Whether air quality meets the standards is an important question, but one posed more often is whether the air quality is improving or deteriorating. In Arizona, because of the phasing out of leaded gasoline in the mid-1970s and the installation of effective controls on copper smelters in the 1980s, the concentrations of both lead and sulfur dioxide decreased rapidly. Although improvements have also been made in the concentrations of carbon monoxide, ozone and particulates, the last two still exceed air quality standards at some sites: the eight-hour ozone standard at several sites in greater Phoenix and the 24-hour and annual PM_{10} standards at a few urban and rural sites. Visibility, the aspect of the urban atmosphere that is most obvious to the population, is measured continuously in Tucson and Phoenix. This discussion examines the trends in these three common air pollutants throughout Arizona and the urban visibility trends.

Carbon Monoxide

Since the mid to late 1970s, carbon monoxide concentrations have declined as much as two-thirds. In Tucson, the maximum annual eight-hour concentration of carbon monoxide at 22nd Street and Alvernon declined from 12 to four parts per million (ppm). In Phoenix at 18th Street and Roosevelt (Central Phoenix), the decline was from 23.0 to 7.1 ppm (Figures I.1 and I.2). The number of exceedances of the eight-hour standard, 9 ppm, in Phoenix decreased from 75 to 0 at Central Phoenix. The entire Phoenix network of carbon monoxide monitors recorded more than 100 exceedances each year from 1981 through 1986, with an average of 134 per year. No exceedances were recorded by this network in 1997 and 1998, but a single exceedance was recorded in 1999. Most of this improvement can be attributed to Federal new-vehicle emission standards, augmented by emission reductions from the Vehicle Inspection and Maintenance Program, which began in 1976, and the use of oxygenated fuels in the winter, beginning in 1989.

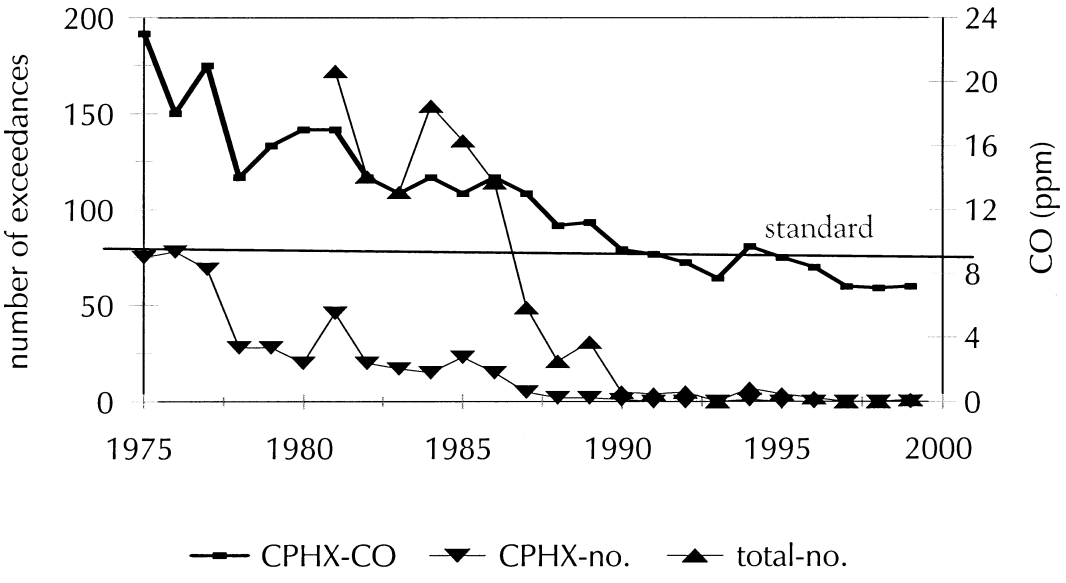

Figure I.1. *Eight-hour maximum carbon monoxide concentrations at Central Phoenix (CPHX), with the number of exceedances of the standard at CPHX and in the entire network.*

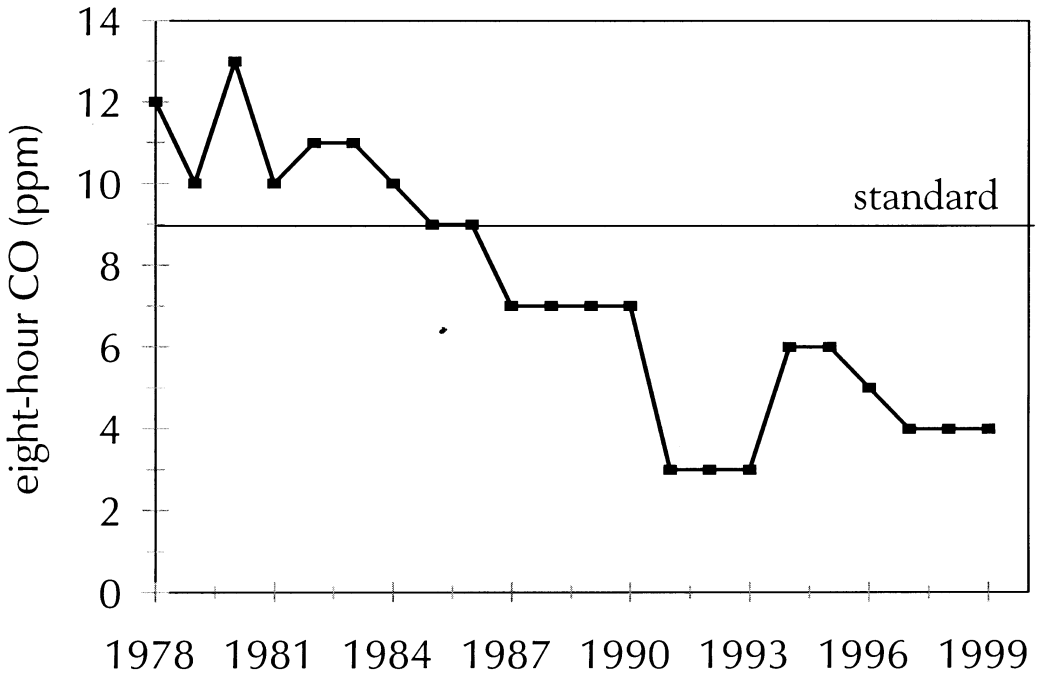

Figure I.2. *Eight-hour carbon monoxide maxima at 22nd Street and Alvernon Way in Tucson.*

Ozone

One-Hour Ozone Concentrations

Maximum one-hour average ozone concentrations have remained steady in Tucson and Yuma, but have declined in Phoenix since 1980 (Figure I.3). The Phoenix decrease in ozone concentrations has been nowhere near as pronounced as its declining carbon monoxide trend, but the net result has been similar: no exceedances of the ozone standard were recorded in 1997-1999. Because of its relatively high background level and its photochemical formation from hydrocarbons and nitrogen oxides, changes in emissions would not be expected to translate into proportional changes in concentrations. Recent atmospheric modeling in Phoenix predicts that ozone concentrations should have remained constant from 1996-1999, but the decrease in measured ambient concentrations contradicts these predictions.

