



Air Resources Board

State of California

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Governor Arnold Schwarzenegger

**October 2005 Revisions\* to  
Chapters 1-2  
Appendix B  
Reference Lists: (Chapters 1-11, Appendix B, and Appendix G)  
of the March 11, 2005 Staff Report  
Review of the  
California Ambient Air Quality Standard  
for Ozone  
October 27, 2005**

***California Environmental Protection Agency***

**Air Resources Board**

**\*Revisions noted in underline (new text) and strikeout (deleted text).**

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For a list of simple ways you can reduce demand and cut your energy costs, see our Website: <http://www.arb.ca.gov>.*

*California Environmental Protection Agency*

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Alan C. Lloyd, Ph.D., Secretary  
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**Chapter 1**  
**Executive Summary**

**Chapter 2**  
**Overview and Staff Recommendations**

# 1 Executive Summary

The California Health and Safety Code in section 39606, requires the Air Resources Board to adopt ambient air quality standards at levels that adequately protect the health of the public, including infants and children, with an adequate margin of safety. Ambient air quality standards are the legal definition of clean air. In December 2000, as a requirement of the Children's Environmental Health Protection Act (Senate Bill 25, Escutia, Stats. 1999, Health and Safety Code 39606 (d)(1)), the Air Resources Board (ARB or Board), approved a report, "Adequacy of California Ambient Air Quality Standards" (ARB and OEHHA, 2000) that contained a brief review of all of the existing health-based California ambient air quality standards.

Following this review, the standard for ozone, currently set at 0.09 parts per million (ppm) for one hour, was prioritized to undergo full review after review of the standards for particulate matter and sulfates. Staff from ARB and the Office of Environmental Health Hazard Assessment (OEHHA) have reviewed the scientific literature on public exposure, atmospheric chemistry, health effects of exposure to ozone, and welfare effects. This Staff Report or Initial Statement of Reasons (Staff Report) presents the findings of the review and the staff recommendations to revise the ozone standard in order to adequately protect public health. The proposed amendments to the ambient air quality standard for ozone are based on the health effects review contained in Volume III of this Report and the recommendation of OEHHA, as required by Health and Safety Code section 39606(a)(2).

## 1.1 Summary of the Staff Report/Initial Statement of Reasons

### 1.1.1 Health Effects of Ozone

Controlled human exposure studies demonstrate that ~~Scientific studies show that exposure to ozone exposure~~ can result in reduced lung function, increased respiratory symptoms, increased airway hyperreactivity, and increased airway inflammation. Epidemiologic studies indicate that exposure to ozone is also associated with premature death, hospitalization for cardiopulmonary causes, emergency room visits for asthma, and restrictions in activity.

In controlled human exposure studies (see Chapter 9), exercising individuals exposed for 1 hour (hr) to an ozone concentration as low as 0.12 parts per million (ppm) or for 6.6 hours to a concentration as low as 0.08 ppm experienced lung function decrements and symptoms of respiratory irritation such as cough, wheeze, and pain upon deep inhalation. The lowest ozone concentrations at which airway hyperreactivity (an increase in the tendency of the airways to constrict in reaction to exposure to irritants) has been reported are 0.18 ppm ozone following 2-hour exposure in exercising subjects, 0.40 ppm following 2-hour exposure in resting subjects, and 0.08 ppm ozone in subjects exercising for 6.6 hr. Airway inflammation has been reported following 2-hour exposures to 0.20 ppm ozone and following 6.6-hour exposure to 0.08 ppm ozone.

Additional support for the exposure/response relationship for ozone health effects is derived from animal toxicological studies, which have shown that chronic ozone exposure can induce morphological (tissue) changes throughout the respiratory tract, particularly at the junction of the conducting airways and the gas exchange zone in the deep lung. In addition, the magnitude of ozone-induced effects is related to the inhaled dose (ozone concentration times breathing rate times exposure duration). Of these three factors ozone concentration is the most significant in predicting the magnitude of observed effects, followed by ventilation rate. Exposure duration has the least influence of the three factors.

Epidemiological studies (see Chapter 10) have shown positive associations between ozone levels and several health effects, including decreased lung function, respiratory symptoms, hospitalizations for cardiopulmonary causes, emergency room visits for asthma, and premature death. Children may be more affected by ozone than the general population due to effects on the developing lung and to relatively higher exposure than adults. There is little information available on the effects of ozone exposure on infants. Also, asthmatics may represent a sensitive sub-population for ozone. Since most California residents are exposed to levels at or above the current State ozone standard during some parts of the year, the statewide potential for significant health impacts associated with ozone exposure is large and wide-ranging.

### **1.1.2 Summary of Non-health Issues**

The Staff Report contains reviews and discussions of non-health topics to provide a context for the health review and the staff recommendations for the State ozone standard. Almost all of the ozone in California's atmosphere results from reactions between substances emitted from sources including motor vehicles and other mobile sources, power plants, industrial plants, and consumer products. These reactions involve volatile organic compounds (VOC) and oxides of nitrogen ( $\text{NO}_x$ ) in the presence of sunlight (Chapter 3). Ozone is a regional pollutant, as the reactions forming it take place over time, and downwind from the sources of the emissions. As a photochemical pollutant, ozone is formed only during daylight hours under appropriate conditions, but is destroyed throughout the day and night. Thus, ozone concentrations vary depending upon both the time of day and the location. Even in pristine areas there is some ambient ozone that forms from natural emissions that are not controllable (Chapter 4). This is termed "background" ozone. The average "background" ozone concentrations near sea level are in the range of 0.015 to 0.035 ppm, with a maximum of about 0.04 ppm.

The Staff Report includes an overview of statewide ozone precursor emissions that are involved in the formation of ozone (Chapter 5). The Staff Report also includes a discussion of the current ultraviolet photometry monitoring method, and a listing of approved samplers (Chapter 6). Although there are two measurement methods for ozone approved for use in the U.S. by the U.S. Environmental Protection Agency (USEPA), the method based on ultraviolet photometry is almost universally used in practice and is approved for use in California for state air quality standards.

The Staff Report includes a summary of current air quality in California, as well as long-term trends in statewide ozone concentrations (Chapter 7). Ozone is monitored continuously at approximately 175 sites in California. The highest number of exceedance days for both the State and federal 1-hour standards occurred in the San Joaquin Valley Air Basin and the South Coast Air Basin. Both areas had more than 115 State standard exceedance days and 31 or more federal standard exceedance days during each of the three years from 2001 through 2003. The Sacramento Metro Area, Mojave Desert Air Basin, and Salton Sea Air Basin all averaged more than 50 State standard exceedance days and averaged 6 or more federal standard exceedance days during 2001 through 2003. The remaining five areas (Mountain Counties Air Basin, San Diego Air Basin, San Francisco Bay Area Air Basin, South Central Coast Air Basin, and the Upper Sacramento Valley) averaged from 12 to 45 State standard exceedance days. The Upper Sacramento Valley area had no exceedances of the federal standard while the Mountain Counties Air Basin, San Diego Air Basin, San Francisco Bay Area Air Basin, and South Central Coast Air Basin each averaged 1 to 2 federal standard exceedance days for the three-year period.

The range of the measured maximum 1-hour concentrations tends to follow a similar pattern. The South Coast Air Basin showed the highest values, with measured concentrations of 0.169 ppm or higher during 2001 through 2003. The next highest 1-hour ozone concentrations occurred in the Salton Sea Air Basin and San Joaquin Valley Air Basin, which had concentrations of 0.149 ppm or higher during all three years. During 2001 through 2003, neither the State nor federal 1-hour standard was exceeded in the Lake County Air Basin, North Coast Air Basin, or Northeast Plateau Air Basin. Data for four additional areas, Great Basin Valleys Air Basin, Lake Tahoe Air Basin, North Central Coast Air Basin, and the Upper Sacramento Valley show exceedances of the State standard, but not the federal 1-hour standard (as described earlier, representative data for the Northeast Plateau Air Basin and Great Basin Valleys Air Basin are available for 2002 and 2003 only). Both the State and federal 1-hour standards were exceeded during at least two of the three years in all other areas.

Californians' indoor and personal exposures to ozone are largely determined by the outdoor ozone concentrations in their community. Nonetheless, some Californians experience a substantial exposure to ozone indoors, due to the increasing use of certain types of appliances and equipment that emit ozone. Children and those who are employed in outdoor occupations or exercise heavily outdoors, experience substantially greater exposures to ozone than the rest of the population, because they spend time outdoors during peak ozone periods.

A review of welfare effects, including effects of ozone on forest trees, agricultural crops, and materials is also discussed in this report (Chapter 8). Elevated concentrations of ozone can cause adverse effects on agricultural crops, forest trees and materials at current ambient levels, and the proposed health-based ozone standards should also provide protection to crops, forests and materials. In broad terms, impacts to crops are generally more severe than for forest trees owing to their inherently more vigorous rates of growth. Discussed in the

subsection on crops and the methods used to expose plants to ozone. This is followed by an examination of the physiological basis of ozone damage to plants, with special emphasis on carbon metabolism and the resulting impacts on crop growth and yield. Data collected since the 1950s on mixed conifer forests in the San Bernardino Mountains and the Sierra Nevada indicate that increasing numbers of ponderosa and Jeffrey pines exhibit ozone-specific needle damage due to the pollutant's cumulative effects. Also discussed are the impacts of ozone on materials, including building materials, rubber, paint, and fabrics. Although the proposed ozone standards are based on human health effects, progress toward attaining the proposed standards will provide welfare benefits.

## **1.2 Staff Recommendations for the Ozone Standard**

California ambient air quality standards are defined in the Health and Safety Code section 39014, and 17 Cal. Code Regs. section 70101, and comprise four elements: (1) a definition of the air pollutant, (2) an averaging time, (3) a pollutant concentration, and (4) a monitoring method to determine attainment of the standard. The current California ambient air quality standard for ozone is 0.09 ppm averaged over one hour and was set by the Board in 1988. The data indicate that the current standard alone is not sufficiently protective of human health. Based on the review of the scientific literature and recommendations by OEHHA, the staff recommends that the following revisions be made to the California ambient air quality standard for ozone:

1. Ozone will continue to be the pollutant addressed by the standard.
2. Ozone 1-hour-average Standard – retain the current 1-hour-average standard for ozone at **0.09 ppm, not to be exceeded.**
3. Ozone 8-hour-average Standard – establish a new 8-hour-average standard for ozone at **0.070 ppm, not to be exceeded.**
4. Ozone Monitoring Method: retain the current monitoring method for ozone which uses the ultraviolet (UV) photometry method for determining compliance with the State ambient air quality standard for ozone. Incorporate by reference (17 Cal. Code Regs. section 70101) all federally approved UV methods (i.e., samplers) for ozone as "California Approved Samplers". This will result in no change in air monitoring equipment practices, but will align state monitoring requirements with federal requirements.

These recommendations are based on the following findings:

- a. Reduced lung function and increased respiratory or ventilatory symptoms following 1-hour exposure to 0.12 ppm ozone with moderate to heavy exercise.
- b. Increased airway hyperreactivity following 2-hour exposure to 0.18 ppm in exercising subjects.
- c. Airway inflammation following 2-hour exposure to 0.20 ppm ozone in exercising subjects

- d. Reduced lung function, increased respiratory and ventilatory symptoms, increased airway hyperreactivity, and increased airway inflammation following 6.6 to 8-hour exposure to 0.08 ppm ozone.
- e. Evidence from epidemiological studies of several health endpoints at current ambient concentrations of ozone including premature death, hospitalization, respiratory symptoms, and restrictions in activity and lung function.
- f. Evidence from epidemiological studies of emergency room visits for asthma suggesting a possible threshold concentration between 0.075 and 0.11 ppm from analyses based on a 1-hour averaging time, and a possible threshold concentration between 0.070 and 0.10 ppm from analyses based on an 8-hour averaging time.
- g. There is no evidence that children and infants respond to lower ozone concentrations than adults. Their risk is primarily related to their greater ventilation rate and greater exposure duration.
- h. The dose-rate of ozone inhalation influences the magnitude of observed effects.

The staff recommendations for revision of the California ambient air quality standard for ozone are primarily based on controlled human exposure studies. Epidemiologic data contributed to development of the margin of safety.

### **1.3 Other Recommendations**

In light of the adverse health effects observed at current ambient concentrations and the lack of a demonstrated effect threshold for the population as a whole, staff makes the following comments:

1. Fund additional research investigating the responses of human subjects to multi-hour exposures to ozone concentrations between 0.04 and 0.08 ppm.
2. The standards should be revisited within five years, in order to re-evaluate the evidence regarding the health effects associated with ozone exposure.
3. In any air basin in California that currently attains the ambient air quality standards for ozone, air quality should not be degraded from present levels.

### **1.4 Estimated Health Benefits Impacts of Ozone Exposure**

~~Staff estimates that attainment of the proposed ozone standards throughout California would avoid a significant number of adverse health effects each year, specifically:~~

Exposure to ozone at current ambient levels has substantial health impacts, including, but not limited to, death, hospitalization, emergency room visits, and symptoms of respiratory irritation. Staff estimates that the annual health impact

of exposure to ozone at current levels, compared to attainment of the proposed State 8-hour and 1-hour ozone standards throughout California includes:

- 630 (310 – 950 probable range) ~~580 (290 – 870, probable range)~~ premature deaths for all ages.
- 4,200 (2,400 - 5,800, 95% confidence interval (CI)) ~~3,800 (2,200 – 5,400, 95% confidence interval (CI))~~ hospitalizations due to respiratory diseases for all ages.
- 660 (400 – 920, 95% CI) ~~600 (360 – 850, 95% CI)~~ emergency room visits for asthma for children under 18 years of age.
- 4.7 million (1,200,000 – 8,600,000, 95% CI) ~~3.3 million (430,000 – 6,100,000, 95% CI)~~ school absences for children 5 to 17 years of age.
- 3.1 million (1.3 million – 5.0 million, 95% CI) ~~2.8 million (1.2 million – 4.6 million, 95% CI)~~ minor restricted activity days for adults above 18 years of age.

These health impact estimates are based on the results of epidemiologic studies on the health effects of ozone exposure and an exposure reduction methodology modified from analyses conducted by the U.S. EPA and other investigators (see Appendix B). The health impacts estimates were made for only a small number of the known health effects of ozone exposure and, consequently, underestimate the total public health impact. The health impacts assessment was not used to select the appropriate levels of the proposed ozone standards.

For comparison purposes, we also estimated the health impacts of current ozone levels compared to attainment of the federal 8-hour ozone standard of 0.08 ppm, and the health impacts of current ozone levels compared to attainment of the State 1-hour ozone standard alone. Specifically, we estimate that 360 (180 – 550, probable range) premature deaths annually are related to current ozone levels, compared to statewide attainment of the federal 8-hour standard, and about 540 (270 – 810, probable range) premature deaths annually are related to current ozone levels, compared to statewide attainment of the State 1-hour standard. Results for other health endpoints are in Appendix B.

The differences between the results are the “incremental” impacts of not attaining the State 1-hour and 8-hour standards, compared to the federal 8-hour ozone standard. However, it is more reasonable to consider attainment of the two State standards together, compared to current ozone levels, since it is unlikely that control strategies will be geared to first attain one standard and then the other. Nonetheless, the current impact of not attaining the federal 8-hour standard is about 360 premature deaths annually, with an additional 270 deaths associated with not attaining the proposed State 8-hour standard, making the total estimated impact of not attaining both standards 630 deaths. Similarly, the current impact of not attaining the State 1-hour standard is about 540 premature deaths annually, with an additional 90 deaths associated with not attaining the proposed 8-hour standard, making the total estimated impact of not attaining both the State 1-hour and 8-hour ozone standards 630 premature deaths. More detailed discussion of this analysis is available in Appendix B.

As discussed in Appendix B, there are a several important assumptions and uncertainties in this analysis. Some have to do with study design, statistical methods, and choice of epidemiological studies used to develop the concentration-response (CR) functions used in the analysis. Few studies have investigated the shape of the CR function, or whether there is a population response threshold for health endpoints other than emergency room visits for asthma. Further uncertainty is added by assumptions in the statewide exposure assessment. It should also be noted that since several health effects related to acute exposure, and effects of chronic ozone exposure, are not included in the estimates, the health benefits associated with lowering ozone exposure are likely underestimated.

### **1.5 Public and Peer Review of the Staff Recommendations**

The draft version of this Staff Report was released to the public on June 21, 2004 and presented for review and comment at public workshops during 2004 on July 14 in Sacramento, July 15 in El Monte, July 16 in Fresno, and August 25 in Sacramento.

The draft Staff Report was peer reviewed by the Air Quality Advisory Committee (AQAC). AQAC is a scientific peer review committee, appointed by the University of California, to independently evaluate the scientific basis of staff findings and recommendations in the draft Staff Report for revising the California ambient air quality standard for ozone. The AQAC held a public meeting to discuss its review of the draft Staff Report, comments submitted by the public, and staff responses to those comments. AQAC concluded that the report was well written and researched, and that the proposed revision to the State ozone standard was adequately supported. AQAC findings, public comments, and staff responses can be found in Appendices C-E. Following the meeting of the Air Quality Advisory Committee (AQAC), staff revised the draft Staff Report based on comments received from AQAC and the public.

### **1.6 Environmental and Economic Impacts**

The proposed ambient air quality standards will in and of themselves have no environmental or economic impacts. Standards simply define clean air. Once adopted, local air pollution control or air quality management districts are responsible for the adoption of rules and regulations to control emissions from stationary sources to assure their achievement and maintenance. The ARB is responsible for adoption of emission standards for mobile sources and consumer products. A number of different implementation measures are possible, and each could have its own environmental or economic impact. These impacts must be evaluated when the control measure is proposed. Any environmental or economic impacts associated with the imposition of future measures will be considered if and when specific measures are proposed.

### **1.7 Environmental Justice Considerations**

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption,

implementation, and enforcement of environmental laws, regulations, and policies. The available literature suggests there appears to be no special vulnerability related to race, ethnicity or income level, although there may be higher exposure. Ambient air quality standards define clean air; therefore, all of California's communities will benefit from the proposed health-based standards.

## **1.8 Comment Period and Board Hearing**

Release of this Staff Report opens the official 45-day public comment period required by the Administrative Procedure Act prior to the public meeting of the Air Resources Board to consider the staff's recommendations. Please direct all comments to either the following postal or electronic mail address:

Clerk of the Board  
Air Resources Board  
1001 "I" Street, 23rd Floor  
Sacramento, California 95814  
[ozone05@listserve.arb.ca.gov](mailto:ozone05@listserve.arb.ca.gov)

To be considered by the Board, written submissions not physically submitted at the hearing must be received at the ARB no later than 12:00 noon, April 27, 2005. Public workshops will be scheduled for April 2005 to present the final staff recommendations and receive public input on the Staff Report. Information on these workshops, as well as summaries of the presentations from past workshops and meetings are available by calling 1-916-445-0753 or at the following ARB website:

<http://www.arb.ca.gov/research/aaqs/ozone-rs/ozone-rs.htm>.

An oral report summarizing the staff recommendations for revising the ozone standard will be presented to the Board at a public hearing scheduled for April 28, 2005.

The staff recommends that the Board adopt the proposed amendments to the ambient air quality standards for ozone as stated above. The proposed amendments and their basis are described in detail in this Staff Report, which contains the findings of ARB and OEHHA staff's full review of the public health, scientific literature, and exposure pattern data for ozone in California. Due to the extensive nature of the literature review and the hundreds of studies reviewed, the Staff Report is divided into four volumes. Volume I contains the Executive Summary, Overview and Staff Recommendations, and Appendix A, the proposed amendments to the California Code of Regulations (amended regulatory text). Volumes II through IV present more detailed discussions of the material that is summarized in Volume I. Volume II includes background material on non-health topics, including chemistry of ozone formation and deposition, ozone precursor sources and emissions, ozone exposure and background levels, measurement methods, and welfare effects of ozone exposure. Volume III contains a summary of ozone health effects and an in-depth discussion of the basis for the staff recommendation. Volume IV includes several appendices, including an analysis of the estimated health benefits associated with attainment of the proposed

standards, summaries of Air Quality Advisory Committee and public comments and staff responses, and supplemental animal toxicologic data.

## **1.9 References**

Air Resources Board and Office of Environmental Health Hazard Assessment (2000). Adequacy of California Ambient Air Quality Standards: Children's Environmental Health Protection Act. Staff Report. Sacramento, CA. Available at <http://www.arb.ca.gov/ch/programs/sb25/airstandards.htm>.

## 2 Overview and Staff Recommendations

Ozone ( $O_3$ ) can damage human cells upon contact, and has been implicated in a variety of adverse health effects. Scientific studies show that exposure to ozone can result in reduced lung function, increased respiratory symptoms, increased airway hyperreactivity, and airway inflammation. Exposure to ozone is also associated with premature death, hospitalization for cardiopulmonary causes, emergency room visits for asthma, and restrictions in activity. Ozone forms in the atmosphere as the result of reactions involving sunlight and two classes of directly emitted precursors. One class of precursors includes nitric oxide (NO) and nitrogen dioxide ( $NO_2$ ), collectively referred to as nitrogen oxides or  $NO_x$ . The other class of precursors includes volatile organic compounds (VOCs, also called reactive organic gases or ROG), such as hydrocarbons. Ozone forms in greater quantities on hot, sunny, calm days. In metropolitan areas of California and areas downwind, ozone concentrations frequently exceed existing health-protective standards in the summertime. The current California ambient air quality standard for ozone is 0.09 ppm for one hour.

The sources of ozone precursor emissions within California have been grouped into three major categories: point sources, which are distinct facilities such as power plants and factories; mobile sources, which includes cars, trucks, and off-road mobile equipment; and area-wide sources, which include agricultural and construction activities, and consumer products. VOCs are emitted from vehicles, factories, fossil fuels combustion, evaporation of paints, and many other sources.  $NO_x$  is emitted from high-temperature combustion processes, such as at power plants or in motor vehicle exhaust.

The concentrations of ozone measured in the air vary both regionally and seasonally throughout California. For example, the Los Angeles area and the San Joaquin Valley experience highest ozone levels in the state. Ozone concentrations are typically higher during the summer months than the winter months.

To help understand which sources contribute to high ozone levels, the ARB has developed and maintains detailed facility and source specific estimates of the overall estimated ozone precursor emissions. Only the precursor gases are estimated. As a complement to emission inventory and routinely collected air quality monitoring data, the ARB conducts atmospheric modeling, using these precursor emission inventories and other appropriate information, to estimate ozone levels.

### 2.1 Setting California Ambient Air Quality Standards

Ambient air quality standards (AAQS) represent the legal definition of clean air. They specify concentrations and durations of exposure to air pollutants that reflect the relationships between the intensities and composition of air pollution and undesirable effects (Health and Safety Code section 39014). The objective of an AAQS is to provide a basis for preventing or abating adverse health or welfare effects of air pollution (17 Cal. Code Regs. section 70101).

Health and Safety Code section 39606(a)(2) authorizes the Air Resources Board (Board) to adopt standards for ambient air quality "in consideration of public health,

safety, and welfare, including, but not limited to, health, illness, irritation to the senses, aesthetic value, interference with visibility, and effects on the economy." Standards represent the highest pollutant concentration for a given averaging time that is estimated to be without adverse effects for most people. Standards are set to ensure that sensitive population sub-groups are protected from exposure to levels of pollutants that may cause adverse health effects. A margin of safety is added to account for possible deficiencies in the data and measuring methodology. Health-based standards are based on the recommendation of the Office of Environmental Health Hazard Health Assessment (OEHHA).

