The Benefits

of Meeting Federal Clean Air Standards in the South Coast and San Joaquin Valley Air Basins

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Overview

There has long been a tug-of-war about the cost of protecting public health by reducing life-threatening pollution. A central objective of this study is to assess the cost of the status quo, and the health and related economic benefits that will result from achieving the federal ozone and $PM_{2.5}$ standards in the South Coast and San Joaquin Valley air basins.

Both the federal government and California have set health-based air quality standards for ozone and fine particle ($PM_{2.5}$) pollution because there is wide concurrence that these pollutants pose a serious risk to health. Ozone pollution's effect ranges from premature death to school absences and hospitalizations, to symptoms that limit normal daily activity. Exposure to fine particles is tied to a range of effects from premature death and the onset of chronic bronchitis to loss of work days and respiratory symptoms.

Despite the widespread consensus on the danger of these pollutants and the necessity of the health-based standards, the South Coast and San Joaquin Valley air basins of California have air pollution levels that are among the worst in the country. The South Coast Air Basin (SoCAB), which includes Los Angeles, Orange, Riverside and San Bernardino counties, is classified by the U. S. Environmental Protection Agency (EPA) as an extreme nonattainment area for ozone. The San Joaquin Valley Air Basin (SJVAB) also is designated an extreme nonattainment area for ozone. Both air basins are classified as serious nonattainment areas for $PM_{2.5}$. While promising reductions in some pollutants have been achieved, levels of ozone and fine particulate matter remain high.

Between 2005 and 2007 ambient ozone levels in the San Joaquin Valley exceeded the health-based 8-hour National Ambient Air Quality Standard (NAAQS) on from 112 to 139 days a year, while in the South Coast Air Basin exceedances occurred on from 115 to 120 days. Ozone levels are typically elevated in the warmer months, so this suggests that air is unhealthful on most summer days in these regions. Not only is the standard frequently exceeded, but between 2005 and 2007 the maximum 8-hour concentration was significantly above the standard. While ozone levels in much of California have fallen steadily over a period of years, progress in the San Joaquin Valley has been slower than in other major air basins.

To meet the maximum 24-hour standard, fine particulate levels must fall by more than 50%, and annual average concentrations must fall by nearly 30%. These health-based standards will be very difficult to achieve.

HEALTH FINDINGS:
Some Residents More at Risk, but Nearly Everyone is Exposed

Almost every resident of the South Coast Air Basin and San Joaquin Valley Air Basin regularly experiences air pollution levels known to harm health and to increase the risk of early death. Specifically, from 2005 through 2007, each person was on average exposed to unhealthful levels of ozone on nearly 20 and more than 30 days a year in the South Coast and San Joaquin Valley, respectively. In Kern County, this rises to over 50 days each year, and in Riverside and San Bernardino Counties, nearly 50. In the San Joaquin Valley 66% of the population is exposed to health-endangering annual average levels of $PM_{2.5.}$ In the South Coast, this averages over 64%, and in the most populated county – Los Angeles – it is 75%.

Because ozone exceedances typically occur during the warmer months (April through September), and the exceedances of the 24-hour $PM_{2.5}$ standard typically occur in the fall and winter months, there is essentially no "clean" season in either air basin.

These exposures translate directly into poorer health and an elevated risk to every resident exposed, but the adverse impacts of air pollution are not distributed equally. Residents of Fresno, Kern, Kings and Tulare Counties experience significantly more days when the $PM_{2.5}$ standard is exceeded than residents of other counties in the San Joaquin Valley, as do residents of San Bernardino and Riverside Counties, compared to the neighboring counties in the South Coast Air Basin. Tulare County also joins Fresno, Kern, Riverside and San Bernardino in being well above their basin averages for the number of days of exposure above the ozone standards. Children under the age of 5 are exposed to unhealthful ozone concentrations on more days than adults. Blacks and Hispanics experience somewhat more frequent exposures to elevated levels of $PM_{2.5}$ than non-Hispanic whites do. These disadvantaged groups all stand to gain relatively more from successful pollution reduction efforts.

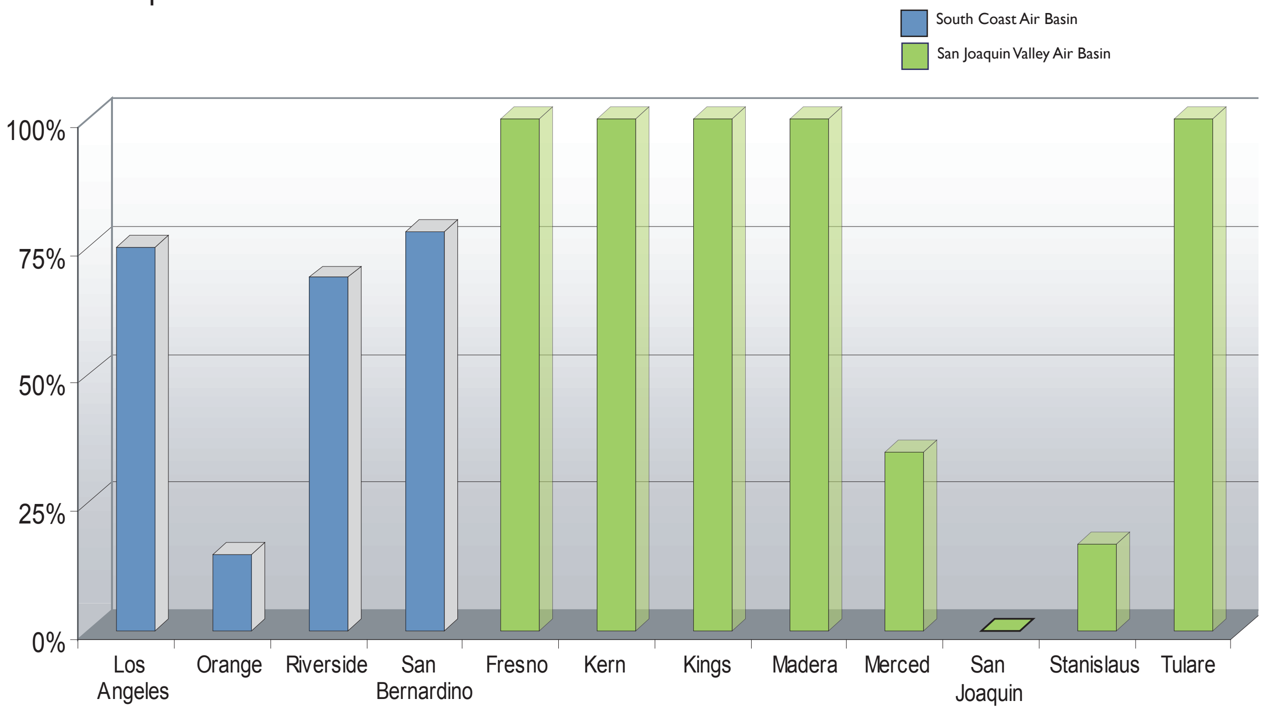

Figure E-1. Percent of the population exposed to $PM_{2.5}$ concentrations above the average annual federal standard (15 μg/m^3) in 2005-2007 by county.

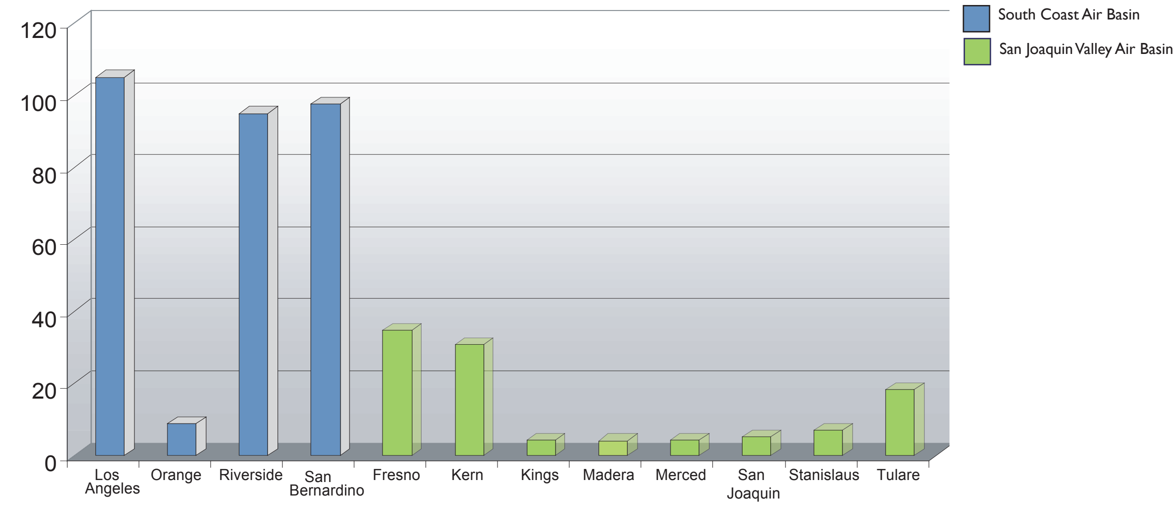

Figure E-2. Person-days per year (in millions) that residents are exposed to ozone concentrations above the 8-hr maximum federal standard (75 ppb) in 2005-2007 by county.

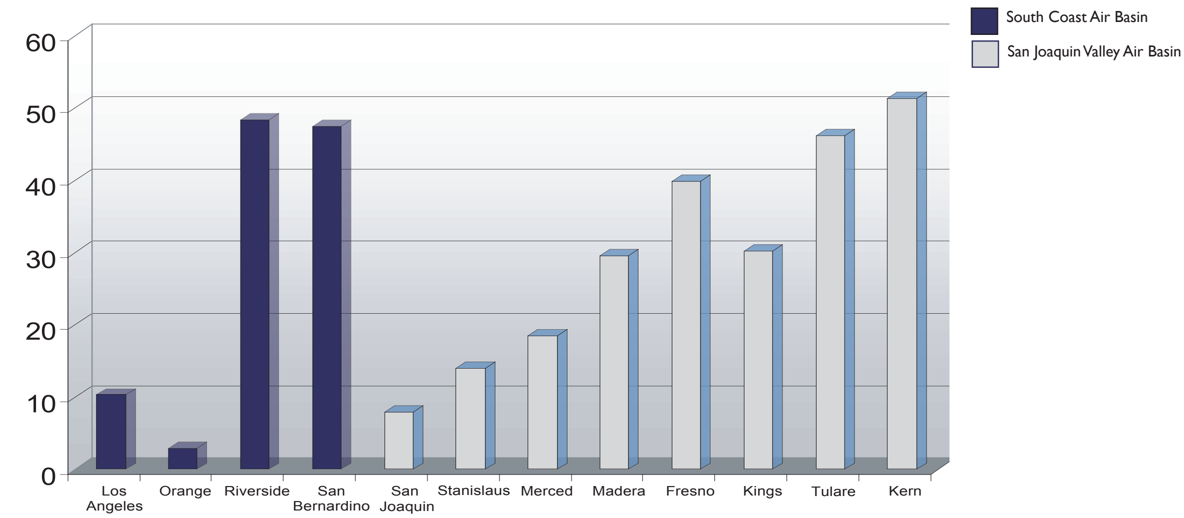

Figure E-3. Average days per year residents are exposed to ozone concentrations above the 8-hr maximum federal standard (75 ppb) in 2005-2007 by county.

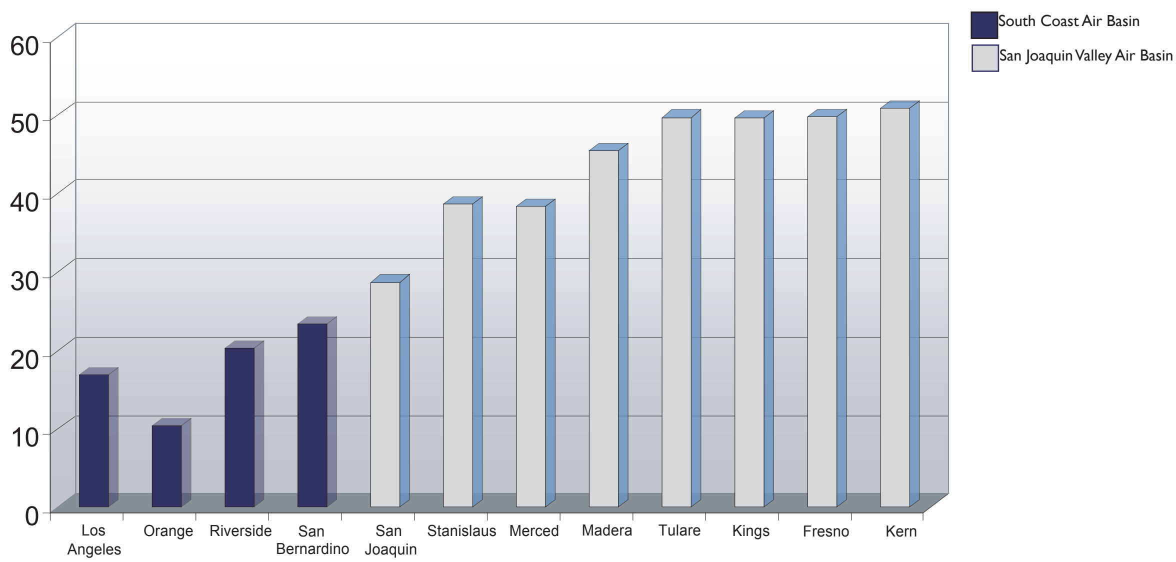

Figure E-4. Average days per year residents are exposed to $PM_{2.5}$ concentrations above the 24-hr maximum federal standard (>35 μg/m^3) in 2005-2007 by county.

ECONOMIC FINDINGS:
The Cost of the Status Quo and the Benefits of Meeting Federal Standards

In addition to the documented health effects caused by high levels of pollution, residents in these regions pay a high economic price for adverse air quality. Recognizing that some known effects of exposure to these pollutants, such as loss of lung function, cannot yet be quantified in economic terms, the actual economic benefits are likely higher than the results reported here.

Specifically,

- In the San Joaquin Valley overall, the cost of air pollution is more than $1,600 per person per year, which translates into a total of nearly $6 billion in savings if federal ozone and $PM_{2.5}$ standards were met.
- In the South Coast Air Basin, the cost of air pollution is more than $1,250 per person per year, which translates into a total of almost $22 billion in savings if federal ozone and $PM_{2.5}$ standards were met.

These dollar values represent avoiding the following adverse health effects of ozone and $PM_{2.5}$ for the two air basins combined:

- 3,860 fewer premature deaths among those age 30 and older
- 13 fewer premature deaths in infants
- 1,950 fewer new cases of adult onset chronic bronchitis
- 3,517,720 fewer days of reduced activity in adults
- 2,760 fewer hospital admissions
- 141,370 fewer asthma attacks
- 1,259,840 fewer days of school absence
- 16,110 fewer cases of acute bronchitis in children
- 466,880 fewer lost days of work
- 2,078,300 fewer days of respiratory symptoms in children
- 2,800 fewer emergency room visits

To place the reduction in premature deaths in perspective, attaining the federal $PM_{2.5}$ standard would save more lives than reducing the number of motor vehicle fatalities to zero in most of the counties in this study. In Los Angeles County, $PM_{2.5}$–related deaths are more than double the number of motor vehicle-related deaths.

Ozone-Related Economic Benefits by County

	Respiratory Hospital Admissions (All ages)	Asthma Attacks Asthmatic population	Emergency Room Visits	Days of School Absences	Minor Restricted Activity Days	Mortality	Total
San Joaquin Valley Air Basin							
Fresno	$1,730,000	$301,000	$6,040	$3,350,000	$2,780,000	$19,880,000	$28,050,000
Kern	$1,550,000	$246,000	$4,620	$3,020,000	$2,240,000	$19,880,000	$26,940,000
Kings	$190,000	$47,000	$1,070	$480,000	$490,000	$0	$1,210,000
Madera	$230,000	$41,000	$710	$430,000	$410,000	$0	$1,110,000
Merced	$300,000	$58,000	$1,070	$680,000	$520,000	$0	$1,560,000
San Joaquin	$660,000	$121,000	$2,490	$1,210,000	$1,110,000	$0	$3,100,000
Stanislaus	$610,000	$111,000	$2,490	$1,200,000	$980,000	$6,630,000	$9,530,000
Tulare	$910,000	$156,000	$2,840	$1,650,000	$1,410,000	$13,250,000	$17,380,000
South Coast Air Basin							
Los Angeles	$15,400,000	$3,183,000	$54,120	$58,630,000	$31,790,000	$79,510,000	$188,600,000
Orange	$3,530,000	$916,000	$16,240	$22,300,000	$9,350,000	$19,880,000	$56,000,000
Riverside	$7,210,000	$1,210,000	$19,840	$12,170,000	$10,810,000	$ 99,390,000	$130,800,000
San Bernardino	$6,870,000	$1,205,000	$19,840	$12,880,000	$11,220,000	$72,890,000	$105,100,000

$PM_{2.5}$-Related Economic Benefits by County

	Premature & Post-Neo Natal Mortality	Respiratory Symptoms & Bronchitis	Non-Fatal Heart Attacks	Respiratory & Cardio Hospital Admissions	Children's Asthma ER Visits	Minor Restricted Activity Days	Work Loss Days	Total
San Joaquin Valley Air Basin								
Fresno	$1,405,000,000	$41,220,000	$10,940,000	$3,030,000	$42,280	$6,710,000	$2,890,000	$1,470,000,000
Kern	$1,213,000,000	$33,710,000	$8,340,000	$800,000	$33,040	$5,190,000	$2,230,000	$1,263,000,000
Kings	$192,200,000	$7,261,000	$1,890,000	$390,000	$6,040	$1,210,000	$510,000	$203,500,000
Madera	$218,700,000	$6,439,000	$1,680,000	$490,000	$5,680	$1,040,000	$410,000	$228,800,000
Merced	$251,800,000	$8,349,000	$2,310,000	$530,000	$9,950	$1,410,000	$580,000	$265,000,000
San Joaquin	$728,900,000	$20,640,000	$5,470,000	$1,620,000	$19,180	$3,190,000	$1,400,000	$761,200,000
Stanislaus	$656,000,000	$18,940,000	$4,910,000	$1,460,000	$17,760	$2,950,000	$1,280,000	$685,600,000
Tulare	$728,900,000	$20,900,000	$5,400,000	$1,400,000	$22,380	$3,280,000	$1,250,000	$761,200,000
South Coast Air Basin								
Los Angeles	$11,440,000,000	$421,200,000	$137,400,000	$35,790,000	$423,900	$80,460,000	$44,930,000	$12,160,000,000
Orange	$2,697,000,000	$104,700,000	$34,000,000	$6,950,000	$99,200	$19,710,000	$11,090,000	$2,874,000,000
Riverside	$3,055,000,000	$84,000,000	$25,940,000	$8,720,000	$92,000	$14,770,000	$7,160,000	$3,196,000,000
San Bernardino	$2,730,000,000	$89,460,000	$29,090,000	$7,450,000	$110,000	$17,530,000	$8,500,000	$2,882,000,000

IMPACT CHARTS

Ozone-Related Adverse Health Effects By County

	Respiratory Hospital Admissions (All ages)	Asthma Attacks Asthmatic population	Emergency Room Visits	Days of School Absences	Minor Restricted Activity Days	Mortality
San Joaquin Valley Air Basin						
Fresno	46	5,670	17	43,980	42,970	3
Kern	41	4,640	13	37,810	34,620	3
Kings	5	890	3	6,050	7,580	0
Madera	6	780	2	5,500	6,320	0
Merced	8	1,090	3	8,530	8,070	0
San Joaquin	17	2,290	7	13,100	17,170	0
Stanislaus	16	2,100	7	13,500	15,190	1
Tulare	24	2,940	8	23,040	21,830	2
South Coast Air Basin						
Los Angeles	380	59,100	150	653,300	483,840	12
Orange	87	17,010	45	184,500	142,380	3
Riverside	185	22,480	55	125,840	164,470	15
San Bernardino	173	22,380	55	144,690	170,720	11

$PM_{2.5}$-Related Adverse Health Effects By County

	Premature & Post-Neo Natal Mortality	Respiratory Symptoms & Bronchitis	Non-Fatal Heart Attacks	Respiratory & Cardio Hospital Admissions	Children's Asthma ER Visits	Minor Restricted Activity Days	Work Loss Days
San Joaquin Valley Air Basin							
Fresno	212	104,215	156	80	119	103,770	18,500
Kern	183	81,228	119	53	93	80,170	14,280
Kings	29	15,207	27	10	17	18,770	3,340
Madera	33	14,235	24	13	16	16,020	2,850
Merced	38	24,269	33	14	28	21,840	3,880
San Joaquin	110	46,908	78	43	54	49,360	8,740
Stanislaus	99	43,814	70	39	50	45,660	8,120
Tulare	110	54,678	77	37	63	50,750	9,030
South Coast Air Basin							
Los Angeles	1,727	1,000,440	1,960	903	1,175	1,224,600	241,690
Orange	411	233,310	485	175	275	300,010	59,100
Riverside	461	217,570	370	220	255	224,780	44,500
San Bernardino	412	260,480	415	187	305	266,830	52,850

Implications

More than 20,000,000 residents in these air basins face significant public health risks and high economic costs from the present unhealthful levels of ozone and fine particles. The findings in this study show how meeting federal clean air standards would bring substantial economic and health gains to the two regions. The benefits for the more populous or more polluted counties within each air basin would be even more pronounced.

As the state's population continues to increase, the gains from attaining the health-based air quality standards will grow, but also become more difficult to achieve. It is clear that identifying and acting on opportunities now to reduce emissions from the sources of ozone and fine particle pollution would produce substantial gains to more than 20 million Californians.

Research Approach

A well-established three-stage approach is used to determine the benefits of attaining the ozone and $PM_{2.5}$ air quality standards by identifying and quantifying the links between air quality and exposure, exposure and ill health, and avoiding ill health and the resulting economic gain.

Establishing the links between polluted air and exposure is accomplished using the Regional Human Exposure Model (REHEX), which was developed to estimate a population's exposure to concentrations above the air quality standards. This model accounts for the spatial and temporal pollution patterns across a region, which is important because pollution patterns vary significantly across a large area. Exposure for the populations in the SoCAB and SJVAB are estimated using 5x5 kilometer grids and 2005-2007 pollution levels. Averaging over three years reduces the influence of weather anomalies that do not accurately represent longer term trends in air quality. REHEX generates estimates of exposure by county, by age, and by ethnic group as defined by the U.S. Bureau of the Census.

These exposure estimates are then coupled with concentration-response functions from the health science literature to calculate how many fewer adverse health effects and premature deaths would be expected if the 2007 population instantaneously experienced attainment of the NAAQS.

Finally, economic values are applied to the avoided adverse health effects and extended lives to estimate in dollar terms the social value of more healthful air. These values are based on the cost of treating illness and the expressed value that people place on avoiding illness and premature death.

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All statements and conclusions in this study are solely those of the authors.

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ACRONYMS

ACS	American Cancer Society
ARB	California Air Resources Board
CAAQS	California Ambient Air Quality Standards
COI	Cost of illness
COPD	Chronic obstructive pulmonary disease
C-R	Concentration response
CV	Contingent Valuation
EPA	U.S. Environmental Protection Agency
FRM	Federal Reference Method
MRAD	Minor restricted activity day
NAAQS	National Ambient Air Quality Standards
ppb	Parts per billion
ppm	Parts per million
REHEX	Regional Human Exposure Model
RR	Relative risk
SAB-HEES	Science Advisory Board Health and Ecological Effects Subcommittee
SCAQMD	South Coast Air Quality Management District
SJVAB	San Joaquin Valley Air Basin
SJVAPCD	San Joaquin Valley Air Pollution Control District
SoCAB	South Coast Air Basin
SYMVAL	Symptom Valuation Model
VSL	Value of a statistical life
WLD	Work loss day
WTA	Willingness to accept
WTP	Willingness to pay

I. INTRODUCTION

1.1 BACKGROUND

California's Los Angeles region and San Joaquin Valley have air pollution levels of a severity rivaled only by Houston, Texas. Historical and current air quality levels for ozone and fine particles ($PM_{2.5}$) remain unhealthful. Both the South Coast Air Basin (SoCAB) and the San Joaquin Valley Air Basin (SJVAB) are classified by the U. S. Environmental Protection Agency (EPA) as extreme nonattainment areas for ozone and severe nonattainment areas for $PM_{2.5}$.

Both the federal government and California have set health-based air quality standards for ozone and fine particles ($PM_{2.5}$) because there is extensive and convincing evidence, and wide concurrence in the medical community, that these pollutants pose a serious risk to health. Adverse effects clearly associated with ozone range from premature death, hospitalizations, and school absences to symptoms that limit normal daily activity. $PM_{2.5}$ exposure is tied to a range of effects from premature death and the onset of chronic bronchitis to heart attacks, work loss days (WLDs), and respiratory symptoms.

Between 2005 and 2007, ambient ozone levels in the SoCAB exceeded the health-based 8-hr National Ambient Air Quality Standard (NAAQS) for ozone on 115 to 120 days per year. In the SJVAB, exceedances of this standard occurred on 112 to 139 days. Ozone levels are typically elevated in the warm season, which suggests that air is unhealthful on most summer days.

While both regions have achieved reductions in PM_{10}, which includes fine and coarse particles, concentrations of the more dangerous fine particles—$PM_{2.5}$—remain unhealthful. In the SJVAB, the population was exposed to levels that exceeded the 24-hr NAAQS on from 38 to 76 days, and in the SoCAB on from 45 to 48 days per year. To meet the maximum 24-hr standard, accounting for background concentrations, levels must fall by more than 50% in both air basins. These health-based standards will be very difficult to achieve in either region.

1.2 OBJECTIVES OF THIS STUDY

The primary objective of this study is to assess the health and related economic benefits that will result from attainment of the ozone and $PM_{2.5}$ standards, to the extent that they can be quantified with present knowledge.

1.3 OVERVIEW OF THE RESEARCH APPROACH

A well-established three-stage approach is used to determine the benefits of attaining the ozone and $PM_{2.5}$ air quality standards by identifying and quantifying the links between air quality and exposure, exposure and ill health, and avoiding ill health and the resulting economic gain.

Establishing the links between polluted air and exposure is accomplished using the Regional Human Exposure Model (REHEX), which was initially developed in 1989 to estimate a population's exposure to concentrations above the air quality standards. This model accounts for the spatial and temporal pollution patterns across a region, which is important because pollution patterns vary significantly across a large area. Here, exposure for the population is estimated by 5- x 5-km grids relative to pollution levels averaged from 2005 to 2007. Averaging reduces the influence of weather anomalies that do not accurately represent longer term trends in air quality. REHEX generates estimates of exposure by county, by age, and by ethnic group as defined by the U.S. Bureau of the Census.

These exposure estimates are then coupled with concentration-response functions from the health science literature to calculate the expected number of adverse health effects and premature deaths avoided if the population instantaneously experienced attainment of the NAAQS.

Finally, economic values are applied to the avoided health effects and extended lives to estimate in dollar terms the social value of more healthful air. Specific values are derived from the economics literature and have all undergone peer review, both as part of that literature and as part of scientific and technical assessments of which values are most appropriate for valuing health and life in relation to air pollution exposure.

II. POPULATION EXPOSURE TO OZONE AND PARTICULATE MATTER

II.1 THE EXPOSURE ASSESSMENT APPROACH

Accurate estimates of human exposure to inhaled air pollutants are necessary for appraisal of the health risks that these pollutants pose and for the design and implementation of strategies to control and limit those risks. Most exposure estimates are based on measured concentrations of outdoor (ambient) air concentrations obtained at fixed-site air monitoring stations. Ambient concentrations are used as surrogates for personal exposure. Personal exposure to air pollutants depends not only on ambient concentrations in locations or microenvironments (e.g., home, work, schools, vehicles) where individuals spend time, but also on the amount of time individuals spend in the microenvironments and on the concentrations in the microenvironments. Microenvironment concentrations are affected not only by infiltration of outdoor air, but also by indoor sources and indoor pollutant deposition. Outdoor concentrations vary spatially and temporally and are affected by proximity to local outdoor sources, which may result in concentrations that deviate significantly from ambient concentrations at the nearest air monitoring stations.

Despite the recognized discrepancies between personal exposure and exposures based on ambient concentrations obtained from fixed-site air monitoring stations, compliance with the NAAQS depends exclusively on outdoor measurements of pollutants. The NAAQS are intended to protect public health with an adequate margin of safety. Most epidemiologic studies of air pollution health effects use ambient concentrations as surrogates for actual population exposures. In fact, virtually all concentration-response relationships from large population studies use ambient concentrations as the exposure input parameter. The exposure assessment approach for this study is constrained to rely on ambient concentrations not only because the ambient air quality database is the only database with sufficient spatial and temporal coverage to address the population, but also because this study requires quantification of the benefits of attainment of the ambient-based NAAQS and must rely on the ambient-based concentration-response relationships from the health science literature to quantify those benefits. The approach is also guided by the concern for spatial resolution of both the population and ambient concentrations.

The population exposure assessment approach used for this study involves representing the population and ambient concentrations on spatial grids covering California's SoCAB and SJVAB. Each grid square is 5 km x 5 km in size. Five-kilometer resolution is sufficient to capture the urban- and regional-scale spatial gradients in between air quality monitoring stations, which are located from 10 km to 50 km apart in these areas. This resolution is insufficient to capture intra-urban spatial variations associated with close proximity to major roadways or stationary emission sources. Spatially and temporally resolved air quality and population data are used in the REHEX model (Lurmann et al. 1989; Lurmann et al. 1994; Fruin et al. 2001) to quantify the frequency of population exposure to various levels of ambient ozone and particulate matter concentrations over multi-year periods.

II.2 POPULATION

Detailed population data from the 2000 U.S. Census have been previously gridded for use in exposure assessments. For this analysis, gridded population data were developed for eight age groups: <1 year, 1 year, 2-4 years, 5-17 years, 18-21 years, 22-29 years, 30-64 years, and >64 years, and four racial groups: white non-Hispanic, black non-Hispanic, other non-Hispanic, and Hispanic. The age groups were defined by the concentration-response relationships chosen for use in the benefits evaluation. Racial groups were defined by the U.S. Census. The relative age distribution and racial distribution in each grid were assumed to be time-invariant between 2000 and 2007.

The baseline period selected for exposure assessment was 2005 through 2007 because NAAQS compliance assessment requires three years of data and these were the three most recent calendar years with complete data at the time of this analysis. Population data for 2000 were projected to 2007, the most recent year in this period, to be consistent with the baseline period for air quality data and the economic parameters (2007 dollars). The population growth between 2000 and 2007 for the SoCAB was determined from gridded population data for 2005 and 2010 that were used in the South Coast Air Quality Management District's (SCAQMD) Socioeconomic Report for the 2007 Air Quality Management Plan (SCAQMD 2007a; Sue Liu, personal communication). The population growth between 2000 and 2007 in the SJVAB was based on the county population data for 2005 and 2014 presented in the 2008 $PM_{2.5}$ Air Quality Plan (SJVAPCD 2008). Hence, the population data used in this study are consistent with those used in the most recent agency air quality planning efforts.

The spatial distribution of population is illustrated in Figures II-1 and II-2. They show the modeling grids with significant population in the SoCAB and SJVAB. The highest population density is 229,000 and 74,000 persons per grid in the SoCAB and SJVAB, respectively. The population in exposure grids that cover more than one county is tabulated separately. A total of 981 and 1708 county-specific exposure grids were used for assessing exposure in the SoCAB and SJVAB, respectively. Grid squares with extremely low population density (below 2 persons per km^2 or 50 persons per grid) were not included because they account for a very small portion of the total population and they are usually located far from air quality monitors.

The age and racial distribution of the population in each county and air basin are summarized in Tables II-1 through II-4. The estimated 2007 population in the portions of Los Angeles, Orange, Riverside, and San Bernardino Counties that lie within the SoCAB are 10.2, 3.1, 2.0, and 2.0 million, respectively, and totals 17.3 million. The overall age distribution in the SoCAB is 28.6% children (age 17 years or less) and 71.4% adults. The SoCAB population is 40.9% Hispanic, 37.4% white non-Hispanic, 7.5% black non-Hispanic, and 14.1% other non-Hispanic.

The SJVAB covers a substantially larger area than the SoCAB, but its population is only 3.51 million or about one-fifth the population of the SoCAB. The estimated 2007 population in portions of San Joaquin, Stanislaus, Merced, Madera, Fresno, Kings, Tulare, and Kern Counties that lie within the air basin are 639,000, 499,000, 231,000, 137,000, 873,000, 140,000, 395,000, and 598,000, respectively. The SJVAB population is 31.8% children, age 17 years or less, and 68.2% adults. The SJVAB population is 41.6% Hispanic, 46.2% white non-Hispanic, 4.8% black non-Hispanic, and 7.5% other non-Hispanic. The SJVAB population is slightly younger and has proportionately more whites than the SoCAB population.