Eight-Hour Ozone Concentrations

A new eight-hour ozone standard, promulgated by EPA in 1997, is expressed as the three-year average of the annual fourth-highest concentration, not to exceed 0.08 parts per million. This standard was remanded to EPA in a May 14, 1999 court decision. Analysis of ambient ozone concentrations nationwide showed that the eight-hour standard is likely to be exceeded in many areas where the one hour standard is met. Phoenix falls into this category; Tucson and Yuma do not. Long-term trends of the fourth-highest ozone concentrations in Tucson are fluctuating, but, overall, steady, with the exception of Saguaro National Monument East, which shows a slight increase (Figures I.4 and I.5).

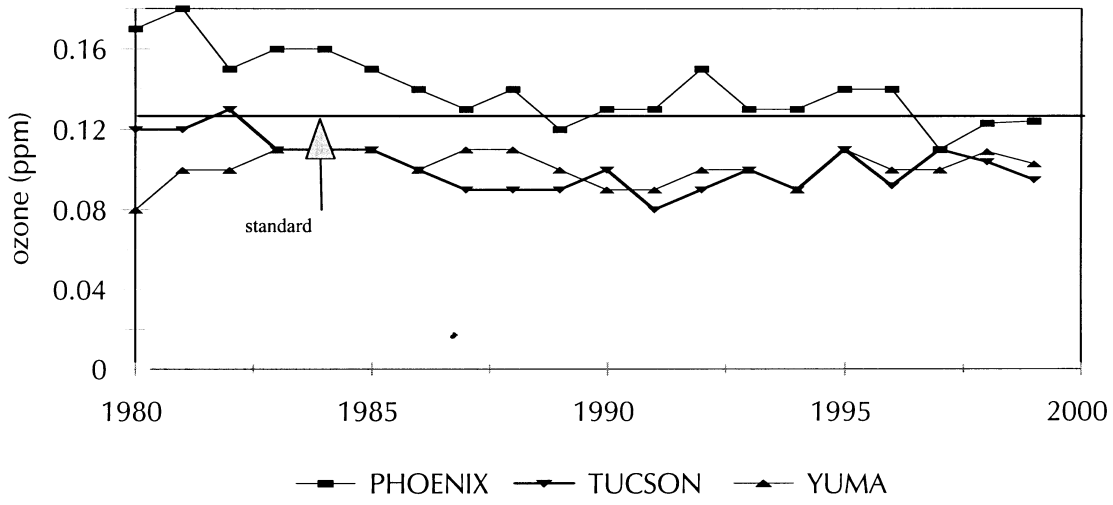

Figure I.3. *Maximum one-hour ozone concentrations in Phoenix, Tucson and Yuma.*

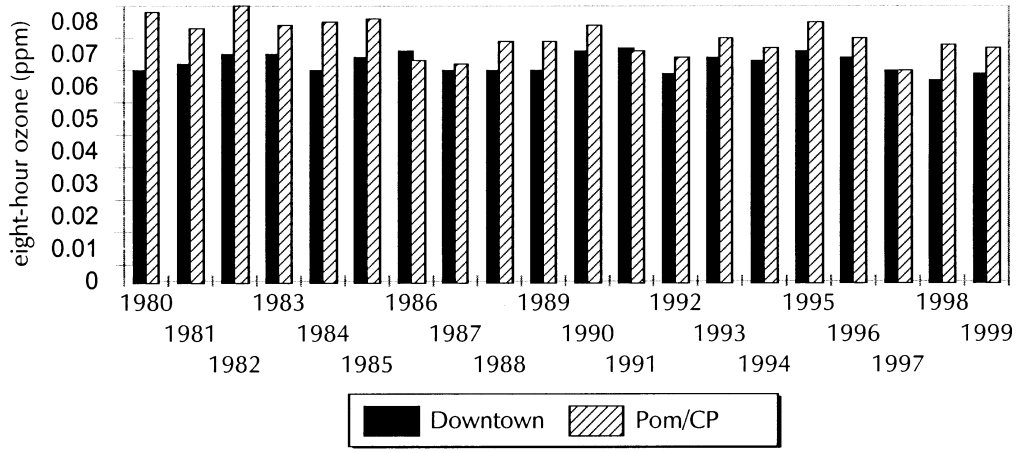

Figure I.4. *Tucson long-term trends in the fourth-highest eight-hour ozone concentrations – two sites ("Pom/CP" is Pomona/Children's Park).*

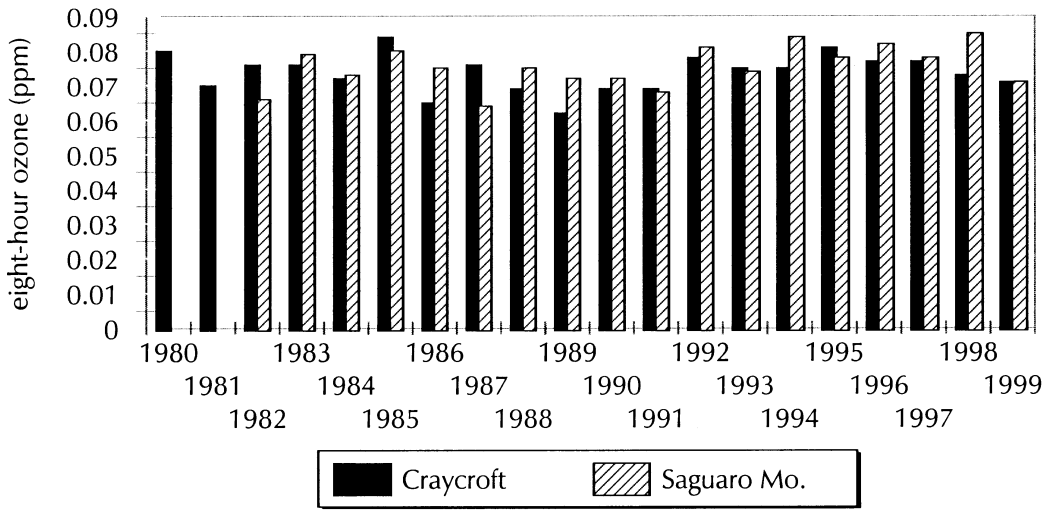

Figure I.5. *Tucson long-term trends in the fourth-highest eight-hour ozone concentrations – two additional sites.*

As the data presented in Table I.23 show, 24 of the 28 sites in greater Phoenix have recorded annual fourth-highest ozone values in excess of the three-year average standard of 0.084 ppm in 1995-1999. The standard of 0.084 ppm is the de facto, or operational standard, in contrast to the statutory standard of 0.08 ppm. This operational standard takes into account the precision of the instrumental method and the rounding off to the nearest 0.01 ppm. Half these sites exceeded the three-year average standard in either 1995-1997, 1996-1998 or 1997-1999 (Figure I.6 and Table I.24). Achieving this standard in Phoenix will undoubtedly be difficult, especially considering the relatively high concentrations in such background sites as Hillside (80 miles northwest of Phoenix).

