Supplement to "A Particulate Matter Risk Assessment for Philadelphia and Los Angeles (Revised, November 1996)"

December 1996

Prepared for
Office of Air Quality Planning and Standards
U.S. Environmental Protection Agency
Research Triangle Park, NC

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Work funded through
Contract No. 68-W4-0029
Work Assignment 20-2

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1. Introduction

An assessment of the current health risks due to PM and the reduction in health risks associated with achieving each of a series of alternative PM standards was carried out for two locations in the United States, Philadelphia County and Southeast Los Angeles County. The method and results of these analyses are presented in a July 3, 1996 report titled, "A Particulate Matter Risk Assessment for Philadelphia and Los Angeles" (hereafter referred to as the July 3rd report).[1] The analyses described in the July 3rd report consider several different combinations of annual and daily PM-2.5 standards in which the forms of the standards are the same as the forms of the current PM-10 standards. In particular, the annual standards require that the annual average at each monitor in a location attains the specified annual standard concentration, and the daily standards require that no more than one day at each monitor in a location may exceed the specified daily standard concentration. Because there are several sources of uncertainty in these analyses, integrated uncertainty analyses, in which several sources of uncertainty are considered simultaneously, accompany the standard analyses.

Several additional analyses, carried out subsequent to the analyses described in the July 3rd report, are described in this supplement to that report. These analyses include integrated uncertainty analyses not included in the July 3rd report and analyses of alternative forms and levels of PM standards. Items 1, 2, and 4 below describe the additional integrated uncertainty analyses of short-term exposure mortality risk reduction (items 1 and 2) and long-term exposure mortality risk reduction (item 4) associated with those standards and standard forms considered in the July 3rd report. Item 3 describes the additional integrated uncertainty analysis of risk associated with long-term exposure mortality. Finally, items 5 and 6 describe the analyses of alternative PM standard forms and levels that were not considered in the July 3rd report.

1. Integrated uncertainty analyses of the reduced risk of short-term exposure mortality associated with meeting an annual PM-2.5 standard of 15 $\mu g/m^3$ and a daily PM-2.5 standard of 50 $\mu g/m^3$ in Philadelphia County. Risk reduction is expressed as the reduction in number of deaths, as a percent of total mortality, and as a percent of total PM-related mortality. The sources of uncertainty included are relative risk, background concentration, cutpoint, slope adjustment method, and form of rollback. The results are given in Exhibit 1. This analysis for

[1] A revised version of the July 3rd report ("A Particulate Matter Risk Assessment for Philadelphia and Los Angeles," Revised November 1996), in which several errors in the orginal report have been corrected, is available. References for all citations in this supplemental report may be found in the November 1996 revised report.

Exhibit 1

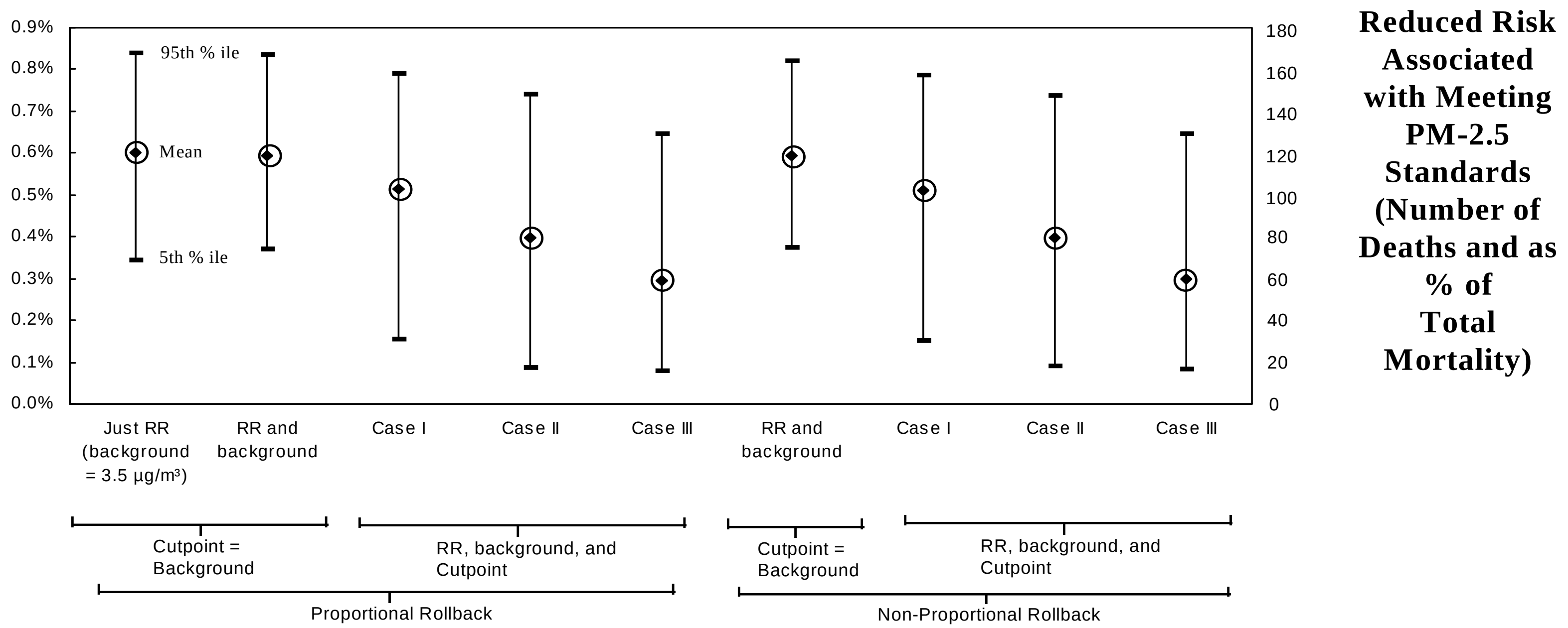
Uncertainty Analysis: Effect of Uncertainty of Relative Risk, Background Concentration, Cutpoint, Slope Adjustment Method, and Form of Rollback

Reduced Risk Associated with Meeting a PM-2.5 Standard of 15 μg/m^3 Annual and 50 μg/m^3 Daily

(Rollback to meet the annual standard is based on the annual average at the highest monitor; rollback to meet the daily standard is based on the second daily maximum at the highest monitor.)

Mortality Associated With Short-term Exposure to PM-2.5

Philadelphia County, September 1992-August 1993 (Population: 1.6 Million)



Cutpoint Weighting Schemes

	Case I	Case II	Case III
Background	0.5	0.2	0.05
10 μg/m^3	0.3	0.3	0.15
18 μg/m^3	0.15	0.3	0.5
30 μg/m^3	0.05	0.2	0.3

Mean Reduced Risk as % of Total PM-Associated Risk

(μg/m^3)	Just RR	RR and Background	Case I	Case II	Case III
Proportional	32.4%	32.9%	40.4%	48.7%	61.5%
Non-Proportional	--	32.9%	40.3%	48.5%	61.8%

Philadelphia is analogous to the analysis for Southeast Los Angeles Countypresented as Exhibit 8.10 in the July 3rd report.

2. Integrated uncertainty analyses of the reduced risk of short-term exposure mortality associated with attainment of an annual PM-2.5 standard of 15 $\mu g/m^3$ alone and in combination with each of a series of daily PM-2.5 standards in Philadelphia County. Risk reduction is expressed as the reduction in number of deaths, as a percent of total mortality, and as a percent of total PM-related mortality. The sources of uncertainty included are relative risk, background concentration, cutpoint, slope adjustment method, and form of rollback. The results are given in Exhibit 2. This analysis for Philadelphia is analogous to the analysis for Southeast Los Angeles County presented as Exhibit 8.11 in the July 3rd report.

3. Integrated uncertainty analysis of the risk of long-term exposure mortality associated with PM-2.5 above a cutpoint for a recent 12 month period in Philadelphia which attains the current PM-10 standards and for a 12 month period in Southeast Los Angeles County where air quality was adjusted to just attain the current PM-10 standards. Risk is expressed as a number of deaths and as a percent of total mortality. The sources of uncertainty included are relative risk, cutpoint, and slope adjustment method. The results are given in Exhibit 3 for Philadelphia and Exhibit 4 for Los Angeles. These analyses are analogous to the analysis for Philadelphia presented as Exhibit 7.33 in the July 3rd report (which, however, did not include slope adjustments).

