REPORT FOR CONSULTATION ON THE PHOENIX-TUCSON INTRASTATE AIR QUALITY CONTROL REGION (ARIZONA)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service
Consumer Protection and Environmental Health Service

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PHOENIX-TUCSON

INTRASTATE AIR QUALITY CONTROL REGION

(ARIZONA)

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
CONSUMER PROTECTION AND ENVIRONMENTAL HEALTH SERVICE
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION
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PREFACE

The Secretary, Department of Health, Education, and Welfare, is directed by the Clean Air Act, as amended, to designate "air quality control regions" as an initial step toward the adoption of regional air quality standards and the establishment of plans to implement those standards. In addition to listing the major factors to be considered in the development of region boundaries, the Act stipulates that the designation of a region shall be preceded by consultation with appropriate State and local authorities.

The National Air Pollution Control Administration, DHEW, has conducted a study of southern Arizona, including the Phoenix and Tucson metropolitan areas. The results of the study are presented in this document. The Region* boundaries recommended in this report reflect a consideration of all available and pertinent data; however, the boundaries remain subject to revision suggested by consultation with State and local authorities. This report is intended to serve as a background document for the formal consultation.

The Administration is appreciative of assistance received either directly during the course of this study, or during previous activities in the State of Arizona, from the Arizona State

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* For the purpose of this report, the word "region", when capitalized, will refer to the proposed Phoenix-Tucson Intrastate Air Quality Control Region (Arizona). When not capitalized, unless otherwise noted, it will refer to air quality control regions in general.

Department of Health, the Maricopa County Health Department, and the Pima County Air Pollution Control District. Useful data was also supplied by the Arizona State Employment Service Division and the Unemployment Compensation Division of the Employment Security Commission of Arizona, the Arizona State Economic Planning and Development Department, the Tucson Department of Community Development, and the Pima County Planning Department.

INTRODUCTION

> "For the purpose of establishing ambient air quality standards pursuant to section 108, and for administrative and other purposes, the Secretary, after consultation with appropriate State and local authorities shall, to the extent feasible, within 18 months after the date of enactment of the Air Quality Act of 1967 designate air quality control regions based on jurisdictional boundaries, urban-industrial concentration, and other factors including atmospheric areas necessary to provide adequate implementation of air quality standards. The Secretary may from time to time thereafter, as he determines necessary to protect the public health and welfare and after consultation with appropriate State and local authorities, revise the designation of such regions and designate additional air quality control regions. The Secretary shall immediately notify the Governor or Governors of the affected State or States of such designation."
>
> Section 107(a)(2), Clean Air Act as Amended.

THE CLEAN AIR ACT

Air pollution in most of the Nation's urban areas is a regional problem. This regional problem demands a regional solution, consisting of coordinated planning, data gathering, standard setting and enforcement. Yet, with few exceptions, such coordinated efforts are notably absent among the Nation's urban complexes.

Beginning with the Section quoted above, in which the Secretary is required to designate air quality control regions, the Clean Air Act, as amended, presents an approach to air pollution control involving coordinated efforts by Federal, State, and local governments, as shown in Figure 1. After the Secretary has (1) designated regions, (2) published air quality criteria, and (3)

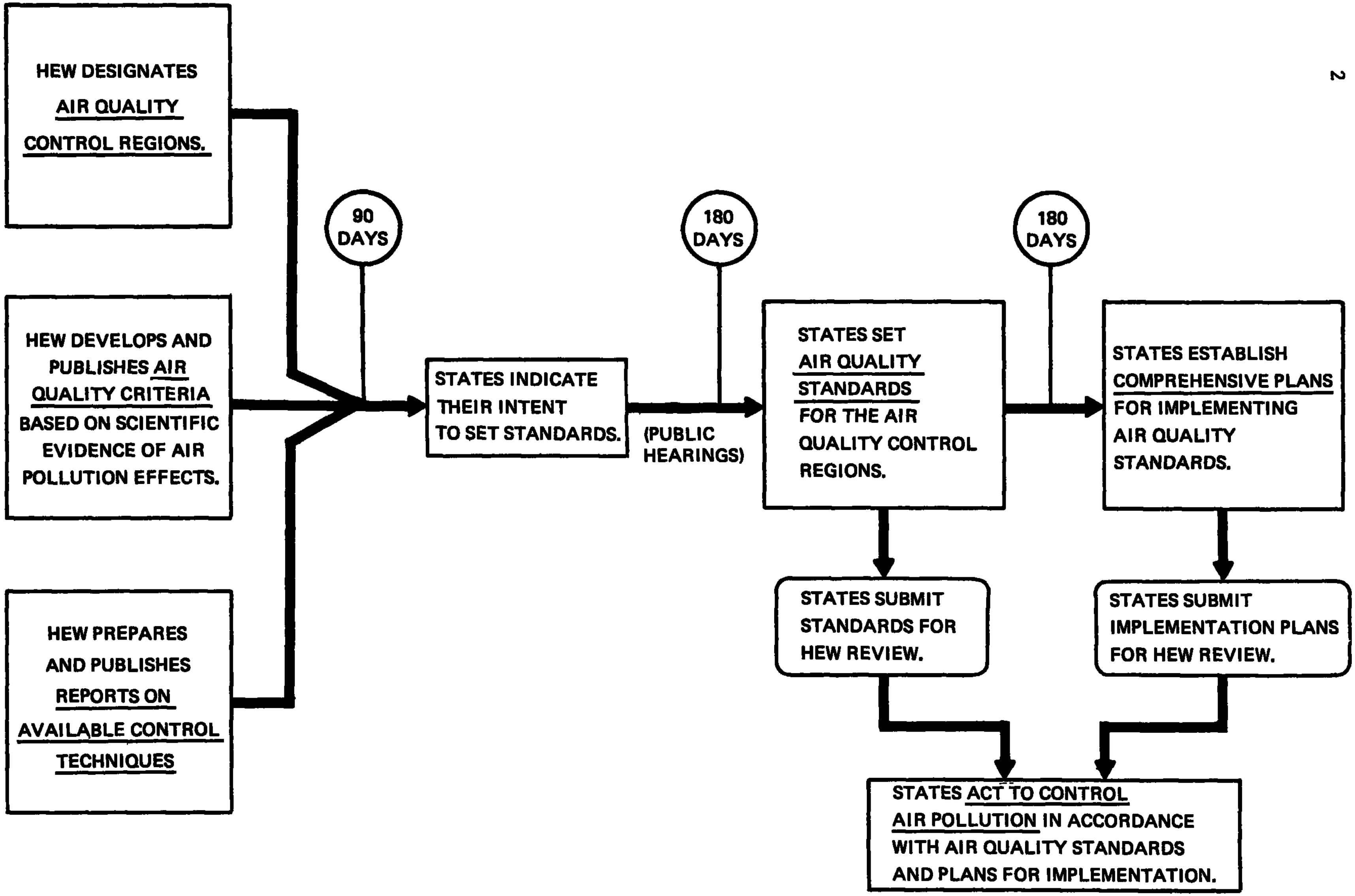


Figure 1. Flow Diagram for Action to Control Air Pollution on a Regional Basis, under the Clean Air Act

published corresponding documents on control technology and associated costs, the Governor(s) of the State(s) must file with the Secretary within 90 days a letter of intent, indicating that the State(s) will adopt, within 180 days, ambient air quality standards for the pollutants covered by the published criteria and control technology documents, and establish within an additional 180 days, plans for the implementation, maintenance, and enforcement of those standards in the designated air quality control region.

The new Federal legislation provides for a regional attack on air pollution and, at the same time, allows latitude in the form which regional efforts may take. While the Secretary reserves approval authority, the States involved in a designated region assume the responsibility for developing standards and an implementation plan which includes administrative procedures for abatement and control. For regions which extend across jurisdictional boundaries, informal cooperative arrangements may be adequate in some cases. In some cases, too, more formal arrangements, such as interstate compacts, may be selected to insure compatible standards and proper enforcement among the jurisdictions. The objective in each instance will be to provide effective mechanisms for control on a regional basis.

PROCEDURE FOR DESIGNATION OF REGIONS

Figure 2 illustrates the procedures used by the National Air Pollution Control Administration for designating air quality control regions.

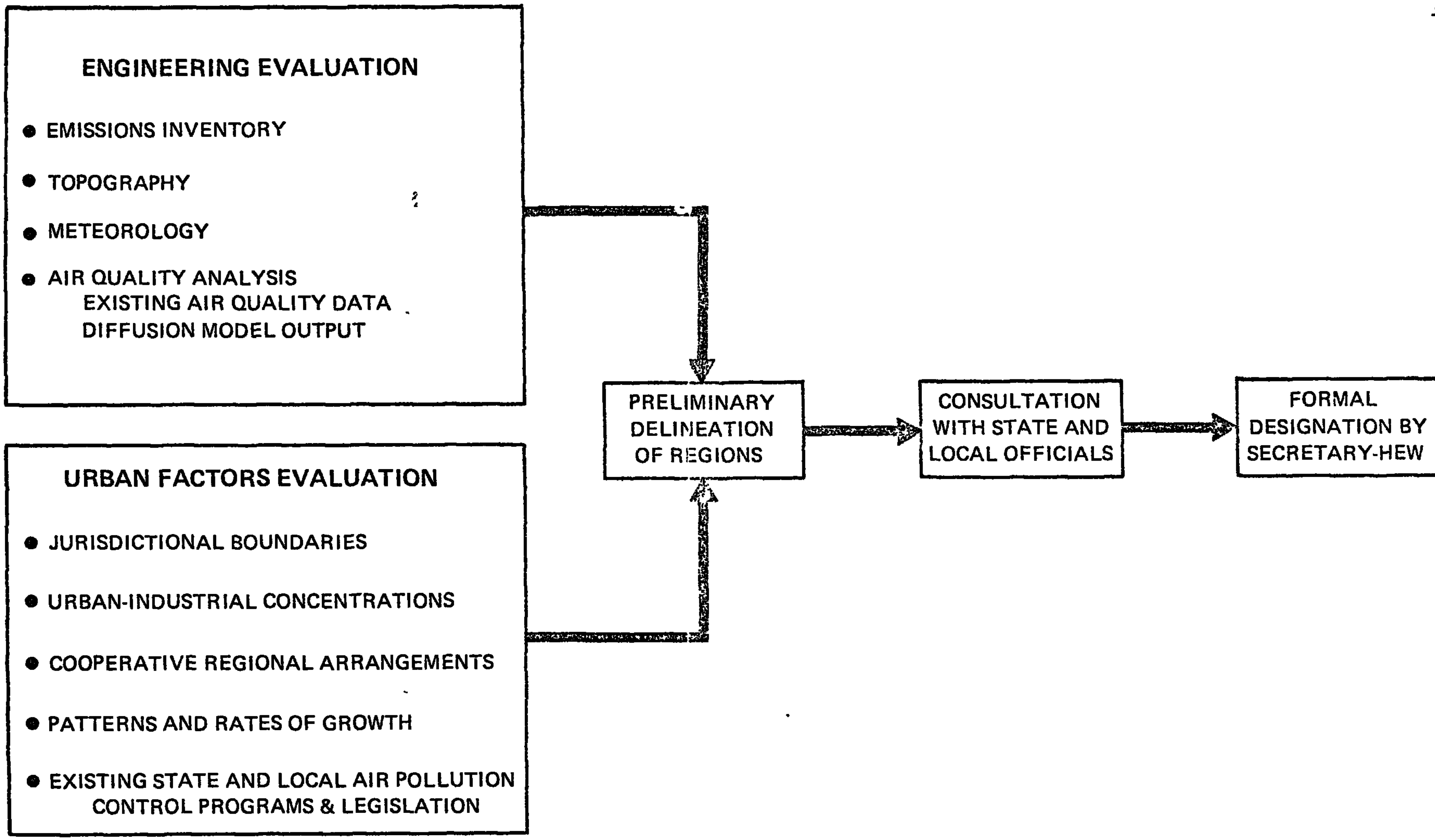


Figure 2. FLOW DIAGRAM FOR THE DESIGNATION OF AIR QUALITY CONTROL REGIONS.

A preliminary delineation of the region is developed by bringing together two essentially separate studies -- the "Evaluation of Engineering Factors," and the "Evaluation of Urban Factors."

The "Evaluation of Engineering Factors" considers pollutant source locations and the geographic extent of significant pollutant concentrations in the ambient air. An inventory of air pollutant emissions determines the geographic location and quantities of the various pollutants emitted from the sources in a region. Major quantities of pollution are emitted by automobiles and industry, and from refuse disposal operations, power generation, and space heating. The subsequent effect of the pollution emitted into the atmosphere is determined by measuring ambient air quality. The air quality analysis presented in this report is divided into two major segments. The first part deals with the topography and meteorology of the area and measured air quality. This section deals with the topographical influences on local meteorological conditions and the subsequent meteorological effect on air quality. The second part of the analysis describes the results of the diffusion model applied to the metropolitan Phoenix and Tucson area in order to predict air quality. Some of the limitations of the model are also described. In addition, basic conclusions drawn from the model results, as they relate to the size of the proposed Region, are outlined.

