LESSON 1

Introduction to SO_2 Monitoring

Goal

To familiarize you with the major sources of SO_2 emissions and the general types of monitoring sites used to measure ambient SO_2 concentrations.

Objectives

At the end of this lesson, you will be able to:

1. describe contributions and effects of natural and anthropogenic sources of SO_2.
2. identify typical concentration patterns of SO_2 emissions from anthropogenic sources.
3. associate major anthropogenic SO_2 source categories with geographical areas of the United States.
4. describe contributions of urban and rural sources of SO_2 emissions.
5. differentiate between point and area sources of SO_2 emissions.
6. define spatial scale of representativeness.
7. associate typical spatial scales of representativeness with physical dimensions of siting areas.
8. associate typical spatial scales of representativeness with general land-use areas.
9. differentiate between proximate and general-level monitoring sites.
10. associate general types of monitoring sites with siting objectives.

Procedure

1. Read pages 1-26 of EPA-450/3-77-013 *Optimum Site Exposure Criteria for* SO_2 *Monitoring.*
2. Complete the review exercise for this lesson.
3. Check your answers against the answer key following the exercise.
4. Review the pages in the reading for any questions you missed.
5. Continue to Lesson 2.

Estimated student completion time: 4 hours

Reading Assignment Topics

- General emission characteristics of SO_2 sources
- Characteristics of anthropogenic sources of SO_2
- Need for objective, uniform siting procedures
- Uses of SO_2 monitoring data
- Monitor siting objectives
- Spatial scales of representativeness
- General types of monitoring sites
- Correlation of general types of monitoring sites with siting objectives

Reading Guidance

In addition to the regulatory concerns pertaining to ambient air monitoring that are described on page 7 of the assigned reading material, the U.S. Environmental Protection Agency has also promulgated regulations specifying monitoring network design and monitor probe siting requirements for State Implementation Plan purposes. These regulations are found in Title 40, Part 58 of the Code of Federal Regulations (40 CFR 58), Revised 4/17/89, and are addressed in Lesson 7 of this book.

Table 2-1 on page 8 of the assigned reading material indicates that the present primary National Ambient Air Quality Standards (NAAQS) for SO_2 are expressed as annual and 24-hour averages and the present secondary NAAQS for SO_2 is expressed as a three-hour average. However, the U.S. Environmental Protection Agency is investigating the need for an SO_2 NAAQS that is based on a five-minute or one-hour average to address adverse health effects experienced by persons suffering from asthma who are exposed to 0.5 to 1 ppm of SO_2 over a one- to five-minute period. (7/20/87).

The neighborhood scale of representativeness is 0.5 to 4 km, not 0.5 to 5 km as indicated by Figure 3-1 in the assigned reading material.

Refer often to Tables 3-1 and 3-2 of the assigned reading material as you progress through the assignment.

Review Exercise

Now that you've completed the assignment for Lesson 1, please answer the following questions to determine whether or not you are mastering the material.

1. Globally, about ________ percent of all SO_2 in the atmosphere comes from natural sources.

   a. 75

   b. 25

   c. 50

   d. 10

2. True or False? Intense concentrations of ambient SO_2 are usually found near anthropogenic SO_2 emission sources.

Match the geographical areas of the United States with their major anthropogenic SO_2 source categories. (Questions 3-5)

3. North
4. South
5. West

a. transportation/power plants/ industrial processes

b. industrial processes/transportation

c. commercial and residential heating/power plants

6. True or False? About 20 percent of anthropogenic SO_2 emissions occur in urban areas.

7. Which of the following is an area source of sulfur compound emissions?

   a. power plant

   b. smelter

   c. highway

   d. none of the above

Match the following spatial scales of representativeness with their corresponding dimensions. (Questions 8-12)

8. microscale
9. middle scale
10. neighborhood scale
11. urban scale
12. regional scale

a. 0.1 to 0.5 kilometer

b. greater than 50 kilometers

c. less than 0.1 kilometer

d. 4 to 50 kilometers

e. 0.5 to 4 kilometers

Match the following land use areas with the spatial scale most likely to be represented by a single SO_2 measurement in each of them. (Questions 13-15)

13. urban
14. suburban
15. rural

a. middle scale

b. neighborhood scale

c. regional scale

16. True or False? Proximate sites are those associated with siting objectives that require information regarding impacts from a specific source or a group of specific sources.

17. True or False? General-level sites are those located in areas where information concerning the total air pollutant concentration is important but where information concerning contributions from individual sources to the total concentration is relatively unimportant.

Match the following SO_2 monitor siting objectives with their appropriate types of monitoring sites. (Questions 18-21)

18. determination of the peak concentration in an urban area
19. determination of the impact of an isolated point source
20. determination of the base concentration in areas of projected growth
21. assessment of background concentrations in rural areas

a. general-level regional scale

b. proximate micro/middle scale

c. general-level middle scale

d. general-level neighborhood scale

Review Exercise Answers

		Page*
1.	c	1
2.	True	1
3.	c	4
4.	a	4
5.	b	4
6.	False	4
7.	c	5
8.	c	17
9.	a	17
10.	e	17
11.	d	18
12.	b	18
13.	a	19
14.	b	19
15.	c	19
16.	True	21
17.	True	21
18.	c	24
19.	b	24
20.	d	24
21.	a	24

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* Refer to pages 1-26 of EPA-450/3-77-013 *Optimum Site Exposure Criteria for SO_2 Monitoring.*

1.0 INTRODUCTION

1.1 GENERAL

Sulfur dioxide (SO_2) is a natural constituent of the air. Globally, about one-half of all SO_2 in the atmosphere comes from natural sources (Robinson and Robbins, 1968). These natural sources are, however, quite diffuse and lead to background concentrations estimated to be a small fraction of a part per billion (parts of air). In contrast, the emissions from anthropogenic processes are relatively quite intense. As SO_2 is dispersed in the atmosphere, its concentration is reduced from noxious levels near the sources to levels comparable to that of SO_2 from natural sources. The general nature of SO_2 (or any pollutant) monitoring, then, is to measure the time and space variability of concentrations from the region of the source, or sources, to where the pollutant has become sufficiently dilute. Such measurements are required to satisfy monitoring program goals or data uses such as determining population exposures and ascertaining compliance with air quality standards.

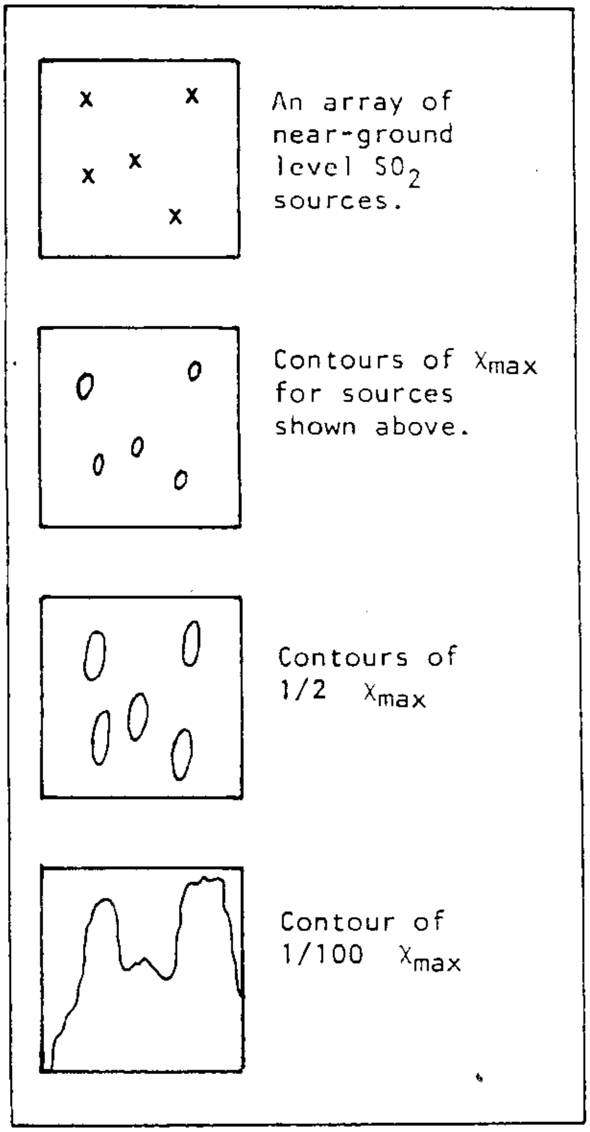

FIGURE 1-1. Concentration contours from an array of sources with steady conditions.

