Development and Evaluation of an Air Quality Modeling Approach for Lead Emissions from Piston-Engine Aircraft Operating on Leaded Aviation Gasoline

United States
Environmental Protection
Agency

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Assessment and Standards Division
Office of Transportation and Air Quality
U.S. Environmental Protection Agency

Prepared for EPA by

ICF International
and
T&B Systems

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Acronyms and Abbreviations

AERMET	AERMET is a meteorological data preprocessor for AERMOD
AERMOD	Atmospheric dispersion modeling system
AERSURFACE	A tool that processes land cover data to determine the surface characteristics
AQMP	Air Quality Management Plan
ASOS	Automated Surface Observation System
avgas	Leaded aviation gasoline
CALINE3	A versatile dispersion model for predicting air pollutant levels near highways and arterial streets
Caltrans	California Department of Transportation
CARB	California Air Resources Board
CEIDARS	California Emission Inventory and Reporting System
CRPAQS	California Regional Particulate Air Quality Study
DEM	Digital Elevation Model
DTIM	Direct Travel Impact Model
EDMS	Emission Dispersion Modeling System
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FOE	Friends of the Earth
FRM	Federal Reference Method
g/gal	Grams/gallon
g/s	Grams/second
GIS	Geographic information system
HEI	Health Effects Institute
HiVols	High-volume particulate samplers
IMS95	1995 Integrated Monitoring Study
kg	kilogram
LPG	Liquefied petroleum gas
LT	Local time
m	Meters
m/s	Meters/second
MATES-III	Multiple Air Toxics Exposure Study III
MDL	Minimum detection limit
mg	Milligram
MiniVols	Low-volume particulate samplers
NAAQS	National Ambient Air Quality Standard
NEI	National Emissions Inventory
ng/m^3	Nanograms per cubic meter
NLCD92	National Land Cover Data 1992
OAQPS	Office of Air Quality Planning and Standards
Pb	Lead
PM_{10}	Particulate matter, 10 micrometers and smaller
$PM_{2.5}$	Particulate matter, 2.5 micrometers and smaller
s	Seconds
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District
SCCs	Source Classification Codes
SIC	Source industrial classification

SMO	FAA designator for Santa Monica Airport
TSP	Total suspended particulate
USGS	U.S. Geological Survey
XRF	X-ray fluorescence
L	Monin-Obukov Length

1 INTRODUCTION

1.1 PROJECT BACKGROUND

Tetraethyl lead is used as an additive in aviation fuel for most piston-engine powered aircraft. The 2005 National Emissions Inventory (NEI) estimates that annual lead (Pb) emissions from the use of leaded aviation gasoline (commonly referred to as leaded "avgas") are 653 tons, or approximately 50 percent of the air emission inventory for lead. Lead is also present as a trace contaminant in gasoline and diesel fuel and is a component of lubricating oil. Additional mobile sources of Pb include automobile brake wear, tire wear, and loss of Pb wheel weights.

In October 2006, EPA received a petition from Friends of the Earth (FOE) requesting that the Agency find that aircraft Pb emissions may reasonably be anticipated to endanger the public health and/or welfare, and to take action to control Pb emissions from piston-engine aircraft. To evaluate this petition, EPA surveyed the available literature and found that there are few monitoring or modeling studies of Pb concentrations near airports servicing piston-engine aircraft that operate on leaded aviation gasoline. The purpose of this local-scale airport modeling and monitoring study is to investigate near source concentration gradients in ambient air attributable to lead from the combustion of leaded aviation gasoline and to investigate changes in these gradients with changes in emissions. The results of this study may be used to draw inferences at other locations, and to provide methods for evaluating air quality impacts from general aviation airports on local Pb concentrations. The results from this study provide information which could be used in a multimedia exposure and risk assessment of Pb near airports servicing avgas-fueled aircraft.

1.2 SELECTED LOCATION

This study included both monitoring and modeling of Pb near an airport which services a large number of piston-engine aircraft operating on leaded avgas. Several airports which service a large number of avgas fueled aircraft were considered for this study. One of the airports considered was the Santa Monica City Airport (SMO), which was identified as an airport with relatively high lead emissions from general aviation activity. In 2002, 363 kg/yr (0.4 tons per year) of Pb was emitted at the Santa Monica Airport, as identified in EPA's National Emissions Inventory. The Santa Monica Airport was selected for this study based on a number of factors that were anticipated to lead to the successful collection of Pb monitoring samples and reduce uncertainty in the air quality modeling. Among the most important factors were:

- The local air agency, South Coast Air Quality Management District (SCAQMD), had conducted recent air monitoring for Pb at and near the Santa Monica Airport;
- SCAQMD would be able to provide some air monitoring equipment;
- Santa Monica Airport was established in 1915 and thus soil samples would likely include contributions of Pb from long-term atmospheric deposition;
- There are no other nearby large sources of Pb emissions;
- Santa Monica Airport's operators supported the study and ICF had conducted previous environmental studies at the airport with much cooperation from the airport staff;
- A large residential population (150,000 within two miles) surrounds the Airport;
- An earlier air quality modeling study was conducted at the Santa Monica Airport (Piazza, 1999); and
- The airport has a single runway configuration.

1.3 Overview of Approach

The primary purpose of the study was to develop and evaluate an air quality modeling approach that could be used to evaluate local-scale concentrations of lead in the vicinity of an airport where piston-engine aircraft operate. Air monitoring was conducted to evaluate the performance of the air modeling approach. Soil and dust measurements for Pb and other metals were also made to help establish the fraction of lead in re-entrained road dust for roadways in the vicinity of the airport and to explore the potential for a gradient in the ambient air Pb concentration with distance from the airport.

The study also included an assessment of the maximum 3-month average Pb concentration and model sensitivity tests. The maximum 3-month average Pb concentration was evaluated in order to compare the model output with the National Ambient Air Quality Standard for Lead which is 0.15 $\mu g/m^3$, reported as the maximum 3-month average concentration.

Based on the results of this study, an outline of a generalized modeling approach has been developed that can be applied to general aviation facilities across the United States.

This report summarizes the findings from the:

- Air, soil and dust monitoring performed at Santa Monica Airport;
- Development of the emission inventory and air quality modeling inputs;
- Results of the model-to-monitor comparison;
- Annual and maximum 3-month average modeling results and;
- Model sensitivity analysis.

The report is divided into four primary discussion areas: air monitoring methodology and results (Chapter 2), soil and dust sampling methodology and results (Chapter 3), air quality modeling methodology and results (Chapter 4), and a conclusion on the findings and implications from the study results (Chapter 5). The references for the report are provided in Chapter 6.

2 AIR MONITORING

2.1 OBJECTIVES

The objectives of the air monitoring program were: to provide Pb measurements for comparison with air quality modeling, to assist in the quantification of the contribution of Pb from general aviation emissions to local air quality, and to provide information about the gradient in Pb concentrations with distance from the airport. The air monitoring section is divided into three subsections: (1) an overview of the Santa Monica Airport location, (2) a description of the winter monitoring program and associated results, and (3) a description of the summer monitoring program and associated results.

2.2 OVERVIEW OF THE SANTA MONICA AIRPORT

Established in 1919, the Santa Monica Airport is the oldest community airport operating in Los Angeles County. The airport is one of the busiest *single* runway airports in the nation, and provides for numerous aviation-related businesses, including fixed-based operators, supply services, and aircraft maintenance. The airport occupies over 200 acres (0.81 square kilometers) in the southeastern portion of the City of Santa Monica, with the City's southern boundary coinciding with the airport's southern property line. A triangular portion (approximately 34 acres) of the site's eastern boundary lies within the City of Los Angeles. This land is owned in fee by the City of Santa Monica.

The site is served by arterial streets with primary access via South Bundy Dr. which borders the airport's eastern boundary. Twenty-third St., which adjoins the airport's western boundary, connects between Ocean Park and Venice Boulevards. Airport access to the north is accomplished by traversing south from Ocean Park Blvd. via Twenty-eighth or Thirty-first St. Airport Ave., which parallels the site's southern boundary, provides internal access to the airport.

The airport is surrounded to the south, east, and west by residential neighborhoods. Commercial structures and recreational facilities predominate to the north. The airport is situated on a plateau above the surrounding community; the local topography provides a relatively horizontal land formation which accommodates a long runway across the length of the property. Along the terminus of the runway, the land mass slopes sharply in a downward trend producing a change in elevation of more than thirty feet. Figure 2-1 presents an aerial view of the airport and surrounding community, with the airport property line indicated in magenta and the airport fence line along the southern border of the airport indicated in yellow. Figure 2-2 provides a view towards the northeast of the observation deck and of a plane taxiing for departure on runway 21.

2.3 WINTER MONITORING PROGRAM

2.3.1 Approach

The winter monitoring program was conducted not only to measure Pb concentrations for the air quality modeling, but also to test whether a lower cost monitoring program could be deployed that could collect adequate samples for measuring Pb using MiniVols (low volume samplers). MiniVols operate with lower cost than HiVol (high volume) samplers and have the added flexibility of operating without commercial power (i.e., via battery). Figure 2-3 below shows the MiniVol (three total devices) and HiVol instrumentation used.

Source: Aerial provided by City of Santa Monica.

Figure 2-1. Santa Monica Airport and vicinity.

Source: ICF International

Figure 2-2. View from Santa Monica Airport towards the northeast and the observation viewing deck.

Source: T&B Systems

Figure 2-3. MiniVol (three) and HiVol instrumentation as deployed at the East Tarmac during a portion of the winter monitoring program.

The winter monitoring period encompassed two 4-day periods—Friday though Monday over successive weekends—March, 12–15 and 27–30, 2009. The program focused on weekends because the Santa Monica Airport historically has higher general aviation activity on weekends than on weekdays. The weekend period encompassed three 24-hour sampling periods: Friday to Saturday, Saturday to Sunday, and Sunday to Monday. Filter samples were changed out at approximately the same time on each of the days, with the operating parameters documented in logs (Appendix A).

Three monitoring sites comprised the network for the winter program. The locations of the two downwind sites relative to the runway and each other are shown in Figure 2-4. The prevailing wind flow is onshore during the day when most aircraft activity takes place. Under this scenario, the West Tarmac site is generally upwind, and the East Tarmac and Clarkson sites are downwind. T&B Systems conducted the deployment and operation of the monitoring system.

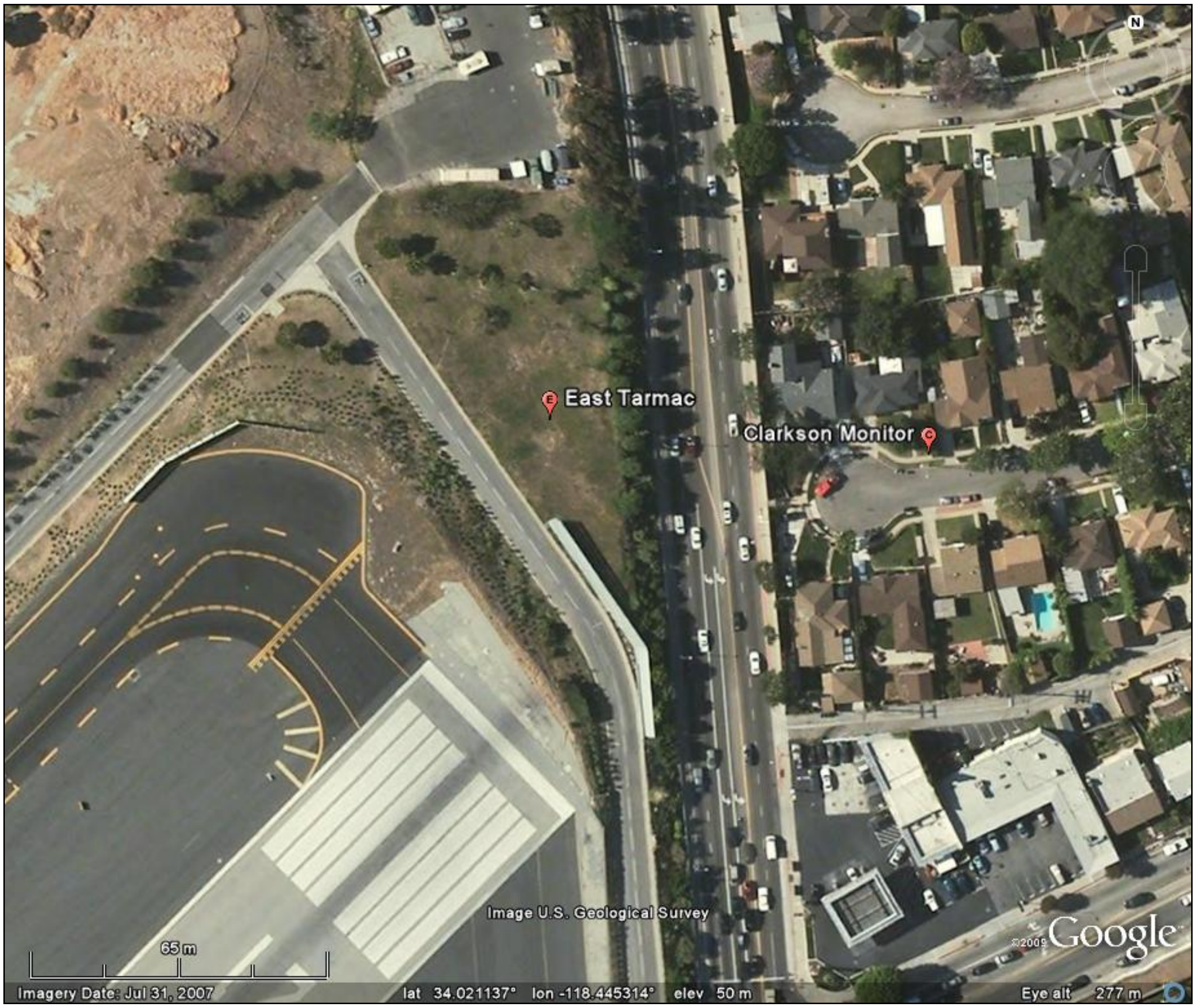
The MiniVol samplers were operated in the total suspended particulate (TSP) mode at all three sites. In addition to the MiniVol sampler operated at each of the three sites, a fourth MiniVol sampler was operated to rotate between the three network sites, and a fifth MiniVol sampler was operated only during airport operational hours[1] at the East Tarmac. This allowed the gathering of more information on instrument precision and bias amongst the samplers. Samples were collected from the fifth MiniVol only during airport operational hours to provide data related specifically to the time period when piston-engine aircraft activity occurs at the airport for comparison to 24-hour average lead concentrations at this location.

The MiniVol samplers are easily portable (battery operated) and can easily be sited at any location that has adequate exposure and is free from vandalism. There have been a number of field studies in which MiniVols have been collocated with Federal Reference Method (FRM) analyzers and compared favorably. These date back to the 1995 Integrated Monitoring Study (IMS95), which was a prelude to the 1999 through 2001 California Regional Particulate Air Quality Study (CRPAQS) (Solomon, P. and Magliano K., 1999; Air Resource Specialists, 2000 and 2001) in which over 100 of the MiniVol samplers were used over the 14 month measurement period. These comparisons were all done using a PM_{10} sampling head and were focused on particulate matter. Nominal flow rates for MiniVols are five liters per minute.

The laboratory selected to analyze the air samples collected for this study was Chester LabNet (www.chesterlabnet.com). XRF (X-ray fluorescence) analysis was used because the method has a minimum detection limit (MDL) of less than 4 ng/m^3 at the nominal flow rate over 24 hours. By comparison, Fine (2007, 2008) reported TSP Pb concentrations at the East Tarmac in samples collected in March through July that ranged from 27 to 149 ng/m^3. Thus, samples collected with the MiniVol while it operated properly over a 24-hour cycle were anticipated to have sufficient mass to exceed the detection limit.

In addition to the MiniVol, the availability of commercial power at the East Tarmac location made an intercomparison between the MiniVol and a TSP HiVol sampler possible, which is the Federal Reference Method (FRM) for Pb. This provided: (1) a reference to the FRM method for Pb sampling, and (2) a collocated site for the MiniVol TSP method with the FRM method. The HiVol TSP instrument was operated on the same schedule as the MiniVol sampler.

[1] The Santa Monica Airport only permits departures during the hours of 0700-2300 Monday through Friday and 0800-2300 Saturday and Sunday, except for emergencies.



Source: GoogleEarth.

Figure 2-4. Sampling locations: East Tarmac (E) and the Clarkson monitor (C). The West Tarmac site is located at the other end of the runway (not shown).

Four filter blanks (two HiVol and two MiniVol) were analyzed during the winter program.[2] The purpose of the filter blanks is to evaluate filter media concentrations of Pb. Ideally, the concentration of lead in blank samples is sufficiently low so that their values are not a significant contributor to sample values. However, when ambient concentrations approach method detection limit values, blank values are important to characterize. Calibrations for all of the equipment were performed using certified flow standards. Pb samples were analyzed by Chester LabNet using XRF. The filter media was Teflon® and quartz for the MiniVol and HiVol samples, respectively. The Teflon filter was used for the MiniVols to yield the lowest detection limit possible for the smaller sample mass, but analysis of these filters can present challenges due to their relatively low optical density which causes artifacts to appear when using the XRF measurement technique. Quartz filters were used in the HiVol to minimize particle bounce.

[2] A third MiniVol filter was analyzed as a filter blank.

2.3.2 Winter Program Monitoring Results

Individual Monitoring Results

Table 2-1 summarizes the ambient Pb air monitoring data collected during the winter monitoring program at the Santa Monica Airport. The table shows the location of the monitor, the starting date, the starting time, the duration of the sample, the Pb concentration, the day of the week in which the sample was collected, the type of monitor used to collect the data, and a description of any problems or invalid measurements in the "Comments" column.

Table 2-1. Pb Air Concentrations from Winter Monitoring Program at SMO

Sample ID	Site	Start Date	Start Time	Duration (hh:mm)	Day of Week	Pb (ng/m^3)	Type	Comments
09-Q46	E.Tarmac	3/12/2009	12:00	07:45	Thursday	24.6	HiVol	
09-T1041	E.Tarmac	3/12/2009	12:06	07:30	Thursday	15.6	MiniVol	
09-T1042	E.Tarmac	3/12/2009	12:08	07:19	Thursday	16.6	MiniVol	
09-T1043	E.Tarmac	3/12/2009	12:05	Unknown	Thursday		MiniVol	Accidentally turned off, not used in analysis
09-T1045	E.Tarmac	3/12/2009	12:00	07:30	Thursday	13.8	MiniVol	
09-T1060	E.Tarmac	3/12/2009	12:00	07:19	Thursday	11.0	MiniVol	
09-Q47	E.Tarmac	3/13/2009	8:04	24:41	Friday	45.6	HiVol	
09-T1048	W.Tarmac	3/13/2009	8:23	24:53	Friday	11	MiniVol	
09-T1052	E.Tarmac	3/13/2009	7:22	24:56	Friday	34	MiniVol	
09-T1055	Residential	3/13/2009	8:46	24:59	Friday	40	MiniVol	
09-T1058	E.Tarmac	3/13/2009	7:19	15: 41	Friday	48	MiniVol	11 p.m. shutoff
09-T1059	E.Tarmac	3/13/2009	7:29	25:08	Friday	25	MiniVol	
09-Q48	E.Tarmac	3/14/2009	9:00	23:38	Saturday	53	HiVol	
09-T1044	E.Tarmac	3/14/2009	8:24	23:53	Saturday	36	MiniVol	
09-T1046	Residential	3/14/2009	9:43	23:53	Saturday	29	MiniVol	
09-T1050	W.Tarmac	3/14/2009	9:23	23:40	Saturday	2	MiniVol	Accidentally turned off, not used use in the analysis
09-T1051	E.Tarmac	3/14/2009	8:35	14:25	Saturday	53	MiniVol	11 p.m. shutoff
09-T1040	E.Tarmac	3/15/2009	9:25	23:52	Sunday	46	MiniVol	Not used in the analysis – location of sample measurement uncertain
09-Q49	E.Tarmac	3/15/2009	8:48	23:54	Sunday	77	HiVol	
09-T1047	W.Tarmac	3/15/2009	9:09	24:03	Sunday	6	MiniVol	
09-T1049	E.Tarmac	3/15/2009	8:33	14:27	Sunday	99	MiniVol	11 p.m. shutoff
09-T1054	Residential	3/15/2009	9:43	23:47	Sunday	50	MiniVol	
09-T1057	Residential	3/15/2009	9:32	23:54	Sunday	38	MiniVol	
09-T1061	W.Tarmac	3/15/2009	8:23	24:07	Sunday	<detection limit	MiniVol	below minimum detection limit – which is 3.2 ng/m^3 at 68% confidence level
09-Q51	E.Tarmac	3/27/2009	8:00	25:02	Friday	83	HiVol	
09-T1062	E.Tarmac	3/27/2009	7:32	25:07	Friday	49	MiniVol	
09-T1063	E.Tarmac	3/27/2009	7:40	15:20	Friday	88	MiniVol	11 p.m. shutoff

Table 2-1. Pb Air Concentrations from Winter Monitoring Program at SMO

Sample ID	Site	Start Date	Start Time	Duration (hh:mm)	Day of Week	Pb (ng/m^3)	Type	Comments
09-T1064	E.Tarmac	3/27/2009	7:45	25:10	Friday	73	MiniVol	
09-T1065	W.Tarmac	3/27/2009	8:22	25:08	Friday	8	MiniVol	
09-T1066	Residential	3/27/2009	8:38	25:14	Friday	46	MiniVol	
09-Q52	E.Tarmac	3/28/2009	9:12	23:39	Saturday	39	HiVol	
09-T1067	E.Tarmac	3/28/2009	8:45	23:49	Saturday	30	MiniVol	
09-T1068	E.Tarmac	3/28/2009	8:52	14:08	Saturday	46	MiniVol	11 p.m. shutoff
09-T1069	W.Tarmac	3/28/2009	9:28	23:53	Saturday	<detection limit	MiniVol	below minimum detection limit, which is 3.2 ng/ m^3 at 68% confidence level
09-T1070	W.Tarmac	3/28/2009	9:35	23:37	Saturday	5	MiniVol	
09-T1071	Residential	3/28/2009	9:55	23:46	Saturday		MiniVol	torn filter
09-Q53	E.Tarmac	3/29/2009	9:00	24:44	Sunday	71	HiVol	
09-T1072	E.Tarmac	3/29/2009	8:39	24:32	Sunday	59	MiniVol	
09-T1073	E.Tarmac	3/29/2009	8:47	14:13	Sunday	88	MiniVol	11 p.m. shutoff
09-T1074	W.Tarmac	3/29/2009	9:17	23:18	Sunday	<detection limit	MiniVol	below minimum detection limit, which here is 3.2 ng/ m^3 at 68% confidence level
09-T1075	Residential	3/29/2009	9:38	23:13	Sunday	28	MiniVol	
09-T1076	Residential	3/29/2009	9:38	23:16	Sunday	37	MiniVol	
09-Q54	E.Tarmac	3/30/2009	9:51	23:25	Monday	44	HiVol	
09-T1077	E.Tarmac	3/30/2009	9:18	23:34	Monday	32	MiniVol	
09-T1078	E.Tarmac	3/30/2009	9:27	13:33	Monday	45	MiniVol	11 p.m. shutoff
09-T1079	E.Tarmac	3/30/2009	9:31	23:28	Monday	26	MiniVol	
09-T1080	E.Tarmac	3/30/2009	9:34	23:28	Monday	26	MiniVol	
09-T1081	E.Tarmac	3/30/2009	9:37	23:26	Monday	34	MiniVol	

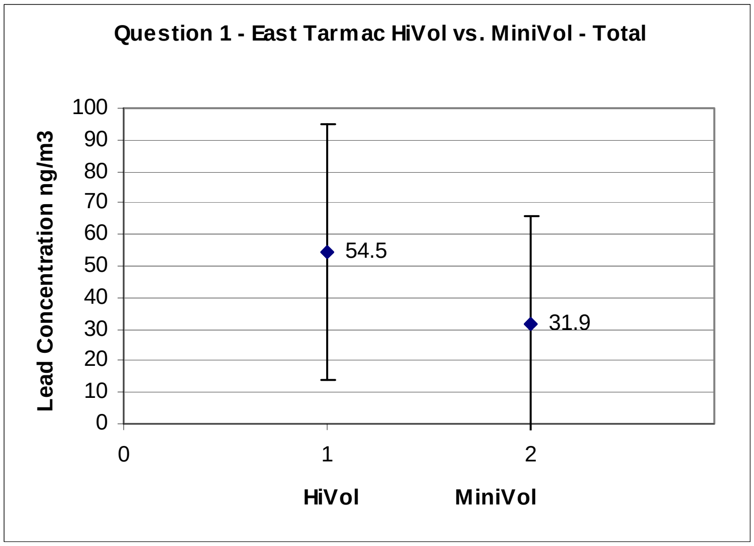
A total of 43 valid data samples were collected over a total of 8 different days. Most samples were measured using the MiniVols and in most cases were well above the detection limit. Only the West Tarmac location was frequently below the detection limit. Valid data from this study were used in the subsequent model-to-monitor comparison. Further details of the filter analysis can be found in Appendix A.

Comparison of HiVols and MiniVols

Data from the monitoring program was evaluated to determine if the sampling system was suitable for the model evaluation and if the summer program could make use of the same monitoring system. To determine the validity of the sampling system using the HiVol and MiniVol samplers, the following set of five questions were developed to characterize instrumentation-based uncertainty and to evaluate the suitability of using the MiniVol samplers in the summer program study. For each question the answer is provided based on the analysis of the monitored data.

Question 1: What is the mean difference between the reference method (HiVol) and the MiniVol when comparing the collocated HiVol samplers (East Tarmac) and the MiniVols which sampled over the full 24-hour period?

Answer 1: Figure 2-5a shows the results in graphic form for Question 1. These results show that the HiVol had a mean monitored concentration of 55 ng/m^3, which was about 72% higher than the mean collocated MiniVol concentration. The day-by-day comparison (Figure 2-5b) shows that this bias occurs on each day and is largest on days with the highest concentrations.