Recent legislation requires that infants and children be given special consideration when ambient air quality standards are adopted. As part of its recommendation to the ARB, the statute requires OEHHA to use current principles, practices, and methods used by public health professionals to assess the following considerations for infants and children:

1. Exposure patterns among infants and children that are likely to result in disproportionately high exposure to ambient air pollutants in comparison to the general population.
2. Special susceptibility of infants and children to ambient air pollutants in comparison to the general population.
3. The effects on infants and children of exposure to ambient air pollutants and other substances that have a common mechanism of toxicity.
4. The interaction of multiple air pollutants on infants and children, including the interaction between criteria air pollutants and toxic air contaminants.

The law also requires that the scientific basis or the scientific portion of the method used to assess these considerations be peer reviewed (Health and Safety Code section 39606(c)). The draft Staff recommendations and their bases, including OEHHA's assessment and recommendation, is peer reviewed by the Air Quality Advisory Committee (AQAC). AQAC is an external peer review committee established in accordance with section 57004 of the Health and Safety Code and appointed by the President of the University of California a University of California. The AQAC meets to independently evaluate the scientific basis of draft recommendations for revising the California ambient air quality standards.

Ambient air quality standards should not be interpreted as permitting, encouraging, or condoning degradation of present air quality that is superior to that stipulated in the standards. Rather, they represent the minimum acceptable air quality. An AAQS adopted by the Board is implemented, achieved, and maintained by numerous rules and regulations that limit pollution from specific sources of ozone precursors. These rules and regulations are primarily, though not exclusively, emission limitations established by the regional and local air pollution control and air quality management districts for stationary sources, and by the Board for vehicular sources and consumer products (see generally, Health and Safety Code sections 39002, 40000, and 40001).

## 2.2 Current California Ambient Air Quality Standard for Ozone

The current California ambient air quality standard for ozone, established in 1988, is 0.09 ppm (180  $\mu\text{g}/\text{m}^3$ ) for a one-hour average. This value is not to be exceeded. This standard was established based on the following most relevant effects, which are listed in the table of standards (17 Cal. Code Regs. section 70200):

a. Short-term exposures:

- (1) Pulmonary function decrements and localized lung edema in humans and animals.
- (2) Risk to public health implied by alterations in pulmonary morphology and host defence in animals.

b. Long-term exposures: Risk to public health implied by altered pulmonary morphology in animals after long-term exposures and pulmonary function decrements in chronically exposed humans.

c. Welfare effects:

- (1) Yield loss in important crops and predicted economic loss to growers and consumers.
- (2) Injury and damage to native plants and potential changes in species diversity and number.
- (3) Damage to rubber and elastomers and to paints, fabric, dyes, pigments, and plastics.

The US EPA has set national ambient air quality standards, as noted in the table below. The federal one-hour standard will be phased out beginning in June 2005. The Federal Clean Air Act gives California authority to set its own ambient air quality standards in consideration of statewide concerns. California has the largest number of exceedances of the Federal 8-hour ozone standard in the United States, supporting California's need to address a significant statewide public health issue.

### Current Ambient Air Quality Standards for Ozone

Averaging Time	California Standard	Federal Standard
1 Hour	0.09 ppm (180 $\mu\text{g}/\text{m}^3$ )	0.12 ppm (235 $\mu\text{g}/\text{m}^3$ )
8 Hour	—	0.08 ppm (157 $\mu\text{g}/\text{m}^3$ )

## 2.3 History of Ozone/Oxidant Standards

The first state oxidant standard was set in December 1959 by the state Department of Public Health (DPH), which had the responsibility for setting air pollution standards before the creation of the ARB. This standard was set at 0.15 ppm, averaged for one hour. The standard was for oxidant, rather than ozone, because the monitoring method available at that time, the potassium iodide (KI) method, measured all ambient oxidant

gases, including ozone and other oxidants such as peroxyacetyl nitrate (PAN) nitrogen dioxide, photochemical aerosols, and other unknown oxidants.

In 1969, the newly-created ARB reviewed the oxidant standard set by DPH and revised the standard to a concentration of 0.10 ppm, averaged over one hour, not to be equaled or exceeded. The information considered by the Board in 1969 included adverse effects upon: (1) the health of humans and animals; (2) vegetation; (3) materials; and (4) visibility. Eye irritation was listed as the most relevant effect of oxidant.

In 1974, the Board introduced ultraviolet photometry as the monitoring method for the standard. However, since ultraviolet photometry measures only ozone, the Board changed the designation of the standard from “oxidant” to “oxidant (as ozone).” Because only ozone was to be measured, the Board changed the most relevant effect from: “eye irritation” (which is caused primarily by peroxyacyl nitrates or PANs) to “aggravation of respiratory disease” (which is caused primarily by ozone).

In 1988, the Board changed the designation of the standard from “oxidant (as ozone)” to “ozone”, and revised the standard to a concentration of 0.09 ppm, averaged over one hour, to reflect that the listed relevant effects were related to ozone exposure, rather than to oxidants in general.

For comparison, in 2000, the World Health Organization established a guideline value for ozone in ambient air of 120  $\mu\text{g}/\text{m}^3$  (0.061 ppm) for a maximum period of 8 hours per day (WHO 2000).

## **2.4 Review of the California Ambient Air Quality Standards**

The Children's Environmental Health Protection Act (Senate Bill 25, Escutia, Stats. 1999, ch. 731) required the ARB, in consultation with the OEHHA, to evaluate all health-based standards by December 31, 2000, to determine whether the standards were adequately protective of the health of the public, including infants and children (Health and Safety Code section 39606 (d)). At its December 7, 2000 meeting, the Board approved a report, “Adequacy of California Ambient Air Quality Standards: Children's Environmental Health Protection Act” (ARB, et al., 2000), prepared by ARB and OEHHA staffs. The Adequacy Report concluded that health effects may occur in infants and children and other potentially susceptible subgroups exposed to ozone at or near levels corresponding to the current standard. The report identified the standard for ozone as having the second highest priority for further detailed review and possible revision. The standard for PM10 (including sulfates) had the highest priority and was reviewed and revised in 2002, including establishment of a new standard for PM2.5.

## **2.5 Findings of the Standard Review**

### **2.5.1 Chemistry and Physics**

Most of the ozone in California's air results from reactions between substances emitted from sources including motor vehicles, power plants, industrial plants, consumer products, and vegetation. These reactions involve volatile organic compounds (VOCs, which the ARB also refers to as reactive organic gases or ROG) and oxides of nitrogen ( $\text{NO}_x$ ) in the presence of sunlight. Ozone is a regional pollutant, as the reactions forming it take place over time, and downwind from the precursor sources. As a

photochemical pollutant, ozone is formed only during daylight hours under appropriate conditions, but is destroyed throughout the day and night. Thus, ozone concentrations vary depending upon both the time of day and the location. Ozone concentrations are higher on hot, sunny, calm days. In metropolitan and downwind areas of California, ozone concentrations frequently exceed regulatory standards during the summer.

### **2.5.2 Ozone Background**

Even in pristine areas there is some ambient ozone that forms from natural emissions that are not controllable. This is termed “background” ozone. Overall, it appears that “background” ozone in California is dominated by natural tropospheric and stratospheric processes. The effects of occasional very large biomass fires and anthropogenic emissions are secondary factors. The foregoing discussion indicates that average “natural background” ozone near sea level is in the range of 0.015 to 0.035 ppm, with a maximum of about 0.04 ppm. Exogenous enhancements to “natural” levels generally are small (about 0.005 ppm), and are unlikely to alter peak concentrations.

At altitudes above 2 km stratospheric intrusions can push peak ambient concentrations to 0.045 to 0.050 ppm. The timing, spatial extent, and chemical characteristics of stratospheric air mass intrusions makes these events recognizable in air quality records, providing that the affected region has a fairly extensive monitoring network and that multiple air quality parameters (CO, VOC, PM, RH) are being measured as well.

Intermittent episodes of “natural” ozone from very large biomass fires in boreal forests (Alaska, Canada, Siberia) can produce short-lived pulses of ozone up to 0.020 ppm that may arrive during the North American ozone season. Present understanding suggests that these are infrequent events at latitudes below about 50N. There are no data documenting such an event in California. Long range transport of anthropogenic ozone may grow as Asian energy consumption increases the continent’s NO<sub>x</sub> emissions. Model studies indicate that the Asian ozone increment in North America could double over the next few decades. Assuming the temporal pattern of transport remains unchanged, such an impact could increase mean ozone concentrations by 0.002 to 0.006 ppm. The potential effect on peak transport events is unknown at this time.

### **2.5.3 Ozone Precursor Emissions**

Ozone is an oxidant gas that forms photochemically in the atmosphere when nitrogen oxides (NO<sub>x</sub>) and reactive organic gases (ROG) are present under appropriate atmospheric conditions (see Chapter 5). Carbon monoxide (CO) is also an ozone precursor. Both ROG and NO<sub>x</sub> are emitted from mobile sources, point sources, and area-wide sources. ROG emissions from anthropogenic sources result primarily from incomplete fuel combustion, and from the evaporation of solvents and fuels, while NO<sub>x</sub> and CO emissions result almost entirely from combustion processes.

### **2.5.4 Monitoring Method**

Two measurement methods for ozone are approved for use in the U.S. by the USEPA: one is based on the chemiluminescence that occurs when ozone and ethylene react, and the other on the attenuation of ultraviolet (UV) radiation by ozone. The method based on UV spectrometry is almost universally used in practice. Specifications and criteria for both methods exist in federal regulation. The UV photometry-based method

is approved for use in California for state air quality standards. Both state and federal requirements are applied directly by the ARB and the air districts in the ozone monitoring network in California.

### **2.5.5 Exposure**

During 2001 through 2003, neither the State nor federal 1-hour standard was exceeded in the Lake County Air Basin, North Coast Air Basin, or Northeast Plateau Air Basin. Data for four additional areas, Great Basin Valleys Air Basin, Lake Tahoe Air Basin, North Central Coast Air Basin, and the Upper Sacramento Valley show exceedances of the State standard, but not the federal 1-hour standard (as described earlier, representative data for the Northeast Plateau Air Basin and Great Basin Valleys Air Basin are available for 2002 and 2003 only). Both the State and federal 1-hour standards were exceeded during at least two of the three years in all other areas.

The highest 8-hour average values were found in the South Coast Air Basin and San Joaquin Valley Air Basin. Maximum 8-hour concentrations in the South Coast Air Basin ranged from 0.144 ppm to 0.153 ppm during 2001 through 2003, while maximum 8-hour concentrations in the San Joaquin Valley ranged from 0.120 ppm to 0.132 ppm during the same three-year period. Three other areas, the Mojave Desert Air Basin, the Sacramento Metro Area, and the Salton Sea Air Basin also had a maximum 8-hour concentration above 0.120 ppm during at least one of the three years.

With respect to the federal 8-hour ozone standard, Lake County Air Basin and North Coast Air Basin showed no exceedance days during 2001 through 2003. One area, the Lake Tahoe Air Basin, averaged only one exceedance day for the three-year period, while the North Central Coast Air Basin averaged three 8-hour exceedance days. In contrast, the San Joaquin Valley Air Basin showed the highest average number of exceedance days (123), followed by the South Coast Air Basin (99). The Sacramento Metro Area, Mojave Desert Air Basin, Mountain Counties Air Basin, and Salton Sea Air Basin each averaged between 42 and 68 exceedance days during 2001 through 2003. The remaining four areas averaged between 7 and 25 federal 8-hour exceedance days during the three-year period.

Californians' indoor and personal exposures to ozone are largely determined by the outdoor ozone concentrations in their community. Nonetheless, some Californians experience a substantial exposure to ozone indoors, due to the increasing use of certain types of appliances and equipment that emit ozone. Others, such as many children and those who are employed in outdoor occupations, may experience substantially greater exposures to ozone than the rest of the population, because they spend time outdoors during peak ozone periods.

### **2.5.6 Welfare Effects**

A review of welfare effects, including effects of ozone on forest trees, agricultural crops, and materials is also discussed in this report (Chapter 8). Elevated concentrations of ozone can cause adverse effects on agricultural crops, forest trees and materials at current ambient levels, and the proposed health-based ozone standards should also provide protection to crops, forests and materials. In broad terms, impacts to crops are generally more severe than for forest trees owing to their inherently more vigorous rates

of growth. Discussed in the subsection on crops and the methods used to expose plants to ozone. This is followed by an examination of the physiological basis of ozone damage to plants, with special emphasis on carbon metabolism and the resulting impacts on crop growth and yield. Data collected since the 1950s on mixed conifer forests in the San Bernardino Mountains and the Sierra Nevada indicate that increasing numbers of ponderosa and Jeffrey pines exhibit ozone-specific needle damage due to the pollutant's cumulative effects. Also discussed are the impacts of ozone on materials, including building materials, rubber, paint, and fabrics. Although the proposed ozone standards are based on human health effects, progress toward attaining the proposed standards will provide welfare benefits.

### **2.5.7 Health Effects**

Review of the controlled human exposure, animal toxicology and epidemiologic literature led to the following conclusions as to the health effects of ozone exposure:

1. The lowest ozone concentration at which reduced lung function and increased respiratory and ventilatory symptoms have been observed following 1-hour exposure is 0.12 ppm with moderate to heavy exercise.
2. The lowest ozone concentration at which increased airway hyperreactivity following 2-hour exposure has been reported is 0.18 ppm in exercising subjects.
3. The lowest ozone concentration at which airway inflammation following 2-hour exposure has been reported is 0.20 ppm ozone in exercising subjects
4. Reduced lung function, increased respiratory and ventilatory symptoms, increased airway hyperreactivity, and increased airway inflammation have been reported following 6.6- to 8-hour exposure to 0.08 ppm ozone.
5. Evidence from epidemiological studies of several health endpoints including premature death, hospitalization, respiratory symptoms, and restrictions in activity and lung function.
6. Evidence from epidemiological studies of emergency room visits for asthma suggests a possible threshold concentration between 0.075 and 0.11 ppm from analyses based on a 1-hour averaging time, and a possible threshold concentration between 0.070 and 0.10 ppm from analyses based on an 8-hour averaging time.
7. There is no evidence that children and infants respond to lower ozone concentrations than adults. Their risk is primarily related to their greater ventilation rate and greater exposure duration.
8. The dose-rate of ozone inhalation influences the magnitude of observed effects.

## **2.6 Summary of Recommendations**

Following a detailed review of the scientific literature on the health and welfare effects of ozone, staff is proposing to revise the ambient air quality standard for ozone. The recommended ozone standards are based on scientific information about the health impacts associated with ozone exposure, recognizing the uncertainties in these data. The definition of California ambient air quality standards assumes a threshold below which effects do not occur. However, the extremely wide range of individual

responsiveness to ozone makes identification of a threshold on a population level somewhat problematic. In addition, the Children's Environmental Health Protection Act [Senate Bill 25, Escutia; Stats. 1999, Ch. 731, H&SC section 39606(d)(2)] requires a standard that "adequately protects the health of the public, including infants and children, with an adequate margin of safety." Recognizing the uncertainties in the database, staff makes the following recommendations.

1. Ozone will continue to be the pollutant addressed by the standard.
2. One-hour ambient air quality standard: staff recommends retaining the current 1-hour ozone standard at a concentration of **0.09 ppm**, not to be exceeded, based on several factors. First, at 0.12 ppm, in several studies 10 - 25% of the subjects experienced a decline of 10% or more in FEV1. In one study, these lung function changes were accompanied by increases in cough. At 0.24 ppm, increases were also observed in shortness of breath and pain on deep breath. These lung function and symptom outcomes have been demonstrated and replicated in several carefully controlled human exposure studies. The population at risk for these effects includes children and adults engaged in active outdoor exercise and workers engaged in physical labor outdoors. Thus, a margin of safety is necessary to account for variability in human responses. In addition, the chamber studies, by design, do not include potentially vulnerable populations (e.g., people with moderate to severe asthma, Chronic Obstructive Pulmonary Disease or COPD, and heart disease) who may be incorporated in the epidemiologic studies.

Second, chamber studies indicate that bronchial responsiveness and pulmonary inflammation occur with 1-hour exposure to 0.18 to 0.20 ppm. Bronchial responsiveness can aggravate pre-existing chronic respiratory disease. The ultimate impact of the inflammatory response is unclear but repeated exposures to high ozone levels may result in restructuring of the airways, fibrosis, and possibly permanent respiratory injury. These latter outcomes are supported by animal toxicology studies, which also suggest the possibility of decreases in lung defense mechanisms.

Third, epidemiological studies completed over the last 10 years indicate the potential for severe adverse health outcomes including premature death, hospitalizations, and emergency room visits. These studies include concentrations to which the public is currently being exposed. It is possible that some of these associations are due to relatively short-term exposures, for example less than two hours, since people at risk of experiencing these endpoints are unlikely to be engaged in multi-hour periods of moderate or heavy work or exercise outdoors. However, since there is high temporal correlation between 1-, 8-, and 24-hour average ozone concentrations, the averaging time of concern cannot be discerned from these studies.

Viewing all of the evidence, staff recommends retention of the 1-hour standard of 0.09 ppm, not to be exceeded, as being protective of public health with an adequate margin of safety.

3. Eight-hour ambient air quality standard: We recommend establishing a new 8-hour average standard of **0.070 ppm**, not to be exceeded. Our recommendation for the 8-hour standard is based primarily on the chamber studies that have been conducted

over the last 15 years, supported by the important health outcomes reported in many of the epidemiologic studies. With exposure for 6.6 to 8-hours to an ozone concentration of 0.08 ppm, several studies have reported statistically significant group effects on lung function changes, ventilatory and respiratory symptoms, airway hyperresponsiveness, and airway inflammation in healthy, exercising individuals. A substantial fraction of subjects in these studies exhibited particularly marked responses in lung function and symptoms. Consequently, a concentration of 0.08 ppm ozone for an 8-hour averaging time can not be considered adequately protective of public health, and does not include any margin of safety, based on the definitions put forth in State law. The one published multi-hour study investigating a concentration below 0.08 ppm showed no statistically significant group mean decrement in lung function or symptoms at 0.04 ppm compared to a baseline of clear air. In addition, all individual subjects had changes in FEV1 of less than 10%. One unpublished multi-hour study at 0.06 ppm (Adams 1998) reported no statistically significant group mean changes, relative to clean air, in either lung function or symptoms including pain on deep inhalation and total symptom score. Therefore, staff has recommended an 8-hour concentration of 0.070 ppm. Many of the studies, and issues and concerns associated with the epidemiological studies listed above concerning the 1-hour standard are also relevant to the 8-hour standard. As discussed above, it may be that the health effects, often correlated with 1-hour exposures in the epidemiologic studies, are actually associated with 8-hour (or other) average exposures. Therefore, these epidemiologic findings were factored into the margin of safety for the 8-hour average.

It should be noted that the recommended 8-hour average concentration has three rather than two decimal places. Staff initially considered selection of 0.07 ppm. However, rounding conventions applied to air quality data (see Section 7.1.4) are such that any measured value up to and including 0.074 ppm would round down to 0.07 ppm. The available data suggested that selection of 0.07 ppm would not include an adequate margin of safety, as required by State law. The one available study at 0.06 ppm did not find a group mean effect. Staff is recommending that the 8 hour average standard have three decimal places, 0.070 ppm, to ensure an adequate margin of safety. Section 6.3 discusses issues related to precision and accuracy of the monitored data.

4. Monitoring method for ozone: Staff recommends retention of the current monitoring method for ozone which uses the ultraviolet (UV) absorption method for determining compliance with the state Ambient Air Quality Standard for ozone. Incorporate by reference all federally approved UV methods for ozone as California Approved Samplers for ozone. This will not change current air monitoring practices, but will align state monitoring requirements with federal requirements.

### **2.6.1 Consideration of Infants and Children**

The Children's Environmental Health Protection Act [Health and Safety Code section 39606 (b)] requires that air pollution effects on children and infants be specifically considered in selection of ambient air quality standards. Children have a higher ventilation rate relative to body weight at rest and during activity than adults. Children also tend to spend more time outside and be more active than adults. Consequently,

virtue of their higher ventilation rates and outdoor behavior patterns, they are likely to inhale larger total doses of ozone than the general population. However, the chamber studies of exercising children suggest that they have responses generally similar to adults, pointing to a similar degree of responsiveness. Epidemiologic studies that have examined both children and adults do not show clear evidence for greater sensitivity in children. Studies in animals at high exposure concentrations (0.5 ppm and higher, 8 hrs/day for several consecutive days) indicate that developing lungs of infant animals are adversely affected by ozone. The recommended standards are well below that level of exposure. Two studies have shown evidence of lower lung function in young adults raised in high ozone areas (Kunzli et al. 1997; Galizia and Kinney 1999). The study by Kunzli et al. (1997) suggested that exposure to ozone prior to age 6 was associated with lower attained lung function. Examination of data for the Los Angeles basin from the early 1980s, show summer averages of the 1-hour maximum to be above 0.10 ppm. This is considerably above present levels and above the recommended 1-hour standard. There is also evidence that children who play three or more sports are at higher risk of developing asthma if they also live in high ozone communities in Southern California. This study needs to be repeated before the effect can be attributed to ozone exposure with greater certainty, but the finding is of concern. The warm season daily 8-hour maximum concentrations of ozone measured in these high ozone areas, over the four years of study, was 0.084 ppm. The proposed 8-hour standard of 0.070 ppm, therefore, should protect most children from asthma induction that may be associated with ozone exposure. Collectively, this body of evidence suggests that although children appear to be similarly responsive to a given dose of ozone as adults, they are at greater risk than adults of experiencing adverse responses to ozone by virtue of their higher level of outdoor activity, and consequently greater total exposure.

## **2.7 Estimated Health Impacts Benefits**

Exposure to ozone at current ambient levels has substantial health impacts, including, but not limited to, death, hospitalization, emergency room visits, and symptoms of respiratory irritation. Staff estimates that the annual health impact of exposure to ozone at current levels, compared to attainment of the proposed State 8-hour and 1-hour ozone standards throughout California includes :

~~It is estimated that attainment of the proposed ozone standards throughout California would avoid a significant number of adverse health effects each year, specifically:~~

- 630 (310 – 950, probable range) ~~580 (290 – 870, probable range)~~ premature deaths for all ages.
- 4,200 (2,400 – 5,400, 95% CI) ~~3,800 (2,200 – 5,400, 95% confidence interval (CI))~~ hospitalizations due to respiratory diseases for all ages.
- 660 (400 – 920, 600 (360 – 850, 95% CI) emergency room visits for asthma for children under 18 years of age.
- 4.7 million (1,200,000 – 8,600,000, 3.3 million (430,000 – 6,100,000, 95% CI) school absences for children 5 to 17 years of age.
- 3.1 million (1.3 million – 5.0 million, 2.8 million (1.2 million – 4.6 million, 95% CI) minor restricted activity days for adults above 18 years of age.

These health impact estimates are based on the results of epidemiologic studies on the health effects of ozone exposure and an exposure reduction methodology modified from analyses conducted by the U.S. EPA and other investigators (see Appendix B). The health impacts estimates were made for only a small number of the known health effects of ozone exposure and, consequently, underestimate the total public health impact. The health impacts assessment was not used to select the appropriate levels of the proposed ozone standards.

For comparison purposes, we also estimated the health impacts o current ozone levels compared to attainment of the federal 8-hour ozone standard of 0.08 ppm, and the health impacts of current ozone levels compared to attainment of the State 1-hour ozone standard alone. Specifically, we estimate that 360 (180 – 550, probable range) premature deaths annually are related to current ozone levels, compared to statewide attainment of the federal 8-hour standard, and about 540 (270 – 810, probable range) premature deaths annually are related to current ozone levels, compared to statewide attainment of the State 1-hour standard. Results for other health endpoints are in Appendix B.

