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Options for Reducing the Costs of Criteria Pollutant Monitoring

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CONTENTS

1 INTRODUCTION

State and local air pollution control agencies currently spend approximately \$55-\$58 million annually on monitoring criteria pollutants. These costs include operating and maintaining monitoring systems, new equipment purchases, quality assurance, laboratory analysis (the portion for air monitoring only), maintaining computerized data bases, and data summary and reporting. Since 1980 there have been increasing efforts to hold or reduce monitoring costs; over the same period pressures for additional monitoring have developed (for PM-10, visibility, air toxics, short-term NO_2, and non-methane hydrocarbon monitoring). Even with new (albeit modest) monitoring activities, budget reductions at both the State and federal levels have been achieved by eliminating bubbler sites for SO_2 and NO_2, by reducing the number of TSP monitors, and moving toward increased automation.* Nevertheless, both the pressures to reduce air monitoring costs and the necessity for additional monitoring continue. The purpose of this document is to provide guidance to State and local agencies on how the monitoring of criteria pollutants can become more cost-effective.

A number of options for improving the cost-effectiveness of monitoring networks have been considered. The options presented, however, do not apply to the NAMS network since it was established to provide the minimum number of sites needed to provide data for national policy analyses and trends, and for reporting to the public on air quality in major metropolitan areas. The options had to be constructed so that they do not hinder EPA air quality objectives. In view of this goal, it was determined that changes in monitoring programs should not

Disturb the NAMS monitoring network,

Disturb designated reference and equivalence method programs,

Reduce measurement precision and accuracy for individual monitoring sites and overall network performance,

Adversely affect the SIP-call process,

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* Reduced monitoring has occurred only at sites with observations well below the NAAQS.

Adversely affect national and regional trend analysis, or

Adversely affect SASD NAAQS review requirements.

Four broad categories of options that meet these constraints have been identified:

A. Reducing the number of operating monitoring sites

B. Streamlining and standardizing nationwide data collection, reduction, and reporting activities

C. Reducing requirements for State and local agency reporting to the EPA

D. Reducing instrument and system maintenance costs

Within these four broad, somewhat overlapping categories, 14 specific options have been identified (Table 1-1). In a previous report these categories were described and ranked as to their potential for monitoring cost savings (Burton and Pollack, 1985); these rankings are indicated in Table 1-1.

This report describes the options for reducing the number of criteria pollutant monitors in operation at any given time in a State network. We consider reductions in monitoring for five of the six criteria pollutants: TSP, SO_2, O_3, NO_2, and CO. We do not consider reductions in monitoring for lead because, due to the relatively recent (1982) requirement for lead monitoring, little lead data is available.

The options are offered as examples only, and the EPA will consider State proposals regarding reduced monitoring on a case-by-case basis, judging their acceptability on their individual merit, with final authority for the SLAMS resting with the Regional Administrator, and for the NAMS, with the Administrator.

Section 2 of the report describes the current nationwide criteria pollutant monitoring network and the data base used to evaluate the monitoring reduction options. The following two sections discuss the three options for reducing the effective number of monitors: shutting down monitors permanently, rotating monitors, and seasonal monitoring. In Section 5 we demonstrate the potential cost savings for an example network of 100 monitoring sites after implementation of some of the suggested options. Finally, Section 6 discusses how statistics on statewide trends can be adjusted after one or more of the suggested options are implemented and how cost-effectiveness can be optimized.

Table 1-1 Options for improving the cost-effectiveness of monitoring criteria pollutants. (Source: Burton and Pollack, 1985).

Rank	Option Category	Option	Description/Comment
(1)	A. Reducing the number of operating SLAMS monitoring sites	A.1 Selected seasonal monitoring	Reduce monitoring from everyday sampling to everyday sampling during peak pollution seasons (as is now permitted for ozone)
		A.2 Mothball selected monitoring sites	Suspend monitoring for sites where the design value concentration is below a specified cutoff value for the controlling NAAQS. Resume monitoring if air quality problems are indicated using other data sources.
		A.3 Rotating sampling schedule for selected monitoring sites	Divide monitoring sites into categories based on emission sources, population, and geographical/climatological patterns. Within each category, rotate monitoring on an annual basis; i.e., each monitor is in operation in alternate years or every third year.
		A.4 Combination of options A.1 to A.3 as desired and feasible	Some monitors are mothballed, others operate on a rotating and/or seasonal schedule.
(2)	B. Streamlining and standardizing nationwide data collection, and reporting activities	B.1 Automation of data collection and data handling	Adopt advanced, standardized data loggers and telemetry together with standardized software for data handling. Adopt verification, reduction and centralized software maintenance.
		B.2 Automation of calibration and data verification	Adopt advanced, standardized component and system calibration as well as automated data verification practices. Integrate with telemetry system as desired and feasible. Adopt centralized software maintenance.
		B.3 Establishment of regional centers at state level	Consolidate among states selected data collection, data handling and software maintenance functions. Certain monitoring activities may also be consolidated along the vicinity of state borders.
		B.4 Combination of options C.1 to C.4 as desired and feasible.	

continued

TABLE 1-1. (Concluded)

Rank	Option Category	Option	Description/Comment
(3)	C. Reducing state and local agency reporting burden to EPA	C.1 Unify reporting frequency	Make NAMS and SLAMS reporting frequency annual.
		C.2 Reports required for subset of SLAMS only	Divide SLAMS sites into categories based on emission sources, population, and geographical/climatoligical patterns. Identify one site as indicator site for each category and state, and report only those data annually.
		C.3 Generalize formats for data submission	Allow states greater flexibility in their submissions to the EPA. EPA would take on the burden of unifying data.
		C.4 Absorption by EPA of greater portion of reporting burden	Allow states to submit reduced data. EPA calculates statistics and prepares reports.
		C.5 Combination of options B.1 to B.4 as desired and feasible	
(4)	D. Reducing instrument and system maintenance costs	D.1 Increase instrument and system reliability	Encourage instrument manufacturers and system integrators to lengthen time between maintenance and failure.
		D.2 Increase instrument functionality	Encourage instrument manufacturers to provide critical component performance status signals. Incorporate these signals into data collection, verification and maintenance practices.

86059 7

2 THE NATIONWIDE CRITERIA POLLUTANT MONITORING NETWORK: DESCRIPTIVE DATA

State and local agencies are required to submit quarterly criteria pollutant data from the NAMS and annual statistics from the SLAMS. Data are submitted in a standard format to EPA's Storge and Retrieval of Aerometric Data (SAROAD) system. From the raw monitoring data submitted, EPA prepares numerous summary statistics and reports. Annual summary statistics from EPA's "Quick Look Report" were used in the analyses in this report.*

The Quick Look Report contains those annual summary statistics necessary to determine whether a site achieves a National Ambient Air Quality Standard (NAAQS) in a given year. The reported summary statistics vary by pollutant, of course, since the forms of the standards are different. Table 2-1 lists the annual summary statistics in the Quick Look Report for each of the five criteria pollutants under consideration. We received and processed tape copies of Quick Look Reports for these five pollutants for the six-year period 1978 to 1983.

Using information provided by State and local air pollution agencies, the EPA maintains a data base of site locations and characteristics; we received a June 1985 version of this SAROAD site file. From this file we extracted, for all sites with data in the interval 1978 to 1983, the site address, latitude and longitude, UTM zone and coordinates, city and AQCR population, station type (e.g., suburban versus rural, industrial versus residential), and site type for each pollutant. The site type for each pollutant was of particular interest in this study. Three site types are defined in the SAROAD site file.

National Air Monitoring Stations (NAMS), which are located in areas with high pollutant concentrations and/or high population exposure; the network was established in 1979 to provide a network of high-

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* The "Quick Look Report" lists annual summary statistics for all monitoring stations reporting data to the NADB. These lists are included in the annual report by the EPA titled Air Quality Data and are available on computer tape.

TABLE 2-1. Annual summary statistics from the EPA's Quick Look Report.

Pollutant	Summary Statistics
Total Suspended Particulate	Number of valid 24-hour observations Maximum 24-hour concentration Second highest 24-hour concentration Number of 24-hour concentrations above 260 $\mu g/m^3$ Number of 24-hour concentrations above 150 $\mu g/m^3$ Annual arithmetic mean Annual geometric mean Annual geometric standard deviation
Sulfur Dioxide	Number of valid 1-hour observations Maximum 24-hour average Second highest 24-hour average Number of 24-hour averages above 365 $\mu g/m^3$ Maximum 3-hour average Second highest 3-hour average Number of 3-hour averages above 1300 $\mu g/m^3$ Maximum 1-hour concentration Second highest 1-hour concentration Annual arithmetic mean
Carbon Monoxide	Number of valid 1-hour observations Maximum 1-hour concentration Second highest 1-hour concentration Number of 1-hour concentrations above 40 mg/m^3 Maximum 8-hour average Second highest 8-hour average Number of 8-hour averages above 10 mg/m^3
Ozone	Number of valid daily maxima Number of days in the ozone season Maximum daily maximum 1-hour concentration Second highest daily maximum 1-hour concentration Third highest daily maximum 1-hour concentration Number of observed daily maxima above 0.125 ppm Number of estimated daily maxima above 0.125 ppm Number of days assumed to have daily maxima below 0.125 ppm
Nitrogen Dioxide	Number of valid 1-hour concentrations Maximum 1-hour concentration Second highest 1-hour concentration Maximum 24-hour average Second highest 24-hour average Annual arithmetic mean

quality data with consistent siting criteria.

State and Local Air Monitoring Stations (SLAMS), which comprise the majority of monitors.

Special Purpose Monitors (SPMs), which are set up generally for a short period of time only and are operated by government agencies or private groups. SPMs were omitted from consideration in this study.

A monitoring site is identified in the SAROAD system by a unique 12-character alphanumeric identification. This 12-character code contains five subcodes for State, city or county local site number, operating agency, and project classification (e.g., population oriented, background surveillance). With this coding, if the controlling agency for a site changed at some point in time, there would appear to be two sites reporting data to the SAROAD system when actually there was only one site. Therefore, if two sites had the same 12-character code except for the operating agency identification, we combined the annual summary statistics from the two separate sites. (For example, to combine two annual means a weighted average of the two separate means was calculated, where the weight for each year is the number of reported observations.) The exception to this rule is the case of duplicate monitors at one location for quality assurance checks (project classification 09); for this study duplicate monitors were omitted.

In the Quick Look Report a two-digit code identifies the monitoring method for each pollutant monitored at a site. With this system, if the monitoring method for a specific pollutant changes during a year, a new site is defined in the Quick Look Report. Therefore we disregarded the method code and combined the annual summary statistics for sites for which the 12-character SAROAD code was otherwise the same (except perhaps for operating agency). Since the 24-hour bubbler methods for NO_2 and SO_2 monitoring are by now almost entirely phased out, we omitted from consideration monitors using these methods.

The number of monitoring sites in operation in 1983 for each criteria pollutant is shown in Table 2-2. The numbers in the table represent actual monitoring sites, i.e., changes in operating agency code or pollutant method codes have been disregarded. In Table 2-2 the total number of monitors for all pollutants is greater than the total number of monitoring stations in the country because many stations monitor more than one pollutant. Table 2-3 shows the number of monitoring stations per number of pollutants monitored.

All the options described in this report involve shutting down a pollutant monitor either temporarily or permanently. The cost savings resulting

TABLE 2-2. Primary national ambient air quality standards and number of 1983 monitoring sites.

Pollutant	Averaging Time	Concentration	NAMS	SLAMS[a]	Total
Total Suspended Particulate	Annual geometric mean	75 $\mu g/m^3$	633	1878	2511
	24-hour	260 $\mu g/m^3$			
Ozone	Maximum daily 1-hour average	0.12 ppm ($235\ \mu g/m^3$)	206	375	581
Sulfur Dioxide[b]	Annual arithmetic mean	80 $\mu g/m^3$ (0.03 ppm)	216	315	531
	24-hour	365 $\mu g/m^3$ (0.14 ppm)			
Carbon Monoxide	8-hour	10 mg/m^3 (9 ppm)	117	322	439
	1-hour	40 mg/m^3 (35 ppm)			
Nitrogen Dioxide*	Annual arithmetic mean	100 $\mu g/m^3$ (0.053 ppm)	57	165	222

[a] Excluding NAMS monitors.
[b] Monitors using 24-hour bubbler methods are not included.

TABLE 2-3. Distribution of the number of pollutants monitored at each monitoring station.

Number of Pollutants Monitored	Number of Stations			Percent of Stations
	NAMS[a]	SLAMS[b]	Total	
1	670	1974	2644	81.9
2	108	204	312	9.7
3	41	87	128	4.0
4	15	68	83	2.6
5	11	49	60	1.9
Total	845	2382	3227	100

[a] In this table a station is designated as NAMS if it is a NAMS for at least one of the pollutants monitored. Generally speaking, a NAMS station is so designated for all pollutants monitored.

[b] Excluding NAMS monitors.

from these shutdowns are clearly related to the number of pollutants monitored. For example, if SO_2 monitoring is discontinued at a station where all other pollutants will continue to be monitored, then the cost savings is less than if SO_2 were the only pollutant monitored at the site, because there are certain fixed costs for the operation of the monitoring shelter. The number of stations monitoring all possible combinations of one, two, three, and four pollutants is provided in Table 2-4; we will return to these tables in the cost savings discussion in Section 5. For now, we note that of the 3,227 stations, 82 percent (2,646) monitor only one pollutant; of these, 80 percent (2,120) monitor TSP. Of the total 3,227 stations, therefore, 66 percent (2,120) monitor TSP only.

At the vast majority of these TSP monitors, the annual geometric mean and second-highest 24-hour maximum concentration are below the NAAQS. Figures 2-1 and 2-2 show the cumulative distribution functions (cdf) of these two annual summary statistics for 1983. From these cdf's one can see what percentage of the sites have annual geometric means or second highest 24-hour maximum below any target concentration. In Figure 2-1, for example, we see that about 95 percent of the sites are below the long-term NAAQS of 75 $\mu g/m^3$ and about 82 percent have annual geometric means below 60 $\mu g/m^3$. Similarly, about 98 percent of the monitors show concentrations below the short-term NAAQS of 260 $\mu g/m^3$, and about 94 percent have second-highest 24 maxima below 200 $\mu g/m^3$. These percentages do not change when one considers only sites with valid data, using NADB's quarterly validity criteria for TSP data (EPA, 1984), as can be seen in the plots.

One can see from the cdf's for 1983 annual average NO_2 concentration (Figure 2-3) and annual average and second-highest 24-hour SO_2 concentration (Figures 2-4 and 2-5) that NO_2 and SO_2 concentrations are well below the standard at most monitors. The same is true for the 1-hour CO NAAQS (Figure 2-6). But the 8-hour CO NAAQS 2-7 is the controlling standard at every monitoring site; while over 99 percent of the monitors have concentrations below the 1-hour NAAQS, only about 67 percent have concentrations below the 8-hour NAAQS (Figure 2-7). Finally, the cdf for the ozone standard (Figure 2-8) shows that only about 40 percent of the monitors have second-highest 1983 daily maximum 1-hour concentration below the NAAQS of 0.12 ppm.

TABLE 2-4. Distribution of pollutants monitored at single and multiple pollutant monitoring stations.

Pollutant Monitored	Number of NAMS[a]	Stations SLAMS[b]	Total
(a) Stations where one pollutant is monitored			
TSP	479	1641	2120
O_3	78	122	200
CO	59	125	184
SO_2	51	84	135
NO_2	3	2	5
(b) Stations where two pollutants are monitored			
TSP, SO_2	38	70	108
TSP, O_3	15	35	50
SO_2, O_3	18	26	44
SO_2, CO	8	21	29
TSP, CO	8	16	24
CO, O_3	7	16	23
O_3, NO_2	7	12	19
CO, NO_2	2	4	6
SO_2, NO_2	4	2	6
TSP, NO_2	1	2	3

(continued)

TABLE 2-4 (concluded).

Pollutant Monitored	Number of NAMS	Stations SLAMS	Total
(c) Stations where three pollutants are monitored			
TSP, O_3, SO_2	11	34	45
TSP, O_3, CO	8	10	18
O_3, SO_2, NO_2	4	14	18
O_3, CO, NO_2	3	8	11
CO, SO_2, NO_2	4	6	10
TSP, O_3, NO_2	3	5	8
TSP, SO_2, NO_2	4	2	6
O_3, CO, SO_2	1	5	6
TSP, CO, SO_2	1	2	3
TSP, CO, NO_2	2	1	3
(d) Stations where four pollutants are monitored			
TSP, O_3, CO, NO_2	3	19	22
TSP, O_3, SO_2, NO_2	4	17	21
O_3, CO, SO_2, NO_2	0	20	20
TSP, O_3, CO, SO_2	6	10	16
TSP, CO, SO_2, NO_2	2	2	4
(e) Stations where all five pollutants are monitored			
There are 11 NAMS and 49 SLAMS, or 60 total, stations where all five pollutants are monitored.			