The "Evaluation of Urban Factors" encompasses all considerations of a nonengineering nature. This evaluation consists of a review of existing governmental jurisdictions, current air pollution legislation and control programs, demographic data, current urbanization, and projected patterns of urbanization.

The findings of the engineering evaluation are combined with the results of the urban factors evaluation, and an initial proposal for the air quality control region is made. As indicated in Figure 2, the proposal contained in this report is submitted as a background document for consultation with State and local officials. After reviewing the official transcript of the consultation proceedings, which provides the viewpoints of State and local officials toward the proposal, the Secretary formally designates the region. Formal designation includes a notice in the Federal Register and a notification to the Governor(s) of the State(s) affected by the designation.

THE SIZE OF A REGION

Several objectives are important in determining how large an air quality control region should be. Basically, these objectives can be divided into three separate categories. First, a region should be self-contained with respect to air pollution sources and receptors. In other words, a region should include most of the important sources in the area as well as most of the people and property affected by those sources. In this way, all the major elements of the regional problem will lie within one unified jurisdiction. Unfortunately, since air pollutants can travel long distances, it is impractical if not impossible to delineate regions which are completely self-contained. The air over a region will usually have at least trace amounts of pollutants from external sources. During episodic conditions, such contributions from external sources may even reach significant levels. Conversely, air pollution generated within a region and transported out of it can affect external receptors to some degree. It would be impractical and inefficient to make all air quality control regions large enough to encompass these low-level effects. Trace effects extend over a much larger area than that which should be the focus of air pollution control efforts. Thus, the first objective, that a region be self-contained, becomes a question of the relative magnitude and frequency of air pollution problems. The dividing line between "important influence" and "trace effect" will be a matter of judgment. The judgment should be based on estimates of the impact a source has upon a region, and the level of pollution to which receptors are subjected. In this respect, annual and seasonal data on pollutant emissions and ambient air concentrations are a better measure of relative influence than short-term data on episodic conditions.

The second general objective requires that region boundaries be designed to meet not only present but also future conditions. In other words, the region should include areas where residential and industrial expansion are likely to create air pollution problems in the foreseeable future. This objective requires careful consideration of existing metropolitan development plans, expected population growth, and projected industrial expansion. Such considerations should result in the designation of regions which will contain the sources and receptors of regional air pollution for a number of years to come. Of course, the region boundaries need not be permanently fixed, once designated. Boundaries should be reviewed periodically and altered when changing conditions warrant readjustment.

The third objective is that region boundaries should be compatible with and even foster unified and cooperative governmental administration of the air resource throughout the region. Air pollution is a regional problem which extends across several municipal, county, and even State boundaries. Clearly, the collaboration of several governmental jurisdictions is prerequisite to the solution of the problem. Therefore, the region should be delineated in a way which encourages regional cooperation among the various governmental bodies involved in air pollution control. In this regard, the existing pattern of governmental cooperation on the whole range of urban problems may become an important consideration. Certainly, the pattern of cooperation among existing air pollution control programs is a relevant factor. In general, administrative considerations dictate that governmental jurisdictions should not be divided. Although it would be impractical to preserve State jurisdictions undivided, usually it is possible to preserve the unity of county governments by including or excluding them in their entirety. In certain instances, the county is not an important decision-making level of government. Under these circumstances, city and town boundaries are followed in determining the region.

Where any two of the above three objectives lead to incompatible conclusions concerning region boundaries, the region selected must represent a reasonable compromise. A region should be determined to satisfy the three objectives in the best way possible.

EVALUATION OF ENGINNERING FACTORS

EMISSIONS INVENTORY

The compilation of an air pollutant emissions inventory makes possible the correlation of pollutant emissions with specific geographic locations. This procedure generally results in the determination of the "core" of an air quality control region -- that is, the area where the bulk of the pollutant emissions occur. In this study, the emissions inventory results are further utilized as input data to a meteorological diffusion model. In this manner the spatial and temporal distribution of the pollution emitted into the atmosphere can be systematically predicted. For these reasons, a presentation of the emissions inventory results serves as a logical starting point in the engineering evaluation.

The emission inventory was conducted by the National Air Pollution Control Administration. The following 8 counties in southern Arizona were included in the inventory study area: Cochise, Gila, Graham, Greenlee, Maricopa, Pima, Pinal and Santa Cruz. The survey area is shown in Figure 3. The total study area encompasses the Phoenix and Tucson urban areas and contains approximately 1,470,000 persons -- about 85% of the estimated 1969 population of Arizona.

The Public Health Service (PHS) rapid survey technique and PHS emission factors were used for the estimation of pollutant emissions. The emissions were calculated from data representative of the year 1967. Table I provides a breakdown, by county, of sulfur dioxide*, total particulate and carbon monoxide emissions in the study

*Emission estimates are based on all oxides of sulfur. These emissions are composed chiefly of sulfur dioxide.

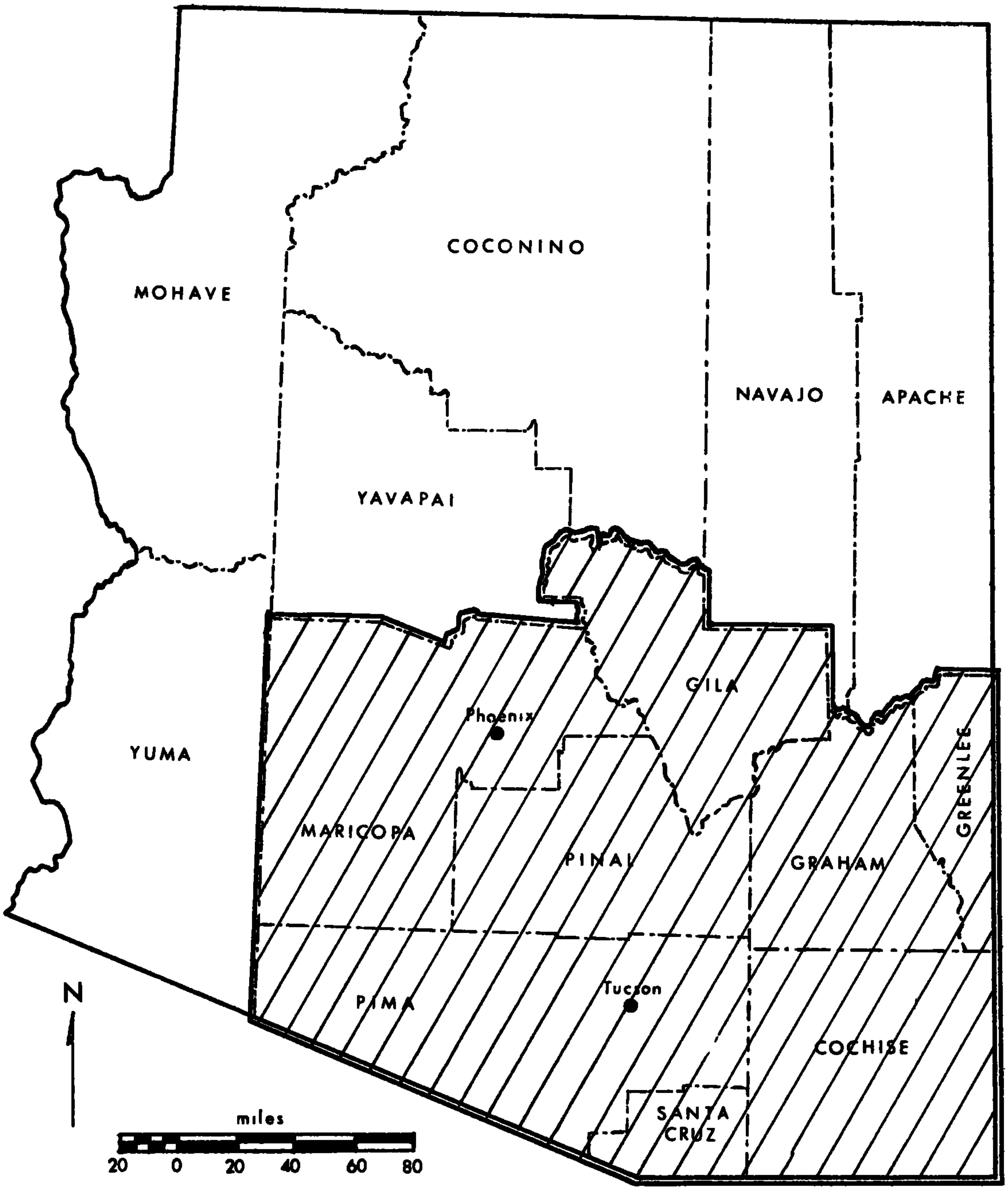


FIGURE 3. EMISSIONS INVENTORY SURVEY AREA.

TABLE I

SUMMARY OF AIR POLLUTANT EMISSIONS IN THE PHOENIX-TUCSON STUDY AREA, 1967 (TONS/YEAR)

		Transportation				Fuel Combustion in Stationary Sources				Solid Waste Disposal		Industrial		
		Motor Vehicles							Steam-	Inciner-	Open	Process		County
	County	Gasoline	Diesel	Aircraft	Railroad	Industrial	Residential	Other	Electric	ation	Burning	Emissions	Agriculture	Total
SULFUR DIOXIDE	Cochise	102	55	N*	210	90	6	20	N	N	N	554,000	290	554,800
	Gila	54	29	↓	160	35	2	7	↓	↓	↓	629,000	30	629,300
	Graham	26	14	↓	160	15	N	4	↓	↓	↓	N	120	300
	Greenlee	12	7	↓	70	10	N	3	↓	↓	↓	422,000	40	422,100
	Maricopa	1,330	370	↓	115	90	37	10	7	37	↓	290	140	2,400
	Pima	480	150	↓	150	440	15	80	3	4	↓	154,000	230	155,500
	Pinal	94	51	↓	180	80	5	20	N	N	↓	303,000	600	304,000
	Santa Cruz	22	11	↓	40	10	N	4	N	N	↓	N	30	100
	Total	2,120	690	N	1,090	770	65	150	10	41	N	2,062,000	1,480	2,068,000
TOTAL PARTICULATES	Cochise	140	150	N	570	190	10	40	15	N	410	90	360	1,680
	Gila	72	81	↓	440	100	4	10	N	↓	205	N	30	940
	Graham	35	39	↓	420	40	2	7	N	↓	105	140	150	940
	Greenlee	17	19	↓	180	20	1	4	N	↓	80	10	50	380
	Maricopa	1,770	1,020	1,560	310	240	140	30	150	120	1,000	5,090	2,220	13,700
	Pima	640	400	710	400	1,170	60	170	120	80	200	6,780	290	11,000
	Pinal	130	140	N	490	190	9	30	8	N	430	920	780	3,130
	Santa Cruz	30	33	N	110	20	2	8	N	N	90	N	30	320
	Total	2,830	1,880	2,270	2,920	1,970	230	300	290	200	2,500	13,000	3,900	32,200
CARBON MONOXIDE	Cochise	21,800	80	N	320	110	5	15	N	N	2,160	N	170	24,700
	Gila	11,900	40	↓	240	50	N	6	↓	↓	1,080	↓	20	13,300
	Graham	6,170	20	↓	230	20	N	3	↓	↓	560	↓	70	7,070
	Greenlee	3,070	10	↓	100	10	N	2	↓	↓	420	↓	20	3,630
	Maricopa	321,000	560	8,850	170	130	15	15	↓	390	5,370	310	200	337,000
	Pima	111,500	220	3,090	220	630	4	70	↓	1,070	1,060	50	130	118,000
	Pinal	20,300	80	N	270	100	1	10	↓	N	2,270	N	350	23,400
	Santa Cruz	4,680	20	N	60	10	N	3	↓	N	490	N	20	5,280
	Total	500,000	1,030	12,000	1,610	1,060	25	120	N	1,460	13,400	360	980	532,000

* N = Negligible

area according to source type in five general categories. These categories are transportation, fuel combustion in stationary sources, solid-waste disposal, industrial processes, and agriculture. The information provided by Table I indicates that industrial processes account for nearly all of the sulfur dioxide emissions and over 40% of the particulate emissions in the survey area. Other source types, including agricultural sources, railroads, gasoline-powered motor vehicles, open burning and aircraft all contribute significantly to the particulate emissions in the survey area. Over 94% of the carbon monoxide emissions in the survey area are attributable to gasoline-powered motor vehicles. Open burning sources and aircraft are also significant contributors of carbon monoxide.

Table I indicates that major sources of sulfur dioxide are located primarily in Gila, Cochise, Greenlee, Pinal, and Pima Counties. The majority of particulates and carbon monoxide emitted in the survey area are from sources located within Maricopa and Pima Counties.