4. Integrated uncertainty analyses of the reduced risk of long-term exposure mortality associated with attainment of an annual PM-2.5 standard of 15 $\mu g/m^3$ alone and in combination with each of a series of daily PM-2.5 standards in Philadelphia County and in Southeast Los Angeles County. The sources of uncertainty included are relative risk, cutpoint and slope adjustment method. The results are given in Exhibit 5, for Philadelphia County, and Exhibit 6, for Southeast Los Angeles County. These analyses are similar to the analyses carried out on short-term exposure mortality in Southeast Los Angeles County presented as Exhibit 8.11 in the July 3rd report. Because the rollback form (proportional or nonproportional) does not affect the predicted risk reduction for effects associated with long-term exposures, however, rollback form is not part of these analyses.

The annual average PM-2.5 concentration in Philadelphia County from September 1992 - August 1993 is 16.5 $\mu g/m^3$. The annual average PM-2.5 concentration in Southeast Los Angeles County in 1995 after rolling back to simulate attainment of current PM-10 standards is 23.0 $\mu g/m^3$. Background is not considered in any of the long-term exposure mortality analyses

Exhibit 2

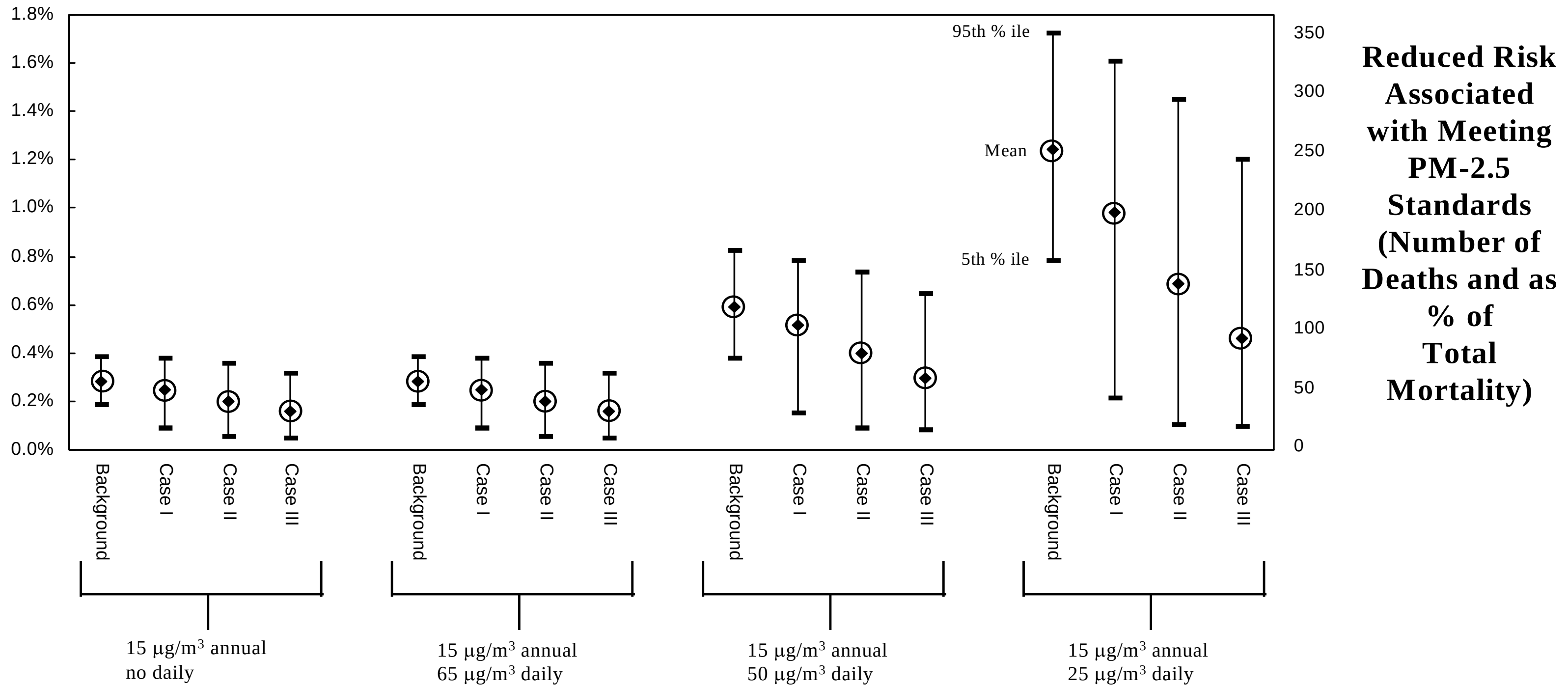
Uncertainty Analysis: Effect of Uncertainty of Relative Risk, Background Concentration, Cutpoint, Slope Adjustment Method, and Form of Rollback

Reduced Risk Associated with Meeting Alternative PM-2.5 Standards

(Rollback to meet the annual standard is based on the annual average at the highest monitor; rollback to meet the daily standard is based on the second daily maximum at the highest monitor.)

Mortality Associated With Short-term Exposure to PM-2.5

Philadelphia County, September 1992- August 1993 (Population: 1.6 Million)



Cutpoint Weighting Schemes

	Case I	Case II	Case III
Background	0.5	0.2	0.05
10 µg/m³	0.3	0.3	0.15
18 µg/m³	0.15	0.3	0.5
30 µg/m³	0.05	0.2	0.3

Mean Reduced Risk as % of Total PM-Associated Risk

(µg/m³)	RR and Background	Case I	Case II	Case III
15 Annual only	15.7%	19.7%	24.8%	32.8%
15 Annual/65 Daily	15.7%	19.7%	24.8%	32.8%
15 Annual/50 Daily	32.9%	40.3%	48.5%	61.8%
15 Annual/25 Daily	69.1%	77.4%	84.3%	95.3%

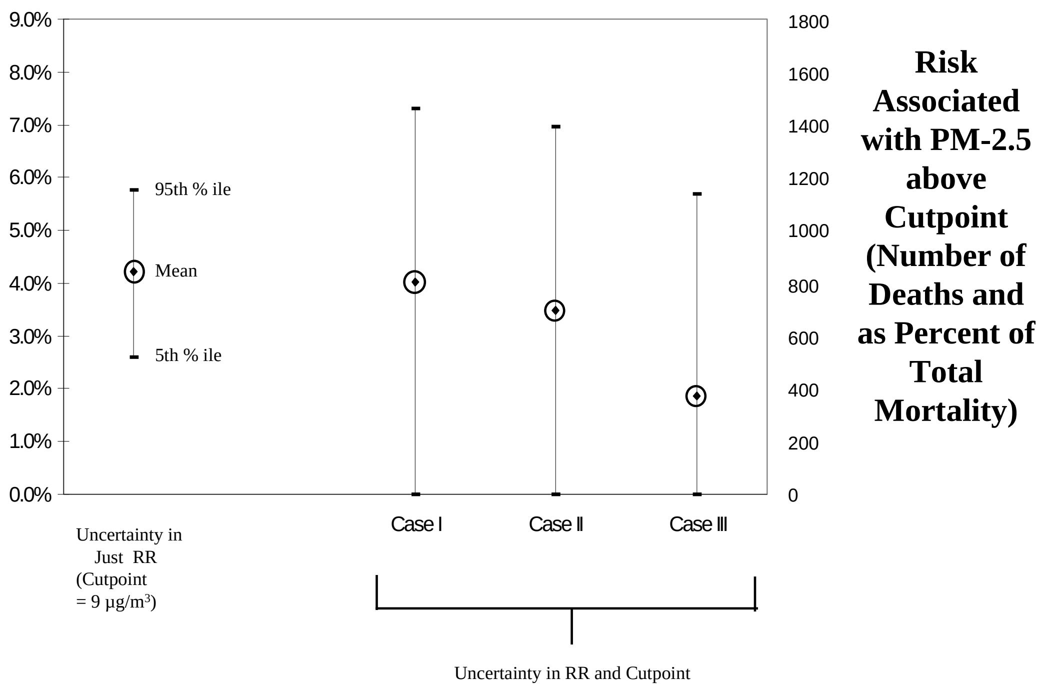
Exhibit 3

Uncertainty Analysis: Effect of Uncertainty of Relative Risk, Cutpoint, and Slope Adjustment

Mortality Associated With Long-Term Exposure to PM-2.5

Philadelphia County, September 1992- August 1993

(Population: 1.6 Million)



