REPORT FOR CONSULTATION ON THE METROPOLITAN PROVIDENCE INTERSTATE AIR QUALITY CONTROL REGION (RHODE ISLAND-MASSACHUSETTS)

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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U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
U.S. PUBLIC HEALTH SERVICE
CONSUMER PROTECTION AND ENVIRONMENTAL HEALTH SERVICE
NATIONAL AIR POLLUTION CONTROL ADMINISTRATION
JULY 1969

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PREFACE

The Secretary, Department of Health, Education, and Welfare, is directed by the Air Quality Act of 1967 to designate "air quality control regions" as an initial step toward the establishment of regional air quality 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 the Providence, Rhode Island, and Fall River-New Bedford, Massachusetts, interstate urban area, the results of which are presented in this report. The Region* boundaries proposed in this report reflect consideration of all available and pertinent data; however, the boundaries remain subject to revision suggested by consultation with State and local authorities. Formal designation of the Region will follow the consultation meeting. This report is intended to serve as background material for the Consultation.

The Administration is appreciative of assistance received either directly during the course of this study or during previous activities in this Rhode Island and Massachusetts interstate area from the Rhode Island State Department of Health and the Massachusetts Department of Public Health. Useful data was also supplied by the Southeastern Regional Planning and Economic Development District, the Massachusetts

*For the purpose of this report, the word "region," when capitalized, will refer to the Metropolitan Providence Interstate Air Quality Control Region (Rhode Island-Massachusetts). When not capitalized, unless otherwise noted, it will refer to air quality control regions in general.

State Division of Employment Security, the Central Massachusetts Regional Planning Commission, the Rhode Island Development Council, the Rhode Island Department of Public Works, and the Rhode Island Statewide Comprehensive Transportation and Land Use Planning Program.

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 concentrations, 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), Air Quality Act of 1967

THE AIR QUALITY 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 Air Quality Act 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) published corresponding documents on control

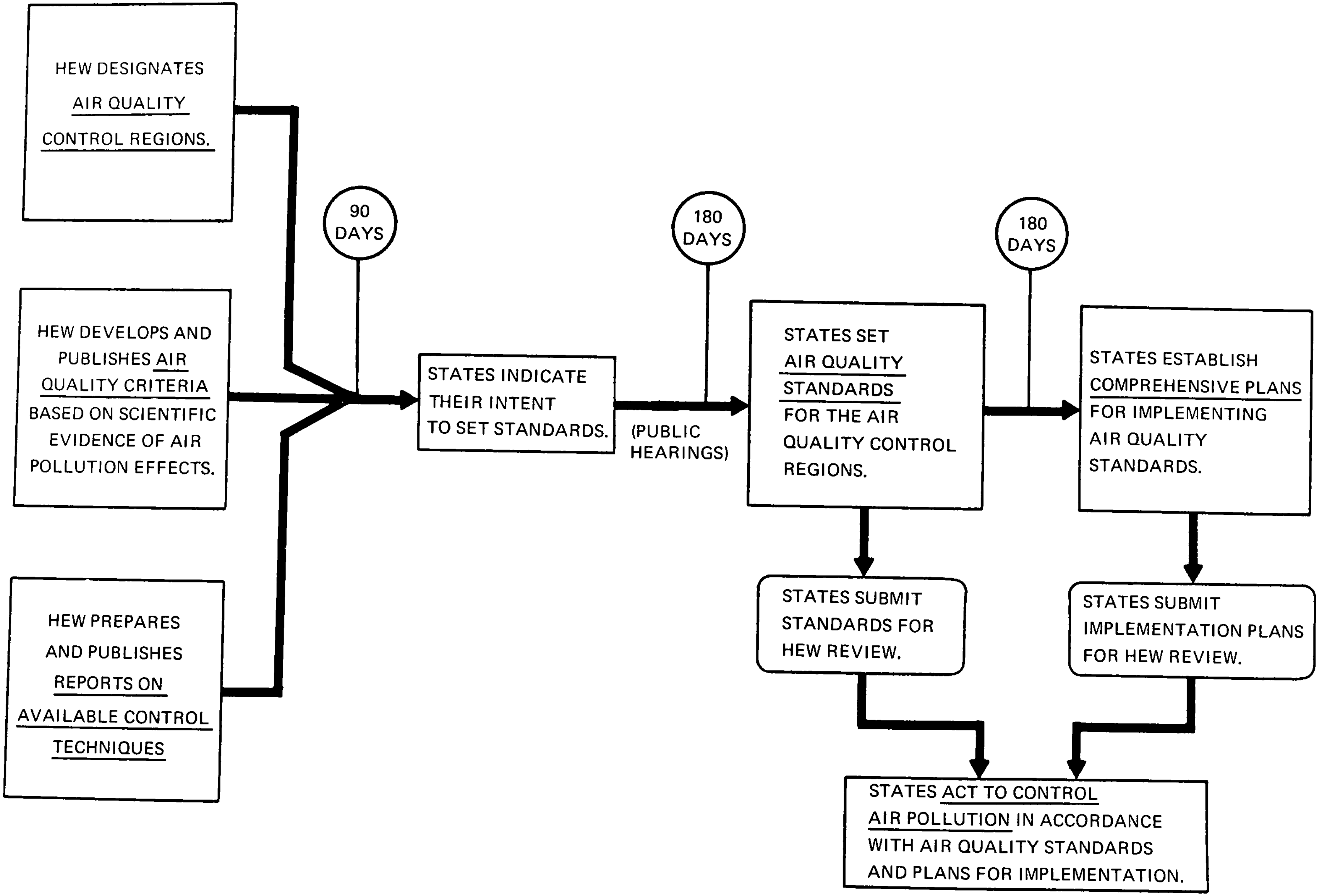

Figure 1 FLOW DIAGRAM FOR ACTION TO CONTROL AIR POLLUTION ON A REGIONAL BASIS, UNDER THE AIR QUALITY ACT.

technology and associated costs, the Governors of the States must file with the Secretary within 90 days a letter of intent, indicating that the States will adopt within 180 days ambient air quality standards for the pollutants covered by the published criteria and control technology documents and adopt 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 retains 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 co-operative 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.

