DRAFT

GUIDELINE SERIES

OAQPS NO. 1.2-012

September 1975

GUIDANCE FOR
AIR QUALITY MONITORING NETWORK
DESIGN AND INSTRUMENT SITTING
(REVISED)

U.S. ENVIRONMENTAL PROTECTION AGENCY

Office of Air Quality Planning and Standards

Research Triangle Park, North Carolina

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ENVIRONMENTAL PROTECTION AGENCY

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SECTION I

GENERAL

I.1 INTRODUCTION

I.1.1 Purpose and Scope

The purpose of this document is to provide the Regional Offices of the Environmental Protection Agency and the various State and local air pollution control agencies with guidance and assistance relating to the technical problems associated with the design of air quality monitoring networks and the selection of sites for instrument placement. It consolidates, updates, and expands the information contained in several previous documents:

- Guidelines: Air Quality Surveillance Networks, Environmental Protection Agency, AP-98, May 1971.
- Guidelines for Technical Services of a State Air Pollution Control Agency - Appendix A, Environmental Protection Agency, APTD-1347, November 1972
- OAQPS Guideline Series 1.2-007, Air Quality Monitoring Interim Guidance, August 1973.
- OAQPS Guideline Series 1.2-012, Guidance for Air Quality Monitoring Network Design and Instrument Siting, DRAFT VERSION, January 1974.

It does not deal specifically with the issues of quality assurance in the operation of air quality monitoring networks, although these issues are closely related to the current topic; for guidance on these issues, the reader should consult the following documents:

- Quality Control Practices in Processing Air Pollution Samples, Environmental Protection Agency, APTD-1132, March 1973.

- Guidelines for Development of a Quality Assurance Program, Environmental Protection Agency, EPA-R4-73-028, a through e, June 1973.

Although the discussion in this document is concerned primarily with the six pollutants for which air quality standards have been set, and with associated meteorological monitoring, the principles on which it is based are equally applicable to monitoring programs directed at other pollutants.

The ultimate purpose of providing this document is to further the goal of increasing the usefulness of, and the compatibility among the various sources of, ambient air quality data throughout the country; the use of this information by States and EPA Regions should lead to a more consistent, more reliable national data base that will minimize the risk of making inappropriate policy choices or of designing control strategies that are either inadequate or unduly stringent.

This document, however, is not intended to, and indeed could not, supplant the need for the States and Regional Offices to develop and maintain expertise in these matters on their own technical staffs. The issues of network design and instrument siting involve difficult tradeoffs between air quality information needs and available resources, and between demands for data representativeness and instrument site availability. There is no reasonable way that specific guidance covering all the possible aspects of these complex tradeoffs can be provided in detail by a document of this type. On the other hand, it is equally clear that the compatibility of the resulting data requires a large degree of adherence to some consistent set of guidelines, so that the practical, close-at-hand problems with resources and site availability do not totally dominate the necessary decisions.

Accordingly, this guideline document has been prepared not as a prespective policy document, but rather as a technical document, intended to identify the problems that typically arise in the process of network design and instrument siting, and to offer the generally-accepted levels of resolution of these problems. It primarily provides the technical information required to permit the State and Regional Office personnel responsible for these issues to make intelligent, informed decisions based on a reasonable knowledge of the consequences.

The reader will likely note that the tone of this document implies that much more consideration, in both manpower and monetary resources, should be applied to the issue of siting monitoring facilities than is currently the common practice. This is a deliberate element of philosophy underlying this guidance material. It is considered inconsistent to undertake a monitoring effort involving resources in the tens of thousands of dollars without investing the far smaller effort involved in resolving the issues of proper siting of the monitoring instruments.

It must be emphasized that this material is guidance, to be applied with judgment, not a set of rigid rules to be applied in isolation. If an existing monitoring site does not meet the placement criteria contained herein, that does not in itself mean the data from that site cannot be used for various purposes. Rather, it merely means that consideration of the effects of the siting must be included in the interpretation of data from the sites. If there are valid reasons for siting a monitoring instrument outside the bounds recommended here, they can and should take precedence, and sites should not be arbitrarily moved. On the other hand, if there are no compelling reasons for the existing siting, gradual changes toward closer conformance with the guidelines are appropriate, in order to reduce the overall national range of variation in siting parameters.

Because the technical information available to bring to bear on these problems is not completely adequate, nor as quantitative as would be desirable, the Monitoring and Data Analysis Division of OAQPS has undertaken an extensive program to develop more quantitative data, especially on the effects of site exposure parameters. As this effort progresses, and such information becomes available, this document will be expanded and revised as appropriate.

I.1.2 Document Organization

The variety of reasons and purposes for ambient air quality monitoring have understandably led to a variety of different types of networks relating to one or another circumstance, each with its own special needs and special sets of problems. To accommodate these differences as meaningfully as possible, this guideline considers three general types of monitoring as distinct situations, although it is of course recognized that there will be some circumstances where monitoring efforts fall into gray areas between these categories. The three major types of monitoring considered are:

- Basic, fixed, ongoing monitoring networks
- Monitoring systems around major single sources
- Monitoring for indirect source review and planning

In this categorization, a basic, fixed, ongoing network is a network deployed throughout a significant geographical area, and intended to provide consistent, ongoing data over a period of many years. Although such networks are labeled "fixed," this is done only in a relative sense, to distinguish them from shorter-term special purpose efforts. The network design and siting decisions in such a network are not immutable; and in fact they must be reevaluated periodically as existing air quality patterns become known and as new land use and population growth and development occurs. In contrast to the basic, ongoing network, the other two types of networks are generally developed for specific shorter-term purposes, and are usually much more intensive in both time and space. Each is intended to monitor the air quality impact from a specific source, rather than the overall air quality from a receptor viewpoint.

Monitoring for such purposes as transportation control planning and air quality maintenance planning, which are basically components of the ongoing implementation planning process, require essentially ongoing monitoring efforts, and hence are considered part of the basic fixed network. The fixed network may be supplemented by mobile or portable type monitoring for short-term surveillance of the local impact of specific control tactics.

This document discusses the objectives of monitoring, in the context of all three categories, and the way in which the careful definition of objectives can assist in making the necessary design and siting decisions, and then considers the first of the three major categories of monitoring listed above, the basic fixed network. Supplement A contains additional detailed guidance on CO siting, summaries of which are contained within this volume. Supplement B, which is still in preparation, will present a discussion of monitoring around isolated point sources.

I.2 MONITORING OBJECTIVES

I.2.1 Definition of Objectives

It is generally agreed that the design of an ambient air quality monitoring network should ultimately depend on the purpose of the network; that is, on the reasons for which the monitoring is to be conducted, or the purposes which the data are intended to serve. Although this is a commonly stated goal, its implementation in practice has generally been difficult. When considered carefully, this difficulty is usually seen to result from variations in the detail with which the objectives are specified. The clear, policy-oriented goal that is provided by the Clean Air Act, for instance, is usually too general to be of specific help in planning monitoring operations, while the specific questions like "How many times do the ambient levels exceed the standards?" frequently seem too prosaic or too narrow to be considered "objectives."

In order to clarify this difficulty, and to provide a framework within which our thinking about monitoring objectives might be structured, it is proposed that monitoring objectives can be conveniently and accurately thought of as occurring in three levels of detail:

- Fundamental goal of monitoring
- General monitoring objectives
- Detailed requirements of data base

I.2.1.1 Fundamental Goal of Monitoring

The basic, fundamental goal of ambient air quality monitoring efforts, as with other air pollution control efforts, is the protection of human health and welfare under the Clean Air Act. Since this is far too general to be of specific help, more definitive objectives have been stated as EPA regulations, and in further guidance, such as this document. All this other information, however, is still rooted in the basic purpose of the law, which should not be overlooked in the process of making network design decisions.

I.2.1.2 General Monitoring Objectives

This category includes those statements about the purpose of monitoring that are derived from the basic fundamental goal, but which are not detailed specifications of needed data. They are derived from the basic goal in the sense that they represent judgments about what is required to protect human health and welfare in an operational sense. These objectives are typically most relevant to the decisions on the station-location aspects of network design, as opposed to the more detailed data specifications, which are more relevant to decisions on sampling frequency and other operating parameters of the network. The list in Table I-1 illustrates the level of definition meant to be associated with this category; it includes the objectives of this type that are believed to be widely meaningful on a national scale.

Table I-1. GENERAL MONITORING OBJECTIVES

- Provide data for research
- Provide data for air quality planning efforts
- Provide data for emergency episode prevention
- Monitor time trends and patterns
- Monitor source compliance with regulations
- Ascertain attainment and maintenance of NAAQS (population exposure)
- Determine impact of specific proposed or constructed facilities or source concentration
- Provide data to support enforcement actions

I.2.1.3 Detailed Requirements of Data Base

The most detailed type of monitoring purposes are those that specify the precise data needed for a specific purpose; e.g., "the number of days particulate levels exceeded the 24-hour standard." These detailed specifications of data requirements, when they can be precisely established, are of great value for planning purposes; primarily for planning the operational aspects of a network rather than the overall configuration or instrument siting aspects. In general, these data needs will differ with the pollutant under consideration, and they may well differ with the changing nature of the pollution problems from one part of the country to another or from one AQCR to another.

I.2.2 Typical Monitoring Objectives

It is apparent that in general it is the monitoring objective, the second level of detail of the three above, that primarily affects the location of sites and the placement of sensors. It is not the purpose of this document to prescribe, as a matter of policy, what the objectives of a monitoring program should be or what priorities various objectives should have. However, some discussion of typical objectives and the structures into which they fall is necessary in order to illustrate the way in which the general objectives are refined into more specific decisions with respect to monitoring sites and the way in which careful consideration of these objectives can assist in the determination of definition of specific data needs.

One useful structure that includes the objectives in Table I-1 can be developed by considering various combinations of the location, or orientation, of a monitoring effort and the intended use of the data from that effort; this matrix-type structure is presented in Table I-2. Clearly, a monitoring site can be primarily directed at pollutant sources, at pollutant receptors (population), or at a background situation where neither sources nor population is generally present, although for some purposes this three-way classification might be usefully subdivided.

The subdivision on the other dimension of the matrix in Table I-2, the subdivision of data uses into compliance, trends, and planning, is somewhat less clear-cut. To focus on the essentials of station placement, the three categories were defined on the basis of the fundamental conceptual requirements made of the data by each intended use. Thus, attainment and maintenance of standards involves primarily the absolute magnitude of the resulting data, while trend evaluation requires only that the data be consistent over time. Most planning purposes require in addition, joint information over various spatial points or for several pollutants.