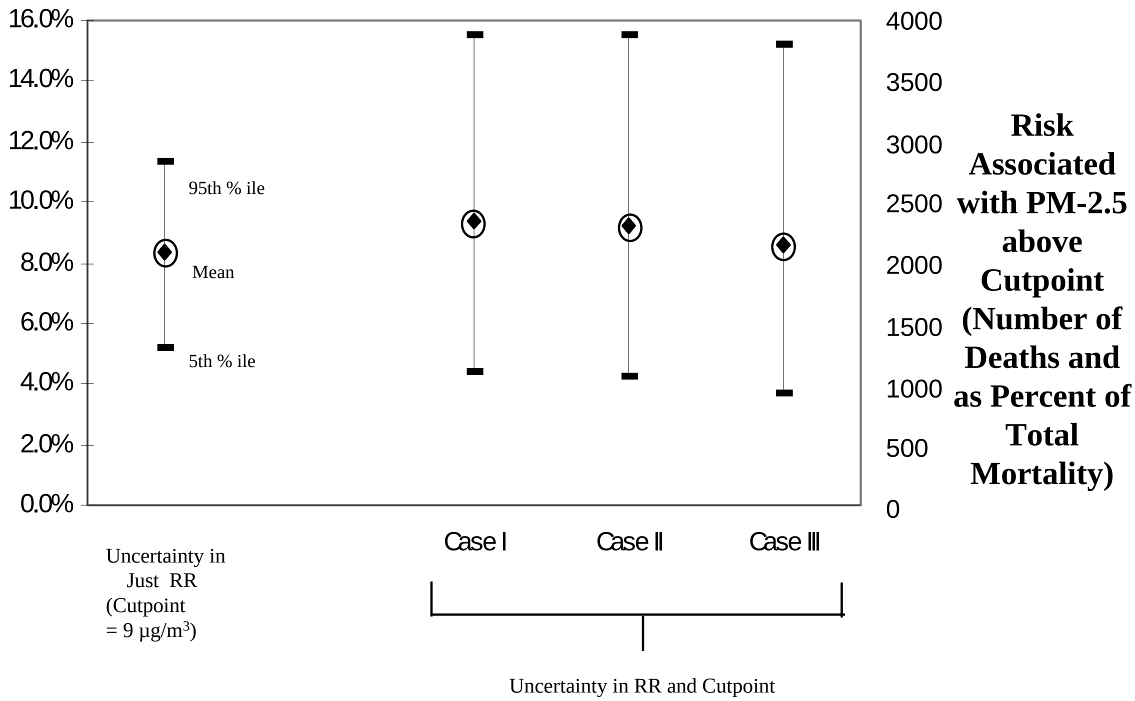
Cutpoint Weighting Schemes

	Case I	Case II	Case III
9 µg/m^3	0.55	0.35	0.10
12.5 µg/m^3	0.20	0.35	0.20
15 µg/m^3	0.15	0.20	0.40
18 µg/m^3	0.10	0.10	0.30

Exhibit 4

Uncertainty Analysis: Effect of Uncertainty of Relative Risk, Cutpoint, and Slope Adjustment

Mortality Associated With Long-Term Exposure to PM-2.5
Upon Meeting the Current PM-10 Standards
Southeast Los Angeles County, 1995 (Population: 3.6 Million)

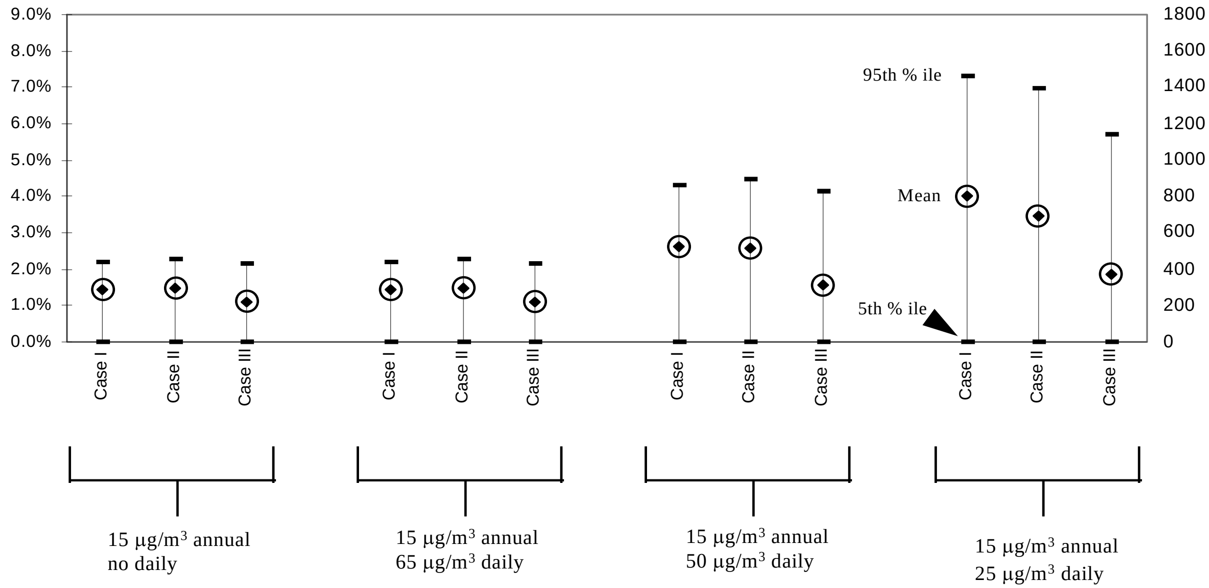


Cutpoint Weighting Schemes

	Case I	Case II	Case III
9 μg/m^3	0.55	0.35	0.10
12.5 μg/m^3	0.20	0.35	0.20
15 μg/m^3	0.15	0.20	0.40
18 μg/m^3	0.10	0.10	0.30

Exhibit 5

Uncertainty Analysis: Effect of Uncertainty of Relative Risk, Cutpoint, and Slope Adjustment
Reduced Risk Associated with Meeting Alternative PM-2.5 Standards
(Rollback to meet the annual standard is based on the annual average at the highest monitor;
rollback to meet the daily standard is based on the second daily maximum at the highest monitor.)
Mortality Associated With Long-term Exposure to PM-2.5
Philadelphia County, September 1992- August 1993 (Population: 1.6 Million)



Reduced Risk Associated with Meeting PM-2.5 Standards (Number of Deaths and as % of Total Mortality)

Cutpoint Weighting Schemes

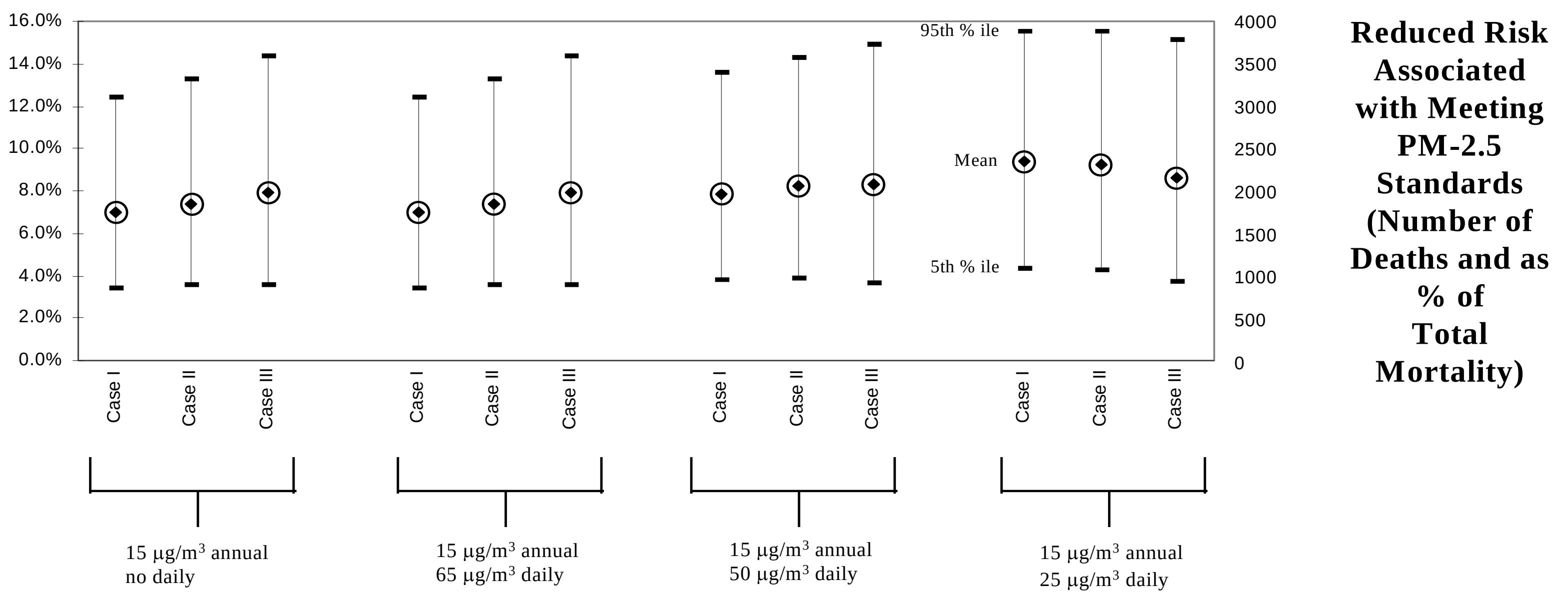
	Case I	Case II	Case III
9 μg/m³	0.55	0.35	0.10
12.5 μg/m³	0.20	0.35	0.20
15 μg/m³	0.15	0.20	0.40
18 μg/m³	0.10	0.10	0.30