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 effect 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. The geographic extent of trace effects overestimates the true problem area which should be the focus of air pollution control efforts. Thus, the first objective, that a region be self-contained, becomes a question of relative magnitude and frequency. 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 conditions 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.

To the extent that any two of the above three objectives lead to incompatible conclusions concerning region boundaries, the region must represent a reasonable compromise. A region should represent the best way of satisfying the three objectives simultaneously.

PROCEDURE FOR DESIGNATION OF REGIONS

Figure 2 illustrates the procedures used by the National Air Pollution Control Administration for designating 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

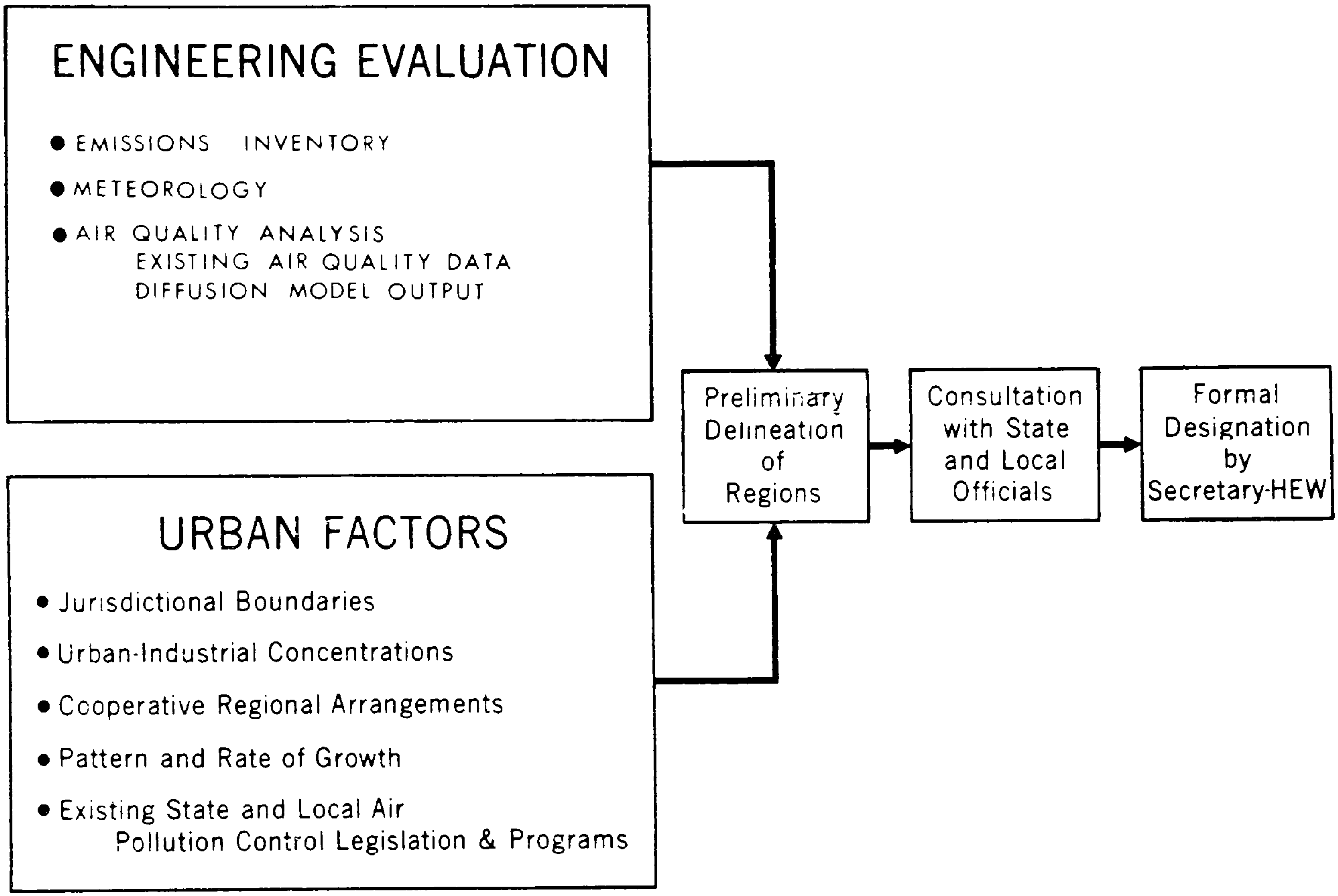

Figure 2. Flow diagram for the designation of air quality control regions.

quality. The second part of the analysis describes the results of the diffusion model applied to the Providence-Fall River-New Bedford 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 non-engineering 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 Governors of the States affected by the designation.

EVALUATION OF ENGINEERING FACTORS

EMISSION INVENTORY

The compilation of an emissions inventory makes possible the correlation of pollutant emissions with specific geographic locations. This procedure generally results in the identification 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. Included within the inventory study area are the Providence-Pawtucket-Warwick, Fall River, and New Bedford Standard Metropolitan Statistical Areas as well as several additional cities and towns in the State of Rhode Island. The survey area is shown in Figure 3. The total study area encompasses 1000 square miles, 270 of which can be considered urban. This area contains the bulk of the population and urbanization in Rhode Island and in southeastern Massachusetts. The estimated 1969 population for the entire survey area is 1,244,000 persons.

The Public Health Service (PHS) rapid survey technique, along with 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 of sulfur dioxide*, total particulate and

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*Estimates are based on all oxides of sulfur, of which the vast majority is composed of SO_2.