The differences between the results are the “incremental” impacts of not attaining the State 1-hour and 8-hour standards, compared to the federal 8-hour ozone standard. However, it is more reasonable to consider attainment of the two State standards together, compared to current ozone levels, since it is unlikely that control strategies will be geared to fist attain one standard and then the other. Nonetheless, the current impact of not attaining the federal 8-hour standard is about 360 premature deaths annually, with an additional 270 deaths associated with not attaining the proposed State 8-hour standard, making the total estimated impact of not attaining both standards 630 deaths. Similarly, the current impact of not attaining the State 1-hour standard is about 540 premature deaths annually, with an additional 90 deaths associated with not attaining the proposed 8-hour standard, making the total estimated impact of not attaining both the State 1-hour and 8-hour ozone standards 630 premature deaths. More detailed discussion of this analysis is available in Appendix B.

As discussed in Appendix B, there are a several important assumptions and uncertainties in this analysis. Some concern the study design, statistical methods, and choice of epidemiological studies used to develop the concentration-response (CR) functions used in the analysis. Few studies have investigated the shape of the CR function, or whether there is a population response threshold for health endpoints other than emergency room visits for asthma. Further uncertainty is added by assumptions in the statewide exposure assessment. It should also be noted that since several health effects related to acute exposure, and effects of chronic ozone exposure, are not included in the estimates noted above, the health benefits associated with lowering ozone exposure are likely underestimated.

## **2.8 Public Outreach and Review**

A draft Staff Report containing staff’s preliminary findings was released to the public on June 21, 2004 titled, “Review of California Ambient Air Quality Standard for Ozone”. Public outreach for the standard review involved dissemination of information through various outlets to include the public in the regulatory process. In an ongoing effort to

include the public in the review of the ozone standard, the ARB and OEHHA integrated outreach into public meetings, workshop presentations, electronic “list serve” notification systems, and various web pages. Notification of release of the Staff Report, the schedule for public meetings and workshops, and invitations to submit comments on the Staff Report were made through the “list serve” notification system. Public workshops on the proposed ozone standard were held on July 14 – 16, 2004 in Sacramento, El Monte, and Fresno. An additional public workshop was held on August 24, 2004 in Sacramento.

Individuals or parties interested in signing up for an electronic e-mail “list serve” notification on the ~~PM~~ozone standards, as well as any air quality-related issue, may self-enroll at the following location: [www.arb.ca.gov/listserv/aaqs/aaqs.htm](http://www.arb.ca.gov/listserv/aaqs/aaqs.htm). Additional information on the standards review process is also available at the ozone standards review schedule website at: [www.arb.ca.gov/research/aaqs/ozone-rs/ozone-rs.htm](http://www.arb.ca.gov/research/aaqs/ozone-rs/ozone-rs.htm).

## **2.9 Air Quality Advisory Committee Review**

The Air Quality Advisory Committee, an external scientific peer review committee that was appointed by the President of the University of California, met January 11 and 12, 2005, in Berkeley, California to review the initial Staff Report and public comments, and to ensure that the scientific basis of the recommendations for the ozone standard are based upon sound scientific knowledge, methods, and practices. The AQAC held a public meeting, which provided time for oral public comments, and discussed their review of the draft Staff Report and the draft recommendations, and provided comments for improving the draft Staff Report. Final findings were received on February 24, 2005.

The AQAC determined that the staff recommendations were well founded on the scientific literature, and voted to endorse them. The Committee made suggestions for minor changes to the draft Staff Report to increase clarity, requested more detailed discussion of several topics, and inclusion of several additional scientific papers. The AQAC findings ~~is~~are included in this Initial Statement of Reasons as Appendix C, in Volume IV.

## **2.10 Environmental and Economic Impacts**

The proposed ambient air quality standards are scientific in nature, and will in and of themselves have no environmental or economic impacts. Standards simply define clean air. Once adopted, local air pollution control or air quality management districts are responsible for the adoption of rules and regulations to control emissions from stationary sources to assure their achievement and maintenance. The Board is responsible for adoption of emission standards for mobile sources. A number of different implementation measures are possible, and each could have its own environmental and/or economic impact. These impacts must be evaluated when the control measure is proposed. Any environmental or economic impacts associated with the imposition of future measures will be considered if and when specific measures are proposed.

## 2.11 Environmental Justice

State law defines environmental justice as the fair treatment of people of all races, cultures, and incomes with respect to the development, adoption, implementation, and enforcement of environmental laws, regulations, and policies (Senate Bill 115, Solis; Stats 1999, Ch. 690; Government Code §65040.12(c)). The Board established a framework for incorporating environmental justice into the ARB's programs consistent with the directives of State law (ARB, 2001). The policies developed apply to all communities in California, but recognize that environmental justice issues have been raised more in the context of low-income and minority communities, which sometimes experience higher exposures to some pollutants as a result of the cumulative impacts of air pollution from multiple mobile, commercial, industrial, areawide, and other sources.

Because ambient air quality standards simply define clean air, all of California's communities will benefit from the proposed health-based standards, as progress is made to attain the standards. Over the past twenty years, the ARB, local air districts, and federal air pollution control programs have made substantial progress towards improving the air quality in California. However, some communities continue to experience higher exposures than others as a result of the cumulative impacts of air pollution from multiple mobile and stationary sources and thus may suffer a disproportionate level of adverse health effects. Since the same ambient air quality standards apply to all regions of the State, these communities will benefit by a wider margin and receive a greater degree of health improvement from the revised standards than less affected communities, as progress is made to attain the standards. Moreover, just as all communities would benefit from new, stricter standards, alternatives to the proposed recommendations, such as not proposing an eight-hour ozone standard, would adversely affect many communities.

While it is possible that residents in environmental justice communities may be particularly sensitive to ozone, only one study investigated whether socioeconomic status (SES) alters responses to ozone exposure, and those results were difficult to explain. Hence, the study did not allow inferences as to whether socioeconomic status impacts on sensitivity to ozone. Moreover, other controlled studies investigating whether gender, ethnicity or environmental factors contribute to the responses to ozone exposure could not convincingly demonstrate a link with responsiveness. Therefore, the database is insufficient to conclude whether differences in ozone susceptibility exist in environmental justice communities. These studies are discussed in more detail in Section 9.6.8.

Once ambient air quality standards are adopted, the ARB and the local air districts will propose emission standards and other control measures designed to result in a reduction of ambient ozone levels. The environmental justice aspects of each proposed control measure will be evaluated in a public forum at this time.

As additional relevant scientific evidence becomes available, the ozone standards will be reviewed again to make certain that the health of the public is protected with an adequate margin of safety.

## 2.12 References

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# **Appendix B**

**Quantifying the Health ~~Benefits of Reducing~~Impacts of Ozone Exposure**

# Appendix B

## Quantifying the Health Benefits of Reducing Impacts of Ozone Exposure

### Quantifying the Health Benefits Impacts of Reducing Ozone Exposure

~~The objectives of this appendix are to quantify the adverse health effects of current ozone levels in California by estimating the health benefits that would accrue from a hypothetical control strategy that achieves the proposed ambient air quality standards for ozone. This health effects assessment is not being used to set the health standards or in any formal cost-benefit analysis. As such, the results from this appendix are provided for public information about the expected benefits of attaining the proposed standards and do not include monetary values.~~

~~There have been several recent published efforts to estimate the health benefits associated with reducing population exposures to ozone (U.S. Environmental Protection Agency 1999; Levy et al. 2000). Numerous epidemiologic studies conducted in the United States and other countries point to the adverse health effects from exposure to ozone. The effects from short-term exposure include, but are not limited to: hospital admissions for respiratory causes, emergency-room visits for asthma, minor restricted activity days, acute respiratory symptoms, exacerbation of asthma, and premature mortality (National Research Council, 2002; U.S. Environmental Protection Agency, 2004). In addition, there is more limited evidence that long-term exposure to ozone may result in new cases of asthma and premature mortality.~~

~~Below we describe the methods, data, results and uncertainties involved with estimating the health benefits of the proposed~~The objective of this appendix is to quantify a subset of adverse health effects attributable to current ozone levels in California to illustrate some of the health impacts of continued ozone exposures. This health impacts assessment was not used to select the appropriate levels of health-based ambient air quality or to perform a cost-benefit analysis. Rather, the results from this assessment provide information to the public on some of the health impacts of current ozone levels. While this section presents the results of our analysis as the impacts of exposure to current levels of ozone, the results can also be viewed as the public health benefits expected to accrue with attainment of the proposed standards.

Specifically, we present results of an analysis of the impacts of the current ozone levels compared to attaining both the proposed State 8-hour standard and the federal 8-hour standard. In addition, we compare the benefits from attaining the proposed State 8-hour standard to the state 1-hour standard.

There have been several recent published efforts to estimate the impacts of ozone on public health, and the health benefits likely to be associated with reducing population exposures to ozone (U.S. Environmental Protection Agency 1999; Levy et al. 2000, Hubbell et al. 2005). This appendix presents a specific analysis of the health impacts of ozone exposure. It describes the methods, data, results and uncertainties involved with estimating the health impacts associated with exposures to current ambient

concentrations of ozone.

The reader should note that health impacts estimates were made for only a small number of known effects of ozone exposure, and consequently this analysis is an underestimate of the total public health impact of current ozone levels.

## **Health Effects Estimation Approach**

Section 812 of the federal Clean Air Act ~~required~~requires the U.S. EPA to periodically conduct an analysis of the health benefits of current federal air pollution regulations, which resulted in a report to the U.S. Congress (U.S. EPA, 1999). These efforts have undergone years of public review and comment as well as full peer review by the U.S. EPA's independent Science Advisory Board and by the National Research Council (2002). We have, therefore, drawn considerably from these prior efforts at the federal level, particularly in the development of concentration-response functions. We have also added new studies ~~published~~ from around the world that have appeared since publication of the most recent U.S. EPA report. ~~The selection~~Selection of the studies and functions ~~to include~~included in our analysis has undergone review by several independent experts on the subject of air pollution and health.

Estimating the health ~~benefits~~impacts associated with ~~reductions in~~current levels of ambient ozone involves four elements:

1. Estimates of the changes in ozone concentrations due to a hypothetical ~~control strategy.~~ ozone reduction control strategy that achieves attainment of a standard.
2. Estimates of the number of people exposed to ozone.
3. Baseline incidence of the adverse health outcomes associated with ozone.
4. Concentration-response (CR) functions that link changes in ozone concentrations with changes in the incidence of adverse health effects. These functions ~~produce~~come from epidemiological studies and are expressed in terms of a beta coefficient, indicating the percent reduction in a given health outcome due to a unit change in ozone.

Health effects results from epidemiological studies are based on various ozone averaging times: 24-hour, 8-hour and 1-hour. As a result, we converted the 8-hour and 24-hour epidemiological results into equivalent values on a 1-hour scale to allow direct comparison of the different studies.

Ultimately, the product of ~~these~~the above four elements generates estimates ~~of the expected number of avoided adverse health outcomes associated with a hypothetical control strategy to reduce current levels of ozone to the proposed standard.~~ that represent the current impact of ozone on public health, compared to attainment of the proposed 8-hour standard, since that is the more stringent of the two standards proposed. Each of these elements is discussed below. Our methods make use of U.S. EPA's ~~development of the Environmental Benefits Mapping and Analysis Program~~

(BenMAP), with modifications where appropriate to reflect the application to California. In addition, we incorporated several recent studies that were not available when the most recent version of BenMAP was California's setting and more recent studies released (Bell et al., 2004; Gryparis et al., 2004). All methods and results presented herein are consistent with those methods used by U.S. EPA in their health benefits assessment (Hubbell et al., 2005). In addition, we have derived substantial material from other previous health impact studies including the U.S. EPA estimates of health benefits of the Clean Air Act (U.S. EPA, 1999), the World Health Organization (WHO) meta-analysis of ozone health effects (Anderson et al. 2004), and the Levy et al. (2001) analysis of the public health benefits of reducing ozone impacts of current ozone concentrations.

## **Exposure Estimation and Assumptions**

The estimation of ozone exposure involves two key elements: assessing changes in ozone concentrations, and estimating the population exposed to these changes in ozone levels.

To assess the changes in the current ozone concentrations necessary to achieve the proposed standards, we first determined the design value, the benchmark used for attainment status. The design value is the Expected Peak Day Concentration, thea value that reflects the highest concentration expected to occur on any given year occur, once per year on average, based on the past three years of air quality monitoring data. The use of three years of data reduces the effect of an anomalous year. Details on how the design values are calculated are presented in Chapter 7. Because the designations of the air quality standards are done mostly generally made at the air basin level, the design value for the basin was used for all counties within the basin.

Monitoring data for 2001 to 2003 were used from all monitors in the State meeting quality assurance criteria for valid data, and were extracted from the ARB ADAM database (ARB, 2004). Chapter 7 provides detailed analyses of exposure to ozone in California.

To calculate changes in exposure to ozone that reflect a hypothetical attainment of the proposed ambient air quality standards, a proportional linear rollback procedure was used. Under real-world conditions, control strategies will likely have some impact on days with low and moderate levels of ozone, as well as on days with high levels. Our rollback procedure reflects this observation. Details on the changes in the distribution of ozone concentrations over time are provided in the Supplement to this appendix.

## Design Value Rollback Method

Rollback factors from the 1-hour and 8-hour ozone design values to the applicable standard were calculated for each air basin to assess the daily reductions in current ozone concentrations estimated to result at all monitoring sites when the standards are achieved. ~~achieved, rollback factors from the 1-hour and 8-hour ozone design values to the applicable standard were calculated for each air basin. The ozone design value selected~~ Rollback factors were based on design values for 2003. The design values reflect measured air quality for three years, 2001 through 2003. The design value was determined for each monitoring site according to the relevant regulatory specifications. For example, the Federal 8-hour design value is the three-year average of the annual 4th highest 8-hour ozone measurements. The design values for the state 1-hour and 8-hour standards are Expected Peak Day Concentrations (the statistically derived value expected to be exceeded once per year, on average – details are in Section 7.1.2 of ~~was the highest for the three-year period (2001 to 2003).~~ Chapter 7). Design values for basins are simply the highest design value at any site within the basin. The basin design values typically determine attainment of each ozone standard. An uncontrollable ozone concentration of 0.04 ppm (see Chapter 4) was factored into the calculation of the rollback factor (see below). This represents the average daily one-hour maximum background ozone concentration. The rollback factor was assumed to apply to each site in the air basin for every day in a given year.

~~This~~ Our methodology assumed that under the hypothetical attainment ~~setting, condition~~ all ozone observations within an air basin were subjected to the same percentage rollback factor based on the basin's three-year high value. To investigate the plausibility of this assumption, we examined the trends in the annual distributions of the 1-hour and 8-hour concentrations of ozone in the South Coast Air Basin (SoCAB). Due to its population and current ozone levels, a significant proportion of current statewide health ~~benefits are projected to accrue~~ impacts occur in the SoCAB. For this region, the estimated downward trend was consistent for both 1-hour and 8-hour concentration reductions from the 1980s to the current levels period. The maximum, the 90th, 80th, 70th, 60th, 50th and 40th percentiles from the annual distribution of the basin's daily high concentrations, as well as the individual site's daily highs, show a consistent downward trend ~~from~~ since the 1980s. More importantly, when we examined the rate of change in the concentrations above background ~~from~~ since the 1980s, it was similar among the percentiles. This analysis justifies supports our application of a constant percentage rollback to all sites within each air basin. Results for several representative sites used in this analysis of ozone trends can be found in the Supplement to this appendix.

## Roll-Back Procedure

For each ~~monitoring site~~ air basin in the State, the rollback factor necessary to move ~~from~~ the basin-high design value to the proposed standard was calculated for both the 1- and

8-hour averages. We assumed that only the portion of each ozone value above a background of 40 ppb will decrease as progress toward attainment takes place. For example, in the table of hypothetical values below (Table B-1), suppose the basin-high design value would need to be reduced by 50% for the portion above 40 ppb to achieve the standard. Thus, an ozone measurement of 100 ppb today would face a reduction of  $(100 - 40) \times 50\% = 30$  ppb. Hence the projected value at attainment would be  $30 \text{ ppb} + 40 \text{ ppb} = 70$  ppb. The effective rollback rate of moving from 100 ppb to 70 ppb is 30%. Similarly, a value close to 40 ppb like 50 ppb would face a reduction of  $(50 - 40) \times 50\% = 5$  ppb. With the projected value at attainment of  $5 \text{ ppb} + 40 \text{ ppb} = 45$  ppb, the effective rollback rate is 10%, calculated from 50 ppb today. In summary, while both measurements in this hypothetical example (100 ppb and 50 ppb) are subject to the same rollback rate of 50%, the effective rollback rate differs due to the rollback procedure taking into account the background of 40 ppb

**Table B-1: Example of Proportional Roll-Back Procedure**

<u>Current ozone</u>		<u>Rollback</u>	<u>Future ozone</u>		<u>Effective</u>
<u>Measured</u>	<u>Above</u>	<u>Rate for Portion</u>	<u>Above</u>	<u>Projected</u>	<u>Rollback</u>
<u>(ppb)</u>	<u>40 ppb</u>	<u>Above 40 ppb</u>	<u>40 ppb</u>		<u>Rate</u>
<u>100</u>	<u>60</u>	<u>50%</u>	<u>30</u>	<u>70</u>	<u>30%</u>
<u>50</u>	<u>10</u>	<u>50%</u>	<u>5</u>	<u>45</u>	<u>10%</u>

For the 1-hour standard, rollback factors based on 1-hour design values were used to project 1-hour observations assuming a scenario where the 1-hour standard of 0.09 ppm was attained. Specifically, the rollback factor for an air basin was:  $(0.094 \text{ ppm} - 0.04 \text{ ppm}) / (1\text{-hour Design Value} - 0.04 \text{ ppm})$ . The concentration of 0.094 was used since this is the highest value considered in attainment (after being rounded to 0.09), based on rounding conventions. This procedure produced basin-specific rollback factors, which were applied to daily maximum 1-hour ozone values at all sites in the applicable basin, considering the background of 0.04 ppm. Basin-specific ratios were used for this purpose since the ratios can be significantly different from one basin to another. For example, in the South Coast Air Basin, the 1-hour design value was 0.178 ppm, so the rollback factor was  $(0.094 - 0.04) / (0.178 - 0.04) = 39\%$ .

For the 8-hour standard, we used basin-specific 1-hour and 8-hour design values to convert the 1-hour data into a form useable for rollback calculations for the 8-hour standard. One-hour ozone concentrations are highly correlated with 8-hour concentrations. Therefore, we calculated the 1-hour value when the 8-hour standard is attained in each air basin and defined this as the “equivalent design value” for the 8-hour standard in that basin. The target for the 8-hour standard (0.070 ppm) was converted to a basin-specific 1-hour equivalent so that the CR functions that were all converted to 1-hour averaging times could be utilized. The conversion was based on the

assumption that the future ratio between 1-hour and 8-hour design values will be similar to its current value. For example, in the South Coast, the 1-hour and 8-hour design values are 0.178 and 0.146 ppm, respectively. To attain the 8-hour standard of 0.070 ppm, the equivalent 1-hour target was projected to be  $0.070 \times (0.178/0.146) = 0.086$  ppm. Therefore, 0.086 is the equivalent 1-hour target for attainment of the proposed State 8-hour standard in the South Coast.

Rollback factors for attainment of the 8-hour standard are calculated as: (Equivalent Target – 0.040 ppm) / (1-hour Design Value – 0.04 ppm). So, for the South Coast Air Basin, the rollback factor was  $(0.086 - 0.04) / (0.178 - 0.040) = 33\%$ .

TheseThe roll-back procedure toward a 0.040 ppm background reflects currently observed rates of change in all parts of the ozone concentration distribution. The rollback factors werethen applied on a site-by-site basis to the ozone readingsfor everymonitoring data for each day. The difference between the observed value and the rolled-back value was calculated for each day of the year in terms of 1-hour maximum ozone (for both standards), thus avoiding the uncertainty associated with converting CR functions into an 8-hour maximum ozone scale.

Similar calculations were made for the federal 8-hour standard. The concentration of 0.084 ppm was used in the rollback since this is the highest value considered in attainment (after being rounded to 0.08), based on rounding conventions.

Health effectsimpacts were then estimated for each day in a given year, summed across sites over the year, and then averaged over the three years of data. We also ensured that no benefitsimpacts would be calculated for any day with an average concentration at or below the assumed background ozone level of 0.04 ppm. For the technical reader, the mathematical formulae for our rollback procedure and evidence forsupporting the rollback assumptions are provided in the Supplement to this appendix.

## Estimation of Exposed Population

To estimate the number of people exposed to the ozone changes observed at each monitoring site, the county population was divided by the number of monitoring sites in a given county. This assumes that the population is equally distributed around each monitoring site within a county. We used county population data from the year 2000 census. For further details, see the Supplement to this appendix. We also examined the sensitivity of this assumption by considering two alternative methods for estimating exposure to ozone: census tract interpolation and county averaging of monitored concentrations. Details of these sensitivity analyses are provided below.

## Estimates of the Baseline Incidence of Adverse Health Outcomes

The health effect baseline incidences are the number of health events per year per unit population. In this analysis, all baseline incidence rates except those for school absenteeism were taken from U.S. EPA's BenMAP software program.

~~For mortality, the~~ Mortality incidence rates were obtained from the U.S. Centers for Disease Control (CDC), as derived from ~~the~~ U.S. death records and the U.S. Census Bureau. Regional hospitalization counts were obtained from the National Center for Health Statistics (NCHS) National Hospital Discharge Survey (NHDS). Per capita hospitalizations were calculated by dividing these counts by the estimated county population estimates derived from the U.S. Census Bureau and the population projections used by NHDS. Hospitalization rates for "all respiratory causes" included ICD-9 codes 460-519. Similarly, regional asthma emergency room visit counts were obtained from the National Ambulatory Medical Care Survey (NHAMCS), combined with population estimates from the 2000 U.S. Census to obtain rates. Illness-related school loss baseline incidence rates were based on Hall et al. (2003). Ostro and Rothschild (1989) provided the estimated rate for minor restricted activity days.

The assumed incidence rates are summarized in Table ~~B-17~~ B-19 in the Supplement to this appendix. All counties and sites within each county were assumed to have the same incidence rate for a given population age group.

## Concentration-Response Functions

Concentration-response (CR) functions are equations developed from epidemiologic studies that relate the change in the number of adverse health effect incidences in a population to a change in pollutant concentration experienced by that population. As reviewed in Chapter 9 (Controlled Exposure 40, Studies) and Chapter 10 (Epidemiologic Studies), a wide range of adverse health effects has been associated with exposure to current ambient concentrations of ozone. However, we only used CR functions derived

from epidemiologic studies in this analysis. Developing concentration-response functions from this vast and not fully consistent literature is a difficult task and ultimately involves subjective evaluations. In this section, we aim to provide a fair and accurate reflection of the current scientific literature. We also aim to provide enough detail so that others may fully evaluate our assumptions and methodology. Below, we provide CR functions for effects of short-term ozone exposure on premature mortality, hospital admissions for respiratory disease, emergency room visits for asthma, school absenteeism, and minor restrictions in activity. Although epidemiologic studies also ~~other effects have been related to~~ report other adverse effects associated with ozone exposure – such as asthma exacerbations, respiratory symptoms, hospital admissions for cardiovascular disease with short-term ozone exposures, and mortality and asthma onset associated with long-term exposure (i.e., several years) – we determined that the existing evidence was either insufficient or too uncertain to serve as a basis for making quantitative ~~CR function~~ impacts estimates. A good example is asthma exacerbations for which several studies have reported associations with ozone. However, different subgroups of asthmatics and different outcome measures were used, making it difficult to develop consensus estimates.

