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AIR POLLUTION CONSIDERATIONS IN RESIDENTIAL PLANNING VOLUME I: MANUAL

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air and Waste Management
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

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AIR POLLUTION CONSIDERATIONS IN RESIDENTIAL PLANNING VOLUME I: MANUAL

by

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Mr. John Robson was Project Officer for the U.S. Environmental Protection Agency and Mr. Charles Z. Szczepanski served as Project Officer for the Department of Housing and Urban Development. Mr. Tom McCurdy of the U.S. Environmental Protection Agency conducted an in-depth review of the manual for overall content and validity of the calculation procedures. The authors appreciate the assistance and cooperation expended to them by members of the U.S. Environmental Protection Agency and the Department of Housing and Urban Development.

The procedures presented in this manual should not be considered accurate estimating methods. They represent a first attempt to present simplified procedures for determining the impact of air pollutants on residential developments. The procedures presented have not been empirically tested to determine their validity. However, the manual calculation methods have been checked by the Environmental Protection Agency and the Department of Housing and Urban Development employing relevant existing data.

The manual has been written for use, primarily by residential planners and assumes the user has little or no formal training in air pollution and related scientific disciplines.

TABLE OF CONTENTS

LIST OF FIGURES

Figure		Page

LIST OF TABLES

1 INTRODUCTION

Over the past several years the responsibilities of the residential development planner have expanded; whereas he once represented primarily the interests of the developer, he is now concerned also with safeguarding the health and welfare of the residents of the proposed development and of the public at large. Environmental impact statements are often required to ensure that development of a site, or the method of development, will not adversely affect the environment. Increasingly stringent zoning laws and building standards are being enacted to preserve the integrity of communities and of the surrounding areas. To protect the potential residents of a development, the planner must also assess land use compatibility, site hazards, and pollution and noise potential of the proposed site and structures.

Within this context of concern for the health and welfare of residents, planners are giving increased attention to the levels of air pollution to which potential residents may be exposed. Possible air pollution exposures are particularly important in urban residential developments. The U.S. Environmental Protection Agency and the Department of Housing and Urban Development, recognizing the need for procedures by which planners can assess potential air pollution exposures, initiated a study to produce guidelines for residential planners. This manual is designed to assist the planner in site selection and planning, in building design, and in determining whether the air pollution levels resulting from activities external to the site as well as from the manner in which the site is developed and used will satisfy standards and provide the best possible air quality.

Detailed procedures are presented for determining anticipated outdoor and indoor air pollutant levels at proposed or existing housing sites. Guidelines that apply to each pollutant are based on national standards citing the pollutant level not to be exceeded.

It is obvious that predicting the concentrations of air pollutants at a given site, for a given time, is extremely complex. Pollutant concentrations depend upon a variety of meteorological, topographical, and emission factors. In preparing this manual we have to compromise the technical accuracy of the estimation procedures to avoid the need for detailed atmospheric dispersion models, which can be solved only with high-speed computers. For this reason, the results obtained by the procedures set forth herein should be considered as approximations.

The manual is generally applicable to a wide variety of residential developments, from single family units to high-rise apartments and from small projects to high acreage developments.

With certain residential sites, use of these procedures may be wholly inappropriate. They would not apply, for example, to very rough terrains, to sites already surrounded by tall buildings, to coastal terrains, and other unusual sites. Further, these procedures do not account for local recessed or elevated thruways, emissions from underground garages, or possible high levels of certain unusual and hazardous pollutants. The planner who is faced with these or other unusual siting considerations should obtain the services of a reliable environmental engineering firm to monitor air quality at the proposed site and to provide consultation regarding site development. Care should be taken that air sampling and monitoring procedures comply with EPA guidelines.

THE POLLUTANTS

The pollutants of concern in these guidelines for residential planning are carbon monoxide, particulates, and sulfur dioxide.

Carbon monoxide (CO), the most common air pollutant, reduces the oxygen-carrying capacity of the blood. Short-term exposures to CO have been shown to cause changes in cardiovascular functioning and impairment of visual and time-interval discrimination. Fuel combustion is the main source of CO. Major sources of CO emission are motor vehicles, industrial processes, and solid waste disposal.

Particulate pollutants (abbreviated TSP, for 'total suspended particulate') have been shown to increase the incidence of respiratory illness, especially in chronic conditions. Certain particulate matter is toxic, and a number of substances are carcinogenic. Particulates can also cause visibility reduction and odors. The major sources of particulate pollutants and of the third pollutant, sulfur dioxide, relate to combustion of fuels.

The biological effects of sulfur dioxide (SO_2) on humans appear to be related to irritation of the respiratory system. SO_2 also reduces visibility and can cause extensive damage to materials and vegetation. The major SO_2 emissions are combustion of coal and oil and certain industrial operations.

Other major pollutants, some of which significantly affect human health, cannot be considered within the scope of these basic guidelines. Hydrocarbons, for example, enter into and promote the formation of photochemical oxidants, which have adverse effects on health, vegetation, and materials. Because of the complexity of the photochemical reactions, procedures for estimating these pollutant concentrations cannot be presented in a simplified format. Likewise, some specific substances, mainly from industrial sources, can produce adverse health effects: asbestos, arsenic, beryllium, cadmium, lead, mercury, organic carcinogens, pesticides, and radioactive materials. An important phase of the planner's analysis of air pollution impact, therefore, is to consider the possibility that these additional pollutants may impinge upon the site proposed for development. Analysis of neighboring industries with respect to the pollutants they emit is considered in a later section on pollutant standards.

USE OF THE MANUAL

When an evaluation of the air pollution impact on a residential site must be made, the following steps are recommended:

1 - Use the Preliminary Evaluation procedure presented in Section 2 to rapidly identify sites and specific site locations with potential air pollution problems.

2 - For small projects from 1 to 50 housing units in size, only the Preliminary Evaluation procedure in Section 2 need be performed if the air quality criteria for TSP, SO_2 and CO are not exceeded.

3 - The complete procedure presented in the manual starting with Section 3 should be followed if:

a) the air quality criteria are exceeded for a small project using the Preliminary Evaluation procedure,

b) the project is sufficiently large to require Special Environmental Clearance according to HUD Handbook 1390-1. This is for design of projects with 50 or more housing lots or 100 or more apartments or both.

4 - For large projects, site monitoring and mathematical modeling or air pollution exposure of the population in the project area are recommended. A general designation of projects in this size range is:

a) projects with an estimated cost above $15 million.

b) Projects requiring approval by local governments in contiguous areas for aggregate value of several applications totalling more than $15 million.

WHAT THIS MANUAL DOES

The main procedures set forth in the manual will enable the user to determine for a given site the following pollutant exposures over the designated time intervals:

Carbon monoxide	1 hour and 8 hours
Particulates	1 day
Sulfur dioxide	3 hours

The time intervals are those specified in National Ambient Air Quality Standards.

In developing an estimate of air pollution impact on a proposed site, the residential planner performs the following calculations:

Total CO concentrations = concentrations due to roadways + concentrations due to parking.

Total particulate and SO_2 concentrations = concentrations due to point sources + concentrations due to space heating (area sources).

Notice that the planner deals basically with four categories of pollution: from roadways, from parking, from point sources, and from heating. Since these four categories form the basis of the computation procedure, let us consider how the terms are used in this manual.

Roadway emissions are treated as infinitely long line pollutant sources. Major intersections are treated separately, since they can generate significantly higher local pollution levels.

Point sources are defined as local industrial and commercial operations including fuel burning and process operations. Typical point sources are power plants, chemical plants, refineries, and asphalt batching plants.

Area sources are considered to be distributed fairly uniformly over an area. We are concerned principally with two types: emissions from ground-level car parking lots (for calculating CO concentrations), and emissions from residential, commercial, and institutional heating (for calculating particulate and SO_2 concentrations). Emissions from airports are handled separately.

ORGANIZATION OF THE MANUAL

The manual is organized in the following manner:

Section 2 provides a procedure for preliminary evaluation to aid in identifying areas with potential air pollution problems and also areas with low air pollution levels that require no further calculations.

Section 3 outlines briefly the basic steps of site analysis, indicating the types of calculations the planner will perform and results he will obtain. Following this overview of the basic procedures are listed the Ambient Air Quality Standards - the yardsticks against which results are measured.

Section 4 gives instructions for information-gathering; it identifies the types of data required and sources from which to obtain them.

Section 5 presents in detail the procedures for determining air pollution impact on a residential site. Each step of the analysis is described; worksheets, graphs, and tables needed for computation are provided.

Section 6 gives procedures for converting outdoor pollutant levels to indoor levels as a function of the structural characteristics of buildings.

Section 7 considers design practices, for both sites and structures, that can minimize outdoor and indoor pollutant concentrations.

Section 8 presents an example of site analysis by the recommended procedures.

2 RAPID EVALUATION OF AIR POLLUTION IMPACT ON RESIDENTIAL SITES

By the procedures presented here, a planner can rapidly identify potential air pollution problems at a proposed residential development site. The rapid evaluation technique also is adequate for calculating air pollution impact on residential projects ranging in size from 1 to 50 housing units. No further evaluation is required for these small projects if the following requirements are met:

1. The local air pollution control agency specifies that there is an air monitoring station within 5 miles of the site and that the annual average levels of both total suspended particulates (TSP) and sulfur dioxide (SO_2) are less than 60 $\mu g/m^3$.

2. The agency specifies that there are no point sources within 1 mile of the site boundary that are likely to cause significant air pollution impact on the site.

3. The procedure presented here for rapid calculation of concentrations of carbon monoxide (CO) indicates a maximum CO impact at the site lower than 10 mg/m^3.

Follow the complete evaluation procedures given in the Manual (starting with Section 3) if:

- Reported levels of TSP and SO_2 exceed 60 $\mu g/m^3$.

- Calculated levels of CO (rapid method) exceed 10 mg/m^3.
- The project is large enough to require Special Environmental Clearance according to HUD Handbook 1390-1. Environmental clearance is required for design of projects with 50 or more housing lots or 100 or more apartments, or both.

Evaluation of very large projects may require air quality monitoring at the proposed site and mathematical modeling of air pollution exposures of the populations in the project areas. This treatment is recommended for:

- Projects with an estimated cost above $15 million.
- Projects requiring approval by local governments in contiguous areas for aggregate value of several applications totalling more than $15 million.

Appendix B presents guidelines to be used by the planner when air quality monitoring is required.

RAPID CALCULATION PROCEDURE

Particulates and Sulfur Dioxide

Contact an engineer with the local or regional air pollution control agency to determine whether an air monitoring station measuring TSP and SO_2 is located within 5 miles of the site boundary. If a monitoring station is located within this distance, obtain the annual average concentrations of TSP and SO_2. Also, ask the engineer to determine whether any point source within 1 mile of the site boundary might cause a significant air pollution impact at the site.

If the air pollution control agency reports that the annual average levels of both TSP and SO_2 are less than 60 $\mu g/m^3$ and that no significant point sources are located within 1 mile of the site, this evaluation indicates no TSP or SO_2 pollution problems. If the levels are higher follow the recommended procedures described on Page 14.

Carbon Monoxide

Obtain the Annual Average Daily Traffic volume (AADT) for all collector streets within 1000 feet of the site boundary and all highways within 2000 feet of the site boundary. If possible, obtain estimated AADT values for these roads 10 years hence. These AADT values can be obtained from A-95 Review Agencies or from the offices of a city, county, or state traffic engineer.

Next, obtain an area map and on it outline an area encompassing 1 mile radius around the site. Select a central location at the site for which to determine the CO pollution impact from roadways. If the site is larger than 5 acres, perform the calculations for several critical site locations. Locations adjacent to major roadways usually have the highest concentration of CO. When the current (today's AADT values) CO impact on the site is determined, repeat the procedure using the AADT values estimated for 10 years hence.

Using the Rapid Evaluation Worksheet, make the following computations and entries.

Line 1: Enter the name of each roadway meeting the criteria cited (collector streets within 1000 feet; highways within 2000 feet).

Line 2: Assign a road number to each roadway.

Line 3: Enter the shortest distance between the roadway and the site location. Use a scale and the area map.

Line 4: Enter the traffic rate, AADT.

Line 5: Determine the CO emission factors for each collector street and highway from Table 2-1.

Select the year to designate either the occupancy date of the project or 10 years after that date.

RAPID EVALUATION WORKSHEET: CO POLLUTION FROM ROADWAYS

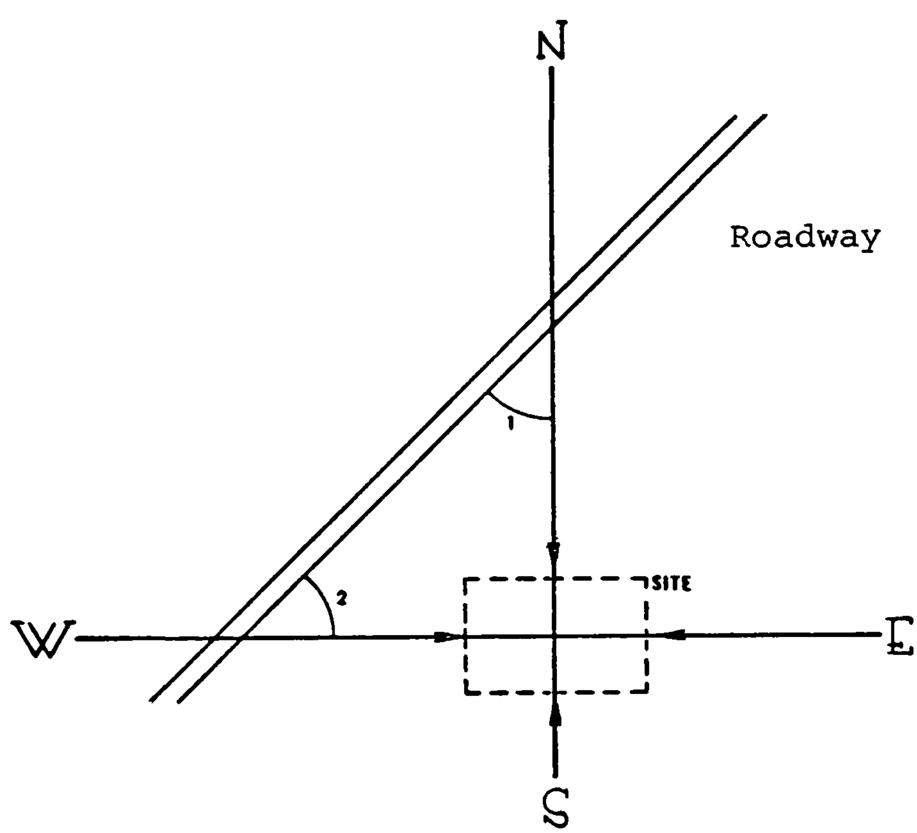
Line								Total CO Impact, mg/m^3
1	Road name							
2	Road number							
3	Normal distance, ft.							
4	AADT, vpd							
5	CO emission factor							
6	Emission rate							
	North Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							________
	East Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							________
	South Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							________
	West Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							________
10	Highest impact, mg/m^3							________
11	Parking lot contribution, mg/m^3							________
12	Total CO impact, mg/m^3							________

Table 2.1 CARBON MONOXIDE (CO) EMISSION FACTORS FOR ROADWAYS

Year	Collector Roads	Highways
1974	8.4×10^{-4}	3.8×10^{-4}
1975	7.6×10^{-4}	3.4×10^{-4}
1976	6.6×10^{-4}	2.9×10^{-4}
1977	5.6×10^{-4}	2.5×10^{-4}
1978	4.8×10^{-4}	2.2×10^{-4}
1979	4.1×10^{-4}	1.9×10^{-4}
1980	3.5×10^{-4}	1.6×10^{-4}
1985	2.1×10^{-4}	0.9×10^{-4}
1990	1.9×10^{-4}	0.8×10^{-4}

Line 6: Enter the emission rate = line 4 x line 5.

To evaluate the pollution impact for different wind directions, complete lines 7, 8 and 9 for each roadway, draw lines representing the four major wind directions, intersecting at the site location as shown below.



Line 7: Determine the angle, in degrees (designated), made by the roadway and each wind direction vector. If the roadway does not intersect a wind direction vector, leave line 7 blank. In the example shown, the roadway intersects wind directions North and West, forming angles 1 and 2, respectively.

Line 8: Refer to Figure 2-1 with normal distance (line 3) and angle with roadway (line 7) to obtain normalized CO concentration. To determine concentration at an elevation 50 feet above ground level at the site, refer to Figure 2-2 with values from line 3 and line 7.

Line 9: Calculate the CO concentration at the site due to the roadway. CO impact = line 6 x line 8.

Determine total CO impact from roadways by summing across the line 9's for each wind direction.

Line 10: Enter the highest roadway impact concentration from values for the four wind directions.

Line 11: If the closest point of one or more residential parking lots is located within 150 feet of the site, enter 2 mg/m^3.

Line 12: For total CO impact at the site, add line 10 and line 11. If the total CO impact is less than 10 mg/m^3, this rapid estimate indicates no CO pollution problems.

AIR QUALITY STANDARDS AND RECOMMENDED ACTION

The primary functioning of this preliminary procedure is to rapidly identify developments with low air pollution levels and circumvent the full procedure presented in the manual. If, however only this preliminary procedure is used to determine site acceptability, the following air quality standards are applicable:

CO	15 mg/m^3,	1 hour concentration
TSP	75 $\mu g/m^3$,	annual average
SO_2	80 $\mu g/m^3$,	annual average

The Department of Housing and Urban Development recommends certain actions for design and construction of residential developments, based on the pollutant values determined in this section.

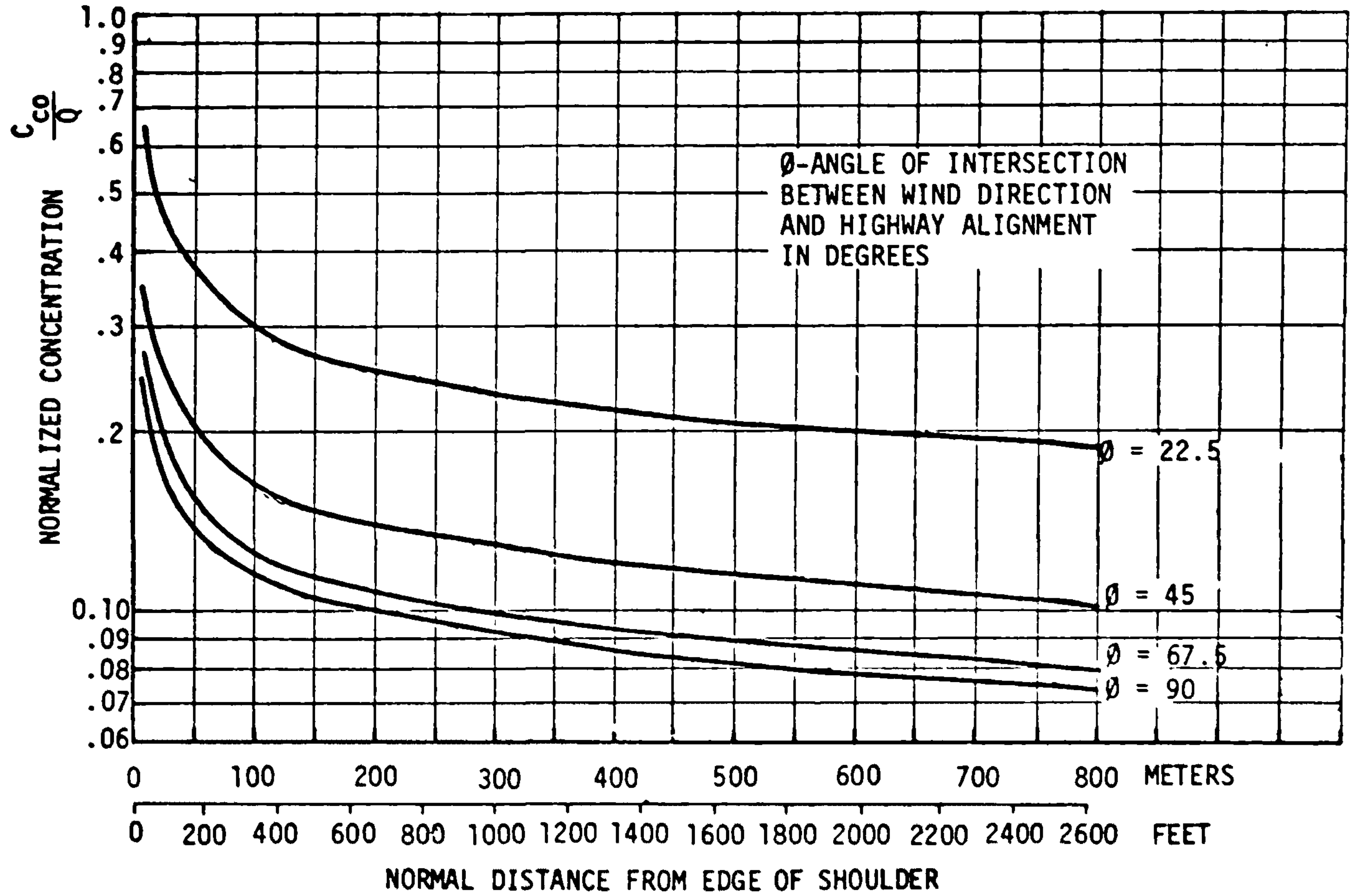


Figure 2-1. Normalized CO concentration at grade due to an at-grade road.

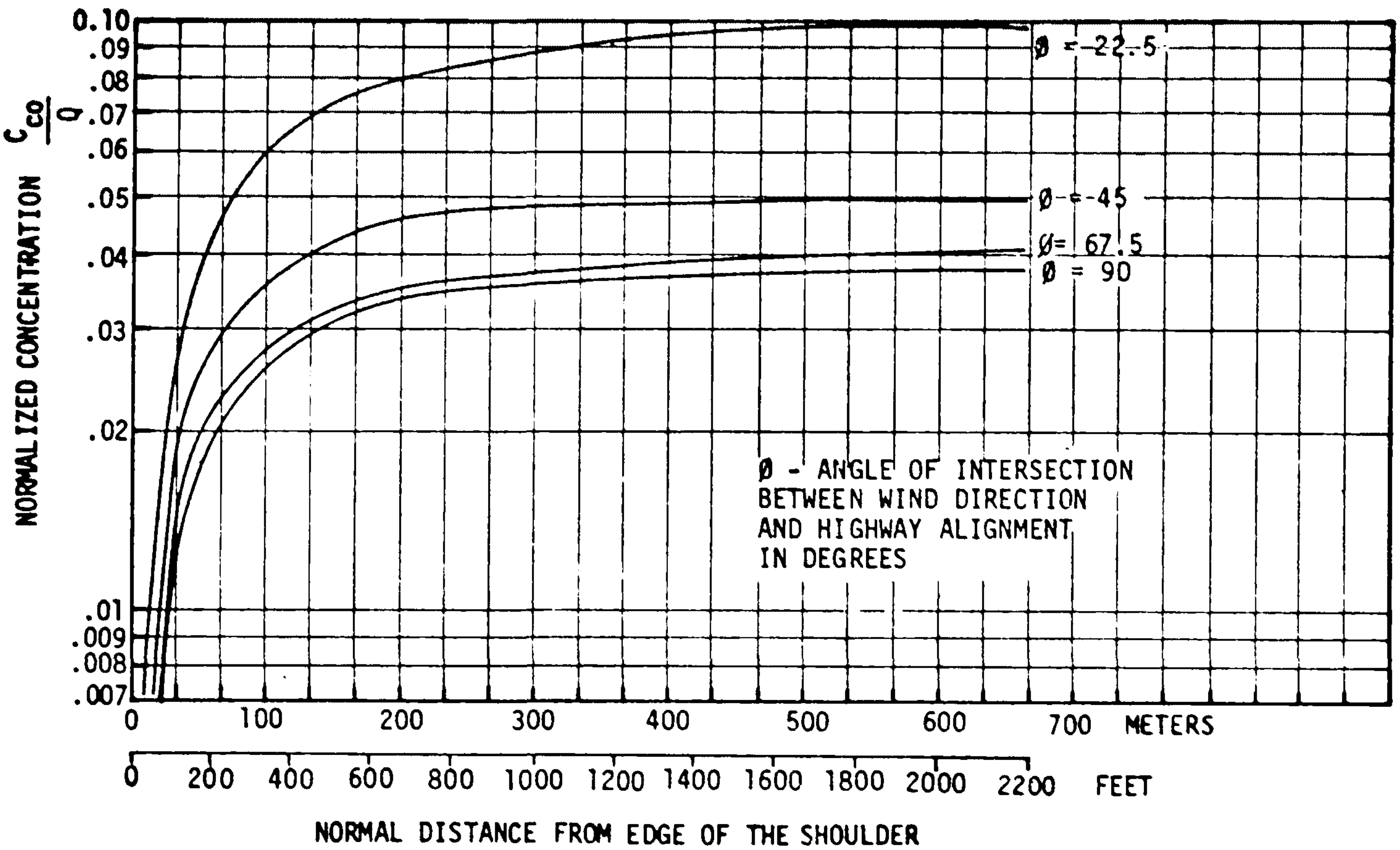


Figure 2-2. Normalized CO concentration at 50 feet above ground level due to an at-grade road.

To determine the appropriate action, apply the following factors to the pollutant values obtained with the rapid evaluation technique and compare results with the standards given above.

1. If the concentration of any pollutant exceeds the air quality standard by a factor of 1.4 or more, the site is not recommended for residential use. Poor air quality constitutes an immediate danger to human health.

2. If the concentration of any pollutant ranges from 1.0 to 1.4 times the standard, do not designate use of outdoor space at the site for recreation or rest, especially for children or the elderly. Building construction will require plastic membrane in walls and ceilings, tight windows and doors, filtration of inside air, and no abutting garages. Kitchen ranges must be non-polluting.

3. If the concentration of any pollutant ranges from 0.7 to 1.0 times the standard, exercise some precautions in design and construction of buildings and use of the property. Refer to Section 7 of the manual for some recommended design practices.

4. If concentrations of all pollutants are lower than 0.7 times the standards, traditional construction methods and unrestricted use of property are possible.

It should be noted here that the air quality standards for TSP and SO_2 used in the rest of the manual are based on short-term exposure levels, not on an annual average.

3 ANALYZING AND EVALUATING THE SITE

In this section we consider briefly the basic steps of site analysis, looking at the process as a whole. This overview is presented to orient the user of the manual so that he can envision from the outset the kind of processes involved and the results they produce.

Pollutant concentrations at the proposed site are determined by summing the effects of all major outdoor emission sources. The procedures yield (1) short-term concentrations of carbon monoxide, sulfur dioxide, and particulates, and (2) the wind directions that produce the worst-case concentrations for each pollutant.

CO CONCENTRATIONS

The analysis will sum the pollutant contributions to the site from automobile emissions from the eight major wind directions. Since two categories of pollutant sources are involved for CO (roadways and parking), the tabulation of CO concentrations takes this form:

Summary: CO Concentrations

	Wind Direction N	NE	E	SE	S	SW	W	NW
	Concentration, mg/m^3*							
1. Roadways								
2. Parking								
3. Total								
4. Maximum 1-hour Concentration								

Detailed instructions showing how to obtain the values needed to complete this table are given in Section 4. The planner will find that because of the geographical distribution of sources there are no values for some wind directions. In any event, the highest CO concentration in any wind direction, recorded on line 4, becomes the value he is to compare with the air quality standard.

PARTICULATE AND SO_2 CONCENTRATIONS

Unlike those for carbon monoxide, the calculations for TSP and SO_2 entail computations for a maximum of four wind directions, which are selected as described fully in Section 5. With these two pollutants the major source categories are individual point sources and the over-all area source comprised of building heating units. The format for summarizing concentrations of TSP and SO_2 is this:

*The units used to express pollutant concentration in this manual are: for CO - mg/m^3 or milligrams/meter^3; for particulate and SO_2 - $\mu g/m^3$ or micrograms/meter^3 = $10^{-3} \times mg/m^3$.

Summary: Particulate and SO_2 Concentrations

	TSP	SO_2
1. Highest impact wind direction number		
2. Point source total concentration, $\mu g/m^3$		
3. Space heating concentration, $\mu g/m^3$		
4. Total $\mu g/m^3$		

If there are no significant point sources of particulate, or if the maximum total concentration calculated for particulates is less than 100 $\mu g/m^3$, it is assumed that the ambient level of this pollutant is in the acceptable region and no further calculations are made. Similarly, if there are no significant sources of SO_2 or if the maximum total is less than 200 $\mu g/m^3$, no further calculations are made. Again, line 4 of the TSP and SO_2 summary table gives the total concentrations for comparison with the standards.

The two formats presented above for summarizing pollutant concentrations are used only for low-density sites. Criteria for determining whether the proposed site is characterized as having high or low density are considered in later sections; the criteria relate primarily to the type and density of roadways in the area and affect chiefly the CO concentrations.

ANALYSIS FOR HIGH-DENSITY SITES

In this manual the analysis for the high-density site is far less rigorous than that for the low-density site because of practical difficulties of dealing with the usually complex urban development site. The user should bear in mind that the simplified procedure discussed here will generate only a very rough approximation of pollutant concentrations at the site. The residential planner should seek professional consultation for a more thorough analysis of air pollution impact at a high-density site.

For the high-density site we analyze only those roadways within one block; i.e., the roadways fronting on the site, together with all other roadways within one block or 500 feet (whichever is closer) of any point on the site. If a highway with traffic volume more than double that of the nearby streets is located within 100 feet of the site at the nearest point, it is included in the analysis.

Analysis for a high-density site also entails data on background levels of the pollutants; these values are obtained through the local air pollution control agency or from the HUD Regional or Areawide Planning Agency, designated as an A-95 Review Agency. The summary of pollutants for a high-density site is presented as follows:

Pollutant Summary: High-Density Site

		1 Roadway Level	2 Background Level	3 Total	
1.	TSP		______	______	$\mu g/m^3$
2.	SO_2		______	______	$\mu g/m^3$
3.	CO (1 hr)	______	______	______	mg/m^3

The three summary formats presented in this section are used throughout the manual. They are adequate for most cases to which the procedures described herein can be applied. As already mentioned, special cases, such as those involving unusual terrain or the proximity of airports, require professional evaluation. In all cases, whether pollutant concentrations are estimated by procedures of this manual or are computed by other means, they are compared with the concentrations set forth in National Ambient Air Quality Standards.

AIR QUALITY STANDARDS

The following pollution levels derived from the National Standards are presented as standards to protect human health:

	OUTDOOR	INDOOR
CO	- 15 mg/m^3, 1-hour level	6 mg/m^3, 8-hour level
TSP	- 210 $\mu g/m^3$, 24-hour level	210 $\mu g/m^3$, 24-hour level
SO_2	- 450 $\mu g/m^3$, 3-hour level	450 $\mu g/m^3$, 3-hour level

These values represent levels not to be exceeded more than 3 percent of the time period per year and they would indicate severe although not emergency air quality conditions. The normal pollutant levels at a residential site should be considerably lower, especially in areas designated for sports or other strenuous activities.

If all the pollutant levels obtained in site analysis are below the standards, the area can be considered acceptable for average uses. If any pollutant concentration is higher than the standard, the pollutant level is considered unacceptable and too high for extended exposure.

If an outdoor pollutant level is unacceptable, efforts should be made to rearrange functional elements of the proposed site so that active recreational areas lie within zones where concentrations are in the acceptable range. The planner should undertake a detailed analysis of methods of reducing outdoor pollution exposures, as outlined in Section 7.

If outdoor pollution concentrations are lower than 80 percent of the standards, the indoor levels should be acceptable and no further calculations are necessary. If this criterion is not met, the procedure described in Section 7 is followed to determine the indoor pollutant concentrations.

If the indoor carbon monoxide level must be determined, the outdoor 1-hour level is translated into an 8-hour indoor level. This transformation is made to represent the effects of building materials and air circulation systems on indoor CO levels in a realistic manner. The 8-hour CO level not to be exceeded more than 3 percent of the time per year is 6 mg/m^3.

If the indoor standards are exceeded, steps must be taken to minimize indoor pollutant levels. Some recommended practices are described in Section 7.

An outline of the site air pollution evaluation procedure is presented in Figure 3-1.