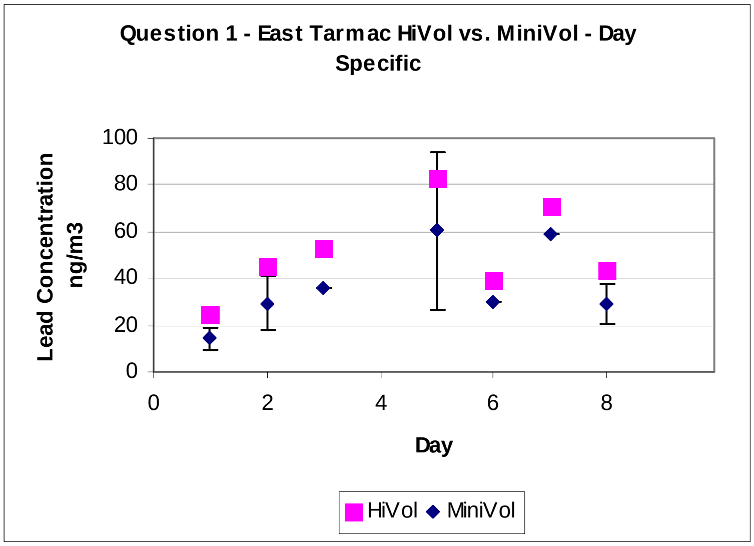


Figure 2-5 a and b. Collocated HiVol versus MiniVol winter monitoring.

Because of the significant low "bias" seen in the MiniVols relative to the FRM HiVol sampler, which used quartz filters, an examination of the field blanks was conducted by Chester LabNet to determine if a correction bias could be applied to the MiniVol Teflon filter samples. Based on an analysis of the laboratory reports (Appendix A) an average bias of -12.8 ng of lead per filter was found. If this correction bias is applied to all of the MiniVol samples and the measurement uncertainty[3] is included, a revised comparison can be made between the HiVol and MiniVol samples. However, even after adjusting the results to account for the bias, an overall bias remains between the MiniVol and HiVol measurements. One potential explanation is the known tendency for the Teflon filters to have a static charge which will cause some larger particles not to adhere to the surface of the filter.

Question 2: For March 12th and March 30th, when **all** samplers were located on the East Tarmac, what is the variability between the MiniVol's measurements in comparison to the HiVol sampler?

Answer 2: Figure 2-6 shows the results in graphic form for Question 2. This figure shows that on the two days when all of the instruments were collocated, the variability amongst the MiniVols is relatively small, twice the standard deviation of the three samples on each of the two days is less than ±35% of the mean value, and that the MiniVols are again biased low relative to the HiVol sampler.

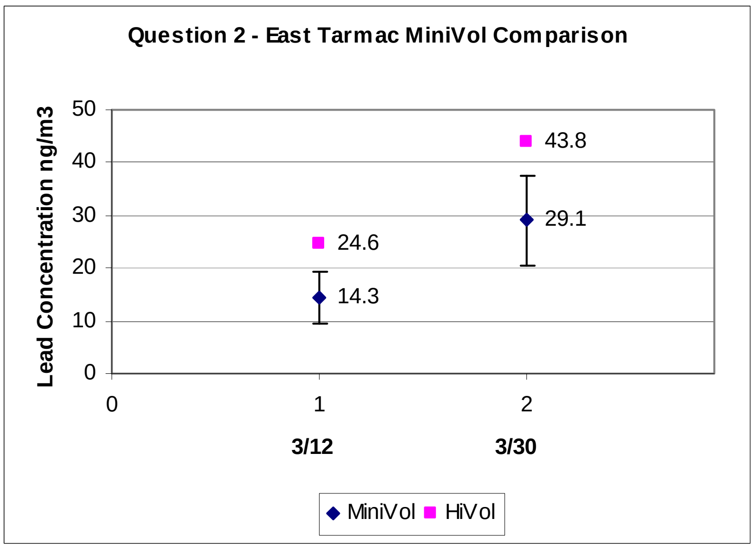


Figure 2-6. Collocated instruments at the East Tarmac (bars are twice the standard deviation).

Question 3: What is the difference between Pb concentrations collected over the full 24-hour period and those collected during airport operation hours (7 a.m. to 11 p.m.)? Can 24-hour Pb concentrations be estimated reasonably well from samples collected during the 18-hour period during which the airport is open?

Answer 3: Figures 2-7a-c show the results in graphic form for Question 3. We observed consistently higher Pb concentrations for samples collected over the 18-hours of airport operation compared with those collected for a full 24-hour day (Figure 2-7a). The 18-hour samples ranged from 16 ng/m^3 to 27.1 ng/m^3 higher than the paired 24-hr samples. This difference is attributed to the piston-engine aircraft emissions during airport operation hours. To evaluate whether we can reasonably estimate a 24-hour concentration from an 18-hour sample, we compared the daily ratio of the 18-hour Pb concentrations with the 24-hour Pb concentrations and observed a range in these ratios (shown in Figure 2-7c) from 0.61 to 0.69 (average 0.66). This average ratio is nearly identical to the ratio of the hours the samples were

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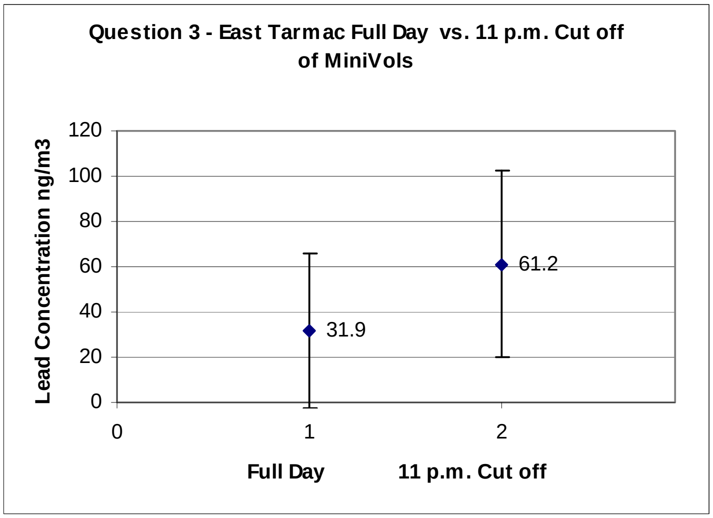
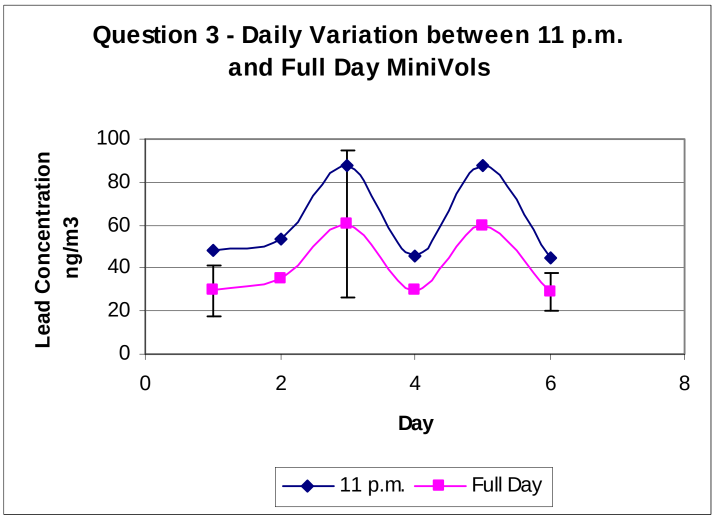
3 This includes uncertainty from instrument calibration, counting statistics, peak overlap correction and absorption as reported by the laboratory.

collected (18/24= 0.67). This implies that when the airport is closed, ambient Pb concentrations at the East Tarmac location return to background levels similar to those measured at the West Tarmac site (e.g., 3-4 ng/m^3). This finding also suggests that monitoring for the summer program could be limited to airport operating hours and the resulting concentrations reasonably adjusted to estimate the 24-hour concentration. Another way to address the question would be to compare the mass of Pb from the 18-hour monitored sample with the mass of Pb from the paired 24-hour sample (Appendix A).





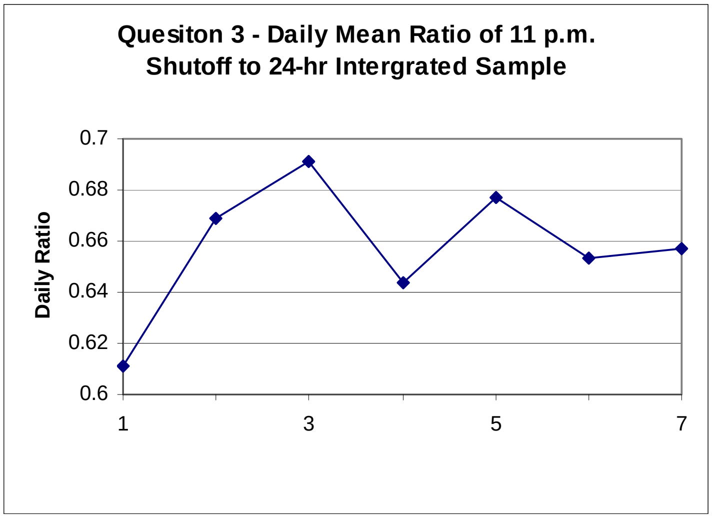


Figure 2-7. Full-day (24-hour) monitoring versus 18-hour[4] monitoring.

Question 4: Using the MiniVols, what are the prevailing upwind (West Tarmac) and downwind (East Tarmac) concentrations as well as the residential concentrations, paired in time? What is the gradient in the Pb concentration between the East Tarmac and residential (Clarkson) concentration (approximately 85 meters) and how does this inform the potential distance at which Pb concentrations return to urban background levels?

Answer 4: Figure 2-8 shows the results in graphic form for Question 4. The results compare the day-by-day upwind (West Tarmac) and downwind (East Tarmac) concentrations as well as the residential concentrations paired in time. With the exception of March 13th (Day 2), these results show that the residential monitor is always lower than the East Tarmac site. The differences between the East Tarmac and residential site are most pronounced on days with the highest ambient concentrations. On March 13th (Day 2), the sample in the residential monitor was not changed until 9:45 a.m. while the East Tarmac location sample was changed between 8:15 and 8:30 a.m. It may be possible that the residential monitor measured emissions during this intervening time period that were not captured on the East Tarmac filter. Based on this finding, March 13th was not recommended for the model-to-monitor comparison study.

Figure 2-8 also shows that the average concentration gradient over the 85-meter distance between the East Tarmac and residential site is 16 ng/m^3. However, the residential site is more to the immediate east of the East Tarmac site rather than in a more northerly location that would place it in the more prevailing downwind direction. The gradient ranged from 27 to 7 ng/m^3, with the exception of March 13th for which the data were considered suspect. These results suggest it may be problematic to measure concentrations much beyond the residential site (Clarkson) using the MiniVols with their generally lower sample collection and biased measurements relative to the HiVols, except on days with high levels of general aviation activity.

[4] The 18-hours coincided with the hours that the airport operates.

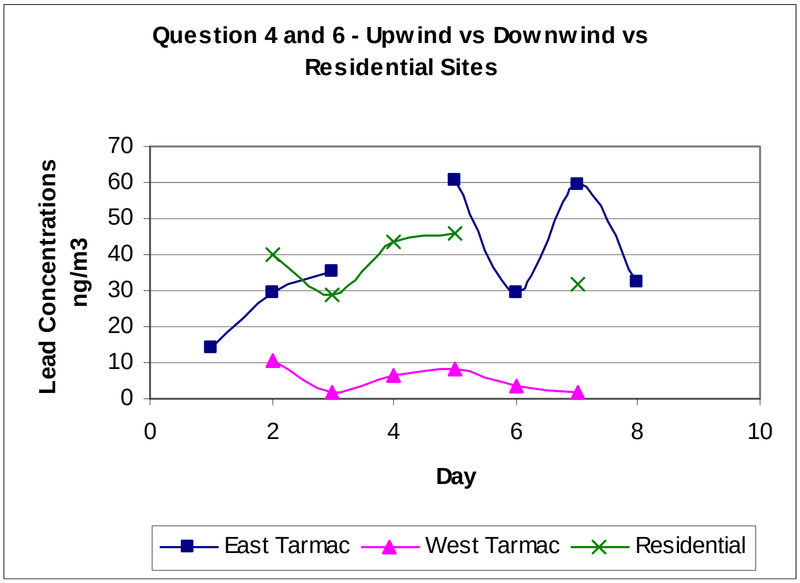


Figure 2-8. Daily average lead concentrations at the three monitoring sites during the winter monitoring program.

Question 5: For locations where the MiniVol samplers were collocated and collected for the same time period, what was the mean and mean difference?

Answer 5: Figure 2-9 shows the results in graphic form for Question 5. These results compare the collocated MiniVol measurements collected for the same time period. This figure shows the mean and means difference (plotted as an error bar). Both the residential and East Tarmac sites showed small differences in 5 of the 6 periods and only on the day with the highest concentration did the mean difference exceed 10 ng/m^3. The West Tarmac site shows small differences in the mean and means difference owing to the very low observed concentration levels.

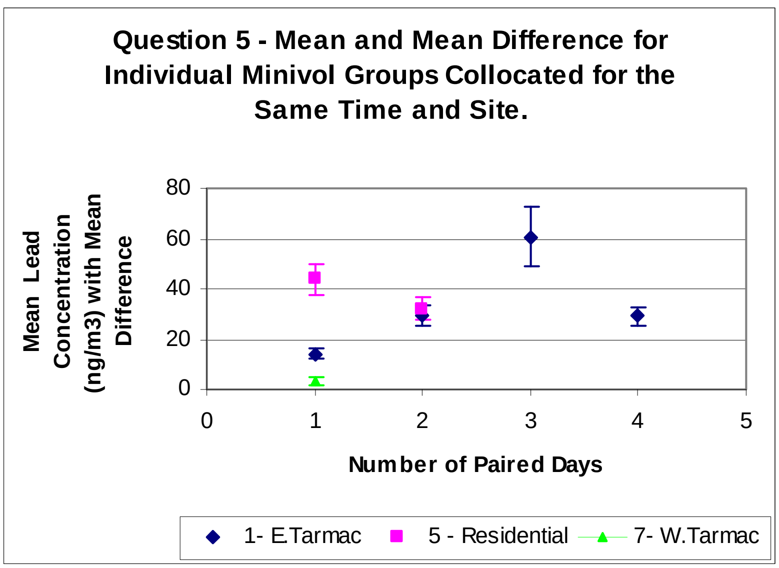


Figure 2-9. Mean and mean difference (error bars) for collocated MiniVols.

Implications for Summer Monitoring Program

Based on the intercomparison between the HiVol and MiniVol measurements, two approaches were considered for the Summer Program:

1. Retain the use of the MiniVols but minimize the differences with the HiVol by:
   - Using an electrostatic charge eliminator for each Teflon filter prior to installation in a MiniVol; and
   - Correcting the Teflon bias and improving accuracy with additional field blanks
2. Use only HiVol instrumentation

Option 2 was selected as the preferred approach for the Summer Monitoring Program because:

1. Use of the HiVol samplers is consistent with the regulatory monitoring;
2. A small but significant bias would remain with the use of the MiniVols, particularly at concentrations near the detection limit;
3. The HiVol samplers would provide a better estimate of the off-airport spatial Pb concentration gradient and could be extended beyond the 85 meter distance;
4. An adequate number of HiVol samplers were available from SCAQMD in support of the study.

2.4 SUMMER MONITORING PROGRAM

2.4.1 Approach

The summer monitoring period extended over a one week period starting on Saturday, July 25th, through Friday, July 31st. During the summer period general aviation activity was similar on both weekdays and weekend days. Filter samples were changed out at approximately the same time on each of the days, with the operating parameters documented in logs (Appendix A).

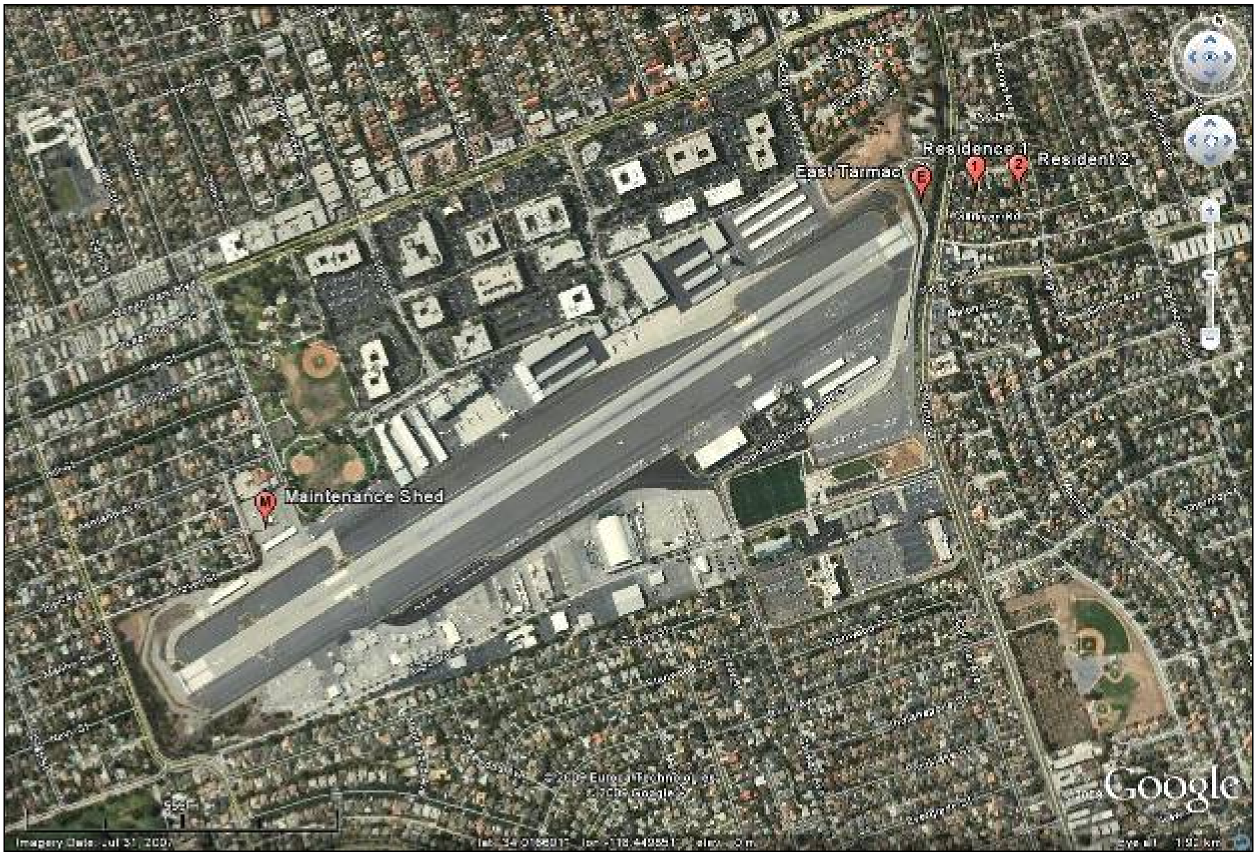
The decision to employ only HiVol samplers during the summer program required that electrical power be available for continuous use and introduced additional complications associated with site security and equipment footprint. As a result, the summer program used a new upwind monitoring location as well as two new additional residential locations. A total of four HiVol samplers were used during the 7-day summer monitoring program. Two of the HiVol samplers were provided by T&B Systems and two by the SCAQMD.

The locations of the four monitors for the summer program are shown in Figure 2-10. The upwind site was adjacent to the airport maintenance[5] shed and is the same location that was used by SCAQMD in their earlier monitoring study (Fine, 2007). We used the same East Tarmac site that was used in the winter program, which is in the prevailing downwind direction from aircraft activity.

Two residential locations in the prevailing downwind direction were used in this study. The site nearest the Airport is designated Residence 1 and is 100 meters from the East Tarmac site. This site used a backyard location with the sampler located near a wall but otherwise with good ambient exposure (Figure 2-11). The residential site (Residence 2) is 175 meters from the East Tarmac site. The HiVol sampler was placed near the wall at the back of the property, but with the top of the inlet above the wall (Figure 2-12).

[5] A new upwind site was used in the summer monitoring program due to the need for off the grid electrical power.

The HiVol samplers were operated in the total suspended particulate (TSP) mode and were mostly operated only during airport operational hours to reduce the potential for noise complaints. The summer program also included one field blank sample that was carried through the process and analyzed. Appendix A contains measurements of all of the sample mass, Pb mass and blank measurements. Calibrations for all of the equipment were performed using certified flow standards. Pb samples were again analyzed by Chester LabNet using XRF and the filter media was quartz in an effort to minimize particle bounce.



Source: GoogleEarth.

Figure 2-10. Sampling locations during the Summer Monitoring Program: East Tarmac, Resident 1, Resident 2, and Maintenance Shed (M).

Source: T&B Systems

Figure 2-11. Location of the HiVol sampler at the Residence 1.

Source: T&B Systems

Figure 2-12. Location of the HiVol sampler at the Residence 2.

2.4.2 Summer Program Monitoring Results

Individual Monitoring Results

Table 2-2 summarizes the ambient Pb air monitoring data collected during the summer monitoring program at Santa Monica Airport. The table shows the location of the monitor, the starting date, starting time and ending time, day of the week in which the sample was first collected, the type of monitor used to collect the data, and a description of any problems or invalid measurements (in the "Comments" column).

A total of 28 valid data samples were collected over a total of 7 days. All samples were measured using HiVol samplers and in most cases were well above the detection limit. Only the Maintenance Shed location (which is located in the predominant upwind direction) showed concentrations below the detection limit. The highest monitored concentration was 79 ng/m^3, measured at Residence 1 on July 26th. Valid data from this study were used in the subsequent model-to-monitor comparison. Further details of the filter analysis can be found in Appendix A.

Table 2-2. Pb Air Concentrations from Summer Monitoring Program at Santa Monica Airport

Sample ID	Site	Start Date	Start Time	Duration (hh:mm)	Day of Week	Pb (ng/m^3)	Comment
09-Q539	East Tarmac	7/25/2009	8:16	24:29	Saturday	38	
09-Q540	Maint.Shed	7/25/2009	8:30	24:40	Saturday	2	Just above detection limit of 1.4 ng/m^3 at 68% confidence
09-Q541	Resident 1	7/25/2009	7:55	23:40	Saturday	44	
09-Q542	Resident 2	7/25/2009	8:02	18:28	Saturday	30	Shutoff at 2:30 a.m.
09-Q543	East Tarmac	7/26/2009	8:53	23:07	Sunday	58	
09-Q544	Maint. Shed	7/26/2009	9:20	23:00	Sunday	4	
09-Q545	Resident 1	7/26/2009	7:40	15:20	Sunday	79	Shutoff at 11 p.m.
09-Q546	Resident 2	7/26/2009	8:27	14:33	Sunday	45	Shutoff at 11 p.m.

Table 2-2. Pb Air Concentrations from Summer Monitoring Program at Santa Monica Airport

Sample ID	Site	Start Date	Start Time	Duration (hh:mm)	Day of Week	Pb (ng/m^3)	Comment
09-Q547	East Tarmac	7/27/2009	8:06	23:05	Monday	53	
09-Q548	Maint. Shed	7/27/2009	8:30	23:25	Monday	4	
09-Q549	Resident 1	7/27/2009	7:22	15:38	Monday	52	Shutoff at 11 p.m.
09-Q550	Resident 2	7/27/2009	7:40	15:20	Monday	32	Shutoff at 11 p.m.
09-Q551	East Tarmac	7/28/2009	7:20	24:25	Tuesday	62	
09-Q552	Maint. Shed	7/28/2009	8:05	23:20	Tuesday	4	
09-Q553	Resident 1	7/28/2009	6:42	16:18	Tuesday	76	Shutoff at 11 p.m.
09-Q554	Resident 2	7/28/2009	7:00	Unknown	Tuesday	50	Unknown sample duration - power lost
09-Q555	East Tarmac	7/29/2009	7:52	23:28	Wednesday	55	
09-Q556	Maint. Shed	7/29/2009	7:30	24:10	Wednesday	6	
09-Q557	Resident 1	7/29/2009	6:47	23:57	Wednesday	32	
09-Q558	Resident 2	7/29/2009	7:08	23:53	Wednesday	23	
09-Q559	East Tarmac	7/30/2009	7:25	23:51	Thursday	34	
09-Q560	Maint. Shed	7/30/2009	7:46	24:51	Thursday	< detection limit	below detection limit of 1.4 ng/m^3 at 68% confidence
09-Q561	Resident 1	7/30/2009	6:50	23:50	Thursday	27	
09-Q562	Resident 2	7/30/2009	7:06	16:09	Thursday	36	Shutoff at 11:15 p.m.
09-Q563	East Tarmac	7/31/2009	7:24	24:55	Friday	45	
09-Q564	Maint. Shed	7/31/2009	7:45	24:18	Friday	3	
09-Q565	Resident 1	7/31/2009	6:46	24:49	Friday	39	
09-Q566	Resident 2	7/31/2009	7:04	16:04	Friday	42	Shutoff at 11 p.m.

3 Soil and Dust Sampling

The purposes of the soil and indoor dust Pb sampling were to explore the potential for a gradient in Pb concentrations in these media with distance from the airport and, as described in Chapter 4, to determine the re-entrained road dust Pb fraction in the vicinity of the Santa Monica Airport. The sampling program consisted of collecting soil and dust samples in locations at and near the Santa Monica Airport.

3.1 SOIL SAMPLING

3.1.1 Approach

The soil sampling program was designed to gather data on the presence and distribution of total Pb in soil. Total Pb may be present in bulk soil samples (i.e., present throughout the soil matrix) or may be preferentially found in the fine-grained components of a bulk sample (sieved soil). It is the fine-grained components (clays and silts) of the soil that are potentially entrainable under certain wind and soil moisture conditions and thus subject to inhalation and ingestion by workers and residents in the surrounding area. Four sampling areas were selected based on: proximity to takeoff and landing areas, availability of relatively undisturbed and non-vegetated surficial earth materials, and accessibility.

These four locations were:

> **Area 1** – Clover Park: baseball fields and playground equipment adjacent to the aircraft parking and idling area near a historically contaminated industrial area.[6]
>
> **Area 2** – Near runway 21 blast fence: maximum impact site for ambient lead from aircraft exhaust emissions.
>
> **Area 3** – Prevailing upwind site.
>
> **Area 4** – Neighborhood sampling: three homes located near the maximum neighborhood air impact sites (ranging from 55, 110 and 150 meters from the runway blast fence) and one home in the prevailing upwind area from the airport (1700 meters from the runway blast fence). Soil sampling in each home consisted of two samples total, one collected at the drip line to test for Pb from Pb-based exterior paint, and one sample collected in the yard. Additionally, two soil samples were collected near roadways: near the corner of Brookhaven Ave and Federal Ave and near the intersection of Ocean and Bundy.