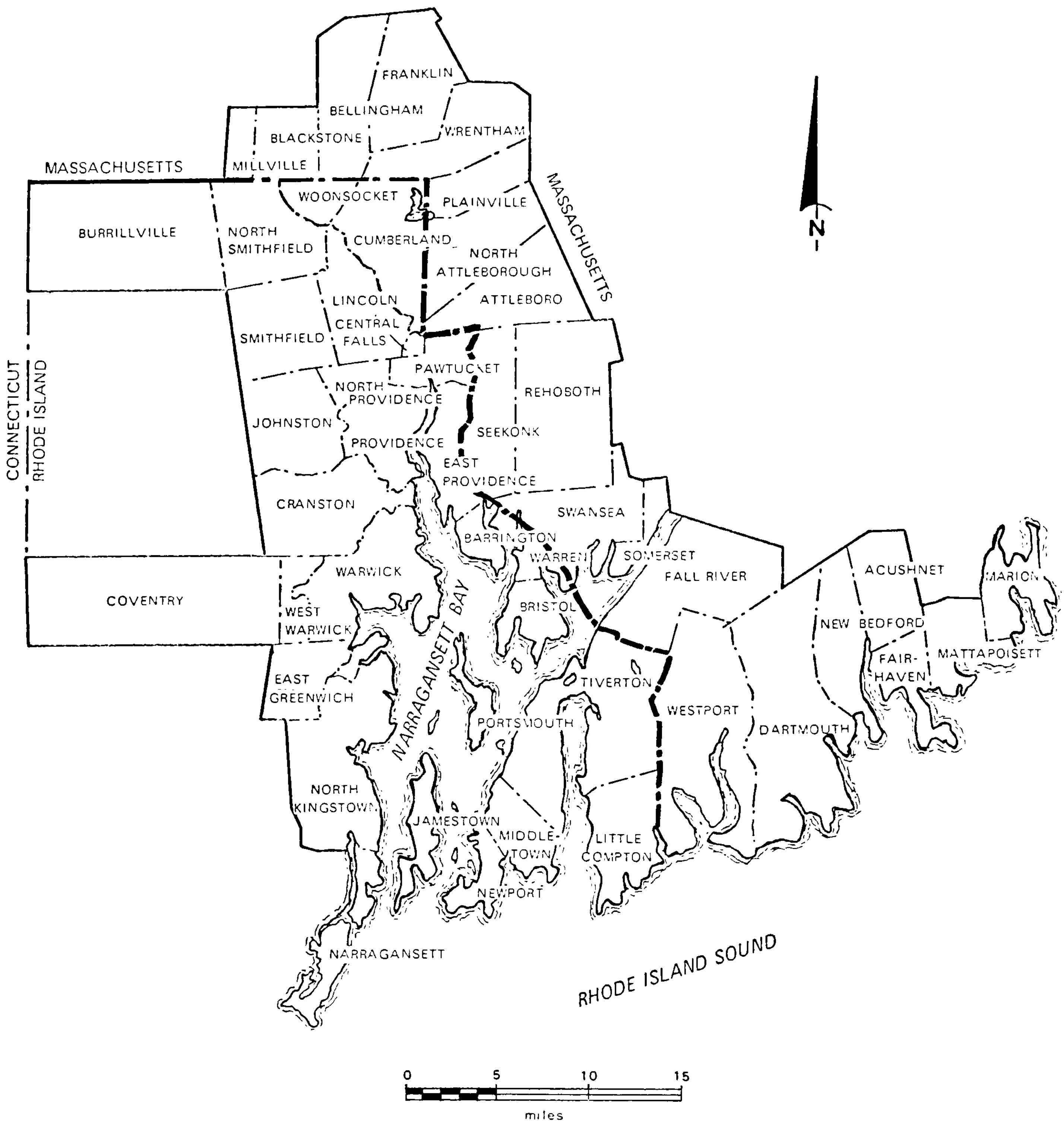

Figure 3 Providence-Pawtucket, Fall River and New Bedford Study Area.

TABLE I. SUMMARY OF AIR POLLUTANT EMISSIONS IN THE PROVIDENCE-FALL RIVER-NEW BEDFORD STUDY AREA, 1967 (Tons/Year).

	Source Category and Type	Sulfur Dioxide	Total Particulates	Carbon Monoxide
I.	TRANSPORTATION	2,550	2,750	415,550
	Road Vehicles	1,700	2,600	407,900
	Aircraft	Neg.*	100	7,650
	Railroads	850	50	Neg.
	Evaporation	0	0	0
II.	COMBUSTION OF FUELS, STATIONARY SOURCES	136,300	14,500	2,600
	Industrial	19,200	2,050	100
	Steam-Electric	87,300	10,400	400
	Residential	24,900	1,800	2,050
	Other	4,900	250	50
III.	REFUSE DISPOSAL	250	5,250	19,200
	Incineration	250	1,800	1,000
	Open-Burning	Neg.	3,450	18,200
IV.	INDUSTRIAL PROCESS EMISSIONS	50	1,100	Neg.
	GRAND TOTAL	139,150	23,600	437,350

*Negligible

carbon monoxide emissions in the study area according to source type in four general categories. These categories are transportation, fuel combustion in stationary sources, refuse disposal and industrial process emissions. The information in this table indicated that 63% of the sulfur dioxide emissions and 44% of total particulate emissions are attributable to steam-electric utilities. Over 93% of the total carbon monoxide pollutant emissions in the survey area are contributed by gasoline-powered motor vehicles.

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 5 kilometers on a side were used in areas of most dense population and industrialization while squares 10 kilometers on a side were used in areas of less dense urbanization. A total of 62 grid squares were used.