Since the dominant anthropogenic sources of SO_2 emissions are from stationary combustion devices, the most striking characteristic of typical SO_2 concentration patterns if that the concentration peaks reproduce the source patterns (see Figure 1-1). Monitoring for the concentration maxima averaged over any time scale may be accomplished with great accuracy by putting an instrument in every chimney. Obviously, it is of more interest to determine time and space patterns of SO_2 concentration away, but not too far away, from one or more sources. Concentrations very far away from all sources must be low; i.e., they approach the global average, and their patterns would contain features associated with only the longest time scales or the broadest space scales.

In the region between "too near" and "too far" from a source, a significant concentration may be expected over only perhaps 5 percent of the area at any one time (see Figure 1-2), because the wind comes from only one direction at a time. This is an order of magnitude rule-of-thumb, no matter what the minimum concentration of interest is. Any given monitor permanently placed in hopes of defining such a region would have one chance in twenty of detecting any SO_2 above the limit, even if all wind directions were equally likely. Also, the varying inner and outer limits of the region, due to the varying dispersive power of the wind would reduce the chances further. In situations where a given wind direction is significantly more likely than others, the chances are significantly increased, but still not as large as one would like. Therefore, instrument siting to monitor a single source even in an ideal environment free of micro- or meso-scale local effects such as topography, cavity wakes, or localized thermal effects is not a straightforward procedure.

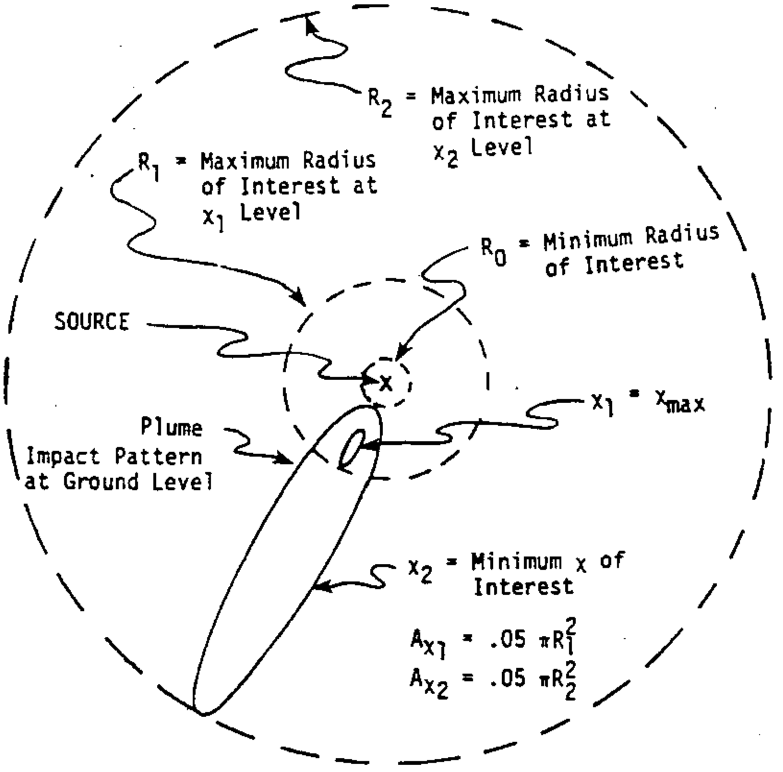

FIGURE 1-2. Instantaneous and potential regions of significant pollution concentration from a single source.

If many sources are near enough to each other so that their "circles of concern" (see Figure 1-2) overlap, then sources relatively far from a potential monitoring site will contribute a relatively steady "background" concentration upon which the relatively narrow plumes from nearer sources will be superimposed more randomly as they undulate past the site (see Figure 1-3). For a widespread and reasonably dense array of homogeneous sources, as, for example, in a large urban residential area, long-term mean concentrations can be determined quite accurately at any site. If the source array contains one or a few sources that are much larger than the rest which are relatively homogeneous, the problem of finding the background levels is as straightforward as for the homogeneous sources alone, but the problem of locating the peaks is as difficult as for the single source.

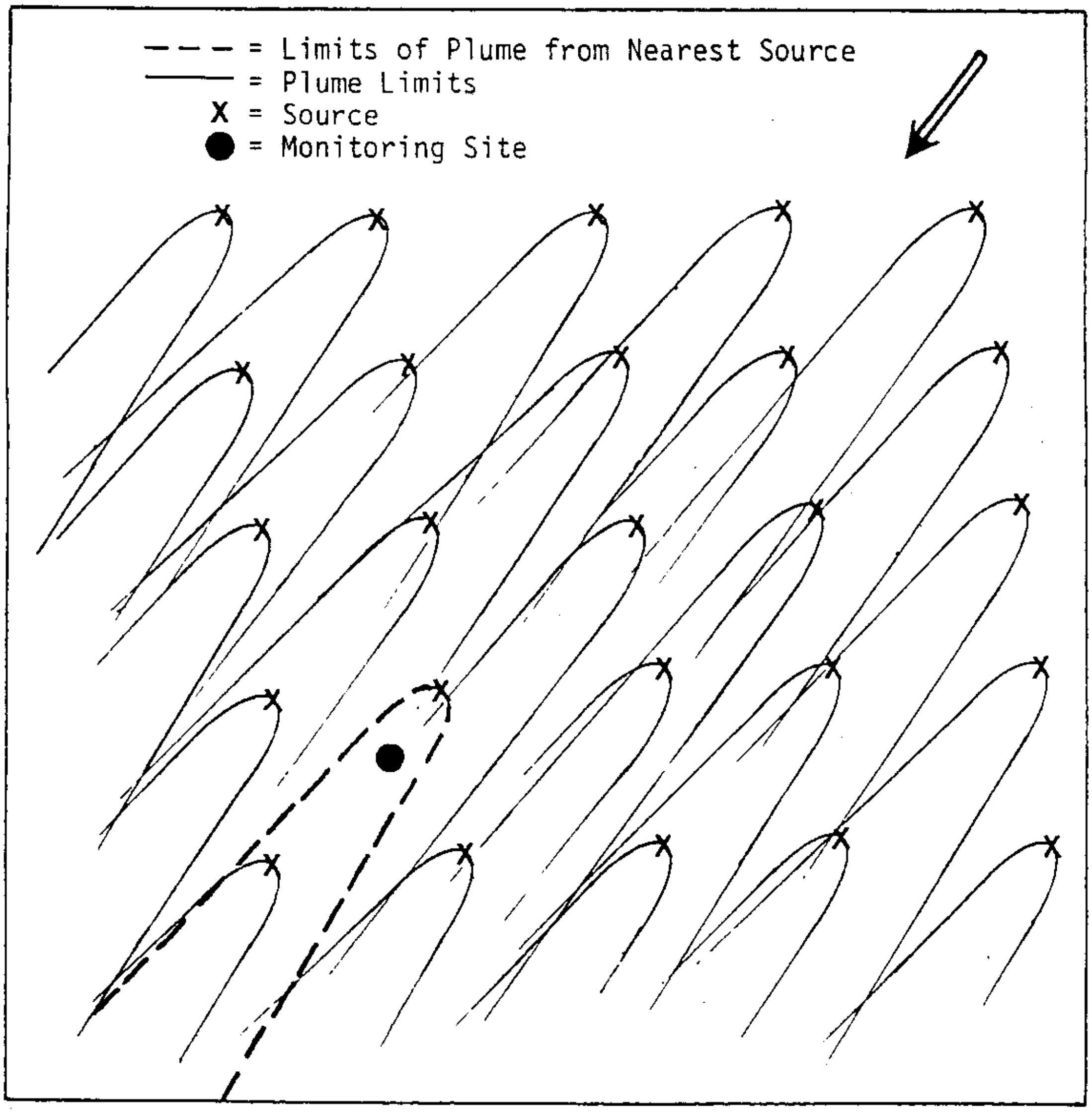

FIGURE 1-3. Superimposed plumes from multiple sources.

1.2 GEOGRAPHICAL AND SOURCE CHARACTERISTICS OF SO$_2$ EMISSIONS

The relative importance of the various SO$_2$ source categories varies geographically as shown in Table 1-1. In the colder areas of the north, exemplified by the Boston Air Quality Control Region (AQCR), commercial and residential heating is the largest category with 48.6 percent of the total for that AQCR. Farther south, the transportation, power generation, and industrial process emission categories are dominant, as indicated by the Atlanta AQCR summary. In the western states, the industrial process category is the largest with 40.1 percent and 37.6 percent of the total SO$_2$ emitted in the Denver and Los Angeles AQCRs, respectively. Transportation sources are also very significant in the west. In the Dallas/Fort Worth AQCR, SO$_2$ emissions from power generation are very small (3 percent of the total) because of the use of relatively sulfur-free natural gas. The largest category here is transportation (43.2 percent), followed by industrial processes (23.7 percent). In Arizona and Texas (as a whole) more than 80 percent of the SO$_2$ is emitted from smelters and refineries (Cavender, et al., 1973).