Geographic source locations over the survey area were defined by the use of grid coordinates based on the Universal Transverse Mercator (UTM) System. Figure 4 shows the numbered grid system superimposed over an outline of the survey area. Grid squares 10 kilometers on a side were used in areas of most dense population and industrialization, while grid zones 20, 40 and 80 kilometers on a side were used in areas of less dense urbanization. A total of 67 grid zones were used.

Figure 5 shows the location of most major "point" sources in the study area. These point sources are distinguished from "area"

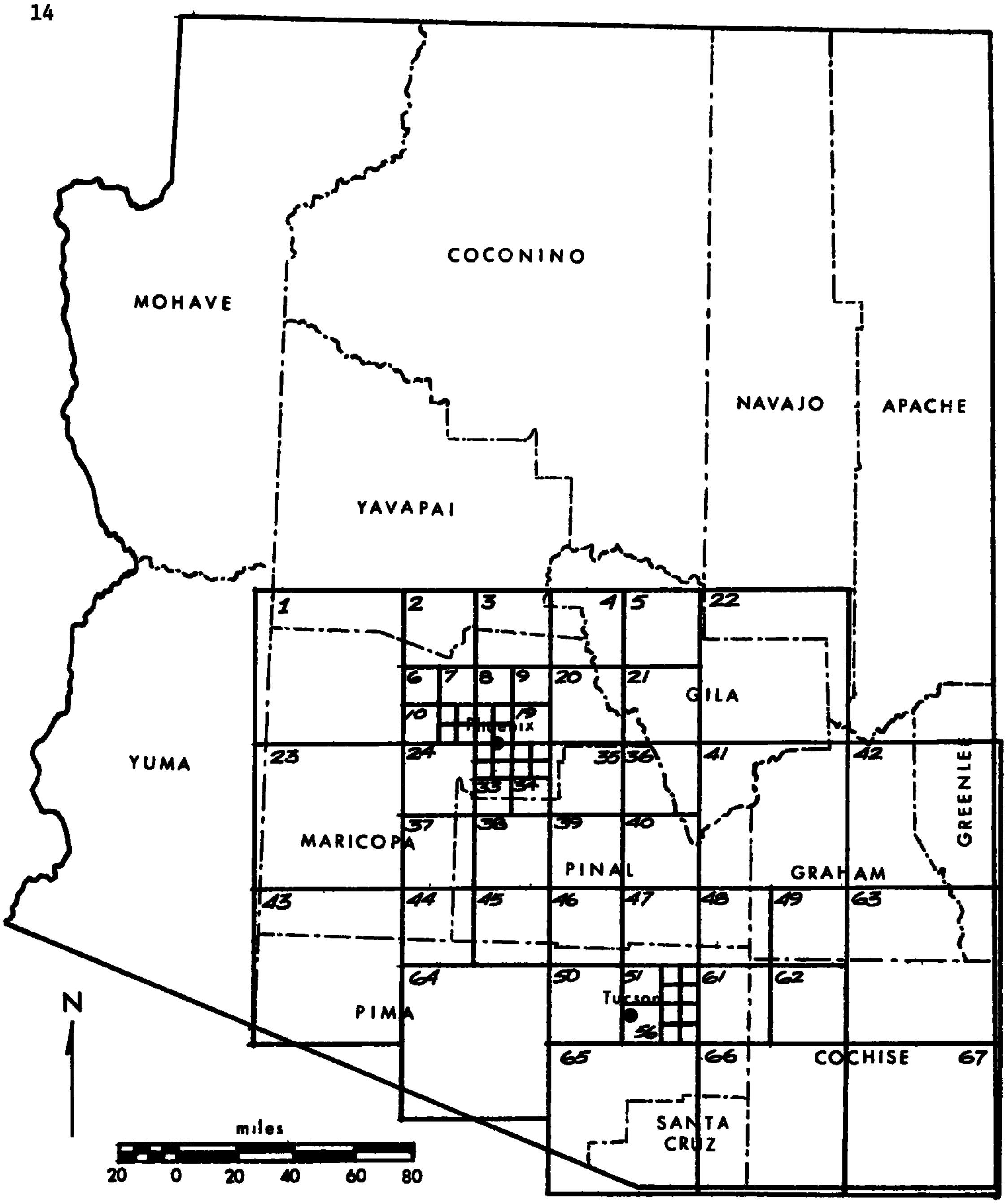
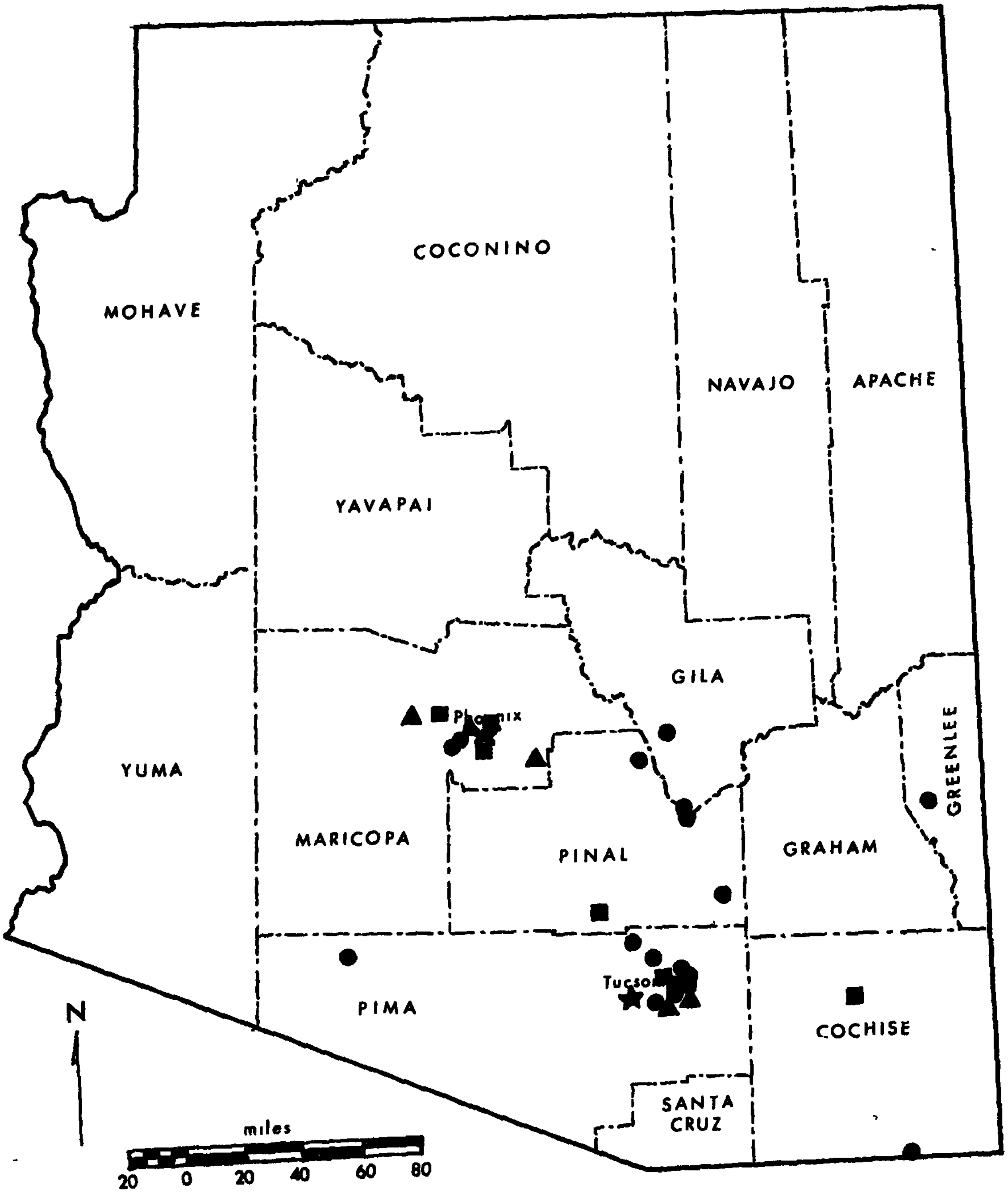
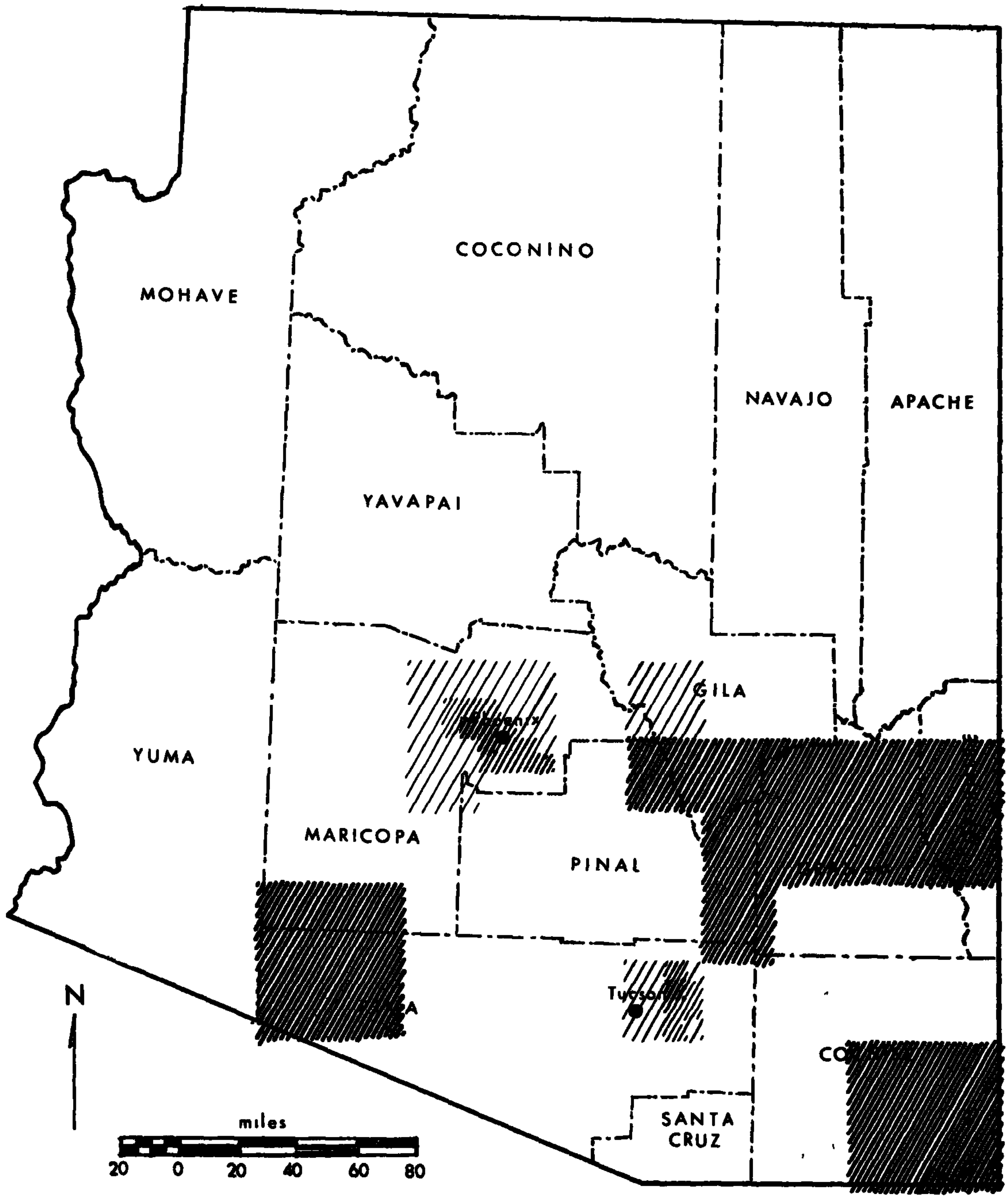


FIGURE 4. GRID COORDINATE SYSTEM FOR THE PHOENIX-TUCSON STUDY AREA.



SOURCE TYPE:
● INDUSTRY
■ POWER PLANT
▲ AIRPORT

FIGURE 5. MAJOR POINT SOURCE LOCATIONS.



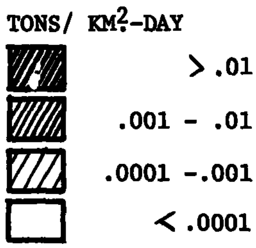


FIGURE 6. SULFUR DIOXIDE EMISSION DENSITIES.

