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Chapter 2: Particulate Matter (PM_{10}) in the Air

Question 2: What is the status of particulate matter in the Ozark-Ouachita Highlands?

The previous chapter provided a description of some of the relevant pollutant emissions characteristics within the Assessment area, including particulate matter. This chapter provides a more indepth analysis of the typical seasonal particulate matter concentration patterns in the atmosphere over the Assessment area that result from the emissions patterns described in Chapter 1.

Particulate matter (PM_{10}) as an air pollutant consists of those particles suspended in the atmosphere that are 10 microns or smaller in diameter. The most important constituents of particulate matter are particles 2.5 microns in diameter ($PM_{2.5}$) or smaller. These tiny particles can be breathed into human lungs and create serious health problems (e.g., respiratory ailments and asthma). White (1995) of the American Lung Association maintains that there is no tolerance level below which particulates do not affect human health. Stated another way—any increase in particulate concentration can cause an increase in human health problems. These problems have been triggered at concentrations well below current National Ambient Air Quality Standards (NAAQS) (White 1995).

Particulates come from many sources: industry, electrical power production, internal combustion engine exhaust, dust from natural and artificial sources, smoke from agricultural and forestry burning, and wildland fires. The U.S. Environmental Protection Agency (EPA) categorizes sources of particulate matter emissions that are 10 microns or smaller in diameter (PM_{10}) as point sources (smokestack emissions) or fugitive process sources (e.g., dust, leaks, uncontrolled vents). Fugitive dust is also generated by wind erosion, agricultural tilling, mining, construction, and both paved and unimproved roads (U.S. EPA 1996).

Even though industrial production has increased nationally during recent decades, pollution control equipment has dramatically reduced PM_{10} emissions from industrial processes (fig. 1.17). Figure 2.1 illustrates that in 1970, smokestacks generated over 12 million tons of PM_{10} particles, while in 1995, they produced only about 2.5 million tons (U.S. EPA 1996). The Clean Air Act

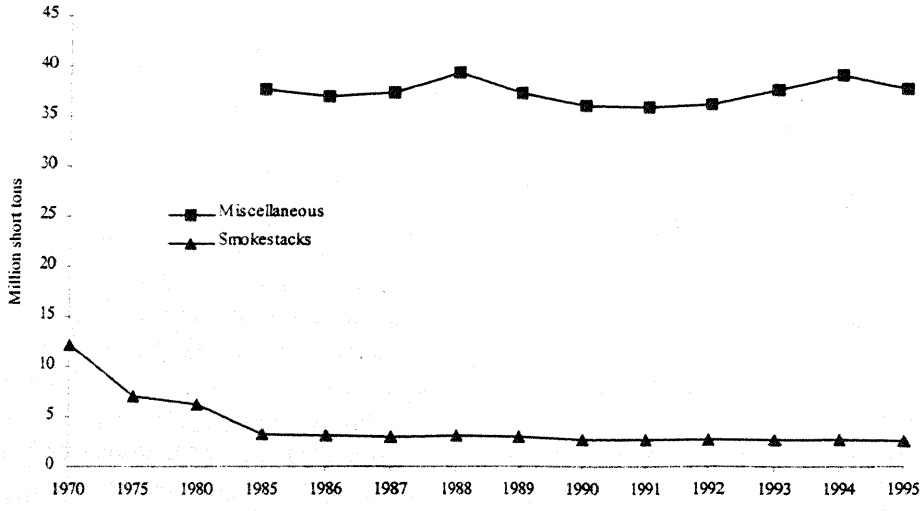


Figure 2.1—National smokestack and miscellaneous particulate matter (PM_{10}) emissions (in million short tons) from 1970 through 1995 (U.S. EPA 1996).

(1970) and its amendments (1977 and 1990) encouraged this abatement.

According to the guidelines of the NAAQS, PM_{10} concentrations at any location are not to exceed 150 micrograms per cubic meter ($\mu g\ m^{-3}$) during a 24-hour period. The NAAQS also limit the average annual exposure of PM_{10} at any location to 50 $\mu g\ m^{-3}$. In July 1997, the EPA implemented a new ambient air quality standard based on particulate matter 2.5 microns or smaller in diameter ($PM_{2.5}$). This new standard states that the average annual and 24-hour concentrations are not to exceed 15 $\mu g\ m^{-3}$ and 65 $\mu g\ m^{-3}$, respectively, at monitoring sites that represent a large-scale area and are not related to a specific source.

In addition to its potential effect on human health, particulate matter reduces visibility (discussed in the next chapter). Within the Assessment area, all areas presently meet the PM_{10} NAAQS. There are no chronic particulate matter (PM) problems on or near national forest lands in Arkansas or Oklahoma. In southern Missouri, however, the charcoal industry has created a locality with reoccurring days of high PM concentrations (Braun 1996). The State is looking into this situation.