[a] In this table a multiple pollutant station is designated as NAMS it if is a NAMS for at least one of the pollutants monitored. Generally speaking, a NAMS station is so designated for all pollutants monitored.

[b] Excluding NAMS monitors.

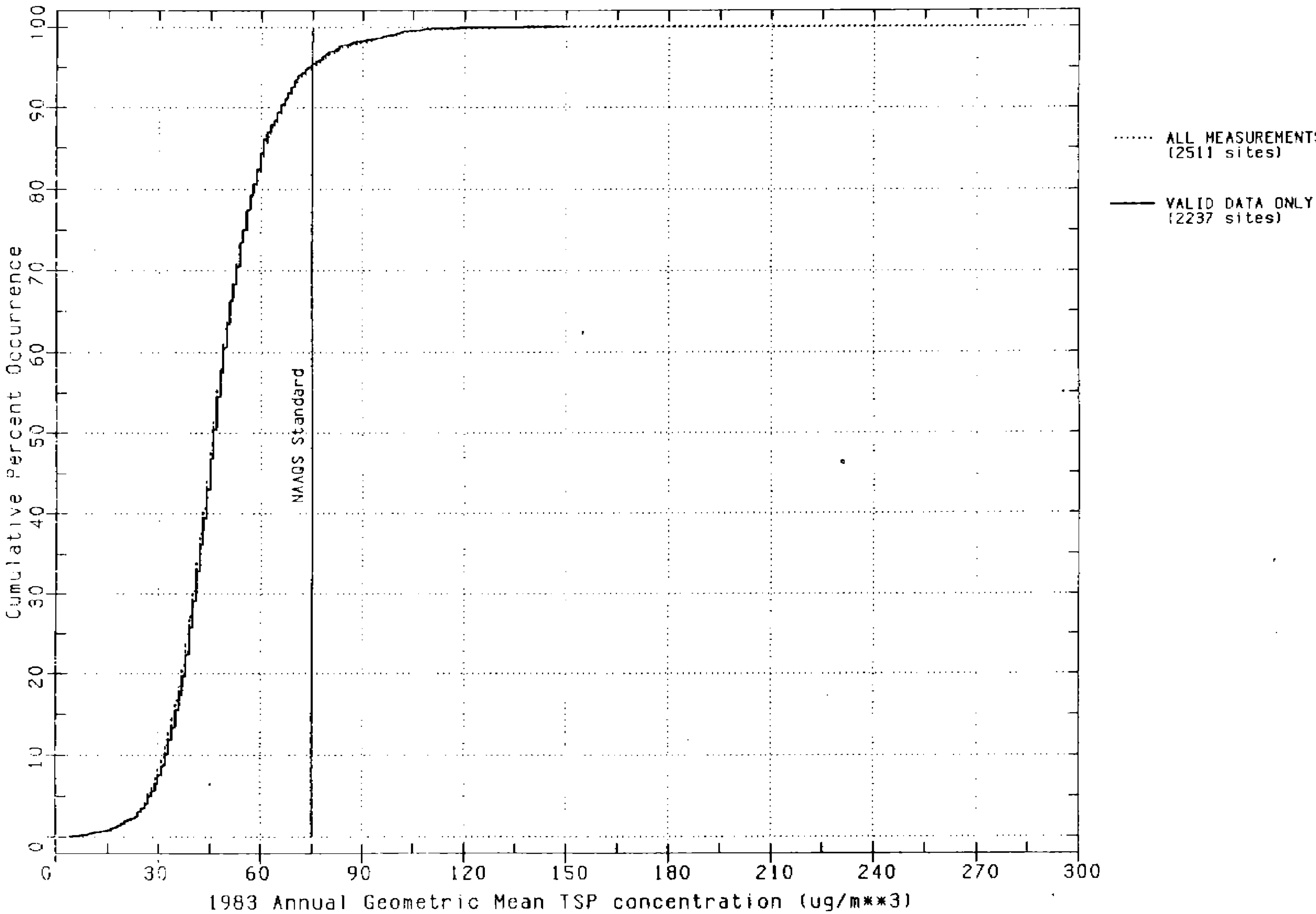

FIGURE 2-1. Cumulative distribution function of annual geometric mean TSP concentration, 1983, for SLAMS (including NAMS) monitors.

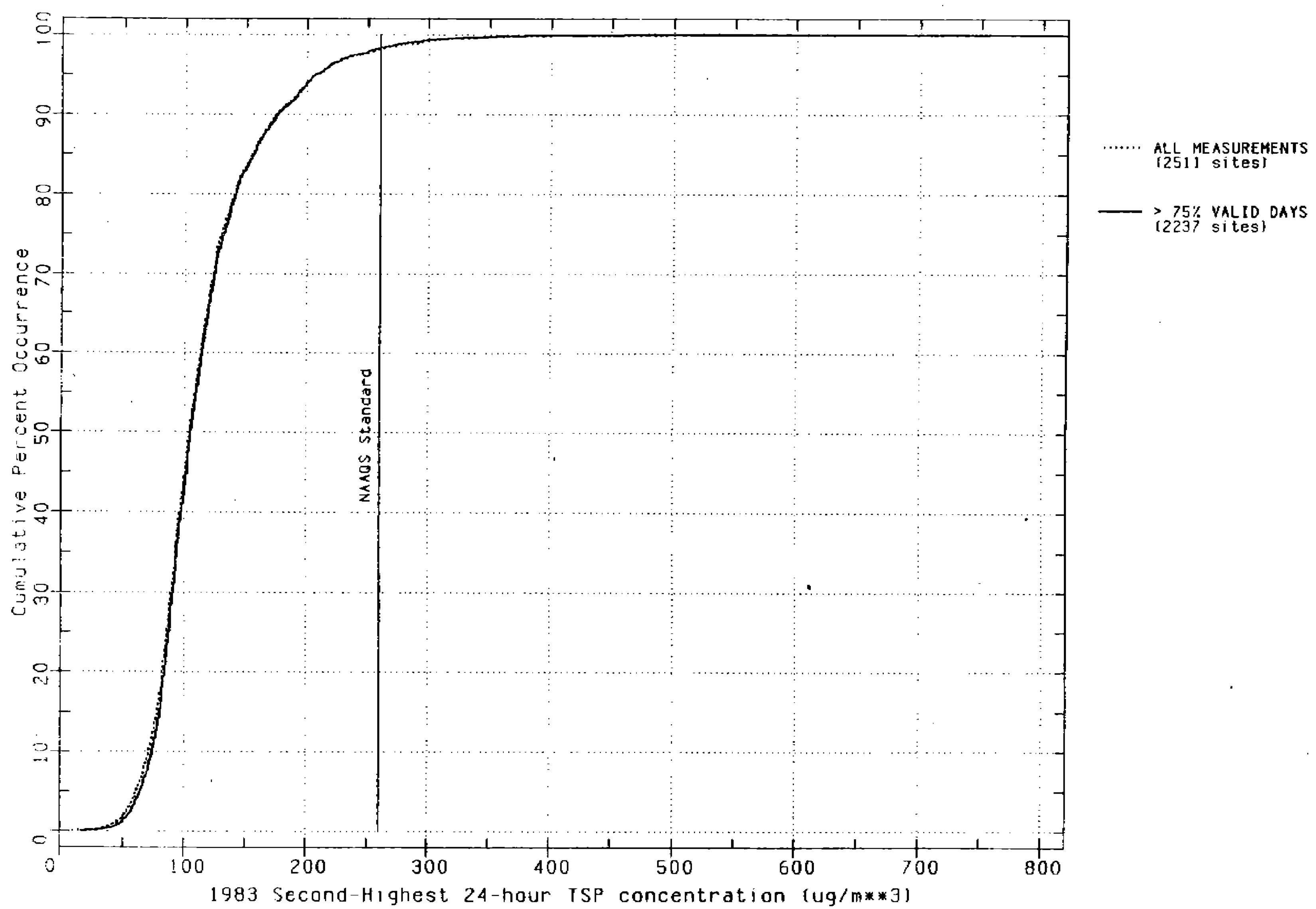

FIGURE 2-2. Cumulative distribution function of second-highest 24-hour TSP concentration, 1983, for SLAMS (including NAMS) monitors.

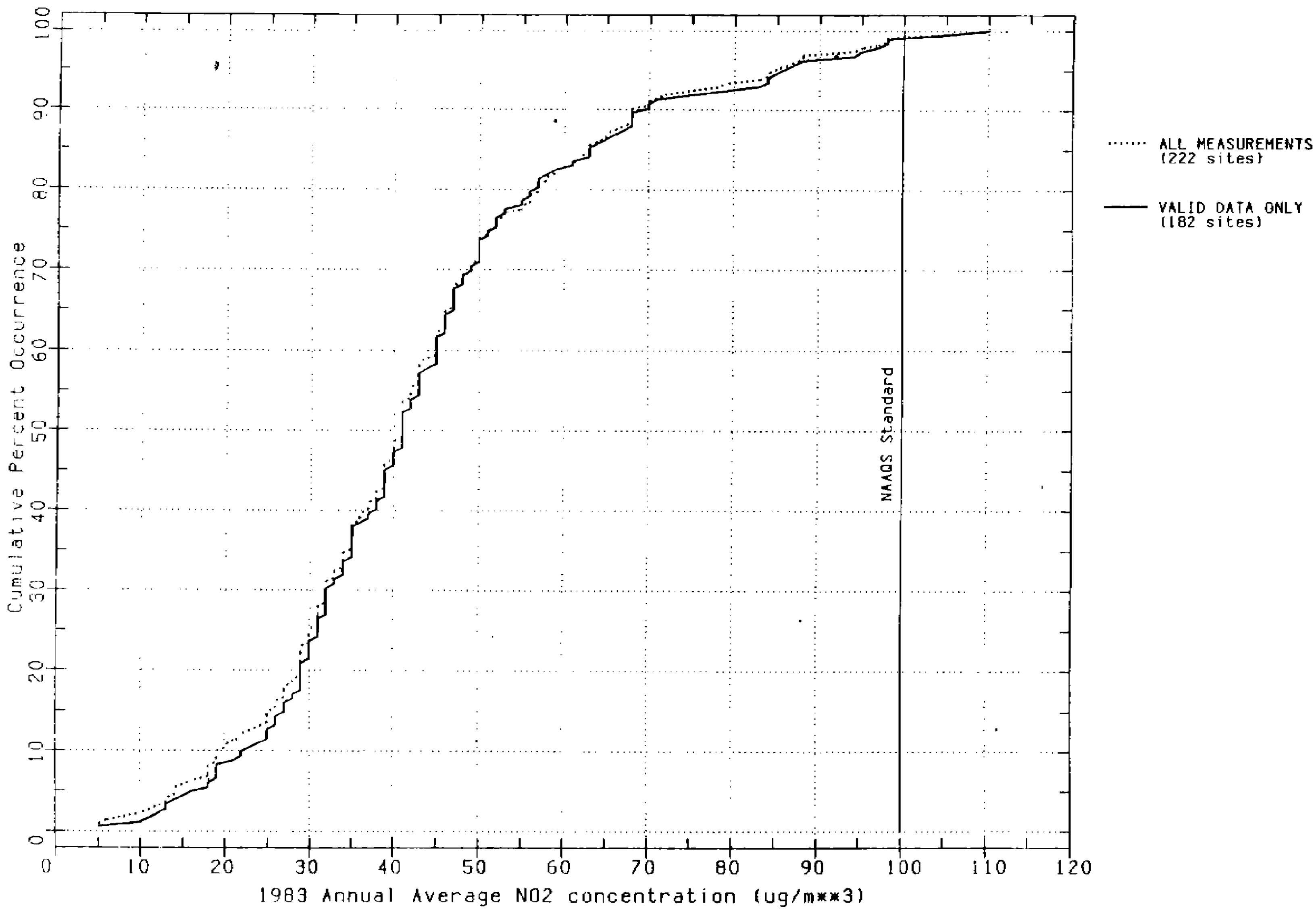

FIGURE 2-3. Cumulative distribution function of annual average NO_2 concentration, 1983, for SLAMS (including NAMS) monitors.

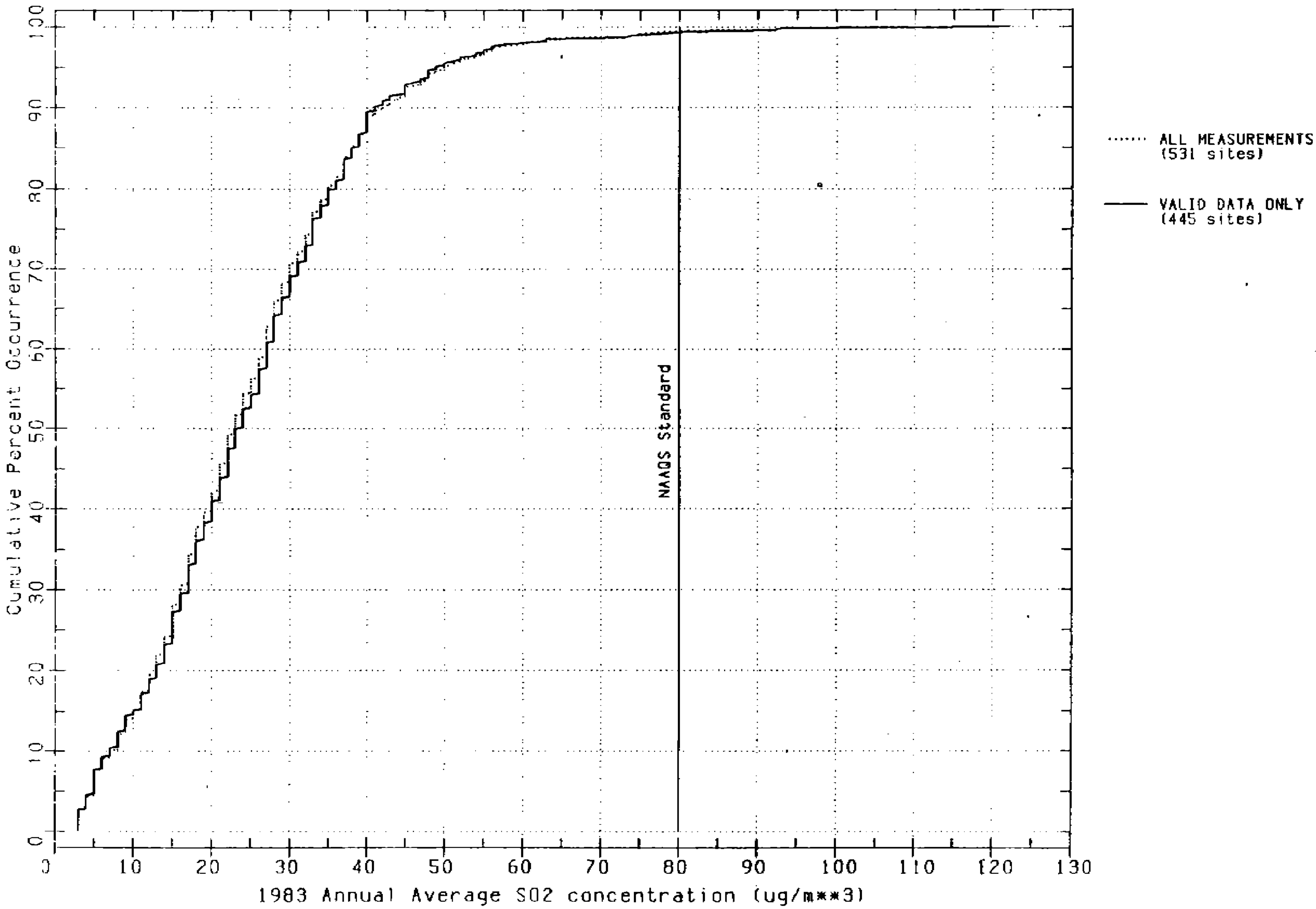

FIGURE 2-4. Cumulative distribution function of annual average SO2 concentration, 1983, for SLAMS (including NAMS) monitors.