Estimates of the population of children attending school were also needed to determine the benefits of reduced school absences associated with air quality improvements. Detailed school enrollment data and schedules have been reviewed in previous studies. On average, the data for Southern California indicate that 91% of children ages 5-17 years attend school in the non-summer period (mid-August through May) and 21% in the summer (June through mid-August) (Hall et al. 2003). In the San Joaquin Valley, more schools operate only on a traditional school schedule. On average, 97% and 21% of school-age children in the SJV attend school in the non-summer period and in the summer, respectively (Hall et al. 2007).

II.3 CURRENT AMBIENT AIR QUALITY

The SoCAB and SJVAB air basins are classified as "extreme" nonattainment areas for ozone and "severe" nonattainment areas for $PM_{2.5}$ by the EPA. The most relevant NAAQS for ozone is the 8-hr daily maximum standard of 75 parts per billion (ppb) (or 0.075 parts per million [ppm]). It has essentially replaced the 1-hr daily maximum ozone standard of 0.12 ppm, which is less stringent[1] in these air basins. To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hr average ozone concentrations measured at each monitor within an area over each year must not exceed 0.075 ppm. For PM NAAQS, both the 35 $\mu g/m^3$ 24-hr $PM_{2.5}$ standard and the 15 $\mu g/m^3$ annual $PM_{2.5}$ standard are more stringent than the 150 $\mu g/m^3$ 24-hr PM_{10} standard. The 24-hr $PM_{2.5}$ standard is the toughest PM standard; it is achieved when the 3-year average of the 98th percentile of 24-hr concentrations at each monitor within an area does not exceed 35 $\mu g/m^3$. Because attainment will be achieved when the more stringent standards are reached, this study focuses on the 8-hr ozone standard and the 24-hr and annual average $PM_{2.5}$ standards. The benefits of compliance with the more stringent California standards (a 70 ppb 8-hr daily maximum ozone and a 12 $\mu g/m^3$ annual average $PM_{2.5}$ standard) are not addressed in this study, but have been estimated in other recent studies (ARB, 2008).

In the 2005-2007 period, the 75 ppb 8-hr ozone level was exceeded on 112 to 139 days per year in the SJVAB and on 115 to 120 days per year in the SoCAB. The spatial patterns of the exceedances frequencies are illustrated in Figures II-3 and II-4. The spatial maps for the SoCAB show that about half of the populated regions exceeded the 8-hr ozone standard more than 30 days per year in 2006 and 2007. Similarly, the maps show that about half of the populated regions in the SJVAB exceeded the 8-hr ozone standard more than 25 days per year in 2005 and 2006. Two communities exceeded the standard more than 100 days per year: Crestline in the SoCAB in 2005 and Arvin in the SJVAB in 2006. The measurement data show that both the frequency and the severity of exceedances are high, especially in the SoCAB. The highest 1-hr and 8-hr daily maximum concentrations in the SoCAB during 2005 to 2007 were 182 and 142 ppb, respectively. The ozone design value (the 3-year average of the fourth-highest daily 8-hr maximum) is 122 ppb in this period. The highest 1-hr and 8-hr daily

[1] Here, stringent means more limiting in terms of the difficulty of attainment.

maximum concentrations in the SJVAB during 2005 to 2007 were 141 and 123 ppb, respectively, and the ozone design value is 107 ppb. Attainment of the 8-hr NAAQS is expected when the air quality improvements reduce the ozone design value to 75.49 ppb. Thus, attainment of the ozone standard requires a 38% and 29% decrease in the design value in the SoCAB and SVJAB, respectively. However, because there is a global background concentration of about 40 ppb, the required reduction of ozone in excess of the background level to reach attainment is 57% and 47% in the SoCAB and SVJAB, respectively. The SCAQMD and SJVAPCD have adopted air quality plans designed to reach attainment of the former NAAQS for ozone of 80 ppb by 2023 (SCAQMD 2007b; SJVAPCD 2007). The agencies have not yet formally released plans to address compliance with the newer 75 ppb standard.

The frequency of exceedances of the 35 μg/m^3 daily $PM_{2.5}$ standard is somewhat lower than that for ozone, ranging from 38 to 76 days per year in the SJVAB and 45 to 48 days per year in the SoCAB. The spatial patterns of daily concentrations exceeding 35 μg/m^3 are shown in Figures II-5 and II-6. For example, we estimate there were 47 days in the SoCAB and 76 days in the SJVAB in 2007 that had one or more locations with $PM_{2.5}$ above 35 μg/m^3. The frequencies are estimated rather than measured because $PM_{2.5}$ is often measured (by the Federal Reference Method) every third day rather than every day (which occurs at only a few stations). The highest measured daily concentrations were 132 μg/m^3 in the SoCAB (in Azusa) and 104 μg/m^3 in the SJVAB (in Fresno). Because $PM_{2.5}$ is derived from primary particle emissions as well as from gaseous emissions (secondary), the highest values can be quite erratic. For example, while the highest $PM_{2.5}$ was 132 μg/m^3 at Azusa, the second highest reading in 3 years at that station was 63 μg/m^3, and the second highest at any SoCAB station was 106 μg/m^3. Fortunately, the standard has a statistical form that relies on the 3-year average of the 98th percentile values for determination of attainment status. As shown in Table II-5, the design values for the 2005-2007 period are substantially lower than these peak levels: 73.4 μg/m^3 in the SoCAB (at Riverside-Rubidoux) and 69.8 μg/m^3 in the SVJAB (at Bakersfield – California St.). These design values have been estimated using EPA's procedures that account for frequency of measurements and substitution of quarterly maximum values for missing data when records are less than 75% complete. Attainment of the daily $PM_{2.5}$ standard will require 52% and 49% reductions in ambient concentrations from 2005-2007 levels in the SoCAB and SJVAB, respectively. If one considers the background concentration of 6 μg/m^3, the reductions in $PM_{2.5}$ in excess of the background are 56% in the SoCAB and 54% in the SJVAB. The SCAQMD and SJVAPCD have adopted air quality plans designed to reach attainment of the former NAAQS for $PM_{2.5}$ of 65 μg/m^3 by 2014. The agencies have not yet formally released plans to address compliance with the newer and much more stringent 35 μg/m^3 standard.

Spatial maps of the estimated annual average $PM_{2.5}$ concentrations in the air basins are shown in Figures II-7 and II-8. Concentrations tend to increase from modest levels in the western areas of Los Angeles and Orange Counties to fairly high levels in the eastern area surrounding the cities of Riverside and San Bernardino. The Riverside-Rubidoux area has consistently recorded the highest annual averages in the SoCAB. Annual $PM_{2.5}$ levels in the SJV are lowest in the northwest, near Stockton, and highest in the southeast, in Bakersfield (Kern County). $PM_{2.5}$ concentrations gradually increase between the northern and southern ends of the San Joaquin Valley. As indicated in Table II-5, the highest 3-year average $PM_{2.5}$

concentration is 19.7 μg/m^3 in Riverside (at the Rubidoux station) and 20.4 μg/m^3 in Bakersfield (at the Planz Road station). Compliance with the annual standard requires 24% and 26% reduction in ambient concentrations in the SoCAB and SJVAB, respectively. Considering the 6 μg/m^3 background concentration, $PM_{2.5}$ concentrations in excess of the background need to be reduced by 34% and 37% in the SoCAB and SJVAB, respectively. The local air pollution management agencies have adopted plans to reach attainment of the annual standard by 2014 (SCAQMD 2007b; SJVAPCD 2008). Because the reductions in concentrations needed to meet the annual standard are significantly less than those needed to meet the new daily standard, additional control emission measures beyond those incorporated in existing air quality management plans will need to be adopted and implemented to achieve the clean air goals.

In summary, air quality conditions in these two air basins are surprisingly similar even though the SJV is much larger, less densely populated, and dominated by agricultural rather than urban land use. The highest annual average $PM_{2.5}$ levels are virtually the same. The frequency of ozone standard exceedances is similar (~100 days per year). The ozone and daily $PM_{2.5}$ exceedances are more severe in the SoCAB than SJVAB; however, the $PM_{2.5}$ exceedances are more frequent in the SJVAB. Significant reductions in emissions are needed in both areas to attain the NAAQS.

II.3.1 Spatial Mapping

Ambient air quality data from California's network of monitoring stations were used to spatially map concentrations to the exposure grids. Measured concentration data were spatially interpolated and extrapolated to provide estimates of concentrations at each population grid. For the 2005-2007 baseline period, hourly ozone data were available for 24 stations within the SoCAB and 19 stations within the SJVAB. Ozone data from additional monitors located just outside the air basin boundaries were used in the spatial mapping. The ozone data were used to create maps of hourly concentrations for each day of the baseline period (1,096 days and 26,304 maps). While $PM_{2.5}$ data are collected using a variety of methods in California, only data collected using the Federal Reference Method (FRM) are used for attainment assessment. Hence, only $PM_{2.5}$ data collected using a FRM were used in the study. Daily $PM_{2.5}$ data were available at 14 stations in the SoCAB and 12 stations in the SJVAB on a variety of frequencies, including every day, every third day, and every sixth day. The spatial mapping of daily $PM_{2.5}$ concentrations was performed using the FRM data on days when at least 8 of the 14 stations in the SoCAB and 6 of the 12 stations in the SJVAB had valid 24-hr data. Daily spatial maps were generated for 356 days (or 119 days per year) in the SoCAB and 318 days (or 106 days per year) in the SJVAB. The annualized frequency of occurrence of daily $PM_{2.5}$ conditions was computed assuming these days were representative of the entire 3-year period. Annual average $PM_{2.5}$ concentrations were calculated from the FRM data using EPA's methodology (i.e., annual average = average of quarterly averages) and mapped for each year.

The spatial mapping method assigns exposure grid concentrations from the nearest station if the station is located within 3 km of the center of the exposure grid. If no stations with valid data are located within 3 km of the center of the exposure grid, the concentration is calculated by inverse-distance squared weighting of the concentrations from the four stations closest to the center of the exposure grid, provided all stations are located within 100 km of the exposure grid center. In areas with sparse network coverage, the algorithm may be applied with one to three stations. This method is very similar to the method used by EPA on its AIRNow web site (www.epa.gov/airnow) for mapping air quality indices and by other recent California health benefit analyses (SCAQMD, 2007a; ARB, 2008). Examples of the maps created with this method are shown in Figures II-7 and II-8. They show the spatially mapped annual average $PM_{2.5}$ concentrations for 2005, 2006, and 2007. The annual $PM_{2.5}$ concentrations are estimated to vary smoothly across the regions. The maps of daily $PM_{2.5}$ and hourly ozone maps often have more spatial variability than these examples because they reflect the day-to-day variations in meteorological conditions that greatly influence the spatial patterns. The ozone maps also reflect the greater spatial coverage of monitoring station data for ozone than for $PM_{2.5}$.

II.4 FUTURE AMBIENT AIR QUALITY

For purposes of this exposure analysis, we are interested in the spatial and temporal distribution of ambient concentrations for a three-year period in which the air quality standard is attained. Attainment of the standard occurs after the design value is reduced to the level of the standard. Two methods are available to estimate future-year air quality conditions. One method involves the application of detailed meteorological, emissions, and air quality models to estimate the distributions of future concentrations under specific emission scenarios. Such models are used to develop emission control strategies to reach attainment in the air quality plans. Typically, the detailed models are applied for relatively short periods (usually less than a few weeks per year) rather than multi-year periods. The resources (time and budget) required to apply this method for a three-year period in these areas are far greater than those available for this study, so this method is not feasible as the primary method for the present study.

The second method involves the application of the simple linear rollback model shown below.

$$C_{xyt}^{Future} = C_{Bkgrd} + \left(C_{xyt}^{Base} - C_{Bkgrd}\right)\left(\frac{C_{Std} - C_{Bkgrd}}{C_{Max} - C_{Bkgrd}}\right) \qquad \text{if } C_{xyt}^{Base} \geq C_{Bkgrd} \qquad (1)$$

$$C_{xyt}^{Future} = C_{xyt}^{Base} \qquad \text{if } C_{xyt}^{Base} < C_{Bkgrd} \qquad (2)$$

where C_{xyt}^{Future} = the future concentration at location *x,y*, and time *t,*

C_{xyt}^{Base} = the baseline period concentration at location *x,y*, and time *t,*

C_{Bkgrd} = the background concentration,

C_{Max} = the baseline or current design value concentration, and

C_{Std} = the air quality standard threshold concentration.

This method assumes that future concentration changes in excess of the background concentration will linearly track changes in the current or baseline maximum concentration (minus the background concentration). It assumes that concentrations in excess of the background concentration with attainment will be linearly reduced in proportion to the ratio of the standard (adjusted for background) to the design value (also adjusted for background).

Concentrations at or below the background level are assumed to be unaffected by changes in emissions. The rollback model is a very simple air quality model that disregards much of the detailed knowledge of the atmospheric chemistry and physics that influence concentrations, yet it is likely the most suitable model when the specific emission control measures needed to reach attainment in a region are not yet identified. The reason is that attainment can be achieved with different sets of control measures that will produce different spatial and temporal patterns of concentrations; without knowledge of the specific path to attainment, it is best to keep the projection method as simple as possible. Nevertheless, the effects of NO_x emission reductions on ozone are nonlinear and the simple linear rollback approach is likely to overestimate ozone reductions in the more heavily populated (or high NO_x) portions of the air basins. The areas with less-than-linear effects of NO_x reductions on ozone are usually areas with high baseline NO_x levels and low or moderate baseline ozone levels.

The parameters used to project the distributions of concentrations with attainment are shown in Table II-5. They project that future ozone levels in excess of the background would be 57% and 47% of current levels in the SoCAB and SJVAB, respectively. Similarly, the future 24-hr and annual $PM_{2.5}$ concentrations in excess of the background are estimated as 56% and 34% of current levels in the SoCAB, and 54% and 37% of current levels in the SJVAB. These factors are applied to the spatially mapped baseline-period concentrations that exceed that background to generate the future-year spatial maps of concentrations for the same time period (three years).

II.5 CURRENT AND FUTURE POPULATION EXPOSURE ESTIMATES

The REHEX model was applied using the population and air quality data described above to estimate the population exposure to ozone and $PM_{2.5}$ in the baseline period and in the future with attainment. The population exposure to air pollution was quantified not only in terms of the exposure metrics relevant to the air quality standards, but also in terms of the exposure metrics used in the concentration-response relationships reported in the health science literature. The exposure metrics for ozone include the 1-hr daily maximum, the 2-week average 1-hr daily maximum, the 5-hr daily maximum, the 8-hr daily maximum, and the 24-hr average concentrations. Certain concentration-response relationships use 8-hr 10 a.m. to 6 p.m. ozone rather than 8-hr daily maximum ozone; the two metrics are almost indistinguishable in these air basins. The exposure metrics for $PM_{2.5}$ include the 24-hr average concentration and the annual average concentrations.

Most of the concentration-response relationships used in this study apply to all days of the year. The school-absence concentration-response relationship applies to exposures on the day preceding the school absence. For this analysis, exposures occurring on Fridays, Saturdays, and holidays were excluded as well as the day preceding each holiday.

II.5.1 Exposure Frequency Distributions

The overall frequency distributions of daily exposure for the population are shown in Figures II-9 through II-20. The total number of person-days of exposure is large for these regions and time period, 6.3 billion per year in the SoCAB (17.3 million x 365 days) and 1.3 billion per year in the SJVAB (3.51 million x 365 days). The figures show the number of person-days of exposures per year to concentrations above various concentration thresholds. The distributions are presented on a logarithmic scale because there is commonly a five order of magnitude difference between the number of person-days of exposure to the highest observed levels compared to the number of person-days of exposure to background concentrations. For example, Figure II-9 shows that the estimated number of person-days per year of exposure in the SoCAB to 8-hr daily maximum ozone above 40, 60, 80, 100, 120, and 140 ppb is 3.2 billion, 901 million, 202 million, 34 million, 3.1 million, and 38,000, respectively, in the baseline case. Figure II-9 also indicates that under the NAAQS attainment scenario, the estimated number of person-days per year of exposure to 8-hr daily maximum ozone above 40, 60, 80, and 100 ppb is 3 billion, 116 million, 200,000, and zero, respectively. Figure II-19 and Figure II-20 show the estimated number of persons exposed to annual average $PM_{2.5}$ concentrations above various concentration thresholds in the air basins. Figure II-20, for example, indicates the estimated number of SJVAB residents exposed to annual average $PM_{2.5}$ concentrations above 14, 16, 18, 20 ,and 22 µg/m^3 is 2.7 million, 2.1 million, 1.1 million, 0.26 million, and 21,000, respectively, in the 2005-2007 period, and 0.66 million, 21,000, 0, 0, and 0, respectively, with attainment. All the distributions show large differences in the frequency of exposure between the baseline and NAAQS attainment scenario.

II.5.2 Spatial Distributions of Exposure

The estimated spatial distributions of exposure to ozone concentrations above 75 ppb are shown in Figures II-21 and II-22. In 2005-2007, the western portions of Riverside and San Bernardino Counties, as well as the San Fernando Valley and Santa Clarita, are estimated to have a large number of ozone exposures (e.g., > 1 million person-days per year per grid) above 75 ppb. Fewer exposures to levels above the standard occurred in the coastal areas and central Los Angeles County. In the SJVAB in 2005-2007, the highest number of person-days of exposure occured in and around the populated urban areas of Bakersfield, Fresno, Visalia, Merced, and Modesto. Exposures above 75 ppb ozone are fewer in Stockton than in the other urban areas. The baseline spatial exposure maps clearly show that areas with high numbers of adverse ozone exposures extend broadly across the air basins. The spatial exposure maps with ozone NAAQS attainment show a dramatic shrinkage of the areas affected and the number of high exposures per year.

Figures II-23 and II-24 show the spatial distribution of estimated population exposure to 24-hr average $PM_{2.5}$ concentrations above 35 µg/m^3. In the San Joaquin Valley, the spatial distribution of exposures to high $PM_{2.5}$ concentrations is similar to those for ozone: the greatest number of exposures occurs in the urban areas. In the SoCAB, the largest number of person-days of exposure to $PM_{2.5}$ above 35 µg/m^3 occurs in central Los Angeles County in the baseline period. Areas in the western portions of Riverside and San Bernardino Counties also have a large number of exposures to high concentrations, even though they are not as densely populated as central Los Angeles County. With attainment, a small number of exposures above the level of the standard is estimated in Fresno, Bakersfield, and western portions of Riverside and San Bernardino Counties. The latter is expected because of the statistical form of the daily standard (i.e., it controls to the 98th percentile of the concentration distribution).

The spatial distributions of population exposures to annual average $PM_{2.5}$ concentrations above 15 µg/m^3 are shown in Figures II-25 and II-26. The number of residents estimated to be exposed to annual average $PM_{2.5}$ concentrations above 15 µg/m^3 is greater in densely populated central Los Angeles County than elsewhere in the SoCAB. Likewise, in the SJVAB, more residents of the central and southern population centers, Fresno, Visalia, and Bakersfield, are exposed to high annual average $PM_{2.5}$ than residents living in the northern urban areas and the rural areas. With attainment of the NAAQS, the area with residents exposed to concentrations above 15 µg/m^3 shrinks substantially from that in the baseline period. Only residents living in Bakersfield and near Riverside are estimated to receive annual $PM_{2.5}$ exposures above 15 µg/m^3 during some years with attainment.

II.5.3 Exposure Frequency by County, Age Group, and Racial/Ethnic Group

8-hr Daily Maximum Ozone Exposures

The estimated number of exposures to 8-hr daily maximum ozone concentrations above 75, 80, and 100 ppb is listed in Table II-6 for the individual counties and for the whole air basins. The REHEX model estimates 306 million and 108 million person-days of exposures per year to 8-hr concentrations above 75 ppb in the SoCAB and SJVAB, respectively, in the baseline period. The estimated number of person-days above 100 ppb is 34 million in the SoCAB (9 times lower than those above 75 ppb) and 2.4 million in the SJVAB (45 times lower than those above 75 ppb). Table II-7. shows a population-weighted average number of days residents are exposed to ozone concentrations above the same thresholds. Residents of the SJVAB are estimated to have 31 days per year with exposures above 75 ppb compared to 18 days per year for residents of the SoCAB. At the 100 ppb threshold, residents of the SJVAB have 0.7 days per year compared to 2 days per year for residents of the SoCAB.

The results for the individual counties reflect the population and air quality differences across the air basins. For example, the total number of exposures above 75 ppb is about 100 million in Los Angeles, Riverside, and San Bernardino Counties and 9 million in Orange County. The average resident of Orange, Los Angeles, San Bernardino, and Riverside Counties experiences 3, 10, 47, and 48 days per year with 8-hr daily maximum ozone concentrations above 75 ppb in the baseline period. The inland counties have lower populations than Los Angeles County, but a much higher frequency of high ozone concentration days. Residents of Riverside and San Bernardino Counties are estimated to have 4.7 and 7.2 days, respectively, above 100 ppb ozone on average, which is substantially higher than in other counties. In the SJVAB, the largest numbers of person-days of exposure to ozone above 75 ppb are estimated for Fresno, Kern, and Tulare Counties. The average number of days above 75 ppb is 51, 46, and 40 days per year in Kern, Tulare, and Fresno Counties, respectively, compared to 8, 14, 18, 30, and 30 days per year in San Joaquin, Stanislaus, Merced, Madera, and Kings Counties. The combination of high population and more frequent adverse air quality conditions results in high numbers of person-days of exposure in Kern, Tulare, and Fresno Counties. The results for the 100 ppb ozone level indicate residents of Fresno and Kern Counties have, on average, 1 and 2 days per year with more severe 8-hr exposures. Residents of the other SJV counties have less than 1 day per year on average with 8-hr ozone exposures above 100 ppb. With NAAQS attainment, we estimate the residents of San Bernardino and Kern Counties will have 0.9 and

0.6 days per year, respectively, with 8-hr ozone above 75 ppb on average. These results are consistent with the statistical form of the NAAQS, which allows for one day on average per year above the level of the standard at the highest station.

Tables II-8 and II-9 show the age distribution of the 8-hr ozone exposures. The largest age group, adults ages 30 to 64 years, reflects the greatest number of person-days of exposure. Because the age distributions are fairly similar across the region, the estimated number of ozone exposure days above 75 ppb is similar for the different age groups. Even without consideration of human time activity, the model results indicate children and young adults in the SJVAB are exposed slightly more frequently than adults over age 30. For example, infants under age 1 are exposed to 8-hr ozone above 75 ppb on 31.6 days per year compared to 30 days per year for adults over age 64. In the SoCAB, children ages 1 to 4 years and elderly adults have a slightly higher frequency of exposures to high ozone than 18- to 64-year-old adults.

Tables II-10 and II-11 show the number of person-days and average days of exposure to the 8-hr ozone concentration thresholds by racial/ethnic group. The results show that Hispanics in the SJVAB and non-Hispanic whites in the SoCAB are exposed more frequently than other racial groups to 8-hr ozone levels above 75 ppb in the 2005-2007 period. For example, the estimated number of days with ozone above 75 ppb is 14, 16, 17, and 21 days per year for other races, blacks, Hispanics, and whites, respectively, in the SoCAB and 27, 29, 32, and 30 days per year for other races, blacks, Hispanics and whites, respectively, in the SJVAB. Spatial differences in the population racial/ethnic makeup in different counties and grids are responsible for the differences in exposure frequencies. The differences in ozone exposure vary more by race/ethnicity than by age group. However, as Table II-7 shows, the largest variations in ozone exposures are by region (or county) rather than by race/ethnicity or age.

24-hr Average $PM_{2.5}$ Exposures

The estimated number of exposures of the population to 24-hr average $PM_{2.5}$ concentrations above 35, 50, and 65 μg/m^3 are shown in Tables II-12 and II-13. The results for the baseline period indicate 289 million and 153 million person-days of exposure to concentrations above 35 μg/m^3 occur annually in the SoCAB and SJVAB, respectively. The estimated number of person-days per year of exposure to daily $PM_{2.5}$ above 65 μg/m^3 is 9 million in the SoCAB and 16 million in the SJVAB. The majority of exposures above 35 μg/m^3 in the SoCAB occur in Los Angeles County. In the SJVAB, the majority of exposures above 35 μg/m^3 occur in Fresno and Kern Counties. Residents of the overall SoCAB, Los Angeles, Orange, Riverside, and San Bernardino Counties are estimated to experience 17, 17, 10, 20, and 23 days per year of exposure to concentrations above 35 μg/m^3 on average. Residents of the SJVAB are estimated to experience 44 days per year of exposure to concentrations above 35 μg/m^3 on average. Residents of Fresno, Kings, Tulare, and Kern Counties are estimated to experience 50 days per year with $PM_{2.5}$ above this threshold. On average, SJVAB residents are estimated to experience 2½ times as many days above the daily $PM_{2.5}$ NAAQS as SoCAB residents in the 2005-2007 period. The estimated average number of days of exposure above the 65 μg/m^3 level is 0.6 days in the overall SoCAB, 2.5 days in San Bernardino County, 4.6 days in the overall SJVAB, and 10.7 days in Kern County. These population-weighted averages strongly suggest SJVAB residents have more frequent exposures to high daily $PM_{2.5}$ than SoCAB residents, which is similar to the results for ozone exposures.

With attainment of the 24-hr NAAQS, population exposure to 24-hr average $PM_{2.5}$ concentrations above 35 $\mu g/m^3$ is estimated to be 3.5 million and 11.4 million person-days per year in the SoCAB and SJVAB, respectively. Residents on average would experience 0.2 days per year in the SoCAB and 3.2 days per year in the SJVAB with $PM_{2.5}$ concentrations above 35 $\mu g/m^3$. Residents of Los Angeles and Orange Counties would experience zero days per year and residents of Riverside and San Bernardino Counties would experience less than one day per year with $PM_{2.5}$ concentrations above 35 $\mu g/m^3$. Similarly, residents of the four northern-most counties in the SJVAB would experience less than 2 days per year with attainment whereas residents of the four southern-most counties would experience 3.2 to 7.5 days per year with attainment. The $PM_{2.5}$ air monitoring site that controls the $PM_{2.5}$ design value for the SJVAB is located in Kern County (Bakersfield) and residents of Kern County, on average, would experience 7.5 days per year with $PM_{2.5}$ concentrations above 35 $\mu g/m^3$ with attainment. This frequency closely matches the 98th percentile requirement of the NAAQS, 7.3 days.

Tables II-14 through II-17 show the results for estimated daily $PM_{2.5}$ exposures by age group and racial/ethnic group. The average number of days per year above 35 $\mu g/m^3$ ranges from 15.9 for elderly adults to 17.1 for children ages 1 to 4 years in the SoCAB, and ranges from 43.1 days for elderly adults to about 44 days for ages 1 to 29 years in the SJVAB. Thus, on average within an air basin, the variation in frequency of exposures to adverse $PM_{2.5}$ levels by age group is small. The exposure estimates for racial and ethnic groups suggest that blacks and Hispanics have slightly more frequent exposure to elevated $PM_{2.5}$ concentrations than whites and other races in both air basins. "Other race" residents are estimated to experience 16% fewer days per year (or 2.9 days) than black residents of the SoCAB and 9% fewer days per year (or 3.7 days) than Hispanic residents of the SJVAB with exposure to $PM_{2.5}$ concentrations above 35 $\mu g/m^3$. The $PM_{2.5}$ exposure differences among racial/ethnic groups are generally smaller than regional (county) differences, and larger than age differences.

Annual Average $PM_{2.5}$ Exposures

The estimated annual average exposure of residents to $PM_{2.5}$ in 2005-2007 and with attainment is summarized in Tables II-18 through II-23. The exposure calculations indicate 91%, 64%, and 15% of the SoCAB population and 100%, 66%, and 30% of the SJVAB population are exposed to annual average $PM_{2.5}$ concentrations above 12, 15, and 18 $\mu g/m^3$, respectively, in the baseline period. Results indicate that 75%, 15%, 69%, and 78% of residents in Los Angeles, Orange, Riverside, and San Bernardino Counties are exposed to annual average $PM_{2.5}$ above the 15 $\mu g/m^3$ standard in 2005-2007. In the SJVAB, we estimate 0%, 17%, and 35% of the residents of San Joaquin, Stanislaus, and Merced Counties, respectively, and 100% of residents of the other counties are exposed to annual average $PM_{2.5}$ above 15 $\mu g/m^3$ in 2005-2007. Age breakdown shows that the percent of population exposed to annual average $PM_{2.5}$ concentrations above 15 $\mu g/m^3$ in the baseline period ranges from 61% for elderly adults to 66% for 18- to 21-year-old adults in the SoCAB, and from 63% for elderly adults to 68% for infants and adults ages 22 to 29 years in the SJVAB. The race/ethnicity breakdown indicates approximately 55%, 60%, 70%, and 78% of white, other race, Hispanic, and black residents, respectively, of the SoCAB are estimated to be exposed to annual $PM_{2.5}$ concentrations above the 15 μg/m^3 NAAQS threshold. In the SJVAB, approximately 61%, 56%, 72%, and 66% of white, other race, Hispanic, and black residents, respectively, are estimated to be exposed to annual $PM_{2.5}$ concentrations above the NAAQS threshold. The race/ethnicity exposure distributions for both daily and annual $PM_{2.5}$ indicate blacks in the SoCAB and Hispanics in the SJVAB receive disproportionately more exposures than other racial or ethnic groups.

With attainment of the annual NAAQS, the model estimates that only 1% of the SoCAB population and 6% of the SJVAB population would be exposed to annual average $PM_{2.5}$ concentrations above 15 μg/m^3. The reason a portion of the population may experience exposure to concentrations above the level of the NAAQS even with attainment is that quantification of individual yearly exposures and the NAAQS is based on three-year average exposure. No exposures to annual $PM_{2.5}$ concentrations above 15 μg/m^3 are estimated to occur in the western half of the SoCAB or in the central and northern portion of the SJVAB (i.e., north of Tulare County) with attainment. However, approximately 1%, 3%, 3%, and 30% of residents in San Bernardino, Riverside, Tulare, and Kern Counties, respectively, are estimated to be exposed to annual $PM_{2.5}$ concentrations above 15 μg/m^3 under the NAAQS attainment scenario. It is important to recognize that the 4-5 μg/m^3 reductions in annual $PM_{2.5}$ to achieve NAAQS attainment represent a dramatic improvement in air quality relative to background levels, and a dramatic reduction in population exposure to harmful levels. Furthermore, since the daily $PM_{2.5}$ standard is more stringent than the annual standard, it is quite possible that the emission control plans adopted to attain the daily $PM_{2.5}$ standard may result in greater reduction in annual $PM_{2.5}$ than estimated in this study.

Table II-1. 2007 SoCAB population by county and age group.

County	<1 Yr	1 Yr	2-4 Yrs	5-17 Yrs	18-21 Yrs	22-29 Yrs	30-64 Yrs	>64 Yrs	All Ages
Los Angeles	157,842	172,032	516,098	2,007,264	564,461	1,226,088	4,543,517	1,011,927	10,199,229
Orange	47,352	52,268	156,808	579,795	158,807	346,449	1,452,627	302,945	3,097,051
Riverside	32,296	44,157	132,478	394,548	104,689	164,762	877,488	263,373	2,013,791
San Bernardino	33,766	40,736	122,212	441,317	117,713	198,286	872,944	174,625	2,001,599
Air Basin (persons)	271,256	309,193	927,596	3,422,924	945,670	1,935,585	7,746,576	1,752,870	17,311,670
Air Basin (percent)	1.6%	1.8%	5.4%	19.8%	5.5%	11.2%	44.7%	10.1%	100.0%

Table II -2. 2007 SoCAB population by county and racial/ethnic group.

Region	White Non-Hispanic	Black Non-Hispanic	Hispanic	Other Non-Hispanic
Los Angeles County	3,134,742	941,660	4,579,977	1,542,861
Orange County	1,552,669	48,103	958,199	538,076
Riverside County	971,793	144,079	713,027	184,874
San Bernardino County	818,438	172,647	832,597	177,917
Air Basin (persons)	6,477,642	1,306,489	7,083,800	2,443,728
Air Basin (percent)	37.4%	7.5%	40.9%	14.1%

Table II-3. 2007 SJVAB population by county and age group.

