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AIR QUALITY ANALYSIS WORKSHOP
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 QUALITY ANALYSIS WORKSHOP VOLUME I - MANUAL

by

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1. INTRODUCTION

1.1 SCOPE AND OBJECTIVES

The development of an air pollution control strategy designed to attain and maintain the National Ambient Air Quality Standards (NAAQS) requires an analysis of current and possible future air quality problems. Previous publications[1-13] by the EPA Office of Air Quality Planning and Standards have been designed to provide guidance to regional, state, and local air pollution control and planning groups in the development of an analysis conforming to the requirements of the current federal regulations.[14] It is the objective of this workshop manual to illustrate, through the use of a ficticious county, some of the quantitative and qualitative procedures used in developing an acceptable plan.

Since it is not possible to incorporate the multitude of different situations that might influence the design of a NAAQS attainment/maintenance plan, this example of control strategy development is necessarily limited in scope. The major emphasis will be on the development of measures for the control of particulates since, of the 268 Air Quality Maintenance Areas designated,[15,16] all but a few have been identified as having particulate problems. Many of the procedures demonstrated here will be equally adequate for any of the other criteria pollutants (i.e., SO_2, NO_2, HC, CO, Oxidants) and the similarities and differences in the analysis will be noted accordingly.

This document likewise does not attempt to address the issues of how states or agencies affect intergovernmental cooperation, how states review and provide for public hearings on proposed plans, or how the mechanisms of plan submission and review are administered. The major emphasis in this volume is on the analytical procedures for the review and development of control options. In order to achieve a measure of realism in this exercise, the data for the ficticious county, "County X," have been based on Fulton County, Georgia. This choice was made due to the large volume of information previously compiled for this area.[13] In certain instances the data have been adjusted for the purpose of creating illustrative problems. Wherever possible, however, the form of the data, as it exists in reality, has been preserved, while only the numerical values have been changed.

It is not the purpose of this review to present new policy statements or to issue new guidelines for analytical procedures. Rather, it is designed to illustrate existing guidelines and to clarify the application of current policy. This document is specifically directed at providing working level state and local air pollution control engineers and planners with this guidance.

1.2 AIR QUALITY ANALYSIS OVERVIEW

Figure 1-1 presents a flow diagram of the Air Quality Analysis System (AQAS) procedure that will be reviewed here. The first step is to determine the level of analysis that is appropriate for the area under study. The objective of this step is to assure the most efficient use of available resources in control plan development. The next step is to compile a baseline data base consisting of air quality data, meteorological information, an air pollutant emission inventory, and regional planning data. This will form the foundation of the analysis. Next, growth and development information must be translated into indices to estimate future emissions. At this point, it may be necessary to revise the level of analysis detail to adjust to special problems identified by these estimates. The baseline and future emissions are then allocated to portions of the study area for the purpose of improving the spatial resolution of the analysis. Next, the air quality impact of the baseline and estimated future emissions are determined through the use of one of several available air quality simulation models. The modeling results are analyzed to determine the type and extent of the air quality problem present in the study area. At this point it may again be necessary to revise the level of analysis to properly treat the identified situations. Should the analysis indicate a NAAQS attainment and/or maintenance problem, then control strategies must be developed and tested through reapplication of the simulation model. After establishing a set of technically adequate control strategies, a final evaluation step should be performed to determine the relative effectiveness of each strategy in meeting the air quality goal. This final evaluation must account for known economic, social, legal, and institutional constraints as well as probable impediments to control strategy implementation.

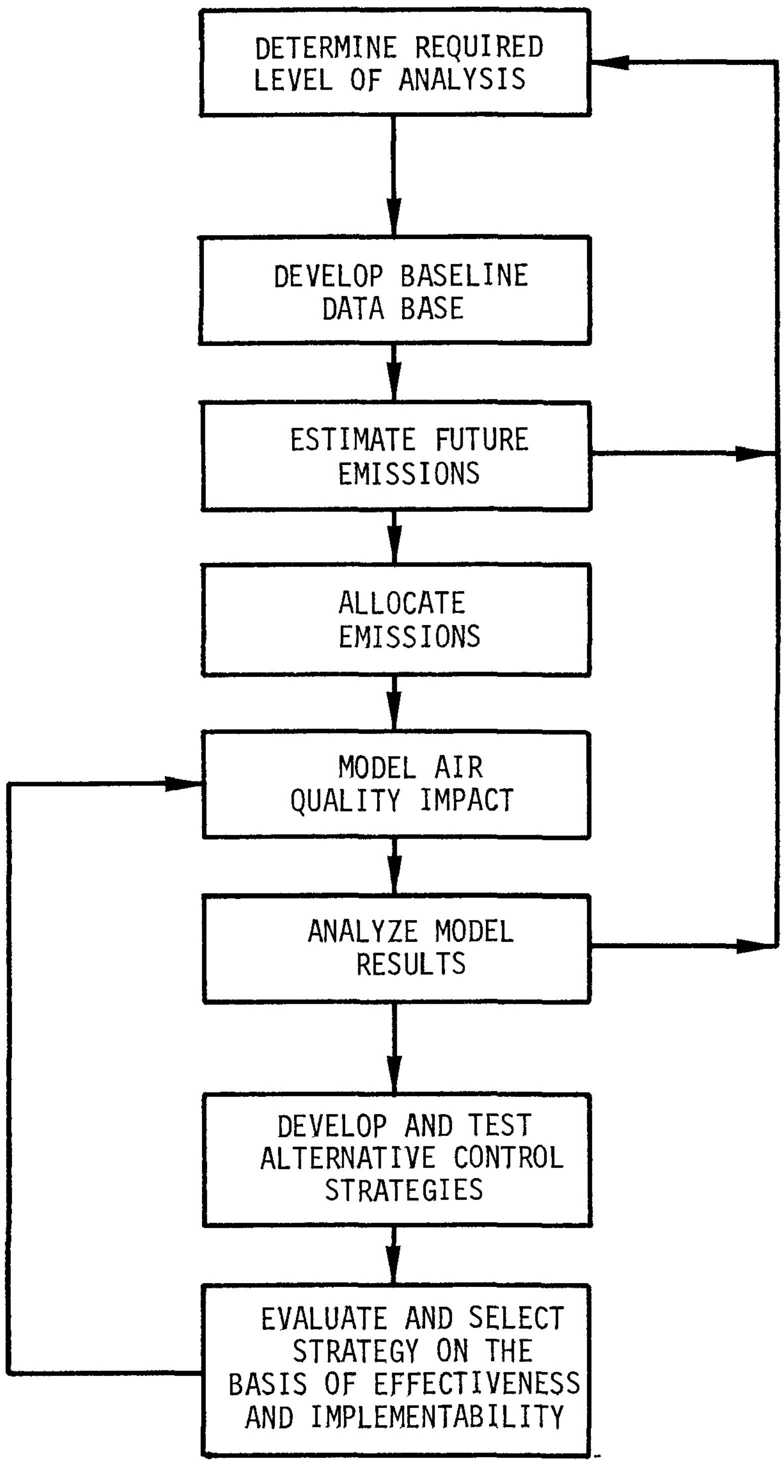


Fig. 1-1. Air Quality Analysis System

1.3 EXAMPLE COUNTY DESCRIPTION

1.3.1 Existing Conditions

County X, as shown in Fig. 1-2, is an elongated county, approximately 56 miles long and 14 miles wide with the long dimension oriented in a northeast-southwest direction. A river forms most of the western boundary, and the topography characterized by low hills and rolling terrain is not extreme.

Urban development dominates the central third of the county, in which the major city of the region and its contiguous suburbs are located. Little usable vacant land exists in the central portion of the urbanized area. The northern and southern thirds of the county are relatively sparcely populated, and less than 5% of the land in areas farthest removed from the center city is devoted to urban land uses (including residential, commercial, and industrial uses).

The largest concentration of commercial activity in the county occurs in the central business district (CBD) of the major city, with nearly 30% of the land area there in commercial use. The CBD is very close to the geographic center of the county. A few additional areas near the CBD also have appreciable commercial development, but clusters of commercial activity large enough to account for as much as 15% of the area of any census tract do not exist farther than about 12 miles from the CBD.

The CBD is also the location of appreciable industrial development. Additional industrial districts occur along railroads to the north, east, and southwest of the CBD. One of the major concentrations of large particulate point sources is in the industrial district about three miles north of the CBD in which a steel rolling mill, a grey iron foundry, and a lead smelting operation are located. Northwest of the CBD, between it and the river, is another significant industrial point source at the site of a brick and structural tile plant. A steam plant located in the CBD and another to the northwest are also large point sources of particulates.

Other industrial point sources beyond the boundaries of the county contribute to the particulate air quality levels over the region. Two coal, oil, and gas fired electric generating plants are closely spaced along the western bank of the river to the northwest of the CBD. Seven stone quarrying operations in neighboring counties form a ring of large particulate emitters

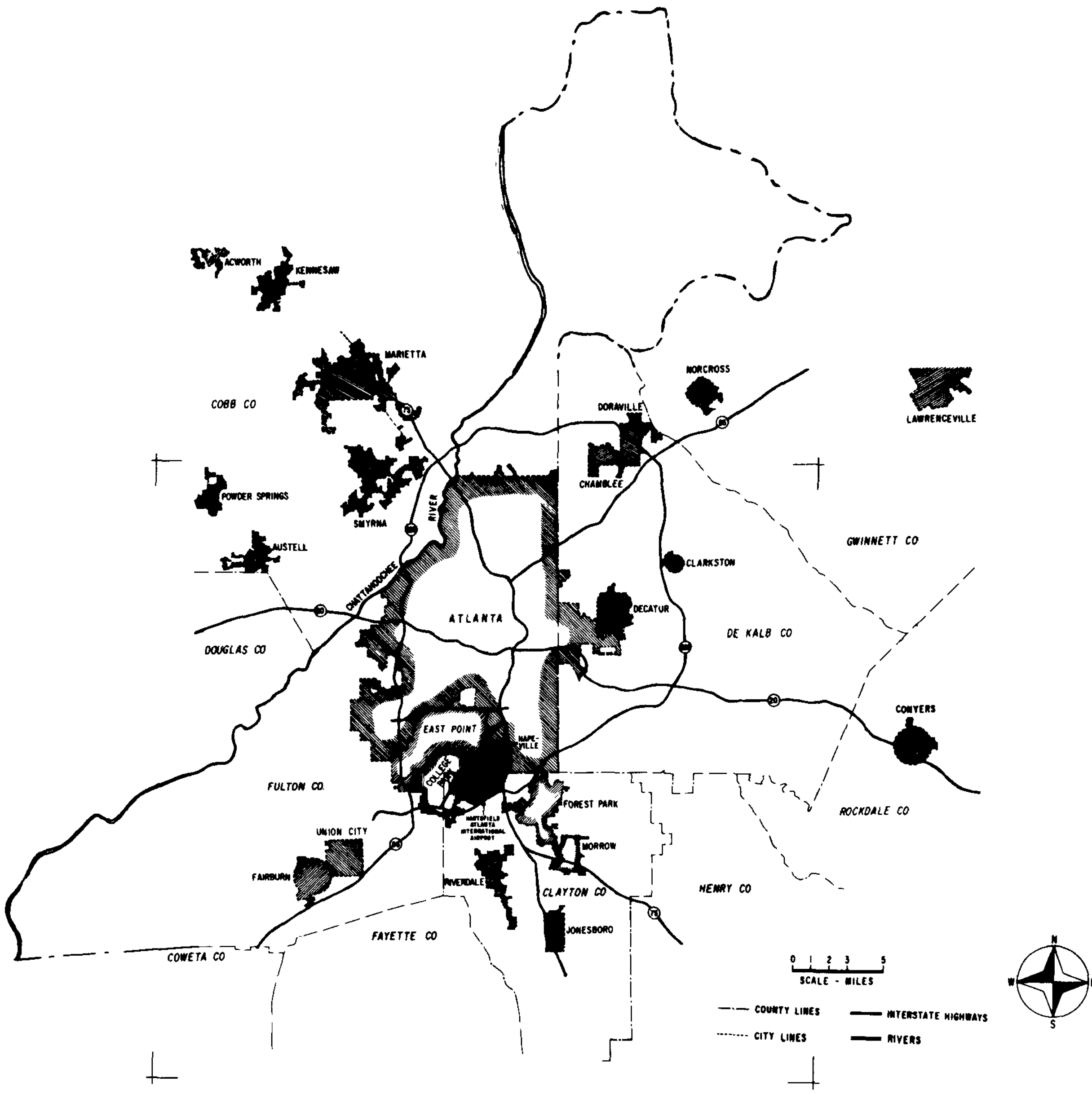


Fig. 1-2. Fulton County, Georgia - County X

around County X. These stone quarries account for more than half of the particulate emissions from point sources in the regional emission inventory.

One large area of predominantly residential development exists relatively near and to the west of the CBD. Suburbs to the north of the central city are primarily residential. Southwestern suburbs have a more diverse mix of urban land uses, but they too are the location of large areas of residential development.

1.3.2 Projected Development

The change in land use between the present and 1985 is typified by withdrawal of some land from urban use in the center of the built-up area, a significant increase in urban development in areas 8 to 10 miles from the CBD that currently are at the edge of the urbanized area (to the north, this rapid growth extends nearly 20 miles from the CBD), and a more modest trend toward urbanization in the northern and southern extremes of the county. While the total percentage of area devoted to urban land use in areas near the CBD appears to be in decline, a more significant trend is the increasing percentage of industrial land use in many of these same areas. Several of the existing industrial districts, in particular the area of foundries and smelting to the north of the CBD, show some decrease in activity, but nearby areas to the northeast and northwest of the CBD have the largest increases in industrial land use in the county. The moderate industrial activity that currently exists in the southeast corner of the urbanized central third of the county is another potential site of industrial expansion.

Residential land use more nearly follows the overall trend in urbanized land area, with reductions nearly universal in areas within 3 or 4 miles of the CBD. The actual locations of the growing residential areas are, in part, determined by the transportation network in the county and changes proposed for it. The completion of a new rail rapid transit system will result in much development activity near the terminals of its branches. Without further transportation investments, which is the assumption made here, this development will be clustered more densely about the terminals. The transit branches within the county extend only to the edges of the central third of the county, and overall growth, correspondingly, tends to be concentrated near the fringes of the current built-up area. Clusters of development, including sizable increases in residential land use will be found by 1985 near the river to the west and northwest of the CBD and also approximately 12 miles to the southwest. Existing residential areas in the suburbs to the north will continue to more steadily northward, although these areas aren't well serviced by the new transportation system.

In summary, the anticipated increase of about 25% in population of the county up to 1985 will be accommodated somewhat less expansively than has been customary for metropolitan growth in the recent past.

2. DETERMINING LEVEL OF ANALYSIS DETAIL

2.1 OVERVIEW

The first step in the Air Quality Analysis System procedure is a determination of the required level of analysis detail (see Fig. 1-1). Ideally, the level of detail should be commensurate with the severity and extent of the existing and/or projected air quality problems. The unavailability of resources or data necessary to perform the analysis at the ideal level can limit the analysis to a less detailed level. The guiding concept should be that all analyses are to be carried out with the maximum reasonable effort.

During the analysis period it may be necessary to revise the estimates of the required level of analysis detail as the extent of the problems become more precisely defined and the limitations of available data and resources become clearer as indicated in Fig. 1-1. It is not possible to, a priori, define the detail required with complete accuracy. The level chosen must be a balance between the ideal of complete detail and what can be done within the available time with the available resources and data. This is often evident only after some experience with the analysis.

The basic steps in determining the level of analysis detail are outlined in Fig. 2-1. Three basic inputs determine the level of analysis:

Level of analysis appropriate to the air quality problems,
Limitations due to available resources, and
Limitations due to available data.

Prior to beginning the full AQAS procedure, some preassessment of these three inputs is necessary so that available resources can be used most efficiently.

It should be emphasized that the description of the process for determining the level of analysis detail is not intended to imply that this must be carried out as part of an acceptable Air Quality Maintenance Plan. It is designed only for the purpose of assisting the states in determining the best allocation of resources and need not be reported or referenced to in any plan submission.

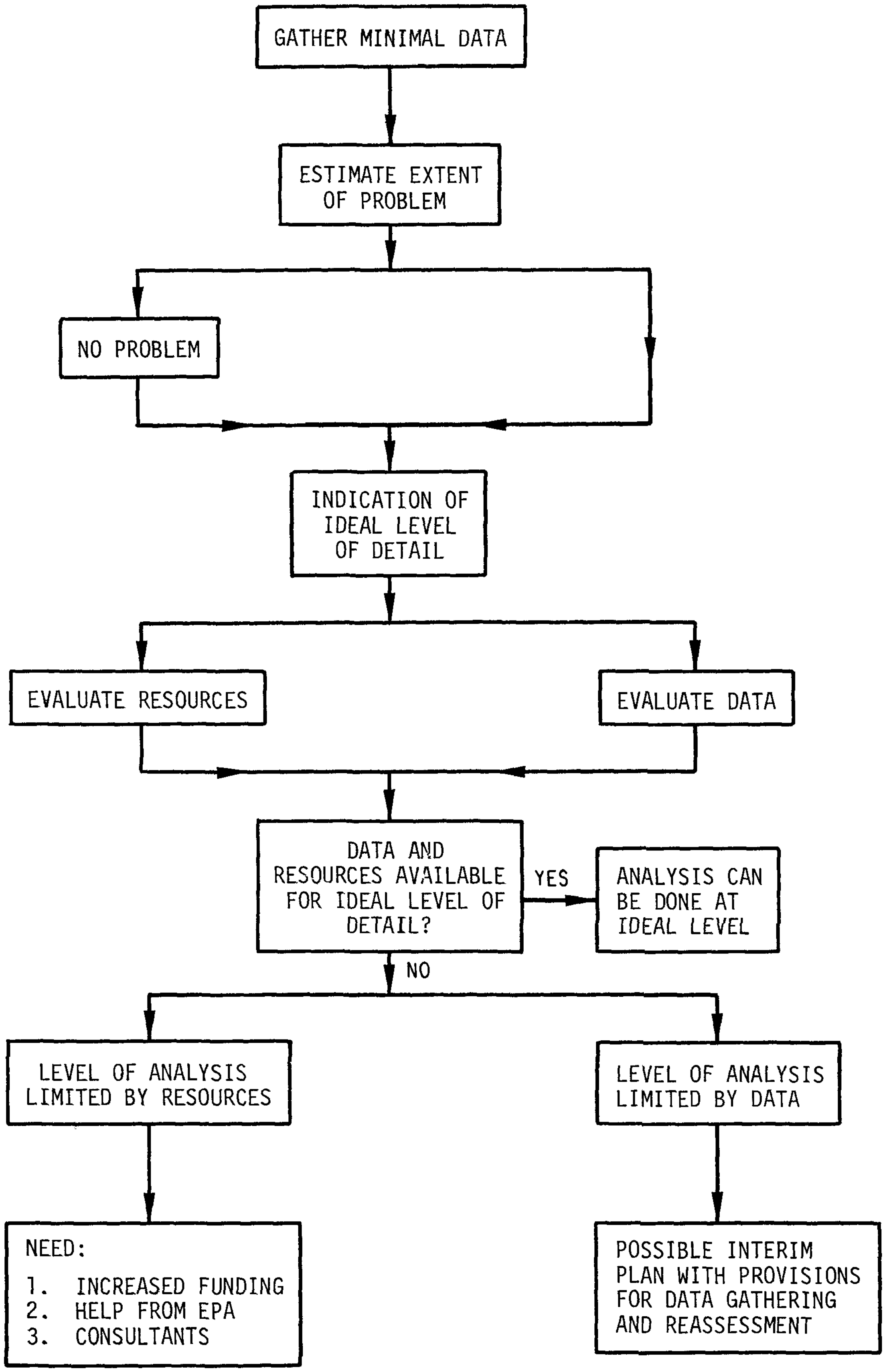


Fig. 2-1. Determining the Required Level of Analysis Detail

2.2 PREASSESSMENT

2.2.1 Gather Minimal Data

The preassessment phase consists of the initial completion of first five steps in Fig. 2-1. If reevaluation of the level of detail becomes necessary as the analysis progresses, the considerations given below would still apply, but the experience already gained during the analysis could be used to limit the reevaluation to those areas where a greater level of detail than was initially indicated would be needed.

The first step is to assemble some minimal data base that must include air quality data and the variables required for emissions projections. A minimal set of air quality data is available from the EPA's Storage and Retrieval of Aerometric Data (SAROAD) information file. Appendix A contains sample tabulations of the SAROAD data. Where more detailed air quality data are available at the state and local levels, it should be used, even in the preassessment phase, since it is important that the most severe problem be found. Several methods of making air quality estimates are discussed in Section 3 and may be used when actual data is unavailable.

The types of data needed to make emission projections are listed in Reference 7 and discussed in Section 4. The preassessment phase will generally be performed at a simple level of detail. Knowledge of local conditions may indicate that intermediate or full detail may be necessary for certain source categories or specific sources. If this type of a priori knowledge is available it can be used to avoid the duplication of effort involved in doing a simple analysis to confirm a result already established by experience. At a minimum, the emissions data from EPA's National Emission Data System (NEDS) are available. Appendix B contains some sample tabulations. Growth projections from the Office of Business Economics and the Economic Research Service (OBERS) are available at this stage. Appendix D contains this data for the Metropolitan Atlanta Air Quality Control Region (AQCR). Alternatively, a dialogue with local planning commissions may generate an insight into the growth prospects for the study area that would be usable for this preassessment.

Local knowledge and experience can, even in this initial phase, aid in guiding and limiting the data gathering efforts. Local air pollution control agencies will usually already have a reasonable estimate, based on experience, what the major problems are and whether they are likely to be due to a few large point sources, numerous small area sources, or mobile sources. The preassessment of air quality data can also provide some guidance at this stage. If the data indicates severe and widespread problems, say areas more than about 20% above allowable levels, then it is likely that a complete analysis will be needed of suspect sources, and efforts to obtain the necessary data can begin early in the analysis process.

At this point a minimal data base has been collected and even before a formal estimate of the extent of the problem has been made, some focusing of the data gathering efforts has been made possible based largely on local experience. Efforts to obtain more detailed data can thus be continuing simultaneously with the first estimates of the extent of the air quality problem.

2.2.2 Estimate Extent of Problem

The most rudimentary type of air quality analysis is that based on subjective judgment or generalized procedures and criteria such as those used in the initial designation of Air Quality Maintenance Areas.[1] During the preassessment phase described here, a preliminary analysis at a simple level but more complete and reflective of local data is carried out. What is desired is a refinement of the indications of where problems will arise and what sources cause them by using readily available data.

Future air quality levels may be projected by using some form of atmospheric simulation model and rough approximations of future emission levels from the minimal data available. (Section 6 discusses the use of atmospheric simulation models.) If a sophisticated dispersion model (e.g., the Air Quality Display Model) is available and the agency performing the analysis has experience in its use, then it may be desirable to perform the preassessment with this tool. Otherwise, a simple proportional model will suffice for this phase. (Note that the modeling requirements described by the regulations[14] for the actual plan are not this slack.)

The preassessment analysis to determine the ideal level of detail can be structured by attempting to provide answers to the questions:

Is there an existing air quality problem?

Is there a maintenance (future) problem only?

What is the magnitude of the problem?
What is the spatial extent of the problem?
What types and categories of sources are involved?
How many sources are involved?

2.2.3 Indicate Ideal Level of Detail

With at least a partial answer to some of these questions, it is possible to determine what the most useful level of detail might be. For example, if the preassessment shows a particular source category to be creating a problem, then some effort should be expended in developing a detailed description of the emission patterns of sources in that category. If the preassessment shows projected air quality to be substantially in violation of the NAAQS, then substantial detail is required. If the preassessment shows air quality levels close to the NAAQS, detailed analysis is required to determine whether the projected problem is real. If the problem is a spatially localized "hot spot" problem due primarily to nearby sources, the greatest detail is necessary for these sources. Problems occurring throughout an analysis region require detailed information from the entire region. If problems occur in the future (beyond about 8 years) and more detailed data is needed, the time to develop the needed data bases is available. If the preassessments show no air quality problems, additional detail will still be needed to substantiate this projection.

2.3 EVALUATE RESOURCES

The available resources must be evaluated to determine the level of detail actually attainable. The steps are indicated in the left-hand branch on Fig. 2-1. The resource evaluation should examine:

The state of the present AQAS effort,
Level and expertise of staffing,
Existing plans affecting air quality,
Existing air quality management programs, and
Modeling capabilities.

Each of these parameters is examined for indications that it limits the level of detail obtainable to less than the ideal level. For example, there may not be enough personnel to perform the analysis at the ideal level. Much of the required detail can already exist in the present State Implementation Plan, transportation control plan, or within other air quality programs such as new source review and variance programs. In other cases, the lack of experts in fields like transportation or planning may limit the level of detail. When the level of analysis detail is limited by resources, aid in increasing the level of detail obtainable can come from:

An increased level of funding,
Assistance provided by the EPA Regional Office, or
The use of consultants.

If these sources can provide no help, the maximum reasonable effort with the available resources must be put forth, knowing that the level of analysis detail will be less than ideal.

2.4 EVALUATE DATA BASES

Air quality projections depend upon several different data bases. The level of detail available in any base limits the level of detail at which the analysis can be done. The level of detail of the following data bases must be considered:

Air quality data,
Emissions inventory,
Growth factors and activity levels,
Transportation data, and
Allocation parameters.

The preassessment analysis will not use the most detailed data. It does indicate what level of detail is ideally needed in the data bases. If completely detailed data is available or can be made available within the limitations imposed by available resources, the air quality analysis can be done at the ideal level of detail. If sufficiently detailed data are not available, a detailed analysis cannot be done. It may be possible to prepare an interim plan using the best detail available with provision for gathering more detailed information. This would, of necessity, be followed by a reassessment of the problems. Otherwise, lack of data will limit the level of analysis to less than ideal.

3. DEVELOPMENT OF BASELINE DATA

The set of information required as a baseline for the development of an air quality analysis is made up of three parts: air quality data, meteorological information, and an emission inventory.

3.1 AIR QUALITY DATA

3.1.1 Uses of Data

Ambient air quality data are necessary for the development of attainment and maintenance strategies. Comparison of measured ambient levels or statistics computed from them with the National Ambient Air Quality Standards (NAAQS) is the primary means of determining whether air quality goals are being achieved. Where the NAAQS are being exceeded, the reason for the high levels must be determined and the need for corrective action evaluated. Comparison of data over a period of years for a specific area is an indicator of developing air quality trends. In areas exceeding the NAAQS, the trend can be used as a monitor of progress in attaining the standards. In areas where NAAQS are being met but where growth and development are occurring, upward trends in measured concentrations may dictate a reevaluation of the need for specific maintenance measures in addition to existing stationary source and mobile source programs.