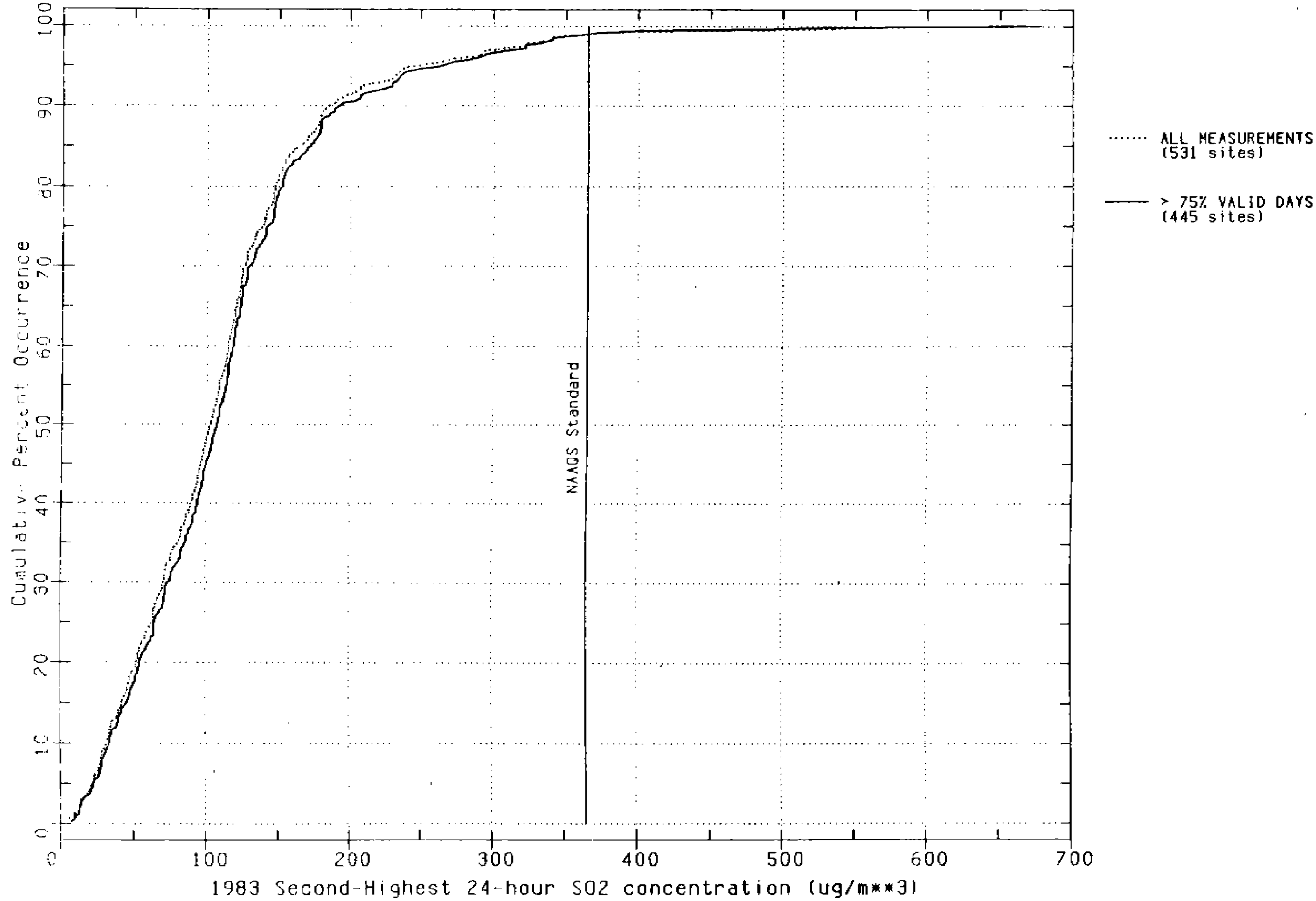

FIGURE 2-5. Cumulative distribution function of second-highest 24-hour SO_2 concentration, 1983, for SLAMS (including NAMS) monitors.

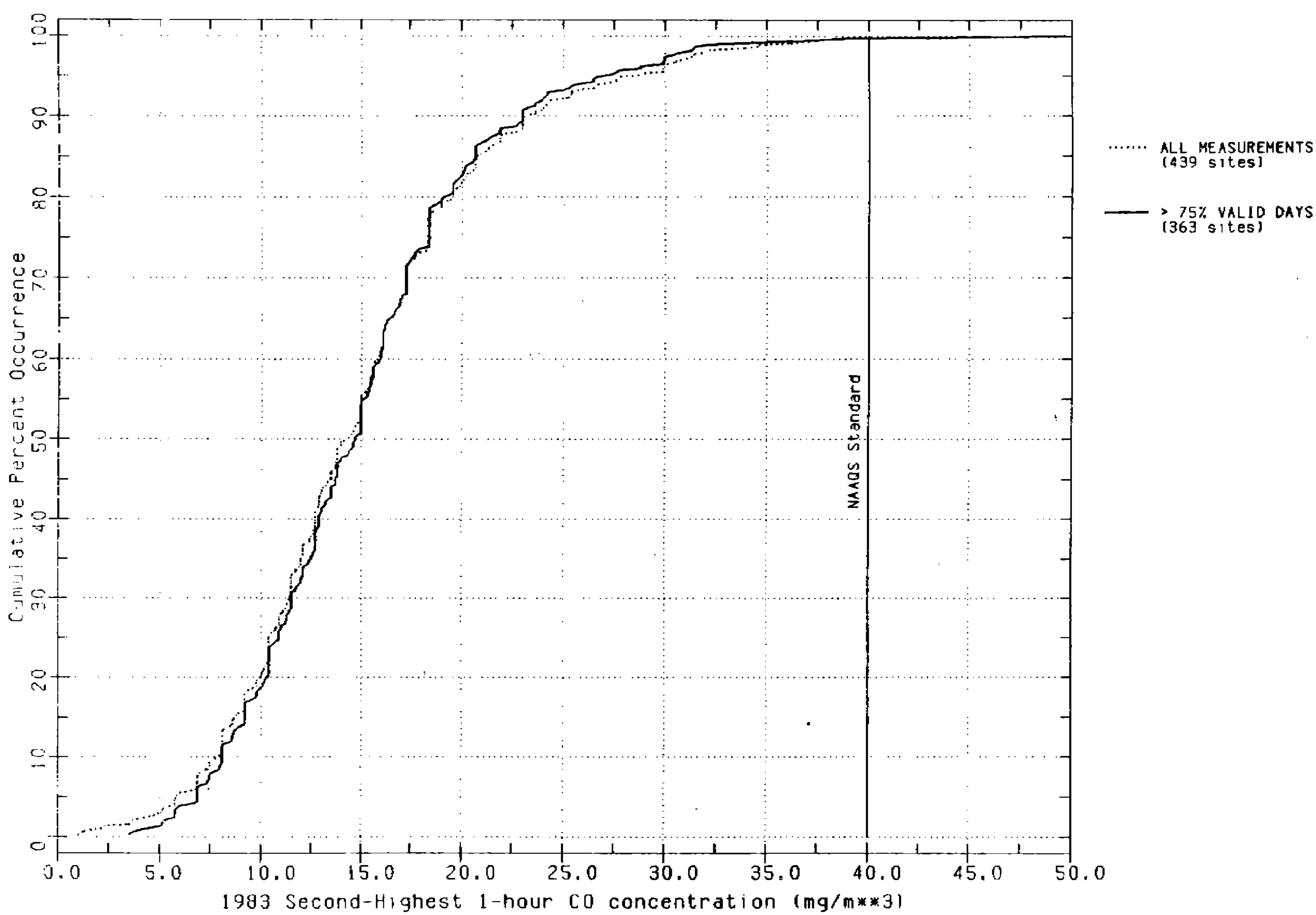

FIGURE 2-6. Cumulative distribution function of second-highest 1-hour CO concentration, 1983, for SLAMS (including NAMS) monitors.

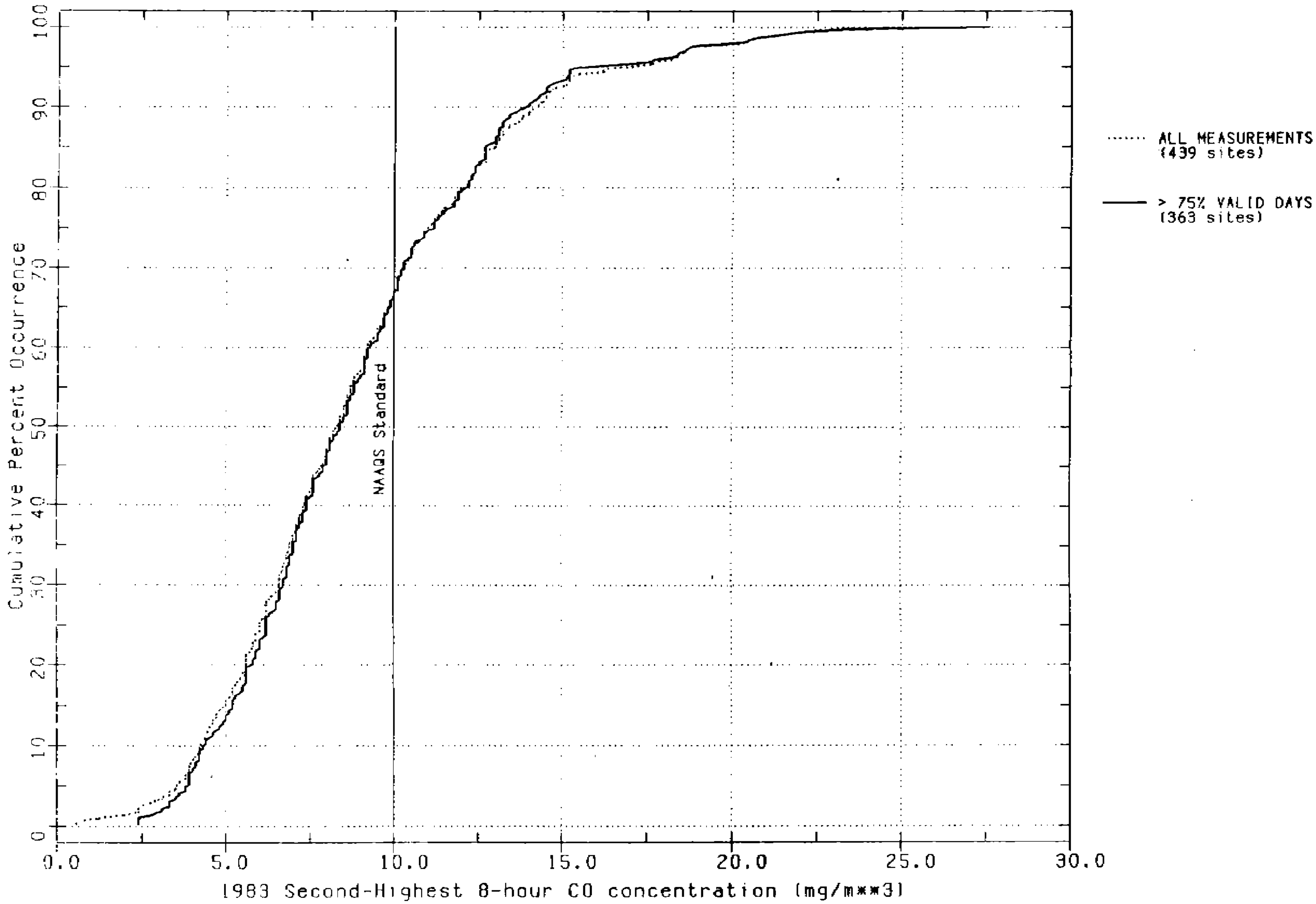

FIGURE 2-7. Cumulative distribution function of second-highest 8-hour CO concentration, 1983, for SLAMS (including NAMS) monitors.

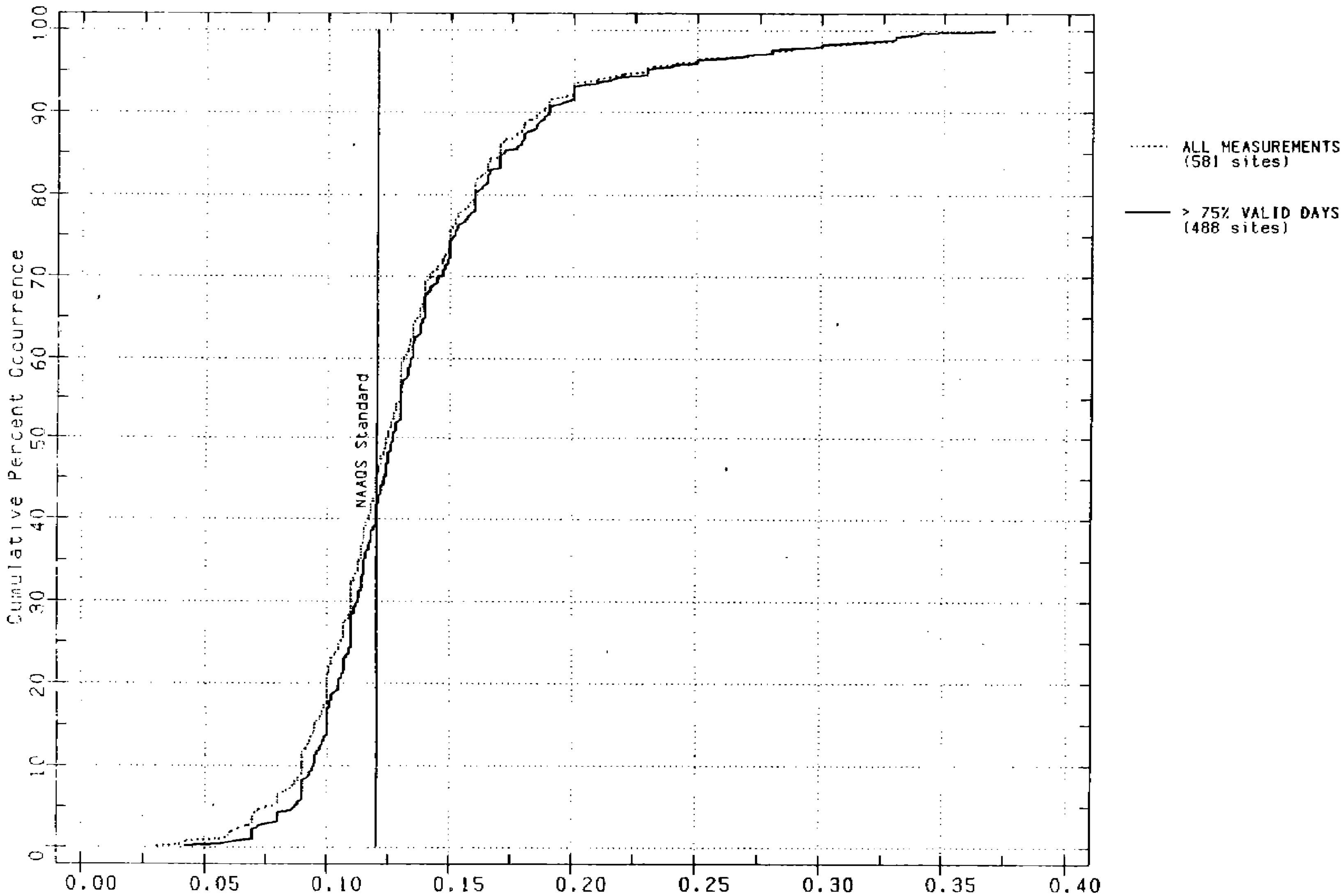

FIGURE 2-8. Cumulative distribution function of second-highest daily maximum 1-hour ozone concentration, 1983, for SLAMS (including NAMS) monitors.

3 PERMANENT OR TEMPORARY SHUTDOWN: MOTHBALLING AND ROTATION OPTIONS

Pollutant concentrations are below the NAAQS at many monitoring stations across the country and have been for many years. At these stations, shutting down the monitoring of low concentration pollutants merits consideration. Pollutant monitors could be permanently shutdown or shutdown for a year or two at a time in tandem with other monitors. We refer to permanent shutdown as the mothballing option and temporary shutdown as the rotation option. Complete monitoring should be reinstituted, however, if there are any indications that the pollutant concentrations might be increasing. In this section we describe decision rules that could be used in considering the permanent or temporary shutdown of monitors and the use of indicators to determine whether monitoring should begin again. We then examine the number of monitors nationally that could be shut down under the example decision rules, and show how the probability of misclassification can be determined under given decision rules.

DECISION RULES FOR MONITOR SHUTDOWN

Four major decision rules must be established in order to determine which pollutant monitors might be permanently or temporarily turned off. The first of these concerns how high the pollutant concentrations are relative to the appropriate NAAQS. The remaining three decision rules are concerned with data quality and completeness and trends in historical data.