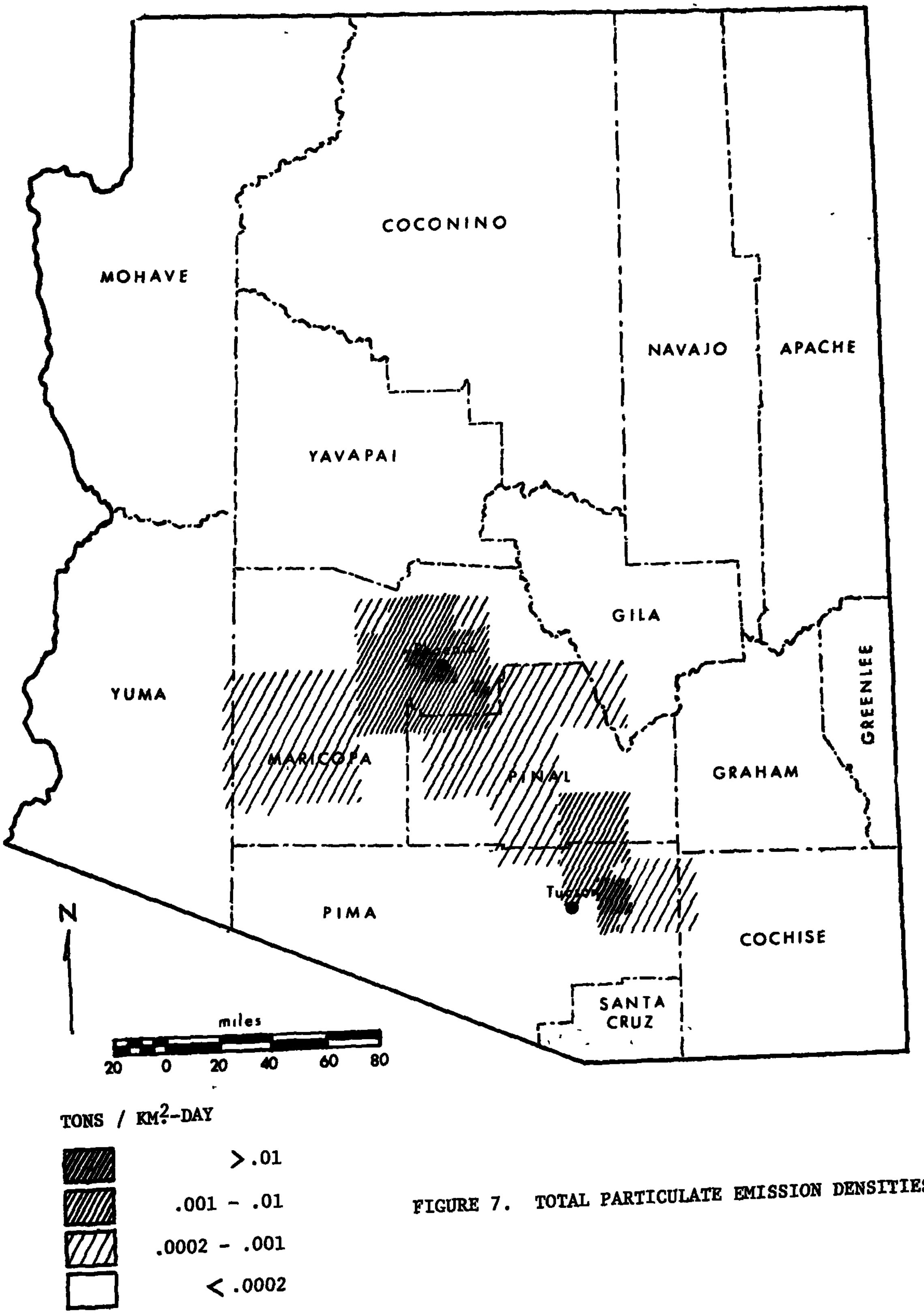


FIGURE 7. TOTAL PARTICULATE EMISSION DENSITIES

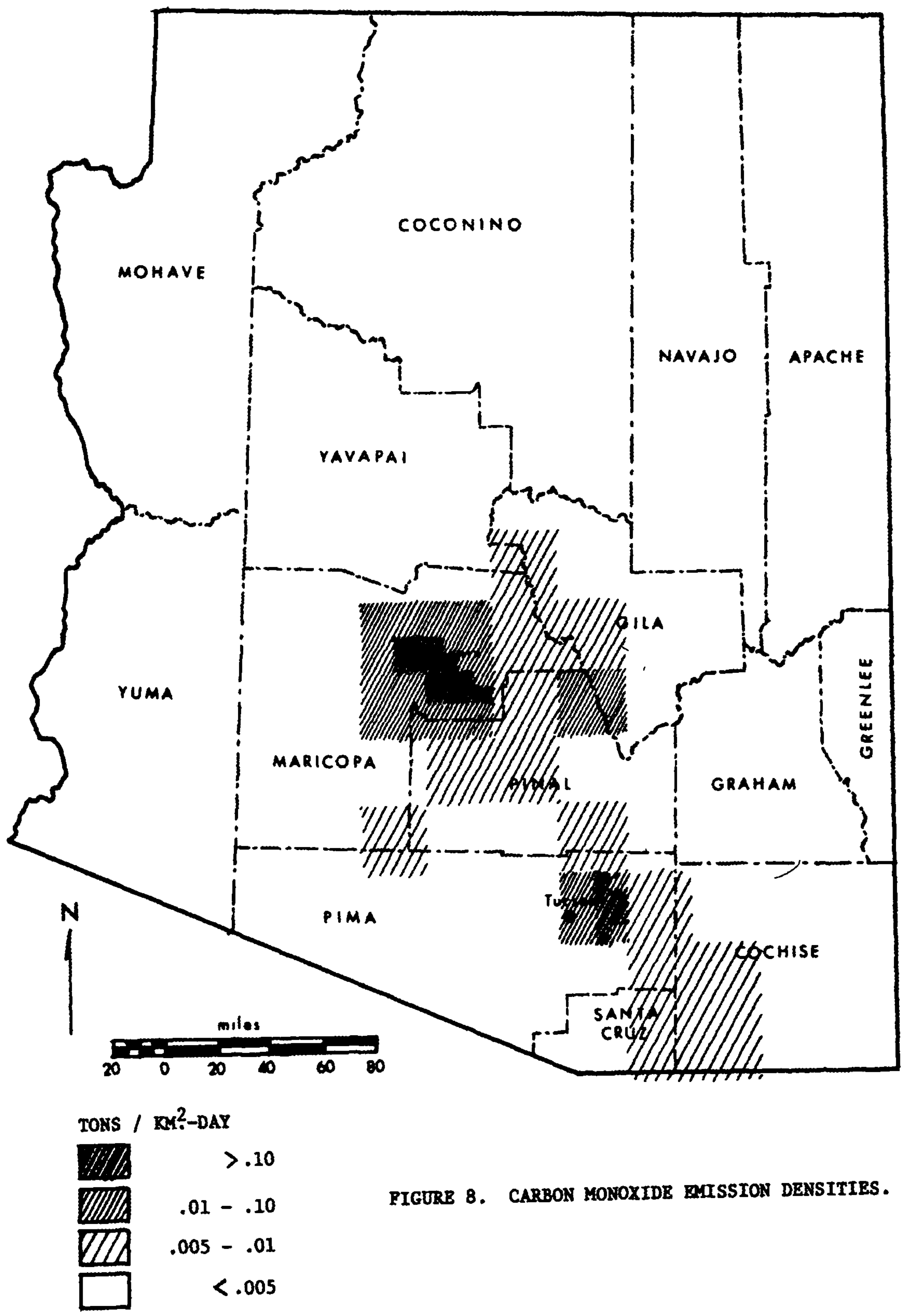


FIGURE 8. CARBON MONOXIDE EMISSION DENSITIES.

sources because of the large quantities of pollutants emitted from them. The majority of these large sources are concentrated in the Phoenix and Tucson urban areas. Several large sources are located in Greenlee, Cochise, southern Gila, eastern Pinal and Western Pima Counties.

Figure 6, 7, and 8 present emission densities for SO_2, total particulates, and CO, respectively, based on the grid system. The densities are computed on the basis of emission from both point and area sources within each grid zone. The pattern of SO_2 emissions shown in Figure 6 corresponds to the development pattern of the Phoenix and Tucson urban areas and to the location of major point sources. A variety of sources contribute significant amounts of total particulate emissions. The total particulate emission density map (Figure 7) reflects the pattern of urbanization in the study area since the sources themselves are representative of the urban pattern. Carbon monoxide emissions are attributable primarily to motor vehicles, as indicated previously; thus, Figure 8 provides an indication of the vehicular traffic density distribution over the survey area. As expected, CO emissions are greatest in and around Phoenix and Tucson and in areas connecting these two cities.

AIR QUALITY ANALYSIS

Introduction

The regional approach to air resource management requires that those jurisdictions containing the majority of the sources of pollution in an urban area be included within a single air quality control region. The air quality control region should also include jurisdictions containing the majority of the people and property adversely affected by air pollutant emissions from those same sources. The core area of a region can be roughly defined on the basis of pollutant point source locations and relative emission densities. However, an analysis of ambient air quality is necessary in order that peripheral pollutant receptor areas may be identified and included in the air quality control region. This procedure will result in an essentially self-contained region which includes within its bounds virtually the entire source-receptor system for a particular area. By using this approach, the possibility of pollutant cross-boundary transport problems will be minimized.

Two alternate approaches have been used to provide an indication of air quality in the southern Arizona study area. The first approach consists of a review of measured air quality data in the study area. The second approach involves the estimation of air quality over the study area through the use of a meteorological diffusion model. This technique was desirable since existing air sampling data was not complete enough to aid in the determination of the outer limits of the Region.

Topography, Meteorology, and Measured Air Quality

The State of Arizona is divided into three distinct regions. The northeast portion of the State is part of the Great Colorado Plateau, whose average elevation varies from 5,000 to 9,000 feet above sea level. The Colorado Plateau includes major portions of Coconino, Navajo and Apache Counties. The second region is known as the Mexican Highland mountain region, which stretches diagonally from the northwest corner of the State to the southeast corner. The mountain region is separated from the northern Plateau region by an abrupt transition slope which also runs diagonally across the entire State. The Highland mountain region varies in width from 150 miles in the State's southeast corner to 70 miles elsewhere. The southwest portion of the State comprises the third region, known as the Sonoran Desert. This region and the Highland mountain region are characterized by numerous mountain ranges which rise abruptly from plainlike floors. The mountain ranges in the Desert region are lower, and the valleys are wider, than are those in the Highland region.

The highly populated Phoenix and Tucson urban areas lie in the Sonoran Desert region. Phoenix is located in the center of the Salt River Valley, whose elevation is approximately 1,100 feet above sea level. Here the climate is of a desert type, with low rainfall and relative humidity. Mountains bordering Phoenix have maximum elevations ranging from 2,300 to 4,000 feet above sea level. These mountains are located at distances of from 6 to 40 miles from Phoenix. The valley floor is generally free of wind, with speeds averaging between 4 and 8 miles per hour. The Phoenix wind roses are shown in Figure 1-A.

Winds are predominantly from the east in the winter and from the east and west during the summer. Wind direction is dependent not only on the time of year, but also on the time of day. Wind flow in Phoenix is greatly influenced by terrain, which causes winds to shift from west to east, depending on the time of day.

Mixing depths, which reflect the volume of air into which pollutants may disperse, are shown in Appendix A. This data indicates that pollutant dispersion is most restricted during the morning hours (especially during the winter) and least restricted during summer afternoons.

Tucson lies in a broad valley through which the Santa Cruz River passes. The elevation of the valley floor is approximately 2,400 feet above sea level. Mountains lie to the east, west, and north of the city. The climate in Tucson is also of a desert type. Like Phoenix, wind flow is greatly influenced by the terrain surrounding Tucson. Also, mixing depths in the Tucson area are subject to the same large seasonal and diurnal variations as is Phoenix.

Generally, topography is a major determinant of localized meteorology in many areas of the State. More specifically, pollutant dispersion in Phoenix and Tucson is influenced by the local topography. The ability of pollutants to carry from the urban cores is affected by mountains surrounding Phoenix and Tucson, particularly during periods of restricted vertical movement of pollutants. Also, pollutants may be channeled in certain directions and over long distances by the mountain-valley systems. The precise impact of topography on meteorology and on the geographic extent of the air pollution problem requires more study than has been undertaken, however.

In general, existing air quality data in Arizona is not sufficiently extensive enough to aid in the determination of the Region boundaries. Most of the SO_2, suspended particulate, and carbon monoxide sampling has occurred in or very close to Phoenix and Tucson. These areas have already been recognized as the core of the air quality control region in Arizona.

Monitoring in Ajo (Pima County), Douglas (Cochise County), and Claypool and Hayden (Gila County) has indicated that local sulfur dioxide concentrations are higher than are corresponding values recorded in Phoenix or Tucson. The sampling sites in Ajo, Douglas, Claypool and Hayden are close to sources which emit large volumes of gaseous oxides of sulfur. The precise geographic extent of the effects of emissions from these sources is not known, however. The largest sources of sulfur dioxide in the State (copper smelters) are located in Ajo, Douglas, Morenci (Greenlee County), San Manuel and Superior (Pinal County), and Miami and Hayden (Gila County).