In addition to the identification of current attainment and maintenance problems, projection of potential future problems and assessment of the effectiveness of present control strategies are based on ambient air quality data. When simulation models are used to either estimate present air quality at locations where no monitors exist or to predict future levels, air quality data should be used to calibrate the model. When proportional techniques of predicting air quality are used, air quality data are a necessary part of the calculations.

3.1.2 Estimation Methods and Averaging Times

In order to be compared with the NAAQS, air quality data must be available for the averaging times specified in Table 3-1. In addition, for averaging times less than one year, the data must include the second highest measured value since the NAAQS specify values "not to be exceeded more than once per year" for other than annual averages.

Table 3-1. National Ambient Air Quality Standards

	Concentrations in μg/m³ Averaging Time				
Pollutant	1-hr	3-hr	8-hr	24-hr	1-yr
Particulates					
Primary				260	75 (G)
Secondary				150	60[a] (G)
SO_2					
Primary				365	80 (A)
Secondary		1300			
CO	40[b]		10[b]		
Hydrocarbons		160[c]			
Oxidants	160				
NO_2					100 (A)

[a]Intended as a guide to meeting the 24-hour secondary standard (40CFR50).

[b]CO concentrations measured in mg/m³.

[c]6 AM to 9 AM only. The hydrocarbon standard is intended as a guide to achieving the oxidant standard.

(A) Arithmetic average.

(G) Geometric average.

NOTE: All averages less than 1 year are not to be exceeded more than once per year.

When data for the averaging times specified in the NAAQS are not available, the following situations arise:

> For continuous data where the hourly averages are available, the appropriate averages and second highest values may be calculated.
>
> For non-sequential data, for incomplete data sets, and for data where only summary statistics are available, the appropriate averages and second highs may be estimated using Larsen's statistical methods.[17,18]

In using continuous data, References 11 and 19 may be consulted to determine how to average data and compute second highest values. In particular, it should be noted that:

> The running average beginning at each clock hour should be used for the short-term standards, and
>
> The maximum second highest non-overlapping value should be used for standards not to be exceeded more than once per year.

It should be emphasized that only measured data can be used to evidence violations of the NAAQS; Larsen's methods can, however, be used to estimate the severity of existing or future air quality problems.

Frequently aerometric data is only available in summary form giving some of the following information:

> Annual arithmetic mean,
>
> Annual geometric mean,
>
> Standard deviation,
>
> Geometric standard deviation,
>
> The total number of samples and the maximum measured value, or
>
> Two percentiles and the corresponding concentration values.

If any pairs of these except the third and sixth or fifth and sixth is available, Larsen's methods can be used to:

> Estimate the concentration likely to be exceeded more than once per year for comparison with the NAAQS, and/or
>
> Use data available for one averaging time to estimate the statistics appropriate to another averaging time.

Larsen also describes a simple graphical method that can be used to estimate the concentrations that are exceeded with a particular frequency when the geometric mean and geometric standard deviation are known. This graphical technique can be used in the simplest level of analysis as a quick means of estimating the values that are exceeded more than once per year.

The validity of Larsen's techniques depends upon how closely the actual data fit the model's assumption that air quality data are lognormally distributed. Unless past experience has shown that Larsen's methods are valid for the pollutant and in the area of interest or unless the individual measured values are available to test for lognormality, his methods must be used with some caution. The test for lognormality can be made either graphically by seeing whether the data fall approximately on a straight line when plotted on lcg-probability paper, or analytically by use of the statistical χ^2 test.

Larsen's methods were based on data taken at Continuous Air Monitoring Program (CAMP) sites in urban locations and would be expected to be applicable in similar locations. They should not be applied in areas dominated by single strong point sources. If the critical assumption of lognormality cannot be tested because only summary statistics are available, then a complete set of individual measurements should be collected to establish the applicability of Larsen's methods.

If the data prove not to be lognormal or if past experience has shown Larsen's methods inappropriate, there are nonparametric statistical tests that do not require the assumption of lognormality. Reference 19 discusses one simple test that can be used to infer whether a certain quantile of a complete data set would exceed a specified value when only a sample of the set is available. The assistance of a trained statistician should be sought when dealing with these problems.

3.1.3 Spatial Distribution of Sites

The spatial distribution of sites with air quality data is also important. EPA regulations for State Implementation Plans require a minimal number of monitors in each Air Quality Control Region (AQCR), but this number is usually too small to provide a detailed assessment of ambient air quality. General guidance in assessing the coverage provided by a monitoring network is provided in References 11 and 19. Ideally, data should be available from:

- Hot spots where concentration maxima occur,
- Clean areas that can be used to estimate background concentrations,
- Areas with the highest population density or total population,

All distinct subareas of the region of interest,

Areas where rapid growth and development are expected,

Areas projected to have the highest future concentrations.

Comprehensive data of this type will generally be lacking and modeled estimates of air quality at various locations will be necessary. In an urban area, about twenty points provide reasonable confidence in a model calibration. Frequently, however, fewer will be available and correspondingly less confidence can be placed in the accuracy of modeled air quality estimates. Since air quality maintenance considerations have not been primary in monitoring network design, data from areas where rapid growth and development are expected and areas projected to have the highest future concentrations are likely to be unavailable. In addition, identification of these areas would emerge only as the air quality analysis process progresses. Expansion of the monitoring network to provide more comprehensive coverage is thus likely to be necessary, especially in areas with anticipated air quality problems.

3.1.4 Time Distribution of Data

When baseline data sets are being gathered, the time period covered and the number of observations at each site must also be considered. Data must be available from the appropriate baseline year and all the data must be from the same year. Since most monitoring programs are expanding, the most recent available year of data will probably be the most comprehensive. The air quality data year must also correspond to the emission inventory year used to calibrate a dispersion model and make projections for attainment and maintenance planning.

3.1.5 Evaluation of Data

Some evaluation of the data should also be done where possible. In References 11 and 19, EPA has provided methods of evaluating the acceptability of air quality data when the full data sets are available. For example, oxidant data taken at night and carbon monoxide data taken during early morning hours are likely to be unrepresentative of potential problems, since the maximum concentrations of these pollutants generally occur at times of high insolation and peak traffic density, respectively. Where non-sequential sampling schedules have been used, the number of samples can be used to estimate the precision of calculated means by the methods of Hunt.[20] Proposed amendments to EPA's requirements for the submission of state implementation plans allow consideration of the accuracy and precision of data and projections in determining whether NAAQS will be attained and maintained. The effect on projected air quality concentrations of factors such as the following may be considered:

> Current air quality concentrations,
>
> The magnitude of past year-to-year variations in air quality concentrations, and
>
> The degree of confidence in the methods used to determine air quality concentrations resulting from projected emissions.

The number of samples in a year's data set also indicates whether the set can be considered complete. If, for example, there are only 2,000 hourly sulfur dioxide values in a data set for a year, the data set should probably be rejected in accordance with the guidelines that require 75% of the possible values to be present before statistics are computed.

3.1.6 Method of Measurement

One further consideration must be given to the data. Only data collected by certain methods can be used as the basis for air quality analysis and planning. A summary of approved, unapproved, and unacceptable methods is given in Table 1 in Reference 11. Unapproved methods are currently employed in many places and for SO_2, CO, and oxidants. They may continue to be used until a federal reference method has been promulgated. For methods not listed in the table as, for example, sulfation methods of measuring sulfur dioxide, the EPA Regional Office should be consulted concerning the acceptability of the data.

3.1.7 Sources of Data

State and local air pollution control agencies will usually be the best sources of air quality data, as they generally have the most complete and recent data sets. A portion of the state and local data is also submitted to EPA through its Regional Offices. This data is stored in the SAROAD

(Storage and Retrieval of Aerometric Data) system from which it can be accessed in reduced data format through the Regional Offices. Submissions to SAROAD are filtered at both the regional and national levels. Hence, state and local agencies usually have more detailed and comprehensive data than is available from SAROAD. Proposed EPA regulations would require that all applicable air quality data collected since October 1, 1972, be used in the analysis and that such data be submitted to SAROAD so that the plan can be evaluated and future progress assessed.

Agencies at all levels sometimes conduct special short-term sampling programs aimed at the evaluation of specific problems. When baseline air quality is being established, data from such programs can often provide information supplementing the more comprehensive data obtained from other sources.

In areas where measured air quality data is lacking, two methods are available to estimate expected levels:

Dispersion modeling, and
Estimates based on measured air quality in similar areas.

Reference 12 discusses the air quality simulation models generally available, their capabilities, and their data requirements. Anticipated amendments to Appendix A Air Quality Estimation[14] will provide explicit guidance as to which models shall be used in developing State Implementation Plan revisions. When measured air quality data are unavailable, the model is used uncalibrated; that is, modeled air quality concentrations are not compared to actual measured air quality data and hence the modeled results must be regarded as approximations until a monitoring program can be established, data collected, and the model predictions compared with actual measured values.

If measured data are available from areas with emission densities, meteorology, topography, and source types similar to those in the area of interest, these data may be used as indications of expected air quality in the area of interest. Such estimates would not account for hot spots caused by large point sources, such as power plants. Any large sources would have to be modeled separately. If this method is used, it is essential that confirmation of the estimates be made through an expanded monitoring program.

3.1.8 Illustration of County X Data

Figure 3-1 shows one of the SAROAD printouts for total suspended particulates from a high volume sampler site in County X. Air quality data for County X was obtained from similar printouts which give:

- The cumulative frequency distribution,
- Number of observations,
- Measured maximum and minimum,
- Arithmetic mean (average),
- Geometric mean,
- Geometric standard deviation,
- Various other information including site name, UTM coordinates, and other locational information.

The NAAQS for particulates are listed on Table 3.1. Since there are two 24-hour particulate standards not to be exceeded more than once per year and since the actual second highest value is not given in the data set, some method must be used to estimate whether the short-term standards are being attained. If the actual second highest measured value is available, it would be sufficient to use this value in the analysis although such a procedure usually underestimates the severity of the short-term problem if data is available for less than about one third of the days (see Reference 11). More than a sufficient amount of information is available on the printout to employ Larsen's methods. The graphical and two analytical methods will be illustrated.

Graphical Method In Fig. 3-2, Larsen's methods have been used to estimate the highest and second highest 24-hour values for comparison with the standards by the graphical method using log-probability paper. Only the geometric mean and the geometric standard deviation are needed to plot the line. The geometric mean plots as the 50% point on the graph. Using the geometric standard deviation, the value to be plotted at the 16% point (C_{16}) can be found from

$$C_{16} = \text{(geometric mean) X (geometric standard deviation)} \qquad (3\text{-}1)$$

where C_{16} is the concentration that is expected to be exceeded 16% of the time. These two points can be plotted and a "Larsen line" drawn through them as in Fig. 3-2. As an aid in drawing the line, a third point may be plotted:

NATIONAL AEROMETRIC DATA BANK
YEARLY FREQUENCY DISTRIBUTION
STATE (11): GEORGIA

11

SITECODE: 110200042
AGENCY/PROJECT: G02
AGENCY TYPE: COUNTY
CITY POPULATION: 496,973
AQCR POPULATION: 1,718,336
EPA-REGION: 4
SUPPORTING AGENCY: FULTON COUNTY HEALTH DEPT AIR POLLUTION CONTROL SECTION
COMMENTS: CHATTAHOOCHEE WATER TREATMENT PLANT CORNER BOLTON RD & MARIETTA BL

LOCATION: ATLANTA
COUNTY (2260): FULTON CO
SITE ADDR: 2532 BOLTON RD
STATION TYPE (21): SUBURBAN - INDUSTRIAL
AQCR (056): METROPOLITAN ATLANTA
SMSA (0520): ATLANTA, GEORGIA

LATITUDE: 33 D. 49 M. 20 S. N
LONGITUDE: 84 D. 27 M. 10 S. W
UTM ZONE: 16
UTM NORTHING: 3745200
UTM EASTING: 00735750
ELEVATION ABOVE GROUND: 027 FT.
ELEVATION ABOVE MSL: 0820 FT.
DIFF. GMT: WEST 05 HOURS

YEAR	POLLUTANT / POLLUTANT-METHOD CODE / METHOD / INTERVAL AND UNITS	NUM OBS	MIN OBS	PERCENTILES 10	30	50	70	90	95	99	MAX OBS	ARITH AVG	GEOMETRIC MEAN	STD DEV
74	PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	55	17.	26.	46.	58.	77.	109.	140.	181.	181.	66.	57.73	1.72
75	PARTICULATE 1110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	24.	25.	35.	60.	70.	105.	124.	124.	124.			

Fig. 3-1. Annual SAROAD Frequency Distribution for TSP Data

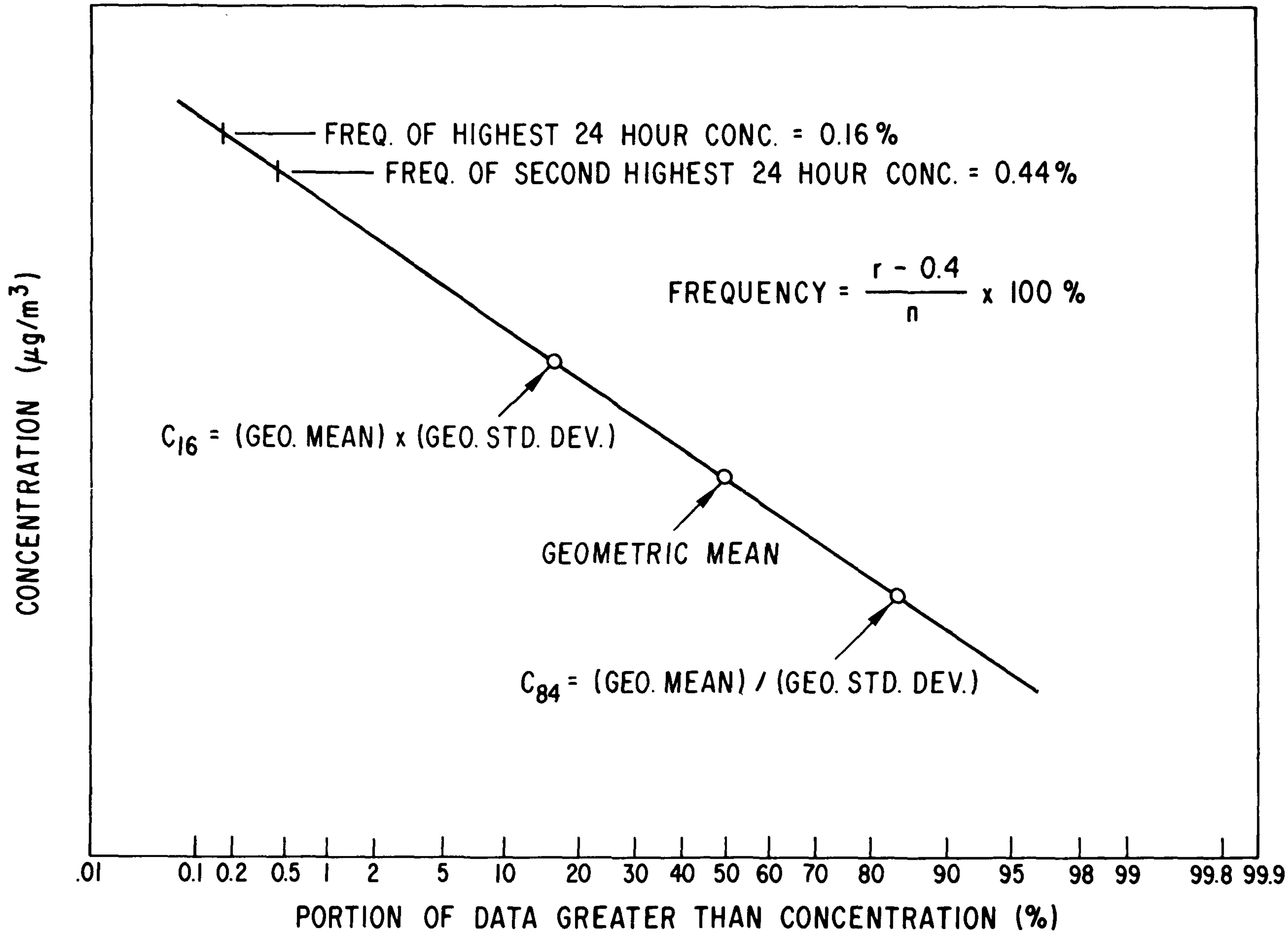


Fig. 3-2. Use of Larsen's Method to Estimate Air Quality

$$C_{84} = \text{(geometric mean)/(geometric standard deviation)} \qquad (3\text{-}2)$$

where C_{84} is the concentration that is expected to be exceeded 84% of the time.

The measured frequency distribution should lie along this line if the data is lognormally distributed. Since Larsen lines are usually plotted so that a frequency-concentration pair gives the percentage of data greater than that concentration while the SAROAD printout pairs give the percentage of data less than the corresponding concentration, the Pth percent point on the SAROAD printout plots as the (100 - Pth) percent point for comparison with the Larsen line.

To estimate the two highest expected concentrations, the frequencies for the highest and second highest values for a year must be calculated. Larsen uses a correction term and the formula:

$$f = \frac{r-0.4}{n} \times 100\% \qquad (3\text{-}3)$$

where f = plotting frequency (%), r = rank order (highest, second, third, ...), and n = the number of samples.

For a year of 24-hour samples, n = 365. The highest expected concentration would occur at a frequency of:

$$f_{highest} = \frac{1-0.4}{n} \times 100\% = 0.16\% \quad \text{and} \qquad (3\text{-}4)$$

the second highest or second most polluted (SMP) day would occur at a frequency of:

$$f_{SMP} = \frac{2-0.4}{365} \times 100\% = 0.44\%. \qquad (3\text{-}5)$$

<u>Analytical Procedures</u> The primary annual standard of 75 $\mu g/m^3$ is apparently being met at the site tabulated on Fig. 3-1, since the measured average is 58 $\mu g/m^3$. Hunt's method[20] can be used to place a confidential interval around this value. For lognormally distributed data, Hunt gives:

$$M1 = 1-\exp(-t \frac{S}{\sqrt{n}} \sqrt{(1-\frac{n}{N})} \ ) \quad \text{and} \tag{3-6}$$

$$M2 = \exp(t \frac{S}{\sqrt{n}} \sqrt{(1-\frac{n}{N})} \ ) - 1, \tag{3-7}$$

where S = ln (geo. std. dev.) = ln 1.72 = 0.5423, n = number of samples = 55, N = number of possible samples = 365, t = the "t-statistic" for n-1 degrees of freedom and the chosen confidence level, and M1 and M2 are the distances between the lower and upper confidence limits, respectively, expressed as a fraction of the measured geometric mean.

If we want 95% confidence limits, the value of t for 54 degrees of freedom (available in standard statistical tables) is about 2.00. Using this value:

$$M1 - .1263 \text{ and } M2 - .1446. \tag{3-8}$$

With a confidence of 95% it can be said that the true geometric mean lies between:

$$\begin{aligned} 57.72(1-.1263) &= 50\ \mu g/m^3 \text{ and} \\ 57.72(1+.1446) &= 66\ \mu g/m^3. \end{aligned} \tag{3-9}$$

Thus, there is a reasonable assurance that even had a full set of 365 daily readings been available, this site would not have violated the primary annual standard, since even the upper 95% confidence limit of 66 $\mu g/m^3$ is well below the standard of 75 $\mu g/m^3$.

The short-term analysis can also be done analytically. The method to be used depends upon the data available. If the geometric mean and geometric standard deviation are available, Larsen gives a simple equation to estimate the second most polluted (SMP) day in Reference 18. His formula is:

$$C = MgSg^{z} \tag{3-10}$$

where C = the required concentration, Mg = geometric mean, Sg = geometric standard deviation, and z = distance of C from the mean measured in standard deviations.

Inability to find z often deters the use of Larsen's analytical formulas. The following simple method permits the calculation of z:

1. Find f from the formula for frequency used in the above graphical analysis, but express the result as a decimal rather than as a percentage:

$$f = \frac{r-0.4}{n}$$

2. Find $U = [\ln(1/f^2)]^{1/2}$.

3. Then $z = U-(2.52 + .8U + .01U^2)/(1.0 + 1.43U + .19U^2 + .001U^3)$.

In this analysis for the SMP value, r=2 and there would be n=365 samples in the year.

$$f = \frac{2-0.4}{365} = .0043835$$

$$U = 3.2954 \qquad (3\text{-}11)$$

$$z = 2.62$$

The SMP value can then be estimated:

$$C_{SMP} = 57.72(1.72)^{2.62} = 239\ \mu g/m^3. \qquad (3\text{-}12)$$

This is in good agreement with the 235 $\mu g/m^3$ value estimated from the graph and certainly within the limits of expected error in drawing the Larsen line and interpolating values.

A second frequently available set of information is the actual number of samples n(=55 in this case), the arithmetic mean m(=66 $\mu g/m^3$), and the maximum measured value C_{max}(=181 $\mu g/m^3$). The frequency appropriate to the observed maximum and the corresponding z can be found as above:

$$f = \frac{r-0.4}{n} = \frac{1-0.4}{55} = 0.019090, \text{ and} \qquad (3\text{-}13)$$

$$z = 2.2939.$$

Equation (34) in Reference 17 can then be used to find Sg:

$$Sg = \exp(z-[z^2-2\ \ln(c/m)]^{0.5})$$
$$= \exp(2.2939-[2.2939^2-2\ \ln(181/66)]^{0.5}) \quad (3\text{-}14)$$
$$= 1.6367$$

Finally, Equation (22) in Reference 17 can be used to estimate the SMP value using the Sg value of Equation (3-14) and the SMP z value of Equation (3-11):

$$C = m\ Sg^{(z-0.5\ \ln\ Sg)}$$
$$C_{SMP} = 66(1.6367)^{(2.62-0.5\ \ln\ 1.6367)} \quad (3\text{-}15)$$
$$= 213\ \mu g/m^3$$

This result is somewhat less than the estimates obtained by the other two methods but is still within the expected degree of precision. This last method depends heavily on the value of the highest measured value, a value that can frequently be somewhat in error. The method using the geometric mean and geometric standard deviation is preferable, since it makes full use of all the data and is computationally simpler.

In conclusion, the area around this site could well be exceeding both short-term TSP standards but probably not the annual standard. An increase in the number of samples per year at the site would allow a better definition of the potential short-term problem and should be undertaken. Modeling should help to better define the extent of the current attainment problems, if any, and to determine the contributions of various categories of sources to the problem.

One further consideration should be given to the data from this site. High volume samplers are required to run at least every sixth day, giving 60 or 61 samples per year. There are only 55 samples from this site. However, there are over 75% of the minimum required number of samples and statistics can be computed. Figure 3-3 shows the SAROAD frequency distribution by quarters for this site. The five "missing samples" belong in the first quarter of the year when only 10 samples were recorded. However, every quarter is represented by an adequate number of samples and the set is probably representative of the TSP situation at the site for 1974.

10-02-75 NATIONAL AEROMETRIC DATA BANK 11
QUARTERLY FREQUENCY DISTRIBUTION
STATE (11): GEORGIA

SITECODE: 110200042
AGENCY/PROJECT: G02
AGENCY TYPE: COUNTY
CITY POPULATION: 496,973
AQCR POPULATION: 1,718,336
EPA-REGION: 4

LOCATION: ATLANTA
COUNTY (2260): FULTON CO
SITE ADDR: 2532 BOLTON RD
STATION TYPE (21): SUBURBAN - INDUSTRIAL
AQCR (056): METROPOLITAN ATLANTA
SMSA (0520): ATLANTA, GEORGIA

SUPPORTING AGENCY: FULTON COUNTY HEALTH DEPT AIR POLLUTION CONTROL SECTION
COMMENTS: CHATTAHOOCHEE WATER TREATMENT PLANT CORNER BOLTON RD & MARIETTA RD

LATITUDE: 33 D. 49 M. 20 S. N
LONGITUDE: 84 D. 27 M. 10 S. W
UTM ZONE: 16
UTM NORTHING: 3745200
UTM EASTING: 00735750
ELEVATION ABOVE GROUND: 027 FT.
ELEVATION ABOVE MSL: 0820 FT.
DIFF. GMT: WEST 05 HOURS

YEAR-QUARTER POLLUTANT / POLLUTANT-METHOD CODE / METHOD / INTERVAL AND UNITS	NUM OBS	MIN OBS	PERCENTILES 10	30	50	70	90	95	99	MAX OBS	ARITH AVG	GEOMETRIC MEAN	GEOMETRIC STD DEV
74-01 PARTICULATE 110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	10	18.	18.	60.	71.	95.	109.	173.	173.	173.	83.	72.27	1.84
74-02 PARTICULATE 110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	30.	35.	43.	57.	69.	98.	181.	181.	181.	65.	58.13	1.59
74-03 PARTICULATE 110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	17.	20.	26.	47.	56.	106.	109.	109.	109.	51.	43.69	1.81
74-04 PARTICULATE 110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	32.	38.	54.	59.	86.	125.	140.	140.	140.	71.	65.24	1.55
75-01 PARTICULATE 110191 HI-VOL GRAVIMETRIC 24-HOUR UG/CU METER (25 C)	15	24.	25.	35.	60.	70.	105.	124.	124.	124.	59.	52.30	1.69

Fig. 3-3. SAROAD Frequency Distribution by Quarter for TSP Data

PROBLEM 3-1

Given the SAROAD printout (Fig. 3-1) and the outline of Larsen's graphical method, use log-probability graph paper to determine whether it is reasonable to expect a short-term particulate problem at this site. Are there any indications that Larsen's methods are not applicable at this site? Determine if the data are lognormally distributed.

3.2 METEOROLOGY

3.2.1 Uses of Data

Baseline data defining the meteorology of the region must also be collected. This data is needed to:

Input to dispersion models,

Identify the frequency and duration of conditions when short-term, high air pollution levels can exist, and

Estimate fuel consumption for and emissions from space heating.

With the exception of proportional techniques, all models used to relate emissions to air quality require meteorological input whose level of detail depends upon the specific model employed. Unless scaling or statistical techniques, such as Larsen's method, are used, comparison of modeled air quality levels with short-term standards requires the identification of the frequency and duration of short-term periods when meteorological conditions conducive to high pollution levels exist. The methods commonly used to estimate fuel usage for space heating require that the number of "degree days" be known. This parameter is a necessary input for the methods used in Reference 7 to develop emission inventories.

3.2.2 Data Required

The meteorological parameters required include:

Wind speed,
Wind direction,
Atmospheric stability,
Mixing height,
Temperature,
Pressure,
Solar radiation intensity,
Cloud cover,
Ceiling height, and
Degree days.

Which of these parameters are required depends upon the level of detail of the analysis employed and the model to be used. A list of the meteorological inputs required by the various models available from EPA is given in Reference 12.

Requirements vary from no meteorological input for proportional techniques to hourly variations of wind direction, wind speed, stability, and mixing height.

Wind Speed, Wind Direction, and Atmospheric Stability The National Climatic Center (NCC) in Asheville, North Carolina has wind speed and wind direction data available as part of hourly or three-hourly weather records. This data is also frequently available locally from measurements made by state or local air pollution control agencies or from airports.