Figure 5 shows the location of most major point sources. These sources are concentrated in or close to the cities of Providence, Fall River, and New Bedford. Figures 6, 7, and 8 are emission density maps for SO_2, total particulates and CO, respectively, based on the grid system. The densities are computed on the basis of emissions from both point sources and area sources within each grid zone. The majority of the SO_2 emissions are attributable to power plants in the survey area, though industrial and residential sources are also substantial contributors. Accordingly, the pattern of SO_2 emissions shown in Figure 6 corresponds closely to the pattern of point source locations in the survey area as well as to the pattern of urbanization. Most source types contribute significant amounts of total particulate emissions. The total particulate emission density map (Figure 7) reflects the pattern of urbanization over the study area since the source

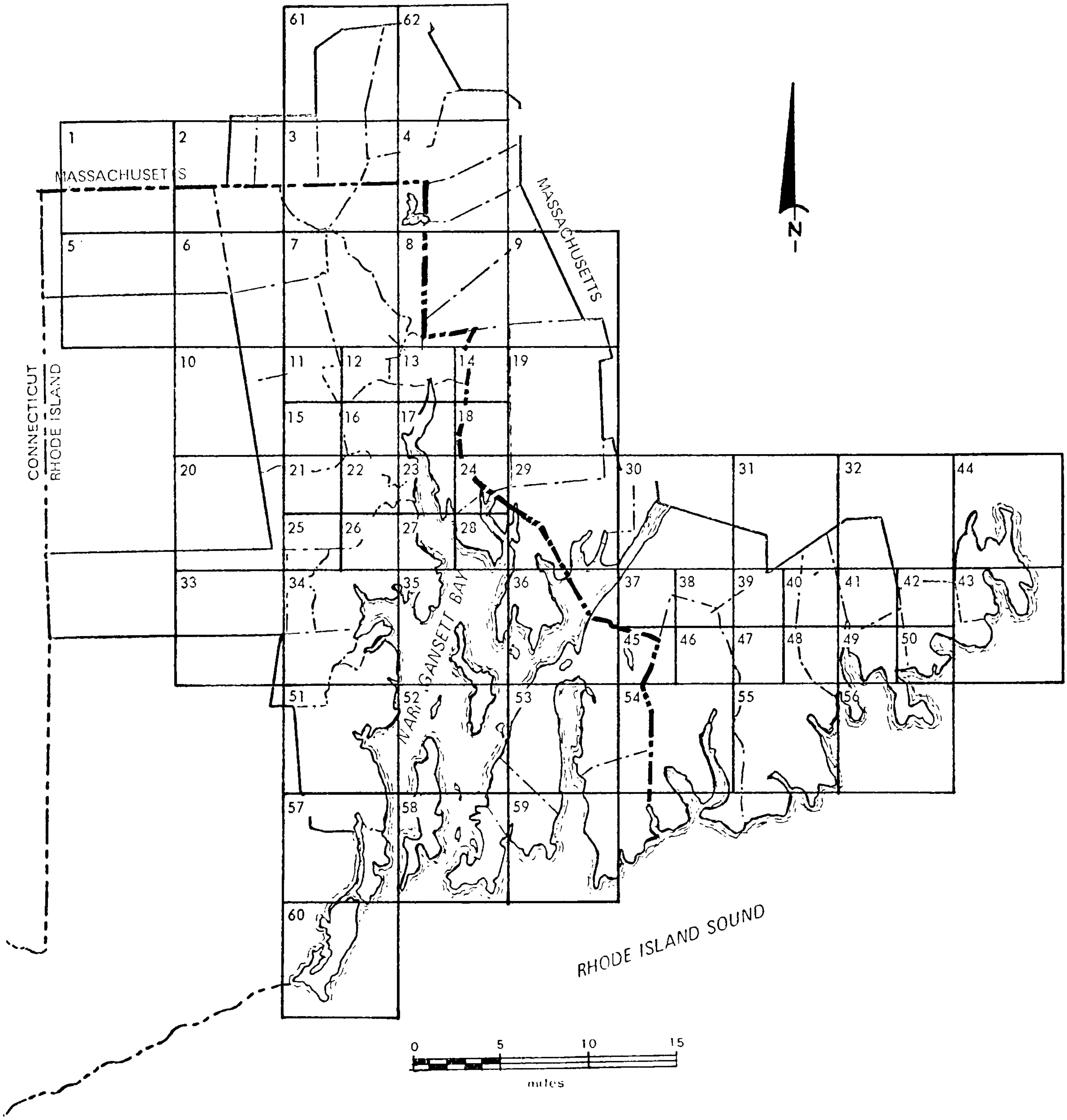

Figure 4. Grid system of Providence Study Area.