Sulfation data indicates that the Phoenix and Tucson areas have lower sulfation values than do extensive areas in Pima County, southern Gila County, western Pima County, and Graham, Greenlee and Cochise Counties. State Health Department data indicates that areas surrounding the copper smelters referred to above have the highest sulfation values. The smelters in Pinal and Gila County are closest to the Phoenix and Tucson urban areas. Because of the limited data that now exists, the exact extent of the influence of these sources is not known. During the period of the copper strike (July 1967 to March 1968), however, visibility in Phoenix was markedly improved*, while SO_2 concentrations and sulfation rates in Tucson were notably lower.**

Sampling for suspended particulates has been conducted over extended lengths of time at stations located in Maricopa and Pima Counties. An average of 1960 to 1968 yearly-average concentrations of suspended particulates measured at a site in Tucson was 108 $\mu g/m^3$. Similar measurements for Phoenix over these same years resulted in an average concentration of 168 $\mu g/m^3$. Another sampling site in Tucson recorded annual average suspended particulate concentrations ranging from 100 to 115 $\mu g/m^3$ over the years 1966 to 1968. A second site in Phoenix recorded an average of 1957 to 1960 yearly average values of 209 $\mu g/m^3$. Measurements taken at the Maricopa County Health Department from 1961 to 1967 revealed an average of yearly average values of 213 $\mu g/m^3$. Other sampling stations in Maricopa County recorded yearly average suspended particulate concentrations ranging from 143 $\mu g/m^3$ in Mesa (1966) to 300 $\mu g/m^3$ at Boys Ranch (1967). Sampling for

* According to U.S. Weather Bureau visibility data taken at Sky Harbor Airport, Phoenix, and from data at Mummy Mountain Observatory, Scottsdale, Arizona.

** Based on data collected by the Pima County Health Department.

suspended particulates in Ajo (Pima County), Florence and Superior (Pinal County), Hayden and Claypool (Gila County), Douglas (Cochise County), and East Plantsite (Greenlee County) indicated concentrations which equal or exceed those in Phoenix and Tucson.

Carbon monoxide sampling in the study area has been limited to the city of Phoenix and thus provides no indication of the necessary extent of the Region.

Diffusion Model Results*

The meteorological diffusion model has been used to compute sulfur dioxide, suspended particulate, and carbon monoxide concentrations in the ambient air at specified receptor points in southern Arizona. The model predicts these concentrations from a mathematical treatment of pollutant emission and meteorological data. A more detailed discussion of the model is presented in Appendix A. While the model contains inherent limitations, it still has merit in providing reasonable spatial distribution of long term (seasonal and annual)** average pollutant concentrations. The validity of the model as applied to southern Arizona is somewhat questionable, however, due to the probable influences of topography on pollutant dispersion patterns. The diffusion model, as applied here, did not consider variations in ground

* Graphic presentation of the model results does not appear here due to time limitations placed on the production of this report.

** Averaging times are as follows:
Winter: December, January, and February
Summer: June, July, and August
Annual: All 12 months of the year

elevations. This fact was considered in the interpretation of the model results.

The model output indicates that SO_2 concentrations are the greatest in Phoenix and Tucson and over localized areas of Gila, Pinal, Graham, Greenlee, Cochise, and Pima Counties. The concentration centers in these outlying areas are caused by large individual sources of sulfur gas emissions.

The diffusion model indicates that the areas of highest CO concentrations are the Phoenix and Tucson urban cores. This was the expected result since motor vehicle traffic, the prime producer of CO pollution, is most dense in these two core cities. The diffusion model equal concentration contours also indicate that larger areas of Maricopa and Pima Counties, a major portion of Pinal County, and lesser portions of the surrounding counties are likely to experience the greatest concentrations of CO.

The pattern of relative-concentration contours for suspended particulates was similar to that for CO. The centers of the greatest concentrations were predicted to occur in Phoenix and Tucson. The diffusion pattern correlates with the distribution of pollutant emissions indicated in Figure 7.

EVALUATION OF URBAN FACTORS

INTRODUCTION

The Clean Air Act, as amended, calls for the designation of air quality control regions based on "jurisdictional boundaries, urban industrial concentrations, and other factors" to provide an inter-governmental system for the prevention and control of air pollution. The designation of air quality control regions must also be based on a consideration of existing cooperative regional arrangements, State and local air pollution control programs and enabling legislation, and patterns and rates of urban growth. The following discussion of urban factors will present these considerations as they apply to the State of Arizona.

POPULATION DISTRIBUTION

Human activity in its many forms is the basic cause of air pollution. Thus, existing and potential air pollution problems may be related to geographic areas by studying present and projected population statistics for those areas.

Table II presents estimated 1969 population statistics for the State of Arizona. These statistics indicate that Maricopa County contains 930,000 persons, or about 53% of Arizona's total 1969 population of 1,741,000. Pima County, with a present population of 343,200, contains about 20% of the State's population. Together, Maricopa and Pima Counties contain close to three-fourths of the State's present population.

The city of Phoenix which lies within Maricopa County contains an estimated 515,000 persons. The Salt River Valley, in

TABLE II

PRESENT AND PROJECTED POPULATION DATA AND MANUFACTURING EMPLOYMENT BY JURISDICTION

County	Land Area (Mi.^{2})	1969 Estimated Population[1]	1969 Population Density (Persons/Mi^2)[2]	1980 Projected Population[2]	1980 Population Density (Persons/Mi^2)[2]	Additional Residents 1969-1980	Additional Residents/ Mile^2 1969-1980	% Growth 1969-1980	Estimated 1967 Ave. Manufacturing Employment[3]
Apache	11,171	46,500	4.2	64,800	5.8	18,300	1.6	39.4	800
Cochise	6,256	66,500	10.6	95,200	15.2	28,700	4.6	43.2	1,400
Coconino	18,562	56,200	3.0	77,400	4.2	21,200	1.2	37.7	1,500
Gila	4,747	26,900	5.7	38,700	8.2	11,800	2.5	43.8	600
Graham	4,618	15,400	3.3	22,300	4.8	6,900	1.5	44.7	200
Greenlee	1,879	9,700	5.2	14,300	7.6	4,600	2.4	47.4	50
Maricopa	9,238	930,000	101	1,284,600	139	354,600	38	38.1	60,800
Mohave	13,227	21,000	1.6	26,500	2.0	5,500	0.4	26.2	600
Navajo	9,910	49,900	5.0	69,500	7.0	19,600	2.0	39.3	1,000
Pima	9,240	343,200	37	473,900	51	130,700	14	38.1	8,700
Pinal	5,386	63,600	11.8	91,100	16.9	27,500	5.1	43.3	1,300
Santa Cruz	1,246	14,400	11.5	20,100	16.1	5,700	4.6	39.5	100
Yavapai	8,091	34,700	4.3	49,000	6.1	14,300	1.8	41.2	700
Yuma	9,991	63,000	6.3	87,800	8.8	24,800	2.5	39.4	750
Arizona TOTAL	113,562	1,741,000	15.4	2,415,000	21.3	674,000	5.9	38.7	78,500

1, 2. Data obtained from projections of data analysis section, Arizona State Department of Health, based on U. S. Bureau of Census Data.

3. From <u>Arizona Basic Economic Data</u>, Research and Information Series No. ECO-2-68, Arizona State Employment Service, April 1968.

which Phoenix is located, contains four of the remaining five largest cities in the State: Scottsdale, Mesa, Tempe, and Glendale. Phoenix, together with these four cities and adjacent urban areas, accounts for the bulk of Maricopa County's total population -- nearly 750,000 persons. Phoenix is the central city for a Standard Metropolitan Statistical Area (SMSA) which consists of Maricopa County.

The city of Tucson, located within Pima County, contains an estimated 240,000 persons, or 70% of the County's total population. The greater Tucson urban area contains about 300,000 persons, which accounts for an even greater percentage of the County's total population. Tucson is the central city for an SMSA which is Pima County. The city of Ajo, with a population of about 10,000, lies approximately 120 miles west of Tucson. The remainder of the county is sparsely populated and contains only a few small, scattered communities.

Figure 9 presents 1969 estimated populations and population densities for Arizona by county. This Figure indicates that Maricopa and Pima Counties are by far the most densely populated counties in the State. Maricopa County has a population density of 101 persons per square mile while Pima County has a population density of about 37 persons per square mile. Pinal, Santa Cruz, and Cochise Counties follow, with present population densities of 11.8, 11.5, and 10.6 persons per square mile, respectively. In terms of total population, however, Cochise, Pinal, and Yuma Counties, in that order, follow Maricopa and Pima Counties. All

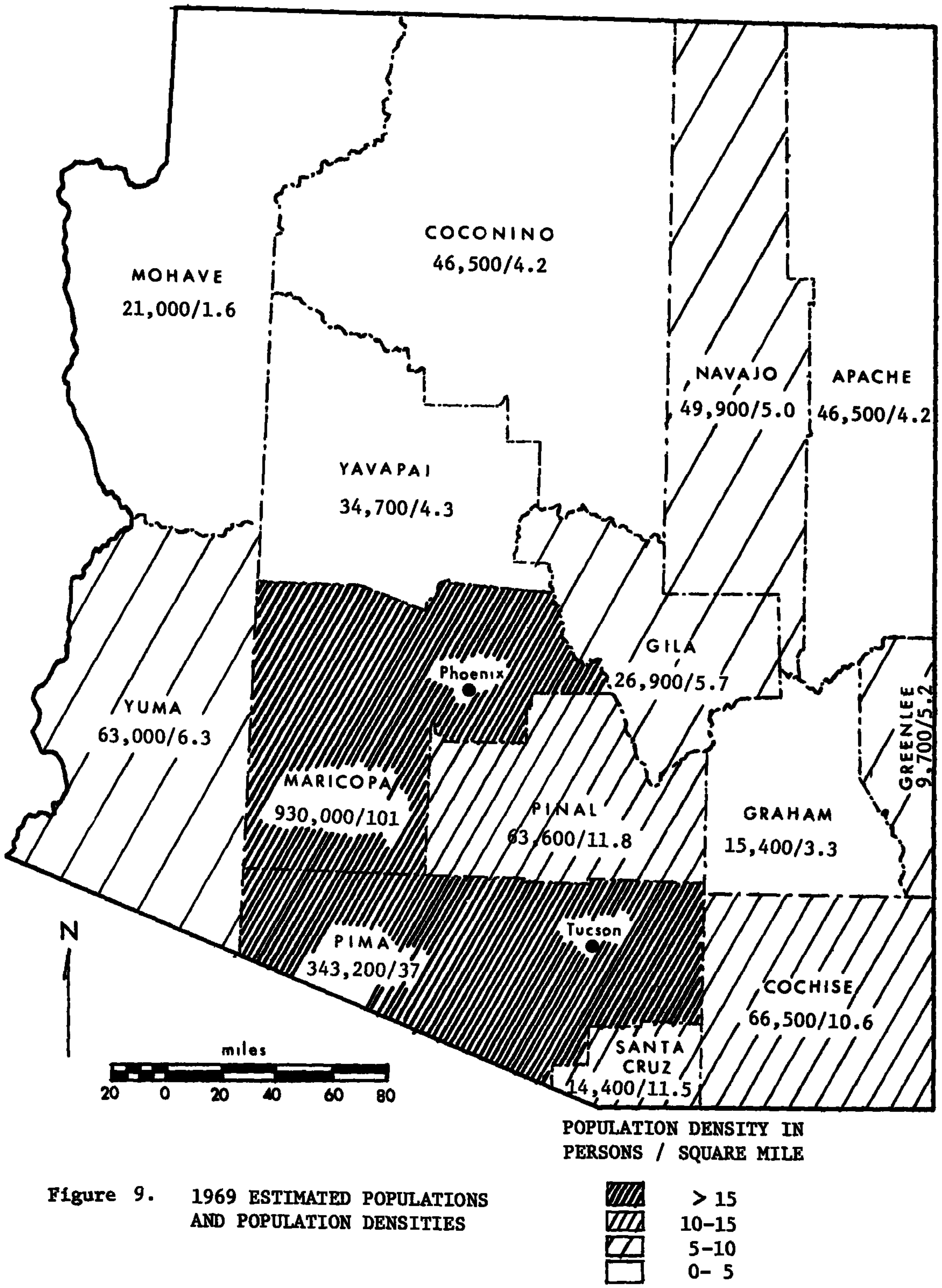


Figure 9. 1969 ESTIMATED POPULATIONS AND POPULATION DENSITIES

other Arizona counties contain significantly less population or population densities than do the counties mentioned above.