Table I-2. MATRIX OF MONITOR ORIENTATION AND DATA USES

Data uses	Monitor orientation		
	Source-oriented	Population-oriented	Background
Standards attainment and maintenance	• Enforce property-line regulations	• Peak population exposure • Typical population exposure	
Trends	• Monitor control progress trends of grouped sources	• Trends in exposure	
Air quality planning	• New source permit review and planning	• Geographic pattern for control strategy planning	• Control strategy planning • Determine urban impact

Table I-3. MONITORING OBJECTIVES BY POLLUTANT

Objective	Total suspended particulates	Sulfur dioxide	Carbon monoxide	Photochemical oxidants	Nonmethane hydrocarbons and nitric oxide	Nitrogen dioxide
Attainment and Maintenance of NAAQS	• Estimate annual geometric mean • Estimate distribution of high 24-hour average levels	• Estimate annual mean • Estimate frequency of 24-hour and 3-hour averages above standard	• Monitor distribution of 8-hour and 1-hour averages	• Monitor distribution of daily maximum 1-hour averages		• Estimate annual mean
Monitor time trends and patterns	• Trends in annual/seasonal mean levels • Day of week patterns	• Trends in annual/seasonal mean levels • Day of week and diurnal patterns	• Trends in annual/seasonal mean levels • Day of week and diurnal patterns	• Patterns of oxidant as an indication of formation/transport • Trends in oxidant as indicator of control progress		• Trends in annual/seasonal mean levels • Day of week patterns
Data for research	• Population-oriented data base for effects research; long-term, daily values	• Population-oriented data base for effects research, long-term, daily values	• Population-oriented data base for effects research; 8-hour levels, long-term averages	• Population-oriented data base for effects research; daily maximum hours	• Variety of research needs associated with estimating and projecting HC-oxidant relationship	• Trends, patterns, levels as aid in oxidant-control research
Emergency episode prevention	• Short-term monitoring in areas of maximum levels during alert	• Short-term monitoring in areas of maximum levels during alert	• Short-term monitoring over generalized area during alert	• Short-term monitoring at general urban sites during alert		
Monitor source compliance	• Monitoring directed at specific major point source	• Monitoring directed at specific major point source • Monitoring to support supplementary control system	• Document progress in control plan implementation	• Document progress in control plan implementation • Document need and provide support for control plan	• Document progress in control plan implementation • Document need and provide support for control plan	• Monitoring directed at specific major point source
Support enforcement actions	• Monitoring directed at specific major point source	• Monitoring to support supplementary control system	• Document need and provide support for control plan			
Impact of proposed facilities	• Before/after monitoring at site of major point source	• Before/after monitoring at site of major point source	• Before/afted monitoring at sites of indirect sources			
Air quality planning	• Quarterly/annual monitoring in undeveloped areas	• Before/after monitoring at site of major point source	• Indirect source review			

reasoning behind the common practice of monitoring for the two pollutants at the same sites. Similarily, the general lack of similarity among the other gaseous pollutants indicates that each will require separate consideration, rather than routinely placing all gaseous instrumentation together.

These latter points illustrate the type of conclusions concerning network configuration that can be drawn from various approaches to structuring the objectives. The first four rows and to some extent the last row of Table I-3 are the objectives that are normally intended to be met by the basic fixed network, the others being relevant to source-oriented networks. Similarly, in Table I-2, the source-oriented column would be generally assigned to specific source-oriented networks, other than possibly an isolated single fixed site in a heavy industrial area, which might be used to observe air quality trends admist a complex of sources. Based on consideration of these two structures, several different types of stations (Peak, Neighborhood, and Background) have been defined for each of the six major pollutants, primarily for purposes of discussion throughout this document:

- Peak Station - Located at one of the points within the Region where the highest concentrations and exposures are expected to occur.
- Neighborhood Station - Located to typify a broad area of uniform land use, not necessarily residential, but including also homogeneous industrial or commercial areas.
- Background Station - Located in nonurban or rural areas to provide information on levels of a pollutant transported into a Region.

SECTION II

BASIC MONITORING NETWORKS

Basic fixed monitoring networks, in the context of this discussion, are those monitoring systems that are directed at the overall, ongoing, regional problem of guiding the federal-state-local pollution control programs designed to attain and maintain the National Ambient Air Quality Standards. This includes the basic network established in support of the original State Implementation Plan, and any extensions and expansions subsequently made in conjunction with transportation control planning, air quality maintenance planning, prevention of significant deterioration, and so on, as these latter efforts are essentially just SIP extensions for specific purposes.

The ongoing development of a permanent air quality monitoring network involves the determination of the number and location of sampling sites, selection of appropriate instrumentation, determination of the frequency and schedule of sampling, and establishment of instrument and probe siting criteria. These four basic elements of any air quality monitoring network are discussed separately in subsequent portions of this section.

2.1 DESIGN OF THE NETWORK CONFIGURATION

The configuration of an air quality monitoring network involves two elements: the number of sensors or sampling sites of various types, and their geographical location. Under differing circumstances, decisions on the two elements can be made in either order; an overall number of sensors or sites may be selected, based on a criterion such as resource availability, and then distributed geographically, or specific sites may be selected first, based on a criterion such as the need for the data, with the aggregate number of sites then being just the total number of sites selected. In the past, and to some extent still at the present time, the first approach has been necessarily taken, and approaches to determining network size are discussed herein. In the longer term, however, it is considered appropriate that actual data needs be the ultimate determinant of network size, and that the availability of resources should affect only the speed with which that ultimate size is reached. With this approach, one considers the various requirements of the network, establishes sites to provide the required data, and lets the size of the network be whatever it turns out to be. In this way, the relevant parameters of the area - the overall size, the distribution of "unique" pockets of sources and receptors, the topography, etc., - are all taken into account.

2.1.1 Network Size

Historically, when the national control effort under the Clean Air Act began, emphasis was on developing not only new networks but also the resources, both manpower and monetary, to support them. Consequently, it was necessary that networks be sized directly or indirectly in relation to the resources available, and the sites then distributed with as much consideration of sources, topography, etc., as was possible.

The Environmental Protection Agency Regulations (40 CFR 51.17)[1] detailing the requirements for a State Implementation Plan include specification of a minimum number of monitoring sites in the AQCR as a function of the AQCR population and the priority classification assigned to it for each criteria pollutant. Population is a meaningful index for determining the number of sites because geographic area, fuel use, industrial capacity, and many other relevant parameters which affect air quality are roughly correlated with population.

These minimum regulatory requirements are tabulated in Table II-1; they are designed to meet the bare minimum essential requirements of a network, in the context of the resource situation of the early 1970's. It is generally recognized that, in the present context, these minimum requirements are not adequate in every urban area or AQCR, nor are they necessarily adequate for proper conduct of those implementation planning responsibilities that have arisen since the original SIP planning process. For example, in some AQCR's carbon monoxide and oxidant monitoring is inadequate for control planning purposes, and the geographical extent of monitoring in relatively unpolluted areas is inadequate for use in air quality maintenance planning.

As was indicated above, the ultimate determination of a monitoring network configuration should be made on the basis of data needs to meet specified monitoring objectives, rather than on the basis of any prior determination of the number of sensors to be included. However, recognizing that for at least the next several years, resource availability will continue to operate as a constraint. A reallocation of network facilities may be more feasible than an increase in network size. Redistribution of instruments from densely monitored urban core areas to sparsely monitored suburbs and rural areas, necessitated by non-degradation and air quality maintenance area considerations may be needed. Trade-offs between too much monitoring in some areas, such as TSP and SO_2, and too little monitoring for pollutants like ozone and CO may need to be considered in the light of budgeting requirements. However, the monitoring budget should not be the overriding factor. For example, the resources required to establish and operate additional CO and oxidant stations should be considered not in isolation, but rather in light of the resources required to develop, promulgate, and implement (and possibly litigate) a state implementation plan based on the data developed.

Table II-1. REGULATORY MINIMUM NUMBER OF MONITORING SITES[1]

Classification of region	Pollutant	Region population	Minimum number of air quality monitoring sites[a]
I	Suspended particulates	Less than 100,000	4
	- hi-vol	100,000-1,000,000	4+0.6 per 100,000 population.
		1,000,001-5,000,000	7.5+0.25 per 100,000 population.
	- tape sampler	Above 5,000,000	12+0.16 per 100,000 population.
			One per 250,000 population up to eight sites.
	Sulfur dioxide	Less than 100,000	3
	- bubbler	100,000-1,000,000	2.5+0.5 per 100,000 population.
		1,000,001-5,000,000	6+0.15 per 100,000 population.
		Above 5,000,000	6+0.05 per 100,000 population.
	- continuous	Less than 100,000	1
		100,000-5,000,000	1+0.15 per 100,000 population.
		Above 5,000,000	6+0.05 per 100,000 population.
	Carbon monoxide	Less than 100,000	1
		100,000-5,000,000	1+0.15 per 100,000 population.
		Above 5,000,000	6+0.05 per 100,000 population.
	Photochemical oxidants	Less than 100,000	1
		100,000-5,000,000	1+0.15 per 100,000 population.
		Above 5,000,000	6+0.05 per 100,000 population.
	Nitrogen dioxide[b]		
	- continuous		3
	- bubbler	Less than 100,000	3
		100,000-1,000,000	4+0.6 per 100,000 population.
		Above 1,000,000	10
II	Suspended particulates		3 hi-vols 1 tape sampler
	Sulfur dioxide		3 bubbler 1 continuous
III	Suspended particulates		1 hi-vol
	Sulfur dioxide		1 bubbler
	Nitrogen dioxide[b]		2 bubblers

[a]In interstate AQCR's, number of samplers to be distributed among state portions on the basis of population.

[b]**Will be proposed as new requirements**

2.1.2 Factors Influencing Network Design

The factors that are typically involved in estimating an adequate network size are of course also the factors involved in designing an ultimate network configuration as well, primarily climatological and topographic factors. These factors are typically cited as meaningful in network design, but it is frequently difficult to make practical use of them. This is because they are significant primarily in the extremes, as noted below, rather than in the broad middle range prevalent throughout most of the country.

2.1.2.1 Meteorology and Climatology - The meteorological factors that have the greatest effects on ambient pollution concentrations are the horizontal wind (speed and direction, and the vertical distribution of both) and the vertical mixing structure (stability, mixing heights). At most locations, however, these parameters vary significantly over time scales in hours and distance scales in tens of meters. Thus, while they are of significance in a number of air pollution areas, they are not of much help in the design of networks, which depends on longer-term average parameters.

Dilution climatology is defined as the long-term average combination of those meteorotogical conditions that affect the interchange and dispersion of pollutants over relatively large areas and long time intervals. These factors, the frequency, persistence, and height variations of wind speed and direction, of stable (inversion) layers of air, and of mixing heights, collectively provide a measure of the dilution climatology of an area. Dilution climatology accounts for the effects of large scale topographic features, such as large bodies of water and mountain ranges, that exert their influence at that scale. The relative frequency of recurrence of short-term phenomena such as stagnation episodes is also considered. Small scale obstructions such as hills and buildings are classified as localized influences and are not considered in dilution climatology. Atmospheric areas possessing similar dilution climatologies have been defined on a geographic basis for the contiguous United States. They are illustrated in Figure II-1 and described in Table II-2; interim definitions for areas outside the contiguous United States in which AQCR's have been designated are also included in Table II-2. Figure II-2 presents isopleths of mean annual solar radiation which, in conjunction with the dispersion characteristics of the various atmospheric areas, relates to the potential for formation of photochemical pollutants.

As was noted above, these climatological factors are of primary significance in the extremes. The Great Plains Area has frequent high winds which, coupled with the nature of the fuel use patterns, reduces concern with SO_2; however, because of increased fugitive dust entrainment, particulate problems require increased concern. Considering north-to-south variations in solar radiation, it is apparent that the Southwest and the Gulf Coast will have an accordingly greater concern with photochemical oxidant levels.

2.1.2.2 Topography - The dispersion patterns in some sectors of an Air Quality Control Region can be significantly altered by local topographical factors. The most significant with respect to their influence on a monitoring network are:

- Valley Effects - Valleys tend to channel the wind flow along their axis, restrict horizontal dispersion, increase the tendency for inversions to form, and may cause aerodynamic downwash from stacks not extending above the valley walls. Air quality discontinuities between valley-ridge sectors often exist. Thus, valleys almost always need monitors in excess of the requirement for level terrain.