Table I.23. Annual fourth-highest eight-hour ozone concentrations in greater Phoenix in parts per million (ppm)

	Blue Pt.	Central Phx	Humbolt Mt.	South Phx	Maryvale	Mount Ord	North Phx
1995	0.093	0.085	0.077	0.084	0.088	0.081	0.092
1996	0.098	0.076	0.092	0.091	0.087	0.098	0.095
1997	0.083	0.077	0.081	0.075	0.078	0.084	0.091
1998	0.089	0.079	0.090	0.080	0.086	0.088	0.089
1999	0.087	0.078	0.086	0.075	0.077	0.087	0.084
	S. Scottsdale	**Mesa**	**Emer. Mgt.**	**P. Peak**	**Falcon Fd**	**W. Chandl**	**Fountain H.**
1995	0.089	0.092	0.108	0.091	0.095	0.084	ND
1996	0.087	0.090	0.095	0.091	0.09	0.086	0.09
1997	0.076	0.084	0.085	0.082	0.081	0.077	0.088
1998	0.078	0.080	0.081	0.086	0.083	0.074	0.086
1999	0.072	0.083	0.086	0.083	0.082	0.069	0.086
	Arrowhead	**Glendale**	**W. Phx**	**Perryville**	**Phx. S.S.**	**Phx. VEL**	**SR-Pima-IR**
1995	ND	0.088	0.084	ND	0.102	0.099	0.092
1996	0.098	0.085	0.081	0.086	0.087	0.095	0.092
1997	0.060	0.076	0.078	ND	0.079	ND	0.082
1998	0.076	0.070	0.086	0.075	0.079	ND	0.087
1999	ND	0.081	0.091	ND	0.061	ND	0.082
	Roosevelt	**Rio Verde**	**CAP**	**Lk. Pleasant**	**Hillside**	**Palo Verde**	**Apache Jct.**
1995	ND	ND	ND	ND	ND	ND	0.095
1996	ND	ND	ND	ND	0.085	0.070	0.093
1997	0.086	0.085	ND	ND	0.076	0.077	0.082
1998	0.085	0.079	0.081	0.082	0.083	0.080	0.083
1999	ND	0.086	ND	0.081	0.084	0.080	0.080

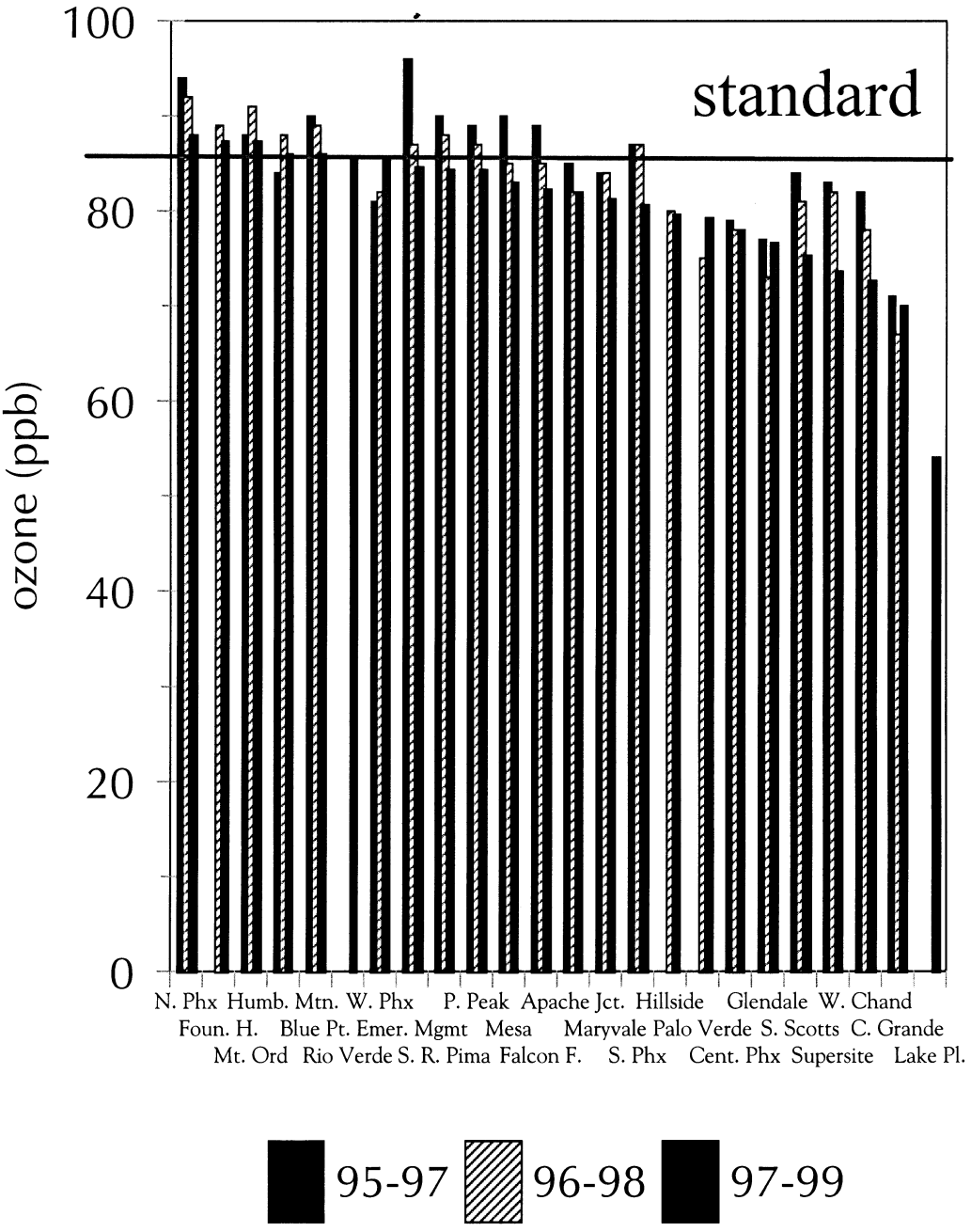

Figure I.6. *Three-year averages of the fourth-highest eight-hour ozone concentrations in Phoenix and environs.*

Table I.24. Three-year averages of the annual fourth-highest eight-hour ozone concentration in Phoenix and environs

Units are in parts per billion ppb; bold values exceed the operational standard of 84 ppb.