Key Findings

1. Particulate matter concentrations (PM_{10}) show a definite seasonal trend over the Assessment area. The highest concentrations between 1991 and 1995 were during the summer months, with an average period concentration of 33.05 micrograms per cubic meter ($\mu g\ m^{-3}$); the average winter concentration was 19.84 $\mu g\ m^{-3}$.
2. Rural areas have lower PM_{10} concentrations than urban areas.
3. There is a spatial distribution of PM_{10} across the Assessment area, with the lowest annual average PM_{10} concentrations occurring in western Arkansas.
4. The Assessment area is well within the National Ambient Air Quality Standards (NAAQS) for PM_{10}. Implementation of the new $PM_{2.5}$ regulations may create a challenge to prescribed burning programs of farmers and land management agencies such as the USDA Forest Service.

Data Sources and Methods of Analysis

Most data analyzed for this Assessment are from the EPA's Aerometric Information Retrieval System (AIRS). In addition, the team used data from the Interagency Monitoring of Protected Visual Environment (IMPROVE) monitoring network.

The AIRS data base is the national data storage system for all Criteria Pollutants. Data were obtained from AIRS sites both inside and within 100 miles (mi) of the Assessment area boundary. The EPA sets rigid data collection standards and assures the quality of all data entered into the system. Because the EPA changed PM standards in 1987 from measurement of total suspended particles (TSP) to PM_{10}, the team decided to avoid using TSP data and instead chose PM_{10} data from 1991 to 1995 because all sites were monitoring with PM_{10} equipment by 1991. The point data were displayed using the Geographic Information System (GIS) software called ArcInfo®. These data were analyzed across the Assessment area using the "inverse distance weighting method" (Burrough 1988) and then displayed in a grid format. Each grid was assigned a value. These grid values represent estimated rather than measured values. This limitation needs to be considered when making assertions or recommendations using these or similar data.

Patterns and Trends

Table 2.1 shows the seasonal, annual, and period means of PM_{10} concentrations over the entire Assessment area based on observational data from the AIRS network (mainly urban areas). The numbers in table 2.1 represent averages of all the PM_{10} monitors inside the Assessment area from 1991 through 1995. The seasonality of PM_{10} is clearly evident in table 2.1, with the average PM_{10} concentrations at AIRS monitoring sites over the entire Assessment area typically increasing from wintertime minimum values to summertime maximum values. Figure 2.2 shows the typical, large-scale spatial distributions of PM_{10} concentrations for each season over the Assessment area based solely on AIRS network data. Because most observation sites in the AIRS network are in urban areas where PM_{10} concentrations tend to be higher than in rural settings, the interpolated spatial patterns of PM_{10} concentrations across the Assessment area most likely overestimate nonurban PM_{10} concentrations. Nevertheless, the spatial patterns shown in figure 2.2 provide a general indication of the impact of urban PM_{10} emission sites on PM_{10} concentrations in the Assessment area.

The interpolated mean winter PM_{10} data from the AIRS network shown in figure 2.2 indicate that most PM_{10} concentrations in the Assessment area are less than 22.5 $\mu g\ m^{-3}$ (based on 1991 to 1995 data). Concentrations tend to increase during the spring months over parts of the Assessment area, particularly over the western and eastern sections of the Assessment area as well as in southern Missouri (fig. 2.2). The interpolated AIRS PM_{10} data indicate average spring concentrations in these regions are about 22.51 to 27.5 $\mu g\ m^{-3}$, although actual mean concentrations in some of the more rural locations in these regions are probably less. In central Arkansas, average springtime concentrations are generally lower. The highest particulate matter concentrations throughout the Assessment area are usually found during the summer months (fig. 2.2). The interpolated AIRS data suggest summertime PM_{10} concentrations in the Assessment area often exceed 27.5 $\mu g\ m^{-3}$ (especially in urban areas). Particulate matter concentrations tend to decrease during the fall months, although they are still relatively high compared to the wintertime minimum concentrations (fig. 2.2). The far northern sections of the Assessment area experience the most dramatic decrease in PM_{10} concentrations from the summer to fall seasons. Based solely on AIRS network data, the annual mean PM_{10} concentrations for the entire period over most of the Assessment area range from 22.51 to 27.5 $\mu g\ m^{-3}$ (fig. 2.3), well within the present NAAQS of 50 $\mu g\ m^{-3}$.