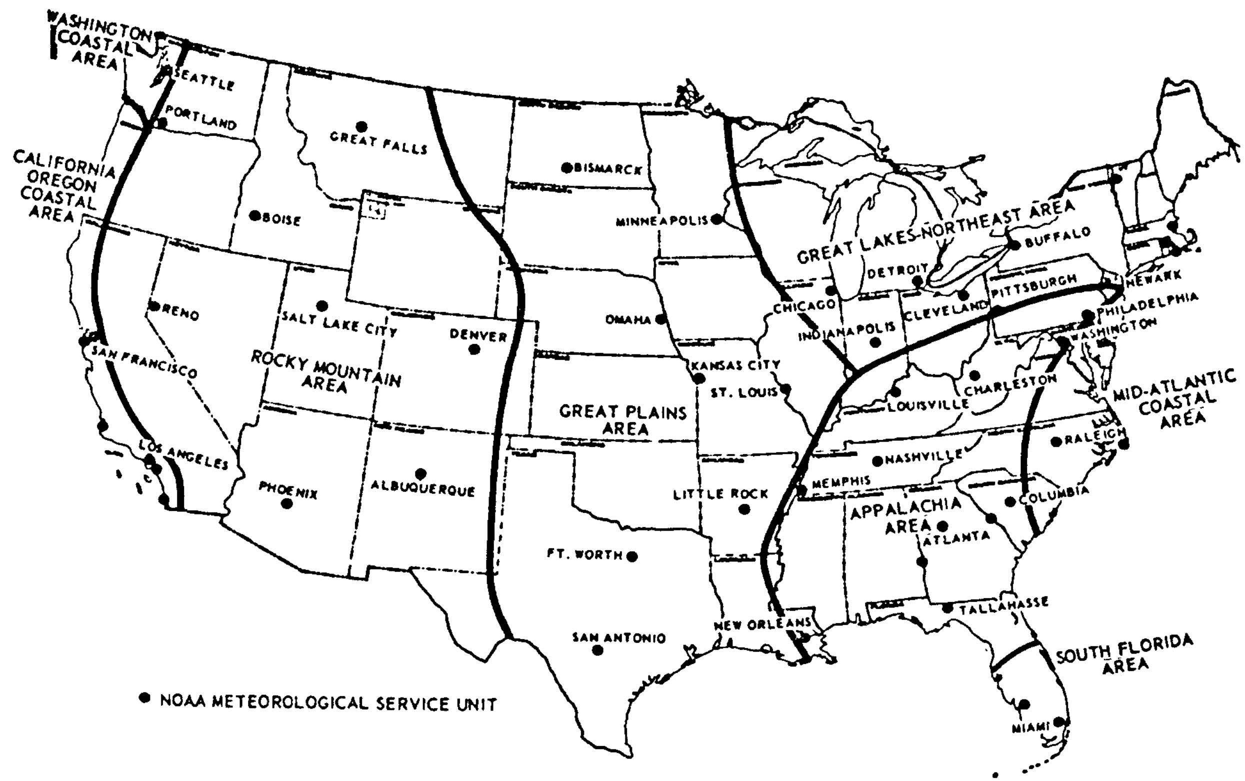

Figure II-1. Atmospheric Areas of the Contiguous United States[2]

Table II-2. ATMOSPHERIC AREAS OF THE UNITED STATES

Atmospheric area	Extent of area	Meteorological and topographical characteristics
California-Oregon coastal area	Extends about 20 to 50 miles inland from the Pacific Ocean.	Maritime air penetration prevailing shallow vertical mixing depths; topographic restraints on ventilation in coastal valleys and basins.
Washington coastal area	Extends about 20 to 30 miles inland from the Puget Sound region, from which the eastern boundary extends southwestward to the vicinity of Longview on the Columbia River and then westward to the coast.	Precipitation, cloudiness, and relatively high winds are dominant features of the climate, which distinguishes this area from the adjacent areas. Storm activity is frequent, particularly during winter and spring seasons, the frequent storm passages result in a low occurrence of persistent stagnation.
Rocky Mountain area	Extends eastward from the California Oregon and Washington coastal areas to terminate as a north-south oriented eastern boundary, essentially corresponding to the 3,000 to 4,000 foot mean sea level contour interval which in general defines the eastern most extension of the major mountain ranges. This eastern boundary stretches from the Canadian border in Montana southward through extreme eastern Colorado, eastern New Mexico, to the Mexican border, to include the Beg Bend region of Texas.	Topographic restriction, channeling of winds, particularly frequent surface-based inversions at night, and relatively deep mixing depths during the afternoon are prevalent features of the dilution climate of the area.
Great Plains area	Extends eastward from the Rocky Mountain area to the Mississippi River south of Missouri; to the north it includes most of Illinois, southwestern Indiana, southwestern Wisconsin, and all but extreme northeast Minnesota.	Relatively flat terrain, which stretches from the Canadian border in the Gulf of Mexico, characterizes the topography. The dilution climate is characterized by negligible persistent atmospheric stagnation and the frequent occurrence of relatively high winds with rapidly changing meteorological conditions.
Great Lakes Northeast area	In addition to regions adjacent to the Great Lakes, this area includes the northern two-thirds of the States of Indiana and Ohio, the Allegheny Plateau area of northwestern Pennsylvania, all of New York State but the extreme southern part of the Hudson River Valley, and the New England States north of the Connecticut-Rhode Island coastal area.	The meteorology is characterized by frequent storm passages with attendant high winds and generally good dilution conditions. During the spring and early summer months, winds blowing from over the cold waters of the Great Lakes and Atlantic Ocean enhance low-level stability in regions adjacent to those bodies of water.
Appalachian area	The eastern boundary of this area, which extends from northern New Jersey southward through southeastern Pennsylvania, eastern Virginia to the Atlantic coastline at the South Carolina border, is correlative for the most part with the 300- to 500-feet mean sea level contour interval. This contour interval at the foothills of the Blue Ridge Mountain Range distinguishes the relatively flat coastal plain to the east from the Appalachian Mountains. The area extends southward to the Gulf of Mexico, including northern Florida, and is bounded in the west and north by two other Atmospheric areas.	Dominant features of the dilution climate include light wind speeds and the most frequent stagnation conditions of any region east of the Rocky Mountains.

Table II-2 (continued). ATMOSPHERIC AREAS OF THE UNITED STATES

Atmospheric area	Extent of area	Meteorological and topographical characteristics
Mid-Atlantic area	Encompasses the Atlantic coastal plain from extreme southwestern Connecticut, including the New York City and Long Island region, southward to the South Carolina border at the coastline, and extends inland to the Appalachian area.	Shallow mixing depths, less frequent low-level stability and higher wind speeds are features of the dilution climate that distinguish this coastal area from those adjacent.
South Florida-Caribbean area	Extends south from the Daytona Beach Cedar Key line to include the southern half of Florida, Puerto Rico, and the Virgin Islands.	The climate of this area is predominantly tropical-marine in nature. Atmospheric stagnation is practically nonexistent; there is a small frequency of low-level stability; and relatively good vertical mixing prevails.
Hawaiian-Pacific area	Includes all of the islands making up the State of Hawaii, and the territories of Guam and American Samoa.	Relatively good ventilation; occasional surface-based nocturnal inversions in inland areas; persistent periods of stagnation are rare.
Alaskan Pacific Maritime area	Bounded by the United States-Canada border to the southeast, the Chugatch Mountain Range to the north, and the Aleutian Range to the northwest. As such this area includes the Alexander Archipelago, the coastal regions of the Gulf of Alaska, Kodiak Island, the Alaskan Peninsula, and the Aleutian Islands.	Under the influence of Pacific Maritime weather patterns; relatively good ventilation associated with frequent storms; occasional strong nocturnal inversions may persist throughout the daytime during the winter season; persistence of such conditions is not marked, however, because of the frequency of storminess.
Alaskan Bering Maritime area	Bounded by the southwestern and western slopes of mountain ranges and the ridge line of the Seward Peninsula. As such, the area includes the coastal plateaus and valleys of the southwest and western mainland, the southern half of the Seward Peninsula, and offshore islands.	Under the influence of Bering Maritime weather conditions. Air Pollution climatology varies from that of the Pacific Maritime area because of less frequent storm activity and the resultant potential of greater persistence of surface-based inversions. In spite of differences, persistent stagnations are not frequent.
Alaskan Arctic Maritime area	Bounded by the western slopes of mountains from the Seward Peninsula northward to the Brooks Mountain Range then eastward to United States-Canadian border. As such, this area includes the northern half of the Seward Peninsula, the coastal regions to the north, and the tundra region between the Brooks Range and the Arctic Ocean.	Under the influence of two, seasonally-oriented weather conditions; continental during the winter months when the ocean is frozen; maritime during the warmer months when the ocean is partially free of ice. Relatively high wind speeds provide good ventilation; the lack of solar radiation in the winter and cold maritime winds during summer days result in the highest annual frequency of daytime surface-based inversions of any of the areas discussed here.
Alaskan Continental area	Bounded by the inland portion of the Alaska-Canadian border to the east and the previously described Atmospheric Area boundaries to the north, south, and west.	Under the influence of continental weather conditions; sheltered from maritime influence by medium-to-high mountain ranges on all sides; has the highest annual frequency of nighttime, surface-based inversions of any of the adjacent areas; low wind speed during the winter, combined with extremely persistent ground-level inversions, gives this area the most restrictive pollution climatology of any Atmospheric Area.

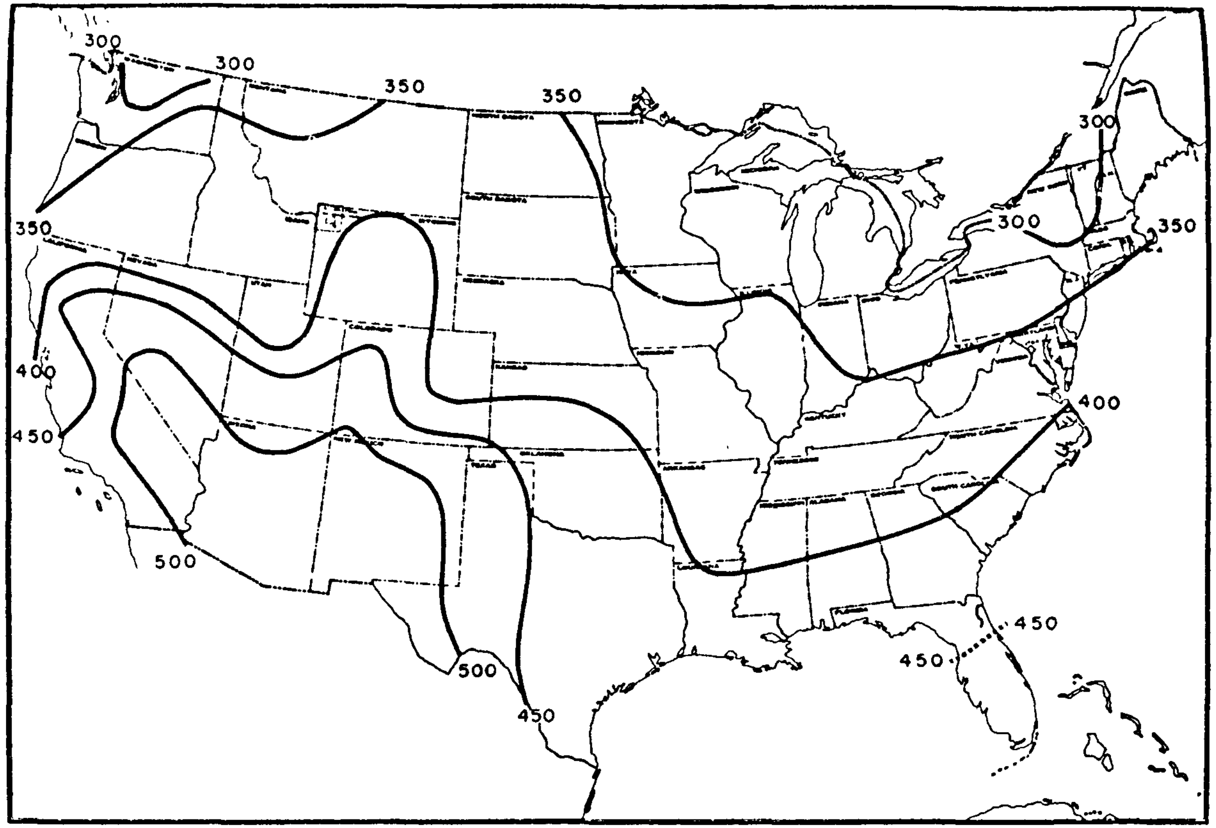

Figure II-2. Mean Daily Solar Radiation (Langleys), Annual[3]

- Shoreline Effects - Airflow along shorelines undergoes frequent changes brought about by the changes in relative temperature of the air and water. Discontinuities and convergence zones in the dispersion patterns occur which indicate need for monitoring beyond required minimums.