Mean Reduced Risk as a % of Total PM-Associated Risk

μg/m³	Case I	Case II	Case III
15 annual only	36%	42%	58%
15 annual/65 daily	36%	42%	58%
15 annual/50 daily	65%	75%	85%
15 annual/25 daily	100%	100%	100%

Exhibit 6

Uncertainty Analysis: Effect of Uncertainty of Relative Risk, Cutpoint, and Slope Adjustment
Reduced Risk Associated with Meeting Alternative PM-2.5 Standards
(Rollback to meet the annual standard is based on the annual average at the highest monitor;
rollback to meet the daily standard is based on the second daily maximum at the highest monitor.)
(PM-2.5 was rolled back prior to analysis to simulate attainment of current PM-10 standards.)
Mortality Associated With Long-term Exposure to PM-2.5
Southeast Los Angeles County, 1995 (Population: 3.6 Million)



Cutpoint Weighting Schemes

	Case I	Case II	Case III
9 μg/m³	0.55	0.35	0.10
12.5 μg/m³	0.20	0.35	0.20
15 μg/m³	0.15	0.20	0.40
18 μg/m³	0.10	0.10	0.30

Mean Reduced Risk as a % of Total PM-Associated Risk

μg/m³	Case I	Case II	Case III
15 annual only	75%	80%	92%
15 annual/65 daily	75%	80%	92%
15 annual/50 daily	84%	89%	96%
15 annual/25 daily	100%	100%	100%

(Exhibits 3 through 6) because in both Philadelphia County and Southeast Los Angeles County it is lower than the lowest observed level in the long-term exposure mortality study (Pope et al., 1995), which was 9 $\mu g/m^3$.

In addition to the sources of uncertainty that affect the slope of the concentration-response function for mortality associated with short-term exposure, the slope of the concentration-response function for mortality associated with long-term exposure has an additional source of uncertainty. This is described in Section 2 below, along with an explanation of how this additional source of uncertainty is included in the integrated uncertainty analyses for long-term exposure mortality (items 3 and 4 above).

5. Analyses of the risk reductions associated with attainment of alternative forms of annual and daily standards. The alternative annual standard is based on a spatial average of the annual averages at the monitors in a location, rather than the highest of the annual averages. In Exhibits 7 and 8, the alternative daily standard is based on the 98th percentile of the daily averages at each monitor in a location, rather than the second daily maximum. In Exhibits 9 and 10, a spatial average form of an annual standard of 15 $\mu g/m^3$ is considered in conjunction with a daily standard of 50 $\mu g/m^3$, using the 95th percentile, 98th percentile, 99th percentile, and second daily maximum forms of the daily standard. These analyses are analogous to the analyses presented in Exhibits 8.1 and 8.2 in the July 3rd report.

6. Integrated uncertainty analyses of the reduced risk of short-term exposure mortality associated with attainment of each of the combinations of alternative standard form annual and 98th percentile daily standards considered in item 5 above. Risk reduction is expressed as the reduction in number of deaths, as a percent of total mortality, and as a percent of total PM-related mortality. The sources of uncertainty included are relative risk, background concentration, cutpoint, slope adjustment method, and form of rollback. The results are given in Exhibit 11 for Philadelphia County and Exhibit 12 for Southeast Los Angeles County. These analyses of the alternative standard forms are analogous to the analysis for Southeast Los Angeles County presented as Exhibit 8.11 in the July 3rd report.

A more detailed description of the alternative standard forms and the particular combinations of annual and daily alternative form standards that were considered is given in Section 3.

Exhibit 7. Estimated Changes in Health Risks Associated with Meeting Alternative PM-2.5 Standards in Philadelphia County, September 1992 - August 1993 (for base case assumptions)

The Daily Standards are 98th Percentile Standards; the Annual Standards are Either Highest Monitor Avg. or Spatial Avg.#

Health Effects*		PM-2.5-Associated Incidence associated with current standards**	Reduction in Incidence Associated with Meeting Alternative Standards				
			20 ug/m3 annual (high monitor) and 65 ug/m3 daily	20 ug/m3 annual (spatial avg) and 65 ug/m3 daily	15 ug/m3 annual (high monitor) and 50 ug/m3 daily	15 ug/m3 annual (spatial avg) and 50 ug/m3 daily	12.5 ug/m3 annual (spatial avg) and 50 ug/m3 daily
Mortality	(A) Associated with short-term exposure (all ages)	370 (230 - 510)	0 (0 - 0)	0 (0 - 0)	60 (40 - 80)	50 (30 - 60)	120 (70 - 160)
	Percent Reduction in PM-Associated Incidence:* Percent Reduction in Total Incidence:********		0.0% 0.0%	0.0% 0.0%	16.2% 0.3%	13.5% 0.2%	32.4% 0.6%
	(B) Associated with long-term exposure (age 30 and over)	860 (540-1170)	0 (0 - 0)	0 (0 - 0)	230 (140-320)	190 (120-250)	470 (300-650)
	Percent Reduction in PM-Associated Incidence: Percent Reduction in Total Incidence:		0.0% 0	0.0% 0.0%	27.4% 1.3%	22.1% 1.0%	54.7% 2.6%
Hospital Admissions Respiratory	(C) Total Respiratory (all ages)	260 (70 - 450)	0 (0 - 0)	0 (0 - 0)	40 (10 - 70)	30 (10 - 60)	80 (20 - 140)
	Percent Reduction in PM-Associated Incidence: Percent Reduction in Total Incidence:		0.0% 0.0%	0.0% 0.0%	15.4% 0.3%	11.5% 0.2%	30.8% 0.6%
Hospital Admissions Cardiac	(D) Ischemic Heart Disease***** (>64 years old)	70 (30 - 120)	0 (0 - 0)	0 (0 - 0)	10 (0 - 20)	10 (0 - 10)	20 (10 - 40)
	(E) Congestive Heart Failure***** (>64 years old)	100 (50 - 150)	0 (0 - 0)	0 (0 - 0)	20 (10 - 20)	10 (10 - 20)	30 (20 - 50)
	Range of Percent Reductions in PM-Associated Incidence: Range of Percent Reductions in Total Incidence:		0.0% - 0.0% 0.0% - 0.0%	0.0% - 0.0% 0.0% - 0.0%	14.3% - 20.0% 0.1% - 0.3%	10.0% - 14.3% 0.1% - 0.1%	28.6% - 30.0% 0.2% - 0.4%
(F) Lower Respiratory Symptoms (8-12 yr. olds) ******		< 11000 > (6000 - 15000)	< 0 > (0 - 0)	< 0 > (0 - 0)	< 2000 > (1000 - 3000)	< 2000 > (1000 - 2000)	< 4000 > (2000 - 6000)
	Percent Reduction in PM-Associated Incidence: Percent Reduction in Total Incidence:		0.0% 0.0%	0.0% 0.0%	18.2% 3.6%	18.2% 3.6%	36.4% 7.3%

* Health effects are associated with short-term exposure to PM, unless otherwise specified.

** Health effects incidence was quantified across the range of PM concentrations observed in each study, when possible, but not below background PM-2.5 level. Background PM-2.5 is assumed to be 3.5 ug/m3 in Philadelphia County.

*** The percent reduction in PM-associated incidence achieved by attaining alternative standards as opposed to the current standards is the reduction in incidence divided by the incidence associated with current standards. For example, the percent reduction in PM-associated incidence of mortality associated with short-term exposure to PM-2.5 achieved by meeting both a 15 ug/m3 spatial average annual and a 50 ug/m3 daily standard is 50/370=13.5%

**** The percent reduction in total incidence achieved by attaining current or alternative standards is the reduction in incidence achieved by attaining the standard divided by the total (not only PM-associated) incidence.

***** PM-2.5 results based on using PM-2.5 mass as PM-10 mass in the PM-10 functions.

******Angle brackets <> indicate incidence calculated using baseline incidence rates reported in studies, with no adjustment for location-specific incidence rates. This increases the uncertainty in the incidence estimates.