Data for wind speed and wind direction are frequently combined with atmospheric stability in a joint frequency distribution called a stability wind rose. Various stability wind roses are available from NCC in tabular form, on punched cards, and on tape. The tapes include the hourly or three-hourly observations upon which the stability wind rose is based. Five-year, annual, seasonal, and monthly stability wind roses are available. These stability wind roses are the primary meteorological inputs required by the common dispersion models for annual averages.

Mixing Height Holzworth[21] has provided climatological summaries of mixing heights based on radiosonde observations. He presents isopleth maps of the United States giving morning and afternoon mixing heights on a seasonal and annual average basis. The isopleths for annual average afternoon mixing height (required for the AQDM model) are presented on Fig. 3-4. Mixing heights can be calculated from the radiosonde observations available from NCC by the methods outlined in Reference 10. The calculations are, however, laborious and it is preferable to use Holzworth. If daily morning and afternoon mixing heights are needed, it may be possible to obtain them from a nearby weather station or meteorological data center. Otherwise, the calculations based on other meteorological parameters must be made.

Temperature and Pressure Temperature and barometric pressure data are needed in the calculation of plume rise. NCC can supply the data. In addition to the hourly and three-hourly temperature records, various summaries, some of which are listed in Reference 10, are available. Since variations in temperature and pressure cause only small changes in calculated ground-level concentrations, most calculations simply use the annual mean values

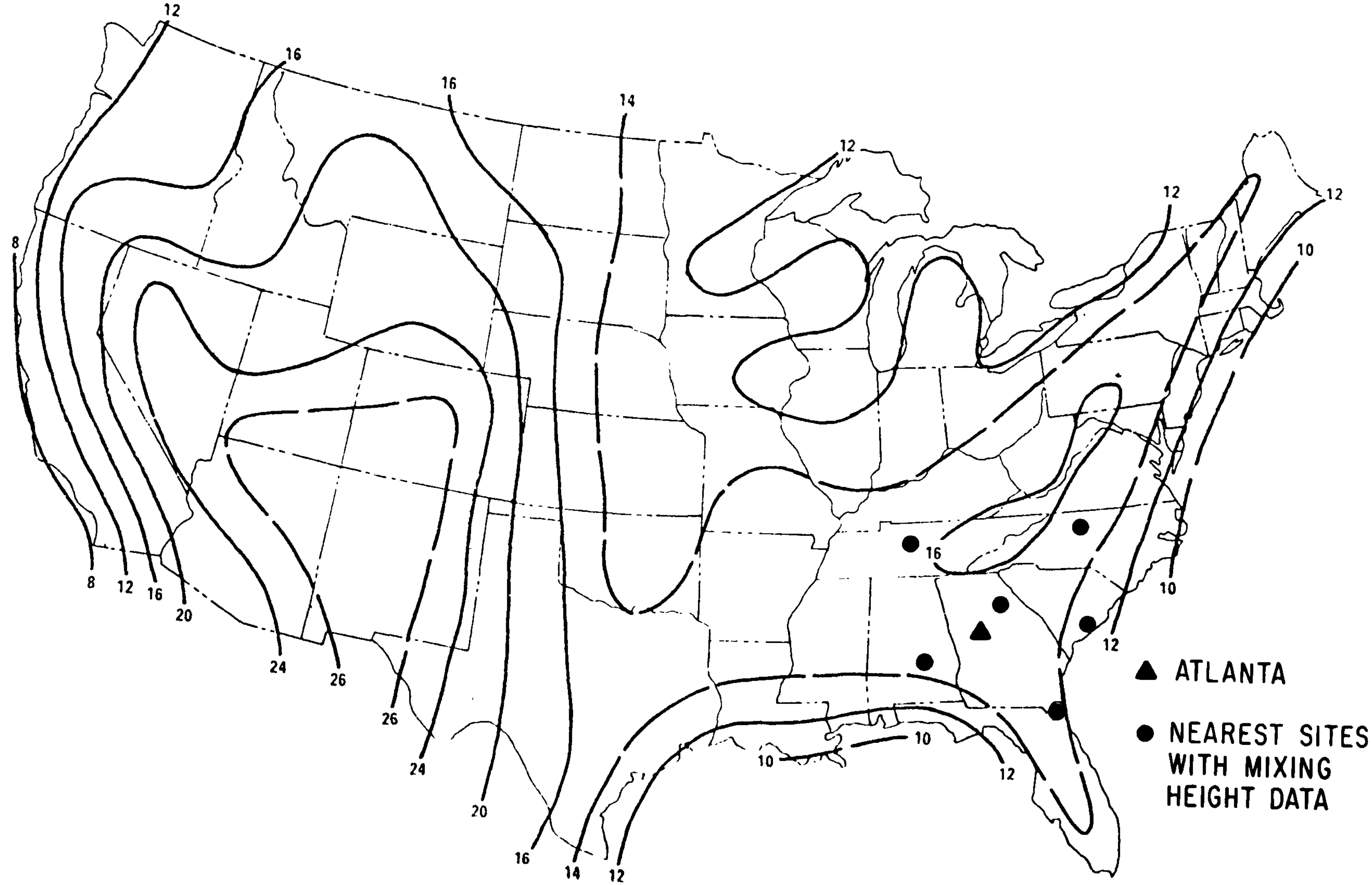


Fig. 3-4. Isopleths (m x 10^2) of Mean Annual Afternoon Mixing Heights

from the nearest weather station. Barometric pressure is also available from NCC in annual average form as well as the hourly or three-hourly observations.

Solar Radiation Intensity, Cloud Cover, and Ceiling Height If atmospheric stability data are unavailable, they may be estimated from other meteorological parameters by Turner's method,[22] which is also explained in Reference 10. The method requires: solar altitude, cloud cover, ceiling, and wind speed. The solar altitude can be obtained from Table 170, Solar Altitude and Azimuth, in the Smithsonian Meteorological Tables.[23] Cloud cover and ceiling are available as hourly or three-hourly observations from NCC. The solar altitude, time of day, cloud cover, and ceiling can be used to index the solar radiation intensity that, together with the wind speed, determines the atmospheric stability. Turner[24] has also presented another method of determining stability based on the same meteorological observations but not requiring the ceiling. When a stability wind rose from NCC can be used, the stability has already been determined and is available on the tape at hourly or three-hourly intervals.

Degree Days Heating degree-days are used to estimate fuel consumption for space heating. The number of degree-days is determined from the number of days the average daily temperature drops below 65°F. For example, a day with an average temperature $\left(\frac{\text{high temperature + low temperature}}{2}\right)$ of 64°F counts as 1 degree-day; a day with an average temperature of 50 degrees counts as 15 degree-days. The data are available from NCC or Reference 39.

3.2.3 Worst Case Data

It is generally assumed sufficient for predicting annual average concentrations to use a stability wind rose for a typical year or one representing an average over several years rather than to attempt to identify those meteorological conditions causing the highest possible annual average. A sensitivity analysis comparing modeled air quality concentrations for stability wind roses from several years, while keeping the emissions inventory constant, allows an estimate to be made of the variations expected from changes in the weather alone. Such an analysis could be used in the discussion of factors affecting the accuracy of the calculations of projected air quality concentrations.

For the 3, 8, and 24-hour standards, the situation is more complex, since the persistence in time of conditions giving rise to high concentrations must be determined. If short-term concentrations are modeled, two methods can be used to determine a reasonable estimate of short-term worst-case conditions:

Consultation with an air pollution meteorologist, and/or

A review of past meteorological records to determine what conditions have led to high concentrations.

In situations where short-term concentrations are to be modeled by repetitive application of a model for each hour, consultation with an <u>experienced</u> air pollution meteorologist, particularly one who has knowledge of the local situation, offers perhaps the best chance of determining what conditions, consistent with local meteorology, would constitute a worst case. Otherwise a search of air quality and weather records to determine the conditions associated with high pollution levels must be made. Meteorological records are generally available over a longer time than air quality records, so after the weather conditions associated with high pollution levels have been determined, the search for a worst historical case can be carried back through the available years of meteorological data. Such a procedure is complicated by fact that the concentration levels are also dependent upon emissions. Some sensitivity analysis should be carried out to investigate the effect of changes in the meteorological input on predicted concentration levels. If the predicted levels do not change significantly for various estimates of worst-case conditions, then finding the true worst case meteorology is probably not important. If, however, the predicted levels are significantly dependent upon the assumed worst case meteorology, the accuracy of the predicted air quality results is questionable, since the true worst case can only approximated by this procedure. In making this assessment, changes in concentration levels are significant if they are on the order of the changes expected due to errors in the other input variables. For example, if a change in the mixing height from 1000 m to 1500 m produces only a one or two percent change in predicted concentration levels and larger errors, say 8-10%, could be caused by suspected inaccuracies in the emission inventory, an attempt to determine precisely what series of hourly mixing heights constitutes a worst case would unnecessary.

3.2.4 Representativeness of Data

Two problems frequently arise when gathering meteorological data:

> The data has been taken at a site remote from the expected problem area, and
>
> The site for which data exists is not similar to the problem area.

Meteorological data is often frequently available only from local airports that are generally located in rural or semi-rural areas. If the problem area is urban, there may be differences between the values measured at the airport and those appropriate to the urban area. This is particularly true of temperature, wind speed, mixing height, and stability, which are affected by the urban heat island and the difference in surface roughness between rural and urban areas. As another example, mixing heights are calculated from soundings taken at points on a grid of approximately 400 km, and hence their spatial resolution is limited. Also, the data may be available from a site on a hilltop, while the expected problem area is in a valley.

Two courses of action can be followed when representative meteorological data is unavailable:

> Adjust existing data, or
>
> Use data from the closest similar site.

In both cases, a meteorologist should be consulted either to suggest ways of adjusting the data or to help choose among candidate sites if more than one is available. This person could also aid in the assessment of the probable errors resulting from the adjustment of the data or from use of data at another site. If there is some limited data available from the problem area, it may be possible to develop a relationship between values or averages at the problem site and those measured at the remote site. Such a relationship could then be used to estimate values for the problem area from the more extensive records at the remote or dissimilar site. A meteorologist may be able to suggest alternative ways of adjusting data as, for example, rotating or compressing wind roses to account for the effects of local topography.

In some cases, the data on file with the National Climatic Center is incomplete or represents only a short observation period (e.g., one or two years). In these cases, the same option of adjusting existing data or using more complete data from another site would have to be exercised.

3.2.5 Illustration from County X Data

In Fig. 3-5, the part of the stability wind rose for County X for C stability is presented as it comes in printed format from NCC. The entries in the table give the relative frequency under conditions of C stability with which winds from sixteen different directions occurred within six different speed categories. For example, conditions of C stability with south-southeast winds between seven and ten knots occur .002260 or 0.2260% of the time in County X. The stability wind rose data in this format was used to punch cards as input to the AQDM model used for County X.

The stability wind rose is based on data taken at the Atlanta International Airport. Figure 3-6 shows the outline of County X and the location of the airport. The airport is located close to the portion of the county that is an area of low rolling hills. No attempt was made to change any of the wind rose data to correct for topographic effects.

Atlanta is located by the dot on Holzworth's map of afternoon mixing heights on Fig. 3-4. It lies midway between the 1400 m and 1600 m isopleths and 1500 m was used as the input to the model. The nearest stations where data upon which the isopleths were based are also shown. Since these are relatively far from Atlanta, the representativeness of the 1500-m value might be questioned. However, substitution of 900 m for the mixing height produced less than a 2% change in modeled TSP concentrations and hence, within the accuracy to be expected from the model itself, the value assumed for the mixing height is not critical over this range. From the isopleths it seems unlikely that a lower mixing height would be appropriate, particularly since Atlanta is not located in a deep valley where greatly reduced mixing heights can occur.

3.3 EMISSION INVENTORY

The air pollutant emission inventory forms the basis of making an assessment of air quality management problems. Substantial guidance in the development of an emission inventory has already been published.[7,13,25]

ANNUAL RELATIVE FREQUENCY DISTRIBUTION STATION =13874 ATLANTA,GA 67-71

	SPEED(KTS)						
DIRECTION	0 - 3	4 - 6	7 - 10	11 - 16	17 - 21	GREATER THAN 21	TOTAL
N	0.000624	0.002603	0.003562	0.000274	0.000000	0.000000	0.007063
NNE	0.000170	0.001370	0.000685	0.000000	0.000000	0.000000	0.002225
NE	0.000195	0.000685	0.001233	0.000000	0.000000	0.000000	0.002113
ENE	0.000263	0.001644	0.002123	0.000411	0.000000	0.000000	0.004441
E	0.000541	0.002466	0.006781	0.001096	0.000000	0.000000	0.010884
ESE	0.000527	0.002260	0.003219	0.000342	0.000000	0.000000	0.006349
SE	0.000547	0.001507	0.002945	0.000274	0.000000	0.000000	0.005273
SSE	0.000356	0.001918	0.002260	0.000205	0.000000	0.000000	0.004739
S	0.000551	0.002603	0.002945	0.000274	0.000000	0.000000	0.006373
SSW	0.000199	0.001781	0.001781	0.000137	0.000000	0.000000	0.003898
SW	0.000409	0.002671	0.003493	0.000479	0.000000	0.000000	0.007053
WSW	0.000395	0.002466	0.003562	0.000548	0.000000	0.000000	0.006970
W	0.000712	0.003836	0.007740	0.000959	0.000000	0.000000	0.013246
WNW	0.000473	0.002534	0.007055	0.001164	0.000000	0.000068	0.011295
NW	0.000653	0.004041	0.011301	0.001507	0.000000	0.000000	0.017502
NNW	0.000301	0.003219	0.007466	0.001027	0.000000	0.000000	0.012014
TOTAL	0.006918	0.037603	0.068151	0.008699	0.000000	0.000068	

RELATIVE FREQUENCY OF OCCURRENCE OF C STABILITY = 0.121438

RELATIVE FREQUENCY OF CALMS DISTRIBUTED ABOVE WITH C STABILITY = 0.002945

Fig. 3-5. Portion of Stability Wind Rose for Class C Stability

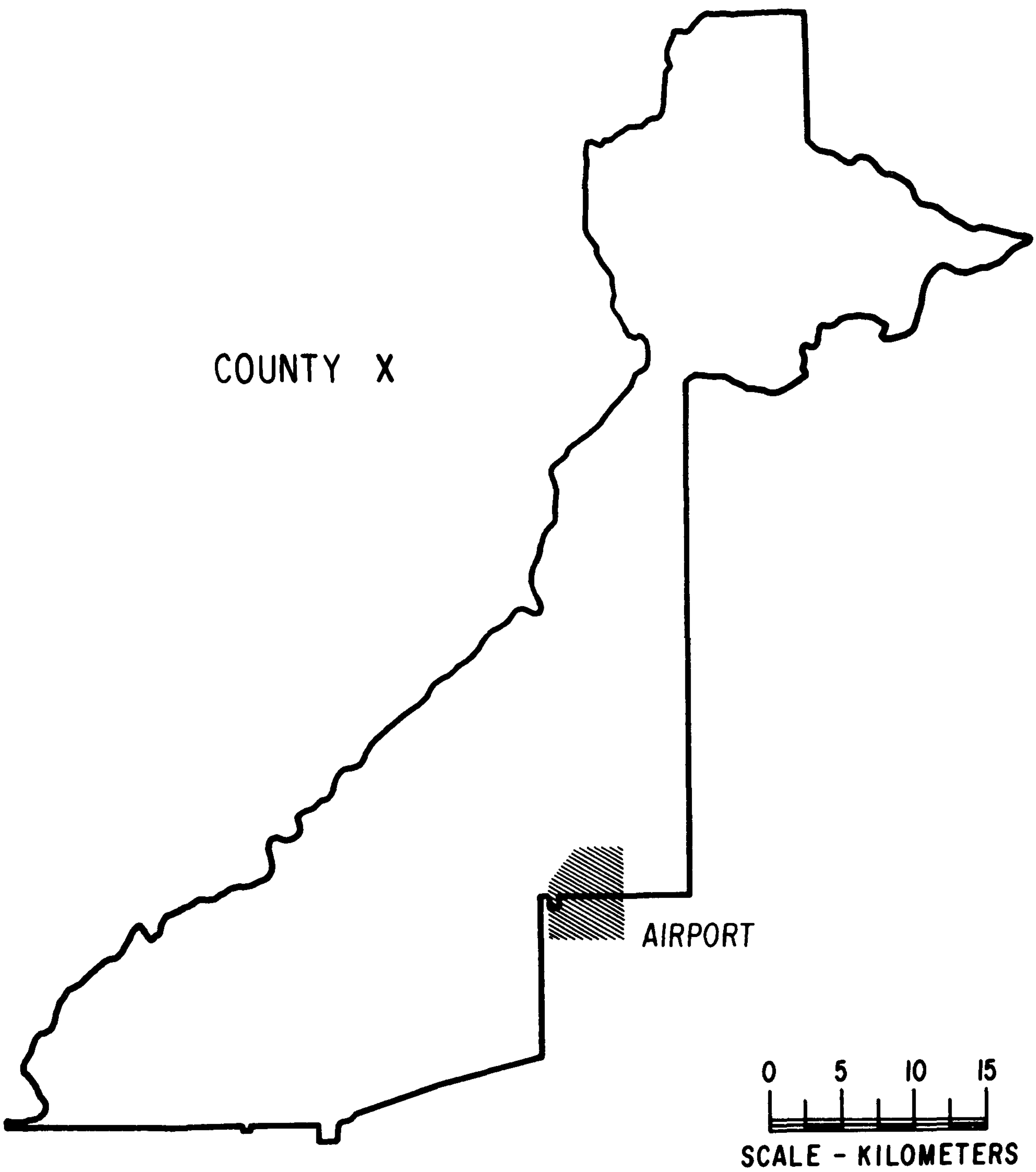


Fig. 3-6. Location of Airport Used for Meteorological Data

3.3.1 Definitions

Because of growth, development, and regulatory programs applied to pollutant-producing activities, the emission inventory can be expected to change with time. Three distinct inventory types can be identified for the purpose of the air quality analysis. They are:

Current inventory,
Updated inventory, and
Projected inventory.

The current inventory is that which exists on file with either the state air pollution control agency or with the federal EPA in the National Emissions Data System (NEDS). Most of this information was developed in the course of the original State Implementation Plan (SIP) development and represents data valid for the 1969-71 period. In many cases, states have updated portions of the inventory in the process of conducting enforcement activities or special studies.

The updated inventory, which will form the basis of the air quality analysis, represents information that is brought up to the most recent time period for which adequate data are available. In most cases this will probably be a 1973 or 1974 inventory. All portions of the inventory should be adjusted to the same year.

The projected inventory(ies) is a forecast of what emissions will amount to when growth, development, and regulatory programs have been accounted for. The projected inventory will be made for several years into the future starting with 1975. (In the unusual situation where there is adequate information available, the 1975 inventory can be developed as the updated inventory with succeeding years being projected inventories.)

This section will deal primarily with the development of an updated inventory using the current inventory as a starting point. The projected inventories will be discussed in the next section.

3.3.2 Data Required

The emission data is generally divided into the following six source categories:

Industrial process,
Fuel combustion,
Transportation,
Electricity generation,
Incineration, and
Miscellaneous.

Table 3-2 lists the subdivisions of each source category and the type of source included in each. Point sources are any stationary source emitting more than some designated minimum (usually 100 tons/year) of a pollutant. An area source is a collection of sources whose individual emission rates are small but whose collective impact may be large. A line source is a source that can be geometrically described best as a line (e.g., a highway). The line source description is used primarily in microscale analyses and need not be employed in all circumstances.

Table 3-3 lists the type of information desired for each source type. The list assumes that some form of modeling and strategy testing will be applied to the emission inventory and so includes parameters other than emission rates.

3.3.3 Sources of Information

Reference 7 lists numerous sources of information that can be used to develop an emission inventory. These fall into three basic categories:

Nationally available data - information published by sources that treat all areas of the country (e.g., Bureau of the Census; Departments of Interior, Commerce, Transportation, Treasury, and Army; National Coal Association, etc.).

Locally available data - information published for the region, state, or local area under study by local agencies (e.g., transportation, land use, air or water quality, energy studies, etc.).

EPA data - information published by EPA providing guidance on translating the above two activity data sets into estimates of emissions.

It must be emphasized that many forms of information are available and experience and judgment are the only guides as to which are the most useful.

Table 3-2. Emission Source Categories[a]

Source Category	Subdivisions	Source Description
Industrial Process	Chemical manufacture Food/agriculture Primary metals Secondary metals Mineral products Petroleum industry Wood products Evaporation Metal fabrication Leather products Textiles Inprocess fuel Other	Point
Fuel Combustion	Internal combustion External combustion	Point, Area
Transportation	Highway Vehicles Light duty gasoline autos Light duty gasoline trucks Motorcycles Heavy duty gasoline trucks Heavy duty diesel trucks Off-highway vehicles Rail locomotives Vessels Aircraft	Area, Line
Electricity Generation		Point
Incineration		Point, Area
Miscellaneous	Solvent evaporation Fires Fugitive dust	Point, Area, Line

[a]These categories are based on those described in References 7 and 13.

Table 3-3. Emission Source Data Required

Source Type	Data Desired
Point	Pollutant emission rates Process activity - type of process, process weight rate Control equipment - type and efficiency Stack parameters Geocoded location Compliance information Land area[a] Employment[a]
Area	Pollutant emission rates Area geometry Area geocoded location Area source type and activity level
Line	Pollutant emission rates Line geometry Line geocoded location Line source type and activity level

[a]May be useful for certain strategy considerations.

3.3.4 Special Considerations

There are several special considerations that will influence the development of the emission inventory.

Level of detail The level of detail in the inventory must be suitable to the analysis to be performed. It is not adequate to develop an inventory of a source category, for example, via crude approximation methods if the analysis will require a detailed consideration of that source's impact on air quality. Should the inventory be developed in an approximate way and the analysis show the need for more detail, it will be necessary to revise the data base. A judicious evaluation of the expected problem areas as outlined in Section 2 should avoid most of these false starts but even a careful preliminary review may not be able to foresee all the potential problems and some iteration may be necessary.

Reference 7 provides for several levels of effort in developing the inventory. The most detailed level (Level 3) should be used on major sources that are expected to impact significantly on regional air quality. The less detailed procedures (Levels 1 and 2) can be used for minor sources. One method suggested for determining which are the major and minor sources is to start with the National Emissions Report[26] on emissions by Air Quality Control Region. The major sources can be identified as those that contribute greater than a threshold percentage (e.g., 5%) to the regional emission level. Sources that contribute less than the threshold level may be treated as minor sources. The threshold level chosen will vary with the resources available, the magnitude of the existing air quality problem and the degree of existing air pollution controls.

In general, it can be said that significant plan revisions based on the use of only Level 1 analyses throughout will not be acceptable without prior approval of the EPA Regional Office. This level of analysis will not give adequate accuracy for a substantial plan revision submission; an analysis comparable to Level 1 will be permitted only in special circumstances.

Subcounty spatial resolution Reference 13 describes methods of allocating emissions compiled on a countywide basis to subcounty areas for the purpose of improving the spatial resolution of the analysis. However, if data are available with a better-than-county resolution, Reference 13 presents techniques that project and allocate emissions directly to subcounty areas. The procedures outlined in Reference 7 and 13 may be used either in parallel or in series for all emission source categories. Familiarity with both references prior to starting the analysis is essential.

Actual v. allowable emissions In the development of the emission inventory it is important to keep in mind that the desired inventory is one that represents, as closely as possible, the actual situation. In this light, the effect of the following things must be considered:

Variances granted,
Non-compliance,
Compliance schedules, and
Improved performance.

The incorporation of stack test data into the inventory whenever possible will ensure that these considerations are included. For sources not yet in operation or for the projected inventories, the first approximation of assuming that sources will just meet the emission regulations will be adequate; however, where information is available to the contrary, it should be included.

Applicability of strategies In developing the emission inventory, it is necessary to foresee what type of information might be needed to evaluate alternative control strategies. If, for example, it is felt that a strategy based on emission density (i.e., emissions per unit area) will receive consideration, then it is necessary to know what land area is currently owned by the sources in the inventory. If a strategy will be directed toward a certain type of process activity, it will be necessary to know which sources use that process. Although it will not be possible to foresee all potential problems, a careful preliminary review will eliminate most of the false starts.

3.3.5 Updating Procedures

The methods of generating an updated emission inventory as described in Reference 7 are schematically illustrated in Figs. 3-7 to 3-12. In general, the most detailed level of analysis relies on the use of an interview procedure to determine the necessary parameters directly from the major sources. The less detailed levels rely on estimates based on county or statewide data and/or national average values of several key items.

For industrial process emissions, the most reliable form of updating the inventory is to use the interview procedure. This is due primarily to the source-specific character of the emission sources. The Level 1 and 2 procedures illustrated by Fig. 3-7 will give only rough estimates of actual emissions.

For fuel combustion sources, the Level 1 and 2 procedures shown on Fig. 3-8 are somewhat more reliable than for process sources because of the availability of detailed fuel consumption data. However, as the next exercise will show, there is still a great deal of approximation that goes into these procedures.

For highway vehicles, the Level 1 procedures in Fig. 3-9 are very crude and should be used only in the event of complete lack of any other information. Data from transportation planning agencies is usually available to some degree to enable an analysis better than Level 1 to be performed.

INDUSTRIAL PROCESS EMISSIONS
(IPE)

LEVEL 1

[NEDS POINT SOURCE FILE EMISSIONS] → [AGGREGATE TO 13 NER CATEGORIES] X [EMPLOYMENT ADJUSTMENT FACTOR FROM COUNTY BUSINESS PATTERNS] = IPE

LEVEL 2

METHOD 1

USE LOCAL INVENTORY DATA.

METHOD 2

SAME AS LEVEL 1.

METHOD 3

SAME AS LEVEL 1, ONLY AGGREGATE TO SCC CLASSIFICATION AND USE SCC EMPLOYMENT.

LEVEL 3

METHOD 1

INTERVIEW TOP 95% OF EMITTERS FROM NEDS FILE.

METHOD 2

INTERVIEW TOP 90% OF EMITTERS FROM NEDS FILE.

METHOD 3

INTERVIEW TOP 90% OF EMITTERS OF MAJOR POLLUTANT FROM NEDS FILE.