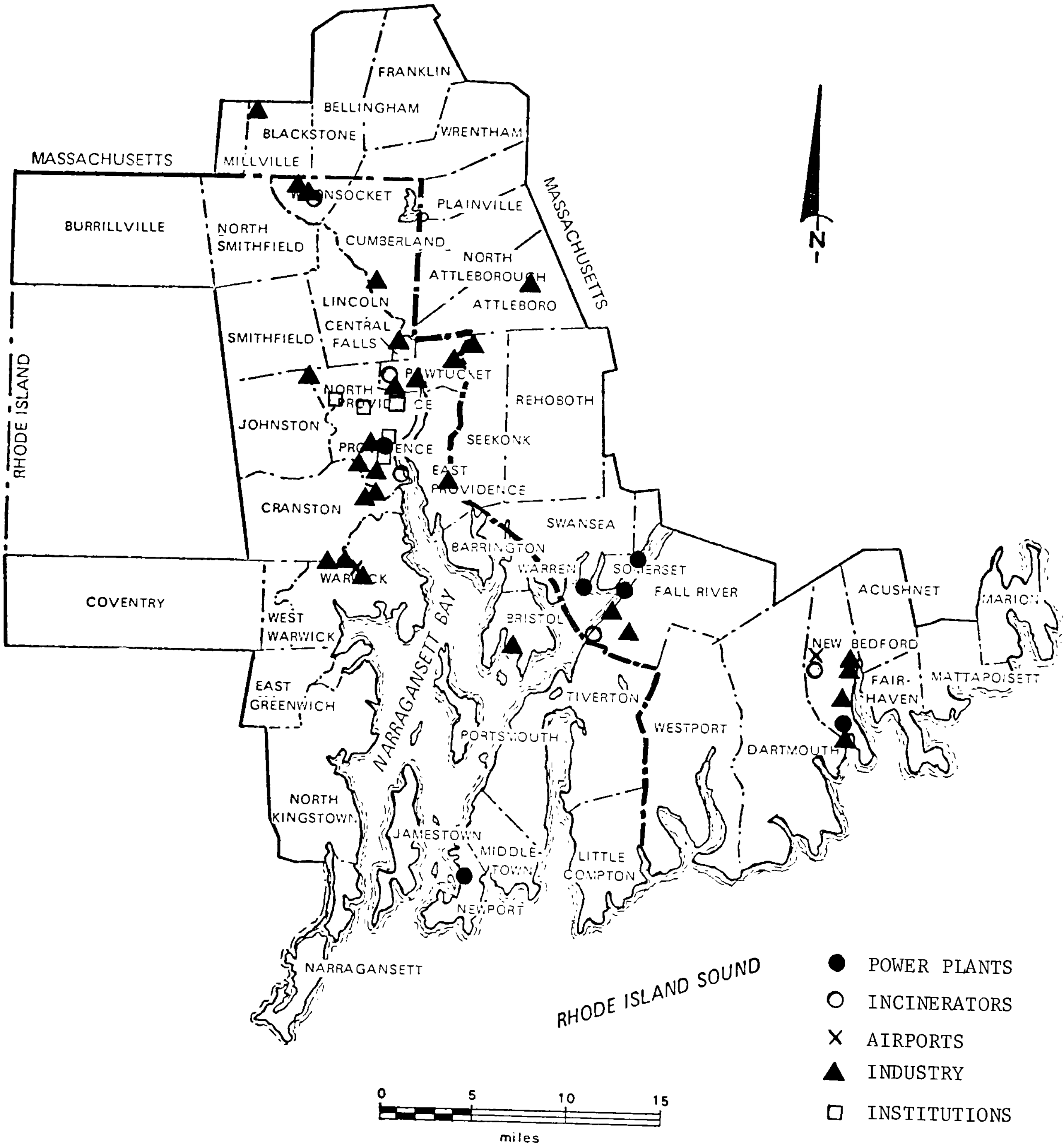

FIGURE 5. MAJOR POINT SOURCE LOCATIONS.