In this appendix, the primary studies used in the health ~~benefit~~ impacts assessment are ~~generally~~ epidemiological. There are a number of reasons for using epidemiological studies. While human chamber studies have the merit of being able to carefully control for dose and response, they usually involve small sample sizes that ~~do~~ may not include the most sensitive subpopulations, and cannot capture severe outcomes like hospitalization or premature death. Lagged or cumulative effects are similarly omitted, and only a limited range of exposures is examined. In short, human chamber studies are helpful to support causality and to determine effects of short-term exposure on measures like lung function ~~in generally healthy individuals, and~~ airways inflammation, but they do not necessarily ~~provide the information on~~ general population responses to exposure to ozone. For the latter purpose, epidemiological studies which incorporate varying subgroups, exposure scenarios, behaviors, and health outcomes will best serve to ~~determine~~ estimate the overall potential human ~~response to a particular pollutant~~ health impact of air pollutants and be the source of CR functions used for quantitative ~~estimates for~~ health impact assessment.

Besides the primary studies, some CR functions were developed from previous estimates of the health impacts of ozone exposures. Sources for these studies include the U.S. EPA estimates of the health effects associated with the Clean Air Act under Section 812 (U.S. EPA, 1999), the World Health Organization (~~WHO~~) meta-analyses on ozone (Anderson et al., 2004), and the Levy et al. (2001) analysis of the public health benefits of reducing ozone.

This section discusses some factors that impact health effect estimates and outlines the epidemiological studies that were used for the basis of the CR functions.

## Conversions for Ozone Measurements of Various Averaging Times

Most health studies considered in our analysis were conducted with ozone levels measured as 1-hour maximum or 8-hour maximum. However, there were some studies that measured ozone averaged over other time increments. Since these studies were conducted throughout the United States and other parts of the world, a national average of adjustment factors were used to convert all measurements to 1-hour and 8-hour averages (Schwartz 1997). The 1-hour maximum was assumed to be 2.5 times the 24-hour average, and 1.33 times the 8-hour average concentration. These conversion factors have been used in previous meta-analyses of the ozone epidemiological literature (Levy et al., 2001; Thurston and Ito 2001). Our examination of California monitoring data for 2001-2003 in the San Francisco Bay Area and South Coast indicates that the ratios in California are similar. To reduce the uncertainty associated with converting the results into both the 1-hour and 8-hour time scales, we converted the epidemiological results into a common 1-hour scale only. Because the majority of studies report findings in term of ppb, CR functions were calculated per ppb, and air quality measurements were converted from ppm to ppb accordingly in the calculation of health effects.

## Thresholds

Assumptions regarding the appropriateness of applying thresholds, and at what level, can have a major effect on health ~~effects~~impacts estimates. One important issue in estimating ~~ozone health effects~~ozone-related health impacts is whether it is valid to apply the CR functions throughout the range of predicted changes in ambient concentrations, even changes occurring at levels approaching the natural background concentration (without any human activity).

As reviewed in Chapter 10, most of the epidemiologic studies include very low ozone concentrations in their analysis and no clear threshold for effects has been reported, although the issue has not been fully investigated except with reference to ER visits for asthma. These latter studies, reviewed in Section 10.2.3 suggest a population threshold in the range of 0.075 to 0.110 ppm for 1-hour exposures, and 0.056 to 0.084 ppm (using a ratio of 1.33) for 8-hour exposures (see pg. 8-14; figure 8-1). In our approach of applying a constant percent change rollback to all of the basin-wide monitors, many of the reductions in ozone concentrations will occur below the proposed standard. Thus, for some days, our estimate of ~~benefits~~impacts of ozone exposure will be based on ozone concentrations that are within the range of the original epidemiologic studies, but below the proposed standards. In our ~~base case~~base-case model, we assumed that there was no effect threshold was in evidence and concentration, and therefore we used the background level of 0.04 ppm as the no effects level. ~~As an alternative for a~~For the sensitivity analysis, we assumed a ~~several~~no effects level at 0.075 ppm levels but adjusted the remaining slope to account for application of a threshold to the concentration-response function. This is described in greater detail below.

## Developing the Concentration-Response Function

Most of the epidemiologic studies used in our estimates have used a log-linear model to ~~represent~~describe the relationship between ozone exposure and the health endpoint. In this case, the relationship between ozone levels and the natural logarithm of the health effect is estimated by a linear regression. This regression model generates a beta coefficient that relates the percent change in the health outcome to a unit ~~increase~~change in ozone. Existing studies have reported either a beta coefficient for a unit change in exposure or a relative risk (RR) for a specified change in ozone concentrations, such as 10 ppb ~~4-hour~~1-hour maximum. The RR is defined as the ratio of the health effect predicted from the higher exposure relative to some baseline exposure. Health effect estimates presented in a given study as RR for a specified change in ozone,  $\Delta O_3$ , were converted into an estimated beta using the equation:

$$\beta = \ln(RR) / \Delta O_3$$

.The daily change in ozone at each monitoring site i.e., the difference between current ozone and the standard (=  $\Delta O_3$ ) was used to calculate RR:

$$RR = \exp(\beta \Delta O_3)$$

Then, the RR estimates were used to determine the population attributable risk (PAR), which represents the proportion of the health effects in the whole population that may be prevented if the cause (ozone pollution in our case) is reduced by a given amount. Specifically,

$$PAR = (RR - 1) / RR$$

Ultimately, the estimated impact on the health outcome is calculated as follows:

$$\Delta y = PAR \times y_0 \times pop$$

where:

$\Delta y$  = changes in the incidence of a health endpoint corresponding to a particular change in ozone,

$y_0$  = baseline incidence rate/person within a defined at-risk subgroup, and

pop = population size of the group exposed.

The parameters in the functions differ depending on the study. For example, some studies considered only members of a particular subgroup of the population, such as individuals 65 and older or children, while other studies considered the entire population in the study location. When using a CR function from an epidemiological study to estimate changes in the incidence of a health endpoint corresponding to a particular change in ozone in a location, it is important to use the appropriate parameters for the CR function. That is, the ozone averaging time, the subgroup studied, and the health endpoint should be the same as, or as close as possible to, those used in the study that

estimated the CR function.

In some cases, results from several studies of the same health endpoint were combined to estimate the health effect. An inverse-variance weighting scheme was used to pool results from these studies, allowing studies with greater statistical power to receive more weight in the pooled assessment. This approach implicitly assumes that all studies are equally valid and representative of the population in question, and is the standard approach applied in many impact analysis settings.

### **Mortality from Short-Term Exposure**

Chapter 10 concludes that there is sufficient evidence for an effect of daily exposure to ozone (possibly with a lag response of a day or two) on premature mortality. These effects are based on daily time-series studies of counts of daily all-cause mortality within a given city reviewed over several years. The studies control for most other factors that may impact daily mortality such as weather, time trends, seasonality, day of week, and other pollutants. In addition, the studies have been undertaken over a wide range of weather conditions, seasonal patterns, covarying pollutants, baseline population characteristics. Chapter 10 reviews the uncertainties inherent in these studies. The U.S. EPA ~~is currently funding~~ has funded several meta-analyses ~~of the ozone-mortality~~ investigating the association but this information is currently not ~~between ozone and mortality, but the results of these analyses are not yet~~ available. Therefore, below we present the effect estimates from the available literature and develop our rationale for a central estimate and probable bounds that reflect the observed range of effect estimates. Figure 1 summarizes the most relevant meta-analytic studies to date. Additional information about these studies is provided in Chapter 10.

The World Health Organization (~~WHO~~) (Anderson et al., 2004) conducted a meta-analysis of the 15 cities in Europe (Anderson et al. 2004). Their meta-estimates indicate a relative risk of 1.003 (95% CI = 1.001 – 1.004) for a 10  $\mu\text{g}/\text{m}^3$  change in 8-hour ozone. For standard pressure (1 atmosphere) and temperature (25° C), 1 ppb ozone equals 1.96  $\mu\text{g}/\text{m}^3$ . We have assumed the ratio between 1-hour and 8-hour ozone of 1.33 and between 1-hour and 24-hour of 2.5 (Schwartz 1997). Making the conversions, the WHO estimate implies a 1.13% change (95% CI = 0.38 - 1.51) in daily mortality per 10 ppb change in ~~24-hour~~ 24-hour average ozone. The WHO also provided an estimate correcting for possible publication bias using a trim and fill technique. Under an assumption that bias was present, the adjusted estimate is 0.75 % (95% CI = 0.19 – 1.32) per 10-ppb change in 24-hour average ozone.

This estimate is very similar to that produced by Levy et al. (2001). In their meta-analysis they began with 50 time-series analyses from 39 published articles. A set of very strict inclusion criteria was applied, which eliminated all but four studies. Reasons for exclusion included: studies outside the US, use of linear temperature terms (versus non-linear and better modeled temperature), lack of quantitative estimates, and failure to include particulate matter (PM) in the regression models. Ultimately, their analysis

generated an estimate of 0.98% (95% CI = 0.59 – 1.38) per 10 ppb change in 24-hour average ozone. If the criteria are loosened to include eleven more studies, the pooled estimate decreases to 0.80 (0.60 – 1.00). Stieb et al. (2002) also reported a similar effect estimate based on 109 previous studies (including those with single- and multi-pollutant models) of 1.12 (0.32 – 1.92). Thurston and Ito (2001) reviewed studies published prior to the year 2000. When the authors focused on seven studies that more carefully specified the effect of a possible confounder, daily temperature, by using non-linear functional forms, the resulting meta-estimate was 1.37% (95% CI = 0.78 – 1.96). Relaxing this constraint to include all 19 available studies, the resulting risk estimate was 0.89% (95% CI = 0.56 – 1.22) per 10-ppb change in 24-hour ozone.

Two more recent meta-analyses have been published that provide lower effect estimates. Gryparis et al. (2004) is an analysis of 23 European cities from the ~~APEHA2~~APEAH2 study. The study controlled for potential confounders by including average daily temperature and humidity, respiratory epidemics, day of week in the regression model. The overall full-year estimate was 0.5% (95% CI = -0.38 – 1.30) per 10-ppb change in 24-hour average ozone. A meta-analysis was also conducted using summer-only data. Presumably this estimate will be less confounded by seasonality and also represent a time when the population would be spending more time outdoors. The summer-only estimate was 1.65% (95% CI = 0.85 – 2.60) per 10-ppb change in 24-hour average ozone. This summer-specific estimate might be particularly relevant for California due to its ~~milder~~ climate. A meta-analysis of the 95 largest U.S. cities from the National Morbidity, Mortality, and Air Pollution Study (NMMAPS) data base provided estimates using a similar natural spline model for every city (Bell et al., 2004). Ultimately, the model suggested an effect estimate of 0.25% (95% CI = 0.12 – 0.39) per 10-ppb change in 24-hour average ozone. The NMMAPS study may generate an underestimate of the impact of mortality due to the modeling methodology used to control weather factors. Specifically, this effort included four different controls for temperature and dewpoint, where most other times-series analyses used only two or modeled extreme weather events more carefully and used city-specific models to ensure the best fits. In comparing the results for particulate matter (PM) for a given city with studies of individual cities by other researchers, the NMMAPS results are usually lower (Samet al ~~et., et al.~~, 2000). This estimate was based on a lag consisting of today's and yesterday's ozone concentrations. When a longer period 7-day lag was used the estimate increased to 0.52% (95% CI = 0.27 – 0.77) per 10-ppb change in 24-hour ozone.

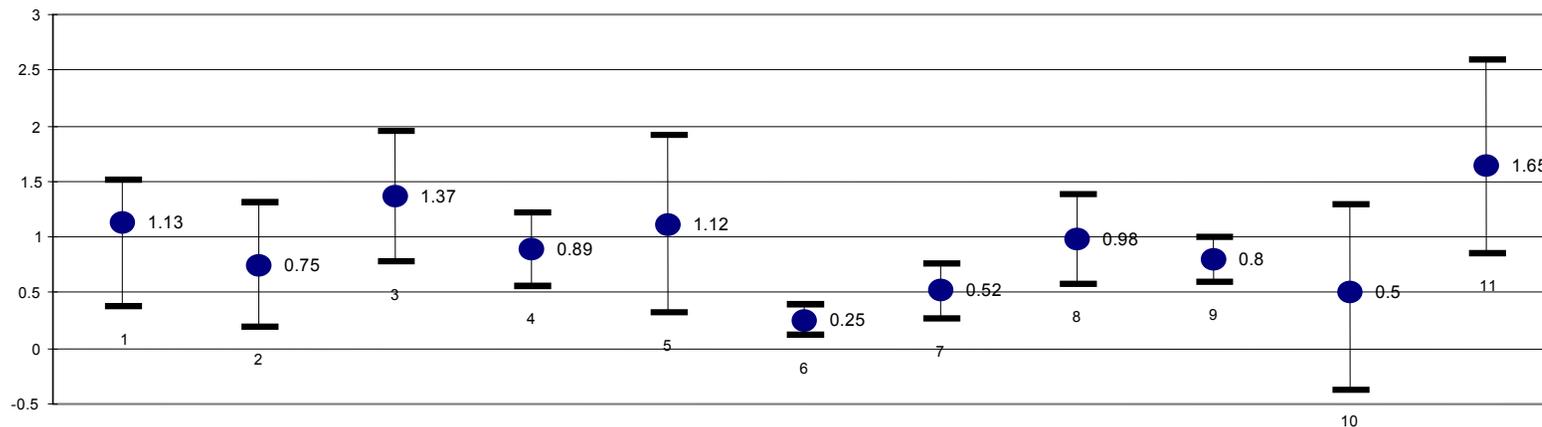
Our estimates for the effects of ozone on mortality ~~attempt to~~ reflect the range provided in the ~~above-cited~~above-cited studies. Table B-2 summarizes the effect estimates reported in these studies. Figure B-1 provides a graphical summary of the range of effect estimates and our suggested central, low and high estimates. A low estimate of 0.5% per 10 ppb, 24-hour average ozone, corresponds to ~~the best~~ estimates from the NMMAPS study (using a one-week cumulative lag) and the ~~APEHA2~~APEAH2 European study, but is below most of the other central estimates. ~~A central estimates~~The central estimate of 1% per 10 ppb is very similar to the central estimate generated by WHO (Anderson et al., 2004), Levy et al. (2001), and Stieb (2003). Finally,

as a high estimate, we use 1.5% per 10 ppb, which reflects the central estimates of Thurston and Ito (using non-linear functions for temperature) and the summer-only estimates of Gryparis et al. (2004). ~~Bates (personal communication, 2005) suggested that these concentration response relationships may be underestimated.~~ Our range of estimates is applied to all age groups.

On the 1-hour scale, a 1% change per 10 ppb of 24-hour ozone is about 0.4% per 10 ppb change in 1-hour daily maximum ozone based on an assumed the ratio between 1-hour and 8-hour ozone of 1.33 and between 1-hour and 24-hour of 2.5 (Schwartz 1997). Specifically,

$$\frac{1\%}{10 \text{ ppb}24\text{hr}} = \frac{1\%}{10 \text{ ppb}24\text{hr}} \times \frac{1 \text{ ppb}24\text{hr}}{2.5 \text{ ppb}1\text{hr}} = \frac{0.40\%}{10 \text{ ppb}1\text{hr}}$$

**Figure B-1: Percent Change in Mortality Associated with Ozone (per 10 ppb 24-hour average)**



<u>Study #</u>	<u>Author</u>	<u># of studies</u>	<u>Comment</u>
1	Anderson (2004)	15	European
2	Anderson (2004)	20	Euro, corrected for possible publication bias
3	Thurston+Ito (2001)	7	<u>Studies using non-linear temperature</u>
4	Thurston+Ito (2001)	19	All studies
5	Stieb et al. (2003)	109	All studies
6	Bell et. al. (2004)	95	NMMAAPS, lag(01)
7	Bell et. al. (2004)	95	NMMAAPS, lag(06)
8	Levy et al. (2001)	4	Strict criteria
9	Levy et al. (2001)	15	Less strict criteria
10	Gryparis et al. (2004)	23	All year Europe
11	Gryparis et al. (2004)	23	Summer Europe

## Hospital Admissions for Respiratory Diseases

Studies of a possible ozone-hospitalization relationship have been conducted for a number of locations in the United States, including California. These studies use a daily time-series design and focus on hospitalizations with a first-listed discharge diagnosis attributed to diseases of the circulatory system (ICD9-CM codes 390-459) or diseases associated with the respiratory system (ICD9-CM codes 460-519). Various age groups are also considered, which vary across studies. For ~~this~~our estimate, we ~~rely~~relied on the meta-analysis by Thurston and Ito (1999). These authors used a random effects model ~~using~~based on three studies from North America. The studies were Burnett et al. (1994), Thurston et al. (1994), and Burnett et al. (1997). The category of all respiratory admissions for all ages yielded an estimate of relative risk of 1.18 (95% CI = 1.10 – 1.26) per 100 ppb change in daily 1-hour maximum ozone. This category includes hospital admissions for asthma and bronchitis, so separate estimates of these outcomes are not necessary. The estimate converts to a 1.65% change in hospital admissions (95% CI = 0.95 – 2.31%) per 10 ppb change in 1-hour daily maximum ozone. This estimate was applied to all age groups. Additional studies of respiratory admissions for specific diseases or subpopulations provide additional support for the above relationship, but are not quantified to avoid double counting. For example, Anderson et al. (1997) reported a relative risk of 1.04 (95% CI = 1.02-1.07) for hospital admissions for COPD for all ages for a ~~50  $\mu\text{g}/\text{m}^3$~~ 50  $\mu\text{g}/\text{m}^3$  change in 24-hour ozone. This converts to ~~2.05%~~0.63% per 10 ppb change in 1-hour maximum ozone. Burnett et al. (2001) investigated respiratory hospitalizations in children under age 2, and reported a ~~relative risk of 1.348 (95% CI = 1.193 – 1.523), which converts to a 6.6%~~7.8% increase in hospital admissions per 10 ppb change in five-day moving average of 1-hour daily maximum ozone.  
ozone concentrations.

## Emergency Room Visits for Asthma

Some studies have examined the relationship between air pollution and emergency room (ER) visits for pediatric asthma. Because most ER visits do not result in an admission to the hospital, we ~~treated~~evaluated hospital admissions and ER visits separately, taking into account ~~of~~ the fraction of ER patients that were admitted to the hospital. Our estimate is based on five studies which provide CR functions across the full range of ozone concentrations: Tolbert et al. (2000), Friedman et al. (2001), Jaffe et al. (2003), Romieu et al. (1995), and Stieb et al. (1996). Tolbert et al. (2000) report an association between pediatric emergency room visits (age < 16) for asthma and ozone in Atlanta during the summers of 1993-1995. The authors report a relative risk of 1.04 (95% CI = 1.008 – 1.074) per 20 ppb change in 8-hour ozone. Friedman et al. (2001) reported an association between daily counts for asthma in two pediatric emergency departments (age 1 to 16) and ozone in Atlanta during the summer of 1996. They report a RR of 1.2 (95% CI = 0.99 – 1.56) per 50 ppb change in 1-hour maximum ozone. This model included PM10 as a co-pollutant. Jaffe et al. (2003) reported an association between ozone and emergency room visits for asthma (ages 5 to 34) among Medicaid recipients in three cities in Ohio for the summer months from 1991- 1996. Estimates for the combined three cities indicate a RR of 1.03 (1.00 – 1.06) for a 10 ppb change in the

8-hour average of ozone. Romieu et al. (1995) reported results for emergency visits for asthma (age < 16) in Mexico City from January to June, 1990. A RR of 1.43 (95% CI= 1.24 – 1.66) was obtained for a 50 ppb change in 1-hour maximum ozone. Finally, Stieb et al. (1996) reported a beta of 0.0035 (95% CI = 0.00 –0.0070) for a 1 ppb change in 1 hour maximum ozone for ER visits for asthma in Saint John, New Brunswick, Canada.

Using an inverse variance weight for these five studies, we obtained a meta-analytic result of 2.4% per 10 ppb in daily 1-hour maximum ozone with a 95% CI = 1.46 to 3.34%. This estimate was applied over the entire range of ozone concentrations to children under 18. Several studies on ER visits for asthma report a non-linear response consistent with an effect threshold (see Section 8.3.3.2 and Figure 8-1, and Section 10.2.5). The threshold level appears to be somewhere between 0.075 and 0.110 ppm for a 1-hour average (or, using a ratio of 1.33, an 8-hour average of 0.056 to 0.084)-ppm. This threshold may be due to lower power in detecting effects at low concentrations. In addition, the studies indicate some increased risks observed at below threshold concentrations. Regardless, if a zero slope (implying a threshold) is applied to the lower portion of the data, the concentration-response function for the remaining portion of the data must be larger than the slope for the entire data set. Below we ~~use some of the available information on~~describe how to adjust the slope ~~in order of the CR function~~ to investigate the implications of imposing a threshold on the CR function.

## **School Absences**

In addition to hospital admissions and ER visits, there is considerable scientific research that has reported significant relationships between elevated ozone levels and other morbidity effects. Controlled human studies have established relationships between ozone and symptoms such as cough, pain on deep inhalation, shortness of breath, and wheeze. In addition, epidemiological research has found relationships between ozone exposure and acute infectious diseases (e.g., bronchitis, and sinusitis) and a variety of “symptom-day” categories. Some “symptom-day” studies examine excess incidences of days with identified symptoms such as wheeze, cough, or other specific upper or lower respiratory symptoms. Other studies estimate relationships with a more general description of days with adverse health impacts, such as “respiratory restricted activity days” or work loss days. We selected a few endpoints that reflect some minor morbidity effects and carefully adjusted estimates to avoid double counting (e.g., adjusted minor restricted activity days by number of asthma-related emergency room visits).

One of these studies demonstrated that absence from school was associated with ozone concentrations in a study of 1,933 fourth grade students from 12 southern California communities participating in the Children’s Health Study (Gilliland et al. 2001). For illness-related absences, verified through telephone contact, further questions assessed whether the illness was respiratory or gastrointestinal, with respiratory including runny nose/sneeze, sore throat, cough, earache, wheezing, or asthma attack. Associations were observed between 8-hour average ozone and school absenteeism due to several different respiratory-related illnesses. Specifically, the authors report a 62.9% (95% CI = 18.4 -124.1%) change in new episodes of absences from all illnesses

associated with a 20 ppb change in 8-hour average ozone. This provides the basis for our quantitative estimate, which was applied to all schoolchildren aged 5-17.

On the 1-hour scale, 62.9% change per 20 ppb change of 8-hour ozone is about 21.2% per 10 ppb change in 1-hour daily maximum ozone using the assumed ratio between 1-hour and 8-hour ozone of 1.33 and between 1-hour and 24-hour of 2.5 (Schwartz 1997). Thus, we estimated:

$$\frac{62.9\%}{20 \text{ ppb}8\text{hr}} \times \frac{1 \text{ ppb}8\text{hr}}{1.33 \text{ ppb}1\text{hr}} = \frac{21.2\%}{10 \text{ ppb}8\text{hr}}$$

In calculating the change ~~in school loss days~~, in episodes of school loss, we assumed children did not attend school during weekends and holidays, that about 20% of students attended year-round schools, and adjusted the attendance rate for each month of the year. The baseline absence rate reported by Hall et al. (2003), based on a telephone survey of school districts, was applied.

To convert episodes of school loss into days, we estimated 1.265 days as the average duration of an illness-related school absence, the result of dividing the average daily school loss rate from BenMAP by the episodic absence rate from Gilliland et al. (2001).