Fig. 3-7. Update Procedures for Industrial Process Sources

FUEL COMBUSTION EMISSIONS
(FCE)

LEVEL 1,2

[ESTIMATE FUEL CONSUMPTION FROM STATEWIDE DATA] → [PRORATE STATE FUEL USE TO COUNTY] X [EMISSION FACTORS] = FCE

LEVEL 3

[INTERVIEW DEALERS AND MAJOR USERS TO DETERMINE FUEL CONSUMPTION] X [EMISSION FACTORS] = FCE

Fig. 3-8. Update Procedures for Fuel Combustion Sources

TRANSPORTATION EMISSIONS

HIGHWAY VEHICLE EMISSIONS (HVE)

LEVEL 1

[DETERMINE COUNTY GAS AND DIESEL OIL SALES FROM TAX DATA] → [ESTIMATE VMT BY (GAS SOLD) X (VEHICLE TYPE DISTRIBUTION) X (AVERAGE MPG)] X [VEHICLE EMISSION FACTORS] = HVE

LEVEL 2

[DETERMINE VMT FROM LOCAL STUDIES] → [DISAGGREGATE BY VEHICLE TYPE IF NECESSARY] X [VEHICLE EMISSION FACTORS] = HVE

LEVEL 3

[DETERMINE VMT, SPEED, VEHICLE CLASS AND AGE DISTRIBUTION FROM LOCAL STUDIES] X [VEHICLE EMISSION FACTORS] = HVE

Fig. 3-9. Update Procedures for Highway Vehicles

ELECTRIC GENERATION EMISSIONS
(EGE)

LEVEL 1,2

[DETERMINE FUEL USE, % SULFUR, % ASH FROM LOCAL OR NATIONAL SOURCES] X [EMISSION FACTORS] = EGE

LEVEL 3

[DETERMINE FUEL USE, % SULFUR, % ASH FROM LOCAL OR NATIONAL SOURCES] → [USE STACK TEST DATA AND/OR EMISSION FACTORS] = EGE

Fig. 3-10. Update Procedures for Electric Generation Sources

INCINERATION EMISSIONS
(IE)

LEVEL 1

[ESTIMATE QUANTITY OF WASTE INCINERATED USING NATIONAL AVERAGES] → [DISAGGREGATE TO POINT AND AREA SOURCE USING EXISTING DISTRIBUTION] X [EMISSION FACTORS] = IE

LEVEL 2,3

[DETERMINE QUANTITY OF WASTE INCINERATED FROM LOCAL STUDIES] X [EMISSION FACTORS] = IE

Fig. 3-11. Update Procedures for Incineration Sources

MISCELLANEOUS SOURCE EMISSIONS

GASOLINE HANDLING EVAPORATION EMISSIONS
(GHE)

SOLVENT USE EVAPORATION EMISSIONS
(SUE)

LEVEL 1,2

GASOLINE HANDLING [DETERMINE GAS SALES FROM TAX DATA] X [EMISSION FACTORS] = GHE

SOLVENT USE [ESTIMATE SOLVENT USE FROM NATIONAL PER CAPITA AVERAGES] X [EMISSION FACTORS] = SUE

LEVEL 3

[INTERVIEW GASOLINE AND SOLVENT DEALERS TO DETERMINE USE] X [EMISSION FACTORS] = GHE, SUE

OTHER SOURCE CATEGORIES HANDLED AS NEEDED

Fig. 3-12. Update Procedures for Miscellaneous Sources

For electric generation, there are adequate sources of information for virtually the entire country such that even a Level 1 analysis as shown on Fig. 3-10 should be fairly accurate. This is probably the source category that can be analyzed in the most detailed fashion with the smallest effort needed for information gathering.

For incineration, the Level 1 analysis shown on Fig. 3-11 is crude since national averages are used. The use of local studies is significantly more accurate.

For the gasoline handling and solvent use, miscellaneous sources on Fig. 3-12, the Level 1 and 2 analyses are crude because of the use of national average consumption figures, but the Level 3 analysis would require a fairly extensive effort due to the large number of small sources.

3.3.6 Illustration of County X

Table 3.4 summarizes the baseline year emissions for County X tabulated in the National Emissions Report format specified in Reference 7. The total particulate emissions are 29,524 tons/year. The biggest contributors are industrial process sources (37%), especially the primary metals and mineral products industries, industrial fuel combustion (11%), industrial and commercial/institutional incineration (27%), and fugitive dust from agriculture, unpaved roads, and construction (20%).

Table 3-4. County X Baseline Emissions, 1973

County Base Year Emissions Report

COUNTY X
YEAR ~~1973~~ Baseline

SOURCE				EMISSIONS, TONS PER YEAR				
				PART	SOX	NOX	HC	CO
FUEL COMBUSTION-EXTERNAL	RESIDENTIAL FUEL (AREA)	ANTHRACITE COAL						
		BITUMINOUS COAL		18				
		DISTILLATE OIL		18				
		RESIDUAL OIL						
		NATURAL GAS		193				
		WOOD						
		TOTAL		229				
	ELECTRIC GENERATION (POINT)	ANTHRACITE COAL						
		BITUMINOUS COAL						
		LIGNITE						
		RESIDUAL OIL						
		DISTILLATE OIL						
		NATURAL GAS						
		PROCESS GAS						
		COKE						
		SOLID WASTE/COAL						
		TOTAL						
	INDUSTRIAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	67				
			POINT	2705				
		LIGNITE	POINT					
		RESIDUAL OIL	AREA	2				
			POINT	570				
		DISTILLATE OIL	AREA	106				
			POINT	1				
		NATURAL GAS	AREA	153				
			POINT	7				
		PROCESS GAS	AREA					
			POINT					
		COKE	POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		BAGASSE	POINT					
		OTHER	POINT					
		TOTAL	AREA	328				
			POINT	3283				

Table 3-4. County X Baseline Emissions, 1973 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
FUEL COMBUSTION-EXTERNAL (CONTINUED)	COMMERCIAL-INSTITUTIONAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	61				
			POINT					
		LIGNITE	POINT					
		RESIDUAL OIL	AREA					
			POINT					
		DISTILLATE OIL	AREA	29				
			POINT					
		NATURAL GAS	AREA	138				
			POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		OTHER	POINT					
		TOTAL	AREA	228				
			POINT					
	OTHER		POINT					
	TOTAL EXTERNAL COMBUSTION		AREA	785				
			POINT	3283				
FUEL COMBUSTION INTERNAL	ELECTRIC GENERATION	DISTILLATE OIL						
		NATURAL GAS						
		DIESEL						
		OTHER						
		TOTAL						
	INDUSTRIAL FUEL	DISTILLATE OIL						
		NATURAL GAS						
		GASOLINE						
		DIESEL						
		OTHER						
		TOTAL						
	COMMERCIAL-INSTITUTIONAL FUEL	DIESEL						
		TOTAL						
	ENGINE TESTING	AIRCRAFT						
	TOTAL INTERNAL COMBUSTION							
TOTAL FUEL COMBUSTION		AREA		785				
		POINT		3283				

Table 3-4. County X Baseline Emissions, 1973 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
INDUSTRIAL PROCESS (POINT)	CHEMICAL MANUFACTURING			1				
	FOOD/AGRICULTURE			5				
	PRIMARY METAL			6274				
	SECONDARY METALS			41				
	MINERAL PRODUCTS			4476				
	PETROLEUM INDUSTRY							
	WOOD PRODUCTS							
	PROCESS EVAPORATION							
	METAL FABRICATION							
	LEATHER PRODUCTS							
	TEXTILE MANUFACTURING							
	INPROCESS FUEL							
	OTHER/NOT CLASSIFIED							
	TOTAL			10797				
SOLID WASTE DISPOSAL	GOVERNMENT (POINT)	MUNIC. INCIN.						
		OPEN BURNING						
		OTHER		8				
		TOTAL		8				
	RESIDENTIAL (AREA)	ON-SITE INCIN.						
		OPEN BURNING						
		TOTAL						
	COMMERCIAL-INSTITUTIONAL	ON-SITE INCIN-ERATION	AREA	917				
			POINT					
		OPEN BURNING	AREA	1703				
			POINT					
		APARTMENT	POINT					
		OTHER	AREA					
			POINT					
		TOTAL	AREA	2 620				
			POINT					
	INDUSTRIAL	ON-SITE INCIN-ERATION	AREA	170				
			POINT	436				
		OPEN BURNING	AREA	4688				
			POINT					
		AUTO BODY INCIN.	POINT					
		OTHER	POINT					
		TOTAL	AREA	4858				
			POINT	436				
	TOTAL SOLID WASTE DISPOSAL		AREA	7478				
			POINT	444				

Table 3-4. County X Baseline Emissions, 1973 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
TRANSPORTATION (AREA)	LAND VEHICLES	GASOLINE	LIGHT DUTY	713				
			HEAVY DUTY	108				
			OFF HIGHWAY					
			TOTAL					
		DIESEL	HEAVY DUTY					
			OFF HIGHWAY					
			RAIL					
			TOTAL					
	AIRCRAFT	MILITARY						
		CIVIL						
		COMMERCIAL						
		TOTAL						
	VESSELS	BITUMINOUS COAL						
		DIESEL FUEL						
		RESIDUAL OIL						
		GASOLINE						
		TOTAL						
	GAS HANDLING EVAPORATION LOSS							
	TOTAL TRANSPORTATION			821				

Table 3-4. County X Baseline Emissions, 1973 (Continued)

SOURCE			PART	SOX	NOX	HC	CO
MISCELLANEOUS (AREA)	SOLVENT EVAPORATION	INDUSTRIAL SOURCES (AREA)					
		DRY CLEANING					
	FIRES	STRUCTURAL					
		FROST CONTROL					
		SLASH BURNING					
		WILD FOREST					
		AGRICULTURAL					
	DUST CAUSED BY HUMAN AGITATION OF THE AIR	UNPAVED ROADS	1439				
		UNPAVED AIRSTRIPS					
		PAVED ROADS					
		MINERAL PROCESSING					
		TILLING ACTIVITIES	877				
		LOADING CRUSHED ROCK, SAND, GRAVEL					
		CONSTRUCTION	3600				
	AIRBORNE DUST CAUSED BY NATURAL WINDS	STORAGE PILES					
		TILLED LAND					
		UNTILLED LAND					
		Total Miscellaneous	5916				
GRAND TOTAL	AREA		15000				
	POINT		14524				

PROBLEM 3-2

Update the County X emission inventory for fuel combustion sources using a Level 2 analysis; that is, use statewide fuel consumption data and determine the county's share. Follow the procedures in Reference 7 using the copies of Tables 2.1, 2.3, 2.4, and 2.5 from that report, which are attached here as Figs. 3-13 to 3-16. All of the necessary data are in the appendixes.

Table 2.1
Baseline County Fuel Use
(External Combustion Unless Noted Otherwise)

SOURCE		MAJOR FUELS								MINOR FUELS										ELECTRICITY
		COAL			OIL															
		ANTHRACITE	BITUMINOUS	LIGNITE	RESIDUAL	DISTILLATE	DISTILLATE (INTERNAL)*	NATURAL GAS	NATURAL GAS (INTERNAL)*	PROCESS GAS	LPG	COKE	WOOD	BAGASSE	DIESEL (INTERNAL)*	GASOLINE (INTERNAL)*	ENGINE TESTING (INTERNAL)*	OTHER	OTHER (INTERNAL)*	(USED AS FUEL SUBSTITUTE)
INDUSTRIAL	POINT																			
	AREA																			
COMMERCIAL/ INSTITUTIONAL	POINT																			
	AREA																			
RESIDENTIAL	AREA																			
UNITS		TONS			1000 GALLONS			10^6 CU FT			1000 GAL	TONS			1000 GALLONS					KWH

CALCULATION LEVEL ________________

DATA SOURCES ________________

*ALL INTERNAL COMBUSTION REFERS TO STATIONARY SOURCES ONLY

Fig. 3-13. Baseline County Fuel Use, Table 2.1 from Ref. 7

Table 2.3
Sulfur and Ash Content of Coal and Heating Oil

	PERCENT SULFUR*					PERCENT ASH*		
SOURCE	ANTHRACITE COAL	BITUMINOUS COAL	LIGNITE COAL	RESIDUAL OIL	DISTILLATE OIL	ANTHRACITE COAL	BITUMINOUS COAL	LIGNITE COAL
INDUSTRIAL								
COMMERCIAL/ INSTITUTIONAL								
RESIDENTIAL								
ELECTRICITY GENERATION								

DATA SOURCES: __________

BASE YEAR: __________

*SULFUR AND ASH CONTENT ARE GIVEN PER UNIT WEIGHT FOR COAL, PER UNIT VOLUME FOR OIL

Fig. 3-14. Sulfur and Ash Content of Coal and Heating Oil, Table 2.3 from Ref. 7

Table 2.4
Apportionment of State Heating Oil Sales Totals to Customer Categories

LINE	SALES COMPONENT	FUEL USE, 1000 GAL.	
		RESIDUAL	DISTILLATE
1	TOTAL HEATING OIL SALES		
2	COMM/INST EMPLOYMENT FACTOR		
3	INDUSTRIAL EMPLOYMENT FACTOR		
4	COMM/INST OIL FRACTION		
5	INDUSTRIAL OIL FRACTION		
6	SALES TO MILITARY		
7	SALES TO INDUSTRY		
8	OIL COMPANY USE		
9	RESIDENTIAL USE		
10	TOTAL COMM/INST USE		
11	TOTAL INDUSTRIAL USE		

CALCULATION LEVEL ________

Fig. 3-15. Apportionment of State Heating Oil Sales Totals to Consumer Categories, Table 2.4 from Ref. 7

Table 2.5
Baseline State Fuel Use
(External Combustion Unless Noted Otherwise)

		MAJOR FUELS								MINOR FUELS										ELECTRICITY
		COAL			OIL															
SOURCE		ANTHRACITE	BITUMINOUS	LIGNITE	RESIDUAL	DISTILLATE	DISTILLATE (INTERNAL)*	NATURAL GAS	NATURAL GAS (INTERNAL)*	PROCESS GAS	LPG	COKE	WOOD	BAGASSE	DIESEL (INTERNAL)*	GASOLINE (INTERNAL)*	ENGINE TESTING (INTERNAL)*	OTHER	OTHER (INTERNAL)*	(USED AS FUEL SUBSTITUTE)
INDUSTRIAL	POINT																			
	AREA																			
COMMERCIAL/ INSTITUTIONAL	POINT																			
	AREA																			
RESIDENTIAL	AREA																			
UNITS		TONS			1000 GALLONS			10^6 CU FT			1000 GAL	TONS			1000 GALLONS					KWH

CALCULATION LEVEL ____________
DATA SOURCES ____________

*ALL INTERNAL COMBUSTION REFERS TO STATIONARY SOURCES ONLY

Fig. 3-16. Baseline State Fuel Use, Table 2.5 from Ref. 7

PROBLEM 3-3

Estimate the emissions from fugitive dust sources in County X. The necessary equations can be found in Appendix F. Assume the following information is known:

Agricultural tilling: 194,000 acres are under cultivation; the land is tilled, on the average, once a year; the silt content (i.e., portion of particles in the surface soil of size between 2 μ and 50 μ in diameter as determined by the Buoyocous hydrometer) is 45%.

Unpaved roads: 30 miles of unpaved roads with an average traffic load of 60 veh/day, the average speed is 35 miles per hour, the road silt content is 12%.

Heavy construction: 250 acres are under construction, the activity continues year-round.

4. ESTIMATING FUTURE EMISSIONS

Accumulated experience in the preparation and evaluation of air quality attainment and maintenance plans has emphasized the need for considering the effect of growth and development on pollutant emission levels. This was recognized in the early State Implementation Plan (SIP) efforts but has only lately become a significant aspect of all SIP revision actions. This section is aimed at describing the methodologies for projecting future trends in emission levels.

4.1 PROJECTION REQUIREMENTS

The initial regulations for the development of air quality maintenance plans[14] indicated that the time period to be covered was the 10-year span between 1975 and 1985. Proposed revisions to these regulations recognize that the uniform 10-year period:

> Does not reflect coordination with other on-going federal planning programs and
>
> Does not recognize the unique problems of each study area.

To address these situations, the revisions include the requirements indicated on Fig. 4-1.

Where another federally-sponsored planning program is underway (e.g., Department of Transportation 3-C plan, Department of Housing and Urban Development's 701 comprehensive plan, or EPA's area-wide wastewater treatment plan under Section 208 of the Water Pollution Control Act Amendments of 1972) then the air quality analysis must address the time period extending furthest into the future of these programs. Where there is no additional federally-funded planning program, then the analysis must address, at a minimum, the 10-year period to 1985. These same timing considerations must be reflected in any submitted air quality maintenance plan.

To allow for flexibility in addressing the problems of each study area, the EPA Regional Administrators are given the authority to allow for a less detailed analysis for the period beyond 1985. Similarly, discretion is given to the Regional Administrator to accept air quality maintenance or long-range air quality management plans covering less than the 10-year period but not less than 3 years.

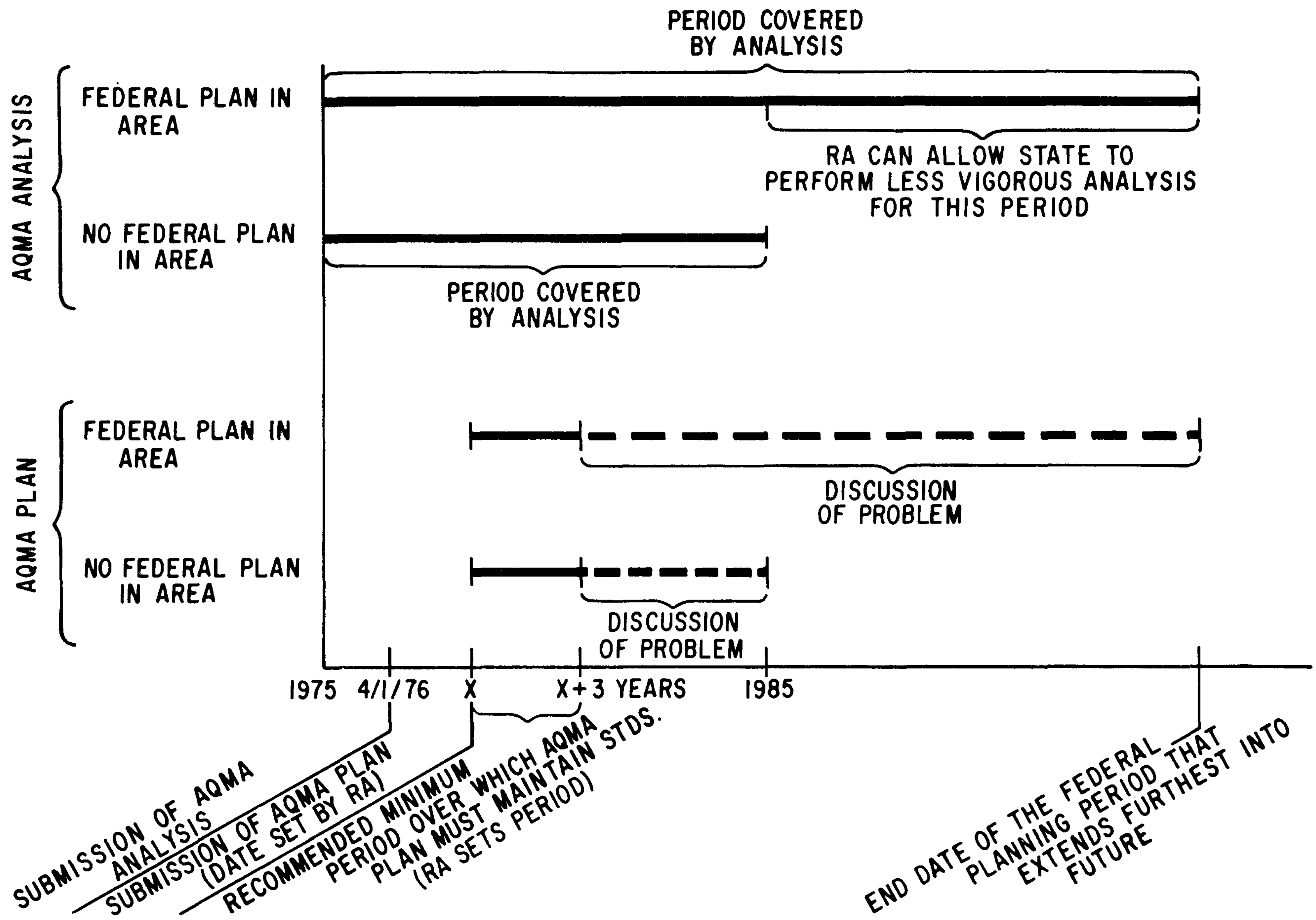


Fig. 4-1. Air Quality Analysis Time Period Requirements

4.2 PROJECTED VARIABLES

The projection of future emissions brings the air quality analysis to the least rigorous portion of the analysis procedures. Forecasting the future has never been amenable to a truly scientific approach and relies, in the case of the air quality analysis, on a combination of considered judgment and best guesses. Using the six emission categories, the variables that must be projected are the following:

Industrial process activity,
Fuel consumption,
Transportation activity,
Electricity demand,
Solid waste generation, and
Miscellaneous emission-producing activity.

These may be converted to emissions using emission factors.[27] In addition, the temporal and spatial distribution of these variables (e.g., when new plants will come on line and where they will be located) is important to the air quality analysis. In most situations, projections of these parameters are not available or are available only on a cruder scale than needed for an adequate air quality analysis, especially in attainment/maintenance problem areas. Reliance must then be placed on surrogate variables such as population, employment, land use, earnings, and others that are projected with reasonable accuracy and precision and that can then be transformed into growth factors for the desired variables. Figure 4-2 illustrates this process. The surrogate variables are those most frequently used by planning groups in developing comprehensive regional plans.

Projections of population, and to some extent employment, have customarily been the starting point for the projection of other variables. Overall size is the most important factor in population projection, but other characteristics of the population composition can be important for determining activity levels. The age distribution of the population, distribution of household sizes, and the income composition of the population affect the details of the need for residential areas and community facilities. Likewise, more than just the total employment figures are of value in projecting the future industrial and commercial/institutional growth of the region.

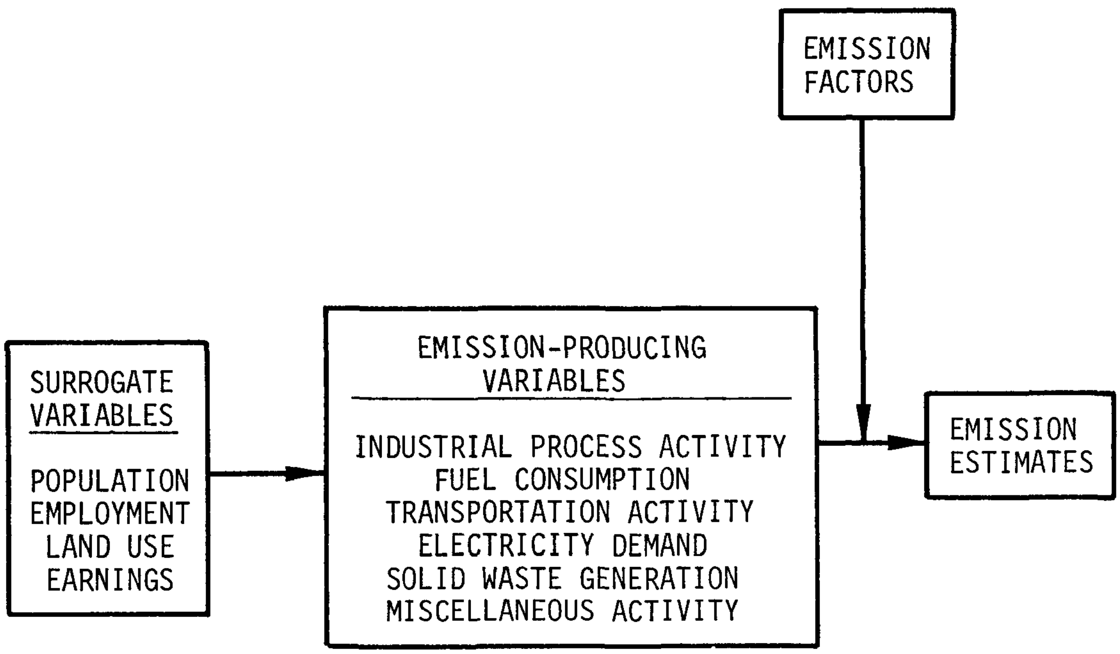


Fig. 4-2. Use of Surrogate Variables

Separation into basic and non-basic employment, for example, leads to some indication of the probable land requirements for industrial and commercial/institutional areas. Further disaggregation of the projected employment on the basis of Standard Industrial Classification (SIC) categories or EPA's Source Classification Code (SCC) System will be useful in a refinement of these requirements.

Changes in population are accompanied by changes in the area occupied by various land uses (e.g., residential, commercial/institutional, industrial, transportation, vacant, etc.). New plant locations and industrial process activity (measured, for example, by earnings estimates) are private decisions that integrate site-specific characteristics (physical features, local regulations, access) with regional and, in some cases, extraregional considerations (demand patterns, regional and interregional transportation, location of inputs).

There are numerous techniques available to regional planners to make estimates of the surrogate variables. Reference 4 outlines some of the more widely used procedures. Appendix D contains some of the background material and a computer printout of the projected population and land use for County X based on the regional planning commission's efforts. It is emphasized that, while the data are based on the Atlanta Regional Commission's work, some information has been changed to suit the needs of this example. Thus, the data should not be viewed as corresponding to actual projections for the Atlanta area and is included here for illustrative purposes only.

4.3 ACTIVITY SCENARIOS

Estimates of future activity are dependent on the assumptions made concerning levels of growth and growth management policies. Every regional planning group uses its own methodologies and assumptions in arriving at these estimates. A set of assumptions leads to one possible picture, or scenario, of the future. Because it is not possible to fully predict the detailed decisions that will determine the future nor to foresee the events and discoveries that influence the decisions, a number of futures can be hypothesized. Several scenarios of the future might be available for air quality management planning that indicate both the more likely future activity levels and the range of levels that is readily conceivable.

An elusive, but valuable, concept is that of the most probable growth scenario. Most probable growth customarily is taken as projections of current trends, altered by known constraints and incorporating already apparent changes in growth-affecting policies and actions. As such, it is a basic reference scenario for evaluating the desirability of intervention and the effectiveness of proposed alternatives. Planning agencies often develop such a scenario for just this purpose.

Often the reason for variations in projected development scenarios is the mandated orientation of the agencies preparing the estimates. Transportation planning groups base their projections on various transportation scenarios (e.g., highway development emphasis, transit emphasis, etc.). Comprehensive planning groups may use land-use development scenarios as the driving mechanism. These differences can result in wide discrepancies in the projection of regional development. One of the problems that the lead agency in the air quality analysis has is the reconciliation of the various planning outputs. In order to use information from the various groups, it will be necessary to insure that they are based on compatible assumptions and data bases. The need for a coordinated effort on the part of the involved organizations is reemphasized by this need for a unified projection plan upon which to base the analysis. The question of how many alternative scenarios should be evaluated as part of the air quality analysis is answered by the available resources. Certainly the "most probable growth" situation should be given detailed review. In the interest of determining the compatibility of other alternatives with air quality constraints, it may be useful to consider additional possibilities although this would not be required for the analysis. If, however, there is strong feeling that other scenarios have a reasonable chance of being implemented and would impact on the region's air quality, then analysis of their air quality conditions at this stage may save the necessity of developing a major revision to the air quality management plan at a later date.