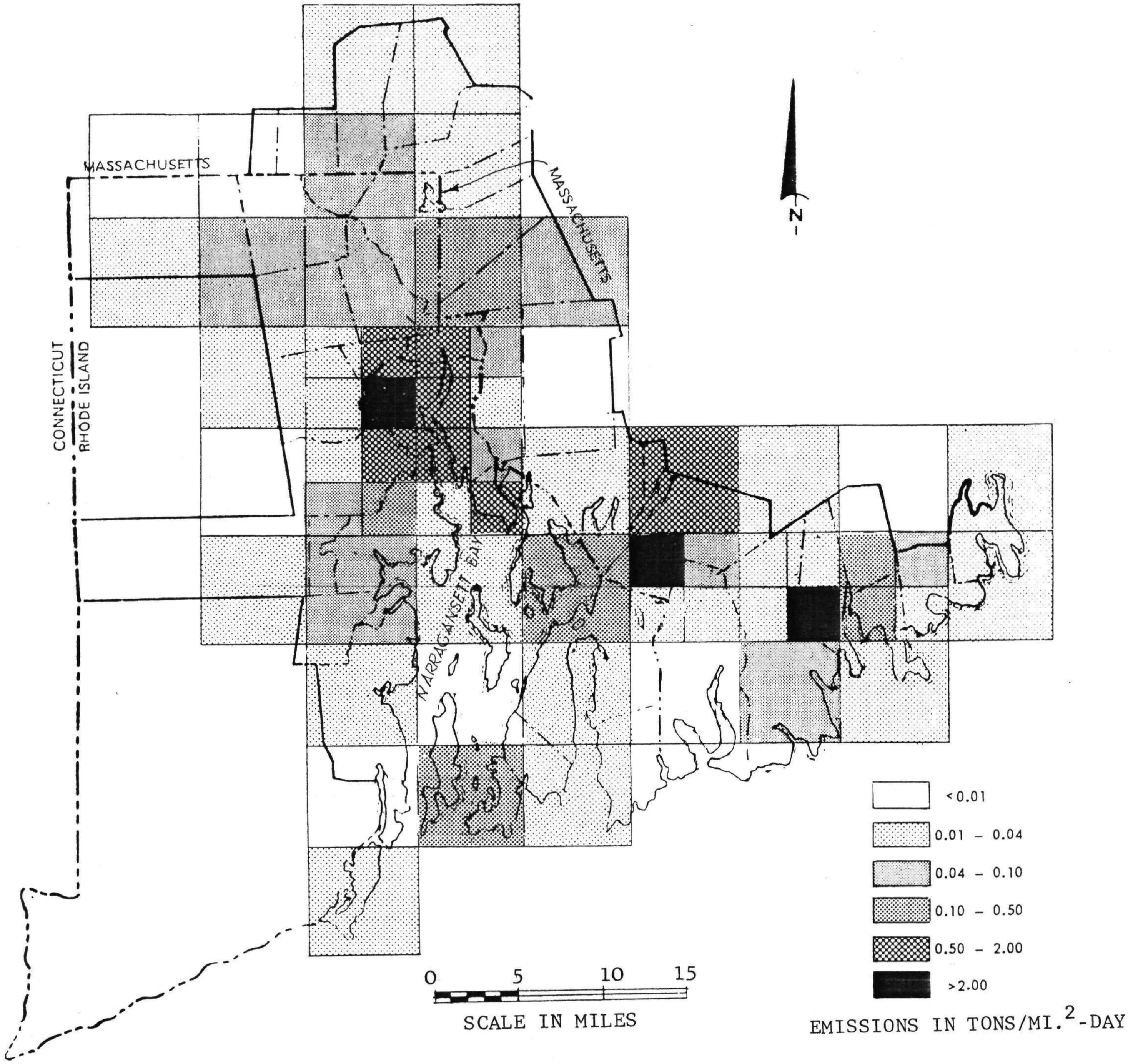

FIGURE 6. SULFUR DIOXIDE EMISSION DENSITIES

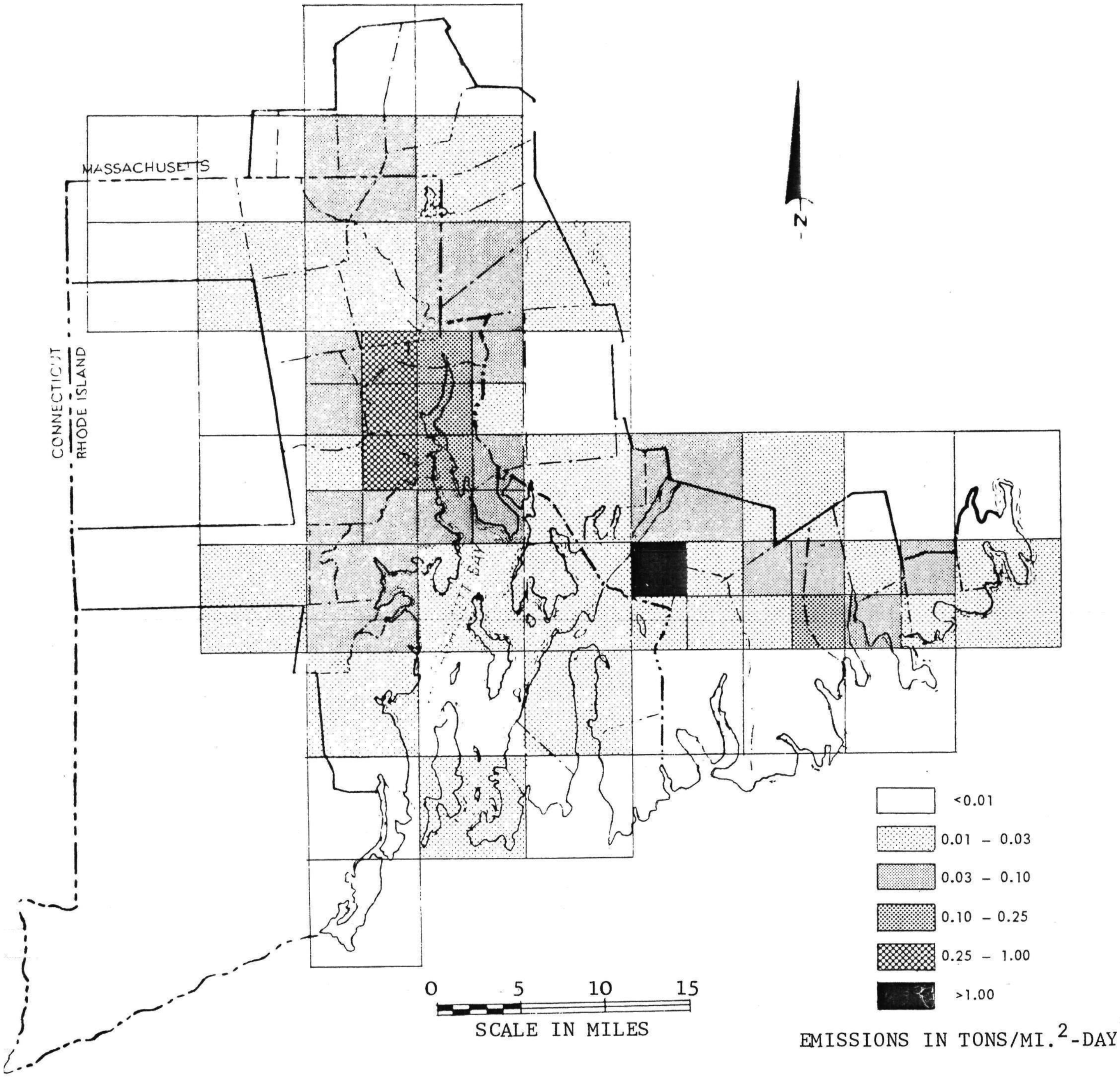

FIGURE 7. TOTAL PARTICULATE EMISSION DENSITIES

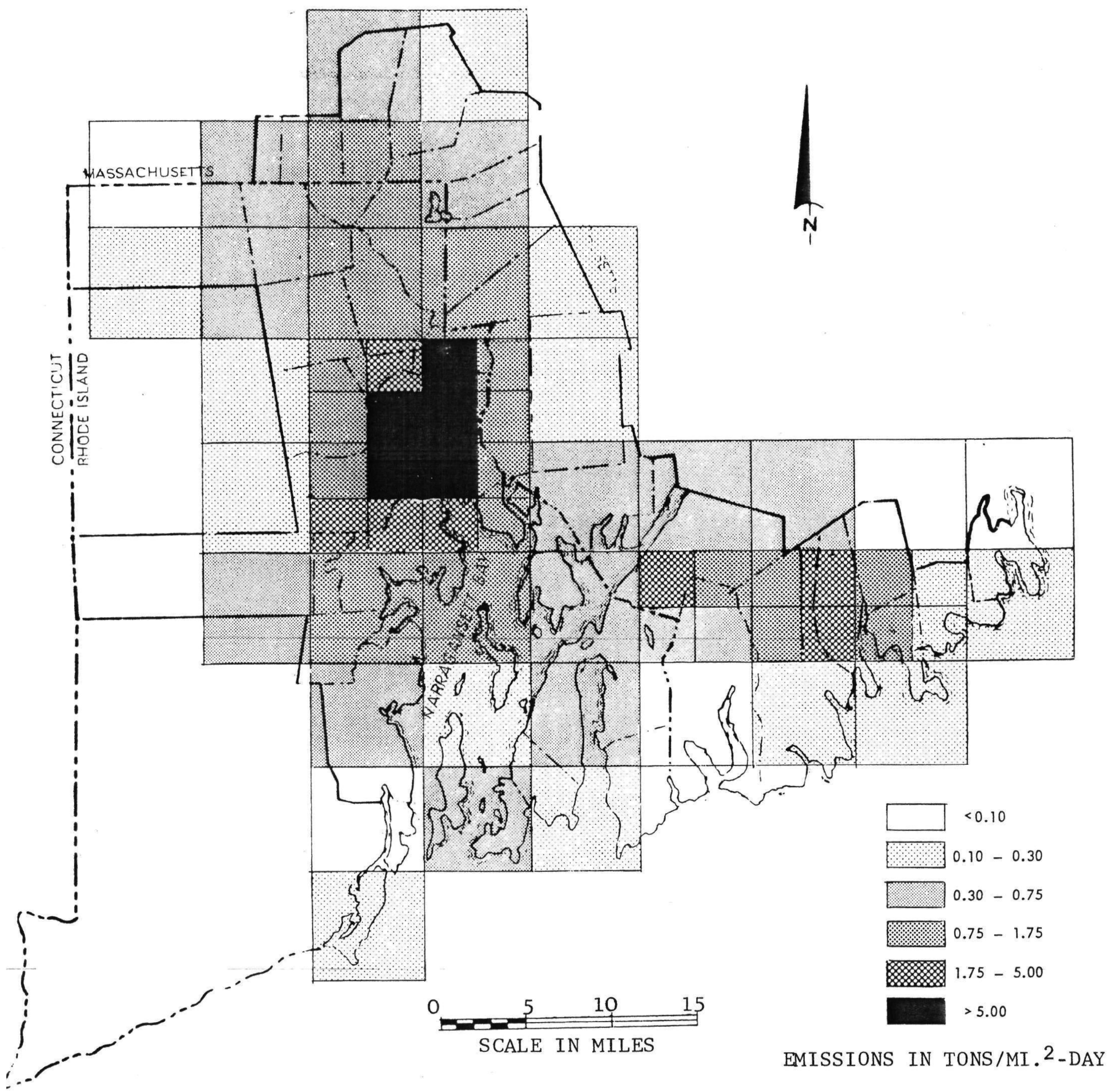

FIGURE 8. CARBON MONOXIDE EMISSION DENSITIES

types themselves are an integral part of the urban pattern. Carbon monoxide emissions are primarily attributable to motor vehicles; thus, Figure 8 provides an indication of the vehicular traffic density distribution over the survey area. As expected, the more heavily populated cities (Providence, Fall River, and New Bedford) are the areas of greatest CO emissions.

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 those jurisdictions containing the majority of the people and property adversely affected by the source emissions. 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 the 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, one which includes within its bounds virtually the entire source-receptor system for a particular area. In this way, too, 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 Providence-Fall River- New Bedford study area. The first and more logical approach for the determination of air quality is to measure quantitatively pollutant concentrations in the ambient air. For the purposes of this report, a review of existing air quality data was made. The second approach consists of estimating air quality over the study area. This has been done by the use of a meteorological diffusion model. This technique was particularly desirable in the study area since existing air sampling networds were not extensive enough to help define the outer limits of the Region.

Topography, Meteorology, and Measured Air Quality

The Providence-Fall River-New Bedford area lies in the coastal lowland region of eastern Rhode Island and southeastern Massachusetts. The eastern portion of Rhode Island lies within the Narragansett basin bordering Narragansett Bay. Upland areas lie to the west of this interstate area in Rhode Island and to the north of it in Massachusetts. The Blackstone River flows through Massachusetts and Rhode Island and drains into Narragansett Bay. The Taunton River in Massachusetts flows southward and also drains into the Bay.

Their proximity to Narragansett Bay and the Atlantic Ocean plays an important part in determining the climate of Providence and its vicinity. The presence of these water bodies tends to create changeable weather, while moderating climatic extremes. Prevailing winter winds are from the northwest (see Figure A-1), while prevailing summer winds are from the southwest. Since inversions in this area are infrequent and average wind speeds are high, the meteorological conditions favor dispersion of pollutants. The potential for dilution of pollutants is high during summer afternoons, although pollutant dilution is restricted during summer mornings. In general, the topography and meteorology in the study area tend to relieve rather than aggravate the air pollution problem.