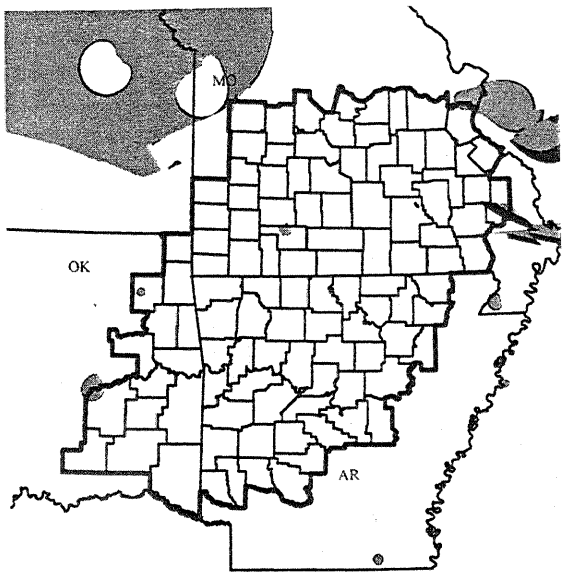
The seasonality of PM_{10} is partly due to increased dust production in the spring and summer months compared to the winter months—especially during dry years—as well as increased power production for air conditioning. Also, emissions from automobiles and other internal combustion engines increase during the summer. Another source of particulate matter is the natural increase in atmospheric moisture (water vapor) during the summer. Certain kinds of particles, especially sulfates, are hygroscopic (meaning they attract water), which increases their weight. The AIRS data also appear to indicate the effects of agricultural tillage. For example, in March, higher PM_{10} values show up in southwestern Missouri during tillage; in April and May, these higher concentrations are in the agricultural areas in Arkansas (tillage occurs later because the area retains wetness). (Monthly maps are available upon request from the Forest Service in Arkansas—see information inside the front cover of this report.)

Figure 2.4 illustrates the average PM_{10} mass concentrations in $\mu g\ m^{-3}$ from 1992 to 1995 at sites in the IMPROVE network. These are Class I wilderness areas—wildernesses that are larger than 5,000 acres and national parks larger than 6,000 acres in existence on or before August 7, 1977. Class I areas are defined by the Clean Air Act (CAA) amendments of 1977 as having "special protection" from effects of air pollution because

Table 2.1—Average PM_{10} concentrations (in $\mu g\ m^{-3}$) in the Assessment area by season, year, and 5-year period

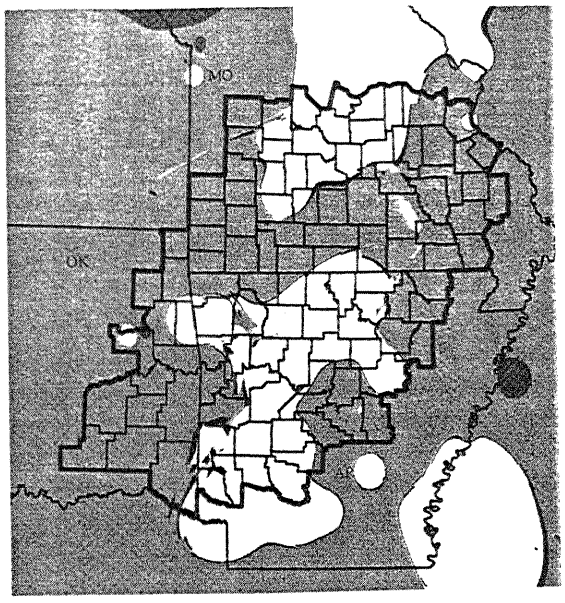
Season	1991	1992	1993	1994	1995	1991–1995
Winter	21.68	21.04	19.47	19.74	18.33	19.84
Spring	23.75	25.05	22.32	25.53	24.69	24.08
Summer	34.04	31.29	34.12	25.47	32.81	33.05
Fall	26.74	23.52	21.61	23.59	28.09	24.77
Annual	26.35	25.20	24.29	25.43	25.93	25.47

PM_{10} = particulate matter 10 microns or smaller; $\mu g\ m^{-3}$ = micrograms per cubic meter.



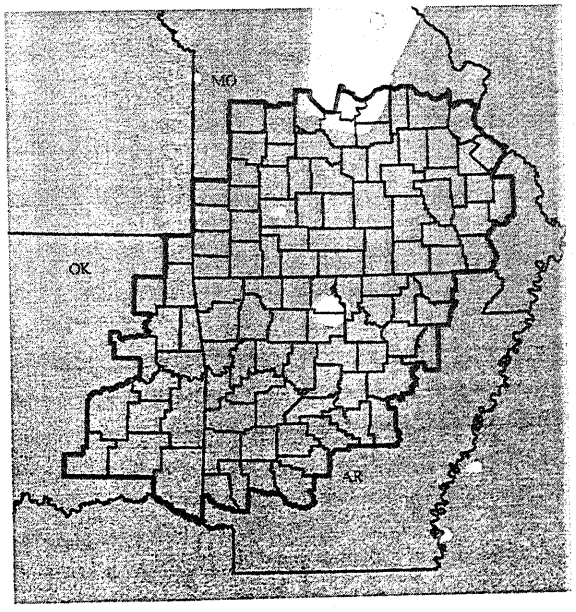
Average PM_{10} values for winter, 1991-1995