Design Value Concentration

Pollutant monitors should be eligible for shutdown only if the design value concentration (DVC) is below some level or percentage of the corresponding NAAQS. This cutoff concentration must be chosen to be low enough so that the probability of attainment misclassification is very low, provided that other criteria discussed below are also met. At the same time the DVC for each pollutant cannot be so high that so many monitors are turned off, thus leaving insufficient data for the SIP-call process and for NAAQS-review data analysis. Since increasing the DVC cutoff provides a potential for greater misclassification, States must demonstrate that the probability of such misclassification, based on historical data, is low. An example of how these probabilities may be assessed is provided at the end of this section.

The DVC cutoff value, expressed as a percent of the NAAQS, need not be the same for all five pollutants. In fact, it need not be the same for all States for a given pollutant. What should be constant, though, is the low probability of misclassification. The selection of a misclassification probability and cutoff concentrations is the responsibility of the EPA; the States must provide substantive analyses of historical air quality data to demonstrate that EPA objectives may be met.

For TSP and SO_2 there are two primary NAAQS, a long-term annual mean NAAQS and a short-term 24-hour NAAQS. For these two pollutants a monitor would be eligible for shutdown only if the DVC cutoffs for both the short- and long-term NAAQS were met.

Test Period and Data Completeness

A pollutant monitor should be eligible for shutdown only if specific data quality and data completeness tests are met. The second decision rule is therefore the number of years for which the DVC has been below the cutoff concentration; this period of time is referred to as the test period. During the test period, quality assurance performance standards must be achieved for the pollutant monitors being considered for shutdown. The third decision rule is the level of data completeness required during the test period. A monitor at which the DVC is less than the cutoff concentration only for the most recent year and where only half of the days have valid measurements should not be eligible for shut down. The longer the concentrations are less than the DVC, and the higher the level of historical data completeness, the less likely is the chance of future attainment misclassification.

It might be desirable to relate data completeness criteria to the DVC; i.e., the lower the DVC, the less historical data would be required (above a predefined minimum and as long as misclassification probabilities are still low). Also, in the case of pollutants showing seasonal concentration patterns, e.g., CO at some urban sites, data completeness criteria should be developed for each season within a year. Applying seasonal criteria would preclude shutting down a pollutant monitor with a strongly seasonal pattern, where on average data completeness is high enough only because of being extremely high in the nonpeak season while low in the peak season.

Data completeness criteria should be stricter (i.e., more data should be required) for short-term standards than for long-term standards. This is because the probability of attainment misclassification is higher for short-term standards than for long-term standards for a given level of data completeness. This relationship has been demonstrated for the two SO_2 standards by Pollack and Hunt (1984).

Historical Trends

The fourth criterion for shutdown is the desired trend in the annual NAAQS summary statistics during the test period. Such a criterion must be established so that sites with increasing pollutant concentrations are not eligible for shutdown. An example of a statistical criterion that addresses the trend in pollutant concentrations in the test period is provided in the example application at the end of this section.

To summarize, four criteria are used to judge whether a monitor is eligible for a reduced sampling frequency:

The design value concentration (DVC) must be below some percent of the level specified in the NAAQS.

The DVC criterion must persist for some number of years, the test period.

EPA data completeness criteria must be met for each year in the test period.

Upward trends in the DVCs should not be evident in the DVC over the test period.

ROTATING MONITORS AS AN ALTERNATIVE TO PERMANENT SHUTDOWN

The four criteria above must be established in such a way that when monitors are completely shut down there is little probability of attainment misclassification. Some States may wish to consider less restrictive criteria for temporary shutdowns, i.e., rotating the operation of monitors on one-year or two-year cycles. For example, the EPA-approved DVC cutoff might be 50 percent for mothballing but only 75 percent for rotation. It may be the case that only 10 percent of the State's monitors meet the criteria for mothballing but 30 percent meet the less restrictive criteria for rotation. In this case the rotation option may be more cost-effective than the mothballing option.

Under the rotation option pollutant monitors with similar characteristics would be paired; one monitor would be in operation for a full year and then shut down while the second was put in operation for a full year. The cycle would be repeated unless there was some indication that pollutant concentrations were increasing (this is discussed further below). Alternatively, three monitors could operate on a rotation schedule of one year on and two years off. The longer the period a specific monitor is shut down, though, the more restrictive the four criteria need to be. One could allow, for example, every-other-year rotation for monitors that have DVC's below the required cutoff concentration and meet the validity criterion for the most recent year only. If these criteria were met for the most recent two years, the monitor might be considered for rotation on a once-every-three-years schedule.

Pollutant monitors that are rotated in pairs or triplets should have similar characteristics, because the monitor that is in operation in any given year serves as an indicator of the pollutant concentrations at the monitoring sites that are shut down. Monitors rotated together should, for example, be located relatively close to each other, should have the same EPA project classification (i.e., population-oriented versus source-oriented), and should have similar patterns of pollutant concentrations. The exact nature of the characteristics used to group monitors eligible for rotation would be approved by the EPA on a case-by-case basis.

RESTARTING POLLUTANT MONITORING: THE USE OF INDICATORS

Pollutant monitors that have been shut down after meeting established eligibility requirements may need to be reinstated if nonattainment becomes a possibility because of changes in emission patterns in the vicinity of the monitoring site. For example, if a large SO_2 source is built near a shutdown SO_2 monitor, then certainly that monitor should be restarted. There may be cases, however, in which a potential cause of nonattainment is not so obvious. We therefore suggest the use of indicator variables to determine whether or not monitoring should be reinstated.

The simplest example of an indicator for a shut-down monitor is the DVC of a "nearby" monitor that was not shut down. Under the rotation option, the operational monitor serves as an indicator for the nonoperational monitor(s). At the outset of the design of a mothballing strategy, consideration could be given to identifying and designating indicator monitoring sites. Thus, if nearby monitors show DVCs approaching the established pollutant cutoff concentration, then the mothballed monitors should be turned back on. The definition of "nearby" and "approaching cutoff concentration" are EPA choices and may be made on a case-by-case basis.

Other data routinely collected by State and local agencies may also be used as indicator variables. Examples of indicator variables are airport visibility or increased agricultural activities for fine particle and PM-10 concentrations; population trends (as evidence of growth, shifts in emissions density, etc.) emissions trends (paying particular attention to new point sources); and gasoline sales and total vehicle registrations for ozone and NO_2.

For each specific indicator a threshold level needs to be established above which pollutant monitoring will be reinstated. These threshold levels require careful definition, for there is often a substantial time delay between data collection and examination, and yet another time lag before monitors are restarted.

It is possible that a monitor could be restarted because an indicator exceeded a specified threshold only to reveal that pollutant concentrations are still well below the NAAQS. In the restart year the indicator may have reversed direction and move back toward the direction of reduced nonattainment probability (i.e., lower gasoline sales, reduction in population).* Again a set of decision rules must be applied to determine when a pollutant monitor can again be mothballed. One might argue for a test period shorter than the original mothballing test period, though the DVC and data completeness requirements should probably be the same.

EXAMPLE DECISION RULES

The Quick Look Report data base described in Section 2 can be used to determine how many pollutant monitors in each State would be eligible for shutdown under example criteria. Two example cutoff concentrations for each pollutant were chosen, so two complete sets of eligible sites can be tallied. The exemplary set of decision rules is as follows.

1. <u>Cutoff concentrations</u>. The two cutoff values (CV) we chose are 50 percent and 75 percent of the NAAQS levels. For TSP and SO_2, where there are two primary standards, pollutant monitors must have DVCs below the CVs for both the short- and long-term standards. For CO there is an 8-hour and a 1-hour standard, but the 8-hour standard is the limiting standard without exception, and so we do not consider the 1-hour standard in this analysis.

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* It is also possible that even if the indicator in the restart year is still rising, pollutant concentrations are still low because atmospheric dispersion conditions are above average. While such meteorological fluctuations should be considered in developing a revised monitoring strategy, this topic is outside the scope of this report.

2. Test period and statistical rule. The average pollutant level for the most recent three calendar years must be below the CV. In addition, the most recent year must be below the CV.

3. Data completeness. For continuously monitored pollutants, data completeness in the test period must be at least 75 percent. For SO_2, NO_2, and CO this means that there must be valid data for at least 6,570 hours in each of the three years. For ozone at least 75 percent of the days in the ozone season in each of the three years must have valid daily maxima. TSP data for each of the three years must satisfy the NADB data completeness criteria. (In some cases, these criteria for TSP may be too lenient, and the EPA may opt for stricter criteria.)

These criteria were applied to the three-year period 1981 to 1983, the most recent years for which complete annual summary statistics were available at the beginning of this study. The results for all pollutant monitors in the nation are summarized in Table 3-1. For all pollutants, the number of sites eligible for mothballing is far less than what might be inferred from the cumulative distribution functions of the annual summary statistics (Figures 2-1 to 2-8). There are two reasons for the apparent discrepancy. First, the figures in Section 2 are for 1983 only; the example criteria we are using specify that concentrations must be below the cutoff for 1983 and for the average of the three years 1981 to 1983. More important is the fact that the example data completeness requirements would disallow many sites. The last two columns in Table 3-1 show just how restrictive our data completeness requirements are. On average, only about half of all pollutant monitors meet the NADB annual validity criteria for three years in a row.

Using the cutoff DVC of 75 percent of the NAAQS for TSP, almost half of the monitors are eligible for shutdown; this represents a substantial potential cost savings. Very few of the TSP monitors are below the 50 percent CV; however, the annual geometric mean cutoff concentration of 37.5 $\mu g/m^3$ is not much higher than continental background concentrations in many parts of the country.

The 50 percent CV concentration of 0.06 ppm for ozone is also in the vicinity of the continental background concentration, and only one monitor in the entire country is eligible for shutdown under such restrictions. Even at a CV of 0.08 ppm (75 percent of NAAQS) only 20 of 581 monitors are eligible for mothballing. Although national trends in O_3 levels are decreasing (EPA, 1986), ozone continues to be a pollution problem of major concern. Carbon monoxide levels are also still too high in many parts of

TABLE 3-1. Total number of sites nationally eligible for mothballing under two example cutoff values. Pollutant monitors must be below the CV in the most recent year, and below the CV on average in the most recent three years; data completeness requirements listed in text must also be satisfied.

Pollutant	Total Number of Monitors in Operation in 1983	Sites Eligible for Mothballing: CV = 50% of NAAQS Count	CV = 50% of NAAQS Percent	CV = 75% of NAAQS Count	CV = 75% of NAAQS Percent	Sites Meeting 1981-1983 Data Completeness Requirements Count	Percent
TSP	2511	185	7.4	1110	44	1670	66.5
O_3	581	1	0.2	20	3.4	327	56.3
SO_2	531	215	40.5	255	48.0	270	50.8
CO	439	15	3.4	62	14.1	223	50.8
NO_2	222	63	28.4	80	36.0	93	41.9

the country, despite a decreasing trend since monitoring began (EPA, 1986), and very few CO monitors qualify for shutdown under the example criteria.

In 1983 and 1984 virtually all SO_2 and NO_2 monitors had concentrations below the NAAQS. Nevertheless, at the 75 percent CV fewer than half of the monitors are eligible for shutdown, not because of high pollutant concentrations but because of the three-year data completeness requirement. For example, Table 3-1 shows that whereas only 51 percent (270) of the SO_2 monitors meet the data completeness requirements, nearly all of those (255) meet the 75 percent CV requirements.

Table 3-2 lists the number and percent of pollutant monitors in each State that could be eligible for shutdown under the example criteria. Since pollutant standards are commonly met in some States while being exceeded or approached in others, there is much variation across States in the percent of pollutant monitors eligible for shutdown. For example, in the arid western States, where TSP concentrations can be high, especially in the summer, few of the monitoring sites meet the example criteria.

MISCLASSIFICATION PROBABILITIES AFTER MONITOR SHUTDOWN

The criteria for permanent or temporary shutdown, particularly the cutoff concentration, should be restrictive enough so that there is little chance that air pollution standards will be exceeded in an area in a given year where the pollutant monitor has been shut down for the year. The likelihood of attainment misclassification in the absence of monitoring (because monitors have been shut down after meeting eligibility criteria) can be examined by using historical data. We demonstrate these important calculations by applying our example shutdown criteria to the 1978-1983 data in the Quick Look Report.

We applied the example criteria to historical pollutant concentrations for 1978-1983 and calculated the probability of exceeding a NAAQS one, two, and three years after a monitor meets the criteria and is turned off. The results are presented in Table 3-3. As an example of the calculations, consider the 24-hour standard for TSP, under a cutoff concentration of 75 percent of NAAQS (i.e., 195 $\mu g/m^3$) and the three-year data completeness requirement. Using the 1980 to 1982 data, 1,253 TSP monitors satisfy the criteria; of these, only two monitors exceeded the 24-hour standard in the following year, 1983. Using the 1979 to 1981 data, 1,121 TSP monitors satisfy the criteria; of these only one exceeded the standard in 1982. Finally, using the 1978 to 1980 data, 953 TSP monitors were found to meet the criteria, and only three of these exceeded the standard in 1981. In total, then, of 3,327 cases (953 + 1,121 + 1,253) where the example

TABLE 3-2a. Number and percent of sites satisfying example shutdown criteria, 1981-1983 data, by state, total suspended particulates.

State/Territory	No. of Sites	CV = 50% of NAAQS		CV = 75% of NAAQS	
		No. of Sites	% of Sites	No. of Sites	% of Sites
Alabama	68	5	7	41	60
Alaska	13	2	15	2	15
Arizona	40	7	18	14	35
Arkansas	26	0	0	12	46
California	105	4	4	39	37
Colorado	61	1	2	9	15
Connecticut	40	8	20	33	83
Delaware	9	0	0	9	100
District of Columbia	9	0	0	7	78
Florida	101	26	26	71	70
Georgia	48	0	0	9	19
Hawaii	11	4	36	6	55
Idaho	18	3	17	8	44
Illinois	91	0	0	28	31
Indiana	79	0	0	30	38
Iowa	50	2	4	26	52
Kansas	20	0	0	5	25
Kentucky	61	0	0	19	31
Louisiana	26	1	4	15	58
Maine	14	1	7	7	50
Maryland	36	3	8	15	42
Massachusetts	26	3	12	17	65
Michigan	76	6	8	39	51
Minnesota	44	4	9	20	45
Mississippi	20	1	5	17	85
Missouri	41	2	5	16	39
Montana	21	0	0	0	0
Nebraska	34	2	6	12	35
Nevada	33	3	9	11	33
New Hampshire	20	1	5	8	40
New Jersey	22	2	9	7	32
New Mexico	51	0	0	0	0
New York	198	39	20	117	59
North Carolina	76	6	8	62	82
North Dakota	20	6	30	15	75
Ohio	240	3	1	117	49
Oklahoma	34	0	0	9	26
Oregon	35	6	17	24	69
Pennsylvania	133	2	2	61	46
Puerto Rico	14	0	0	6	43
Rhode Island	12	0	0	8	67
South Carolina	16	0	0	9	56
South Dakota	20	6	30	16	80
Tennessee	62	1	2	7	11
Texas	73	0	0	15	21
Utah	11	0	0	0	0
Vermont	6	1	17	2	33
Virginia	78	3	4	20	26
Washington	37	5	14	21	57
West Virginia	31	0	0	8	26
Wisconsin	79	10	13	33	42
Wyoming	14	5	36	7	50
American Samoa	0	-	-	-	-
Gaum	4	1	25	1	25
Virgin Islands	4	0	0	0	0
Total	2511	185	7	1110	44

TABLE 3-2b. Sulfur Dioxide

State/Territory	No. of Sites	CV = 50% of NAAQS No. of Sites	CV = 50% of NAAQS % of Sites	CV = 75% of NAAQS No. of Sites	CV = 75% of NAAQS % of Sites
Alabama	3	0	0	0	0
Alaska	0	-	-	-	-
Arizona	12	1	8	3	25
Arkansas	2	1	50	1	50
California	52	36	69	36	69
Colorado	2	2	100	2	100
Connecticut	14	6	43	7	50
Delaware	7	3	43	5	71
District of Columbia	2	2	100	2	100
Florida	20	10	50	11	55
Georgia	9	0	0	0	0
Hawaii	0	-	-	-	-
Idaho	4	1	25	2	50
Illinois	26	16	62	17	65
Indiana	15	5	33	8	53
Iowa	6	1	17	2	33
Kansas	2	2	100	2	100
Kentucky	12	3	25	4	33
Louisiana	6	1	17	1	17
Maine	6	1	17	1	17
Maryland	9	1	11	1	11
Massachusetts	17	7	41	8	47
Michigan	17	3	18	4	24
Minnesota	12	5	42	5	42
Mississippi	2	1	50	1	50
Missouri	11	6	55	7	64
Montana	1	0	0	0	0
Nebraska	1	0	0	0	0
Nevada	0	-	-	-	-
New Hampshire	7	0	0	0	0
New Jersey	14	5	36	8	57
New Mexico	9	5	56	6	67
New York	39	18	46	23	59
North Carolina	6	2	33	2	33
North Dakota	4	4	100	4	100
Ohio	42	13	31	18	43
Oklahoma	8	1	13	1	13
Oregon	2	2	100	2	100
Pennsylvania	41	19	46	26	63
Puerto Rico	2	0	0	0	0
Rhode Island	4	3	75	3	75
South Carolina	2	0	0	0	0
South Dakota	0	-	-	-	-
Tennessee	4	1	25	1	25
Texas	11	2	18	2	18
Utah	6	1	17	2	33
Vermont	3	1	33	1	33
Virginia	14	12	86	12	86
Washington	11	8	73	8	73
West Virginia	11	0	0	1	9
Wisconsin	19	4	21	5	26
Wyoming	0	-	-	-	-
American Samoa	0	-	-	-	-
Gaum	0	-	-	-	-
Virgin Islands	2	0	0	0	0
Total	531	215	40	255	48

TABLE 3-2c. Ozone.