- Hilly and Mountainous Terrain Effects - Complexities introduced by hills and mountains include disrupted airflow patterns, intersection of their interface by elevated plumes, induced mechanical turbulence and more frequent inversions in low-lying protected areas. Hilly and mountainous terrain usually increase the need for monitors.

In general, these concerns are greatest in the case of SO_2 and particulates which are often dispersed from major point sources. They are of lesser importance for automotive pollutants such as CO, or secondary pollutants like O_3 and NO_2.

2.1.3 General Patterns of Basic Networks

The overall configuration of a basic fixed network is primarily a function of the purpose of the monitoring and the typical spatial distribution of the pollutant under consideration. It is important to initially design a separate network for each pollutant under consideration, and only then to consider whether and to what extent the networks may be combined, with sensors at common sites. The following sections consider each pollutant in turn, discussing the configuration of networks as they typically exist and suggesting changes as appropriate.

2.1.3.1 Sulfur Dioxide - The general configuration of a typical sulfur dioxide network is one of roughly uniform distribution over the built-up or populated portion of a Region, usually with a decreasing density in the areas farther from the urban center. One or more of the sites is usually in the area of anticipated maximum levels, to monitor for the attainment and maintenance of NAAQS, while the others serve to monitor the exposure in neighborhoods (residential, downtown, commercial, etc.). The primary goals of SO_2 monitoring are all relatively well-served by such a population-oriented network with a typical site-to-site distance of at least 2 to 4 kilometers. Typically regional SO_2 networks consist of a mixture of continuous instrumentation and bubbler sites, and this is considered appropriate; an acceptable distribution between the two types is presented in Table II-3. The use of continuous instrumentation at more sites than indicated in Table II-3 at all sites, is acceptable (if somewhat expensive); the use of less continuous and more bubbler sites is not recommended.

Table II-3. DISTRIBUTION OF CONTINUOUS AND BUBBLER SO_2 INSTRUMENTATION

Number of SO_2 Sensors		
Total	Continuous	Bubbler
1	0	1
2	0	2
3	0	3
4	1	3
5	1	4
6	2	4
10	3	7
15	5	10
20	7	13
25	10	15
30	13	17
35	15	20
40	17	23

This overall assessment of adequacy of SO_2 networks is based on the use of emission inventories to develop SO_2 emission density patterns with special consideration given to any major industrial process SO_2 source that might cause significant deviations from a relatively smooth geographic distribution. In those few Regions with no significant SO_2 emissions, relatively less dense networks are adequate.

It there are significant industrial sources, or concentrations of smaller sources, the network should include additional sites to monitor exposures in any adjacent residential areas. In this context, significant SO_2 source is intended to refer to such as refineries, smelters, etc., that have numerous emission points. Major fuel-burning sources, such as power plants, which have only a very few elevated emission points, should be considered in the context of the discussions in Supplement B. A third situation requiring a significant deviation in the density of the network is that of unusual topography. Major topographic features, such as hills and valleys, that destroy the smooth uniformity of air quality patterns, require additional monitoring to define the discontinuity.

In general, current SO_2 state monitoring efforts are typically adequate in comparison to the monitoring efforts directed at other pollutants. The primary need in the near future will be for some reallocation of monitors in the form of increased density in designated Air Quality Maintenance Areas for SO_2 and around major isolated point sources, from the urban core area or the CBD.

2.1.3.2 Suspended Particulate Matter - The general pattern of particulate networks is usually similar to that for SO_2, in many cases consisting of the same sites. This is reasonable, since the two pollutants both have a widespread multitude of small sources, frequently the same sources. There are, however, differences in the nature of the two pollutants that may lead to some differences in the network configuration. Since entrainment from the ground and other "fugitive dust" sources can be important for particulates, the issues of actual siting become of greater importance than with SO_2. In the past, a suspended particulate network that was largely coincident with the SO_2 configuration was generally considered adequate. However, as the traditionally important particulate sources (industrial processes and fuel combustion, small coal-fired boilers) have been eliminated or controlled, other types of sources (re-entrained urban dust, rural fugitive emissions) have become of jajor concern. Hence, a reallocation of monitors to neighborhood and rural sites, as opposed to industrial peak sites, will be needed to understand these new problems and develop appropriate control tactics.

2.1.3.3 Carbon Monoxide - In contrast to the case with SO_2 and particulates, the general configuration of a typical CO monitoring network is neither well-defined nor adequate. In most cases, CO monitoring is conducted at only three or four sites in an urban AQCR. Because the measured CO levels are very sensitive to the exact placement of the inlet probe, the possibility of biased information resulting from this scarcity of sites is greatly increased.

Designing a CO monitoring network is, thus, quite complicated in comparison to other pollutants. This is because of the nature of the NAAQS for CO, and the differing circumstances in which they are typically violated. As there is no long-term (annual or seasonal) standard for CO, the objective of determining trends and patterns is of a good bit less importance, and the objective of monitoring attainment and maintenance of NAAQS is more complicated. The issue is further complicated by the differing circumstances under which the 1-hour and 8-hour standard are typically violated, which is determined by the interaction of the strong daily cycle in CO source strength with the seasonal and daily cycles of atmospheric mixing potential. The 1-hour NAAQS for CO is typically violated under circumstances of maximum traffic during the morning rush hour, often on mornings when a nocturnal radiation inversion has persisted until the time of the rush hours. Because they depend on having heavy traffic for a short period, the peak 1-hour levels typically occur near points of major traffic volumes. In contrast, the highest 8-hour CO levels tend to occur in the evening and overnight, and may well occur quite apart from short-term traffic peaks. This is due primarily to differential cooling, down slope drainage and a general reduction in mixing height, commonly occuring in the evenings and early morning.

It is recommended that the overall CO network configuration should involve sites of four types which are discussed in detail and prioritized in Supplement A. These types are:

- Street Canyon
  - Peak
  - Average
- Neighborhood
  - Peak
  - Average
- Corridor
- Background

As discussed in Supplement A, there is generally little likelihood of totally defining an area's CO air quality patterns with a monitoring network, because the variation in CO levels is so dramatic over such short distances that the number of monitoring sites required would be totally prohibitive. Rather, it is considered appropriate to monitor a few carefully selected neighborhood and street canyon sites. These should be selected to typify population exposures under a variety of conditions, so that one can develop from these a relationship adequate to project the impact in other similar areas.

2.1.3.4 Photochemical Oxidants/Ozone - The typical configuration used for oxidant or ozone monitoring has been too often only one site in the urban center of an AQCR, and frequently the precursor pollutants are monitored at the same site. Because oxidant, as a secondary pollutant, is not closely related to any geographic source pattern, oxidant levels have been presumed to be relatively uniform over large areas, and one downtown sampling site was not considered too grossly inadequate. This is not neces-necessarily the wisest practice, however, due to the scavenging effect of freshly generated NO from mobile sources. Figure II-3 presents the typical diurnal aatern experienced at such a combined site. The maximum oxidant levels are not coincident in time with the peak levels of the precursors and hence are not likely to be coincident in space either. This leads to the recommendation that peak sites be located 15 to 25 km from the center of the city in at least two general directions. These two general areas should be selected based on wind directions during the ozone season. This season varies, according to local climatology, from May to September in the North to April to October in the South. Generally, ozone levels above the NAAQS are not found when daytime ambient temperatures are below 15°C (60°F). Consideration may well be given to reduced operation of isolated O_3 monitors during the winter months.

In addition to these peak sites, several neighborhood sites may be necessary for monitoring population exposures in residential, commercial, and downtown areas, depending on the population and size of the Region. For purposes of determining possible transport of ozone into the region, it may be necessary to have sites in remote areas upwind.

2.1.3.5 Nitrogen Dioxide - Nitrogen dioxide has a dual role in air pollution, so that two different sets of network needs must be considered. There is an NAAQS for NO_2, so that peak and neighborhood population exposure must be monitored. Because of the lag time indicated in Figure II-3, the peak NO_2 exposure will not necessarily be at major traffic points of high NO emissions. However, the timing of the peak can vary significantly through the year (Figure II-4), so that it does not provide a very rigorous guide for placing sites. In general, in areas where levels exceed the standards, a population-oriented network involving both bubbler and continuous monitoring should be done in peak areas, while the intermittent monitoring should be at neighborhood and background sites. The peak sites should be located similar to the peak ozone sites, except that they should be only 10 to 15 km from the center city.

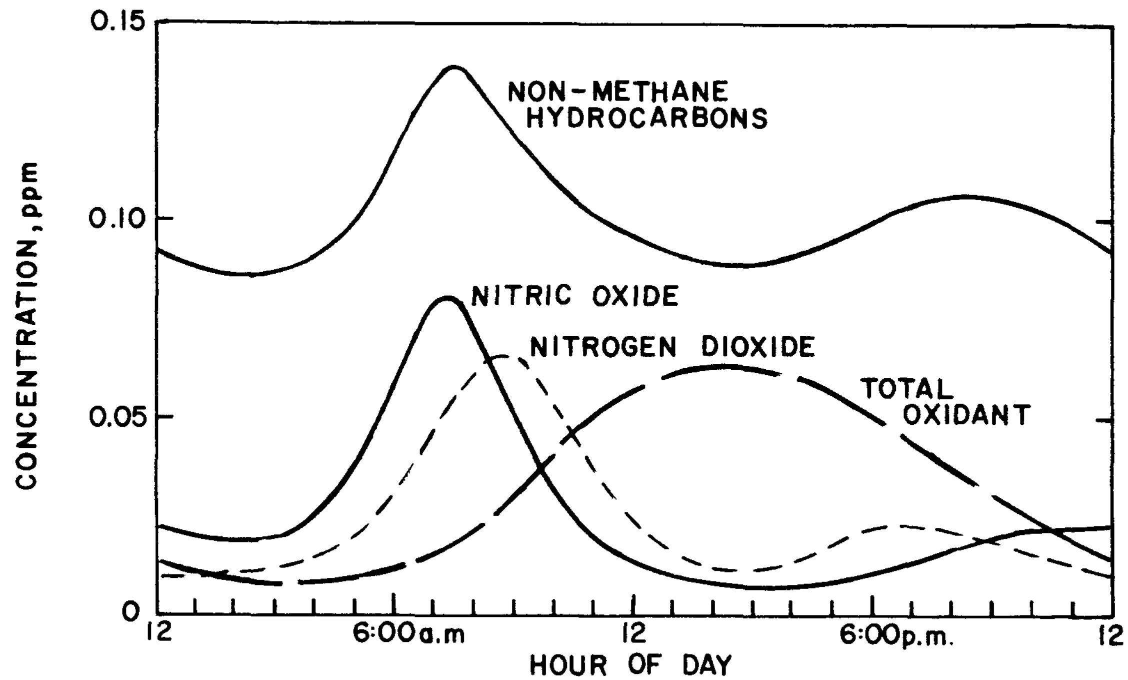

Figure II-3. Typical chronology of photochemical smog[4] formation during the day