OTHER POLLUTANTS

Listed below are compounds that have been identified as potentially harmful contaminants in the atmosphere. If any plant

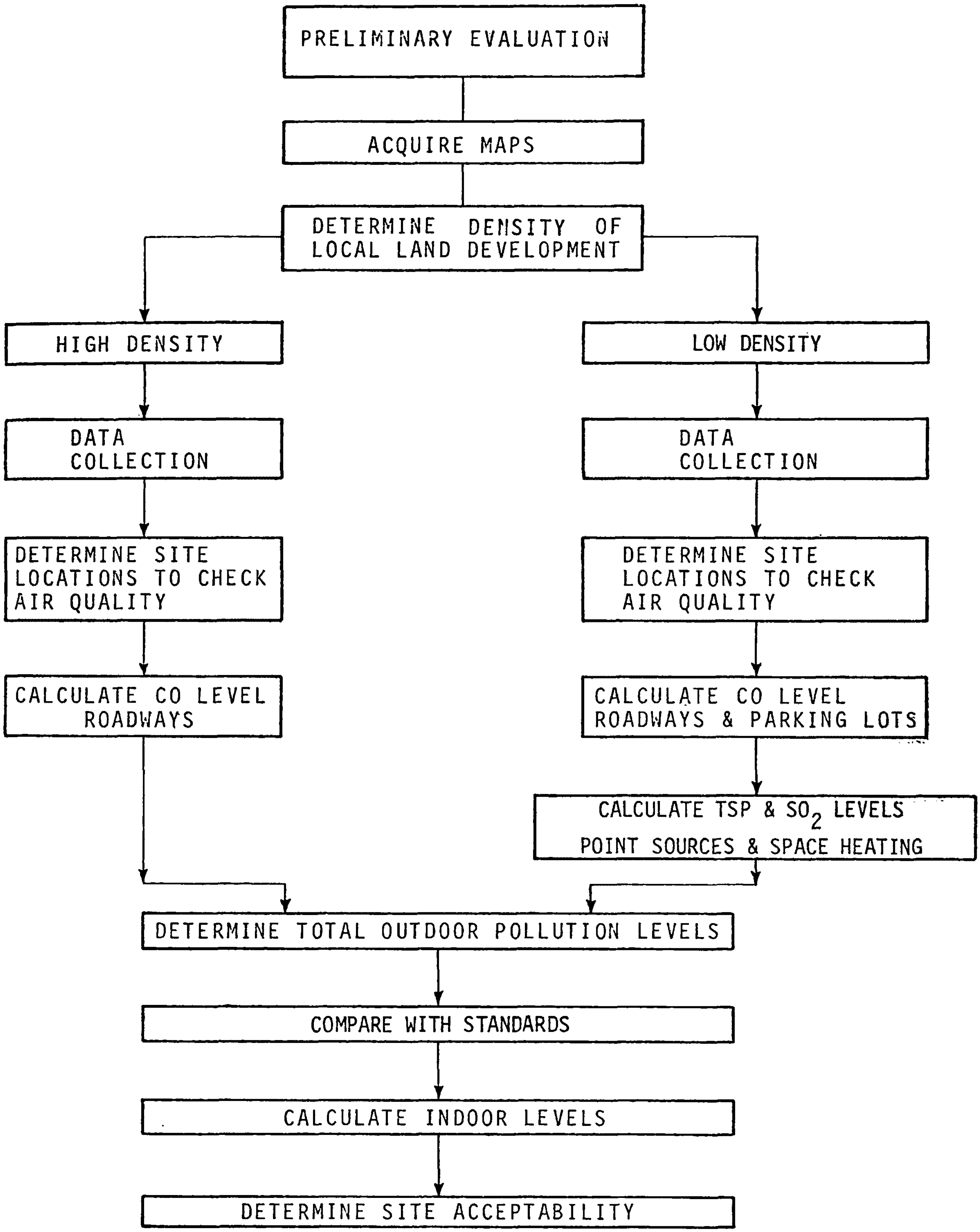


Figure 3.1 Outline of site evaluation.

located within 2 km (1.25 miles) of the proposed site emits one or more of these compounds, the planner should consult the local air pollution agency to determine whether the site presents a human health hazard. A more detailed analysis of pollutants from industrial sources is given in Appendix A.

- Aldehydes (includes acrolein and formaldehyde)
- Ammonia
- Arsenic and its compounds
- Asbestos
- Barium and its compounds
- Beryllium and its compounds
- Boron and its compounds
- Cadmium and its compounds
- Chloride gas
- Chromium and its compounds (includes chromic acid)
- Hydrochloric acid
- Mercury and its compounds
- Nickel and its compounds
- Organic carcinogens
- Pesticides
- Phosphorus and its compounds
- Radioactive substances
- Selenium and its compounds
- Vanadium and its compounds
- Zinc and its compounds

OVERALL ANALYSIS OF AIR POLLUTION IMPACT

In this section we have touched briefly upon the major elements of analysis and evaluation of proposed residential sites. By way of further delineating the total evaluation process, Figure 3-2 depicts the sequential flow of analytical procedures, which are discussed in detail in the following sections.

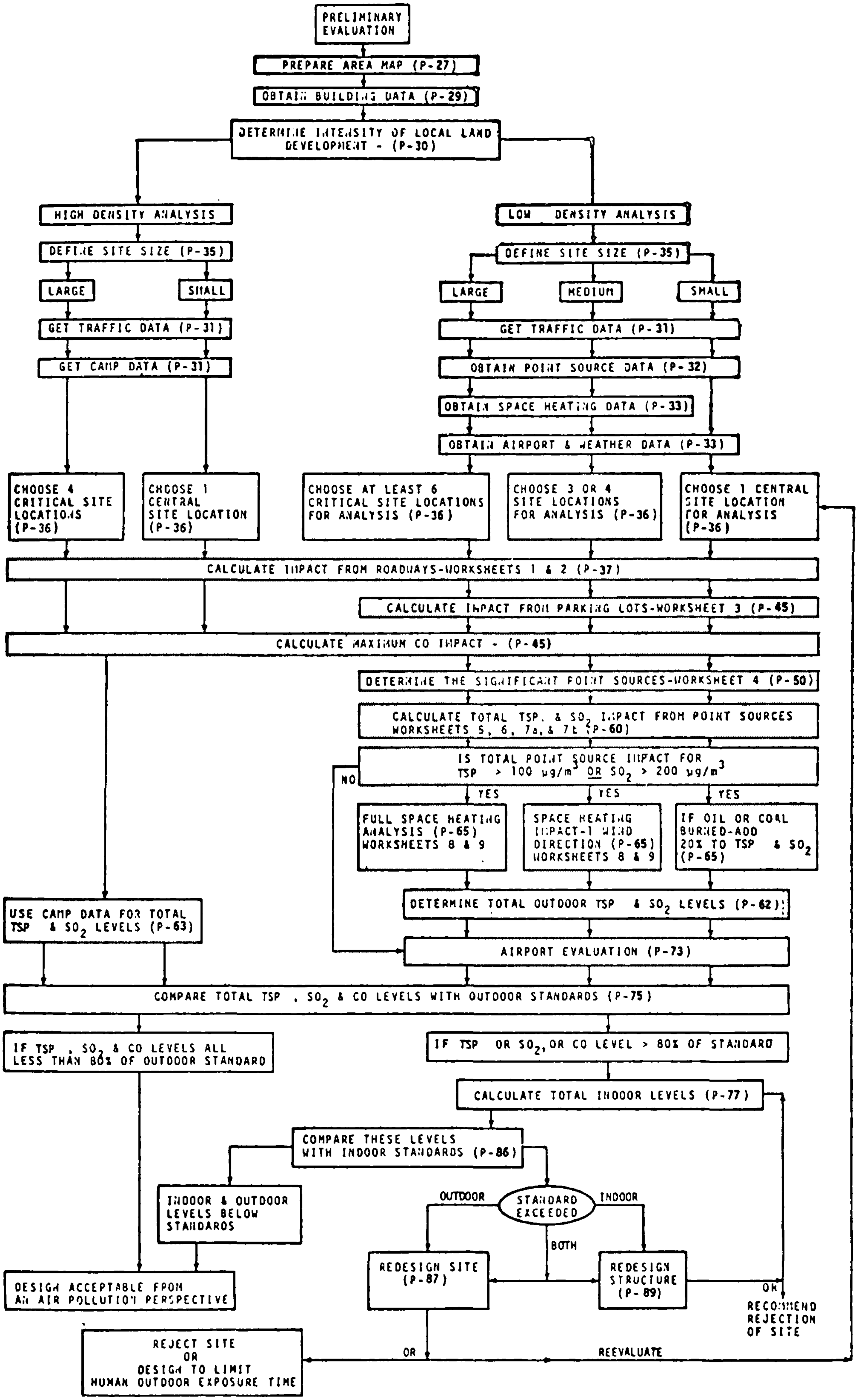


Figure 3-2 Evaluation flowsheet.

4 ASSEMBLING MATERIALS AND DATA

MATERIALS

Most of the basic materials and data required for this analysis can be obtained from the A-95 Review Agency.

The chief materials required for site analysis are a base map or aerial photograph of the area and a site plan. If no A-95 Review Agency is available, in most locations a public agency such as the local Director of Public Works, the U.S. Geological Survey, or the office of the City, County, or Township Engineer can provide the required area maps. An area map at a scale of 1 inch = 200 feet is recommended for the CO analysis; the map should indicate all streets and highways, political subdivisions, zoning plans, and topography within a 1-mile perimeter of the site. An area map of 1 inch = 1000 feet is recommended for the TSP and SO_2 analyses; this map should be large enough to show clearly a 3-mile perimeter around the site.

If terrain within 500 feet of the site includes a 100-foot change in ground elevation, the assistance of an experienced consultant is needed.

Add to the area map in a prominent location (see Figure 4-1) the following information:

1. Name of the project.
2. Name and address of the developer.

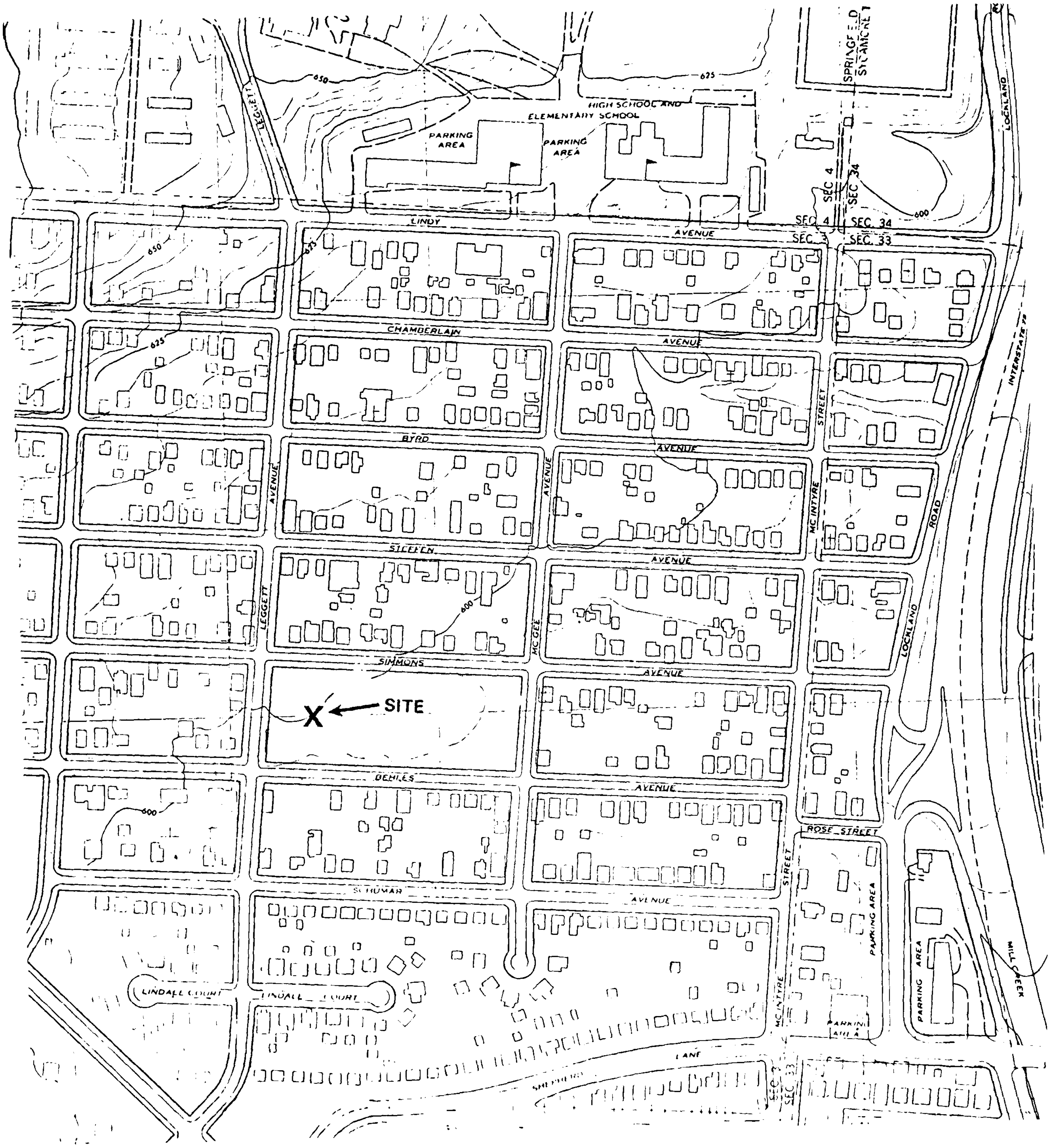


Figure 4-1. Sample area map.

3. Name and address of the site planner.
4. Scale indication and north arrow.
5. Boundaries of the project.

The site plan can be prepared at any scale that shows clearly all on-site building locations, site boundaries, parking and other auxiliary land uses, and bounding roadways.

It is assumed that the planner will supplement these basic materials with the drafting implements, calculation aids, and general reference materials he is accustomed to working with. To the extent possible, all tables, graphs, and factors required for conversion and computation are incorporated into this manual.

DATA, GENERAL

Although different procedures are entailed for evaluation of high- and low-density sites, certain types of data are needed in all cases.

Building Construction Data

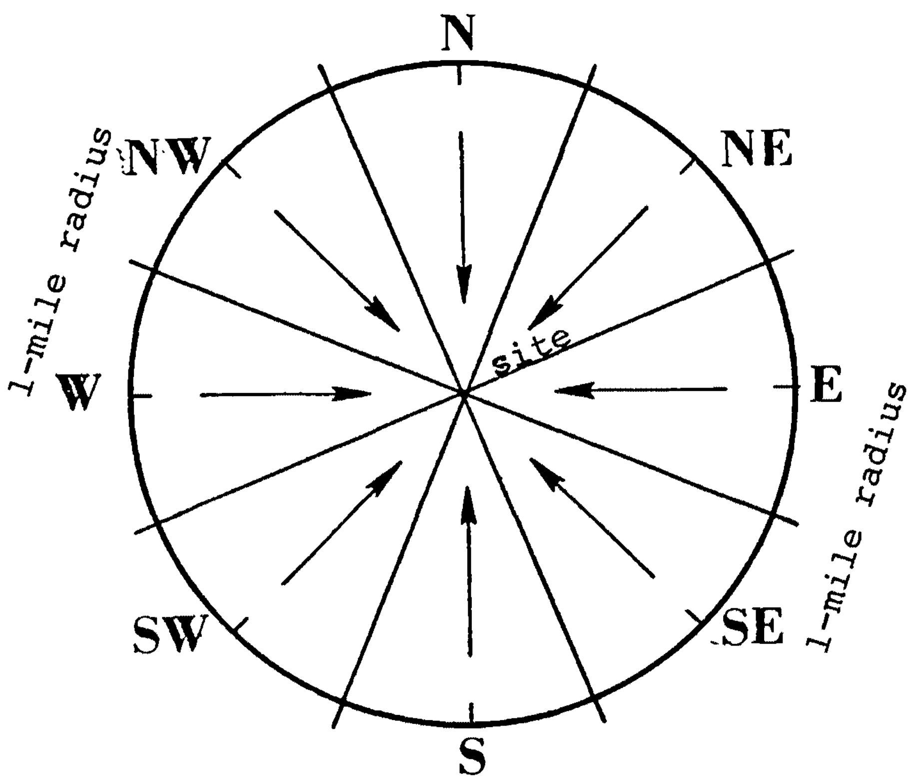
The following data are required for analysis of indoor pollutant concentrations on site:

- Exterior wall and ceiling areas of on-site structures.
- Volume of heated or air-conditioned spaces in on-site structures.
- Characteristics of the heating/circulation system including type and efficiency of filter and whether the design includes make-up air and return air ducting.
- Construction materials of all windows, doors, and exterior walls.

If detailed structural plans are not yet available, preliminary construction and specification information may be used for input to the computations.

Data for High/Low Density Case Determination

The need for further data is governed by whether the site under evaluation is classified as having high or low density. Having secured an area map, you are prepared to make that determination. On the area map, plot eight 45-degree sectors centered on the site, in the following manner:



From the map, scale the total length of all roadways with traffic volume within each sector exceeding 15,000 AADT. If the total length in any sector exceed 5 miles, the site is considered high density. If the total length in each of the eight sectors is less than 5 miles, the site is considered low density.

DATA, HIGH-DENSITY SITE

For a high-density site, the principal additional data required for computing air pollution impact consist of background data on the pollutants of interest. The local air pollution control agency will be able to provide or to secure these data from the closest representative CAMP station (Continuous Air Monitoring Program). The values needed are the upper 3 percentile concentrations (mg/m^3) of CO (1 hr), ($\mu g/m^3$) of TSP (24 hr), and ($\mu g/m^3$) of SO_2 (3 hr).

Analyze only those roadways within one block of the site, i.e., those roadways fronting on the site, together with all other roadways within one block or 500 feet (whichever is closer) of any point on the site. If a highway with traffic volume more than double that of the nearby streets is located within 1000 feet of the site at the nearest point, it is to be included in the analysis. Traffic data are collected as described under Traffic Counts below.

DATA, LOW-DENSITY SITE

Computations for evaluation of low-density sites require considerably more data, including information on population, business and industry, pollutant emissions, parking, aircraft activity, and weather.

Traffic Counts

Data on peak hourly traffic volume are required for all collector streets and highways at the site. These values are available at A-95 Review Agencies or are usually obtainable from the office of the City, County, or State Traffic Engineer. If not, obtain values for average daily traffic volume for all roadways having traffic volume greater than 15,000 vehicles per day and lying within the following distances from the site:

Freeways	1000 meters (3000 feet)
Collector Roads	500 meters (1500 feet)

The values for traffic volume are normally rates projected for the date of the completion of the project and 10 years after that. Thus, for calculating potential pollution from roadways, the target date for completion must be known. Note that at present we can undertake long-term projections of concentration only for carbon monoxide. No data are available that allow calculation of future emissions of the other pollutants.

Point Source Data

A listing of the main point sources in the site vicinity, as delineated in Section 5, can be obtained from the local air pollution control agency. If this is not possible, acquire a city directory containing names of householders and businesses tabulated by street address. Two widely used directories are the Polk Directory and the Haines "Criss-Cross". Census data and directories are usually kept in reference sections of public and university libraries.

Data on emissions from point sources are available from the A-95 Review Agency or from the local air pollution control agency. You will have need for the National Emission Data System (NEDS) forms relating to local point sources of pollutants.

Parking Lots

Parking areas on the site should be located on the map and their dimensions recorded.

Off-site parking areas within 200 meters (about 600 feet) of the site can be identified by inspecting the site area. The facilities of concern are those of greater than 100-car capacity in use from 6 to 9 a.m.

Building Data

Building data will be required only if the point source calculation shows a sufficiently high pollution level to warrant determining emissions from space heating.

A. Contact the A-95 Review Agency to determine whether aerial photographs of the site vicinity are listed in the SCS National Index. If aerial photographs are not available, follow the alternative procedure B.

B. Obtain census data for the area from the U.S. Department of Commerce Field Office or the U.S. Government Printing Office. You will need:

1. "Detailed Housing Characteristics" compiled for counties, cities over 10,000 population, and Standard Metropolitan Statistical Areas (SMSA's).

2. "Census Tracts", published for counties and SMSA's.

Aircraft and Weather Data

Data on aircraft activity are needed for all airports within a 5-mile radius of the site. Information on the yearly commercial aircraft landings and takeoffs from these airports can be obtained from the A-95 Review Agency, the FAA control tower, or the airport manager's office.

Weather data are obtained from the nearest office of the U.S. Weather Service or from ASHRAE Handbook of Fundamentals.[1] You will need values for:

- The 97.5 percentile temperature (coldest day occurring 2.5 percent of the days per year, on an average) from the nearest recording weather station.
- The annual average temperature.

[1] American Society of Heating, Ventilating and Air Conditioning Engineers (ASHRAE). "Handbook of Fundamentals", 1971 Edition.

5 CALCULATING OUTDOOR POLLUTANT LEVELS

This section presents in detail the procedures for calculation of outdoor pollutant concentrations to be expected at a proposed development site. As indicated earlier, the four major categories to be considered are pollution from roadways, parking lots, point sources, and area sources (in this case, space heating of buildings). For each of these categories and for certain preliminary calculations, the planner will develop a worksheet. When these are completed, he can then summarize the expected pollutant concentrations, using the formats given in Section 3, for comparison with listed standards.

CRITICAL SITE POINTS

First, critical points at the site are identified for analysis. These are the areas of the highest anticipated pollutant levels. For CO analysis these points are normally on the first floor of lowest-level living quarters opening to major roadways or adjacent to an on-site parking lot. For particulate and SO_2 analysis, the critical points are those closest to major industrial emitters. For each pollutant, the number of site points selected for analysis depends upon the size and complexity of the site and the number of major pollutant emitters. Analyses for multiple site points can be made concurrently if care is taken to separate the data.

Following are guidelines for determining how many site points should be analyzed. The number is based on magnitude and density of the site development.

Site in High-Density Area

Two categories are considered, as a function of development size:

Small - 100 or fewer housing units or 2 acres or less of site development.

Large - All other developments.

The numbers of site points needed for analysis are:

Small High-Density - One central site point.

Large High-Density - At least four site points, including different site exposures and different activity areas (e.g., patios, children's play area).

Site in Low-Density Area

Small, medium, and large site developments are differentiated as follows:

Small - 50 or fewer housing units or 5 acres or less of site development.

Medium - 50 to 250 housing units or 5 to 25 acres of site development.

Large - All other developments.

The numbers of site points needed for analysis are:

Small Low-Denisty - One central site point.

Medium Low-Density - Three or four site points.

Large Low-Density - At least six site points.

Different site points can be designated for analysis of TSP, SO_2, and CO levels as a function of their respective major emission sources. For medium and large sites, the choice of site points should be predicated upon the pollution impacts from different site exposures and impacts at different site activity areas. Points closest to major roadways and parking lots should be considered for CO analysis and locations in the direction of any heavy industrial development should be chosen for TSP ans SO_2 analysis.

NOTE - To avoid confusion when evaluating multiple site points, use different site maps or a system of coding.

POLLUTION FROM ROADWAYS

Worksheet 1 is to be completed for each street or freeway near the site. Following are line-by-line instructions.

Line 1: Projected year for which roadway emissions are calculated.

Line 2: Assign a road number.

Line 3: Road name.

Line 4: Enter the measured shortest distance from the roadway to the site location in kilometers (km).

Line 5: Enter the peak-hour traffic volume (V), if it is available, and skip lines 6 through 12.

Fill in lines 6 to 12 only if line 5 cannot be completed.

Line 6: If the peak-hour traffic volume is not available, enter the average traffic volume, termed Annual Average Daily Traffic (AADT), in vehicles/day.

Line 7: Enter the number of traffic lanes under peak traffic load during morning rush-hour.

Worksheet 1. EMISSIONS FROM SINGLE ROADS

Line						
1	Projection year					
2	Road number					
3	Road name					
4	Normal distance, km					
5	Peak traffic volume (V), vph					
	Complete lines 6 through 12 only if traffic data for line 5 is not available.					
6	AADT, vpd					
7	Peak lanes (N)					
8	Off-peak lanes					
9	Daily traffic/lane pair					
10	Peak lane volume, vph					
11	Off-peak lane volume, vph					
12	Total traffic (v), vph					
13	V/Ca for highways					
14	Traffic speed, mph					
15	CO emission factor (Eco) gm/mi					
16	CO emission rate (Qco), mg/sec-m					
17	Intersection emissions (Rco), mg/sec-m					

Line 8: Enter the number of traffic lanes under off-peak traffic volume per lane pair

Line 9: Determine the traffic volume per lane pair

$$\text{Line 9} = \frac{\text{line 6}}{0.5\ [\text{line 7} + \text{line 8}]}$$

Refer to Figure 5-1, using the volume per lane pair (line 9) to obtain:

Line 10: Volume per lane in peak periods, vehicles per hour.

Line 11: Volume per lane in non-peak periods, vehicles per hour.

Line 12: Determine the total traffic volume per hour (v):

Total traffic = Off-peak lanes (line 8 x Volume (line 11) + Peak lanes (line 7) x Volume (line 10)

NOTE: Off-peak means not in rush hour condition.

EXAMPLE - Determining rush-hour traffic volume on a highway:

AADT = 36,000 vehicles per day, 3-lane pair highway: 3 peak and 3 off-peak traffic lanes during rush hour.

$$\text{Daily traffic per lane pair} = \frac{36{,}000}{3} = 12{,}000 \text{ veh/day.}$$

Referring to Figure 5-1:

1) Peak lane volume = 750 vph

2) Off-peak lane volume = 285 vph

$$\begin{aligned}\text{Total traffic (line 12)} &= 3 \times 750 + 3 \times 285 \\ &= 2250 + 855 \\ &= 3105 \text{ vph}\end{aligned}$$

Line 13: For highways only. Determine the V/Ca* ratio as follows:

$$V/Ca = \frac{\text{Traffic volume (line 5 or 10)}}{1800 \times \text{peak traffic lanes (line 7)}}$$

*V/Ca is used instead of the normal designation V/C to avoid confusing C with concentration.

Line 14: Enter the rush-hour average traffic speed. For roads on which the speed limit is 45 mph or lower, the posted speed limit can be used as the average traffic speed. For highways, refer to Figure 5-2 with the V/Ca ratio and the posted speed limit to arrive at the average traffic speed, mph.

Line 15: Determine the average CO emission factor (Eco) in gm/mile by referring to Table 5-1 for local roads and Table 5-2 for highways. The 'year' column on the tables refers to the 'projected' year for which pollution impact is being determined.

Line 16: Determine the CO emission rate (Qco) as follows:

$$Qco = 1.73 \times 10^{-4} \times V \text{ (line 5 or 12)} \times Eco \text{ (line 15)} \text{ (mg/sec-m)}$$

Line 17: Roadway intersections are considered as an added pollution impact in accordance with these criteria:

2-lane roads intersecting within 200 m (600 ft) of the site.
3-or 4-lane roads intersecting within 300 m (900 ft).
4-to 6-lane roads intersecting within 400 m (1200 ft).

Where roadways of different sizes intersect, apply the distance criterion for the larger road. Determine values for intersection emissions as follows:

$$Rco = 1.30 \times Qco \text{ (line 16) mg/sec-m.}$$

Worksheet 2 is used to determine the total CO pollution from all significant roads near the site with respect to the eight wind direction lines drawn in Section 4 to characterize the site as high or low density. Six data entries are required for each roadway.

Line 1: Enter the road number as assigned on Worksheet 1, line 2.

Line 2: Determine the angle made by intersection of the centerline of the roadway and the vector lines for wind direction. In the example below, angles 1, 2, 7, and 8 are formed by intersection of the road with wind directions N, NE, W, and NW. Wind directions E, SE, S, and SW do not intersect and spaces for these directions are left blank on line 2.

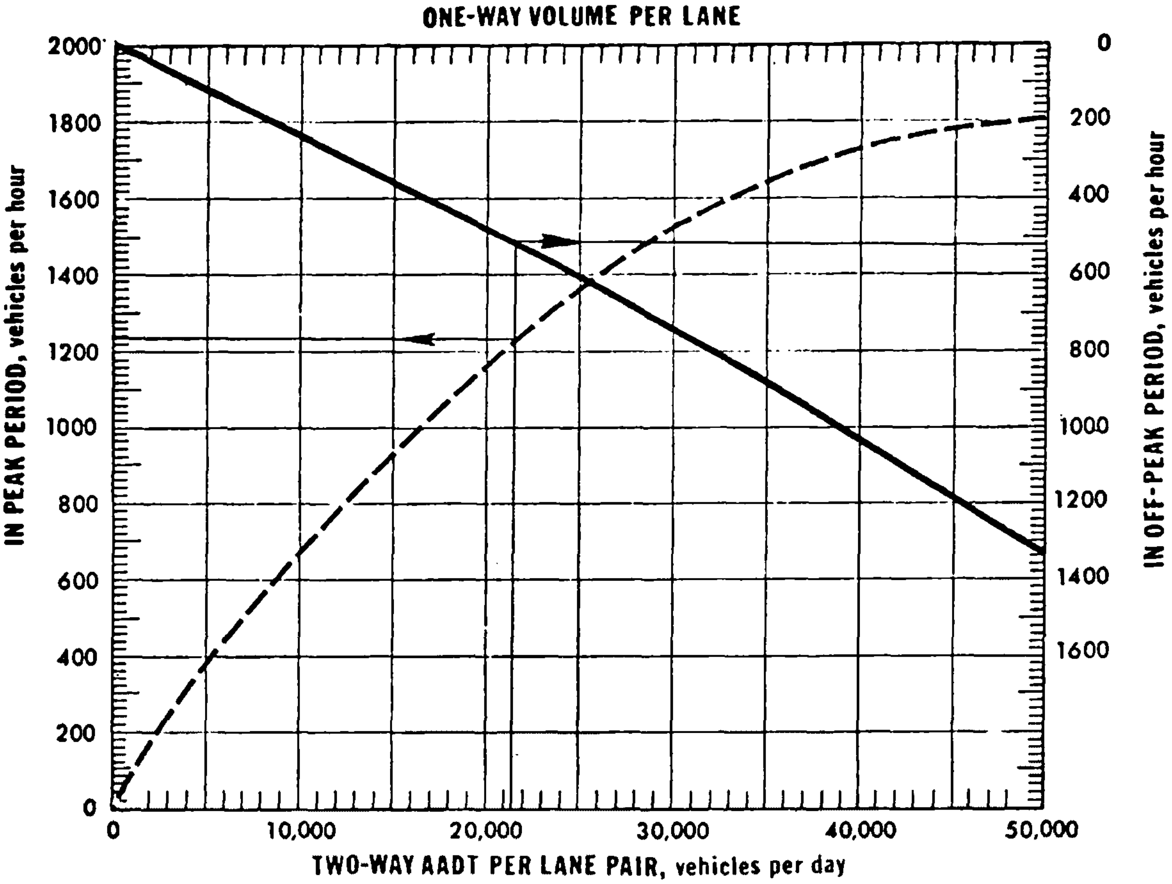


Figure 5-1. Conversion from AADT to peak and off-peak hourly traffic volume.

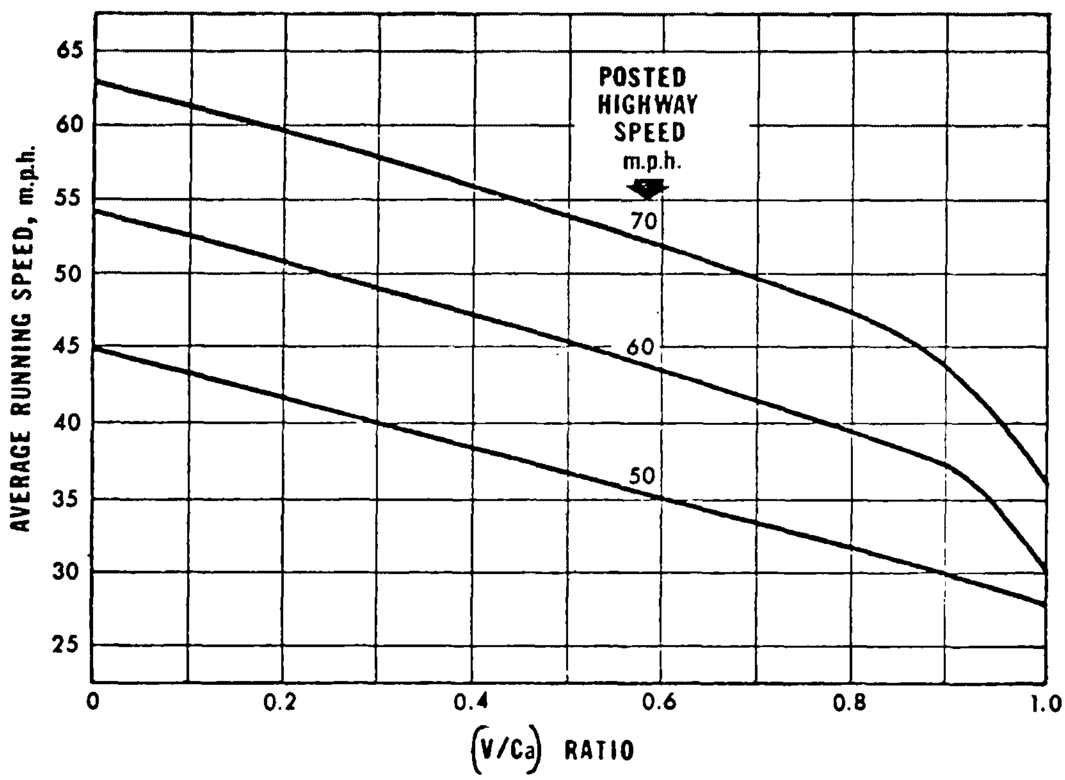


Figure 5-2. Determination of average highway speed.