TABLE 1-1*

Sulfur Oxide Emission Inventories for the United States and for Selected Air Quality Control Regions, (NEDS Data for 1972)

Geographical Area	United States	Boston AQCR	Atlanta AQCR	St.Louis AQCR	Dallas, Ft.Worth AQCR	Denver AQCR	Los Angeles AQCR
	SO$_2$ Emissions in 10^3 Tons/Year						
Total Sulfur Oxide Emissions	32,000	332	94.7	1,234	17.3	33.5	238
Source Cagetory	Percentage of Sulfur Oxide Emissions by Source Category						
Stationary Source Fuel Combustion							
Electric Power Plants	54.3	41.6	70.8	76.2	3.0	34.2	16.8
Industrial	15.3	8.2	5.6	6.0	5.0	10.4	14.6
Commercial and Residential	7.1	48.6	5.7	1.9	19.8	5.3	18.8
Industrial Processes	21.1	0.5	12.3	15.3	23.7	40.7	37.6
Other Stationary Sources	0.2	0.1	0.5	0.1	5.3	0.2	1.6
Transportation Sources	2.0	1.0	5.1	0.5	43.2	9.2	10.6

* Taken from NAS (1975).

About two-thirds of SO$_2$ emissions occur in urban areas, with very large fractions contributed by industrial, commercial, and residential heating. These sources are also emitted near the ground which increases their ground-level impact. In rural areas, much of the SO$_2$ is emitted by a relatively small number of large sources such as smelters. Also, about one-half of the nation's power plants are located in rural areas. Although power plants comprise the largest emission category, their SO$_2$ is emitted from tall stacks which reduce ground-level impacts.

It will be seen later (in Section 4.0) that the physical configuration of the SO_2 source (i.e., point versus area source), whose SO_2 air quality impact is to be monitored, is important in regard to specific siting procedures. Point sources include large individual sources such as power plants and certain industrial processes. Commercial/residential heating and transportation categories are considered collectively as "area" sources.

1.3 SITE LOCATION STANDARDS

Most of the literature reporting air quality data and data summaries (e.g., EPA, 1973) emphasizes that interpretation of the data must be tempered by an understanding of the limitations imposed by inadequacies of surveillance methodologies. These inadequacies include inconsistencies between the specific objectives for which a monitoring station is established and the intended use of the resulting data and sampling maldistributions in both a geographical and temporal sense; these have been brought about by non-uniform siting procedures and/or a lack of an understanding of the atmospheric processes that affect the temporal and spatial distributions of pollutants. To illustrate these points, EPA (1973a) shows maximum 24-hour SO_2 concentration measurements within individual cities varying typically by a factor of from 5 to 10, and in extreme cases by 100 or more. Ott (1975) has shown similar variations in carbon monoxide measurements in United States cities. Clearly, data from most of these sites are not representative of the cities as a whole, but merely reflect what is occurring in the immediate vicinity of the sites.

Yamada (1970) showed that little consistency existed among sampling site locations and instrument inlet exposures. His study was based on a national survey of monitoring site characteristics. Further, the early Continuous Air Monitoring Program (CAMP) stations had inlet locations from 10 to 15 feet above the ground (Jutze & Tabor, 1963) while most state network station inlets were located on building roofs. A similar situation presently exists, although the development and deployment of instrumented trailers, of generally uniform dimensions, has reduced the problem somewhat.

From the above discussion, it is clear that a need exists for objective, uniform procedures for locating and categorizing SO_2 monitoring stations consistent with the intended use of the resulting data.

1.4 THE ORGANIZATION OF THIS REPORT

In Section 2.0, the major uses of SO_2 monitoring data is reviewed and a list of siting objectives, each consistent with a specific data use or group of uses is developed. It will be seen that the siting objective (along with the spatial scale of representativeness) is the major controlling factor in determining the desired physical characteristics of a site and its surroundings.

Section 3.0 discusses two basic monitoring network concepts, the spatial scales of representativeness relevant to SO_2 monitoring, and an SO_2 monitoring universe. A full review of these topics provides a basis to proceed with the development of the siting procedures which are discussed in Section 4.0.

Section 4.0 is the working part of the report and provides detailed step-by-step procedures for locating monitoring sites and the exposure of instrument inlets to satisfy the requirements for the various siting objectives. The discussion proceeds from the largest spatial scale to the smallest considered.

In Section 5.0, the rationale behind the site location procedures and other support documentation are presented. Topics include some of the relevant meteorological aspects of air pollution, topographical effects, urban modifications, washout/rainout, and chemical/physical interactions.

In determining monitoring site locations, the site selector will be required to use information and/or techniques with which he may be unfamiliar. To obviate this problem, a set of appendices has been included which describe the various kinds of data and techniques required as well as the sources from which these may be obtained. Topics addressed include a general approach for determining worst case meteorological conditions, the sources of meteorological and land use data, a list of available air quality models which may be useful in selecting a site, and some concepts of mobile sampling.

A bibliography (see Appendix F) is included showing a sample of the body of information available on all relevant topics covered in this report.

2.0 SO_2 DATA USES AND RELATED SPECIFIC MONITOR SITING OBJECTIVES

In this section, general SO_2 monitoring program elements and uses of SO_2 data are first reviewed; then, based on the review, a list of specific monitor siting objectives is developed. The main thrust of this section is to give some perspective to the various data uses and to relate them to the specific siting objectives. This latter point is important since it was from the siting objectives that a relatively small group of monitoring site types was developed for which site selection procedures and instrument inlet exposure criteria were prepared (Section 4.0).

2.1 GENERAL

Selecting and/or redistributing SO_2 monitoring sites on a priority basis is becoming critical in view of issues that have arisen since the promulgation of the Clean Air Act Amendments of 1970.* For example, air quality maintenance planning (AQMP)(Federal Register, 1973a), prevention of significant deterioration (PSD)(Federal Register, 1974), transportation control plans (Federal Register, 1973b), supplemental control systems (SCS) or intermittent control strategies (Federal Register, 1973c), and the Energy Supply and Environmental Coordination Act (ESECA) of 1974 have resulted in, either directly or by implication, requirements for expanded and/or reconfigured air monitoring networks. In addition, complexities and problems associated with photochemical pollutants (e.g., Stasiuk and Coffey, 1975; and Spicer, et al., 1976) which were unforeseen at the time of the passage of the "Amendments" will require an expansion of photochemical and photochemical precursor pollution monitoring. The total impact of these issues will require a reallocation of resources for ambient air monitoring. It will, therefore, be essential for the site selector to optimize ambient SO_2 monitoring systems in response to these new monitoring requirements.

Foremost in the discussion of SO_2 monitoring are the National Ambient Air Quality Standards (NAAQS) which must be attained and maintained in each AQCR across the country. These standards are summarized in Table 2-1. The primary standards were set to protect human health and the secondary standard was set

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* The "Act" resulted in the requirement for the states to prepare, adopt, and implement air pollution control plans or "state implementation plans" (SIPs) to attain and maintain air quality standards (Federal Register, 14 August, 1971). These plans included provisions for the design, establishment, and operation of air monitoring networks.

to protect the public welfare. The primary standards were to be attained in each AQCR by June of 1975 and the secondary standards attained within a reasonable time thereafter.

TABLE 2-1

NAAQS for SO_2

	Primary Standards	Secondary Standard
Annual Average	80 $\mu g/m^3$	---
24-hour Maximum	365 $\mu g/m^3$	---
3-hour Maximum	---	1300 $\mu g/m^3$

2.2 USES OF SO_2 MONITORING DATA

The list of SO_2 data uses presented below was compiled from a literature survey (see Appendix F). The order in which the uses are listed does not necessarily reflect the priority or relative importance of the uses; obviously, the priority of a given use in a given area would depend on the nature of the SO_2 problems that characterize that area. However, most of the uses that are listed are common to most areas of the country and are generally required to successfully implement those federal and state clean air policies that require the use of ambient SO_2 data.

1) Judging attainment of SO_2 NAAQS.

2) Evaluating progress in achieving/maintaining the NAAQS or state/local standards.

3) Developing or revising state implementation plans (SIPs) to attain/maintain NAAQS; evaluating control strategies.

4) Reviewing new sources.

5) Establishing baseline air quality levels for preventing significant deterioration and air quality maintenance planning.

6) Developing or revising national SO_2 control policies [e.g., new source performance standards (NSPS), tall stacks, supplementary control systems (SCS)].

7) Providing data for model development and validation.

8) Providing data to implement the provisions of the Energy Supply and Environmental Coordination Act (ESECA) of 1974,

9) Supporting enforcement actions.

10) Documenting episodes and initiating episode controls.

11) Documenting population exposure and health research.

12) Providing information to
    a) public - air pollution indices; and
    b) city/regional planners, air quality policy/decision makers - for activities related to programs such as air quality maintenance planning (AQMP), prevention of significant deterioration (PSD), and the preparation of environmental impact statements.