4.4 SOURCES OF DATA

Long-range planning has been carried out for many years in a number of areas. The information required for the air quality analysis should build on the experience and background of the planning groups that have been involved in these activities. There are four federally-funded planning programs that should be able to provide some framework for the projections. They are:

HUD 701 planning,
FHWA 3-C planning,
EPA 208 planning,
CZM planning, and
OBERS growth projections.

There are, of course, numerous local and regional studies that can be used to supplement this information.

4.4.1 HUD 701 Planning

The planning assistance program defined by Section 701 of the Housing Act of 1954 and subsequent revisions is the Department of Housing and Urban Development's (HUD) main program of support for comprehensive planning. It has been in existence for a number of years and presently provides funds to all the states, 70% of the cities of over 50,000 population, more than 80% of the metro and non-metro area-wide planning organizations, and approximately 1,200 counties and smaller municipalities. Because the priorities are set by such a broad scope of recipients, a variety of approaches is permitted to the general requirement that 701-supported activities address the major growth or no growth decisions facing the jurisdiction; the diversity is represented by such subjects as controls over strip mining, preservation of prime agricultural land, government cost cutting, energy saving programs, and review of the status of local land controls and land use planning.

The Housing and Community Development Act of 1974 contains new requirements for 701 recipients. The requirement that the planning effort be comprehensive has been specified to mean, at a minimum, the inclusion of a housing element and a land use element that reflects consideration of the principal land use issues facing the jurisdiction. Many of the previous 701-supported planning programs did not include a land use element, but satisfactory progress toward developing a land use plan must be demonstrated for assistance to be continued after August 1977. It is also necessary that each jurisdiction should work toward the establishment of a unified or integrated system for land use planning and policy making, which includes the principal land use related planning and regulatory process. As part of this coordination requirement, the 701 activities must include a consideration of the current status of other planning that impacts land use (e.g., coastal zone, air and water quality, transportation, and solid-waste planning), related implementation activities, and the relationship between the 701 work program and such other planning or implementation efforts.

Three additional requirements are a part of the current 701 program: (1) The planning must attempt to deal with the complexities of the intergovernmental structure; (2) citizens must be involved at significant points in the process; and (3) the planning should serve the needs of growth management as well as protection of critical environmental features.

4.4.2 FHWA 3-C Planning

The Federal Highway Administration has been administering the requirements of the Federal Highway Act of 1962, which states that all federally-assisted highway projects be a part of Continuing, Comprehensive transportation planning process carried on Cooperatively in the state and local communities. The 3-C process has been carried out with varying levels of sophistication throughout the country. The basic procedure is divided into four phases. The data collection phase assembles information on current land use, population, dwelling units, employment, traffic volume and patterns, and existing transportation facilities. In the analysis phase, analytical methods such as comprehensive land use models and trip generation, distribution and modal split models are used to develop the pattern of travel demand and form the basis for developing travel projections. In the projection phase, land use and travel demand are forecast for a variety of alternatives. The continuing planning and implementation phase results in the development of the area's long-range transportation program. Reference 4 gives a more detailed description of the 3-C process.

4.4.3 EPA 208 Planning

EPA is administering the requirements of Section 208 of the Federal Water Pollution Control Act, which deals with areawide wastewater treatment management. In regions that require management plans for the attainment of water quality standards, areawide agencies have been designated to carry out the planning effort. Other agencies may have the responsibilities for implementation of the plans. In many ways similar to the air quality analysis process, the 208 planning process seeks to identify water quality problems associated with construction and growth over a 20-year period and to suggest appropriate technical and regulatory alternatives as well as growth and development options, to assure continuing achievement of satisfactory water quality. Most 208 plans will be due about mid-1977. It is entirely possible that a single regional planning agency could and should be responsible for developing projection indices for both air quality and water quality planning. A critical parameter in attempting to coordinate the goals of these two, or any other planning programs, is the time scale frame by which results are required.

4.4.4 CZM Planning

The Coastal Zone Management Act of 1972 establishes a national policy for the development of a program to manage the land and water resources of the coastal zone. The act recognizes the multiplicity of uses and values ascribed to lands and waters within the coastal zone and encourages the management of these lands through an approved plan that incorporates important ecological, cultural, esthetic, and economic values. States are encouraged to rely upon and coordinate their activities with appropriate local governments and regional agencies in the development of a coastal zone management plan (CZMP). Incentives to prepare and administer a comprehensive CZMP are provided, but no specific land or water use decisions are made. States submitting grant requests for programs that impinge on the CZMP must show that these programs are consistent with the approved plan. Further, according to Section 307(f) of the act, requirements of the Clean Air Act as amended and subsequent federal regulations will be incorporated into the CZMP. An important point of the act is that the state land use control authority, when necessary, can supersede local governmental authority. This is in marked contrast to the tradition under which all 50 states have delegated land use regulation power to local city or county governments.

4.4.5 OBERS Growth Projections

The projections of growth based on the work of the Office of Business Economics (OBE), presently the Bureau of Economic Analysis of the Department of Commerce, and the Economic Research Services (ERS) of the Department of Agriculture form a last resort to be used in areas where no other planning information is available. The projections are available by state, water resource area, OBE economic area, Air Quality Control Region, and Standard Metropolitan Statistical Area and include population, employment, and earnings (disaggregated by 27 industrial categories that are basically 2-digit SIC classes). The projections are derived by an apportioning of national data to the smaller subareas and are, as such, only crude estimates. Appendix D contains a tabulation of the OBERS projections for the Atlanta Metropolitan AQCR that contains County X.

4.5 PROJECTION METHODOLOGIES

The methodology used to forecast emission levels is conceptually simple, although, in practice, one encounters some difficulty in identifying the appropriate parameters to insert into the equations. Emissions are generally estimated by the following equation:

$$\text{Emissions} = \begin{matrix}\text{Process}\\\text{Activity}\end{matrix} \times \begin{matrix}\text{Emission}\\\text{Factor}\end{matrix} \times \left(1 - \begin{matrix}\text{Control}\\\text{Efficiency}\end{matrix}\right) \qquad (4\text{-}1)$$

The process activity is measured in units such as fuel consumption, raw material input or quantity of finished product. The emission factor is an emission rate per unit of process activity and usually represents uncontrolled emissions. The control efficiency accounts for the use of some form of control device to reduce emissions and is a percentage removal of pollutant.

When projecting emissions, the established procedure is to forecast the change in process activity that will result from economic growth and development. The implementation of air pollution control regulations may affect the activity (e.g., in a transportation control plan) but will most often affect the emission factor and/or the control efficiency applicable to specific sources. Because many regulatory programs differentiate between existing, modified, or new sources in the application of control regulations, it is necessary to maintain this distinction in an air quality analysis. Thus, projected emissions must be disaggregated into three components:

$$\begin{matrix}\text{Projected}\\\text{Emissions}\end{matrix} = \begin{matrix}\text{Emissions}\\\text{from existing}\\\text{sources}\end{matrix} + \begin{matrix}\text{Emissions from}\\\text{modifications to}\\\text{existing sources}\end{matrix} + \begin{matrix}\text{Emissions}\\\text{from new}\\\text{sources}\end{matrix} \qquad (4\text{-}2)$$

The emissions from each of these types of sources is computed in the standard way (i.e., as the product of a process activity, emission factor, and control efficiency factor), but with different values for these parameters. Unfortunately, it is not always straightforward to identify the distribution among them. For example, planning data generally indicates overall growth for a given industry (e.g., steel) but does not identify how much of the growth will be at existing sources and how much will be at new sources.

To accurately estimate emissions, the process activity must be disaggregated into its three components:

$$\text{Projected Activity} = \begin{array}{c}\text{Activity due}\\ \text{to existing}\\ \text{sources}\end{array} + \begin{array}{c}\text{Activity due}\\ \text{to modifications}\\ \text{of existing sources}\end{array} + \begin{array}{c}\text{Activity due}\\ \text{to new}\\ \text{sources}\end{array} \qquad (4\text{-}3)$$

In the application of air pollution control regulations, the last two components are generally subject to more stringent emission controls (either more stringent state regulations or federal New Source Performance Standards). Also, the first two components can be used to identify the spatial distribution of emissions, while the last component represents an unknown in terms of source location. A further complication to the calculation of projected emissions is the fact that the activity at existing sources is variable and dependent upon two important factors: the maximum capacity available at existing facilities (e.g., if a plant is operating at 90% capacity it can only absorb a 10% increase without modification), and the rate of retirement of existing facilities (e.g., the activity at existing facilities is not, in general, constant over the entire projection period because of the closing down of obsolete equipment).

In the ideal situation, the agency performing an air quality analysis would have information available on projected activity disaggregated into its three components, disaggregated by industry type, and disaggregated spatially. In reality, only a portion of this information will be available and estimates of the disaggregation will have to be made. This section will focus on estimating the component and industry distinctions, while the next will concentrate on the spatial distributions.

Figures 4-3 to 4-8 schematically illustrate the emission projection procedures outlined in Reference 7. For industrial process emissions, as

PROJECTED INDUSTRIAL PROCESS EMISSIONS
(PIPE)

LEVEL 1

METHOD 1

$$\begin{bmatrix}\text{BASELINE}\\ \text{EMISSIONS}\end{bmatrix} \times \begin{bmatrix}\text{OBERS GROWTH}\\ \text{FACTORS FOR 13 NER}\\ \text{PROCESS CATEGORIES}\end{bmatrix} \times \begin{bmatrix}\text{CONTROL EFFICIENCIES}\\ \text{FOR 13 NER}\\ \text{PROCESS CATEGORIES}\end{bmatrix} = \text{PIPE}$$

METHOD 2

SAME AS METHOD 1, ONLY USE SCC CATEGORIES.

LEVEL 2

SAME AS LEVEL 1, METHOD 2, ONLY USE LOCALLY AVAILABLE GROWTH PROJECTIONS.

LEVEL 3

INTERVIEW INDUSTRIES TO DETERMINE GROWTH AND EXPANSION PLANS.

Fig. 4-3. Emission Projection Procedures for Industrial Process Sources

PROJECTED FUEL COMBUSTION EMISSIONS
(PFCE)

LEVEL 1

[CONVERT BASELINE COUNTY FUEL USE TO BTU EQUIVALENTS]	X	[SCALE RESIDENTIAL BTU GROWTH BY POPULATION GROWTH, ALL OTHERS BY OBERS]	X	[DISTRIBUTE BTU GROWTH BY FUTURE FUEL MIX]	X	[EMISSION FACTORS INCLUDING CONTROLS]	=	PFCE

LEVEL 2

SAME AS LEVEL 1, ONLY USE LOCALLY AVAILABLE GROWTH PROJECTIONS FOR EACH CATEGORY.

LEVEL 3

SAME AS LEVEL 1, ONLY USE LOCALLY AVAILABLE GROWTH PROJECTIONS FOR EACH CATEGORY AND INTERVIEW RESULTS FOR FUEL MIX AND OTHER DISTRIBUTION CHANGES.

Fig. 4-4. Emission Projection Procedures for Fuel Combustion Sources

PROJECTED TRANSPORTATION EMISSIONS

PROJECTED HIGHWAY VEHICLE EMISSIONS
(PHVE)

LEVEL 1

$$\begin{bmatrix}\text{BASELINE}\\ \text{VMT}\end{bmatrix} \text{ X } \begin{bmatrix}\text{POPULATION}\\ \text{GROWTH}\\ \text{FACTOR}\end{bmatrix} \text{ X } \begin{bmatrix}\text{VEHICLE}\\ \text{EMISSION}\\ \text{FACTORS}\end{bmatrix} = \text{PHVE}$$

LEVEL 2,3

$$\begin{bmatrix}\text{DETERMINE PROJECTED}\\ \text{VMT FROM LOCAL}\\ \text{STUDIES}\end{bmatrix} \text{ X } \begin{bmatrix}\text{VEHICLE}\\ \text{EMISSION}\\ \text{FACTORS}\end{bmatrix} = \text{PHVE}$$

Fig. 4-5. Emission Projection Procedures
for Highway Vehicles

PROJECTED ELECTRIC GENERATION EMISSIONS
(PEGE)

LEVEL 1

[DETERMINE PROJECTED QUANTITY OF ELECTRICITY TO BE GENERATED] → [DETERMINE FUEL USE DISTRIBUTION AND FUEL REQUIRED PER KWH] → [COMPUTE FUEL USE] X [EMISSION FACTORS] = PEGE

LEVEL 2

[DETERMINE PROJECTED FUEL USE FROM PUBLISHED DATA] X [EMISSION FACTORS] = PEGE

LEVEL 3

SAME AS LEVEL 2, USING INTERVIEW RESULTS.

Fig. 4-6. Emission Projection Procedures for Electric Generation Sources

PROJECTED INCINERATION EMISSIONS
(PIE)

LEVEL 1

[BASELINE SOLID WASTE GENERATED] X [OBERS GROWTH FACTORS FOR MFG, COMM/INST, RESID] → [APPORTION BY DISPOSAL METHOD] X [EMISSION FACTORS] = PIE

LEVEL 2

SAME AS LEVEL 1, ONLY USE LOCALLY AVAILABLE GROWTH FACTORS.

LEVEL 3

USE INTERVIEW RESULTS TO DETERMINE WASTE GENERATED AND DISPOSAL METHODS.

Fig. 4-7. Emission Projection Procedures for Incineration Sources

PROJECTED MISCELLANEOUS SOURCES EMISSIONS

GASOLINE HANDLING EMISSIONS
(PGHE)

SOLVENT USE EVAPORATION EMISSIONS
(PSUE)

LEVEL 1,2,3

GASOLINE HANDLING	[SCALE GASOLINE USE BY VMT PROJECTION OR INTERVIEW]	X	[EMISSION FACTORS]	=	PGHE
SOLVENT USE	[SCALE SOLVENT USE BY POPULATION GROWTH]	X	[EMISSION FACTORS]	=	PSUE

OTHER SOURCE CATEGORIES HANDLED AS NEEDED

Fig. 4-8. Emission Projection Procedures for Miscellaneous Sources shown in Fig. 4-3, the Level 1 and 2 analyses rely on the application of a growth factor for an industry. This will, in general, mean that no information will be available to directly identify new, modified, and existing source contributions and some estimates must be made. Only the Level 3 analysis can supply this information, and even there, it may not do so in all cases. For fuel combustion sources, as shown on Fig. 4-4, the same comments apply as for process sources; i.e., only Level 3 will give a direct indication of the source contributions.

For highway vehicles, shown on Fig. 4-5, the "activity" of new sources is represented by the vehicle age distribution that is available from local registration data. For electric generation, as shown on Fig. 4-6, there is a significant amount of information available on power plant expansion plans to enable a good estimate of future activity to be made. A Level 2 or 3 analysis should be relatively easy to effect.

For incineration, on Fig. 4-7, the Level 1 and 2 analyses provide no information on new, modified, and existing source contributions. Only Level 3 provides data to make the necessary distinctions. For the gasoline handling and solvent use sources, on Fig. 4-8, there is no provision for making a separation of the emission contributions. The nature of the sources (i.e., small and generally treated as area sources) renders this situation more tolerable.

Another possibility for projecting emissions is given in Reference 4. This procedure relies on the utilization of land-use-based emission factors rather than source-specific emission rates. This procedure has been tried in several places with varying success. It is significantly less detailed and subject to more error than the methods described here.

4.6 ESTIMATING SOURCE CONTRIBUTIONS

When a projection technique other than Level 3 is used to forecast emissions, then estimates of the contributions from new, modified, and existing sources can be made. The most frequently encountered situation is one in which the growth rate for the industry category is specified by planning data without regard to whether this will entail utilization of existing capacity, modifications to increase production capacity, or development of new facilities. The projected activity is then computed by:

$$\text{Projected Activity} = \text{Existing Capacity} \times \text{Growth Factor} \tag{4-4}$$

A first-order approximation to the source contributions is that all growth will occur via modifications to existing facilities or via new facilities. The implicit assumption is that existing capacity is being utilized at its maximum rate. The calculation procedure is the following:

$$\text{Activity from New Sources and Modified Existing Sources} = \text{Projected Activity} - \text{Existing Activity} \tag{4-5}$$

In computing emissions, the new and modified source activity would be subject to federal New Source Performance Standards or more stringent state standards (if applicable), while the existing activity would be subject to existing regulations. The calculation is the following:

$$\text{Emissions} = \text{Activity from New and Modified Sources} \times \text{NSPS or more stringent State Standards} + \text{Existing Activity} \times \text{Existing Regulations} \tag{4-6}$$

A further refinement of this estimate can be made if some information on facility retirements is known. In this case, the existing activity is reduced by the retirements. The new and modified source activity is increased by the corresponding amount and the activity calculation becomes:

$$\text{Activity from New and Modified Sources} = \text{Projected Activity} - [\text{Existing Activity} - \text{Retirements}] \tag{4-7}$$

Note that this assumes that total industrial capacity remains the same. Further detail to improve the disaggregation would probably not be available except from a Level 3 analysis. It is important to note that these calculations are carried out over a series of time increments that span the air quality analysis time frame. The application of growth, retirement, and new source standards may take place at discreet points in that span and should be accounted for. In reality, this amounts to nothing more than repeating the calculation for every year using the previous year as the baseline and, at each point, reevaluating the distribution and the applicability of standards. Where parameters vary continuously or where there is no change for several consecutive years, the computations can be shortened. Mathematically, the entire procedure can be expressed as follows:

In the baseline year:

$$E_o = P_o \, (EF)_e \tag{4-8}$$

where E_o are the emissions for the base year, 0; P_o is the existing activity for the source category (e.g., steel) in year 0; and $(EF)_e$ is the emission factor considering only existing regulations and control equipment.

In the first projection year:

$$P_1 = P_0 \, G_{01} \tag{4-9}$$

$$E_1 = P_1 \, (EF)_e = P_0 \, G_{01} \, (EF)_e \tag{4-10}$$

where P_1 is the projected process activity in this first year, G_{01} is the growth factor between the base year and the first year. Note that the emission factor is unchanged since no change in regulations has been assumed to take place.

In the second projection year:

$$P_2 = P_1 \, G_{12} = P_0 \, G_{01} \, G_{12}$$
$$= P_0 \, G^2 \text{ (if the growth factor is constant)} \tag{4-11}$$

$$E_2 = P_2 \, (EF)_e = P_0 \, G^2 \, (EF)_e \tag{4-12}$$

where G_{12} is the growth factor from year 1 to year 2. Note the simplification if the growth rate is constant. Note also that the emission factor is still unchanged.

In any year, k, prior to the promulgation of a more stringent standard for new source:

$$P_k = P_{k-1}\, G_{k,k-1} = P_0 (G_{01}\, G_{12} \cdots G_{k,k-1})$$

$$= P_0\, G^k \text{ (if the growth rate is constant)} \qquad (4\text{-}13)$$

$$E_k = P_k\, (EF)_e = P_0\, G^k\, (EF)_e \qquad (4\text{-}14)$$

This is a general equation suitable for all years prior to the setting of a new source standard. A disaggregation of source contributions is not necessary since all sources are under the same regulation.

In the year, ℓ, in which a new source standard becomes effective:

$$(P_\ell)_{total} = P_{\ell-1}\, G_{\ell-1,\ell} = P_0\, G^\ell \text{ (for constant growth rate)} \qquad (4\text{-}15)$$

This must be disaggregated into contributions from existing sources and new and modified sources. Using the assumption that the growth occurs entirely at new or modified facilities:

$$(P_\ell)_{\substack{new\,+\\modified}} = (P_\ell)_{total} - (P_{\ell-1})_{total}$$

$$= P_0\, (G^\ell - G^{\ell-1})$$

$$= P_0\, G^{\ell-1}\, (G-1)$$

$$= P_{\ell-1}\, (G-1) \qquad (4\text{-}16)$$

Emissions are then computed as:

$$E_\ell = P_{\ell-1}\, (EF)_e + (P_\ell)_{\substack{new\,+\\modified}}\, (EF)_n$$

$$= P_{\ell-1}\, [(EF)_e + (G-1)(EF)_n]$$

$$= P_0\, G^{\ell-1}\, [(EF)_e + (G-1)(EF)_n] \qquad (4\text{-}17)$$

where $(EF)_n$ is the emission factor under the new source standard.

In the next year after a promulgated standard (year ℓ+1):

$$P_{\ell+1} = P_\ell \, G_{\ell,\ell+1} = P_0 \, G^{\ell+1} \qquad (4\text{-}18)$$

Using the same assumptions that all growth is at new or modified sources:

$$\begin{aligned}
(P_{\ell+1})_{\substack{\text{new +}\\ \text{modified}}} &= (P_{\ell+1})_{\text{total}} - (P_{\ell-1})_{\text{total}} \\
&= P_0 \, (G^{\ell+1} - G^{\ell-1}) \\
&= P_0 \, G^{\ell-1} \, (G^2 - 1) \\
&= P_{\ell-1} \, (G^2 - 1) \qquad (4\text{-}19)
\end{aligned}$$

Note that the last term of the equation implies that the existing source activity is frozen at that level that existed in the year prior to the promulgation of the standard (i.e., year ℓ-1). The emissions are then computed as:

$$\begin{aligned}
E_{\ell+1} &= P_{\ell-1} \, (EF)_e + (P_{\ell+1})_{\substack{\text{new +}\\ \text{modified}}} \, (EF)_n \\
&= P_{\ell-1} \, (EF)_e + P_{\ell-1} \, (G^2 - 1)(EF)_n \\
&= P_{\ell-1} \, [(EF)_e + (G^2 - 1)(EF)_n] \\
&= P_0 \, G^{\ell-1} \, [(EF)_e + (G^2 - 1)(EF)_n] \qquad (4\text{-}20)
\end{aligned}$$

At any year after the promulgation of a new source standard (year ℓ+p), the general equation is:

$$P_{\ell+p} = P_0 \, G^{\ell+p} \qquad (4\text{-}21)$$

With the same distribution assumption:

$$(P_{\ell+p})_{\substack{\text{new +}\\ \text{modified}}} = (P_{\ell+p})_{\text{total}} - (P_{\ell-1})_{\text{total}}$$

$$= P_0 \; (G^{\ell+p} - G^{\ell-1})$$

$$= P_0 \; G^{\ell-1} \; (G^{p+1} - 1)$$

$$= P_{\ell-1} \; (G^{p+1} - 1) \tag{4-22}$$

Emissions are computed by:

$$E_{\ell+p} = P_{\ell-1} \; (EF)_e \; + \; (P_{\ell+p})_{\substack{\text{new +}\\ \text{modified}}} \; (EF)_n$$

$$= P_{\ell-1} \; (EF)_e + P_{\ell-1} \; (G^{p+1} - 1) \; (EF)_n$$

$$= P_{\ell-1} \; [(EF)_e + (G^{p+1} - 1) \; (EF)_n]$$

$$= P_0 \; G^{\ell-1} \; [(EF)_e + (G^{p+1} - 1) \; (EF)_n] \tag{4-23}$$

In summary, the key equations are the following:

$$E_k = P_0 \; G^k \; (EF)_e \tag{4-24}$$

for year k prior to the setting of a new source standard

$$E_{\ell+p} = P_0 \; G^{\ell-1} \; [(EF)_e + (G^{p+1} - 1) \; (EF)_n] \tag{4-25}$$

for year ℓ+p where a new source standard is set in year ℓ

and the assumptions that are implicit are (1) a constant growth rate and (2) all growth is at new and modified sources. If there are data on capacity retirements and/or unused capacity it can be incorporated into this framework easily; the existing capacity is either reduced (in the case of retirements) or increased (in the case of utilization of currently unused capacity) by the appropriate amounts.

Equations 4-24 and 4-25 produce exactly the same results as the equations given in the supplement to Reference 13 recently issued by EPA.[28] Some algebraic manipulations will illustrate the compatibility of the two descriptions. For example, the term RF in the Reference 28 description is the emission reduction factor for new source regulations. This is equivalent to $(EF)_n/(EF)_e$ in this description. The Reference 28 term NGR is the growth rate for sources covered by new source regulations and is equivalent to $(G^{p+1} - 1)$ in this formulation. The term CGR, which is the growth rate for increasing production activity up to full capacity, and the term RR, which is the retirement rate, are not used in the simplified formulation presented here.

A detailed description of the formulation described here is given in Appendix G.

4.7 FEDERAL NEW SOURCE PERFORMANCE STANDARDS

The implementation of federal New Source Performance Standards (NSPS) has a marked effect on the computation of future emissions. To date, NSPS have been promulgated for only a few of the 250 odd possible candidate source categories. The issued supplement to Reference 13 contains preliminary estimates of the standards that will be set in the time period of the air quality analysis.[28] These estimates are not to be treated as promulgated regulations and are only to be used as guidelines of the expected emission levels. The Regional Office should be consulted for the latest available information prior to conducting the analysis.

In determining the effect of NSPS on an industry or on a specific facility, Reference 7 gives the following guidelines:

NSPS are applicable to:

Replacement of obsolete equipment at an existing plant.
Additions of new equipment at an existing plant.
All equipment at a new plant.

NSPS are not applicable to:

Existing equipment at a plant whether used or not.

In the terminology of the previous section, the replacement of obsolete equipment and the addition of new equipment constitutes a plant modification, while the new plant is a new source.

4.8 SUMMARY OF COUNTY X DATA

Table 4.1 summarizes the emission projections for County X. Tables 4.2 to 4.4 give the emission projections for 1975, 1980, and 1985, respectively, in the NER format described in Reference 7. The emission projections account for existing state regulations, for available compliance information, and for those federal New Source Performance Standards that are expected to apply prior to 1985. It is evident that countywide emissions are expected to increase by about 40% between 1975 and 1985. The largest increases occur in the mineral products industry, industrial fuel combustion, and the primary metals industry. The incineration and miscellaneous (fugitive dust in this case) categories sustain smaller increases but still account for substantial portions of the total emissions.

Table 4-1. County X Particulate Emission Projections

	Emissions[a] (tons/year)												
	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
Industrial Process													
Chemical Manufacturing	1	1	1	1	2	2	2	2	2	2	2	2	2
Food/Agriculture	5	5	5	5	6	6	6	6	6	6	7	7	7
Primary Metals	6,274	6,599	6,923	7,248	7,572	7,897	8,221	8,546	8,717	8,888	9,058	9,229	9,400
Secondary Metals	41	43	45	47	50	52	54	56	57	59	60	62	63
Mineral Products	4,476	5,319	6,161	7,004	7,846	8,689	9,531	10,374	10,569	10,764	10,958	11,153	11,348
All Others	0	0	0	0	0	0	0	0	0	0	0	0	0
Total	10,797	11,967	13,135	14,305	15,476	16,646	17,814	18,984	19,351	19,719	20,085	20,453	20,820
Fuel Combustion													
Residential	229	242	254	267	279	292	304	317	330	343	356	369	382
Commercial/Institutional	228	232	235	239	243	247	250	254	259	265	270	276	281
Industrial	3,611	3,858	4,104	4,351	4,598	4,845	5,091	5,338	5,586	5,834	6,082	6,330	6,578
Total	4,068	4,332	4,593	4,857	5,120	5,384	5,645	5,909	6,175	6,442	6,708	6,975	7,241
Transportation	821	833	845	857	869	881	893	905	929	952	976	999	1,023
Electric Generation	0	0	0	0	0	0	0	0	0	0	0	0	0
Incineration	7,922	8,059	8,196	8,333	8,469	8,606	8,743	8,880	9,052	9,224	9,395	9,567	9,739
Miscellaneous	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916	5,916
GRAND TOTAL	29,524	31,107	32,685	34,268	35,850	37,433	39,011	40,594	41,423	42,253	43,080	43,910	44,739

[a] Based on existing state regulations and expected federal New Source Performance Standards.