Sampling locations for the soil and dust (See Section 3.2) analysis for the north runway area and near roadway samples are shown in Figure 3-1. Sampling locations for Clover Park, the south runway area, and observation deck are shown in Figure 3-2.

The choice of specific sample locations within these areas was dependent upon on a number of factors, including: accessibility, degree of disturbance (non-disturbed is best), degree of leaching from irrigation (samples were collected in areas least affected by irrigation water), vegetative cover (exposed soil is best), and soil type (predominantly fine-grained soil is best for collecting resuspended dust).

[6] The Clover Park samples were taken before the summer 2009 construction began

Source: GoogleEarth.

Figure 3-1. North runway area, nearby neighborhood, and near roadway soil and dust sample locations.

Source: GoogleEarth

Figure 3-2. South runway, observation deck, and Clover Park soil sampling sites.

Soil samples were collected using shovels, stainless steel hand trowels, and stainless steel mixing bowls. For each soil sample, we removed the top 2 inches of soil throughout a circular area with a diameter of approximately 18 inches (approximately 6 lbs of bulk soil was collected for each bulk sample). The excavated soil was placed in a stainless steel mixing bowl and mixed to blend the soil. Approximately 4 oz of soil was placed in a laboratory-provided glass jar and labeled using a unique sample naming protocol. A subsample of the blended soil was removed for analysis of the bulk soil Pb concentration. The remainder of the blended sample was collected in a heavy duty plastic bag for submittal to the analysis laboratory for sieve processing using ASTM Method D1140. A minimum of 4 oz of soil passing through a #60 sieve was provided to the laboratory for analytical analysis. All sampling equipment was cleaned between sample locations using a mild detergent (tri-sodium phosphate or equivalent).

The soil samples were submitted under chain-of-custody protocols to the State of California-certified analytical testing laboratory, Test America. Bulk soil samples were analyzed for a suite of metals including Pb by ICP-MS (EPA Methods 7471A/6020). The specific analyses for soil samples collected in each area are summarized below in Table 3-1.

Table 3-1. Soil Sampling

Area	No. of Bulk Samples	No. of Total Metal Analyses	No. of Total Lead Analyses	No. of Sieve Analyses for Pb
Area 1 (Clover Park)	2	2	2	2
Area 2 (Blast Fence)	1	1	1	1
Area 3 (Upwind Site)	1	1	1	1
Area 4 (Neighborhood)[1]	10	10	10	10
Totals	**14**	**14**	**14**	**14**

[1] Three homes in the downwind neighborhood, one home in the upwind neighborhood, and two sites in the near roadway environment were sampled. Two bulk samples were collected at each home (one from the roof drip line and one from an area where dirt might be tracked into the house) and one bulk sample was collected at two separate roadways. Each bulk sample was analyzed for total metals. A sieve analysis was conducted on the bulk samples and the material passing a #60 sieve was analyzed for lead.

3.1.2 Results

Table 3-2 describes the sample ID, sampling locations, date of the collection, and type of soil sample collected. Table 3-3 reports the soil sampling results including the Pb concentration (mg/kg) as well as other metal concentrations for the bulk samples.

Concentrations of soil Pb on airport property ranged from 16 to 63 mg/kg. Concentrations of Pb in soil collected at Clover Park ranged from 9.4 to 35 mg/kg. Concentrations of Pb in samples collected near roads ranged from 32 to 53 mg/kg with the sieved samples having Pb concentrations ranging from 77 to 120 mg/kg. Residential soil samples had Pb concentrations ranging from 12 to 150 mg/kg in the bulk soil and 14 to 150 mg/kg in the sieved fraction. For comparison, the EPA standard for Pb in residential soil in play areas is 400 mg/kg and for non-play area soils 1,200 mg/kg (EPA, 2001).

Table 3-2. Soil Sample Locations, Descriptions, and Types in the Vicinity of Santa Monica Airport

Sample ID	Collection Date	Sample Type	General Location	Specific Location
Area1SS1061209	6/12/2009	Bulk Soil	Clover Park	Near fence adjacent to aircraft parking area
Area1SS2061209	6/12/2009	Bulk Soil	Clover Park	Adjacent to ball field spectator stands
Area1WSBlank061209	6/12/2009	Blank	Clover Park	Not applicable
Area1SS1061209	6/12/2009	Sieved Soil	Clover Park	Sieved sample from Area 1 location.
Area1SS2061209	6/12/2009	Sieved Soil	Clover Park	Sieved sample from Area 2 location.
NH1_SS072409	7/24/2009	Bulk Soil	Neighborhood	Near corner of Brookhaven Ave and Federal Ave.
NH1_SS072409	7/24/2009	Sieved Soil	Neighborhood	Near corner of Brookhaven Ave and Federal Ave.
NH2_SS072409	7/24/2009	Bulk Soil	Neighborhood	Residence 1
NH2_SSDL072409	7/24/2009	Bulk Soil - Drip Line	Neighborhood	Residence 1
NH2_SS072409	7/24/2009	Sieved Soil	Neighborhood	Residence 1
NH2_SSDL072409	7/24/2009	Sieved Soil	Neighborhood	Residence 1
NH3_SS072409	7/24/2009	Bulk Soil	Neighborhood	Residence 2
NH3_SSDL072409	7/24/2009	Bulk Soil - Drip Line	Neighborhood	Residence 2
NH3_SS072409	7/24/2009	Sieved Soil	Neighborhood	Residence 2
NH3_SSDL072409	7/24/2009	Sieved Soil	Neighborhood	Residence 2
NH4_SS072409	7/24/2009	Bulk Soil	Neighborhood	Residence 4
NH4_SSDL072409	7/24/2009	Bulk Soil - Drip Line	Neighborhood	Residence 4
NH4_SS072409	7/24/2009	Sieved Soil	Neighborhood	Residence 4
NH4_SSDL072409	7/24/2009	Sieved Soil	Neighborhood	Residence 4
NH5_SS072409	7/24/2009	Bulk Soil	Neighborhood	Residence 3
NH5_SSDL072409	7/24/2009	Bulk Soil - Drip Line	Neighborhood	Residence 3
NH5_SS072409	7/24/2009	Sieved Soil	Neighborhood	Residence 3
NH5_SSDL072409	7/24/2009	Sieved Soil	Neighborhood	Residence 3
NH6_SS072409	7/24/2009	Bulk Soil	Neighborhood	Roadway sample from planter at Bundy and Ocean Park
NH6_SS072409	7/24/2009	Sieved Soil	Neighborhood	Roadway sample from planter at Bundy and Ocean Park
FB_WS_072909	7/29/2009	Field Blank	Airport	Various
2_BW_SS1072909	7/29/2009	Bulk Soil	Airport	Blast wall area - Blast wall dirt site – ~13ft along curve from left side of blast wall and ~17ft perpendicular to the curb into the field.
2_BW_SS1072909	7/29/2009	Sieved Soil	Airport	Blast wall area - Blast wall dirt site – ~13ft along curve from left side of blast wall and ~17ft perpendicular to the curb into the field.
3_UW_SS1072909	7/29/2009	Bulk Soil	Airport	Upwind area - ~44 ft from the curb where the bend in the road ends & 35 ft from tripod staked in dirt. Small sandy patch near some pieces of blacktop.
3_UW_SS1072909	7/29/2009	Sieved Soil	Airport	Upwind area - ~44 ft from the curb where the bend in the road ends & 35 ft from tripod staked in dirt. Small sandy patch near some pieces of blacktop.
NHBLANK_WSC073109	7/31/2009	Field Blank	Neighborhood	Various

Table 3-3. Soil Sampling Metal Fractions Collected in the Vicinity of Santa Monica Airport (mg/kg)

Sample Name	Sample Date	Soil Sample Type	Metals by EPA Methods 7471A/6020																
			Mercury	Antimony	Arsenic	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Molybdenum	Nickel	Selenium	Silver	Thallium	Vanadium	Zinc
Area1SS1061209	6/12/2009	Bulk	0.057	<1.0	1.6	110	<0.30	<0.50	14	3.6	12	17	<1.0	7.6	<1.0	<0.50	<0.50	18	250
Area1SS2061209	6/12/2009	Bulk	0.068	<1.0	2.2	62	0.32	0.52	13	4.0	11	9.4	<1.0	8.9	<1.0	<0.50	<0.50	23	100
Area1SS1061209	6/12/2009	Sieved	NA	NA	NA	NA	NA	NA	NA	NA	NA	35	NA	NA	NA	NA	NA	NA	NA
Area1SS2061209	6/12/2009	Sieved	NA	NA	NA	NA	NA	NA	NA	NA	NA	16	NA	NA	NA	NA	NA	NA	NA
NH1_SS072409	7/24/2009	Bulk	0.042	1.6	32	110	1.5	1.9	34	10	29	53	2.8	27	1.8	<0.50	1.6	54	160
NH1_SS072409	7/24/2009	Sieved	NA	1.1	21	120	0.45	1.5	45	9.4	41	120	2.4	29	<1.0	<0.50	<0.5	61	340
NH2_SS072409	7/24/2009	Bulk	0.063	<1.0	12	130	0.45	0.75	33	7.4	30	38	1.8	24	<1.0	0.59	<0.50	48	85
NH2_SSDL072409	7/24/2009	Bulk	0.033	<1.0	6.8	120	0.35	0.63	26	6.4	32	26	1.7	17	<1.0	<0.50	<0.50	37	100
NH2_SS072409	7/24/2009	Sieved	NA	<1.0	18	170	0.64	0.56	48	9.5	43	49	2.5	32	<1.0	0.78	0.5	82	110
NH2_SSDL072409	7/24/2009	Sieved	NA	1.0	11	170	0.52	<0.50	51	9.0	57	45	2.5	28	1.0	<0.50	<0.50	64	140
NH3_SS072409	7/24/2009	Bulk	0.085	<1.0	2.2	94	<0.30	<0.50	14	2.8	32	12	<1.0	6.8	<1.0	0.76	<0.50	18	74
NH3_SSDL072409	7/24/2009	Bulk	0.12	<1.0	11	140	0.39	0.95	32	8.0	42	35	2.3	23	1.0	0.71	<0.50	47	250
NH3_SS072409	7/24/2009	Sieved	NA	<1.0	2.3	61	<0.30	<0.50	21	4.6	28	14	<1.0	9.5	<1.0	0.93	<0.50	92	66
NH3_SSDL072409	7/24/2009	Sieved	NA	1.0	16	160	0.63	0.96	54	10	55	47	2.9	33	1.1	0.51	<0.50	81	770
NH4_SS072409	7/24/2009	Bulk	0.036	<1.0	2.3	38	<0.30	<0.50	13	1.9	12	24	<1.0	4.7	<1.0	<0.50	<0.50	14	50
NH4_SSDL072409	7/24/2009	Bulk	0.11	<1.0	1.1	45	<0.30	0.60	12	2.4	19	50	<1.0	5.7	<1.0	<0.50	<0.50	12	280
NH4_SS072409	7/24/2009	Sieved	NA	<1.0	5.0	54	<0.30	<0.50	25	3.0	20	37	<1.0	8.1	<1.0	<0.50	<0.50	35	77
NH4_SSDL072409	7/24/2009	Sieved	NA	<1.0	2.8	47	<0.30	<0.50	23	2.7	21	66	<1.0	7.1	<1.0	<0.50	<0.50	18	330
NH5_SS072409	7/24/2009	Bulk	0.62	1.4	16	180	0.52	2.6	56	7.3	77	150	2.7	28	1.4	2.2	<0.50	45	240
NH5_SSDL072409	7/24/2009	Bulk	0.097	1.3	21	110	0.38	1.1	37	7.7	46	130	2.5	26	<1.0	<0.50	<0.50	46	220
NH5_SS072409	7/24/2009	Sieved	NA	2.6	19	200	0.60	2.2	74	8.6	87	150	3.5	35	1.8	2.1	<0.50	65	260
NH5_SSDL072409	7/24/2009	Sieved	NA	1.8	26	120	0.47	0.67	46	8.1	47	150	2.9	29	1.0	<0.50	<0.50	55	220
NH6_SS072409	7/24/2009	Bulk	<0.020	<1.0	2.9	120	<0.30	<0.50	19	5.9	23	32	1.0	9.4	<1.0	<0.50	<0.50	32	120
NH6_SS072409	7/24/2009	Sieved	NA	3.2	6.5	140	<0.30	<0.50	33	6.3	57	77	3.5	18	<1.0	<0.50	<0.50	51	230
2_BW_SS1072909	7/29/2009	Bulk	NA	<1.0	4.4	76	0.42	<0.50	21	5.1	13	16	<1.0	12	<1.0	<0.50	<0.50	37	37
2_BW_SS1072909	7/29/2009	Sieved	NA	<1.0	6.4	120	0.48	<0.50	28	7.7	23	40	1.1	17	<1.0	<0.50	<0.50	51	57
3_UW_SS1072909	7/29/2009	Bulk	NA	<1.0	3.4	110	0.33	0.69	24	4.9	25	17	<1.0	12	<1.0	1.2	<0.50	28	75
3_UW_SS1072909	7/29/2009	Sieved	NA	<1.0	5.8	160	0.69	0.65	34	7.7	39	63	1.4	20	1.5	1.8	<0.50	48	140

NOTE:
NA = Not analyzed.

3.2 DUST SAMPLING

3.2.1 Approach

Dust sampling was conducted on selected surfaces in each of the sample areas described above. Dust samples were collected by rubbing a laboratory-prepared absorbent material over a specified, measured area. The dust sample was then placed in a laboratory-provided glass jar. Dust sampling was conducted at several locations on or adjacent to the airport (in Areas 1, 2, and 3[7]) and at five homes in the vicinity of the airport as shown in Figures 3-1 and 3-2.

Two types of dust samples were collected at the neighborhood homes: uncontrolled and controlled. Uncontrolled dust samples are samples collected from surfaces, typically windowsills, that were undisturbed and exposed to airborne matter prior to the start of this study. Uncontrolled dust samples were collected at Areas 1, 2, 3 and 4. Controlled dust samples are samples collected from surfaces which

[7] Note that Area 3 for the dust sampling is not the same as Area 3 for the soil sampling; dust sampling Area 3 is at the refueling station

had been pre-cleaned using water or isopropyl alcohol to remove residual material. These surfaces were then allowed to accumulate dust for approximately one week. Controlled dust samples were collected in Area 4. Table 3-4 shows the dust sample wipe locations and a description of the sample location.

Table 3-4. Dust Sample Locations, Descriptions, and Types in the Vicinity of Santa Monica Airport

Sample ID	Collection Date	Sample Type	General Location	Specific Location
Area1WS1061209	6/12/2009	Wipe	Clover Park	From rubberized surface at Tot Lot
Area1WS2061209	6/12/2009	Wipe	Clover Park	From corner of red stair (3rd from bottom) leading to platform
NH2_WSJ072409	7/24/2009	Wipe – Uncontrolled	Neighborhood	Residence 1– 1st floor west facing window sill
NH2_WSC073109	7/31/2009	Wipe – Controlled	Neighborhood	Residence 1– 1st floor west facing window sill
NH3_WSJ072409	7/24/2009	Wipe – Uncontrolled	Neighborhood	Residence 2– 1st f west facing window sill
NH3_WSC073109	7/31/2009	Wipe – Controlled	Neighborhood	Residence 2– 1st floor west facing window sill
NH4_WSJ072409	7/24/2009	Wipe – Uncontrolled	Neighborhood	Residence 4– 1st floor east facing window sill
NH4_WSC073109	7/31/2009	Wipe – Controlled	Neighborhood	Residence 4– 1st floor east facing window sill
NH5 _WSJ072409	7/24/2009	Wipe – Uncontrolled	Neighborhood	Residence 3- 2nd floor east facing window sill
NH5_WSC073109	7/31/2009	Wipe – Controlled	Neighborhood	Residence 3- 2nd floor east facing window sill
NH7_WSJ072409	7/24/2009	Wipe	Neighborhood	Residence 5 – 2nd story south facing window sill
2_BW_WS1072909	7/29/2009	Wipe	Airport	Blast wall area - 6th ridge down from the 1st large opening in the blast wall on the far left edge.
3_RF_WS2073009	7/30/2009	Wipe	Airport	Refueling area - eastern corner post of the overhang of the refueling office.
3_OD_WS1072909	7/29/2009	Wipe	Airport	Observation deck area - Second 'T' shaped connection to the left of the railing ending outside administration building.
3_RF_WS1073009	7/30/2009	Wipe	Airport	Refueling area – in the middle of the hexagonal table near the office entrance.
3_OD_WS2072909	7/29/2009	Wipe	Airport	Observation deck area - Centered above light to the right of the rightmost planter.
2_BW_WS2072909	7/29/2009	Wipe	Airport	Blast wall area - behind 1st post in the guard rail along the road, last ridge on the lowest slat of wall.
NH2_WSC073109	7/31/2009	Wipe - Controlled	Neighborhood	Residence 1 – 1st floor west facing window sill
NH3_WSC073109	7/31/2009	Wipe - Controlled	Neighborhood	Residence 2 – 1st floor west facing window sill (
NH4_WSC073109	7/31/2009	Wipe - Controlled	Neighborhood	Residence 4 – 1st floor east facing window sill
NH5_WSC073109	7/31/2009	Wipe - Controlled	Neighborhood	Residence 3 - 2nd floor east facing window sill
NH7_WSC073109	7/31/2009	Wipe - Controlled	Neighborhood	Residence 5 – 2nd story south facing window sill

All dust samples (both controlled and uncontrolled) were analyzed by certified testing laboratory for a suite of metals following EPA Method 6020. A summary of the dust sampling program is provided in Table 3-5.

Table 3-5. Dust Sampling Program

Area	No. of Dust Samples	No. of Total Metal Analyses
Area 1 (Clover Park)	2	2
Area 2 (Blast Fence and Observation Deck)	4	4
Area 3 (Refueling Station)	2	2
Area 4 (Neighborhood)	10	10
Totals	**18**	**18**

3.2.2 Results

Table 3-6 provides the results of Pb and other metal concentrations in dust wipe samples (in micrograms per square foot). Of the 18 dust samples, only three had Pb concentrations above the detection limit. The Pb concentration in these samples was 65, 94, and 684 $\mu g/ft^2$ at Residences 1, 3, and 5, respectively. All other controlled dust samples were less than the detection limit. For comparison, EPA's standard for Pb in residential floor dust is 40 $\mu g/ft^2$ and for interior window sill dust it is 250 $\mu g/ft^2$ (EPA, 2001).

Table 3-6. Dust Sampling Measurements in micrograms per square foot in the Vicinity of Santa Monica Airport

Sample Name	Sample Date	Sample Type	Wipe Area	Metals Results EPA Method 6020 Units (micrograms per square foot)															
				Antimony	Arsenic	Thallium	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Molybdenum	Nickel	Selenium	Silver	Vanadium	Zinc
Area1WS 1061209	6/12/2009	U	1 sq ft	<2.0	<1.0	<1.0	<2.5	<0.50	<1.0	1.7	<1.0	<2.0	<1.0	<1.0	<1.0	<2.0	<1.0	<1.0	<20
Area1WS 2061209	6/12/2009	U	1 sq ft	<2.0	<1.0	<1.0	<4.5	<0.50	<1.0	2.0	<1.0	<2.0	<1.0	<1.0	<1.0	<2.0	<1.0	<1.0	<20
Area1WS BLANK061209	6/12/2009	Blank	NA	<72	<36	<36	<1.0	<0.50	<1.0	<1.0	<1.0	<2.0	<1.0	<1.0	<1.0	<2.0	<1.0	<1.0	<20
NH2_WS J072409	7/24/2009	U	4 sq in	468	<36	<36	1440	<18	<1.0	234	<36	2088	684	72	130	<72	<36	101	3960
NH2_WS C073109	7/31/2009	C	4 sq in	<72	<36	<36	97	<18	<36	<72	<36	176	<36	<36	<36	<72	<36	43	<720
NH3_WS J072409	7/24/2009	U	4 sq in	86	<36	<36	353	<18	<36	<72	<36	328	94	<36	<36	<72	<36	<36	2016
NH3_WS C073109	7/31/2009	C	4 sq in	<72	<36	<36	54	<18	<36	<72	<36	<72	<36	<36	<36	<72	<36	<36	<720
NH4_WS J072409	7/24/2009	U	4 sq in	<72	<36	<36	64.8	<18	<36	<72	<36	227	<36	<36	<36	<72	<36	<36	<720
NH4_WS C073109	7/31/2009	C	4 sq in	<72	<36	<36	36	<18	<36	<72	<36	<72	<36	<36	<36	<72	<36	<36	<720
NH5_WS J072409	7/24/2009	U	4 sq in	<72	<36	<36	83	<18	<36	<72	<36	<72	<36	<36	<36	<72	<36	<36	<720
NH5_WS C073109	7/31/2009	C	4 sq in	<72	<36	<36	47	<18	<36	<72	<36	<72	<36	<36	<36	<72	<36	<36	<720
NH7_WS J072409	7/24/2009	U	4 sq in	<72	<36	<36	292	<18	<36	75.6	<36	216	65	<36	<36	<72	<36	<36	828
NH7_WS C073109	7/31/2009	C	4 sq in	<72	<36	<36	54	<18	<36	<72	<36	<72	<36	<36	<36	<72	<36	<36	<720

Table 3-6. Dust Sampling Measurements in micrograms per square foot in the Vicinity of Santa Monica Airport

Sample Name	Sample Date	Sample Type	Wipe Area	Metals Results EPA Method 6020 Units (micrograms per square foot)															
				Antimony	Arsenic	Thallium	Barium	Beryllium	Cadmium	Chromium	Cobalt	Copper	Lead	Molybdenum	Nickel	Selenium	Silver	Vanadium	Zinc
NHBLANK_ WSC073109	7/31/2009	Blank	NA	<72	<36	<36	<1.0	<0.50	<36	<72	<36	<72	<36	<36	<36	<72	<36	<36	<720
2_BW_WS 1072909	7/29/2009	U	4 sq in	<72	<36	<36	36	<18	<36	<72	<36	<72	<36	<36	<36	<72	<36	<36	3420
2_BW_WS 2072909	7/29/2009	U	4 sq in	<72	<36	<36	<47	<18	<36	54	<36	<72	<36	<36	<36	<72	<36	<36	2016
3_RF_WS 1073009	7/30/2009	U	4 sq in	<72	<36	<36	<47	<18	<36	50.4	<36	<72	<36	<36	<36	<72	<36	<36	<720
3_RF_WS 2073009	7/30/2009	U	4 sq in	<72	<36	<36	<47	<18	<36	<72	<36	<72	<36	<36	<36	<72	<36	<36	<720
3_OD_WS 1072909	7/29/2009	U	4 sq in	<72	<36	<36	<47	<18	<36	<72	<36	<72	<36	<36	<36	<72	<36	<36	<720
3_OD_WS 2072909	7/29/2009	U	4 sq in	<72	<36	<36	<47	<18	<36	50.4	<36	<72	<36	<36	<36	<72	<36	<36	<720
FB_WS 1072909	7/29/2009	Blank	NA	<72	<36	<36	<1.0	<0.50	<36	2.8	<36	<72	<36	<36	<36	<72	<36	<36	<720

NOTES:
U = Uncontrolled wipe sample; sample surface not cleaned prior to sampling
C = Controlled wipe sample: sample surface cleaned allowed to accumulate dust for 1 week prior to sampling
NA = Not applicable
NH = Neighborhood sample
RF = Airport refueling area
BW = Airport blast wall
OD = Airport observation deck
[1] Concentrations in table have *not* been converted to concentration per unit area

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4 AIR QUALITY MODELING

This chapter begins by presenting the methodology used in developing an emission inventory for aircraft Pb emissions (the principal source of Pb air emissions), and the procedures used to estimate emissions from other mobile and stationary sources. A discussion of the selection of the air quality model used in this study is presented along with the methods used to develop the air quality modeling inputs (including meteorology, terrain, land use, and background concentration). It concludes with a summary of the modeling results for the model-to-monitor comparison, the annual air quality modeling scenario, and a set of model sensitivity analyses.

4.1 EMISSION INVENTORY

4.1.1 Aircraft Sources

For the scenarios examined in this analysis, the overall primary sources of Pb emissions to air are single- and multi-engine piston-powered fixed-wing aircraft using avgas and piston-engine helicopters. To accurately incorporate these emission sources into the air quality model and to track each mode of operation, aircraft activity was modeled separately for each mode and aircraft type. The fixed-wing modes include taxi, run-up, takeoff, climb, approach, and landing. The helicopter modes include taxi, climb, and landing.

Data were assembled for this assessment from a variety of sources, including activity data provided by the Santa Monica Airport's Operations Manager, fuel consumption information from FAA's Emission Dispersion Modeling System (EDMS), and on-site survey data of general aviation activity collected as part of this study.

Activity Data

Two sets of aircraft activity data were needed for this analysis: an annual activity dataset and activity data for the two periods in which ambient monitoring data were collected (described in Chapter 2). The Airport only maintains records of the number of total operations[8], jet operations, and helicopter operations. Fixed-wing piston-engine aircraft activity was assumed to be the difference between the total operations less the jet and helicopter operations.

Daily records of one year of aviation activity were provided by Santa Monica Airport's Operations Manager, Stelios Makrides. At the time of the analysis, only January 2008 through November 2008 was available. When analyzing the 3-month seasonal averages for 2008, the winter season consisted of only January and February since December 2008 data were unavailable.

For the 2009 model-to-monitor comparisons, Mr. Makrides provided day-specific counts for the periods: March 12th – March 17th, March 26th – March 31st, and July 25th – July 31st, as shown in Table 4-1. These observed activity data were used in the model-to-monitor comparisons and are typical activity levels, with the exception of July 26, 2009 (see explanation in Table 4-1).

[8] "Operations" are the number of landings plus takeoffs.

Table 4-1. Daily Aircraft Operations at Santa Monica Airport

DATE	Total Operations	Jets	Helicopter	Propeller
3/12/09	251	34	5	212
3/13/09	352	48	8	296
3/14/09	238	22	2	214
3/15/09	319	34	2	283
3/16/09	337	36	6	295
3/17/09	464	48	2	414
3/26/09	295	34	6	255
3/27/09	453	54	18	381
3/28/09	448	30	8	410
3/29/09	347	42	1	304
3/30/09	349	26	8	315
3/31/09	422	36	8	378
7/25/09	238	32	3	203
7/26/09[1]	153	50	7	96
7/27/09	216	38	4	174
7/28/09	409	32	6	371
7/29/09	297	44	10	243
7/30/09	251	30	20	201
7/31/09	329	50	14	265

[1] These anomalously low activity data for a Sunday were cross checked with the FAA's ATADS Airport Operations database, which reported a total of 288 operations for the same day, of which 7 were helicopters. These values were used in the monitor-to-model comparison assuming the typical jet aircraft fraction determined from other weekend days of 15% or 43 jets, 7 helicopters, and 238 fixed-wing aircraft.