County	<1 Yr	1 Yr	2-4 Yrs	5-17 Yrs	18-21 Yrs	22-29 Yrs	30-64 Yrs	>64 Yrs	All Ages
San Joaquin	9,498	9,706	30,965	145,247	39,147	66,011	269,929	68,788	639,291
Stanislaus	7,372	7,676	24,180	114,748	29,419	52,567	210,335	53,059	499,356
Merced	3,842	3,912	12,576	59,091	14,520	24,625	90,810	21,943	231,319
Madera	1,924	2,054	6,435	29,476	7,659	14,322	59,960	14,904	136,734
Fresno	14,249	14,406	44,735	205,401	58,319	101,530	346,688	87,199	872,527
Kings	2,175	2,194	6,643	28,868	9,089	19,893	60,517	10,405	139,784
Tulare	6,895	6,725	21,339	97,960	25,550	43,509	154,567	38,639	395,184
Kern	10,216	10,281	31,547	143,345	37,542	69,619	243,733	51,544	597,827
Air Basin (persons)	56,171	56,954	178,420	824,136	221,245	392,076	1,436,539	346,481	3,512,022
Air Basin (percent)	1.6%	1.6%	5.1%	23.5%	6.3%	11.2%	40.9%	9.9%	100.0%

Table II-4. 2007 SJVAB population by county and racial/ethnic group.

County	White Non-Hispanic	Black Non-Hispanic	Hispanic	Other Non-Hispanic
San Joaquin	311,729	43,091	203,052	81,515
Stanislaus	297,327	12,319	161,931	27,850
Merced	96,823	8,596	108,380	17,761
Madera	69,259	5,283	56,985	5,309
Fresno	348,392	46,061	398,085	80,375
Kings	60,007	11,212	62,629	6,128
Tulare	168,158	5,615	205,226	16,556
Kern	272,036	35,892	263,007	27,401
Air Basin (persons)	1,623,731	168,069	1,459,295	262,895
Air Basin (percent)	46.2%	4.8%	41.6%	7.5%

Table II-5. Parameters used to estimate ambient ozone and $PM_{2.5}$ concentrations with NAAQS attainment.

Pollutant and Averaging Time	SoCAB Design Value, 2005-2007	SJV Design Value, 2005-2007	Attainment Level	Background Concentration
Ozone 8-hr Daily Maximum	122 ppb	107 ppb	75.49 ppb	40 ppb
$PM_{2.5}$ 24-hr Daily Maximum	73.4 μg/m^3	70.0 μg/m^3	35.49 μg/m^3	6 μg/m^3
$PM_{2.5}$ Annual Average	19.7 μg/m^3	20.4 μg/m^3	15.05 μg/m^3	6 μg/m^3

Table II-6. The estimated population exposure to 8-hr daily maximum ozone concentrations above 75, 80, and 100 ppb in the 2005-2007 baseline period and with NAAQS attainment by county.

Region	Person-days of Exposure Above Concentration (in millions per year)				
	In the 2005-2007 Baseline Period			With NAAQS attainment	
	>75 ppb	>80 ppb	>100 ppb	>75 ppb	>80 ppb
South Coast Air Basin	306.28	202.27	33.96	2.61	0.20
Los Angeles County	104.97	65.93	9.70	0.48	0.09
Orange County	8.86	4.18	0.34	0	0
Riverside County	97.48	65.42	9.552	0.32	0
San Bernardino County	94.98	66.74	14.37	1.82	0.11
SJV Air Basin	108.20	69.03	2.42	0.68	0.01
San Joaquin County	5.07	2.99	0.03	0	0
Stanislaus County	6.97	4.37	0	0	0
Merced County	4.28	2.17	0	0	0
Madera County	4.05	2.35	0.07	0.02	0
Fresno County	34.69	22.43	0.97	0.32	0
Kings County	4.22	2.40	0.06	0	0
Tulare County	18.24	11.19	0.07	0	0
Kern County	30.67	21.13	1.22	0.34	0.01

Table II-7. The estimated average number of days per year that the population is exposed to 8-hr daily maximum ozone concentrations above 75, 80, and 100 ppb in the 2005-2007 baseline period and with NAAQS attainment by county.

Region	Average Number of Days Per Year Above Concentration				
	In the 2005-2007 Baseline Period			With NAAQS attainment	
	>75 ppb	>80 ppb	>100 ppb	>75 ppb	>80 ppb
South Coast Air Basin	17.7	11.7	2	0.2	0
Los Angeles County	10.3	6.5	1	0	0
Orange County	2.9	1.4	0.1	0	0
Riverside County	48.4	32.5	4.7	0.2	0
San Bernardino County	47.5	33.3	7.2	0.9	0.1
SJV Air Basin	30.8	19.7	0.7	0.2	0
San Joaquin County	7.9	4.7	–	0	0
Stanislaus County	14.0	8.8	–	0	0
Merced County	18.5	9.4	–	0	0
Madera County	29.6	17.2	0.5	0.1	0
Fresno County	39.8	25.7	1.1	0.4	0
Kings County	30.2	17.2	0.4	0	0
Tulare County	46.2	28.3	0.2	0	0
Kern County	51.3	35.3	2.0	0.6	0

Table II-8. The estimated population exposure to 8-hr daily maximum ozone concentrations above 75, 80, and 100 ppb in the 2005-2007 baseline period and with NAAQS attainment by age group.

Air Basin	Age Group	Person-days of Exposure Above Concentration (in millions per year)				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>75 ppb	>80 ppb	>100 ppb	>75 ppb	>80 ppb
South Coast	Children < 1 Year	4.88	3.24	0.55	0.04	0.003
	Children 1 Year	5.94	3.96	0.67	0.05	0.004
	Children 2-4 Years	17.833	11.87	2.03	0.16	0.012
	Children 5-17 Years	62.90	41.77	7.13	0.57	0.043
	Adults 18-21 Years	16.81	11.15	1.91	0.15	0.011
	Adults 22-29 Years	29.34	19.31	3.31	0.26	0.018
	Adults 30-64 Years	135.88	89.52	15.05	1.14	0.094
	Adults >64 Years	32.69	21.46	3.30	0.23	0.017
San Joaquin	Children < 1 Year	1.77	1.13	0.04	0.01	0
	Children 1 Year	1.79	1.14	0.04	0.01	0
	Children 2-4 Years	5.57	3.55	0.13	0.04	0.001
	Children 5-17 Years	25.54	16.28	0.59	0.16	0.002
	Adults 18-21 Years	6.89	4.39	0.16	0.04	0.001
	Adults 22-29 Years	12.31	7.86	0.28	0.08	0.001
	Adults 30-64 Years	43.91	28.05	0.96	0.26	0.003
	Adults >64 Years	10.41	6.63	0.22	0.06	0.001

Table II-9. The estimated average number of days per year that the population is exposed to 8-hr daily maximum ozone concentrations above 75, 80, and 100 ppb in the 2005-2007 baseline period and with NAAQS attainment by age group.

Air Basin	Age Group	Average Number of Days Per Year Above Concentration				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>75 ppb	>80 ppb	>100 ppb	>75 ppb	>80 ppb
South Coast	Children < 1 Year	18	11.9	2	0.2	0
	Children 1 Year	19.2	12.8	2.2	0.2	0
	Children 2-4 Years	19.2	12.8	2.2	0.2	0
	Children 5-17 Years	18.4	12.2	2.1	0.2	0
	Adults 18-21 Years	17.8	11.8	2	0.2	0
	Adults 22-29 Years	15.2	10	1.7	0.1	0
	Adults 30-64 Years	17.5	11.6	1.9	0.1	0
	Adults >64 Years	18.6	12.2	1.9	0.1	0
San Joaquin	Children < 1 Year	31.6	20.2	0.7	0.2	0
	Children 1 Year	31.4	20.1	0.7	0.2	0
	Children 2-4 Years	31.2	19.9	0.7	0.2	0
	Children 5-17 Years	31.0	19.8	0.7	0.2	0
	Adults 18-21 Years	31.1	19.8	0.7	0.2	0
	Adults 22-29 Years	31.4	20.0	0.7	0.2	0
	Adults 30-64 Years	30.6	19.5	0.7	0.2	0
	Adults >64 Years	30.0	19.1	0.6	0.2	0

Table II-10. The estimated population exposure to 8-hr daily maximum ozone concentrations above 75, 80, and 100 ppb in the 2005-2007 baseline period and with NAAQS attainment by race/ethnicity group.

Air Basin	Age Group	Person-days of Exposure Above Concentration (in millions per year)				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>75 ppb	>80 ppb	>100 ppb	>75 ppb	>80 ppb
South Coast	White*	133.56	88.31	14.37	1.13	0.114
	Black*	20.76	14.00	2.52	0.23	0.013
	Hispanic	117.67	77.76	13.43	1.02	0.057
	Other*	34.29	22.19	3.64	0.23	0.016
San Joaquin	White*	48.71	31.25	1.00	0.27	0.002
	Black*	4.96	3.20	0.14	0.04	0
	Hispanic	47.52	30.08	1.13	0.32	0.006
	Other*	7.07	4.55	0.16	0.05	0

* Non-Hispanic

Table II-11. The estimated average number of days per year that the population is exposed to 8-hr daily maximum ozone concentrations above 75, 80, and 100 ppb in the 2005-2007 baseline period and with NAAQS attainment by race/ethnicity group.

Air Basin	Age Group	Average Number of Days Per Year Above Concentration				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>75 ppb	>80 ppb	>100 ppb	>75 ppb	>80 ppb
South Coast	White*	20.6	13.6	2.2	0.2	0
	Black*	15.9	10.7	1.9	0.2	0
	Hispanic	16.6	11	1.9	0.1	0
	Other*	14	9.1	1.5	0.1	0
San Joaquin	White*	30	19.2	0.6	0.2	0
	Black*	29.5	19	0.8	0.3	0
	Hispanic	32.6	20.6	0.8	0.2	0
	Other*	26.9	17.3	0.6	0.2	0

* Non-Hispanic

Table II-12. The estimated population exposure to daily $PM_{2.5}$ concentrations above 35, 50, and 65 $\mu g/m^3$ in the 2005-2007 baseline period and with NAAQS attainment by county.

Region	Person-days of Exposure Above Concentration (in millions per year)				
	In the 2005-2007 Baseline Period			With NAAQS attainment	
	>35 $\mu g/m^3$	>50 $\mu g/m^3$	>65 $\mu g/m^3$	>35 $\mu g/m^3$	>50 $\mu g/m^3$
South Coast Air Basin	289.04	67.45	9.00	3.55	0
Los Angeles County	171.44	37.37	1.48	0.31	0
Orange County	32.16	4.90	0.73	0.00	0
Riverside County	39.47	11.72	2.55	1.44	0
San Bernardino County	45.97	13.46	4.71	1.80	0
SJV Air Basin	153.08	57.70	16.15	11.37	0
San Joaquin County	18.34	2.91	0.26	0.07	0
Stanislaus County	19.25	6.90	1.13	0.93	0
Merced County	8.88	2.33	0.53	0.50	0
Madera County	6.23	2.54	0.56	0.28	0
Fresno County	43.33	18.87	4.45	2.76	0
Kings County	6.94	2.82	0.79	0.56	0
Tulare County	19.67	7.88	2.05	1.76	0
Kern County	30.44	13.44	6.38	4.50	0

Table II-13. The estimated average number of days per year that the population is exposed to daily $PM_{2.5}$ concentrations above 35, 50, and 65 $\mu g/m^3$ in the 2005-2007 baseline period and with NAAQS attainment by county.

Region	Average Number of Days Per Year Above Concentration				
	In the 2005-2007 Baseline Period			With NAAQS attainment	
	>35 µg/m³	>50 µg/m³	>65 µg/m³	>35 µg/m³	>50 µg/m³
South Coast Air Basin	17	4.1	0.6	0.2	0
Los Angeles County	16.9	3.8	0.1	0	0
Orange County	10.4	1.7	0.1	0	0
Riverside County	20.3	6.1	1.3	0.7	0
San Bernardino County	23.4	6.8	2.5	0.9	0
SJV Air Basin	43.6	16.4	4.6	3.2	0
San Joaquin County	28.7	4.6	0.4	0.1	0
Stanislaus County	38.6	13.8	2.3	1.9	0
Merced County	38.4	10.1	2.3	2.2	0
Madera County	45.5	18.6	4.1	2	0
Fresno County	49.7	21.6	5.1	3.2	0
Kings County	49.6	20.2	5.6	4	0
Tulare County	49.8	20	5.2	4.5	0
Kern County	50.9	22.5	10.7	7.5	0

Table II-14. The estimated population exposure to daily $PM_{2.5}$ concentrations above 35, 50, and 65 $\mu g/m^3$ in the 2005-2007 baseline period and with NAAQS attainment by age group.

Air Basin	Age Group	Person-days of Exposure Above Concentration (in millions per year)				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>35 µg/m³	>50 µg/m³	>65 µg/m³	>35 µg/m³	>50 µg/m³
South Coast	Children < 1 Year	4.60	1.11	0.15	0.06	0
	Children 1 Year	5.30	1.29	0.19	0.08	0
	Children 2-4 Years	15.90	3.86	0.57	0.23	0
	Children 5-17 Years	58.23	13.95	1.95	0.77	0
	Adults 18-21 Years	16.15	3.88	0.52	0.20	0
	Adults 22-29 Years	32.65	7.67	0.91	0.34	0
	Adults 30-64 Years	128.38	29.44	3.91	1.55	0
	Adults >64 Years	27.83	6.26	0.81	0.33	0
San Joaquin	Children < 1 Year	2.48	0.94	0.27	0.19	0
	Children 1 Year	2.51	0.95	0.27	0.19	0
	Children 2-4 Years	7.83	2.97	0.84	0.59	0
	Children 5-17 Years	36.03	13.59	3.83	2.70	0
	Adults 18-21 Years	9.68	3.66	1.03	0.72	0
	Adults 22-29 Years	17.27	6.57	1.86	1.31	0
	Adults 30-64 Years	62.34	23.44	6.54	4.60	0
	Adults >64 Years	14.94	5.57	1.52	1.07	0

Table II-15. The estimated average number of days per year that the population is exposed to daily $PM_{2.5}$ concentrations above 35, 50, and 65 μg/m³ in the 2005-2007 baseline period and with NAAQS attainment by age group.

Air Basin	Age Group	Average Number of Days Per Year Above Concentration				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>35 μg/m³	>50 μg/m³	>65 μg/m³	>35 μg/m³	>50 μg/m³
South Coast	Children < 1 Year	17.0	4.1	0.6	0.2	0
	Children 1 Year	17.1	4.2	0.6	0.2	0
	Children 2-4 Years	17.1	4.2	0.6	0.2	0
	Children 5-17 Years	17.0	4.1	0.6	0.2	0
	Adults 18-21 Years	17.1	4.1	0.5	0.2	0
	Adults 22-29 Years	16.9	4.0	0.5	0.2	0
	Adults 30-64 Years	16.6	3.8	0.5	0.2	0
	Adults >64 Years	15.9	3.6	0.5	0.2	0
San Joaquin	Children < 1 Year	44.1	16.8	4.8	3.4	0
	Children 1 Year	44.0	16.7	4.8	3.4	0
	Children 2-4 Years	43.9	16.6	4.7	3.3	0
	Children 5-17 Years	43.7	16.5	4.6	3.3	0
	Adults 18-21 Years	43.8	16.5	4.6	3.3	0
	Adults 22-29 Years	44.0	16.8	4.7	3.3	0
	Adults 30-64 Years	43.4	16.3	4.6	3.2	0
	Adults >64 Years	43.1	16.1	4.4	3.1	0

Table II-16. The estimated population exposure to daily $PM_{2.5}$ concentrations above 35, 50, and 65 μg/m³ in the 2005-2007 baseline period and with NAAQS attainment by race/ethnicity group.

Air Basin	Age Group	Person-days of Exposure Above Concentration (in millions per year)				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>35 μg/m³	>50 μg/m³	>65 μg/m³	>35 μg/m³	>50 μg/m³
South Coast	White*	102.66	21.68	3.56	1.51	0
	Black*	24.12	5.68	0.76	0.29	0
	Hispanic	124.07	31.20	3.79	1.44	0
	Other*	38.19	8.89	0.89	0.32	0
San Joaquin	White*	69.57	26.06	7.18	5.07	0
	Black*	7.29	2.76	0.83	0.60	0
	Hispanic	65.48	25.07	7.18	5.03	0
	Other*	10.83	3.84	0.98	0.68	0

* Non-Hispanic

Table II-17. The estimated average number of days per year that the population is exposed to daily $PM_{2.5}$ concentrations above 35, 50, and 65 μg/m³ in the 2005-2007 baseline period and with NAAQS attainment by race/ethnicity group.

Air Basin	Age Group	Average Number of Days Per Year Above Concentration				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>35 μg/m³	>50 μg/m³	>65 μg/m³	>35 μg/m³	>50 μg/m³
South Coast	White*	15.8	3.3	0.5	0.2	0
	Black*	18.5	4.3	0.6	0.2	0
	Hispanic	17.5	4.4	0.5	0.2	0
	Other*	15.6	3.6	0.4	0.1	0
San Joaquin	White*	42.8	16.1	4.4	3.1	0
	Black*	43.4	16.4	4.9	3.6	0
	Hispanic	44.9	17.2	4.9	3.4	0
	Other*	41.2	14.6	3.7	2.6	0

* Non-Hispanic

Table II-18. The estimated population exposed to annual average $PM_{2.5}$ concentrations above 12, 15, and 18 μg/m³ in the 2005-2007 baseline period and with NAAQS attainment by county.

Region	Persons Exposed to Concentrations Above Threshold				
	In the 2005-2007 Baseline Period			With NAAQS attainment	
	>12 μg/m³	>15 μg/m³	>18 μg/m³	>12 μg/m³	>15 μg/m³
South Coast Air Basin	15,711,063	10,999,438	2,548,726	10,837,698	91,124
Los Angeles County	9,880,253	7,606,792	455,088	7,496,553	–
Orange County	2,625,391	457,175	1,643	408,903	–
Riverside County	1,557,753	1,381,850	909,272	1,381,799	68,104
San Bernardino County	1,647,666	1,553,621	1,182,723	1,550,442	23,020
SJV Air Basin	3,511,874	2,310,467	1,064,496	2,146,628	192,733
San Joaquin County	639,291	0	0	0	0
Stanislaus County	499,356	86,854	0	0	0
Merced County	231,319	81,945	0	10,300	0
Madera County	136,586	136,365	0	131,870	0
Fresno County	872,527	872,508	61,625	871,751	0
Kings County	139,784	139,784	46,368	139,784	0
Tulare County	395,184	395,184	361,848	395,184	12,941
Kern County	597,827	597,827	594,655	597,740	179,792

Table II-19. The estimated percent of population that is exposed to annual average $PM_{2.5}$ concentrations above 12, 15, and 18 μg/m^3 in the 2005-2007 baseline period and with NAAQS attainment by county.

Region	Percent of Population Exposed to Concentrations Above Threshold				
	In the 2005-2007 Baseline Period			With NAAQS attainment	
	>12 μg/m^3	>15 μg/m^3	>18 μg/m^3	>12 μg/m^3	>15 μg/m^3
South Coast Air Basin	91%	64%	15%	63%	1%
Los Angeles County	97%	75%	4%	73%	0%
Orange County	85%	15%	0%	13%	0%
Riverside County	77%	69%	45%	69%	3%
San Bernardino County	82%	78%	59%	77%	1%
SJV Air Basin	100%	66%	30%	61%	6%
San Joaquin County	100%	0%	0%	0%	0%
Stanislaus County	100%	17%	0%	0%	0%
Merced County	100%	35%	0%	4%	0%
Madera County	100%	100%	0%	96%	0%
Fresno County	100%	100%	7%	100%	0%
Kings County	100%	100%	33%	100%	0%
Tulare County	100%	100%	92%	100%	3%
Kern County	100%	100%	99%	100%	30%

Table II-20. The estimated population exposed to annual average $PM_{2.5}$ concentrations above 12, 15, and 18 μg/m^3 in the 2005-2007 baseline period and with NAAQS attainment by age group.

Air Basin	Age Group	Persons Exposed to Concentrations Above Threshold				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>12 μg/m^3	>15 μg/m^3	>18 μg/m^3	>12 μg/m^3	>15 μg/m^3
South Coast	Children < 1 Year	246,924	174,868	43,920	172,870	1,550
	Children 1 Year	280,137	200,073	54,680	197,845	2,052
	Children 2-4 Years	840,403	600,219	164,043	593,536	6,156
	Children 5-17 Years	3,113,354	2,216,524	562,616	2,190,628	20,411
	Adults 18-21 Years	867,061	619,824	153,427	613,326	5,319
	Adults 22-29 Years	1,801,743	1,267,463	261,276	1,251,500	7,667
	Adults 30-64 Years	7,019,920	4,856,905	1,107,740	4,776,388	41,710
	Adults >64 Years	1,541,522	1,063,562	201,023	1,041,605	6,258
San Joaquin	Children < 1 Year	56,171	38,139	18,169	35,572	3,279
	Children 1 Year	56,954	38,401	18,081	35,764	3,290
	Children 2-4 Years	178,418	119,438	56,125	111,047	10,127
	Children 5-17 Years	824,117	546,182	255,156	506,573	46,659
	Adults 18-21 Years	221,240	148,448	67,492	138,397	12,053
	Adults 22-29 Years	392,067	266,753	122,937	249,262	22,115
	Adults 30-64 Years	1,436,459	933,647	429,002	866,957	78,713
	Adults >64 Years	346,448	219,459	97,534	203,056	16,498

Table II-21. The estimated percent of population that is exposed to annual average $PM_{2.5}$ concentrations above 12, 15, and 18 μg/m³ in the 2005-2007 baseline period and with NAAQS attainment by age group.

Air Basin	Age Group	Percent of Population Exposed to Concentrations Above Threshold				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>12 μg/m³	>15 μg/m³	>18 μg/m³	>12 μg/m³	>15 μg/m³
South Coast	Children < 1 Year	91%	64%	16%	64%	1%
	Children 1 Year	91%	65%	18%	64%	1%
	Children 2-4 Years	91%	65%	18%	64%	1%
	Children 5-17 Years	91%	65%	16%	64%	1%
	Adults 18-21 Years	92%	66%	16%	65%	1%
	Adults 22-29 Years	93%	65%	14%	65%	0%
	Adults 30-64 Years	91%	63%	14%	62%	1%
	Adults >64 Years	88%	61%	11%	59%	0%
San Joaquin	Children < 1 Year	100%	68%	32%	63%	6%
	Children 1 Year	100%	67%	32%	63%	6%
	Children 2-4 Years	100%	67%	31%	62%	6%
	Children 5-17 Years	100%	66%	31%	61%	6%
	Adults 18-21 Years	100%	67%	30%	63%	5%
	Adults 22-29 Years	100%	68%	31%	64%	6%
	Adults 30-64 Years	100%	65%	30%	60%	5%
	Adults >64 Years	100%	63%	28%	59%	5%

Table II-22. The estimated population exposed to annual average $PM_{2.5}$ concentrations above 12, 15, and 18 μg/m³ in the 2005-2007 baseline period and with NAAQS attainment by race/ethnicity group.

Air Basin	Age Group	Persons Exposed to Concentrations Above Threshold				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>12 μg/m³	>15 μg/m³	>18 μg/m³	>12 μg/m³	>15 μg/m³
South Coast	White*	5,659,709	3,570,354	911,014	3,483,248	31,560
	Black*	1,218,513	1,022,610	214,995	1,018,202	6,266
	Hispanic	6,587,126	4,944,164	1,183,072	4,903,746	46,799
	Other*	2,245,717	1,462,310	239,651	1,432,502	6,499
San Joaquin	White*	1,623,593	998,309	472,513	918,878	89,917
	Black*	168,069	110,289	47,848	103,972	10,725
	Hispanic	1,459,285	1,055,670	495,287	989,507	83,827
	Other*	262,889	147,866	49,727	135,842	8,427

* Non-Hispanic

Table II-23. The estimated percent of population that is exposed to annual average $PM_{2.5}$ concentrations above 12, 15, and 18 μg/m³ in the 2005-2007 baseline period and with NAAQS attainment by race/ethnicity group.

Air Basin	Age Group	Percent of Population Exposed to Concentrations Above Threshold				
		In the 2005-2007 Baseline Period			With NAAQS attainment	
		>12 μg/m³	>15 μg/m³	>18 μg/m³	>12 μg/m³	>15 μg/m³
South Coast	White*	87%	55%	14%	54%	0%
	Black*	93%	78%	16%	78%	0%
	Hispanic	93%	70%	17%	69%	1%
	Other*	92%	60%	10%	59%	0%
San Joaquin	White*	100%	61%	29%	57%	6%
	Black*	100%	66%	28%	62%	6%
	Hispanic	100%	72%	34%	68%	6%
	Other*	100%	56%	19%	52%	3%

* Non-Hispanic

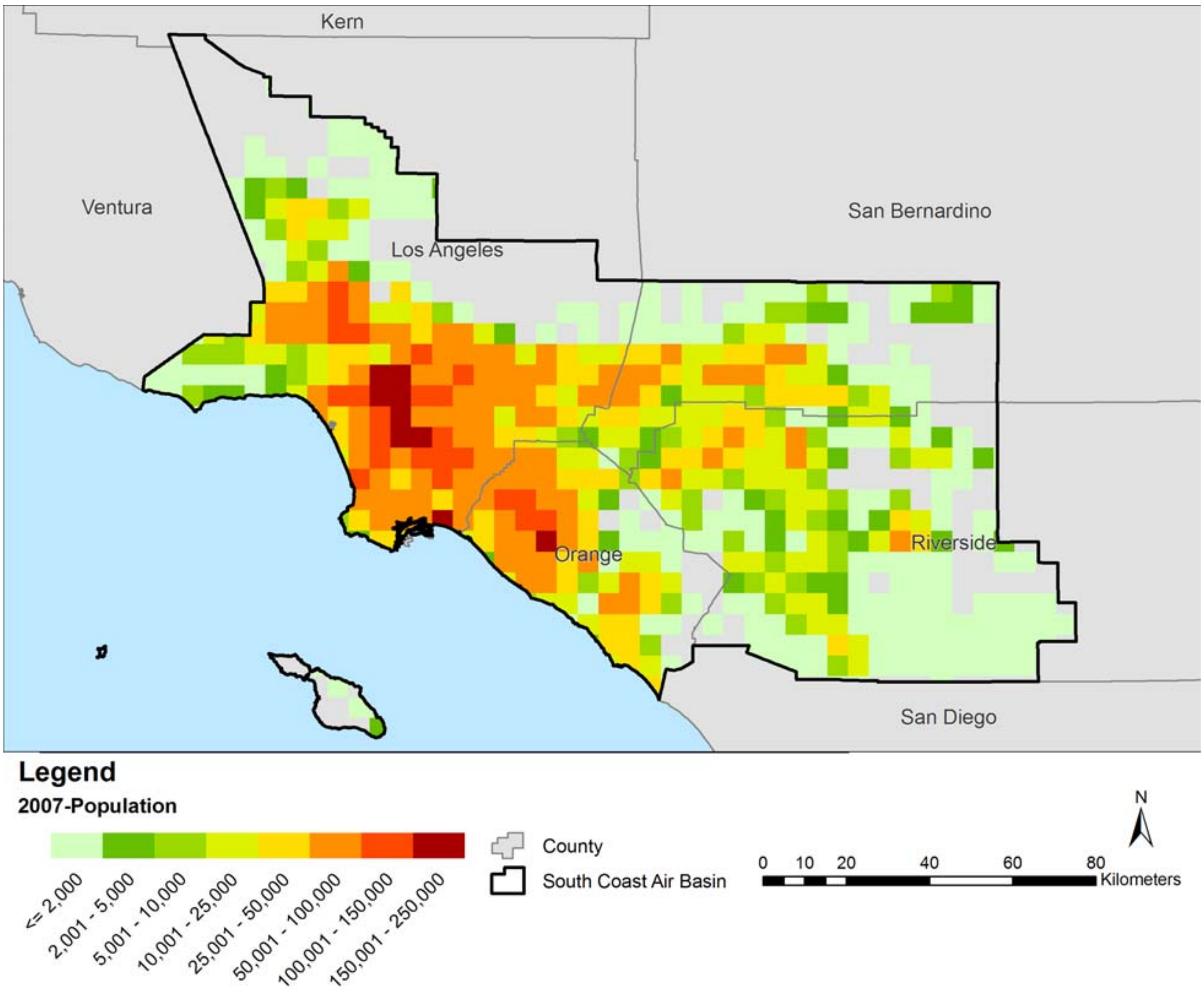

Figure II-1. The 2007 population density in the South Coast Air Basin resolved to the 5- x 5-km exposure grids.

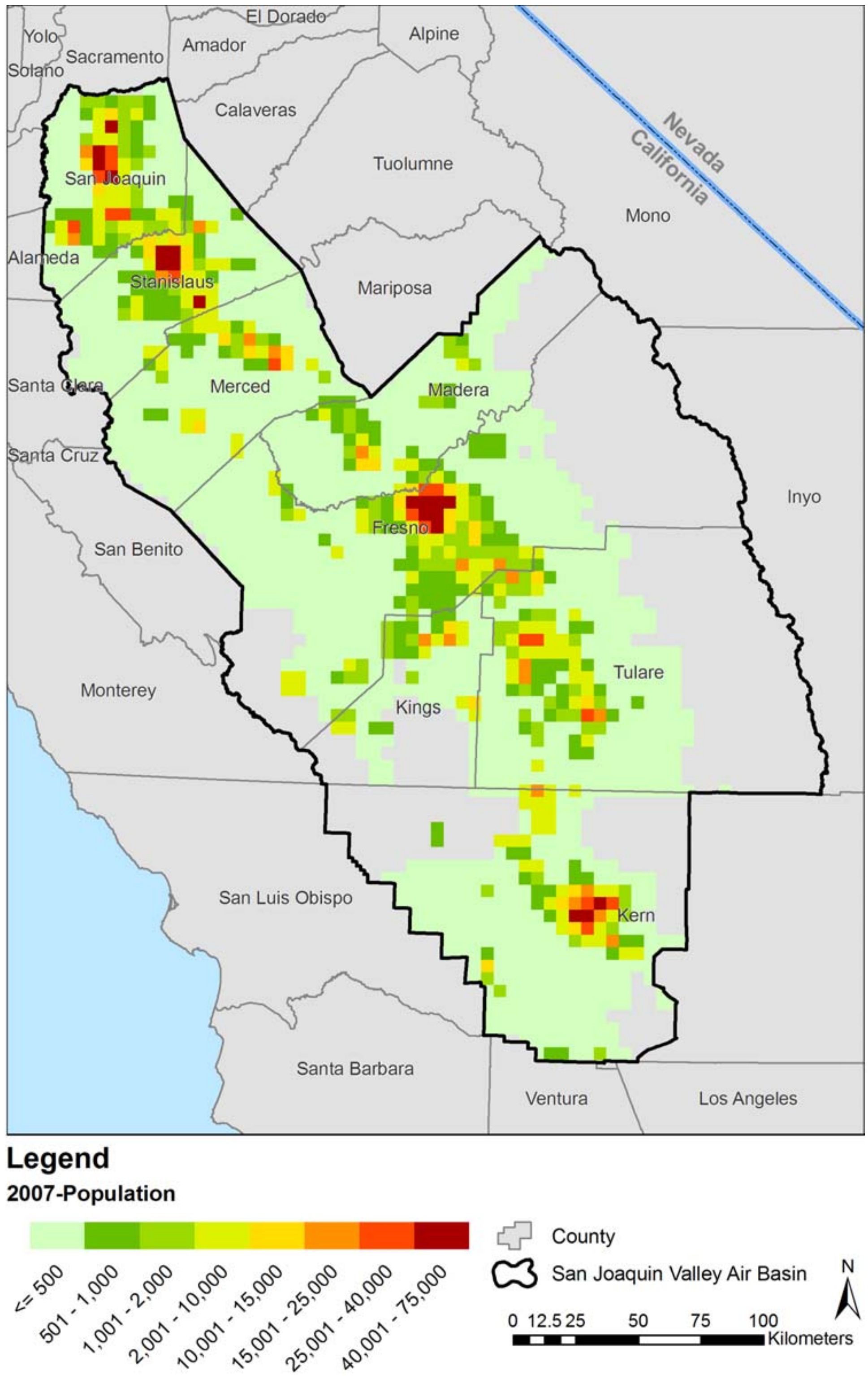

Figure II-2. The 2007 population density in the San Joaquin Valley Air Basin resolved to the 5- x 5-km exposure grids.