0 - 17.5
17.51 - 22.5
22.51 - 27.5
27.51 - 55



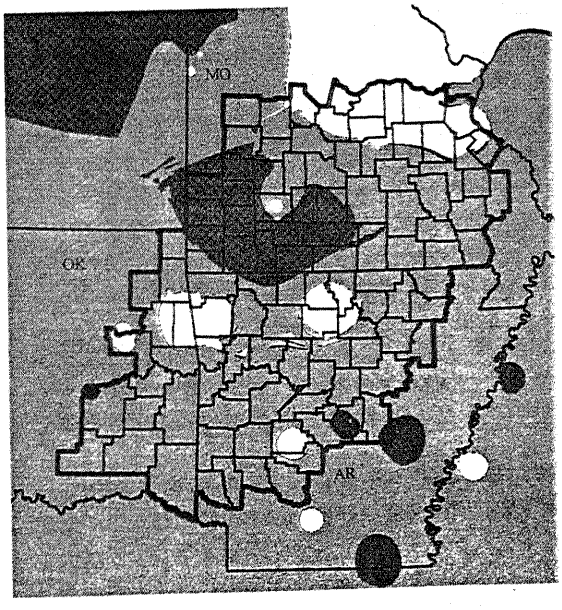
Average PM_{10} values for spring, 1991-1995

0 - 17.5
17.51 - 22.5
22.51 - 27.5
27.51 - 55



Average PM_{10} values for summer, 1991-1995

0 - 17.5
17.51 - 22.5
22.51 - 27.5
27.51 - 55



Average PM_{10} values for fall, 1991-1995

0 - 17.5
17.51 - 22.5
22.51 - 27.5
27.51 - 55

Figure 2.2—Average PM_{10} values ($\mu g\ m^{-3}$) during winter, spring, summer, and fall from 1991 through 1995.