Site	1995-97	1996-98	1997-99
Hillside	N/A	80	80
Palo Verde	N/A	75	79
Lake Pleasant	N/A	N/A	54
Maryvale	84	84	81
Glendale	77	73	77
West Phoenix	81	82	**85**
Super Site	83	82	74
South Phoenix	**87**	**87**	81
North Phoenix	**94**	**92**	**88**
Central Phoenix	79	78	78
Emer. Mgmt	**96**	**87**	**85**
West Chandler	82	78	73
Casa Grande	71	67	70
S. Scottsdale	84	81	75
Mesa	**90**	**85**	83
Salt River Pima	**90**	**88**	84
Pinnacle Peak	**89**	**87**	84
Falcon Field	**89**	**85**	82
Fountain Hills	N/A	**89**	**87**
Blue Point	**90**	**89**	**86**
Humbolt Mt.	84	**88**	**86**
Rio Verde	N/A	N/A	**86**
Apache Junction	**85**	82	82
Mt. Ord	**88**	**91**	**87**

N/A – Not Available

Particulates

PM_{10}

The concentrations of PM_{10} have decreased considerably throughout the state, in both urban and rural settings. For example, annual PM_{10} concentrations in South Phoenix averaged 63 μg/m3 from 1985 through 1989, but only 49 μg/m3 in 1995-97, a decrease of 22 percent. Similar percentage decreases occurred from the beginning to the end of the monitoring record at Central Phoenix and West Phoenix (Figures I.7 and I.8). In 1999, however, the concentrations increased, presumably because of the unusually dry weather from mid-September through the end of the year.

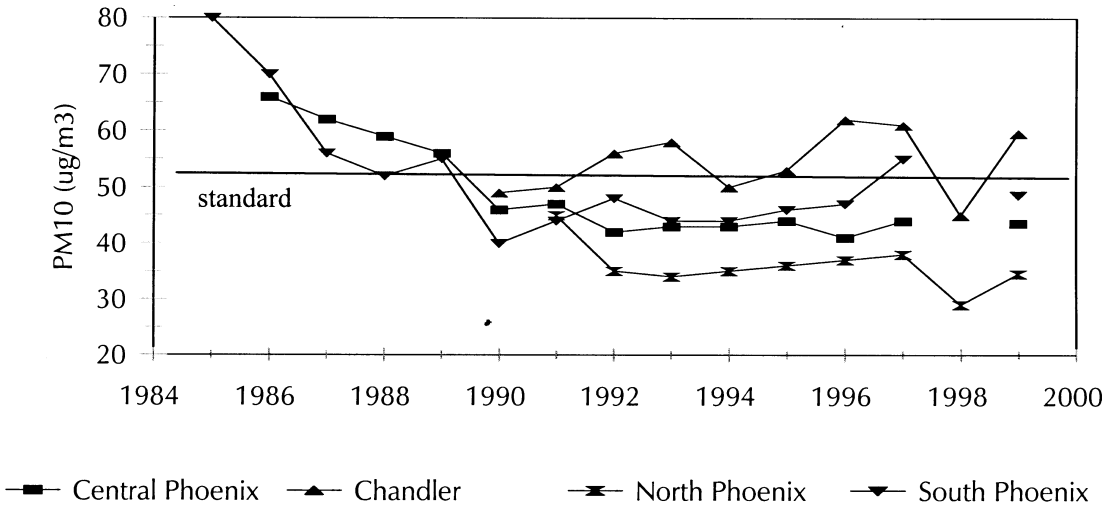

Figure I.7. *Annual PM_{10} concentrations at four sites in greater Phoenix.*

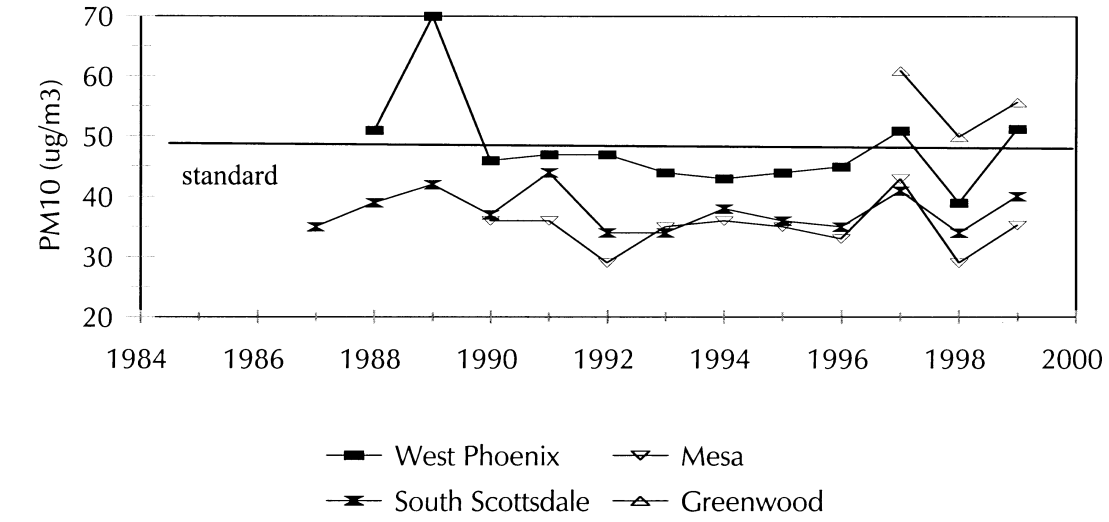

Figure I.8. *Annual PM_{10} concentrations at four additional sites in greater Phoenix.*

In Tucson, the background site of Corona de Tucson and the rural site of Green Valley have had steady, even trends of PM_{10}, but the four long-term urban sites all show substantial decreases. Orange Grove averaged 45.5 $\mu g/m^3$ in 1985-86, but steadily decreased in the next 15 years to an average concentration in 1997-98 of 27.5 μg/m3, which is a decrease of 40 percent. South Tucson, Prince Road and Broadway/Swan showed smaller, but substantial, decreases (Figure I.9). Similar to the Phoenix monitoring sites, the 1999 concentrations in Tucson increased substantially over their 1998 levels, again due to the drier weather.

These PM_{10} reductions in the urban settings can probably be attributed to a reduction of coarse particulate emissions from paving roads and alleys, from paving road shoulders, and from better controls of construction dust emissions.

Throughout the state, PM_{10} concentrations have declined since 1985 at many sites.