Sources of Concentration-Response (C-R) Functions:
(A) C-R function based on pooled results from studies in six locations.
(B) Pope et al., 1995
(C) Thurston, et al., 1994
(D) Schwartz & Morris, 1995
(E) Schwartz & Morris, 1995
(F) Schwartz, et al., 1994

The numbers in parentheses for pooled functions are NOT standard confidence intervals. All the numbers in parentheses are interpreted as 90% credible intervals based on uncertainty analysis that takes into account both statistical uncertainty and possible geographic variability. See text in Chapter 7 for details.

#The 98th percentile form of the daily std. requires that the 98th percentile concentration at each monitor (rounded to the nearest ug/m3) meets the std. The highest 98th percentile concentration at a monitor in Philadelphia is 48 ug/m3. Therefore neither of the daily standards in this exhibit is the controlling standard.
The high monitor form of the annual standard requires that the annual average at each monitor (rounded to the nearest 0.1 ug/m3) meets the std. The highest annual avg. at a monitor in Philadelphia is 17.1 ug/m3. Therefore the 20 ug/m3 high monitor annual standard is not the controlling standard.
The spatial average form of the annual standard requires that the average of the annual averages at the monitors (rounded to the nearest 0.1 ug/m3) meets the std. The spatial avg. of annual averages in Philadelphia is 16.6 ug/m3. Therefore the 20 ug/m3 spatial average annual standard is not the controlling standard.

Exhibit 8. Estimated Changes in Health Risks Associated with Meeting Alternative PM-2.5 Standards in Southeast Los Angeles County, 1995* (for base case assumptions)

The Daily Standards are 98th Percentile Standards; the Annual Standards are Either Highest Monitor Avg. or Spatial Avg.#

Health Effects		PM-2.5-Related Incidence associated with current standards**	Reduction in Incidence Associated with Meeting Alternative Standards*: 20 ug/m3 annual (high monitor) and 65 ug/m3 daily	20 ug/m3 annual (spatial avg) and 65 ug/m3 daily	15 ug/m3 annual (high monitor) and 50 ug/m3 daily	15 ug/m3 annual (spatial avg) and 50 ug/m3 daily	12.5 ug/m3 annual (spatial avg) and 50 ug/m3 daily
Mortality	(A) Associated with short-term exposure (all ages)	710 (430 - 970)	230 (140 - 320)	230 (140 - 320)	350 (210 - 480)	350 (210 - 480)	370 (220 - 500)
	Percent Reduction in PM-Associated Incidence:*** **Percent Reduction in Total Incidence:*******		32.4% 0.9%	32.4% 0.9%	49.3% 1.4%	49.3% 1.4%	52.1% 1.5%
	(B) Associated with long-term exposure (age 30 and over)	2050 (1290-2770)	1000 (620-1360)	1000 (620-1360)	1470 (930 - 2020)	1470 (930 - 2020)	1550 (970-2120)
	Percent Reduction in PM-Associated Incidence: **Percent Reduction in Total Incidence:**		48.8% 4.2%	48.8% 4.2%	72.0% 6.2%	72.0% 6.2%	75.8% 6.5%
Hospital Admissions Respiratory	(C) Total Respiratory (all ages)	940 (250 - 1630)	310 (80 - 530)	310 (80 - 530)	460 (120 - 790)	460 (120 - 790)	480 (130 - 830)
	Percent Reduction in PM-Associated Incidence: **Percent Reduction in Total Incidence:**		33.0% 2.0%	33.0% 2.0%	48.9% 3.0%	48.9% 3.0%	51.1% 3.1%
Hospital Admissions Cardiac	(D) Ischemic Heart Disease ***** (>64 years old)	130 (50 - 200)	40 (20 - 70)	40 (20 - 70)	60 (20 - 100)	60 (20 - 100)	70 (20 - 110)
	(E) Congestive Heart Failure ***** (>64 years old)	140 (70 - 210)	50 (20 - 70)	50 (20 - 70)	70 (30 - 110)	70 (30 - 110)	70 (40 - 110)
	Range of Percent Reductions in PM-Associated Incidence: **Range of Percent Reductions in Total Incidence:**		30.8% - 35.7% 0.3% - 0.7%	30.8% - 35.7% 0.3% - 0.7%	46.2% - 50.0% 0.5% - 1.0%	46.2% - 50.0% 0.5% - 1.0%	50.0% - 53.8% 0.6% - 1.0%
(F) Lower Respiratory Symptoms (8-12 yr. olds)******		< 43000 > (23000 - 58000)	< 17000 > (8000 - 24000)	< 17000 > (8000 - 24000)	< 24000 > (12000 - 34000)	< 24000 > (12000 - 34000)	< 25000 > (13000 - 35000)
	Percent Reduction in PM-Associated Incidence: **Percent Reduction in Total Incidence:**		39.5% 11.3%	39.5% 11.3%	55.8% 16.0%	55.8% 16.0%	58.1% 16.7%

Health effects are associated with short-term exposure to PM, unless otherwise specified.

* Los Angeles County was not in attainment of current PM-10 standards in 1995. Figures shown assume actual PM-10 concentrations are first rolled back to simulate attainment of these standards, and that actual PM-2.5 concentrations are rolled back by the same percent as PM-10. See text in Chapter VI for details.

** Health effects incidence was quantified across the range of PM concentrations observed in each study, when possible, but not below background PM-2.5 level. Background PM-2.5 is assumed to be 2.5 ug/m3 in Southeast Los Angeles County.

*** The percent reduction in PM-associated incidence achieved by attaining alternative standards as opposed to the current standards is the reduction in incidence divided by the incidence associated with current standards. For example, the percent reduction in PM-associated incidence of mortality associated with short-term exposure to PM-2.5 achieved by meeting both a 12.5 ug/m3 annual and a 50 ug/m3 daily standard is 370/710 = 52.1%.

**** The percent reduction in total incidence achieved by attaining current or alternative standards is the reduction in incidence achieved by att the standard divided by the total (not only PM-associated) incidence.

***** PM-2.5 results based on using PM-2.5 mass as PM-10 mass in the PM-10 functions.

******Angle brackets <> indicate incidence calculated using baseline incidence rates reported in studies, with no adjustment for location-specifi incidence rates. This increases the uncertainty in the incidence estimates.

Sources of Concentration-Response (C-R) Functions:
(A) C-R function based on pooled results from studies in 6 locations
(B) Pope et al., 1995
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(D) Schwartz & Morris, 1995
(E) Schwartz & Morris, 1995
(F) Schwartz, et al., 1994

The numbers in parentheses for pooled studies are NOT standard confidence intervals. All the numbers in parentheses are interpreted as 90% credible intervals based on uncertainty analysis that takes into account both statistical uncertainty and possible geographic variability. See text in Chapter 7 for details.

#The 98th percentile form of the daily std. requires that the 98th percentile concentration at each monitor (rounded to the nearest ug/m3) meets the std. The highest 98th percentile concentration at a monitor in L.A. is 95 ug/m3.
The high monitor form of the annual standard requires that the annual average at each monitor (rounded to the nearest 0.1 ug/m3) meets the standard.
The highest annual average at a monitor in L.A. is 24.1 ug/m3.
The spatial average form of the annual standard requires that the average of the annual averages at the monitors (rounded to the nearest 0.1 ug/m3) meets the standard.
The spatial avg. of annual averages in L.A. is 23.0 ug/m3.