### **Minor Restricted Activity Days**

Ostro and Rothschild (1989) estimated the impact of PM2.5 on the incidence of minor restricted activity days (MRADs) and respiratory-related restricted activity days (RRADs) in a national sample of the adult working population, ages 18 to 65, living in metropolitan areas. The annual national survey results used in this analysis were conducted in 1976-1981. Controlling for PM2.5, two-week average ozone concentration has a highly variable but statistically significant association with MRADs but not with RRADs. MRADs are days where people reduced their activity, but did not miss work, and can therefore be viewed as relatively minor and transient symptom days.

For our MRAD estimate, we initially reanalyzed on an individual year basis each of the six years of data from Ostro and Rothschild (1989) using their multi-pollutant model that included PM2.5. We then used an inverse variance-weighted meta-analysis to combine the six individual year results. This resulted in an estimate of a 0.112% change (95%CI 0.046 – 0.178%) per  $\mu\text{g}/\text{m}^3$  of 1-hour maximum ozone. Conversion to ppb yielded an effect estimate of 2.24% change (95%CI = 0.92 – 3.56%) per 10 ppb change in 1-hour maximum ozone concentration. This estimate was applied to all adults above age 18.

### **Sensitivity Analysis**~~Analyses~~

~~Several~~We also performed several additional analyses ~~were run to indicate~~to evaluate the sensitivity of the results to our assumptions. In our first analysis, we considered two alternative ways to characterize ozone exposure and population. First, we ~~re-estimated the assignment of exposure for each of the county residents~~estimated ozone concentration at the census-tract level. Specifically, we used population data from the

year 2000 census and determined the population centroid for every census tract in the state. The assigned ozone concentration at each centroid was determined using the inverse square distance weighted interpolation of the ozone concentrations observed at the monitors within a 50-kilometer radius of the centroid. This value was then assigned to each resident in the census tract. Second, we averaged the observed concentrations at the monitors within each county and assigned the county average concentration to the entire county population.

As a second sensitivity analysis, we imposed a threshold on all of the CR functions and accompanied this assumption with a re-estimated, higher CR function for the remaining data. Most of existing studies assume a non-threshold model, either linear or logistic, over the entire range of ozone concentrations. If one were to impose a threshold or no-effects level over the lower range of the data, the remaining slope estimate would have to increase to fit the remaining observations. Unfortunately, there is only limited data to suggest the magnitude of the increase in the slope. Specifically, several of the studies of emergency room visits for asthma estimated a slope for both the full range and for an upper portion of the data. Therefore, as a sensitivity analysis, we attempted to draw inference about how the slope would increase, drawing on both the direct and indirect evidence. evidence, described below.

Stieb et al. (1996) examined the effects of ozone on emergency department (ED) visits for asthma in Saint John, Canada. In the basic analysis, they report a beta coefficient for the full population of 0.0035 for a change of 1 ppb in 1-hr maximum average of ozone, using a lag of 0 and 1 day. When a dichotomous model was developed to examine the effect of concentrations above versus below 75 ppb, the beta increased to 0.45. Based on graphical and descriptive data presented in the paper, the mean concentrations above and below 75 ppb were assumed to be 95 and 35 ppb, a difference of 60. This results in a beta of 0.0076 and a ratio of the slope using the highest quartile, where effects are observed, versus the slope for the full range of data of approximately 2.16.

Tolbert et al. (2000) examined the effects of ozone on pediatric ED visits in Atlanta. In the basic analysis, a relative risk (RR) of 1.042 was reported for a 20 ppb change in the 8-hour maximum daily ozone. This relates to a beta of 0.00206 ( $= \ln(1.042)/20$ ) ( $\beta = \ln(1.042)/20$ ) or converting to a 1-hr maximum using a ratio of 1.33, a beta of 0.0015. The authors also report an RR of 1.23 for concentrations above 100 ppb range versus low concentrations (< 50 ppb) of ozone. Assuming the mean for concentrations above 100 ppb was 105 ppb and the mean concentrations for values below 50 ppb was 40 ppb, the resulting beta coefficient is 0.00318 ( $= \beta = \ln(1.23)/(105-40)$ ) for an 8-hour change in ozone or 0.0024 for a 1-hour change which is 1.6 times the slope using all of the ozone data.

Finally, Romieu et al. (1995) studied ozone and pediatric ED visits in Mexico City. The authors report an RR of 1.43 for a 50 ppb change in 1-hour maximum ozone, using a one-day lag. This relates to a beta of 0.00715 for a 1-hour change in ozone. However, when they examined multiple days with high peaks greater than 110 ppb, the RR increased to 1.68 for a cumulative lag of 0 and 1 and to a RR of 2.33 for a cumulative

lag of 1 and 2 days. Based on personal communication with the authors, the mean concentration for days below 110 ppb was 67 ppb versus a mean for days above 110 ppb of 127 ppb. Thus, the resultant betas become  $0.0086$  ( $=\ln(1.68)/60$ ) and  $0.0141$  ( $=\ln(2.33)/60$ ),  $(\beta = \ln(1.68)/60)$  and  $0.0141$  ( $\beta = \ln(2.33)/60$ ), respectively. This suggests a ratio of the slope based on data above a threshold relative to the slope for the full data of between 1.21 and 1.97.

Overall, the empirical evidence confirms the logical expectation that the slope for only the upper end of the distribution of concentrations will be much larger than that for the entire distribution. The existing evidence, however, involves different cutpoints for the higher end and different averaging times, which clearly will affect the ultimate slope. However, given these results, it appears that for a sensitivity analysis, an increase of 40% in the slope above a threshold of 60 ppb (8-hour average) is a reasonable approximation. We also examined a presumed threshold of 50 ppb (8-hour average) using a slope increase of 100%. As additional sensitivity analysis, we determined, assuming a 40% increase in the slope in the upper segment of the data, what the threshold concentration would have to be to generate effects similar to those from a non-threshold model. Finally, we determined what the increase in the slope would have to be in the upper segment, given a threshold of 70 ppb 8-hour average, to generate effects similar to a non-threshold model.

Note, however, that these presumed threshold values are well within the range of concentrations observed in most, if not all, of the original epidemiologic studies. In fact, these values are often in the upper end of the range of values, rendering this assumption somewhat unlikely. Nevertheless, it is of interest to examine the effects of such an assumption.

## Health Effects Results

Table B-2B-3 presents the estimated statewide annual health benefits from reducing the impacts of current (2001-2003) levels of ozone to achieve the 1-hour standard of 0.09 ozone, compared to attainment of the Federal 8-hour standard of 0.08 ppm. For most of the endpoints, the 95% confidence intervals around each central estimate reflects the uncertainty associated reflect the uncertainty associated with the beta coefficient derived from the epidemiological studies used in the calculation. As discussed above, for mortality, the uncertainty was based on the range of estimates generated from several meta-analyses with the beta coefficient derived from the epidemiological studies used in the calculation. For mortality, the uncertainty was based on the range of estimates generated from several meta-analyses. For example, the results indicate that the impact of not attaining the federal 8-hour standard of 0.08 full attainment of the proposed 1-hour standard would result in 580 fewer ppm statewide is 360 cases of premature mortality (probable range = 290 – 870), 3,800 fewer (180 – 550), 2,400 hospital admissions (95% CI = 2,200 – 5,400) and 3,300,000 fewer days of (1,400 – 3,500), 380 emergency room visits for asthma (95% CI = 230-530), 2.5 million days of illness-related school loss (95% CI = 690,000 – 4,200,000), and 1.8 million (95% CI

430,000—6,100,000)= 730,000 – 2,800,000) minor restricted activity days per year. Since the results for premature mortality due to short-term exposures were derived from examining the evidence from several papers, rather than combining the results into a confidence interval, we use the terminology of a “probable range,” rather than 95% confidence interval.

Table B-4 presents the estimated annual statewide health impacts of current (2001-2003) levels of ozone, compared to attainment of the State 1-hour standard of 0.09 ppm. Again, for most of the endpoints, the 95% confidence intervals around each central estimate reflect the uncertainty associated with the beta coefficient derived from the epidemiological studies used in the calculation. As discussed above, for mortality, the uncertainty was based on the range of estimates generated from several meta-analyses. The results indicate that the current impact of ozone compared to attainment of the proposed 1-hour standard of 0.09 ppm statewide is 540 cases of premature mortality (probable range = 270 – 810), 3,600 hospital admissions (95% CI = 2,000 – 5,000), 560 emergency room visits for asthma (95% CI = 340-790), 3.8 million days of illness-related school loss (95% CI = 1,040,000 – 6,900,000), and 2.6 million (95% CI = 1,100,000 – 4,200,000) minor restricted activity days per year.

Similar to Table B-2, Table B-3 presents statewide results from achieving B-4, Table B-5 presents the impact of current ozone levels compared to attainment of the proposed State 8-hour standard of 0.070 ppm. Generally speaking, the health benefits from impacts of not attaining the 4-hour 8-hour standard are greater than those associated with not attaining the 8-hour standard. Since 1-hour and 8-hour standard. For example, the results indicate that the impact of current ozone levels, compared to full attainment of the proposed 8-hour standard statewide is 630 cases of premature mortality (probable range = 310 – 950), 4,200 hospital admissions (95% CI = 2,400 – 5,800), 660 emergency room visits for asthma (95% CI = 400-920), 4.7 million days of illness-related school loss (95% CI = 1,200,000 – 8,600,000), and 3.1 million (95% CI = 1,300,000 – 5,000,000) minor restricted activity days per year.

concentrations are highly correlated, it is not appropriate to add the estimated benefits from Tables B-2 and B-3 together. Tables B-4 and B-5 Tables B-6, B-7 and B-8 present estimates of the annual health benefits of impacts of not attaining the federal 8-hour, and the proposed State 1-hour and 8-hour standards, respectively, by air basin.

Table B-6 presents estimates of the annual health benefits of attaining either of the standards, whichever provides the greatest amount of control.

### **Incremental Impacts Discussion**

The differences between the results in Tables B-3 (federal 8-hour standard), B-4 (State 1-hour standard) and B-5 (State 8-hour standard) are the “incremental” impacts of not attaining the State 1-hour and 8-hour standards, compared to the federal 8-hour ozone standard, respectively. However, it is more reasonable to consider attainment of the two state standards together, compared to current ozone levels, since it is unlikely that control strategies will be geared to first attain one standard and then the other. Therefore, the impacts are not separable and should not be treated as such. Nonetheless, the following discussion can be helpful in understanding the incremental

impacts.

Comparing Tables B-3 and B-5, the current impact of not attaining the federal 8-hour standard is about 360 premature deaths, with an additional 270 deaths associated with not attaining the proposed State 8-hour standard, making the total estimated impact of not attaining both standards 630 premature deaths. Similarly, statewide about 2,400 hospital admissions annually are associated with nonattainment of the federal 8-hour standard, and an additional 1,800 hospitalizations are due to nonattainment of the proposed State 8-hour standard, making the total estimated impact of not attaining both the federal 8-hour and State 8-hour standards 4,200 hospital admissions. For ER visits, we estimate that 380 cases are associated with nonattainment of the federal 8-hour standard, and an additional 280 cases with nonattainment of the proposed State 8-hour standard, for a total of 660 cases associated annually with nonattainment of the proposed 8-hour standard. For school loss, 2.5 million days are estimated to be associated with the nonattainment of the federal 8-hour standard, and an additional 2.2 million days, a total of 4.7 million days, associated with nonattainment of the proposed State 8-hour standard. Lastly, we estimated that the impact of current ozone levels is about 1.8 million minor restricted activity days due to nonattainment of the federal 8-hour standard, and an additional 1.3 million, for a total of 3.1 million days, associated with nonattainment of the proposed State 8-hour standard.

A similar examination of Tables B-4 and B-5 reveals the incremental impacts of not attaining the proposed State 8-hour standard compared to the State 1-hour standard. The current impact of not attaining the State 1-hour standard is about 540 premature deaths, with an additional 90 deaths associated with not attaining the proposed 8-hour standard, making the total estimated impact of not attaining both the State 1-hour and 8-hour standards 630 premature deaths. Similarly, statewide about 3,600 hospital admissions annually are associated with nonattainment of the State 1-hour standard, and an additional 600 hospitalizations are due to nonattainment of the proposed 8-hour standard, making the total impact of not attaining both the State 1-hour and 8-hour standards 4,200 hospital admissions. For ER visits, we estimate that 560 cases are associated with nonattainment of the 1-hour standard, and an additional 100 cases with nonattainment of the proposed 8-hour standard, for a total of 660 cases associated annually with nonattainment of the proposed 8-hour standard. For school loss, 3.8 million days are estimated to be associated with the nonattainment of the State 1-hour standard, and an additional 900,000 days, a total of 4.7 million days, associated with nonattainment of the proposed 8-hour standard. Lastly, we estimated that the impact of current ozone levels is about 2.6 million minor restricted activity days due to nonattainment of the 1-hour standard, and an additional 500,000, for a total of 3.1 million days, associated with nonattainment of the proposed 8-hour standard.

**Figure B-2: Incremental Impacts of Ozone Exposures Compared to Attainment of Ozone Standards for Premature Deaths and School Absences (Annual statewide cases avoided with attainment of ozone standards. Details are given in the text.)**

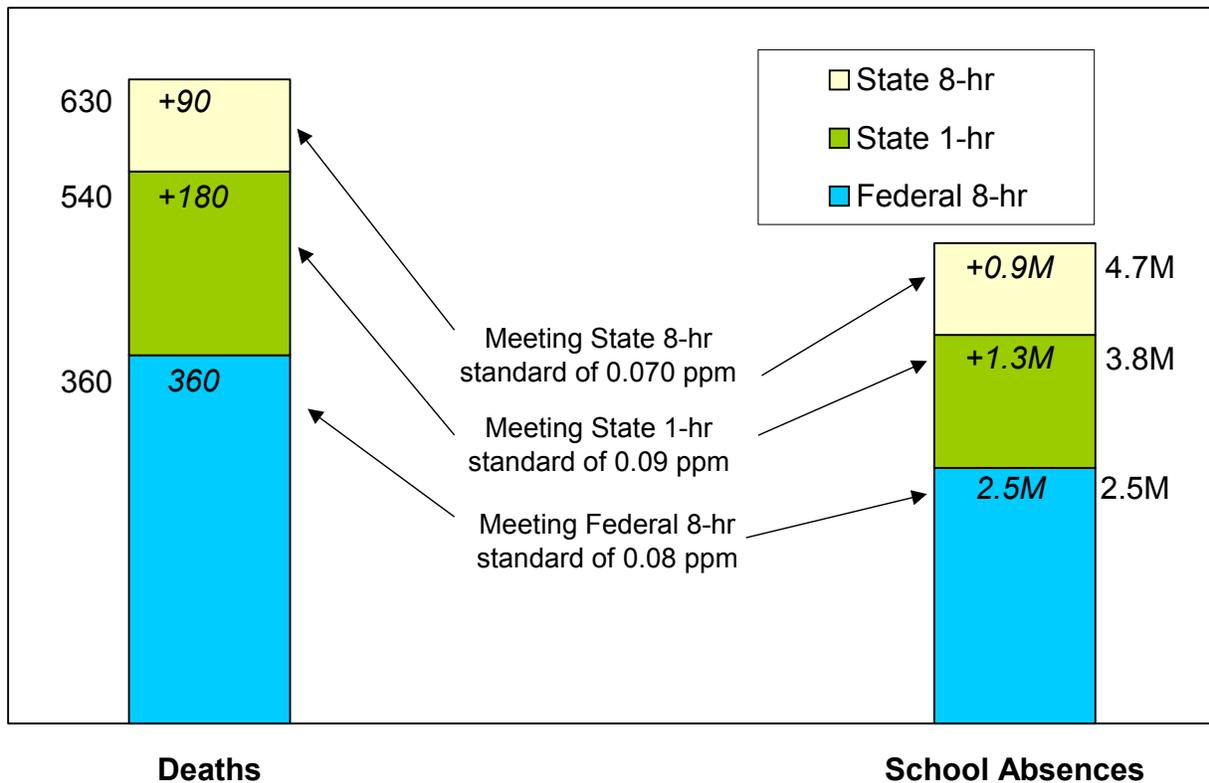


Figure B-2 summarizes the results of the above incremental impacts discussion for two endpoints: premature death and school absences. The numbers within each stacked bar represent the incremental impacts analysis. For premature death, attainment of the federal 8-hour standard would avoid 360 deaths annually in California. An additional 180 deaths, as indicated inside the stacked bar, would be avoided with attainment of the State 1-hour standard, and another 90 deaths would be avoided with attainment of the proposed State 8-hour standard, for a total of 630 deaths avoided annually at full attainment, as indicated on the side next to the bar. For illness-related school absences, the incremental analysis estimates annual avoidance of about 2.5 million school absences with attainment of the federal 8-hour standard, an additional 1.3 million avoided school absences with attainment of the current State 1-hour standard, and another 900,000 (indicated by +0.9M inside the stacked bar) with attainment of the proposed 8-hour standard, for a total of 4.7 million fewer school absences.

**Sensitivity Analysis Results**

We performed several sensitivity analyses to investigate two key assumptions in our analysis. Here, we discuss results on both the State 8-hour standard and the 1-hour

standard. Our first sensitivity analysis examined the implications of an alternative exposure assessments. Specifically, in the first reassessment, we interpolated concentrations for each census tract using nearby monitoring data. The exposure of the population within each census tract was determined using the inverse square distance weighted interpolation of the ozone concentrations observed at the monitors within a 50-kilometer radius of the centroid. The results for mortality are similar to those obtained using the base-case approach. Attaining the 1-hour ozone standard statewide. Not attaining the proposed California 8-hour ozone standard using census-tract interpolations led to 570 an estimated current impact of 610 deaths compared to 580 deaths avoided 630 deaths using our base-case approach. Not attaining the State 1-hour ozone standard using census-tract interpolations lead to an estimated current impact of 530 deaths compared to 540 deaths using our base-case approach. In the second assessment using reassessment of exposure, we assigned residents to their county-wide average ozone concentrations, similar results, about 630 deaths, are obtained concentrations. Similar impacts of about 680 deaths was obtained for the proposed 8-hour standard and 580 deaths was obtained for the State 1-hour standard.

In our second sensitivity analysis, we examined the implications of assuming alternative threshold models. If we assumed a threshold of 60 ppb and a 40% increase of the slope of the remaining higher concentrations, it resulted in about a 10% to 14% decrease in estimated health outcomes impacts. For example, the estimated mortality impact would decrease from 580 to 520 630 to 540 comparing current ozone levels with attainment of the proposed 8-hour standard, and from 540 to 490 comparing current ozone levels with attainment of the 1-hour standard. The breakeven point associated with a 40% increase in the slope would be about 55 ppb for both the 1-hour and 8-hour standards. In other words, if the slope at the higher end of exposure was 40% greater than the slope for the full range of exposures, we would obtain the same number of cases impact estimate as in the base case, if the higher slope estimate was applied to concentrations greater than 55 ppb. For an assumed threshold of 70 ppb, the slope would have to increase by about 140% to get the same number of cases as in 150% for the 8-hour standard or about 130% for the 1-hour standard to obtain about the same impact as in the base case, non-threshold model. If we assumed a threshold at 50 ppb with a 100% increase in the remaining slope, the estimate number of case estimated impact would increase by about 70% for the 8-hour standard and about 75% for the 1-hour standard.

## **Uncertainties and Limitations**

There are a number of uncertainties involved in quantitatively estimating the impacts on health benefits associated with reductions in outdoor ozone air pollution. Over time, some of these will be reduced as new research is conducted. However, some uncertainty will remain in any estimate. Below, we briefly discuss some of the major uncertainties and limitations of these estimated health benefits impacts. These issues are discussed in more detail in Chapter 10 (also see Levy et al., 2001; Thurston and Ito, 1999).

### **Developing concentration-response functions**

A primary uncertainty is the choice of the specific studies and concentration-response

functions used in ~~this~~the quantification. Several challenges and unresolved issues present themselves with respect to designing and interpreting time-series studies of ~~ozone-related~~ozone-related health effects. The principal challenge facing the analyst in ~~the daily time series context~~ is to remove bias due to confounding by short-term temporal factors operating over time scales from days to seasons. The correlation of ozone with these confounding terms tends to be higher than that for PM or other gaseous pollutants. Thus, model specifications that may be appropriate for PM, the primary focus of much of the available literature, may not necessarily be adequate for ozone. Few studies to date have thoroughly investigated these potential effects with reference to ozone, introducing an element of uncertainty into ~~the health benefits~~ analysis.

Of particular importance is the strong seasonal cycle for ozone, high in summer and low in winter, ~~which is~~ opposite to the usual cycle in daily mortality and morbidity, which is typically high in winter and low in summer. Inadequate control for seasonal patterns in time series analyses leads to biased effect estimates. In the case of ozone, inadequate seasonal pattern control generally yields statistically significant inverse associations between ozone and health outcomes. In contrast, for winter-peaking pollutants such as CO and NO<sub>2</sub>, the bias is toward overly positive effect estimates. Also, temporal cycles in daily hospital admissions or emergency room visits are often considerably more episodic and variable than is usually the case for daily mortality. As a result, smoothing functions that have been developed and tuned for analyses of daily mortality data may not work as well at removing cyclic patterns from morbidity analyses.

Potential confounding by daily variations in co-pollutants and weather is another analytical issue to be considered. With respect to co-pollutants, daily variations in ozone tends not to correlate highly with most other criteria pollutants (e.g., CO, NO<sub>2</sub>, SO<sub>2</sub>, PM<sub>10</sub>), but may be more correlated with secondary fine particulate matter (e.g., PM<sub>2.5</sub>) measured during the summer months. Assessing the independent health effects of two pollutants that are somewhat correlated over time is problematic. However, much can be learned from the classic approach of first estimating the effects of each pollutant individually, and then estimating their effects in a two-pollutant model. For this reason, we have emphasized use of studies that have also controlled for PM.

The choice of the studies and concentration-response functions used for health impact assessment can affect the ~~benefits~~impact estimates. Because of differences, likely related to study location, subject population, study size and duration, and analytical methods, effect estimates differ somewhat between studies. We have addressed this issue by emphasizing meta-analyses and multi-city studies, and also by presenting estimates derived from several studies.

To a substantial degree, the growing literature on acute ozone effects is an artifact of interest in studying acute PM effects. For example, of the 84 time-series mortality studies published between 1995 and mid-2004, 35 studies examined PM but not ozone; 47 studies examined both PM and ozone; and only 2 studies examined ozone but not PM. In many of the multi-pollutant studies, ozone is treated primarily as a potential

confounder of the PM effects under study. As a result, many of these studies lack specific hypotheses regarding mortality effects of ozone, and fail to provide the range and depth of analyses, including sensitivity analyses, that would be most useful in judging whether ozone is an independent risk factor for acute mortality. This is in contrast to morbidity studies where hypotheses regarding ozone effects on respiratory symptoms, lung function, hospitalization and ER visits, etc. have been studied with ozone treated as a key pollutant. Fortunately, studies of short-term exposure and mortality have been replicated in many cities throughout the world, under a wide range of exposure conditions, climates and covarying pollutants. As a result, the evidence of an effect of ozone on premature mortality is compelling. Nevertheless, uncertainty remains about the actual magnitude of the effect and the appropriate confidence interval.