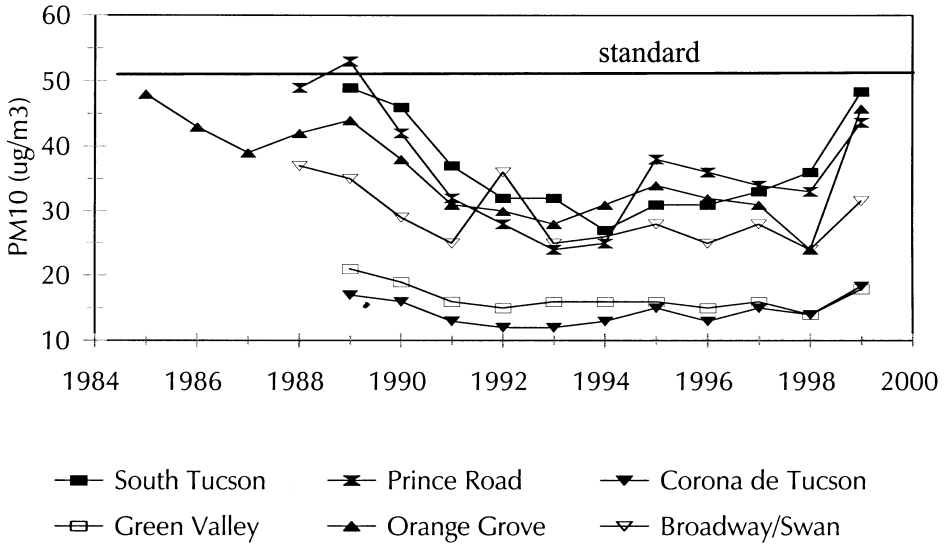

Figure I.9. *Annual PM_{10} concentrations in Tucson.*

Consider a group of high concentration sites: Douglas, Hayden and Nogales concentrations have been cut in half, Payson and Paul Spur have been reduced three-fold, and Rillito and Yuma have decreased 40 percent. In each of these localities, road paving and better industrial dust controls can be given credit for most of the improvement (Figure I.10).

PM_{10} concentrations at the sites with lower concentrations have decreased, as well, with Ajo concentrations cut in half, Bullhead City two-thirds, and Safford by 15 percent. Other lower concentration sites in the lower elevations were steady or slightly decreasing (Figure I.11).

With the exception of Montezuma's Castle, a background site with an even trend, all of the higher-elevation, low-concentration sites showed decreasing trends for PM_{10}.

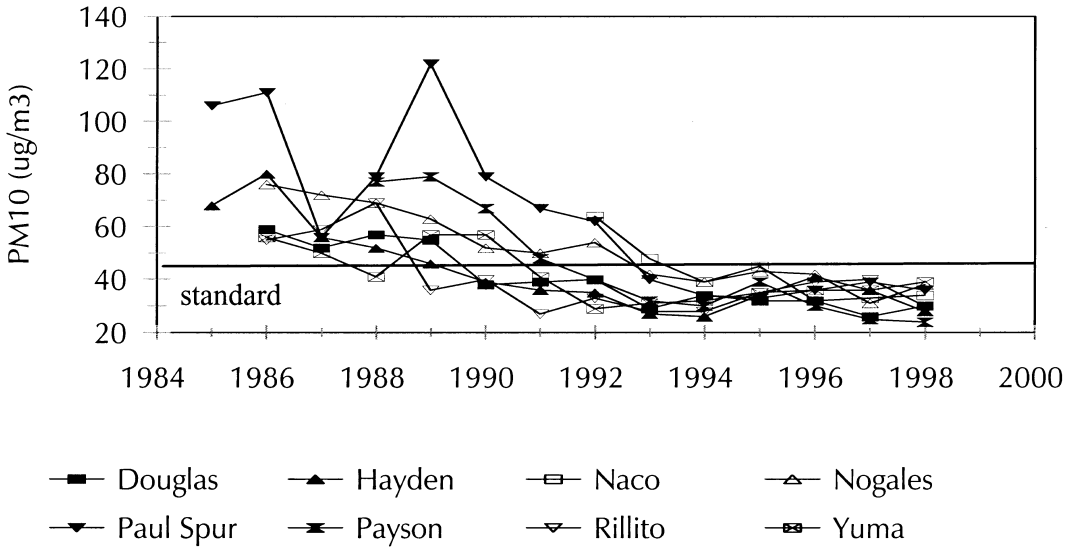

Figure I.10. *Annual PM_{10} concentrations at the higher-concentration sites in Arizona.*

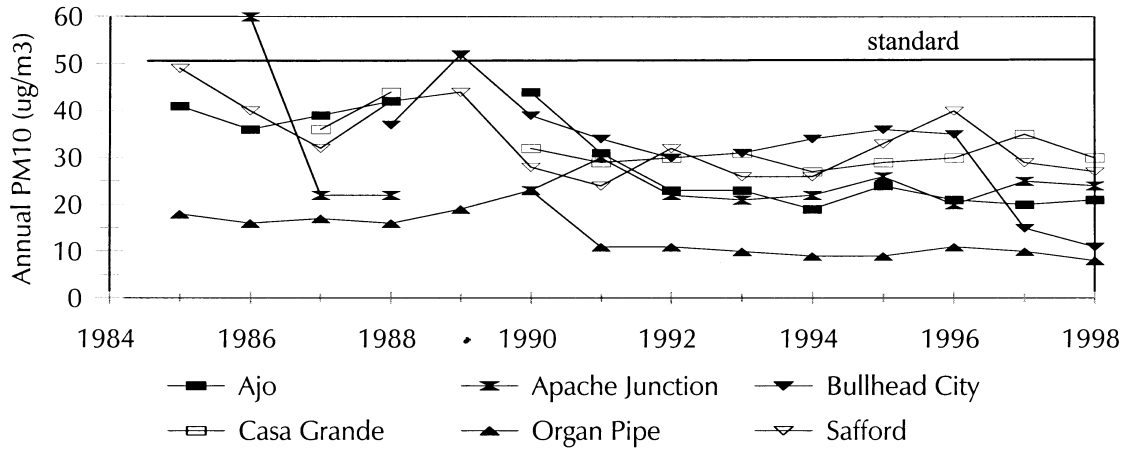

Figure I.11. *Annual PM_{10} concentrations at lower concentration sites at lower elevations.*

Clarkdale decreased 38 percent; Flagstaff, 69 percent; Joseph City, 45 percent; Nelson, 45 percent; and Show Low, 56 percent. Part of these decreases may be attributed to cleaner-burning wood stoves and fireplaces (Figure I.12). What is encouraging in these various sites is that not a single one shows an upward trend, whether urban, industrial, agricultural or rural.