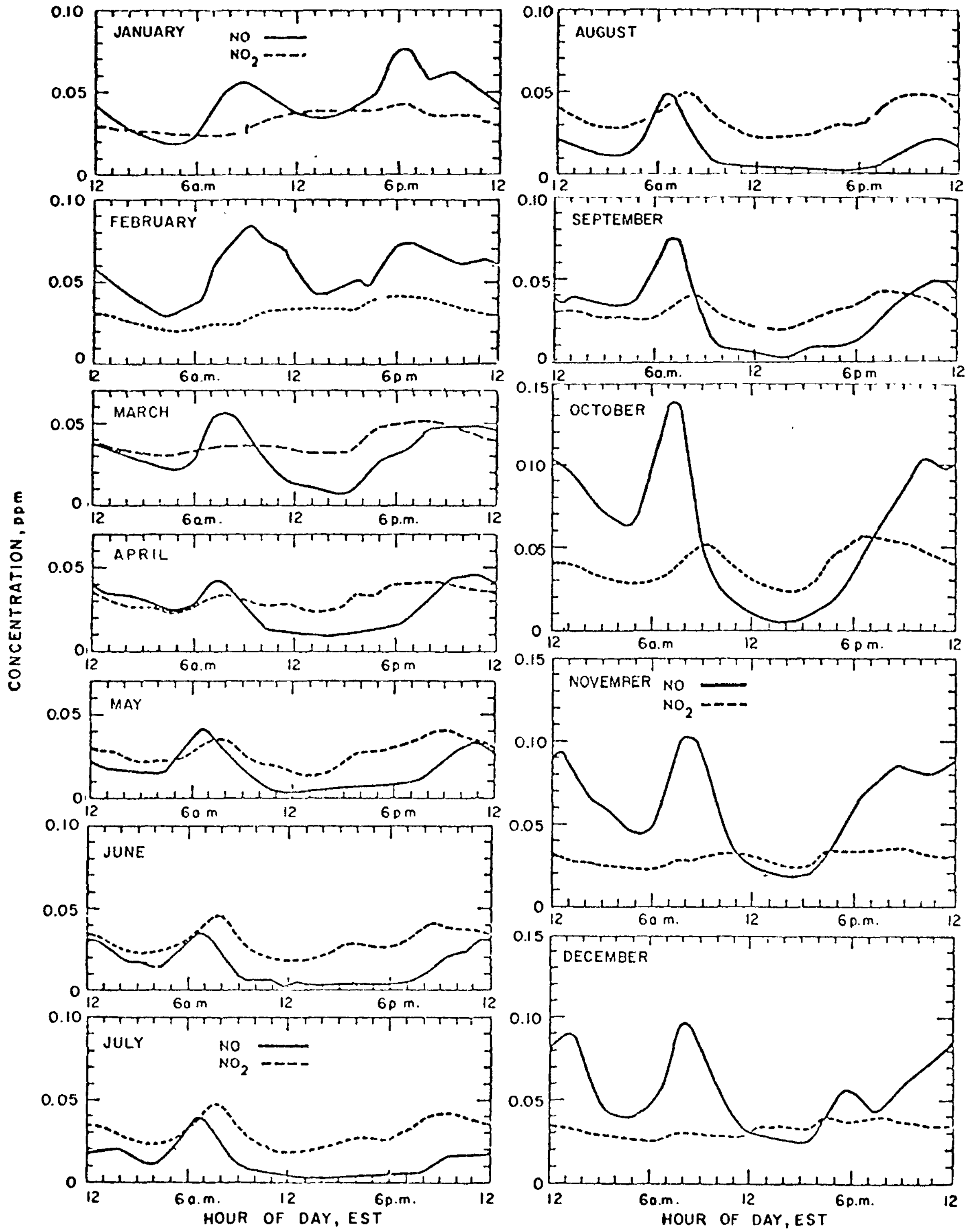

Figure II-4. Seasonal differences in NO and NO_2 peaks[5]

2.1.3.6 Nonmethane Hydrocarbons and Nitric Oxide - The existing monitoring of nonmethane hydrocarbon and nitric oxide is typically a very limited effort with one or a few continuous sites in an area. Since there are no NAAQS, population-oriented monitoring is not necessary and in most areas is not conducted.

However, data on both NO and nonmethane hydrocarbons are required along with NO_2 and oxidant data to provide research and planning information with respect to photochemical oxidant reduction. Single sites at the urban center are clearly not adequate for this purpose, as they do not permit any resolution of spatial distribution and transport-reaction time questions. It is recommended (although not required) that hydrocarbon and paired NO_x sensors be located in the CBD of the urban core area when reliable instruments for measuring non-methane hydrocarbons become available.

2.1.3.7 Meteorological Sensors - In addition to data on pollutant concentrations, it is necessary to have available some source of meteorological data for use in dispersion modeling and other data analysis efforts utilizing the monitoring network data. The data should include wind speed, wind direction, and vertical stability information, although most networks include only wind speed and direction, since vertical temperature parameters are difficult to monitor in urban areas.

Wind data may often be adequately supplied by the National Weather Service or by commercial consultants. In other cases, however, the National Weather Service airport site may be too remote, or the data otherwise less than adequate, and wind speed and direction sensors should be included in the air quality monitoring network. Such sensors, if included, should be placed at sites where several continuous instruments are housed together, in order to obtain the greatest use of the data for modeling and research purposes. An adequate number of meteorological sensors would probably be on the order of one-half or less of the number of such stations.

Information on vertical stability can usually be adequately obtained indirectly by utilizing inferred relationships between wind conditions, time of day, insolation and vertical stability classes. Observations of temperature at several heights near the surface are very useful to infer stability for short-term modeling and air quality forecasting, but extensive measurement of vertical parameters is usually only done on a research basis.

2.1.3.8 Combined Sites - As has been noted above, it has been common practice to consider the configuration of an entire network covering all pollutants, as a whole rather than on a strict pollutant-by-pollutant basis. This is, of course, done as a matter of economy, both of cost and manpower, it generally being more economical to have as many sensors collected at one site as possible.

It is considered appropriate to combine instruments to a certain extent. However, it is not appropriate to routinely house all instruments for all pollutants together as has often been common practice, except for background sites.

The peak and neighborhood type sites for total suspended particulate and SO_2 may very reasonably be combined. As was noted, it is specifically recommended that in the case of research and planning sites, hydrocarbon and oxides of nitrogen sensors be collected together together into stations, which may also reasonably include hi-vols and SO_2 sensors. However, as also noted above, the locations of peak levels of the various pollutants are in most cases not at the same location within the area. Most prominent example of this is carbon monoxide. Although it is obviously convenient to have all the continuous sensors together, it is extremely rare to find a site large enough for a full monitoring station that is also in an appropriate location for peak CO monitoring and, indeed, sites suitable for CO monitoring are not necessarily suitable for other pollutants, depending on the purpose. Hence it is not prudent to presume that CO sensors can be located with the others, although if possible of course it should be done.

2.1.4 Additional Guidance

Other recent and current EPA contract efforts relevant to the issues of network design, optimization, and evaluation include:

Guidelines for Air Quality Maintenance Planning and Analysis, Volume 11: "Air Quality Monitoring and Data Analysis"

Subject Matter: This document provides states with planning information and guidance for the preparation and implementation of a monitoring system which is compatible with the goal of air quality maintenance and the need for the development of Air Quality Maintenance Plans.

Status: The guideline document (also identified as EPA-450/4-74-012 and OAQPS #1.2-030) has been completed by the GCA Corporation, September 1974.

EPA Project Officer: Alan J. Hoffman, MRB, HDAD, OAQPS.

Collection and Integration of Operational Characteristics of Existing Pollutant Monitoring Networks

Subject Matter: This study deals with the analysis of operational data gathered from five superior air and water monitoring networks to identify the most efficient and economical methodology by which a monitoring network can satisfy its responsibilities and optimize the cost-effectiveness of daily operations. The goal of the project is the development of manuals that would furnish the desired techniques for evaluating operations, and to provide methodologies by which the efficiency and/or cost-effectiveness of all operations could be readily considered along with the effects of alternative actions where the evaluation indicates that improvement is needed, while remaining within budgetary constraints and meeting network objectives.

Status: The project is being carried out by URS Research Corp. and is expected to be completed by November 1975.

EPA Project Officers: Edward A. Schuck and
Leslie Dunn, MSA, NERC-LV

2.2 INSTRUMENT SITING AND PROBE EXPOSURE

After the general location of a sampling site is selected, based on consideration of the Region-wide configuration, it is necessary to select a site for the sensor or station, and then within the confines of that choice to determine the precise location of the inlet probe in the case of gaseous pollutants.

2.2.1 Site Selection

The selection of a precise site, once a general area has been selected, is primarily a question of availability, accessibility, security, and the potential effect of surrounding structures. The issues of accessibility and security are the ongoing concerns of the daily operation of a network, and there is little additional guidance to be offered. The issues of ground-level versus rooftop sites might be considered a site-selection problem, as availability is one of the primary reasons for seeking rooftop sites; however, the impact of the choice is more in the nature of a probe placement issue, and it is so considered here.

Sulfur dioxide is considered to be rather well mixed near the ground, at least at receptors not overly affected by specific point sources. Therefore, either ground or roof-top sampling is adequate, and the choice can be made on the basis of site availability. However, care must be taken to ensure that rooftops are 'clean,' i.e., free from space heating vents, laboratory hood vents, and the like, that may have SO_2 emissions. Once above the effect of reentrainment from the ground, it is generally considered that TSP is also fairly well mixed for the next few hundred feet above the ground. Hence rooftop sampling has traditionally been recommended in order to avoid influence of possible reentrainment effect, and rooftops up to several stories high have been used, particularly at center city sites. If the reentrainment is to be considered, however, perhaps as part of the population exposure, then a site that permits ground level (2 to 3 meters) sampling is required. If such a site is not attainable, an alternate arrangement such as a portable sampler should be considered. This is a clear instance where the purpose of the monitoring needs to be very precisely stated to determine the appropriate siting action.

The obvious case where station siting depends on the purpose of the monitoring is with CO, where a station may be either a street canyon, neighborhood, corridor, or background station. In contrast to the case with SO_2, the horizontal distribution of CO across an urban area consists of so many alternating areas of peak and valley levels, one at each street or major traffic center, that one must consider site locations for CO primarily in probe placement terms, in scale of plus or minus a meter or two. Hence a peak station site needs to be essentially adjacent to the street in question and needs to permit nose-level sampling, while a neighborhood site must be located at least 35 meters from the nearest street. This setback will limit the influence of the nearest street to about 1 ppm and make the reading more representative of the general community in which the monitor is located. The strong dependence of carbon monoxide concentration upon distance from the nearest roadway has been illustrated in a number of studies.[6,7] Generally it was found that the concentrations experienced by pedestrians exceeded those measured at a typical air monitoring site, while concentrations at randomly selected locations throughout the survey grid were less than those at the site. More specifically, the data in one study indicated that average concentrations determined by the monitor would be reduced to near the urban background level by moving the monitor approximately 200 feet farther back from the street.[8] Figure II-5 indicates how the CO levels at the various stations in Los Angeles are closely related to the slant distance from the street, despite presumably different traffic volumes in the various locales. It is also known that for peak CO sampling within street canyons, the side of the street which is opposite the side facing the rooftop-level winds will experience the higher concentrations (see Figure II-6). Hence in any location with a significantly prevailing wind direction, even the choice of the side of the street becomes a relevant siting question.