Table 5-1. AVERAGE CARBON MONOXIDE (CO) EMISSION FACTORS (Eco) FOR COLLECTOR ROADS (CO EMISSIONS, GM/MILE/VEHICLE)

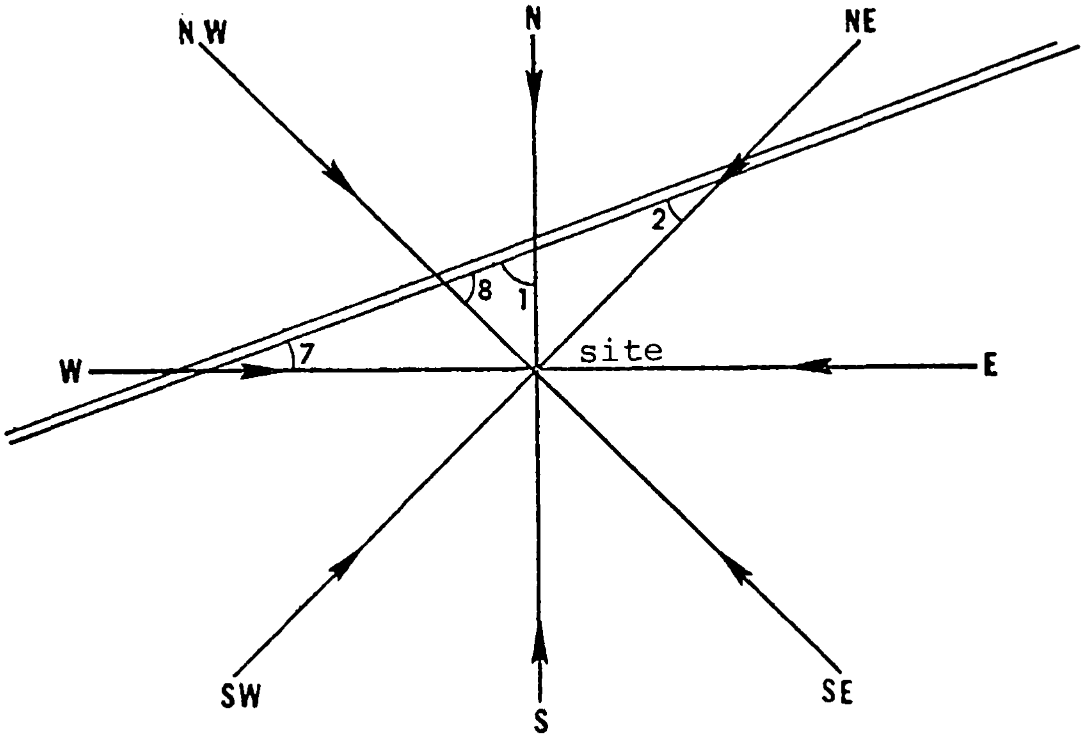
Year	Traffic speed limit				
	15 mph	20 mph	25-30 mph	35-40 mph	45 mph
1974	91.22	63.35	48.65	40.54	34.97
1975	81.99	56.94	43.73	36.44	31.43
1976	71.03	49.33	37.88	31.57	27.23
1977	60.86	42.26	32.46	27.05	23.33
1978	52.04	36.14	27.75	23.13	19.95
1979	44.87	31.16	23.93	19.94	17.20
1980	38.11	26.46	20.32	16.94	14.61
1985	22.54	15.65	12.02	10.02	8.64
1990	20.25	14.06	10.80	9.00	7.76

Table 5-2. AVERAGE CARBON MONOXIDE (CO) EMISSION FACTORS (Eco) FOR HIGHWAYS (CO EMISSIONS, GM/MILE/VEHICLE)

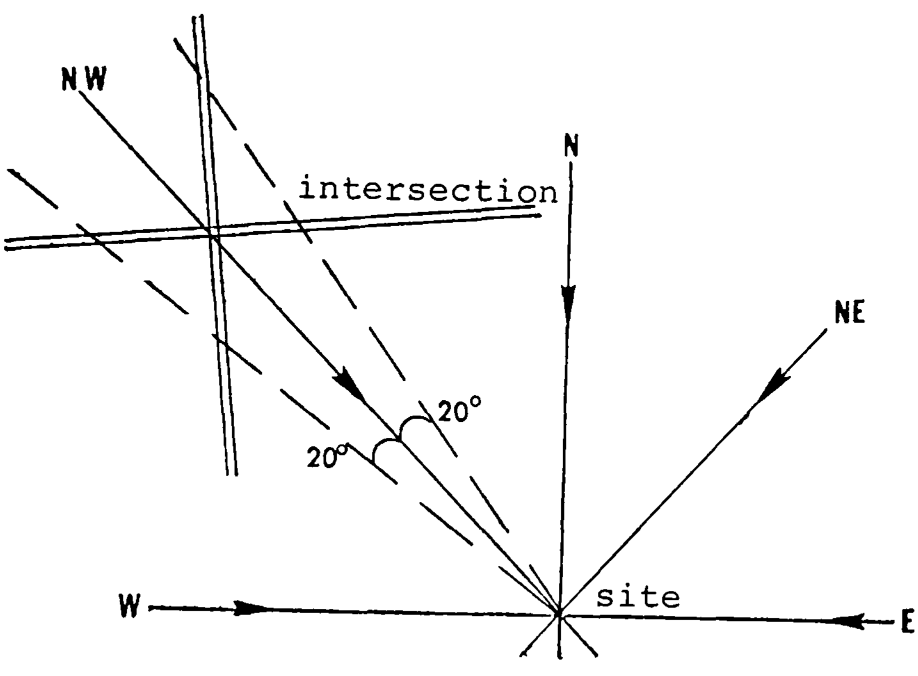
Year	Average Traffic Speed							
	25 mph	30 mph	35 mph	40 mph	45 mph	50 mph	55 mph	60 mph
1974	40.54	34.97	30.91	27.37	21.59	21.81	22.03	22.14
1975	36.44	31.43	27.79	24.60	19.44	19.64	19.84	19.94
1976	31.57	27.23	24.07	21.31	16.86	17.04	17.71	17.30
1977	27.05	23.33	20.62	18.26	14.47	14.62	14.77	14.85
1978	23.13	19.95	17.64	15.61	12.41	12.53	12.66	12.73
1979	19.94	17.20	15.21	13.46	10.74	10.85	10.96	11.02
1980	16.94	14.61	12.91	11.43	9.21	9.30	9.40	9.44
1985	10.02	8.64	7.64	6.76	5.69	5.75	5.81	5.84
1990	9.00	7.76	6.86	6.08	5.21	5.26	5.31	5.34

Worksheet 2. POLLUTION FROM ROADWAYS

	Wind Direction							
	N	NE	E	SE	S	SW	W	NW
1. Road No.								
2. Angle (σ)								
3. Emission Q, mg/sec-m								
4. Distance, m								
5. Norm. Conc.								
6. Cco, mg/m^3 line 3 x line 5								
1. Road No.								
2. Angle (σ)								
3. Emission Q, mg/sec-m								
4. Distance, m								
5. Norm. Conc.								
6. Cco, mg/m^3 line 3 x line 5								
1. Road No.								
2. Angle (σ)								
3. Emission Q, mg/sec-m								
4. Distance, m								
5. Norm. Conc.								
6. Cco, mg/m^3 line 3 x line 5								
Total Concentration mg/m^3								



Line 3: If an intersection falls within ± 20 degrees of the wind direction line and intersection emissions are shown in Worksheet 1, enter the intersection emissions, Rco, (Worksheet 1, line 17). Otherwise, enter the roadway emission, Qco (Worksheet 1, line 16). If the roadway does not intersect a wind direction line, enter zero. In the example that follows, the intersection falls within ± 20 degrees of the northwest wind direction.



Line 4: Enter the distance from the roadway to the site location, measured perpendicular to the roadway alignment. (Worksheet 1, line 4)

Line 5: Refer to Figure 5-3 with values for distance (line 4) and angle (line 2) to obtain the normalized concentration.

Line 6: Calculate the CO concentration at the site (Cco) due this roadway:

Cco = line 3 x line 5

When Cco values are determined for each roadway, summarize the total CO pollution from all roadways at the site for each wind direction. These values are entered in the CO concentration summary, as shown in Section 2 and repeated below.

Summary: CO Concentrations

	N	NE	E	SE	S	SW	W	NW
1) Roadways								
2) Parking								
3) Total								
4) Maximum 1-hr concentration, mg/m^3								

POLLUTION FROM PARKING LOTS

This section is concerned with concentrations of CO resulting from vehicle emissions on (1) the on-site parking areas and (2) all parking lots within 200 meters of the site location having more than 100 parking spaces and substantially occupied during any 1-hour period between 6 and 9 a.m., as identified in Section 4. The eight major wind directions used in analysis of roadways

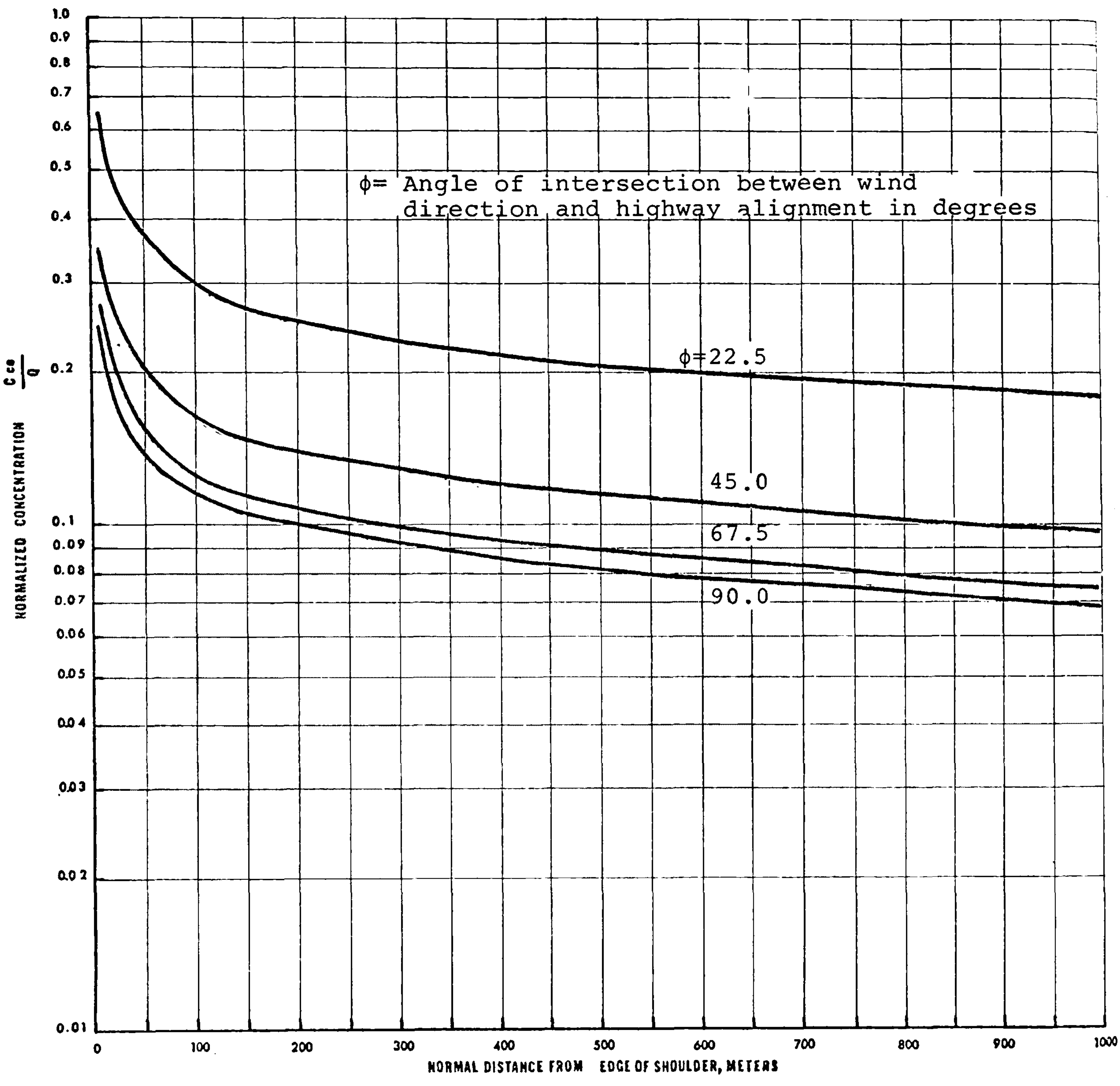


Figure 5-3. Calculation of normalized concentration of CO from roadways.

are again used here. A parking lot is considered to have impact in only those wind directions on whose wind direction vector it lies.

A site map is preferable for this analysis.

Worksheet 3 is used to determine pollution from parking lots.

Line 1: Assign a number to the parking lot. Enter the number on line 1 under the wind direction in which the parking lot lies.

Line 2: Enter depth of the parking lot.

Line 3: Determine the distance from the designated site location to the nearest edge of the parking lot.

Line 4: Determine distance to the far edge of the lot by adding line 2 and line 3.

Line 5: Refer to Figure 5-4 with near-edge distance (line 3) and read CO concentration.

Line 6: Refer to Figure 5-4 with far-edge distance (line 4) and read CO concentration.

Line 7: Obtain net CO concentration by subtracting line 5 from line 6.

Line 8: Sum the concentrations from each wind direction.

Line 9: Correction factor from Table 5-3 for target year of calculation.

Line 10: Corrected total impact for each wind direction, line 8 x line 9, mg/m^3.

Enter the values from line 10 in the CO concentrations summary under the values determined for roadways.

Worksheet 3. POLLUTION FROM PARKING LOTS

Line number	Wind Directions							
	N	NE	E	SE	S	SW	W	NW
1. Parking lot number								
2. Depth, meters								
3. Distance near edge, m								
4. Distance-far edge, m								
5. Near-edge conc., mg/m^3								
6. Far-edge conc., mg/m^3								
7. Net concentration, mg/m^3 line 6 - line 5								
1. Parking lot number								
2. Depth, meters								
3. Distance near edge, m								
4. Distance-far edge, m								
5. Near-edge conc., mg/m^3								
6. Far-edge conc., mg/m^3								
7. Net concentration, mg/m^3 line 6 - line 5								
8. Total impact, mg/m^3								
9. Correction factor								
10. Corrected total impact, mg/m^3, line 8 x line 9								

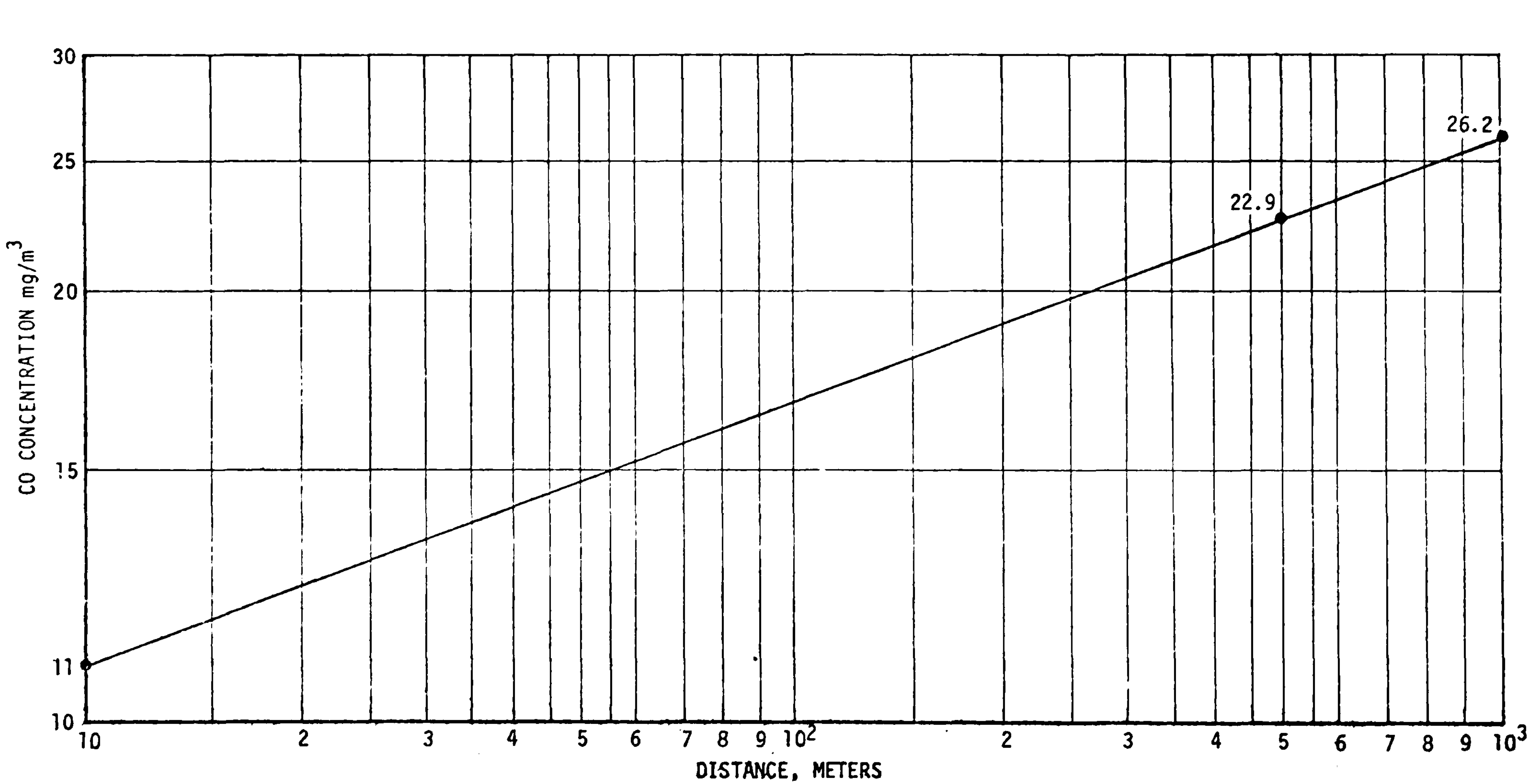


Figure 5-4. CO impact due to parking lots.

Table 5.3 PARKING LOT CORRECTION FACTORS

Year	Correction factor	Year	Correction factor
1974	0.84	1980	0.35
1975	0.76	1981	0.32
1976	0.66	1982	0.29
1977	0.56	1983	0.26
1978	0.48	1984	0.23
1979	0.41	1985 to 1990	0.20

POLLUTION FROM POINT SOURCES

This section presents procedures for computing particulate and sulfur dioxide concentrations to be expected at the site as a result of point source emissions.

First, prepare a point source list showing the name and location of all commercial and industrial establishments within 5 kilometers (3 miles) of the site and any power plants within 24 kilometers (15 miles). Assign a number to each point source.

The impact of a point source* on a site depends on its size (capacity, output) and on its distance from the site. Since we intend to consider only sources having significant impact on the site, the first step in this procedure is to determine the relative significance of sources near the site.

The procedure is simplified if separate maps are used for particulates and SO_2. Each should cover an area approximately

*The term point source refers to a stationary industrial or commercial pollution emitter. A point source may have a large number of individual stacks or emission points.

10 km square.

Determining Impact of Individual Point Sources

Much of the material required for this analysis will be provided by your local air pollution control agency. After the point source list has been assembled, ask for copies of the appropriate forms of the National Emission Data System (NEDS) from the air pollution control agency or the A-95 Review Agency. The NEDS forms are provided by the U.S. Environmental Protection Agency and are intended for use in analyses and studies of the sort you are conducting as well as in governmental pollution control activities. NEDS forms may be available only for the larger plants in the area. A full explanation of the NEDS format and coding system is given in Appendix C.

Worksheet 4 is used for preliminary determination of the significance of a point source with respect to the site. Complete Worksheet 4 as follows.

Line 1: Locate the source on an area map. Measure the straight-line distance (d) between the source and the site location.

Line 2: Using the (d) value, refer to Figure 5-5 to obtain the minimum significant emission rate (Em) at that distance from the site. This value will be used as a cut off for determining significant sources.

Line 3: (Table) Refer to the NEDS form, using Key 10 to calculate the number of hours of stack operation per year:

S (hr/yr) = hr/day x day/week x weeks/year

Using the S value and Figure 5-6, convert the pollutant emission rate (keys 11 and 12) from tons/year to gm/sec. Enter the Point ID (Key 4) and corresponding emission rates. Repeat for each Point ID of the source. Total the emission rates of each pollutant on line 3a.

Worksheet 4. POINT SOURCE SIGNIFICANCE TEST

Plant Name________________________________ Number_______________

Address____

Evaluation of the source

Line Number

1 Straight line distance between the source and the site, d ________ Meters

2 Minimum emission rate for Em for significance (from Figure 5-5) ________ gm/sec

3 (Table)

Point ID	Pollutant, gm/sec	
	Particulate	Sulfur Dioxide
3a TOTAL		

4 Is the total emission rate for particulate or sulfur dioxide greater than the emission rate Em on line 2?

Yes __________ No __________

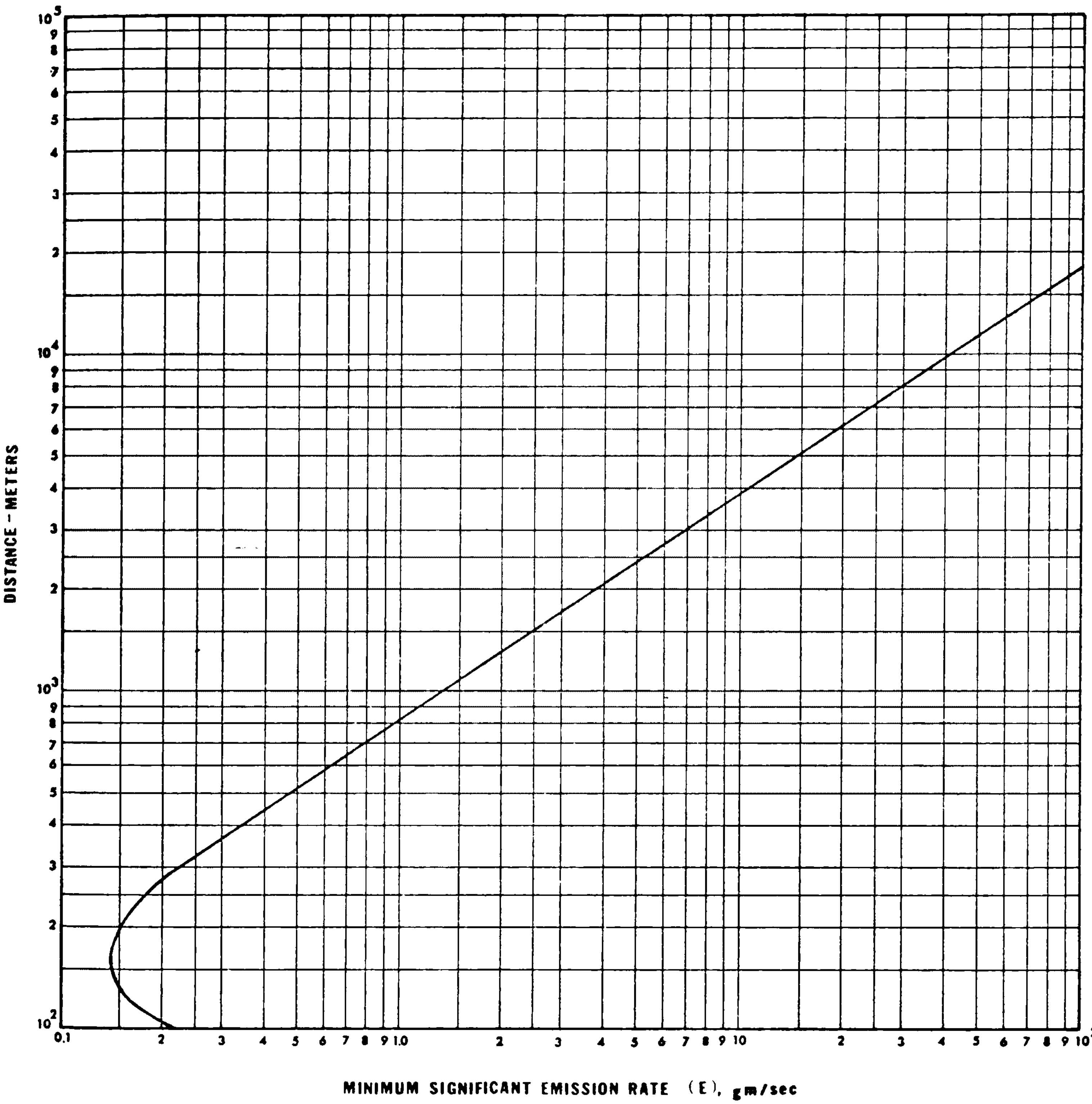


Figure 5-5. Determination of source significance.

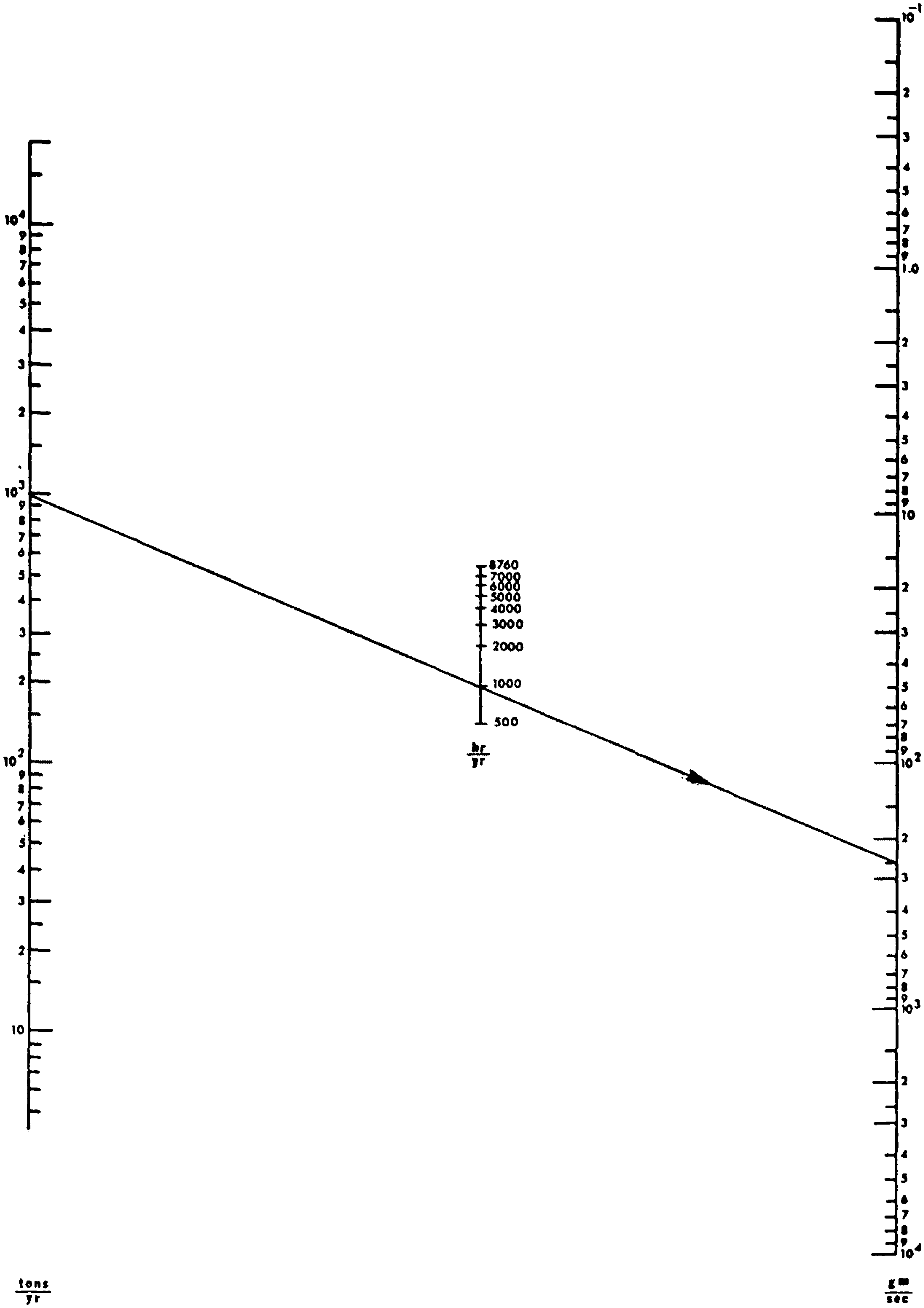


Figure 5-6. Conversion from tons/year to grams/sec.

If the air pollution control agency maintains a file on emission summaries, the total plant emissions can be entered in Figure 5-6.

Line 4: Determine significance. If the source is not significant, it is not included in the calculation procedure and is not analyzed on Worksheet 5.

If the source is determined to be significant, more detailed analysis is required. Locate all significant point sources on the particulate and SO_2 area maps. The next procedure is to determine the pollutant contributions from the sources to the site.

For a plant having more than one stack (i.e., point ID's) with similar parameters, calculations are simplified by grouping the stacks on the basis of stack height and gas flow rate. Stacks are first grouped in three height ranges: 0 to 50 ft, 51 to 100 ft, and 101 to 200 ft. Each group is then subdivided according to gas flow rate in two categories: flow rate less than or equal to 100 ft^3/min and flow rate higher than 100 ft^3/min.

Grouping of stacks is accomplished by calculations on Worksheet 5. You will need six copies of the worksheet to accommodate the six combinations of stack flow range and height range combinations:

Flow Range, ft^3/min	Height Range, ft
$\leq$ 100	0 - 50
$\leq$ 100	51 - 100
$\leq$ 100	101 - 200
> 100	0 - 50
> 100	51 - 100
> 100	101 - 200

Worksheet 5. GROUPING OF STACKS

Line Number

Stack Number ________ (1-6)

Stack Group Characteristics

1 Flow Range ______ ft^3/min or m^3/sec

2 Height Range ______ ft or meters

3 (Table)

Number in Group	Point ID	Height H, ft	Temp. Ts, °F	Gas flow rate ft^3/min	Pollutants, gm/sec	
					TSP	SO_2
1						
2						
3						
4						
5						
n=	TOTAL					

4 Number of Stacks n = ______

5 Average Height $H = \frac{\text{Sum of Heights}}{n}$ = ______ ft x 0.3048 = ______ m

6 Average Temp. $Ts = \frac{\text{Sum of Temps}}{n} = \frac{5}{9}($ ___ °F -32) = ______ °C

7 Average Gas Flow Rate $V_f = \frac{\text{Sum of gas flow rates}}{n}$ =

$\left(\frac{\_\_\_\_\_\_ ft^3/min}{2120}\right)$ = ______ m^3/sec.

EMISSION RATES

8 Particulate = Sum of the emission rates = ________ gm/sec.

9 Sulfur Dioxide = Sum of emission rates = ________ gm/sec.

Lines 1 and 2: Enter the six sets of values on six worksheets.

Line 3 (Table): For each NEDS form for a plant, determine the appropriate worksheet (on the basis of flow rate and stack height range) and enter the point ID, stack height, temperature, gas flow rate and TSP and SO_2 emission rates (the conversion from tons/year to gm/sec is presented in Figure 5-6). Sum the columns as indicated.

Lines 4 through 9: Total the number of stacks (n) and calculate the representative parameters for the group of stacks as shown. These are the stack parameters to be used in further calculations.

Discard any sheets with no stacks listed. Number each group of stacks and each separate stack sequentially. The stack number now represents either a single stack or a group of stacks for use in calculating pollutant contributions from individual sources. These calculations are done on Worksheet 6 as follows.

Line 1: Enter stack number as assigned.

Lines 2, 3 and 4: Enter values for stack height, stack gas temperature, and gas flow rate (NEDS form Keys 7, 8, 9 or Worksheet 5, lines 5, 6, 7).

Line 5: Annual average temperature obtained from weather service.

Line 6: Calculate factor (F) as follows:

$$F = 3.12 \times V_f \text{ (line 4)} \times \frac{Ts \text{ (line 3)} - 20}{Ts \text{ (line 3)} + 273}$$

Line 7: Consult Figure 5-7 with F to obtain the plume rise (h_e).

Line 8: Effective stack height h (meters) = line 2 + line 6.

Lines 9 and 10: For a group of stacks, obtain emission rates for particulate and sulfur dioxide from Worksheet 5, lines 8 and 9.