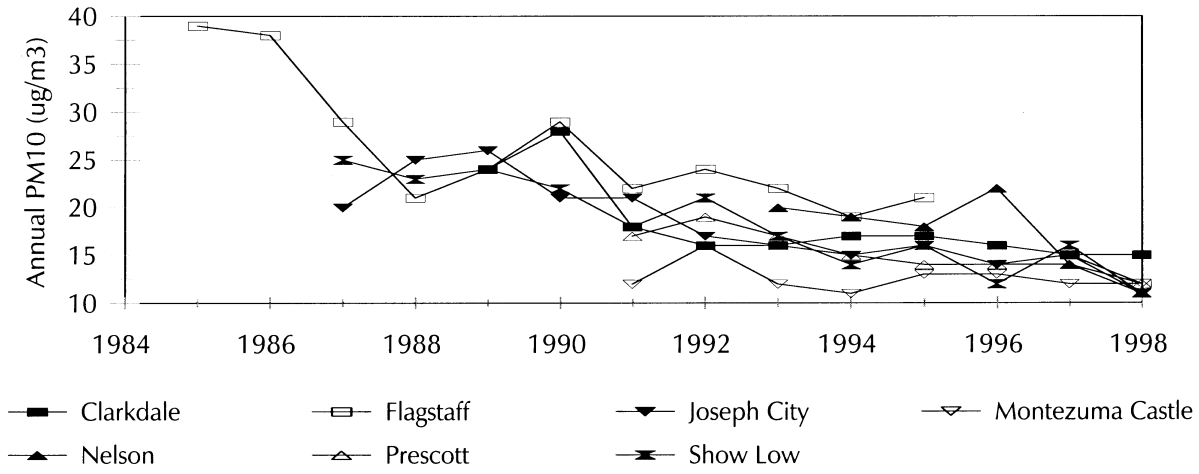

Figure 12. *Annual PM_{10} concentrations at low-concentration sites at higher elevations.*

$PM_{2.5}$

$PM_{2.5}$ has not been monitored as long as PM_{10}. The earliest measurements began in 1991 in the smaller cities and towns, 1994 in Tucson and 1995 in Phoenix. Slight downward trends at the urban sites are apparent. Nogales, Yuma, and Flagstaff have shown even trends, while Payson's is significantly down by 39 percent. Exceedances of the 1997 annual $PM_{2.5}$ standard occurred for four years in Payson and for one year in Higley. Payson, Nogales and the central area of Phoenix have the highest concentrations of fine particulates. Flagstaff and the urban fringe of Tucson (the Tangerine and Fairgrounds sites) have the lowest concentrations. These data are presented in Table I.25 and Figures I.13 to I.15.

Table I.25. Annual $PM_{2.5}$ concentrations throughout Arizona in $\mu g/m^3$

Bold values exceed the standard of 15 $\mu g/m^3$.

Statewide

	Yuma	Flagstaff	Payson	Nogales
1991	7.6	N/A	**17.9**	12.3
1992	5.7	N/A	**17.2**	12.6
1993	6.1	5.4	13.0	9.7
1994	8.3	4.9	**15.8**	10.4
1995	7.2	5.8	**15.7**	14.3
1996	8.7	11.2	14.4	13.3
1997	6.0	5.0	12.2	11.3
1998	8.3	4.7	10.9	12.5
1999	7.9	4.9	9.8	16.0[a]

Phoenix

	Higley	Tempe	Super	ASU West	Estrella
1995	**15.4**	10.0	12.6	11.1	11.7
1996	11.1	10.0	13.4	10.5	11.1
1997	10.4	9.8	12.1	9.1	7.9
1998	9.4	9.4	10.9	8.3	7.1
1999	11.1	10.1	10.8	9.1	8.9

Tucson

	Orange	22 Cray	Tangerine	Fairgrounds	Central
1994	9.4	7.9	5.3	5.8	8.9
1995	8.9	8.6	5.3	5.1	8.9
1996	8.2	6.4	4.9	4.7	7.7
1997	8.7	7.3	5.1	5.5	8.4
1998	7.0	6.0	5.0	5.0	NA
1999	9.6	7.5	N/A	N/A	7.2

N/A - Not available

[a] - Less than 75 percent data recovery.