For the 2008 annual modeling scenario, the average daily activity data are summarized by season and weekday/weekend, as shown in Table 4-2. Propeller operations (i.e., piston-engine aircraft operations) are lowest in winter and there are only slight differences between weekdays and weekends.

Table 4-2. Average Daily Aircraft Counts at Santa Monica Airport for 2008

Season	Total Operations	Helicopter Operations	Jet Operations	Propeller Operations
Weekday				
Dec- Feb	296.59	7.95	46.59	242.05
Mar-May	364.80	10.41	53.14	301.25
Jun-Aug	373.94	12.72	48.06	313.16
Sep-Nov	368.52	7.57	44.77	316.18
Weekend				
Dec- Feb	279.32	5.42	34.89	239.00
Mar-May	355.36	7.46	39.82	308.07
Jun-Aug	330.39	8.68	34.71	287.00
Sep-Nov	287.60	7.00	35.93	244.67

Based on interviews with Airport operational personnel, hourly activity levels were not well known. It was determined that this information could best be established by conducting an on-site survey focusing on activity levels for piston-engine aircraft. A similar study, but focused on jet aircraft, had been led a few years earlier at SMO by Professor Keith Mew, Department of Aviation and Administration, California State University, Los Angeles. Based on experience from his previous study, Dr. Mew led his team of graduate students in conducting a survey of piston-engine aircraft activity during two weekend periods in March 2009. A sample survey was performed for six days: March 13, 14 and 15, and March 27, 28 and 29 for three periods: morning (8 a.m. and 10 a.m.), midday (10:30 a.m. and 1:30 p.m.), and afternoon (2 p.m. and 4 p.m.). These periods were selected based on discussions with SMO personnel, who indicated that these times typically covered the most active periods for piston-engine aircraft.

The survey collected information on the number of takeoffs and landings as well as the time durations of the activities. For departure, data were collected for the following activities: apron to runway end, engine run-up, takeoff roll, and climb-out. For arrival, data were collected for: approach, landing, and taxi to apron (taxi-in). In addition, the following aircraft identification data were collected for each aircraft: tail fin number and number of engines (either single or multiple).

The survey's data on the temporal distribution based on activity level were the basis for establishing the diurnal activity level for aircraft emissions. However, because the survey did not cover all hours of the day, the diurnal profile estimated by SMO personnel was used to estimate the distribution for the remainder of the hours. Thus, the intraday activity levels were estimated by a combination of survey data and professional judgment.

Figure 4-1 shows the piston-engine activity data collected on each survey day, the estimated distribution from an interview with SMO staff (ICF, 2008), and the final smoothed distribution used in the analysis (dark black line). This figure shows both a late morning peak and a secondary late afternoon peak in activity. This temporal profile was used in the modeling for the model-to-monitor comparison for the July 2009 period and for the annual modeling. For the March model-to-monitor comparison, the hourly surveyed data were used.

Time-in-mode data collected from the survey were used to determine the average length of time piston-engine aircraft were in specific modes of operation (i.e., taxi-out, run-up, takeoff, climb-out, approach, landing and taxi-in). Initial data were reviewed for outliers and corrections were made in consultation with Professor Mew. The final dataset was then used to determine average times-in-mode (TIM), which were used in calculating the aircraft Pb emissions for each mode. Table 4-3 shows the average time-in-mode for each activity at the Airport.

Fuel Consumption and Lead Concentration in Fuel

Fuel consumption was the basis for determining the Pb emissions, as most of the Pb is exhausted through the tailpipe following fuel burning. Fuel consumption varies depending on the specific aircraft mode. EPA provided fuel consumption data on six different piston-engine aircraft (two multi- and four single-engine aircraft) in four different aircraft modes (taxi, takeoff, climb, and approach). These fuel consumption rates are the same as those contained in FAA's EDMS model (FAA, 2009).[9] Because landing fuel consumption information was unavailable, it was assumed that landing fuel consumption was the same as takeoff. This is likely an overestimate, but the duration of this activity is relatively short.

[9] Extracted from EDMS Version 5.0.2 - Emissions Inventory Report

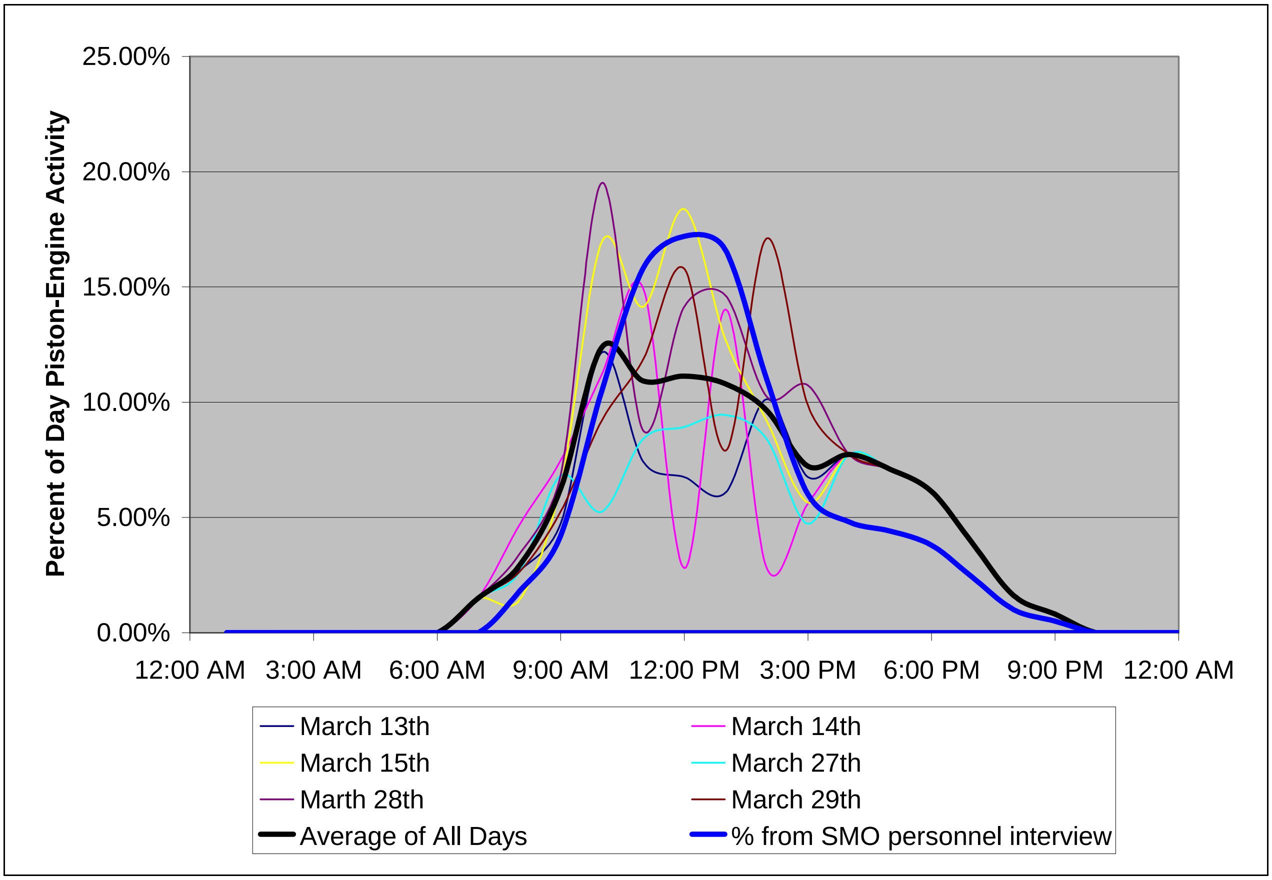


Figure 4-1. Hourly activity for piston-engine aircraft at Santa Monica Airport.

Table 4-3. Average Time-in-mode for Fixed-wing Piston-engine Aircraft at Santa Monica Airport

Mode	Time
Taxi To Runway	5 min 4 sec
Run-up	1 min 29 sec
Takeoff Roll	16 sec
Climb-out	1 min 18 sec
Approach	1 min 4 sec
Landing	15 sec
Taxi to Apron	2 min 17 sec

Because EDMS does not include the run-up mode, the average fuel consumed during run-up was estimated based on fuel consumption data derived from engine operational manuals for four typical single-engine aircraft operating in the run-up mode.[10] The average fuel consumption for these four engines was 7 gallons per hour. For the twin-engines, data from two aircraft operation manuals were used.[11] These manuals reported average fuel consumption during engine run-up of 13 gallons per hour.

[10] Based on operation manual fuel flow curves for four single-engines (Lycoming IO360, Lycoming IO320, Lycoming GSO480 and TCM IO550) operating at recommended rpm.
[11] Lycoming TIO-540-J2B2 and TCM TSIO550

Average engine revolutions during run-up were 1,900 rpm. However, upon review of the site survey fleet data,[12] it was determined that the simple average for the four typical single engines was not representative. The two most common engines at SMO are the Lycoming IO-360 and IO-320, which combined comprise 92% of the single engines. The weighted average of the fuel economy for those two engines provides a fuel consumption rate of 5.0 gallons per hour. This is about 28% lower than the simple four-aircraft average and was considered more representative of the single-engine run-up fuel consumption rate at SMO. Table 4-4 shows the final fuel consumption rates for each operational mode used in the SMO modeling.

Table 4-4. Fuel Consumption Rate (g/s) within Each Operational Mode at SMO

Single Engine			Twin Engines	
Taxi Out	1.6		Taxi Out	5.1
Takeoff	15.3		Takeoff	50.0
Climb out	11.7		Climb out	38.8
Approach	6.6		Approach	20.6
Taxi in	1.6		Taxi in	5.1
Run-up	3.8		Run-up	9.9

Four helicopter piston-engines were used in EDMS 5.1 to estimate fuel consumption per LTO cycle. Table 4-5 lists the four types of helicopter engines and their Pb emission rate per LTO cycle, assuming a Pb concentration in avgas of 2.12 grams per gallon and a 5% engine retention rate.[13] These four engine types were averaged and then allocated across time-in-mode as shown in Table 4-6. The operations manager at SMO estimated that about 25% of all helicopters have piston engines using avgas, therefore helicopter counts were multiplied by 0.25 to include only Pb-emitting-helicopters in the analysis.

Table 4-5. Average Fuel Consumption for Helicopter Engine Type per LTO

Helicopter Engine Type	Fuel Consumed (g Pb/LTO)
Robinson R22 IO-320-D1AD	5.55
Robinson R22 IO-360-B	5.97
Robinson R22 O-320	6.28
Robinson R22 TSIO-360C	8.60
Average	6.60

Table 4-6. Helicopter Time-in-mode Estimates

Mode	Time
Taxi Out	3 min 30 sec
Climb	6 min 30 sec
Approach	6 min 30 sec
Taxi In	3 min 30 sec
Total Time for LTO cycle	20 min

[12] The airport survey identified aircraft as single- or twin-engine in two ways. First, by visual observation of the aircraft and second by the tail number of the airplane. Tail numbers were cross-referenced with the FAA tail number database which provided engine type and number of engines. In cases where the two numbers did not match, the observed aircraft type was used as a default since tail numbers are sometimes reassigned.
[13] The information used to develop this estimate is from the following references: Peterson (2008) and Rindlisbacher (2007).

Emission Calculations

Single- and multi- engine piston-powered aircraft emission rates were estimated based on the following equation for each individual operation mode:

$$Emissions(g/s) = \frac{(fuel/s)\times(Pb/gal)\times(s/mode)\times Count\times(1-RetentionRate)}{(s/hr)\times(g/gal)}$$

fuel/s	=	The amount (in grams) of fuel consumed per second in the particular operation mode.
Pb/gal	=	Amount of Pb in grams per gallon of aviation fuel (2.12 g/gal).
s/mode	=	Average duration (in seconds) that the aircraft is the particular operation mode.
g/gal	=	Weight of avgas fuel per gallon (2730.6 g/gal).
Count	=	Number of aircraft type per hour.
RetentionRate	=	The fraction of Pb that is retained in the engine after the fuel is consumed (5%).
s/hour	=	Number of seconds per hour (3,600).

Helicopter emission rates were estimated based on the following equation for each individual operation mode:

$$Emissions(g/s) = \frac{(Pb\ emiss\ \ per\ \ LTO)\times Count\times(1-RetentionRate)\times(FractionPiston)}{(s/hr)}$$

Where:

Pb emiss per LTO	=	Number of grams of Pb emitted over LTO cycle for a single helicopter.
Count	=	Count of helicopters completing an LTO per hour.
Retention Rate	=	The fraction of Pb that is retained in the engine after the fuel is consumed (5%).
FractionPiston	=	Percentage of total helicopters that have piston engines (25%).
s/hour	=	Number of seconds per hour (3,600).

Emission Totals

Tables 4-7 and 4-8 present the Pb emissions by aircraft type and mode, respectively. These figures show that single-engine aircraft dominate the Pb emissions at SMO and that climb-out and approach modes account for nearly half of Pb emissions. However, as will be discussed later in this chapter, these two sources are relatively minor contributors to the maximum downwind Pb concentration.

Table 4-7. Pb Emissions (kg/yr) by Aircraft Type (2008) at SMO

Aircraft Type	Lead Emissions (%)
Single	107.5 (90.7)
Multi	8.5 (7.2)
Helicopter	2.6 (2.2)

Table 4-8. Pb Emissions (kg/yr) by Aircraft Mode (2008) at SMO

Mode	Lead Emissions (%)
Taxi To Runway	20.4 (17.6)
Run-up	13.5 (11.4)
Takeoff Roll	10.0 (8.4)
Climb-out	37.9 (32.7)
Approach	17.9 (15.8)
Landing	9.4 (7.9)
Taxi to Apron	9.5 (8.4)

Source Locations

The horizontal and vertical locations of the single- and multi-engine piston-powered aircraft emissions used in this study were based on Santa Monica Airport's Fly Neighborly Program, which identifies the preferred fixed-wing operational departure and arrival pathways (http://www01.smgov.net/airport/n_fixedwing.aspx). The flight pathway is the same as was used in the *Report on the Generation and Downwind Extent of Emissions Generated From Aircraft and Ground Support Operations (*Piazza, 1999*)*. Likewise, the location of helicopter emissions were developed based on the description provided in Santa Monica Airport's Fly Neighborly Program, which also identifies the preferred helicopter operational departure and arrival pathways (http://www01.smgov.net/airport/n_helicopter.aspx). These flight paths were divided into a discrete number of source locations for modeling.

Table 4-9 provides summary information on each mode for each aircraft type, including the number of source locations per mode and the altitude range during the mode. Figure 4-2 shows the horizontal location of each discrete emissions source per aircraft type and per mode. In the key in Figure 4-2, "Airplane" corresponds to both single- and multi-engine piston-powered aircraft. Figures 4-3 and 4-4 show the aircraft positions in a three-dimensional illustration from the perspective of a few hundred meters above the ground. Figure 4-3 faces eastward and Figure 4-4 faces westward, with neither differentiating between mode and aircraft type.

Table 4-9. Details on the Emission Source Positions for Each Mode of Each Aircraft Type

Aircraft Type	Mode	Number of Source Locations	Highest Point (m)	Lowest Point (m)	Description and Notes
Piston-engine	Taxi	33	1	1	Piston-engine aircraft are assumed to travel the full length of the taxiway. Single-engine aircraft approach only from the south taxiway. Multi-engine aircraft use the north and south taxiways equally.
Piston-engine	Run-up	1	1	1	Run-up is at the north end of runway.

Table 4-9. Details on the Emission Source Positions for Each Mode of Each Aircraft Type

Aircraft Type	Mode	Number of Source Locations	Highest Point (m)	Lowest Point (m)	Description and Notes
Piston-engine	Takeoff	31	113.7	1	Takeoff corresponds to the initial roll down about half the runway and then the aircraft's initial lift off of the ground until reaching the south end of the runway.
Piston-engine	Climb	11	182	118.4	Climb corresponds to the aircraft's position through about the first 0.5 km beyond the south end of the runway.
Piston-engine	Approach	37	145.8	39.24	Approach is from the northeast.
Piston-engine	Landing	31	21.8	1	Landing begins at the north end of the runway.
Helicopter	Taxi	33	1	1	Helicopters are assumed to use half the length of a taxiway. The north and south taxiways are used equally.
Helicopter	Climb	34	232.88	1	Helicopter departures begin halfway down the runway and are towards the south end of the runway. Helicopters then turn left (southward) at the end of the runway to fly over the Penmar Golf Course.
Helicopter	Landing	45	274.5	0	Landing begins above the north or south taxiway. Helicopters execute a 270-degree descending turn over the taxiway. The north and south taxiways are used equally.

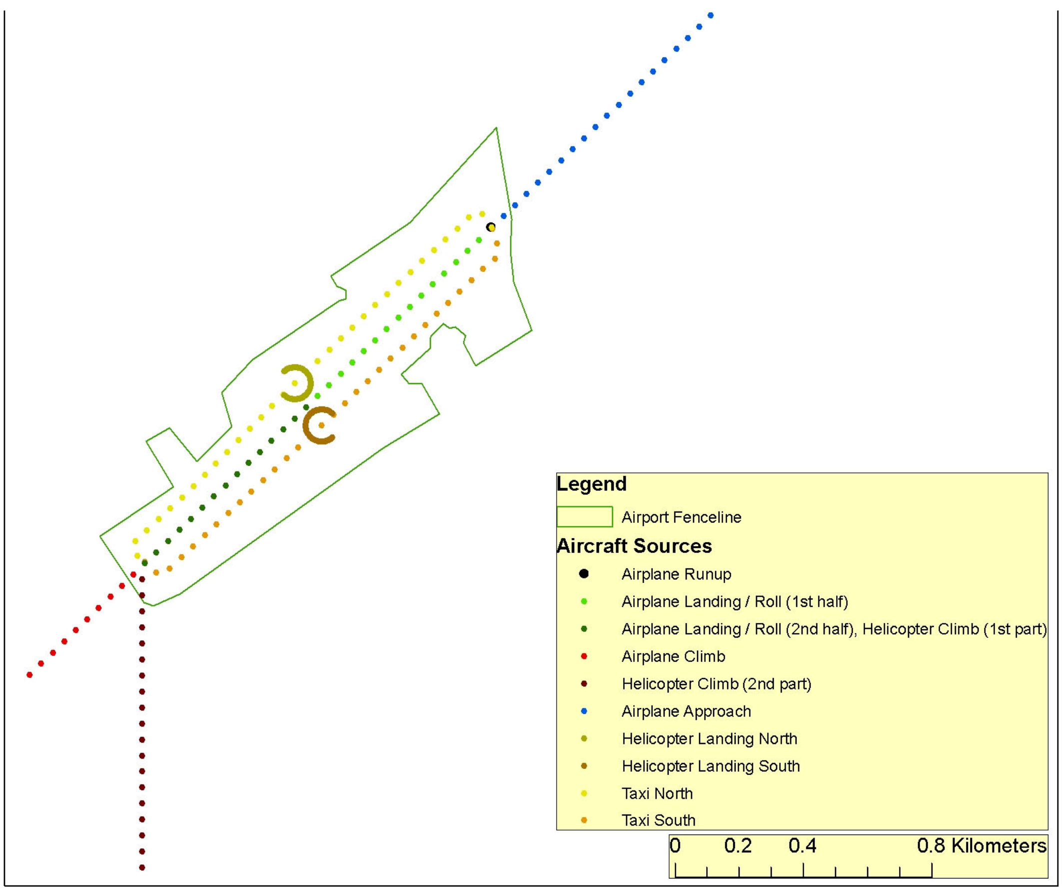
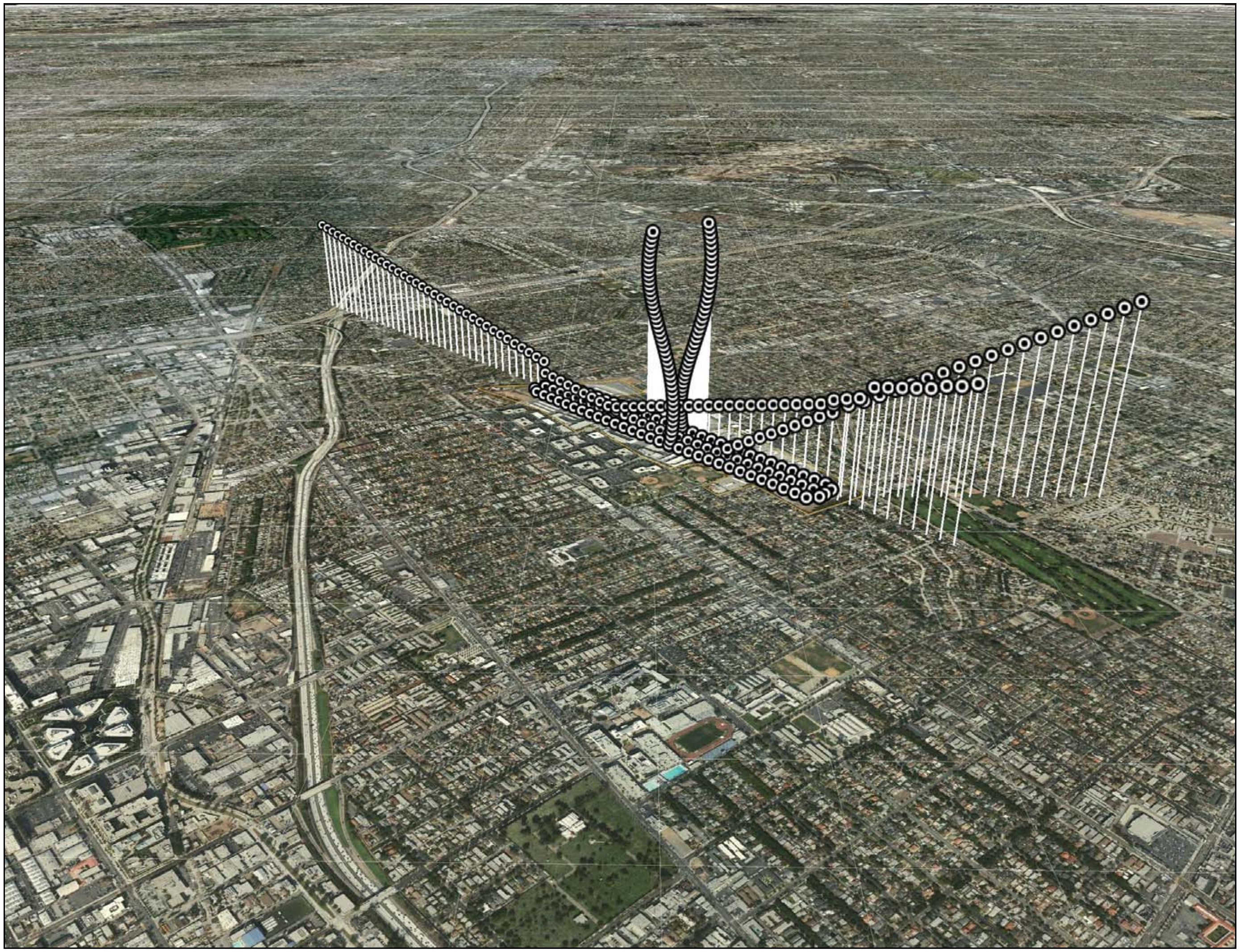


Figure 4-2. Location of each emissions source for each mode by type of aircraft.



Source: GoogleEarth background.

Figure 4-3. The Horizontal and vertical positions of emissions from fixed wing aircraft and helicopters (view is towards the east).

Source: GoogleEarth background.

Figure 4-4. The Horizontal and vertical positions of emissions from fixed wing aircraft and helicopters (view is towards the west).

4.1.2 On-road Sources

Gasoline and diesel fuel contain small quantities of naturally occurring Pb (~ 0.00005 g/L in gasoline [EPA 2006]). To accurately include these emissions in the air modeling impact assessment, roadways in close proximity to the airport were explicitly modeled. Other on-road mobile source emissions (e.g., resuspended road dust) were included as general area source emissions. The Pb emissions from gasoline and diesel vehicles for the three major arterials surrounding the airport that were explicitly included in the analysis are shown in Figure 4-5, and are described as follows:

- 23rd Street (from Ocean Park Blvd. to Rose St.);
- Ocean Park Blvd. (from 30th St. to South Bundy Dr.); and
- Bundy Dr. (from Ocean Park Blvd. to Airport Ave.).

Daily traffic counts with hourly resolution for Ocean Park Blvd. and 23rd Street were provided by the City of Santa Monica. The most recent traffic counts for these two roads were made in 2003. We used U.S. census population data[14] from 2000 to 2007 to project traffic changes for 2008 assuming traffic growth increased linearly with population growth. The population in Santa Monica between 2000 and 2007 only increased by 3,000 people, or 3.6%. Traffic data for South Bundy came from the City of Los Angeles[15] as this roadway is just outside the Santa Monica city limits. The most recent traffic counts available for South Bundy Dr. were for National Blvd. at South Bundy and were collected on November 18, 2003. As with the other two roadways, the traffic data were linearly scaled with Santa Monica population[16] to estimate traffic volumes in 2008. Table 4-10 provides the statistics on each road, including length, area, traffic count, and the year the traffic counts were collected.

The traffic counts did not include estimates on the fleet traffic mix (light duty automobiles, trucks and buses). An estimate of these fractions was obtained as follows. Bus data were retrieved from Santa Monica's Big Blue Bus system.[17] The system-wide map of bus routes was reviewed and only buses that travel on Ocean Park Blvd., South Bundy Dr., and 23rd St. were analyzed. Only bus routes 6, 8, and 14 travel on either Ocean Park Blvd., South Bundy Dr. or both. No buses were found to travel on 23rd St. The bus schedules were reviewed to estimate the number of buses per hour that traveled on each road. Santa Monica has a large fraction (43%) of buses operating with liquefied petroleum gas (LPG) that do not emit Pb. It was assumed that 43% of the buses traveling along Bundy and Ocean Park were fueled with LPG. Table 4-11 lists the total number of daily bus trips operating on Bundy and Ocean Park per weekday and weekend. An additional 5% of the traffic operating on these major arterials was assumed to be diesel fueled trucks.

