quality Forecasting in the Oceano Study Area

In the Oceano study area, proximity to open sand, whether it is sand that accumulates on Pier Avenue or sand on the beach, appears to be the best indicator of PM_{10} impacts. The data demonstrates PM_{10} levels adjacent to disturbed open sand (in the roadway or beach) during wind events can produce significant PM_{10} impacts; however, the data also shows those impacts to be quite limited in spatial extent. As depicted in Figures 20 and 22 above, there was an approximate 40% drop in PM_{10} concentration in the 0.1 mile downwind distance between sites O-C and O-A, and almost no detectable plume presence 0.37 miles downwind from site O-D.

Figure 24, below, presents a close up of the Forecast Zone Map for the Pier Avenue area of Oceano. This forecast map defines the typical areal influence of the dust plume on affected areas of Oceano during strong northwesterly winds. Each forecast zone is related to PM concentrations measured at the following permanent APCD particulate monitoring stations: Green Zone = Mesa2 (Guadalupe Road) and Blue Zone = NRP (Nipomo Regional Park). Areas outside of these zones should use the San Luis Obispo monitoring station for particulate air quality guidance unless otherwise noted.

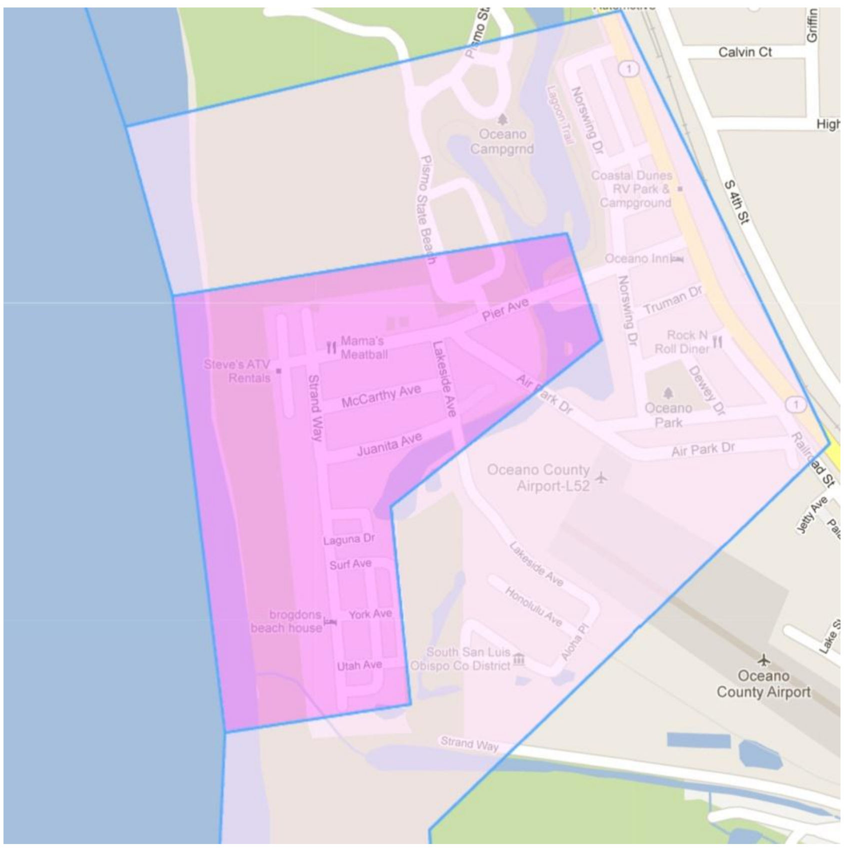

Figure 24 - Forecast map for Pier Avenue area of Oceano. Forecast zones: Medium Pink = Mesa2, Light Pink = NRP

Bibliography

1) EPA AQS Database, www.epa/ttn/aqs
2) San Luis Obispo County APCD Phase 2 Particulate Study, 2009
3) San Luis Obispo County APCD Phase 1 Particulate Study, 2004
4) San Luis Obispo County APCD 2011 School Measurements, 2011
5) Lanane, C., Johnson, D. *A Comparison of PM_{10} Survey Monitors*, Great Basin Unified Air Pollution Control District, presented at the Air & Waste Management Association Symposium on Air Quality Measurement Methods and Technology, Los Angeles, CA, November 2-4, 2010.
6) Numerous phone interviews with Dennis Hart, Design Engineer, MetOne Inc.