Exhibit 9. Estimated Changes in Health Risks Associated with Meeting Alternative PM-2.5 Standards in Philadelphia County, September 1992 - August 1993 (for base case assumptions)

Health Effects*		PM-2.5-Related Incidence associated with current standards**	Reduction in Incidence Associated with Meeting Alternative Standards			
			15 ug/m3 annual# (spatial avg) and 50 ug/m3 daily## (95th %ile)	15 ug/m3 annual# (spatial avg) and 50 ug/m3 daily## (98th %ile)	15 ug/m3 annual# (spatial avg) and 50 ug/m3 daily## (99th %ile)	15 ug/m3 annual# (spatial avg) and 50 ug/m3 daily## (2nd highest)
Mortality	(A) Associated with short-term exposure (all ages)	370 (230 - 510)	50 (30 - 60)	50 (30 - 60)	50 (30 - 60)	120 (70 - 170)
	Percent Reduction in PM-Associated Incidence:***		13.5%	13.5%	13.5%	32.4%
	Percent Reduction in Total Incidence:****		0.2%	0.2%	0.2%	0.6%
	(B) Associated with long-term exposure (age 30 and over)	860 (540 - 1170)	190 (120-250)	190 (120-250)	190 (120-250)	500 (300 - 680)
	Percent Reduction in PM-Associated Incidence:		22.1%	22.1%	22.1%	57.9%
	Percent Reduction in Total Incidence:		1.0%	1.0%	1.0%	2.7%
Hospital Admissions Respiratory	(C) Total Respiratory (all ages)	260 (70 - 450)	30 (10 - 60)	30 (10 - 60)	30 (10 - 60)	90 (20 - 150)
	Percent Reduction in PM-Associated Incidence:		11.5%	11.5%	11.5%	34.6%
	Percent Reduction in Total Incidence:		0.2%	0.2%	0.2%	0.7%
Hospital Admissions Cardiac	(D) Ischemic Heart Disease***** (>64 years old)	70 (30 - 120)	10 (0 - 10)	10 (0 - 10)	10 (0 - 10)	20 (10 - 40)
	(E) Congestive Heart Failure***** (>64 years old)	100 (50 - 150)	10 (10 - 20)	10 (10 - 20)	10 (10 - 20)	30 (20 - 50)
	Range of Percent Reductions in PM-Associated Incidence:		10.0% - 14.3%	10.0% - 14.3%	10.0% - 14.3%	28.6% - 30.0%
	Range of Percent Reductions in Total Incidence:		0.1% - 0.1%	0.1% - 0.1%	0.1% - 0.1%	0.2% - 0.4%
(F) Lower Respiratory Symptoms (8-12 yr. olds) ******		< 11000 > (6000 - 15000)	< 2000 > (1000 - 2000)	< 2000 > (1000 - 2000)	< 2000 > (1000 - 2000)	< 4000 > (2000 - 6000)
	Percent Reduction in PM-Associated Incidence:		18.2%	18.2%	18.2%	36.4%
	Percent Reduction in Total Incidence:		3.6%	3.6%	3.6%	7.3%

* Health effects are associated with short-term exposure to PM, unless otherwise specified.
** Health effects incidence was quantified across the range of PM concentrations observed in each study, when possible, but not below background PM-2.5 level. Background PM-2.5 is assumed to be 3.5 ug/m3 in Philadelphia County.
*** The percent reduction in PM-associated incidence achieved by attaining alternative standards as opposed to the current standards is the reduction in incidence divided by the incidence associated with current standards. For example, the percent reduction in PM-associated incidence of mortality associated with short-term exposure to PM-2.5 achieved by meeting both a 15 ug/m3 spatial average annual and a 50 ug/m3 daily standard is 50/370=13.5%.
**** The percent reduction in total incidence achieved by attaining current or alternative standards is the reduction in incidence achieved by attaining the standard divided by the total (not only PM-associated) incidence.
***** PM-2.5 results based on using PM-2.5 mass as PM-10 mass in the PM-10 functions.
******Angle brackets <> indicate incidence calculated using baseline incidence rates reported in studies, with no adjustment for location-specific incidence rates. This increases the uncertainty in the incidence estimates.

Sources of Concentration-Response (C-R) Functions:
(A) C-R function based on pooled results from studies in six locations.
(B) Pope et al., 1995
(C) Thurston, et al., 1994
(D) Schwartz & Morris, 1995
(E) Schwartz & Morris, 1995
(F) Schwartz, et al., 1994

The numbers in parentheses for pooled functions are NOT standard confidence intervals. All the numbers in parentheses are interpreted as 90% credible intervals based on uncertainty analysis that takes into account both statistical uncertainty and possible geographic variability. See text in Chapter 7 for details.

#The spatial average form of the annual standard requires that the average of the annual averages at the monitors (rounded to the nearest 0.1 ug/m3) meets the standard. The spatial avg. of annual averages in Philadelphia is 16.6 ug/m3.
##The percentile forms of the daily standard require that the given percentile concentration (95th, 98th, or 99th) at each monitor (rounded to the nearest ug/m3) meets the standard. The highest 95th, 98th, and 99th percentile concentrations at a monitor in Philadelphia are 36, 48, and 54 ug/m3, respectively.
The 2nd highest form of the daily standard requires that the 2nd highest concentration at each monitor (rounded to the nearest ug/m3) meets the standard.
The highest 2nd highest concentration at a monitor in Philadelphia is 73 ug/m3.
In all cases except the case for which the daily standard is based on the 2nd highest concentration, the annual std. is the controlling std.

Exhibit 10. Estimated Changes in Health Risks Associated with Meeting Alternative PM-2.5 Standards in Southeast Los Angeles County, 1995* (for base case assumptions)

Health Effects		PM-2.5-Related Incidence associated with current standards**	Reduction in Incidence Associated with Meeting Alternative Standards*			
			15 ug/m3 annual# (spatial avg) and 50 ug/m3 daily## (95th %ile)	15 ug/m3 annual# (spatial avg) and 50 ug/m3 daily## (98th %ile)	15 ug/m3 annual# (spatial avg) and 50 ug/m3 daily## (99th %ile)	15 ug/m3 annual# (spatial avg) and 50 ug/m3 daily## (2nd highest)
Mortality	(A) Associated with short-term exposure (all ages)	710 (430 - 970)	280 (170 - 380)	350 (210 - 480)	360 (210 - 490)	370 (230 - 510)
	Percent Reduction in PM-Associated Incidence:*** **Percent Reduction in Total Incidence:*******		39.4% 1.1%	49.3% 1.4%	50.7% 1.5%	52.1% 1.5%
	(B) Associated with long-term exposure (age 30 and over)	2050 (1290 - 2770)	1190 (750 - 1630)	1470 (930 - 2020)	1510 (950 - 2060)	1580 (990 - 2150)
	Percent Reduction in PM-Associated Incidence: **Percent Reduction in Total Incidence:**		58.3% 5.0%	72.0% 6.2%	73.9% 6.3%	77.3% 6.6%
Hospital Admissions Respiratory	(C) Total Respiratory (all ages)	940 (250 - 1630)	370 (100 - 640)	460 (120 - 790)	470 (130 - 810)	490 (130 - 850)
	Percent Reduction in PM-Associated Incidence: **Percent Reduction in Total Incidence:**		39.4% 2.4%	48.9% 3.0%	50.0% 3.0%	52.1% 3.2%
Hospital Admissions Cardiac	(D) Ischemic Heart Disease ***** (>64 years old)	130 (50 - 200)	50 (20 - 80)	60 (20 - 100)	60 (20 - 100)	70 (30 - 110)
	(E) Congestive Heart Failure ***** (>64 years old)	140 (70 - 210)	60 (30 - 80)	70 (30 - 110)	70 (30 - 110)	70 (40 - 110)
	Range of Percent Reductions in PM-Associated Incidence: **Range of Percent Reductions in Total Incidence:**		38.5% - 42.9% 0.4% - 0.8%	46.2% - 50.0% 0.5% - 1.0%	46.2% - 50.0% 0.5% - 1.0%	50.0% - 53.8% 0.6% - 1.0%
(F) Lower Respiratory Symptoms (8-12 yr. olds)******		< 43000 > (23000 - 58000)	< 20000 > (10000 - 28000)	< 24000 > (12000 - 34000)	< 24000 > (12000 - 35000)	< 25000 > (13000 - 36000)
	Percent Reduction in PM-Associated Incidence: **Percent Reduction in Total Incidence:**		46.5% 13.3%	55.8% 16.0%	55.8% 16.0%	58.1% 16.7%

Health effects are associated with short-term exposure to PM, unless otherwise specified.

* Los Angeles County was not in attainment of current PM-10 standards in 1995. Figures shown assume actual PM-10 concentrations are first rolled back to simulate attainment of these standards, and that actual PM-2.5 concentrations are rolled back by the same percent as PM-10. See text in Chapter VI for details.

** Health effects incidence was quantified across the range of PM concentrations observed in each study, when possible, but not below background PM-2.5 level. Background PM-2.5 is assumed to be 2.5 ug/m3 in Southeast Los Angeles County.

*** The percent reduction in PM-associated incidence achieved by attaining alternative standards as opposed to the current standards is the reduction in incidence divided by the incidence associated with current standards. For example, the percent reduction in PM-associated incidence of mortality associated with short-term exposure to PM-2.5 achieved by meeting the 15 ug/m3 annual standard and a 50 ug/m3 daily standard (2nd highest monitor) is 370/710 = 52.1%.

**** The percent reduction in total incidence achieved by attaining current or alternative standards is the reduction in incidence achieved by attaining the standard divided by the total (not only PM-associated) incidence.

***** PM-2.5 results based on using PM-2.5 mass as PM-10 mass in the PM-10 functions.

******Angle brackets <> indicate incidence calculated using baseline incidence rates reported in studies, with no adjustment for location-specific incidence rates. This increases the uncertainty in the incidence estimates.