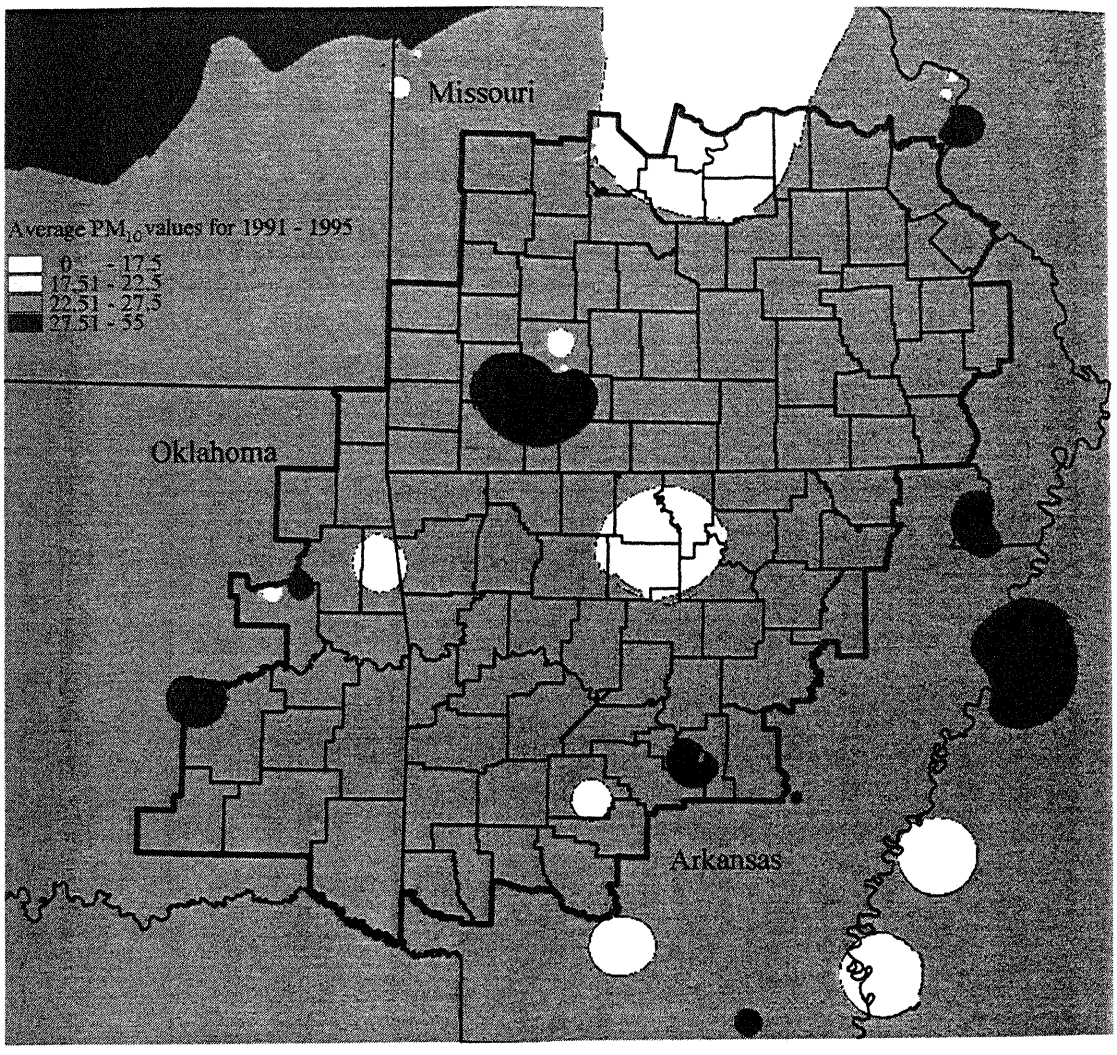


Figure 2.3—Average PM_{10} values ($\mu g\ m^{-3}$) for the 1991 through 1995 period.

of their "air-quality related values (AQRV's)," i.e., water quality, native vegetation, ecosystem integrity, and visibility. Figure 2.4 indicates that the annual mean PM_{10} concentrations in the Class I areas within the Assessment area are between 15 and 18 $\mu g\ m^{-3}$ (average concentration at Deer, AR—a nonurban area—is 17.4 $\mu g\ m^{-3}$). Comparing these values with the annual mean PM_{10} concentration in urban areas (AIRS network data) within the Assessment area (25.47 $\mu g\ m^{-3}$ from table 2.1) suggests that the rural forested regions in the Assessment area have about 30 to 40 percent less particulate matter than the urban areas when averaged over an entire year.

Prescribed burning is currently a minor source of particulate emissions in the Highlands area on a yearly basis. The 1995 level of managed burning reported by the EPA produced 538 short tons of emissions, accounting for 1.3 percent of the national total PM_{10} emissions (U.S. EPA 1996). These emissions include silvicultural and agricultural burning. On shorter time scales, however, prescribed burning can result in significant local emissions of particulate matter. Two studies have been reported in the Southern States where portable PM_{10} monitors were set up adjacent to prescribed fires for 2 to 12 hours. The Florida Department of Environmental Protection and the