[14] U.S. Census Bureau Population Trends: Santa Monica City, CA. Visited March 23, 2008. http://factfinder.census.gov/servlet/SAFFPopulation?_event=ChangeGeoContext&geo_id=16000US0670000&_geoContext=01000US%7C04000US06%7C16000US0670000&_street=&_county=santa+monica%2C+CA&_cityTown=santa+monica%2C+CA&_state=&_zip=&_lang=en&_sse=on&ActiveGeoDiv=geoSelect&_useEV=&pctxt=fph&pgsl=010&_submenuId=population_0&ds_name=null&_ci_nbr=null&qr_name=null&reg=null%3Anull&_keyword=&_industry=

[15] *http://ladot.lacity.org/tf_hist_auto_counts.htm*

[16] Santa Monica population data was used as the change in traffic along this roadway is more affected by Santa Monica population changes than the City of Los Angels which encompasses a population spread over an area of 470 square miles.

[17] http://www.bigbluebus.com/home/index.asp

Source: GoogleEarth.
Figure 4-5. Major roadways in close proximity to Santa Monica Airport explicitly modeled in AERMOD.

Table 4-10. Traffic Counts for the Three Major Roadways near Santa Monica Airport

Street	Length of Road (m)	Area of Road (m^2)	Daily Count	Year of Count
23rd St.	1,046	11,842	23,958	2003
Ocean Boulevard	853	17,343	31,295	1998
Bundy Dr.	821	16,803	17,700	2003

Table 4-11. Daily Bus Trips on Major Roadways near Santa Monica Airport

Street	Weekday	Saturday	Sunday
Bundy Dr.	68	46	32
Ocean Park Blvd.	74	39	39

Emission Calculations

Each roadway source's emissions were determined as follows:

$$Emissions\ g/s\left[g/s\left(\sec * m^2\right)\right] = \frac{\sum_{VehType}\left[\left(Count08_{VehType} * Veh\%_{VehTyp} * Len * EF_{VehTyp}\right)\right] * \left[HrFrac * \left(hr/3600s\right) * \left(g/1000mg\right)\right]}{Area}$$

Where:

$Count08_{VehType}$	=	The 2008 total traffic count for vehicle type, *VehType*
$Veh\%_{VehType}$	=	Fraction of vehicle count comprised of vehicle type, *VehType*. Diesel trucks accounted for 5% of vehicles. The percentage of vehicles that were diesel buses depended on the street, and was calculated by dividing the daily total vehicle count (Table 4-10) by the daily total bus count (in Table 4-11) assuming 57% were diesel fueled. The percentage of vehicles that were gasoline fueled vehicles was determined by (100% - 5% trucks - X% buses).
Len	=	Length of roadway (mile)
$EF_{VehType}$	=	Emission factor, in mg Pb per mile of roadway, for vehicle type, *VehType*. The hot stabilized summer emission factor of 0.002 mg of Pb/mile was used for gasoline vehicles (EPA, 2006; Table 2-19 as obtained from Cadle et al. (1999) from dynamometer testing of in-use, light-duty vehicles model years 1991-1996). The emission factor for diesel fueled truck and bus engines was 0.00724 mg/mile (EPA, 2006; Table 2-20 based on extensive profiles of diesel emissions as developed by Lowenthal et al. [1994])
HrFrac	=	The fraction of daily traffic activity per hour of the day, averaged across all three roads. These fractions are shown graphically in Figure 4-6. An average distribution was used to lessen the bias from the single day of sampling.
Area	=	The area of each roadway (square meters).

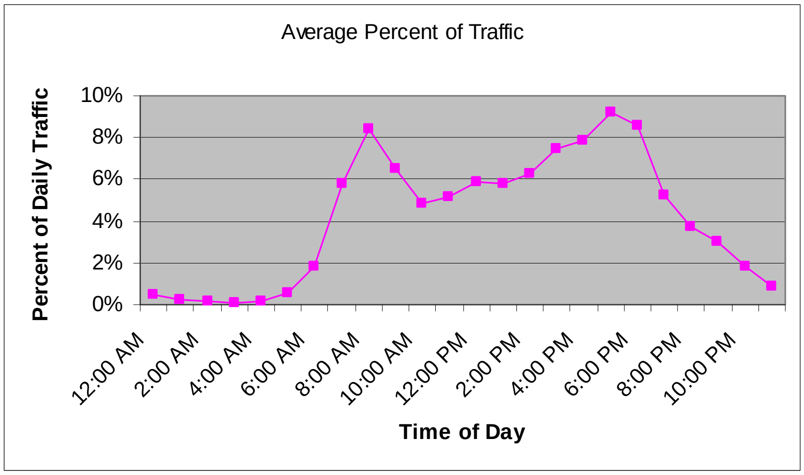


Figure 4-6. Hourly distribution of traffic on three major roadways surrounding Santa Monica Airport.

4.1.3 Area Source Emissions

The area source emission inventory for non-aircraft sources was developed based on the emission inventory previously prepared by SCAQMD and the California Air Resources Board (CARB) for the Multiple Air Toxics Exposure Study III (MATES-III) (SCAQMD, 2008). These emissions include all mobile source emissions not discussed in the preceding sections (e.g., brake and tire wear, re-entrained road dust), and all other types of non-road sources (e.g., construction dust, locomotives, fuel combustion, cooking). MATES-III started with a 2002 baseline emissions (as used in the 2007 Air Quality Management Plan [AQMP]) and was updated to 2005, which was the central year analyzed in MATES-III. Emissions specific to source categories (or Source Classification Codes, SCCs) and to distinct 2x2-km grids were developed for the following criteria pollutants and for total organic and total suspended particulates. Pollutant groups speciation were based on the CARB speciation profiles:

- Carbon monoxide;
- Nitrogen oxides;
- Sulfur oxides;
- Total organic gases;
- Total suspended particulates;
- Particulate matter, 10 micrometers and smaller (PM_{10}); and
- Particulate matter, 2.5 micrometers and smaller ($PM_{2.5}$).

The source categories and source classification codes (SCCs) analyzed were part of three larger groups of area sources: non-mobile area sources, on-road mobile sources (in two groups: heavy-duty vehicles and light- and medium-duty vehicles), and off-road mobile sources. For each of the non-mobile categories, a category-specific methodology was used by SCAQMD to derive the criteria pollutant emissions. For on-road mobile sources, emission factors from CARB's EMFAC2007 (v2.3) were coupled with traffic activity data from the regional transportation modeling performed by the Southern California Association of Governments (SCAG). The coupling of emission factors (g/mile) and traffic activity data (vehicle miles traveled) was done using the Caltrans' Direct Travel Impact Model (DTIM) to generate hourly gridded emissions. For off-road mobile sources, we used CARB's OFF-ROAD model, which incorporates regulations, technology types, seasonal conditions, equipment population, equipment activity, horsepower and load factors, and emissions factors to produce annual emissions. The annual emissions were scaled to seasonal emissions using spatial and temporal features of the various area grids. This analysis excluded from the SCAQMD area source inventory the off-road emissions from aircraft using leaded aviation fuel, as these emissions were already developed as described in the previous sections.

Nine 2x2-km area source grids from the SCAQMD air emission inventory centered approximately on the Santa Monica Airport were used to estimate the area source emissions in the vicinity of Santa Monica Airport. The SCAQMD 2x2 km emission inventory of annual PM_{10} emissions was then used for each source category or source classification code within each grid in combination with speciation profiles to estimate the area source Pb emissions. Speciation profiles were based on several sources as shown in Table 4-12. The paved road dust and engine exhaust are, to a small degree, a double counting of the on-road emissions as included for 23rd Street, Ocean Blvd and Bundy, however the emissions here are distributed over an area of 4 square kilometers and the three additional streets explicitly included represent an increase of less than 0.1 in Pb emissions.

Table 4-12. Pb Emission Factors For Selected Area Sources

Source Type	Weight Percent of PM_{10}	Weight Percent of $PM_{2.5}$
Unpaved road dust[1]	0.013	0.013
Cooking[1]	0.0015	0.0014
Construction dust[1]	0.07	0.083
Paved road dust[2]	0.0077	0.0077
Gasoline engine exhaust[3]	0.016	0.016
Diesel engine exhaust[3]	0.016	0.016
Locomotive[4]	0.03	0.03
Commercial Ships[4]	0.03	0.03

[1] General speciation profiles CARB (2002)
[2] Site-specific road-side soil samples measured in July 2009 at the northern corner of the airport (Bundy Dr. and Ocean Park Boulevard)
[3] Health Effects Institute (HEI) Tunnel Study (HEI, 2006)
[4] EPA supplied information

SCAQMD also provided cycle codes to partition the annual emissions to either: (1) each month, day of the week, and hour of the day (for non-mobile and off-road sources), or (2) each hour of the day (for on-road emissions). The SCAQMD SCC code for the entrained road dust category for paved roadway indicated a flat diurnal profile. This profile was replaced with the diurnal profile for light- and medium-duty vehicles as entrained road dust from paved roadways is expected to be closely related to vehicle activity levels.

All area source categories combined accounted for approximately 67 kg/year of Pb across all nine area source grid cells. The total Pb emissions across all area source types (except piston-fired aircraft) for each Level 1 and Level 2 source classification code are presented in Table 4-13. Entrained road dust sources dominate the collective area source emissions when piston-fired aircraft are excluded, with a total of 41 kg/year of Pb spread over the 36 square kilometer area. By comparison, the Santa Monica airport piston-fired aircraft emissions (exclusive of climb-out and approach) total about 53 kg/year over an area of just one square kilometer. The following three groups of categories together account for another 26% of the total area source Pb emissions:

- Dust from construction and demolition activities accounts for about 6.6 kg/year of Pb (about 10% of the total area source Pb emissions);
- Diesel and gasoline PM from exhaust emissions from on-road vehicles account for about 5.7 kg/year of Pb (about 9% of the total area source Pb emissions); and
- Cooking activities account for about 5.2 kg/year of Pb (about 7% of the total area source Pb emissions).

Table 4-13. Total Area Source Pb Emissions, Across All Nine Area Source Grids

Source Classification Code Level 1 Description	Source Classification Code Level 2 Description	Total Pb Emissions (kg/year)
Paved Road Travel	Entrained Road Dust	38.5
Cooking	Commercial Charbroiling	4.22
Construction And Demolition	Building Construction Dust- Commercial	3.40
Paved Road Travel	Diesel PM [tailpipe exhaust emissions]	3.18
Unpaved Road Travel	Entrained Road Dust	2.70
Paved Road Travel	Gasoline PM [tailpipe exhaust emissions]	2.49
Construction And Demolition	Construction And Mining Equipment	1.93
Construction And Demolition	Building Construction Dust - Institutional	1.79
Paved Road Travel	All Brake Wear	1.39
Construction And Demolition	Building Construction Dust - Residential	1.39
Cooking	Cooking (Unspecified)	1.02
Paved Road Travel	All Tire Wear	9.84E-01
Construction And Demolition	Building Construction Dust- Industrial	5.40E-01
Service And Commercial	Other	3.02E-01
Service And Commercial	Transport Refrigeration Units	2.91E-01
Service And Commercial	Road Construction Dust	2.85E-01
Service And Commercial	Production	2.77E-01
Mineral Processes	Grinding/Crushing	1.91E-01
Mineral Processes	Fuel Combustion - Water Heating	1.82E-01
Mineral Processes	Fuel Combustion - Space Heating	1.81E-01
Mineral Processes	Commercial	9.62E-02
Unplanned Fires	Automobile Fires	9.53E-02
Trains	Locomotives	7.30E-02
Trains	Other	7.08E-02
Trains	Lawn And Garden (Commercial)	6.99E-02
Trains	Other	6.67E-02
Other (Fuel Combustion)	I.C. Reciprocating Engines	5.58E-02
Other (Fuel Combustion)	Lawn And Garden (Residential)	5.08E-02
Other (Fuel Combustion)	Dust From Unpaved Roads And Associated Areas	4.81E-02
Other (Fuel Combustion)	Structural Fires	4.49E-02
Other (Fuel Combustion)	Commercial (Residential)	3.73E-02
Residential Fuel Combustion	Fuel Combustion - Cooking	3.73E-02
Residential Fuel Combustion	Lawn And Garden (Other)	3.52E-02
Residential Fuel Combustion	Manufacturing	3.12E-02
Residential Fuel Combustion	Space Heating	3.05E-02
Residential Fuel Combustion	Water Heating	2.93E-02
Residential Fuel Combustion	Surface Blasting	2.82E-02
Fugitive Windblown Dust	Dust From Pasture Lands	2.10E-02
Metal Processes	Secondary Production	1.21E-02
Manufacturing And Industrial	I.C. Reciprocating Engines	1.21E-02
Manufacturing And Industrial	Sand And Gravel Excavation And Processing	8.48E-03
Manufacturing And Industrial	Metrolink	5.81E-03
Manufacturing And Industrial	Other	5.72E-03
Manufacturing And Industrial	Other	4.72E-03
Manufacturing And Industrial	Commercial (Other)	4.01E-03
Off-Road Equipment	Airport Ground Support Equipment	3.13E-03
Fuel Combustion	Other	1.83E-03
Fuel Combustion	Trains	1.26E-03

Table 4-13. Total Area Source Pb Emissions, Across All Nine Area Source Grids

Source Classification Code Level 1 Description	Source Classification Code Level 2 Description	Total Pb Emissions (kg/year)
Fuel Combustion	Military Tactical Support Equipment	1.04E-03
Fuel Combustion	Other	2.53E-04
Fuel Combustion	Resource Recovery	3.93E-05
Fuel Combustion	Entertainment	2.81E-05

4.1.4 Point Source Emissions

Point sources of Pb include[18] sources such as Pb battery recyclers and battery manufacturers, Pb smelters, waste incineration, metal industries and glass manufacturers. The SCAQMD maintains an emission inventory based on a permit inventory for point source facilities throughout the district. SCAQMD provided the location, source code, operation frequencies, and Pb emissions information for 566 point source facilities within the South Coast Air Basin. These point source locations and emissions are representative of the year 2006, and it was assumed that these data were also representative of 2008. Pb emissions for each facility were provided by SCAQMD at the source category code (SCC) level. Some facilities reported multiple SCCs associated with Pb emissions.

Initially, we proposed modeling all point sources within a 20 km radius of SMO. The 86 Pb-emitting point source facilities within 20 km of the airport emitted a total of 27.5 kg/year of Pb. However, a number of facilities emitting relatively large amounts of Pb were located just outside this radius. These additional facilities emitted a total 1,877.8 kg/year of Pb (see Figure 4-7) and were dominated by a single facility (Exide Technologies – a Pb-acid battery recycling plant as shown on Figure 4-7) that emitted 1,813.5 kg/year Pb. In order to include these substantial Pb emissions in the model, all 144 Pb-emitting point sources within a 25 km radius of the airport were included in the air quality modeling. The Exide Technologies facility and the seven other facilities that together make up 99.5% of the point-source Pb emissions within 25 km of the airport are shown in Table 4-14. Appendix B shows more details on each Pb-emitting SCC at each of the 144 lead-emitting point sources.

Data on physical stack parameters (stack height, diameter, exit gas temperature, and exit gas velocity) are needed to model each Pb emissions point source. While SCAQMD was not able to provide any physical stack parameters as part of their permit inventory, point source facilities can voluntarily report emissions, stack, and process information at the pollutant-level to the EPA's National Emissions Inventory (NEI). However, some of the facilities provided by SCAQMD could not be found in the NEI. In these cases, emissions data from SCAQMD were used and physical stack parameters were estimated based on parameters provided in the NEI for similar facilities and processes.

The facilities provided by SCAQMD were manually cross-referenced to the facilities contained in the 2002 EPA National Emissions Inventory (NEI) Version 3. Though the 2005 NEI is the most current NEI available, it was in its early stages of development at the time of analysis (early 2009) and evolving quickly. The 2002 NEI was selected because it was likely a more quality-assured and stable dataset. In order to account for possible geographic coordinate discrepancies between facilities in both the SCAQMD and the NEI, all Pb-emitting facilities in the 2002 NEI Version 3 that were within 27 km of the airport were manually matched to the facilities provided by SCAQMD that were within 25 km of the airport. The facility matching was based on facility coordinates, facility name, and facility address.

[18] Many other source types are located at fixed locations, but are not significant enough in terms of emissions that they are listed as point sources.

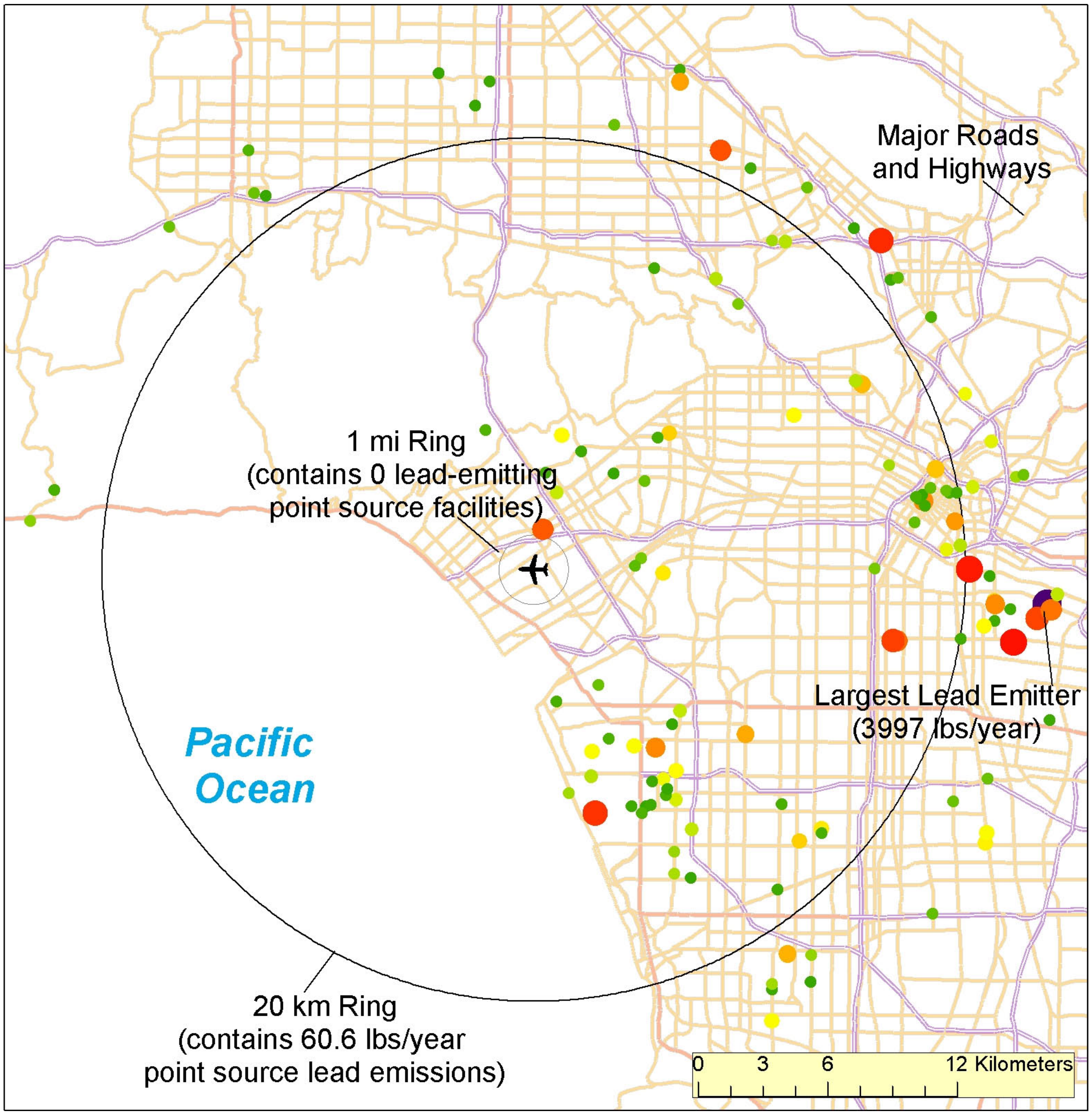


Figure 4-7. Point source facilities emitting Pb near Santa Monica Airport. (Larger circles and warmer colors reflect greater Pb emissions.)

Table 4-14. Facilities that Comprise 99.5% of Point Source Pb Emissions Within 25 km of SMO

Facility Name	Facility City	Facility-Average Latitude (UTM 11N)	Facility-Average Longitude (UTM 11N)	Lead Emissions (kg/year)	Cumulative Percentage Lead Emissions
Exide Technologies	Los Angeles	3763256	389792	1,813.5	95.2%
Owens-Brockway Glass Container Inc	Vernon	3761510	388230	27.7	96.6%
Liberty Mfg Inc	Los Angeles	3764900	386169	19.1	97.6%
Chevron Products Co.	El Segundo	3753601	368842	10.4	98.2%
Glendale City, Glendale Water & Power	Glendale	3780120	382110	10.3	98.7%
Chevron Products Co.	El Segundo	3753601	368842	8.1	99.1%
The Strelitz Co Inc	Los Angeles	3761559	382680	3.9	99.4%
U S Radiator Corporation	Vernon	3762592	389333	2.8	99.5%

Among the 144 SCAQMD Pb-emitting facilities within 25 km of the airport, 22 facilities were matched to facilities in the NEI. Some of the 117 SCAQMD facilities not matched to the NEI may actually be in the NEI, but the facility data presented in each database were not consistent enough to make a match without further information. For each of the 22 Pb-emitting point source facilities provided by SCAQMD that were manually matched to the Pb-emitting point source facilities in the NEI, the physical stack parameters of all Pb-emitting sources at the facility were averaged together.[19] These facility-level averaged physical stack parameters were then used in the air quality modeling.

For facilities not matched to the NEI, each SCC associated with Pb emissions at a facility was cross-referenced to the "Stack Parameters SCC" table within the 2002 NEI Version 3 Stack Parameter Default database. This stack parameter default database provides averages of the physical stack parameters per SCC based on all data in the 2002 NEI Version 3. This SCC match was successful for all but one data record (a record at the SCAQMD Facility ID 800016). For this one data record that was not assigned estimated physical stack parameters based on NEI facility data or on NEI SCC data, the record's source industrial classification (SIC) was cross-referenced to the "Stack Parameters SIC" table within the stack parameter default database. Appendix B shows the physical stack parameters assigned to each SCC associated with Pb emissions at each of the 144 Pb-emitting point source facilities within 25 km of the airport.

In addition to Pb emissions, SCAQMD also provided operating schedules for the Pb-emitting point source facilities. The following operating schedule data were provided for each source location:

- Number of operating hours per day;
- Number of operating days per week; and
- Number of operating weeks per year.

All of the facilities were in operation at least 5 days per week and at least 48 weeks per year in 2006, but without more detailed information about which weeks a facility was non-operational, it was assumed that every facility was in operation for every week of the year. Also, all facilities operating 5 days per week were assumed to operate Monday through Friday. Since information was available on the number of operating hours per day, hourly emissions were developed for three day-of-week groups: weekday (Monday through Friday), Saturday, and Sunday. For example, if a facility was reported to operate 6 days of the week it was assumed to operate Monday through Saturday (see Appendix B for the hourly and daily operation schedules). For hourly operations, the SCAQMD inventory provided the number of hours per day that the facility operated. It was assumed that this hourly activity was centered on 1300 Local Time (LT), though we performed some rounding in order to obtain emission amounts for whole hours rather than half-hours. For example, if a facility operated 13 hours of the day, it was assumed to mean the facility operated 0630 LT to 1930 LT. However, in order for emissions data to occupy whole hours, it was first rounded up to the closing time of 2000 LT (i.e., operating through the 1900 LT hour). This rounding forced the opening time to be 0700 LT (2000 LT - 13 hours). Thus, a facility that operated 13 hours of the day would have emission estimates for the hours of 0700 LT through 1900 LT.

Ninety facilities were reported to operate 24 hours a day, 7 days a week. Of the 54 facilities that did not operate every hour of every day of the week, 37 operated only during 5 days of the week and 11 operated during 6 days of the week. Independent of the number of operating days per week, 25 facilities operated

[19] The 22 SCAQMD matched facilities were matched to 20 facilities in the NEI: 13 of the NEI facilities had only one Pb-emitting stack; 2 had 2 stacks with different stack parameters; 2 had 3 stacks (for one, 2 stacks were the same; for the other, all 3 stacks were the same); 1 had 4 stacks (3 were the same); 1 had 9 stacks (all different); and 1 had 27 stacks (26 were the same).

only 8 hours of the day, 7 operated 10 hours, 5 operated 12 hours, 1 each operated 13 and 14 hours, 8 operated 16 hours, and 3 operated 18 hours.

4.1.5 Emissions Summary

Table 4-15 summarizes the emission inventory in the vicinity of Santa Monica Airport. The inventory shows the emission rates as discussed in each subsection of this Chapter. It should be noted that the area source emission category, while a relatively large source category, is distributed over some 36 square kilometers, while the emissions from the piston-engine aircraft are mostly concentrated within the 0.81 square kilometer of the Santa Monica Airport.

The total emissions for the piston-engine aircraft total some 118.6 kg/yr. This compares with the approach that uses national default data, as described in Section II of EPA (2008), which estimated annual Pb emissions at Santa Monica in 2002 of 363 kg. The inventory developed here reflects an improved inventory because it makes use of site specific information including:

- the fleet of aircraft operating at Santa Monica;
- activity data from 2008 rather than 2002;
- facility specific time-in-mode activity for piston-engine aircraft; and
- the fraction of piston-engine aircraft that are single- versus twin-engine aircraft.

Table 4-15. Summary of the Lead Emissions Inventory for All Sources in the Vicinity of Santa Monica Airport (2008)

Source	Lead Emissions (kg/yr)
Area Sources[1]	67.0
Three Major Roadways	0.04
Point Sources[2]	27.5
Piston-engine Aircraft Emissions by Mode	
Taxi To Runway	20.4
Run-up	13.5
Takeoff Roll	10.0
Climb-out	37.9
Approach	17.9
Landing	9.4
Taxi to Apron	9.5
Total:	**213.1**

[1] Total emissions from all 9 2x2 km grid squares.
[2] All point sources with 20-km radius.