2.3 MONITOR SITING OBJECTIVES

The above data uses are expressed in rather broad terms and are generally program oriented. For this reason, it was difficult to associate a particular data use with a specific site selection procedure. To obviate the problem, a list of siting objectives was developed to provide a link between data uses and specific site selection procedures. The various siting objectives were developed such that each could be related to a specific type of monitoring site that would yield data of a level of quality and spatial and temporal representativeness appropriate for its intended use. Some of the siting objectives are couched in terms more reflective of the means by which the appropriate data will be obtained rather than in terms having a broad program connotation. Other siting objectives are worded closely to their related data uses, since in these cases the intended use is rather specific (e.g., episode monitoring). The monitor siting objectives and their related data uses are listed and discussed in the following sections.

2.3.1 Siting Objective 1 - Determination of Peak Concentration in Urban Areas

State and EPA policies and regulations require that SO_2 levels be brought within the primary NAAQS by June of 1975 and the secondary NAAQS within a reasonable time after that date, and that both are maintained thereafter. Maximum annual, 24- and 3-hour concentrations of SO_2 are usually found in urban centers where the use of sulfur-containing fossil fuel for space heating results in extremely high SO_2 emission densities. Subsequently, people living and working in these areas may be subject to both chronic and acute effects brought about by exposure to these high concentrations. The problem is exacerbated by SO_2 emissions from power plants which are often located in the larger urban centers.

SIP control strategies for SO_2 abatement are usually keyed on achieving the NAAQS at these points of maximum concentration (therefore, inherently related to the maximum economic impact of the strategy). Monitoring sites should be located at or near these points of maximum concentrations as revealed by modeling, to provide a continuing assessment of the situation. The most relevant uses for which such data are required are as follows:

- Judging attainments of SO_2 NAAQS (use 1)*.

- Evaluating progress in achieving/maintaining the NAAQS or state/local standards (use 2).

- Developing or revising state implementation plans (SIPs) to attain/maintain NAAQS; evaluating control strategies (use 3).

Such data will also be relevant to the implementation of the ESECA of 1974 (use 8) in those cities where there are power plants subject to the provisions of the ESECA.** Other uses include the supporting of enforcement actions (use 9) and in providing information to the public, city/regional planners, and air quality decision makers (use 12).

2.3.2 Siting Objective 2 - Determination of the Impact of Individual Point Sources in Multi-Source Urban Settings

This siting objective is similar to Objective 1 except that the monitor is placed at or near the maximum ground-level impact point caused by an individual point source located in an urban area. Because of background "noise" produced by other urban sources, monitor placement and data interpretation must also be done in conjunction with diffusion modeling.

This siting objective is related particularly to the ESECA of 1974 (use 8) which was enacted in response to projected shortages of fuel oil and/or diminished confidence of availability of supplies of such fuels. Under the Act's provisions, sources--mainly power-generating stations--may be required to convert to coal-burning. The conditions of the conversion will depend on the status of the AQCR with respect to the NAAQS. If the NAAQS are not being attained, a regional limitation (on SO_2 emissions) applies and all provisions of the SIP must be met before the conversion. If the NAAQS are being attained, then a primary standard condition applies which results in a variance from SIP emission limits and still results in attainment of the NAAQS. This siting objective particularly addresses the situation for such subject sources located in urban areas.

Another situation applicable to this siting objective is that of a single source located in an urban area that contributes overwhelmingly to SO_2 pollution in that urban area. In such a situation, it would be very desirable to monitor the maximum ground-level contribution from that source since the attainment and maintenance of the NAAQS in the area would be highly dependent on the effectiveness of control measures applied to that source. In this connection, data from monitoring stations so located could be used for:

- Developing or revising SIPs to attain/maintain NAAQS; evaluating control strategies (use 3).

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* Uses are listed from 1 to 12 in Section 2.2.

** A brief, general summary of the ESECA is presented under Siting Objective 2.

- Developing or revising national SO_2 control policies; e.g., new source performance standards (NSPS), tall stacks, and supplementary control systems (SCS)(use 6).

- Supporting enforcement actions (use 9), including SCS surveillance.

- Reviewing new sources (use 4). In this case, the data would be used to provide urban background concentrations at the point of maximum concentration contributed by a proposed new source or at any other point in the major impact area at which the NAAQS may be threatened.

- Providing information to the public, etc. (use 12).

2.3.3 Siting Objective 3 - Determination of the Impact of Isolated Point Sources

This siting objective is similar to Objective 2. Because there will be few, if any, interfering sources in rural areas, area diffusion modeling need not be employed for locating monitoring stations or in data interpretation. However, because of special problems associated with locating maximum impact points from individual sources in rural areas, mobile sampling may be required, particularly in regions of complex terrain. Only the 3-hour and 24-hour average concentrations need to be considered since the annual standard will not likely be contravened by an individual isolated point source.

The primary data uses related to this siting objecitve are the same as those associated with Siting Objective 2, particularly SCS implementation and surveillance. Other uses include establishing baseline air quality levels for PSD planning (use 5) and impact assessments associated with the enforcement of PSD policies.

2.3.4 Siting Objective 4 - Assessment of Interregional SO_2 Transport

Transport or advection of pollution across state or other jurisdictional boundaries received considerable attention in the development of some SIP's (e.g., Ball, et al., 1972). Large urban areas situated near or straddling state boundaries can result in a considerable exchange of SO_2 between the affected states--e.g., New York/New Jersey/Connecticut (New York City); Pennsylvania/New Jersey (Philadelphia); Missouri/Illinois (St. Louis); and Illinois/Indiana (Chicago). A rather detailed study of interstate transport of SO_2 was conducted by the NAPCA in the New York/New Jersey area (DHEW, 1967).

The EPA has acknowledged the existence of these situations and has required their being taken into account in state SIP's. The main objective of monitoring interregional transport of SO_2 is to assess the relative impacts in adjoining states. This assessment can provide information to the air pollution control agencies of these states for refining or optimizing control measures for achieving and maintaining the NAAQS (uses 2 and 3).

In certain situations, monitoring sites set up to monitor incoming SO_2 may also be considered as sites for measuring background concentrations and determining base concentrations for environmental impact studies, AQMP and PSD planning (uses 5 and 12).

2.3.5 Siting Objective 5 - Determination of Base Concentrations in Areas of Projected Growth

The air quality maintenance provisions of the Clean Air Act require that once the NAAQS are attained they must be maintained thereafter. To effectuate this requirement, a series of guideline documents was prepared and issued to the states (EPA, 1974a) to assist them in establishing Air Quality Maintenance Areas (AQMAs), and preparing AQMPs. Volume XI of the series ("Air Quality Monitoring and Data Analysis") addresses rather specifically the air monitoring requirements of AQMPs. The basic requirement involves the design and operation of a monitoring network (or a modification of an existing network) to establish baseline concentration levels from which air quality levels are projected into the future. Ongoing air quality measurements are then matched against projected levels to ascertain AQMP effectiveness. This siting objective satisfies the air monitoring requirements of AQMP development. Data originating from monitoring stations satisfying this siting objective will be particularly relevant to the activities of city/regional planners and air quality policy/decision makers associated with such programs and the preparing of environmental impact statements (uses 5 and 12).

2.3.6 Siting Objective 6 - Initiation of Emergency Episode Abatement Actions

States have established (with EPA guidance) air quality levels at which preplanned abatement strategies must be activitated for precluding air pollution buildup during air stagnations. These plans are usually "triggered" on the basis of real-time monitoring information from appropriately located sites.

Episodal concentrations often represent the highest short-term concentrations ever observed during the year in any given area. The highest peaks occur in the urban core, but are also relatively high and generally uniformly distributed over the areas surrounding the urban core. Since episodes are of relatively short duration (maximum duration of about three days or so), the acute effects on human health and public welfare are of greatest concern.

Most emergency episode plans drawn up by the states provide for a four-stage abatement mechanism. In each successive stage, more stringent emission limitations are imposed on prespecified sources to deal with the pollution buildup in a stepwise manner. The air quality situation is continuously monitored and each stage (and the eventual "all clear") is triggered according to prespecified criteria. Sites established for SO_2 monitoring during air stagnations should use continuous type instruments that output directly (via telemetering) to the air pollution control agency office (and computer) to facilitate rapid data acquisition and evaluation. In most situations, the site should be located in the very heart of the maximum SO_2 emission density zone of an urban area, since during air stagnation conditions wind speeds are low and directions are variable so the maximum concentration should occur near to where the emission density is a maximum. Since it is desirable to maximize monitoring coverage during a stagnation episode, other sites can be used to trigger the episode abatement plan and/or to monitor the progress of each stage. Most often these will be the peak concentration stations and other stations located in the urban area. The relevant data uses here are, therefore:

- Documenting episodes and initiating episode controls (use 10).
- Providing public information via air pollution indices (use 12).