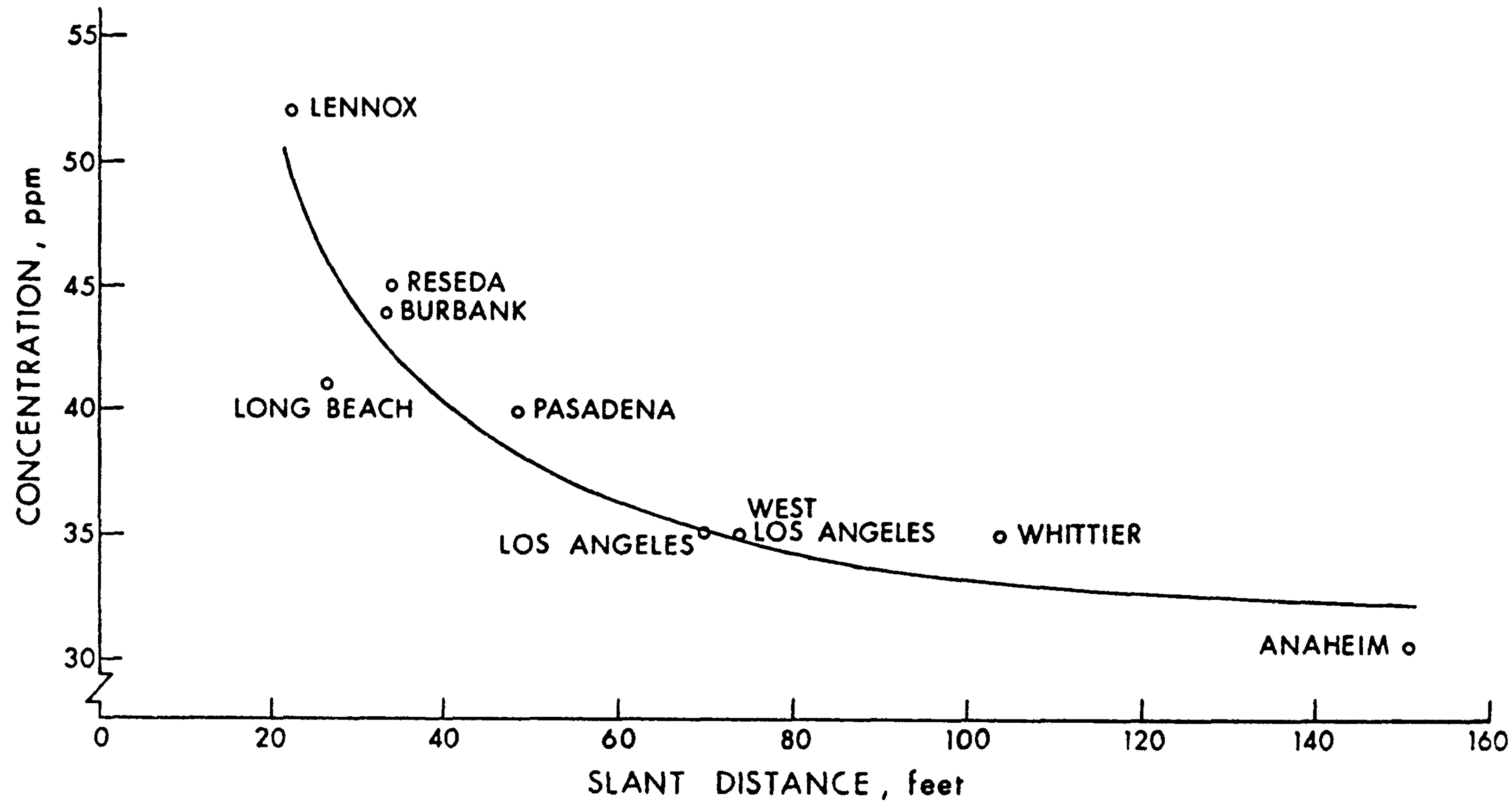

Figure II-5. Averages of the 1969-1970 annual maximum hourly CO concentrations and slant distances at air monitoring stations[6]

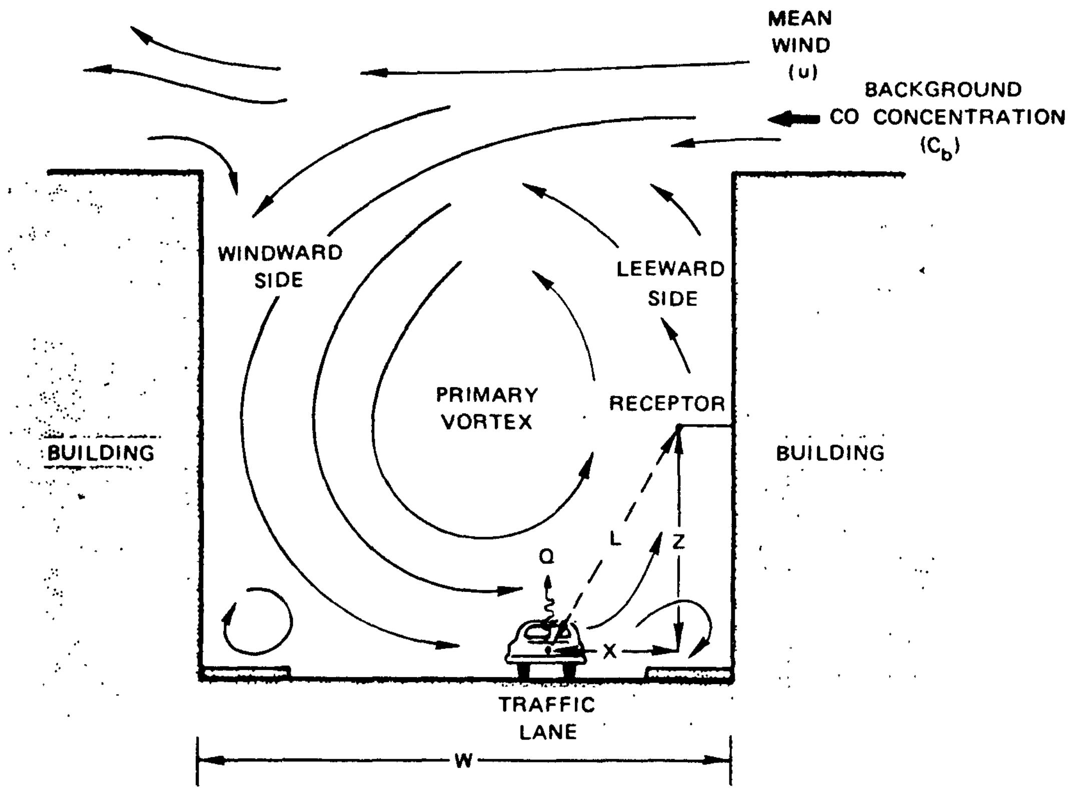

Figure II-6. Schematic of cross-street circulation in street canyon[7]

2.2.2 Probe Placement

Within the several meters scale involved in a typical monitoring site, there is general latitude in the precise placement of the inlet probe. For the gaseous pollutants (excepting CO), this is an issue primarily involving security from vandalism, the avoidance of any restrictions to the air flow, such as from the station itself, trees, etc., and any undue influence from a minor local source, such as a stack located on the roof of a building where the air inlet is located. These requirements are generally taken to indicate a height above the ground of 3 to 15 meters, and either a vertical clearance above the roof of 1 to 2 meters or, in a different configuration, a horizontal clearance beyond the supporting structure of at least 2 meters.

In the case of particulates, the hi-vol represents a special situation. Historically, the NASN hi-vols have been on rooftops, sometimes 8 to 10 stories high. This avoids reentrained surface dust, and the attendant variability, and in so doing provides a smoother, more reliable record for trend purposes. However, it can be argued that elevating the sampler in this way makes the resulting data an inaccurate reflection of true population exposure. Table II-4 provides, as an example, a comparison of 5 months' data from the CAMP Station in Philadelphia and the Franklin Institute site operated by the Philadelphia Department of Public Health. The CAMP Station hi-vol, at 11 feet, reads consistently higher than the City Station, at the same location, which is at about 50 feet. It is probably also true, though perhaps less thoroughly demonstrated, that the distance of the hi-vol from a nearby street is of importance. Since streets, walkways, and other such areas are a source of reentrained particulate matter, it is probable that placing a hi-vol on a one-story roof, for instance, is not the same as placing it in an open area or on a trailer, even if the height above the ground is the same.

The pollutants NMHC, NO, NO_2 and O_3 are tied together in a precursor - secondary product relationship and should therefore be considered as an integrated system in site selection. While hydrocarbons are emitted in much the same pattern as CO, an elevated site in the CBD is more appropriate than a ground level one. This is to limit the influence of any single street and provide a more representative measurement of the CBD as a whole. NO and NO_2 should be monitored at this location to provide information on ratios of NMHC to NO and NO_2.

As photochemically produced secondary pollutants, NO_2 and O_3 are considered to be well mixed vertically and of relatively uniform concentration over a large area. Therefore, either rooftop or ground level sampling are adequate and the prime concern is the location of a favorable distance downwind of the CBD to locate the zone of maximum concentration. Under normal wind speeds, this zone thought to be 10-15 km for NO_2 and 15-25 km for oxidants. Special precaution should be taken not to locate O_3 sites within 100 meters of major traffic arteries or large parking areas due to the scavenging effect of NO emissions.

Table II-4. COMPARISON OF HI-VOL DATA AT TWO DIFFERENT HEIGHTS - FRANKLIN INSTITUTE, PHILADELPHIA

Date	City	CAMP	Ratio
Nov. 1, 1974	199	264	1.33
Nov. 13, 1974	48	76	1.58
Nov. 19, 1974	122	187	1.53
Nov. 25, 1974	69	116	1.68
Dec. 1, 1974	73	117	1.60
Dec. 7, 1974	113	154	1.36
Dec. 13, 1974	174	237	1.36
Dec. 19, 1974	94	133	1.41
Dec. 25, 1974	101	143	1.42
Dec. 31, 1974	54	82	1.52
Jan. 1, 1975	31	52	1.68
Jan. 6, 1975	88	190	2.16
Jan. 8, 1975	107	136	1.27
Jan. 12, 1975	42	71	1.69
Jan. 18, 1975	54	76	1.41
Jan. 24, 1975	153	228	1.49
Jan. 30, 1975	44	81	1.84
Feb. 5, 1975	45	76	1.69
Feb. 23, 1975	64	138	2.16
Mar. 1, 1975	80	254	3.18
Mar. 7, 1975	119	206	1.73
Mar. 13, 1975	84	122	1.45
Mar. 19, 1975	56	92	1.64
Mar. 25, 1975	84	128	1.52
Mar. 31, 1975	46	94	2.15
Geometric mean	76	125	1.64

It is recognized that the effect of height seen in Table 2, and other similar concerns, indicate that many of the hi-vol networks and sampling sites that have been used in the past are generally not as comparable with each other as is the case with other pollutants. Ultimately, the need for a greater degree of homogeneity will likely require that adjustments be made in the way hi-vols are typically placed. However, because of the large number of sites involved, and the length of historical record at many of them, such an adjustment would be an issue of major concern and significance. Since a large amount of good quantitative information on the topic is not currently available, it is considered inappropriate to make major recommendations at the present. The effect of height, etc., can be taken into consideration in interpreting hi-vol data, and it is recommended that this be consistently done. Several study programs are underway that will provide much better information on these questions in the near future, and the guidance material will then be revised as appropriate. It is expected that guidance in this area will be in the form of a supplement to this document, similar to the CO Supplement, and will be issued in early 1976.