Air sampling is conducted at several sites in the State of Rhode Island. Sampling for suspended particulates has occurred over a number of years at urban sites in Providence and East Providence, as well as at a non-urban site in the town of Exeter in Washington County. The average measured concentration of suspended particulates was 103 $\mu g/m^3$ in Providence for the years 1957 through 1967, and was 62 $\mu g/m^3$ in East Providence for the years 1963 through 1967. The 1959 through 1967 average concentration at the Washington County non-urban site was 35 $\mu g/m^3$. This measure of air quality might be considered representative of the non-urban or "background" level of suspended particulate pollution over the remainder of the study area. The concentrations recorded in Providence and East Providence, as anticipated, are substantially above this background level.

More recent measurements of suspended particulate concentrations (winter 1968-1969) reveal the existence of levels in the larger cities which are above background. Measured concentrations were 86, 68, 61, 59, 53, and 52 micro-grams per cubic meter in the cities of Providence, Pawtucket, Warwick, Newport, Woonsocket, and Cranston, respectively. In the town of Westerly, an average concentration of 97 $\mu g/m^3$ was recorded, while measured concentrations in the towns of Bristol, Tiverton, Harrisville, and Block Island were 47 $\mu g/m^3$, 36 $\mu g/m^3$, 34 $\mu g/m^3$, and 34 $\mu g/m^3$, respectively. The sampling results in all these towns (except Westerly) reveal suspended particulate concentrations which approach or are nearly equal to the assumed background level for the State (35 $\mu g/m^3$). With the exception of the sampling results at the Westerly site, the air quality appears to be related to the population size of the various cities and towns.

Recent sampling (winter 1968-1969) for sulfur dioxide pollutant concentrations in several Rhode Island cities and towns has been conducted. Concentrations presented here represent arithmetic means of approximately 10 samples taken over the 3-month winter season with the use of 24-hour gas samplers. Highest measured values were recorded in Providence, where the average SO_2 concentration equalled .016 ppm. Corresponding values were .015 ppm in Pawtucket, .011 ppm in Woonsocket, .009 ppm in Cranston, .008 ppm in Warwick, .007 ppm in Newport, .006 ppm in Westerly, and .005 ppm in Block Island. These values, too, correlate roughly with the population sizes of the communities in which the measurements were recorded.