2.3.7 Siting Objective 7 - Assessment of Background Concentrations in Rural Areas

Background levels of SO_2 in rural areas represent the lowest levels, or the approximate lowest levels (depending on the degree of interregional SO_2 transport) attainable over a large region. They may be considered as the baseline concentrations near urban areas that should be known in order to optimize the degree of control necessary to attain and maintain the NAAQS over the urban area. This siting objective is also closely related to Siting Objectives 4 and 5; in fact, several of these objectives could be satisfied with one site strategically located. The data uses relevant to this siting objective include uses 2, 3, 5 and 12.

2.3.8 Siting Objective 8 - Determination of Population Exposure

Since the primary purpose of the NAAQS is to protect human health, SO_2 monitoring sites should be located in areas characterized by high population density to ascertain the degree of SO_2 exposure to large numbers of people. In most cases, these areas will be the residential areas of cities adjacent to the central business districts (CBDs) and the peripheral suburbs.

In these areas, SO_2 concentrations for the three averaging times may be relatively high. However, the greater spatial variability of the shorter term peaks shifts the major concern to the annual average concentrations where effects on people are most likely to be chronic. This siting objective places the emphasis on the monitoring of SO_2 where most people live (constant exposure to relatively high levels) rather than where they work, which is covered by Siting Objective 1. The relevant data uses are then:

- Documenting population exposure and health research (use 11).
- Providing information to the public via air pollution indices (use 12).

2.3.9 Siting Objective 9 - Diffusion Model Calibration and Refinement

The calibration and refinement of diffusion models is becoming one of the most important objectives of air monitoring (use 7). In fact, many of the objectives described in this section may well, ultimately, be satisfied by the operation of appropriate diffusion models.

Many states used diffusion models to develop control strategies (e.g., Morgenstern and Hagg, 1972) to satisfy EPA SIP requirements. Diffusion modeling by state agencies is expected to continue as an ongoing activity in refining and/or optimizing control strategies and in providing a development/assessment tool in the design and implementation of AQMPs and PSD plans.

A realistic SO_2 model calibration program may require the establishment of a special, temporary network of SO_2 monitors to facilitate spatial as well as temporal correlation studies. For a detailed discussion on the problems of model calibration, see Brier (1973, 1975). Monitoring sites established for other objectives may also be used to supplement data from the special network.

Diffusion models are of two basic types--Gaussian and grid. Gaussian models simulate individual plumes (continuous or puff) by assuming a Gaussian distribution of plume material in the crosswind and vertical dimensions. Grid models, on the other hand, compute mean concentrations for each cell of a three-dimensional matrix of cells. There are several varieties of grid models, one of which is the full-airshed Eulerian (fixed-cell) type.

Several problems are associated with each type of model. A major problem with the Gaussian models, particularly the continuous versions, is their inability to account for complex air flows in which SO_2 source plumes are imbedded (e.g., in urban areas and in other regions of complex terrain). Grid models, however, are difficult to validate because their volume-averaged predictions must be compared to measurements taken at a point. Neither type of model can simulate the effects of micro-scale features of complex flows.

The largest air pollution study ever conducted by the EPA is presently underway in St. Louis, Missouri. The Regional Air Pollution Study (RAPS) has been referred to as the modeler's model. Models have been developed for simulating emissions, meteorology, photochemical reactions, removal processes, etc. Twenty-five air monitoring stations have been established in and around St. Louis for the primary purpose of model validation (Pooler, 1974). All five primary air pollutants and selected meteorological variables will be measured. Each site was carefully chosen in order to prevent contamination from small local sources, dust re-entrainment from the ground, and the measurement of anomalous winds.

Model calibration and refinement work is very highly specialized. Network configurations, instrument specification, characteristics, and other factors all reflect monitoring requirements that are probably unique for any given project. It is difficult to anticipate the monitoring requirements of such projects and impossible to generalize related siting guidelines. An attempt to do so was considered beyond the scope of the objectives of routine monitoring which this report addresses. However, it may be safely stated that ambient data from any source could probably be utilized, to at least a limited extent, in model calibration/validation studies if the conditions under which such data was obtained were known (and documented).

3.0 SPECIAL CHARACTERISTICS ASSOCIATED WITH SO_2 MONITORING

Because of the complex relationships among geographic, topographic, and climatologic factors; SO_2 patterns; and the various averaging times of the NAAQS; the selecting of appropriate sites for SO_2 monitoring can be a very complex process. However, the process can be simplified somewhat by first viewing the various siting objectives in the context of an SO_2 monitoring "universe". Then, through an elimination, consolidation and optimization process, one can establish various site types such that each can be associated with a general siting approach. Initially, it was expected that each site type could be related to a specific siting procedure. However, because of the nature of SO_2 concentration patterns, the requirements of some of the siting objectives, data uses and other factors, this was not possible in many cases. As will be seen in Section 4.0, some procedures are more closely related to the siting objective than site type.

The major objective of this section is to discuss the elements of the universe. This includes spatial scales of representativeness and how these relate to the averaging times of the NAAQS and the nature of urban concentration patterns, terrain characteristics, meteorology, land use, and other elements. Such a discussion will constitute an appropriate introduction to Section 4.0 (which presents the site selection procedures) by providing the site selector a basis for understanding some of the characteristics and problems associated with SO_2 monitoring.

3.1 MONITORING NETWORK CONCEPTS

It might be appropriate to begin this section with some historical perspective of monitoring in general by discussing the two basic types of monitoring networks. Many of the networks of the recent past and several existing ones are typified by these types.

3.1.1 Target Networks

Target networks are source-oriented in that each monitoring site has a specific and unique objective associated with it (e.g., see Stockton, 1970). These objectives may include the assessment of the air quality impact of a specific large source or the combined impacts of many sources in a particular area (usually where the maximum concentration occurs). The main concept behind the target network is that if an objective of a control or surveillance strategy is achieved at a maximum concentration point, then they are achieved in all areas of the affected region. Such a network requires a minimum number of site locations, and for this reason they are often considered optimum networks. This optimization also allows for a greater degree of sophistication regarding instrument types and data acquisition systems.

3.1.2 Area Networks

Prior to the general availability of diffusion models, initial urban air quality surveys were often conducted via an area network where large numbers of monitors were uniformly spaced over a region, usually at each point of a grid. The concepts behind this approach were that the more samples one had in the field, the more likely the concentration pattern characteristics of interest would be revealed, or the more accurately the regional average concentration could be computed. The earlier networks of this type were often established for purposes of research (e.g., see Keagy, et al., 1961). Because of the large number of sites, network maintenance was costly, and the use of expensive, high quality instruments was prohibitive. However, usually after a year or so of experience, one could drastically reduce the number of stations and still achieve all monitoring objectives with a reasonable degree of confidence (as discussed by Herrich, 1966). In a sense, the area network was gradually converted to a quasi-target network.

Area or quasi-target networks have been established in several large metropolitan areas where large sections are characterized by uniform land use such as large residential and commercial areas. In these situations, site locations are often determined on the basis of population and geographical coverage (e.g., see Heller and Ferrand, 1969).

There are some interesting variations of the area network type. Some may be configured on the basis of the orientation of a major topographical feature such as a river valley; others, on the location of a large emission district embedded in a larger, more diffuse emission region. In these situations, individual sampling sites may be located at points along a series of concentric arcs centered on the high emission district (e.g., see Leavitt, et al., 1957; Rossano, 1956) to "normalize" the distance-concentration factor, or at points along a series of lines perpendicular to the valley axis to ascertain concentration flux at each line. Other sites may be located to measure air quality upwind and downwind of the region.

For the routine uses of SO_2 monitoring data, the characteristics of an ideal SO_2 monitoring network should incorporate the desirable characteristics of both network types.

3.2 SPATIAL SCALES OF REPRESENTATIVENESS

Much of the discussion in this section was stimulated by a recent report by Ludwig and Kealoha (1975)--a counterpart report to this one for carbon monoxide monitoring. Since the scales of measurement as presented in that report are directly applicable to SO_2 (or to any pollutant) measurement scales, they are presented below but restated in terms applicable to SO_2 monitoring.

The volume of air sampled by an SO_2 instrument is very small when compared to the volume of air that the resulting air quality reading is supposed to represent (up to tens of thousands of km^2). It is not possible for a single monitor to sample all of the air volume over the area of interest to produce the number which is the actual average air quality reading for the area. Ideally, the monitor must be placed such that the air quality of the small sampled volume is representative of the air quality over the entire area of interest or reasonably so. (This requirement implies a certain degree of homogeneity over this area which is not always met, however.) The size of this area of interest establishes a corresponding spatial scale of representativeness over which one would like the measurement to apply.