However, the issue of probe placement is the most serious concern in the case of CO. Even within the scale of a typical monitoring site, CO levels can vary dramatically. As indicated in Figure II-7, CO levels can change with vertical height at a rate more than 1/2 ppm per meter. Figure II-8 illustrates the sizable changes possible with short horizontal changes in the vicinity of a typical peak site location. Thus, while there is no single "right" position for a CO probe, it is obious that some major degree of standardization is needed to ensure uniformity. The currently recommended positions are discussed in Supplement A. These positions were selected not only to standardize probe and station locations, but also to provide a reasonable measure of population exposure in the breathing zone.

A summary of the current recommendations concerning station siting and probe placement is presented Table II-5.

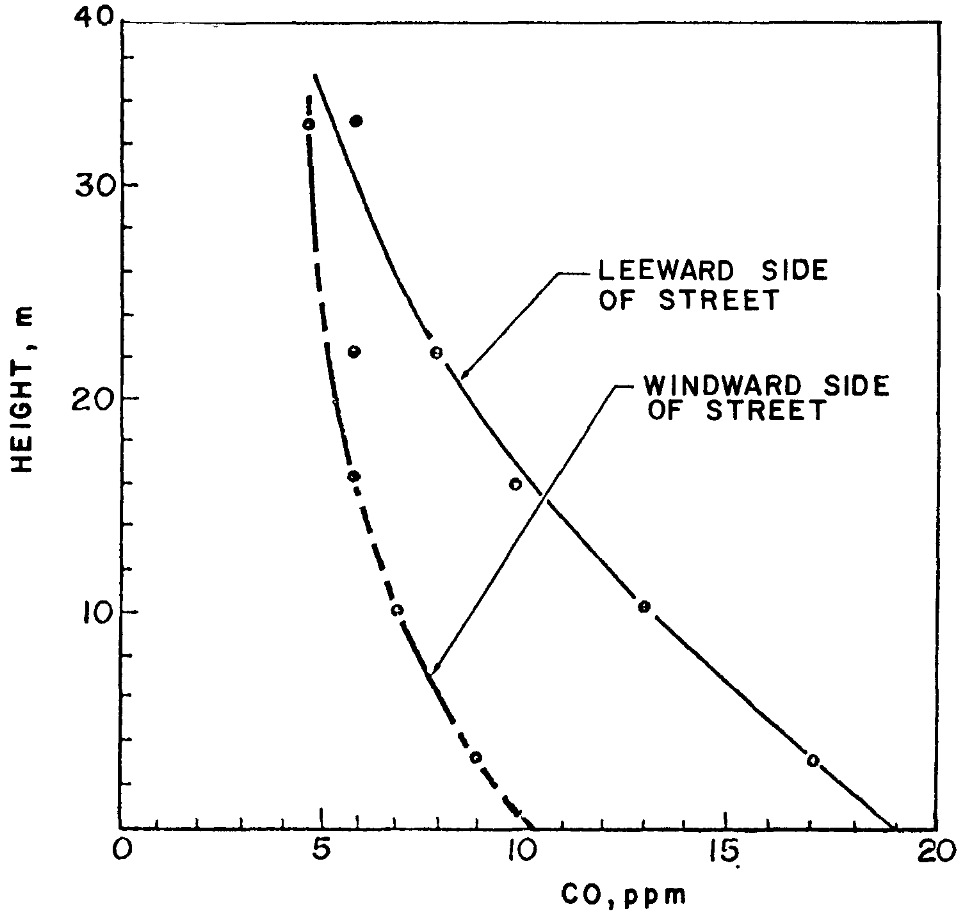

Figure II-7. The vertical distribution of CO concentration on a street with traffic volume of 1,500 vehicles/hour[7]

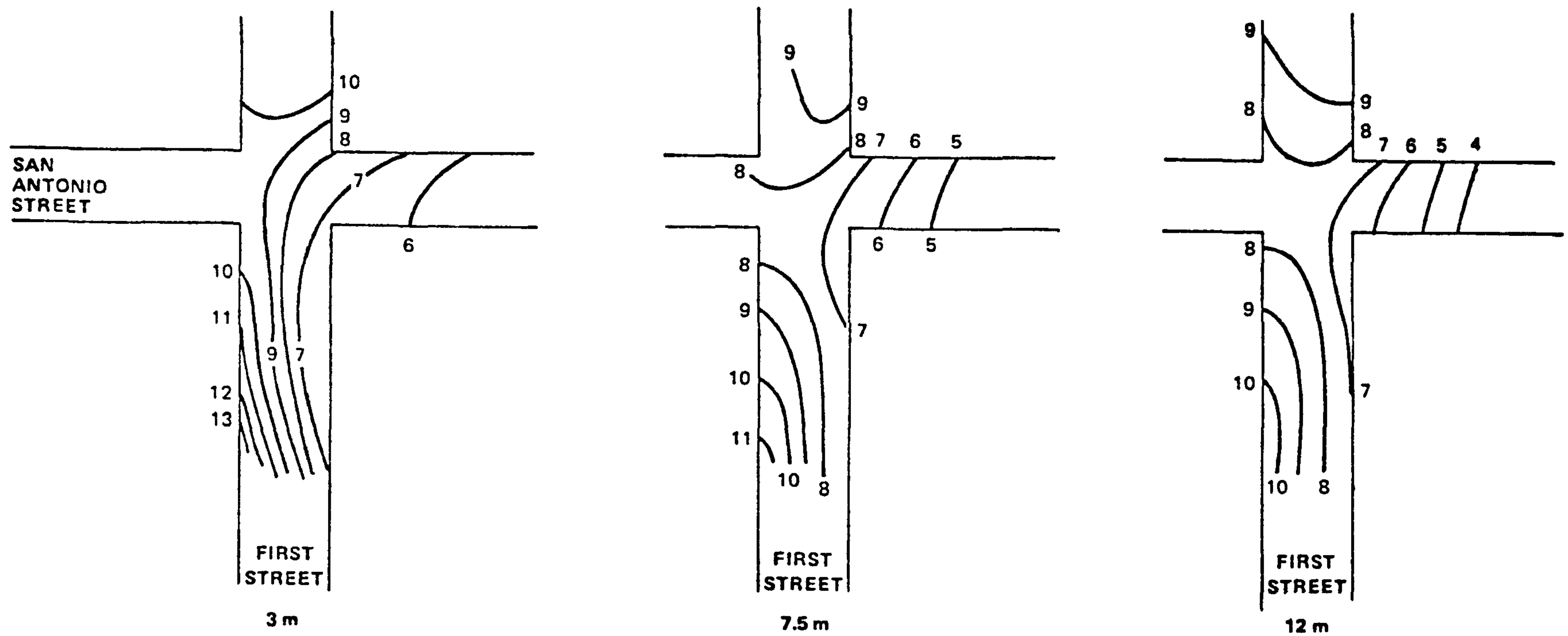

Figure II-8. Horizontal CO patterns at three heights near an intersection[7] measured hour-averages

2.2.3 Additional Guidance

Other recent and current EPA contract studies relevant to the issues of site selection and probe placement include:

"Selecting Sites for Carbon Monoxide Monitoring"

Subject Matter: This report presents procedures and criteria for selecting appropriate locations for CO monitoring stations which fulfill specific monitoring objectives. Procedures are given for selecting locations that will provide CO measurements representative of downtown street canyon areas, urban neighborhoods, and larger interurban regions. Specific recommendations are given for inlet heights, distance from major and minor roadways and placement re ative to urban areas. The rationale behind each specific recommendation is also given.

Status: The first draft report prepared for EPA by Stanford Research Institute is being reviewed. A final report is expected by the end of September 1975

EPA Project Officer: Neil J. Berg, Jr., MRB, MDAD, OAQPS

Table II-5. SUMMARY OF GUIDELINES FOR STATION SITING AND PROBE PLACEMENT

Pollutant	Site type	Site selection	Probe placement (meters)		
		Site location	Height above ground	Vertical clearance[a]	Horizontal clearance[b]
Sulfur dioxide	Peak	Maximum point determined from atmosphere diffusion model, historical data, emission density, and representative of population exposure.	3 to 15	1 to 2	> 2
	Neighborhood	Determined on basis of population patterns and air quality gradients.	3 to 15	1 to 2	> 2
	Background	Nonurban area within Region	3 to 15	1 to 2	> 2
Suspended particulates	Peak	Same as for SO_2.	2 to 15	-	> 2
	Neighborhood	Same as for SO_2.	2 to 15	-	> 2
	Background	Same as for SO_2.	2 to 15	-	> 2
Ozone	Peak	Representing area downwind of the CBD area 15 to 25 km from downtown and > 100 m from major traffic arteries or parking areas.	3 to 15	1 to 2	> 2
	Neighborhood	Sites in center city, residential, commercial areas.	3 to 15	1 to 2	> 2
	Background	Nonurban area within Region	3 to 15	1 to 2	> 2
Nitrogen dioxide	Peak	Same as for Ozone, except distance of 10 to 15 km.	3 to 15	1 to 2	> 2
	Neighborhood	Same as for Ozone	3 to 15	1 to 2	> 2
	Background	Same as for Ozone	3 to 15	1 to 2	> 2

Table II-5 (continued). SUMMARY OF GUIDELINES FOR STATION SITING AND PROBE PLACEMENT

Pollutant	Site selection		Probe placement (meters)		
	Site type	Site location	Height above ground	Vertical clearance[a]	Horizontal clearance[b]
Carbon monoxide	Street Canyon	See Supplement A	3 ± 1/2	1	> 2
	Neighborhood	See Supplement A	3 ± 1/2	1	> 2
	Corridor	See Supplement A	3 ± 1/2	1	> 2
	Background	See Supplement A	3 to 10	1	> 2
Non-Methane hydrocarbons	Research and planning	Generally limited to areas of peak emission density of hydrocarbons, i.e., CBD			
Nitric Oxide	Research and planning	Generally coincident with NMHC sites	3 to 15	1 to 2	> 2
Nitrogen Dioxide	Research and planning	Generally coincident with NMHC sites	3 to 15	1 to 2	> 2

[a]Vertical clearance above rooftop or other supporting structure.

[b]Horizontal clearance from side of supporting structure or other restriction to air flow.

"Determine Optimum Site Exposure Criteria for TSP Monitoring"

Subject Matter: The purpose of this contract is to develop specific optimum site exposure criteria for TSP monitoring which could be applied generally. Criteria will be developed for a limited number of different types of sites, each of which achieves some specific monitoring objective or set of objectives. This will be accomplished by the following: (1) conduct a literature search on the nature and purpose of ambient TSP monitoring; (2) determine a specific set of objectives to be achieved by ambient TSP monitoring and the relative importance of each objective; (3) delineate representative types of monitoring sites which achieve one or more of the monitoring objectives; (4) for each representative type of site, determine optimum exposure criteria which could be applied uniformly to that type of site; and (5) for each type of site, determine the relative effects of various TSP sources both nearby emitters and those further away.

Status: Stanford Research Institute has been chosen to perform this study.

The expected completion date is March 1, 1976.

EPA Project Officer: Neil J. Berg, Jr., MRB, MDAD, OAQPS.

"Determine Optimum Site Exposure Criteria for SO_2 Monitoring"

Subject Matter: This project is similar to the one for TSP monitoring described above.

Status: The Center for Environment and Man has been chosen to perform this study. Estimated completion date is February 1, 1976.

EPA Project Officer: Neil J. Berg, Jr., MRB, MDAD, OAQPS. Monitoring and Data Analysis Division.