For a separate stack, obtain emission rates from Worksheet 4, line 3.

Worksheet 6. ESTIMATION OF POLLUTANT CONTRIBUTION

FROM THE SOURCE TO THE SITE

Line Number	ITEM	STACK OR GROUP OF STACKS				
1	Stack Number					
2	Stack Height (H), m					
3	Stack Gas Temperature (Ts), °C					
4	Gas Flow Rate (V_f), m^3/sec					
5	Ambient Temperature (t), °C					
6	F Value					
7	Plume Rise (h_e), m					
8	Effective Stack Height, m (h total), line 2 + line 6					
9	Particulate (Q_1), gm/sec					
10	Sulfur Dioxide (Q_2), gm/sec					
	NORMALIZED CONCENTRATION					
11	Particulate and SO_2 (C/Q), Figure 5-8					
	ESTIMATED DOWNWIND CONCENTRATIONS					
12	Particulate, μg/m^3					
13	Sulfur Dioxide, μg/m^3					
14	Total Particulate, μg/m^3					
15	Total Sulfur Dioxide, μg/m^3					

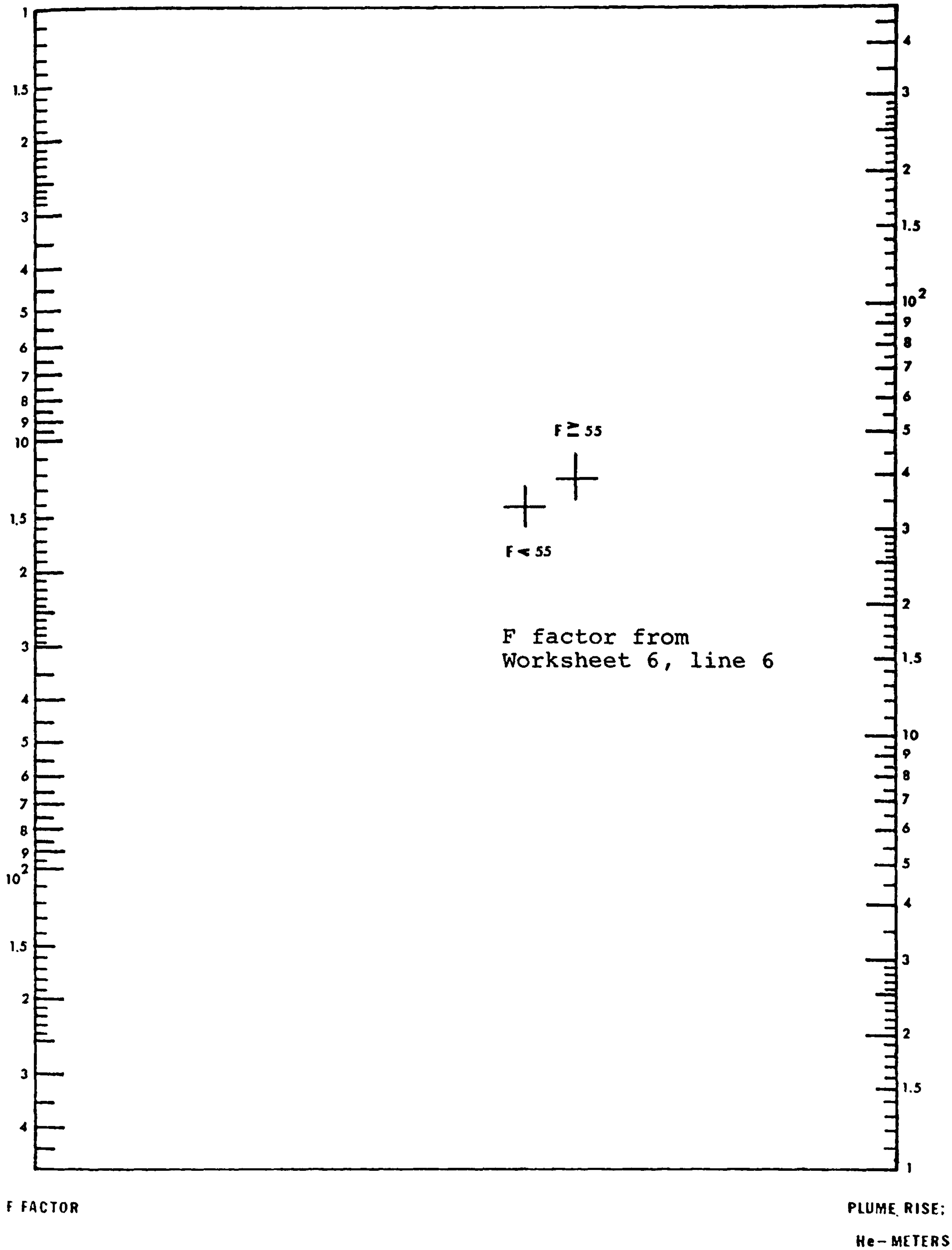


Figure 5-7. Determination of plume rise.

Line 11: Consult Figure 5-8 with distance (d) and effective stack height (line 7) to obtain normalized concentration (C/Q).

Line 12: Particulate concentration = line 11 x line 9 x 0.6.

Line 13: Sulfur dioxide concentration = line 11 x line 10

Line 14: Total particulate concentration = sum of line 12 across the columns.

Line 15: Total sulfur dioxide concentration = sum of line 13 across the columns.

With the completion of these worksheets to determine the impact of individual point sources, you are now prepared to calculate the total expected concentrations at the site resulting from the significant point sources.

Calculating Particulate Concentrations from Point Sources

Select the point source contributing the greatest quantity of particulate from Worksheet 6. Mark one copy of the area map with lines representing wind direction vectors oriented through each of the four sources having highest particulate impact directly to the designated site location. Proceed with Worksheet 7a as follows.

Line 1: Enter the number assigned to the source.

Line 2: Enter downwind particulate concentration (Worksheet 6, line 14).

Lines 3 and 4: These values are used to determine correction factors for a source not falling directly on one of the four wind vectors. If the point source falls on the wind direction, go directly to Line 6. For each point source within ± 15° of a wind vector, plot a perpendicular line from the wind vector to the source, as shown below. This is defined as the "Y" distance. The "X" distance is the distance from the intercept to the site. Record "X" and "Y" distance on Lines 3 and 4.

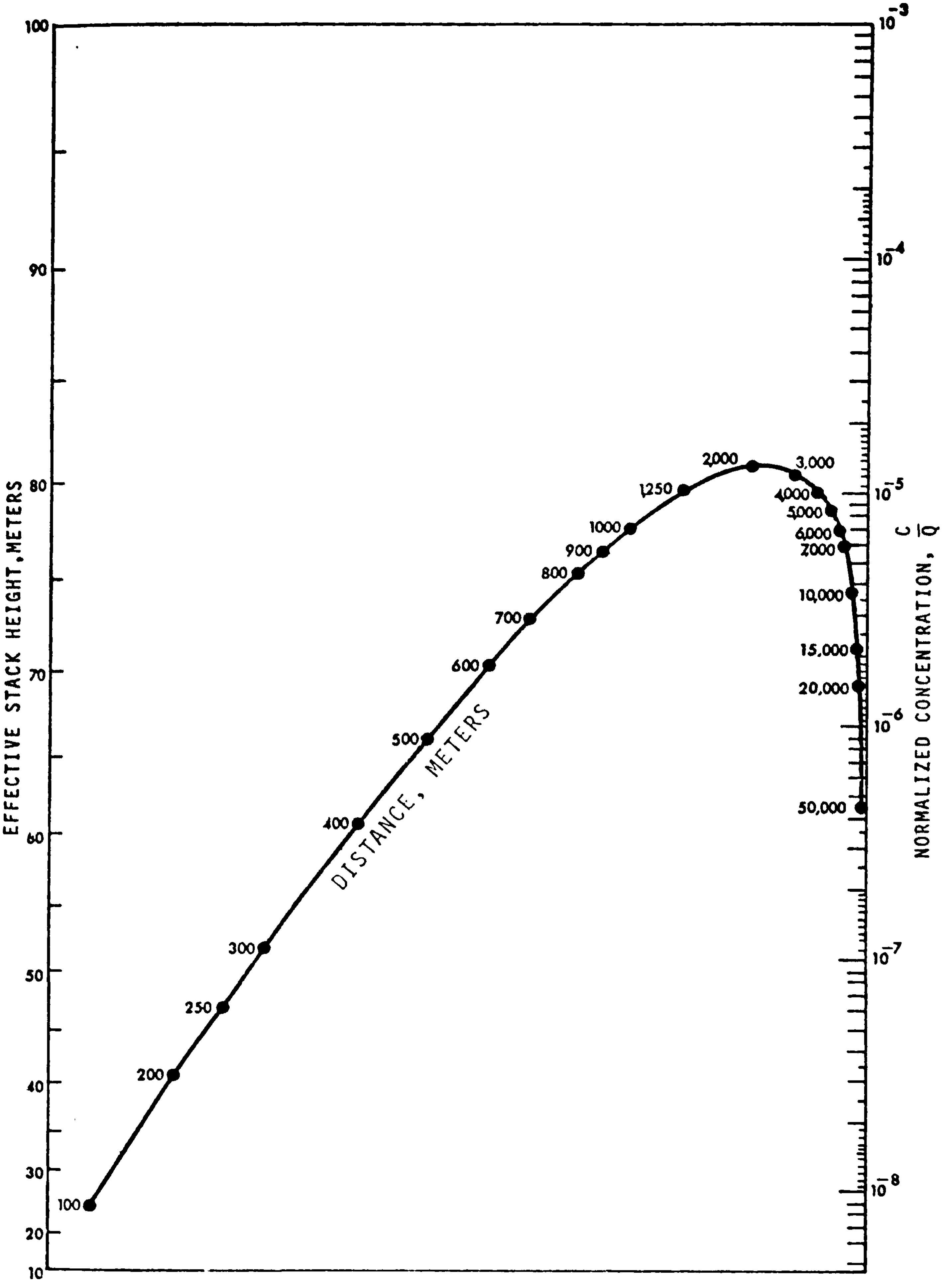
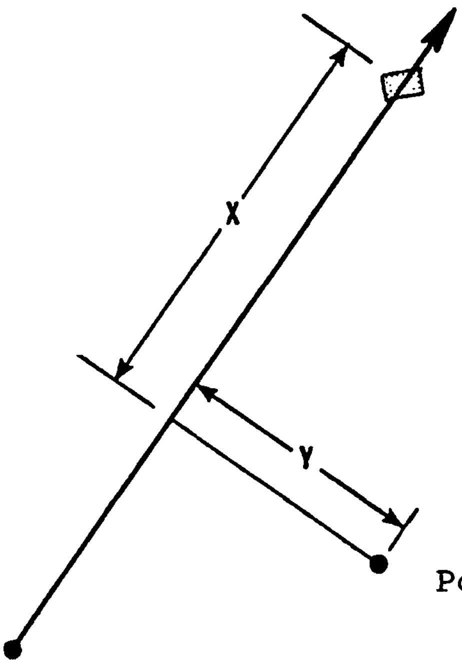


Figure 5-8 Calculation of normalized concentration for point sources.

Worksheet 7a. POLLUTION FROM POINT SOURCES (PARTICULATE)

Line Number	Wind Directions 1	2	3	4
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
TOTAL $\mu g/m^3$				



For point sources outside the ± 15 degree of a given wind direction, do not enter in the table.

Line 5: Refer to Figure 5-9 with X and Y coordinates to determine the correction factor for each of the point sources. If the factor is less than 10^{-2}, enter zero.

Line 6: Particulate contribution from the source in the given wind direction = line 2 x line 5.

When all point sources are evaluated, calculate the total particulate concentration in each wind direction by adding all lines 6 for each wind vector. Enter these values in the 'TOTAL' row of the worksheet. From this row, select the maximum particulate concentration; enter this value and the corresponding wind direction in the Particulate and SO_2 Concentrations Summary, shown in Section 3 and repeated below.

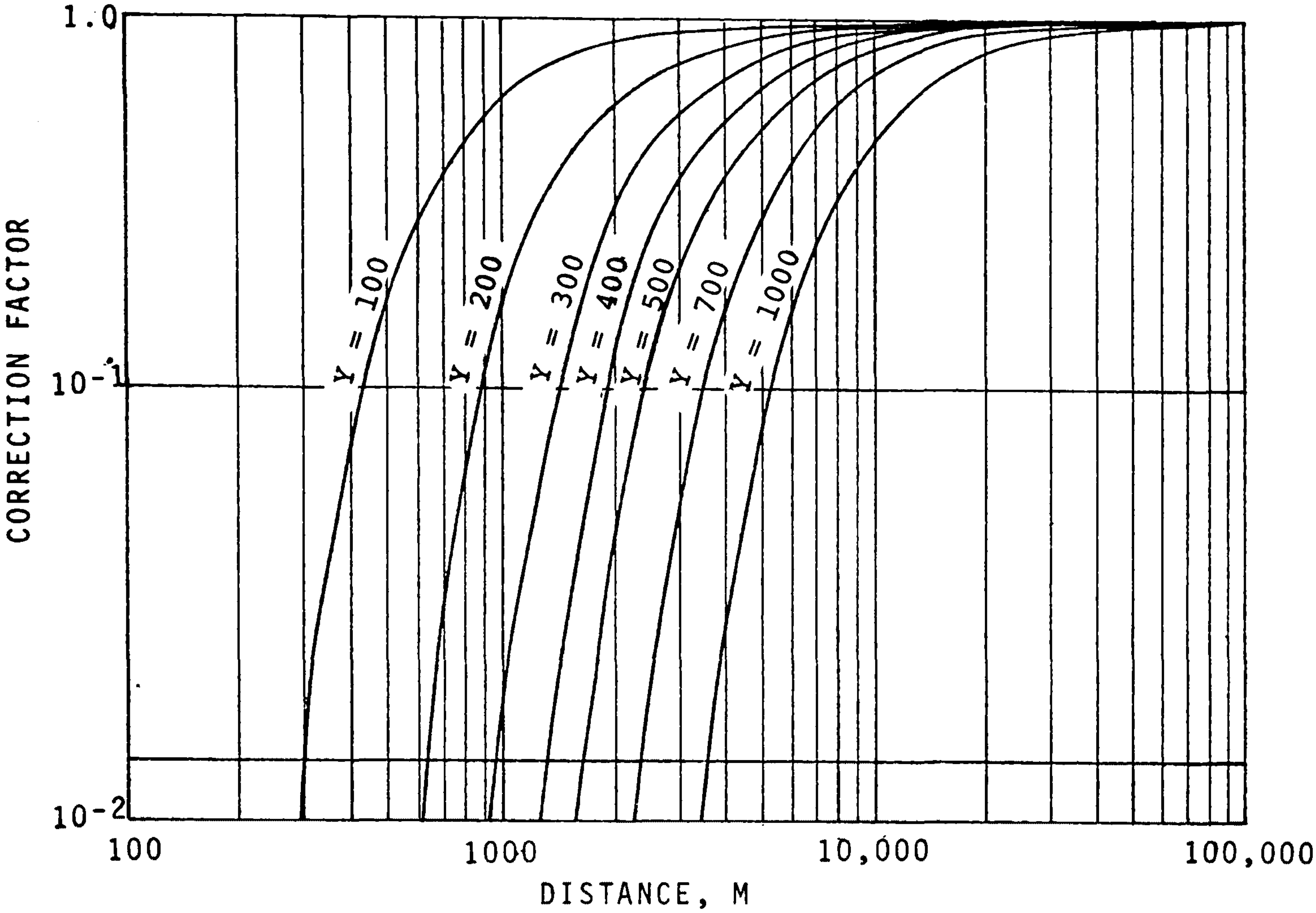


Figure 5-9. Correction factor for particulates.

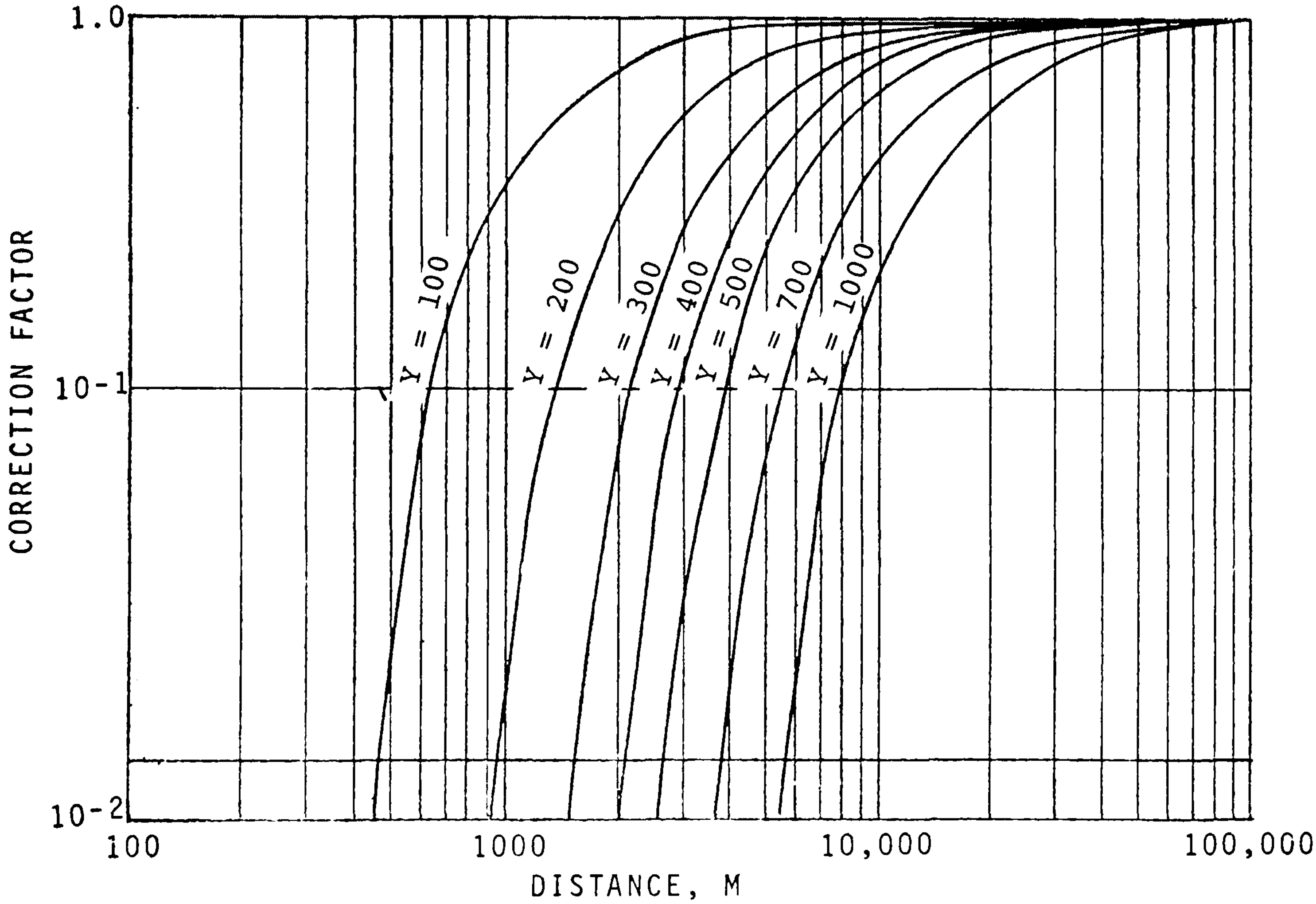


Figure 5-10. Correction factor for SO_2.

Summary: Particulate and SO_2 Concentrations

	TSP	SO_2
1. Wind, direction no. (from Worksheet 7A and 7b)		
2. Point sources		
3. Building heating		
4. Total		

Calculating SO_2 Concentrations from Point Sources

The procedure for calculating sulfur dioxide concentrations is exactly the same as that for particulate. Use worksheet 7b to calculate SO_2 concentrations and Figure 5-10 to determine the correction factor. Enter the maximum SO_2 concentration and the corresponding wind direction in the Particulate and SO_2 Concentrations Summary.

POLLUTION FROM SPACE HEATING

If the maximum impact from point sources is either greater than 100 $\mu g/m^3$ for TSP or greater than 200 $\mu g/m^3$ for SO_2, the impact from space heating should be determined. If not, omit this calculation and go directly to calculating pollution from airports.

This procedure is to be used for analysis of low-density sites, with the following restrictions:

Large Low-Density - Do the full analysis. For each pollutant, for wind directions within 30°, only the impact from the first calculation need be made. For example, when calculating the TSP impact for different site locations, the difference in downwind direction from a given point source is likely

Worksheet 7b. POLLUTION FROM POINT SOURCES (SO_2)

Line Number	Wind Directions			
	1	2	3	4
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
TOTAL $\mu g/m^3$				

less than 30° so the space heating impact for the first site location can be used for all subsequent cases within 30° of this angle.

Medium Low-Density - Determine the space heating impact at only one location for TSP and one location for SO_2. Use the wind direction giving the overall highest impact for TSP and for SO_2 and use the resulting values for all the other wind directions.

Small Low-Density - The full calculation procedure is not required, since the space heating impact can be estimated. First determine if oil or coal is used for space heating in the 1-2 km perimeter of the site. If only a small portion of the space heating fuel is coal or oil (less than about 20%), assume that the pollution impact is negligible and place zeros in the total. If coal and oil are used substantially (by estimate greater than 20% of the total load), use 30 $\mu g/m^3$ for space heating impact for both TSP and SO_2. If coal and oil are used very extensively for space heating (developed area with greater than 75% coal and oil), follow the full procedure described for medium low-density developments.

Procedures for estimating pollution from space heating entail plotting on the map for each pollutant the space heating area to be considered, and computing the floor areas to determine space heating load.

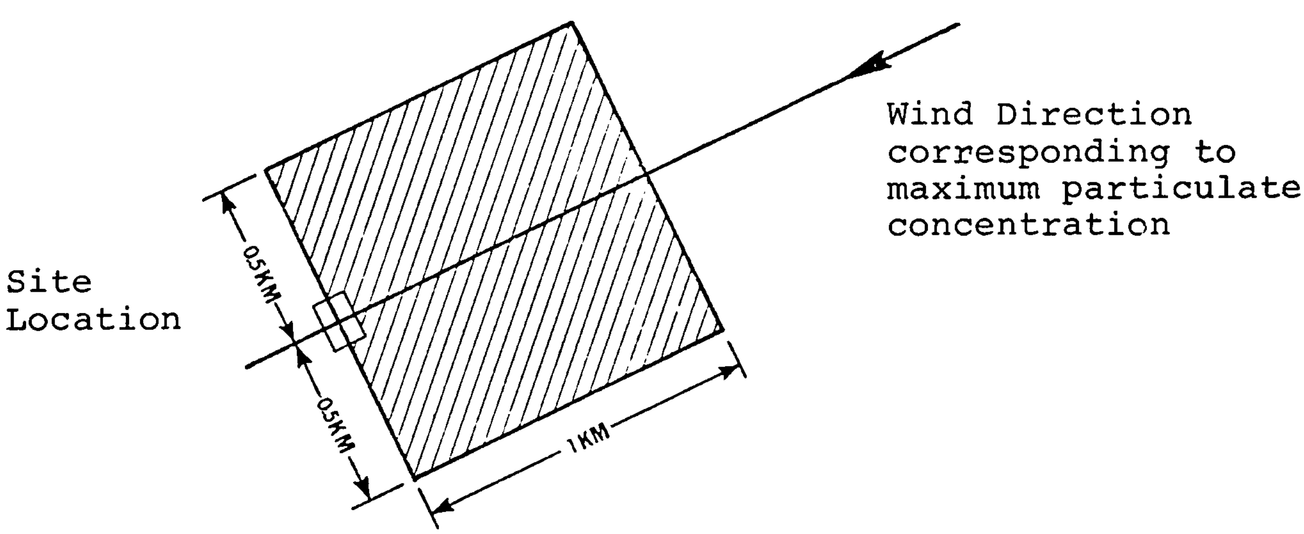
On the map used for calculating point sources contributions of particulate, locate the wind direction vector that yielded the maximum particulate concentration at the site. (Refer to Worksheet 7a.) Construct a square with a 1-kilometer (0.625 mi.) side, centered on the site and the wind direction vector, as illustrated below. You will estimate particulate impact on the site from space heating in buildings located within this square. Use procedure A to estimate floor area if aerial photos are available, if not use procedure B.

A Acquire aerial photos for the designated area and use the photos to estimate the average floor area per floor. A field survey is needed to determine the number of floors per building to give the total floor area which is entered in line 3 of Worksheet 9.

If the scale of the aerial photos is sufficiently large, the number of building floors can be estimated by stereoscopically viewing overlapping 8-1/2- by 11-inch photos.

If a number of buildings are of similar size, estimate the average building size.

B Using maps supplied with "Census Tracts" data as reference, plot boundaries of all tracts lying wholly or partially within the 1-kilometer square.



Follow the same procedure to estimate SO_2 contributions from space heating using the area map on which were plotted the point source contributions of SO_2. As before, locate the maximum-impact wind vector for SO_2 and construct a 1-km square oriented on the SO_2 vector. Follow procedure A if aerial photos are available; otherwise use procedure B and plot census tract boundaries for all tracts lying wholly or partially within this square.

If procedure B is to be followed, complete Worksheet 8.

Worksheet 8 is designed to yield the gross total of floor areas of all heated structures in the 1-kilometer square area under consideration. Complete one worksheet for particulate emissions and a second for sulfur dioxide emissions, using the appropriate area maps.

Input data for the first section of Worksheet 8, listing dwellings having a given number of rooms, are available in "Census Tracts". If a given tract does not lie wholly within the 1-kilometer square, data are entered proportionally to the percentage of the tract that falls within the square. In completing Worksheet 8, proceed as follows.

Line 1: List the number of dwellings in each room-number category for each tract.

Line 2: Total the numbers of dwellings in each column.

Line 3: Multiply each column total by the factor (f) shown to obtain total heated area (in thousands of square feet) in each category.

Line 4: Add the totals for all columns in line 3 to obtain approximate total residential floor space within the 1-kilometer square. Non-residential floor area within the 1-kilometer square is calculated in the next section.

Worksheet 8. DETERMINING FLOOR AREAS (SPACE HEATING LOAD)

POLLUTANT: Particulates__________ SO_2__________ (Check one)

Dwelling Size Categories
Residential Buildings

		Number of rooms per dwelling							
1	Tract Number	1	2	3	4	5	6	7	8
2	TOTAL x f	x.650	x.800	x.950	x1.100	x1.250	x1.400	x1.600	x1.800
3	$\frac{\text{Sq.Ft.}}{1000}$								

4 TOTAL $(\frac{\text{Sq.Ft.}}{1000})$ __________

5 Non-Residential Uses

Street Address Number St. Name	Establishment Name	Floor Area (in thousands of sq. feet)

6 TOTAL - Non-Residential Floor Space __________

7 Update Information - Construction (sq. ft.) __________

- Demolition (sq. ft.) __________

8 GRAND TOTAL (4 + 6 + 7) __________
(Add construction, subtract demolition)

Line 5: Using tabulations from the appropriate sections of Polk or Haines "Criss-Cross", list addresses and full titles of all non-residential occupants within the square.

From the State "Directory of Manufacturers" and "Directory of Retail Businesses", obtain the floor space of each listed establishment, for those establishments not listed, and for other non-residential uses, such as institutional, obtain approximate floor areas by asking building managers or by noting the exterior dimensions of the buildings.

Line 6: Total all non-residential floor space.

Line 7: By consulting engineering records of the appropriate city or county building inspection authority, determine the total floor space constructed in the area since publication of the data. For example, if a site is analyzed in the year 1976, floor space of all residential construction between 1970 (the date of the last census) and 1976 should be determined and added. Floor area lost by demolition is deducted.

Line 8: Total residential and non-residential floor space, plus corrections obtained by checking of building records. Line 8 = line 4 + line 6 + line 7.

The value for total floor area within the 1-km square will be used in completing Worksheet 9, which yields total concentrations of particulate and SO_2 at the site attributable to space heating. Following are instructions for completion of Worksheet 9.

Line 1 and 2: Refer to "Detailed Housing Characteristics" (Bureau of Census publication) to determine the percentages of dwellings in the county (or city or SMSA) using coal and oil.

Line 3: Enter total floor area, from line 8 of Worksheet 5.

Line 4: Calculate amount of floor space heated by coal. Line 4 = line 1 x line 3.

Line 5: Calculate amount of floor space heated by oil. Line 5 = line 2 x line 3.

Worksheet 9. Pollution From Space Heating

Line		Particulates	SO_2
1	Percent of dwellings using coal		Same
2	Percent of dwellings using oil		Same
3	Grand total floor area		
4	Floor space heated by coal line 1 x line 3		
5	Floor space heated by oil line 2 x line 3		
6	65 -Tc = L 65 -____ = L =		Same
7	Particulate Emission: (line 4 + 0.76 x line 5) x line 6 x 10^{-11} gm/sec-m^2		
8	SO_2 Emission: (2.9 x line 4 + 3.2 x line 5) x line 6 x 10^{-11} gm/sec-m^2		
9	Concentration $\mu g/m^3$ (from Figure 5-11)		

Line 6: Enter temperature (Tc) of 97th-percentile coldest day, obtained earlier from U.S. Weather Service. Subtract from 65°F to obtain factor for heating load (L). $65 - T_c = L$

Line 7: Calculate particulate emissions.

$[1.0 \times \text{Line } 4) + (0.76 \times \text{line } 5)] \times L \times 10^{-11} =$ particulate emission in $\frac{\text{grams}}{\text{sec-m}^2}$

Line 8: Calculate SO_2 emissions.
$[2.9 \times \text{Line } 4) + (3.2 \times \text{line } 5)] \times L \times 10^{-11} = SO_2$ emission in $\frac{\text{grams}}{\text{sec-m}^2}$.

Line 9: Refer to Figure 5-11 with TSP emission from Line 7 and read TSP concentration, and with SO_2 emission from line 8 and read SO_2 concentration. Enter these data on line 9 and in the Summary Table.

POLLUTION FROM AIRPORTS

The air pollution impact of an airport on the site depends on the airport's capacity (number of aircraft operations) and its distance from the site. Any commercial airport within 8 kilometers (5 miles) of the site should be evaluated to determine whether airport emissions should be considered in computing total pollution impact.

From the Director, Public Relations, of the airport obtain the number of commercial landing and take-off operations (LTO) per year. Determine the distance (km) from the outer boundary of the airport to the site. Listed below are yearly LTO values and the corresponding distances at which the airport would have no significant impact. If the distance between an airport and the site is less than the distance corresponding to the number of LTO's at the airport, seek professional help in evaluating

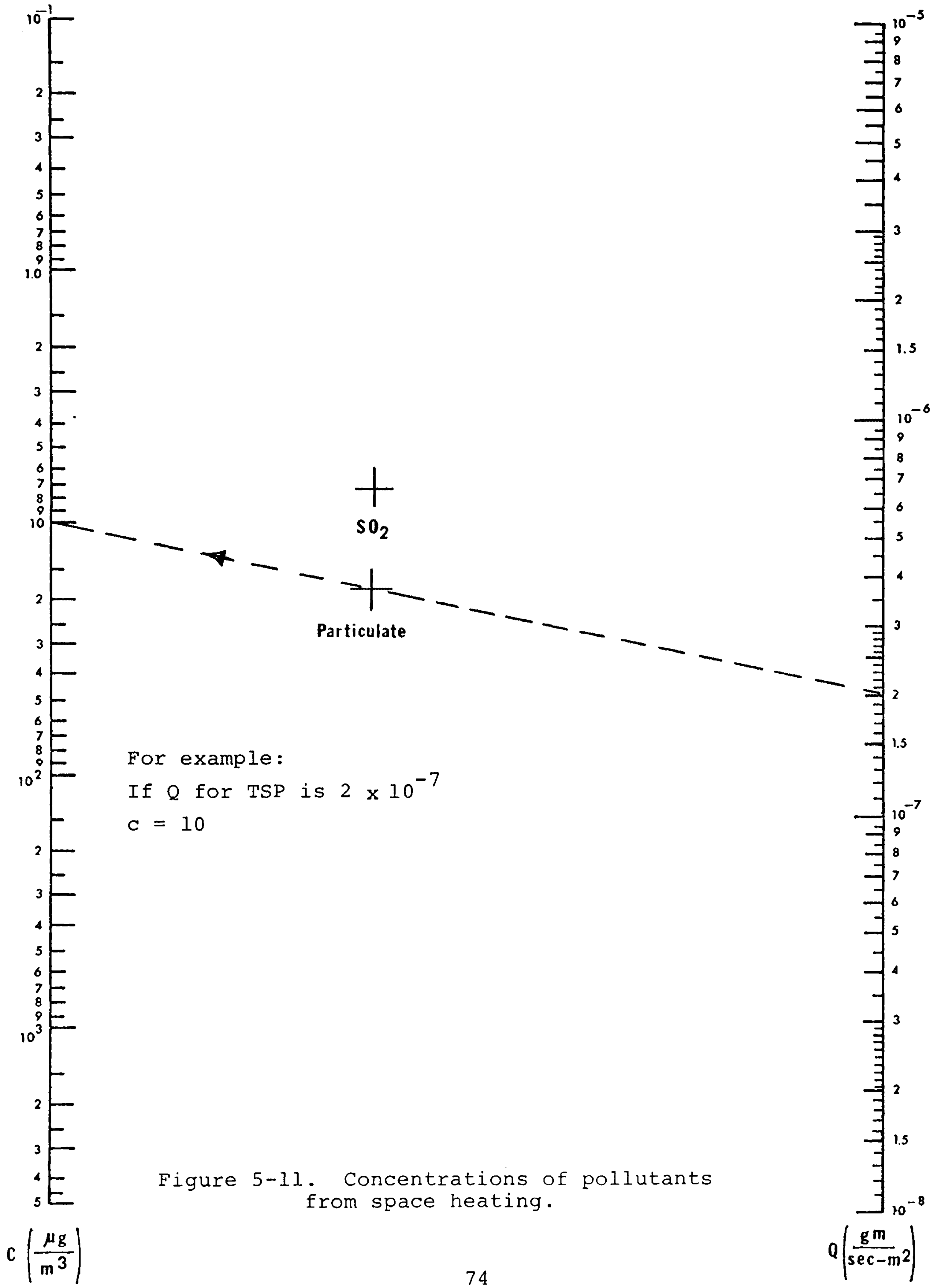


Figure 5-11. Concentrations of pollutants from space heating.

the impact of the airport.