State/Territory	No. of Sites	CV = 50% of NAAQS No. of Sites	CV = 50% of NAAQS % of Sites	CV = 75% of NAAQS No. of Sites	CV = 75% of NAAQS % of Sites
Alabama	6	0	0	0	0
Alaska	0	-	-	-	-
Arizona	12	0	0	0	0
Arkansas	2	0	0	0	0
California	109	0	0	8	7
Colorado	11	0	0	0	0
Connecticut	9	0	0	0	0
Delaware	4	0	0	0	0
District of Columbia	2	0	0	0	0
Florida	18	0	0	2	11
Georgia	4	0	0	0	0
Hawaii	1	1	100	1	100
Idaho	0	-	-	-	-
Illinois	34	0	0	0	0
Indiana	13	0	0	0	0
Iowa	7	0	0	0	0
Kansas	3	0	0	0	0
Kentucky	12	0	0	0	0
Louisiana	14	0	0	0	0
Maine	3	0	0	0	0
Maryland	17	0	0	0	0
Massachusetts	15	0	0	0	0
Michigan	14	0	0	0	0
Minnesota	6	0	0	1	17
Mississippi	0	-	-	-	-
Missouri	13	0	0	0	0
Montana	0	-	-	-	-
Nebraska	3	0	0	2	67
Nevada	7	0	0	0	0
New Hampshire	6	0	0	0	0
New Jersey	11	0	0	0	0
New Mexico	8	0	0	3	38
New York	23	0	0	0	0
North Carolina	10	0	0	0	0
North Dakota	3	0	0	1	33
Ohio	29	0	0	0	0
Oklahoma	7	0	0	0	0
Oregon	5	0	0	0	0
Pennsylvania	33	0	0	0	0
Puerto Rico	1	0	0	0	0
Rhode Island	2	0	0	0	0
South Carolina	7	0	0	0	0
South Dakota	0	-	-	-	-
Tennessee	11	0	0	0	0
Texas	28	0	0	0	0
Utah	7	0	0	0	0
Vermont	2	0	0	0	0
Virginia	15	0	0	0	0
Washington	9	0	0	1	11
West Virginia	4	0	0	0	0
Wisconsin	21	0	0	1	5
Wyoming	0	-	-	-	-
American Samoa	0	-	-	-	-
Gaum	0	-	-	-	-
Virgin Islands	0	-	-	-	-
Total	581	1	0	20	3

TABLE 3-2d. Carbon Monoxide.

State/Territory	No. of Sites	CV = 50% of NAAQS No. of Sites	CV = 50% of NAAQS % of Sites	CV = 75% of NAAQS No. of Sites	CV = 75% of NAAQS % of Sites
Alabama	4	0	0	1	25
Alaska	6	0	0	0	0
Arizona	14	0	0	1	7
Arkansas	0	-	-	-	-
California	73	11	15	23	32
Colorado	13	0	0	0	0
Connecticut	5	0	0	0	0
Delaware	3	0	0	0	0
District of Columbia	3	0	0	0	0
Florida	27	0	0	3	11
Georgia	7	0	0	0	0
Hawaii	2	0	0	1	50
Idaho	2	0	0	0	0
Illinois	12	0	0	1	8
Indiana	7	0	0	0	0
Iowa	5	0	0	1	20
Kansas	3	0	0	1	33
Kentucky	8	0	0	2	25
Louisiana	3	0	0	1	33
Maine	1	0	0	1	100
Maryland	7	0	0	0	0
Massachusetts	9	0	0	0	0
Michigan	10	0	0	3	30
Minnesota	9	0	0	0	0
Mississippi	2	0	0	0	0
Missouri	9	0	0	1	11
Montana	4	0	0	0	0
Nebraska	4	0	0	1	25
Nevada	7	0	0	0	0
New Hampshire	2	0	0	0	0
New Jersey	10	0	0	0	0
New Mexico	9	0	0	2	22
New York	14	0	0	3	21
North Carolina	10	0	0	0	0
North Dakota	0	-	-	-	-
Ohio	17	1	6	3	18
Oklahoma	6	0	0	0	0
Oregon	7	0	0	0	0
Pennsylvania	24	0	0	0	0
Puerto Rico	3	0	0	0	0
Rhode Island	2	0	0	1	50
South Carolina	2	0	0	0	0
South Dakota	0	-	-	-	-
Tennessee	11	0	0	1	9
Texas	13	1	8	3	23
Utah	10	0	0	0	0
Vermont	1	1	100	1	100
Virginia	11	1	9	4	36
Washington	17	0	0	1	6
West Virginia	3	0	0	0	0
Wisconsin	8	0	0	2	25
Wyoming	0	-	-	-	-
American Samoa	0	-	-	-	-
Gaum	0	-	-	-	-
Virgin Islands	0	-	-	-	-
Total	439	15	3	62	14

TABLE 3-3. Number of sites exceeding each standard one, two, and three years after meeting example shutdown criteria (based only on site-years with valid data).

			One Year Ahead[a]		Two Years Ahead[b]		Three Years Ahead[c]	
Pollutant	Standard	CV(%)	Number of Sites	Number Above Standard	Number of Sites	Number Above Standard	Number of Sites	Number Above Standard
TSP	24-hour	50	1968	3	1068	1	474	0
		75	3327	6	1940	4	889	0
	Annual Mean	50	233	0	119	0	56	0
		75	1839	0	968	0	425	0
SO_2	24-hour	50	356	0	170	0	70	0
		75	434	0	219	0	89	0
	Annual Mean	50	347	0	166	0	65	0
		75	442	0	223	0	92	0
CO	8-hour	50	28	0	14	0	5	0
		75	98	1	46	1	21	0
NO_2	Annual Mean	50	64	0	28	0	12	0
		75	99	0	50	0	21	0

[a] Three sets of results combined: criteria applied to 1978-1980 data, 1981 exceedances counted; criteria applied to 1979-1981 data, 1982 exceedances counted; criteria applied to 1980-1982 data, 1983 exceedances counted.

[b] Two sets of results combined: criteria applied to 1978-1980 data, 1982 exceedances counted; criteria applied to 1979-1981 data, 1983 exceedances counted.

[c] Criteria applied to 1978-1980 data, 1983 exceedances counted.

TABLE 3-2e. Nitrogen Dioxide.

State/Territory	No. of Sites	CV = 50% of NAAQS No. of Sites	CV = 50% of NAAQS % of Sites	CV = 75% of NAAQS No. of Sites	CV = 75% of NAAQS % of Sites
Alabama	0	-	-	-	-
Alaska	0	-	-	-	-
Arizona	4	1	25	1	25
Arkansas	1	1	100	1	100
California	64	25	39	30	47
Colorado	4	1	25	2	50
Connecticut	3	1	33	1	33
Delaware	2	0	0	0	0
District of Columbia	2	1	50	1	50
Florida	10	1	10	1	10
Georgia	2	0	0	0	0
Hawaii	1	0	0	0	0
Idaho	0	-	-	-	-
Illinois	7	0	0	2	29
Indiana	3	0	0	1	33
Iowa	0	-	-	-	-
Kansas	1	0	0	0	0
Kentucky	6	3	50	3	50
Louisiana	4	0	0	0	0
Maine	0	-	-	-	-
Maryland	8	1	13	1	13
Massachusetts	6	1	17	1	17
Michigan	3	0	0	0	0
Minnesota	2	1	50	1	50
Mississippi	0	-	-	-	-
Missouri	9	2	22	2	22
Montana	0	-	-	-	-
Nebraska	0	-	-	-	-
Nevada	2	0	0	1	50
New Hampshire	0	-	-	-	-
New Jersey	5	0	0	3	60
New Mexico	1	1	100	1	100
New York	6	0	0	0	0
North Carolina	0	-	-	-	-
North Dakota	2	0	0	0	0
Ohio	7	2	29	3	43
Oklahoma	4	1	25	1	25
Oregon	1	0	0	0	0
Pennsylvania	22	14	64	16	73
Puerto Rico	0	-	-	-	-
Rhode Island	1	0	0	0	0
South Carolina	0	-	-	-	-
South Dakota	0	-	-	-	-
Tennessee	0	-	-	-	-
Texas	9	1	11	1	11
Utah	2	0	0	0	0
Vermont	0	-	-	-	-
Virginia	10	4	40	5	50
Washington	2	0	0	0	0
West Virginia	4	1	25	1	25
Wisconsin	2	0	0	0	0
Wyoming	0	-	-	-	-
American Samoa	0	-	-	-	-
Gaum	0	-	-	-	-
Virgin Islands	0	-	-	-	-
Total	222	63	28	80	36

criteria were met, only 6 (3 + 1 + 2), or 0.2 percent, exceeded the standard in the year following shutdown. Based on historical data, then, there is a very, very small chance that shutting down a site after the three-year criteria were met would result in erroneously classifying the site as not exceeding the standard.

Similarly, we applied the three-year criteria to 1978-1980 and 1979-1981 data for all pollutants and counted how many monitors exceeded each standard two years after meeting the criteria, i.e., in 1981 and 1982, respectively. Finally, we counted how many sites exceeded the standard in 1983, three years after meeting the criteria applied to 1978-1980 data. The complete set of misclassification results for TSP, SO_2, CO, and NO_2 are contained in Table 3-3. (Ozone is not included in this analysis because so few sites meet the example criteria.) When these shutdown criteria were applied with a DVC cutoff of either 50 or 75 percent of the NAAQS, only a few monitors for the 24-hour TSP standard and one for the 8-hour CO standard were counted.

We have not looked closely at those few sites that exceeded the standard after meeting the criteria, but it is possible that there would have been prior indications that the standard would be exceeded (e.g., new source permits for nearby emissions) so that pollutant monitoring at these sites would have been reinstated. Thus, the example criteria are restrictive enough that the chances of misclassification of a site are extremely small. Such small misclassification probabilities seem to suggest that the example criteria are unnecessarily restrictive, and that some relaxation resulting in acceptably low misclassification probabilities is possible.

4 SEASONAL MONITORING

Regulations for seasonal monitoring of ozone were recently proposed.* Ozone concentrations reach their peak in the hot summer months when meteorological conditions are most conducive to ozone formation and precursor emissions increase. The promulgated seasonal monitoring schedule was determined on a state-by-state basis; monitoring is not required in those months when exceedances are unlikely to occur. April through October monitoring is required for over half of the States, but the season can be as short as June to September (for Montana and South Dakota). In States where ozone pollution is a year-round problem, such as California, Florida, and Texas, full-year monitoring is still required.

In most areas of the country, seasonal monitoring for ozone is a cost-effective measure and entails virtually no chance of site misclassification. The ozone standard is a short-term standard (maximum daily concentration not to be exceeded on the average more than once per year) and is ideally suited for seasonal monitoring. We have considered the possibility of seasonal monitoring for other criteria pollutants, and recommend seasonal monitoring only for carbon monoxide. In this section we discuss first why seasonal monitoring is not recommended for TSP, SO_2, and NO_2, and then when and how seasonal monitoring of CO is a feasible option. As noted in Section 1, seasonal monitoring is also not applicable to the NAMS network.

TSP, SULFUR DIOXIDE, AND NITROGEN DIOXIDE

Controlling Standards

TSP and SO_2 have both short-term and long-term standards. One or the other is the controlling standard at a site. The controlling standard is determined by the ratio of the percent DVC for the short-term standard divided by the percent DVC for the long-term standard.

$$\frac{\text{second maximum 24-hour average}}{\text{24-hour NAAQS}} \div \frac{\text{annual average}}{\text{annual NAAQS}} .$$

* 51 Fed. Reg. 9597 (1980) (to be codified at 40 CFR. part 58) (proposed March 19, 1986).

If this ratio is greater than one, the 24-hour standard is the controlling standard; conversely, if the ratio is less than one, the annual standard is the controlling one.

There may be strong seasonal variation in short-term averaging periods depending on the location of the monitor and the types of emission sources that influence the air quality at the site. For example, a monitor located near a large facility with high emissions may have strong seasonal peaks. If the GEP stack height of the facility is low, the monitor might record winter/spring peaks; if it is high, the monitor might record summer peaks, provided the facility is in flat terrain. Alternatively, an SO_2 monitor that is influenced primarily by emissions from area sources may record winter peaks.

If there is seasonal variation in the 24-hour averages at a site, in the sense that the short-term standard is exceeded only during some months of the year, then one might consider seasonal monitoring as an option. But seasonal monitoring should be considered only if the short-term standard is clearly the controlling standard. The controlling standard, however, often changes from year to year at a site. Scatterplots of the ratios determining the controlling standards for TSP and SO_2 at all monitors satisfying NADB completeness requirements in both years for 1982 versus 1983 are shown in Figures 4-1 and 4-2 (based on data from the Quick Look Reports). The horizontal line corresponds to a ratio of one for 1982, and the vertical line corresponds to a ratio of one for 1983.

For TSP (Figure 4-1) the long-term standard, the annual geometric mean, is the controlling standard at the majority of sites in both years, as most of the sites are in the lower left quadrant of the plot. For a small percentage of sites the short-term (24-hour) standard controls in both 1982 and 1983 (upper right quadrant). But there are many sites at which the 24-hour standard controls in one year and the annual standard in the other. If 1981 data are included, there are relatively few sites where the short-term standard is the controlling standard for three consecutive years.

For SO_2 (Figure 4-2) a larger percentage of the sites are controlled by the short-term standard in any one year than is the case for TSP, but there are still many sites in the lower right and upper left quadrants of the plot. That is, at many monitors, the controlling SO_2 standard changes from one year to the next. As in the case of TSP, if the 1981 data are included, there are even fewer sites where the short-term standard is the controlling one for three consecutive years.