"Study of the Feasibility of Determining Optimum Site Exposure Criteria for O_x, NO_2, and Hydrocarbon Monitoring"

Subject Matter: The purpose of this contract is to investigate the feasibility of determining optimum site exposure criteria for O_x, NO_2 and hydrocarbon monitoring which could be applied generally. This will be accomplished by the following: (1) conduct a literature search on the nature and purposes of O_x, NO_2 and HC monitoring; (2) determine a specific set of objectives to be achieved by O_x, NO_2 and HC monitoring, and the relative importance of each (if there is a lack of data which precludes this determination of monitoring objectives, fully document this data void and suggest means to obtain the necessary information); (3) delineate representative types of monitoring sites which achieve one or more of the monitoring objectives; and (4) prepare a final report summarizing assumptions, findings, and conclusions of this study.

Status: Stanford Research Institute has been chosen to perform this study. Estimated completion date is December 1, 1975.

EPA Project Officer: Neil J. Berg, Jr., MRB, MDAD, OAQPS

"Development of a Study Plan to Determine the Air Quality Gradients at Air Monitoring Sites"

Subject Matter: The purpose of this contract is to develop a study plan to define the area for which a point samplers data may be "representative." The study plan should address various pollutants, differing monitoring objectives, and site exposure criteria in determining the three-dimensional air quality gradients around monitoring sites. The plan should define limits of "representativeness" as well.

Status: Rockwell International Air Monitoring Center has been chosen to perform this study. The expected completion date is December 1, 1975

EPA Project Officer: Alan J. Hoffman, MRB, MDAD, OAQPS

2.3 NETWORK OPERATION

In addition to defining the configuration of the network and actually siting the monitors, the process of monitoring network design also includes the selection of appropriate instrumentation and the definition of various procedures for the operation of the network.

2.3.1 Monitoring Equipment Selection

The selection of monitoring instruments for use in a network is an important aspect of overall network planning. EPA has established a set of procedures for establishing whether monitoring methods are reference methods or equivalents, and thus acceptable for meeting SIP requirements. This was published as a regulation in 40 CFR 53 on February 18, 1975. The burden of proof of whether an analyzer is a reference method or equivalent falls upon the manufacturer. Many analyzers currently in use are no longer manufactured per se (that is the specific make and model). Since the vendor will have no incentive to test these analyzers for reference method or equivalency, EPA will in most cases make the necessary tests.

2.3.1.1 Reference Method Determination - For SO_2 and TSP, the measurement principle specified is a manual method. (Pararosaniline for SO_2, hi-vol for TSP) thus, there is only one reference method for SO_2 and TSP since the method consists of a series of mechanical steps or chemical operations to be performed. For CO, ozone and NO_2, only the measurement principle and calibration procedure has been specified. Any analyzer utilizing the specified measurement principle and calibration procedure and which meets the performance specifications in 40 CFR 53 will be designated as a reference method. Thus, as an example, there could be as many reference methods for CO as there are different models of NDIR analyzers.

2.3.1.2 Equivalency Determination - In general, equivalency to a reference method is determined by passing the tests for demonstrating a consistent relationship to a reference method and by meeting performance specifications. If the candidate equivalent method is a manual method only the consistent relationship need by established. If the method is an automated method then both the consistent relationship and performance specification tests must be passed in order to be designated as an equivalent method.

At the present time, reference methods exist only for SO_2 and TSP which are described in 40 CFR 50. They are the high volume procedure for TSP and the pararosaniline (sulfamic acid) procedure for SO_2. Any other manual methods for these pollutants are unacceptable.

For CO and ozone, EPA is awaiting data from manufacturers before designating any reference methods. For the present time, any instrument utilizing the NDIR measurement principle for CO and the chemiluminescent principle for ozone will be acceptable. It is possible that instruments utilizing the NDIR principle for CO or the chemiluminescent for O_3 will be unacceptable. This situation could occur if the manufacturer fails (or if EPA tests the analyzer and it fails) to pass the performance specifications tests.

For NO_2, no reference measurement principle or methods exists since the Jacobs-Hochheiser (J-H) technique was rescinded. The chemiluminescent measurement principle will be proposed very soon to replace the J-H technique. The triethanolamine guiacol sulfite orifice method (TGS) and the sodium arsenite orifice (ARS) method will be tested for equivalency as soon as a reference method is designated.

Unacceptable manual methods should be changed to the reference method or equivalent within 6 months. Unacceptable analyzers (automated methods) should be changed to a reference method or equivalent as soon as practicable but no later than 5-years (February 1980).

Automated analyzers not utilizing the reference measurement principle and calibration procedure and which fail equivalency tests should be replaced with a reference method as soon as practicable but no later than 5-years (February 1980).

2.3.2 Operating Procedures

There are at least two types of operational decisions that affect the design of the network in the sense that they affect the type of data produced. In the case of intermittent sampling, the frequency of operation is such a decision, and in the case of continuous monitoring, the selection of the instrument operation range is also. Note that the many other operating procedures associated with the quality assurance aspects of a monitoring network are not considered here, although they are nonetheless of major importance also.

2.3.2.1 Intermittent Sampling Frequency - The entire point of sampling intermittently, such as the every-6-days schedule used for hi-vols and bubblers, is to provide some measure of air quality knowledge at a cost less than that associated with more frequent sampling. Such a program necessarily introduces some uncertainty into the statements that can be made based on the resulting data. However, standard statistical procedures are available to provide estimates of this uncertainty, and to indicate how to adjust the sampling frequency to provide an appropriate degree of uncertainty.

Figure II-9 indicates how the range of uncertainty with respect to the NAAQS varies with the sampling frequency. At 61 samples per year, an annual mean TSP level of 75 may be 8 $\mu g/m^3$ higher or lower (95 percent confidence limits); if the sampling frequency is tripled, the uncertainty drops to $\pm$ 3 $\mu g/m^3$. Thus, with sites having levels near the standard, greater sampling frequency may be needed to precisely define compliance, while at sites with levels well above or well below the standard, less frequent sampling may be adequate. It should also be noted that the uncertainty increases or decreases linearly with the value of the standard geometric deviation; the 1.6 used to calculate Figure II-9 is a typical value.

Table II-6 presents similar information relevant to the 24-hour standards; specifically the table presents the probability, for each of three sampling frequencies, that at least 2 of the days over the 24-hour standard will be detected; i.e., that the site will be considered in violation of the standard. Note that, again, if the site is only marginally in violation, quite frequent sampling is needed to detect this, while a site a large number of excursions is almost assured of being so identified.

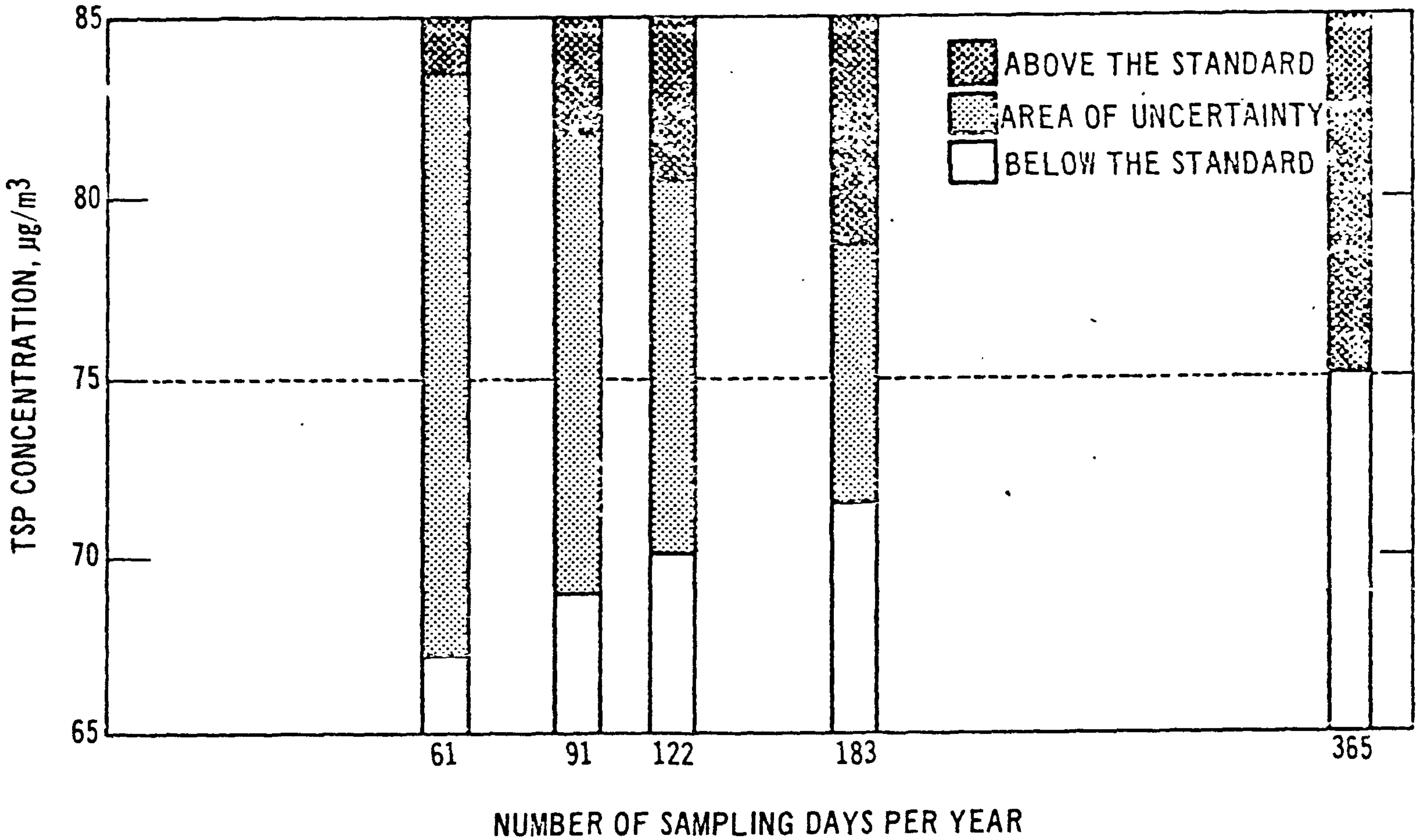

Figure II-9. Ninety-five percent confidence intervals about the annual primary standard for TSP for various sampling frequencies (assume the standard geometric deviation equals 1.6)[9]

Table II-6. PROBABILITY OF SELECTING TWO OR MORE DAYS WHEN SITE EXCEEDS STANDARD

Actual number of excursions	Sampling frequency, days/year		
	61/365	122/365	183/365
2	0.03	0.11	0.25
4	0.13	0.41	0.69
6	0.26	0.65	0.89
8	0.40	0.81	0.96
10	0.52	0.90	0.99
12	0.62	0.95	0.99
14	0.71	0.97	0.99
16	0.78	0.98	0.99
18	0.83	0.99	0.99
20	0.87	0.99	0.99
22	0.91	0.99	0.99
24	0.93	0.99	0.99
26	0.95	0.99	0.99

2.3.2.2 Instrument Operating Range - Since continuous instruments can usually be adjusted electronically to operate in various concentration ranges, the selection of such range is a necessary decision in the process of network design. Generally, the decision is simply to utilize the smallest range that will encompass the maximum expectable levels, and this is usually adequate. However, in the case where very high levels (usually SO_2) from a major source are received at a site that normally experiences low background levels, the use of a single range may not be possible. If the range is set too low, accurate documentation of the peaks is lost offscale, while if it is chosen high, there will not be adequate precision in the data concerning the low levels. There is no way to resolve this with a single instrument. In such a case, one or the other orientation (population or source) must be selected as primary, and the instrument site coded 01 or 02 as appropriate. A good solution would be to have a continuous instrument adjusted to measure the peak levels, and a bubbler for long term population exposure.

SECTION III

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Date Due