Yearly LTO	Minimum distance between the outer boundary of the airport and the site at which airport has insignificant impact. (kilometer)
Less than 36,500	0.5
Less than 73,000	1.3
Less than 365,000	2.0
Above 365,000	5.0

EVALUATING OUTDOOR POLLUTANT LEVELS

The maximum outdoor levels of CO, particulates and SO_2 just calculated should now be compared with the standards.

CO - 15 mg/m^3, 1-hour level

TSP - 210 $\mu g/m^3$, 24-hour level

SO_2 - 450 $\mu g/m^3$, 3-hour level

If any of these standards have been exceeded, refer to Section 7 in an effort to minimize the outdoor levels. If any of the calculated levels are above 80 percent of a standard, proceed with Section 6 to calculate the indoor levels. If all levels are below 80 percent of each standard, no further calculations are required, however refer to Sections 6 and 7 for methods of minimizing site pollution levels.

6 CALCULATING INDOOR POLLUTANT LEVELS

This section presents procedures for calculating indoor concentrations of pollutants that penetrate the structure from the outside by various means and that are generated indoors. To some extent, the planner/designer can control certain factors affecting the ratio of indoor to outdoor concentrations: mass and shape of the building, permeability of the walls to pollutants, mechanical circulation and filtration characteristics, and the amount and treatment of pollutants generated within the structure.

The primary goal of the planner is to develop the site and the structures in such a way that pollutant levels indoors are maintained at an acceptable level. A further goal is to incorporate into the plans the means for achieving a superior level of indoor air quality.

An analysis is made for each structure in an area where outdoor pollutant levels are estimated to exceed 80 percent of the Federal standards. It is not necessary to perform duplicate analyses for identical structures exposed to virtually identical outdoor pollution loads. If the anticipated levels outside the structures do not exceed 80 percent of the standards, no analysis is required. For purposes of this analysis, 'structure is defined as a single dwelling or a number of dwellings within a common exterior wall and roof, such as an apartment building.

PRELIMINARY CALCULATIONS

Structural Analysis

The first step of the analysis is to assign a number to each structure to be analyzed and enter the numbers on the site map. Next, determine the structural characteristics of the buildings by preparation of Worksheet 10.

Line 1: Calculate and enter total volume (V) of the interior heated or cooled portions of the structure.

Line 2: Calculate and enter the total exterior surface area (SA) of the structure.

a) SA_C: Ceiling or roof surface, whichever forms the exterior boundary of heated or air-conditioned volume.

b) SA_W: Wall surface, including fixed windows.

c) SA_O: Area of moveable windows and doors

$$SA = SA_C + SA_W + SA_O$$

Line 3: Calculate and enter Volume to Surface area ratio (F).

$$F = V/SA$$

Permeability Coefficients

Line 4: Calculate and enter the proportion (P) of each component of surface area to the total surface area. Again, subscripts c, w, and o indicate ceiling, wall, and movable areas.

a. $P_C = \dfrac{SA_C}{SA}$

b. $P_W = \dfrac{SA_W}{SA}$

c. $P_O = \dfrac{SA_O}{SA}$

Worksheet 10. STRUCTURAL CHARACTERISTICS OF BUILDINGS

	Structure Number 1	2	3
Dimensional Parameters			
1. Volume (V)			
2. Surface Area			
a. SA_c			
b. SA_w			
c. SA_o			
d. Total SA			
3. Ratio (F) of Volume to Surface Area $F = V/SA$			
Coefficients Permeability			
4. Proportion (P) of each component			
a. $P_c = \frac{SA_c}{SA}$			
b. $P_w = \frac{SA_w}{SA}$			
c. $P_o = \frac{SA_o}{SA}$			
5. Permeability Coefficient (K)			
a. K_w (from Table 6-1)			
b. K_o (from Table 6-1)			
6. Weighted Permeability Coefficients			
a. $X = P_c K_w$			
b. $Y = P_w K_w$			
c. $Z = P_o K_o$			
d. $K = X + Y + Z$			
7. Indoor-Outdoor Ratios — CO			
TSP			
SO_2			

Line 5: Refer to Table 6-1. Select permeability coefficients corresponding to wall and ceiling construction, and window construction and enter in Line 5a and b.

Table 6-1. STRUCTURAL PERMEABILITY COEFFICIENTS

Wall and ceiling construction	Permeability coefficient (K_w)
Frame construction with infiltration barrier*	0.15
Frame construction without infiltration barrier	2.50
Masonry construction with infiltration barrier	0.25
Masonry construction without infiltration barrier	3.50
Window and door construction	**Permeability Coefficient (K_o)**
All weatherstripped windows	15
Casement, non-weatherstripped	25
Double hung or horizontal sliding, non-weatherstripped	50

* Infiltration barrier materials in order of effectiveness: metal film, mylar film polyester film, stucco, plaster, plasterboard.

Line 6: Compute and enter the weighted permeability coefficients (K), using appropriate K factor as selected from Table 6-1.

a) $X = P_c K_w$

b) $Y = P_w K_w$

c) $Z = P_o K_o$

d) $K = X + Y + Z$

Line 7: Indoor/outdoor ratios for CO, SO_2 and particulates are presented below. Figure numbers refer to graphs developed for relationships of different pollutants and heating/circulation systems.

The E shown in Figure 6-1 to 6-4 refers to the filter removal efficiency.

Pollutant	Heating/circulation system	$\frac{\text{Indoor}}{\text{outdoor}}$ Ratio or	Figure number
CO	All Systems		6-1
SO_2	All Systems	0.60	Constant
TSP	Unfiltered Systems*	0.96	Constant
TSP	No Make-Up Air		6-2
TSP	Make-Up Air Filtered		6-3
TSP	Recirculated Air and Make-Up Air Both Filtered		6-4

* Unfiltered systems include hot water and steam radiator (hydronic) systems, electric room units, electro-hydronic systems, and forced-air systems without filtration.

The indoor/outdoor ratios can be read directly from the graphs by use of the appropriate permeability coefficient (K) (Worksheet 10, line 5) and volume to surface area ratio (F) (Worksheet 10, line 3).

Pollutants Generated Indoors

In addition to the pollutants that infiltrate structure walls or are drawn into air intakes, pollutants generated within dwelling structures affect interior pollution levels, sometimes significantly. The activities that produce pollutants within our range of consideration are cooking and attached garages, which produce measurable amounts of CO and hydrocarbons; walking

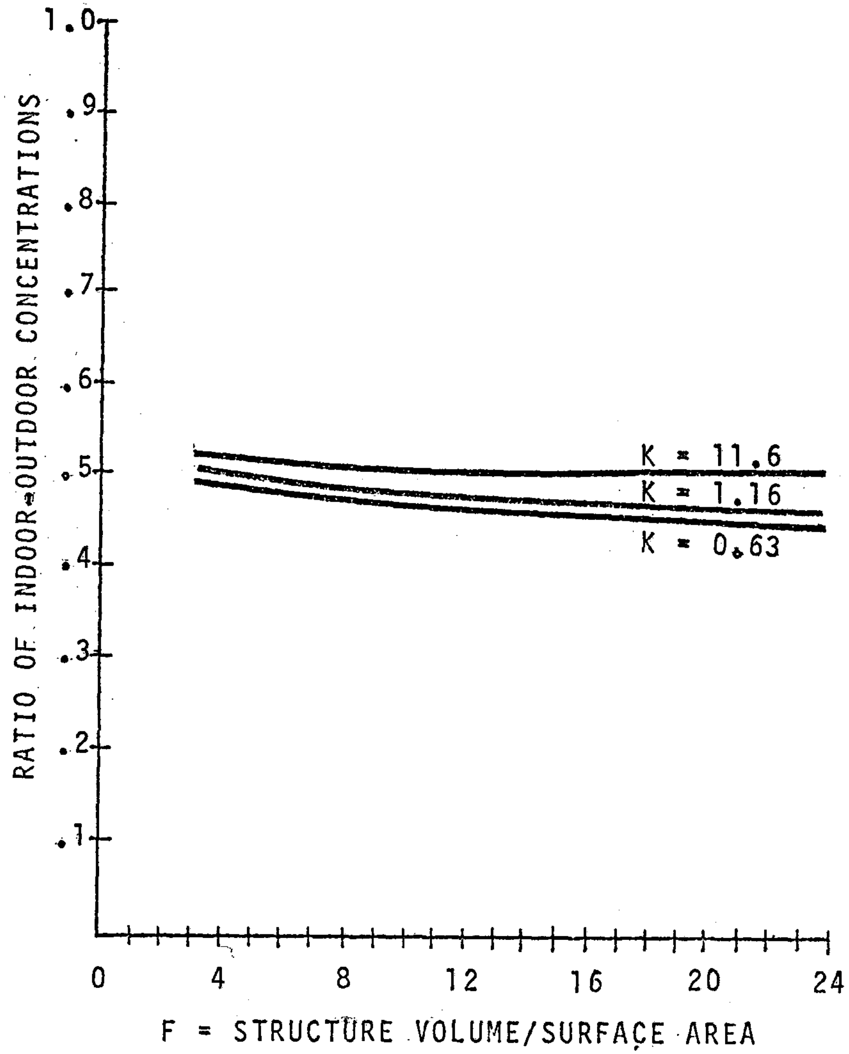


Figure 6-1. Indoor-outdoor ratios: carbon monoxide, all systems.

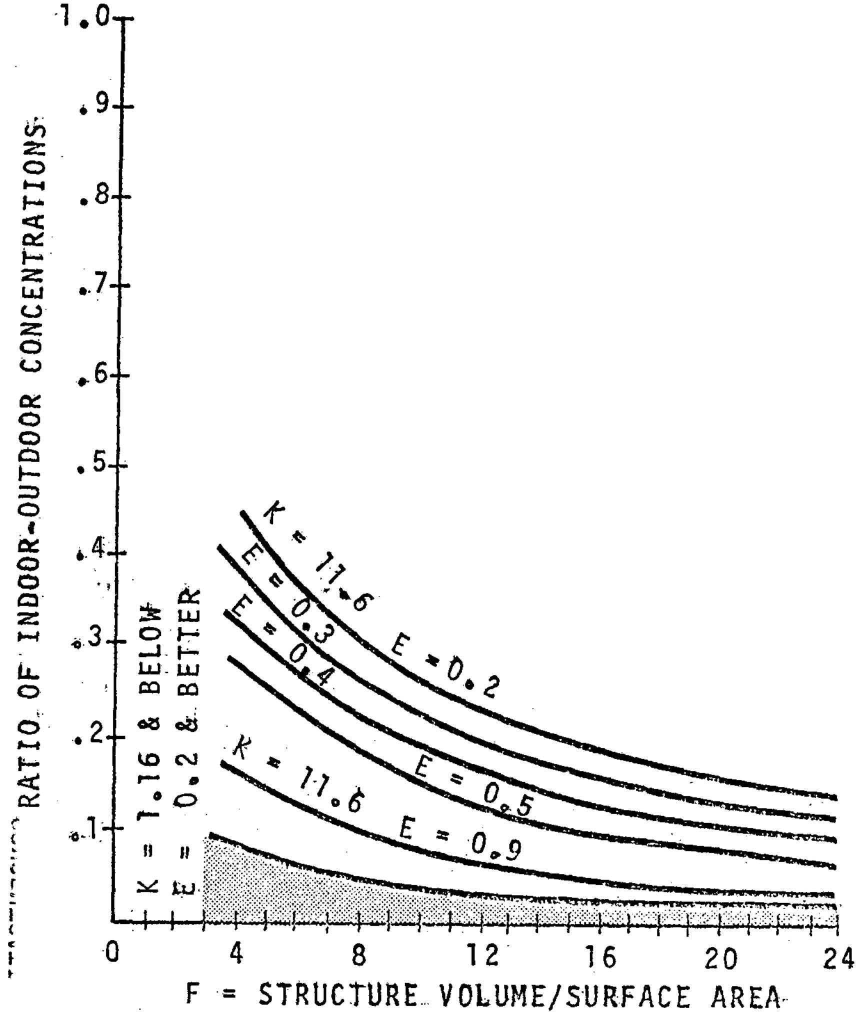


Figure 6-2. Indoor-outdoor ratios: particulates, recirculation, no make-up air.

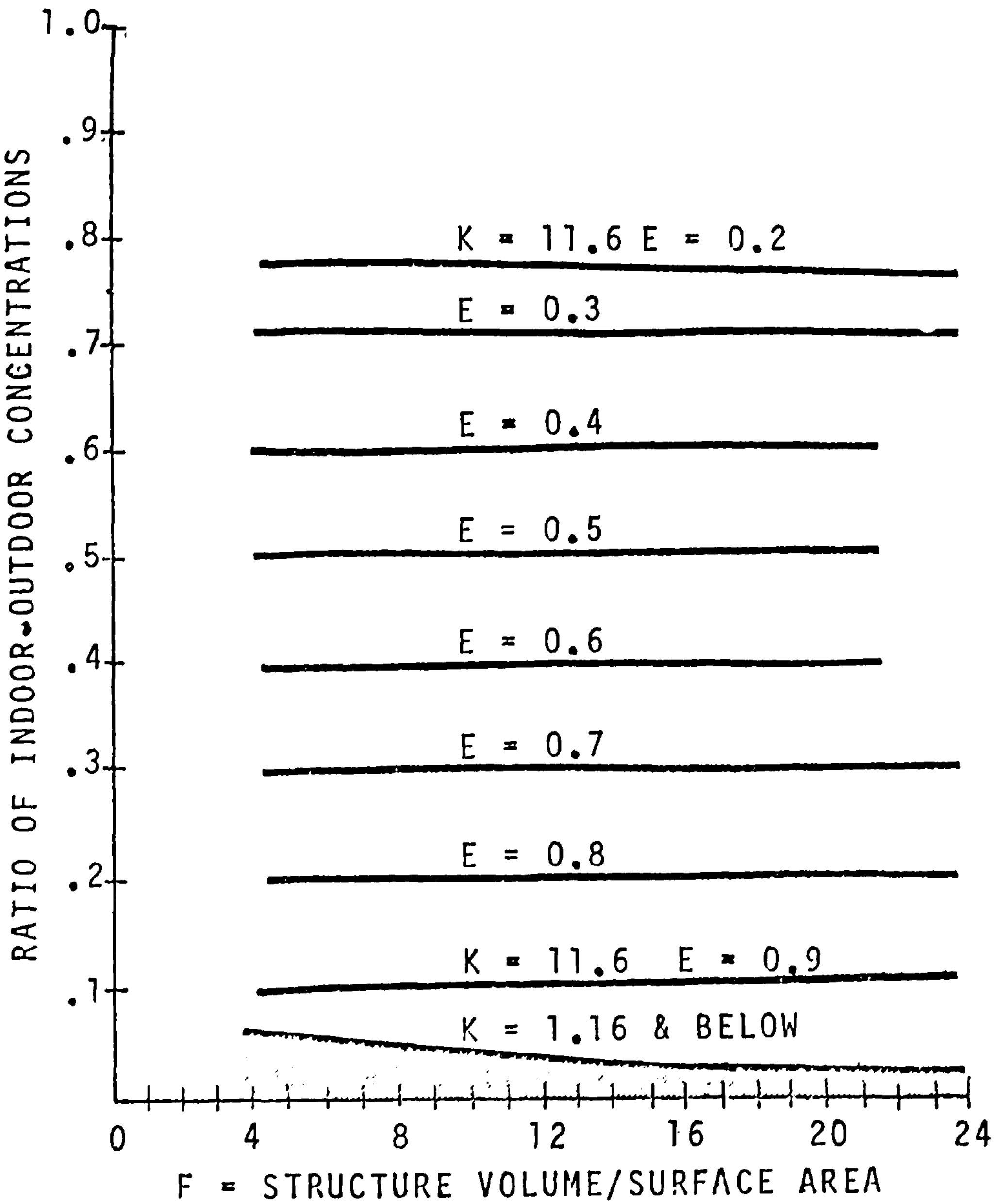


Figure 6-3. Indoor-outdoor ratios: particulates, make-up air only filtered.

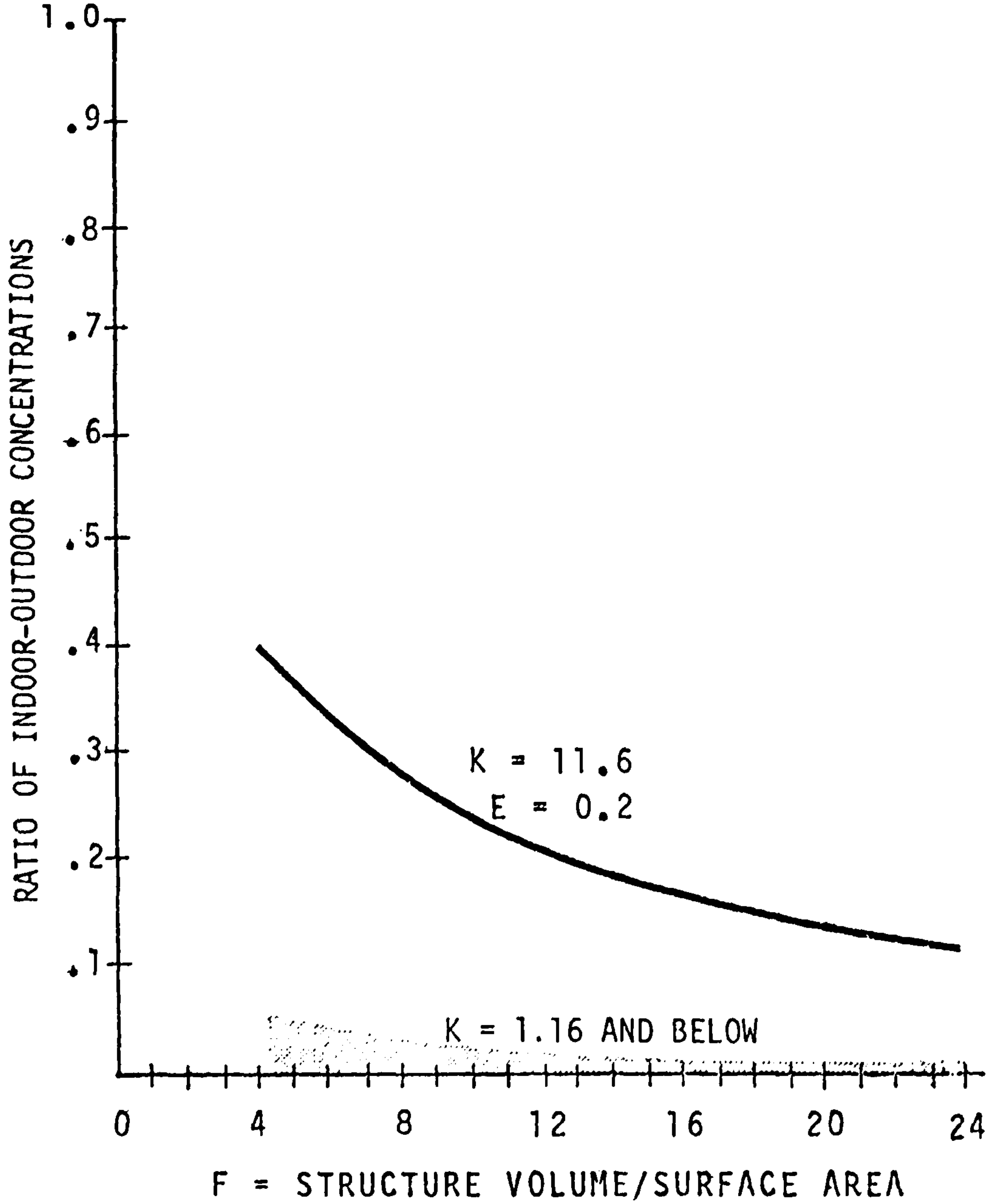


Figure 6-4. Indoor-outdoor ratios: particulates, recirculation and make-up air.

and cleaning, which increase the dust level; and tobacco smoking, which produces fine particulate materials. On the basis of limited test data, some average increases in pollutant concentration to be expected from indoor factors have been estimated. These factors are listed in instructions (line 4) for completion of Worksheet 11, which summarizes total potential concentrations of indoor pollutants at the site.

TOTAL INDOOR POLLUTANT CONCENTRATIONS

Worksheet 11 will yield the total pollutant concentrations to be expected within structures at the site.

Line 1: Enter total outdoor levels calculated for each pollutant (from pollutant concentration summaries).

Line 2: Enter indoor/outdoor ratios (Worksheet 10, line 7).

Line 3: Calculate indoor concentrations from outdoor sources (line 1 x line 2).

Line 4: Enter concentrations due to indoor pollutant generation, as shown below:

CO:

For attached garage, add 0.5 mg/m^3 (single family residence).

For gas cooking, add 0.5 mg/m^3 per dwelling unit.*

Particulate:

For forced-air systems without filtration, add 0.10 to values derived from graphs.

For non-forced-air systems, add 0.22 to the indoor/outdoor ratios used on Worksheet 10.

Line 5: Calculate total indoor concentrations (line 3 + line 4).

---

* Multi-family garages are highly variable in configuration, auto density, method of attachment to structure, and type and location of ventilation exhausts. Thus, they have been excluded from the manual.

Worksheet 11 - TOTAL INDOOR POLLUTANT CONCENTRATIONS

Line		Structure Number 1	2	3
1	Total Outdoor Levels CO (Section 5) mg/m^3 TSP (Section 5) $\mu g/m^3$ SO_2 (Section 5) $\mu g/m^3$			
2	Indoor-Outdoor Ratio CO TSP SO_2			
3	Indoor Concentration from Outdoor Source CO mg/m^3 TSP $\mu g/m^3$ SO_2 $\mu g/m^3$			
4	Concentrations due to Indoor Generation CO mg/m^3 TSP $\mu g/m^3$			
5	Total Indoor Concentration CO mg/m^3 TSP $\mu g/m^3$ SO_2 $\mu g/m^3$			

The indoor CO level obtained here is for an 8-hour period. This change from time duration of the outdoor level was made to incorporate the effects of building construction on pollutant dispersion.

EVALUATING INDOOR POLLUTANT LEVELS

The following standards cite pollutant levels not to be exceeded more than 3 percent of the time period:

Particulates	210 $\mu g/m^3$ for 24 hr
SO_2	450 $\mu g/m^3$ for 3 hr
CO	6 mg/m^3 for 8 hr

Compare these values with those on Worksheet 11, line 5. If the worksheet values are higher, the indoor levels are considered too high for exposure for the general population.

If indoor concentrations exceed the standards, there is often a potential for reducing the concentrations by manipulation of certain elements of design, such as structure permeability and the configuration or operation of the air circulation system. Refer to Section 7 (Structural Design) for ways to reduce indoor pollutant levels. A more rigorous analysis of potential for structural reduction of air pollution levels requires access to a computer and probably the services of a specialist in air conditioning and heating. If any structural or mechanical characteristics of the building are changed, follow the procedures of Worksheets 7 and 8 for analysis of the new configuration.

7 RECOMMENDED DESIGN PRACTICES

Although the residential developer may consult with the site planner before he selects parcels of land for a proposed development, it is much more likely that he will have purchased the land long before site planning begins. The planner, therefore, usually has little control over the kinds and quantities of pollutants that may reach the development site. Certain means are available, however, by which the planner and the developer may reduce the impact of pollutants on future residents of the complex. These design practices are recommended for consideration though their effects are not yet fully known. Some entail very little cost. Each has been shown to constitute a step toward the goal of reducing the impact of air pollution in and around residences.

SITE DESIGN

Setbacks. Studies have shown that concentrations of pollutants from heavily traveled roadways decrease almost exponentially with distance from the center of the road (see Figure 5-3). Setback of structures or of heavily frequented areas of the site from major roadways can therefore reduce the average exposure of the residents. For site locations at which the standards are exceeded, this is normally the first method used to reduce pollutant impact.

Landscaping. Although trees, shrubs, and other landscape features do not significantly affect the reduction of pollutants, either by screening or by biochemical action, they do affect wind speeds and the mixing of air. Trees and landscape masses tend to induce turbulence in air flow, which in turn tends to reduce the intensity of air pollution at ground level because of improved mixing. Placing trees and other landscape masses next to structures also can reduce wind pressures against exterior walls of the structures in the windward direction. Conversely, in the leeward direction, trees tend to break up the "vacuum" effect. In general then, trees tend to reduce pressures and vacuums against walls of buildings and therefore, the infiltration of pollutants into structures. Because of these considerations, as well as aesthetic and ecological concerns, site developers show increasing interest in conserving mature trees and wooded areas of a site and in placement of structures in optimum relation to these natural features.

Parking. Whenever possible, planners should avoid large masses of parking space in favor of smaller parking areas more broadly distributed. This scheme will tend to reduce the peak pollution load on any given structure, although it will also increase the average exposure throughout the development. Setbacks from parking areas are beneficial.

Grading. Planners should avoid site grading that creates low sump areas, since these spaces tend to trap pollutants. During cold weather, these sumps collect a laminar stratified body of air in which pollutants of all kinds are trapped.

Arrangement of Structures. Arrangement of structures in such a manner as to block the through movements of prevailing winds tends to trap, pool, and stagnate air masses. Planners therefore should avoid long linear blocks of structures without breaks if at all possible. Along the street-ward side of structures, long linear facades, especially those of uniform height, tend to create a 'canyon' effect, which can, in certain conditions of wind velocity and direction, greatly increase the localized wind speeds (as much as 4 to 5 times the prevailing wind speeds at rooftop levels). Whenever possible, varying setbacks should be introduced in order to break up the canyon effect. Use of setbacks and other features of site design are illustrated in Figure 7-1.

BUILDING AND CONSTRUCTION

Permeability. All structures should include in the exterior walls vapor barrier material having an effective permeance of approximately 2 perms per 100 square inches, as defined in ASTM Standard C-355. Reduction of infiltration will greatly reduce the peak pollution values below those encountered outside the structure.

Door and Window Sealing. By far most of the infiltration delivered to the interior of a structure is through seams and cracks in windows and doors and through the openings of openable windows and doors. Therefore, it is recommended that all openable doors and windows be properly weather-sealed, with a seal

SETSBACKS (HORIZONTAL AND VERTICAL)

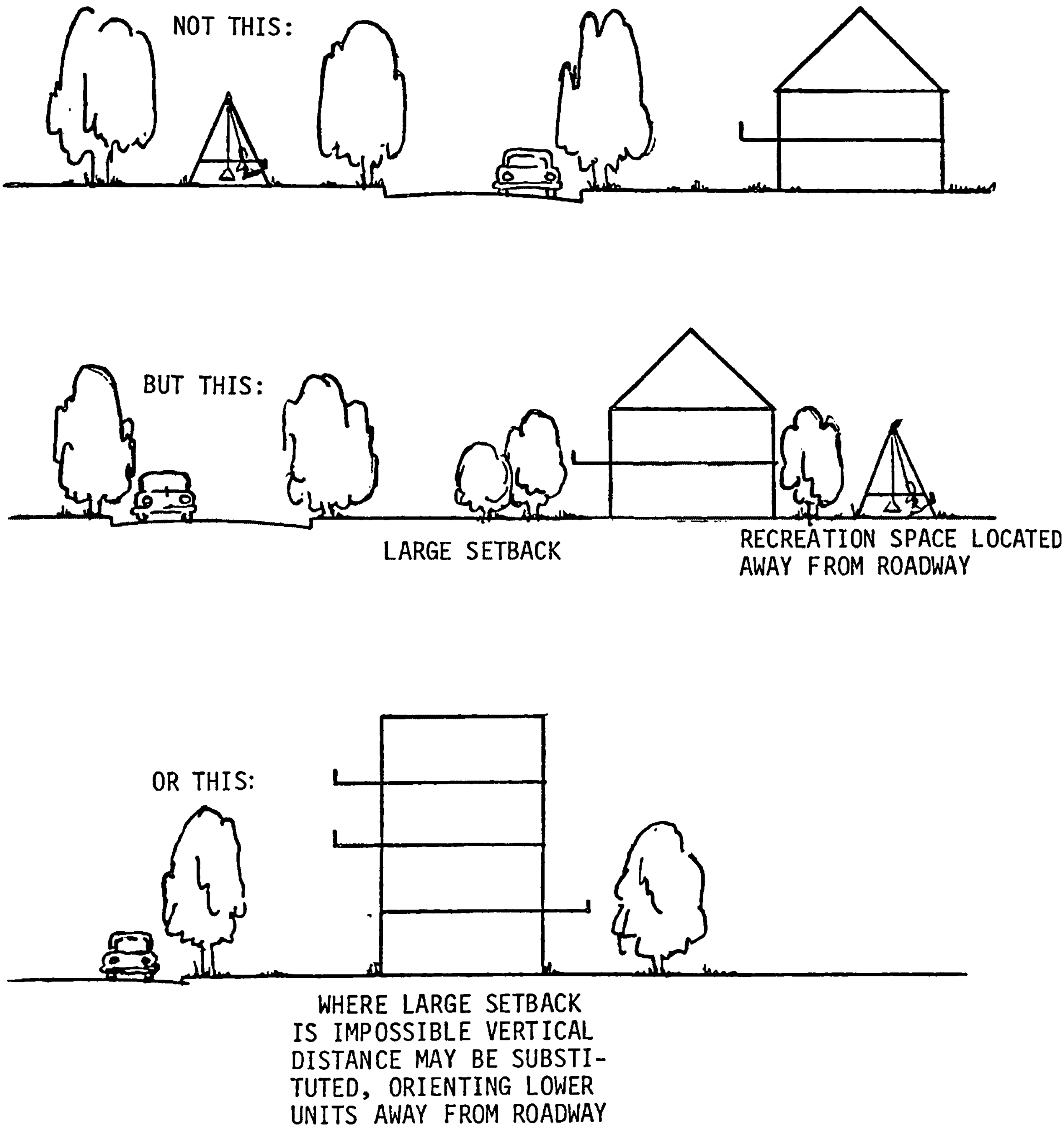


Figure 7-1. Illustrations of good and poor design practices.