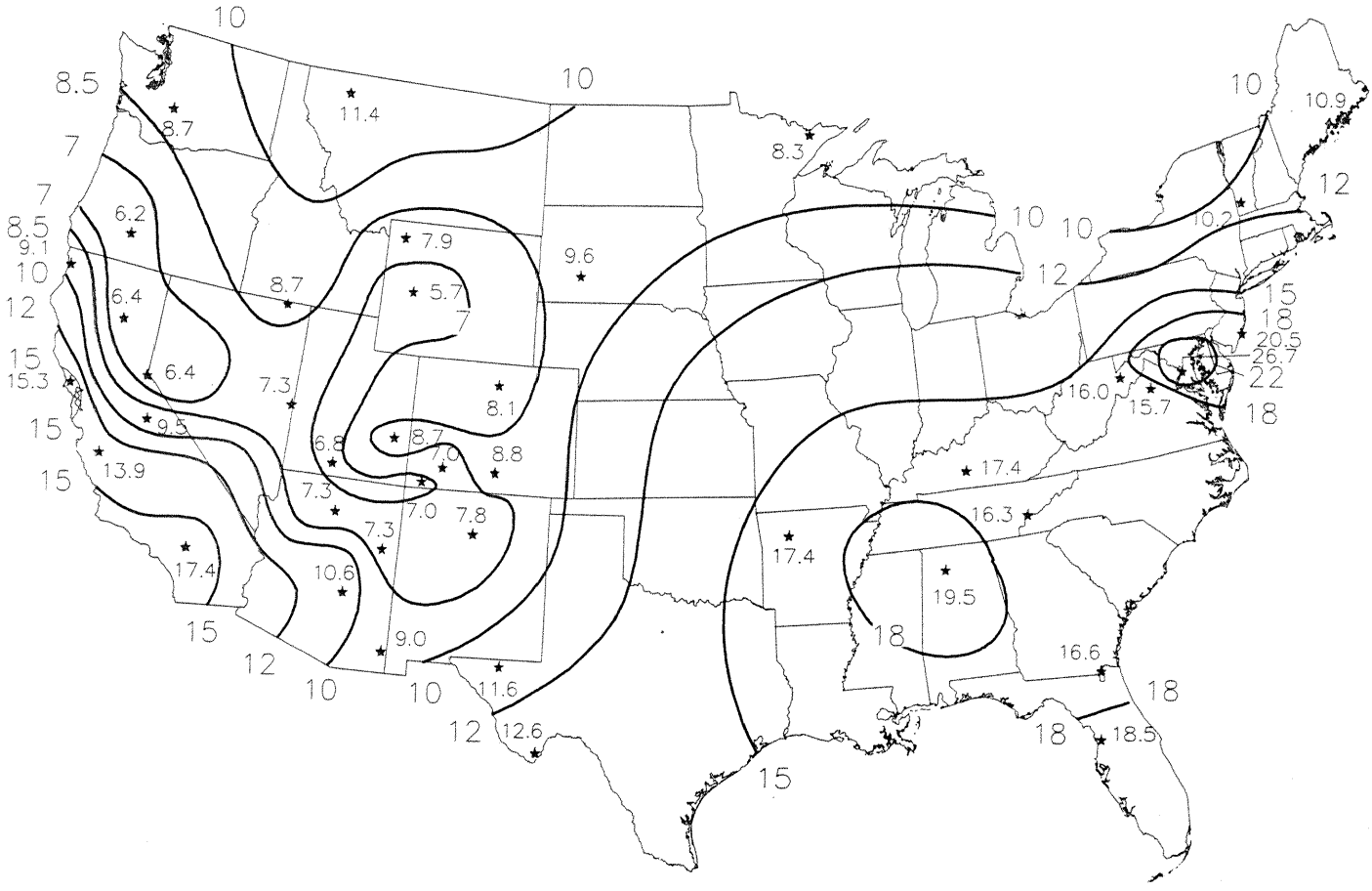


Figure 2.4—Average PM_{10} mass concentration ($\mu g\ m^{-3}$) for each site in the IMPROVE network for the 1992 through 1995 period (CIRA 1997).

Apalachicola National Forest conducted one study (FL DEP 1993), and the Texas Forest Service and the National Forests in Texas conducted the second (Hunt and others 1994).

In 90 percent of the cases from these prescribed fire studies, particulate-matter concentrations were less than 150 $\mu g\ m^{-3}$ when measured more than 1 mi from the control line of the prescribed fire. The standard was usually maintained as close as 1 mi from the control line. However, the likelihood of exceeding the 24-hour NAAQS for particulate matter of 150 PM_{10} $\mu g\ m^{-3}$ increased as fire control lines were approached, with only a few cases noted where the 24-hour standard was not exceeded at the control line. Both studies showed that prior to burning, the PM_{10} concentrations in the air mass were 15 to 30 $\mu g\ m^{-3}$, well below both the annual and 24-hour standards. The PM_{10} concentrations associated with prescribed burns are dependent on weather, type and amount of fuel, fuel moisture, and the intensity and duration of the burn. These conditions are variable in time and space over the area of the burn and downwind of the burn.

Implications and Opportunities

Any future trends in particulate matter concentrations over the Assessment area will likely be influenced by the new, stricter NAAQS for $PM_{2.5}$. The smaller particle is considered a health hazard since it can be breathed deeply into the lungs. The smaller particle also is more efficient at scattering light, so reductions for health concerns will also improve visibility. Any improvements in the exhaust systems of internal combustion engines, both gasoline and diesel, could result in emission reductions of

particulate matter. Also, dust abatement on gravel roads may become necessary in some areas. Until the $PM_{2.5}$ monitoring system mandated by the new NAAQS provides the data, the impact of the stricter standards on the use of prescribed fire will remain conjecture. It will be approximately 5 years before these data will be available.

How will the new $PM_{2.5}$ regulations impact the use of prescribed fire? Haddow (1990) found that approximately 70 percent of the particulate matter produced by wildland fuels is within the $PM_{2.5}$ size class. The proposed regulations call for the 24-hour standard to be less than 65 $\mu g\ m^{-3}$ and the annual average to be less than 15 $\mu g\ m^{-3}$. Figure 2.5 illustrates that the 1992 to 1995 annual average concentration of fine mass particles (diameter of 2.5 microns or smaller) was between 9 and 11 $\mu g\ m^{-3}$ over the more rural areas of the Assessment area based on interpolated IMPROVE network data. These concentrations represent between 60 and 73 percent of the proposed standard annual average of 15 $\mu g\ m^{-3}$ and 18 to 22 percent of the current annual standard of 50 $\mu g\ m^{-3}$. Thus, even with the implementation of the new $PM_{2.5}$ standards, the more rural sections of the Assessment area should still be in compliance if current $PM_{2.5}$ concentration averages continue to characterize the region.