## Thresholds

A second major uncertainty relates to the general shape of the concentration-response function and the existence of a threshold. This is discussed in detail earlier, with the conclusion that there is little evidence for a threshold. An important consideration in determining if a safe level of ozone can be identified is whether the CR relationship is linear across the full concentration range or instead shows evidence of a threshold. Among the ozone epidemiology literature, only a few studies of hospital admissions and emergency room visits have examined the shape of the CR function. These studies also provide the only epidemiologic investigations into whether or not there is an ozone effect threshold. Since only a few studies have investigated whether there is an effect threshold, and the few studies available do not cover all endpoints, the epidemiologic literature does not provide a basis for concluding whether or not there is a population level effect threshold. However, many of the available studies were conducted at fairly low concentrations of ambient ozone, so we are never extrapolating beyond the range of the studies. Therefore, for this analysis, we have assumed that there is no threshold for ozone effects and we estimated ~~benefits~~impacts down to an assumed background concentration of 0.04 ppm. To the extent that there may not be health effects below the proposed ozone standard, the analysis may overestimate the impacts of ~~reducing~~ambient ozone. However, we also conducted a sensitivity analysis ~~with an assumption of~~assuming several different possible thresholds. In doing so, we also adjusted the slope of the upper segment of the ozone concentrations to conform with the implications of a threshold model. If we had assumed zero ~~benefits~~impacts accrue below the proposed standards and provided no adjustment to the concentration-response functions, our estimates would be reduced by about 80%.

A related issue is that limited data suggest that ozone effects may be seasonal. While analysis of year round data suggests positive associations between a number of endpoints and ozone exposure, some data sets that have been analyzed seasonally report positive RR estimates for summer and negative RR estimates for winter. The cause of this phenomenon has not been adequately investigated, but may be related to thresholds, differences in personal exposure between seasons, or to co-pollutant exposures. In light of this uncertainty, this analysis used year-round effect ~~estimates~~.

~~In~~ ~~estimates,~~ ~~addition,~~ ~~although~~ the relatively long, warm season in California may make the summer estimates more relevant than those of the winter season.

### **Assumptions about rollback**

A further uncertainty concerns the process used to design and implement strategies for controlling ozone-producing compounds. Such control strategies have been designed with the objective of reducing ozone episodes during worst-case meteorological conditions. In addition, basin-wide strategies have focused on the ozone concentrations at the highest (design) site in each basin. How these strategies would affect other sites during dissimilar episodes cannot be answered with certainty. Site-by-site analyses almost always have found that trends for multiple sites within a basin are very similar to each other. Similarly, monthly trends within a basin have usually proved to be similar, while the prevalence of different episode types may be markedly different for different months during the overall ozone season. (See trend analysis in the Supplement).

### **Unquantified adverse effects**

An additional limitation in this analysis is the inability to quantify all possible ~~health benefits that could be~~ impacts that are associated with current ozone concentrations, achieving the proposed ozone standards, since estimates are provided for only a subset of possible adverse outcomes. For example, estimates of the effects of ozone on asthma exacerbation, asthma exacerbation, induction, respiratory symptoms, airway inflammation, and acute and long-term changes in lung function are not presented. Although there is some evidence for such effects, the available data were either too inconsistent or sparse to justify quantification of possible ~~benefits of achieving the proposed ozone standards.~~ impacts of not achieving the proposed ozone standards, or the evidence comes from controlled exposure studies that can not be used to make population level effects estimates. To the extent that certain important health outcomes were excluded, we may have underestimated the health ~~benefits~~ impacts of the proposed standards.

### **Baseline rates of mortality and morbidity**

There is also uncertainty in the baseline rates for the investigated health outcomes in the studied population. Often, one must assume a baseline incidence level for the city or country of interest. In addition, incidence can change over time as health habits, income and other factors change.

### **Exposure assessment**

There are likely uncertainties in the statewide exposure assessment, and in whether the existing monitoring network provides representative estimates of exposure for the general population. We have attempted to reproduce the same relationship between monitor readings and exposure as in the original epidemiological studies. Most of these studies use population-oriented, background, fixed site monitors, often aggregated to

the county level. The available epidemiological studies have used multiple pollutant averaging times, and we have proposed conversion ratios for 1-hour to 8-hour and 24-hour ozone concentrations based on national estimates. A preliminary examination of the California monitoring data indicates that the ratios are similar to those found in the highly populated areas of the State. However, uncertainty is added to the estimated ~~benefits of attainment of~~impacts of not attaining the proposed standards to the extent the converted concentration bases differ from monitored concentrations.

## Summary

The purpose of this appendix is to provide quantitative estimates of some of the health ~~benefits that may accrue from~~impacts of current levels of ozone, compared to those that would occur under a hypothetical control strategy that brings the State into attainment with the proposed ozone standards. This assessment should not be regarded as exhaustive, since we have provided estimates only for a ~~selection of the most plausible effects for which there were high quality studies from which to derive CR functions.~~subset of health effects endpoints. However, the results presented support the conclusion that significant public health ~~benefits would result from statewide~~impacts are associated with current ozone concentrations in California that would not occur with attainment of the proposed ambient air quality standards for ozone. ~~ozone standards.~~ It is estimated that attainment of the proposed ozone standards throughout California would ~~avoid a significant~~significantly reduce the number of ozone-related adverse health effects each year. ~~The higher central estimate between the values calculated for 1-hour and 8-hour averaging times is given below.~~

Specifically, we estimate that the current impact of exposures above the proposed standard is:

- ~~580 (290 – 870),~~630 (310 – 950, probable range) premature deaths for all ages.
- ~~3,800 (2,200 – 5,400),~~4,200 (2,400 – 5,800, 95% confidence interval (CI)) hospitalizations due to respiratory diseases for all ages.
- ~~600 (360 – 850),~~660 (400 – 920, 95% CI) emergency room visits for asthma for children under 18 years of age.
- ~~3.3 million (430,000 – 6,100,000, 95% CI)4.7 million (1,200,000 – 8,600,000, 95% CI) illness-related school absences for children 5 to 17 years of age.~~
- ~~2.8~~3.1 million (~~1.2~~1.3 million – ~~4.6~~5.0 million, 95% CI) minor restricted activity days for adults above 18 years of age.

These estimates are based on attainment of the proposed State 8-hour standard, as it is the more stringent of the two (1-hour and 8-hour) proposed standards. The reader is cautioned that since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated ~~benefits from Tables B-2 and B-3 together.~~impacts from Tables B-3, B-4 and B-5 together. Instead, the estimates above represent the total impacts estimated to accrue from attaining both the proposed 8-hour and 1-hour standards. For a discussion of the incremental impacts of current ozone levels

compared to attainment of the proposed 8-hour standard over the State 1-hour standard and the federal 8-hour standard, see page B-19.

As noted above, there are several important assumptions and uncertainties in this analysis. Some concern the study design, the statistical modeling methodologies used, and the selection of studies from which the CR functions are derived. Few studies have investigated the shape of the CR function, or whether there is a population response threshold for health endpoints other than emergency room visits for asthma. Further, but likely small, uncertainty is added by assumptions in the statewide exposure assessment. Nonetheless, when new evidence on mortality from short-term exposures to ozone is published from the recent meta-analyses sponsored by the US EPA, we will update our estimates and use the census-tract interpolation to characterize ambient ozone exposure. It should also be noted that since several health effects related to acute exposure, and ~~effects of chronic ozone exposure, exposures~~ are not included in the estimates, the health ~~benefits~~impacts associated with lowering ozone exposure are likely underestimated.

**Table B-1:B-2: Summary of Meta-Analyses Linking Daily Ozone to Mortality (for 10 ppb change in 24-hour average ozone)**

Study Number	Author	# of studies	% Change in Mortality (95% CI)	comment
1	Anderson (2004)	15	1.13 (0.38 - 1.51)	European studies only
2	Anderson (2004)	20	0.75 (0.19 – 1.32)	European studies corrected for possible publication bias
3	Thurston+Ito (2001)	7	1.37 (0.78 – 1.96)	Earlier studies using non-linear specification for temperature
4	Thurston+Ito (2001)	19	0.89 (0.56 – 1.22)	All earlier studies
5	Stieb et al. (2003)	109	1.12 (0.32 – 1.92)	Meta-analysis including single and multi-pollutant models
6	Bell et. al. (2004)	95	0.25 (0.12 – 0.39)	NMMAAPS, using lag(01)
7	Bell et. al. (2004)	95	0.52 (0.27 – 0.77)	NMMAAPS,lag(06)
8	Levy et al. (2001)	4	0.98 (0.59 – 1.38)	Using relatively stringent inclusion criteria
9	Levy et al. (2001)	15	0.80 (0.60 – 1.00)	Using less stringent inclusion criteria
<u>10</u>	<u>Gryparis et al. (2004)</u>	<u>23</u>	<u>0.5 (-0.38 – 1.30)</u>	<u>APEHA2/APEAH2 studies in Europe, all year</u>
<u>11</u>	<u>Gryparis et al. (2004)</u>	<u>23</u>	<u>1.65 (0.85 – 2.60)</u>	<u>APEHA2/APEAH2 studies in Europe, summer only</u>

**Table B-2:B-3: California Annual Health Benefits from Attaining a 1-hour Impacts of Current Ozone Concentrations Compared to the Federal 8-hour Ozone Standard of 0.090.08 ppm\***

<u>Health Endpoint</u>	<u>Population</u>	<u>Estimated Beta (% per 10 ppb) (95% Confidence Interval)-Estimated Beta** (% per 10 ppb 1-hour ozone) (95% Confidence Interval)</u>	<u>Avoided Incidence (cases/year) Mean 95% Confidence Interval Incidence (cases/year) (95% Confidence Interval)</u>
<u>Premature Mortality due to Short-term Exposures</u>	<u>All ages</u>	<u>0.0040 (0.0020 - 0.0060) **</u>	<u>580 (290 – 870) ** 360 (180 – 550) ***</u>
<u>Hospital Admissions for Respiratory Diseases</u>	<u>All ages</u>	<u>0.0164 (0.0095 - 0.0228)</u>	<u>3,800 (2,200 – 5,400) 2,400 (1,400 – 3,500)</u>
<u>Emergency Room Visits for Asthma</u>	<u>Age &lt; 18</u>	<u>0.0237 (0.01446 – 0.0329)</u>	<u>600 (360 – 850)-380 (230 – 530)</u>
<u>School Loss Days</u>	<u>Age 5-17</u>	<u>0.2123 (0.0334 – 0.3295) 0.2123 (0.06672 – 0.3295)</u>	<u>3,300,000 (430,000 – 6,100,000) 2,500,000 (690,000 – 4,200,000)</u>
<u>Minor Restricted Activity Days</u>	<u>Age &gt; 18</u>	<u>0.0222 (0.0092 - 0.0350)</u>	<u>2,800,000 (1,200,000 – 4,600,000) 1,800,000 (730,000 – 2,800,000)</u>

\*Base period 2001-2003. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated impacts from Tables B-3, B-4 and B-5 together. Due to rounding conventions in the process of determining attainment of the federal 8-hour standard, the concentration of 0.084 ppm was used since this is the highest value considered in attainment.

\*\*As discussed in detail in the text, the evaluation of impacts of not attaining the 8-hour standard was based on the equivalent 1-hour concentration. Therefore, the beta coefficients here are in 1-hour scale.

benefits from Tables B-2 and B-3 together. ~~\*\*Results~~\*\*\*Results for premature mortality represent a probable range of likely values rather than a 95% confidence interval since the coefficients were derived from examining the evidence from several studies separately rather than combining their results in a formal meta-analysis.

**Table B-3:B-4: California Annual Health Benefits from Attaining an 8-hour Impacts of Current Ozone Concentrations Compared to the State 1-hour Ozone Standard of 0.0700.09 ppm\***

<u>Health Endpoint</u>	<u>Population</u>	<u>Estimated Beta (% per 10 ppb) (95% Confidence Interval)-Estimated Beta (% per 10 ppb 1-hour ozone) (95% Confidence Interval)</u>	<u>Avoided Incidence (cases/year) Mean (95% Confidence Interval)-Incidence (cases/year) (95% Confidence Interval)</u>
Premature Mortality due to Short-term Exposures	All ages	0.0053 (0.0027 – 0.0079)** 0.0040 (0.0020 - 0.0060)	540 (270 – 810) **
Hospital Admissions for Respiratory Diseases	All ages	0.0218 (0.0126 – 0.0302) 0.0164 (0.0095 - 0.0228)	3,600 (2,000 – 5,000)
Emergency Room Visits for Asthma	Age < 18	0.0314 (0.0192 – 0.0434) 0.0237 (0.01446 – 0.0329)	570 (340 – 800) 560 (340 – 790)
School Loss Days	Age 5-17	0.2440 (0.0844 – 0.4034) 0.2123 (0.06672 – 0.3295)	2,600,000 (760,000 – 5,200,000) 3,800,000 (1,040,000 – 6,900,000)
Minor Restricted Activity Days	Age > 18	0.0294 (0.0121 – 0.0462) 0.0222 (0.0092 - 0.0350)	2,600,000 (1,100,000 – 4,200,000)

\*Base period 2001-2003. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated impacts from Tables B-3, B-4 and B-5 together. Due to rounding conventions in the process of determining attainment of the 1-hour standard, the concentration of 0.094 benefits from Tables B-2 and B-3 together. ppm was used since this is the highest value considered in attainment.

\*\*Results for premature mortality represent a probable range of likely values rather than a 95% confidence interval since the coefficients were derived from examining the evidence from several studies separately rather than combining their results. results in a formal meta-analysis.

**Table B-5: California Annual Health Impacts of Current Ozone Concentrations Compared to the State 8-hour Ozone Standard of 0.070 ppm\***

<u>Health Endpoint</u>	<u>Population</u>	<u>Estimated Beta** (% per 10 ppb 1-hour ozone) (95% Confidence Interval)</u>	<u>Incidence (cases/year) (95% Confidence Interval)</u>
<u>Premature Mortality due to Short-term Exposures</u>	<u>All ages</u>	<u>0.0040 (0.0020 - 0.0060)</u>	<u>630 (310 – 950) ***</u>
<u>Hospital Admissions for Respiratory Diseases</u>	<u>All ages</u>	<u>0.0164 (0.0095 - 0.0228)</u>	<u>4,200 (2,400 – 5,800)</u>
<u>Emergency Room Visits for Asthma</u>	<u>Age &lt; 18</u>	<u>0.0237 (0.01446 – 0.0329)</u>	<u>660 (400 – 920)</u>
<u>School Loss Days</u>	<u>Age 5-17</u>	<u>0.2123 (0.06672 – 0.3295)</u>	<u>4,700,000 (1,200,000 – 8,600,000)</u>
<u>Minor Restricted Activity Days</u>	<u>Age &gt; 18</u>	<u>0.0222 (0.0092 - 0.0350)</u>	<u>3,100,000 (1,300,000 – 5,000,000)</u>

\*Base period 2001-2003. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated impacts from Tables B-3, B-4 and B-5 together.

\*\*As discussed in detail in the text, the evaluation of impacts of not attaining the 8-hour standard was based on the equivalent 1-hour concentration. Therefore, the beta coefficients here are in 1-hour scale.

\*\*\*Results for premature mortality represent a probable range of likely values rather than a 95% confidence interval since the coefficients were derived from examining the evidence from several studies separately rather than combining their results in a formal meta analysis.

**Table B-4: Annual Health Benefits from Attaining 1-hour Ozone Standard of Air Basin of 0.09 ppm** **Table B-6: Annual Health Impacts of Current Ozone Concentrations Compared to the Federal 8-hour Ozone Standard of 0.08 ppm by Air Basin (cases/year).**

<u>Air Basin</u>	<u>Mortality</u>	<u>Hospital Admissions</u>	<u>Emergency Room Visits</u>	<u>School Absences</u>	<u>Minor Restricted Activity Days</u>
<u>Great Basin Valley</u>	<1	<1	<1	340 <u>280</u>	370 <u>250</u>
<u>Lake County</u>	0	0	0	0	0
<u>Lake Tahoe</u>	<1	3 <1	<1	2,500 <u>450</u>	2,400- <u>360</u>
<u>Mountain Counties</u>	40 <u>7</u>	52 <u>36</u>	7 <u>5</u>	40,000 <u>33,000</u>	41,000 <u>29,000</u>
<u>Mojave Desert</u>	43 <u>26</u>	300 <u>180</u>	50 <u>29</u>	280,000 <u>190,000</u>	220,000 <u>130,000</u>
<u>North Coast</u>	<4 <u>0</u>	<4 <u>0</u>	<4 <u>0</u>	370 <u>0</u>	330 <u>0</u>
<u>North Central Coast</u>	4 <u>0</u>	40 <u>0</u>	2 <u>0</u>	9,000- <u>0</u>	7,700- <u>0</u>
<u>Northeast Plateau</u>	0	0	0	0	0
<u>South Coast</u>	300 <u>220</u>	2,100- <u>1,500</u>	330 <u>230</u>	1,700,000 <u>1,400,000</u>	1,600,000 <u>1,100,000</u>
<u>South Central Coast</u>	46 <u>7</u>	440 <u>48</u>	46 <u>7</u>	97,000 <u>50,000</u>	83,000 <u>36,000</u>
<u>San Diego</u>	24 <u>11</u>	460 <u>71</u>	22 <u>10</u>	120,000 <u>67,000</u>	120,000 <u>55,000</u>
<u>San Francisco Bay</u>	23 <u>1</u>	450 <u>5</u>	21 <u>1</u>	400,000 <u>3,700</u>	420,000 <u>3,900</u>
<u>San Joaquin Valley</u>	95 <u>62</u>	640 <u>400</u>	110 <u>70</u>	650,000 <u>480,000</u>	440,000 <u>280,000</u>
<u>Salton Sea</u>	20 <u>15</u>	420- <u>86</u>	20 <u>14</u>	420,000 <u>105,000</u>	88,000 <u>62,000</u>
<u>Sacramento Valley</u>	39 <u>19</u>	220 <u>103</u>	32 <u>15</u>	470,000 <u>94,000</u>	470,000 <u>78,000</u>
<u>Statewide</u>	580 <u>360</u>	3,800- <u>2,400</u>	600 <u>380</u>	3,300,000 <u>2,500,000</u>	2,800,000 <u>1,800,000</u>

Note: Some columns may not add up to the statewide totals due to rounding. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated benefits/impacts from

Tables ~~B-4 and B-5~~B-6, B-7 and B-8 together. Table ~~B-6~~B-8 should be used to estimate the maximum health ~~benefit~~impact per air basin. The uncertainty behind the mortality estimates is on the order of +/- 50% and varies for other endpoints.

**Table B-5:B-7: Annual Health Benefits from Attaining 8-hour Impacts of Current Ozone Concentrations Compared to the State 1-hour Ozone Standard of 0.0700.09 ppm by Air Basin (cases/year).**

<u>Air Basin</u>	<u>Mortality</u>	<u>Hospital Admissions</u>	<u>Emergency Room Visits</u>	<u>School Absences</u>	<u>Minor Restricted Activity Days</u>
<u>Great Basin Valley</u>	<1	4 <1	<1	650 300	820 260
<u>Lake County</u>	<1 0	<1 0	<1 0	35 0	53 0
<u>Lake Tahoe</u>	4 <1	9 2	4 <1	6,100 1,900	6,600 1,400
<u>Mountain Counties</u>	12 9	62 48	8 6	41,000 45,000	50,000 38,000
<u>Mojave Desert</u>	54 40	350 270	59 45	280,000 310,000	260,000 200,000
<u>North Coast</u>	<1	4 <1	<1	720 0	750 0
<u>North Central Coast</u>	2 1	12 7	2 1	9,100 7,600	8,800 5,300
<u>Northeast Plateau</u>	<1 0	<1 0	<1 0	88 0	140 0
<u>South Coast</u>	260 290	1,700 2,000	270 310	1,100,000 2,000,000	1,300,000 1,500,000
<u>South Central Coast</u>	17 14	120 97	18 14	92,000 106,000	91,000 73,000
<u>San Diego</u>	25 21	170 140	23 19	110,000 130,000	130,000 100,000
<u>San Francisco Bay</u>	14 20	192 40	13 18	51,000 110,000	72,000 110,000
<u>San Joaquin Valley</u>	400 89	670 570	120 100	600,000 740,000	470,000 410,000
<u>Salton Sea</u>	21 19	130 110	21 19	110,000 140,000	91,000 81,000
<u>Sacramento Valley</u>	39	220 200	32 29	140,000 200,000	160,000 150,000
<u>Statewide</u>	540	3,600	570 560	2,600,000 3,800,000	2,600,000

Note: Some columns may not add up to the statewide totals due to rounding. Since 1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated benefits/impacts from

Tables ~~B-4 and B-5~~B-6, B-7 and B-8 together. Table ~~B-6~~B-8 should be used to estimate the maximum health ~~benefit~~impacts per air basin. The uncertainty behind the mortality estimates is on the order of +/- 50% and varies for other endpoints.

**Table B-6: Annual Health Benefits from Attaining Both 1-hour and 8-hour Ozone Standards by Air Basin**

**Table B-8: Annual Health Impacts of Current Ozone Concentrations Compared to the State 8-hour Ozone Standard of 0.070 ppm by Air Basin (cases/year).**

<u>Air Basin</u>	<u>Mortality</u>	<u>Hospital Admissions</u>	<u>Emergency Room Visits</u>	<u>School Absences</u>	<u>Minor Restricted Activity Days</u>
<u>Great Basin Valley</u>	<1	4 <1	<1	650 1,100	820 870
<u>Lake County</u>	<1 0	<1 0	<1 0	35 49	53 48
<u>Lake Tahoe</u>	4 <1	9 8	4 <1	6,100 8,600	6,600 6,400
<u>Mountain Counties</u>	42 10	62 61	8	41,000 61,000	50,000 49,000
<u>Mojave Desert</u>	54 50	350 340	59 58	280,000 420,000	260,000 250,000
<u>North Coast</u>	<1	1	<1	720 1,400	750 990
<u>North Central Coast</u>	2	42 17	2 3	9,100 19,000	8,800 12,700
<u>Northeast Plateau</u>	<1 0	<1 0	<1 0	88 270	140 270
<u>South Coast</u>	300 320	2,100 2,200	330 350	4,700,000 2,300,000	1,600,000
<u>South Central Coast</u>	47 19	420 130	48 19	97,000 150,000	91,000 97,000
<u>San Diego</u>	25 33	470 220	23 30	420,000 220,000	430,000 170,000
<u>San Francisco Bay</u>	23 21	450 140	24 19	400,000 120,000	420,000 110,000
<u>San Joaquin Valley</u>	100	670 650	420 110	650,000 880,000	470,000 460,000
<u>Salton Sea</u>	24 24	430 150	24 24	420,000 200,000	91,000 110,000
<u>Sacramento Valley</u>	39 45	220 250	32 37	470,000 250,000	470,000 190,000
<u>Statewide</u>	630	4,200	660	4,700,000	3,100,000

Note: The higher central estimate for the benefit values (either 1-hour or 8-hour averaging times) is given above for each endpoint by Some columns may not add up to the statewide totals due to rounding. Since

1-hour and 8-hour concentrations are highly correlated, it is not appropriate to add the estimated impacts from Tables B-6, B-7 and B-8 together. Table B-8 should be used to estimate the maximum health impacts per air basin. The uncertainty behind the mortality estimates is on the order of +/- 50% and varies for other endpoints.

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## Supplement to Appendix B

### Rollback Formulae

For the technical reader, the mathematical formulae for our rollback procedure follow. Denote:

OzCurrent = current daily ozone observed value,  
BasinMax = design value based on three years of measured data,  
BG = background ozone of 0.04 ppm,  
Std = ~~proposed standard (0.09 ppm for 1-hour and 0.070 ppm for 8-hour),~~ 0.094 ppm for 1-hour, or basin-specific equivalent 1-hour design value for 8-hour standard of 0.070 ppm, or basin-specific equivalent 1-hour design value for federal 8-hour standard of 0.084 ppm, and  
OzAttain = rolled-back ozone value in the “attainment” scenario.