NOT THIS:

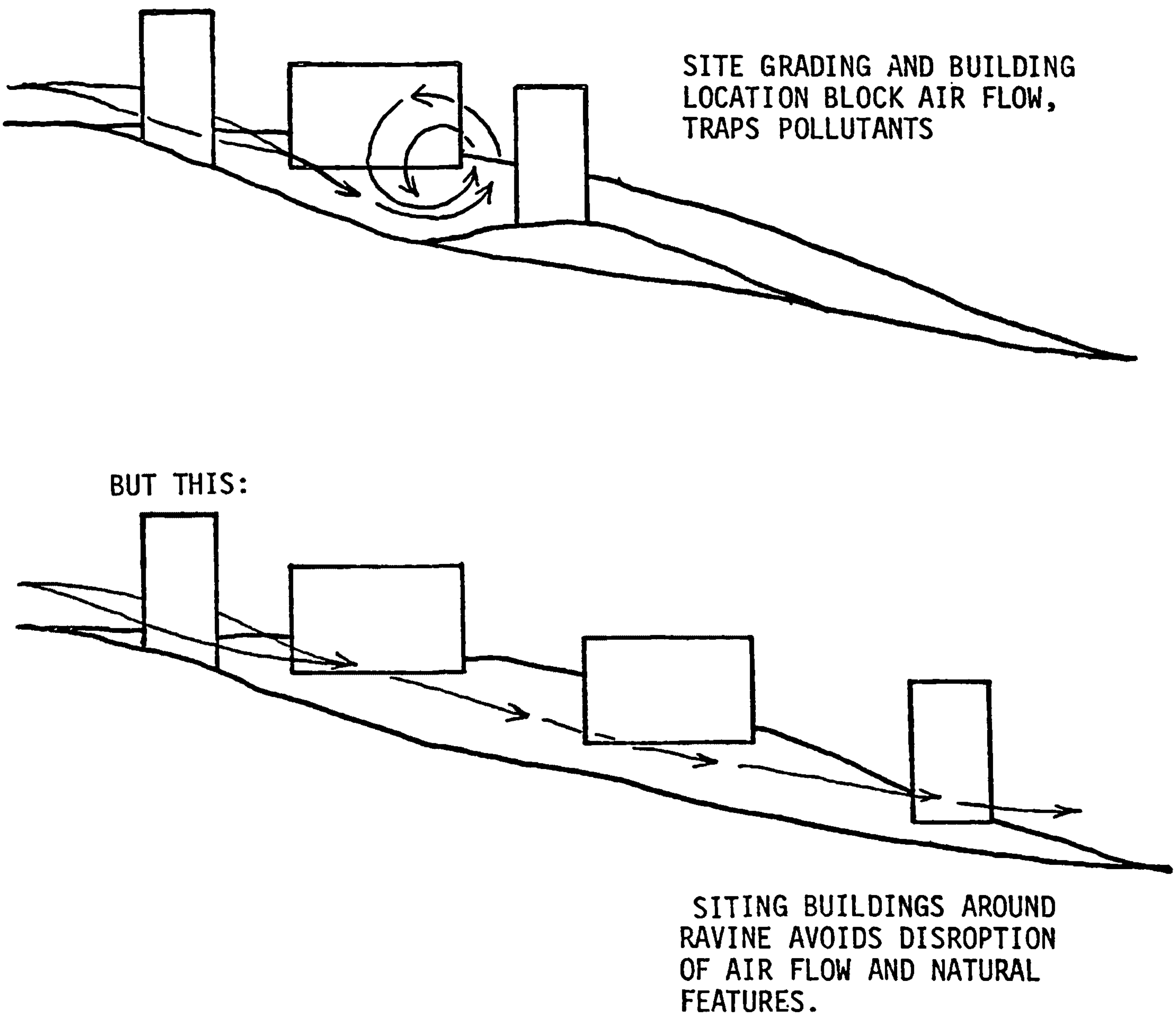
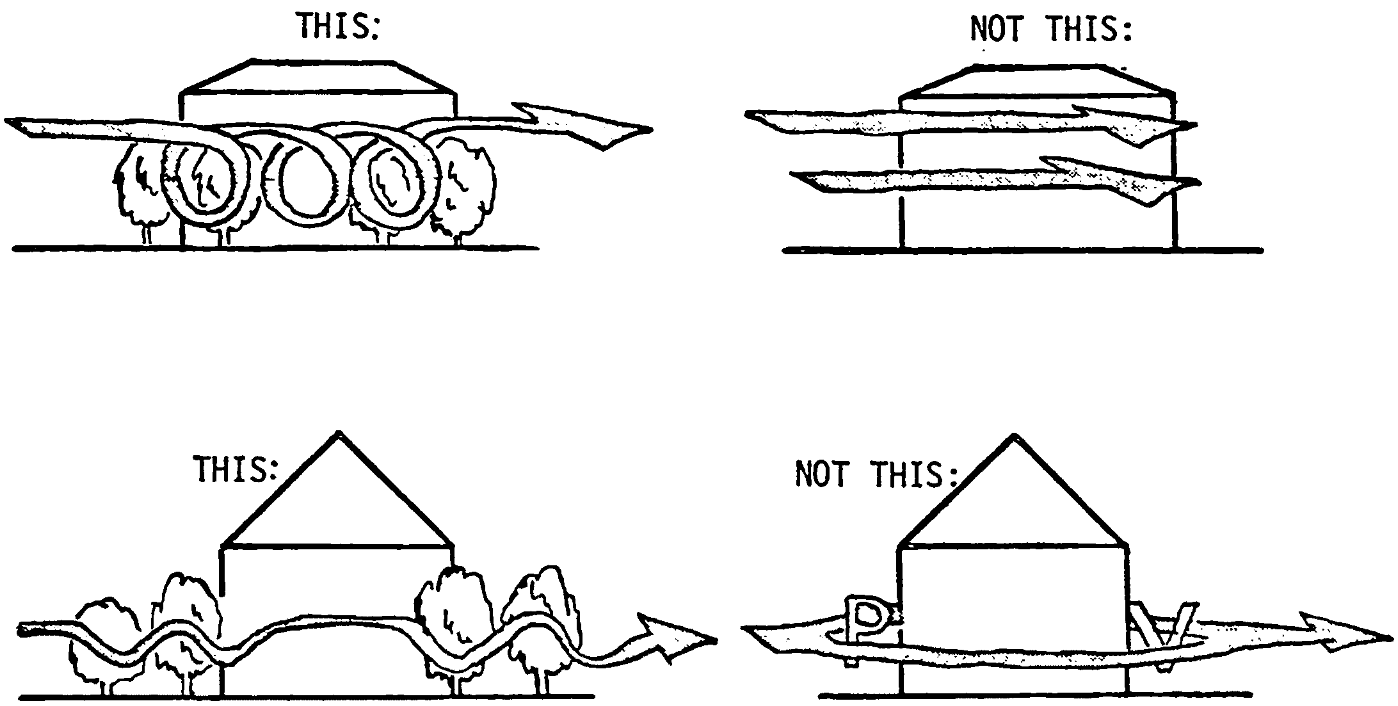


Figure 7-1. (Continued).
Illustrations of good and poor design practices.

LANDSCAPING



PARKING

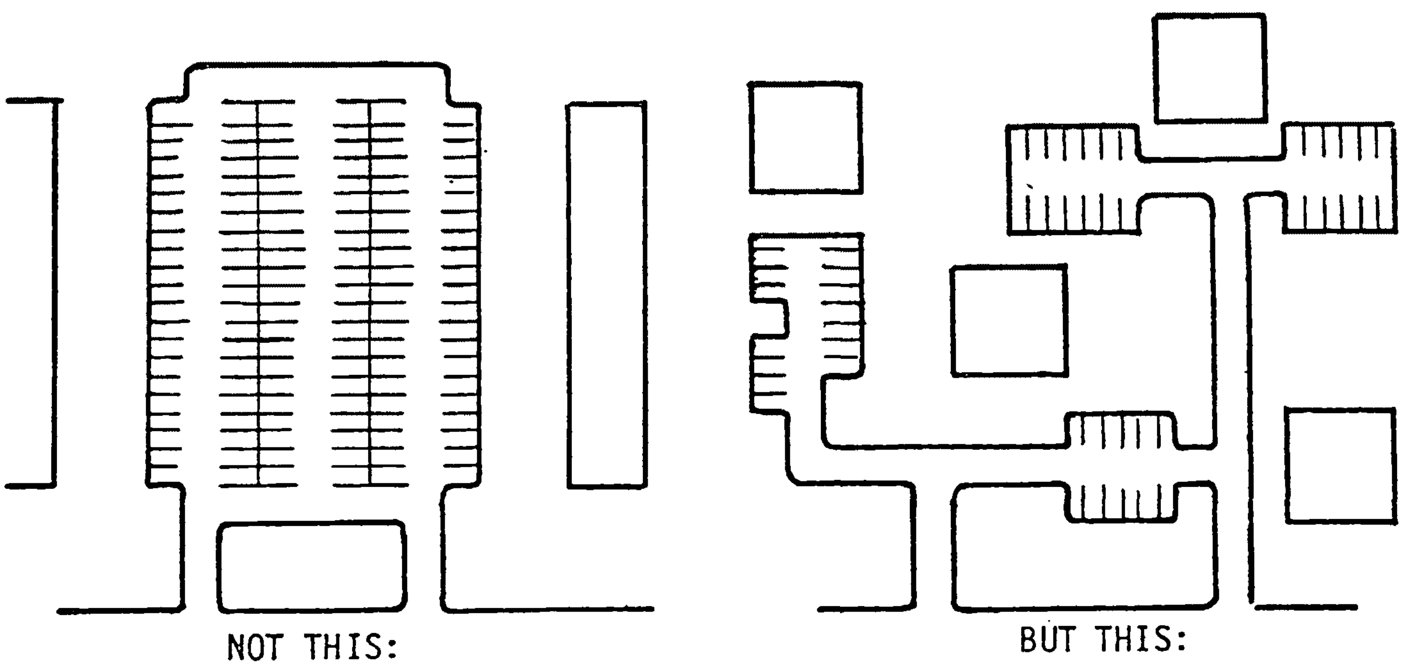


Figure 7-1. (Continued).
Illustrations of good and poor design practices.

ARRANGEMENT OF STRUCTURES

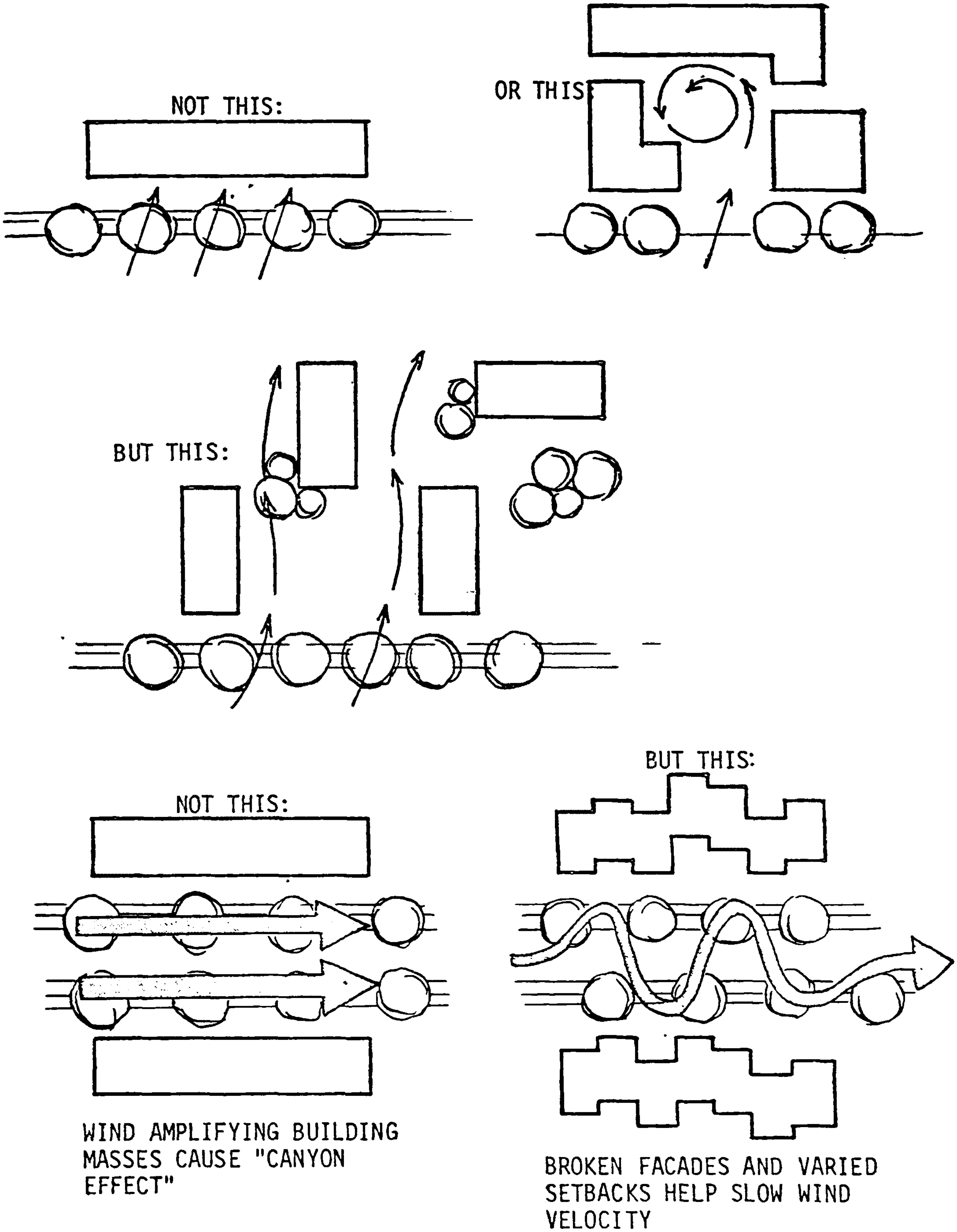
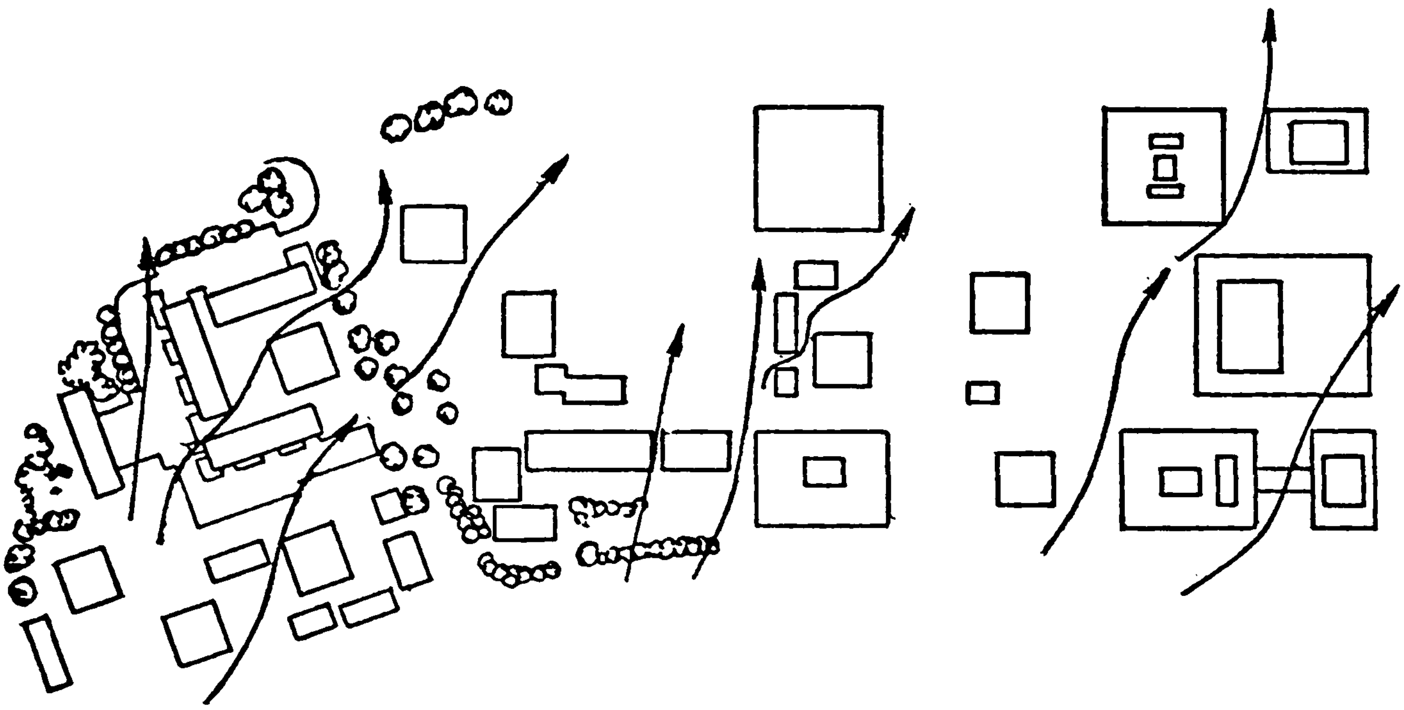


Figure 7-1. (Continued).
Illustrations of good and poor design practices.

Note openness of the plan to wind movements.



Towers tied together form a wind barricade. A redeeming factor is rough aerodynamics of the surface and a good setback.

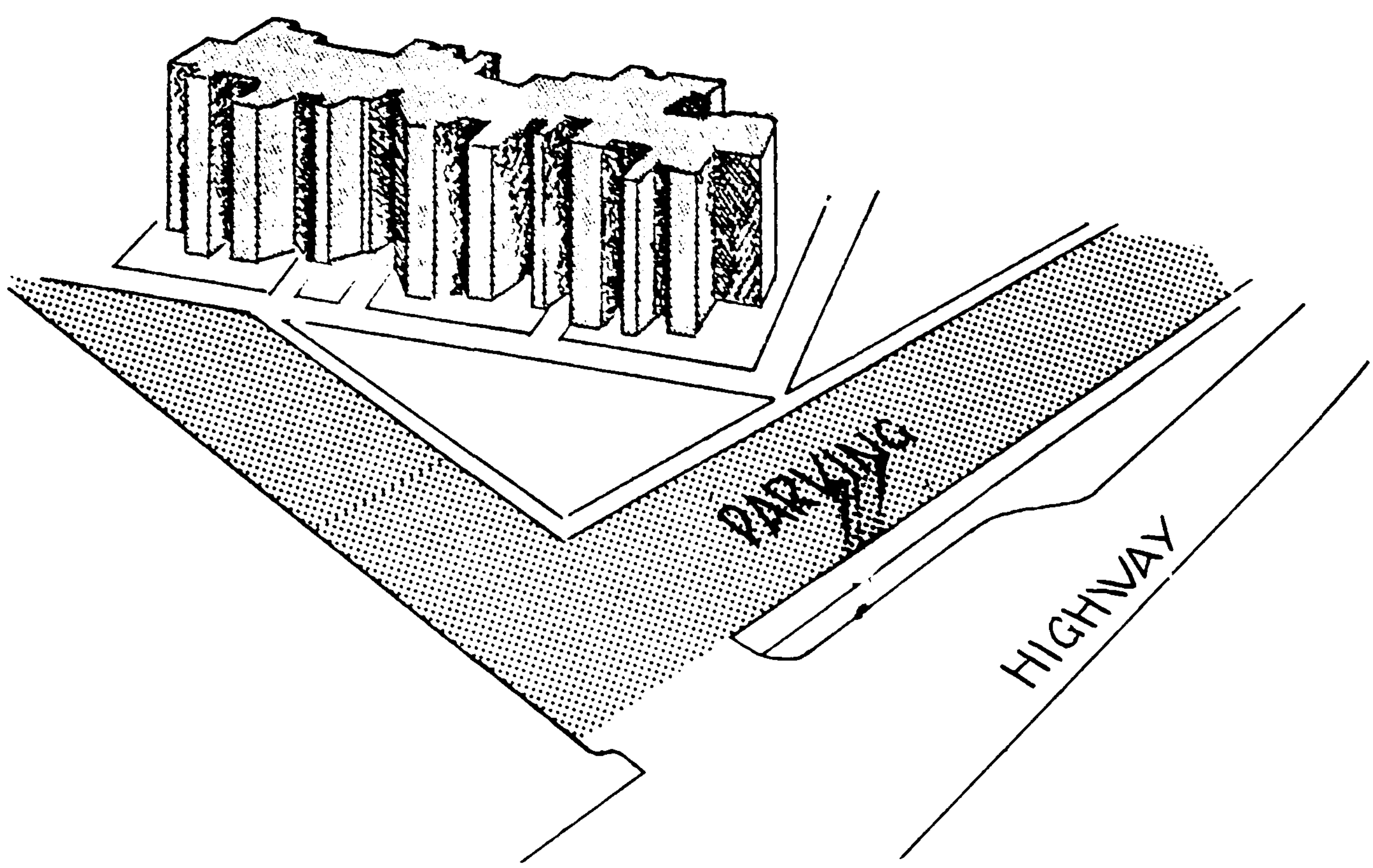


Figure 7-1. (Continued).
Illustrations of good and poor design practices.

that meets a test specification of passing no more than 10 cubic feet per hour per linear foot of opening along an interface between window and frame (or door and frame). For high-rise structures, it is recommended that main entry doors be vestibule doors, that is double swinging doors structures, or that entrances having extremely high traffic be equipped with revolving doors. Vestibule doors or positive air pressure locks between spaces and parking garage structures are also required.

Circulation. Introduction of outside air for circulation within the structure should be reduced to the absolute minimum required for oxygen supply to inhabitants, for interior combustion, and for reduction of odors within the structure. This value is usually about 7 cubic feet per minute per inhabitant. Even this level could be reduced by use of effective filtration devices in a central air conditioning plant.

Filtration. It is recommended that all central air circulation and air conditioning systems incorporate a high-efficiency filter (overall filtration efficiency of over 90 percent for particulate removal). Most electronic filters on the market and many low-rate mechanical filters now provide this degree of efficiency.

Oxidizing Agents. Oxidizing agents such as the permanganates and activated charcoal have a marked effect in reducing odors in the air and also a lesser effect in reducing levels of certain hydrocarbons, some of the oxides of sulfur, and a fair amount of oxides of nitrogen. Use of devices incorporating activated charcoal or permanganate wash as oxidizing agents is encouraged in central air conditioning systems.

Central Air Conditioning. In warm-weather areas, central air conditioning greatly reduces peak interior concentrations of air pollutants during hot weather periods. With open windows in all types of structures, the interior concentrations of every pollutant tend to approximate outdoor values very closely. Structures can be sealed and closed only if they are properly air-conditioned. Air conditioning devices, in themselves, provide a slight filtering effect since particulates tend to condense on the cooling coils and fallout of dust is caused by turbulence around the coils.

Air Conditioning Programming. There is a potential for reducing both short-term peaks and long-terms averages of air pollutant levels in tightly sealed structures by properly timing the introduction of makeup air into the system. Many commercial systems recharge makeup air into the system when they start in the morning, at approximately 7:00 a.m. If the charging period is moved ahead to a time at which outdoor pollutant levels are extremely low, the levels inside can be reduced throughout the entire daytime period. This application is also a possibility for homes, especially for multi-family home heating and air conditioning systems.

Venting of Structures. The architect and designer should be aware of the potential for polluting a building by reintroduction of pollutant materials from its own or closely adjacent flues and vents. Certain design rules should be followed as a matter of course:

1. Air intakes for ventilation systems should be well separated from major exhaust vents and chimney flues.

2. Chimney flues should project well beyond the roof ridge lines.

Cooktop-Vents - Emissions from gas-fired cooktops are concentrated in the cooking area. Effective venting to the outside will reduce pollutant concentrations. Vents that recycle polluted air from the cooktop area through an activated charcoal filter are not effective for removal of carbon monoxide or nitrogen dioxide. Vents should be located directly above the cooktop surface, no more than 4 feet away, and should be constructed with effective backflow prevention valves to prevent infiltration of outside air during periods when the vent is not operating.

8 SITE ANALYSIS: AN EXAMPLE

This section presents an example of analysis of potential air pollution impact on a suburban residential housing site. In this illustration we follow the procedures outlined earlier, using the suggested worksheet formats and consulting the figures and tables provided. The target year for the analysis is 1974.

COLLECTING DATA

The first step in data collection is acquisition of a 1 inch = 200 feet area map for the roadway calculations and a 1 inch = 10,000 feet map for point source calculations. Although the entire map cannot be reproduced here, Figure 8-1 shows a simplified sketch of the area and Figure 8-2 depicts the immediate vicinity of the proposed site. The development will contain four 3-story, 12-unit apartment buildings on 4 acres of land.

We next identify and categorize the six significant roadways indicated in Figure 8-2. We obtain traffic counts and speed limits for these roads from the local traffic engineer. On the basis of 45-degree sectors plotted on the area map, we determine total "collector" and "highway" street length; in this instance the site qualifies as "low density".

Since the only parking facility meeting the significance test is the proposed on-site parking, we estimate dimensions of the parking area. It is noted also that no airports are

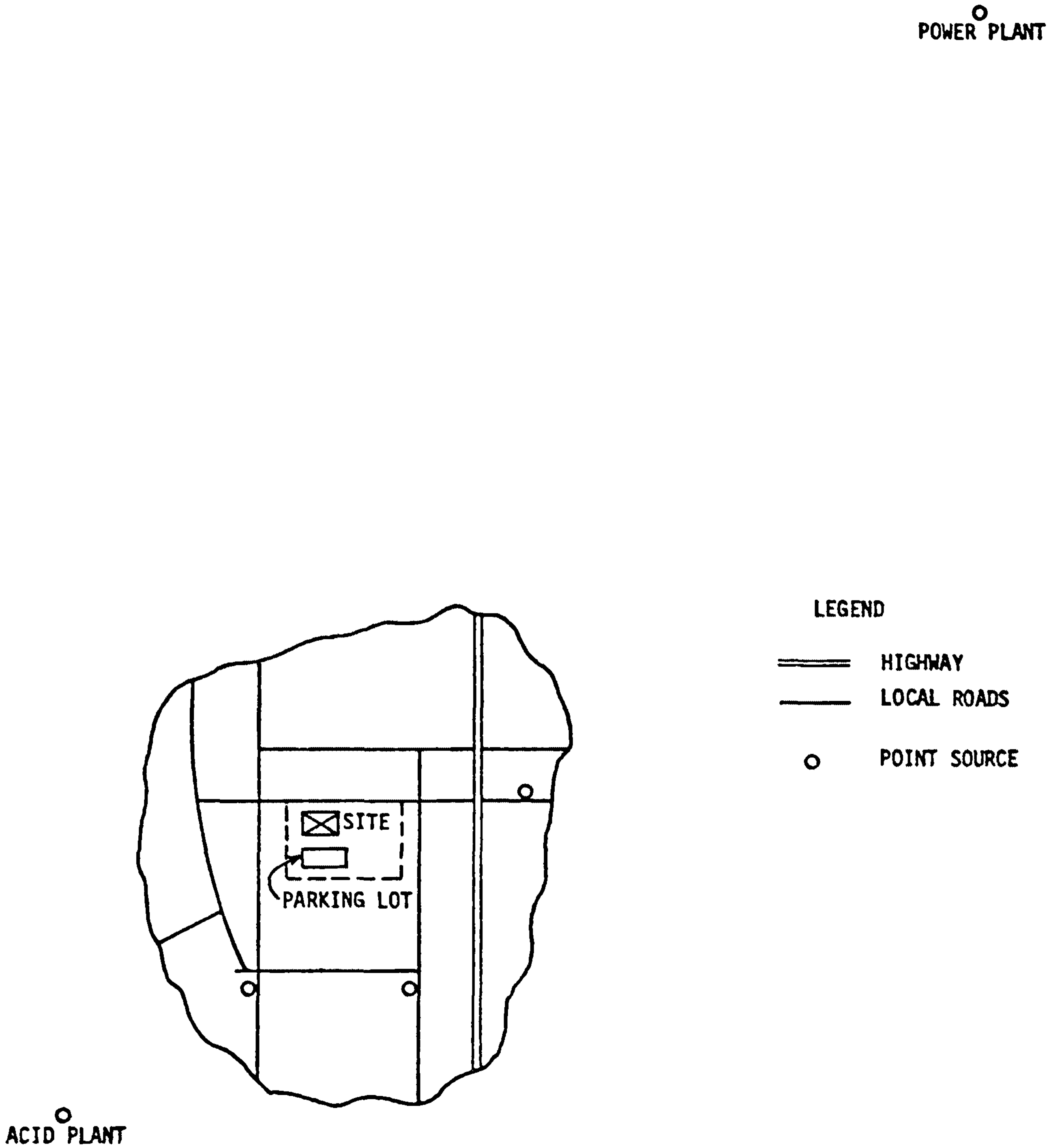


Figure 8-1. Simplified area map for the example.

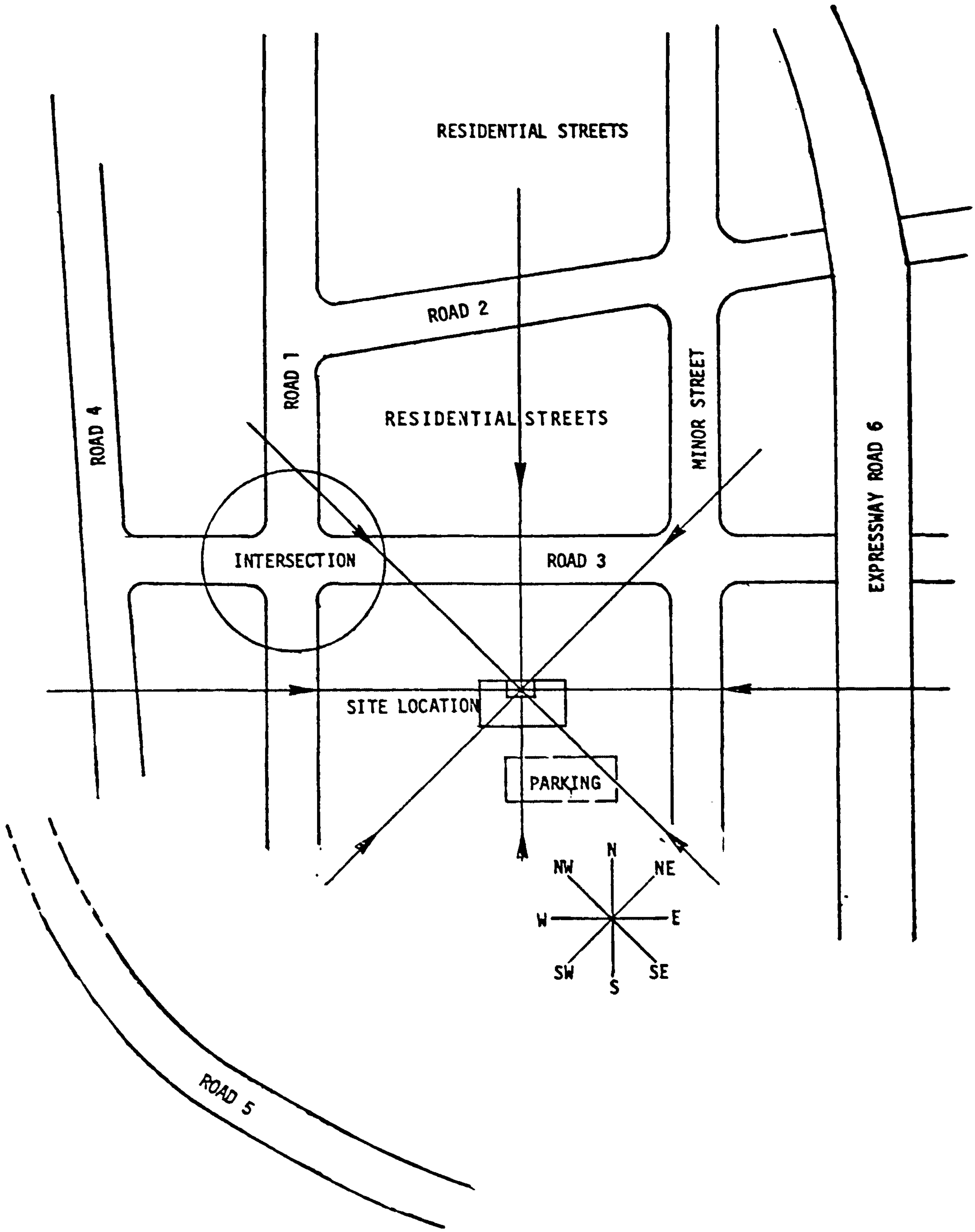


Figure 8-2. Schematic representation of a section of an area map for the example.

located within 5 miles of the site.

Since aerial photographs of the area are not available, maps and "Census Tract" data are obtained from the local A-95 Review Agency. Calling the U.S. Weather Service, we learn that the local mean temperature is 20°C and the 97.5 percentile low temperature is 0°C.

With this preliminary information, we are prepared to begin computing the pollution levels at the site.

The site will contain 48 housing units on 4 acres of land; according to the criteria given in Section 4, we can categorize the development as small low-density. Thus, only one central site location is used for the calculation procedure for each pollutant.

COMPUTING CO CONCENTRATIONS

Emissions from Roadways

The first step is completion of Worksheet 1, providing traffic data for each of the six significant roadways affecting the site.

Next the specific site location must be identified to check the CO level. A location at the center of the four buildings at first-floor elevation is selected. Other site locations should be evaluated if results of this analysis indicate a high pollution level.