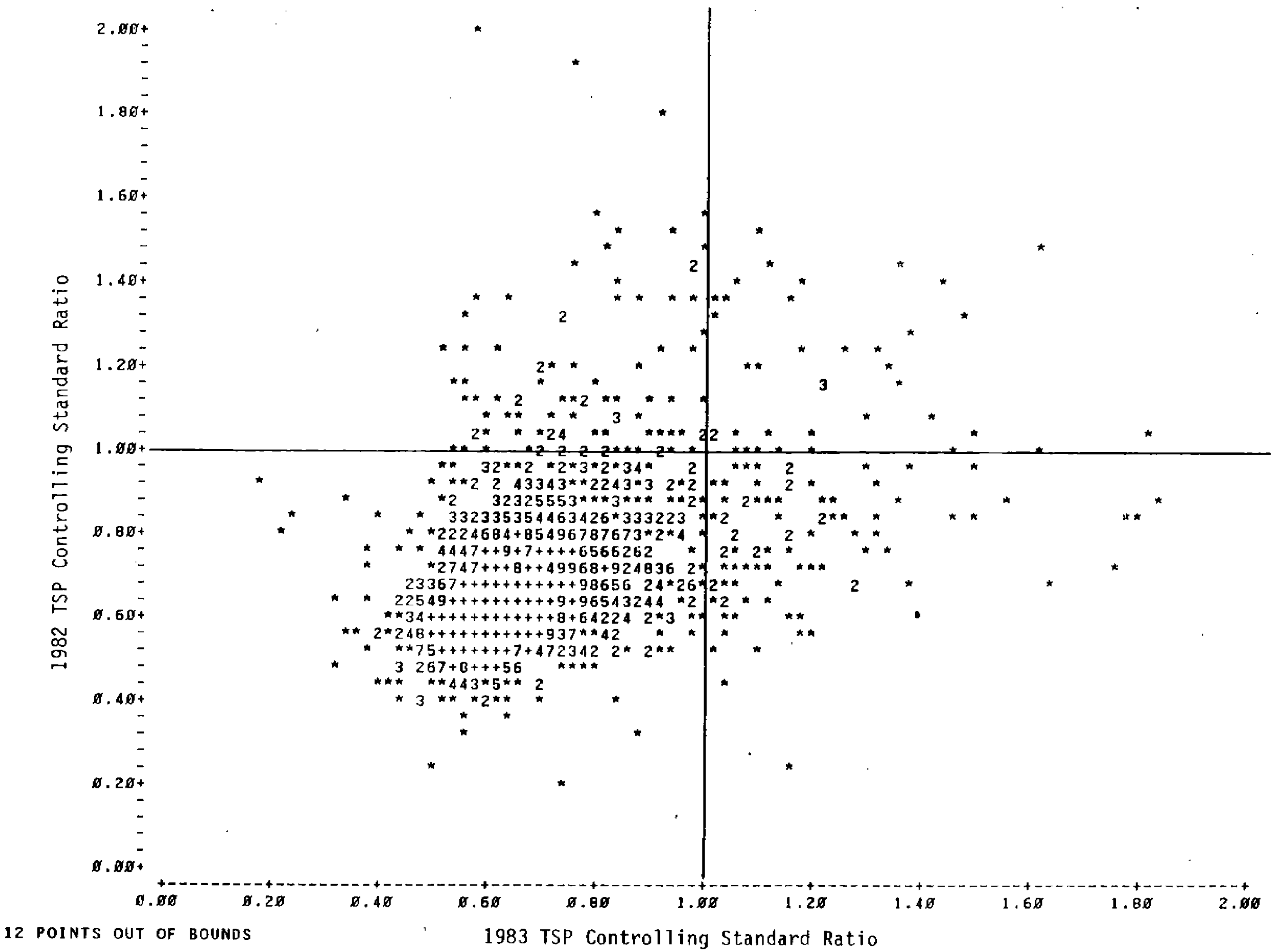

FIGURE 4-1. Controlling standard ratios for TSP, 1982 versus 1983. (An '*' indicates one site; a '2' indicates two sites; and so on for other integers; a '+' indicates 10 or more sites.)

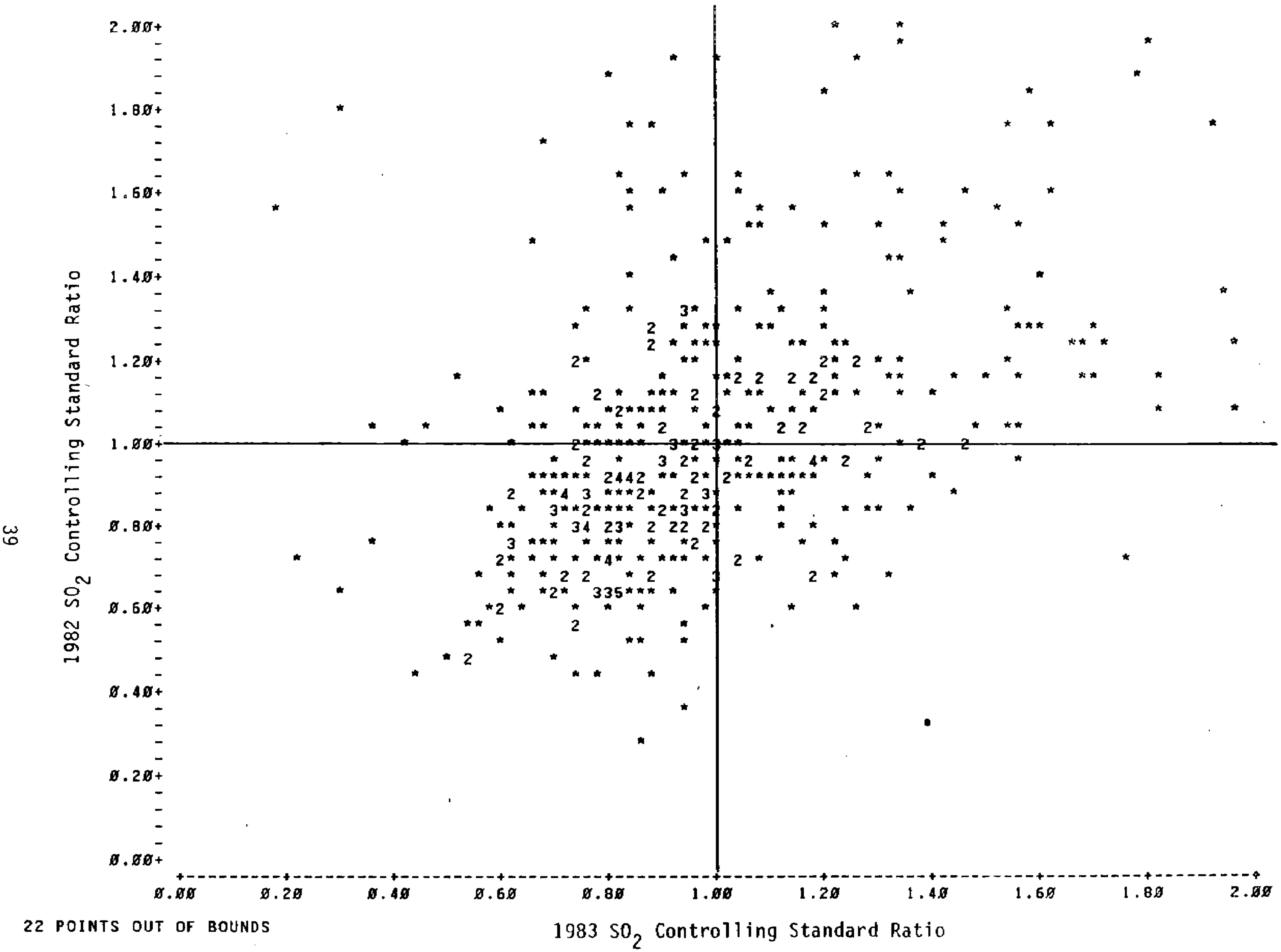

FIGURE 4-2. Controlling standard ratios for SO_2, 1982 versus 1983.

Estimation of the Annual Mean From Seasonal Monitoring Data

If TSP and SO_2 are monitored seasonally, then an annual average must be estimated to check for exceedance of the long-term standard. The annual mean will be some multiple, less than one, of the seasonal mean, but selecting the appropriate multiplier is difficult. It would not be appropriate to use the historical ratio of the seasonal mean to the annual mean at a site as the multiplier, because changes in emissions would require an updated multiplier. A reasonable alternative would be to use a multiplier determined from other sites, i.e., nearby sites with similar emissions sources and seasonal patterns, but presumably these other sites would also qualify for seasonal monitoring. We are left with the possibility of having one or two sites continuing to monitor for the entire year and acting as indicator sites from which we would determine the ratio of seasonal mean to annual mean. However, from a statistical point of view, data from more than one site would be necessary to determine an appropriate multiplier with any degree of confidence.

If seasonal monitoring were allowed for those TSP and SO_2 sites where the short-term standard controls consistently from year to year and the short-term averages exhibit seasonal behavior, we would not be able to develop a reliable estimate of the appropriate annual mean from the seasonal mean, and so would not be able to reliably state whether the long-term standard was exceeded or not. (This is important for sites where both standards are exceeded but the short-term standard is the controlling standard.) More important, the only standard for NO_2 is a long-term standard, so if seasonal monitoring of NO_2 were allowed, the annual mean would also have to be estimated from seasonal data. In some areas, e.g., Los Angeles, NO_2 does exhibit seasonal patterns; NO_2 levels reach their peak in fall and early winter when inversion layers are low and there is consequently less atmospheric mixing. Because of the difficulties in reliably estimating annual means from seasonal data, though, we conclude that seasonal monitoring does not appear viable for the three pollutants with annual standards.

CARBON MONOXIDE

Ambient CO concentrations exhibit seasonal patterns in most areas of the country. Carbon monoxide levels reach their peak in the fall and early winter months when strong radiation cooling results in strong surface inversion, which in turn reduces mixing and confines the spread of pollutants from ground-level sources. An example of strong seasonality in the maximum monthly 8-hour CO average is seen at the Denver CAMP site in Figure 4-3. In the three years of monthly maxima plotted for the site,

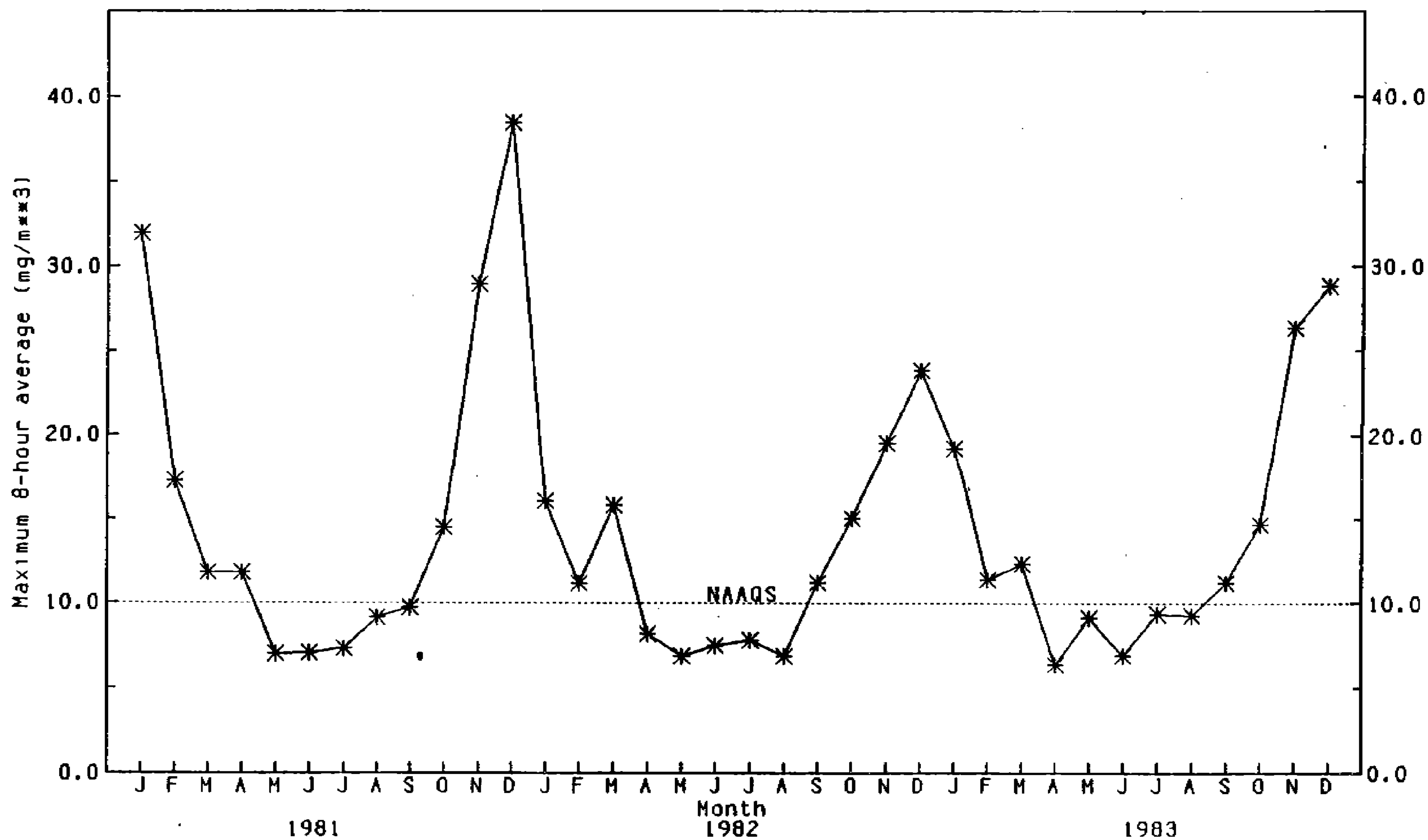

FIGURE 4-3. Seasonal variation in monthly maximum 8-hour average carbon monoxide concentration, Denver CAMP site, 1981-1983.

the highest 8-hour concentrations occur in December or January of each year. At this site the maximum monthly 8-hour average does not exceed the NAAQS of 10 mg/m^3 during the months of March through August in each of the three years shown.

The Denver CAMP site exhibits obvious cyclical behavior, but a similar time series of monthly maximum 8-hour averages for other sites may not show such strong seasonal patterns. Should strong seasonality of monthly maximum 8-hour average CO be the criterion for seasonal monitoring? If not, how should we determine whether or not a site is eligible for seasonal monitoring? One possibility is to perform a statistical test for seasonal patterns. But we recommend against first deciding if there are seasonal patterns and then determining what the monitoring season should be.

To see why such a testing procedure is impractical, consider two hypothetical sites. Site A has a strong seasonal pattern with peaks (and exceedances) in the winter and valleys in the summer. Site B has relatively constant monthly 8-hour maxima with an infrequent exceedance of the standard. The time series of monthly 8-hour maxima for these two sites is shown in Figure 4-4. The standard is never exceeded at site B except when site A has exceedances, therefore site B should not have to monitor more than site A. Yet site A is strongly seasonal and site B is not, so if we performed a statistical test for seasonality first, site A would be allowed to monitor seasonally but site B would not.

Determination of Monitoring Season

We therefore recommend the following procedure for determining the CO monitoring season. The required monitoring season, a period of fall and winter months, is determined by examining some previous years of data with some data completeness requirements (these decision rules are discussed futher below). The starting month of the required monitoring season is the earliest fall or winter month in which an exceedance of some cutoff concentration (also discussed below) occurred. Similarly, the last month of required monitoring is the latest winter month in which an exceedance of the cutoff concentration occurred in the years examined.

Consider the Denver CAMP site in Figure 4-3 as an example. The earliest fall/winter month in which there is an exceedance of the NAAQS in the three-year period is September, in both 1982 and 1983. The latest month where an exceedance occurred is March, in 1982. The required monitoring season for this site would therefore be September through March.

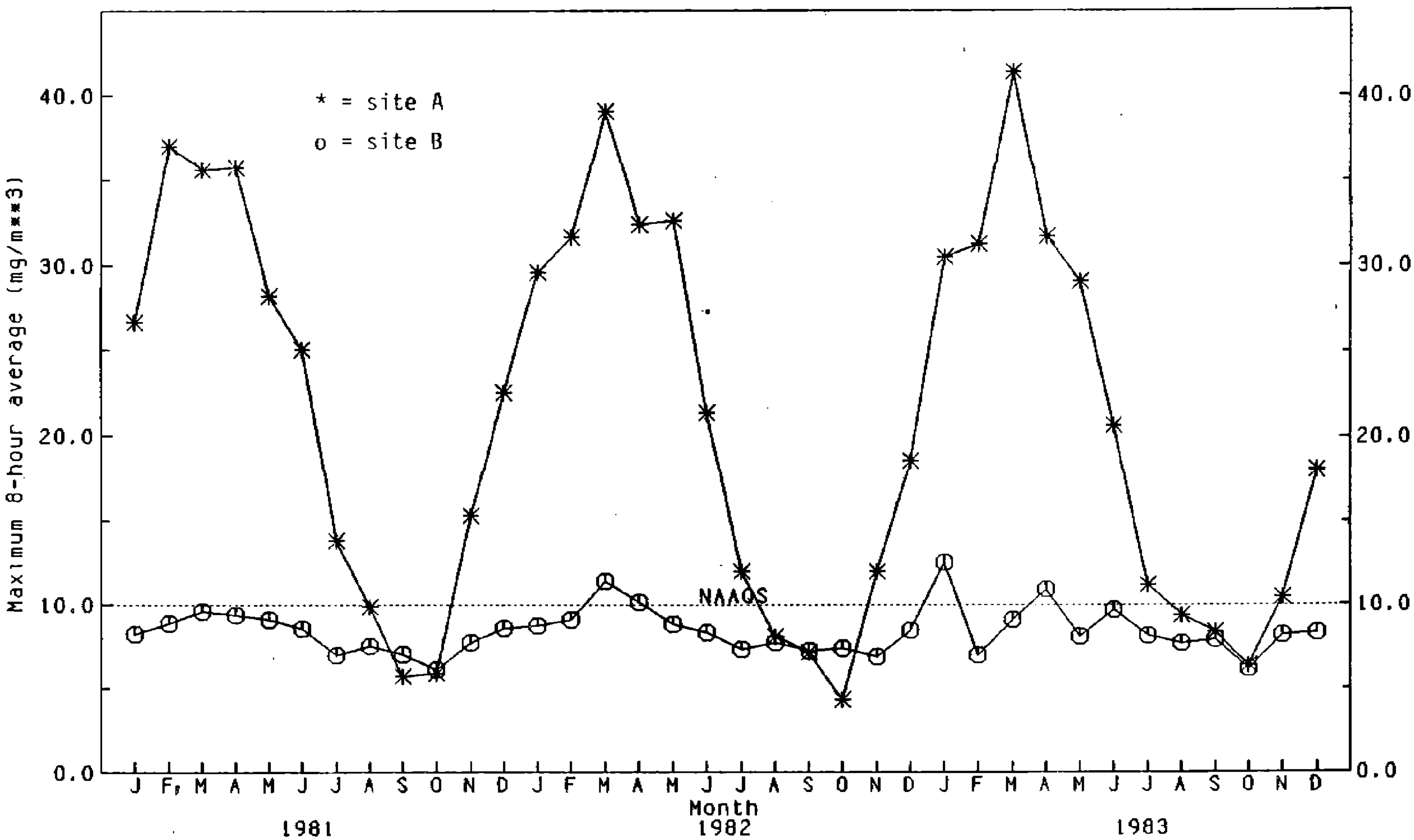

FIGURE 4-4. Seasonal variation in monthly maximum 8-hour carbon monoxide concentration, two hypothetical sites.