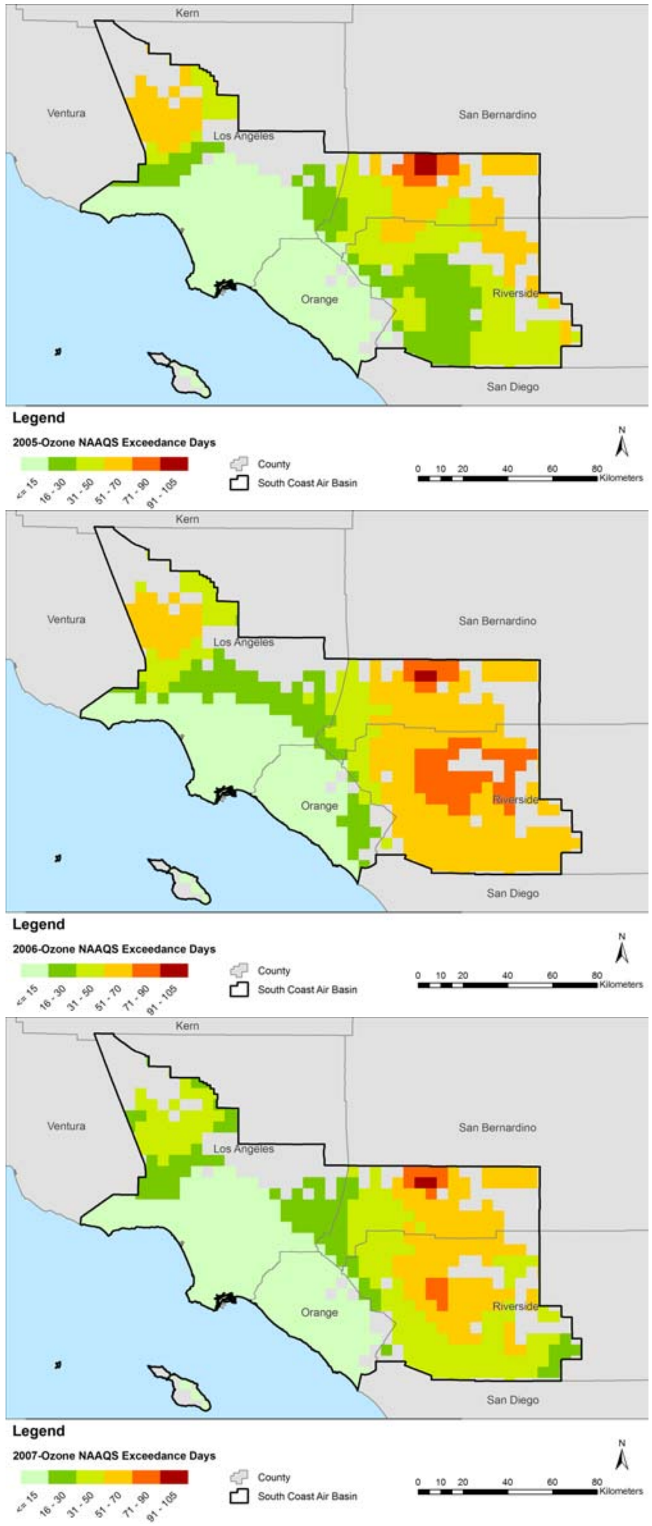

Figure II-3. Spatial maps of the number of days per year that the 8-hr daily maximum ozone concentration exceeded 75 ppb in the South Coast Air Basin in 2005 (top), 2006 (middle), and 2007 (bottom).

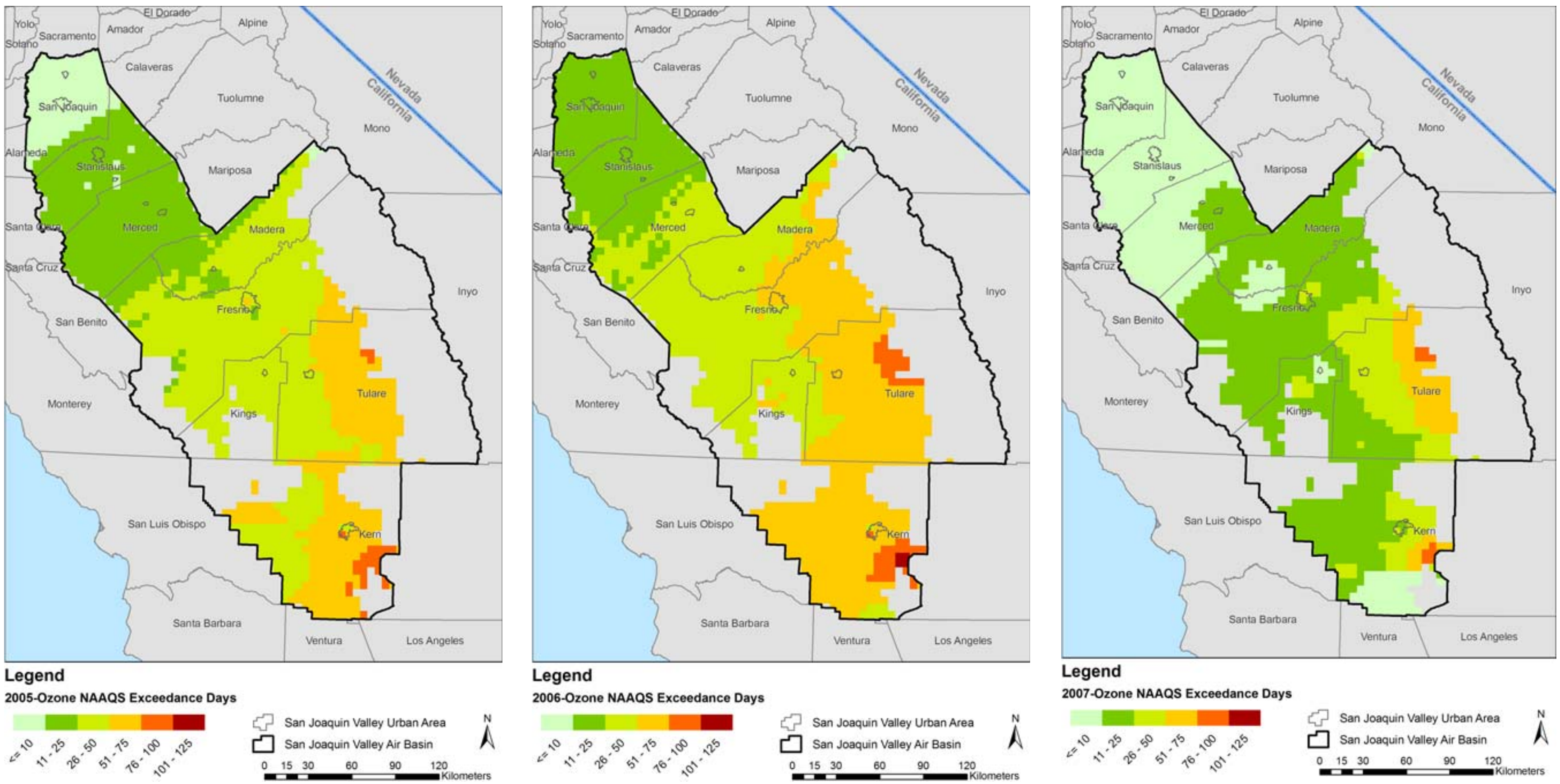

Figure II-4. Spatial maps of the number of days per year that the 8-hr daily maximum ozone exceeded 75 ppb in the San Joaquin Valley Air Basin in 2005 (left), 2006 (middle), and 2007 (right).

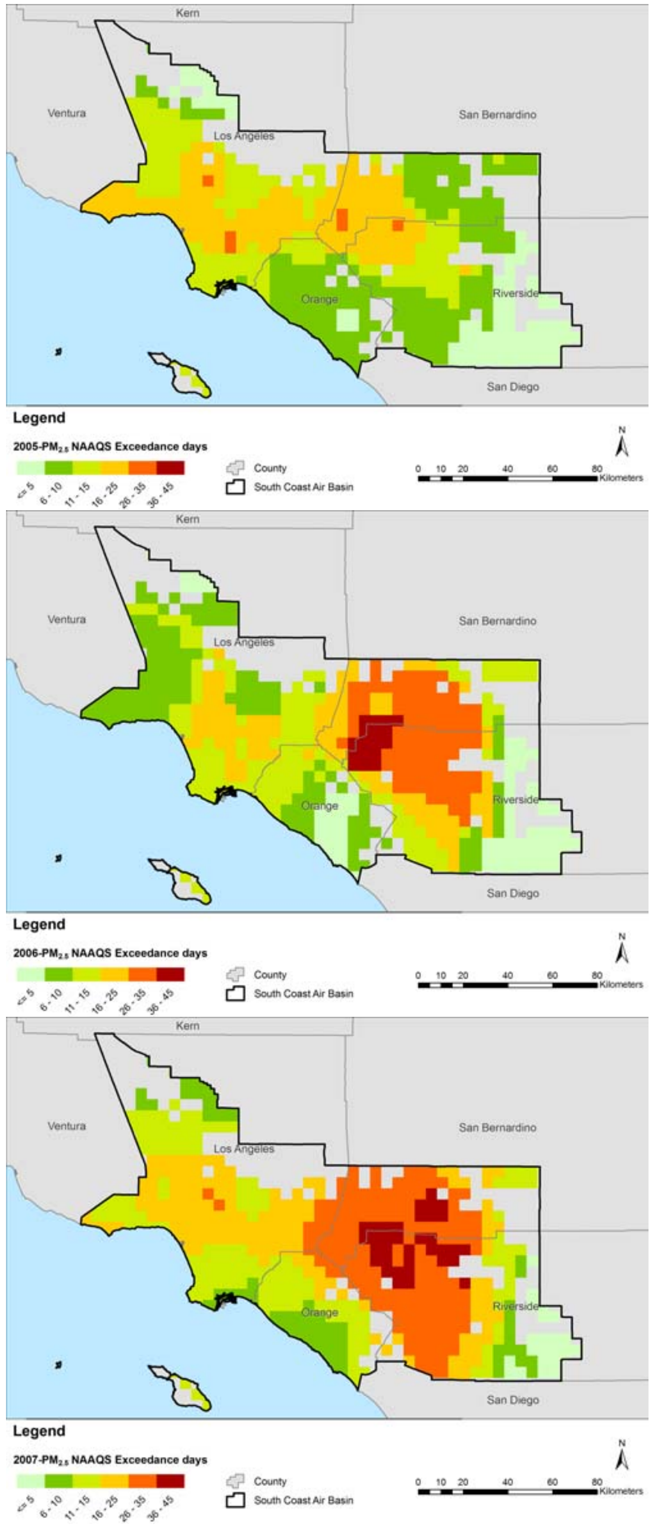

Figure II-5. Spatial maps of the number of days per year that the 24-hr $PM_{2.5}$ concentration exceeded 35 $\mu g/m^3$ in the South Coast Air Basin in 2005 (top), 2006 (middle), and 2007 (bottom).

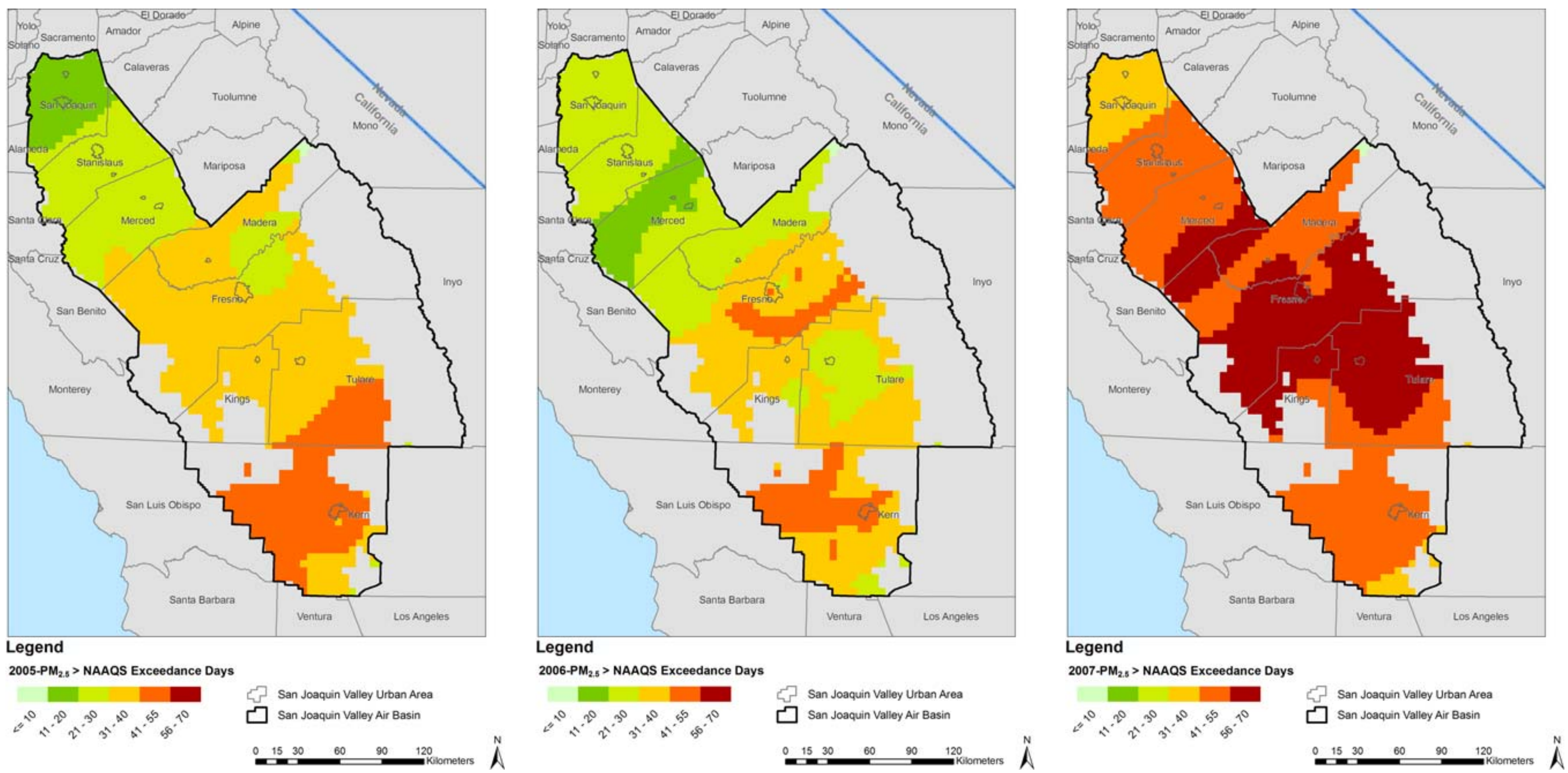

Figure II-6. Spatial maps of the number of days per year that the 24-hr $PM_{2.5}$ concentration exceeded 35 $\mu g/m^3$ in the San Joaquin Valley Air Basin in 2005 (left), 2006 (middle), and 2007 (right).

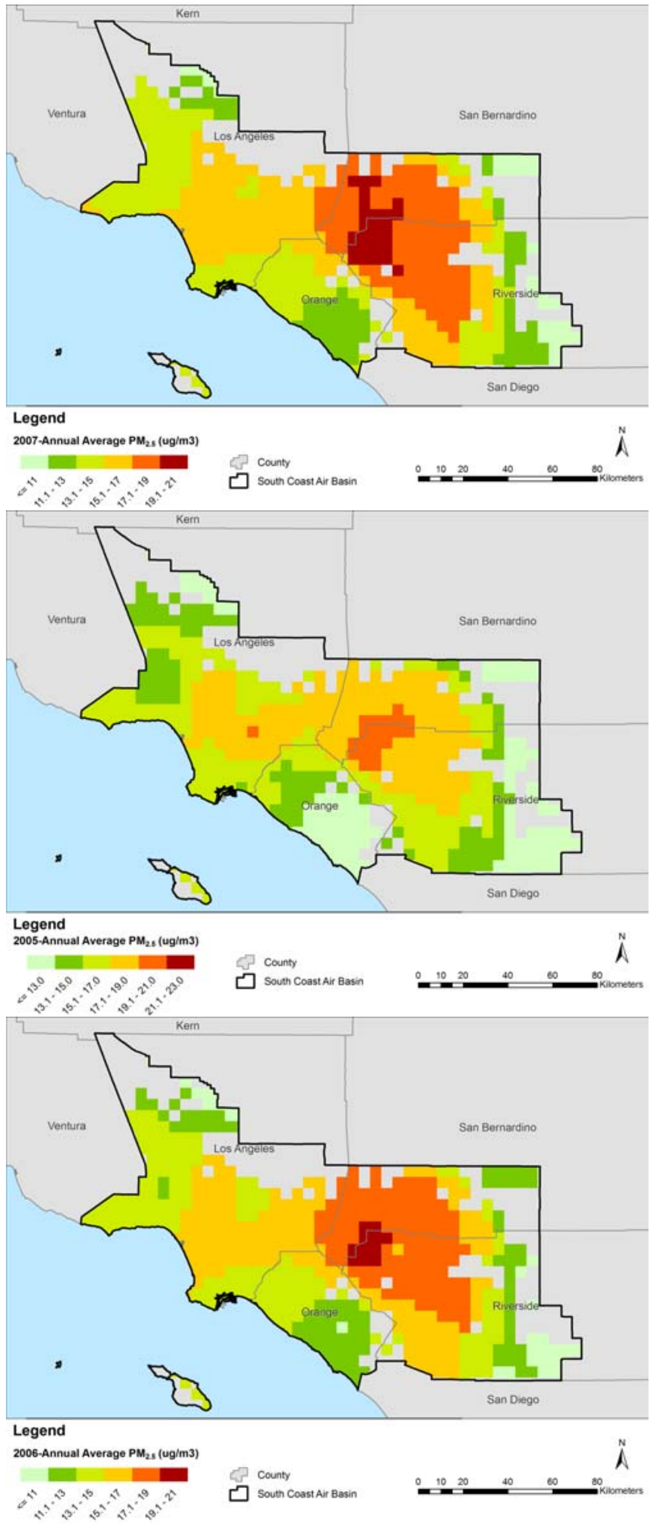

Figure II-7. Spatial maps of the estimated annual average $PM_{2.5}$ concentration in the South Coast Air Basin in 2005 (top), 2006 (middle), and 2007 (bottom).

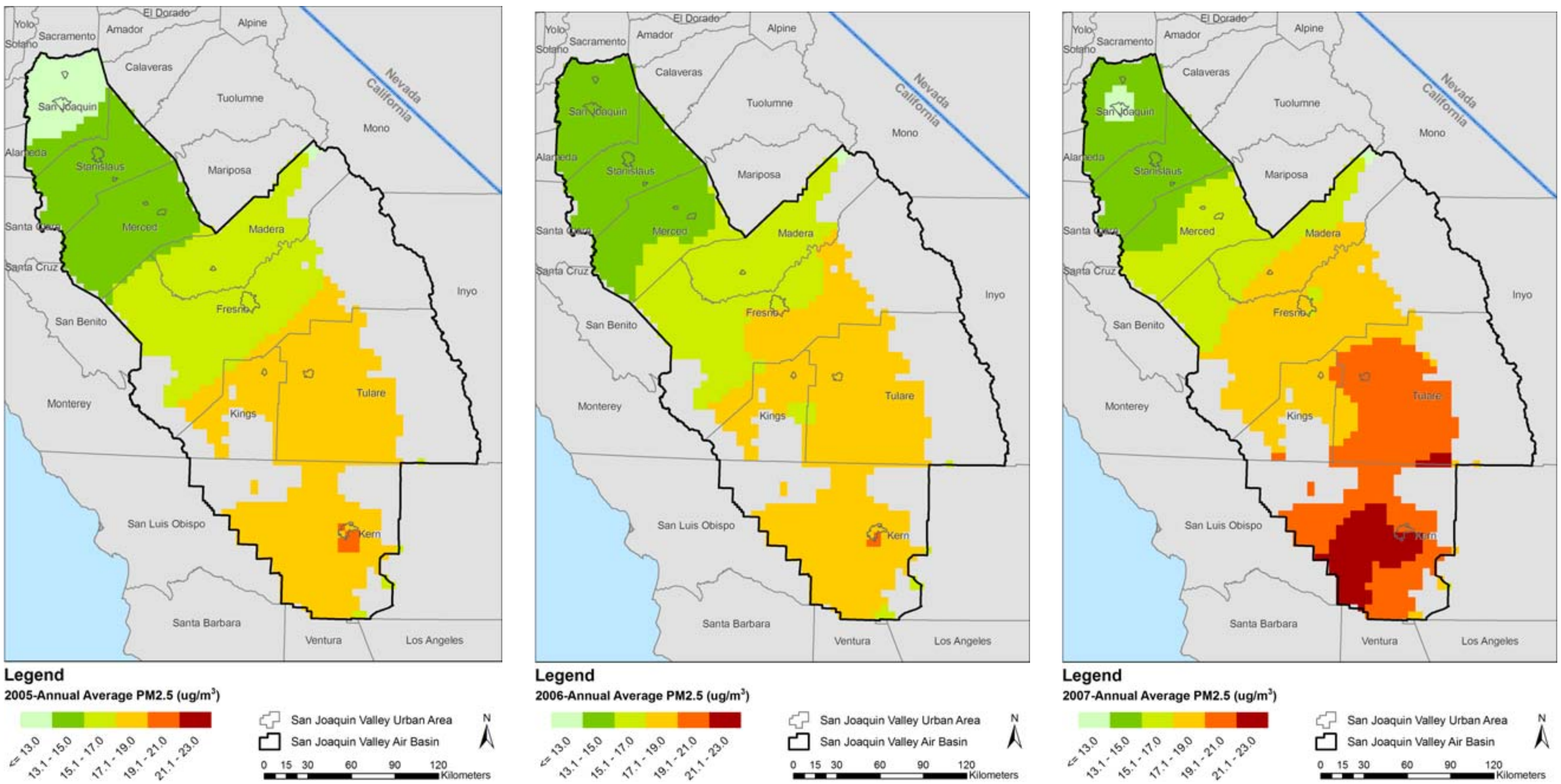

Figure II-8. Spatial maps of the estimated annual average $PM_{2.5}$ concentration in the San Joaquin Valley Air Basin in 2005 (left), 2006 (middle), and 2007 (right).

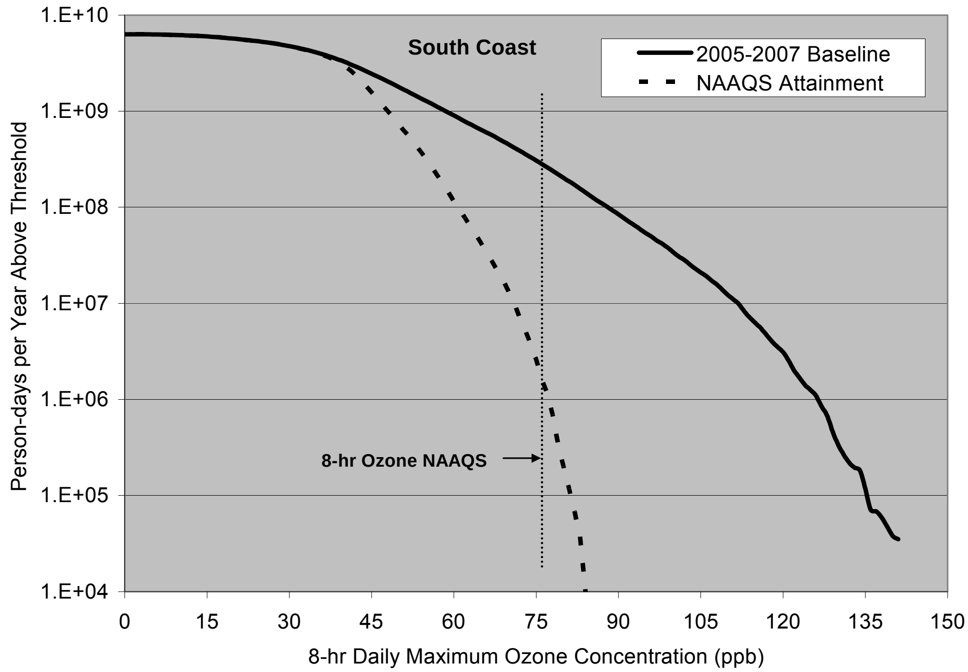

Figure II-9. The distribution of estimated exposures to 8-hr average daily maximum ozone concentrations above various thresholds in 2005-2007 and with NAAQS attainment in the South Coast Air Basin.

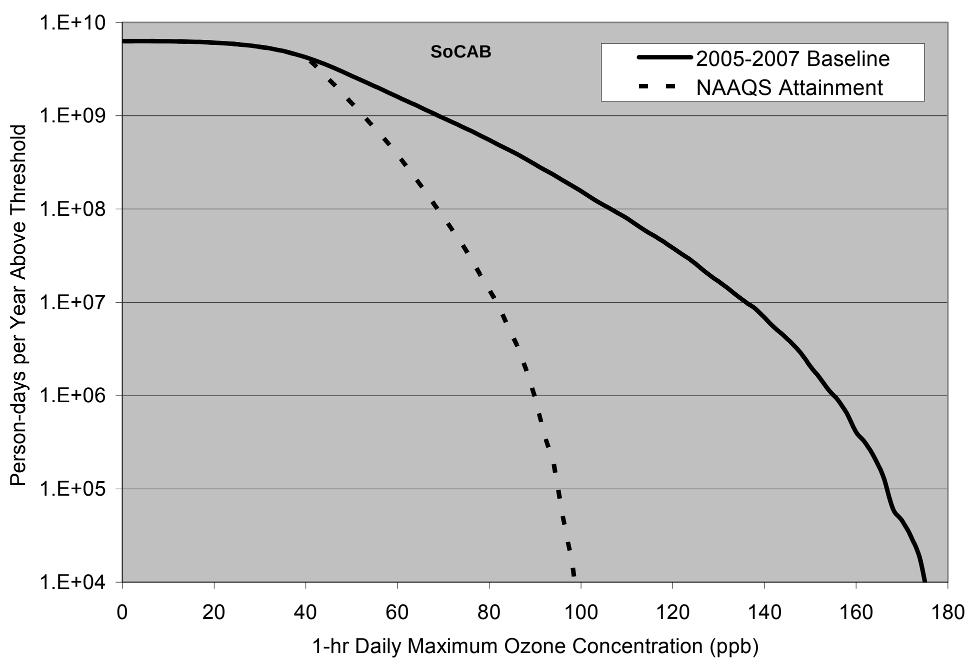

Figure II-10. The distribution of estimated exposures to 1-hr average daily maximum ozone concentrations above various thresholds in 2005-2007 and with NAAQS attainment in the South Coast Air Basin.

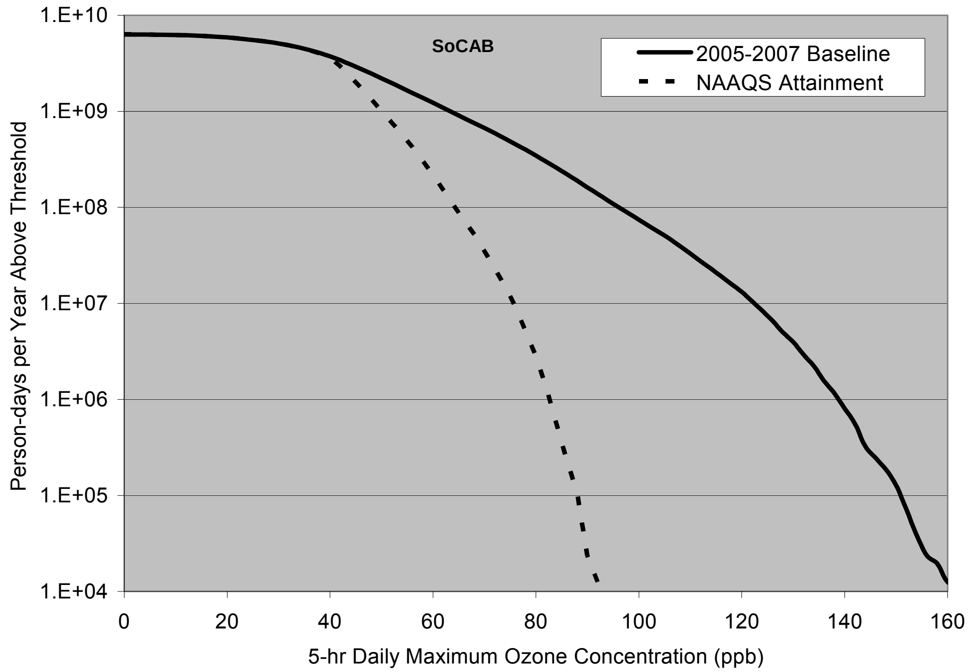

Figure II-11. The distribution of estimated exposures to 5-hr average daily maximum ozone concentrations above various thresholds in 2005-2007 and with NAAQS attainment in the South Coast Air Basin.

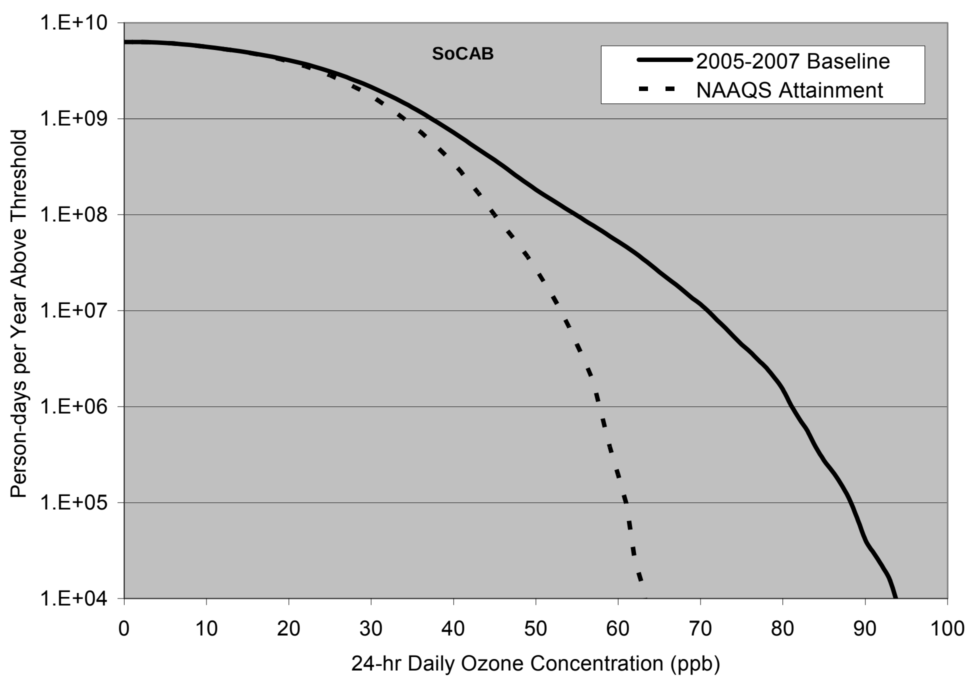

Figure II-12. The distribution of estimated exposures to 24-hr ozone concentrations above various thresholds in 2005-2007 and with NAAQS attainment in the South Coast Air Basin.

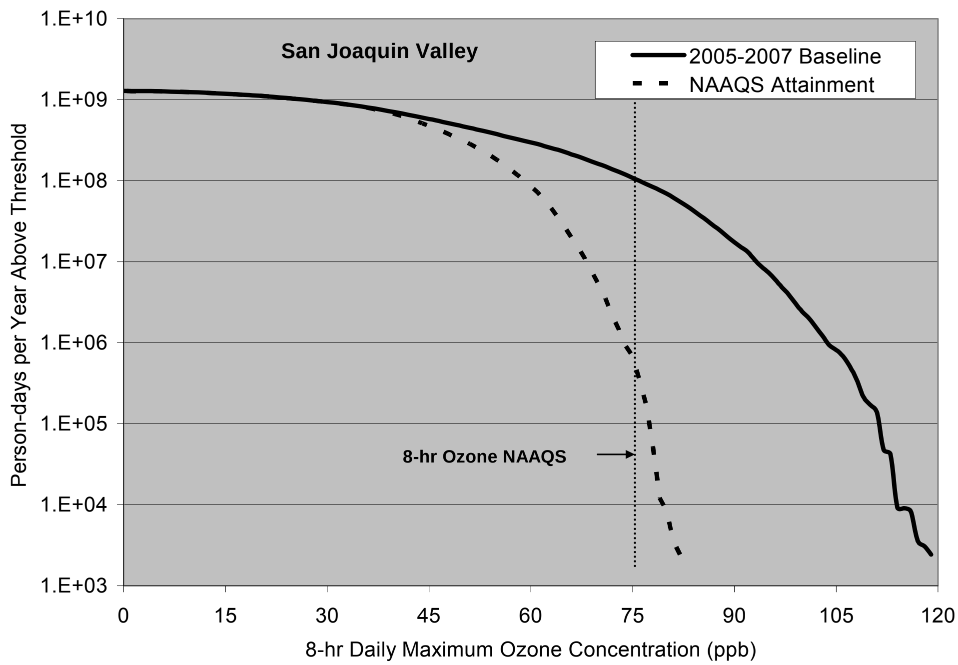

Figure II-13. The distribution of estimated exposures to 8-hr average daily maximum ozone concentrations above various thresholds in 2005-2007 and with NAAQS attainment in the San Joaquin Valley Air Basin.