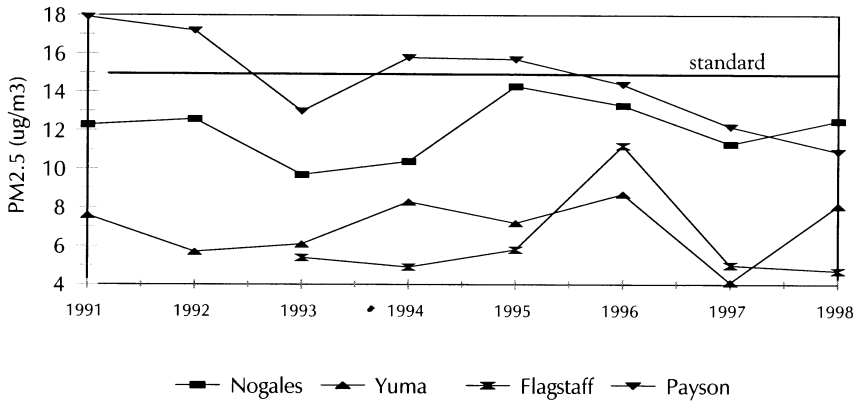

Figure I.13. *Statewide annual $PM_{2.5}$ concentrations.*

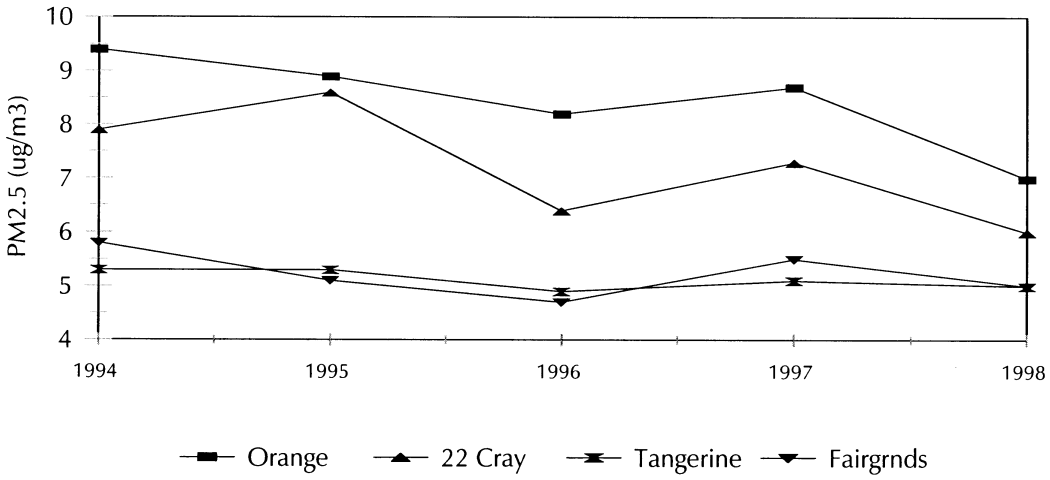

Figure I.14. *Annual $PM_{2.5}$ concentrations in Tucson.*

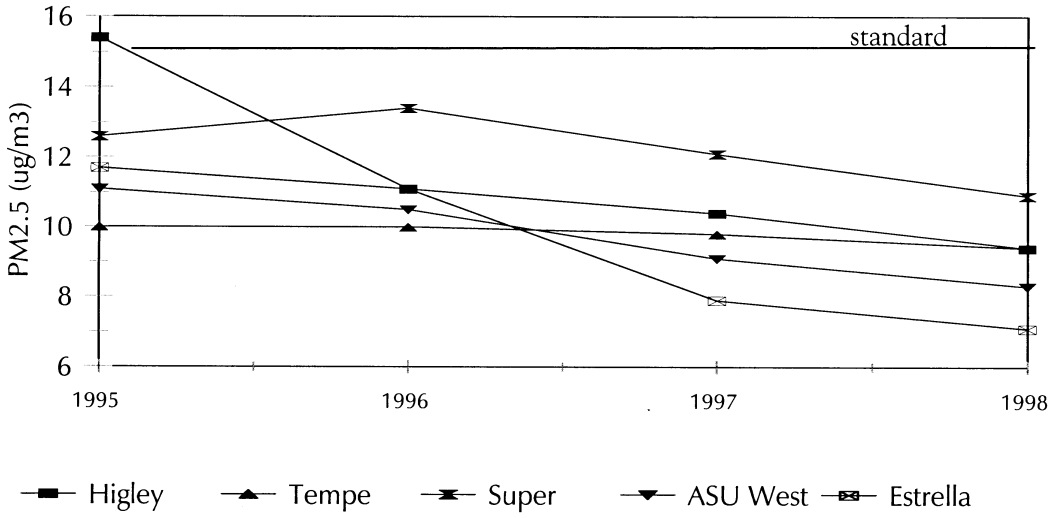

Figure I.15. *Annual $PM_{2.5}$ concentrations in Phoenix.*

Visibility

Optical measurements of visibility have been made continuously since 1993 in Tucson and since 1994 in Phoenix. Light extinction – the degree to which sunlight is reduced by its interaction with fine particles and gases in the atmosphere – is measured continuously with transmissometers. These measurements have been divided into six categories: the mean of the dirtiest 20 percent of all hours, the mean of all hours, and the mean of the cleanest 20 percent of all hours – for both the entire day and the 5-11 a.m. period. Table I.26 and Figures I.16 and I.17 present these data.

Table 26. Light extinction in Phoenix and Tucson in inverse megameters (Mm^{-1})

Phoenix

Year	All Hours			5-11 a.m.		
	Dirtiest 20 Percent	Mean	Cleanest 20 Percent	Dirtiest 20 Percent	Mean	Cleanest 20 Percent
1994	123	63	28	129	70	33
1995	138	75	38	134	78	42
1996	133	78	44	129	80	45
1997	137	83	50	136	87	54
1998	135	79	46	138	85	51
1999	125	71	38	124	75	42
percent difference 94 to 98						
annual percentage						

Tucson

Year	All Hours			5-11 a.m.		
	Dirtiest 20 Percent	Mean	Cleanest 20 Percent	Dirtiest 20 Percent	Mean	Cleanest 20 Percent
1993	108	64	35	129	74	39
1994	92	58	35	110	68	40
1995	102	61	35	116	68	38
1996	104	65	39	116	73	43
1997	91	59	36	105	66	38
1998	103	57	28	121	69	34
1999	97	60	36	111	67	39
percent difference 93 to 98						
annual percentage						

Note: The percentage difference between either 1993 or 1994 and 1998 is divided by the number of years to give the average annual percentage change.