Table 4-2. County X Projected Emissions, 1975

COUNTY X
YEAR 1975

County Base Year Emissions Report

SOURCE				EMISSIONS, TONS PER YEAR				
				PART	SOX	NOX	HC	CO
FUEL COMBUSTION: EXTERNAL	RESIDENTIAL FUEL (AREA)	ANTHRACITE COAL						
		BITUMINOUS COAL		20				
		DISTILLATE OIL		20				
		RESIDUAL OIL						
		NATURAL GAS		214				
		WOOD						
		TOTAL		254				
	ELECTRIC GENERATION (POINT)	ANTHRACITE COAL						
		BITUMINOUS COAL						
		LIGNITE						
		RESIDUAL OIL						
		DISTILLATE OIL						
		NATURAL GAS						
		PROCESS GAS						
		COKE						
		SOLID WASTE/COAL						
		TOTAL						
	INDUSTRIAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	76				
			POINT	3074				
		LIGNITE	POINT					
		RESIDUAL OIL	AREA	2				
			POINT	648				
		DISTILLATE OIL	AREA	121				
			POINT	1				
		NATURAL GAS	AREA	174				
			POINT	9				
		PROCESS GAS	AREA					
			POINT					
		COKE	POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		BAGASSE	POINT					
		OTHER	POINT					
		TOTAL	AREA	373				
			POINT	3732				

Table 4-2. County X Projected Emissions, 1975 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL (CONTINUED)	COMMERCIAL-INSTITUTIONAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	64				
			POINT					
		LIGNITE	POINT					
		RESIDUAL OIL	AREA					
			POINT					
		DISTILLATE OIL	AREA	30				
			POINT					
		NATURAL GAS	AREA	141				
			POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		OTHER	POINT					
		TOTAL	AREA	235				
			POINT					
	OTHER		POINT					
	TOTAL EXTERNAL COMBUSTION		AREA	862				
			POINT	3732				
FUEL COMBUSTION INTERNAL	ELECTRIC GENERATION	DISTILLATE OIL						
		NATURAL GAS						
		DIESEL						
		OTHER						
		TOTAL						
	INDUSTRIAL FUEL	DISTILLATE OIL						
		NATURAL GAS						
		GASOLINE						
		DIESEL						
		OTHER						
		TOTAL						
	COMMERCIAL-INSTITUTIONAL FUEL	DIESEL						
		TOTAL						
	ENGINE TESTING	AIRCRAFT						
	TOTAL INTERNAL COMBUSTION							
TOTAL FUEL COMBUSTION		AREA		862				
		POINT		3732				

Table 4-2. County X Projected Emissions, 1975 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
INDUSTRIAL PROCESS (POINT)	CHEMICAL MANUFACTURING			1				
	FOOD/AGRICULTURE			5				
	PRIMARY METAL			6923				
	SECONDARY METALS			45				
	MINERAL PRODUCTS			6161				
	PETROLEUM INDUSTRY							
	WOOD PRODUCTS							
	PROCESS EVAPORATION							
	METAL FABRICATION							
	LEATHER PRODUCTS							
	TEXTILE MANUFACTURING							
	INPROCESS FUEL							
	OTHER/NOT CLASSIFIED							
	TOTAL			13135				
SOLID WASTE DISPOSAL	GOVERNMENT (POINT)	MUNIC INCIN.						
		OPEN BURNING						
		OTHER		10				
		TOTAL		10				
	RESIDENTIAL (AREA)	ON-SITE INCIN.						
		OPEN BURNING						
		TOTAL						
	COMMERCIAL-INSTITUTIONAL	ON-SITE INCIN-ERATION	AREA	948				
			POINT					
		OPEN BURNING	AREA	1761				
			POINT					
		APARTMENT	POINT					
		OTHER	AREA					
			POINT					
		TOTAL	AREA	2710				
			POINT					
	INDUSTRIAL	ON-SITE INCIN-ERATION	AREA	176				
			POINT	452				
		OPEN BURNING	AREA	4848				
			POINT					
		AUTO BODY INCIN	POINT					
		OTHER	POINT					
		TOTAL	AREA	5024				
			POINT	452				
	TOTAL SOLID WASTE DISPOSAL		AREA	7734				
			POINT	462				

Table 4-2. County X Projected Emissions, 1975 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
TRANSPORTATION (AREA)	LAND VEHICLES	GASOLINE	LIGHT DUTY	734				
			HEAVY DUTY	111				
			OFF HIGHWAY					
			TOTAL					
		DIESEL	HEAVY DUTY					
			OFF HIGHWAY					
			RAIL					
			TOTAL					
	AIRCRAFT	MILITARY						
		CIVIL						
		COMMERCIAL						
		TOTAL						
	VESSELS	BITUMINOUS COAL						
		DIESEL FUEL						
		RESIDUAL OIL						
		GASOLINE						
		TOTAL						
	GAS HANDLING EVAPORATION LOSS							
	TOTAL TRANSPORTATION			845				

Table 4-2. County X Projected Emissions, 1975 (Continued)

SOURCE			PART	SOX	NOX	HC	CO
MISCELLANEOUS (AREA)	SOLVENT EVAPORATION	INDUSTRIAL SOURCES (AREA)					
		DRY CLEANING					
	FIRES	STRUCTURAL					
		FROST CONTROL					
		SLASH BURNING					
		WILD FOREST					
		AGRICULTURAL					
	DUST CAUSED BY HUMAN AGITATION OF THE AIR	UNPAVED ROADS	1439				
		UNPAVED AIRSTRIPS					
		PAVED ROADS					
		MINERAL PROCESSING					
		TILLING ACTIVITIES	877				
		LOADING CRUSHED ROCK, SAND, GRAVEL					
		CONSTRUCTION	3600				
	AIRBORNE DUST CAUSED BY NATURAL WINDS	STORAGE PILES					
		TILLED LAND					
		UNTILLED LAND					
		Total Miscellaneous	5916				
GRAND TOTAL	AREA		15357				
	POINT		17329				

Table 4-3. County X Projected Emissions, 1980

COUNTY X
YEAR 1980

County Base Year Emissions Report

SOURCE				EMISSIONS, TONS PER YEAR				
				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL	RESIDENTIAL FUEL (AREA)	ANTHRACITE COAL						
		BITUMINOUS COAL		24				
		DISTILLATE OIL		24				
		RESIDUAL OIL						
		NATURAL GAS		269				
		WOOD						
		TOTAL		317				
	ELECTRIC GENERATION (POINT)	ANTHRACITE COAL						
		BITUMINOUS COAL						
		LIGNITE						
		RESIDUAL OIL						
		DISTILLATE OIL						
		NATURAL GAS						
		PROCESS GAS						
		COKE						
		SOLID WASTE/COAL						
		TOTAL						
	INDUSTRIAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	99				
			POINT	3995				
		LIGNITE	POINT					
		RESIDUAL OIL	AREA	3				
			POINT	843				
		DISTILLATE OIL	AREA	157				
			POINT	2				
		NATURAL GAS	AREA	226				
			POINT	13				
		PROCESS GAS	AREA					
			POINT					
		COKE	POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		BAGASSE	POINT					
		OTHER	POINT					
		TOTAL	AREA	485				
			POINT	4853				

Table 4-3. County X Projected Emissions, 1980 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
FUEL COMBUSTION: EXTERNAL (CONTINUED)	COMMERCIAL-INSTITUTIONAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	71				
			POINT					
		LIGNITE	POINT					
		RESIDUAL OIL	AREA					
			POINT					
		DISTILLATE OIL	AREA	34				
			POINT					
		NATURAL GAS	AREA	149				
			POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		OTHER	POINT					
		TOTAL	AREA	254				
			POINT					
	OTHER		POINT					
	TOTAL EXTERNAL COMBUSTION		AREA	1056				
			POINT	4853				
FUEL COMBUSTION: INTERNAL	ELECTRIC GENERATION	DISTILLATE OIL						
		NATURAL GAS						
		DIESEL						
		OTHER						
		TOTAL						
	INDUSTRIAL FUEL	DISTILLATE OIL						
		NATURAL GAS						
		GASOLINE						
		DIESEL						
		OTHER						
		TOTAL						
	COMMERCIAL-INSTITUTIONAL FUEL	DIESEL						
		TOTAL						
	ENGINE TESTING	AIRCRAFT						
	TOTAL INTERNAL COMBUSTION							
TOTAL FUEL COMBUSTION		AREA		1056				
		POINT		4853				

Table 4-3. County X Projected Emissions, 1980 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
INDUSTRIAL PROCESS (POINT)	CHEMICAL MANUFACTURING			2				
	FOOD/AGRICULTURE			6				
	PRIMARY METAL			8546				
	SECONDARY METALS			56				
	MINERAL PRODUCTS			10374				
	PETROLEUM INDUSTRY							
	WOOD PRODUCTS							
	PROCESS EVAPORATION							
	METAL FABRICATION							
	LEATHER PRODUCTS							
	TEXTILE MANUFACTURING							
	INPROCESS FUEL							
	OTHER/NOT CLASSIFIED							
	TOTAL			18984				
SOLID WASTE DISPOSAL	GOVERNMENT (POINT)	MUNIC. INCIN.						
		OPEN BURNING						
		OTHER		14				
		TOTAL		14				
	RESIDENTIAL (AREA)	ON-SITE INCIN						
		OPEN BURNING						
		TOTAL						
	COMMERCIAL-INSTITUTIONAL	ON-SITE INCIN-ERATION	AREA	1027				
			POINT					
		OPEN BURNING	AREA	1907				
			POINT					
		APARTMENT	POINT					
		OTHER	AREA					
			POINT					
		TOTAL	AREA	2934				
			POINT					
	INDUSTRIAL	ON-SITE INCIN-ERATION	AREA	191				
			POINT	492				
		OPEN BURNING	AREA	5249				
			POINT					
		AUTO BODY INCIN.	POINT					
		OTHER	POINT					
		TOTAL	AREA	5440				
			POINT	492				
	TOTAL SOLID WASTE DISPOSAL		AREA	8374				
			POINT	506				

Table 4-3. County X Projected Emissions, 1980 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
TRANSPORTATION (AREA)	LAND VEHICLES	GASOLINE	LIGHT DUTY	786				
			HEAVY DUTY	119				
			OFF HIGHWAY					
			TOTAL					
		DIESEL	HEAVY DUTY					
			OFF HIGHWAY					
			RAIL					
			TOTAL					
	AIRCRAFT	MILITARY						
		CIVIL						
		COMMERCIAL						
		TOTAL						
	VESSELS	BITUMINOUS COAL						
		DIESEL FUEL						
		RESIDUAL OIL						
		GASOLINE						
		TOTAL						
	GAS HANDLING EVAPORATION LOSS							
	TOTAL TRANSPORTATION			905				

Table 4-3. County X Projected Emissions, 1980 (Continued)

SOURCE			PART	SOX	NOX	HC	CO
MISCELLANEOUS (AREA)	SOLVENT EVAPORATION	INDUSTRIAL SOURCES (AREA)					
		DRY CLEANING					
	FIRES	STRUCTURAL					
		FROST CONTROL					
		SLASH BURNING					
		WILD FOREST					
		AGRICULTURAL					
	DUST CAUSED BY HUMAN AGITATION OF THE AIR	UNPAVED ROADS	1439				
		UNPAVED AIRSTRIPS					
		PAVED ROADS					
		MINERAL PROCESSING					
		TILLING ACTIVITIES	877				
		LOADING CRUSHED ROCK, SAND, GRAVEL					
		CONSTRUCTION	3600				
	AIRBORNE DUST CAUSED BY NATURAL WINDS	STORAGE PILES					
		TILLED LAND					
		UNTILLED LAND					
		Total Miscellaneous	5916				
GRAND TOTAL	AREA		16251				
	POINT		24343				

Table 4-4. County X Projected Emissions, 1985

COUNTY X
YEAR 1985

County Base Year Emissions Report

SOURCE				EMISSIONS, TONS PER YEAR				
				PART	SOX	NOX	HC	CO
FUEL COMBUSTION EXTERNAL	RESIDENTIAL FUEL (AREA)	ANTHRACITE COAL						
		BITUMINOUS COAL		29				
		DISTILLATE OIL		29				
		RESIDUAL OIL						
		NATURAL GAS		324				
		WOOD						
		TOTAL		382				
	ELECTRIC GENERATION (POINT)	ANTHRACITE COAL						
		BITUMINOUS COAL						
		LIGNITE						
		RESIDUAL OIL						
		DISTILLATE OIL						
		NATURAL GAS						
		PROCESS GAS						
		COKE						
		SOLID WASTE/COAL						
		TOTAL						
	INDUSTRIAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	122				
			POINT	4926				
		LIGNITE	POINT					
		RESIDUAL OIL	AREA	4				
			POINT	1038				
		DISTILLATE OIL	AREA	193				
			POINT	2				
		NATURAL GAS	AREA	280				
			POINT	13				
		PROCESS GAS	AREA					
			POINT					
		COKE	POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		BAGASSE	POINT					
		OTHER	POINT					
		TOTAL	AREA	599				
			POINT	5979				

Table 4-4. County X Projected Emissions, 1985 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
FUEL COMBUSTION: EXTERNAL (CONTINUED)	COMMERCIAL-INSTITUTIONAL FUEL	ANTHRACITE COAL	AREA					
			POINT					
		BITUMINOUS COAL	AREA	78				
			POINT					
		LIGNITE	POINT					
		RESIDUAL OIL	AREA					
			POINT					
		DISTILLATE OIL	AREA	38				
			POINT					
		NATURAL GAS	AREA	165				
			POINT					
		WOOD	AREA					
			POINT					
		LIQUID PETROL GAS	POINT					
		OTHER	POINT					
		TOTAL	AREA	281				
			POINT					
	OTHER		POINT					
	TOTAL EXTERNAL COMBUSTION		AREA	1262				
			POINT	5979				
FUEL COMBUSTION: INTERNAL	ELECTRIC GENERATION	DISTILLATE OIL						
		NATURAL GAS						
		DIESEL						
		OTHER						
		TOTAL						
	INDUSTRIAL FUEL	DISTILLATE OIL						
		NATURAL GAS						
		GASOLINE						
		DIESEL						
		OTHER						
		TOTAL						
	COMMERCIAL-INSTITUTIONAL FUEL	DIESEL						
		TOTAL						
	ENGINE TESTING	AIRCRAFT						
	TOTAL INTERNAL COMBUSTION							
TOTAL FUEL COMBUSTION		AREA		1262				
		POINT		5979				

Table 4-4. County X Projected Emissions, 1985 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
INDUSTRIAL PROCESS (POINT)	CHEMICAL MANUFACTURING			2				
	FOOD/AGRICULTURE			7				
	PRIMARY METAL			9400				
	SECONDARY METALS			63				
	MINERAL PRODUCTS			11348				
	PETROLEUM INDUSTRY							
	WOOD PRODUCTS							
	PROCESS EVAPORATION							
	METAL FABRICATION							
	LEATHER PRODUCTS							
	TEXTILE MANUFACTURING							
	INPROCESS FUEL							
	OTHER/NOT CLASSIFIED							
	TOTAL			20820				
SOLID WASTE DISPOSAL	GOVERNMENT (POINT)	MUNIC INCIN.						
		OPEN BURNING						
		OTHER		17				
		TOTAL		17				
	RESIDENTIAL (AREA)	ON-SITE INCIN.						
		OPEN BURNING						
		TOTAL						
	COMMERCIAL-INSTITUTIONAL	ON-SITE INCIN-ERATION	AREA	1127				
			POINT					
		OPEN BURNING	AREA	2093				
			POINT					
		APARTMENT	POINT					
		OTHER	AREA					
			POINT					
		TOTAL	AREA	3220				
			POINT					
	INDUSTRIAL	ON-SITE INCIN-ERATION	AREA	209				
			POINT	520				
		OPEN BURNING	AREA	5773				
			POINT					
		AUTO BODY INCIN	POINT					
		OTHER	POINT					
		TOTAL	AREA	5982				
			POINT	520				
	TOTAL SOLID WASTE DISPOSAL		AREA	9202				
			POINT	537				

Table 4-4. County X Projected Emissions, 1985 (Continued)

SOURCE				PART	SOX	NOX	HC	CO
TRANSPORTATION (AREA)	LAND VEHICLES	GASOLINE	LIGHT DUTY	889				
			HEAVY DUTY	134				
			OFF HIGHWAY					
			TOTAL					
		DIESEL	HEAVY DUTY					
			OFF HIGHWAY					
			RAIL					
			TOTAL					
	AIRCRAFT	MILITARY						
		CIVIL						
		COMMERCIAL						
		TOTAL						
	VESSELS	BITUMINOUS COAL						
		DIESEL FUEL						
		RESIDUAL OIL						
		GASOLINE						
		TOTAL						
	GAS HANDLING EVAPORATION LOSS							
	TOTAL TRANSPORTATION			1023				

Table 4-4. County X Projected Emissions, 1985 (Continued)

SOURCE			PART	SOX	NOX	HC	CO
MISCELLANEOUS (AREA)	SOLVENT EVAPORATION	INDUSTRIAL SOURCES (AREA)					
		DRY CLEANING					
	FIRES	STRUCTURAL					
		FROST CONTROL					
		SLASH BURNING					
		WILD FOREST					
		AGRICULTURAL					
	DUST CAUSED BY HUMAN AGITATION OF THE AIR	UNPAVED ROADS	1439				
		UNPAVED AIRSTRIPS					
		PAVED ROADS					
		MINERAL PROCESSING					
		TILLING ACTIVITIES	877				
		LOADING CRUSHED ROCK, SAND, GRAVEL					
		CONSTRUCTION	3600				
	AIRBORNE DUST CAUSED BY NATURAL WINDS	STORAGE PILES					
		TILLED LAND					
		UNTILLED LAND					
		Total Miscellaneous	5916				
GRAND TOTAL	AREA		17403				
	POINT		27336				

PROBLEM 4-1

Estimate the future particulate emissions for the clay products industry in County X in the period 1975 to 1985. Assume the following information is known.

There are currently two clay products plants in County X with the following characteristics:

Company ABC - current production is 35,000 tons of finished product per year.

Company DEF - current production is 15,000 tons of finished product per year.

Regional planning data estimates a growth in demand for the product from the region of 2.5% per year. A federal New Source Performance Standard is expected in 1983 that will limit emissions to 4.5 lb per ton of finished product. The current state regulation is 10 lb per ton. Also, it is known that Company DEF is scheduled to shut down its current plant at the end of 1984. Assume the air quality analysis is being performed for 1980 and 1985 and the baseline inventory is for 1973.

5. ALLOCATION OF EMISSIONS

To this point, the focus of the emission inventory portion of the analysis has been to generate the emission pattern on a county-by-county basis for the region under study. Prior experience with air quality management has shown the following:

> Countywide spatial resolution of emissions is too coarse for particulates, SO_2, and CO.
>
> Countywide spatial resolution of emissions is too fine for oxidants, nitrogen oxides, and hydrocarbons.

The latter three pollutants are reactive under ambient conditions and their impacts on air quality can be felt at large distances from the emitting sources. For this reason, there is no pressing need to develop an analysis with finer spatial resolution for these pollutants. Rather, they will be treated on a regionwide basis. The exception to this general guideline is when an analysis of one or more of these pollutants will be made with a photochemical dispersion model. In this case, the model requires, as input, a better spatial description of emissions than is available from countywide data and the same allocation procedures that will be described for the other pollutants can be used.

For particulates, SO_2, and CO, the effects of individual sources are much more localized in impact and an adequate analysis and control strategy development relies on a fine spatial resolution of emissions. The objective of this section is to describe techniques that can be used to achieve this resolution.

These procedures should not be viewed as necessarily separate and distinct from the development of the baseline inventory or the estimation of future emissions. In many instances these techniques can be used in parallel rather than in series with the previous methods.

5.1 DETERMINATION OF GEOGRAPHIC SCALE

The identification of the level of spatial resolution is a function of several variables:

Available data
Anticipated problem areas

Anticipated problem sources
Applicability to modeling
Applicability to strategies
Resources available

The principle constraint on spatial resolution is, of course, the available data. If the information is on too coarse a geographical scale, then an extensive effort is usually required to improve the data base. In general, this will be required only in special circumstances and only for special sources. It is not unusual to have data from different source categories with different spatial resolutions. For example, population data may be available on census tract subcounty resolution, while transportation data may be on planning district resolution. This presents no special problems since all sources eventually will be mapped into a master grid.

The spatial resolution should be fine enough to distinguish special problem areas and special problem sources. As an illustration, it is not possible to treat a major metropolitan city in its entirety. The spatial resolution should be able to distinguish the Central Business District (CBD) from industrial parks and from residential neighborhoods.

The use of dispersion models dictates certain limits on the size of sources and hence on the spatial resolution. Although the models can theoretically treat any size areas, the accuracy suffers if the sources are too large and computation expense suffers if they are too small. This consideration becomes more significant when the master grid is developed and will be discussed later.

The applicability of control strategies is an important consideration and is one of the prime reasons for using a subcounty resolution. In general, control strategies may not be appropriate for application to an entire county across the board. From an enforceability standpoint, however, a control strategy will, most likely, be applied within political boundaries (as opposed to arbitrary areas) and the analysis should be sensitive to these considerations.

Finally, the resources available will dictate the level of spatial disaggregation that can be tolerated. The large number of calculations required for each subcounty area dictates the need for computer assistance if any significant number of areas are to be considered.

5.2 ALLOCATION PARAMETERS

5.2.1 Population

There are a number of sources whose emission distribution may be linked directly to the population distribution. For each county there are several different geographical descriptions of population distribution, any one of which may be used. The Census of Population and Housing provides the most widely available demographic data, although some areas have regional planning commissions, which normally embellish the resolution of the Census data.

The types of subcounty areas for which demographic data are normally available include municipalities, census tracts, Master Enumeration Districts, regional planning districts, and townships. In every area there are population data available on at least a municipality basis. This information is tabulated in the Census of Population for all places containing a population of 2500 or more. The geographical location of these municipalities may be found either in the census publications or on regional maps. It should be noted, however, that the municipalities may not cover an entire county, since there may be extensive unincorporated areas. In these cases, the total of the municipality populations is subtracted from the total county population (also tabulated by the Census Bureau) to determine the residual county population (the number of people living outside of municipal boundaries). This selection of subareas will generally result in delineating only a small number of districts within each county, and population-based allocations can, therefore, be easily handled without a computer.

For most large, urbanized areas, the region is subdivided into tracts by the Census Bureau. These tracts, while lying within county boundaries, do not necessarily lie along municipal boundaries and may overlap several political jurisdictions. The tracts are large in the less densely populated areas and small in centers of population concentration. Because tracts are delineated according to population density, they portray the distribution of a county's population at a high degree of resolution. Nevertheless, choice of census tracts as the population-based subareas must be made with careful consideration. In some regions the number of tracts, though larger than the number of municipalities, is still small enough to be managed without computer assistance (the Atlanta SMSA has 238 tracts). On the other hand, some regions have a large number of tracts, which make hand computations unwieldy (the Chicago SMSA has over 1500 tracts). Census tracts should therefore be used as subcounty areas only when sufficient computational resources are available and good detail is needed. In any case, the Bureau of the Census publishes the tract information both in printed form and on computer-compatible magnetic tape.

Master Enumeration Districts are essentially the same as census tracts in areas that are tracted and have other definitions in untracted areas. Data for these districts are tabulated on computer-compatible magnetic tape, available from the Census Bureau. A set of computer programs has been written to enable one to process this information and to develop a grid system for the allocation of area source emissions. These programs and gridding procedures are documented in Ref. 8.

Areas in which there are active regional planning commissions will usually be subdivided into planning districts that the commissions use for displaying data. In some areas, these planning districts lie along municipal or census tract boundaries. In other areas, they are drawn up to meet the specific requirements of a particular commission and do not correspond to any other subarea definition.

In most areas of the country, a political jurisdiction, referred to as a township, is superimposed on existing municipal jurisdictions. The townships are normally square-gridded with 36 square-mile sections in each. These townships can be used as regional planning districts, as in Northern Illinois.

The main conclusion to be drawn from this discussion is that there are a variety of subcounty areas for which population distribution information is displayed. In any given region, there may be more than one subarea set. Choice of the appropriate set of subareas for use in allocating emissions is based on identifying which one contains the most detailed set of information and yet is manageable within the resources of the planning agency charged with maintaining air quality. It is recommended that the subareas to be used for the transportation allocation and the commercial/institutional-industrial allocation be investigated prior to making a final choice of the data resolution needed to allow for the possibility that one subarea set may provide information more appropriate for all stages of the air quality analysis system.

5.2.2 Transportation

As with the population-based subcounty areas, there are a number of subarea sets available for describing the distribution of transportation systems. In some areas of the country, the transportation planning agency may use one of the regional planning grids for developing its data base, in which case the population-based subareas and the transportation-based subareas can be selected as being one and the same.

In other regions, the transportation planning grid may be developed separately. This separation presents no unusual problems in the allocation procedure, and there is no need at this point to try to convert one grid system to another.

Some regions will have no grid system that is used for transportation-related data display and all that will be available will be highway department road maps. In most areas where this situation prevails, vehicle count data will be available only for the major expressways and busy arterials.

In some instances, however, the state transportation department will have developed traffic data on a link-by-link basis as part of the Continuing, Comprehensive, and Coordinated (3-C) transportation planning process. The links will generally be described by the UTM coordinates for their end points and have vehicle count data on them.

5.2.3 Commercial/Institutional, Industrial, and Electric Generation

The most definitive form of spatial resolution of these source categories is the location of point sources in which their specific coordinates are specified. The display of area source data is generally in one of the forms previously described, such as census districts, regional planning districts, or townships. An additional information display may be a land-use map of the area on which the various land uses are coded to indicate the distribution of activity. While this type of presentation does not rely on a grid network, it can nevertheless provide useful data for the analysis by describing the spatial development of the land in the area. This data may be converted to a grid network using the techniques described in Reference 29.

5.3 ALLOCATION PROCEDURES

There are basically three procedures for determining spatial allocations of emission-producing activity:

Locate the activity directly from available data,

Develop a distribution function of activity using an allocation parameter (e.g., population), and

A combination of the above procedures.