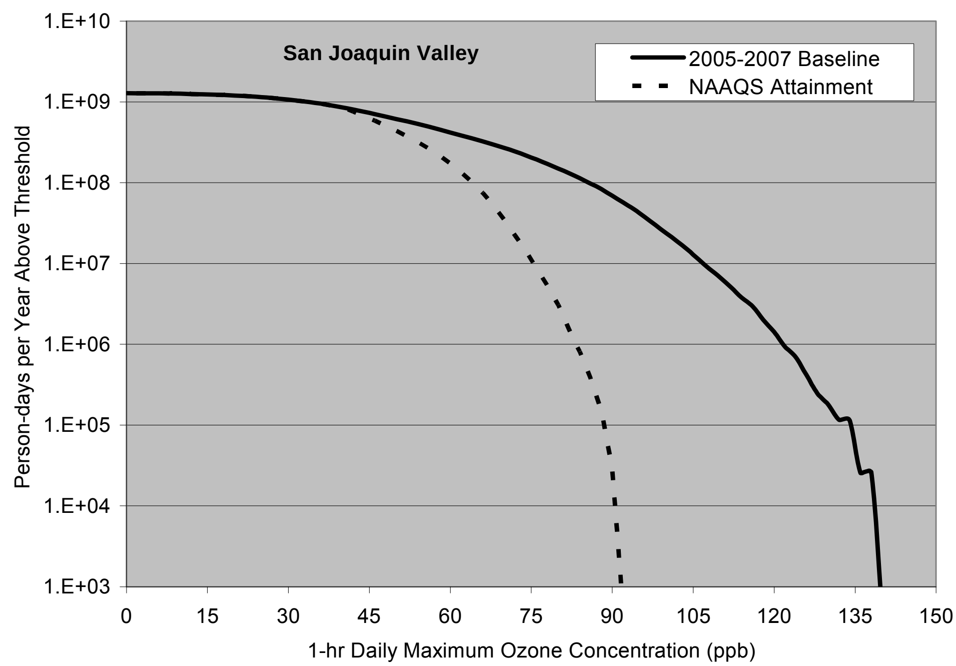

Figure II-14. The distribution of estimated exposures to 1-hr average daily maximum ozone concentrations above various thresholds in 2005-2007 and with NAAQS attainment in the San Joaquin Valley Air Basin.

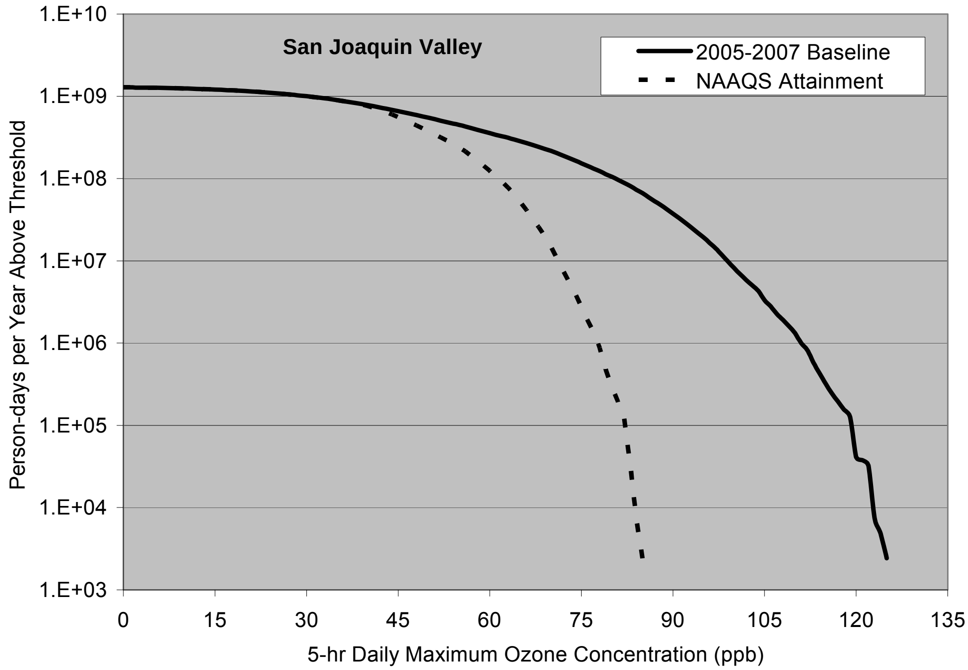

Figure II-15. The distribution of estimated exposures to 5-hr average daily maximum ozone concentrations above various thresholds in 2005-2007 and with NAAQS attainment in the San Joaquin Valley Air Basin.

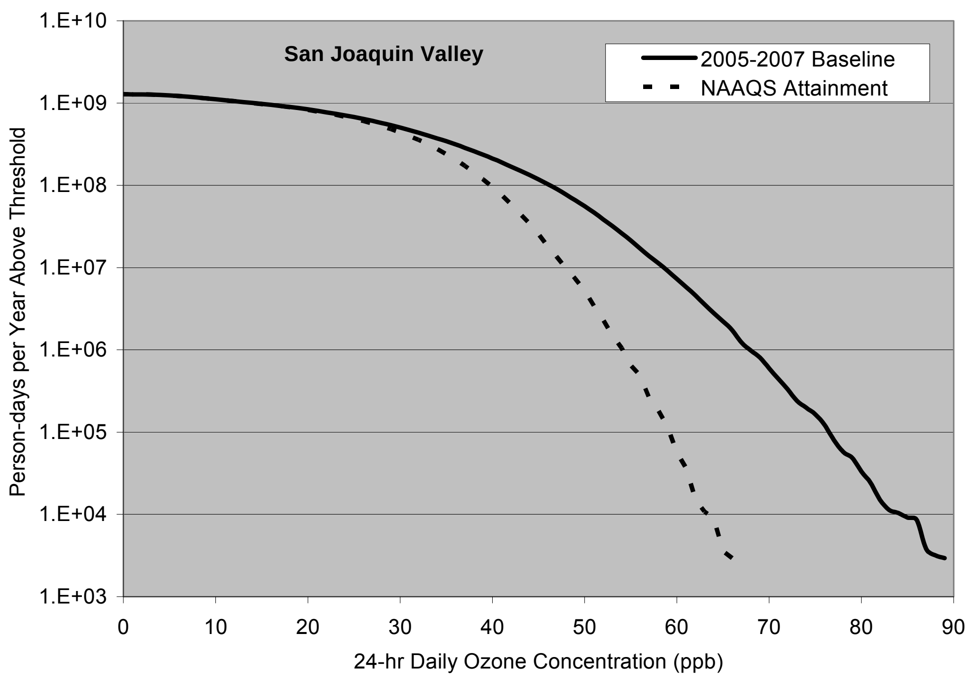

Figure II-16. The distribution of estimated exposures to 24-hr average ozone concentrations above various thresholds in 2005-2007 and with NAAQS attainment in the San Joaquin Valley Air Basin.

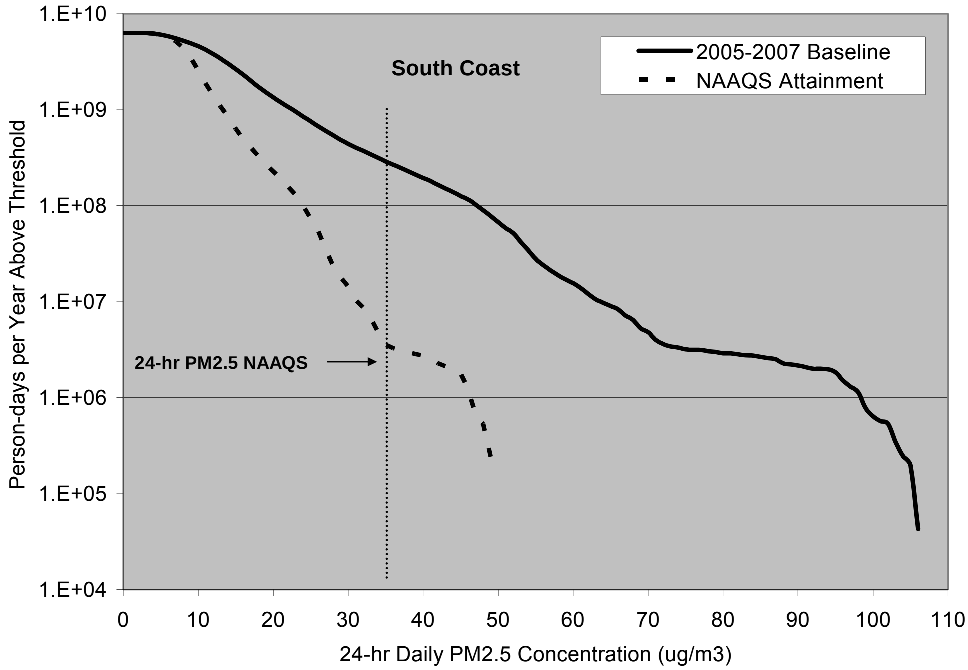

Figure II-17. The distribution of estimated exposures to daily $PM_{2.5}$ concentrations above various thresholds in 2005-2007 and with 24-hr NAAQS attainment in the South Coast Air Basin.

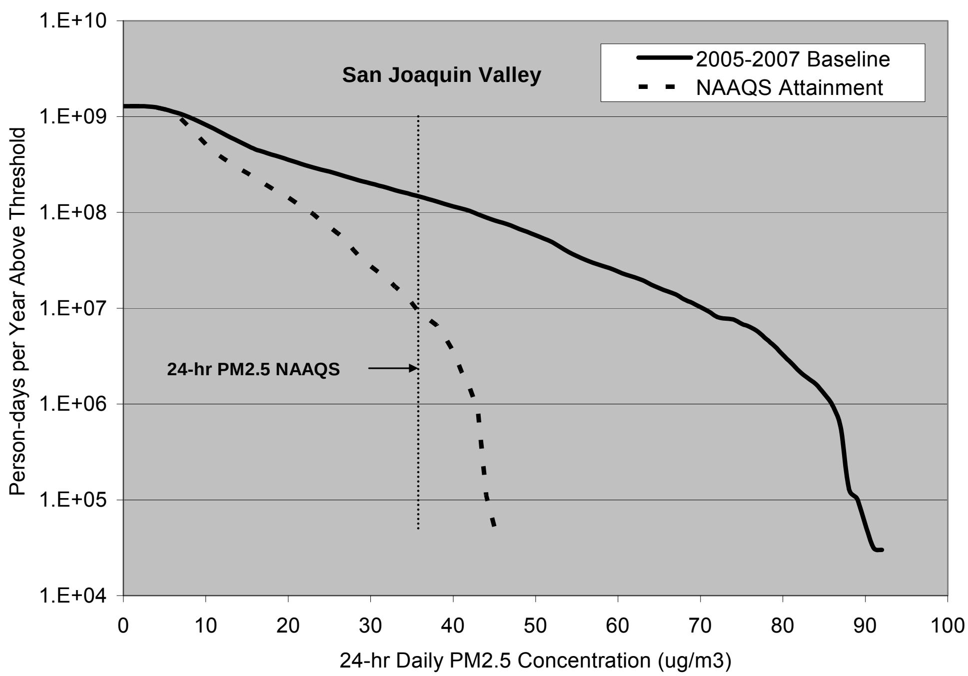

Figure II-18. The distribution of estimated exposures to daily $PM_{2.5}$ concentrations above various thresholds in 2005-2007 and with 24-hr NAAQS attainment in the San Joaquin Valley Air Basin.

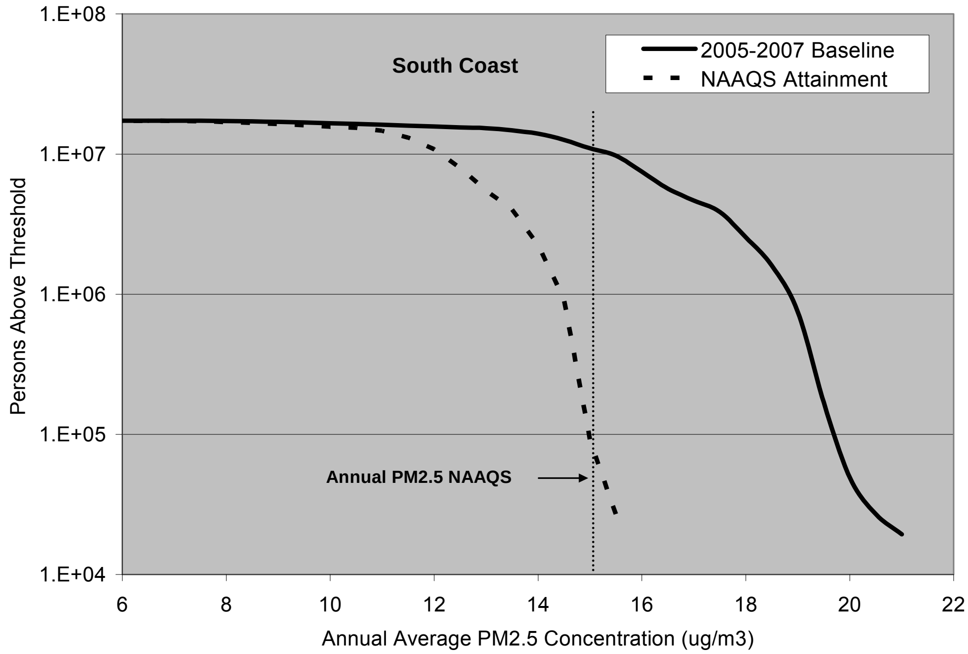

Figure II-19. The distribution of estimated exposures to annual average $PM_{2.5}$ concentrations above various thresholds in 2005-2007 and with annual NAAQS attainment in the South Coast Air Basin.

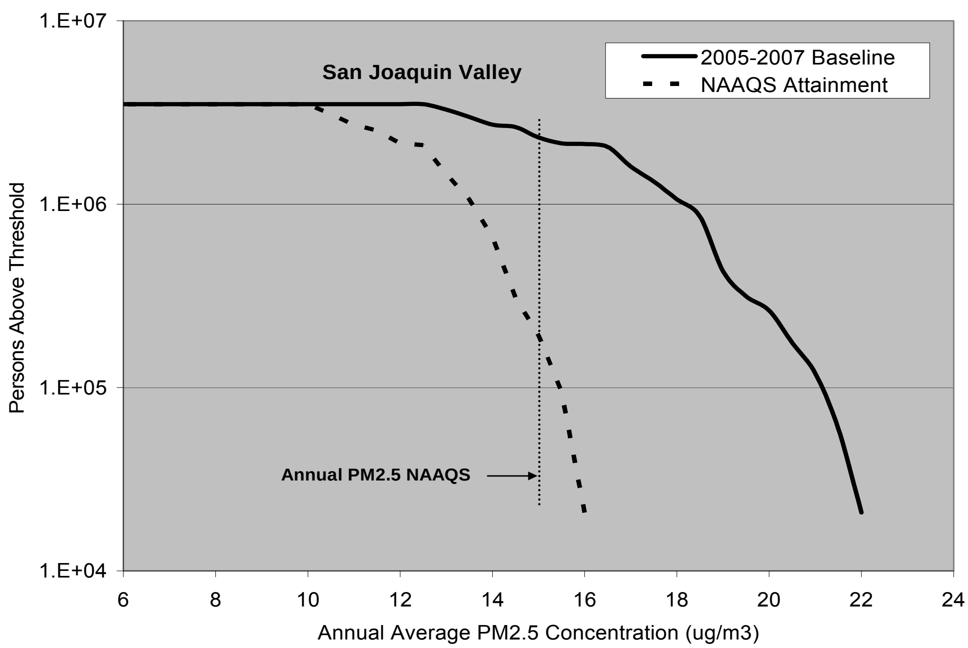

Figure II-20. The distribution of estimated exposures to annual average $PM_{2.5}$ concentrations above various thresholds in 2005-2007 and with annual NAAQS attainment in the San Joaquin Valley Air Basin.

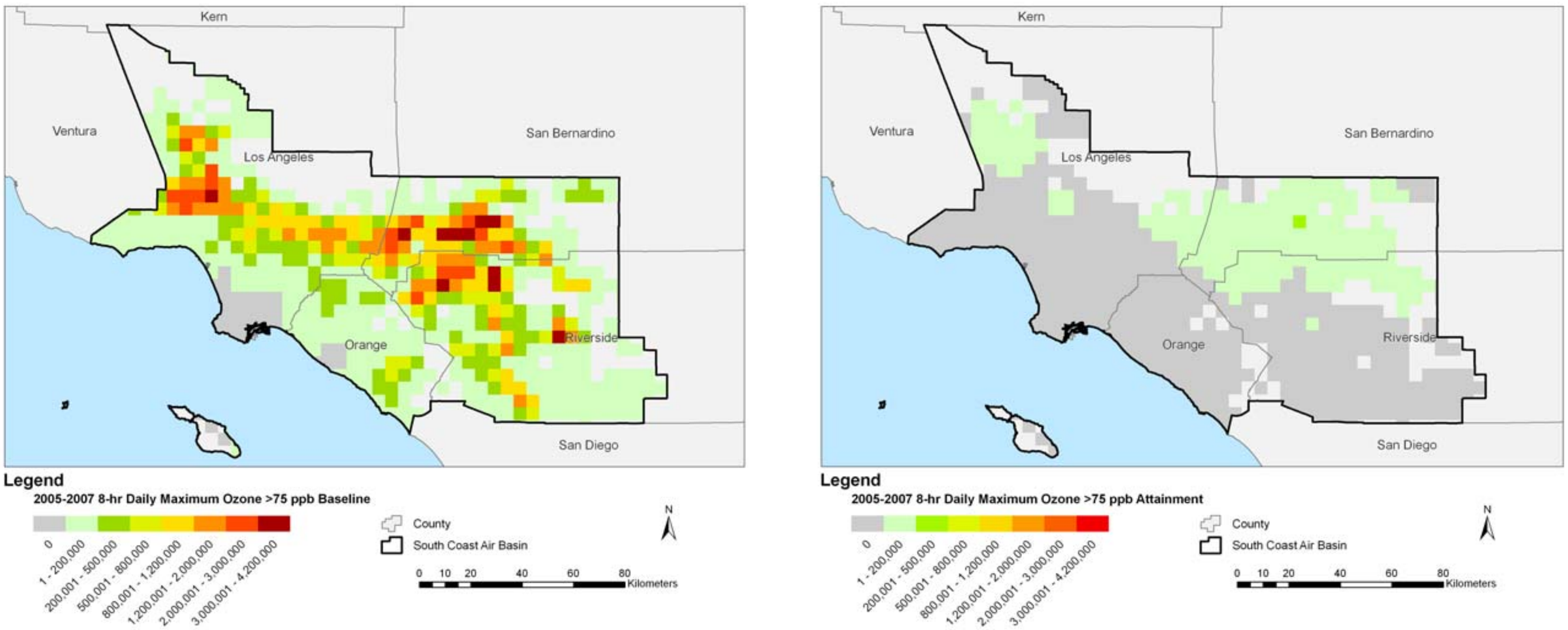

Figure II-21. Spatial map of the estimated number of persons-days per year of exposure to ozone concentrations above 75 ppb in 2005-2007 (left) and with attainment (right) in the South Coast Air Basin.

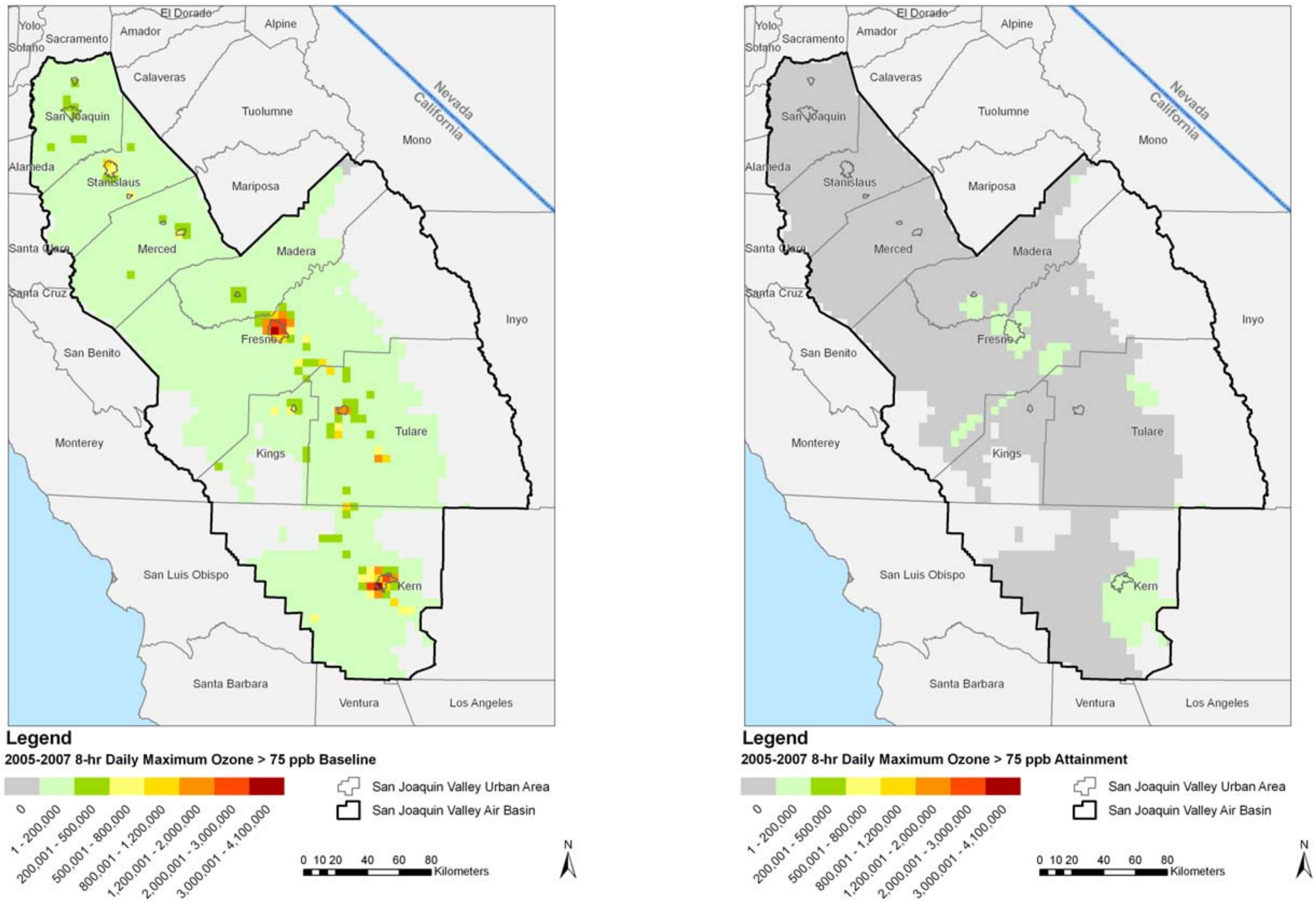

Figure II-22. Spatial map of the estimated number of persons-days per year of exposure to ozone concentrations above 75 ppb in 2005-2007 (left) and with attainment (right) in the San Joaquin Valley Air Basin.

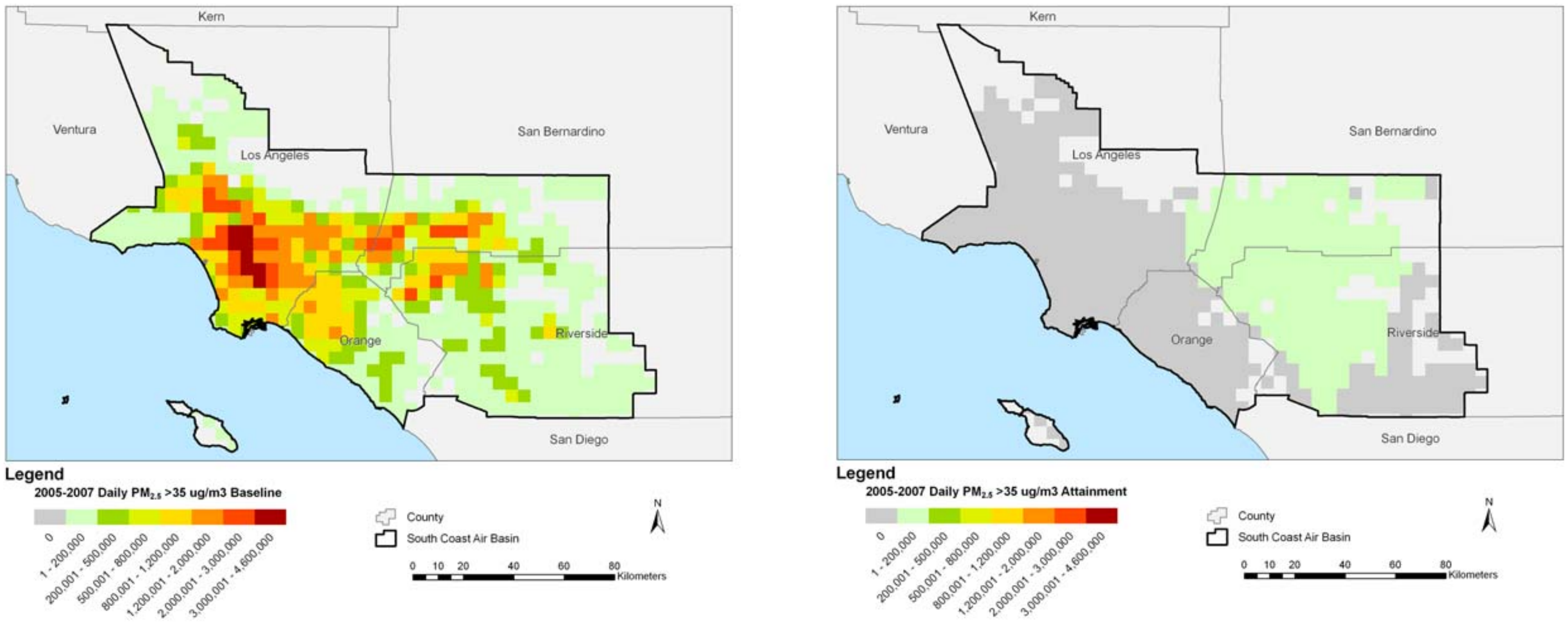

Figure II-23. Spatial map of the estimated number of persons-days per year of exposure to $PM_{2.5}$ concentrations above 35 $\mu g/m^3$ in 2005-2007 (left) and with attainment (right) in the South Coast Air Basin .

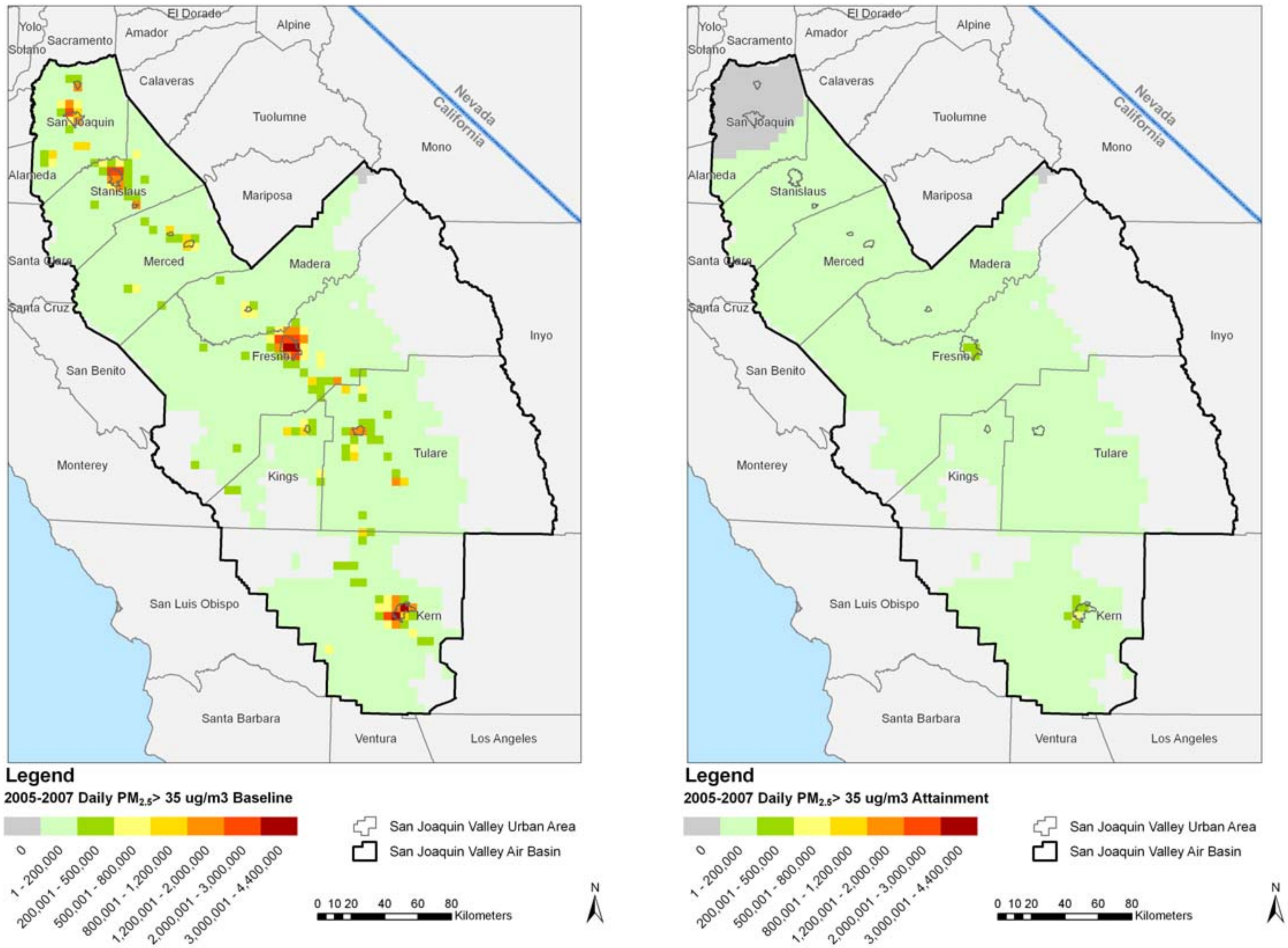

Figure II-24. Spatial map of the estimated number of persons-days per year of exposure to $PM_{2.5}$ concentrations above 35 $\mu g/m^3$ in 2005-2007 (left) and with attainment (right) in the San Joaquin Valley Air Basin .

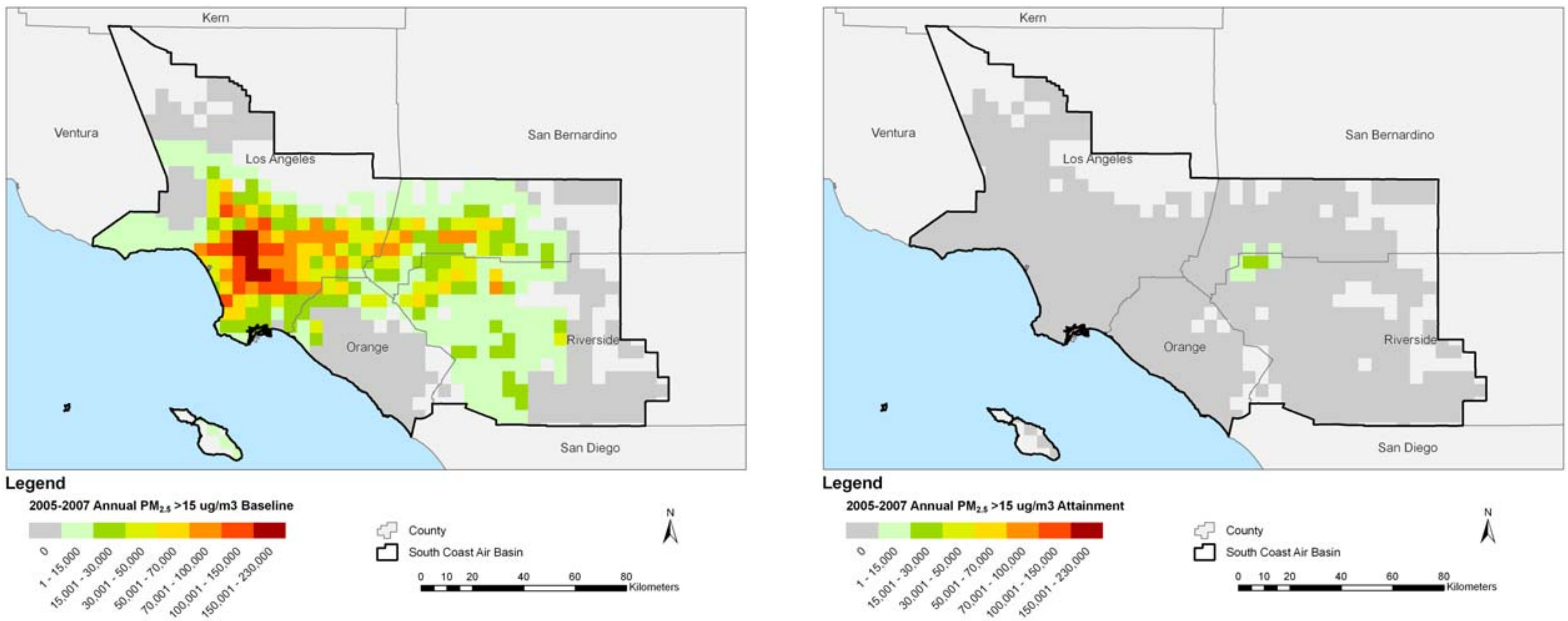

Figure II-25. Spatial map of the estimated number of people exposed to annual average $PM_{2.5}$ concentrations above 15 $\mu g/m^3$ in 2005-2007 (left) and with attainment (right) in the South Coast Air Basin .