Sources of Concentration-Response (C-R) Functions:
(A) C-R function based on pooled results from studies in 6 locations
(B) Pope et al., 1995
(C) Thurston, et al., 1994
(D) Schwartz & Morris, 1995
(E) Schwartz & Morris, 1995
(F) Schwartz, et al., 1994

The numbers in parentheses for pooled studies are NOT standard confidence intervals. All the numbers in parentheses are interpreted as 90% credible intervals based on uncertainty analysis that takes into account both statistical uncertainty and possible geographic variability. See text in Chapter 7 for details.

#The spatial average form of the annual standard requires that the average of the annual averages at the monitors (rounded to the nearest 0.1 ug/m3) meets the standard. The spatial avg. of annual averages in L.A. is 23.0 ug/m3.

##The percentile forms of the daily standard require that the given percentile concentration (95th, 98th, or 99th) at each monitor (rounded to the nearest ug/m3) meets the standard. The highest 95th, 98th, and 99th percentile concentrations at a monitor in L.A. are 66, 95, and 97 ug/m3, respectively.
The 2nd highest form of the daily standard requires that the 2nd highest concentration at each monitor (rounded to the nearest ug/m3) meets the standard. The highest 2nd highest concentration at a monitor in L.A. is 102 ug/m3.

Exhibit 11

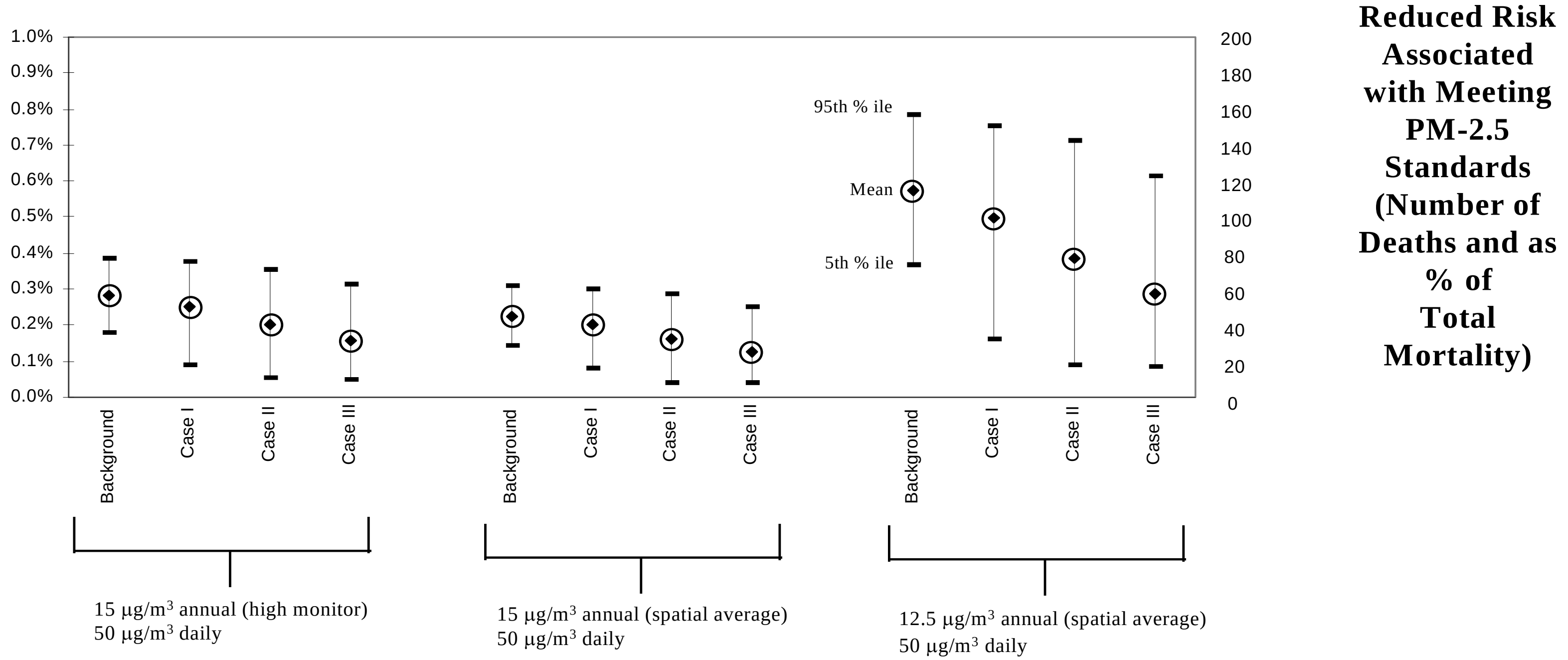
Uncertainty Analysis: Effect of Uncertainty of Relative Risk, Background Concentration, Cutpoint, Slope Adjustment Method, and Form of Rollback

Reduced Risk Associated with Meeting Alternative Form PM-2.5 Standards

(Annual standard is based on either the annual average at the highest monitor or the spatial average of annual averages; daily standard is based on the 98th percentile concentration at the highest monitor.)

Mortality Associated With Short-term Exposure to PM-2.5

Philadelphia County, September 1992 - August 1993 (Population: 1.6 Million)



Cutpoint Weighting Schemes

	Case I	Case II	Case III
Background	0.5	0.2	0.05
10 μg/m^3	0.3	0.3	0.15
18 μg/m^3	0.15	0.3	0.5
30 μg/m^3	0.05	0.2	0.3

Mean Reduced Risk as % of Total PM-Associated Risk

(μg/m^3)	RR and Background	Case I	Case II	Case III
15 Annual/50 Daily (high monitor)	15.7%	19.8%	24.7%	32.9%
15 Annual/50 Daily (spatial average)	12.4%	15.8%	19.6%	26.4%
12.5 Annual/50 Daily (spatial average)	31.9%	39.1%	47.4%	59.6%

Exhibit 12

Uncertainty Analysis: Effect of Uncertainty of Relative Risk, Background Concentration, Cutpoint, Slope Adjustment Method, and Form of Rollback

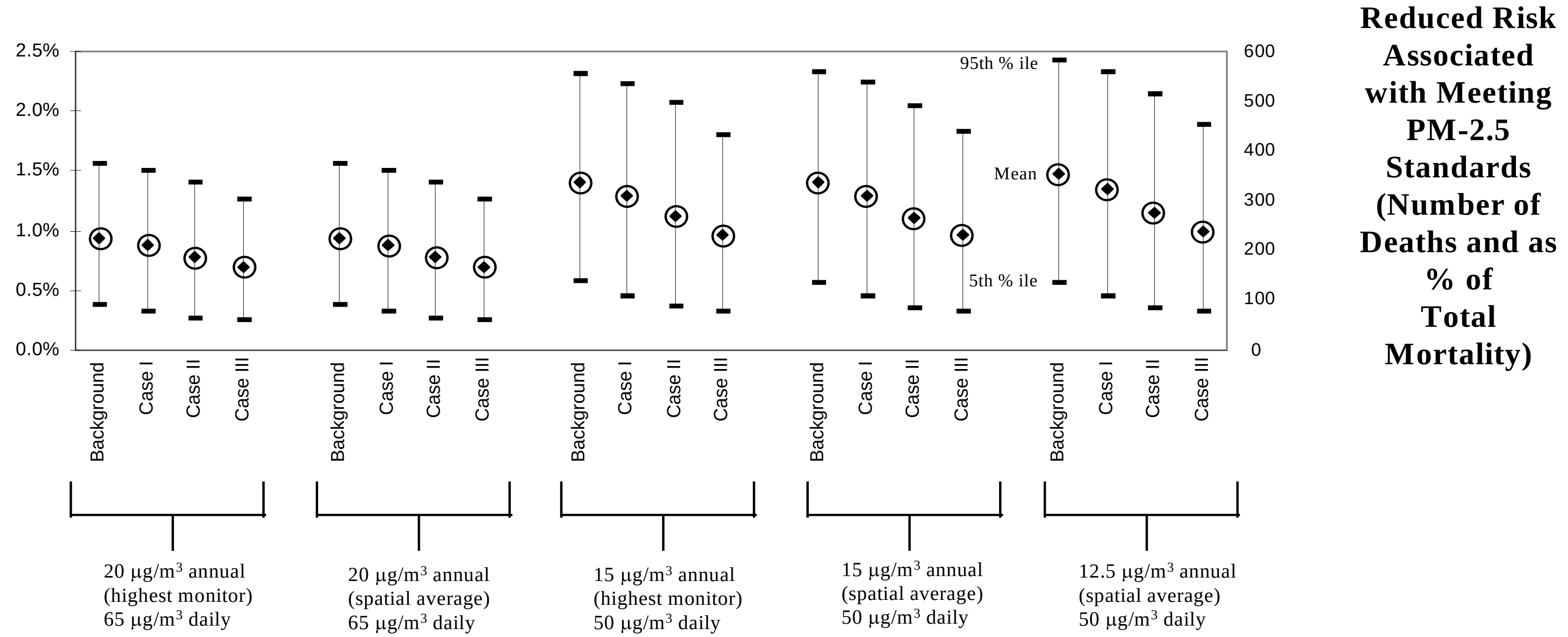
Reduced Risk Associated with Meeting Alternative PM-2.5 Standards

(Annual standard is based on either the annual average at the highest monitor or the spatial average of annual averages; daily standard is based on the 98th percentile concentration at the highest monitor.)