First, the reduction percentage (or reduction factor RF) was calculated for each basin as follows:

If BasinMax > Std, then  $RF = (BasinMax - Std) / (BasinMax - BG)$ .  
If BasinMax ≤ Std, then RF = 0.

The rollback factor, 1-RF, is applied as follows. For all sites within the basin, the portion of the site’s current ozone levels above background was adjusted:

If OzCurrent > BG, then  $OzAttain = BG + (1 - RF) \times (OzCurrent - BG)$ .  
If OzCurrent ≤ BG, then OzAttain = OzCurrent.

The change in ozone concentrations is OzCurrent – OzAttain, calculated at the daily level for each site, which is the difference between the observed value and the rolled-back value for each site on each day of the year.

Note that we used the actual levels of the standards, 0.09 and 0.070 ppm, in the rollback rather than the maximal values that round to the standards as is done with air quality modeling. Such modeling usually assumes worst-case meteorology, unlike our methodology of using the three-year high value.

### Rollback Method Development

The assumption of a constant rollback factor applied to an entire air basin was justified through an empirical analysis of the trends in the percentiles at South Coast Air Basin monitoring sites. This air basin was selected for the analysis since the air quality trends were clear, there is a range of coastal and inland environments, and a majority of benefits are projected to occur in that air basin. ~~Figures B-2 through B-11 and Tables B-7 through B-16~~ B-3 through B-12 and Tables B-9 through B-18 provide examples of the results from that analysis, and the materials are representative of the results used for development of the rollback factor applied in the benefits analysis. In the graphs, the

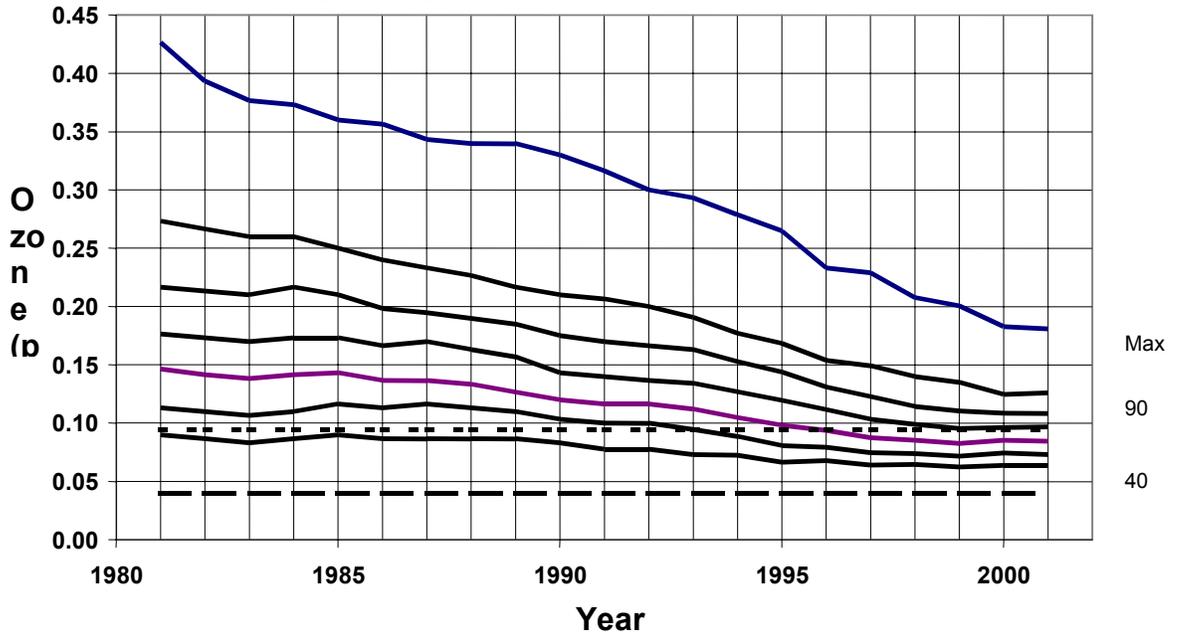
dotted line indicates the ozone standard, and the dashed line represents the assumed background level. Due to space limitations, the legend for every percentile line was not provided. However, the reader is advised to examine the solid lines in each graph, from top to bottom, to represent the maximum, 90<sup>th</sup> percentile, 80<sup>th</sup> percentile, 70<sup>th</sup> percentile, 60<sup>th</sup> percentile, 50<sup>th</sup> percentile, and 40<sup>th</sup> percentile of the annual distribution of ozone measurements.

Briefly, the analysis showed that since 1980, the trend in the monitored values associated with the distribution of percentiles was consistently downward, and that the relationships were relatively parallel and linear. Consequently, we assumed a constant rollback factor based on a basin's three-year high value, and applied it to all daily high values at all sites within the basin. In other words, when a control strategy is geared towards reducing the highest ozone levels in an air basin, its impact on days with low and moderate ozone levels is comparable to those days with high ozone levels.

### **Estimation of Exposed Population**

To estimate the number of people exposed to the ozone changes observed at each monitoring site, the county population was divided by the number of monitoring sites in a given county. For example, suppose a county has N monitoring stations and population POP according to year 2000 census. Then we would estimate that (POP/N) persons were exposed to ozone levels at each of the N monitors within this county. The health incidences were then calculated based on the concentration-response functions relating changes in ozone concentrations and exposed population for each day at each monitor. The sensitivity of this methodology is discussed in detail on page ~~B-15~~B-16.

**Trends in Annual Percentiles of the  
Daily Max. 1-Hr Ozone in the South Coast Air Basin**  
(three-year averages for percentiles 40, 50, 60, 70, 80, 90 and Max)



**Figure B-2-B-3: Trends in Annual Percentiles of Daily Max 1-hour Ozone in the South Coast Air Basin**

**Table B-7:B-9: Summary of Trends in Annual Percentiles of the Daily Max. 1-Hr Ozone in the South Coast Air Basin**

Indicator	Average Value During Period		
	1980-1982	1990-1992	2000-2002
<b>Maximum</b>	<b>0.427</b>	<b>0.317</b>	<b>0.183</b>
Δ% above background		28%	63%
<b>90<sup>th</sup> Percentile</b>	<b>0.273</b>	<b>0.207</b>	<b>0.125</b>
Δ% above background		29%	64%
<b>80<sup>th</sup> Percentile</b>	<b>0.217</b>	<b>0.170</b>	<b>0.109</b>
Δ% above background		26%	61%
<b>70<sup>th</sup> Percentile</b>	<b>0.177</b>	<b>0.140</b>	<b>0.096</b>
Δ% above background		27%	59%
<b>60<sup>th</sup> Percentile</b>	<b>0.147</b>	<b>0.117</b>	<b>0.086</b>
Δ% above background		28%	57%
<b>50<sup>th</sup> Percentile</b>	<b>0.113</b>	<b>0.100</b>	<b>0.075</b>
Δ% above background		18%	53%
<b>40<sup>th</sup> Percentile</b>	<b>0.090</b>	<b>0.078</b>	<b>0.064</b>
Δ% above background		24%	52%
note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.			

### Trends in Annual Percentiles of the Daily Max. 8-Hr Ozone in the South Coast Air Basin

(three-year averages for percentiles 40, 50, 60, 70, 80, 90 and Max)

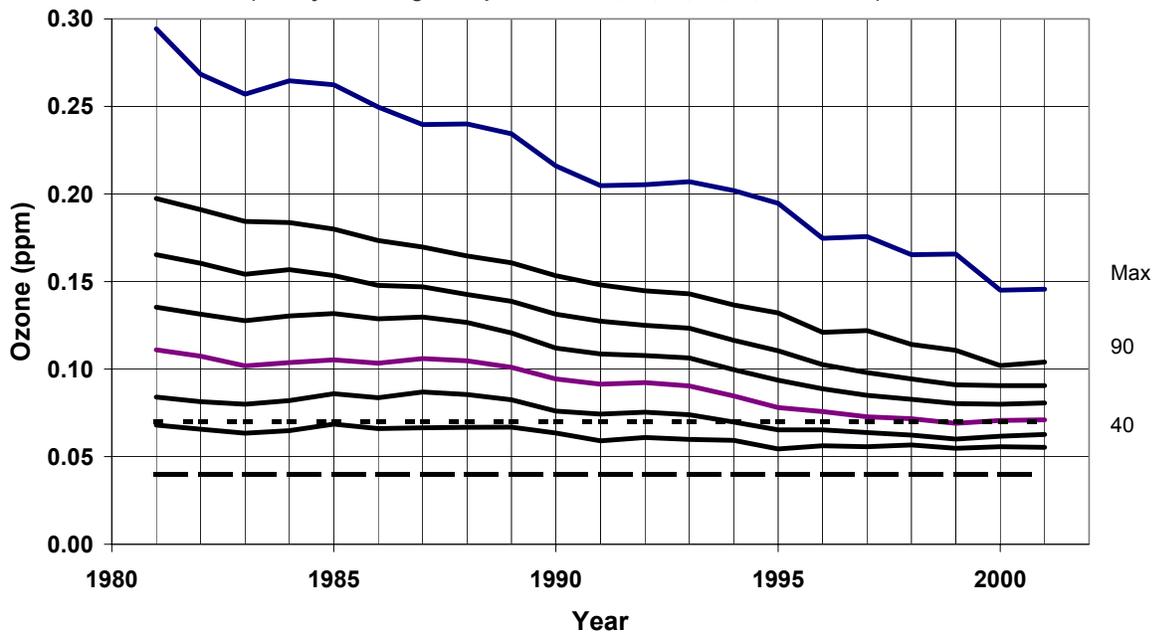
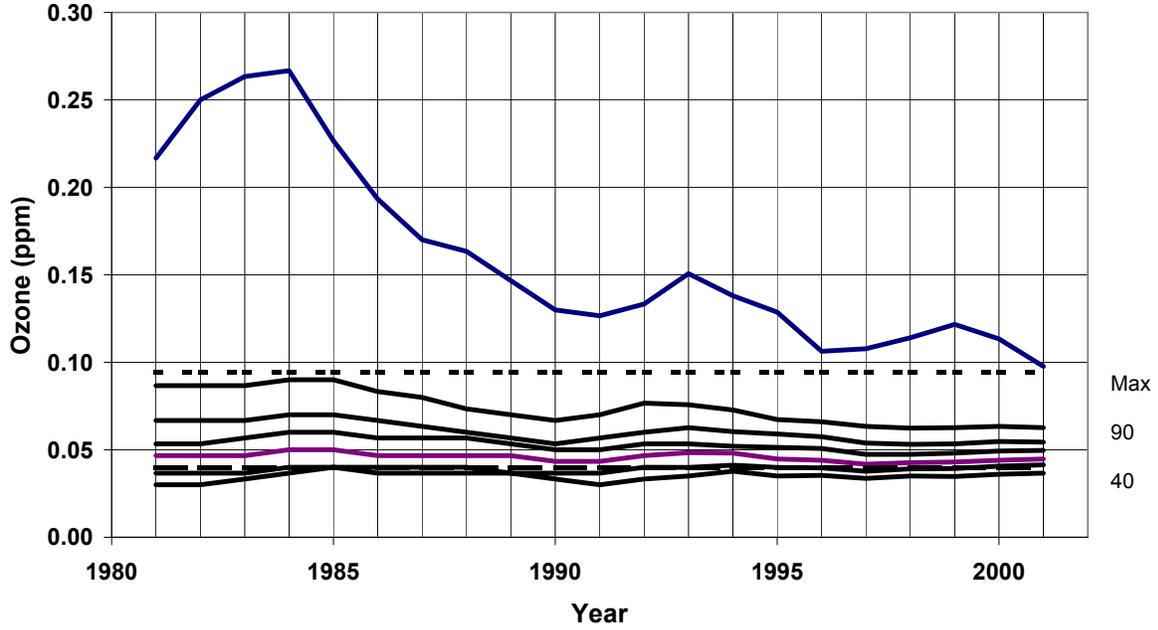


Figure B-3:B-4: Trends in Annual Percentiles of Daily Max 8-hour Ozone in the South Coast Air Basin

**Table B-8:B-10: Summary of Trends in Annual Percentiles of the Daily Max. 8-hr Ozone in the South Coast Air Basin**

Indicator	Average Value During Period		
	1980-1982	1990-1992	2000-2002
<b>Maximum</b>	<b>0.294</b>	<b>0.205</b>	<b>0.145</b>
Δ% above background		35%	59%
<b>90<sup>th</sup> Percentile</b>	<b>0.197</b>	<b>0.148</b>	<b>0.102</b>
Δ% above background		31%	61%
<b>80<sup>th</sup> Percentile</b>	<b>0.165</b>	<b>0.127</b>	<b>0.091</b>
Δ% above background		30%	60%
<b>70<sup>th</sup> Percentile</b>	<b>0.135</b>	<b>0.109</b>	<b>0.080</b>
Δ% above background		28%	58%
<b>60<sup>th</sup> Percentile</b>	<b>0.111</b>	<b>0.091</b>	<b>0.071</b>
Δ% above background		28%	57%
<b>50<sup>th</sup> Percentile</b>	<b>0.084</b>	<b>0.074</b>	<b>0.062</b>
Δ% above background		22%	51%
<b>40<sup>th</sup> Percentile</b>	<b>0.068</b>	<b>0.059</b>	<b>0.056</b>
Δ% above background		32%	44%
note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.			

**Trends in Annual Percentiles of the  
Daily Max. 1-Hr Ozone at N. Long Beach**  
(three-year averages for percentiles 40, 50, 60, 70, 80, 90 and Max)

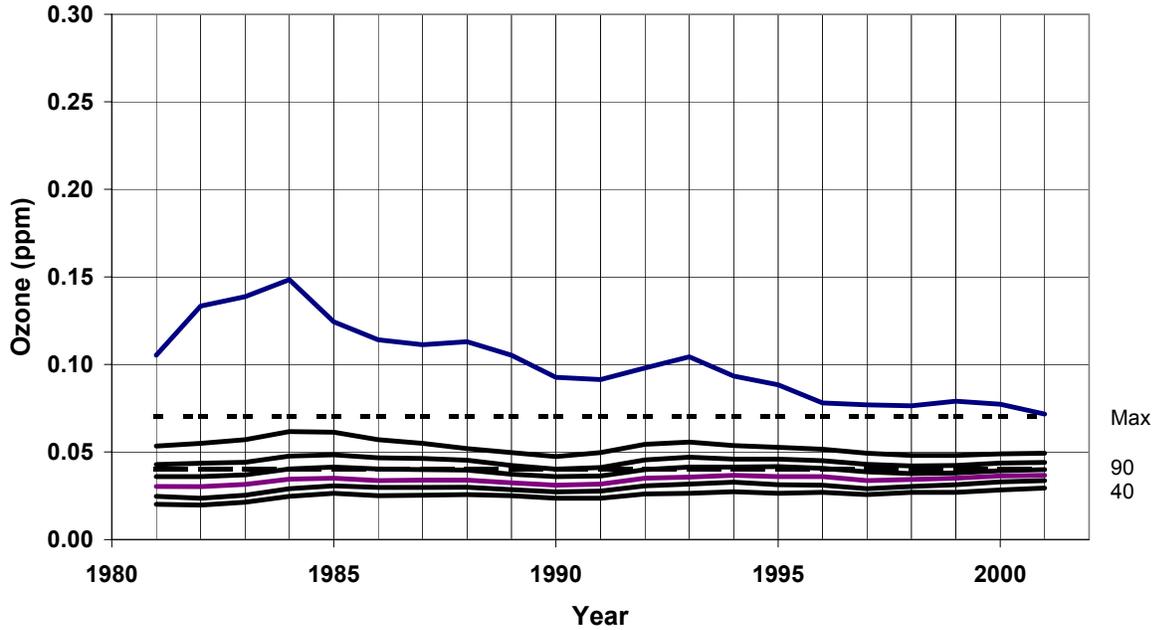


**Figure B-4: Trends in Annual Percentiles of Daily Max 1-hour Ozone at N. Long Beach**

**Table B-9:B-11: Summary of Trends in Annual Percentiles of the Daily Max 1-hour Ozone at N. Long Beach**

Indicator	Average Value During Period		
	1980-1982	1990-1992	2000-2002
<b>Maximum</b>	<b>0.217</b>	<b>0.127</b>	<b>0.113</b>
Δ% above background		51%	58%
<b>90<sup>th</sup> Percentile</b>	<b>0.087</b>	<b>0.070</b>	<b>0.063</b>
Δ% above background		36%	50%
<b>80<sup>th</sup> Percentile</b>	<b>0.067</b>	<b>0.057</b>	<b>0.055</b>
Δ% above background		38%	45%
<b>70<sup>th</sup> Percentile</b>	<b>0.053</b>	<b>0.050</b>	<b>0.049</b>
Δ% above background		25%	30%
<b>60<sup>th</sup> Percentile</b>	<b>0.047</b>	<b>0.043</b>	<b>0.044</b>
Δ% above background		50%	40%
<b>50<sup>th</sup> Percentile</b>	<b>0.037</b>	<b>0.037</b>	<b>0.041</b>
Δ% above background		Percentiles are below background.	
<b>40<sup>th</sup> Percentile</b>	<b>0.030</b>	<b>0.030</b>	<b>0.036</b>
Δ% above background		Percentiles are below background.	
note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.			

**Trends in Annual Percentiles of the  
Daily Max. 8-Hr Ozone at N. Long Beach**  
(three-year averages for percentiles 40, 50, 60, 70, 80, 90 and Max)

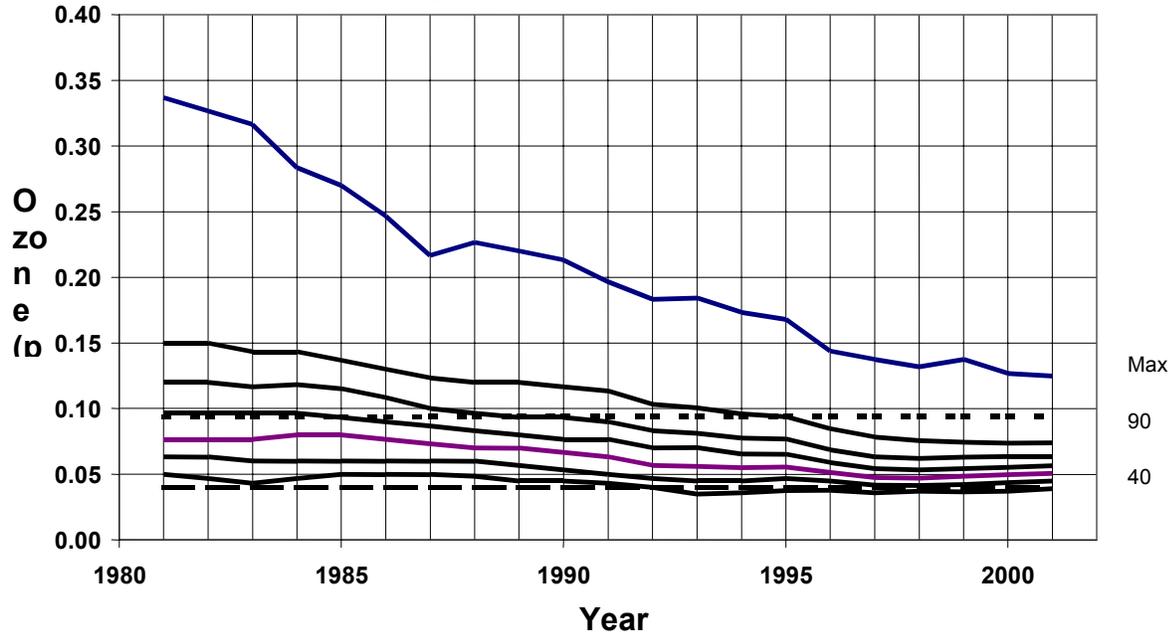


**Figure B-5:B-6: Trends in annual percentiles of daily max 8-hour ozone at N. Long Beach**

**Table B-10:B-12: Summary of Trends in Annual Percentiles of the Daily Max 8-hour Ozone at N. Long Beach**

Indicator	Average Value During Period		
	1980-1982	1990-1992	2000-2002
<b>Maximum</b>	<b>0.105</b>	<b>0.091</b>	<b>0.077</b>
Δ% above background		21%	43%
<b>90<sup>th</sup> Percentile</b>	<b>0.053</b>	<b>0.050</b>	<b>0.049</b>
Δ% above background		28%	33%
<b>80<sup>th</sup> Percentile</b>	<b>0.043</b>	<b>0.041</b>	<b>0.044</b>
Δ% above background		59%	-29%
<b>70<sup>th</sup> Percentile</b>	<b>0.036</b>	<b>0.036</b>	<b>0.039</b>
Δ% above background		Percentiles are below background.	
<b>60<sup>th</sup> Percentile</b>	<b>0.030</b>	<b>0.032</b>	<b>0.036</b>
Δ% above background		Percentiles are below background.	
<b>50<sup>th</sup> Percentile</b>	<b>0.025</b>	<b>0.028</b>	<b>0.033</b>
Δ% above background		Percentiles are below background.	
<b>40<sup>th</sup> Percentile</b>	<b>0.020</b>	<b>0.024</b>	<b>0.028</b>
Δ% above background		Percentiles are below background.	
note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.			

**Trends in Annual Percentiles of the  
Daily Max. 1-Hr Ozone at L.A. - N. Main**  
(three-year averages for percentiles 40, 50, 60, 70, 80, 90 and Max)

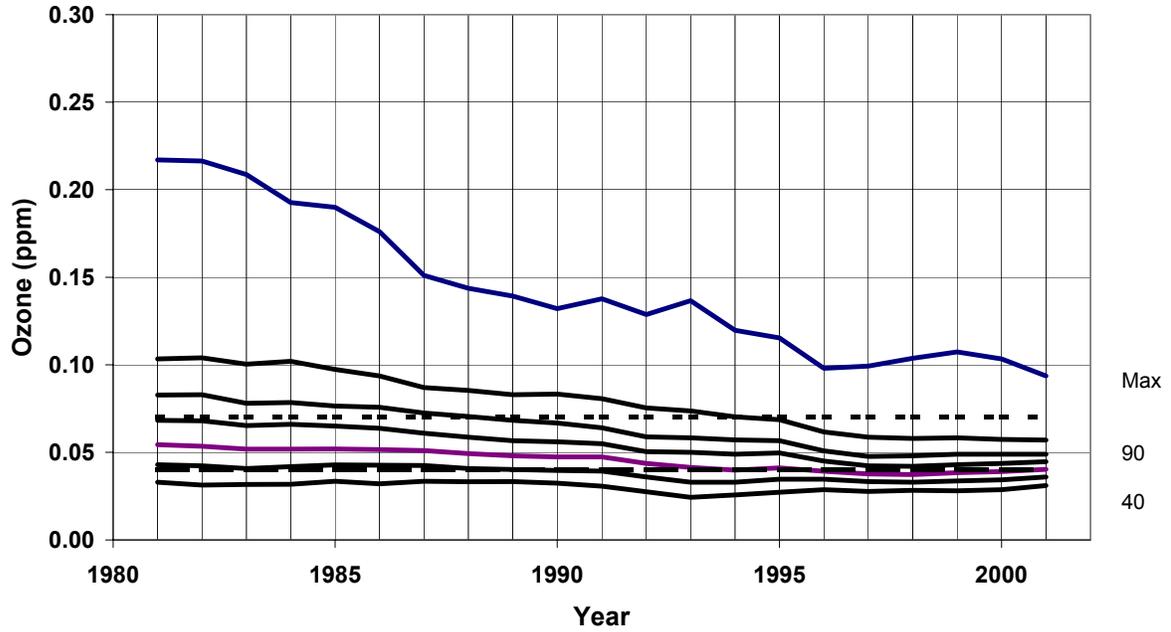


**Figure B-6:B-7: Trends in annual percentiles of daily max 1-hour ozone  
L.A. – N. Main**

**Table B-11:B-13: Summary of Trends in Annual Percentiles of the Daily  
Max 1-hour Ozone at L.A. - N. Main**

Indicator	Average Value During Period		
	1980-1982	1990-1992	2000-2002
<b>Maximum</b>	<b>0.337</b>	<b>0.197</b>	<b>0.127</b>
Δ% above background		47%	71%
<b>90<sup>th</sup> Percentile</b>	<b>0.150</b>	<b>0.113</b>	<b>0.074</b>
Δ% above background		33%	69%
<b>80<sup>th</sup> Percentile</b>	<b>0.120</b>	<b>0.090</b>	<b>0.064</b>
Δ% above background		38%	70%
<b>70<sup>th</sup> Percentile</b>	<b>0.097</b>	<b>0.077</b>	<b>0.055</b>
Δ% above background		35%	73%
<b>60<sup>th</sup> Percentile</b>	<b>0.077</b>	<b>0.063</b>	<b>0.050</b>
Δ% above background		36%	74%
<b>50<sup>th</sup> Percentile</b>	<b>0.063</b>	<b>0.050</b>	<b>0.044</b>
Δ% above background		57%	84%
<b>40<sup>th</sup> Percentile</b>	<b>0.050</b>	<b>0.043</b>	<b>0.037</b>
Δ% above background		67%	100%
note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.			