The typical spatial scales of representativeness associated with most SO_2 siting objectives and related data uses are illustrated schematically in Figure 3-1 and discussed below, sequentially, from the smallest scale. In some situations, there are special problems associated with the representiveness of some SO_2 measurements; these problems are discussed in Section 3.2.1.

- Microscale. Ambient air volumes with dimensions ranging from meters up to about 100 meters are associated with this scale. Studies of the distribution of SO_2 within plumes either over flat or complex terrain or within building wake cavities require measurements of this scale. The development of special models designed to simulate such small scale SO_2 distributions also require microscale measurements for model verification and refinement.

- Middle Scale. This scale represents dimensions of the order from about 100 meters to 0.5 kilometer and characterizes air quality in areas up to several city blocks in size. Some data uses associated with middle scale measurements include assessing the effects of control strategies to reduce urban peak concentrations (especially for the 3-hour and 24-hour averaging times) and monitoring air pollution episodes.

- Neighborhood Scale. Neighborhood scale measurements would characterize conditions over areas with dimensions in the 0.5 km to 4 km range. As will be discussed later, this scale applies in areas where the SO_2 concentration gradient is relatively flat--mainly suburban areas surrounding the urban center--or to large sections of small cities and towns. In general, these areas are quite homogeneous in terms of SO_2 emission rates and population density. Neighborhood scale measurements may be associated with baseline concentrations in areas of projected growth and in studies of population responses to exposure to SO_2 (or health effects). Also, concentration maxima associated with air pollution episodes may be reasonable uniformly distributed over areas of neighborhood scale, and measurements taken within such an area would represent neighborhood as well as middle scale concentrations.

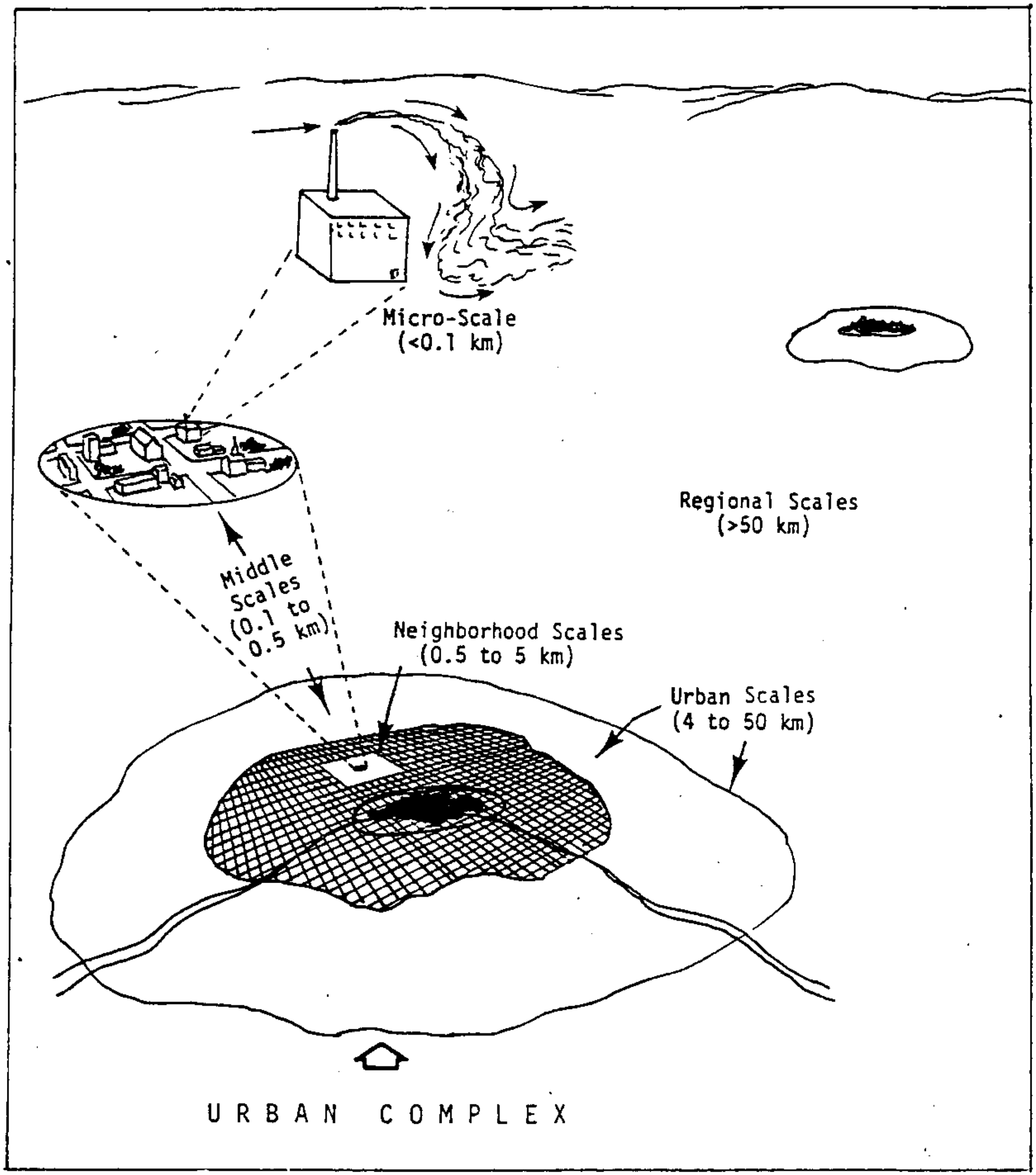

FIGURE 3-1. Illustration of various spatial scales of representativeness.

- Urban Scale. Urban scale measurements would be made to represent conditions over areas with dimensions on the order of 4 to 50 km. Such data could be used for the assessment of air quality trends, the effect of control strategies on urban scale air quality.

- Regional Scale. Conditions over areas with dimensions of as much as hundreds of kilometers would be represented by regional scale measurements. These measurements would be applicable mainly to large homogeneous areas, particularly those which are sparsely populated. Such measurements could provide information on background air quality and interregional pollutant transport.

- National and Global Scales. These measurement scales represent concentrations characterizing the nation and the globe as a whole. Such data would be useful in determining pollutant trends, in studying international and global transport processes, and in assessing the effects of control policies on national and global scales.

3.2.1 Measurement Scales Relevant to SO_2 Monitoring

In SO_2 monitoring, a distinction should be made between the spatial scale desired to be represented by a single measurement and the spatial scale actually represented by that measurement. The former is determined by the size of the area of interest which is associated with the intended use of the data and associated siting objective, while the latter is a function of the spatial variation of concentration in the horizontal over the area of interest. This variation results not only from the impacts of local sources within the area, but, more importantly, from the collective impacts of all sources located outside of the area of interest. These collective impacts result in background concentration patterns and gradients over the area of interest that essentially dictate the spatial scale that will be represented by a single measurement taken at a station located anywhere in that area. This dilemma may be stated in another way--the distance from a monitoring station at which measurements become significantly different from those at the monitoring station determines the spatial scale represented by measurements at the monitoring station. This distance is a function of the background concentration gradient. SO_2 concentrations over urban areas generally decrease rapidly outward from a peak near the urban center, and rather smoothly for annual averaging times (e.g., see Larsen, et al., 1961; and Figure 2-3, Stern, et al., 1973) as shown in Figure 3-2. Also, superimposed on the relatively smooth concentration pattern are "bumps"* due to large point sources. Hence, SO_2 concentrations in cities are, in general, neither uniform over large, homogeneous land use areas within the city, nor are they contained within numerous individual independent cells or street canyons as is the case for carbon monoxide (c.f., Figure 3, Ott, 1975).

Because of this nature of SO_2 distributions over urban areas, the middle scale is the most likely scale to be represented by a single measurement in an urban area, and only if the undue effects from local sources (minor or major point sources) can be eliminated. Neighborhood scales would be those most likely to be represented by single measurements in suburban areas where the concentration gradients are less steep. Regional scale measurements would be

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* For shorter averaging times these bumps become large "spikes" superimposed on a greatly irregular background pattern.

associated with rural areas. Microscale measurements may be required in certain situations. For example, in monitoring the impact of an isolated point source in complex terrain, initially it may be desirable to use mobile sampling or to establish a dense, area-type network to determine the general location of the maximum impact point. This will provide guidance for locating permanent sites for measurements representing the more relevant middle scale. Normally, investigators making such microscale measurements have specific siting requirements that reflect the specific and often unique purposes of their projects; these requirements would be difficult to generalize.

Because of the great variation of SO_2 concentrations in urban areas, it is unlikely that urban scale concentrations could be measured at a single site.

National and global scale concentrations are not of sufficient interest to state and local agencies to justify specific treatment. However, concentrations characterizing areas on these scales may be estimated by synthesizing regional, and then national scale measurements.