Notice on the example worksheet that not all information is required for all roads. For road 6, however, which is the only highway, the V/Ca ratio (line 13) is required.

$$V/Ca = \frac{11{,}200 \text{ (line 10)}}{2000 \times 6 \text{ (line 7)}} = 0.93$$

Worksheet 1. EMISSIONS FROM SINGLE ROADS

Line						
1	Projection year	1974	1974	1974	1974	1974
2	Road number	1	2	3	4	5
3	Road name					
4	Normal distance, km	40	120	30	150	200
5	Peak traffic volume (V), vph	1600	560	700	1000	2100
	Complete lines 6 through 12 only if traffic data for line 5 is not available.					
6	AADT, vpd	—	—	—	—	—
7	Peak lanes (N)	—	—	—	—	—
8	Off-peak lanes	—	—	—	—	—
9	Daily traffic/lane pair	—	—	—	—	—
10	Peak lane volume, vph	—	—	—	—	—
11	Off-peak lane volume, vph	—	—	—	—	—
12	Total traffic (v), vph	—	—	—	—	—
13	V/Ca for highways	—	—	—	—	—
14	Traffic speed, mph	25	20	15	30	25
15	CO emission factor (Eco), gm/mi	48.7	63.4	91.2	48.7	48.7
16	CO emission rate (Qco), mg/sec-m	13.4	6.1	11.0	8.4	17.7
17	Intersection emissions (Rco), gm/sec-m	17.4	—	14.3	—	—

Worksheet 1. EMISSIONS FROM SINGLE ROADS (Continued)

Line						
1	Projection year	1974				
2	Road number	6				
3	Road name					
4	Normal distance, km	400				
5	Peak traffic volume (V), vph	11 200				
	Complete lines 6 through 12 only if traffic data for line 5 is not available.					
6	AADT, vpd	—				
7	Peak lanes (N)	—				
8	Off-peak lanes	—				
9	Daily traffic/lane pair	—				
10	Peak lane volume, vph	—				
11	Off-peak lane volume, vph	—				
12	Total traffic (v), vph	—				
13	V/Ca for highways	0.93				
14	Traffic speed, mph	37				
15	CO emission factor (Eco), gm/mi	29.0				
16	CO emission rate (Qco), mg/sec-m	56.2				
17	Intersection emissions (Rco), mg/sec-m	—				

This V/Ca ratio and the speed limit of 70 mph are entered on the graph, Figure 5-2, to determine that the traffic speed for road 6 is 42 mph; this value is rounded off to the nearest 5 mph and replaces the speed limit on line 12.

The target date for the analysis is 1974. We therefore consult the appropriate tables (5-1 and 5-2) to determine emission factors for each of the local roads and for the highway. These data are entered on line 13.

To calculate the roadway emission rates (Qco, line 14), we proceed as follows, with road 1:

$$1.73 \times 10^{-4} \text{ (constant)} \times 1600 \text{ (line 5)} \times 48.7 \text{ (line 15)} = 13.4 \text{ mg/sec-m}$$

We perform this calculation for all roadways and complete line 14.

The Rco values, for intersections, are determined for roads 1 and 3, the two significant roads that intersect near the site. This is the calculation for road 1:

$$\text{Rco} = 1.3 \text{ (constant)} \times 13.4 \text{ (line 14)} = 17.4 \text{ mg/sec-m}$$

After computation of a similar value for road 3, Worksheet 1 is complete. We turn now to Worksheet 2, which will provide the required total concentrations of CO from roadways expected at the site for each of the eight wind directions. Values for each roadway are calculated separately.

The impact of the individual roadways for the eight wind directions is calculated on Worksheet 2.

Worksheet 2. POLLUTION FROM ROADWAYS

		Wind Direction							
		N	NE	E	SE	S	SW	W	NW
1.	Road No.						1	1	1
2.	Angle (σ)						45°	90°	45°
3.	Emission Q, mg/sec-m						13.4	12.4	13.4
4.	Distance, m						40	40	40
5.	Norm. Conc.						0.23	0.145	0.23
6.	Cco, mg/m^3 line 3 x line 5						3.1	2.0	3.1
1.	Road No.	2	2						
2.	Angle (σ)	80°	35°						
3.	Emission Q, mg/sec-m	6.1	6.1						
4.	Distance, m	120	120						
5.	Norm. Conc.	0.11	0.16						
6.	Cco, mg/m^3 line 3 x line 5	0.7	1.0						
1.	Road No.	3	3						
2.	Angle (σ)	90°	45°						
3.	Emission Q, mg/sec-m	11.0	11.0						
4.	Distance, m	30	30						
5.	Norm. Conc.	0.15	0.235						
6.	Cco, mg/m^3 line 3 x line 5	1.7	2.6						
	Total Concentration								

Worksheet 2. POLLUTION FROM ROADWAYS

	Wind Direction							
	N	NE	E	SE	S	SW	W	NW
1. Road No.						4	4	4
2. Angle (σ)						45°	90°	45°
3. Emission Q, mg/sec-m						8.4	8.4	8.4
4. Distance, m						150	150	150
5. Norm. Conc.						0.155	0.10	0.155
6. Cco, mg/m^3 line 3 x line 5						1.3	0.8	1.3
1. Road No.					5	5	5	5
2. Angle (σ)					45°	90°	90°	45°
3. Emission Q, mg/sec-m					17.7	17.7	17.7	17.7
4. Distance, m					200	200	200	200
5. Norm. Conc.					0.155	0.10	0.10	0.155
6. Cco, mg/m^3 line 3 x line 5					2.7	1.8	1.8	2.7
1. Road No.		6	6	6				
2. Angle (σ)		45°	90°	45°				
3. Emission Q, mg/sec-m		56.2	56.2	56.2				
4. Distance, m		400	400	400				
5. Norm. Conc.		0.13	0.08	0.13				
6. Cco, mg/m^3 line 3 x line 5		7.3	4.5	7.3				
Total Concentration	2.4	10.9	4.5	7.3	2.7	6.2	4.6	7.1

First we determine the angle made by each roadway with each wind direction vector (line 2). Lines for roadways with angles less than 22.5 degrees are left blank.

The roadway emissions just calculated for Worksheet 1 are entered on line 3. The only intersection qualifying for pollution impact on the site (see instructions for Worksheet 1, line 15) is the junction of roads 1 and 3 in the northwest wind direction. The values calculated for emissions at this intersection are used here.

Distances from the roadways to the site are entered on line 4.

Normalized concentrations for each road are determined by referring to Figure 5-3 with values for distance (line 4) and angle (line 2).

Concentrations at the site are obtained for each road by multiplying line 3 x line 5.

The total concentration for each wind direction is determined at the end of the worksheet by summing values for all roads. These total values for the eight wind directions are entered in the CO Concentrations Summary.

Summary: CO Concentrations

		Wind Direction							
		N	NE	E	SE	S	SW	W	NW
		Concentration -mg/m^3							
1	Roadways	2.4	10.9	4.5	7.3	2.7	6.2	4.6	7.1
2	Parking				1.3	1.3			
3	Total	2.4	10.9	4.5	8.6	5.0	6.2	4.6	7.1
4	Largest 1-hour concentration, mg/m^3		10.9						

Emissions from Parking Lots

The pollution impact due to the on-site parking lot is calculated on Worksheet 3. Note that the distances used are the distances normal to the parking lot, that is, along a line drawn at right angles to the parking lot. Line 3 is the distance from the site location to the near edge of the lot, and line 4 is the sum of lines 2 and 3.

We refer to Figure 5-4 with distance values from lines 3 and 4 and record the resulting concentrations in lines 5 and 6, respectively. The difference is the net CO concentration at the site.

Impact of pollution from the parking lot on the site occurs only from directions that cross the lot, in this case winds from the south and the southeast. CO concentrations for those wind directions are entered in the CO Concentrations Summary.

Total CO concentrations resulting from roadways and the parking lot are now summed for the eight wind directions on the Concentrations Summary. Line 4 shows the highest CO concentration, which is 10.9 mg/m^3 from the northeast.

COMPUTING PARTICULATE AND SO_2 CONCENTRATIONS

Emissions from Point Sources

Following the procedures outlined for determining pollution from point sources, we locate nine point sources within a 3-mile radius of the center of the site (15 miles for power plants) and list the names and addresses. First we call the local air pollution control agency having jurisdiction at the site. The local agency provides the NEDS forms for the nine point sources

Worksheet 3. POLLUTION FROM PARKING LOTS

Line number	Wind Directions N	NE	E	SE	S	SW	W	NW
1. Parking lot number				1	1			
2. Depth, m				40	40			
3. Distance near edge, m				50	50			
4. Distance-far edge, m				90	90			
5. Near-edge conc., mg/m^3				14.5	14.5			
6. Far-edge conc., mg/m^3				16.0	16.0			
7. Net concentration, mg/m^3 line 6 - line 5				1.5	1.5			
1. Parking lot number								
2. Depth, m								
3. Distance near edge, m								
4. Distance-far edge, m								
5. Near-edge conc., mg/m^3								
6. Far-edge conc., mg/m^3								
7. Net concentration, mg/m^3 line 6 - line 5								
8. Total impact, mg/m^3				1.5	1.5			
9. Correction factor				0.84	0.84			
10. Corrected total impact, mg/m^3, line 8 x line 9				1.3	1.3			

on our list.

We check significance of the point sources using Worksheet 4. Only one of the nine significance tests is illustrated here. In this case the distance from the site to the plant is 3000 meters, recorded on line 1. We consult Figure 5-5 to determine the emission rate for significance, 7.0 gm/sec.

Emissions of particulate and SO_2 are found on the NEDS forms for this plant and recorded on line 3. We convert from tons/yr to gm/sec by using Figure 5-6 and the operating hours per year, also from the NEDS forms. The total emissions of TSP are higher than the minimum rate for significance, and emissions of SO_2 are close. This point source therefore is significant and is included in the calculations.

Proceeding with the analysis, we find that five of the nine point sources are calculated to be significant. The stacks are grouped for the significant sources by use of Worksheet 5. Site locations of maximum particulate and maximum SO_2 concentrations are selected. For simplicity only one site location is selected for each, as shown in Figure 8-3. The Worksheet 5 calculation is illustrated for only one of the point sources. The NEDS forms obtained for the source show that stacks fall into two groups based on height and flow ranges. We therefore complete two copies of Worksheet 5, using data from the NEDS forms. Since the TSP and SO_2 emissions are expressed in tons/yr,

Worksheet 4. POINT SOURCE SIGNIFICANCE TEST

Plant Name APEX CHEMICAL CO. Number ______

Address ——

Evaluation of the source

Line Number

1 Straight line distance between the source and the site, d 3000 Meters

2 Minimum emission rate for Em for significance (from Figure 5-5) 7.0 gm/sec

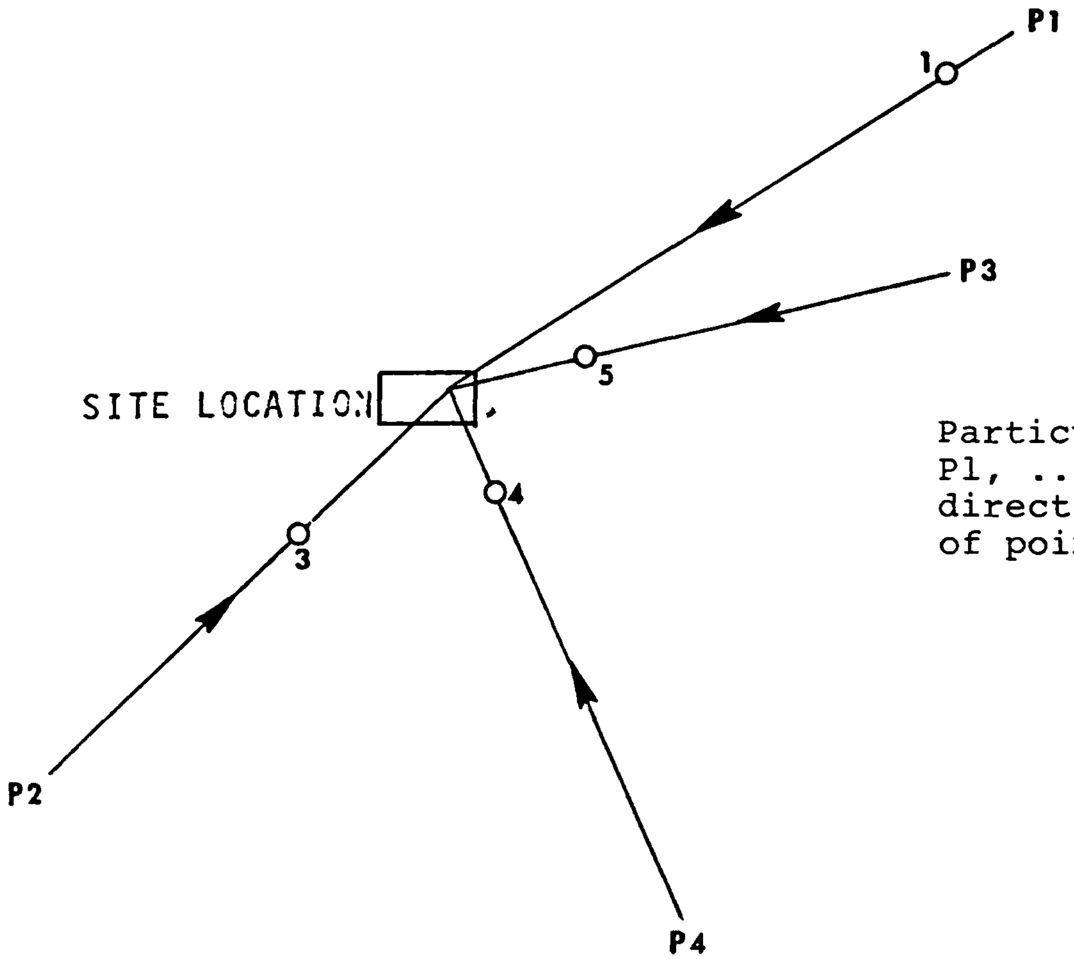
3 (Table)

Point ID	Pollutant, gm/sec	
	Particulate	Sulfur Dioxide
1	0.42	1.86
2	1.14	—
3	2.58	—
4	4.30	5.05
TOTAL	8.44	6.91

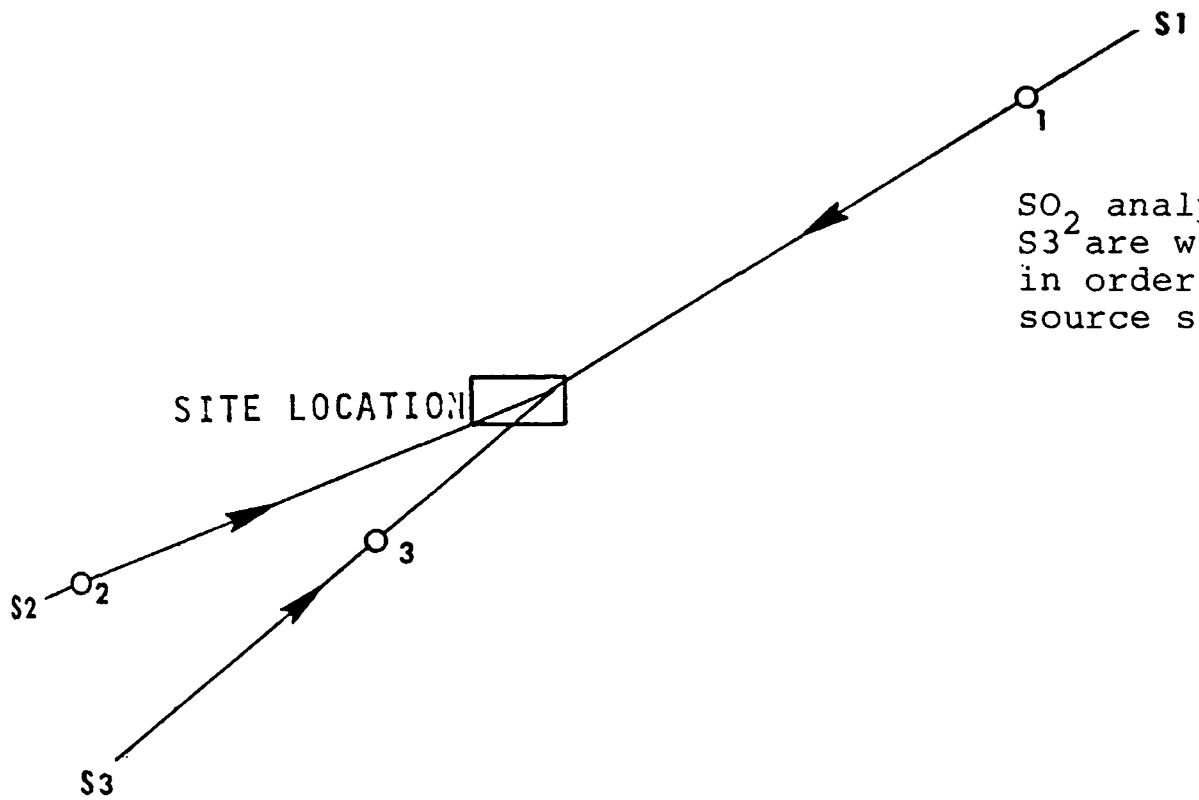
3a TOTAL

4 Is the total emission rate for particulate or sulfur dioxide greater than the emission rate Em on line 2?

Yes ✓ No ______



Particulate analysis P1, ..., P4 are wind directions in order of point sources.



SO_2 analysis S1, S2, S3 are wind directions in order of point source size.

Figure 8-3. Schematic representation of the area map for point source evaluation.

Worksheet 5. GROUPING OF STACKS

Line Number

Stack Number 1 (1-6)

Stack Group Characteristics

1 Flow Range >100 ft^3/min or m^3/sec

2 Height Range 50 -100 ft

3 (Table)

Number in Group	Point ID	Height H, ft	Temp. Ts, °F	Gas flow rate ft^3/min	Pollutants, gm/sec	
					TSP	SO_2
1	1	76	400	60,000	0.42	1.86
2	2	55	70	47,900	1.14	—
3						
4						
5						
n= 2	TOTAL	131	470	107 900	1.56	1.86

4 Number of stacks n = 2

5 Average Height $H = \frac{\text{Sum of Heights}}{n}$ = 65.5 ft x 0.3048 = 20 m

6 Average Temp. $Ts = \frac{\text{Sum of Temps}}{n} = \frac{5}{9}$(235 °F -32) = 113 °C

7 Average Gas Flow Rate $V_f = \frac{\text{Sum of gas flow rates}}{n}$ =

$\frac{(53950 \text{ ft}^3/\text{min})}{2120}$ = 25.4 m^3/sec.

EMISSION RATES

8 Particulate = Sum of the emission rates = 1.56 gm/sec.

9 Sulfur Dioxide = Sum of emission rates = 1.86 gm/sec.

Worksheet 5. GROUPING OF STACKS
(Continued)

Line Number

Stack Number 2 (1-6)

Stack Group Characteristics

1 Flow Range >100 ft^3/min or m^3/sec

2 Height Range 0-50 ft

3 (Table)

Number in Group	Point ID	Height H, ft	Temp. Ts, °F	Gas flow rate ft^3/min	Pollutants, gm/sec	
					TSP	SO_2
1	3	45	70	39100	2.58	—
2	4	20	190	48000	4.3	5.05
3						
4						
5						
n=	TOTAL	65	260	87100	6.88	5.05

4 Number of stacks n = 2

5 Average Height $H = \frac{\text{Sum of Heights}}{n}$ = 32.5 ft x 0.3048 = 9.9 m

6 Average Temp. $Ts = \frac{\text{Sum of Temps}}{n} = \frac{5}{9}($130 °F $-32)$ = 54.5 °C

7 Average Gas Flow Rate $V_f = \frac{\text{Sum of gas flow rates}}{n}$ =

$\frac{(43550 \text{ ft}^3/\text{min})}{2120}$ = 20.5 m^3/sec.

EMISSION RATES

8 Particulate = Sum of the emission rates = 6.88 gm/sec.

9 Sulfur Dioxide = Sum of emission rates = 5.05 gm/sec.

we convert to gm/sec by determining the plant operating hours (NEDS forms) and consulting Figure 5-6. The totalled values are divided by the number of stacks to give the average values recorded in lines 5 through 9. The two Worksheets 5 containing the grouped stack data for this plant are now applied to Worksheet 6. The values for stack gas flow rate (line 4) and gas temperature (line 3) are used to calculate the correction factor F:

$$F = 3.12 \times Vf \text{ (Line 4)} \times \frac{(Ts \text{ (line 3)} - 20)}{(Ts \text{ (line 3)} + 273}$$

$$= 3.12 \times 25.4 \text{ m/sec} \times \frac{(113 - 20)}{113 + 273}$$

$$= 19.1$$

Plume rise is determined by consulting Figure 5-7 with the F factor. The plume rise value, 45 m, is recorded on line 7.

Effective stack height (line 8) is determined by adding stack height (line 2) and plume rise (line 7). The TSP and SO_2 emission values from Worksheet 5 are recorded on lines 9 and 10.

To obtain normalized concentration (line 11), we refer to Figure 5-8 with effective stack height (line 8) and distance to the site. We then determine downwind TSP concentration (line 12) by multiplying Line 9 x Line 11 x 0.60. The SO_2 concentration (line 13) is determined by multiplying line 11 x line 10. The total TSP and SO_2 levels (lines 14 and 15) result from summing across the groups of stacks.

Worksheet 6. ESTIMATION OF POLLUTANT CONTRIBUTION FROM THE SOURCE TO THE SITE

Line Number	ITEM	STACK OR GROUP OF STACKS				
1	Stack Number	1	2	3	4	5
2	Stack Height (H), m	20	9.9			
3	Stack Gas Temperature (Ts), °C	113	55			
4	Gas Flow Rate (V_f), m^3/sec	25.4	20.5			
5	Ambient Temperature (t), °C	20	20			
6	F Value	14.1	6.8			
7	Plume Rise (h_e), m	45	20			
8	Effective Stack Height, m (h total), line 2 + line 6	65	29.9			
9	Particulate (Q_1), gm/sec	1.56	6.88			
10	Sulfur Dioxide (Q_2), gm/sec	1.86	5.05			
	NORMALIZED CONCENTRATION					
11	Particulate and SO_2 (C/Q), Figure 5-8	1.4×10^{-5}	2.4×10^{-5}			
	ESTIMATED DOWNWIND CONCENTRATION					
12	Particulate, μg/m^3	13	99			
13	Sulfur Dioxide, μg/m^3	26	121			
14	Total Particulate, μg/m^3	112				
15	Total Sulfur Dioxide, μg/m^3	147				

The downwind TSP and SO_2 concentrations at the site, determined by calculations on Worksheets 7a and 7b are shown below.

Source No.	Downwind Concentration, μg/m^3	
	TSP	SO_2
1	112	147
2	0	100
3	80	27
4	61	0
5	71	0

Point Source Pollutants at the Site

In computing pollutant concentrations at the site, we select the four point sources showing the highest TSP and SO_2 levels and draw lines from these sources to the site. Figure 8-3 shows the four principal sources for both pollutants (three for SO_2). The wind direction lines are numbered sequentially starting with the source making the largest pollutant impact. Next we sum the concentrations from each plant for each wind direction by use of Worksheets 7a and 7b. The pollution impacts are considered only if the source-to-receptor locations are within 15 degrees on the given wind direction. The downwind concentrations (line 2) were determined on Worksheet 6. To determine the pollutant impact from a point source for a wind direction through another point source, tangential distances X and Y are plotted on the map and measured. They are then used with Figure 5-9 to obtain the correction factor for particulate and with Figure 5-10 for SO_2. The correction factors are multiplied by the downwind concentrations to yield concentrations at the site (Line 6).

Worksheet 7a. POLLUTION FROM POINT SOURCES (PARTICULATE)

Line Number	Wind Directions 1	2	3	4
1. Source Number	1		1	
2. Downwind Particulate, $\mu g/m^3$	112		112	
3. X meters	15×10^3		14.1×10^3	
4. Y meters	0		6.3×10^3	
5. Correction Factor	1.0		LOW	
6. Particulate $\mu g/m^3$	112		—	
1. Source Number		3		3
2. Downwind Particulate, $\mu g/m^3$		80		80
3. X meters		1000		707
4. Y meters		0		707
5. Correction Factor		1.0		LOW
6. Particulate $\mu g/m^3$		80		—
1. Source Number	5		5	
2. Downwind Particulate, $\mu g/m^3$	71		71	
3. X meters	753		800	
4. Y meters	274		0	
5. Correction Factor	LOW		1.0	
6. Particulate $\mu g/m^3$	—		71	
1. Source Number		4		4
2. Downwind Particulate, $\mu g/m^3$		61		61
3. X meters		353		500
4. Y meters		248		0
5. Correction Factor		LOW		1.0
6. Particulate $\mu g/m^3$		—		61
TOTAL $\mu g/m^3$	112	80	71	61

Worksheet 7b. POLLUTION FROM POINT SOURCES (SO_2)

Line Number	Wind Directions 1	2	3	4
1. Source Number	1			
2. Downwind SO_2 $\mu g/m^3$	147			
3. X meters	15×10^3			
4. Y meters	0			
5. Correction Factor	1.0			
6. SO_2 $\mu g/m^3$	147			
1. Source Number		2	2	
2. Downwind SO_2 $\mu g/m^3$		100	100	
3. X meters		3000	2960	
4. Y meters		0	510	
5. Correction Factor		1.0	0.22	
6. SO_2 $\mu g/m^3$		100	22	
1. Source Number		3	3	
2. Downwind SO_2 $\mu g/m^3$		27	27	
3. X meters		985	1000	
4. Y meters		174	0	
5. Correction Factor		0.05	1.0	
6. SO_2 $\mu g/m^3$		1	27	
1. Source Number				
2. Downwind SO_2 $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2 $\mu g/m^3$				
TOTAL $\mu g/m^3$	147	101	49	

The total impacts at the site from the different wind directions are summarized. The highest TSP and SO_2 levels and their corresponding wind directions are entered in the particulate and SO_2 Concentrations Summary.

Summary: PARTICULATE AND SO_2 EMISSIONS

		TSP	SO_2
1.	Highest impact wind direction	1	1
2.	Point source total concentration, $\mu g/m^3$	112	147
3.	Building heating, $\mu g/m^3$	20	15
4.	Total, $\mu g/m^3$	132	162

Emissions from Space Heating

For a small low-density development, a simplified procedure can be used to determine air pollution impact, as described in Section 5. For illustrative purposes the more involved procedure used for medium and large low-density developments is described.

In calculating the pollution at the site attributable to space heating, we construct on the area map a 1-kilometer square centered on the site and the maximum particulate wind vector as shown in Section 5. Using maps supplied with "Census Tracts" data as reference, we plot the boundaries of all census tracts within this square. We use Worksheet 8 to calculate total floor area for buildings in this square, as illustrated in the example. We then calculate emission rates for TSP and SO_2 on Worksheet 9, and by referring to Figure 5-11, derive estimated concentrations

Worksheet 8. DETERMINING FLOOR AREAS (SPACE HEATING LOAD)

POLLUTANT: Particulates__________ SO_2__________ (Check one)

Dwelling Size Categories
Residential Buildings

1 Tract Number	Number of rooms per dwelling							
	1	2	3	4	5	6	7	8
1				8	60	11		
2				5	51	22		
3				6	65	10		
4				9	75	2		
5				30	45	3		
6			2	7	70	1		
7				3	61	7		
8				10	69	2		
2 TOTAL			2	78	496	58		
x f	x.650	x.800	x.950	x1.100	x1.250	x1.400	x1.600	x1.800
3 Sq.Ft./1000			1.9	85.8	620.0	81.2		

4 TOTAL (Sq.Ft./1000) 788.9

5 Non-Residential Uses

Street Address Number	St. Name	Establishment Name	Floor Area (in thousands of sq. feet)
		A	100
		B	300
		C	350
		D	150

6 TOTAL - Non-Residential Floor Space 900

7 Update Information - Construction 0

- Demolition 0

8 GRAND TOTAL (4 + 6 + 7) 1689

Worksheet 9. POLLUTION FROM SPACE HEATING

Line		Particulates	SO_2
1	Percent of dwellings using coal	30%	Same
2	Percent of dwellings using oil	70%	Same
3	Grand total floor area	1689	
4	Floor space heated by coal line 1 x line 3	395	
5	Floor space heated by oil line 2 x line 3	1184	
6	65 -Tc = L 65 - 35 = L =	30	Same
7	Particulate Emission: (line 4 + 0.76 x line 5) x line 6 x 10^{-11}	3.9×10^{-7}	
8	SO_2 Emission: (2.9 x line 4 + 3.2 x line 5) x line 6 x 10^{-11}		1.48×10^{-6}
9	Concentration $\mu g/m^3$ (from Figure 5-11)	20	15

of TSP and SO_2 at the site. These concentrations are entered on line 9 of the worksheet, then on the Particulate and SO_2 Concentration Summary. The total TSP and SO_2 concentrations from point sources and space heating are entered on line 4 of the Summary.

EVALUATING THE SITE

Outdoor Pollutant Levels

The total outdoor pollution levels shown in the pollutant concentrations summaries are compared with the Federal Standards:

	Total Levels at Site	Federal Standard
CO	10.9 mg/m3	15 mg/m3, 1 hr
TSP	132 μg/m3	210 μg/m3, 24 hr
SO_2	162 μg/m3	450 μg/m3, 3 hr

The concentrations at the site are all below the standards, and thus pollution levels at the site are acceptable. Since none of the levels are as high as 80 percent of the standard, indoor pollutant levels need not be calculated. By way of illustration, however, we determine indoor pollutant levels in the following section.

Calculation of Indoor Pollutant Levels

Following the procedures presented in Section 6, we determine structural characteristics of the building on Worksheet 10. For this example we assume a single building of dimensions 50 by 100 by 40 feet, with no forced-air system. The dimensional parameters give an F value of 11.9.

To derive the overall permeability coefficient, K, we assume that the building is made of brick with a vapor barrier and that all windows are weather stripped. From permeability

Worksheet 10. STRUCTURAL CHARACTERISTICS OF BUILDINGS

	Structure Number 1	2	3
Dimensional Parameters			
1. Volume (V)	200.000		
2. Surface Area			
a. SA_c	5000		
b. SA_w	11,400		
c. SA_o	600		
d. Total SA	17,000		
3. Ratio (F) of Volume to Surface Area $F = V/SA$	11 8		
Coefficients Permeability			
4. Proportion (P) of each component			
a. $P_c = \frac{SA_c}{SA}$	0.29		
b. $P_w = \frac{SA_w}{SA}$	0.67		
c. $P_o = \frac{SA_o}{SA}$	0.03		
5. Permeability Coefficient (K)			
a. K_w (from Table 6-1)	0.25		
b. K_o (from Table 6-1)	25		
6. Weighted Permeability Coefficients			
a. $X = P_c K_w$	0.07		
b. $Y = P_w K_w$	0 17		
c. $Z = P_o K_o$	0.75		
d. $K = X + Y + Z$	0.99		
7. Indoor-Outdoor Ratios CO	0.48		
TSP	0.96		
SO_2	0.60		

coefficients in Table 6-1, we calculate the weighted permeability coefficient. Using the F and K values, we determine the pollutant Indoor-Outdoor ratios taking the CO value from Figure 6-1 and the TSP value from Page 81. The SO_2 is a constant, 60 percent.

Total indoor pollutant concentrations are calculated on Worksheet 11, multiplying the outdoor level (Line 1) by the Indoor-Outdoor ratio (Line 2) and adding any indoor generation in a given apartment, which in this case is limited to carbon monoxide from gas cooking.

The total indoor levels (Worksheet 11, line 5) are also lower than the standards. Thus, the site subjected to this analysis is completely acceptable with respect to the air pollution impact on human health.

Worksheet 11 - TOTAL INDOOR POLLUTANT CONCENTRATIONS

Line		Structure Number 1	2	3
1	Total Outdoor Levels			
	CO (Section 5) mg/m^3	10.4		
	TSP (Section 5) $\mu g/m^3$	132		
	SO_2 (Section 5) $\mu g/m^3$	162		
2	Indoor-Outdoor Ratio			
	CO	0.48		
	TSP	0.96		
	SO_2	0.60		
3	Indoor Concentration from Outdoor Source			
	CO mg/m^3	5.2		
	TSP $\mu g/m^3$	127		
	SO_2 $\mu g/m^3$	97		
4	Concentrations due to Indoor Generation			
	CO mg/m^3	0.5		
	TSP $\mu g/m^3$	—		
5	Total Indoor Concentration			
	CO mg/m^3	5.7		
	TSP $\mu g/m^3$	127		
	SO_2 $\mu g/m^3$	97		

GLOSSARY OF TERMS

AADT - Annual Average Daily Traffic. Average daily traffic rate based on annual data.

Ambient Air Quality Standard - The air quality level established by Federal or State agencies to be achieved or maintained. Primary standards are promulgated to protect public health and secondary standards to protect the public welfare from any known or anticipated adverse effects of a pollutant.

Cco - The concentration of carbon monoxide at the site location due to emissions from a roadway in mg/m^3.

CO - Carbon monoxide.

C/Q - The normalized particulate or SO_2 concentration at a site location due to a point source emission. C is concentration in $\mu g/m^3$ and Q is point source emission rate in gm/sec.