Figure 4-5 shows a three-year record of another hypothetical site (actually the Denver CAMP data of Figure 4-3 with the May 1983 maximum increased to a concentration just above the NAAQS). At this site the earliest exceedance month is still September. But here the latest month with an exceedance is May. Even though there were no exceedances in the month of April in the three-year record, the required monitoring period would be the continuous nine-month period of September through May.

As control programs for CO are implemented, and CO concentrations are reduced, there may be some sites where exceedances in the first and last months of the required monitoring period no longer occur. We therefore recommend that if three years (or however many years are used to determine eligibility for seasonal monitoring) pass with no exceedances in the beginning or ending month of the required monitoring period, and if in all years those months had acceptably complete data, then the monitoring period can be shortened accordingly.

Decision Rules for Seasonal Monitoring of Carbon Monoxide

Three decision rules can be established in order to determine the required monitoring season for CO. These are similar to the decision rules for the mothballing and rotation options: (1) the cutoff concentration above which "exceedances" are counted, (2) the length of the test period, and (3) data completeness during the test period.

The cutoff concentration and the length of the test period must be the same as for the mothballing option, if both shutdown and seasonal monitoring are available options. Otherwise, if the requirements for seasonal monitoring are less restrictive, we are faced with a potential paradox: a site might not meet the requirement for mothballing but could meet the requirements for seasonal monitoring with a 12-month off-season. Consider, for example, a site where concentrations are at about 60 percent of the standard in each and every month. If the cutoff concentrations were 50 percent of the standard for shutdown and 75 percent for seasonal monitoring, and the remainder of the criteria are the same, then the example site could not be mothballed but is below the seasonal cutoff concentration in each and every month and so qualifies for seasonal monitoring with a 12-month off-season.

Likewise, data completeness requirements need to be as strict or stricter for seasonal monitoring than for the mothballing and rotation options. Rather than annual or seasonal data completeness requirements, however, there should be monthly requirements for the seasonal monitoring option. If this is not the case, then a site with no exceedances of the cutoff concentration before October 1 in the test period would be eligible for

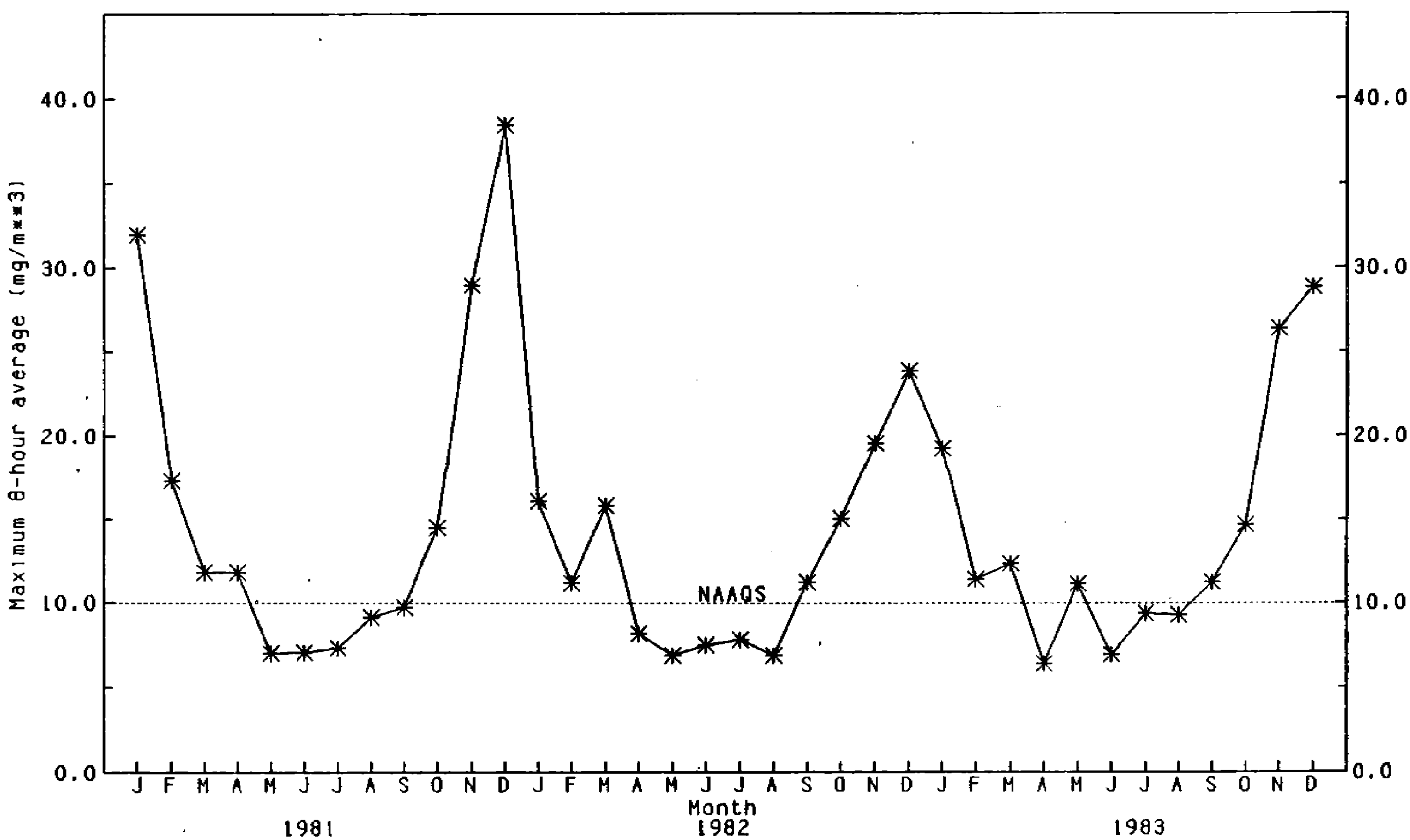

FIGURE 4-5. Seasonal variation in monthly maximum 8-hour average carbon monoxide concentration, hypothetical site.

shutdown in September. But one would not want to consider September part of the off-season if in the first test year September had no valid data and in the third test year only half a month's data. Of course, if a given month does not meet the data completeness requirements but there is an exceedance of the cutoff concentration in the month, then obviously that month must be included in the required monitoring season.

5 MONITORING COSTS AND AN EXAMPLE OF NETWORK COST SAVINGS

The purpose of this section is to demonstrate the potential for cost savings if one of the options suggested in this report is followed. The annual costs for pollutant monitoring are based on tables in the recent report "Cost of Ambient Air Monitoring for Criteria Pollutants and Selected Toxic Pollutants" by PEI Associates, Inc. (1985) and discussions with the PEI project manager.

The monitoring costs and cost structure in the PEI report are based on PEI field experience and discussions with manufacturers and State and local air pollution control agencies. The costs are estimated averages; clearly there is much variabilty from state to state, and even from one agency to another within the same State. We use the PEI estimates to demonstrate how one would calculate estimates of the cost savings if one of the suggested options is implemented; State and local agencies can perform similar calculations with their own known costs to determine their actual cost savings.

COST COMPONENTS

The biggest cost component for pollutant monitoring is technical labor. In the PEI report four classes of technical staff are identified:

> "Labor requirements are based on PEI field experience in implementing and operating monitoring networks. PEI assumed four standard labor categories that are typical for a State or local agency. The labor categories and associated responsibilities are as follows:
>
> Technician I--Operates the monitoring site, maintains the site and instrument log(s), and reduces raw data from the analyzer(s).
>
> Technician II--Performs instrument precision, span, and audit checks; does routine and remedial instrument maintenance; makes data computations; maintains site records; and trains site operators.

Technical Supervisor--Coordinates staff work assignments, reviews data, develops status reports for submittal to management, assists in equipment procurement and site selection, reviews program problems, ensures adequate training, maintains and reports quality assurance activities, and coordinates modeling efforts.

Management--Reviews, analyzes, and evaluates monitoring objectives; regulates budgets and procurement activities; and reviews results to ensure that program objectives are met.

The assumed labor rates for costs developed in this report are based on an average of rates from three Ohio and Indiana air pollution control agencies. The rates represent base wages multiplied (burdened) by a factor of two to account for benefits and agency overhead. Both the base wage rates and the burdening factor will differ among agencies, depending on geographic location, agency size, and training and length of service of employees."

The burdened hourly rates are $16.00 for Technician I, $20.00 for Technician II, $22.00 for Technical Supervisor, and $26.00 for Management. These labor rates and all other costs in the PEI report are for 1984 dollars; to reflect 1986 dollars all costs are increased by eight percent, which is approximately the increase in the U.S. Consumer Price Index for Urban Wage Earners over the past two years (1984 and 1985).

The annual operating costs for criteria pollutant monitors (except lead) are presented in Tables 5-1 and 5-2. TSP sampling costs are the most straightforward, since no shelter is required. Table 5-1 shows annual operating costs for intermittent (once every six days) 24-hour TSP sampling using the required hi-volume sampler. The total annual cost for sample collection, analysis, maintenance, and quality assurance for a single TSP monitor is $2,972.

For the other four criteria pollutants under consideration, a temperature-controlled environment is required for continuous monitoring. This is normally an aluminum shelter or a room in an office building. The annual costs for operating such a shelter are listed in Table 5-2a, along with selected operating costs; these costs are dependent on the number of pollutants monitored at the site. As noted in the table, the time spent on routine visits and on precision and span checks varies with the number of continuous monitors at the site. The total of these costs, summarized in Table 5-2b, for one or two pollutants is $6,312; for three pollutants the cost is $9,526; and for four pollutants the total is $12,740.

TABLE 5-1. Annual operating costs for TSP sampling. (Adapted from Table 2-5, PEI, 1985)

Cost Item	Annual Cost (dollars)
Sampling	1190
Utilities at $7/month	84
Sample recovery	
Labor (1 hour per sample, Technician I*, 61 samples)	976
100 Type A glass-fiber filters	60
100 filter holders/envelopes	50
100 recorder charts/inks	20
Analysis	340
Tare weighing, numbering, conditioning--3 hours, Technician II*	60
Filter weighing--2 hours per quarter, Technician II,	160
Data reduction--6 hours, Technician II	120
Maintenance/repair	878
Routine maintenance/calibration--32 hours, Technician II	640
Remedial maintenance--8 hours, Technician II	160
Supplies	
4 brush sets at $6 each	24
4 motor cushions at $6 each	24
1 Neoprene gasket at $6 each	6
4 filter holder gaskets at $6 each	24
Quality assurance and supervision	344
Reweighing of samples, review of calibrations and audits--12 hours, Technical Supervisor*	264
Certification of calibration and audit units--4 hours, Technician II	80
Total, 1984 dollars	2752
Total, 1986 dollars (1.08 x 1984 dollars)	2972

* Assumed hourly labor rates are $16 for Technician I, $20 for Technician II, and $22 for Technical Supervisor, 1984 dollars.

TABLE 5-2a. Annual facility costs and selected operating costs for a continuous monitoring site. (Adapted from Table 2-9, PEI, 1985)

Cost Item	Annual Cost (dollars)
Utilities, at $75 per month	900
Scheduling/supervision--24 hours, Technical Supervisor (2 hours per month, $22 per hour)	528
Routine site visits--156 hours, Technician I* (three visits per week, 1 hour per visit, $16 per hour)	2496
Precision/span checks--96 hours, Technician II* (two 4-hour visits per month, $20 per hour)	1920
Total, 1984 dollars	5844
Total, 1986 dollars (1.08 x 1984 dollars)	6312

* Cost for one or two pollutant monitors. Add 1 hour per visit for each additional pollutant monitor.

TABLE 5-2b. Facility and operating costs from Table 5-2a summarized by the number of continuous pollutant monitors at the site.

Cost Item	Annual Cost for Specified Number of Continuous Monitors (dollars)		
	1 or 2	3	4
Utilities	900	900	900
Scheduling/supervision	528	528	528
Routine site visits	2,496	4,992	7,488
Precision/span checks	1,920	2,400	2,880
Total, 1984 dollars	5,844	8,820	11,796
Total, 1986 dollars	6,312	9,526	12,740

TABLE 5-2c. Remaining annual operating costs for continuous pollutant monitors. (Adapted from Table 2-9, PEI, 1985).

Cost Item	Annual Cost (1984 Dollars)
Operating Supplies	420
Data reduction	
Automated:	
Cassette pickup, 1 hour/week, Technician I*	832
Cassette pickup, .25 hour/month, Technician II*	60
Manual:	
6 hours/month, Technician I	1152
1 hour/month, Technician II	240
1 hour/week to pick up strip charts, Technician I	832
4 hours/month data entry, Technician I	768
Maintenance/Repair	
Routine maintenance:	
16 hours, Technician II	320
8 hours, Technical Supervisor*	176
Remedial maintenance, 8 hours, Technician II	160
Replacement components	400
Calibration	
Routine calibration, 4 hours/quarter, Technician II	320
Supervision, 1 hour/quarter, Technical supervisor	88
Calibration gases or permeation tubes:	
SO_2	460
NO_2	460
CO	1560
Quality Assurance and Reporting	
Data validation, 1.5 hours/week, Technician I	1248
Data assessment and reporting, 3 hours/quarter, Technical supervisor	264
Audits:	
4 hours, Technician I	64
4 hours, Technician II	80
1 hour, Technical supervisor	22
Audit gases or permeation tubes:	
SO_2	230
NO_2	230
CO	780

* Assumed hourly labor rates are $16 for Technician I, $20 for Technician II, and $22 for Technical Supervisor, 1984 dollars.

TABLE 5-2d. Summary of Table 5-2c operating costs for continuous pollutant monitors.

Pollutant	Data Reduction Method		Average Cost	
	Automated	Manual	1984	1986
SO_2	$5144	$7244	$6194	$6690
NO_2	5144	7244	6194	6690
O_3	4454	6554	5504	5944
CO	6794	8894	7844	8472

The remaining annual operating costs for continuous pollutant analyzers--operating supplies, data reduction, maintenance and repair, calibration, and quality assurance--are listed in Table 5-2c. (These costs assume that data is picked up at the site rather than transmitted automatically because relatively few sites currently have telemetric equipment.) The costs for each pollutant are summarized in Table 5-2d.* Because of the labor involved in data reduction from strip charts, operating costs for automated samplers are far lower (about 25 to 30 percent) than for manual samplers. In the network example below we use the average cost between the automated and manual data reduction methods since about half of the samplers currently use automated data loggers.

EXAMPLE SAVINGS

To demonstrate how to calculate the potential cost savings if one of the recommended monitoring reduction options is implemented, we constructed a network of 100 sites. The distribution of pollutants monitored at each of the 100 sites in the network was chosen to be representative of most State networks (see Table 2-4). Although just seven States have more than 100 criteria pollutant monitoring sites (California, Florida, Illinois, New York, Ohio, Pennsylvania, and Wisconsin; 1983 data), we chose a large network to demonstrate the cost savings at a variety of sites, each with different numbers of monitors. Our purpose is to indicate the percentage reduction in costs, not the actual amount of cost savings, that may be possible in many States.