Figure 3-2 shows relative locations of sites in an urban area for measuring concentrations representing several spatial scales of measurement.

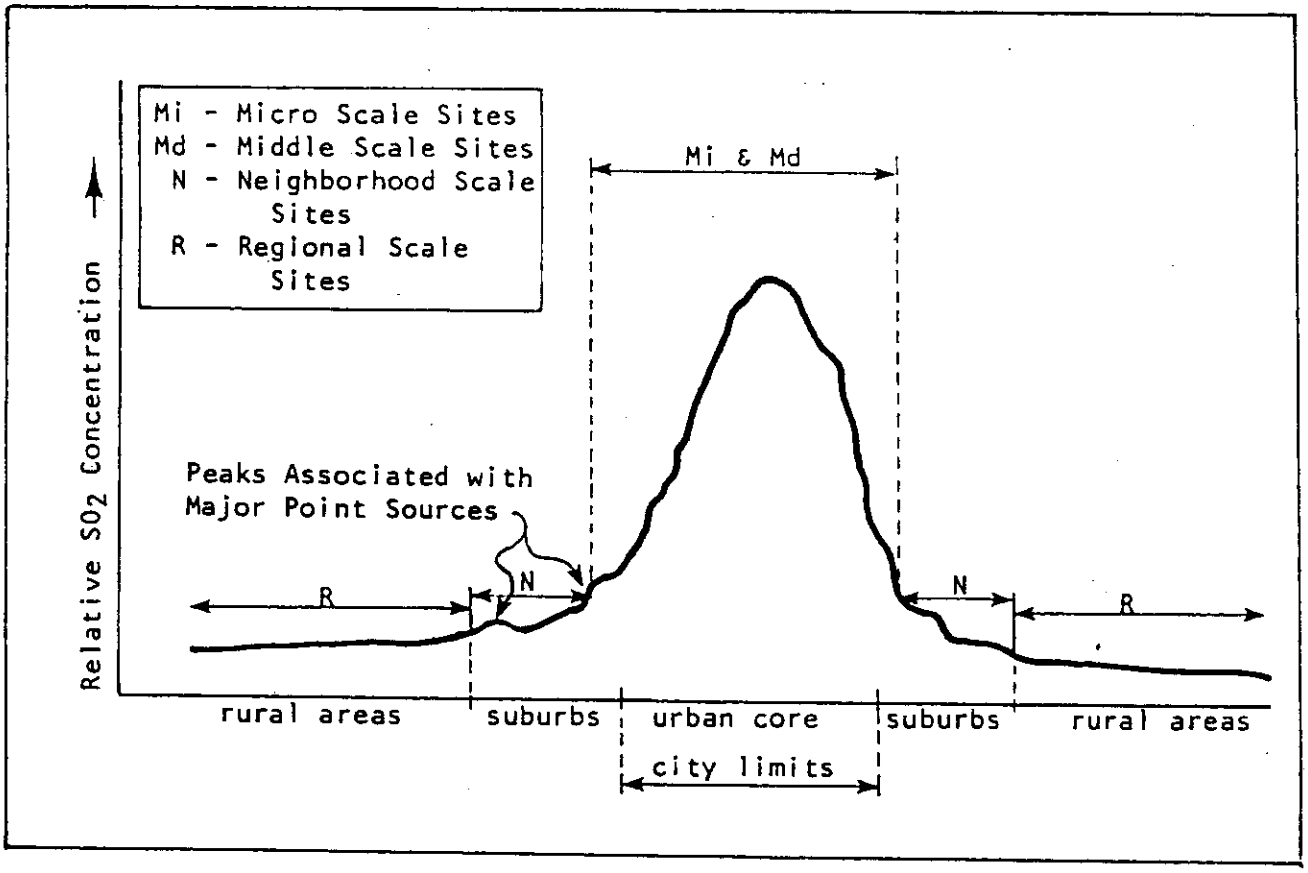

FIGURE 3-2. Relative locations of sites for measuring concentrations representing several spatial scales of measurement in an urban complex, with respect to annual averaging times.

3.3 MONITORING SITE TYPES AND ASSOCIATED SITING OBJECTIVES AND DATA USES

Our survey of the literature indicated that SO_2 monitoring sites can be classified as either proximate or general level. Proximate sites are those associated with siting objectives that require information regarding impacts from a specific source or a group of specific sources. These sources may be isolated, such as a smelter complex in a remote area, or a power plant so located in a city that it constitutes a large fraction of the total observed SO_2. General-level sites are those located in areas where the total concentration is important but contributions from individual sources to that concentration are relatively unimportant.

The siting objectives and related data uses and their associated site types and spatial scales of representativeness are summarized in Table 3-1. Blank spaces indicate those scales of measurement that are either inconsistent with the siting objective, or are simply not very useful. Proximate site types are indicated by "Pr" and general level by "GL". The underlined Xs indicate the desired spatial scale to be represented by a single measurement. The remaining Xs indicate other spatial scales that may actually be represented by a single measurement (because of the conditions imposed by the background concentration gradients). The letters (P) and (F) within the site type column indicate whether the siting objective is concentration pattern oriented or is associated with a fixed geographical area independent of the SO_2 pattern. For example, an urban peak concentration site (P) will be located as close as possible to the peak concentration point in the city without regard to the geographical setting of the siting area, while a site established to determine base concentrations in areas of projected growth (F) will be located within the growth area regardless of the characteristics of the prevailing SO_2 concentration pattern. It also might be worthwhile here to mention that the less complicated the source mix and density (i.e., as one approaches rural conditions) the wider the range of spatial scales a reading will represent; for example, in a homogeneously rural area, an individual reading will represent all spatial scales ranging from micro to regional and over any averaging time.

3.4 THE SO_2 MONITORING UNIVERSE

In the foregoing discussions, we have identified the uses of SO_2 data and their relationships to specific monitor siting objectives; we have also related the individual siting objectives to appropriate spatial scales of representiveness (see Table 3-1). However, there are other variables that must be considered in the site selection process--namely the averaging times of the NAAQS and the land use and topographical settings. All combinations of the above variables that must be accounted for in the selecting of monitoring sites, and to a certain extent, in determining probe exposure and monitoring mode, constitute an SO_2 monitoring "universe". It is from this universe that specific site types are selected to which are attached specific site selection procedures.

The five basic variables (the first two have already been discussed) that constitute the SO_2 monitoring universe are listed following Table 3-1.

TABLE 3-1

Relationships Among Siting Objectives and Related Data Uses, Site Types, and Scales of Representativeness

(a) If the assumption is made that the peak concentration point will only rarely occur (within middle-scale limits) at the monitoring site, then the reading will better represent typical maximum values on the neighborhood scale in the maximum impact area.

(b) Microscale measurements may be required to define plume structure via either area network or mobile sampling to simulate plume or to estimate permanent middle scale site locations.

(c) Under stagnation conditions, the maximum concentration zone will probably expand in area, in which case the reading may represent neighborhood scale averages as well as middle scale averages.

(d) Because of the multitude of scales on which models are designed to simulate air pollution, data on any scale may be required in model calibration/refinement work.

* The "Spatial Scale of Representativeness" is keyed as follows: I - microscale; II - middle scale; III - neighborhood scale; and IV - regional scale.

Siting Objectives/ Data Uses	Site Type	Spatial Scale of Representativeness*			
		I	II	III	IV
1. Determination of Peak Concentrations in Urban Areas. Judging attainment/maintenance of NAAQS. Evaluating progress in achieving/maintaining of NAAQS. Developing/revising SIPs/evaluating control strategies. Providing data to facilitate the ESECA of 1974. Supporting enforcement actions. Public information.	GL (P)		(a)X	X	
2. Determination of the Impact of Individual Point Source in Multi-Source Urban Setting. Developing/revising SIPs/evaluating control strategies. Reviewing new sources. Developing/revising national SO_2 control policies(NSPS,SCS, tall stacks). Providing data to facilitate ESECA of 1974. Supporting enforcement actions.	Pr (P)		X		
3. Determination of the Impact of Isolated Point Sources. Developing/revising SIPs/evaluating control strategies. Reviewing new sources. Developing/revising national SO_2 control policies(NSPS,SCS, tall stacks). Providing data to facilitate the ESECA of 1974. Supporting enforcement actions.	Pr (P)	(b)X	X		
4. Assessment of Interregional SO_2 Transport Establishing baseline air quality levels for PSD planning and AQMP. Evaluating progress in achieving/maintaining NAAQS. Developing/revising SIPs to attain/maintain NAAQS. Public information.	GL (P)				X
5. Determination of Base Concentration in Areas of Projected Growth. Establishing baseline air quality levels for PSD planning and AQMP. Evaluating progress in achieving/maintaining NAAQS. Developing/revising SIPs to attain/maintain NAAQS. Public information.	GL (F)		X	X	X
6. Emergency Episode Abatement Initiation and Monitoring. Documenting episodes and initiating episode controls Public information.	GL (P)		X	(c)X	
7. Assessment of Background Contration in Rural Areas. Establishing baseline air quality levels for PSD planning and AQMP. Developing/revising SIPS to attain/maintain NAAQS. Public information.	GL (P)				X
8. Determination of Population Exposure in Populated Areas. Documenting population exposure and health research. Public information.	GL (F)		X	X	X
9. Diffusion Model Calibration and Refinement. (d)	GL Pr (P)	X X	X X	X	X