4.2 Model Selection and Configuration

The U.S. EPA's AERMOD (Version 07026) model was selected as the preferred model for the air quality analysis. AERMOD has undergone extensive model testing and evaluation in recent years and represents the current state-of-the-science. It is the most appropriate air quality model tool for assessing the Pb emission impacts from piston-engine aircraft using leaded avgas, as well as the other smaller but widely dispersed emission sources within the local community. The model includes treatment for an urban nighttime boundary layer; applicability for all terrain types; a state-of-the-science approach for characterizing the fundamental boundary layer parameters; a treatment for plume meander; and a state-of-the-science wet and dry deposition model. Both the plume meander and the updated planetary boundary layer surface and mixed layer scaling formulations are critical to the modeling of the near-field concentration gradient.

AERMOD was run using the following options:

- U.S. EPA regulatory default options;
- URBANOPT with default urban surface roughness;
- No treatment for building downwash effects;
- Direction-specific dispersion processing (land use based using AERSURFACE);
- Complex/intermediate terrain algorithms; and
- Wet and dry deposition.

The URBANOPT option was coupled with the URBANSRC keyword for developing a nighttime urban boundary layer. The urban boundary layer height was determined based on population, per discussion with the South Coast Air Quality Management District (Tom Chico), using a Los Angeles County population of 10,000,000.

Wet and dry deposition was included in modeling the air quality impacts. AERMOD has two methods for estimating dry deposition. Method 2 is used when the particle size mass distribution is not well known and only a small fraction of the total Pb mass is in particles with diameters larger than 10 microns. This is the case in this study so Method 2 was used in the analysis. Wet deposition makes use of hourly rainfall information using the algorithm implemented in AERMOD.

Point sources were modeled using standard point source information on location, stack height, stack diameter, exit velocity, and temperature. All aircraft-related emission sources were modeled as volume sources. Roadways near the facility (Bundy/Centennial, Ocean Park and 23rd St.) were modeled as "areapolygon" sources.

4.2.1 Runway Configuration and Aircraft Wake Turbulence

Fixed-wing Aircraft

To address the near-field spatial distribution of emitting sources and accommodate the characteristics of aviation source configurations, a grid spacing of 50 meters was used for the runway and takeoff and climb out for fixed-wing aircraft. This distance balances the computational requirements with sufficient source density to preserve the horizontal geometry of the source configuration and accurately simulate the near-field concentration gradient. The approach used here is similar to the approach developed by Piazza (1999) but with some additional enhancements, particularly for the modeling of the run-up.

Vertical (sigma z) and horizontal (sigma y) dispersion parameters were developed for moving (dynamic) sources following a mixing zone residence time approach. Sigma y parameters were developed by dividing the source separation distance by a standard deviation of 2.15; this is the standard methodology used in AERMOD. For initial sigma z, we used the mixing zone residence as defined in CALINE3 model by the following equation:

$$SZI = \left[(1.8 + 0.11) * \left(\frac{W2}{U}\right)\right] * \left(\frac{60}{30}\right)^{0.2}$$

Where:

SZI = initial vertical dispersion (m)

$W2$ = half width of the runway or taxiway (m)
U = average wind speed (m/s) over the modeling period
θ = angle between the runway and wind direction

This equation accounts for the longer time an air parcel spends in the turbulent mixing zone and hence the greater initial vertical dispersion. Initial sigma y and initial sigma z were developed for each mode of aircraft operation as described below:

Taxi

Initial sigma z

Width of taxiway = 80 feet (24.4 m) or W2 = 12.2 m; then apply equation above to estimate initial sigma z using the period average wind speed, U.

Initial sigma y

The horizontal separation distance between source centers is 50 m, thus the initial sigma-y = 50/2.15 or 23.8 m.

Takeoff/Approach/Landing/Climb-out (all treated the same)

Initial sigma z

Width = 35 feet[20] (average aircraft wingspan) or W2 = 5.34 m, using the equation above using the period average wind speed, U.

Initial sigma y

The horizontal separation distance between source centers is 50 m, thus the initial sigma-y = 50/2.15 or 23.8 m.

For the in-flight segment for fixed-wing aircraft, an additional consideration was made to account for the wake turbulence created by the forces that lift the aircraft. High pressure air from the lower surface of the wings flows around the wing tips to the lower pressure region above the wings. A pair of counter-rotating vortices is shed from the wings where the right and left wing vortices rotate. It is within this region of rotating air behind the aircraft where wake turbulence occurs. To account for this effect, the effective emission height was adjusted for the angle of climb (takeoff) and glide slope angle for landing. This adjustment lowers the effective emission height to approximate the maximum downward extent of the aircraft’s trailing wake. For SMO, this resulted in an angle of climb out for takeoff of approximately 4.8 degrees, while for landing this was 2.8 degrees.

[20] Based on Montgomery and Foster (2006).

Run-up

Initial sigma z

Initial sigma z (total) is a total combination of:

$$Height\ above\ ground + Exhaust\ buoyancy + Wind\ flow\ over\ stationary\ aircraft$$

Where:

Height above ground	=	1.0 m (typical tailpipe height on piston-engine aircraft)
Exhaust buoyancy	=	0.65 m[21]
Wind flow over stationary aircraft	=	Typically two aircraft undergo run-up testing in staging area (total area with safe separation distance 100 feet) thus W = 30.48 m or W2 = 15.24 m. Then the initial sigma z equation (SZI = (1.8 + 0.11* (W2 / U)) * $(60/30)^{0.2}$) is used to determine contribution from wind flow over aircraft.

Then sum these three terms using the period average wind speed, U, to estimate the initial sigma z

Initial sigma z

Initial sigma-y is a total combination of:

$$Wingspan\ wake + Horizontal\ momentum + propeller\ turbulence\ wake$$

Where:

Wingspan wake	=	Typically has two wing spans over run-up area (100 feet) or W=30.48 m, thus the initial sigma-y from wingspan wake = 30.48/2.15 or 14.18 m
Horizontal momentum	=	0.6 m[22]
Propeller turbulence wake	=	0.85 m[23]

Total initial sigma-y during run-up = (14.18+0.60+ 0.85) m = 15.63 m

Rotorcraft (Helicopters)

For rotorcraft, initial sigma z during idle was based on the typical piston-engine helicopter source height of 2.0 m divided by 2.15, or 0.93 m. Initial sigma y was based on the typical helicopter rotor width of 10 m divided by 4.13, or 2.33 m. For takeoff and climb-out, the flight pathway was based on what was used for the fixed-wing aircraft because Santa Monica's noise mitigation program asks that helicopters operate in the same flight path as fixed-wing aircraft.[24] For landing, the rotorcraft are asked to approach from the

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[21] Based on sensitivity test with SCREEN3 with and without exhaust temp of 573K.
[22] Based on a sensitivity test with SCREEN3 with and without typical exhaust flow of 100 ft^3 per minute
[23] Based on a typical 6-foot propeller size or 1.83 m; thus initial sigma-y equals 1.83 m/2.15 or 0.85 m
[24] City of Santa Monica – Requested Flight Paths (d) Helicopter, available at http://www01.smgov.net/airport/n_flights.aspx

north or south, perpendicular to the runway, and then descend in a circular motion through 270 degrees onto the taxiway with a descent rate of 3 m/s starting at about 275 m (900 feet). The wake turbulence also occurs for rotorcraft as high pressure air on the lower surface of the rotor blades flows around the tips to the lower pressure region above the blades. Consequently, air is forced in a downward trend below the main rotor. This combination of actions results in an angle of descent for rotorcraft of 3.7 degrees.

4.2.2 Terrain and Land Use

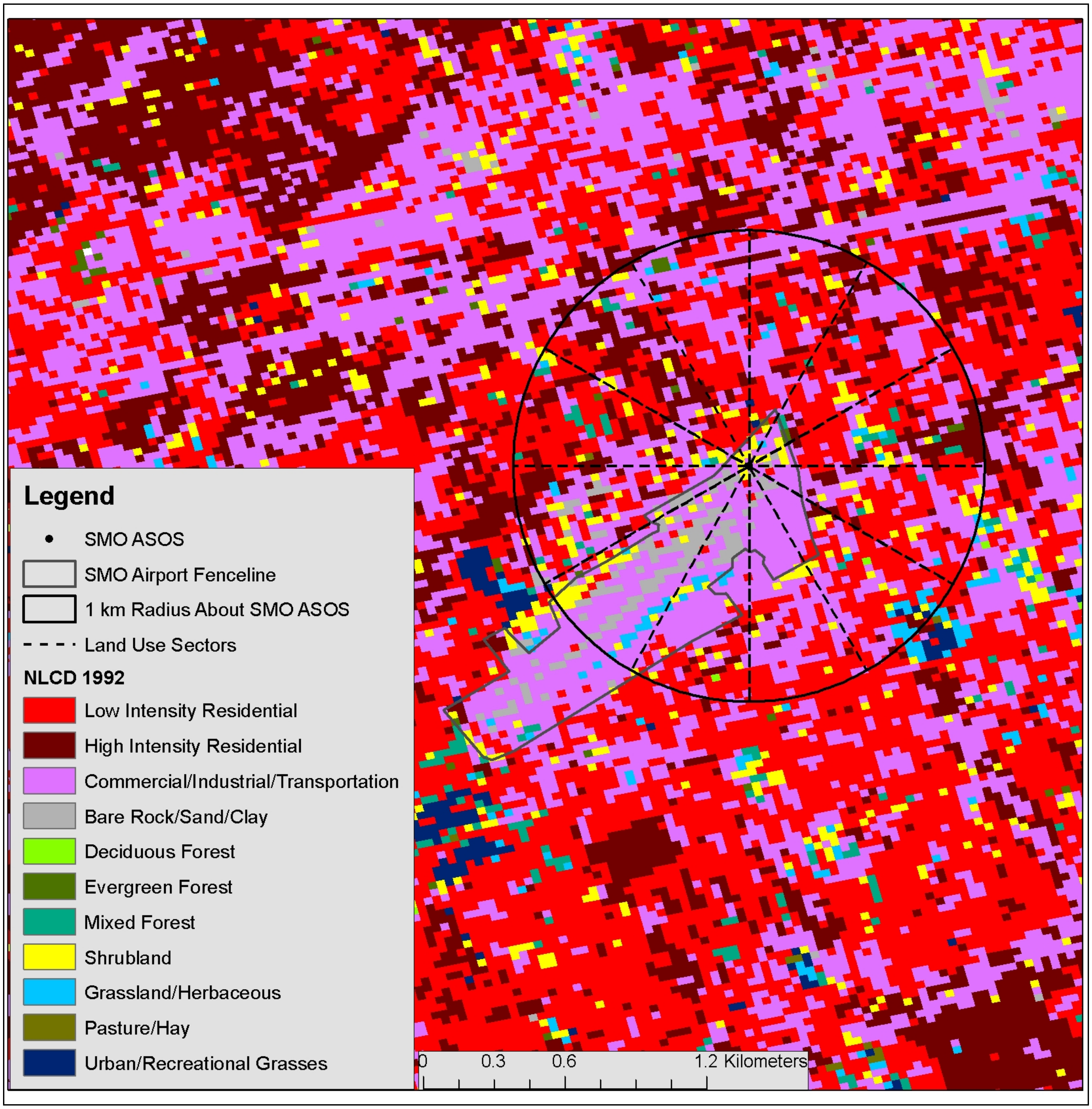
The preprocessor tool AERMAP was used to characterize the terrain height and hill height scale. This analysis used data from the Digital Elevation Model (DEM) dataset with 7.5-minute arrays and 30-m horizontal resolution. These data were also used to determine the heights for each of the receptor locations.

The preprocessor tool AERSURFACE was used to characterize the land use for the site and season specific albedo, Bowen ratio[25], and surface roughness length. AERSURFACE uses as input the land cover data from the U.S. Geological Survey (USGS) National Land Cover Data 1992 archives (NLCD92). Given that the area has been urbanized for well over 30 years, the 1992 land use was considered representative of the area today. The recommended surface roughness radius of 1-kilometer (centered on the meteorological tower) was used in determining the local surface roughness. Examination of the land use using GIS showed no obvious way to create sectors, thus generic 30-degree sectors were developed as shown in Table 4-16. Figure 4-8 illustrates the land use pattern in the vicinity of the ASOS meteorological tower. By far the three most predominant land uses within 1-km of SMO are low intensity residential, commercial/industrial/transportation, and high intensity residential, which combined comprise 86% of all land use types. By default, both the albedo and Bowen ratio were evaluated out to 10 km without a sector approach using AERSURFACE.

Table 4-16. Surface Land Use Types (%) within 1 Kilometer Radius of SMO

Sector	1	2	3	4	5	6	7	8	9	10	11	12	
Starting Direction	**0**	**30**	**60**	**90**	**120**	**150**	**180**	**210**	**240**	**270**	**300**	**330**	**Total**
Low Intensity Residential	30.9	16.1	38.1	44.8	61.9	58.1	47.1	29.9	41.0	34.5	38.1	41.1	40.1
High Intensity Residential	17.5	6.2	1.7	5.5	4.1	6.2	2.7	3.5	14.8	23.2	28.2	19.5	11.1
Commercial/ Industrial/ Transportation	33.7	50.7	46.7	41.0	26.5	28.5	43.3	45.5	28.6	20.8	24.7	25.3	34.6
Bare Rock/Sand/ Clay	8.6	18.8	0.7	0.0	0.0	0.0	0.7	9.0	2.4	3.1	2.1	3.1	4.0
Deciduous Forest	0.0	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Evergreen Forest	0.3	0.7	0.0	0.0	0.3	0.3	0.3	0.7	0.0	1.4	0.0	0.3	0.4
Mixed Forest	0.3	0.7	0.7	0.0	1.4	1.0	0.3	5.6	2.8	0.7	1.4	3.8	1.5
Shrubland	7.6	6.2	8.3	3.1	4.5	3.4	3.1	3.8	5.9	5.5	4.8	6.2	5.2
Grasslands/ Herbaceous	0.3	0.3	3.5	4.8	1.0	2.1	2.4	1.4	1.7	1.4	0.7	0.3	1.7
Pasture/Hay	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1
Urban/Recreational	0.7	0.0	0.0	0.7	0.0	0.3	0.0	0.7	2.8	9.6	0.0	0.0	1.2

[25] Bowen ratio: ratio of sensible heating to latent heating.



Source: NLCD (1992).

Figure 4-8. Land use in the Vicinity of the Santa Monica Airport.

Seasonal adjustments for input to AERSURFACE were made to reflect the two predominant seasons of the Mediterranean climate of Santa Monica: a rainy mild season from November through April and a very dry mild season from April through November. The albedo varied from 0.16 to 0.17 and the Bowen ratio from 1.91 (September through February) to 1.70 (March through August).

4.2.3 Meteorological Data

Santa Monica Airport began collecting meteorological data in March of 2007 using a Handar/Vaisala 2-D sonic anemometer for wind speed and direction. The meteorological tower is located near the north end of the runway. This sonic anemometer is able to measure low wind speeds (< 1 m/s) and an archive of the rolling 2-minute wind data (recorded every minute) is archived by the National Climatic Data Center

(NCDC). This wind monitoring system is operated as part of NOAA's Automated Surface Observation System (ASOS). The 2-minute average wind data were downloaded from the National Climatic Data Center website at: ftp://ftp.ncdc.noaa.gov/pub/data/asos-onemin/ for both the winter and summer monitoring periods, as well as the 2008 one-year modeling period. The wind data were then provided to EPA to process (using a utility that is being developed for eventual public release) 2-minute average wind speed and direction data into hourly averages for use in AERMET. This processing involves a number of steps dealing with issues such as missing data and data truncation. For periods in which the 2-minute wind data were missing, the routine hourly ASOS data as archived on the NCDC website was used in the analysis. In addition, these hourly data include the hourly temperature and cloud cover data for use in AERMET.

The nearest upper air station is the SCAQMD's RASS profiler located at LAX, which measures hourly virtual temperature profiles starting at about 150 to 200 meters above ground level with additional temperatures reported at about 60 meter intervals up to approximately 700 to 1500 meters, depending on atmospheric conditions. However, the profiler was down during both the summer and winter monitoring period and was also frequently intermittent during 2008. In its place we used the SCAQMD-recommended upper-air data from the Miramar Naval Air Station (KNKX), which is the station routinely used by SCAQMD in their air quality assessments.

In all cases, the meteorological data were processed through the AERMET (version 06341) using the upper-air data to determine the convective mixing height (an estimate of the potential daytime mixing height). The convective mixing height is determined from the surface temperature and the vertical variation in the potential temperature as observed from the morning sounding. The daytime mixing height is determined as the highest between the convective and mechanical mixing height. In addition, AERMET calculates the local sensible heat flux, convective velocity scale, vertical potential temperature gradient, and Monin-Obukhov length, all of which are used as input to AERMOD.

4.2.4 Background Ambient Conditions

Pristine background air quality concentrations have been summarized by EPA's Office of Air Quality Planning and Standards (OAQPS) in the Regulatory Impact Analysis (RIA) for the proposed revision of the Lead NAAQS (USEPA, 2008). The pristine background ambient Pb concentration in the RIA is 0.5 ng/m^3. Additional emissions from regional point sources and other area wide sources, as discussed earlier, increase pristine background levels to levels termed either 'regional' or 'urban' background levels. The regional background concentrations, as measured during MATES-III, ranged from 5 to 10 ng/m^3, as reported by SCAQMD for the basin-wide ambient air measurements of Pb concentrations made during the MATES-III monitoring program (April 2004 through March 2006). The monitored SCAQMD values are shown in Figure 4-9 below. The nearest monitoring site to SMO is Burbank.

4.2.5 Receptors

To fully define the spatial extent of elevated Pb concentrations within the vicinity of the airport, receptors were placed in a nested Cartesian grid with receptor spacing as follows:

- 50-meter grid spacing extending 1 km around the facility boundary; and
- 100-meter grid spacing extending out to 2 km around the facility boundary.

Receptors were also placed at 50 meter intervals around the airport boundary fence line. In addition, receptors were placed on the airport property to evaluate Pb concentrations where members of the general public may visit, such as the airport hangars, access roadways, and observation locations. The only area excluded was the active runway. A total of 178 on-airport receptors were identified. Figure 4-10 shows the location of the on-airport property receptors.

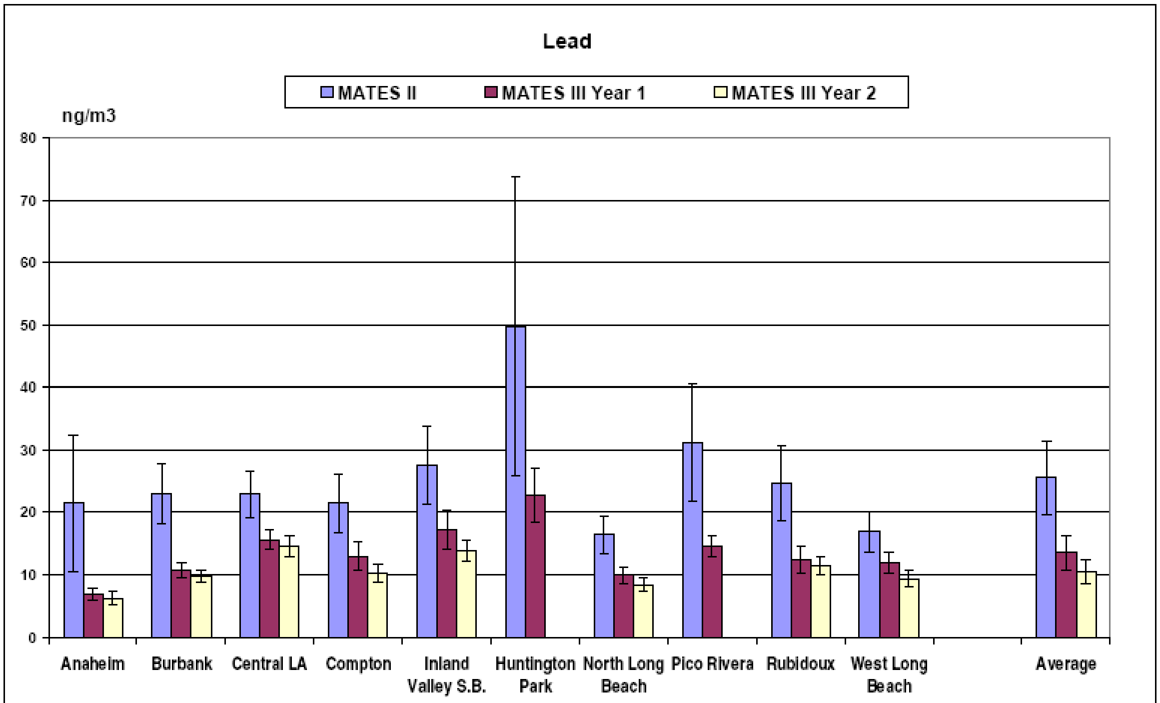


Figure 2-10 Average Concentrations of Lead in Total Suspended Particulate (TSP)

Source: MATES-III South Coast Air Basin, Final Report, September, 2008.

Figure 4-9. Ambient lead monitoring in the South Coast Air Basin (April 2004 – March 2006).

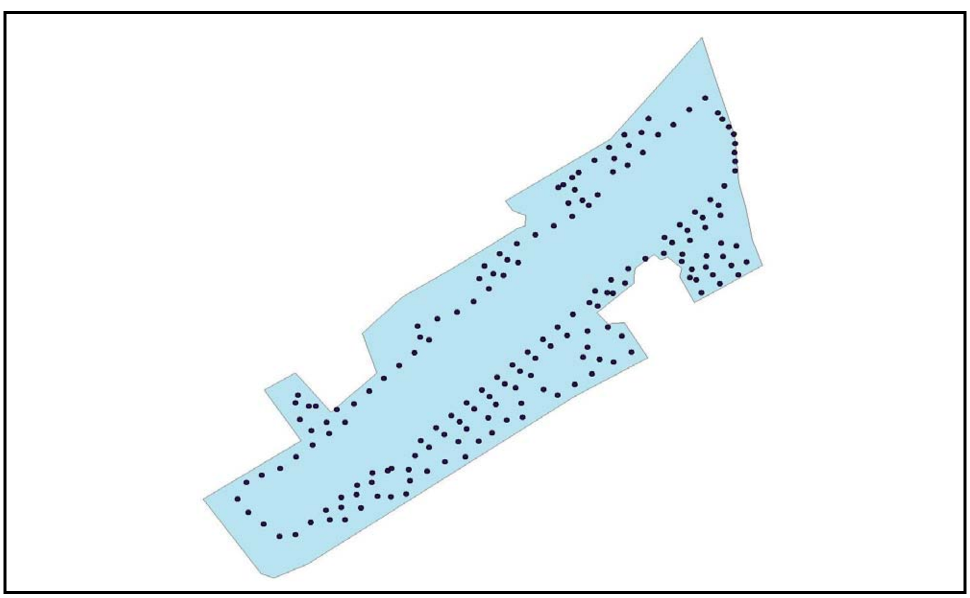


Figure 4-10. On-airport air quality modeling receptors.

Sensitive Receptors

Site-specific sensitive receptor locations were included within 2 kilometers of the airport. Sensitive receptors are specific locations where Pb concentrations are needed for the study. For this analysis we identified sensitive receptors for day care centers, senior centers, hospitals, schools, recreational areas, and playgrounds. Sensitive receptors were identified through a combination of ESRI ArcGIS v9.3 "shapefiles" and GoogleEarth. A total of 62 sensitive receptors were identified, including 28 schools, 21 churches, 2 hospitals/health centers, 7 parks/playgrounds/golf courses, 1 senior center, and 3 recreation centers. Figure 4-11 shows the locations of the nearby neighborhood and sensitive receptors.

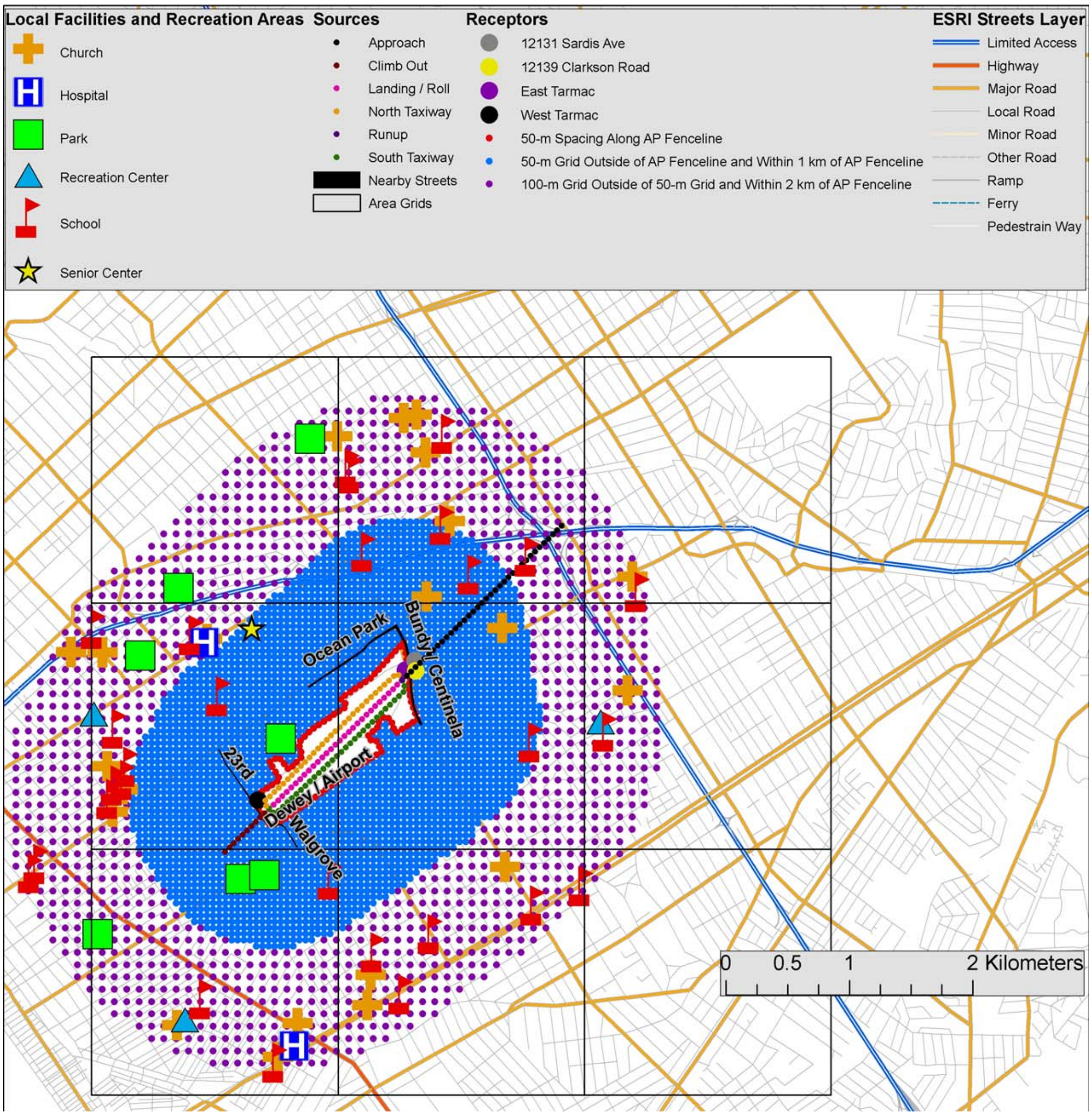


Figure 4-11. Air quality modeling receptors in the vicinity of SMO.