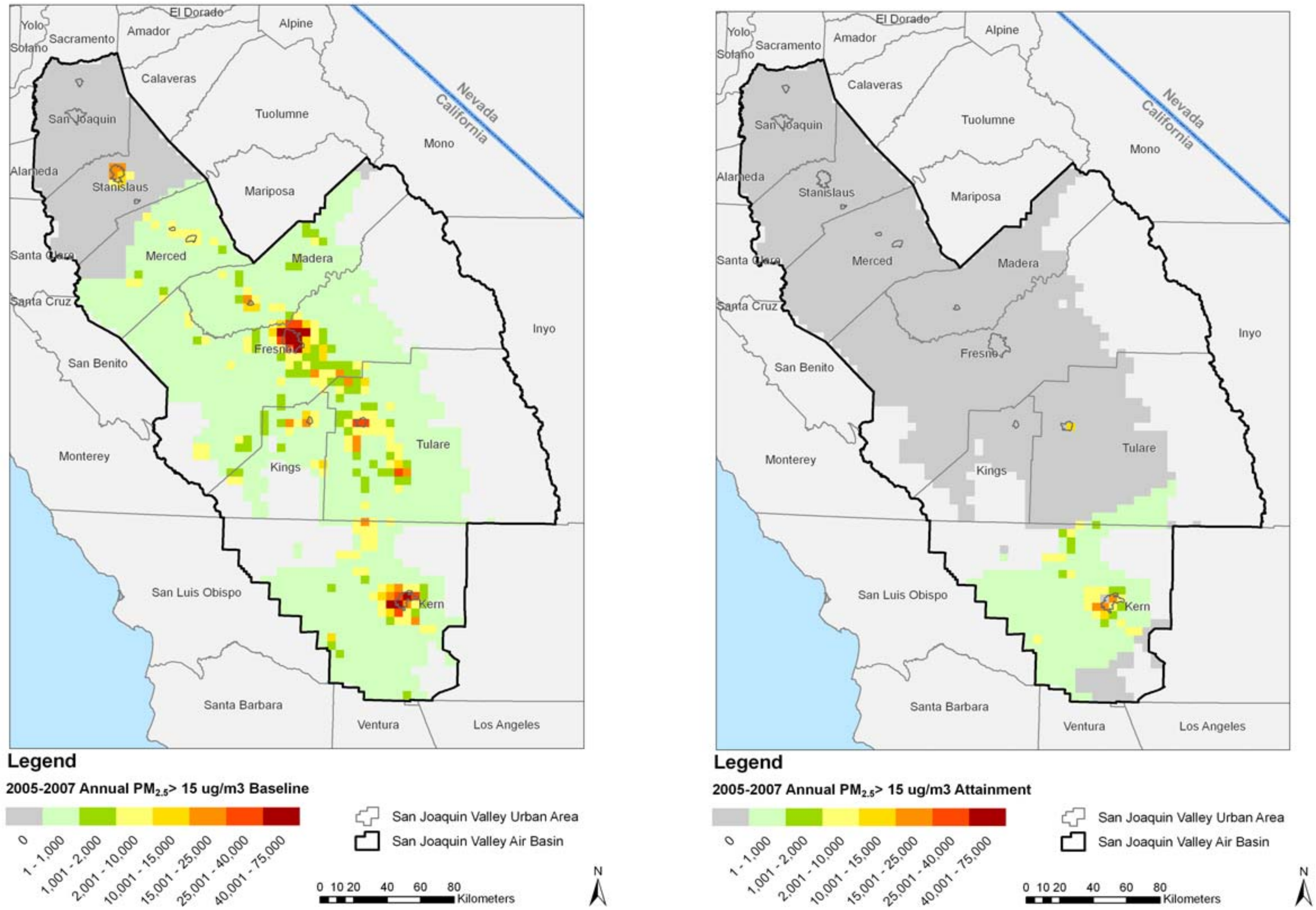

Figure II-26. Spatial map of the estimated number of people exposed to annual average $PM_{2.5}$ concentrations above 15 $\mu g/m^3$ in 2005-2007 (left) and with attainment (right) in the San Joaquin Valley Air Basin .

III. ADVERSE OZONE AND PM-RELATED HEALTH EFFECTS

Ozone and fine particles ($PM_{2.5}$) have long been associated with adverse health effects, and a growing body of health science literature enables us to quantify how changes in air quality translate into changes in the number of adverse health effects in a population. In order to select specific studies to estimate such changes for the purposes of this study, we consider a number of factors. In particular, to be used a study:

- Must be peer-reviewed
- Must account for potential confounders such as other pollutants and weather
- Must use reasonable measures of pollutants
- Must be based on a population not significantly different from the population being assessed
- Must provide a basis to estimate changes in an effect that can be valued in economic terms
- Is preferred if it is more recent, using more advanced analytical methods and reflecting more recent demographics
- Is preferred if it covers longer periods and larger populations
- Is preferred if it meets other criteria and is also region-specific
- Is preferred if it meets other criteria and has been used in previous peer-reviewed benefits assessments

Given this, we identified six ozone-related and twelve $PM_{2.5}$-related effects that would be appropriate for inclusion in this study.[2] These effects are summarized in Table III-1.

III.1 DEVELOPING HEALTH (CONCENTRATION-RESPONSE) FUNCTIONS

To quantify the expected changes in health effects associated with reduced exposure to ozone and $PM_{2.5}$, we have used the basic exponential concentration-response (C-R) function developed in the EPA's first comprehensive analysis of the costs and benefits of the Clean Air Act (EPA 1999), and widely used in benefit assessments since.[3]
Specifically, the functional form used is as follows:

$$\Delta C = -C_0(e^{-\beta\Delta P} - 1)$$

where:

ΔC = the change in the number of cases (of a particular health outcome)
C_0 = the number of baseline cases (of the health outcome)
ΔP = the change in ambient pollution concentrations
β = an exponential "slope" factor derived from the health literature pertaining to that specific health outcome.

---

[2] Some effects, such as individual respiratory symptoms, or eye irritation, are not included here because they are at least in part captured by effects such as MRADs, work loss days, school absence days and upper and lower respiratory symptom days.

[3] The one exception is the case of ozone-related emergency room visits, for which we use a linear C-R function.

In most of the recent health literature, "relative risk" factors are reported which relate change in pollution levels to the increased odds of developing various health effects. These risk factors are related to the β in the EPA concentration-response functions in the following manner:

$$\beta = (1 + \text{Increased Odds})/(\text{Change in Pollution})$$

The specific health studies used to develop these β values are described in the following sections.

III.1.1 Ozone Morbidity

Minor Restricted Activity Days (MRADs)

Minor restricted activity days (MRADs) are days when various (often, respiratory) symptoms reduce normal activities, but do not prevent going to work or attending school. The combination of symptoms that induces an MRAD is more restrictive than any individual symptom. A study by Ostro and Rothschild (1989), which used a national sample of the adult (18-65) working population over six years (1976-1981) to determine some of the health consequences of ozone and fine particles, is used here. They found an association between ozone and minor restrictions in activity, after controlling for fine particles, that can be used to derive an exponential ozone C-R function. Using a weighted average of the coefficients reported in the analysis, the EPA (2003b) developed a best estimate β coefficient of 0.0022; an annual (baseline) number of 7.8 MRADs per person was also derived from the study. Further following Ostro and Rothschild, we apply this function to the nonelderly, or "working" adult portion of the population. The EPA (2003b) notes that this application is likely to produce a somewhat conservative health outcome estimate, since elderly adults are likely at least as susceptible to ozone pollution as are individuals under the age of 65.

Asthma Emergency Room Visits

Several studies have established a relationship between increases of ozone and a variety of asthmatic symptoms. In one of the more comprehensive works undertaken, Weisel et al. (1995) conducted a five-year retrospective study of the relationship between summer ozone concentrations and asthma-induced emergency room (ER) visits. Specifically, they examined the relationship between ambient ozone levels and ER visits by asthmatics in central and northern New Jersey for five consecutive years (1986-1990). A similar study was undertaken by Cody et al. (1992) for the same geographic area and the summer months of 1988 and 1989. While Weisel et al.'s results derive from a single pollutant equation, the Cody et al. study includes SO_2 as a co-pollutant. In each case, though, multiple linear regression analyses were conducted for each year, generating positive and significant coefficients of daily ER visits with ozone concentrations. From these studies' coefficients, the EPA (2003b) derived slope coefficients for a linear C-R function. For our analysis, we average these two linear coefficients, resulting in a β value of 0.0323. It is this value that forms the basis for our calculation of reductions in asthma-related emergency room visits from improved ozone levels. The specific function thus developed is as follows:

Δ asthma-related ER visits = (β/ Base Pop) ΔO3 pop,

where: β = ozone coefficient = 0.0323

Base Pop = original studies' baseline population in NJ = 4,436,976

ΔO3 = change in daily 5-hr average ozone concentration (ppb)

pop = the affected population (all ages).

School Absences

Ozone-related school absences is a health outcome that has been examined in two recently published health studies. The first, by Chen et al. (2000), considered the association between air pollution and daily elementary school absenteeism in Washoe County, Nevada, from 1996 to 1998. Student absenteeism was regressed on three air pollutants (ozone, PM_{10}, and carbon monoxide), weather variables, and other confounding factors, using autoregression analysis. The second study, by Gilliland et al. (2001), examined 1996 school absences for 12 southern California communities with differing concentrations of multiple pollutants (ozone, NO_2, and carbon monoxide). These researchers used a two-stage time series regression model, controlling for day of the week and temperature, to assess whether there were any associations between pollution levels and absences. Both studies found ozone to be statistically associated with daily absenteeism. More specifically, Chen et al. predicted that for every 50 ppb increase in ozone the overall absence rate increased by 13.01 percent. In contrast, Gilliland et al. found that a 20 ppb increase in 8-hr average ozone concentrations was associated with a 16.3 percent increase in the all-absence rate. From these results, we can derive exponential β values of 0.002446 and 0.00755, which we then average, resulting in an ozone-related school absence concentration-response β value of 0.004998. Finally, EPA (2003b) reports a daily school absence rate of 0.055, obtained from the U.S. Department of Education.

Asthma Attacks

In an early, yet still widely cited, study, Whittemore and Korn (1980) examined daily asthma attack diaries from 16 panels of asthmatics living in six communities of southern California during the mid-1970s. They used multiple logistic regression analysis to test for relationships between daily attack occurrences and daily levels of two types of pollutants (photochemical oxidants and total suspended particulates), plus a variety of weather variables. Results for the two pollutant models showed significant relationships between daily levels of both pollutants and reported asthma attacks. The EPA (2003b) adjusted the model's oxidant results so that they could be used with ozone data. The resulting β value of 0.001843 can then be applied to the asthmatic portion of the population, which we assume to be 3.86 percent of the all-age population (as reported in American Lung Association, 2002). Finally, a daily incidence rate of wheezing attacks for adult asthmatics of 0.055 is assumed as our baseline rate, based on an analysis of the 1999 National Health Interview Survey (EPA 2003b).

Respiratory Hospital Admissions

For non-elderly (ages 0-64), ozone-related respiratory hospital admissions, we turn to a report by Thurston and Ito (1999), which summarized an extensive literature on hospital admissions that included ozone as one of the explanatory variables In this report, a statistical synthesis of three Canadian studies (Burnett et al. 1994; Thurston et al. 1994; and Burnett et al.

1997) yielded a quantitative estimate of the respiratory hospital admission effect associated with ozone exposures for the non-elderly general population. Specifically, they calculated a relative risk factor of 1.18 per 100 ppb increase in daily 1-hr maximum ozone levels. From this, we derive a concentration-response β estimate of 0.001655. For respiratory hospital baseline admission rates, we turn to the Office of Statewide Health Planning and Development's Inpatient Hospital Discharge Frequencies for California (2003) and the U.S. National Hospital Discharge Survey(USDHHS 2005) to construct age-specific hospital discharge numbers for each county.

To estimate ozone-related avoided incidences of respiratory hospital admissions for patients 65 and older, we generate a pooled β value using several health studies referenced by the EPA (2003b). All of these studies found significant associations between ozone and various categories of respiratory hospital admissions. The studies include: Schwartz (1995), which analyzed the relationship between ozone and all respiratory admissions for the cities of New Haven, Connecticut and Tacoma, Washington; and Moolgavkar et al. (1997), Schwartz (1994a), and Schwartz (1994b), which considered pneumonia and chronic obstructive pulmonary disease (COPD) admissions in Minneapolis and Detroit. Our pooled β estimate is equal to 0.004536. Finally, as described for the under-65 case, our county-specific baseline figures come from the California and U.S. Hospital Discharge reports.

III.1.2 Ozone Mortality

Recent reviews of new health scientific literature on the relationship between ozone and premature mortality (see Deck and Chestnut 2008; NRC 2008) recommend that ozone mortality now be included in health benefit analyses. We therefore make use of five recent ozone mortality studies: three EPA-funded meta-analyses (Bell et al. 2005; Ito et al. 2005; Levy et al. 2005); a time-series analysis for 98 U.S. urban communities by Bell et al. (2006); and a case-crossover analysis of 48 U.S. cities by Zanobetti and Schwartz (2008). We pool the results of these five studies to derive a β coefficient of 0.0004556, using the inverse of reported variances as weights. Baseline death rates for each county are obtained from the California Department of Health Services Death Statistical Data (CDHS 2004).

III.1.3 $PM_{2.5}$ Morbidity

<u>Chronic Bronchitis</u>

A case of chronic bronchitis is typically considered to be a recurring condition of mucus in the lungs and wet cough during at least 3 months per year for several years in a row. Abbey et al. (1995) studied the association between fine particles (including $PM_{2.5}$) and new occurrences of these chronic respiratory symptoms in a survey group of nearly 1,900 Californian Seventh Day Adventists. The survey period extended from 1977 to 1987, and the study found a statistically significant relationship between $PM_{2.5}$ and the development of chronic bronchitis in adults aged 27 and over. From this work, the EPA calculated a concentration-response β value of 0.0137 and from an earlier work by Abbey (1993), they obtained an annual bronchitis incidence rate per person of 0.00378. We apply these factors to the proportion of our adult population (27 years of age and older) without chronic bronchitis (which, according to the American Lung Association, is 95.57 percent of the population).

Cardiovascular Hospital Admissions

For non-elderly (ages 18-64), particulate-related, cardiovascular hospital admissions, we rely on a technical paper by Moolgavkar (2000) which used generalized additive models to study the associations between daily admissions and several pollutants in three major metropolitan areas, including Los Angeles County. Utilizing their estimated change of 0.9 percent in daily cardiovascular admissions associated with a 10 μg/m^3 increase in $PM_{2.5}$, we derive a concentration-response β value of 0.000896. For cardio hospital baseline admissions rates, we use the Office of Statewide Health Planning and Development's Inpatient Hospital Discharge Frequencies for California (2003) and the U.S. National Hospital Discharge Survey (March 2005) to construct age-specific hospital discharge numbers for each county in the two study areas.

To estimate $PM_{2.5}$-related occurrences of cardio hospital admissions for patients 65 and older, we combine the results of two health studies (Moolgavkar 2003; Ito 2003), which presented re-analyses of the associations between particulate pollution and elderly hospital admission data in Los Angeles and Cook Counties and for Detroit, Michigan. Both works found statistically significant relationships between $PM_{2.5}$ and cardiovascular admissions, and from these studies, we calculate an average β value of 0.0014375. Lastly, our county-specific baseline numbers again come from the California and U.S. Hospital Discharge reports (USDHHS 2005).

Non-Fatal Heart Attacks

To calculate reductions in non-fatal heart attacks, we utilize a study by Peters et al. (2001) which used a case-crossover approach to investigate whether high levels of particulates can trigger the onset of nonfatal acute myocardial infarctions (MI). With multivariate analyses of data gathered in the greater Boston area, they found that the risk of MI onset increased as particulate levels rose. Specifically, they calculated an estimated odds ratio of 1.69 for a 24-hr $PM_{2.5}$ increase of 20 μg/m^3. From this, we estimate the concentration-response β to be equal to 0.02412. Finally, to estimate a baseline per-person incidence rate, we rely on the 1999 NHDS public use data files, adjusted by 0.93 for the probability of surviving a heart attack after 28 days. The daily incidence rate per person for the western United States is reported to be 0.00001 (see Rosamond et al. 1999).

Minor Restricted Activity Days

As noted above in the ozone morbidity section, minor restricted activity days (MRADs) are days when various (often, respiratory) symptoms reduce normal activities, but do not prevent going to work or attending school. Ostro and Rothschild (1989), noted above, used six years (1976-1981) of data from the Health Interview Survey (HIS)—a large cross-sectional database collected by the National Center for Health Statistics—to determine some of the health consequences of particulate matter and ozone. They also found a statistical association between fine particles and minor restrictions in activity, after controlling for ozone, that can be used to derive an exponential $PM_{2.5}$ C-R function. From the data included in the analysis, the

EPA (2003b) developed a $PM_{2.5}$ β coefficient of 0.00741, which is again a weighted average of the coefficients reported in Ostro and Rothschild (1989). As in the ozone case, an annual (baseline) number of 7.8 MRADs per person was derived. Finally, we again apply this function to the non-elderly, or "working" adult portion of the population. As we noted earlier, this application is likely to produce a somewhat conservative health outcome estimate, since elderly adults are probably at least as susceptible to fine particles as are individuals under the age of 65.

Work Loss Days

Ostro (1987) examined the effect of fine particulate matter on work loss days using a national survey of working adults (aged 18-64) in 49 metropolitan areas in the United States. He found a significant link between $PM_{2.5}$ levels and work loss days for each of the six years of the study (1976-1981), estimating separate coefficients for each year of the analysis. The β coefficient developed by the EPA (2003b) from this work (0.0046) is a weighted average of the coefficients estimated by Ostro, using the inverse of the variance as the weight. In addition, the EPA used a more recent data set (Adams et al. 1999) to determine a daily work loss days incidence (baseline) rate of 0.00595, which we use in our analysis.

Acute Bronchitis

Dockery et al. (1996) examined the respiratory health effects of exposure to a number of pollutants, including fine particles, on a sample of over 13,000 children (8-12 years old) from 24 communities in the United States and Canada. Using a two-stage logistic regression model, and adjusting for the potential confounding effects of gender, parental asthma and education, history of allergies, and current smoking in the home, they found $PM_{2.1}$ to be significantly related to cases of bronchitis. From this work, the EPA developed a $PM_{2.5}$ concentration-response function for acute bronchitis in children. The estimated β value of 0.0272 results from combining Dockery et al.'s odds ratio of 1.50 with the study's observed difference in particles of 14.9 $\mu g/m^3$ between the most and least polluted cities. In addition, the EPA recommends using a baseline incidence rate of 0.043 cases per child per year, as reported by the American Lung Association (2002). Finally, while the Dockery et al. sample focused on children within a 5-year age range, we extend their results to include all school-aged children, based on the assumption that the response of all school-aged children will be similar to those in the study's more specific age group.

Lower Respiratory Symptoms

In an earlier health study, Schwartz et al. (1994) used logistic regression and found a statistical association between lower respiratory symptoms (defined as cough, chest pain, phlegm and wheeze) in children and a number of pollutants, including PM_{10}, acid aerosols, gaseous pollutants, and fine particles. The study was conducted in six cities over a five-year period (1984-1988) and considered a sample of over 1,800 students enrolled in grades two through five. More recently, Schwartz and Neas (2000) replicated the earlier analysis, focusing their efforts on $PM_{2.5}$. In a model that also included coarser particulate matter ($PM_{10-2.5}$), an odds ratio of 1.29 was associated with a 15 $\mu g/m^3$ change in $PM_{2.5}$. From this work, we generate an exposure-response function, with an estimated β value of 0.01698 and a daily baseline rate of 0.0012. Finally, while the Schwartz and Neas work is suggestive of an age range from 7 to 14, we again extend these results to include all school-aged children because the response of older teenagers and younger children is likely to be similar to the children in the studied cohort.

Upper Respiratory Symptoms

In a study of Utah school children (ranging in age from 9 to 11), Pope et al. (1991) examined the association between daily occurrences of upper respiratory symptoms and daily PM_{10} concentrations. A day of upper respiratory symptoms was defined as consisting of one or more of the following symptoms: runny or stuffy nose; wet cough; and burning, aching, or red eyes. Using logistic regression, the study found that PM_{10} was significantly associated with upper respiratory symptoms. The EPA (2003b) used this work to develop a concentration-response function with a β estimate of 0.0036. We convert this PM_{10}-derived β value to its $PM_{2.5}$ counterpart (0.0072) and also rely on Pope et al.'s daily upper respiratory symptom incidence rate per child of 0.3419. Finally, we note that the sample size in the Pope et al. study was quite small, and is most representative of the asthmatic children's population, not the total school-aged population. We therefore apply this exposure-response function only to asthmatic children, who are assumed to represent 11 percent of the total children's population.

Respiratory hospital admissions

To estimate $PM_{2.5}$-related occurrences of respiratory hospital admissions for patients 65 and older, we again combine the results of two health studies (Moolgavkar 2003; Ito 2003) which present reanalyses of the associations between particulate pollution and elderly hospital admission data in Los Angeles and Cook Counties and for Detroit, Michigan. Both works find statistically significant relationships between $PM_{2.5}$ and respiratory admissions, and from these studies, we calculate an average β value of 0.001977. Then, for the respiratory hospital baseline admissions rates, we again use the Office of Statewide Health Planning and Development's Inpatient Hospital Discharge Frequencies for California (2003) and the U.S. National Hospital Discharge Survey (March 2005) to construct age-specific hospital discharge numbers for each county in the two study areas.

Asthma emergency room visits

Children's Asthma ER Visits

For particulate-related children's asthma emergency room (ER) visits, we rely on a study by Norris et al. (1999), who examined the relation between air pollution and childhood hospital ER visits for asthma in Seattle from 1995 to 1996. By regressing daily ER counts against fine particulate matter (PM) levels, along with other pollutants, they determined that a change of 11 μg/m3 in fine PM was associated with a relative rate of 1.15 in daily ER visits. This generates a mid-range β value of 0.0127. Finally, a daily incidence baseline rate is derived from the National Center for Health Statistics.

III.1.4 $PM_{2.5}$ Mortality

Adult Mortality

The scientific literature that assesses associations between $PM_{2.5}$ and premature mortality in adults has expanded rapidly over the past decade, with several large-scale multi-city studies that extend or reanalyze earlier studies (for example, Pope et al. 1995; Krewski et al. 2000; Pope et al. 2002; Laden et al. 2006) as well as a California-specific study that focuses on the Los Angeles basin (Jerrett et al. 2005). To estimate $PM_{2.5}$-related mortality for regions in California requires determining which of these studies is most appropriate for conditions in this region. In general, as noted above, studies are preferred that are peer reviewed, cover longer periods, are more recent (better reflecting current demographics and lifestyles), include larger samples, account for confounding factors, and were conducted in locations that have the greatest similarity to the study population. There is also an increasing literature that measures (Woodruff et al. 1997) or indicates the probability- of (Loomis et al. 1999; Pereira et al. 1998; Wang et al. 1997; Chay and Greenstone 2003) an association between $PM_{2.5}$ and mortality in children less than one year of age.

Both EPA and CARB have conducted recent benefit assessments for $PM_{2.5}$ reduction (EPA 2003a; EPA 2004; EPA 2005; CARB 2005; CARB 2006, CARB 2008), as has the SCAQMD (SCAQMD 2007) and these assessments have also undergone review of the analytical approaches used, including the choice of C-R functions. The consensus has been that for national studies, Pope et al. (2002) is the preferred basis to estimate adult mortality. The EPA Science Advisory Board Health Effects Committee (SAB-HEES 2004) and a recent National Research Council panel (NRC 2008) further recommend that neonatal mortality now be included in the base analysis using the C-R function from Woodruff et al. (1997). For California, there is agreement that Pope et al. provides the best C-R function from the *national* literature, but there is also agreement that Jerrett et al. (2005) could better represent California (ARB 2005 and peer-review comments thereon). However, Deck and Chestnut (2008), after assessing a number of explanations for the significantly higher risk found by Jerrett et al. relative to the national American Cancer Society (ACS) results, conclude that until the reason(s) are better understood, this study should not be the primary basis for a central estimate of $PM_{2.5}$-related mortality.

Following the professional consensus, and based on the reasons further discussed below, we rely on a combination of the following studies to estimate adult mortality effects.

<u>Pope et al. (2002)</u>

This study meets all of the essential criteria noted above for the choice of a C-R function. It is a large-scale, longitudinal cohort study that follows a large nationally representative population (ages 30 and older) across 61 cities over a 16-year follow-up period from a base of 1979-1983. Extending the follow-up period to 16 years increases the mortality data set by a factor of three compared to earlier studies. This study also included $PM_{2.5}$ measurements from 1999 and the first three quarters of 2000, and controled more closely for a series of personal risk factors, including lifestyle and occupation. The increase for the all-cause mortality associated with annual average $PM_{2.5}$ is 6% per 10 $\mu g/m^3$.

Jerrett et al. (2005)

This study is based on the Los Angeles area population subset from the national cohort included in Pope et al. (2002), accounted for the same confounders, and also assessed the association between average annual $PM_{2.5}$ and differences in mortality in the age 30 and older population. The authors found a substantially higher association between $PM_{2.5}$ and mortality, with a 17% increase in all-cause mortality for every 10 $\mu g/m^3$ increase in $PM_{2.5}$. While this is quite a large difference, contrasted with the 6% increase found by Pope et al. for the 61 cities overall , there are sound reasons to conclude that the results better represent the Los Angeles Basin population. A primary reason is that Jerrett et al. used a detailed intra-urban exposure measure supported by 23 $PM_{2.5}$ monitors across the region. This contrasts with the national cohort studies that compare inter-urban exposure and have much less spatial resolution. Another is that traffic-generated primary particles have a greater association with observed effects, and traffic in the Los Angeles basin accounts for nearly five times the proportion of total primary particles emitted than is typical in most of the United States, at 3.7% compared to 0.75%.

For purposes of assessing benefits in California, the Jerrett et al. work could be more appropriate than Pope et al. in that the exposure measure more closely fits the approach that we use in REHEX. However, because there is no clear explanation for the much higher relative risk value, relative to the national data (ACS) on which Jerrett et al. is based, we are reluctant to rely entirely on this result until the work has been replicated.

Laden et al. (2006)

This study includes no California cities, but relies on a more rigorous random selection process than was used to form the ACS panel, and includes information on more personal characteristics. It also followed subjects for a long period, more than 20 years. The authors report a relative risk of 1.16, which is close to the Jerrett et al. result, and higher than Pope et al. (2002), both of which are based on the ACS data.

Relative Risk Factor Used in the Study

Research in this area has expanded considerably over the past two decades, both strengthening scientific confidence that the effect of fine particulate exposure on mortality is "real", and offering the conundrum of risk factors that vary significantly from study to study. In 2006, EPA sponsored an expert elicitation as part of the process of determining what risk factor(s) should be used in risk assessments conducted to inform policy decisions at the agency. Twelve experts provided responses, with a significant majority choosing a relative risk (RR) at or above 1.10. None recommended a value lower than 1.06. (Deck and Chestnut 2008; Roman et al. 2008)

Given the differing strengths of the primary underlying health studies, and the conclusions from the expert elicitation, we use a weighted average of Jerrett et al. (RR=1.17) and Laden et al. (RR=1.16), and Pope et al. (RR=1.06). This results in a relative risk factor of 1.10 and a C-R β of 0.009531. We assign greater weight (two-thirds) to Pope et al. because of the national scope of the study, and the inclusion of California residents. Both of the other studies include smaller samples, in one case including only cities outside of California, and in the other including only Southern California. Finally, we again use county-specific baseline death rates obtained from the California Department of Health Services Death Statistical Data (CDHS, 2004).

<u>Post-neonatal Mortality</u>

<u>Woodruff et al. (1997)</u>

This is the first comprehensive national study to assess the impact of particles (PM_{10}) on infant mortality in the United States. It includes a sample size of four million infants less than one year of age across 86 metropolitan areas for the interval 1989-1991. Overall, the study estimates an increase of 4% for all-cause infant mortality for every 10 $\mu g/m^3$ increase in PM_{10}. The EPA SAB-HEES (2004) now recommends that neonatal mortality be included in primary benefit analyses conducted by EPA, and that the Woodruff et al. C-R be used. We note that the Woodruff study, however, did not include infants in a number of states, including California (because maternal education levels were not reported for California). While the study is likely representative of national conditions, it is impossible to determine whether the omission of California infants makes it less representative of the California population. Nevertheless, we include post neonatal deaths in this primary benefit analysis, using a C-R β value of 0.007844 derived from the Woodruff study.

Table III-1. Health endpoints.

Ozone	$PM_{2.5}$
School absences Ages 5-17	Acute bronchitis Ages 5-17
Emergency room visits All ages	Lower respiratory symptoms in children Ages 5-17
Respiratory hospital admissions	Upper respiratory symptoms in children Ages 5-17 asthmatic population
Asthma attacks All ages of the asthmatic population	Respiratory hospital admissions Ages 65 and older
Premature death (mortality) All ages	Premature death (mortality Ages 30 and older
Minor restricted activity days Ages 18-64	Asthma emergency room visits Under age 18
	Minor restricted activity days All ages
	Onset of chronic bronchitis Ages 27 and older
	Non-fatal heart attacks Ages 18 and older
	Cardiovascular hospital admissions Ages 18 and older
	Neo-natal mortality Under age 1
	Work loss days Ages 18-64

IV. ECONOMIC VALUATION

IV.1 THE BASIS FOR VALUE

If we know how much illness and premature death might be avoided as a result of meeting the health-based air quality standards, why assign monetary values at all, and what is the basis for those values? First, neither society nor individuals can afford to do everything that would be worthwhile. As a result, we must choose among the things that we do. The social choice to control emissions in order to improve air quality and health is one of these things, and one that is a high priority for Californians. It is therefore useful to have a sense in economic terms of the scale of gains from successfully implementing pollution control policies and programs. This study is designed to provide a transparent measure of these gains, that uses the best available information, reflects social preferences, and can readily be compared against the value of other social choices.

The basis for each value begins with the premise that, within limits[4], society accepts individual choices as valid, and as reflecting the actual value that individuals place on their choices, whether it is which news channel to watch or which college is best for their child. That is, what an individual chooses to do accurately represents what is best for him or her, and by inference for society, which is simply the sum of the individuals that make up that society. Social value—what we want to capture here—is then simply the sum of value to individuals. To determine the value to individuals of reducing pollution-related health risks we use prices or implied prices (hedonic measures) when available, along with survey (contingent valuation) results.

One objective of this study is to provide a monetary, or dollar, measure of the benefits that would accrue from avoiding some of the known adverse health effects that result from exposure to unhealthful air. A critical aspect of such a measure is determining the value that society places on avoiding specific adverse effects. These range from symptoms that are less severe, such as days when activities are limited, through hospitalization, emergency room visits, asthma attacks and the onset of chronic bronchitis, to premature death. Individuals value reducing these effects to avoid:

- Loss of productive time (work and school) and the direct medical costs that result from avoiding or responding to adverse health effects
- The pain, inconvenience and anxiety that result from adverse effects, or efforts to avoid or treat them
- Loss of enjoyment and leisure time
- Adverse effects on others resulting from their own adverse health effects

[4] Most people readily accept limits on individual choices that are necessary to protect others. This includes things such as criminal statutes, speed laws, and a variety of environmental protections ranging from vehicular exhaust standards to protection of endangered species.

IV.2 CONCEPTS AND MEASURES OF VALUE

Ideal measures of value would represent all of the losses that result from adverse health effects. They would also accurately reflect real preferences and decision-making processes similar to those we use to make basic choices every day. Our decisions about which goods or services to buy are based on which items give the most satisfaction, or utility, relative to prices and income. Market prices are therefore accepted as reasonable measures of the value of those items that can be purchased. However, there is no market in which cleaner air (like many other environmental goods) can be bought. Consequently, values for such goods cannot be directly observed from prices. Economists have developed alternatives to market prices to measure the value of environmental improvements, including health benefits resulting from cleaner air.