Figure 10 presents 1980 projected population statistics by county. Maricopa and Pima Counties are expected to remain the most densely populated counties in the State since population will continue to concentrate itself in the Phoenix and Tucson urban areas. Pinal, Santa Cruz, and Cochise Counties, respectively, are projected to remain the next most densely populated counties in Arizona.

As Table II indicates, Maricopa County will add 354,600 additional residents by 1980, followed by Pima County with 130,700 new residents. Cochise and Pinal Counties each will experience a population increase of over 25,000 persons. Figure 11 provides an indication of the growth which the various counties are expected to undergo in terms of total additional residents to 1980.

In terms of per square mile growth to 1980, Maricopa and Pima Counties will increase at the greatest rate, with 38 and 14 additional residents per square mile, respectively. These are followed by Pinal, Santa Cruz, and Cochise Counties, with 5.1, 4.6 and 4.6 additional residents per square mile, respectively. In terms of added residents per square mile, all remaining Arizona counties will increase at a lesser rate than either Pinal or Cochise Counties since these remaining Counties possess far greater land areas. These statistics are presented in Table II.

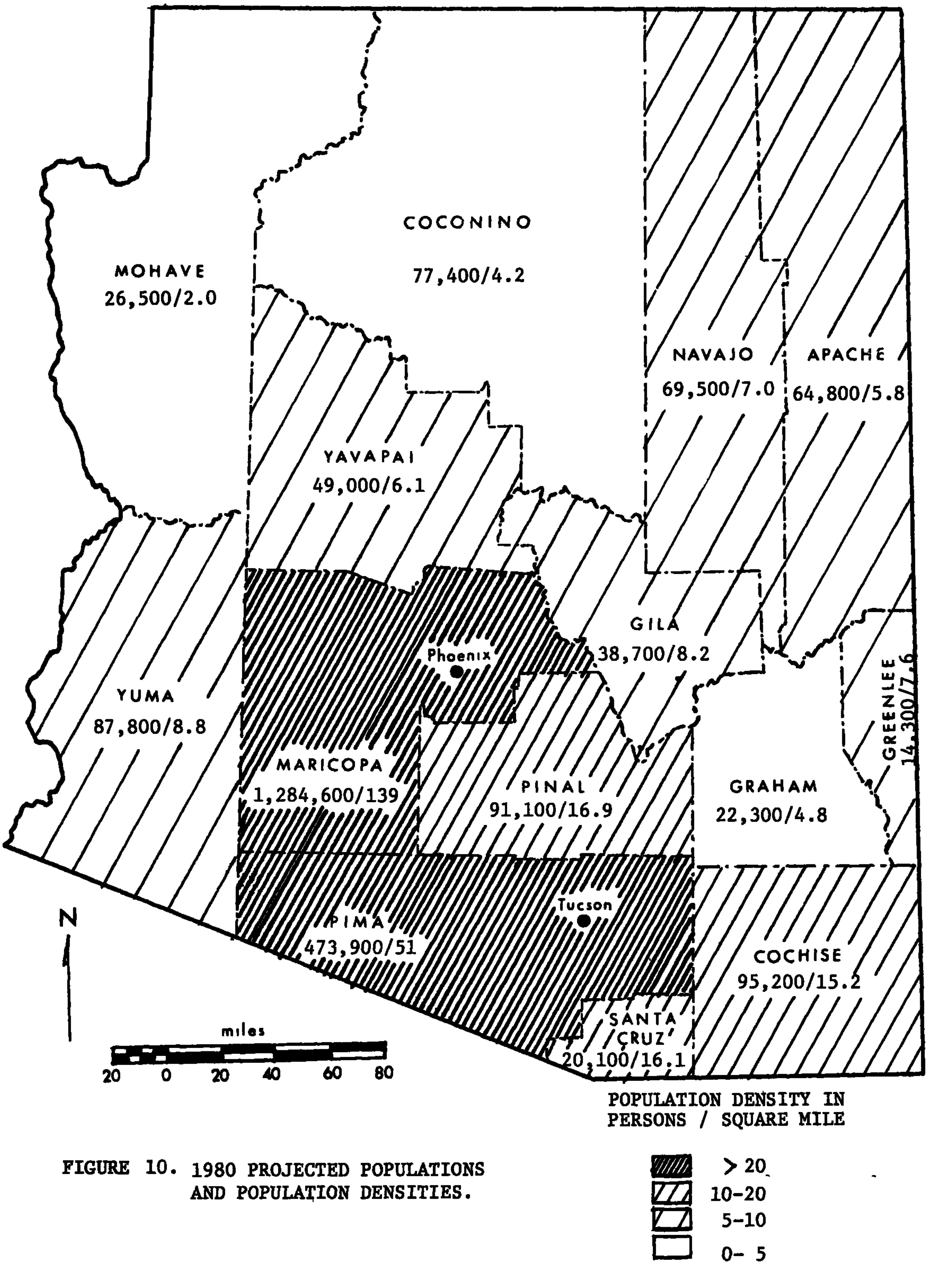


FIGURE 10. 1980 PROJECTED POPULATIONS AND POPULATION DENSITIES.

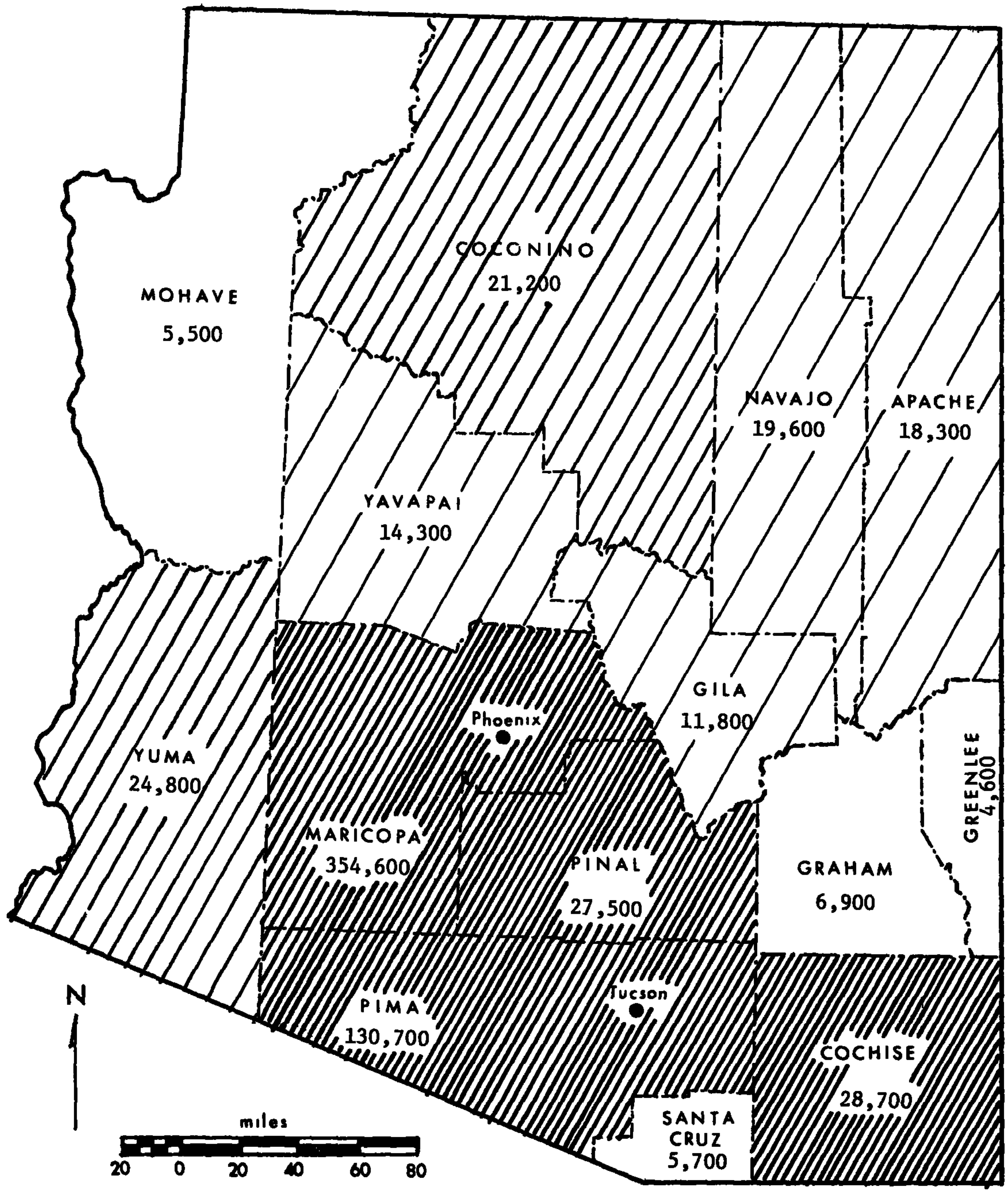


FIGURE 11. TOTAL ADDITIONAL RESIDENTS, 1969-1980

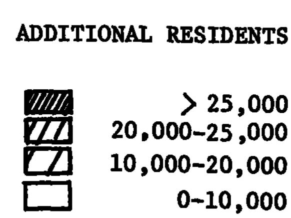


Table II also indicates that Greenlee, Graham, Gila, Pinal, and Cochise Counties will experience a percentage growth increase substantially greater than will the State as a whole. The percentage increase to 1980 for these counties is 47.4%, 44.7%, 43.8%, 43.3%, and 43.2%, respectively. The increase for the State as a whole is projected to be 38.7%. By 1980 Pima and Maricopa Counties will experience a population increase of about 38% above present levels.

The population statistics and population density maps presented above do not provide a good indication of the geographic distribution of population within the various counties. It has been mentioned that the greater Phoenix and Tucson urban areas account for the bulk of the population within Maricopa and Pima Counties. These urban areas account for only a small portion of the land areas of their respective counties. Thus, population densities in these core areas are far greater than are indicated in Figures 9 and 10, which are based on the land areas of the entire counties.

The remaining counties in the southern Arizona study area do not contain single, large urban cores similar to Phoenix and Tucson, but instead are composed of small, scattered communities. The majority of Gila County's population is located in the southern portion of that County, in the cities of Globe, Miami, Hayden, and Winkelman. Pinal County's population centers are scattered throughout its area. The major cities are Casa Grande, Eloy and Coolidge in the west-central portion of the County, Superior and Apache Junction in the northern portion of the County, and Mammoth, San Manuel and Oracle in the southeast corner. Most of Cochise County's population lies in the southern half of that County. The majority of Yuma County's development is at the southwestern corner of the County. Population centers are scattered in a random fashion throughout Graham and Santa Cruz Counties.

POLLUTANT PRODUCING ACTIVITY

The location of manufacturing activity is helpful in determining the size of an air quality control region since industrial sources are major contributors of air pollutant emissions. Manufacturing employment statistics serve as an indicator of the geographic distribution of industrial activity. Estimated 1967 yearly average manufacturing employment data is presented in Table II and Figure 12.

These statistics indicate that Maricopa County employs by far the greatest number of workers engaged in manufacturing activities, with 60,800. Pima County follows with 8,700 manufacturing employees. Most of the workers in Maricopa and Pima are employed in the Phoenix and Tucson urban areas. The majority of manufacturing workers in Maricopa County are employed in the manufacture of machinery, aircraft parts, apparel and primary metal production. Primary and fabricated metals, machinery, printing and publishing and the production of other nondurable goods are the major industries in Pima County.