4.2.6 Selected Modeling Scenarios

This section first discusses the basis for the selection of the days for air quality modeling for the model to monitor comparison. For this model-to-monitor comparison, three days each were selected from the winter and summer air monitoring campaigns. Also discussed is the basis used for selecting the maximum 3-month average from the year long modeling of 2008, which was then used in the sensitivity analysis.

Winter Modeling Days

Ideal days for the model-to-monitor comparison are characterized as having a full set of Pb monitoring data for both the upwind and downwind monitoring sites as well as day-specific hourly meteorological data and information on the hourly aircraft activity data, particularly the number and type of piston-engine aircraft and duration of engine run-up times (these are important source contributors for the east tarmac and residential monitoring locations). The time-in-mode survey data on taxi, engine run-up, climb out, approach, landing and takeoff times were collected on March 13, 14, 15 and then again on March 27, 28 and 29. Subsequent review of the survey data showed that engine run-up time duration was improperly collected on three of these days and not representative of the actual period in which the aircraft engine operated at high RPM. Thus, the three remaining days (March 14^{th}, 28^{th} and 29^{th}) were selected for the winter model-to-monitor comparison.

Summer Modeling Days

Likewise, three days from the summer monitoring program were selected for model-to-monitor comparison. Monitoring was conducted from July 25^{th} through July 31^{st}. Unlike the winter program, no hour-specific aircraft activity data were collected. Thus, the availability of valid data and high concentrations were the determining factors for selecting the three preferred modeling days. The daily total number of piston-engine aircraft operations was provided by Santa Monica Airport staff. The two days with the highest monitored concentrations were July 26^{th} and July 28^{th}, which had similar high concentrations of 58 and 62 ng/m^3 at the East Tarmac site but had very different numbers of daily total piston-engine aircraft operations, 103 and 377, respectively. The meteorology appeared similar between these two days. These two days were selected for modeling to evaluate how well the model could simulate these differences in aircraft operations. The third highest day (without background) was July 27th and it was selected as the third day for the model-to-monitor comparison.

Modeling 2008 and the Maximum 3-month Average

All emission sources were modeled with AERMOD for each day of 2008. This was done to determine the local gradient in Pb concentrations and to identify the sources contributing to elevated ambient Pb in the vicinity of the airport. In addition, the modeling results for 2008 were analyzed to determine the maximum 3-month rolling average Pb concentrations at all receptors to provide data that could be compared with the National Ambient Air Quality Standard for Lead of 150 ng/m^3. The maximum 3-month average period was also the focus of the sensitivity analysis. All emission sources were modeled with AERMOD for all of 2008 and the the results were analyzed to determine the highest 3-month rolling average Pb concentrations. The analysis showed that the highest Pb concentrations occurred at most receptors during the summer months (June to August). Thus, the three summer months of June through August were selected as the maximum 3-month period for the sensitivity analysis.

A review of the general aviation activity data at Santa Monica Airport showed that month-to-month variation in general aviation and air taxi activity was small (less than 15% variation) in 2008 (Figure 4-12). Thus, the meteorology was the cause of the higher Pb concentrations modeled during the summer months (June to August). The meteorological factors influencing ambient Pb concentrations in the vicinity of the airport are discussed in Section 4.3.5.

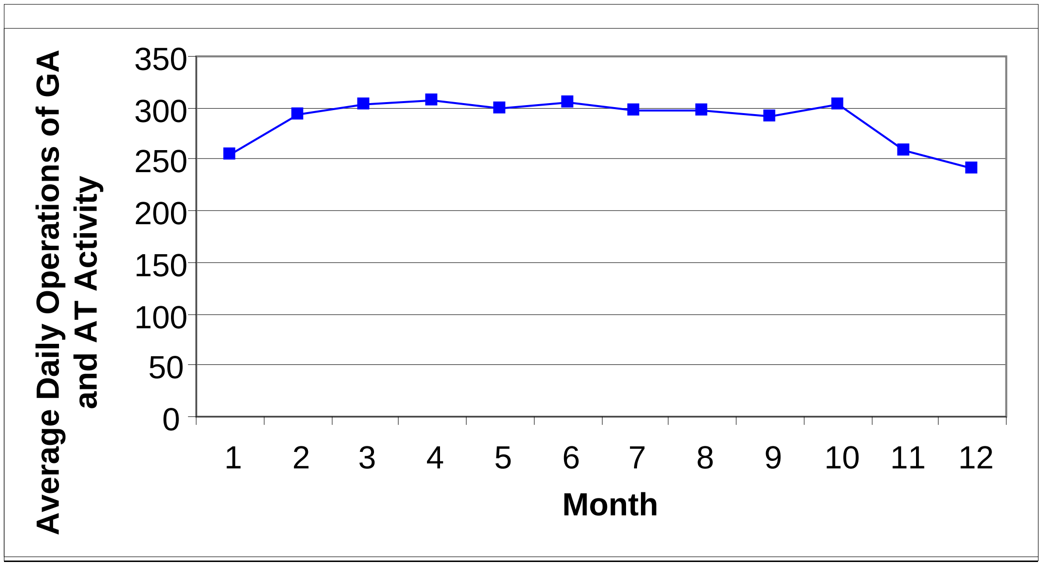


Figure 4-12. 3-month daily average general aviation (GA) and air taxi (AT) activity at Santa Monica Airport.

4.3 Modeling Results

4.3.1 Winter Model-to-monitor Comparison

Modeling results for the downwind receptors for the three March days are summarized in Table 4-17. For two of the three days (March 14th and March 29th), the modeled values paired in both time and space compare favorably to the measurements, with the mean absolute model-to-monitor difference less than 30%. On March 28th, AERMOD over predicts, but the differences appear to be driven primarily by a few high hours in the early evening hours. For all three days modeled, the bias was -16.9 ng/m^3, the absolute bias was 19.5 ng/m^3 and the absolute fractional bias was 0.29, well within a factor of two (0.67). The standard deviation was 17.4 ng/m^3 and the root mean square error was 5.8 ng/m^3.

Table 4-17. Model-to-Monitor Comparison for Winter 2009 at Santa Monica Airport Using ASOS SMO (1-min wind data)

Station	March 14th	March 28th	March 29th
	Modeled (ng/m^3)		
Clarkson	56.5	86.0	75.4
East Tarmac	46.1	61.8	94.1
	Observed (ng/m^3)		
Clarkson	41.7	N/A	44.9
East Tarmac	52.6	39.3	70.6

The time series results presented in Appendix C (Figures C-1 through C-6) show stacked plots of the modeled source contribution by emission source type: taxi, run-up, takeoff, climb-out, approach, and landing, with differentiation between southern (S) and northern (N) approach for taxi and landing as well as stratification by aircraft type – helicopter (H), multi-engine fixed wing aircraft (M) and single-engine fixed wing aircraft (S). The stack height for each source shows the relative contribution for that source type. In all cases, the single-engine run-up is the most important source contributor followed by the south taxi emissions from single-engines and then single-engine takeoff. This analysis of source contribution in the vicinity of the expected highest concentration reaches a markedly different conclusion about the most important emission source than an analysis that only examines total airport Pb emissions, which would show that approach and climb-out emissions are the most important emission sources. Finally, the time-series figures all show a strong increase in concentration during the late afternoon/early evening hours when a ground-based inversion acts to limit the vertical mixing leading to high ground-level concentrations. To some extent this is likely real, but the increase in ground-level concentrations is likely overstated by the model. Hourly Pb concentrations would be needed to evaluate this phenomenon.

Isopleth figures for each day modeled are presented in Appendix C (Figures C-7 through C-9). These figures show the elevated spatial Pb concentration gradient as well as monitored values. On the 14th, elevated concentrations above the Los Angeles basin-wide background concentration of 10 ng/m^3 extend to the northeast to about Stoner Ave., about 500 meters from the airport fence line, and then north-northwest to south-southeast from Ivy to Malone about 400 meters. Elevated Pb concentrations are also predicted in the observation deck area of about 15 ng/m^3. Spatial gradients on the 29th show elevated concentrations above the basin-wide background level extending to about 900 meters downwind and the concentrations in the observation deck area are predicted to be about the same as on the 14th. The 28th shows a similar pattern.

4.3.2 Summer Model-to-monitor Comparison

Modeling results for the three July days are summarized in Table 4-18. For two of the three days (July 26th and July 28th), the model-to-monitor comparison shows excellent model performance, with the mean absolute model-to-monitor difference less than 10%. For July 27th, AERMOD over predicts; however, the AERMOD results on this day are strongly influenced by a few high hourly concentrations during midday.[26] For all three days modeled, the bias was 5.7 ng/m^3, the absolute bias 4.4 ng/m^3 and the absolute fractional bias was 0.13, well within a factor of two (0.67). The standard deviation was 13.3 ng/m^3 and the root mean square error was 8.8 ng/m^3.

Table 4-18. Model-to-Monitor Comparison for Summer 2009 at Santa Monica Airport Using ASOS from SMO (1-min wind data)

Station	July 26th	July 27th	July 28th
Modeled (ng/m^3)			
East Tarmac	54.6	33.0	56.7
Resident 1	49.4	30.0	51.7
Resident 2	38.3	19.6	35.7
Observed (ng/m^3)			
East Tarmac	57.7	53.1	62.2
Resident 1	56.1[1]	37.9[1]	53.8[1]
Resident 2	33.1[1]	24.9[1]	33.6[2]

[1] Data are adjusted from operating hours of the airport to 24-hour averages assuming a South Coast Basin background concentration of 10 ng/m^3 during hours in which the airport is closed.

[2] Estimated 24-hour concentration as it was unknown when the air monitor stopped operating.

[26] Unlike the winter program, hourly activity information was unavailable for the summer program. The average piston-engine aircraft activity levels from the winter study were used in assigning the hourly activity levels.

The time-series results presented in Appendix D (Figures D-1 through D-9) show stacked plots of the modeled source contribution by emission source type: taxi, run-up, takeoff, climb-out, approach, and landing with differentiation between southern (S) and northern (N) approach for taxi and landing as well as stratification by aircraft type – helicopter (H), multi-engine fixed wing aircraft (M) and single-engine fixed wing aircraft (S). The stack height for each source shows the relative contribution for that source type. In all cases, the single-engine run-up is the most important source contributor, followed by the south taxi emissions from single-engines and then the single-engine landing or multi-engine run-up. The highest concentration from point sources (almost 13 ng/m^3) occurs on July 27th, hour 6-7, at the East Tarmac.

Similar to the winter sampling period, the time-series figures all show a strong increase in concentration during the late afternoon/early evening hours when a ground-based inversion acts to limit the vertical mixing, leading to high ground-level concentrations. To some extent this is likely real, but the increase in ground-level concentrations is most likely overstated by the model. Hourly Pb concentrations would be needed to evaluate this phenomenon.

Isopleth figures for each day modeled are presented in Appendix D (Figures D-10 through D-12). These figures show the elevated spatial Pb concentration gradient as well as the monitored values. On the 26th, elevated concentrations above the Los Angeles basin-wide background concentration of 10 ng/m^3 extend to the northeast to about Stoner Avenue, about 500-meters from the airport fence line, and then north-northwest to south-southeast from Ivy to Malone about 400 meters. Spatial gradients are predicted to be similar for the 28th. On the 27th, however, elevated concentrations above the basin-wide background level extend only to Berkshire, about 400 meters downwind, and the concentrations at the observation deck area are predicted to be less than 10 ng/m^3.

4.3.3 Summary of the Model-to-monitor Comparison

Overall, the model-to-monitor performance was considered good to excellent as the results show good agreement with observations, particularly on 4 of the 6 days modeled. Modeling results have been paired in both time and space and have shown good overall agreement, well within the factor of two frequently sited as a goal in model-to-monitored air quality evaluations. Modeling results consistently show that run-up emissions are a significant contributor to the highest concentrations at all of the downwind monitoring locations. In addition, both the summer and winter modeling studies made use of a detailed emission inventory for aircraft and other sources of Pb within 25 kilometers of Santa Monica Airport. This detailed emission inventory, along with the use of on-site ASOS data, were critical elements leading to the good to excellent model-to-monitor comparison.

Further model-to-monitor comparisons could potentially be performed using the other days for which ambient monitoring data were collected, as well as using the additional 24-hour Pb concentration data collected by South Coast AQMD between April 2006 and March 2007 and the airport activity data available from FAA's Air Traffic Activity Data System. A particularly interesting day to model would be November 19, 2006, which is when South Coast reported an observed daily average concentration of 299 ng/m^3 at the East Tarmac monitoring location.

4.3.4 Full Year Modeling Results

Air quality modeling was performed using AERMOD for the 2008 calendar year. Year-long modeling results are provided in Appendix E. These data were evaluated to describe the spatial gradient in Pb concentrations, the seasonal variability in Pb concentrations and the relative influence of roadway Pb on ambient Pb concentrations. As shown in Appendix E the rolling 3-month average results show a similar spatial pattern in air Pb concentrations over the entire year, but with higher concentrations extending further downwind of the prevailing wind direction during the summer months. Concentrations above the South Coast urban background of 10 ng/m^3 are modeled out to a distance of about 450 meters beyond the

East Tarmac during June-August, but only extend out to about 300 meters from the East Tarmac during the December-February period. The lateral extent of concentrations above South Coast background is about 300 meters along Bundy Drive during the summer and winter periods and gradually shrinks with downwind distance.

Roadway Contribution

The year-long modeling results were also used to assess the relative importance of Pb exhaust emissions from on-roadway sources[27]. For this analysis, modeled air Pb concentration data were examined by looking at upwind/downwind differences across 23rd Street over the one-year modeling period. A pair of upwind/downwind receptors, as shown in Figure 4-13, were chosen such that the airflow between the receptors crossed the roadway. The wind directions that satisfy these conditions are between 190 and 230 degrees. For 2008, a total of 1,984 hours fell within these wind directions. For all but one hour, the upwind concentration had zero concentration. Table 4-19 shows the average concentration differences in each 10-degree wind direction bin between 190 and 240 degrees. The maximum increase across the receptors (0.15 ng/m^3) occurred on December 10th with a wind direction of 194 degrees. The average increase for the 190-200 degree wind direction bin, however, was substantially less (0.029 ng/m^3). In Table 4-13 it is identified that the total entrained Pb road dust of 41.2 kg/yr is about 7.5 times higher than the total exhaust Pb emissions for the region (5.5 kg/yr). Thus the entrained Pb road dust average concentration should be no higher than 0.23 ng/m^3. The combined impacts from on-roadway mobile source Pb exhaust and entrained emissions are expected to be less than the average pristine ambient background concentration of 0.5 ng/m^3 and are therefore not expected to be a significant contributor to ambient Pb concentration levels. However, for 24-hour periods the Pb concentration from both exhaust and entrained road dust could reach as high as 1.3 ng/m^3.

4.3.5 Maximum 3-month Average Modeled Concentrations

The results from the full year 2008 modeling were compiled into 3-month rolling averages (e.g., January-March, February-April, March-May, etc.) to facilitate selection of the maximum 3-month average concentration period and to identify the meteorological conditions which influence the highest concentrations of Pb. As shown in Figure 4-12, general aviation activity patterns are not particularly seasonally dependent at SMO (levels decrease less than 15% during the winter months). This analysis was designed to investigate whether there are large seasonal variations in air Pb concentrations and, if so, what meteorological conditions are the most important drivers.

The 3-month rolling average concentrations for the 12 receptors with the highest concentrations are shown in Figure 4-14 (See Appendix F for the relative locations of these receptors). This figure shows a strong seasonal pattern for most of these high concentration locations, with most receptors showing a peak during the June-August period. The two receptors with 3-month average concentrations above 150 ng/m^3 are located on airport property. Since the general aviation emission activity did not exhibit a similar pattern of seasonal change, the underlying cause was attributed to changes in meteorology. To investigate which meteorological variables were most important to the changes in 3-month average Pb concentrations, 3-month rolling averages were developed for the meteorological variables most likely to affect the concentration at a near source location. The set of meteorological variables examined were the 3-month average of: wind speed, convective and mechanical mixing height, the atmospheric stability (in terms of anemometer height and the Monin-Obukov Length [z/L]), and the persistence of wind direction. These averages were determined using only those hours in which the airport was operating.

[27] Entrained road dust was not included as this information was only available at the 2 km x 2 km emission inventory resolution

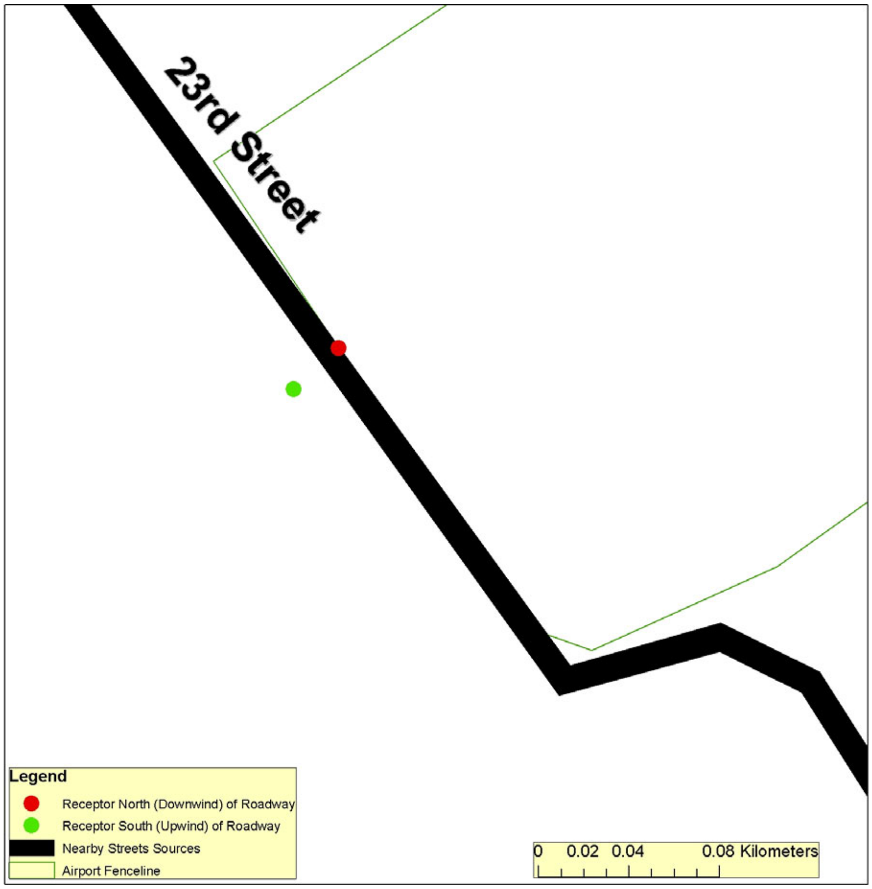


Figure 4-13. Upwind/downwind receptors along 23rd St. near Santa Monica Airport.

Table 4-19. Average Increase in Ambient Pb Concentration along 23rd St. from On-road Mobile Source Exhaust Emissions

Wind Direction	Average increase in concentration (ng/m^3)
190-200	0.029
200-210	0.028
210-220	0.020
220-230	0.018
230-240	0.016

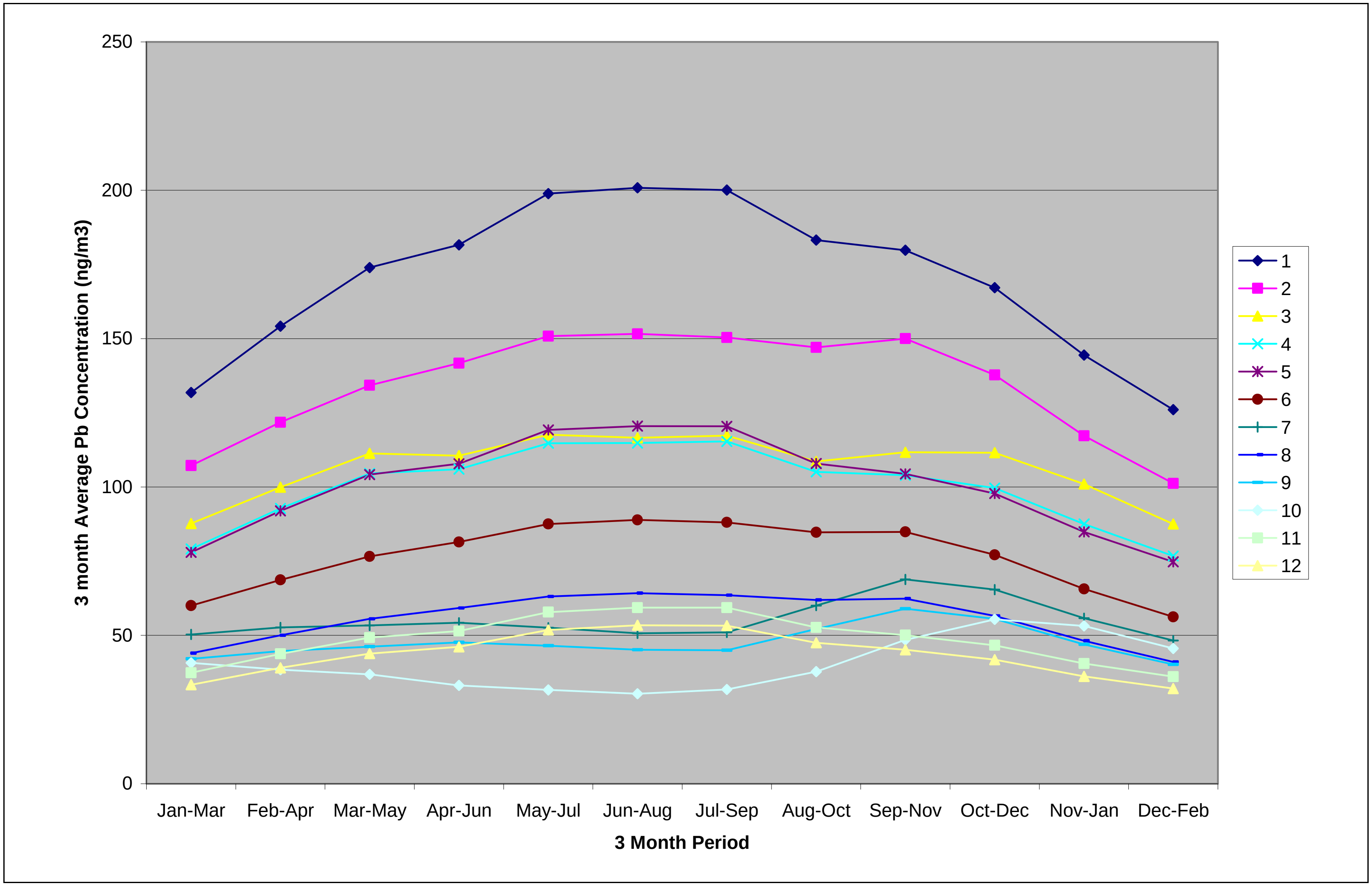


Figure 4-14. 3-month rolling average concentrations for the 12 highest receptor locations for 2008 at Santa Monica Airport.

Figure 4-15 shows the seasonal wind speed pattern. Average wind speeds are about 1 m/s higher for the highest 3-month average Pb concentration period compared with the lowest 3-month average Pb concentration period. This pattern is not coincident with the Pb concentration pattern and does not appear to explain the maximum 3-month average concentration seen during the summer months. Similarly, the convective (Figure 4-16) and mechanical mixing heights (Figure 4-17) show lowest mean heights in the 3-month period beginning in October or November and do not correspond with the concentration profile (i.e., lower mixing heights are typically related to higher ambient concentrations of pollutants emitted at ground-level). This finding is not entirely unexpected because aircraft run-up and taxi emissions dominate peak concentrations and should not be affected by the mixing height given the close proximity.

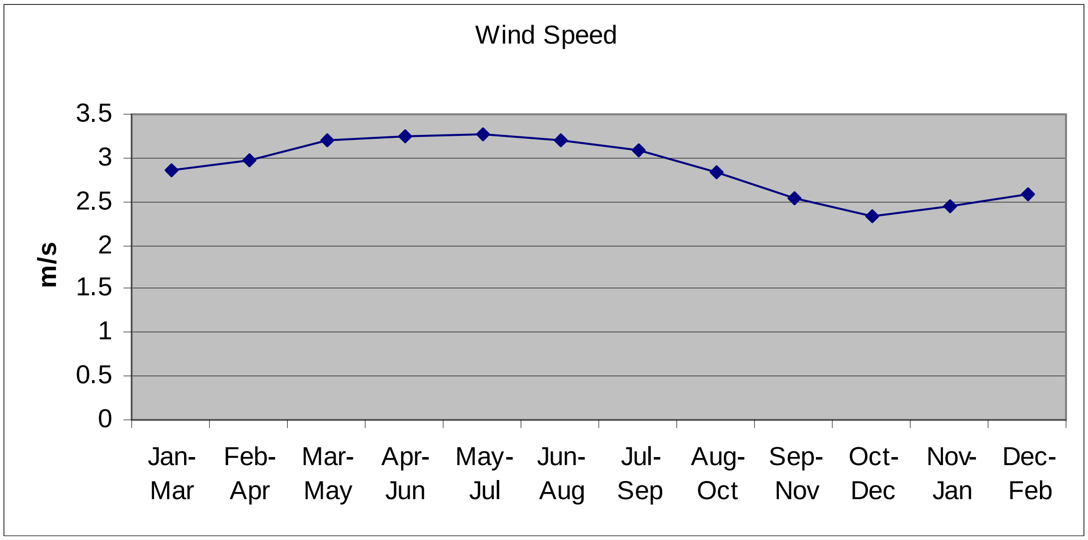


Figure 4-15. 3-month rolling average wind speed at SMO.