(PM-2.5 was rolled back prior to analysis to simulate attainment of current PM-10 standards.)

Mortality Associated With Short-term Exposure to PM-2.5

Southeast Los Angeles County, 1995 (Population: 3.6 Million)



Cutpoint Weighting Schemes

	Case I	Case II	Case III
Background	0.5	0.2	0.05
10 μg/m³	0.3	0.3	0.15
18 μg/m³	0.15	0.3	0.5
30 μg/m³	0.05	0.2	0.3

Mean Reduced Risk as % of Total PM-Associated Risk

(μg/m³)	RR and Background	Case I	Case II	Case III
20 Annual/65 Daily (high monitor)	32.9%	39.2%	46.7%	55.0%
20 Annual/65 Daily (spatial average)	32.9%	39.2%	46.7%	55.0%
15 Annual/50 Daily (high monitor)	49.4%	57.5%	67.0%	76.4%
15 Annual/50 Daily (spatial average)	49.3%	57.5%	66.1%	76.0%
12.5 Annual/50 Daily (spatial average)	51.9%	60.4%	69.1%	78.5%

2. Slope Adjustment for Long Term Exposure Mortality Integrated Uncertainty Analyses

There are four sources of uncertainty in the slope of the concentration-response function (β) for long-term exposure mortality, all of which should be incorporated in an integrated uncertainty analysis. The first three sources of uncertainty are common to the short-term exposure and the long-term exposure studies. These are:

1. the usual uncertainty surrounding any estimate of β associated with sampling error;

2. the uncertainty associated with applying a concentration-response function estimated in one location to another location; and

3. uncertainty about the functional form of the concentration-response relationship -- e.g., whether a no-threshold exponential model is appropriate or whether a threshold ("hockey stick") model is appropriate -- and, if a hockey stick model is appropriate, what is the correct form of the hockey stick.

The first two of these sources of uncertainty are characterized by the estimated distribution of β's, as described in the July 3rd report (Section 5.2). Because there is only one long-term exposure mortality study being considered in the PM risk assessment (Pope et al., 1995), the uncertainty from these two sources is characterized by a normal distribution with mean equal to the β reported by Pope et al. and standard deviation equal to the standard error reported by Pope et al.

In addition to the above three sources of uncertainty, the slope of the concentration-response function for long-term exposure mortality has a fourth source of uncertainty, namely,

4. uncertainty about whether Pope et al.'s estimate of β was biased upward, because PM concentrations in the years prior to the study were higher than the PM concentration that was used to characterize levels during the study. The sensitivity of results to this source of uncertainty was illustrated in Exhibit 7.27 in the July 3rd report.

The integrated uncertainty analyses on short-term exposure mortality characterized the uncertainty from the first three sources by doing the following on each iteration: first randomly select a β from the distribution of β's, and then adjust that β, given a randomly selected cutpoint, by one of two slope adjustment methods, with each of the methods having a 50% chance of being used.

To include the fourth source of uncertainty for the integrated uncertainty analyses of long-term exposure mortality, an additional step is included. On each iteration,

(1) randomly select a β from the normal distribution of β's that is used to characterize the uncertainty surrounding the concentration-response function from the first two sources;

(2) randomly select an adjustment factor, α, from the uniform distribution on the interval [0.5, 1]. α is the adjustment for the fourth source of uncertainty.

(3) multiply α by β to get a new, adjusted value, β'. This first adjustment accounts for the possibility that the estimated β may have been upward biased to some degree. That is, β' may be anywhere from one-half the selected β to the full selected β.

(4) Randomly select a slope adjustment method, with each of the two methods having a 50 percent chance of selection. Adjust β' according to the slope adjustment method selected and the cutpoint selected. The twice adjusted β, denoted β", is used to calculate long-term exposure mortality.

3. Analyses of Alternative Standard Forms

3.1 The spatial average form of the annual standard

The steps required to calculate the spatial average of PM concentrations for the spatial average form of the annual standard and to roll back these concentrations to simulate attainment of the standard are as follows:

3.1.1 At each monitor in a given area, the average of the mean PM concentrations for each quarter in the year is calculated as follows:

$$a = avg(q_1, q_2, q_3, q_4)$$

where q_i is the average of the observed PM concentrations in the ith quarter.

3.1.2 The average of all monitors used for the spatial average is then calculated as:

$$A = \frac{1}{n} \sum_{j=1}^{n} a_j$$

where a_j is the annual average at the jth monitor and n is the number of monitors designated for spatial averaging in an area.

3.1.3 The final average (*A*) is then rounded to the nearest 0.1 μg/m^3.

3.1.4 The concentrations are then rolled back to meet the annual standard according to the method described in the July 3rd report.

3.2 The 98th percentile form (and other percentile forms) of the daily standard

The steps used to calculate the 98th percentile of PM concentrations and rollbacks to meet the 98th percentile form of the daily standard are as follows:

3.2.1 At each monitor, the PM concentrations are ordered from smallest to largest. The symbol $x_{[1]}$ denotes the smallest concentration and $x_{[n]}$ denotes the largest concentration.

3.2.2 The 98th percentile from the ordered series at the monitor is calculated by the following steps:

> 0.98*n = “i.d”, where i denotes the integer part and d denotes the decimal part of the resulting value.
>
> If $d \neq 0$, the 98th percentile is x[i+1], and
> If $d = 0$, the 98th percentile is $(x_{[i]} + x_{[i+1]})/2$

3.2.3 Because each monitor must be in attainment of the 24-hour standard for the county to be in attainment, the controlling monitor is the monitor with the highest 98th percentile concentration.

3.2.4 The highest 98th percentile concentration is rounded to the nearest 1 $\mu g/m^3$.

3.2.5 Daily concentrations are then rolled back to meet the daily standard according to the method described in the July 3rd report.

The same process is used for the 95th and 99th percentile forms, substituting 0.95 or 0.99 for 0.98 in the equation in section 3.2.2.

3.3 Alternative (and original) standard forms considered

The following combinations of annual and daily standards (using the alternative standard forms as well as the 'highest monitor' annual standard[2] and the second daily maximum investigated in the July 3rd report) were analyzed:

Annual (μg/m^3)	Daily (μg/m^3)	Exhibits
20 (spatial average)	65 (98th percentile)	7, 8
20 (highest monitor)	65 (98th percentile)	7, 8
15 (spatial average)	50 (95th percentile)	9, 10
15 (spatial average)	50 (98th percentile)	7-10
15 (spatial average)	50 (99th percentile)	9, 10
15 (spatial average)	50 (second daily maximum)	9, 10
15 (highest monitor)	50 (98th percentile)	7, 8
12.5 (spatial average)	50 (98th percentile)	7, 8

As in the analyses in the July 3rd report, the standard (annual or daily) requiring the largest reduction in PM concentrations is the 'controlling' standard. Reductions in risks of morbidity and mortality are calculated based on the reduction in PM concentrations required to meet the controlling standard.

4. Summary

The analyses presented in this supplemental report are additions to the risk assessment analyses presented in the July 3, 1996 report, "A Particulate Matter Assessment for Philadelphia and Los Angeles." The analyses presented in Exhibits 1 through 6 are additional integrated uncertainty analyses either of risk associated with long-term exposure mortality or of reduced risk of short-term and long-term exposure mortality associated with attainment of those standards and standard forms that were considered in the July 3rd report. Exhibits 7 through 12 present the results of analyses involving forms and levels of standards that were not considered in the July 3rd report. The underlying methods used for the analyses presented in the July 3rd report were used for the analyses presented in this supplement as well. The assumptions and caveats noted in the July 3rd report (discussed in Sections 3 and 9 of that report) are therefore also applicable to these additional analyses.

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[2]The 'highest monitor' annual standard is based on the monitor with the highest annual average of all population-oriented monitors in an area.