Reference 13 outlines the recommended procedures for these methods as applicable to each of the source categories. The sources that can be spatially located directly are:

Industrial point sources -- existing and some new,

Commercial/Institutional point sources -- existing and some new,

Electric generation -- existing and most new, and

Limited access highways -- existing and most new.

For all existing sources, the spatial coordinates are available from the emission inventory. (Although limited access highways are not normally specifically included in an emission inventory, their coordinates are easily determined from maps.) For industrial and commercial/institutional new sources, there is often only limited information available on new plant locations. Where these data are available, they can be used to identify source coordinates. For power plants, the location of new facilities is well documented in References 30 and 31. There may be uncertainty in the location of some new sites, but, in general, the utility planning horizon is long-range enough to identify most new installations. In a similar way, the location of most new limited access highways is sufficiently well documented (at least in terms of alternative possibilities) to enable their geographic location to be well defined.

Source activity that cannot be located directly can use a distribution function to allocate emissions. A simple model would start with the knowledge of the activity on a countywide basis and then distribute this activity to each subcounty area based on that area's proportion of some countywide parameter, such as population or employment. For example, if a county is divided into 20 subcounty areas and the 5th area contains 12% of the county's population, then all emission-producing activity that is related to population (e.g., solid waste disposal) can have 12% of the countywide emissions allocated to subarea 5. The types of distribution functions that can be developed include:

population
dwelling units
dwelling units by fuel use
employment
land use
area

An illustration of the effect of using different distribution functions is found in Appendix B of Reference 13 dealing with residential fuel combustion emissions. The three orders of allocation procedures illustrate the use of a population distribution function, a dwelling unit distribution function, and a fuel-use and building-size distribution function available for each subarea, respectively. In all three cases, the countywide total fuel use and emissions are the same. Use of the population and dwelling unit distributions give only slightly different results among the various subareas. The most detailed distribution, however, results in a change in the calculated emissions of 19% in the largest subarea (i.e., Atlanta).

The third type of allocation procedure is a combination of the specific location information and the distribution function. Its aim is to use whatever specific location data are available for a source category and allocate the remainder by some form of distribution function. Its prime utility is in allocating activity from new sources that cannot be placed with any degree of certainty. Starting with the computation of emissions on a countywide basis (with account taken of new source regulations where applicable), the procedure can take one of three paths with regard to locating new source emissions:

1. Assume all new source emissions occur at the same location as existing sources (i.e., growth-in-place).

2. Assume all new source emissions occur at new sites and allocate according to an employment or land-use distribution function.

3. Determine the mix between existing and new source activity and allocate accordingly.

The first method is the easiest since the location of the source activities are already known and are assumed to remain the same. It is also the least accurate since it does not reflect realistic development in most areas. The second and third methods are more accurate but require significantly more data.

In some situations it may be possible to utilize a sophisticated growth and development model to determine the spatial distribution of emissions. Models that can be used for this purpose are represented by the work of Lowry[32] and the Hackensack Meadowlands Project.[33] These models generally follow the third allocation procedure (i.e., combine existing locational information with distribution function approaches) but in a much more analytical way than the simple approaches described here. The experience and resources of the agency performing the air quality analysis will determine if this approach is useful.

PROBLEM 5-1

Using the previously calculated data for the clay products industry in County X (Problem 4-1), allocate these emissions to the ten subcounty areas defined by the planning commission data in Appendix D for 1980 and 1985. Company ABC is in Superdistrict 16 and Company DEF is in Superdistrict 15. Assume that both plants are currently operating at 100% capacity and that the allocation of new source emissions will be based on the growth in industrial land area in each superdistrict (see Table D-9 in Appendix D for a summary of this calculation). Tables 3.4-1 to 3.4-4 from Reference 13 (reproduced here as Figs. 5-1 to 5-4) may be used to structure the computation. Tables 3.4-1 and 3.4-2 may be filled in directly using the results of Problem 4-1. In using Table 3.4-3 note that the Employment Allocation Proportion is replaced by an industrial land use growth proportion.

Table 3.4-1

Point Source Industrial Process Emissions

A. County ________________
B. Year ________________
C. Allocation Order 1, 2, and 3

(1) Industrial Process Category	Source Identification					Process Emission Forecast (tons/yr)											
	(2) Name	(3) Process	(4) Subarea	(5) Coord.		(6)	(7) Part.		(8) SO_x		(9) CO		(10) HC		(11) NO_x		(12)
				X	Y	GF**	Cont.	Emis.	Cont.	Emis.	Cont.	Emis.	Cont.	Emis.	Cont.	Emis.	Emp.*

*Employment
**Growth Factor

Fig. 5-1. Point Source Industrial Process Emissions, Table 3.4-1 from Ref. 13

Table 3.4-2

Industrial Point and New Source Process Emissions by Process Category

A. County ______________

B. Year ______________

C. Allocation Order 2 and 3

(1) Industrial Process Category	Baseline Year Existing Point Sources						Forecast Year - All Sources							Forecast Year Existing Point Sources						Forecast Year - New Sources										
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21) Part.		(22) SO_x		(23) CO		(24) HC		(25) NO_x		(26)
	Part.	SO_x	CO	HC	NO_x	Emp*	GF**	Part.	SO_x	CO	HC	NO_x	Emp*	Part	SO_x	CO	HC	NO_x	Emp*	Cont.	Emis.	Cont	Emis	Cont.	Emis	Cont.	Emis.	Cont.	Emis.	Emp.*
D. COUNTY TOTAL																														

* Employment
**Growth Factor

Fig. 5-2. Industrial Point and New Source Process Emissions by Process Category, Table 3.4-2 from Ref. 13

Table 3.4-3

Process Emissions by Process Category and Subarea

A. County ____________
B. Subarea ____________
C. Year ____________
D. Allocation Order 2 and 3

Industrial Process Category (1)	Total Emp. (2)	Point Source Emp. (3)	New Source Emp. (4)	EAP* (5)	New Source Emissions (tons/yr)				
					(6) Part.	(7) SO_x	(8) CO	(9) HC	(10) NO_x
E. SUBAREA TOTAL									

*Employment Allocation Proportion = $\frac{\text{Subarea Category New Source Employment}}{\text{Total Category New Source Employment}}$

Fig. 5-3. Process Emissions by Process Category and Subarea, Table 3.4-3 from Ref. 13

Table 3.4-4

Industrial Point and New Source Process Emissions - Subarea Summary

A. County ____________
B. Subarea ____________
C. Year ____________
D. Allocation Order 1, 2, and 3

Industrial Process Category (1)	Point Source Emissions							New Source Emissions						Total Emissions					
	(2) No. of Sources	(3) Emp.*	(4) Part.	(5) SO_x	(6) CO	(7) HC	(8) NO_x	(9) Emp.*	(10) Part	(11) SO_x	(12) CO	(13) HC	(14) NO_x	(15) Emp.*	(16) Part.	(17) SO_x	(18) CO	(19) HC	(20) NO_x
E. SUBAREA TOTAL																			

*Employment

Fig. 5-4. Industrial Point and New Source Emissions - Subarea Summary, Table 3.4-4 from Ref. 13

5.4 MASTER GRIDDING

To this point, the allocations for each source category may have been done with different spatial resolutions. It is possible that the county emission pattern may be described as in Fig. 5-5 with a variety of source presentations. It is now necessary to coordinate all of these results onto a single master grid system that can be used for modeling and strategy analysis.

Choice of Coordinates There are a variety of rectilinear coordinate systems that can be used in developing a master grid. It is desirable, however, to use Universal Transverse Mercator (UTM) coordinates, which are universally available on U.S. Geological Survey maps. The UTM coordinates offer the widest generality and applicability. The only translation problem occurs when an analysis area lies between two UTM zones where the abscissas are not continuous. This is easily treated via careful bookkeeping.

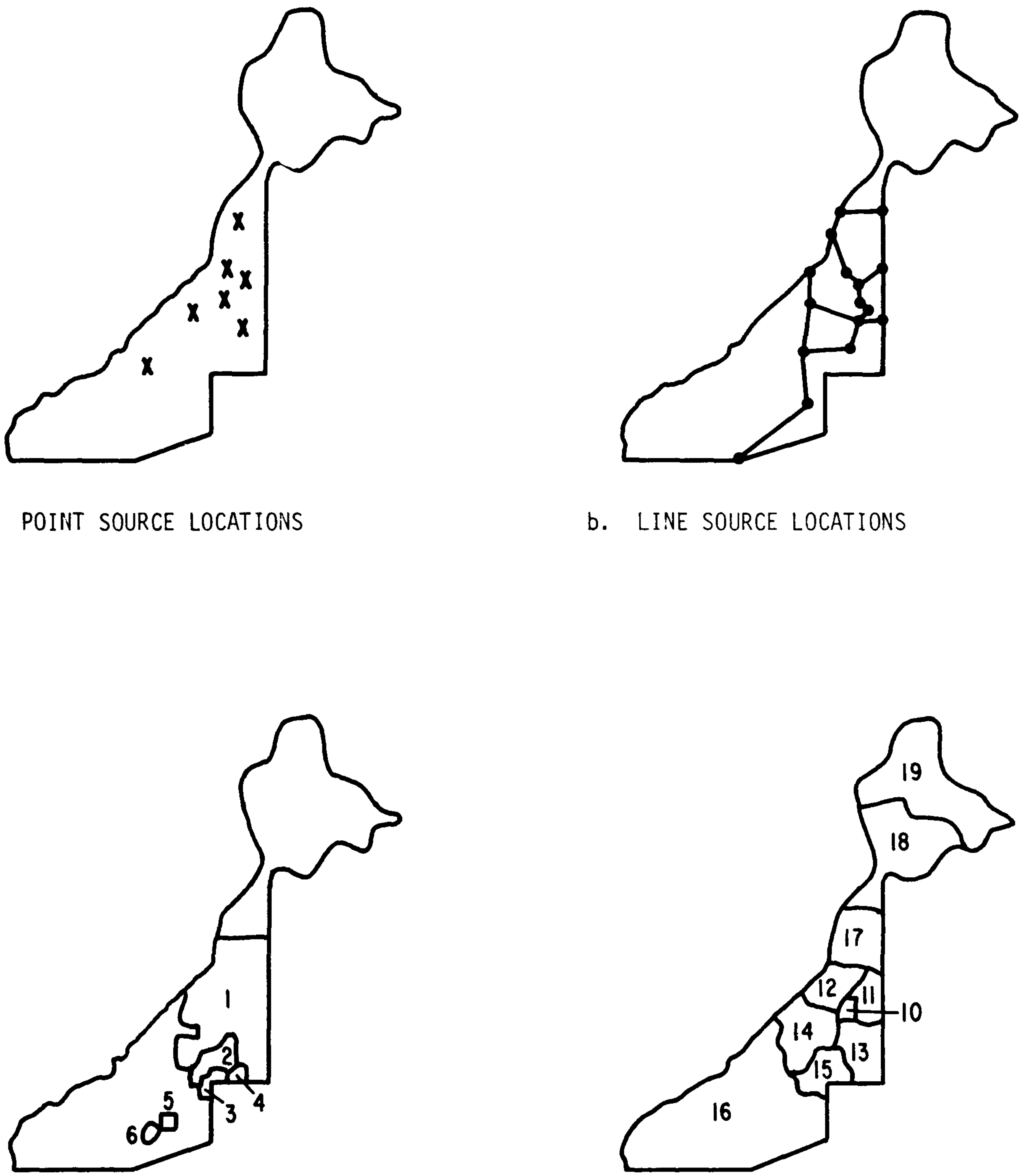
Some states have local coordinate systems that may be considered. Uncertainty as to the reference points will make these systems difficult to use for anyone unfamiliar with the area.

Selection of Grids The master grids chosen should, in general, be square with variations in size depending on the resolution of the subcounty areas. The smallest grid square chosen should be 1 km x 1 km. Smaller grids would result in data that does not, in all probability, exist in the original data set. The largest grid square chosen should be 8 km x 8 km. Larger grids would cancel some of the subcounty resolution already achieved.

Reference 8 describes a procedure for using Bureau of the Census computer tapes and the EPA-developed CAASE program (Computer-Assisted Area Source Emissions) for developing a grid based on population density. The process involves the interaction of a series of five computer programs and some manual techniques. This is one way in which the grid configuration can be developed.

An alternative method of developing a grid system is to rely on a review of the available subcounty areas. The process starts with an overlay of the largest grid squares (e.g., the 8 km x 8 km grid) placed on the subcounty area map. The grids are then subdivided until the smallest chosen grid size is reached or until the subdivision grid contains primarily one subcounty area.

COUNTY X



a. POINT SOURCE LOCATIONS

b. LINE SOURCE LOCATIONS

c. MUNICIPALITIES

d. PLANNING DISTRICTS

Fig. 5-5. Possible Displays of Spatial Emission Patterns

When the grid has been developed for one subcounty set (e.g., municipalities), it can then be laid over the other sets and be modified accordingly. This modification consists of further subdivisions to match the differing resolutions. Figure 5-6 gives the final grid system chosen for County X.

Subcounty Area Mapping Once the grid system has been chosen, it is necessary to map the subcounty areas into the master grid. This is done on an areal apportioning basis; that is, it is determined what fraction of a subcounty area (e.g., a census tract, municipality, etc.) is within the overlying grid square. All emissions from that area are then allocated to the master grid using this fraction. The computation is:

$$\begin{array}{c}\text{Contribution of Subcounty}\\ \text{Area i to total emissions}\\ \text{in Grid j}\end{array} = \begin{array}{c}\text{Fraction of area of}\\ \text{Subcounty Area i}\\ \text{that lies in}\\ \text{Grid j}\end{array} \times \begin{array}{c}\text{Total emissions}\\ \text{in Subcounty}\\ \text{Area i}\end{array} \quad (5\text{-}1)$$

As an example, if 35% of the area of census tract 70 lies in grid square no. 5, then 35% of the emissions computed for census tract 70 will be assigned to grid 5. The area fractions may be determined using a planimeter or by using an "eyeball" estimation procedure.

Appendix H documents a computer code that can be used to map emissions from the subcounty areas onto the master grid once a complete set of area fractions is assembled.

Model Inputs With the development of the master grid network, it is now possible to use the emission data as input to a dispersion model. The master grids may be used as area sources and the previously identified point and line sources can be input directly. Alternatively, the point and line sources can be located in their appropriate master grids and the entire system modeled as a set of area sources.

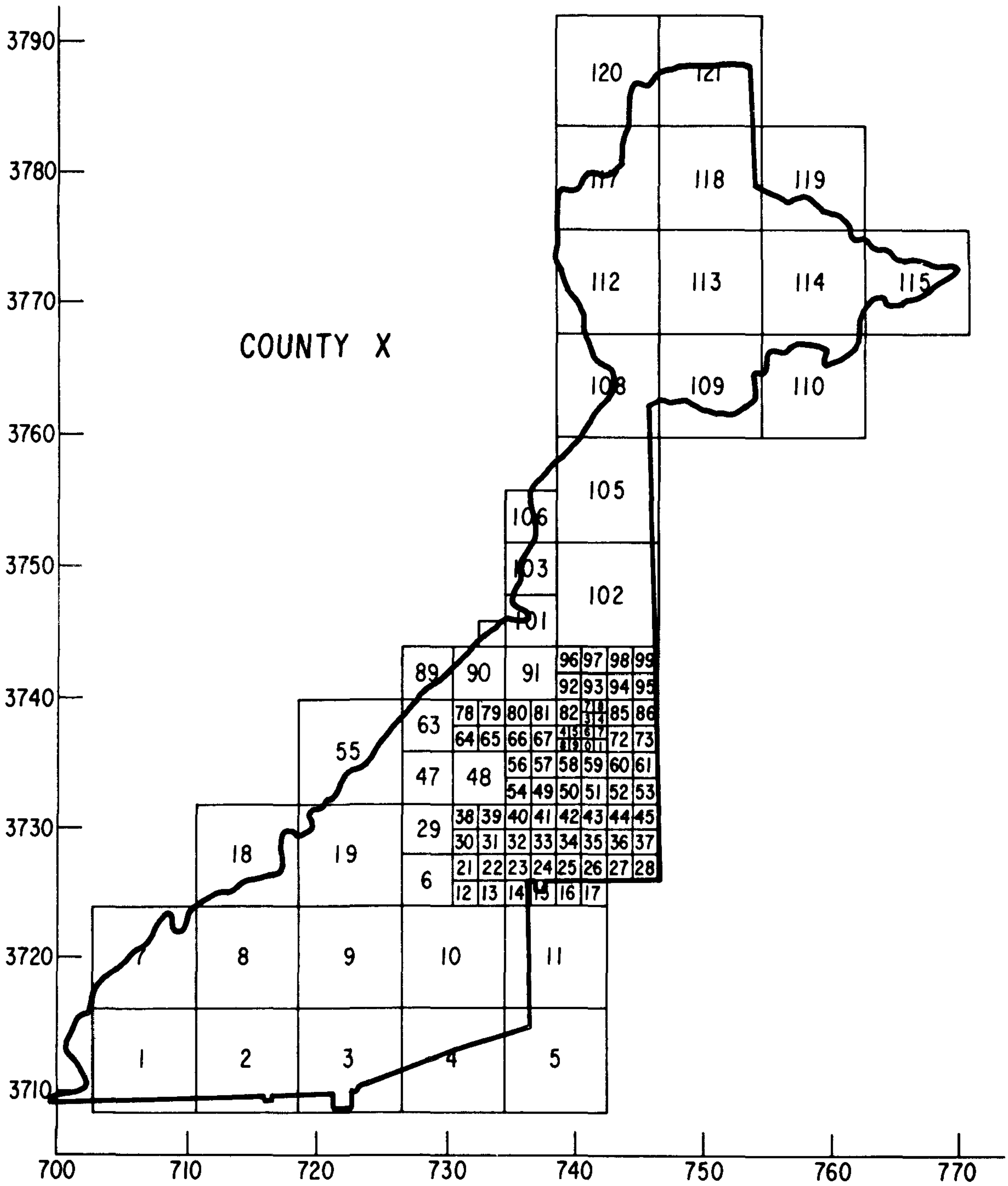


Fig. 5-6. Master Grid System for County X

PROBLEM 5-2

Using the grid map of a portion of County X given on Fig. 5-7, develop a grid system that matches the resolution of the indicated subcounty areas.

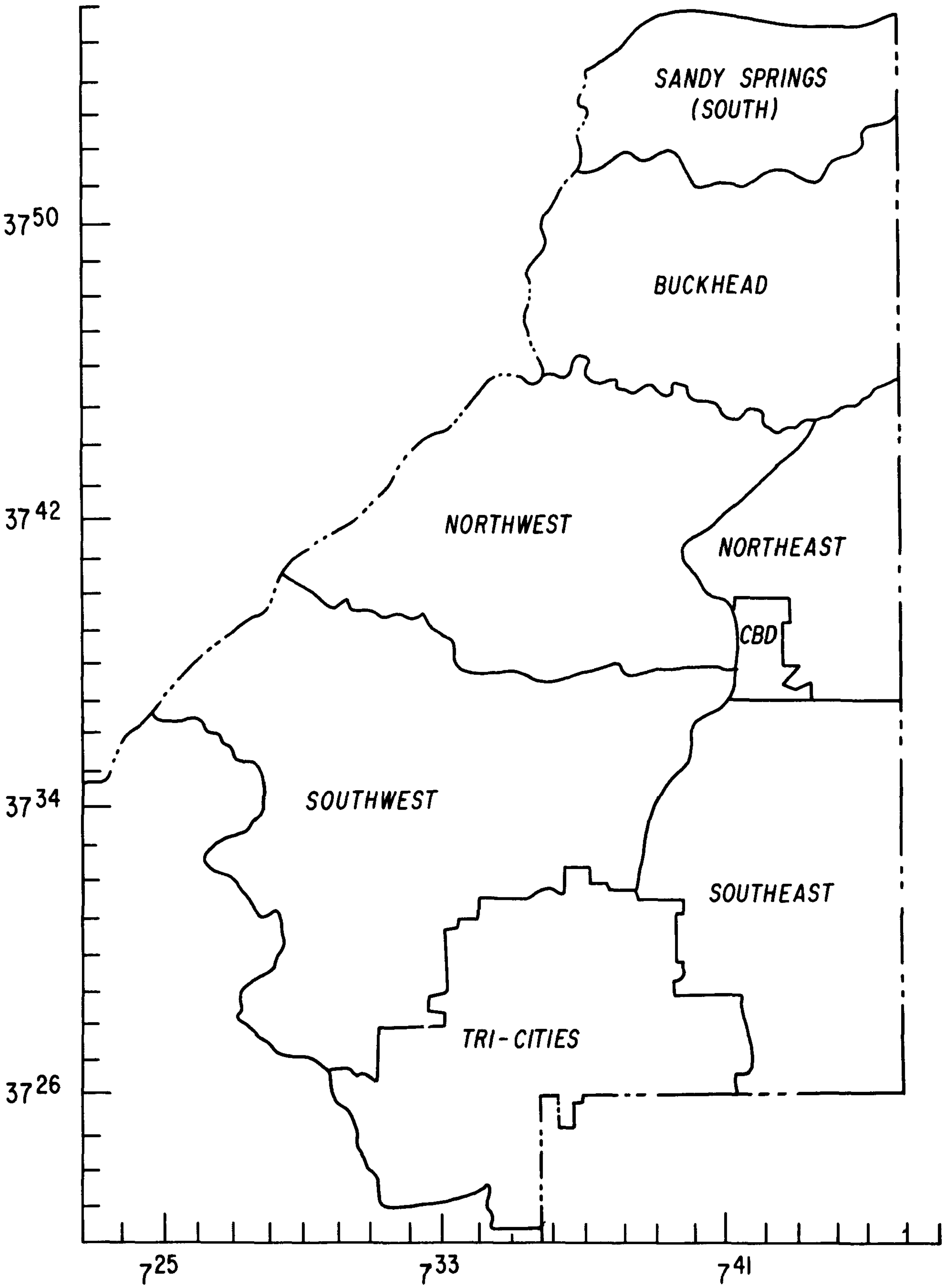


Fig. 5-7. Portion of County X for Gridding Problem 5-2

PROBLEM 5-3

Using the solution map of Problem 5-2, determine the area fractions for the Northwest Superdistrict into its overlaying grid squares. The total area of the district is known to be 77.0 sq km.

6. MODELING PROCEDURES

An atmospheric simulation model is used to convert the air pollutant emission data into ambient air pollutant concentration estimates. The model is an analytical tool that helps the air quality analyst determine the effectiveness of his control strategies. Like any tool, the model is useful only if the user understands its strengths and weaknesses and does not attempt to apply it beyond its capabilities. Perhaps the most widespread abuse of atmospheric simulation is to regard the model as a mystical "black box" that magically transforms emissions into air quality. This approach to modeling is most likely to lead to erroneous results and to an analysis that will not withstand technical challenge.

6.1 CHOICE OF MODEL

There are numerous simulation models available to the air quality analyst. These models vary widely in their data requirements, complexity, accuracy, and applicability. Reference 12 gives concise descriptions of some of the more widely used multi-source models (i.e., models that can be used to study the impact of many sources or source categories on air quality), and these are summarized on Table 6.1. The Rollback and Appendix J models rely on proportional reduction assumptions; that is, if emissions are reduced by a given amount, the concentrations will be reduced proportionately. Both are only useful for rough approximations of air quality impacts. The Miller-Holzworth model uses a dispersion equation that is integrated over an entire urban area. It is a step better than Rollback in that it can be used where there are no observed air quality data available. Both the annual and short-term versions of the Hanna-Gifford model use a simplified dispersion equation to compute the concentration over each area in which a receptor is located. The basic Hanna-Gifford model can be improved with the addition of either a point source or line source model to provide better spatial resolutions. The Air Quality Display Model (AQDM) and its companion, the Climatological Display Model (CDM) use a Gaussian-plume calculation to estimate specific source-receptor contributions on an annual average. These are the most widely used models in air quality analyses. The Sampled Chronological Input Model (SCIM) and the Real Time Air Quality Simulation Model (RAM) also use a Gaussian-plume calculation, but on an hourly basis. The APRAC-1A model is used for mobile source emissions and is a line source formulation for use with highway links. The SAI model is a photochemical model that incorporates both dispersion and atmospheric chemical reactions.

Table 6.1. Multi-Source Atmospheric Dispersion Models

Model	Model Technique
1. Rollback	Proportional reduction
2. Appendix J	Proportional reduction of oxidant concentration to hydrocarbon emissions
3. Miller-Holzworth	Integration of Gaussian dispersion across an urban area
4. Hanna-Gifford	Simplified dispersion equation over an area
5. Hanna-Gifford with Point Source	Addition of specific point source calculations to basic Hanna-Gifford
6. Hanna-Gifford with HIWAY	Addition of line source calculations to basic Hanna-Gifford
7. Air Quality Display Model (AQDM) (also Climatological Display Model (CDM))	Gaussian plume concentration calculations for annual averages
8. Sampled Chronological Input Model (SCIM) (also Real Time Air Quality Simulation Model (RAM))	Gaussian plume concentration calculations for 1-hour averages
9. APRAC-1A	Line source calculations for highway and street links
10. SAI	Photochemical reaction and dispersion calculations

In addition to these multi-source models, there are a variety of single source models available that can be used to evaluate the impact of isolated point sources or to develop control measures applicable to only a few sources in an urban area. These models can be used to conduct microscale analyses to further clarify and amplify the macroscale results of the multi-source models. (This has been alluded to in the discussion of the Hanna-Gifford

Model.) Descriptions of the available models are given in References 10, 24, 34, and 35. Computerized models are also available.[36,37] The discussion of Reference 10 indicates how such models might be used to implement a new source review program to identify the impacts of large, new emission sources. An indirect source review program[9] can also make use of some of the microscale analysis techniques.

There are numerous other models available for use in an air quality analysis. Appendix A in Chapter 40, Part 51 of the Code of Federal Regulations, presents EPA's general position as to the appropriate and acceptable use of specific air quality simulation models. The EPA Regional Office should, however, be consulted to determine the acceptability of comparable models.

The choice of model is a function of many considerations including the following:

Pollutant	Ease of use
Averaging time	Availability
Data requirements	Reliability
Model output	Applicability to air quality analysis

Table 6.2, taken from Reference 12, evaluates each of these considerations for the ten most commonly used models. In some cases a model that specifies one averaging time can be used to estimate concentrations for other averaging times by using statistical techniques such as those described by Larsen[17] and Turner.[24]

Proposed regulations require that, at a minimum, AQDM or equivalent model be used for the air quality analysis of particulates and SO_2 with appropriate estimations made for short-term standards.[14] Proportional modeling will be acceptable for CO and NO_2, while Appendix J will be acceptable for oxidants. Table 6.3 gives the applicability of each model to an analysis of each of the NAAQS pollutants. Deviations from these general guidelines are possible with EPA Regional Office concurrence.