Table 5-3 shows the pollutants monitored at each of the 100 sites in the example network, and the annual operating costs at each of the sites. At 59 of the 100 sites, only TSP is monitored, so no shelter is required; the annual cost of $2,972 for these sites is the total cost in Table 5-1. There are 15 sites where only one pollutant is continuously monitored (12 for O_3, 1 for SO_2, and 2 for CO), and eight sites where all five pollutants are monitored. The site costs for those sites where at least one pollutant is continuously monitored are derived from Table 5-2. The total annual cost for operation of the 100-site network is $1,138,218, or about $11,000 per site per year. We also note that approximately 15 percent of estimated annual costs are attributable to sites with TSP monitors only and approximately 13 percent to sites with ozone monitors only. All sites with single monitors (74 of the 100 sites) account for approximately 32 percent of the estimated annual operating costs. Another 31 percent of the estimated cost is attributable to the eight sites that monitor five

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* The annual operating costs in Tables 5-2a and 5-2c were split this way because it was convenient for cost savings calculations.

TABLE 5-3. Estimated annual operating costs for example monitoring network of 100 sites (1986 dollars).

		Annual Operating Costs ($)							
		From	From Table 5-2d†						
Pollutant Monitored	Count	Table 5-2b*	TSP	SO_2	O_3	CO	NO2	Total Cost Per Site ($)	Total Cost ($)
TSP	59		2,972					2,972	175,348
O_3	12	6,312			5,944			12,256	147,072
SO_2	1	6,312		6,690				13,002	13,002
CO	2	6,312				8,472		14,784	29,568
SO_2, O_3	3	6,312		6,690	5,944			18,946	56,838
O_3, NO_2	1	6,312			5,944		6,690	18,946	18,946
TSP, CO	2	6,312	2,972			8,472		17,756	35,512
TSP, SO_2	1	6,312	2,972	6,690				15,974	15,974
TSP, O_3, NO_2	1	6,312	2,972		5,944		6,690	21,918	21,918
TSP, O_3, CO	3	6,312	2,972		5,944	8,472		23,700	71,100
TSP, SO_2, NO_2	1	6,312	2,972	6,690			6,690	22,664	22,664
TSP, SO_2, O_3	1	6,312	2,972	6,690	5,944			21,918	21,918
O_3, CO, NO_2	2	9,526			5,944	8,472	6,690	30,632	61,264
TSP, SO_2, O_3, CO	1	9,526	2,972	6,690	5,944	8,472		33,604	33,604
TSP, O_3, CO, NO_2	1	9,526	2,972		5,944	8,472	6,690	33,604	33,604
TSP, SO_2, O_3, NO_2	1	9,526	2,972	6,690	5,944		6,690	31,822	31,822
TSP, SO_2, O_3, CO, NO_2	8	12,740	2,972	6,690	5,944	8,472	6,690	43,508	348,064
Total	100								$1,138,218

* These costs include facility and some operating costs.
† Remaining operating costs.

86059 7

criteria pollutants. Approximately 21 percent of estimated annual costs is attributable to TSP monitoring.

We chose the every-other-year rotation option to demonstrate the calculations; it has a greater potential for cost savings than a seasonal monitoring strategy, but probably a smaller cost savings than the mothballing approach. The number of monitors assumed eligible for rotation was based on the example criteria in Section 3: concentrations less than 75 percent of the NAAQS (less than 75 percent of the controlling NAAQS when there are two standards) in the most recent year and on average for the most recent three years, with 75 percent data completeness requirement for each of the three years. The percentage of sites in the U.S. eligible under these criteria applied to 1981-1983 data are listed in Table 3-1; these percentages were applied to the sites in the example 100-site network, with the constraint that sites must be rotated in pairs and therefore only an even number can be rotated. For example, Table 3-1 shows that 48 percent of SO_2 monitors nationally meet the eligibility criteria. There are 17 SO_2 monitors distributed throughout the 100-site network, as shown in Table 5-3. Eight of the 17 monitors, or about 48 percent, are considered eligible for rotation in this example. Similarly, 32 of the 79 TSP monitors, none of the 34 O_3 monitors, 2 of the 19 CO monitors, and 4 of the 15 NO_2 monitors in the example network are considered to be eligible for every-other-year rotation.

Those monitors eligible for rotation were distributed among the monitoring site types listed in Table 5-3 in a somewhat arbitrary manner, since our purpose is to demonstrate the cost savings calculations. Those sites with at least one pollutant monitor eligible for rotation are listed in Table 5-4; the underlined pollutants at each site indicate which monitors are to be rotated. The table shows the two-year rotation cycle for the pollutant monitors at each of the sites. Since the purpose of this example is to demonstrate cost savings and not how to derive a rotation schedule, we assume that the eligible pollutant monitors were paired for every-other-year rotation using an EPA-approved method as discussed in Section 3 of this report.

The last two columns of Table 5-4 show the annual cost savings at each monitoring site for each of the two rotation years. The annual savings were computed from the costs in Tables 5-1 and 5-2. The simplest example of the calculations is for the 22 TSP monitors. Since the total annual operating cost for a monitoring site with only a TSP monitor is $2,792 (first line of Table 5-3), the savings is $2,972 in the shutdown year and none in the monitoring year. As a second example of the calculated savings, consider a site with TSP and CO monitors. Since both monitors are eligible for rotation, the site can be completely shut down for one year at a time. The total annual operating cost for such a monitoring

TABLE 5-4. Annual operating costs savings for the 100-site example network under an every-other-year rotation option. Underlined pollutants are those meeting eligibility requirements for rotation.

Pollutants Monitored	Pollutant Monitors Shut Down Year A	Pollutant Monitors Shut Down Year B	Annual Operating Cost Savings (1986 Dollars) Year A	Annual Operating Cost Savings (1986 Dollars) Year B
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
TSP	TSP	None	2,972	
TSP	None	TSP		2,972
SO_2	SO_2	None	13,002	
SO_2, O_3	None	SO_2		6,690
TSP, CO	TSP, CO	None	17,756	
TSP, CO	None	TSP, CO		17,756
TSP, SO_2	TSP, SO_2	None	15,083	
TSP, O_3, CO	None	TSP		2,972
TSP, SO_2, NO_2	None	TSP, SO_2, NO_2		22,664
TSP, SO_2, O_3	SO_2	TSP	6,690	2,972
TSP, SO_2, O_3, CO	None	SO_2		9,904
TSP, O_3, CO, NO_2	TSP	None	2,972	
TSP, SO_2, O_3, CO, NO_2	SO_2, NO_2	None	19,808	
TSP, SO_2, O_3, CO, NO_2	None	TSP		2,972
TSP, SO_2, O_3, CO, NO_2	TSP, NO_2	None	12,876	
TSP, SO_2, O_3, CO, NO_2	TSP	SO_2, NO_2	2,972	19,808
		Total Savings	$123,851	$118,430

site is seen to be $17,756 (seventh line of Table 5-3), so the savings is $17,756 in the year the monitoring site is completely shut down and none in the year when both monitors are in operation.

For a final, more complex example of the calculations, consider the last site in Table 5-4. At this site all five criteria pollutants are monitored, and the TSP, SO_2, and NO_2 monitors are considered for a rotation operation schedule. In Year A, the TSP monitor is shut down, and the annual cost savings is $2,972 (see Table 5-1). In Year B the continuous SO_2 and NO_2 monitors are shut down. The cost savings is $6,690 for shutting down the SO_2 monitor, plus $6,690 for shutting down the NO_2 monitor (see Table 5-2d), plus $6,428 for reducing the number of continuous monitors from four to two (see Table 5-2b), for a total annual cost savings of $19,808.

In this example, the total 100-site network cost savings is $123,851 in Year A and $118,430 in Year B, or between 10 and 11 percent of the $1,138,218 total annual operating costs for the network in each year. Approximately 40 percent ($50K) of the annual cost savings is attributed to reduction in TSP monitoring, of which $33K (27 percent) is due to rotation at sites that have only TSP monitors. Remember that in this hypothetical network approximately 21 percent of estimated annual operating costs are attributable to TSP monitoring.

If the same eligibility criteria used in the example qualified the monitors for mothballing instead of rotation, then the total annual savings would be $242,281, or about 21 percent of the annual network operating cost. However, this savings would not likely be the net savings since other data (not air quality) that can serve as indicators of air quality would have to be gathered and analyzed, and there may be additional shutdown costs.

We believe that somewhat greater than 11 percent annual operating costs savings is realistic for many State monitoring networks. The example may be conservative for three reasons. First, annual facility costs do not include amortization of shelter capital costs (these costs were not calculated in the PEI report); if mobile shelters are used for those monitoring locations at which complete shutdown is possible, then the total number of shelters in the network can be reduced. Second, the example includes rotated monitors only; seasonal monitoring for nonrotated CO monitors would result in additional savings. Third, and most important, the example was based on a three-year test period for determining shutdown eligibility. Since only about half of all pollutant monitors satisfy data completeness requirements for three consecutive years (see Table 3-1), a one- or two-year test period would result in substantially more monitors eligible for rotation. We believe that these additional cost savings would be greater than any costs associated with monitor and site shut-downs.

6 FURTHER STRATEGIES FOR POTENTIAL COST REDUCTIONS AND CONCLUDING REMARKS

In this section we first consider the possibility of combining the three suggested options for maximal monitoring costs reduction, and then discuss the adjustment of statewide trend statistics after one or more of the options have been implemented. We then summarize the three options considered, the eligibility criteria, and the overall potential for state monitoring costs reduction.

COMBINATIONS OF OPTIONS: MAXIMIZING REDUCTION OF MONITORING COSTS

States are not limited to using only one of the three options to reduce the effective number of criteria pollutant monitors. Some combination of all three options may in fact be the most cost-effective approach. For example, a state might opt for seasonal monitoring of CO, and mothballing or rotation of other monitors. Permanent shutdown might be considered for monitors meeting a cutoff of 50 percent of NAAQS concentration during a specified test period, and rotation for those monitors between 50 and 75 percent of the NAAQS.

Consider the number of sites in the U.S. that meet our example criteria (Table 3-1). Suppose that the EPA approved a 50 cutoff concentration as the criterion for mothballing and a 75 percent cutoff concentration for rotation in a particular state, and that the percent of sites meeting these criteria for each pollutant were similar to the national percents in the table. In this case it would likely be most cost-effective to permanently shut down the eligible SO_2 monitors but rotate the eligible TSP monitors. This is because most of the SO_2 sites that are below the 75 percent cutoff concentration are also below the 50 percent cutoff concentration; the limiting criterion for SO_2 (as shown in Table 3-1) is data completeness rather than annual summary statistics. For TSP, on the other hand, a majority of the sites meet the data completeness criterion, and the cutoff concentration is the limiting criterion.

If only the rotation option is considered, or if the rotation option is considered in combination with other options, then the cost savings achieved each year depends on the rotation schedule. As shown in Section

5, since there are fixed costs associated with operating a continuous pollutant monitoring shelter, cost savings are greatest if all of the monitors at a site can be rotated off in the same year. If the rotation option is chosen for more than one pollutant, then, there is not one unique rotation schedule, but rather many. Not only are there different rotation schedules for each pollutant, but there may be choices for rotating groups for specific pollutants. For example, one might have SO_2 monitors A, B, C, and D all eligible for rotation on an every-other-year schedule. If all four monitors have the same characteristics, then there are six possible pairings of the monitors. Which of the six pairings is optimal, and what the rotation schedule for each pairing should be, is a type of linear optimization problem. When there are many choices to be made, it is not practical to calculate cost savings for all possible rotation schedules. In that case, the linear optimization techniques of dynamic programming (Dreyfus and Law, 1977) or combinational optimization (Lawler, 1976) can be used to derive the rotation schedule resulting in maximal annual operating cost reduction.

ADJUSTMENT OF STATE TREND STATISTICS

Many state air pollution control agencies publish annual pollution summary statistics each year, and show trends in recent years (e.g., the California Air Resource Board's California Air Quality Data). If these same statistics are calculated after some of the suggested options are implemented, then it will appear that pollutant concentrations in the state are increasing, because the monitors with very low pollutant concentrations have been permanently or temporarily shut down and are not included in the averages. Some adjustments to the usual trend statistic calculations must therefore be made.

Adjustments to trend statistics depend on which options are implemented. If seasonal monitoring for CO is implemented, then no adjustment of trend statistics need be made since normally only the maximum 1-hour and 8-hour concentrations are considered. These maximum concentrations will, presumably, occur during the season when the CO monitors are in operation.

If monitors are rotated in pairs or triplets, then the monitor in operation in any given year provides the best estimate of the monitors not in operation that year. Therefore a weighted average across sites can be calculated, with the rotation monitor in operation receiving double or triple weight as appropriate. Suppose, for example, that there are four monitors (A, B, C, D) of a pollutant, and that in 1987 monitors C and D begin a rotation schedule, with C in operation the first year and D in operation the second year. Suppose also that the summary statistic of interest is the annual mean $\overline{X}_i$ at monitor i. Then for 1986 and preceding years the average summary statistic for the four months is calculated as $(\bar{X}_A + \bar{X}_B + \bar{X}_C + \bar{X}_D)/4$. For 1987 the annual average statistic of interest would be $(\bar{X}_A + \bar{X}_B + 2\bar{X}_C)/4$, and for 1988 the average across the sites would be $(\bar{X}_A + \bar{X}_B + 2\bar{X}_D)/4$.

If mothballing or permanent shutdown is implemented, then adjustment of trends statistics is difficult. There are three possible alternatives for reporting statewide trends. First, weighted averages could be calculated if one of the monitors eligible for mothballing was kept in operation to act as an indicator site; in this case the weight for the indicator monitor would be one plus the number of mothballed monitors it represents. The second possibility is to base trend statistics on only those monitors with continuous data, i.e., those monitors not mothballed. The percent change from year to year in the average of the operational monitors' statistics could be considered representative of the percent change that would be seen if all monitors continued to operate, but obviously the absolute levels of the average summer statistics would not be representative. The third possibility is to report the averages across time for the operating monitors, but to also show the average across all monitors for those years before mothballing was implemented. The two trend lines would then show the percent changes from year to year as well as the difference between the averages across all monitors and the averages across the operational monitors.

SUMMARY

Current air monitoring costs nationally are about $55 to $58 million annually. Many of the more than 4,000 criteria pollutant monitors show concentrations below the NAAQS, and so one way to reduce ambient air monitoring costs would be to shut down those monitors in low pollutant concentration areas for some period of time. In this report we suggest three options, to be used singly or in combination, to reduce criteria pollutant monitoring costs. These options are mothbablling, or permanent shutdown, of monitors; operation of monitors on an annual rotation schedule; and seasonal monitoring recommend for CO in addition to the current practice for O_3.

Four criteria are used to judge whether a monitor is eligible for mothballing or rotation:

The design value concentration (DVC) must be below some percent of the level specified in the NAAQS.

The DVC criterion must be met for some number of years, the test period.

EPA data completeness criteria must be met for each year in the test period.

Upward trends in the DVCs should not be evident in the DVC over the test period.

To be eligible for seasonal CO monitoring, a monitor must meet data completeness requirements for a specified period. The monitoring season is defined by the earliest and latest months in which exceedances of some percent of the 8-hour CO NAAQS occurred in the test period.

The number of monitors eligible for any of the three options, and thus the potential cost savings, depends on the eligibility criteria used. We calculated potential cost savings for an example statewide network of 100 monitoring sites with a total of 155 monitors. The number of monitors in the example network eligible for temporary or permanent shutdown for each pollutant was based on the national percent of monitors eligible under strict eligibility criteria applied to recent air quality data. For this network, we calculated that approximately 10 percent of the total annual operating costs would be saved if the eligible monitors were rotated; if the eligible monitors were mothballed instead then the cost savings could be as much as 20 percent. We believe that these savings for the example network would be achievable in many statewide ambient air quality monitoring networks.

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16. ABSTRACT

The primary purpose of this report is to provide guidance in reducing costs associated with operating and maintaining monitoring systems, new equipment purchases, quality assurance, laboratory analysis, maintaining computerized data bases, and data summary and reporting. Since 1980 there have been increasing efforts to hold or reduce monitoring costs; over the same period pressures for additional monitoring have been developed. This document provides guidance to State and local agencies on how the monitoring of criteria pollutants can become more cost effective.

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