According to Forest Service records, most prescribed burning occurs during March in the Assessment area. Average PM_{10} concentrations in the Assessment area during March (from 1991 through 1995)—when prescribed burning is common—ranged from a minimum of 10 to 20 $\mu g\ m^{-3}$ to a maximum of 30 to 40 $\mu g\ m^{-3}$ (fig. 2.6) with a mean of 22.7 $\mu g\ m^{-3}$ (based on

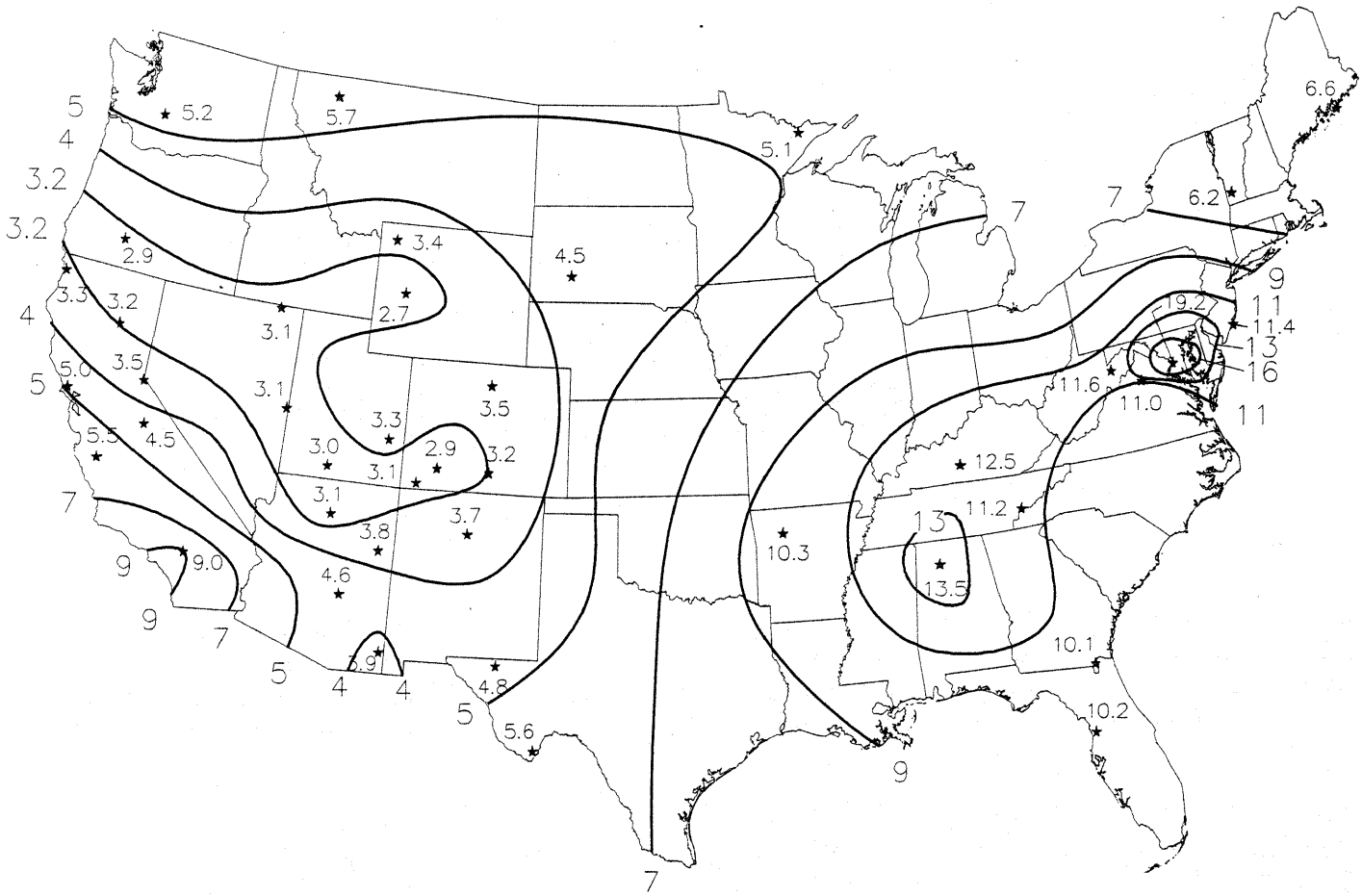


Figure 2.5—Average fine particle mass ($PM_{2.5}$) concentrations ($\mu g\ m^{-3}$) for each site in the IMPROVE network for the 1992 through 1995 period (CIRA 1997).