1) Site Type

Proximate
General Level

2) Spatial Scale of Representativeness

Microscale
Middle Scale
Neighborhood Scale
Regional Scale

3) Averaging Time of NAAQS

3-hour (second highest)
24-hour (second highest)
Annual

4) Land Use Setting

Urban
Suburban
Rural

5) Topographical Setting

Coastal
Ridge-valley
Interior Plain
Rugged, Irregular (interior)
Rugged, Irregular (coastal)

Only a portion of the monitoring universe is presented in Figure 3-3 which shows only 15 combinations of variables. For the entire universe, the combinations total 360. Each combination could theoretically require a unique set of siting procedures depending on the siting objective, data use, and the commonality and availability of meteorological data for the various combinations. However, it will be seen that the combinations of these universe elements that reflect the stated siting objectives can be accommodated by a relatively small number of site types.

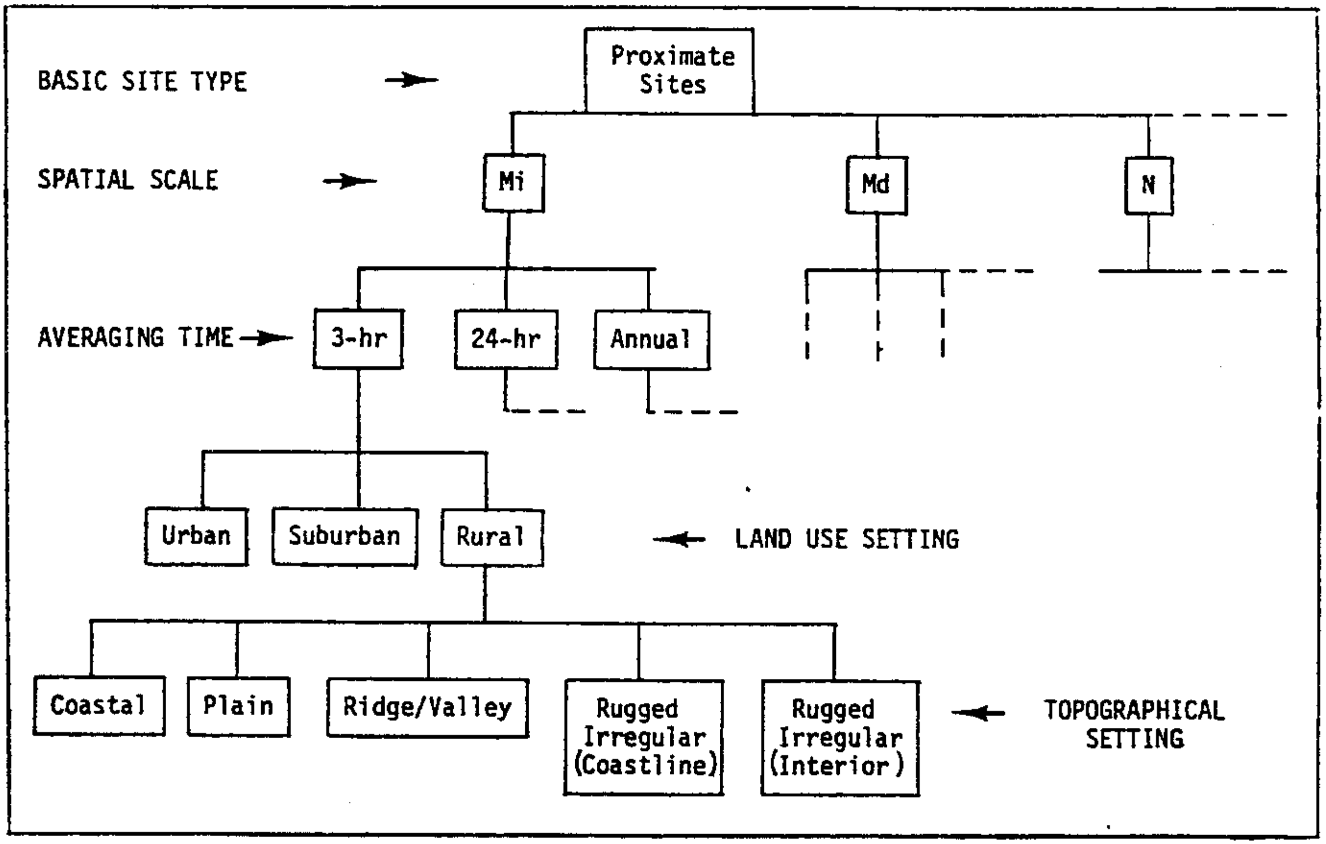

FIGURE 3-3. Portion of SO_2 monitoring universe.

3.5 THE FIVE RELEVANT MONITORING SITE TYPES

The concept of the monitoring universe as presented above can be converted to more convenient tabular format. Tables 3-2 and 3-3 show the resulting universe after considering only the elements of Table 3-1, and the desirable spatial scale to be represented by a single measurement. For example, an SO_2 reading representing a regional 3-hour mean concentration associated with an isolated point source either does not exist or is irrelevant. From Table 3-2, all siting objectives can be accommodated by five monitoring site types:

1) General Level, Regional Scale.

2) General Level, Neighborhood Scale.

3) General Level, Middle Scale.

4) Proximate, Middle Scale.

5) Proximate, Microscale.

TABLE 3-2

Relationships Among Table 3-1 Elements and Associated Relevant Averaging Times

		Basic Site Type	Averaging Time		
			3-hour	24-hour	Annual
SITING OBJECTIVES	1	Pr			
		GL (P)	Md	Md	Md
	2	Pr (P)	Md	Md	Md
		GL			
	3	Pr (P)	Mi,Md	Mi,Md	*
		GL			
	4	Pr			
		GL (P)	R	R	R
	5	Pr	**		
		GL (F)		N	N
	6	Pr			†
		GL (P)	N	N	
	7	Pr			
		GL (P)	R	R	R
	8	Pr	‡		
		GL (F)		N	N
	9	Pr (P)	Mi,Md	Md	Md
		GL (P)	Mi,Md, N,R	Md, N,R	Md, N,R

KEY

Mi - Microscale.

Md - Middle Scale.

N - Neighborhood Scale.

R - Regional Scale.

Pr - Proximate.

GL - General Level.

(P) - Pattern Oriented Site.

(F) - Fixed Geographically Oriented Site.

* Not likely for an isolated point source.

** Difficult to estimate since no specific source is impacting.

† No episodes occur in this time scale.

‡ Secondary standard; no significant effects.

TABLE 3-3

Matrix of Topographical and
Land Use Types

	Topographical Type (A, B, C, D, E)				
Land (U)	A,U	B,U	C,U	D,U	E,U
Use (S)	A,S	B,S	C,S	D,S	E,S
Type (R)	A,R	B,R	C,R	D,R	E,R

KEY

U - Urban
S - Suburban
R - Rural
A - Coastal
B - Plain
C - Ridge/Valley
D - Rugged, Irregular, Interior
E - Rugged, Irregular, Coastal

Each of these site types is associated with a basic procedural siting approach with variations from the basic approach being functions of the siting objective, averaging time, and physical setting.

It would be appropriate at this point to summarize the material presented in this section by showing an example of the process that ties the site type to the intended use of the data. This can be accomplished in a stepwise manner as follows:

a) Decide the use to which the data will be put.

EXAMPLE: *Providing data to implement the provisions of the ESECA of 1974.*

b) Determine all siting objectives that will satisfy the data use.

From Table 3-1, siting objectives 1, 2, and 3 will satisfy the proposed use of the data.

c) From Table 3-2, determine the site type and averaging times of concern that apply to each siting objective.

SITING OBJECTIVE 1: *General-Level, Middle-Scale, all averaging times.*

SITING OBJECTIVE 2: *Proximate, Middle-scale, all averaging times.*

SITING OBJECTIVE 3: *Proximate, Middle and/or Microscale 3-hour and 24-hour averaging times.*

d) From Table 3-3, determine the physical setting of the siting area. There are 15 combinations of physical settings that are relevant to the SO_2 monitoring site selection process.

The specific siting procedures associated with each site type are presented in the next section.