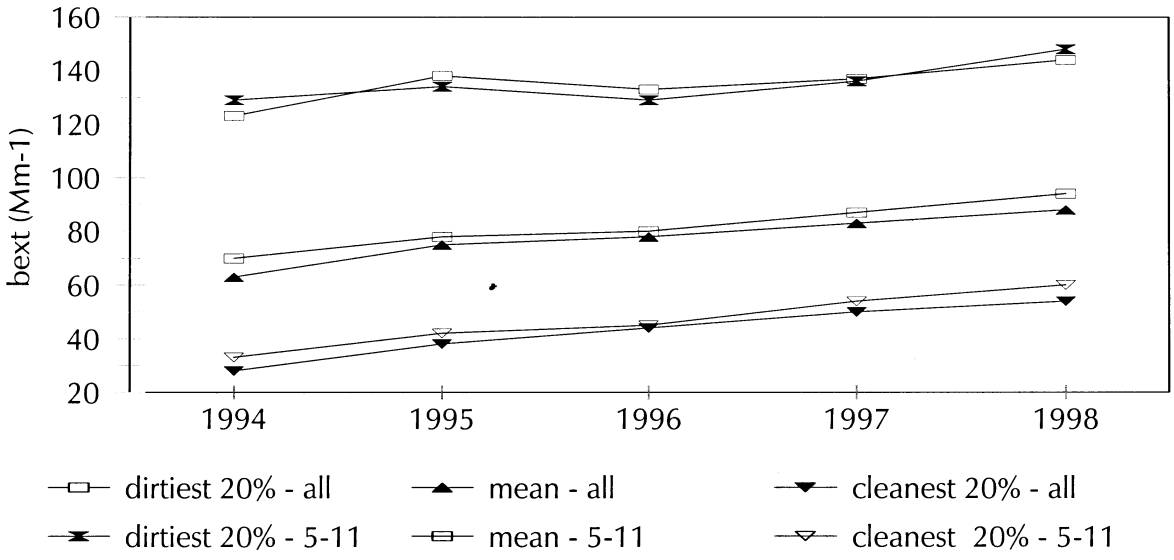

Figure I.16. *Light extinction trends in Phoenix.*

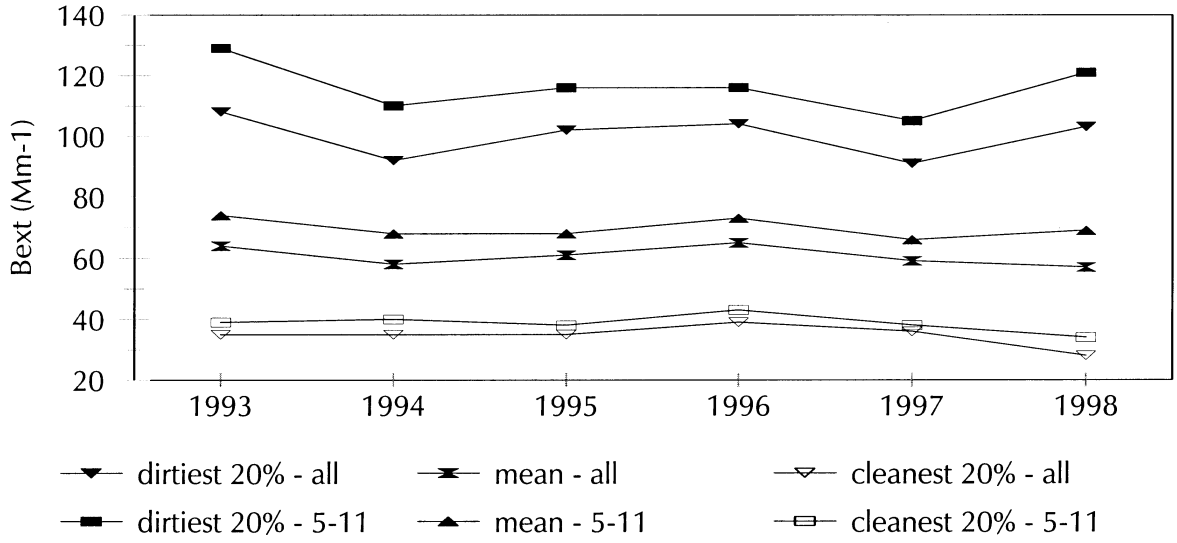

Figure I.17. *Light extinction trends in Tucson.*

Tucson visibility shows improving trends in all six categories, although these trends are not strong and are somewhat obscured by considerable year-to-year variability. Phoenix has much stronger trends, but in the opposite direction: all six categories of light extinction have steadily increased from 1994 to 1998. Because the cleanest 20 percent of the hours has increased about five times faster than the dirtiest 20 percent, the increasing mean values have resulted because of a migration from the cleanest 20 percent to the mean. If these trends continue, the mean value in just five years will equal the dirtiest 20 percent value of 1998. This increase can be attributed to increases in nitrogen oxides and carbonaceous fine particulate emissions from motor vehicles; metropolitan Phoenix vehicle miles traveled increases about 3 percent a year, and has now reached 64 million miles on an average weekday.

Seasonal patterns also vary between the two cites, with the mean and dirtiest 20 percent of all hourly light extinction values in Phoenix showing more pronounced winter and fall maxima than the Tucson counterparts (Figure I.18). Both cities show almost no seasonal variation in the cleanest 20 percent of all hours. The seasonal light extinction values in Phoenix are considerably higher than Tucson's: for the dirtiest 20 percent of all hours, 52 percent higher in winter, 19 percent higher in spring, 13 percent higher in summer, and 49 percent higher in fall. These measurements of the poorer visibility in Phoenix will come as no surprise to Arizonans familiar with both airsheds.

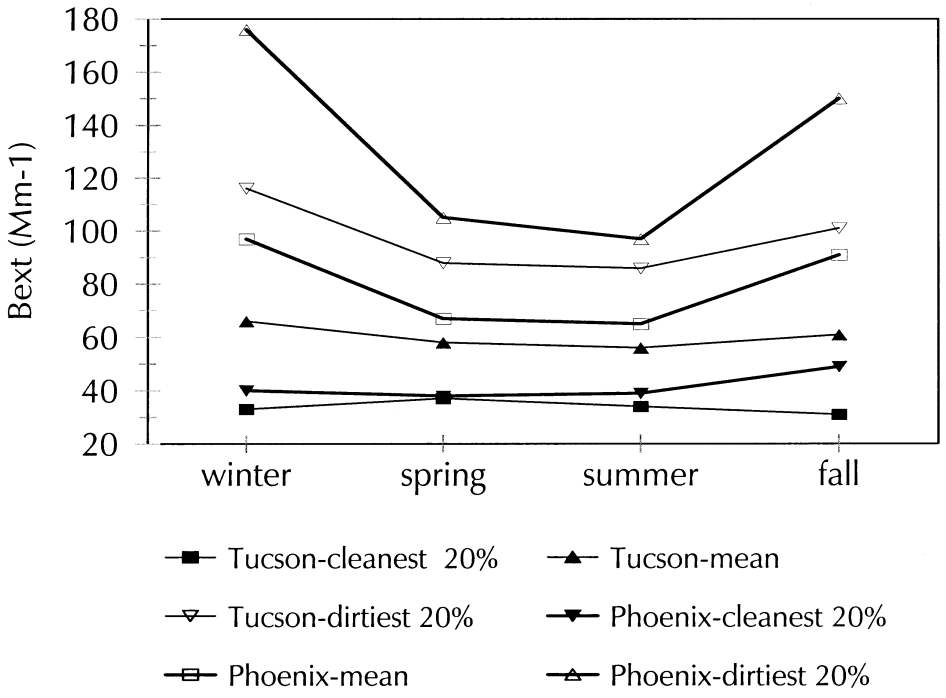

Figure I.18. *Seasonal patterns of hourly light extinction in Tucson and Phoenix from 1993 to 1998.*

Conclusions

Since monitoring of air pollutants began in the late 1960s in Arizona, considerable progress has been made in reducing concentrations of lead, sulfur dioxide, and carbon monoxide. Lead has been reduced to near background levels; sulfur dioxide concentrations near copper smelters, which chronically exceeded the standards until the mid-1980s, are now well within these standards; and carbon monoxide concentrations, which regularly exceeded standards in neighborhoods and near busy intersections in Phoenix (and to a far lesser extent in Tucson), now meet the standards. One hour ozone concentrations in Phoenix met the standard in 1997, 1998 and 1999, the first years since monitoring began. Phoenix ozone concentrations in the 1980s and early 1990s used to range as high as 0.15 to 0.18 parts per million (the standard is 0.12 ppm), in contrast to the highest, most recent reading of 0.14 ppm in 1996. Six of 20 ozone monitoring sites in greater Phoenix exceeded the new eight-hour ozone standard in 1996-1997.

Elevated concentrations of PM_{10} have been reduced substantially since the mid-1980s, with decreases of 20 to 70 percent in the urban areas and in most smaller cities and towns. In Payson and at some industrial sites, PM_{10} concentrations have been reduced by as much as two-thirds. By 1998, monitored violations of the PM_{10} standard, a common occurrence at many sites only 10 years ago, were limited to a few sites. Fine particulates concentrations ($PM_{2.5}$) have decreased in Phoenix and Tucson since 1995 and 1994, respectively; for example, at the centrally located Phoenix Supersite, the decrease has been 21 percent; at 22nd and Craycroft, in east-central Tucson, the decrease has been 24 percent. The Phoenix decreases are inconsistent with the increasing trends in light extinction, caused primarily by small particles.

In spite of the continued growth in Arizona, with the exception of Phoenix visibility in the last five years, not a single air pollutant at any site shows a consistent upward trend. Most standards are met most of the time, with the exceptions being the eight-hour ozone standard in Phoenix summers and the PM_{10} standards on both an episodic and annual basis at those sites affected by localized dense emissions. These improving air quality trends, resulting from control programs at the federal, state and local levels, have improved the respiratory health of the citizenry and can be considered a testament to the public support for a cleaner environment.