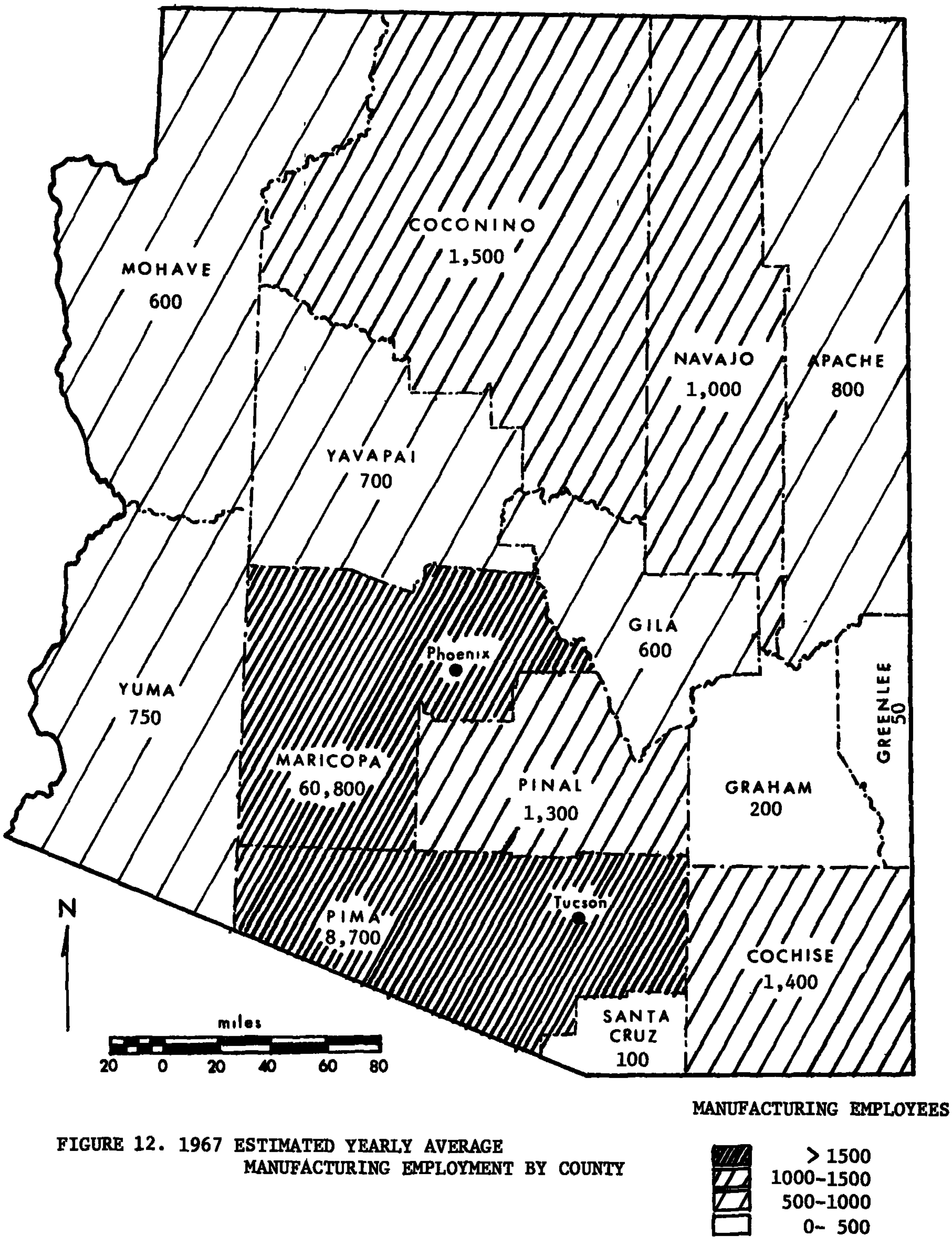


FIGURE 12. 1967 ESTIMATED YEARLY AVERAGE MANUFACTURING EMPLOYMENT BY COUNTY

Coconino, Cochise, Pinal and Navajo Counties each have 1000 or more manufacturing employees. Graham, Santa Cruz, and Greenlee Counties have relatively insignificant numbers of manufacturing employees. The bulk of the manufacturing activity in Coconino County involves the production of wood and paper products. Manufacturing employment in Cochise County is predominantly located in the extreme southern portion of that County. The major industries are involved in the manufacture of garments and vegetable processing. In addition, the copper smelting industry in Douglas accounts for a large portion of Cochise County's manufacturing employment.

Manufacturing in the west-central portion of Pinal County is highly diversified. Included are the manufacture of garments, furniture and fertilizer, and fabricated metal products. Primary metal production is the major manufacturing activity in the eastern portion of the County. Copper smelters in San Manuel and Superior account for about one-third of all manufacturing employment in Pinal County.

The principal manufactured products in Navajo County are lumber and paper. Manufacturing employment in Gila County is primarily associated with mining, copper smelting, food processing and lumber products.

Generally, Arizona's manufacturing industry will increase its share of the State's total employment. The percentage of jobs in Arizona in the manufacturing sector is expected to increase from 12.9% in 1965 to about 16.7% by 1975. The manufacturing industry will show the greatest growth among the various sectors of Arizona's economy. By 1975, approximately 125,000 jobs in manufacturing are expected -- nearly double the number in 1965 (64,900).

Trends indicate a continuing centralization of population, labor force and employment in the major metropolitan areas of the State. Maricopa County's growth in its share of the State's total employment has been greater than its share of Arizona's total population growth. It is projected that by 1975, about 60% of all jobs in Arizona will be in Maricopa County. At present, about 20% of the workers in Maricopa County are employed in manufacturing. It can be expected that the bulk of the State's manufacturing workers will continue to be employed in Maricopa County in the foreseeable future.

Manufacturing employment in Pima County is expected to remain second in numbers to that in Maricopa County. Approximately 48.6% of Pima County's employed workers are engaged in manufacturing activity. Employment in all other counties is expected to remain relatively low with respect to the number of workers employed, and the percentage of total employees engaged in manufacturing activities.

Mining and quarrying operations and the production of primary and fabricated metals, especially copper, constitute a major portion of Arizona's economy. The economy of several counties in the State is dominated by copper mining and smelting operations. The location of these operations is an important consideration since copper smelting is a major source of pollution in Arizona.

Copper mining and smelting are the primary sources of employment in the northern and eastern portions of Pinal County. The principal towns in these areas are Superior, Kearny, and Winkelman in the County's northern projection and Mammoth, San Manuel and Oracle in the County's southeast corner. Copper smelters are located in Superior and San Manuel.

The mining and smelting of copper provides employment for over one-third of the work force in Gila County. Mining operations are concentrated in the Globe-Miami area. Copper smelters are located in Miami and Hayden at the southern tip of the County.

Copper mining and smelting operations are concentrated in the extreme southern part of Cochise County. Mines are located chiefly in Bisbee, while a smelter is located in Douglas. Copper mining and smelting form the core of Greenlee County's economy. Clifton, the Greenlee County seat, is a large copper mining district. A smelter is located in the town of Morenci. Nearly half of all workers in Greenlee County are engaged in copper mining and smelting activities.

Copper mining activities in Maricopa County are not very extensive. In Pima County, however, mining and smelting activities account for a large portion of that County's economy. More persons are employed by mining and quarrying activities in Pima County than in any other Arizona County. A copper smelter is located in Ajo in the western sector of the County. All remaining counties within the State contain relatively limited mining operations and no smelters.

EXISTING REGIONAL ARRANGEMENTS

The geographic extent of regional councils, planning agencies, State-defined planning and economic development districts, and region-wide statistical data-gathering bases are an important consideration affecting air quality control region boundaries. The designation of a region compatible with existing regional arrangements is desirable since the implementation of a regional air pollution program is dependent upon cooperation at the various levels of government and since region planning programs may be capable of providing assistance in the development of air quality standards and a plan to implement those standards.

In Arizona, multi-county planning regions are non-existent. Furthermore, State planning and development districts have not been determined. The two Standard Metropolitan Statistical Areas in Arizona -- Phoenix and Tucson -- consist only of the county in which each of these cities are located (Maricopa County and Pima County, respectively).

The Counties surrounding Maricopa and Pima Counties are, to varying degrees, tied economically and socially to the Phoenix and Tucson urban areas. Pinal County, because of its geographic location, is tied to both these major urban areas. It is expected that Pinal County will be affected by Phoenix and Tucson growth forces. A system of new and improved highways passing through Pinal County, including Interstate 10 and U.S. Highways 80-89, will connect portions of that County to Phoenix and Tucson. As a result of this improved accessibility, these highways should stimulate development and cause Phoenix and Tucson to grow toward one another. Portions of eastern Pinal County have developed social and economic ties with Globe and other major towns in Gila County due to their remoteness from other communities in western Pinal County.

The populated portions of southern Gila County are connected to the Phoenix urban area by U.S. Routes 60 and 70. Gila County provides recreational facilities and scenic attractions for the residents of Central Arizona, which contains the Salt River Canyon and the White Mountain recreation areas.

Generally, the basic trading area for Gila, Graham, Greenlee, Pinal, Yavapai and the remainder of Maricopa County is Phoenix. The basic trading area for Pima County is Tucson.

EXISTING AIR POLLUTION CONTROL PROGRAMS

In Arizona, statewide responsibility for air pollution control rests with the Air Pollution Control Division of the Arizona State Department of Health. The current law authorizes the Division to identify air sheds and establish air pollution control districts, to determine the quality and nature of air pollutant emissions, and to determine meteorological conditions and other matters related to the problem of air pollution. Further, the Division is authorized to conduct air monitoring, determine standards, conduct inspections, hold hearings, prepare and develop a comprehensive State plan for the abatement and control of air pollution, and encourage political subdivisions of the State to handle air pollution problems within their respective jurisdictions.

The present law states that the abatement of air pollution shall be primarily by the county except when a county or region specifically requests that the Division assume jurisdiction over a part or all of the county, or when a source in one county causes air pollution beyond the territorial limits of that county, or when a county has failed to establish an adequate control program.

The Division of Air Pollution has established rules and regulations for reducing visible emission, air-borne or wind-borne particulate matter and vapor emissions from storage tanks. In addition, emission standards for particulate matter have been established for all sources except incineration and fuel burning equipment.

State law authorizes the board of supervisors of a county to investigate the degree to which the atmosphere of the county is contaminated by air pollution. The board of supervisors is further authorized to adopt rules and regulations, or to establish a multi-county air quality control region with one or more counties by agreement with the board of supervisors of the other county or counties. A region formed in this manner is to be governed by all of the provisions in the State law applicable to a county.

County air pollution control agencies are authorized to study air pollution within a county and study possible effects on adjoining counties, hold hearings, adopt rules and regulations, issue permits, and conduct inspections. At the present time, Maricopa County and Pima County have the largest county control programs in the State.

THE PROPOSED REGION

Subject to the scheduled consultation, the Secretary, Department of Health, Education, and Welfare proposes to designate an air quality control region for the Phoenix and Tucson, Arizona intrastate urban area. The proposed Region consists of the following jurisdictions in the State of Arizona:

Gila County
Maricopa County
Pima County
Pinal County.

As so proposed, the Phoenix-Tucson Intrastate Air Quality Control Region would consist of the territorial area encompassed by the outermost boundaries of the above jurisdictions and the territorial area of all municipalities located therein and as defined in Section 302(f) of the Clean Air Act, as amended (42 U.S.C. 1857h(f)).

Figure 13 shows the geographic relationship of the proposed Region to surrounding counties and to the State of Arizona as a whole. The proposed Region covers an area of 28,611 square miles and contains 1,363,700 persons.

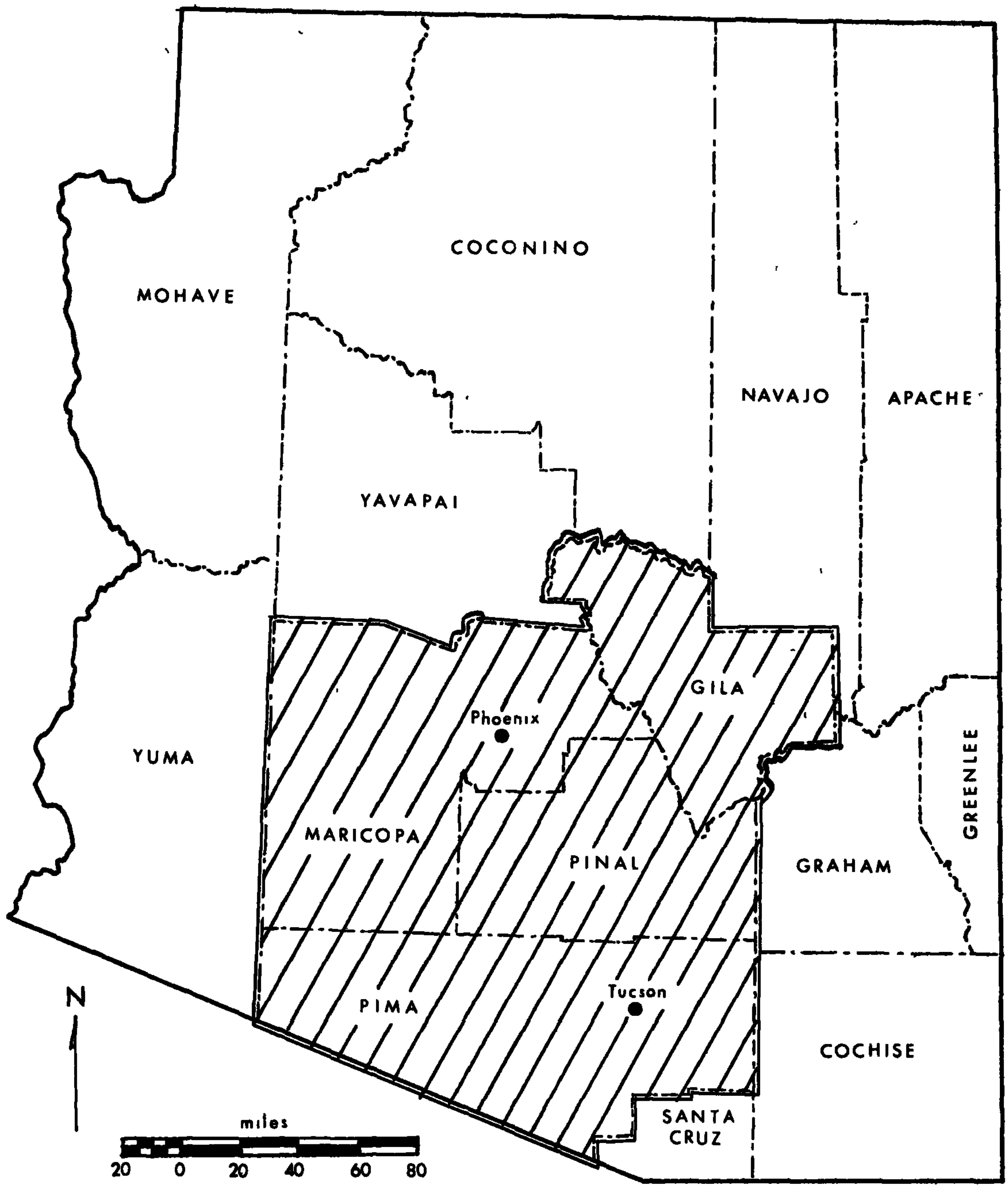


FIGURE 13. PROPOSED PHOENIX-TUCSON INTRASTATE AIR QUALITY CONTROL REGION.