6.2 MODEL OUTPUTS

The output of the models varies considerably as indicated on Table 6.2. The Rollback, Appendix J, Miller-Holzworth, and basic Hanna-Gifford

Table 6-2. Summary of Simulation Model Characteristics

Model Name	Pollutant Specification	Averaging Time Specification	Emission Data	Meteorological Data	Concentration Estimates	Ease of Use	Availability	Reliability	Applicability to AQAS
Rollback	Any	Any	1	1	3	1	1	3	3
Appendix J	O_x	1 hr	1	1	3	1	1	3	3
Miller-Holzworth	SO_2,TSP	1 hr, Annual	1	3	3	1	1	1	3
Hanna-Gifford	SO_2,TSP CO	Annual	1	2	3	1	1	1	3
Hanna-Gifford	SO_2,TSP	1-24 hr	2	5	2	2	1	1	2
w/PS[a] model	SO_2,TSP	1-24 hr	3	5	1	2	2	1	1
w/HIWAY	CO	1-24 hr	3	5	1	2	2	1	1
AQDM, CDM	SO_2,TSP	Annual	3	4	1	3	2	1	1
SCIM,[b] RAM[b]	SO_2,TSP	1-24 hr	3	5	1	3	3	2	1
APRAC-1A	CO	1-24 hr	3	5	1	3	2	2	1
SAI[b]	CO,NO_2,O_x	1-10 hr	2	5	2	3	3	2	2

[a]Point Source

[b]These models are currently in a developmental and debugging phase; they are not available for general distribution as computer programs.

Key to Table 6.2

A. Pollutant Specification
- Any pollutant
- Specific Pollutants (SO_2, TSP, CO, O_x, NO_2)

B. Averaging-time Specification
- Any averaging-time
- Annual Average
- 1 to 24 hour Average

C. Emission Data
1. Area-wide Emissions Total
2. Total emission distributed as finite area sources
3. Detailed point, line, and area sources

D. Meteorological Data
1. None
2. Average wind speed
3. Average wind speed and mixing height
4. Frequency distribution of wind direction, wind speed, stability, and mixing height
5. Hourly variations of wind direction, wind speed, stability, and mixing height

E. Concentration Estimates
1. Estimates at any specified point
2. One estimate for each area source grid
3. One estimate applicable to entire AQMA

F. Ease of Use
1. Slide-rule
2. Small computer effort
3. Major computer effort

G. Availability
1. Open literature
2. National Technical Information Service
3. EPA, upon request

H. Reliability
1. Can be verified and calibrated
2. Verification is incomplete, possibility of calibration is uncertain
3. Questionable; acceptable for crude estimates only

I. Applicability to AQAS
1. Can distinguish between specific source and land use type
2. Can distinguish between land use types only
3. Considers no distinction between sources or land uses

Table 6-3. Models Applicable to Specific Pollutants and Averaging Times

Pollutant and Averaging Times	Preferred Model	Alternative Models	
		Model	Condition of Applicability
SO_2, TSP Annual Average	1. AQDM 2. CDM	1. Hanna-Gifford	Inadequate computer facilities
		2. Rollback	Complex topography and/or Meteorology
		3. More sophisticated model	Complex topography and/or meteorology
		4. Miller-Holzworth	No circumstances currently envisioned permit its use
SO_2, TSP 24-hr and 3-hr Averages	1. AQDM[a] 2. CDM[a] 3. Single-source models	1. SCIM,[b] RAM[b]	Availability
		2. Hanna-Gifford w/point source[b]	Inadequate computer facilities
		3. Rollback	Complex topography and/or meteorology
		4. More sophisticated model	Complex topography and/or meteorology
		5. Miller-Holzworth	No circumstances currently envisioned permit its use
CO 1-hr and 8-hr Averages	1. APRAC-1A 2. Hanna-Gifford w/ HIWAY	Rollback	Unavailability of other models
Oxidants 1-hr Average	1. SAI 2. Appendix J	Rollback	Demonstration that Appendix J is not applicable to region
NO_2 Annual Average	1. Rollback 2. Single-source models[c]		

[a]Statistical conversion of averaging times required.

[b]Repetitious application of model to each hour under consideration is required for averaging times longer than 1-hr.

[c]Usable only when atmospheric chemical reactions are not significant over the impact area.

models result in a single estimate of pollutant concentration applicable over the entire region under study. These models are, therefore, applied to the expected worst receptor in the region. The short-term Hanna-Gifford model can generate a concentration estimate over an area source grid. It can also give concentrations at any point when coupled with a point source model or with the HIWAY model. The SAI photochemical model calculates concentrations over an area source grid. All the other models can compute concentrations at any specified receptor point. A sample printout of the AQDM model is given on Fig. 6-1. The receptor coordinates and the computed concentrations are shown.

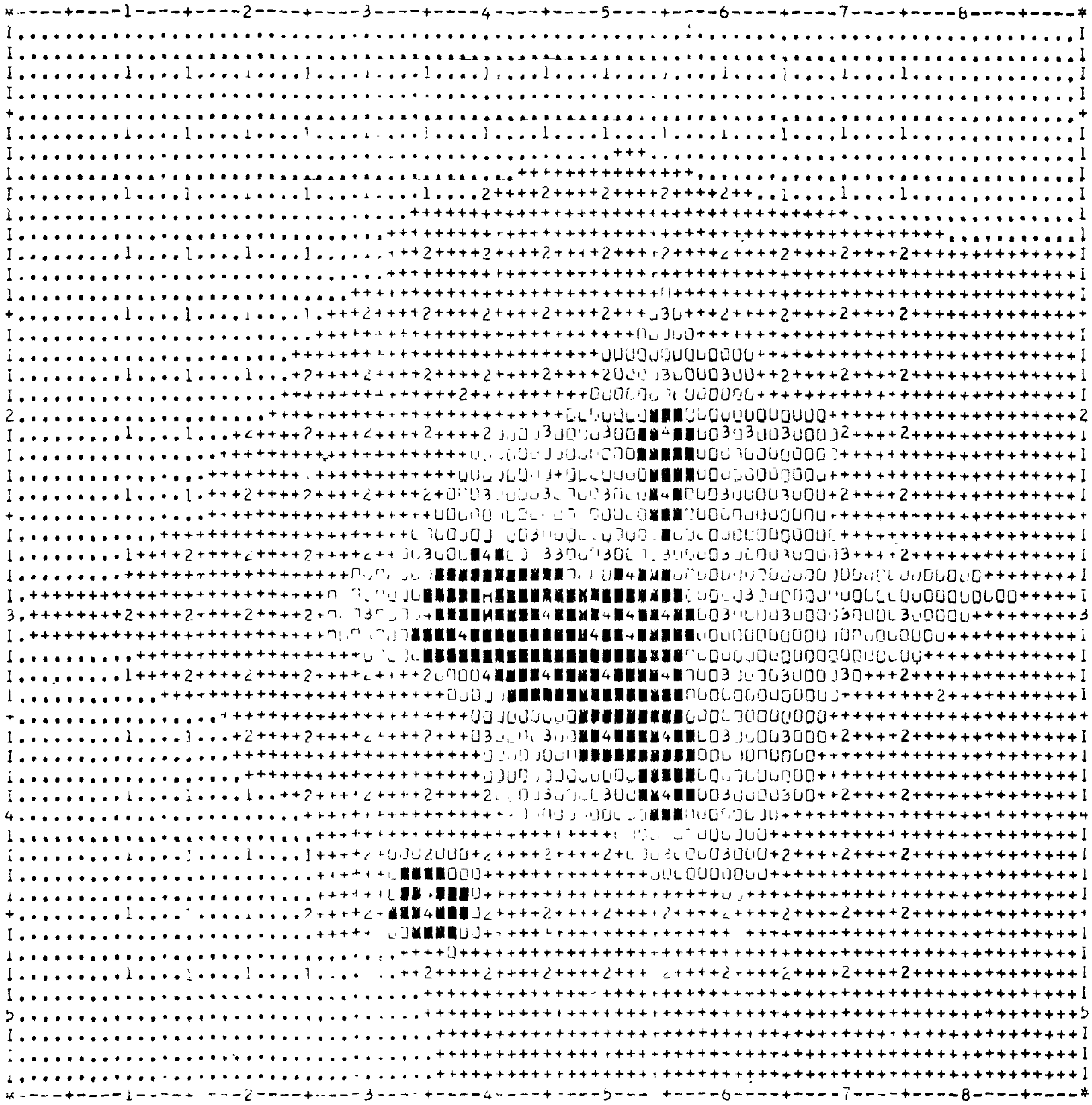
Another useful form of output for those models that can compute concentrations at any point is the isopleth or line of constant concentration. If the computations are made at a large enough number of receptor points, then the isopleths are easily drawn by interpolating between adjacent points. A standardized computer program, SYMAP, is available,[38] which uses a computer line printer to draw the isopleths. Figure 6-2 is a sample output of the SYMAP program, which has been coupled to the AQDM model. The printer draws a symbol to represent the concentration level and also prints the computed concentration at each selected receptor point. The concentration intervals can be determined manually or automatically. The use of isopleths is an extremely valuable tool in visualizing the general air quality situation and identifying "hot spots," although its use is not critical to the air quality analysis.

In determining the impact of various sources on air quality at a given location, it is necessary to develop a culpability list; that is, a list of the contributions of each source to the calculated concentration at a given receptor. Since all of the models make use of the principle of superposition in that the concentration is calculated as the sum of the emissions dispersed from each individual source, it is conceptually straightforward to develop the list. In practice, without computer assistance the task would be extremely laborious for all but a very small number of sources. The AQDM model has a routine incorporated into it that prepares such a list with no additional burden on the user. Figure 6-3 demonstrates the output of this routine. This information is extremely useful in control strategy development and analysis. If a model is being used that does not have such a routine built-in, it is highly recommended that the effort be expended to develop and incorporate one.

RECEPTOR CONCENTRATION DATA

RECEPTOR NUMBER	RECEPTOR LOCATION (KILOMETERS) HORIZ	VERT	EXPECTED ARITHMETIC MEAN (MICROGRAMS/CU. METER) SO2	PARTICULATES
121	735.0	3750.0	0.	60.
122	735.0	3755.0	0.	61.
123	735.0	3760.0	0.	57.
124	735.0	3765.0	0.	55.
125	735.0	3770.0	0.	53.
126	735.0	3775.0	0.	51.
127	735.0	3780.0	0.	49.
128	735.0	3785.0	0.	48.
129	740.0	3710.0	0.	53.
130	740.0	3715.0	0.	55.
131	740.0	3720.0	0.	58.
132	740.0	3725.0	0.	66.
133	740.0	3730.0	0.	78.
134	740.0	3735.0	0.	75.
135	740.0	3740.0	0.	77.
136	740.0	3745.0	0.	69.
137	740.0	3750.0	0.	62.
138	740.0	3755.0	0.	70.
139	740.0	3760.0	0.	60.
140	740.0	3765.0	0.	55.
141	740.0	3770.0	0.	55.
142	740.0	3775.0	0.	52.
143	740.0	3780.0	0.	50.
144	740.0	3785.0	0.	48.
145	745.0	3710.0	0.	54.
146	745.0	3715.0	0.	57.
147	745.0	3720.0	0.	62.
148	745.0	3725.0	0.	101.
149	745.0	3730.0	0.	80.
150	745.0	3735.0	0.	78.
151	745.0	3740.0	0.	81.
152	745.0	3745.0	0.	72.
153	745.0	3750.0	0.	80.
154	745.0	3755.0	0.	96.
155	745.0	3760.0	0.	67.
156	745.0	3765.0	0.	63.
157	745.0	3770.0	0.	57.
158	745.0	3775.0	0.	51.
159	745.0	3780.0	0.	50.
160	745.0	3785.0	0.	48.

Fig. 6-1. Sample AQDM Output



SYMAP

1.14 SECONDS FOR MAP

TIME IS 0.05 MINUTES

Fig. 6-2. Sample SYMAP Output

SOURCE CONTRIBUTIONS TO FIVE SELECTED RECEPTORS

ANNUAL PARTICULATES

MICROGRAMS PER CUBIC METER

SOURCE	RECEPTOR 151	RECEPTOR 119	RECEPTOR 132	RECEPTOR 171	RECEPTOR 233
43	0.00 %	0.00 %	0.01 %	0.00 %	0.00 %
	0.0026	0.0029	0.0023	0.0002	0.0006
44	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
	0.0016	0.0023	0.0002	0.0003	0.0005
45	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
	0.0047	0.0002	0.0005	0.0002	0.0015
46	0.18 %	0.35 %	0.08 %	0.05 %	0.24 %
	0.1466	0.2971	0.0231	0.0321	0.2057
47	0.00 %	0.01 %	0.00 %	0.00 %	0.02 %
	0.0120	0.0108	0.0022	0.0021	0.0187
48	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
	0.0007	0.0012	0.000[illegible]	0.0000	0.0014
49	0.00 %	0.01 %	0.00 %	0.00 %	0.01 %
	0.0036	0.0026	0.0006	0.0004	0.0069
50	0.01 %	0.02 %	0.01 %	0.01 %	0.01 %
	0.0032	0.0186	0.0006	0.0040	0.0123
51	2.28 %	3.01 %	0.48 %	0.22 %	7.80 %
	1.8529	2.5023	0.3149	0.1390	6.3811
52	0.46 %	0.32 %	0.09 %	0.05 %	0.27 %
	0.3727	0.2786	0.0619	0.0337	0.2248
53	0.61 %	0.30 %	0.11 %	0.08 %	0.61 %
	0.4990	0.2613	0.07[illegible]	0.0482	0.5184
54	0.35 %	0.54 %	2.16 %	0.44 %	1.03 %
	0.7705	0.4661	1.4324	0.2747	0.8665
55	3.43 %	1.97 %	7.82 %	1.61 %	3.72 %
	2.7827	1.6891	5.1868	0.9946	3.1372
56	1.00 %	0.19 %	0.35 %	1.48 %	0.56 %
	0.8348	0.1661	0.2300	0.9198	0.4724
57	4.15 %	0.78 %	1.40 %	6.01 %	2.27 %
	3.3741	0.6718	0.[illegible]	3.7210	1.9110
58	0.00 %	0.01 %	0.00 %	0.01 %	0.01 %
	0.0021	0.0030	0.0005	0.0041	0.0054
59	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
	0.0018	0.0022	0.0022	0.0014	0.0019
60	0.00 %	0.00 %	0.00 %	0.00 %	0.00 %
	0.0018	0.0020	0.0022	0.0014	0.0019
61	0.89 %	0.82 %	1.85 %	0.82 %	0.91 %
	0.7227	0.7141	1.2229	0.5059	0.7685
62	2.65 %	1.73 %	0.35 %	1.69 %	2.44 %
	2.1512	1.4892	0.0248	1.0463	2.0548
63	13.65 %	35.11 %	18.05 %	6.55 %	17.27 %
	11.1163	30.1[illegible]	11.[illegible]	4.0599	14.5644

Fig. 6-3. Sample AQDM Culpability List

6.3 MODEL VALIDATION AND CALIBRATION

6.3.1 Validation Procedures

As with all analytical tools, air quality simulation models are subject to errors that cause the computed concentrations to differ from observed values. The errors are of two basic types:

Errors in predicting variations in concentrations, and
Errors in predicting absolute levels.

The first type are systematic errors that indicate that the model is not accurately accounting for variations in emissions or dispersion. The second type of error indicates that the model is accounting for variations properly but the computed concentration is in error by some across-the-board quantity. This is most frequently explained by a background level that is not accounted for and is the least serious of the two errors.

There are numerous statistical tests that can be used to evaluate how well the calculated values compare to the observed. These include skill scores, contingency tables, comparison of time series and spatial variations, and correlation analyses. The latter, illustrated on Fig. 6-4, is the easiest to use and is incorporated into the AQDM model. It uses a graph of observed versus calculated values of concentration either at one receptor location (for several meteorological or emission conditions) or at a number of locations for a fixed set of conditions.

A least-square regression line of observed concentration values on the calculated values is then obtained. To determine the validity of using the model to calculate air quality levels, the coefficient of correlation, a measure of data-scatter about the regression line, is calculated and compared with the maximum theoretical value that could arise due to chance. The maximum theoretical value for a 5% confidence level (that is, there are fewer than 5 chances in 100 that a coefficient of correlation as high as this value would arise due to random sampling variation) is used as the criterion for acceptable validation in AQDM. A poor correlation coefficient warns the user that the input data and the model assumptions must be reviewed.

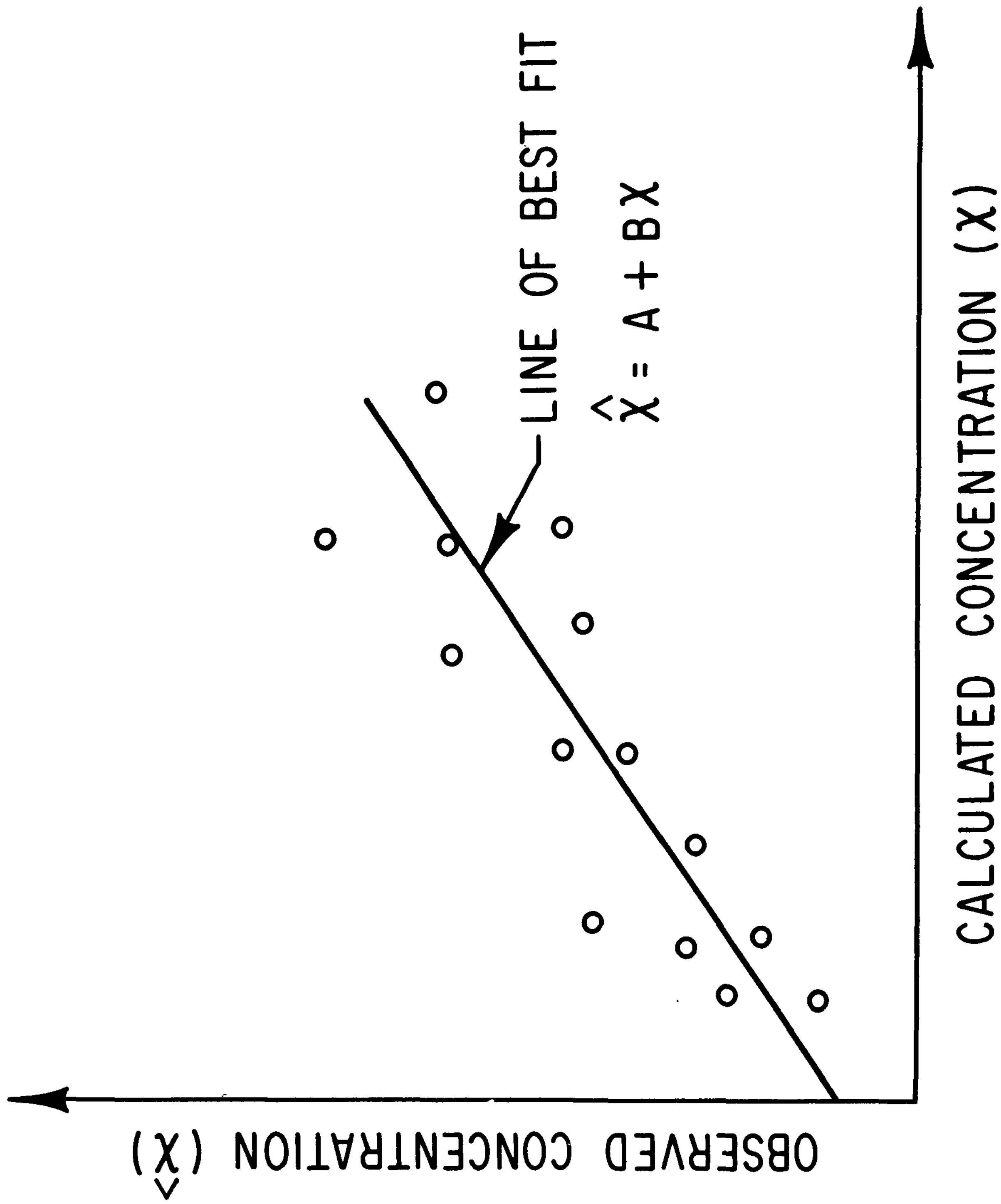


Fig. 6-4. Regression Analysis for Model Validation

6.3.2 Sources of Errors

The most frequently occurring reasons for a poor correlation between computed and observed concentrations are:

- Inadequate emission inventory,
- Unrepresentative air quality data,
- Complex topography and/or meteorology,
- Incomplete description of source variations, and
- Unaccounted-for atmospheric processes.

By the nature of how emission inventories are developed, there is substantial room for error. This is especially true when the lower levels of emission estimation and spatial allocation are used. Some of the more glaring errors (e.g., the excessive domination of a single source) are correctable by further investigation of specific sources. The more subtle errors may elude a quick solution and may require substantial reinvestigation to identify the problems.

The unrepresentativeness of the observed data against which the calculations are compared is another source of a poor correlation. Data collected in an area dominated by a single source is often not suitable for comparison to the predicted values obtained from some multi-source models. Likewise, data collected from areas influenced by unusual emission patterns or terrain features make for poor validation points. These problems are relatively easy to compensate for by reviewing the locations of all the monitors and screening out unacceptable model validation data. References 11 and 19 give some guidelines on determining the representativeness of various monitor locations.

Only a few specialized models are adequate for use in complex terrain (e.g., mountain or valley locations) or for unusual meteorology (e.g., lake or ocean breeze circulation). Attempts to use other models in these circumstances will lead to erroneous results and misleading conclusions. Advice from EPA Regional Offices and/or headquarters is available to determine the suitability of various models.

Errors in calculated concentrations occur when the model is not capable of representing variations in the emission patterns of major sources.

If, for example, space heating emissions are significant, then the model must be able to distinguish between summer and winter emission patterns. Problems of this type can be identified by reviewing the culpability list to determine if the major sources are adequately treated in the simulation.

Atmospheric processes such as photochemical reactions, scavenging, and settling have a dramatic effect on concentrations. Of the models listed on Table 6.1, only the SAI model takes account of photochemistry. The state of the art of this type of model is still developmental and widespread applicability of these models has yet to be demonstrated. The removal of pollutants by scavenging (e.g., by washout, ground absorbtion, etc.) has been treated in some models by incorporating a half-life term in the dispersion equations. This term results in a steady reduction in concentrations in addition to the dispersion effects. Gravitational settling of particulates reduces concentrations in the same fashion as scavenging. The larger particulates (> 30 μm) tend to settle relatively quickly and hence should not be part of the observed concentrations. The emission inventory may be adjusted to reflect this situation by using emission factors representing source particulate size distribution. Sources for which this type of adjustment is most applicable are the industrial process sources (especially things like stone quarrying, rock crushing, etc.) and some fugitive dust sources (e.g., unpaved roads, agricultural tilling, etc.). Appendix F gives some further expansion of this.

6.3.3 Model Calibration

Once the dispersion model estimates have been validated or determined to be acceptable, the model may be calibrated. The calibration should account for systematic errors in the estimates. If the coefficient of correlation (calculated in AQDM, for example) is greater than the theoretical value for a 5% confidence level, the regression line is used to calibrate the calculated values. The slope of the regression line is used to adjust systematic errors in predicting variations in concentrations, and the intercept adjusts the prediction of absolute levels by accounting for missing input background concentration values.

Figure 6-5 gives the correlation analysis for County X using the baseline inventory and air quality data. The calculation shows the 5% confidence level to correspond to a correlation coefficient of 0.532. The

REGRESSION PARAMETERS FOR CALCULATED (X-AXIS) VS. OBSERVED (Y-AXIS) CONCENTRATIONS

POLLUTANT	Y-INTERCEPT (MICROGRAMS/CU. METER)	SLOPE	REGRESSION COEFFICIENTS	
			COMPUTED	5% CONE. LEVEL
PARTICULATES	31.2	0.1992	0.629	0.532

CORRELATION DATA				
PARTICULATE MONITORING STATION	RECEPTOR LOCATION (KILOMETERS)		PARTICULATE CONCENTRATION (MICROGRAMS/CU. METER)	
	HORIZONTAL	VERTICAL	OBSERVED	CALCULATED
1	742.2	3737.9	58.	132.
2	744.1	3730.2	50.	111.
3	742.3	3744.0	50.	120.
4	741.9	3739.6	59.	148.
5	728.5	3737.9	45.	92.
6	734.1	3743.0	61.	120.
7	743.8	3736.5	61.	129.
8	738.7	3738.7	53.	111.
9	735.8	3745.2	58.	103.
10	751.9	3741.6	49.	94.
11	767.9	3734.2	49.	80.
12	751.6	3754.6	63.	147.
13	724.5	3716.2	40.	107.
14	727.8	3758.9	55.	86.

Fig. 6-5. AQDM Regression Analysis for County X

computed correlation coefficient is 0.629, thus indicating an acceptable validation. The y-intercept of 31.2 μg/m³ is within acceptable levels for background particulate levels, but the small slope indicates the model to be relatively insensitive to changes in emission patterns. The calibration equation is the following:

$$\chi_{observed} = 0.199\ \chi_{calculated} + 31.2 \qquad (6\text{-}1)$$

This equation is then used to correct all future concentration calculations.

6.3.4 Background Concentrations

Some pollutants occur naturally in the atmosphere independently of any human activity. Since simulation models rely on a description of all emission sources, they are likely to underpredict the absolute concentration by an amount equal to this background level and must be corrected. In another context, background concentrations can be interpreted as the material transported into the region of study from external sources, the nature of which is unknown. In both cases, the background level is added to all computed concentrations.

Background levels may be determined from air quality monitors upwind of major source activities. The levels can be expected to lie in the ranges given in Table 6-4.

Table 6-4. Range of Background Concentrations

Pollutant	Concentration (μg/m³)
Particulates	30-40
SO_2	∿ 0
CO	∿ 0
NO_2	∿ 0
Oxidants	∿ 0[a]

[a]The Appendix J model is based on a zero background concentration of hydrocarbons and oxidants.

6.4 COUNTY X MODELING RESULTS

The Air Quality Display Model (AQDM) was used to perform the air quality analysis for County X. Figures 6-6 to 6-8 illustrate the particulate air quality computed for 1975, 1980, and 1985 as plotted from the SYMAP routine. Table 6.5 is a composite of the computed air quality from the AQDM output tables. In making these computations it was assumed that no new control programs were in force, only existing regulations and federal New Source Performance Standards were assumed to be in effect, and source compliance data, where available, were used to determine actual emissions.

It is evident from Fig. 6-6 that there are several areas in the county exceeding the primary NAAQS for particulates of 75 $\mu g/m^3$ and that there are much wider-spread violations of the secondary standard of 60 $\mu g/m^3$. By 1980, Fig. 6-7, growth and development has caused significant increases in the area in excess of both the primary and secondary standards. In the period between 1980 and 1985 (Fig. 6-8), the growth in NAAQS violation areas has slowed markedly to a point of little increase. This is the result of the imposition of New Source Performance Standards that arrest the growth in emissions. This fact is evidenced by the change in county emissions as illustrated on Table 4-1.