CAMP - Continuous Air Monitoring Program. These stations make-up a network of major air contaminant monitoring locations in major metropolitan areas in the U.S.

Collector Street - defined for this Manual as any street or roadway with greater than 15,000 vehicles per day traffic volume and not a limited access road.

Concentrations - A measure of the average density of pollutants, specified as pollutant mass per unit volume in this manual.

Correction Factor - for Point Sources. A multiplier to the downwind pollutant concentration to account for a different wind direction.

E - Filter pollutant removal efficiency.

Eco - Carbon monoxide emission factor from roadways, in gm/mile.

Effective Stack Height - Total height a point source emission rises in the atmosphere. Equal to the stack height plus plume rise.

Emissions - Effluents to the atmosphere, specified as weight per unit time for a given pollutant from a given source.

F - An intermediate factor used to determine a point source plume rise. Determined from the stack gas flow rate and the stack gas temperature.

NEDS - National Emission Data System - A data collection system which records relevant information of all significant point sources in the U.S. A standard computer input form is completed for each significant point source emitter in a facility.

97% Percentile Level - The air pollutant concentration that will not be exceeded in 97% of a given time interval per year.

Peak-Hour Traffic - The traffic rate for the highest volume hour in the day for a given road

Permeability Coefficient - (Kw, Ko) is the infiltration rate in $ft^3/hr/ft^2$ of building area for a given building construction. Kw is the ceiling and wall rate and Ko is the window and door rate.

Plume Rise - The height an emission from a point source stack rises in the atmosphere above the stack height.

Point Sources - Localized emissions emanating from industrial and commercial fuel burning and from process operations.

Qco - Emission rate from roadways in gm/sec/m of road length

Rco - Emission rate from roadway intersections in grams/sec/meter of road length.

SO_2 - Sulfur dioxide.

TSP - Total suspended particulate, also just referred to as particulate.

$\mu g/m^3$ - Micrograms per cubic meter.

V/Ca - Traffic volume to roadway traffic capacity ratio.

Wind Direction - Designates the direction from which the wind is approaching the site.

σ - Angle between the wind direction and the roadway.

APPENDIX A

INDUSTRIAL SOURCES OF POLLUTANTS

An alphabetical listing of pollutants with their major industrial sources is presented below.

Aldehydes

Insulated wire reclaiming, covering

Meat smokehouses

Mineral wool production

Phthalic acid plant

Varnish cooking kettles

Ammonia

Ammonia liquor storage

Ammonia production

Ammonium carbonate production

Ammonium nitrate production

Ammonium sulfate production

Arsenic

Arsenic ore mining and concentrating

Arsenic production

Pesticide production

Gold and copper smelters

Asbestos

Asbestos, manufacture of

Asbestos strip-mining and processing

Asbestos insulation

Barium

Barium chloride production

Beryllium

Production of fluorescent lamps

Metallurgical industry

Boron

Detergent manufacture

Weather proofing wood

Cadmium

Metallurgical alloying

Lead mine drainage

Dye production

Chlorine

Chlorinated hydrocarbon production

Chlorine production

Chlorine storage tanks

Electrolysis of alkali solution

Chromium

Chromium salt production

Metallurgical industry

Chromate-producing industry

Cyanide Compounds

Cyanide compound production

Hydrochloric Acid

Hydrochloric acid production

Metal and industrial cleaning

Lead

Lead ore mining and concentrating

Lead reduction and melting

Mercury

Mercury production

Nickel

Nickel production (aqueous solution electrolysis)

Nickel

Plating plants

Incineration of nickel products

Pesticides

Pesticide production

Phosphorus

Phosphorite mining and production

Phosphorus production

Selenium

Fuels and ores used by industry

Vanadium

Vinyl Chloride

Plastic manufacturing

Refrigerant

Organic synthesis

Polyvinyl chloride manufacture- (PVC) - many PVC applications

Zinc

Zinc alloying, smelting, galvanizing, refining

Zinc production

Lead industries

Brass alloy manufacturing

APPENDIX B

AIR QUALITY MONITORING REQUIREMENTS

Limitations on applicability of the procedures were presented in the manual, including these situations which the procedures cannot adequately handle:

1. Very uneven topography where more than a 100-foot difference in ground elevations occurs within 500 feet of the site.

2. Site location close to a large body of water.

3. Airport situated within the distance parameters listed in the manual.

4. Very large residential developments, roughly greater than 1,000 housing units or 100 acres. These require a more detailed air pollution analysis.

5. Sites situated close to any of the industrial operations listed in Appendix A of the manual. For such sites the impact of specific air pollutant(s) should be measured. A preliminary estimate of the potential hazard should be obtained from an engineer at the local air pollution control agency.

In the cases cited above, monitoring of air pollutant levels is recommended. The purpose of this section is to provide guidelines for the planner concerning the scope of air sampling work required.

Sampling locations are a function of the site size, topography, and number and location of pollution sources. We therefore recommend that the planner engage a consulting firm experienced in air sampling to determine the location and number of sampling points, pollutants to be monitored at each point, sampling time, and type of sampling equipment required. The consulting firm should be selected from a list of those recommended by the state air pollution control agency or the Regional office of the EPA.

Following are some rough guidelines to aid in evaluating the scope of work required:

1. A 2-week sampling period is a minimum time that is adequate to generate meaningful data. For very large developments, a more extended study might be justified to generate recommended uses for different parts of the site.

2. For sites of 10 acres or less, one central sampling point should be adequate. In rehabilitation projects, structural features of the buildings may require additional sampling locations.

3. For sites in the 50- to 100-acre size range with no unusual topographical features, two sampling points should be adequate. If high-traffic-volume roadways are adjacent to more than one site exposure, more sampling locations for carbon monoxide may be required.

4. For sites in the 100- to 500-acre size range, four sampling points are recommended.

5. The choice of air pollutants to be measured can only be determined after a professional site evaluation based on knowledge of the local air pollution problems. Measurement of photochemical oxidants is often advisable. Since the oxidant level would not be expected to fluctuate as a function of site location as much as do the levels of primary air pollutants, one or two sampling locations should be adequate.

6. A more intensive sampling program may be advisable where rows of tall buildings cause a canyon or funnel effect. Also, if the site design includes high-rise structures, sampling at elevated points may be recommended, particularly where significant pollution impact is anticipated from point sources.

The monitoring should include measurements of wind speed and direction near the sampling points and determination of surface atmospheric stability.

Site Selection

Although few site locations are ideally located for monitoring of all pollutants, for purely economic reasons it is common practice to consolidate sampling equipment for a number of pollutants at each sampling site. Within this restriction, the factors that affect site selection are distribution of the buildings and the site, location of pollutant emission sources, meteorology, and topography.

If a major portion of the pollution impact at a sampling point results from a dominant point source, an effort should be made to determine the extent of this impact on the entire site. The same is true for the downwash of air masses from adjacent buildings.

Meteorological conditions determine the ability of the atmosphere to transport and diffuse air pollutants. Among the factors are wind speed and direction, atmospheric stability, and mixing depth. For most regions the only meteorological data available are those from the local airport weather station. Because these airport measurements are not representative of the microscale meteorology throughout a region, some air pollution control agencies include meteorological instrumentation in their continuous air monitoring stations.

The microscale meteorological conditions for any land areas are significantly affected by local topographical features. Their effects should be considered in locating sampling points. In urban areas topographical effects are often further complicated by the grouping of buildings and structures and by elevated or recessed highways.

Recommended methods and instruments for monitoring of particulates, SO_2, CO, hydrocarbons, oxidants, and nitrogen oxides are described thoroughly in "Air Quality Monitoring Systems Training Course Manual."[1] Methods of analysis of other air pollutants are described in "Methods of Air Sampling and Analysis."[2]

The cost of field monitoring is proportional to the number of sampling points and number and type of pollutants sampled.

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1. Air Quality Monitoring Systems Training Course Manual, Environmental Protection Agency, Contract No. 68-02-0783, October 1973.

2. Methods of Air Sampling and Analysis, Intersociety Committee, American Public Health Assoc., 1972.

APPENDIX C

INFORMATION NEEDED FROM NEDS FORMS

The NEDS form, shown in Figure C-1, is a computer input form for a point source. A source may have more than one stack emitting pollutants. We shall consider that each stack is coded on a separate form. Thus, there may be more than one NEDS form for a source.

The horizontal rows on the NEDS form in Figure C-1 are numbered 1 through 7. Further, each important field (group of columns) is assigned a Key Number for easy identification. The explanation of NEDS coding is given, by rows and keys, in Table C-1. For example, Key 7 gives stack height in Columns 33-36 of Row 3.

Point ID: Point ID is the sequential number given to a stack at the source for identification. Thus, Point ID represents an individual stack.

NATIONAL EMISSIONS DATA SYSTEM (NEDS)
ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF AIR PROGRAMS

POINT SOURCE
Input Form

Date. ____________

Name of Person Completing Form ____________________________

Card 1

State	County ③	AQCR	Plant ID Number
1 2	3 4 5 6	7 8 9	10 11 12 13

Card 2

City ②	Utm Zone	Year of Record	Establishment Name and Address ①	Contact - Personal	OWN		Action		cd
14 15 16 17	18 19	20 21	22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61	62 63 64 65 66 67 68 69 70 71 72 73	74	75 76 77	78	79	80
							A	P	1

Card 3

Point ID ④	Year of Record ⑤	SIC ⑥	IPP Process	UTM COORDINATES Horizontal km	UTM COORDINATES Vertical km	STACK DATA Height (ft) ⑦	Diam (ft)	Temp (°F) ⑧	Flow Rate (ft³/min) ⑨	Plume Height If no stack-ft.		Action		cd
14 15	16 17	18 19 20 21	22 23	24 25 26 27	28 29 30 31 32	33 34 35 36	37 38 39	40 41 42 43	44 45 46 47 48 49 50	51 52 53 54	55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77	78	79	80
												A	P	2

Card 4

Year of Record	Boiler Design Capacity 10^6 BTU hr	CONTROL EQUIPMENT Primary Part.	Secondary Part.	Primary SO_2	Secondary SO_2	Primary NO_x	Secondary NO_x	Primary HC	Secondary HC	Primary CO	Secondary CO	ESTIMATED CONTROL EFFICIENCY (%) Part.	SO_2	NO_x	HC	CO		Action		cd
16 17	18 19 20 21 22	23 24 25	26 27 28	29 30 31	32 33 34	35 36 37	38 39 40	41 42 43	44 45 46	47 48 49	50 51 52	53 54 55	56 57 58	59 60 61	62 63 64	65 66 67	68 69 70 71 72 73 74 75 76 77	78	79	80
																		A	P	3

Card 5

Year of Record	% ANNUAL THRUPUT Dec Feb	Mar May	June Aug	Sept Nov	⑩ NORMAL OPERATING Hr day	D wk	Wk yr	EMISSION ESTIMATES (tons/year) Particulate ⑪	SO_2 ⑫	NO_x	HC	CO	Pa'	ESTIMATION METHOD SO_2	NO_x	HC	CO	% Space Heat		Action		cd
16 17	18 19	20 21	22 23	24 25	26 27	28	29 30	31 32 33 34 35 36 37	38 39 40 41 42 43 44	45 46 47 48 49 50 51	52 53 54 55 56 57 58	59 60 61 62 63 64 65	66	67	68	69	70	71 72 73	74 75 76 77	78	79	80
																				A	P	4

Card 6

Year of Record	ALLOWABLE EMISSIONS (tons/year) Particulate	SO_2	NO_x	HC	CO	Comp. Stat.	COMPLIANCE SCHEDULE Year	Month	COMPLIANCE STATUS UPDATE Year	Month	Day	ECAP	CONTROL REGULATIONS Reg 1	Reg 2	Reg 3		Action		cd
16 17	18 19 20 21 22 23 24	25 26 27 28 29 30 31	32 33 34 35 36 37 38	39 40 41 42 43 44 45	46 47 48 49 50 51 52	53	54 55	56 57	58 59	60 61	62 63	64	65 66 67 68	69 70 71 72	73 74 75 76	77	78	79	80
																	A	P	5

Card 7

Year of Record	SCC I	II	III	IV	Fuel, Process Solid Waste Operating Rate	Maximum Design Rate	Sulfur Content %	Ash Content %	Heat Content 10^6 BTU/scc	Comments	Source	Confid.		Action		cd
16 17	18	19 20	21 22 23	24 25	26 27 28 29 30 31 32	33 34 35 36 37 38 39	40 41 42	43 44 45	46 47 48 49 50	51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70	71	72	73 74 75 76 77	78	79	80
														A	P	6
														A	P	6
														A	P	6
														A	P	6
														A	P	6

EPA (DUR) 220
3/72

Figure C-1. Point source coding form.

Table C-1. NEDS FORM CODING

Key number	Information	Row number	Field (columns)
1	Source name and address	1	22 - 61
2	City	2	14 - 17
3	County	1	3 - 6
4	Point ID	3	14 - 15
5	Year of data	3	16 - 17
6	SIC (Standard Industrial Classification)	3	18 - 21
7	Stack height, ft	3	33 - 36
8	Stack gas temp, °F	3	40 - 43
9	Stack gas flow rate	3	44 - 50
10	Operating Schedule hr/day, days/wk, wk/year	5	26 - 30
11	Particulate emission rate tons/year	5	31 - 37
12	Sulfur dioxide emission rate, tons/year	5	38 - 44

APPENDIX D

CONVERSION FROM ENGLISH TO METRIC UNITS

English Unit	Metric Unit
1 Foot	30.48 centimeters 0.3048 meter
1 Inch	2.54 centimeters
1 Square Foot	0.0929 square meter
1 Cubic Foot	0.0283 cubic meter
1 Mile	1609.3 meters 1.609 kilometers
1 $Ft.^3/min$	$4.72 \times 10^{-4}\ M^3/sec$
1 Pound	453.6 grams
1 Ton	907.2 kilograms
	1 gm = 1000 mg
	$= 10^6\ \mu g$
°F	$°C = \frac{5}{9}(°F - 32)$

SAMPLE WORKSHEETS

RAPID EVALUATION WORKSHEET: CO POLLUTION FROM ROADWAYS

Line								Total CO Impact, mg/m^3
1	Road name							
2	Road number							
3	Normal distance, ft.							
4	AADT, vpd							
5	CO emission factor							
6	Emission rate							
	North Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							
	East Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							
	South Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							
	West Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							
10	Highest impact, mg/m^3							
11	Parking lot contribution, mg/m^3							
12	Total CO impact, mg/m^3							

RAPID EVALUATION WORKSHEET: CO POLLUTION FROM ROADWAYS

Line								Total CO Impact, mg/m^3
1	Road name							
2	Road number							
3	Normal distance, ft.							
4	AADT, vpd							
5	CO emission factor							
6	Emission rate							
	North Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							
	East Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							
	South Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							
	West Wind Direction							
7	Angle with roadway (ø)							
8	Normal concentration (Figure 2.1)							
9	Impact, mg/m^3							
10	Highest impact, mg/m^3							
11	Parking lot contribution, mg/m^3							
12	Total CO impact, mg/m^3							

Worksheet 1. EMISSIONS FROM SINGLE ROADS

Line						
1	Projection year					
2	Road number					
3	Road name					
4	Normal distance, km					
5	Peak traffic volume (V), vph					

Complete lines 6 through 12 only if traffic data for line 5 is not available.

Line						
6	AADT, vpd					
7	Peak lanes (N)					
8	Off-peak lanes					
9	Daily traffic/lane pair					
10	Peak lane volume, vph					
11	Off-peak lane volume, vph					
12	Total traffic (v), vph					
13	V/Ca for highways					
14	Traffic speed, mph					
15	CO emission factor (Eco) gm/mi					
16	CO emission rate (Qco), mg/sec					
17	Intersection emissions (Rco), gm/sec-m					

Worksheet 1. EMISSIONS FROM SINGLE ROADS

Line						
1	Projection year					
2	Road number					
3	Road name					
4	Normal distance, km					
5	Peak traffic volume (V), vph					

Complete lines 6 through 12 only if traffic data for line 5 is not available.

Line						
6	AADT, vpd					
7	Peak lanes (N)					
8	Off-peak lanes					
9	Daily traffic/lane pair					
10	Peak lane volume, vph					
11	Off-peak lane volume, vph					
12	Total traffic (v), vph					
13	V/Ca for highways					
14	Traffic speed, mph					
15	CO emission factor (Eco) gm/mi					
16	CO emission rate (Qco), mg/sec-m					
17	Intersection emissions (Rco), mg/sec-m					

Worksheet 2. POLLUTION FROM ROADWAYS

	Wind Direction							
	N	NE	E	SE	S	SW	W	NW
1. Road No.								
2. Angle (σ)								
3. Emission Q, mg/sec-m								
4. Distance, m								
5. Norm. Conc.								
6. Cco, mg/m^3 line 3 x line 5								
1. Road No.								
2. Angle (σ)								
3. Emission Q, mg/sec-m								
4. Distance, m								
5. Norm. Conc.								
6. Cco, mg/m^3 line 3 x line 5								
1. Road No.								
2. Angle (σ)								
3. Emission Q, mg/sec-m								
4. Distance, m								
5. Norm. Conc.								
6. Cco, mg/m^3 line 3 x line 5								
Total Concentration mg/m^3								

Worksheet 2. POLLUTION FROM ROADWAYS

	Wind Direction N	NE	E	SE	S	SW	W	NW
1. Road No.								
2. Angle (σ)								
3. Emission Q, mg/sec-m								
4. Distance, m								
5. Norm. Conc.								
6. Cco, mg/m^3 line 3 x line 5								
1. Road No.								
2. Angle (σ)								
3. Emission Q, mg/sec-m								
4. Distance, m								
5. Norm. Conc.								
6. Cco, mg/m^3 line 3 x line 5								
1. Road No.								
2. Angle (σ)								
3. Emission Q, mg/sec-m								
4. Distance, m								
5. Norm. Conc.								
6. Cco, mg/m^3 line 3 x line 5								
Total Concentration mg/m^3								

Worksheet 3. POLLUTION FROM PARKING LOTS

Line number	N	NE	E	SE	S	SW	W	NW
1. Parking lot number								
2. Depth, meters								
3. Distance near edge, m								
4. Distance-far edge, m								
5. Near-edge conc., mg/m^3								
6. Far-edge conc., mg/m^3								
7. Net concentration, mg/m^3 line 6 - line 5								
1. Parking lot number								
2. Depth, meters								
3. Distance near edge, m								
4. Distance-far edge, m								
5. Near-edge conc., mg/m^3								
6. Far-edge conc., mg/m^3								
7. Net concentration, mg/m^3 line 6 - line 5								
8. Total impact, mg/m^3								
9. Correction factor								
10. Corrected total impact, mg/m^3, line 8 x line 9								

Worksheet 3. POLLUTION FROM PARKING LOTS

Line number	N	NE	E	SE	S	SW	W	NW
1. Parking lot number								
2. Depth, meters								
3. Distance near edge, m								
4. Distance-far edge, m								
5. Near-edge conc., mg/m^3								
6. Far-edge conc., mg/m^3								
7. Net concentration, mg/m^3 line 6 - line 5								
1. Parking lot number								
2. Depth, meters								
3. Distance near edge, m								
4. Distance-far edge, m								
5. Near-edge conc., mg/m^3								
6. Far-edge conc., mg/m^3								
7. Net concentration, mg/m^3 line 6 - line 5								
8. Total impact, mg/m^3								
9. Correction factor								
10. Corrected total impact, mg/m^3, line 8 x line 9								

Column heading: Wind Directions

Worksheet 4. POINT SOURCE SIGNIFICANCE TEST

Plant Name________________________________ Number_______________

Address____

Evaluation of the source

Line Number

1 Straight line distance between the source and the site, d _______ Meters

2 Minimum emission rate for Em for significance (from Figure 5-5) _______ gm/sec

3 (Table)

Point ID	Pollutant, gm/sec	
	Particulate	Sulfur Dioxide
3a TOTAL		

4 Is the total emission rate for particulate or sulfur dioxide greater than the emission rate Em on line 2?

Yes __________ No __________

Worksheet 4. POINT SOURCE SIGNIFICANCE TEST

Plant Name________________________________ Number_______________

Address____

Evaluation of the source

Line
Number

1 Straight line distance between the source and the site, d _______ Meters

2 Minimum emission rate for Em for significance (from Figure 5-5) _______ gm/sec

3 (Table)

Point ID	Pollutant, gm/sec	
	Particulate	Sulfur Dioxide
TOTAL		

3a TOTAL

4 Is the total emission rate for particulate or sulfur dioxide greater than the emission rate Em on line 2?

Yes __________ No __________

Worksheet 5. GROUPING OF STACKS

Line Number

Stack Number________(1-6)

Stack Group Characteristics

1 Flow Range ______ ft^3/min or m^3/sec

2 Height Range ______ ft or meters

3 (Table)

Number in Group	Point ID	Height H, ft	Temp. Ts, °F	Gas flow rate ft^3/min	Pollutants, gm/sec	
					TSP	SO_2
1						
2						
3						
4						
5						
n=	TOTAL					

4 Number of Stacks n = _____

5 Average Height $H = \frac{\text{Sum of Heights}}{n} =$ _____ ft x 0.3048 = _____ m

6 Average Temp. $Ts = \frac{\text{Sum of Temps}}{n} = \frac{5}{9}($____ °F $-32) =$ _____ °C

7 Average Gas Flow Rate $V_f = \frac{\text{Sum of gas flow rates}}{n} =$

$\left(\frac{\_\_\_\_\_\ ft^3/min}{2120}\right) =$ ______ m^3/sec.

EMISSION RATES

8 Particulate = Sum of the emission rates = _______ gm/sec.

9 Sulfur Dioxide = Sum of emission rates = ______ _gm/sec.

Worksheet 5. GROUPING OF STACKS

Line Number

Stack Number________(1-6)

Stack Group Characteristics

1 Flow Range ______ft^3/min or m^3/sec

2 Height Range ______ft or meters

3 (Table)

Number in Group	Point ID	Height H, ft	Temp. Ts, °F	Gas flow rate ft^3/min	Pollutants, gm/sec	
					TSP	SO_2
1						
2						
3						
4						
5						
n=	TOTAL					

4 Number of Stacks n = _____

5 Average Height $H = \frac{\text{Sum of Heights}}{n}$ = _____ft x 0.3048 = _____m

6 Average Temp. $Ts = \frac{\text{Sum of Temps}}{n} = \frac{5}{9}($ ____ °F -32) = _____°C

7 Average Gas Flow Rate $V_f = \frac{\text{Sum of gas flow rates}}{n}$ =

$\left(\frac{\text{\_\_\_\_\_ ft}^3\text{/min}}{2120}\right)$ = ______m^3/sec.

EMISSION RATES

8 Particulate = Sum of the emission rates = _______gm/sec.

9 Sulfur Dioxide = Sum of emission rates = _______ _gm/sec.

Worksheet 6. ESTIMATION OF POLLUTANT CONTRIBUTION FROM THE SOURCE TO THE SITE

Line Number	ITEM	STACK OR GROUP OF STACKS				
1	Stack Number					
2	Stack Height (H), m					
3	Stack Gas Temperature (Ts), °C					
4	Gas Flow Rate (V_f), m^3/sec					
5	Ambient Temperature (t), °C					
6	F Value					
7	Plume Rise (h_e), m					
8	Effective Stack Height, m (h total), line 2 + line 6					
9	Particulate (Q_1), gm/sec					
10	Sulfur Dioxide (Q_2), gm/sec					
	NORMALIZED CONCENTRATION					
11	Particulate and SO_2 (C/Q), Figure 5-8					
	ESTIMATED DOWNWIND CONCENTRATIONS					
12	Particulate, $\mu g/m^3$					
13	Sulfur Dioxide, $\mu g/m^3$					
14	Total Particulate, $\mu g/m^3$					
15	Total Sulfur Dioxide, $\mu g/m^3$					

Worksheet 6. ESTIMATION OF POLLUTANT CONTRIBUTION

FROM THE SOURCE TO THE SITE

Line Number	ITEM	STACK OR GROUP OF STACKS				
1	Stack Number					
2	Stack Height (H), m					
3	Stack Gas Temperature (Ts), °C					
4	Gas Flow Rate (V_f), m^3/sec					
5	Ambient Temperature (t), °C					
6	F Value					
7	Plume Rise (h_e), m					
8	Effective Stack Height, m (h total), line 2 + line 6					
9	Particulate (Q_1), gm/sec					
10	Sulfur Dioxide (Q_2), gm/sec					
	NORMALIZED CONCENTRATION					
11	Particulate and SO_2 (C/Q), Figure 5-8					
	ESTIMATED DOWNWIND CONCENTRATIONS					
12	Particulate, μg/m^3					
13	Sulfur Dioxide, μg/m^3					
14	Total Particulate, μg/m^3					
15	Total Sulfur Dioxide, μg/m^3					

Worksheet 7a. POLLUTION FROM POINT SOURCES (PARTICULATE)

Line Number	Wind Directions 1	2	3	4
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
TOTAL $\mu g/m^3$				

Worksheet 7a. POLLUTION FROM POINT SOURCES (PARTICULATE)

Line Number	Wind Directions 1	2	3	4
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
1. Source Number				
2. Downwind Particulate, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. Particulate $\mu g/m^3$				
TOTAL $\mu g/m^3$				

Worksheet 7b. POLLUTION FROM POINT SOURCES (SO_2)

Line Number	Wind Directions 1	2	3	4
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
TOTAL $\mu g/m^3$				

Worksheet 7b. POLLUTION FROM POINT SOURCES (SO_2)

Line Number	Wind Directions 1	2	3	4
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
1. Source Number				
2. Downwind SO_2, $\mu g/m^3$				
3. X meters				
4. Y meters				
5. Correction Factor				
6. SO_2, $\mu g/m^3$				
TOTAL $\mu g/m^3$				

Worksheet 8. DETERMINING FLOOR AREAS (SPACE HEATING LOAD)

POLLUTANT: Particulates__________ SO_2__________ (Check one)

Dwelling Size Categories
Residential Buildings

1 Tract Number	Number of rooms per dwelling							
	1	2	3	4	5	6	7	8
2 TOTAL x f	x.650	x.800	x.950	x1.100	x1.250	x1.400	x1.600	x1.800
3 $\frac{\text{Sq.Ft.}}{1000}$								

4 TOTAL $\left(\frac{\text{Sq.Ft.}}{1000}\right)$ __________

5 Non-Residential Uses

Street Address Number St. Name	Establishment Name	Floor Area (in thousands of sq. feet)

6 TOTAL - Non-Residential Floor Space __________

7 Update Information - Construction (sq. ft.) __________

- Demolition (sq. ft.) __________

8 GRAND TOTAL (4 + 6 + 7) __________
(Add construction, subtract demolition)

Worksheet 8. DETERMINING FLOOR AREAS (SPACE HEATING LOAD)

POLLUTANT: Particulates__________ SO_2__________ (Check one)

Dwelling Size Categories
Residential Buildings

1 Tract Number	Number of rooms per dwelling 1	2	3	4	5	6	7	8
2 TOTAL x f	x.650	x.800	x.950	x1.100	x1.250	x1.400	x1.600	x1.800
3 $\frac{Sq.Ft.}{1000}$								

4 TOTAL $(\frac{Sq.Ft.}{1000})$ __________

5 Non-Residential Uses

Street Address Number St. Name	Establishment Name	Floor Area (in thousands of sq. feet)

6 TOTAL - Non-Residential Floor Space __________

7 Update Information - Construction (sq. ft.) __________

- Demolition (sq. ft.) __________

8 GRAND TOTAL (4 + 6 + 7)
(Add construction, subtract demolition) __________

Worksheet 9. Pollution From Space Heating

Line		Particulates	SO_2
1	Percent of dwellings using coal		Same
2	Percent of dwellings using oil		Same
3	Grand total floor area		
4	Floor space heated by coal line 1 x line 3		
5	Floor space heated by oil line 2 x line 3		
6	65 -Tc = L 65 -____ = L =		Same
7	Particulate Emission: (line 4 + 0.76 x line 5) x line 6 x 10^{-11} gm/sec-m^2		
8	SO_2 Emission: (2.9 x line 4 + 3.2 x line 5) x line 6 x 10^{-11} gm/sec-m^2		
9	Concentration $\mu g/m^3$ (from Figure 5-11)		

Worksheet 9. Pollution From Space Heating

Line		Particulates	SO_2
1	Percent of dwellings using coal		Same
2	Percent of dwellings using oil		Same
3	Grand total floor area		
4	Floor space heated by coal line 1 x line 3		
5	Floor space heated by oil line 2 x line 3		
6	65 -Tc = L 65 -____ = L =		Same
7	Particulate Emission: (line 4 + 0.76 x line 5) x line 6 x 10^{-11} gm/sec-m^2		
8	SO_2 Emission: (2.9 x line 4 + 3.2 x line 5) x line 6 x 10^{-11} gm/sec-m^2		
9	Concentration $\mu g/m^3$ (from Figure 5-11)		

Worksheet 10. STRUCTURAL CHARACTERISTICS OF BUILDINGS

	Structure Number 1	2	3
Dimensional Parameters			
1. Volume (V)			
2. Surface Area a. SA_c b. SA_w c. SA_o d. Total SA			
3. Ratio (F) of Volume to Surface Area $F = V/SA$			
Coefficients Permeability			
4. Proportion (P) of each component a. $P_c = \frac{SA_c}{SA}$ b. $P_w = \frac{SA_w}{SA}$ c. $P_o = \frac{SA_o}{SA}$			
5. Permeability Coefficient (K) a. K_w (from Table 6-1) b. K_o (from Table 6-1)			
6. Weighted Permeability Coefficients a. $X = P_c K_w$ b. $Y = P_w K_w$ c. $Z = P_o K_o$ d. $K = X + Y + Z$			
7. Indoor-Outdoor Ratios CO TSP SO_2			

Worksheet 10. STRUCTURAL CHARACTERISTICS OF BUILDINGS

	Structure Number 1	2	3
Dimensional Parameters			
1. Volume (V)			
2. Surface Area			
a. SA_c			
b. SA_w			
c. SA_o			
d. Total SA			
3. Ratio (F) of Volume to Surface Area $F = V/SA$			
Coefficients Permeability			
4. Proportion (P) of each component			
a. $P_c = \frac{SA_c}{SA}$			
b. $P_w = \frac{SA_w}{SA}$			
c. $P_o = \frac{SA_o}{SA}$			
5. Permeability Coefficient (K)			
a. K_w (from Table 6-1)			
b. K_o (from Table 6-1)			
6. Weighted Permeability Coefficients			
a. $X = P_c K_w$			
b. $Y = P_w K_w$			
c. $Z = P_o K_o$			
d. $K = X + Y + Z$			
7. Indoor-Outdoor Ratios CO			
TSP			
SO_2			

Worksheet 11 - TOTAL INDOOR POLLUTANT CONCENTRATIONS

Line		Structure Number 1	2	3
1	Total Outdoor Levels CO (Section 5) mg/m^3 TSP (Section 5) $\mu g/m^3$ SO_2 (Section 5) $\mu g/m^3$			
2	Indoor-Outdoor Ratio CO TSP SO_2			
3	Indoor Concentration from Outdoor Source CO mg/m^3 TSP $\mu g/m^3$ SO_2 $\mu g/m^3$			
4	Concentrations due to Indoor Generation CO mg/m^3 TSP $\mu g/m^3$			
5	Total Indoor Concentration CO mg/m^3 TSP $\mu g/m^3$ SO_2 $\mu g/m^3$			

Worksheet 11 - TOTAL INDOOR POLLUTANT CONCENTRATIONS

Line		Structure Number 1	2	3
1	Total Outdoor Levels CO (Section 5) mg/m^3 TSP (Section 5) $\mu g/m^3$ SO_2 (Section 5) $\mu g/m^3$			
2	Indoor-Outdoor Ratio CO TSP SO_2			
3	Indoor Concentration from Outdoor Source CO mg/m^3 TSP $\mu g/m^3$ SO_2 $\mu g/m^3$			
4	Concentrations due to Indoor Generation CO mg/m^3 TSP $\mu g/m^3$			
5	Total Indoor Concentration CO mg/m^3 TSP $\mu g/m^3$ SO_2 $\mu g/m^3$			

TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

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16. ABSTRACT
A practical procedure is presented for use by HUD staff and housing planners and designers in determining the air pollution exposure of residential developments. Methods are presented to determine the short term worst case concentrations at specific site locations of carbon monoxide from roadways and parking lots and particulate and sulfur dioxide from point sources and space heating. Procedures are also presented to convert total outdoor pollutant concentrations to indoor levels as a function of building structural characteristics. Outdoor and indoor pollutant levels are compared to air quality standards to determine site acceptability. Recommended design practices are also presented to aid the planner in minimizing the impact of air pollution on residents of the development.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Land Use, Planning and Zoning, Design Standards, Urban Areas, Residential Areas, Diffusion		

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