Generally accepted measures of the value of changes in well-being due to reducing the adverse health effects of air pollution include the cost of illness (COI) measure and the willingness to pay (WTP) or willingness to accept (WTA) measures. All three measures have limitations but, when taken together, they yield a generally accepted range of values for the health benefits of improvements in air quality. In this study, we use the most appropriate available value for each health endpoint.

IV.2.1 Cost of Illness

The cost of illness (COI) method was the first to be developed and described in the health and safety literature as a basis to value reductions in risk. It requires calculating the actual direct expenditures on medical costs, plus indirect costs (usually lost wages), incurred due to illness. This method is still the primary measure used to value the benefit of avoiding hospital admissions and other medical treatments. The COI method has the advantage of being based on real dollars spent to treat specific health effects and the actual market value of work time. Since it includes only monetary losses, however, and does not include losses associated with the value of leisure time, of school or unpaid work time, or of general misery, it does not capture all of the benefits of better health. The method is therefore generally viewed as limited and representing a lower bound on value. The basic limitation is that it is a measure of the *financial* impact of illness, not the *change in well being* due to illness, since financial loss is only part of the value forfeited by illness and discomfort. Other factors associated with illness, most notably pain, inconvenience, and anxiety, can result in a significant disparity between COI estimates and WTP (or WTA) estimates. As discussed below, the COI approach has been shown to produce a lower-bound value estimate. Overall, COI measures are used when more complete measures are unavailable for a specific effect. While they generally represent a lower bound of value, using them allows the valuation of some adverse effects, such as emergency room visits, which might otherwise not be quantified.

IV.2.2 Market-based Values

Because we know that COI measures undervalue adverse health effects, many studies have been conducted to determine more complete values. For improvements in health, for example, we use WTP measures, which are both more complete than COI and consistent with accepted economic concepts about markets and individual economic choices. Market choices that reduce risks to health or life indirectly indicate the WTP for lower risks, or the WTA for higher risks. Values derived from these market-based methods are based on relating differences in wages or consumer costs to differing degrees of risk. Those differences indicate the demand for and the WTP for lower risk, or the WTA for greater risk. Because air quality is not a market commodity and has no observable market price, many of the values used in benefit assessments for environmental improvements depend on studies of market-determined wage differentials and consumer expenditures in relation to lower risk of harm from other causes. These differentials and expenditures are then surrogates for the market price for reduced risk of harm from air pollution.

There is an extensive economics literature assessing the value of reduced workplace risk of death. It is, however, important to control for factors other than risk that can influence wage differentials, such as unpleasant working conditions. Studies conducted in the past 20 years do control carefully for job attributes that are not related to differences in risk (Viscusi 1992, 1993, 2004; Viscusi and Aldy 2003). There is a smaller literature that investigates differences in consumer expenditures relative to risk of injury or death associated with product use. The results for the most carefully conducted work, which controls for product characteristics other than relative risk, are generally consistent with the wage-risk studies (Atkinson and Halvorsen 1990; Viscusi 1992). Finally, there are several "meta-analyses" that assess the value of reduced risk based on statistical amalgamation of multiple underlying studies.

IV.2.3 Contingent Valuation

When values inferred from markets are not available, another means to estimate value involves the use of surveys. This method is referred to as contingent valuation (CV) because people are asked to determine what something would be worth to them *as if* they were able to purchase or sell it. CV has become a significant source of values over the past two decades, as the methodology has matured and become more accepted, and as policy-makers (and the courts) have become more engaged with the application of economic values to decision-making. CV-based values, as with wage-risk based WTA values, are conceptually better than COI because they are more inclusive. Respondents can value loss of enjoyment and discomfort, as well as the direct costs of an adverse health effect. The survey approach is, however, expensive to administer and the validity of values derived from this method depends on careful design and application of the survey instrument. Nonetheless, CV measures are in many cases well-supported and add useful information to benefits assessment (Carson et al. 2001).

IV.2.4 Strengths and Limitations of Methods

The most appropriate basis for valuing reductions in adverse health effects is presently WTP values based on CV studies and WTA based on wage-risk studies (Viscusi 1993). COI measures are used when preferred measures are unavailable because a lower bound value is preferable to zero value, which is implied when an effect is not included in the benefits assessment. We use four criteria to choose specific values from the literature.

1. The value used should be appropriate for the type of risk. For example, involuntary risk might carry a higher value than voluntary risk. The degree of risk (1 in 10,000 or 1 in 1,000,000) is a factor, as is whether the risk of harm is increasing or decreasing. Whether harm is prospective or has already occurred is also a factor.[5]
2. A measure should be as complete as possible. That is, it should represent gains or losses in well-being as fully as possible.
3. If similar values are derived from studies using different methods, for example from market-based studies and CV studies, those values are given a greater weight on the premise that convergence implies a closer representation of true value.
4. If more than one valid study produces values that are similar for comparable adverse effects, those values are given greater weight.

Given these criteria, CV results for WTP are most highly ranked for appropriateness and validity, followed by WTA from wage-risk studies (supported by WTP from a valid consumer behavior study), and then COI measures.

IV.3 SPECIFIC VALUES FOR PREMATURE DEATH

Premature mortality is the most significant effect of exposure to unhealthful levels of air pollution that can presently be quantified. Consequently, determining a socially appropriate value to attach to reducing the risk of premature mortality is a crucial part of any benefit assessment. It is very important to keep in mind that we are not valuing the life of any identifiable individual, but rather the value of reducing a very small risk over a large population enough so that some people would live longer than would otherwise have been the case.

IV.3.1 The Concept of the Value of a Statistical Life

Wage-risk studies tell us how much more compensation workers must be paid to accept jobs with very slightly elevated risks of job-related death. Consider this example:

There are 10,000 workers and the annual risk of job-related death is 1/10,000 greater than in a lower wage job. This means that we would expect one job-related death in this group annually (10,000 x 1/10,000). Let's say that each worker is paid $700 per year more as a result of this risk, and workers not facing this risk are paid $700 per year less than those at risk. The implied value of reducing risk just enough to prevent one death is $700 x 10,000 = $7,000,000. This is what economists call the value of a statistical life (VSL). Studies of consumer choices and product risk are based on the same approach—the small difference that each consumer pays to reduce a slight risk aggregated to the level of reducing risk enough to prevent a single death.

[5] The human capital method used in damage award legal cases is not used here, for example, because harm has already occurred. In assessing the benefits of environmental improvements we are considering the avoidance of harm, not compensation for harm.

IV.3.2 The Range of Values

There is a very wide range across all studies that assess VSL. However, this range can be narrowed significantly by considering the policy objectives with which we are concerned (attainment of the NAAQS), and by reviewing the methods used in each study. In a meta-analysis of VSL from U.S. wage-risk studies (Viscusi and Aldy 2003), most estimates fell into the range of $3.8-$9.0 million (in 2000 dollars) with a median for "prime-aged workers" of $7.6 million in 2007 dollars. This range is also consistent with the most robust consumer choice study (Atkinson and Halvorsen 1990), which found a VSL of $6.1 in 2007 dollars. Mrozek and Taylor (2002), however, using a method that controls for inter-industry wage differentials, report a value of $2.5 million. Finally, Kochi et al. (2006) used an empirical Bayes pooling method to combine VSL estimates from 40 selected studies and reported a value of $10.6 million for their U.S. sample.

IV.3.3 Issues in Selecting Specific Values

To assess the value to society of reducing the risk of premature death associated with elevated levels of air pollution, we want a value that is based on risk of a similar scale (in this case a very small annual risk) and is based on the preferences of people similar to the population at risk from pollution exposure. The need to match the degree of risk and population characteristics as closely as possible raises several issues, largely relating to factors such as age and income.

<u>Groups Most at Risk</u>

For mortality, we have evidence for the very young—newborns—and those aged 30 and over associating elevated pollution with premature death. We also know that the very young, those whose health is already compromised, and those aged 65 and older are at greater risk than the general population.

<u>Age and the Value of Life</u>

Because wage-risk studies are based largely on blue collar workers, they reflect the preferences of younger workers, and not those outside the workforce who are very young or older, but who are likely at greater risk of early death related to air pollution. Since younger people have longer life expectancies, using a VSL based on their preferences might overstate the appropriate VSL for the older population. Similarly, it is likely to understate society's value for young children, as several studies indicate that parents, and society more broadly, place greater value on preventing harm to children than to adults. Further, to the extent that blue collar workers have incomes below the average, their job choices might reflect a lower VSL than would be the case for white collar workers. Complicating this further, older adults are more likely to experience impaired health and could therefore have a lower VSL than is the case for a healthy younger or middle-aged adult or a child, although evidence suggests that this effect, if any, is small (Alberini et al. 2004). In determining which VSL to use to value air quality improvements, these factors are all considered.

The most recent research regarding health status and older age (Alberini et al. 2004) finds no strong evidence that VSL declines significantly with age, and then only at age 70 and above. Further, those with underlying health conditions report little difference in VSL than those who are healthier. At the other end of life, there is evidence (Dickie and Messman 2004; EPA 2003a and the references therein) that families and society place a higher value on children's well-being, but there is no well-established basis to adjust adult values to account for this. Although there are some studies that assess how much more we are willing to pay for children's health, relatively little has been done work regarding how we value their lives.

Consistent with these findings and the recommendations of peer-review advisory groups, benefit assessments carried out for proposed federal and state rules and programs (EPA 2003b, 2004, 2005; CARB 2005; CARB 2008) do not make any adjustment for age or health status. A recent National Research Council panel (NRC 2008), while recommending that further study is necessary, concluded that there is presently no adequate basis to adjust VSL for age.

IV.3.4 The Value of a Statistical Life Used in this Study

Given the range noted above, it is necessary to determine how to narrow this range and select a single value. There is no clear theoretical or mathematical logic for accomplishing this. For example, there is no basis to give any single study greater weight than another, which argues for averaging over a group of studies. Also, it is preferable (EPA-SAB 2007; NRC 2008) to include both wage-risk and stated preference (CV) values. This is in part because the VSL used needs to reflect in some way the age distribution of the population at greatest risk (i.e., the older population). CV studies include this population, whereas wage-risk studies largely do not.

For the purposes of this study, we construct a value based on the meta-analyses of Mrozek and Taylor, Viscusi and Aldy, and Kochi et al. Further, we rely on the U.S.-only values reported by Viscusi and Aldy, and Kochi et al., and include the expanded revealed preference estimate (based on Kochi et al., developed by Deck and Chestnut 2008). The mean of the Viscusi and Aldy U.S. values is $7.6 million, which we average with $2.5 million from Mrozek and Taylor and $10.6 million from Kochi et al. This yields $6.9 million based on hedonic wage-risk studies. Then we give equal weight to the average wage-risk VSL and the CV value of $6.3 million calculated by Deck and Chestnut, which they based on CV studies underlying the Kochi et al. meta-analysis, to determine a final VSL of $6.63 million. (All values are in 2007 dollars.)

IV.4 SPECIFIC VALUES FOR HEALTH ENDPOINTS

Generally accepted values for many endpoints have been developed over the past decade and are widely used in benefit assessments and regulatory analyses by the EPA and the states. These values have been peer-reviewed by advisory bodies, including committees of EPA's Scientific Advisory Board, and many have also been published in the peer-reviewed literature. We generally follow this established protocol, adjusting specific values for inflation and California-specific incomes. Where California-specific COI data are available, as for hospitalizations, we use those values.

IV.4.1 Onset of Chronic Bronchitis

Apart from premature death, the onset of chronic bronchitis is one of the most serious adverse effects that is associated with PM exposure and is quantifiable. The value of avoiding this effect has been estimated in two CV studies (Krupnick and Cropper 1989; Viscusi et al. 1991) and is $402,800 and $396,600 in 2007 dollars (for the SoCAB and SJVAB, respectively), beginning with the value used by EPA (2003b; 2004; 2005) to account for the severity of the disease relative to the underlying studies and updating to reflect current price levels in the two air basins.

IV.4.2 Hospitalizations

Respiratory-related and cardiovascular-related hospitalizations are costly both in terms of treatment and loss of work, household, and leisure time. We use a series of California-based values derived from Chestnut et al. (2006), again adjusting to 2007 dollars using region-specific consumer price indexes, and also separating hospital values for patients over 65 (who mostly are no longer active in the labor force, thus lowering their opportunity cost). In addition, while Chestnut et al. assessed the COI and WTP for adults, we apply this value to the entire population because when children are hospitalized, one or more adults faces the opportunity cost of time diverted from work, caring for other children and other normal activities. The values we apply are as follows:

- Respiratory Hospital Admissions, under 65—$39,550 (SoCAB) and $41,300 (SJVAB)
- Respiratory Hospital Admissions, 65 and over—$34,970 (SoCAB) and $33,490 (SJVAB)
- Cardio Hospital Admissions, under 65—$46,610 (SoCAB) and $44,630 (SJVAB)
- Cardio Hospital Admissions, 65 and over—$40,090 (SoCAB) and $38,390 (SJVAB)

IV.4.3 Minor Restricted Activity Days

Willingness to pay to avoid a day when normal activities are limited by a combination of pollution-related symptoms derives from Tolley et al.'s 1986 study, reported by EPA (2005) as $51 in 1999 dollars and 1990 income. We convert this to current dollars and adjust for income, yielding values of $65.70 and $64.70 in the SoCAB and SJVAB, respectively, per MRAD.

<u>Work Loss Days</u>

Apart from MRADs, when productivity might be lower, some work days are lost outright as a result of $PM_{2.5}$ exposure. These days are valued at the daily wage rate for each county, ranging from $138 in Tulare County to $188 in Orange County (EDD 2008).

Valuing Nonfatal Heart Attacks

Following EPA (2005) and Deck and Chestnut (2008), we note the absence of any WTP values for reduction in nonfatal heart attacks and turn to a COI-based approach. Our monetary value for this health endpoint considers the direct medical costs and the opportunity cost (foregone wages) associated with the heart attack. To calculate the direct medical costs, we combine the results of two studies: Eisenstein et al. (2001), who use a statistical regression model to estimate the first-year (or acute phase) direct medical costs of treating patients to be $24,921 in 1997 dollars; and Russell et al. (1998), who calculate the first year direct costs as $15,540 in 1995 dollars. Averaging these, and updating to 2007 dollars, gives us a direct cost figure of $30,168. For the opportunity costs, we use an age-specific annual lost earnings approach first developed by Cropper and Krupnick (1990). Updating their estimated average annual change in lost earnings to 2007 dollars gives us a foregone earnings estimate of $39,935. Combining this with the direct medical costs, our total annual cost of a nonfatal heart attack becomes $70,103.

School Absence Days

To value days of school absence, Smith et al. (1997) estimated lost productivity to the adult care-giver, under the assumption that one adult stayed home to take care of the sick child. In situations where two caregivers were involved, the lower income was used to estimate lost productivity. In cases where only one adult had an income (about 39 percent of the cohort studied), an imputed value for household work was used.

Using this methodology, Smith et al. estimated the total indirect cost of 3.6 million school loss days to be $194.5 million (in 1994 dollars) This translates into a per-day value of $54.03 (again, in 1994 dollars).

To apply these national figures to our analysis, two adjustments were then made. First, the value was updated to 2007 dollars. Second, it was modified to reflect wage levels in the two air basins. This is the approach adopted by EPA (2005) and used by Hall et al. (2003). This method produces a range of values from $98 in Tulare County to $165 in Orange County.

Upper and Lower Respiratory Symptom Days

For these effects, we adjusted the value that EPA (2005) has adopted, again adjusting for income and inflation to 2007 values. A lower respiratory symptom day is valued at $21.50 and $21.20, and an upper respiratory day at $34.50 and $33.90, for the SoCAB and SJVAB, respectively.

Acute Bronchitis

Bronchitis typically involves multiple symptoms and each occurrence has a duration of about six days (EPA 2005). To construct a value for this effect, we combine Loehman et al.'s (1979) values for chest discomfort and cough and update this number to 2007 dollars, producing values for one day of $19.70 and $19.40 for the SoCAB and SJVAB, respectively. Over a six-day period, these reach a total of $118 and $116.

Asthma Attack

This effect is valued based on a 1986 CV study conducted in Los Angeles (Rowe and Chestnut 1986) that estimated WTP to avoid a "bad asthma day." Adjusting EPA's most recent peer-reviewed figure to current dollars and adjusting for income, this value becomes $53.85 for the SoCAB and $53 for the SJVAB per event.

Emergency Room Visits

Emergency room visits are valued at $361 and $355 for the SoCAB and SJVAB in 2007 dollars, based on two combined COI studies (EPA 2005). This dollar measure does not include time lost at work or school, or the value of avoiding the pain and anxiety caused by the underlying condition and ER visit.

V. RESULTS: THE ESTIMATED ECONOMIC VALUE FROM REDUCED ADVERSE HEALTH EFFECTS WITH ATTAINMENT OF THE FEDERAL AIR QUALITY STANDARDS

Failure to attain health-based air quality standards poses a pervasive and ongoing threat to public health in much of California, as represented by this assessment of the scale of illness and premature death in the South Coast and San Joaquin Valley Air Basins.

V.1 THE SOUTH COAST AIR BASIN

Unsurprisingly, given the large value that individuals and society more broadly place on life, the overall economic benefits of attaining the NAAQS are dominated by premature mortality. It is estimated that across the SoCAB, 3,000 people would avoid premature death each year, accounting only for the effect of $PM_{2.5}$ and only for the population aged 30 and older. With a value for each life of $6.63 million, this effect by itself offers a benefit of attainment of nearly $20 billion each year. While this consequence of elevated fine particle levels is by far the most striking, other effects are also important.

For example, 1,590 new cases of adult-onset chronic bronchitis could be avoided every year with attainment of the $PM_{2.5}$ NAAQS. At a value of over $400,000 for each new case—reflecting the significant costs of treatment and loss of enjoyment and activity—avoiding this effect would generate benefits of over $640 million each year. In addition, attaining the federal fine particulate standard would prevent over 3,200 nonfatal heart attacks annually, generating an economic benefit of more than $226 million, and would reduce days of lost work by nearly 400,000, worth an estimated $72 million. Days of reduced upper respiratory symptoms to the region's asthmatic children would be lessened by more than 1.6 million cases, valued at over $55 million each year.

Ozone attainment offers the benefit of more than a million fewer school absence days, conservatively valued at more than $105 million per year. It should be noted that this only reflects the value of time lost to an adult caregiver and not any medical costs or loss of educational opportunity. MRADs would cost adults nearly 3 million days per year when their daily routine is limited to some degree by exposure to elevated ozone or $PM_{2.5}$. Avoiding MRADs offers an economic benefit of more than $195 million annually.

Tables V-1 through V-4 show the overall benefits in numbers of adverse health effects and annual deaths avoided and in dollars for ozone and for $PM_{2.5}$. Looking at the overall benefits, residents of the SoCAB could expect annual benefits of $21.23 billion if both the ozone and $PM_{2.5}$ NAAQS were attained.

The per capita benefits are also noteworthy and provide a sense of perspective. On a basin-wide average, annual benefits are over $1,225 per person. This varies across counties with the levels of pollution and the size of the more vulnerable populations, and very slightly with income (which determines or influences the value of some effects). The county-level average benefits per resident range from $955 in Orange County to over $1,650 in Riverside County.[6]

V.2 THE SAN JOAQUIN VALLEY AIR BASIN

In the SJVAB, the overall benefits of attaining the NAAQS are dominated by premature mortality. Again, this reflects the large value that individuals and society place on the value of a statistical life. Across the SJVAB, over 800 people are estimated to avoid premature death annually, accounting only for the effect of $PM_{2.5}$ and only for the population aged 30 and older. With a value for each life of $6.63 million, this effect alone offers a benefit of attainment of over $5 billion each year. While this consequence of elevated $PM_{2.5}$ levels is by far the most dominant, there are other important health outcomes to be realized as well.

For example, more than 580 nonfatal heart attacks could be avoided each year with attainment of the fine particulate standards, generating an economic benefit of more than $40 million for the SJVAB. Work loss days would also be reduced by nearly 70,000, with an estimated monetary value of $10.5 million, and over 360,000 cases of upper respiratory symptoms to the region's asthmatic children would be avoided, valued at more than $12 million annually. Finally, more than 360 new cases of chronic bronchitis could be avoided each year with attainment of the $PM_{2.5}$ NAAQS. At a value of almost $400,000 per case—reflecting the significant costs of treatment and loss of enjoyment and activity—avoiding this adverse outcome would generate benefits of over $140 million each year.

The attainment of $PM_{2.5}$ and ozone standards would generate a benefit of more than 540,000 fewer MRADs, valued at $35 million annually. Ozone attainment also offers the benefit of over 150,000 fewer school absence days, conservatively valued at more than $12 million per year. It should be noted that this only reflects the value of time lost to an adult caregiver and not any medical costs or loss of educational opportunity.

Tables VI-5 through VI-8 show the overall benefits in numbers of adverse health effects avoided and in dollars for ozone and for $PM_{2.5}$. Looking at the overall benefits, SJVAB residents could expect annual benefits of $5.73 billion with the attainment of both the ozone and $PM_{2.5}$ standards.

Finally, to provide a sense of perspective, we also examine the per capita benefits of these pollution reductions. For the SJVAB overall, annual benefits average over $1,600 per person, with county-level average benefits per resident ranging from $1,150 in Merced County to over $2,150 in Kern County.[7] These estimates vary across counties with the levels of pollution and the size of the more vulnerable populations, and very slightly with income (which determines or influences the value of some effects).

We note that these results report larger benefits from attaining the NAAQS than our previous analysis of the SJVAB (Hall et al. 2006, 2008). The differences are explained primarily

[6] Los Angeles $1,211; Orange $955; Riverside $1,652; San Bernardino $1,492; entire SOCAB $1,226.
[7] Fresno $1,716; Kerns $2,159; Kings $1,459; Madera $1,682; Merced $1,150; San Joaquin $1,195; Stanislaus $1,392; Tulare $1,969; entire SJVAB $1,631.

by increased exposures to $PM_{2.5}$, a higher relative risk factor for premature mortality (based on newer health studies), and the inclusion of non-fatal heart attacks and ozone-related premature mortality.

Table V-1. $PM_{2.5}$-related health effects in the South Coast Air Basin.

	Los Angeles	Orange	Riverside	San Bernardino	All Counties
Minor Restricted Activity Days Ages 18-64	1,224,600	300,010	224,780	266,830	2,016,220
Premature Mortality Ages 30 and older	1,720	410	460	410	3,000
Post Neo-Natal Mortality	7	1	1	2	11
Work Loss Days Ages 18-64	241,690	59,100	44,500	52,850	398,140
Lower Respiratory Symptoms Ages 5-17	47,160	10,930	9,540	11,970	79,600
Upper Respiratory Symptoms Asthmatic Children	944,900	220,400	206,300	246,500	1,618,100
Acute Bronchitis Ages 5-17	7,420	1,740	1,540	1,810	12,510
Chronic Bronchitis Ages 27 and older	960	240	190	200	1,590
Children's Asthma ER Visits	1,175	275	255	305	2,010
Non-Fatal Heart Attacks	1,960	485	370	415	3,230
Respiratory Hospital Admissions 0-64	95	14	19	27	155
Respiratory Hospital Admissions 65+	257	48	57	50	412
Respiratory Hospital Admissions Total	352	62	76	77	567
Cardio Hospital Admissions 0-64	121	25	26	27	199
Cardio Hospital Admissions 65+	430	88	118	83	719
Cardio Hospital Admissions Total	551	113	144	110	918

Table V-2. $PM_{2.5}$-related economic values in the South Coast Air Basin.

	Los Angeles	Orange	Riverside	San Bernardino	All Counties
Minor Restricted Activity Days (millions)	$80.46	$19.71	$14.77	$17.53	$132.5
Premature Mortality (millions)	$11,397	$2,717	$3,048	$2,717	$19,878
Post Neo-Natal Mortality (millions)	$46.38	$6.63	$6.63	$13.25	$72.89
Work Loss Days (millions)	$44.93	$11.09	$7.16	$8.50	$71.67
Lower Respiratory Symptoms (millions)	$1.02	$0.24	$0.21	$0.26	$1.71
Upper Respiratory Symptoms (millions)	$32.56	$7.59	$7.11	$8.49	$55.76
Acute Bronchitis (thousands)	$877.4	$205.8	$182.1	$214.0	$1,479.0
Chronic Bronchitis (millions)	$386.7	$96.7	$76.5	$80.5	$640.4
Children's Asthma ER Visits (thousands)	$423.9	$99.2	$92.0	$110.0	$725.1
Non-Fatal Heart Attacks (millions)	$137.4	$34.0	$25.94	$29.09	$226.4
Respiratory Hospital Admissions (millions)	$12.91	$2.26	$2.78	$2.86	$20.81
Cardio Hospital Admissions (millions)	$22.88	$4.69	$5.94	$4.59	$38.10
Total Value in Millions	$12,164	$2,900	$3,195	$2,882	$21,141

Table V-3. Ozone-related health effects in the South Coast Air Basin.

	Los Angeles	Orange	Riverside	San Bernardino	All Counties
Respiratory Hospital Admissions Ages 0-64	333	77	117	129	656
Respiratory Hospital Admissions Ages 65+	47	10	68	44	169
Respiratory Hospital Admissions All ages	380	87	185	173	825
Asthma Attacks Asthmatic population all ages	59,100	17,010	22,480	22,380	120,970
Emergency Room Visits All ages	150	45	55	55	305
School Absences Ages 5-17	408,310	115,320	78,650	90,430	692,710
Days of School Absences Ages 5-17	653,300	184,500	125,840	144,690	1,108,330
Minor Restricted Activity Days Ages 18-64	483,840	142,380	164,470	170,720	961,410
Mortality	12	3	15	11	41

Table V-4. Ozone-related economic values in the South Coast Air Basin.

	Los Angeles	Orange	Riverside	San Bernardino	All Counties
Respiratory Hospital Admissions (millions)	$15.40	$3.53	$7.21	$6.87	$33.0
Asthma Attacks (millions)	$3.183	$0.916	$1.21	$1.205	$6.514
Emergency Room Visits (thousands)	$54.12	$16.24	$19.84	$19.84	$110.04
Days of School Absences (millions)	$58.63	$22.30	$12.17	$12.88	$105.97
Minor Restricted Activity Days (millions)	$31.79	$9.35	$10.81	$11.22	$63.16
Mortality (millions)	$79.51	$19.88	$ 99.39	$72.89	$271.67
Total Value in Millions	$188.6	$56.0	$130.8	$105.1	$480.5

Table V-5. $PM_{2.5}$-related health effects in the San Joaquin Valley Air Basin.

	Fresno	Kern	Kings	Madera	Merced	San Joaquin	Stanislaus	Tulare	All Counties
Minor Restricted Activity Days Ages 18-64	103,770	80,170	18,770	16,020	21,840	49,360	45,660	50,750	386,340
Premature Mortality Ages 30 and older	211	182	29	33	38	110	99	110	812
Post Neo-Natal Mortality	1	1	0	0	0	0	0	0	2
Work Loss Days Ages 18-64	18,500	14,280	3,340	2,850	3,880	8,740	8,120	9,030	68,740
Lower Respiratory Symptoms Ages 5-17	4,900	3,830	710	670	1,170	2,280	2,100	2,600	18,260
Upper Respiratory Symptoms Asthmatic Children	98,270	76,530	14,340	13,420	22,870	44,130	41,260	51,520	362,340
Acute Bronchitis Ages 5-17	950	790	140	130	210	450	410	510	3,600
Chronic Bronchitis Ages 27 and older	95	78	17	15	19	48	44	48	364
Children's Asthma ER Visits	119	93	17	16	28	54	50	63	440
Non-Fatal Heart Attacks	156	119	27	24	33	78	70	77	584
Respiratory Hospital Admissions 0-64	8	5	2	1	1	4	3	3	27
Respiratory Hospital Admissions 65+	24	18	2	4	5	14	13	12	92
Respiratory Hospital Admissions Total	32	23	4	5	6	18	16	15	119
Cardio Hospital Admissions 0-64	11	7	2	2	2	5	5	5	39
Cardio Hospital Admissions 65+	37	23	4	6	6	20	18	17	131
Cardio Hospital Admissions Total	48	30	6	8	8	25	23	22	170

Table V-6. $PM_{2.5}$-related economic values in the San Joaquin Valley Air Basin.

	Fresno	Kern	Kings	Madera	Merced	San Joaquin	Stanislaus	Tulare	All Counties
Minor Restricted Activity Days (millions)	$6.71	$5.19	$1.21	$1.04	$1.41	$3.19	$2.95	$3.28	$24.98
Premature Mortality (millions)	$1,398.0	$1,206.0	$192.2	$218.7	$251.8	$728.9	$656.0	$728.9	$5,380.0
Post Neo-Natal Mortality (millions)	$6.63	$6.63	$ 0	$ 0	$ 0	$ 0	$ 0	$ 0	$13.25
Work Loss Days (millions)	$2.89	$2.23	$0.51	$0.41	$0.58	$1.40	$1.28	$1.25	$10.55
Lower Respiratory Symptoms (thousands)	$103.9	$81.2	$15.1	$14.2	$24.8	$48.4	$44.5	$55.2	$387.3
Upper Respiratory Symptoms (millions)	$3.33	$2.60	$0.49	$0.46	$0.76	$1.50	$1.40	$1.75	$12.29
Acute Bronchitis Value (thousands)	$110.6	$92.0	$16.3	$15.1	$24.5	$52.4	$47.7	$59.4	$418.0
Chronic Bronchitis Value (millions)	$37.68	$30.94	$6.74	$5.95	$7.54	$19.04	$17.45	$19.04	$144.4
Children's Asthma ER Visits (thousands)	$42.28	$33.04	$6.04	$5.68	$9.95	$19.18	$17.76	$22.38	$156.3
Non-Fatal Heart Attacks (millions)	$10.94	$8.34	$1.89	$1.68	$2.31	$5.47	$4.91	$5.40	$40.94
Respiratory Hospital Admissions (millions)	$1.12	$0.80	$0.15	$0.17	$0.21	$0.63	$0.55	$0.52	$4.15
Cardio Hospital Admissions (millions)	$1.91	$1.20	$0.24	$0.32	$0.32	$0.99	$0.91	$0.88	$6.77
Total Value in Millions	$1,469	$1,264	$203	$229	$265	$761	$686	$761	$5,638

Table V-7. Ozone-related health effects in the San Joaquin Air Basin.

	Fresno	Kern	Kings	Madera	Merced	San Joaquin	Stanislaus	Tulare	All Counties
Respiratory Hospital Admissions Ages 0-64	32	30	4	4	6	15	13	17	121
Respiratory Hospital Admissions Ages 65+	14	11	1	2	2	2	3	7	42
Respiratory Hospital Admissions All ages	46	41	5	6	8	17	16	24	163
Asthma Attacks Asthmatic population all ages	5,670	4,640	890	780	1,090	2,290	2,100	2,940	20,400
Emergency Room Visits All ages	17	13	3	2	3	7	7	8	60
School Absences Ages 5-17	27,490	23,630	3,780	3,440	5,330	8,190	8,440	14,400	94,700
Days of School Absences Ages 5-17	43,980	37,810	6,050	5,500	8,530	13,100	13,500	23,040	151,510
Minor Restricted Activity Days Ages 18-64	42,970	34,620	7,580	6,320	8,070	17,170	15,190	21,830	153,750
Mortality	3	3	0	0	0	0	1	2	9

Table V-8. Ozone-related economic values in the San Joaquin Valley Air Basin.

	Fresno	Kern	Kings	Madera	Merced	San Joaquin	Stanislaus	Tulare	All Counties
Respiratory Hospital Admissions--All ages (millions)	$1.73	$1.55	$0.19	$0.23	$0.30	$0.66	$0.61	$0.91	$6.19
Asthma Attacks Asthmatic population (thousands)	$301	$246	$47	$41	$58	$121	$111	$156	$1,081
Emergency Room Visits (thousands)	$6.04	$4.62	$1.07	$0.71	$1.07	$2.49	$2.49	$2.84	$21.32
Days of School Absences (millions)	$3.35	$3.02	$0.48	$0.43	$0.68	$1.21	$1.20	$1.65	$12.02
Minor Restricted Activity Days (millions)	$2.78	$2.24	$0.49	$0.41	$0.52	$1.11	$0.98	$1.41	$9.95
Mortality (millions)	$19.88	$19.88	$ 0	$ 0	$ 0	$ 0	$6.63	$13.25	$59.63
Total Value in Millions	$28.05	$26.94	$1.21	$1.11	$1.56	$3.10	$9.53	$17.38	$88.88

VI. CONCLUSIONS AND IMPLICATIONS

VI.1 CONCLUSIONS

Almost every resident of the South Coast Air Basin, and *every* resident of the San Joaquin Valley Air Basin, regularly experiences air pollution levels known to harm health and to increase the risk of early death. For example, from 2005 through 2007, each person was on average exposed to unhealthful levels of ozone on nearly 20 and more than 30 days per year in the SoCAB and SJVAB, respectively. In Riverside and San Bernardino Counties this rises to nearly 50 days each year, and in Kern County, over 50 days. This is unsurprising, given how frequently and pervasively the health-based air quality standards are violated. These exposures translate directly into poorer health and an elevated risk of premature death. Further, some groups are more at risk than the average, with somewhat greater exposure for children. In the SJVAB, *66%* of the population is exposed to health-endangering annual average levels of $PM_{2.5}$. In the SoCAB, this averages over 64%, and in the most populated county—Los Angeles—it averages 75%.