DISCUSSION OF PROPOSAL

To implement a successful air resource management program, an air quality control region should be sufficiently large so as to encompass most pollution sources as well as most people and property affected by those sources. The boundaries should also encompass those locations where present development creates, or where projected urbanization and industrialization will create, significant air pollution problems. Finally, the proposed region should be compatible with or hopefully even foster unified and cooperative governmental administration of the air resource. The proposed Phoenix-Tucson Intrastate Air Quality Control Region was designed to satisfy these requirements to the greatest degree possible.

The nature and location of pollutant sources were revealed by the inventory of air pollutant emissions. The inventory survey area encompassed 8 of Arizona's 14 counties and about 85% of the State's population. The concentration of pollutant point sources and the density of total particulate and CO emissions generally are greatest in the Phoenix and Tucson urban cores. Total particulate and CO emissions are also relatively high in portions of Gila, Pinal and Cochise Counties. Major individual stationary sources of sulfur dioxide pollution are located in western Pima, southern Cochise, southern Gila, eastern Pinal and Greenlee Counties.

The results of the emission inventory indicate that Phoenix and Tucson are the logical core areas for the Region. Thus

Maricopa and Pima Counties are recommended for inclusion in the Region. Pinal County is also recommended due to its significant contribution of air pollutants and its geographic proximity to both the Phoenix and Tucson urban areas. Source areas in southern Gila County are adjacent to receptor areas in Pinal County and vice versa. Gila County has been suggested for inclusion in the region because of its potential source-receptor interaction with Pinal County, and under more extreme circumstances, with greater Phoenix.

Topography in southern Arizona has a great effect upon both localized and large-scale air flow patterns. Air pollution problems in Phoenix and Tucson are likely to be accentuated under certain conditions where limited pollutant mixing depths and negligible wind speeds exist. Both these Phoenix and Tucson urban areas lie in valleys surrounded by mountain ranges at various distances from those cities. The mountains are likely to affect the horizontal dispersion of air pollutants. Similarly, pollutants are likely to be channeled into these populated urban cores over long distances as a result of the mountain-valley systems. Inclusion in the region of major source areas in Gila and Pinal Counties, along with Maricopa and Pima Counties, should create, under all but the most extreme conditions, an essentially self-contained air quality control region.

Air monitoring data indicates that Phoenix and Tucson are areas of significant pollutant concentrations. This data also indicates that pollutant concentrations equal to or exceeding those in Phoenix and Tucson exist in smaller communities in the study area, including Florence and Superior (Pinal County), Hayden and Claypool (Gila County), Douglas (Cochise County), Ajo (Pima County), and East Plantside (Greenlee County). The large concentrations of particulates and SO_2, and the high sulfation rates in the smaller communities, generally reflect the impact of nearby large stationary sources. The air pollution problem in these areas is not reflective of a large-scale problem caused by combined emissions from a vast number of individual sources.

Diffusion model results reflect the geographic pattern and relative intensity of air pollutant emissions over the survey area. Centers of high concentrations, from a relative viewpoint, occur in Phoenix and Tucson and at the scattered locations of large individual pollutant sources. The proposed 4-county Region will include within its bounds the areas where widespread urban-area air pollution problems exist, as well as most of the large isolated sources of air pollution.

Population statistics indicate that Maricopa and Pima Counties are presently the most highly populated counties in Arizona. The statistics also indicate that Maricopa and Pima Counties are the most densely populated in the State. The bulk of Maricopa County's population lies within the Phoenix urban area, while the Tucson urban area accounts for the majority of Pima County's population. Projected population data indicates that these two counties will undergo by far the greatest absolute growth to 1980.

Employment statistics reveal that Maricopa County has the greatest number of manufacturing workers, followed by Pima County. The continued centralization of population, labor force, and employment in the major metropolitan areas of the State -- Phoenix and Tucson -- indicates that Maricopa and Pima Counties will contain the bulk of Arizona's industrial activity in the foreseeable future. On the basis of population and employment statistics, Maricopa and Pima Counties form a logical core for an air quality control region.

Pinal County, which has been recommended for inclusion in the Region, is expected to undergo a significant population growth during the next decade. Much of Pinal County's growth is expected to result from Phoenix and Tucson growth forces. Pinal County is, because of its geographic location, tied both economically and socially to both Phoenix and Tucson. A system of new and improved highways connecting Phoenix and Tucson will strengthen these ties as a result of increased accessibility. In addition, portions of eastern Pinal County have developed ties to major towns in Gila County. The inclusion of both Gila and Pinal Counties in the Region will reflect the economic and social ties which have developed between those two counties and Maricopa and Pima Counties.

Because of the nature of the problem of air pollution, there is always the possibility that pollutant transport into or out of the region may exist. An air quality control region can never be completely self-contained with respect to sources and receptors of air pollution. The 4-county Region proposed by the Federal

Government is considered to be the most cohesive and yet inclusive area within which an effective regional effort can be mounted to prevent and control air pollution.

Official designation of the Region will follow the formal Consultation with appropriate State and local officials, and after due consideration of comments presented for the record at the Consultation or of those written comments received by the Commissioner of the National Air Pollution Control Administration.

APPENDIX A. DESCRIPTION OF DIFFUSION MODEL

The diffusion model is based on the Gaussian diffusion equation, described by Pasquill[1,2] and modified for long-term averages[3,4] for application to the multiple-source situation typical of an urban complex. The basic equation assumes that the concentration of a pollutant within a plume has a Gaussian distribution about the plume centerline in the vertical and horizontal directions. The dispersion of the plume is a function of the emission rate, effective sources and receptor heights, atmospheric stability and the distance from the source. The plume is assumed to move downwind according to the mean wind.

The model was used to predict concentrations of SO_2 and CO, and total suspended particulates. The averaging times were the summer and winter seasons and the year. In order that the theoretical pollutant levels could be determined, it was necessary to evaluate certain meteorological input parameters. These parameters are wind direction and frequency of occurrence in each direction, effective wind speeds for each direction, and mixing depths for various averaging times.

Figure I-A shows the wind roses for the summer, winter, and year for the Phoenix area taken from U.S. Weather Bureau data.* They represent graphically the frequency of occurrence of the wind from the various compass directions. This data, along with

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* Wind data recorded at Sky Harbor Airport, Phoenix, Arizona, 1951 through 1960.

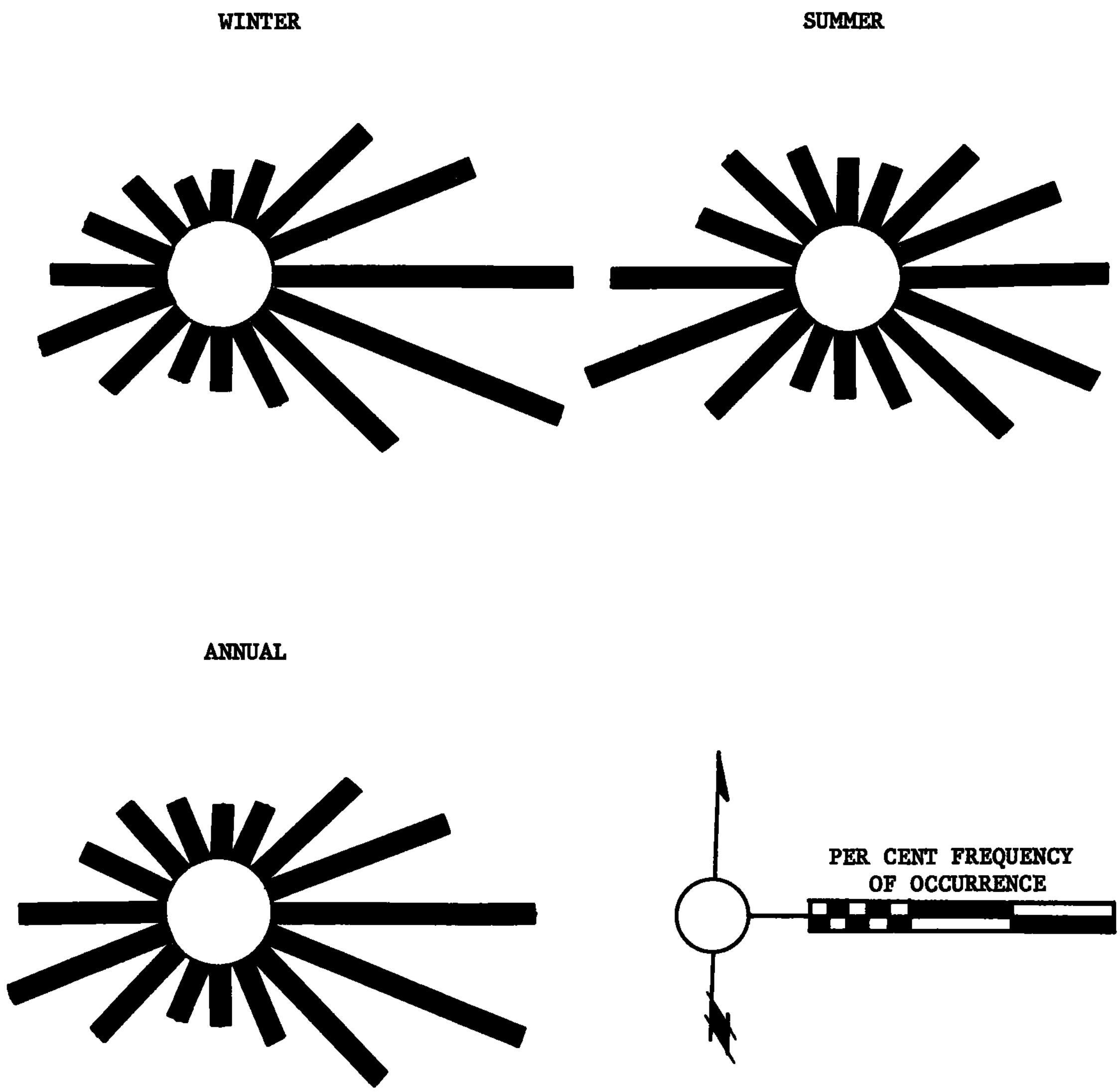

FIGURE 1-A. WIND DIRECTION PER CENT FREQUENCY OF OCCURRENCE FOR VARIOUS AVERAGING TIMES.

effective wind speeds for the respective compass directions, was used as input data to the computerized model. The characteristic prevailing wind directions for each of the averaging times, as depicted by the length of the wind rose radials, produce a direct influence over the dispersion of pollutants.

Table I-A shows average mixing depths for the seasons and for the annual averaging period.* A significant diurnal variation in the mixing depth is indicated. These mixing depths define the volume of air above the surface through which pollutants are allowed to mix, and are assumed to have no spatial variation (i.e., mixing depth is constant) over the receptor grid system.

Table I-A

Average Mixing Depths for Phoenix
by Season and Time of Day (meters)

Season	Morning Average	Afternoon Average	Average, Morning and Afternoon
Winter	205	1250	728
Spring	295	2700	1498
Summer	280	3300	1790
Fall	220	2000	1110
Annual (four seasons)	250	2312	1281

The diffusion model was used to compute the ground level concentrations of pollutants at 225 receptor points. Their locations were defined by an orthogonal grid system with mesh points 15

* Computed mixing depths documented by Holzworth[5,6] and by recent tabulations furnished to the Meteorological Program, NAPCA, by the National Weather Record Center, ESSA.

kilometers apart. An effective source height of 75 meters was assumed for all pollutant point sources, while topographical features were neglected for area-source emissions and for the 225 receptor points.

APPENDIX A. REFERENCES

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