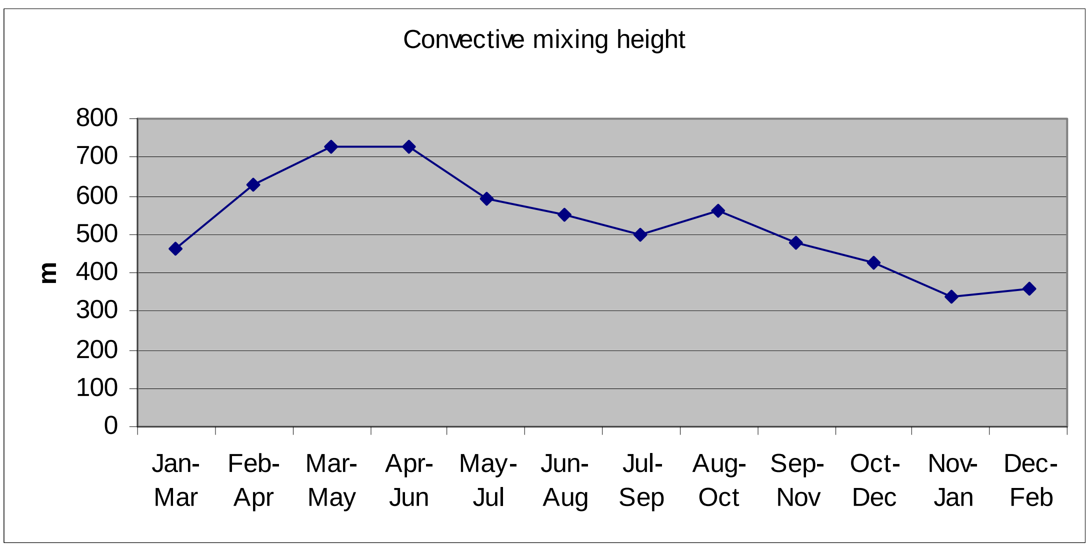


Figure 4-16. 3-month rolling average convective mixing height at SMO.

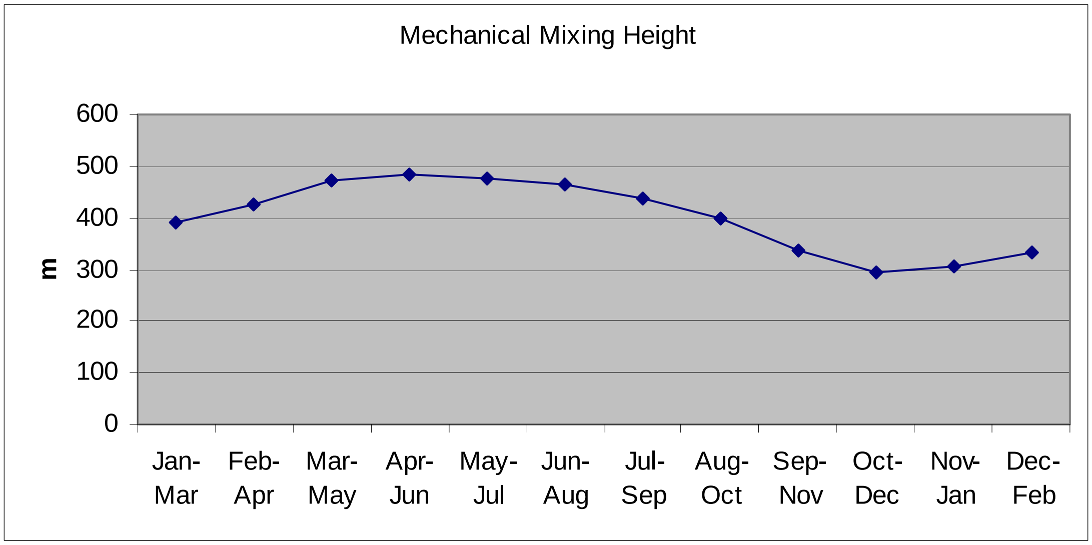


Figure 4-17. 3-month rolling average mechanical mixing height at SMO.

Table 4-20 shows the number of hours of stable, neutral, and unstable conditions over the 3-month period. The number of hours with stable conditions reaches a minimum during the summer, which suggests that Pb concentrations should reach a minimum during the summer months due to more hours with better turbulent mixing conditions. However, this is the opposite of what is observed in the Pb concentrations.

Table 4-20. Number of Hours over 3-month Period with Unstable, Neutral, and Stable Conditions at SMO

Period	Number of Hours Unstable ($z/L < -1$)	Number of Hours Neutral ($-1 \le z/L \le 1$)	Number of Hours Stable ($z/L > 1$)
Jan-Mar	87	1,000	278
Feb-Apr	89	983	278
Mar-May	63	1,059	258
Apr-Jun	43	1,101	221
May-Jul	19	1,194	167
Jun-Aug	29	1,203	148
Jul-Sep	37	1,185	158
Aug-Oct	77	1,054	249
Sep-Nov	89	956	320
Oct-Dec	104	895	381
Nov-Jan	86	950	344
Dec-Feb	90	963	312

An examination of the persistency of wind direction was performed by binning the wind direction into ten degree bins during the hours in which the airport was open. The bins were grouped into six 10-degree bins (see Figure 4-18), spanning wind directions from 195-255 degrees. The runway is oriented at 223 degrees.[28] Examination of the downwind concentration pattern (Appendix E) shows that the highest

[28] Although the runway is labeled as 210, this is the magnetic compass reading rather than the true angle relative to north. SMO has a magnetic declination of 15 degrees east.

concentration has an orientation axis of about 230 degrees. Figure 4-18 shows that the highest frequencies of this wind direction occur during July, with the second and third highest in August and June, respectively. Figure 4-18 shows that from June through August, over 50 percent of all hours had a wind direction between 225 and 245 degrees when the airport was open. This wind direction frequency pattern closely follows the pattern shown for the highest Pb concentrations. Thus, it appears that the persistency of wind direction plays an important role in determining the highest Pb concentrations.

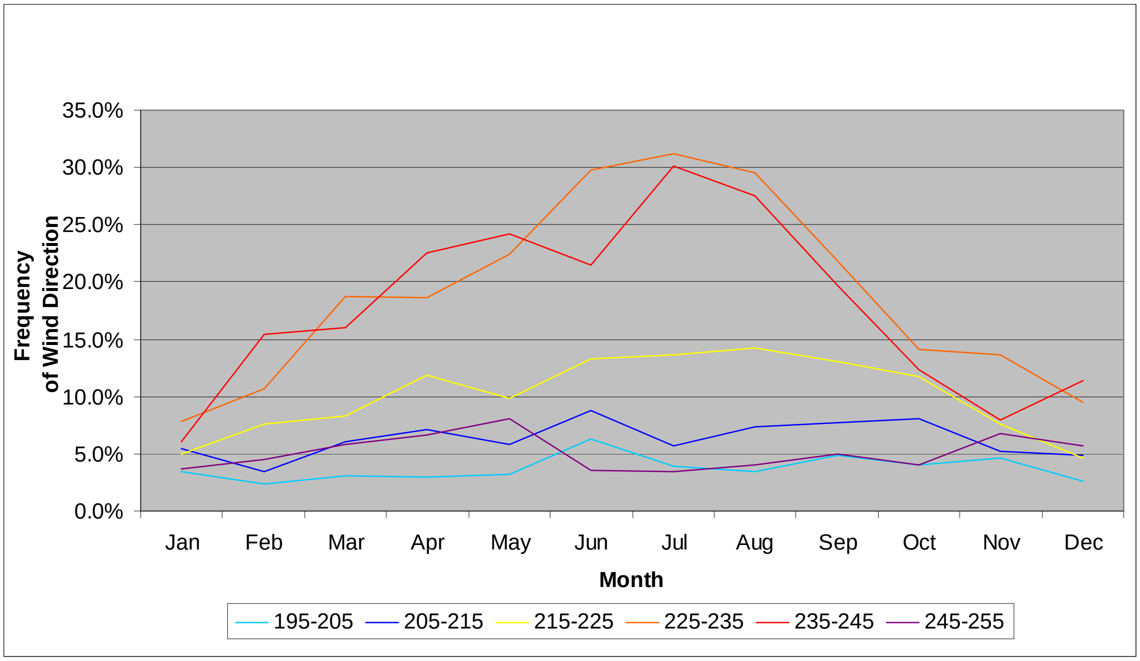


Figure 4-18. Frequency of wind direction at SMO.

4.3.6 Sensitivity Analysis

A set of seven sensitivity tests, plus the baseline, were conducted using the meteorological conditions for the maximum 3-month Pb concentration period (June-Aug). The seven tests that were chosen for those parameters were: (1) expected to represent the possible ranges that might be found at similar airport locations, and (2) expected to result in the largest changes in peak Pb concentrations. The concentrations for the top 12 receptors are shown graphically for each sensitivity test in Figure 4-19. All 12 receptors are located in close proximity to runway 21, both on-airport and off-airport. Figure 4-20 shows the locations of the top 12 receptors for the baseline case.

A set of sensitivity tests were selected with the intent to characterize the impact of these parameters on ambient Pb concentrations. The key parameters used in the sensitivity analysis are identified in Table 4-21. The set of sensitivity analyses were applied to the maximum 3-month average and included receptors both within the airport property where the public might have access, at the fence line, and downwind of the airport. The specific sensitivity tests and their associated baseline, low-end, and high-end values are provided in Table 4-21.

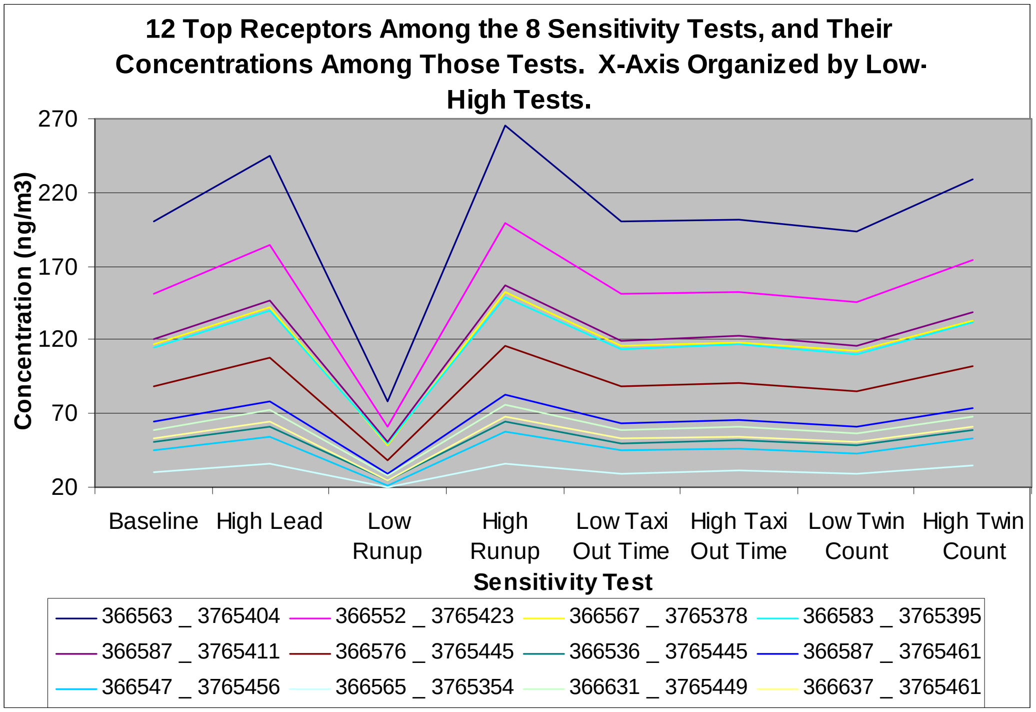


Figure 4-19. Sensitivity tests for the maximum 3-month average period (June-August).

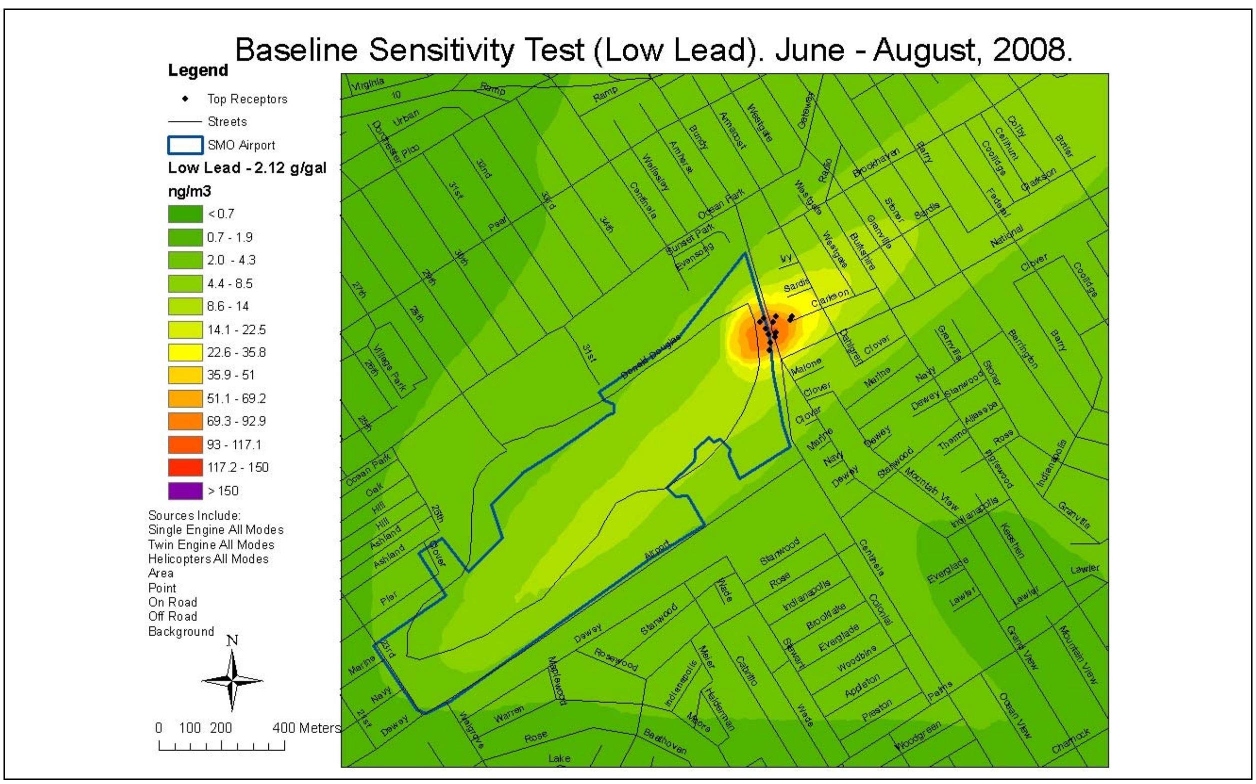


Figure 4-20. Locations of top 12 receptors found in sensitivity tests.

Table 4-21. Ranges in Key Parameters for Pb Sensitivity Tests at Santa Monica Airport

Parameter	Low End	Baseline	High End
Fraction of Fixed-wing Multi-engine Piston-engine Aircraft	0	0.025	0.12
Average "Run-up" time (seconds)	30	89	120
Taxi-out Time (seconds)	160	304	549
Lead Content in Avgas (g/gal)	2.12	2.12	2.59

All of the baseline values come from the time-in-mode survey data described in section 4.1.1 except for the Pb content in avgas, which was based on the ASTM standard for 100LL. The range of the fraction of activity conducted by multi-engine aircraft was derived from the number of aircraft based at the airport, as reported to FAA in its Master data records available through www.airnav.com. For the period ending May 2009, 35 of the 303 aircraft (12%) based at SMO were multi-engine aircraft. The range in "run-up" time was based on interviews with two pilots and a flight instructor.[29] The range in taxi-out time was based on the 5th and 95th percentiles observed during the time-in-mode survey. The Pb content in avgas reflects that at the Santa Monica Airport only 100LL avgas is available and the ASTM standard for 100LL is 2.12 g/gal. The high end represents the highest Pb concentration measured from fuel samples collected at the Santa Monica Airport in March 2009.

As shown in Figure 4-19, the increase in Pb fuel content over the baseline resulted in modest increases in air Pb concentration. The range of air Pb concentration increases was higher for the increase in the fraction of multi-engine aircraft. The largest changes in air Pb concentrations occurred over the span between the shortest engine run-up time of 30 seconds and the high end run-up time of 120 seconds. In all cases, except the low-end engine run-up, at least one receptor showed a concentration greater than 150 ng/m^3. The highest number of receptors above 150 ng/m^3 occurred for the high engine run-up scenario, with five receptors above 150 ng/m^3. Based on this analysis, the engine run-up time was determined to be one of the most important parameters in determining near-field Pb concentrations. The parameter which appeared least sensitive was the taxi-out time.

Appendix F shows the air Pb concentrations by sensitivity test at each receptor by color-coded bins and by contours for the maximum 3-month concentration period. Each figure shows the spatial concentration gradient for each sensitivity test. The high run-up time shows that air Pb concentration levels remain above the South Coast Basin background (10 ng/m^3) out to a distance of 500 meters from the airport property line, whereas the low engine run-up only showed elevated concentrations out to 300 meters from the airport property line.

4.3.7 AERMOD (07026) versus AERMOD (09292)

Near the completion of this study, EPA released a new version of AERMOD (09292). To evaluate the potential implications of this new version of the model on this study's findings, the new version of AERMOD (09292) was run for March 29, 2009, using only the emissions associated with the single-engine run-up. These results were then compared with the earlier results for the same scenario using AERMOD 07026 for any receptor where the simulated concentrations exceeded a minimum of 10 ng/m^3.

[29] Dr. Richard Pat Anderson, Director of the Flight Research Center at Embry-Riddle Aeronautical Universtiy in Daytona, FL reported that their experienced pilots conduct run-up checks for a total of 1 minute and their pilots in training for 2 minutes. Two private pilots reported lower estimates of about 30 seconds total.

A total of 204 receptors had hourly concentrations that exceeded 10 ng/m^3. These receptors had multiple hourly occurrences resulting in a total of 725 unique time and locations exceeding the 10 ng/m^3 threshold. In all cases, the percent difference between the two versions of AERMOD was less than 1%. Figure 4-21 shows the percent difference at each unique receptor/time combination. The largest difference (0.72%) was along the fence line near the run-up location but it was not the highest concentration (only 126^{th} highest out of the 725 pairings); otherwise, all of the differences were less than 0.5%. Similar results would be expected for other days and scenarios. As a result, it is not anticipated that the latest version of AERMOD will have any appreciable impact on any of the findings or conclusions from this study.

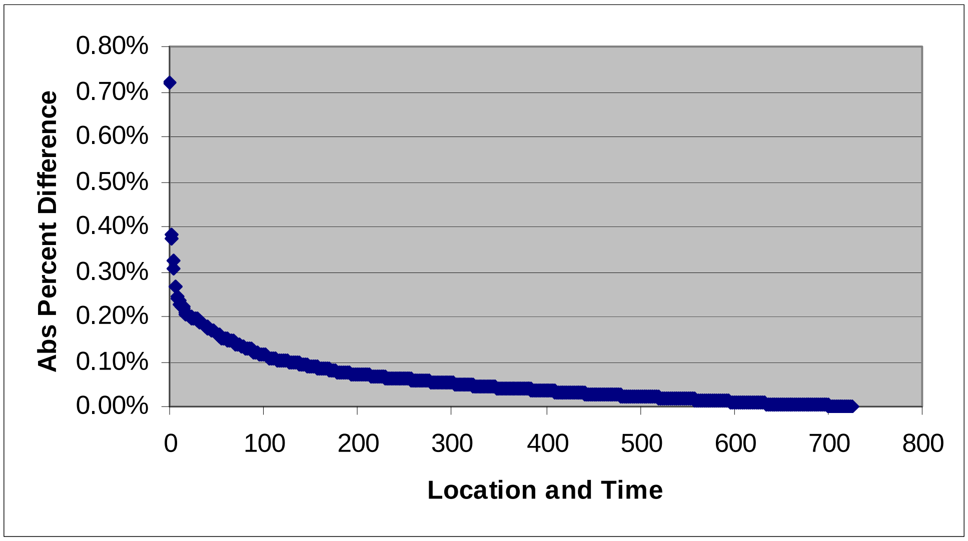


Figure 4-21. Ranked absolute value of percent difference of AERMOD (09292) and AERMOD (07026) for single-engine run-up emissions on March 29, 2009.

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5 Summary and Conclusions

In this study, data inputs for AERMOD were developed and applied to evaluate local-scale concentrations of Pb in the ambient air in the vicinity of an airport servicing piston-engine aircraft operating on leaded avgas. Specific analyses included model evaluation by comparing modeled data to ambient air quality monitoring during two seasons in 2009, spatial and seasonal variability in modeled Pb concentrations for 2008, and evaluation of the factors influential for the maximum 3-month average in 2008.

The air quality monitoring was performed in two campaigns: a winter campaign over two weekend periods in March 2009 and a summer campaign over a one week period in July 2009. Monitoring data were collected on a 24-hour basis at up to 4 locations in the vicinity of the airport. Dust and soil Pb sampling was collected during the summer air monitoring campaign.

The comprehensive emission inventory developed for this study included a detailed characterization of: stationary sources, area sources, on-road and non-road sources, and a detailed piston-engine aircraft emission inventory. The aircraft emissions data used in the model simulated the various aircraft operating modes, with the following modes considered: taxi-out, engine run-up, takeoff, climb-out, approach, landing, and taxi-in. A time-in-mode site survey was performed on aircraft operations during the winter campaign to collect information on the characteristics of the aircraft (specifically, the number of engines) and length of time piston-engine aircraft spend in each operating mode.

Site-specific air quality modeling was performed using day-specific aircraft operations, on-site two-minute rolling average wind speed and direction data, and site-specific terrain and land use information. Receptors were placed both within the airport property as well as in the surrounding community.

A detailed model-to-monitor comparison was completed for both the winter and summer campaigns. In addition, a complete one-year period (2008) was modeled using daily aircraft activity and, using these results, the maximum 3-month average Pb concentration period was identified for subsequent sensitivity tests. The sensitivity tests evaluated Pb concentration responses to changes in avgas Pb content, duration of engine run-up, taxi duration times, and fraction of multi-engine aircraft activity.

5.1 CONCLUSIONS

The model-to-monitor comparison for the winter campaign showed good agreement between the modeled and observed results (paired in time and space), with an absolute mean bias of 19.5 ng/m^3 and an absolute fractional bias of 0.29, well within a factor of two (0.67) of the observed and modeled concentrations. The most important source contributors to the highest air Pb concentrations were emissions associated with the single-engine aircraft run-up, followed by the taxi and takeoff emissions from single-engine aircraft. For the winter campaign, the model predicts elevated concentrations above the South Coast basin-wide background concentration of 10 ng/m^3 extend downwind of the airport ranging from about 500 to 900 meters from the airport fence line relative to a concentration of 56 to 86 ng/m^3 at the East Tarmac.

The model-to-monitor comparison for the summer campaign showed even better agreement than those in the winter campaign, with an absolute mean bias of 4.4 ng/m^3 and an absolute fractional bias of just 0.13, again well within the factor of two (0.67) of the observed and modeled concentrations. The summer modeling continued to show that single-engine run-up is the most important contributor to the peak air Pb concentrations. For the summer campaign, the model predicts elevated concentrations above the Los Angeles basin-wide background concentration of 10 ng/m^3 extend downwind of the airport ranging from about 400 to 500 meters from the airport fence line relative to a concentration of 33 to 55 ng/m^3 at the East Tarmac.

Both the summer and winter modeling studies made use of a detailed emission inventory for aircraft and other sources of Pb within 20 kilometers of Santa Monica Airport. This detailed emission inventory, along with the use of on-site ASOS data, were critical elements leading to the good to excellent model-to-monitor comparison.

Year-long modeling showed that the maximum 3-month concentration was highly influenced by the persistency in wind direction during the period (June-August) and not by changes in aircraft activity. It was observed that during airport operating hours from June through August, over 50 percent of all hours had wind directions between 225 and 245 degrees. Modeling results showed that two receptors had the potential for having a 3-month average concentration above 150 ng/m^3; both receptors are located on the airport property in close proximity to the blast fence. Concentrations off airport property were modeled to have concentrations as high as 120 ng/m^3.

A set of seven sensitivity tests were completed for the maximum 3-month average period. The tests were chosen for those parameters expected to represent the possible ranges that might be found at similar airport locations and that were expected to have the largest impacts on ambient Pb concentrations. The parameter which resulted in the largest changes over the ranges modeled was the engine run-up time, followed by the Pb concentration in the fuel, and then the fraction of multi-engine aircraft. Little change in concentration occurred with changes in taxi times. The run-up time showed the greatest impact on the spatial extent of the Pb concentration levels. The high run-up time showed that the Pb concentration could remain above South Coast Basin background (10 ng/m^3) out to a distance of 500 meters from the airport property line, whereas the low engine run-up only showed elevated concentrations out to a distance of about 300 meters from the airport property line.

The year-long modeling results were also examined to determine the relative importance of Pb exhaust and entrained road dust emissions from on-roadway sources. Modeled receptors were examined looking at upwind/downwind differences across the relatively busy road, 23rd Street. The combined impacts from on-roadway mobile source Pb exhaust and entrained Pb emissions were shown to be less than the average pristine ambient background concentration of 0.5 ng/m^3 and are therefore not expected to be a significant contributor to ambient Pb concentration levels.

5.2 Implications for Other Airports

The approach used here would be fully applicable to other airports. However, complications not dealt with here that may occur at other airport locations include multiple runways and multiple prevailing wind directions. These additional complications can be handled within the framework used in this study, but would require additional effort to include runway layout geometry and changes in emission source locations depending upon wind direction.

Based on the experience gained from this analysis, it is recommended that modeling for other airport locations focus available resources on efforts to assemble data for the following key areas:

- Conduct an on-site survey of the duration and location of LTO modes for piston-engine aircraft, with particular emphasis on the duration of run-up times and location(s)
- Collect information on hourly activity patterns of piston-engine aircraft and gather information on aircraft type (multi- and single-engine) via tail fin number[30]

[30] Modeling results suggest strong peaks in hourly concentrations due either to increased piston-engine aircraft activity or meteorological conditions. Properly characterizing these peak periods are likely critical to the overall daily as well as seasonal average.

- Use 2-minute ASOS on-site wind speed and wind direction data – these data may be particularly important to accurately reflect wind direction, particularly during low wind speed periods
- Use site-specific terrain and land use data following procedures as recommended in EPA's AERMOD implementation guide
- Gather information on stationary sources within at least 20 km of the airport

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