**Trends in Annual Percentiles of the  
Daily Max. 8-Hr Ozone at L.A. - N. Main**  
(three-year averages for percentiles 40, 50, 60, 70, 80, 90 and Max)

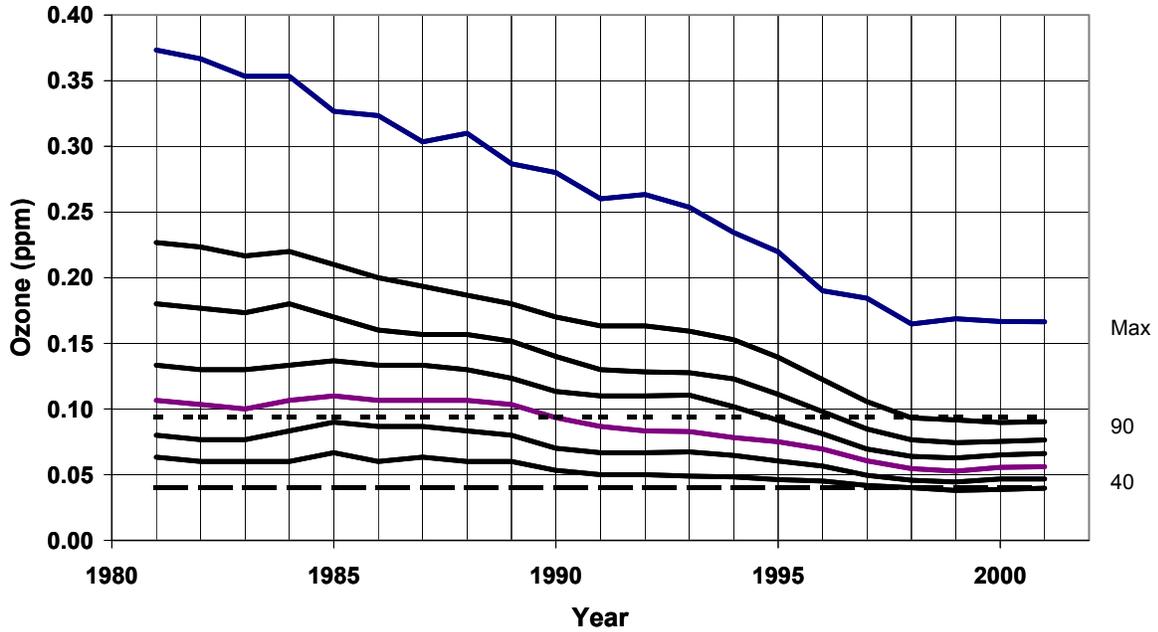


**Figure B-7:B-8: Trends in annual percentiles of daily max 8-hour ozone at L.A.-N. Main**

**Table B-12:B-14: Summary of Trends in Annual Percentiles of the Daily Max 8-hour Ozone at L.A. - N. Main**

Indicator	Average Value During Period		
	1980-1982	1990-1992	2000-2002
<b>Maximum</b>	<b>0.217</b>	<b>0.138</b>	<b>0.103</b>
Δ% above background		45%	64%
<b>90<sup>th</sup> Percentile</b>	<b>0.103</b>	<b>0.081</b>	<b>0.057</b>
Δ% above background		36%	73%
<b>80<sup>th</sup> Percentile</b>	<b>0.083</b>	<b>0.064</b>	<b>0.049</b>
Δ% above background		44%	79%
<b>70<sup>th</sup> Percentile</b>	<b>0.068</b>	<b>0.055</b>	<b>0.044</b>
Δ% above background		47%	87%
<b>60<sup>th</sup> Percentile</b>	<b>0.054</b>	<b>0.047</b>	<b>0.039</b>
Δ% above background		49%	100%
<b>50<sup>th</sup> Percentile</b>	<b>0.043</b>	<b>0.039</b>	<b>0.034</b>
Δ% above background		100%	100%
<b>40<sup>th</sup> Percentile</b>	<b>0.033</b>	<b>0.031</b>	<b>0.029</b>
Δ% above background		Percentiles are below background.	
<p>note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.</p>			

**Trends in Annual Percentiles of the  
Daily Max. 1-Hr Ozone at Azusa**  
(three-year averages for percentiles 40, 50, 60, 70, 80, 90 and Max)

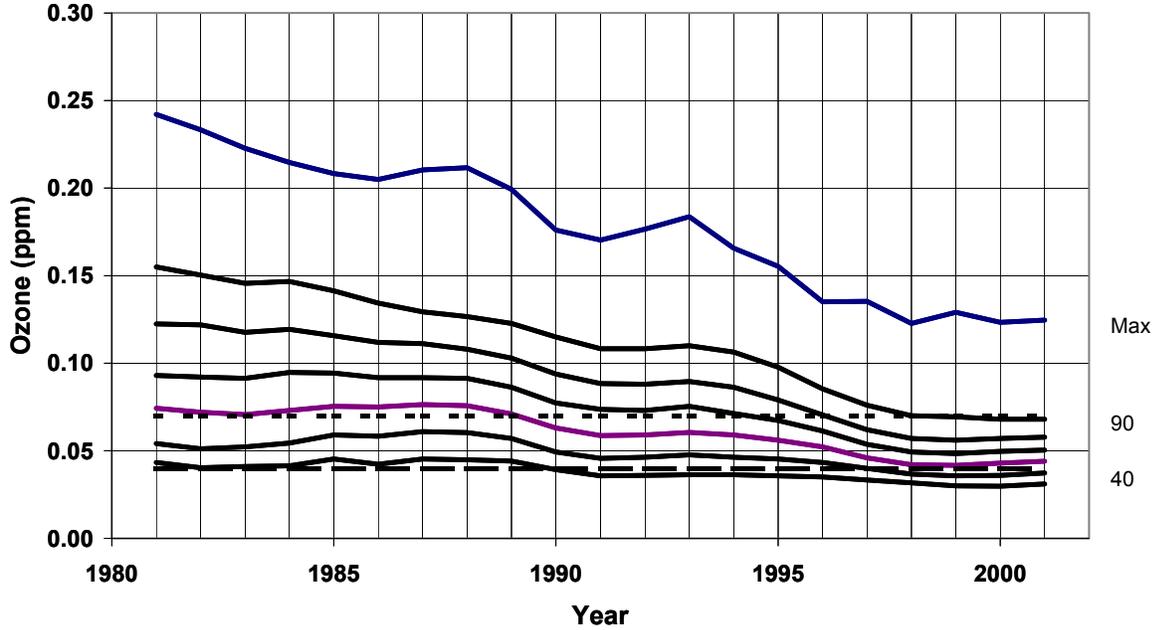


**Figure B-8:B-9: Trends in annual percentiles of daily max 1-hour ozone at Azusa**

**Table B-13:B-15: Summary of Trends in Annual Percentiles of the Daily Max 1-hour Ozone at Azusa**

<b>Summary of Trends in Annual Percentiles of the Daily Max. 1-Hr Ozone at Azusa</b>			
<b>Indicator</b>	<b>Average Value During Period</b>		
	<b>1980-1982</b>	<b>1990-1992</b>	<b>2000-2002</b>
<b>Maximum</b>	<b>0.373</b>	<b>0.260</b>	<b>0.167</b>
Δ% above background		34%	62%
<b>90<sup>th</sup> Percentile</b>	<b>0.227</b>	<b>0.163</b>	<b>0.090</b>
Δ% above background		34%	73%
<b>80<sup>th</sup> Percentile</b>	<b>0.180</b>	<b>0.130</b>	<b>0.075</b>
Δ% above background		36%	75%
<b>70<sup>th</sup> Percentile</b>	<b>0.133</b>	<b>0.110</b>	<b>0.065</b>
Δ% above background		25%	73%
<b>60<sup>th</sup> Percentile</b>	<b>0.107</b>	<b>0.087</b>	<b>0.056</b>
Δ% above background		30%	77%
<b>50<sup>th</sup> Percentile</b>	<b>0.080</b>	<b>0.067</b>	<b>0.047</b>
Δ% above background		33%	83%
<b>40<sup>th</sup> Percentile</b>	<b>0.063</b>	<b>0.050</b>	<b>0.039</b>
Δ% above background		57%	100%
note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.			

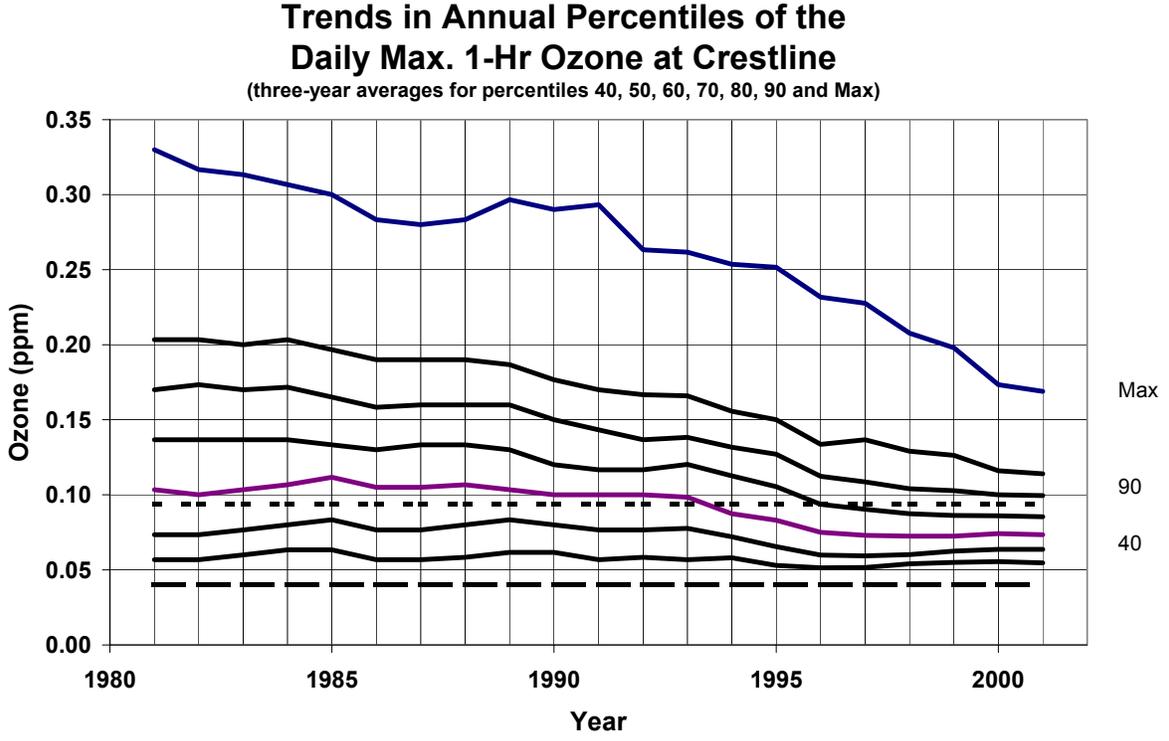
**Trends in Annual Percentiles of the  
Daily Max. 8-Hr Ozone at Azusa**  
(three-year averages for percentiles 40, 50, 60, 70, 80, 90 and Max)



**Figure B-9:B-10: Trends in annual percentiles of daily max 8-hour ozone at  
Azusa**

**Table B-14:B-16: Summary of Trends in Annual Percentiles of the Daily Max 8-hour Ozone at Azusa**

Indicator	Average Value During Period		
	1980-1982	1990-1992	2000-2002
<b>Maximum</b>	<b>0.242</b>	<b>0.170</b>	<b>0.123</b>
Δ% above background		35%	59%
<b>90<sup>th</sup> Percentile</b>	<b>0.155</b>	<b>0.108</b>	<b>0.068</b>
Δ% above background		41%	76%
<b>80<sup>th</sup> Percentile</b>	<b>0.123</b>	<b>0.088</b>	<b>0.057</b>
Δ% above background		41%	79%
<b>70<sup>th</sup> Percentile</b>	<b>0.093</b>	<b>0.074</b>	<b>0.050</b>
Δ% above background		36%	82%
<b>60<sup>th</sup> Percentile</b>	<b>0.074</b>	<b>0.059</b>	<b>0.043</b>
Δ% above background		46%	100%
<b>50<sup>th</sup> Percentile</b>	<b>0.054</b>	<b>0.046</b>	<b>0.036</b>
Δ% above background		60%	100%
<b>40<sup>th</sup> Percentile</b>	<b>0.043</b>	<b>0.036</b>	<b>0.030</b>
Δ% above background		100%	100%
note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.			

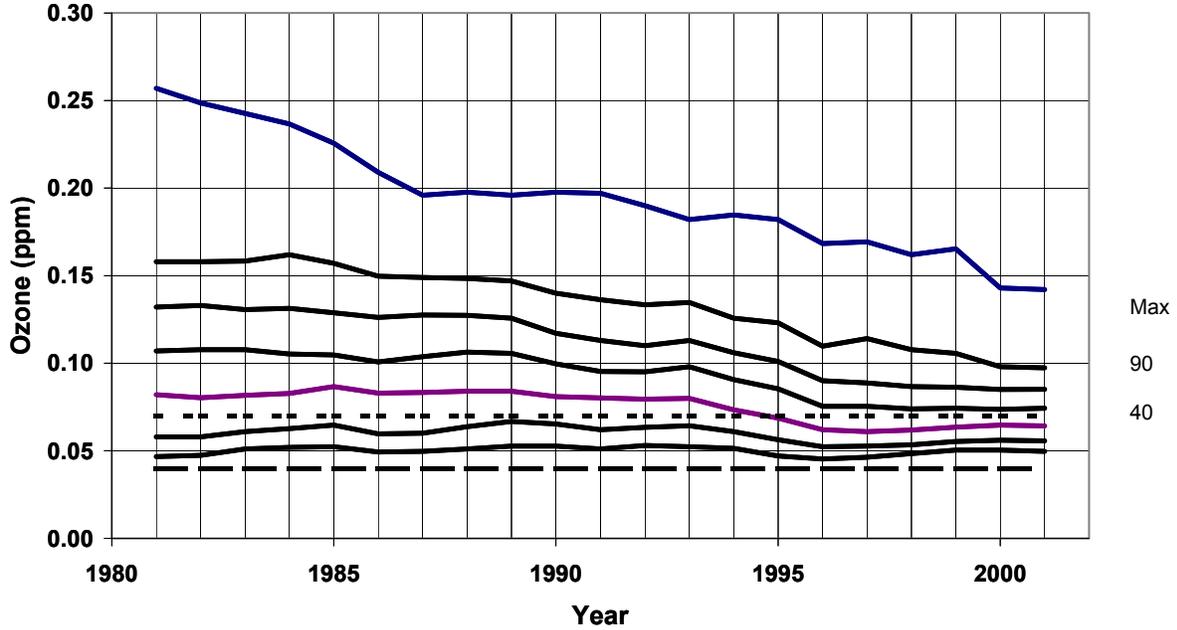


**Figure B-10: Trends in annual percentiles of daily max 1-hour ozone at Crestline**

**Table B-15:B-17: Summary of Trends in Annual Percentiles of the Daily Max 1-hour Ozone at Crestline**

Indicator	Average Value During Period		
	1980-1982	1990-1992	2000-2002
<b>Maximum</b>	<b>0.330</b>	<b>0.293</b>	<b>0.173</b>
Δ% above background		13%	54%
<b>90<sup>th</sup> Percentile</b>	<b>0.203</b>	<b>0.170</b>	<b>0.116</b>
Δ% above background		20%	53%
<b>80<sup>th</sup> Percentile</b>	<b>0.170</b>	<b>0.143</b>	<b>0.100</b>
Δ% above background		21%	54%
<b>70<sup>th</sup> Percentile</b>	<b>0.137</b>	<b>0.117</b>	<b>0.086</b>
Δ% above background		21%	52%
<b>60<sup>th</sup> Percentile</b>	<b>0.103</b>	<b>0.100</b>	<b>0.074</b>
Δ% above background		5%	46%
<b>50<sup>th</sup> Percentile</b>	<b>0.073</b>	<b>0.077</b>	<b>0.064</b>
Δ% above background		-10%	29%
<b>40<sup>th</sup> Percentile</b>	<b>0.057</b>	<b>0.057</b>	<b>0.056</b>
Δ% above background		0%	7%
note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.			

**Trends in Annual Percentiles of the  
Daily Max. 8-Hr Ozone at Crestline**  
(three-year averages for percentiles 40, 50, 60, 70, 80, 90 and Max)



**Figure B-11:2: Trends in annual percentiles of daily max 8-hour ozone at Crestline**

**Table B-16:B-18: Summary of Trends in Annual Percentiles of the Daily Max 8-hour Ozone at Crestline**

Indicator	Average Value During Period		
	1980-1982	1990-1992	2000-2002
<b>Maximum</b>	<b>0.257</b>	<b>0.197</b>	<b>0.143</b>
Δ% above background		28%	53%
<b>90<sup>th</sup> Percentile</b>	<b>0.158</b>	<b>0.136</b>	<b>0.098</b>
Δ% above background		18%	51%
<b>80<sup>th</sup> Percentile</b>	<b>0.132</b>	<b>0.113</b>	<b>0.085</b>
Δ% above background		21%	51%
<b>70<sup>th</sup> Percentile</b>	<b>0.107</b>	<b>0.095</b>	<b>0.074</b>
Δ% above background		17%	50%
<b>60<sup>th</sup> Percentile</b>	<b>0.082</b>	<b>0.080</b>	<b>0.065</b>
Δ% above background		4%	41%
<b>50<sup>th</sup> Percentile</b>	<b>0.058</b>	<b>0.062</b>	<b>0.056</b>
Δ% above background		-22%	11%
<b>40<sup>th</sup> Percentile</b>	<b>0.047</b>	<b>0.051</b>	<b>0.050</b>
Δ% above background		-65%	-55%
note: Delta % above background is the change in the portion of measured ozone since 1980-82 above "background", where background is defined as 0.04 ppm.			

**Table B-17:B-19: Baseline Incidence Rates (Incidence/1000 Persons/Year)**

County Name	Mortality (Short-Term Exposures) Non-Accidental, All Ages	Hospital Admissions, All Respiratory, All Ages	ER Visits for Asthma, Age Under 18	School Loss Days, All Illness, Age 5-17	MRAD Age>18
Alameda County	6.60	10.13	3.81	5990.10	7805.39
Alpine County	7.40	10.13	3.81	5990.10	7805.39
Amador County	9.99	10.13	3.81	5990.10	7805.39
Butte County	10.40	10.13	3.81	5990.10	7805.39
Calaveras County	8.90	10.13	3.81	5990.10	7805.39
Colusa County	7.10	10.13	3.81	5990.10	7805.39
Contra Costa County	6.78	10.13	3.81	5990.10	7805.39
Del Norte County	8.41	10.13	3.81	5990.10	7805.39
El Dorado County	6.29	10.13	3.81	5990.10	7805.39
Fresno County	6.41	10.13	3.81	5990.10	7805.39
Glenn County	7.71	10.13	3.81	5990.10	7805.39
Humboldt County	8.51	10.13	3.81	5990.10	7805.39
Imperial County	5.44	10.13	3.81	5990.10	7805.39
Inyo County	11.81	10.13	3.81	5990.10	7805.39
Kern County	6.60	10.13	3.81	5990.10	7805.39
Kings County	5.66	10.13	3.81	5990.10	7805.39
Lake County	13.13	10.13	3.81	5990.10	7805.39
Lassen County	5.75	10.13	3.81	5990.10	7805.39
Los Angeles County	6.08	10.13	3.81	5990.10	7805.39
Madera County	6.35	10.13	3.81	5990.10	7805.39
Marin County	7.47	10.13	3.81	5990.10	7805.39
Mariposa County	9.48	10.13	3.81	5990.10	7805.39
Mendocino County	8.89	10.13	3.81	5990.10	7805.39
Merced County	6.29	10.13	3.81	5990.10	7805.39
Modoc County	11.62	10.13	3.81	5990.10	7805.39
Mono County	3.87	10.13	3.81	5990.10	7805.39
Monterey County	5.88	10.13	3.81	5990.10	7805.39
Napa County	10.45	10.13	3.81	5990.10	7805.39
Nevada County	8.56	10.13	3.81	5990.10	7805.39
Orange County	5.68	10.13	3.81	5990.10	7805.39

Placer County	7.00	10.13	3.81	5990.10	7805.39
Plumas County	10.08	10.13	3.81	5990.10	7805.39
Riverside County	7.37	10.13	3.81	5990.10	7805.39
Sacramento County	7.14	10.13	3.81	5990.10	7805.39
San Benito County	5.06	10.13	3.81	5990.10	7805.39
San Bernardino County	6.10	10.13	3.81	5990.10	7805.39
San Diego County	6.41	10.13	3.81	5990.10	7805.39
San Francisco County	8.78	10.13	3.81	5990.10	7805.39
San Joaquin County	6.98	10.13	3.81	5990.10	7805.39
San Luis Obispo County	7.87	10.13	3.81	5990.10	7805.39
San Mateo County	6.77	10.13	3.81	5990.10	7805.39
Santa Barbara County	6.80	10.13	3.81	5990.10	7805.39
Santa Clara County	5.19	10.13	3.81	5990.10	7805.39
Santa Cruz County	6.56	10.13	3.81	5990.10	7805.39
Shasta County	9.50	10.13	3.81	5990.10	7805.39
Sierra County	9.26	10.13	3.81	5990.10	7805.39
Siskiyou County	10.42	10.13	3.81	5990.10	7805.39
Solano County	5.90	10.13	3.81	5990.10	7805.39
Sonoma County	8.17	10.13	3.81	5990.10	7805.39
Stanislaus County	7.22	10.13	3.81	5990.10	7805.39
Sutter County	7.43	10.13	3.81	5990.10	7805.39
Tehama County	9.90	10.13	3.81	5990.10	7805.39
Trinity County	10.73	10.13	3.81	5990.10	7805.39
Tulare County	6.71	10.13	3.81	5990.10	7805.39
Tuolumne County	9.50	10.13	3.81	5990.10	7805.39
Ventura County	5.76	10.13	3.81	5990.10	7805.39
Yolo County	6.37	10.13	3.81	5990.10	7805.39
Yuba County	7.26	10.13	3.81	5990.10	7805.39

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