Other noteworthy results of the analysis include

1. For the San Joaquin Valley Air Basin overall, the economic benefits of meeting the federal $PM_{2.5}$ and ozone standards average more than $1,600 *per person per year*, or a total of nearly $6 billion.
2. Residents of the South Coast Air Basin, on average, would gain an annual economic benefit of more than $1,250 in improved health if the federal ozone and $PM_{2.5}$ standards were met, totaling nearly $22 billion.

These dollar values represent the following for the two air basins and two pollutants combined:

- 3,860 fewer premature deaths among those age 30 and older
- 13 fewer premature deaths in infants
- 1,950 fewer new cases of adult onset chronic bronchitis
- 3,517,720 fewer days of reduced activity in adults
- 2,760 fewer hospital admissions
- 141,370 fewer asthma attacks
- 1,259,840 fewer days of school absence
- 16,110 fewer cases of acute bronchitis in children
- 466,880 fewer lost days of work
- 2,078,300 fewer days of respiratory symptoms in children
- 2,800 fewer emergency room visits

To place the reduction in premature deaths in perspective, attaining the federal $PM_{2.5}$ standard would save more lives than reducing the number of motor vehicle fatalities to zero in most of the counties in this study. In Los Angeles County, $PM_{2.5}$-related deaths (CHP 2007) are *more than double* the number of motor vehicle-related deaths. Table VI-1 shows vehicular and $PM_{2.5}$-related deaths for all counties.

Table VI-1. $PM_{2.5}$-related vehicular deaths[8] relative to $PM_{2.5}$-related deaths annually.

County	Vehicular	$PM_{2.5}$-related
Los Angeles	801	1,720
Orange	210	410
Riverside	349	460
San Bernardino	387	410
SoCAB	1,747	3,000
Fresno	154	211
Kern	198	182
Kings	45	29
Madera	48	33
Merced	57	38
San Joaquin	93	110
Stanislaus	81	99
Tulare	98	110
SJV	774	812
Total	2,521	3,812

VI.2 IMPLICATIONS

The majority of California residents face significant public health risks from the present unhealthful levels of ozone and fine particles. This is in addition to other health challenges, including a high rate of poverty (which exceeds 30% in Fresno County, compared to a statewide rate below 20%) and lack of access to health care. Substantial economic and health gains would result from effective policies to reduce pollution levels.

The adverse impacts of air pollution are not distributed equally. Residents of Fresno, Kern, Kings, and Tulare Counties experience significantly more days when the $PM_{2.5}$ standards are violated than the basin-wide averages, as do San Bernardino and Riverside Counties. Tulare, Riverside and San Bernardino Counties join Fresno and Kern in being well above the basin average for the number of days of exposure above the ozone standards. Children under the age of 5 are exposed to unhealthful ozone concentrations on more days than adults. Blacks and Hispanics experience somewhat more frequent exposures to elevated levels of $PM_{2.5}$ than non-Hispanic whites do. These groups all stand to gain relatively more from successful pollution reduction efforts.

Because ozone is typically more often elevated during the summer months, and the $PM_{2.5}$ 24-hr standard is typically violated more frequently in the winter months, there is essentially no “clean” season in either air basin.

[8] http://www.chp.ca.gov/switrs/pdf/2006-sec8.pdf

As the population continues to increase, with associated increases in vehicle traffic and economic activity, the gains from attaining the health-based air quality standards will grow, but will also become more difficult to achieve. Identifying and acting on opportunities now would produce substantial gains for more than 20 million Californians.

REFERENCES

Abbey D.E., B.E. Ostro, F. Petersen and R.J. Burchette. (1995) Chronic respiratory symptoms associated with estimated long-term ambient concentrations of fine particulates less than 2.5 microns in aerodynamic diameter (PM2.5) and other air pollutants, *Journal of Exposure Analysis and Environmental Epidemiology* **5**(2), 137-159.

Abbey D.E., F. Petersen, P.K. Mills and W.L. Beeson. (1993) Long-term ambient concentrations of total suspended particulates, ozone and sulfur dioxide and respiratory symptoms in a nonsmoking population, *Archives of Environmental Health* **48**(10), 33-46.

Adams P.F., G.E. Hendershot and M.A. Marano. (1999) Current Estimates from the National Health Interview Survey, 1996, *Vital Health Statistics* **10**(100), 1-212.

Alberini A., M. Cropper, A. Krupnick, and N. Simon. (2004) Does the value of a statistical life vary with age and health status? Evidence from the US and Canada, *Journal of Environmental Economics and Management* **48**(1), 769-792.

American Lung Association. (2002) *Trends in Morbidity and Mortality: Pneumonia, Influenza, and Acute Respiratory Conditions*. American Lung Association, Best Practices and Program Services, Epidemiology and Statistics Unit.

Atkinson S.E. and R. Halvorsen. (1990) The valuation of risks to life: evidence from the market for automobiles, *Review of Economics and Statistics* **72**(1), 133-136.

Bell M.L., F. Dominici and J.M. Samet. (2005) A meta-analysis of time-series studies of ozone and mortality with comparison to the national morbidity, mortality, and air pollution study, *Epidemiology* **16**(4), 436-445.

Bell M.L., R.D. Peng and F. Dominici. (2006) The exposure-response curve for ozone and risk of mortality and the adequacy of current ozone regulations, *Environmental Health Perspectives On-line* (available at http://dx.doi.org/).

Burnett R.T., J.R. Brook, W.T. Yung, R.E. Dales and D. Krewski. (1997) Association between ozone and hospitalization for respiratory disease in 16 Canadian cities, *Environmental Research* **72**(1), 24-31.

Burnett R.T., R.E. Dales, M.E. Raizenne, D. Krewski, P.W. Summers, G.R. Roberts, M Raadyoung, T. Dann and J. Brook. (1994) Effects of low ambient levels of ozone and sulfates on the frequency of respiratory admissions to Ontario hospitals, *Environmental Research* **65**(2), 172-194.

California Highway Patrol (CHP). (2007) 2006 Annual Report of Fatal and Injury Motor Vehicle Traffic Collisions. Sacramento, CA. http://www.chp.ca.gov/switrs/

California Air Resources Board (CARB). (2006) *Quantification of the Health Impacts and Economic Valuation of Air Pollution from Ports and Goods Movement in California*, Staff Report, March, Sacramento, CA.

California Air Resource Board (CARB). (2008) *Methodology for Estimating Premature Deaths Associated with Long-term Exposures to Fine Airborne Particulate Matter in California*, Draft Staff Report, May, Sacramento, CA.

California Air Resources Board (CARB). (2005) *Emission Reduction Plan for Ports and International Goods Movement in California*, California Environmental Protection Agency, Sacramento, CA.

California Department of Health Services (CDHS). (2004) *Death Statistical Data*, Sacramento, CA.

Carson R.T., N.E. Flores and N.F. Meade. (2001) Contingent valuation: controversies and evidence, *Environmental and Resource Economics* **19**(2), 173-210.

Chay K.Y. and M. Greenstone. (2003) The impact of air pollution on infant mortality: evidence from geographic variation in pollution shocks induced by a recession, *Quarterly Journal of Economics* **118**(3), 1121-1167.

Chen L., B.L. Jennison, W. Yang and S.T. Omaye. (2000) Elementary school absenteeism and air pollution, *Inhalation Toxicology* **12**, 997-1016.

Chestnut L.G., M.A. Thayer, J.K. Lozo and S.K. Van Den Eeden. (2006) The economic value of preventing respiratory and cardiovascular hospitalizations, *Contemporary Economic Policy* **24**(1), 127-143.

Cody R.P., C.P. Weisel, G. Birnbaum and P.J. Lioy. (1992) The effect of ozone associated with summertime photochemical smog on the frequency of asthma visits to hospital emergency departments, *Environmental Research* **58**(2), 184-194.

Cropper M. L. and A. J. Krupnick. (1990) *The Social Costs of Chronic Heart and Lung Disease*. Resources for the Future, Discussion Paper QE 89-16-REV, Washington, DC.

Deck L. and Chestnut. (2008) *Recommended Health Benefit Assessment Methods for the 2007 AQMP Socioeconomic Assessment*, Final Report Stratus Consulting to the South Coast Air Quality Management District, Diamond Bar, CA.

Deck, L. and Chestnut, L.G. (2008). Recommended Health Benefit Assessment Methods for the 2007 AQMP Socioeconomic Assessment (Final Report), Stratus Consulting Inc., Washington, DC.

Department of Health Services (DHS). (2005) *County Health Status Profiles 2005*, Sacramento, CA. http://www.dhs.ca.gov/hisp/chs/OHIR/reports/healthstatusprofiles/2005/

Dickie M. and V.L. Messman. (2004) Parental altruism and the value of avoiding acute illness: are kids worth more than their parents? *Journal of Environmental Economics and Management* **48**(3), 1146-1174.

Dockery D.W., J. Cunningham, A.I. Damokosh, L.M. Neas, J.D. Spengler, P. Koutrakis, J.H. Ware, M. Raizenne and F.E. Speizer. (1996) Health effects of acid aerosols on North American children: respiratory symptoms, *Environmental Health Perspectives* **104**(5), 500-505.

Ebelt S.T., M. Brauer and W.E. Wilson. (2003) A comparison of health effects from exposure to ambient and non-ambient particles. Poster P02-08 presented at the *2003 AAAR PM Meeting, Particulate Matter: Atmospheric Sciences, Exposure and the Fourth Colloquium on PM and Human Health*, Pittsburgh, PA, March 31 – April 4.

Eisenstein E.L., L.K. Shaw, K.J. Anstrom, C.L. Nelson, Z. Hakim, V. Hasselblad and D.B. Mark. (2001) Assessing the clinical and economic burden of coronary artery disease: 1986-1998, *Medical Care* **39**(8), 824-835.

Employment Development Department (EDD). (2003) *Occupational Employment Statistics Survey*, Sacramento, CA.

EPA SAB-HEES. (2004) *Advisory on Plans for Health Effects Analysis in the Analytical Plan for EPA's Second Prospective Analysis – Benefits and Costs of the Clean Air Act 1990-2020*, EPA-SAB-Council-ADV-04-002, Washington, D.C.

EPA. (1999) *The Benefits and Costs of the Clean Air Act, 1990-2010*. Prepared for U.S. Congress by U.S. EPA, Office of Air and Radiation/Office of Policy Analysis and Review, Washington, DC. November; EPA report no. EPA-410-R-99-001.

EPA. (2003a) *Children's Health Valuation Handbook*, Washington D.C.

EPA. (2003b) *Benefits and Costs of the Clean Air Act 1990-2020: Revised Analytical Plan for EPA's Second Prospective Analysis*, May, Washington D.C.

EPA. (2004) *Final Regulatory Analysis: Control of Emissions from Nonroad Diesel Engines*, May, Washington D.C.

EPA. (2005) *Clean Air Interstate Rule: Regulatory Impact Analysis*, March, Washington D.C.

EPA-SAB. (2007). *SAB Advisory on EPA's Issues in Valuing Mortality Risk Reduction*, EPA-SAB-08-001. Washington, D.C. Available: http://yosemite.epa.gov/sab/sabproduct.nsf/4128007E7876B8F0852573760058A978/$File/sab-08-001.pdf .

Fruin S.A., M.J. St. Denis, A.M. Winer, S.D. Colome and F.W. Lurmann. (2001) Reductions in human benzene exposure in the California South Coast Air Basin. *Atmospheric Environment* **35**(6), 1069-1077.

Gilliland F.D., K. Berhane, E.B. Rappaport, D.C. Thomas, E. Avol, W.J. Gauderman, S.J. London, H.G. Margolis, R. McConnell, K.T. Islam and J.M. Peters. (2001) The effects of ambient air pollution on school absenteeism due to respiratory illnesses, *Epidemiology* **12**(1), 1-11.

Hall J.V., A.M. Winer, M.T. Kleinman, F.W. Lurmann, V. Brajer and S.D. Colome. (1992) Valuing the health benefits of clean air, *Science* **255**(5046): 812-817.

Hall J.V., Brajer V., Lurmann F.W. (2003) Economic Valuation of Ozone-Related School Absences in the South Coast Air Basin of California. Contemporary Economic Policy Vol. 21(4): 407-417.

Hall J.V., Brajer V., Lurmann F.W. (2007) Measuring the Gains from Improved Air Quality in the San Joaquin Valley. Journal of Environmental Management. doi:10.1016/j.jenvman.2007.05.002 (available at http://dx.doi.org/)

Hall J.V., V. Brajer and F. W. Lurmann. (2003) Economic valuation of ozone-related school absences in the South Coast air basin of California. *Contemporary Economic Policy* **21**(4), 407-417.

Hall J.V., V. Brajer and F. W. Lurmann. (2008) Measuring the Gains From Improved Air Quality in the San Joaquin Valley. *Journal of Environmental Management*, **88**:1003-1115

Ito K. (2003) Associations of particulate matter components with daily mortality and morbidity in Detroit, Michigan, in: *Revised Analyses of Time-Series Studies of Air Pollution and Health*, Special Report, Health Effects Institute, Boston, MA.

Ito K., S.F. De Leon, and M. Lippman. (2005) Associations between ozone and daily mortality: Analysis and meta-analysis, *Epidemiology* **16**(4): 446-457.

Jerrett M., R.T. Burnett, R. Ma, C.A. Pope, D. Krewski, K.B. Newbold, G. Thurston, Y. Shi, N. Finkelstein, E.E. Calle and M.J. Thun. (2005) Spatial analysis of air pollution and mortality in Los Angeles. *Epidemiology* **16**(6), 727-736.

Jones-Lee M.W. (1976) *The Value of Life: an Economic Analysis*, University of Chicago Press, Chicago.

Jones-Lee M.W. (1992) Paternalistic altruism and the value of statistical life*, The Economic Journal* **102**(410), 80-90.

Kochi I., B. Hubbell and R. Kramer. (2006) An empirical Bayes approach to combining and comparing estimates of the value of statistical life for environmental policy analysis. *Environ. Resour. Econ.* **34**(3): 385-406

Krewski D., R. Burnett, M. Goldberg, K. Hoover, J. Siemiatycki, M. Jerrett, M. Abrahamowicz and M. White. (2000) *Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality*, Health Effects Institute, Cambridge, MA.

Krupnick A.J. and M.L. Cropper. (1989) *Valuing Chronic Morbidity Damages: Medical Costs, Labor Market Effects, and Individual Valuation*, Final Report to U.S. EPA, Office of Policy Analysis, Washington D.C.

Laden F., F.E. Schwartz, F.E. Speizer, and D.W. Dockery. (2006) Reduction in fine particulate air pollution and mortality: Extended follow-up of the Harvard six cities study, *American Journal of Respiratory and Critical Care Medicine* **173**: 667-672.

Levy J.I., S. M. Chemerynski and J.A. Sarnat. (2005) Ozone exposure and mortality: An empiric Bayes metaregression analysis, *Epidemiology* **16** (4): 458-468.

Liu J.T., J.K. Hammitt, J.-D. Wang and J.-L. Liu. (2000) Mother's willingness to pay for her own and her child's health: a contingent valuation study in Taiwan, *Health Economics* **9**(4), 319-326.

Loehman E., S. V. Berg, A. A. Arroyo, R. A. Hedinger, J. M. Schwartz, M. E. Shaw, R. W. Fahien, V. H. De, R. P. Fishe, D. E. Rio, W. F. Rossley and A. E. S. Green. (1979) Distributional analysis of regional benefits and cost of air quality control, *Journal of Environmental Economics and Management* **6**(3), 222-243.

Loomis D., M. Castillejos, D.R. Gold, W. McDonnel, V.H. Borja-Arbuto. (1999) Air pollution and infant mortality in Mexico City, *Epidemiology* **10**(2), 118-123.

Lurmann F.W. and M.E. Korc. (1994) User's guide to the regional human exposure (REHEX) model. Draft report prepared for Bay Area Air Quality Management District, San Francisco, CA, by Sonoma Technology, Inc., Santa Rosa, CA, STI-93150-1414-DR, April.

Lurmann F.W. and N. Kumar. (1996) *Symptom-valuation model SYMVAL Version 1.1: User's Guide*, South Coast Air Quality Management District, Diamond Bar, CA, September.

Lurmann F.W., A.M. Winer and S.D. Colome. (1989) Development and application of a new regional human exposure (REHEX) model. In *Proceedings from the U.S. Environmental Protection Agency and Air & Waste Management Association Conference on Total Exposure Assessment Methodology: New Horizons, Las Vegas, NV, November 27-30*, Air & Waste Management Association, Pittsburgh, PA.

Lurmann F.W., J.V. Hall, M. Kleinman, L.R. Chinkin, V. Brajer, D. Meacher, F. Mummery, R.L. Arndt, T.L. Haste-Funk, S.B. Hurwitt and N. Kumar. (1999) *Assessment of the Health Benefits of Improving Air Quality in Houston, Texas*, City of Houston Office of the Mayor, November.

Moolgavkar S.H. (2000) Air pollution and hospital admissions for diseases of the circulatory system in three U.S. metropolitan areas, *Journal of the Air and Waste Management Association* **50**, 1199-1206.

Moolgavkar S.H. (2003) Air pollution and daily deaths and hospital admissions in Los Angeles and Cook Counties. In *Revised Analyses of Time-Series Studies of Air Pollution and Health*, Special Report, Health Effects Institute, Boston, MA.

Moolgavkar S.H., E.G. Luebeck and E.L. Anderson. (1997) Air pollution and hospital admissions for respiratory causes in Minneapolis St. Paul and Birmingham, *Epidemiology* **8**(4), 364-370.

Moore, K., Neugebauer, R., Lurmann, F., Hall, J., Brajer V., Alcorn, S., Tager, I. (2008) Ambient Ozone Concentrations Cause Increased Hospitalizations for Asthma in Children An 18-Year Study in Southern California. Environ Health Perspect. doi:10.1289/ehp.10497 (available at http://dx.doi.org/)

Mrozek J.R. and L.O. Taylor. (2002) What determines the value of life? A meta-analysis. *J. Policy Anal. Manage*. **21**(2): 253-270.

Nation Research Council (NRC). (2008) *Estimating Mortality Risk Reduction and Economic Benefits from Controlling Ozone Air Pollution*, National Academies Press, Washington D.C.

Norris G., S.N. YoungPong, J.Q. Koenig, T.V. Larson, L. Sheppard and J.W. Stout. (1999) An association between fine particles and asthma emergency department visits for children in Seattle, *Environmental Health Perspectives* **107**(6), 489-493.

Office of Statewide Health Planning and Development (OSHPD). (2003) *Inpatient Hospital Discharge Frequencies for California*, California Health and Human Services Agency, Sacramento, CA.

Ostro B.D. (1987) Air pollution and morbidity revisited: a specification test, *Journal of Environmental Economics and Management* **14**(11), 87-98.

Ostro B.D. and S. Rothschild. (1989) Air pollution and acute respiratory morbidity: an observational study of multiple pollutants, *Environmental Research* **50**(2), 238-247.

Pereira L.A.A., D. Loomis, G.M.S. Conceicao, A.L.F. Braga, R.M. Arcas, H.S. Kishi, R.M. Singer, G.M. Bohm and P.H.N. Saldiva. (1998) Association between air pollution and intrauterine mortality in Sao Paulo, Brazil, *Environmental Health Perspectives* **106**(6), 325-329.

Peters A., D.W. Dockery, J.E. Muller and M.A. Mittleman. (2001) *Circulation* **103**(23): 2810-2815.

Pope C.A., D.W. Dockery, J.D. Spengler and M.E. Raizenne. (1991) Respiratory health and PM10 pollution—a daily time series analysis, *American Review of Respiratory Disease* **144**(3), 668-674.

Pope C.A., M.J. Thun, M.M. Namboodiri, D.W. Dockery, J.S. Evans, F.E. Speizer and C.W. Heath. (1995) Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults, *American Journal of Respiratory Critical Care Medicine* **151**(3), 669-674.

Pope C.A., R.T. Burnett, M.J. Thun, E.E. Calle, D. Krewski, K. Ito and G.D. Thurston. (2002) Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution, *Journal of the American Medical Association* **287**(9), 1132-1141.

Roman H.A., K.D. Walker, T.L. Walsh, L. Conner, H.M. Richmond, B.Y. Hubbell and P.L. Kinney. (2008) Expert judgment assessment of the mortality impact of changes in ambient fine particulate matter in the U.S., *Environmental Science and Technology* **42**(7): 2268-2274.

Rosamond W., G. Broda, E. Kawalec, S. Rywik, A. Pajak, L. Cooper and L. Chambless. (1999) Comparison of medical care and survival of hospitalized patients with acute myocardial infarction in Poland and the United States, *American Journal of Cardiology* **83**, 1180-1185.

Rowe R.D. and L.G. Chestnut. (1986) *Oxidants and Asthmatics in Los Angeles: A Benefits Assessment,* Report to the U.S. EPA, Office of Policy Analysis, EPA-230-09-86-018, Washington, D.C.

Russell M.W., D.M. Huse, S. Drowns, E.C. Hamel and S.C. Hartz. (1998) Direct medical costs of coronary artery disease in the United States, *American Journal of Cardiology* **81**(9), 1110-1115.

San Joaquin Valley Air Pollution Control District (SJVAPCD). (2005) State implementation plans for federal 8-hr ozone and $PM_{2.5}$ standards for the San Joaquin Valley, Public meeting presentation, San Joaquin Valley Unified Air Pollution Control District, Fresno, CA, January 4.

SCAQMD (2007a). Final Socioeconomic Report for the 2007 Air Quality Management Plan, South Coast Air Quality Management District, Diamond Bar, CA.

SCAQMD (2007b). 2007 Air Quality Management Plan, South Coast Air Quality Management District, Diamond Bar, CA.

Schwartz J. (1994a) Air pollution and hospital admissions for the elderly in Detroit, Michigan, *American Journal of Respiratory and Critical Care Medicine* **150**(3), 648-655.

Schwartz J. (1994b) PM(10), ozone and hospital admissions for the elderly in Minneapolis St. Paul, Minnesota, *Archives of Environmental Health* **49**(5), 366-374.

Schwartz J. (1995) Short term fluctuations in air pollution and hospital admissions of the elderly for respiratory disease, *Thorax* **50**(5), 531-538.

Schwartz J. and L.M. Neas (2000) Fine particles are more strongly associated than coarse particles with acute respiratory health effects in schoolchildren, *Epidemiology* **11**(1), 6-10.

Schwartz J., D.W. Dockery, L.M. Neas, D. Wypij, J.H. Ware, J.D. Spengler, P. Koutrakis, F.E. Speizer and B.G. Ferris, Jr. (1994) Acute effects of summer air pollution on respiratory symptom reporting in children, *American Journal of Respiratory Critical Care Medicine* **150**(5), 1234-1242.

SJVAPCD (2007). 2007 Ozone Plan, San Joaquin Valley Air Pollution Control District, Fresno, CA.

SJVAPCD (2008). 2008 $PM_{2.5}$ Plan, San Joaquin Valley Air Pollution Control District, Fresno, CA.

Smith D.H., D.C. Malone, K.A. Lawson, L.J. Okamoto, C. Battista and W.B. Saunders. (1997). A national estimate of the economic costs of asthma, *American Journal of Respiratory and Critical Care Medicine* **156**(3), 787-793.

South Coast Air Quality Management District (SCAQMD). (2007) *Final Socioeconomic Report for the 2007 AQMD*, June, Diamond Bar, CA.

Sue Liu (2008). Personal communication of the detailed population data used for the SoCAB 2007 Air Quality Management Plan, July 14.

Thurston G.D. and K. Ito. (1999) Epidemiological studies of ozone exposure effects, in: *Air Pollution and Health*, edited by Holgate S.T., J.M. Samet, H.S. Koren and R.L. Maynard, Academic Press, San Diego, CA.

Thurston G.D., K. Ito, C.G. Hayes, D.V. Bates and M. Lippmann. (1994) Respiratory hospital admissions and summertime haze air pollution in Toronto, Ontario: consideration of the role of acid aerosols, *Environmental Research* **65**(2), 271-290.

Tolley G.S. and L. Babcock, et al. (1986) *Valuation of Reductions in Human Health Symptoms and Risks*, Final Report to USEPA, Office of Policy Analysis, Washington, D.C.

U.S. Department of Health and Human Services (USDHHS). (2005) *National Hospital Discharge Survey*, National Center for Health Statistics, Hyattsville, MD.

USBLS http://www.economagic.com/em-cgi/data.exe/blscu/CUUR0400SA0

Viscusi W.K. (1992) *Fatal Tradeoffs: Public and Private Responsibilities for Risk*, Oxford University Press, New York.

Viscusi W.K. (1993) The value of risks to life and health, *Journal of Economic Literature* **31**(4), 1912-1946.

Viscusi W.K. (2004) The value of life: estimates with risks by occupation and industry, *Economic Inquiry* **42**(1), 29-48.

Viscusi W.K. and J. Aldy. (2003) The value of statistical life: a critical review of market estimates throughout the world, *Journal of Risk and Uncertainty* **27**(1), 5-76.

Viscusi W.K., W.A. Magat and J. Huber (1991) Pricing environmental health risks: survey assessments of risk-risk and risk-dollar trade-offs for chronic bronchitis *Journal of Environmental Economics and Management* **21**(1), 32-51.

Wang X., H. Ding, L. Ryan and X. Xu. (1997) Association between air pollution and low birth weight: a community-based study, *Environmental Health Perspectives* **105**(5), 514-520.

Weisel C.P., R.P. Cody and P.J. Lioy. (1995). Relationship between summertime ambient ozone levels and emergency department visits for asthma in central New Jersey, *Environmental Health Perspectives* **103** Suppl(2), 97-102.

Whittemore A.S. and E.L. Korn. (1980). Asthma and air pollution in the Los Angeles area, *American Journal of Public Health* **70**(7), 687-696.

Wilson W.E., D.T. Mage and L.D. Grant. (2000) Estimating separately personal exposure to ambient and nonambient particulate matter for epidemiology and risk assessment: why and how, *Journal of the Air & Waste Management Association* **50**(7), 1167-1183.

Woodruff T.J., J. Grillo and K.C. Schoendorf. (1997) The relationship between selected causes of postneonatal infant mortality and particulate air pollution in the United States, *Environmental Health Perspectives* **105**(6), 608-612.

Zanobetti A., and J. Schwartz. (2008) Mortality displacement in the association of ozone with mortality: An analysis of 48 U.S. cities, *Am. J. Respir. Crit. Care Med.* **177**(2): 184-189.

Appendix A. SENSITIVITY ANALYSIS BY ENDPOINT

The results presented in Section VI report a mid-value for each health effect, based on professional consensus regarding the concentration-response relationships that "best" represent the association between exposure and resulting adverse health effects. It is generally accepted, however, that the real association lies within a range. Here we present the results of sensitivity tests that estimate benefits based on such a range, generally based on 95% confidence intervals obtained from the original health studies. This analysis produces an expected wide range in the results, which are shown in Tables A-1 through A-4.

One noteworthy result is the high estimate for premature mortality, indicating nearly 4,900 deaths per year associated with violations of the NAAQS for $PM_{2.5}$ in the SoCAB and over 1,300 deaths per year in the SJVAB. This contrasts with our base case results of 3,000 and 800 avoided deaths in the SoCAB and SJVAB, respectively. The differences result from the use of the expert elicitation's (Roman et al. 2008) central value for the "base" case and Jerrett et al.'s (2005) result for the high case. As noted in Section IV.1, Jerrett et al. may be a better representation of risk, especially for the SoCAB population, than is the Roman et al. result, a conclusion reached by several peer reviewers who addressed this question recently for ARB (CARB 2005). However, as discussed in section IV.1 and in Deck and Chestnut (2008), the reasons why the Jerrett et al. results indicate a larger association between premature mortality and elevated levels of $PM_{2.5}$ is not yet fully understood.

Table A-1. Ozone-Related Effects Low and High Case Ranges – South Coast Air Basin.

Adverse Effect	All Counties – Range of Effects	All Counties – Range of Value
Respiratory Hospital Admissions All ages	490 – 1,140	$19,510,000 – 45,420,000
Asthma Attacks Asthmatic population all ages	27,730 – 210,960	$1,493,000 – 11,360,000
Emergency Room Visits All ages	210 – 400	$75,770 – 144,300
Days of School Absences Ages 5-17	521,500 – 1,666,000	$49,860,000 – 159,300,000
Minor Restricted Activity Days Ages 18-64	391,200 – 1,517,000	$25,310,000 – 98,150,000
Mortality All ages	30 – 50	$198,800,000 – 351,200,000

Table A-2. $PM_{2.5}$-Related Effects Low and High Case Ranges – South Coast Air Basin.

Adverse Effect	All Counties – Range of Effects	All Counties – Range of Value
Minor Restricted Activity Days Ages 18-64	1,650,00 – 2,376,000	$106,800,000 – 153,700,000
Premature Mortality Ages 30 and older	1,840 – 4,880	$12,190,000,000 – 32,330,000,000
Post Neo-Natal Mortality	6 – 20	$39,760,000 – 132,500,000
Work Loss Days Ages 18-64	337,340 – 458,400	$60,720,000 – 82,520,000
Lower Respiratory Symptoms Ages 5-17	18,410 – 131,700	$396,600 – 2,837,000
Upper Respiratory Symptoms Asthmatic Children	280,200 – 2,858,500	$9,656,000 – 98,500,000
Acute Bronchitis Ages 5-17	4,790 – 19,780	$566,400 – 2,339,000
Chronic Bronchitis Ages 27 and older	810 – 2,350	$326,300 – 946,600
Children's Asthma ER Visits	1,145 – 2,865	$413,100 – 1,034,000
Non-Fatal Myocardial Infarctions (Heart Attacks)	830 – 5,165	$58,180,000 – 362,100,000
Respiratory Hospital Admissions All ages	345 – 850	$12,400,000 – 31,520,000
Cardio Hospital Admissions All ages	740 – 1,150	$30,500,000 – 48,110,000

Table A-3. Ozone-Related Effects Low and High Case Ranges – San Joaquin Valley Air Basin.

Adverse Effect	All Counties – Range of Effects	All Counties – Range of Value
Respiratory Hospital Admissions All ages	100 – 225	$3,672,000 – 8,586,000
Asthma Attacks Asthmatic population all ages	4,660 – 35,650	$247,100 – 1,890,000
Emergency Room Visits All ages	40 – 80	$14,210 – 28,420
Days of School Absences Ages 5-17	71,260 – 227,800	$5,650,000 – 18,070,000
Minor Restricted Activity Days Ages 18-64	62,480 – 243,000	$4,042,000 – 15,720,000
Mortality All ages	6 – 14	$39,360,000 – 92,760,000

Table A-4. $PM_{2.5}$-Related Effects Low and High Case Ranges – San Joaquin Valley Air Basin.

Adverse Effect	All Counties – Range of Effects	All Counties – Range of Value
Minor Restricted Activity Days Ages 18-64	317,900 – 452,800	$20,570,000 – 29,300,000
Premature Mortality Ages 30 and older	500 – 1,320	$3,313,000,000 – 8,746,000,000
Post Neo-Natal Mortality	0 – 5	$ 0 – 33,130,000
Work Loss Days Ages 18-64	58,400 – 78,890	$8,970,000 – 12,120,000
Lower Respiratory Symptoms Ages 5-17	4,440 – 28,820	$94,170 – 611,300
Upper Respiratory Symptoms Asthmatic Children	64,280 – 625,000	$2,181,000 – $21,200,000
Acute Bronchitis Ages 5-17	1,390 – 5,660	$161,800 – 659,000
Chronic Bronchitis Ages 27 and older	185 – 540	$73,370,000 – 214,200,000
Children's Asthma ER Visits	260 – 615	$92,360 – 218,500
Non-Fatal Myocardial Infarctions (Heart Attacks)	160 – 880	$11,220,000 – 61,690,000
Respiratory Hospital Admissions All ages	60 – 175	$2,060,000 – 6,181,000
Cardio Hospital Admissions All ages	140 – 215	$5,540,000 – 8,636,000