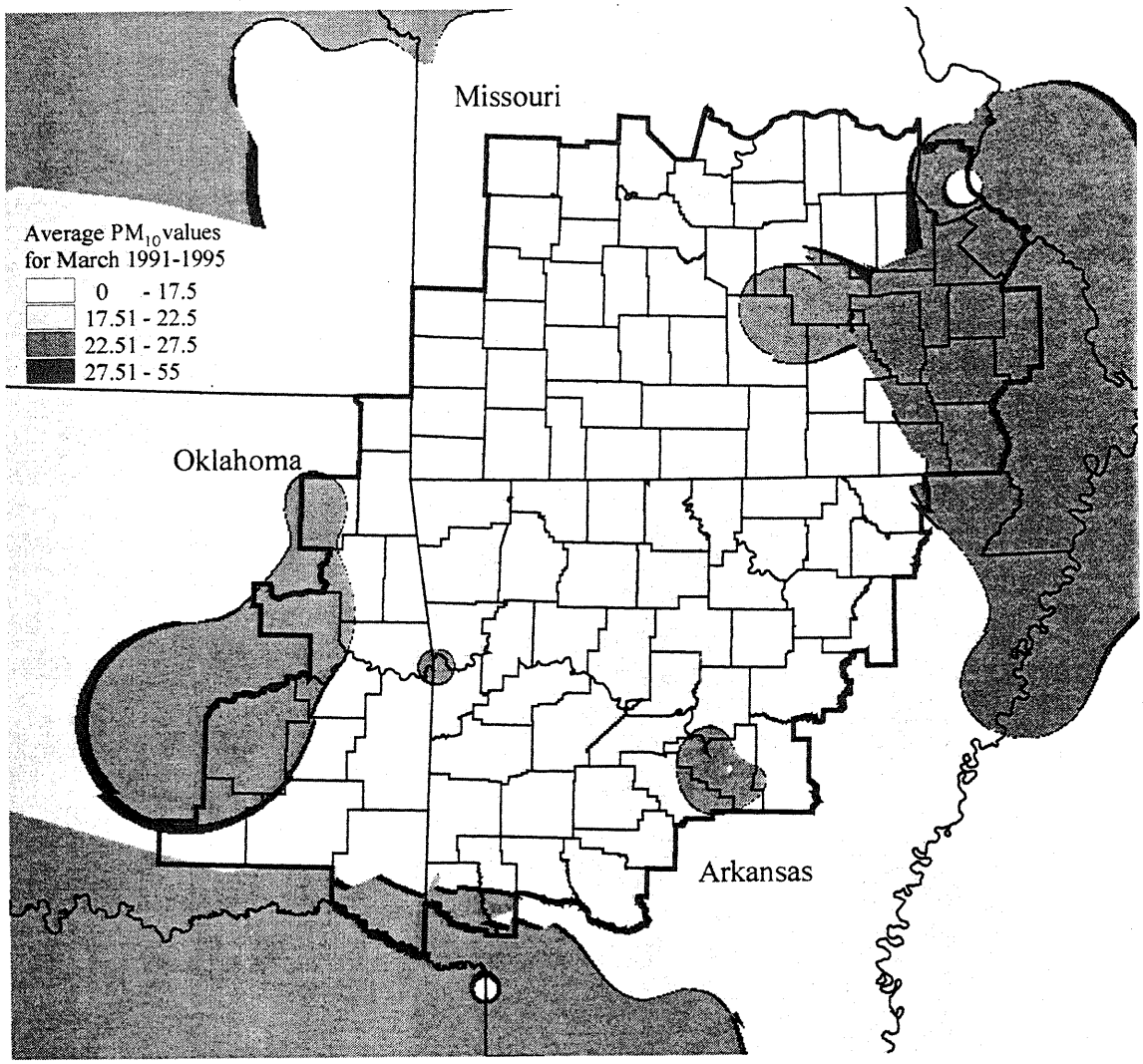


Figure 2.6—Average PM_{10} concentrations ($\mu g\ m^{-3}$) during March for the 1991 through 1995 period.

interpolated AIRS data). If prescribed fire becomes a more widely used land management tool in the Assessment area during the normal prescribed fire season, total PM_{10} and $PM_{2.5}$ emissions and concentrations in the atmosphere will likely increase during the springtime. These increases would lead to a more dramatic degradation of air quality from the winter to spring seasons than what is currently observed (fig. 2.2).

Ozark-Ouachita Highlands Assessment:

Air Quality

Eastern Region
U.S. Department of Agriculture
Forest Service
Milwaukee, WI

North Central Research Station
U.S. Department of Agriculture
Forest Service
St. Paul, MN

Southern Region
U.S. Department of Agriculture
Forest Service
Atlanta, GA

Southern Research Station
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Chapter 2: Particulate Matter in the Air

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Chapter 3: Visibility

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Chapter 5: Acid Deposition

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This publication provides information about the atmospheric conditions in and near the national forests in the Ozark-Ouachita Highlands: the Mark Twain in Missouri, the Ouachita in Arkansas and Oklahoma, and the Ozark-St. Francis National Forests in Arkansas. This report includes information about particulate matter, visibility, ozone concentrations, and acid deposition in the Ozark-Ouachita Highlands Assessment area.

Keywords: Acid deposition, Clean Air Act, ozone, particulate matter, pollution, visibility.