In Massachusetts, a limited amount of air sampling for suspended particulates has been conducted in Fall River and New Bedford. The 1967 average concentration of suspended particulates in New Bedford was 58 $\mu g/m^3$, and the 1959 through 1967 average was 54 $\mu g/m^3$. In Fall River, the 1962 average concentration of suspended particulates was 95 $\mu g/m^3$, and was 91 $\mu g/m^3$ averaged over the years 1958-1962. No sampling for SO_2 has taken place on a continuing basis in southeastern Massachusetts. Carbon monoxide sampling, likewise, has not been conducted in either southeastern Massachusetts or Rhode Island.

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. The model predicts these concentrations from a mathematical treatment of pollutant emission and meteorological data.* While the model contains inherent limitations, it still has merit in providing reasonable <u>spatial distribution</u> of long term (seasonal and annual)** average pollutant concentrations.

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*See Appendix A for a more detailed discussion.

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

Theoretical sulfur dioxide concentrations are shown in Figure 9. Results for the winter averaging time are presented since the greatest build-up of SO_2 concentrations occurs during this season due to the high rates of SO_2 smissions and unfavorable meteorological conditions. A 3-hour half life for sulfur dioxide is used in the model as the assumed rate of decay of SO_2. This produces values which correlate best with measured concentrations. The dispersion pattern shown in Figure 9 reflects the influence of predominating northwest winter winds (see Figure A-1). Greatest SO_2 concentrations are predicted in and around the city of Providence. Predicted concentrations in and near Providence appear to overestimate measured SO_2 levels however. Conversely, the model underestimates measured levels of air quality at sampling sites in Newport and Woonsocket.

Figure 10 presents theoretical suspended particulate concentrations in $\mu g/m^3$ for the winter averaging time. During this season the greatest suspended particulate concentrations occur, according to the model. This is due in part to the greater quantity of particulate matter emitted during the winter and due in part to winter season meteorological conditions. The model does not consider concentrations of particulate matter from natural sources or from nearby urban areas which combine to make up the background level in the area. For this reason, the predicted concentration values shown in Figure 10 are not considered absolute. The predicted concentrations underestimate true levels of air quality according to comparison with measured data. Figure 10 indicates that the winter season dispersion pattern for suspended particulates is similar to the winter SO_2 dispersion pattern. Greatest concentrations are predicted to occur

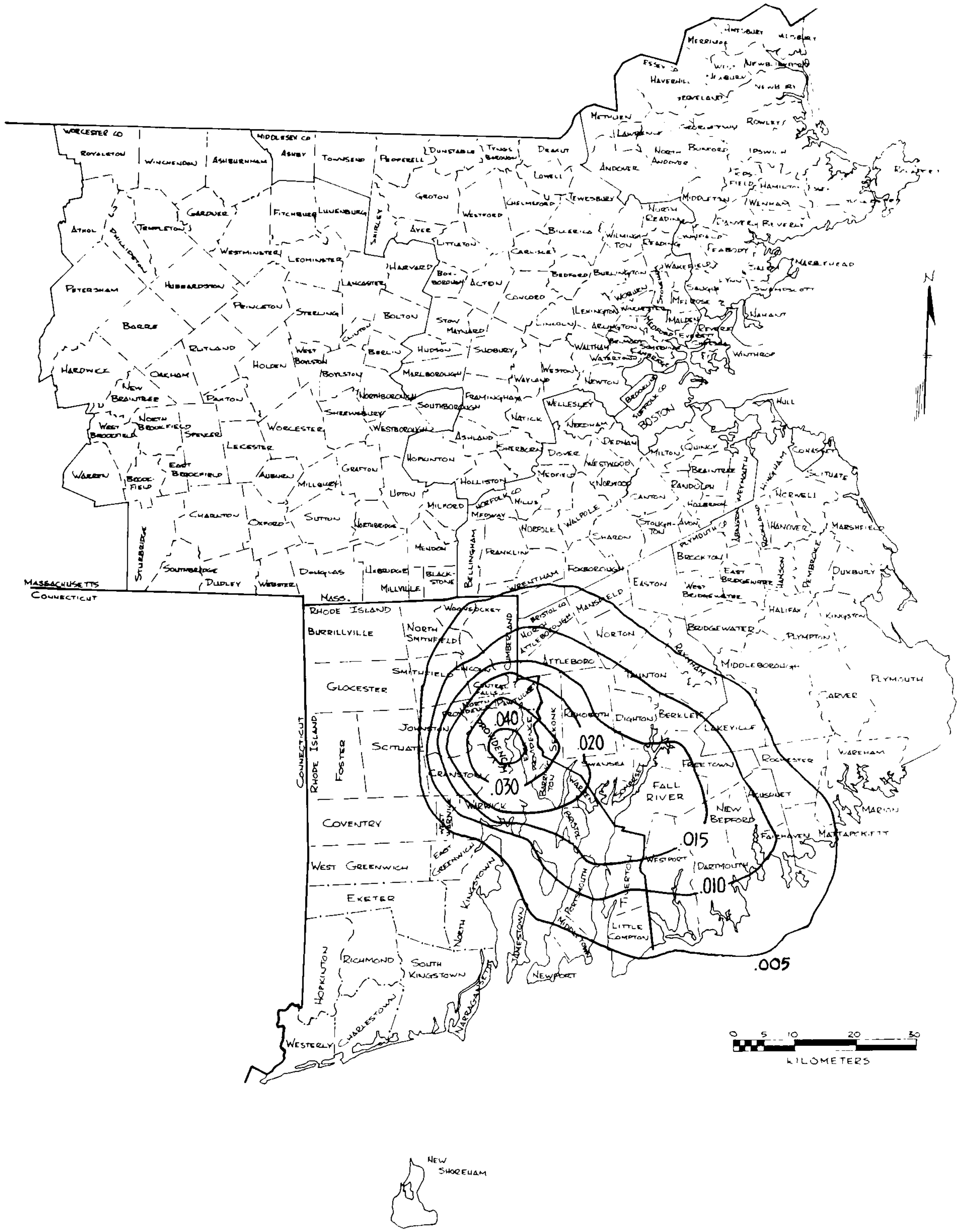


FIGURE 9. THEORETICAL SO_2 CONCENTRATIONS IN PPM, WINTER AVERAGE (ASSUMED 3 HOUR HALF-LIFE).

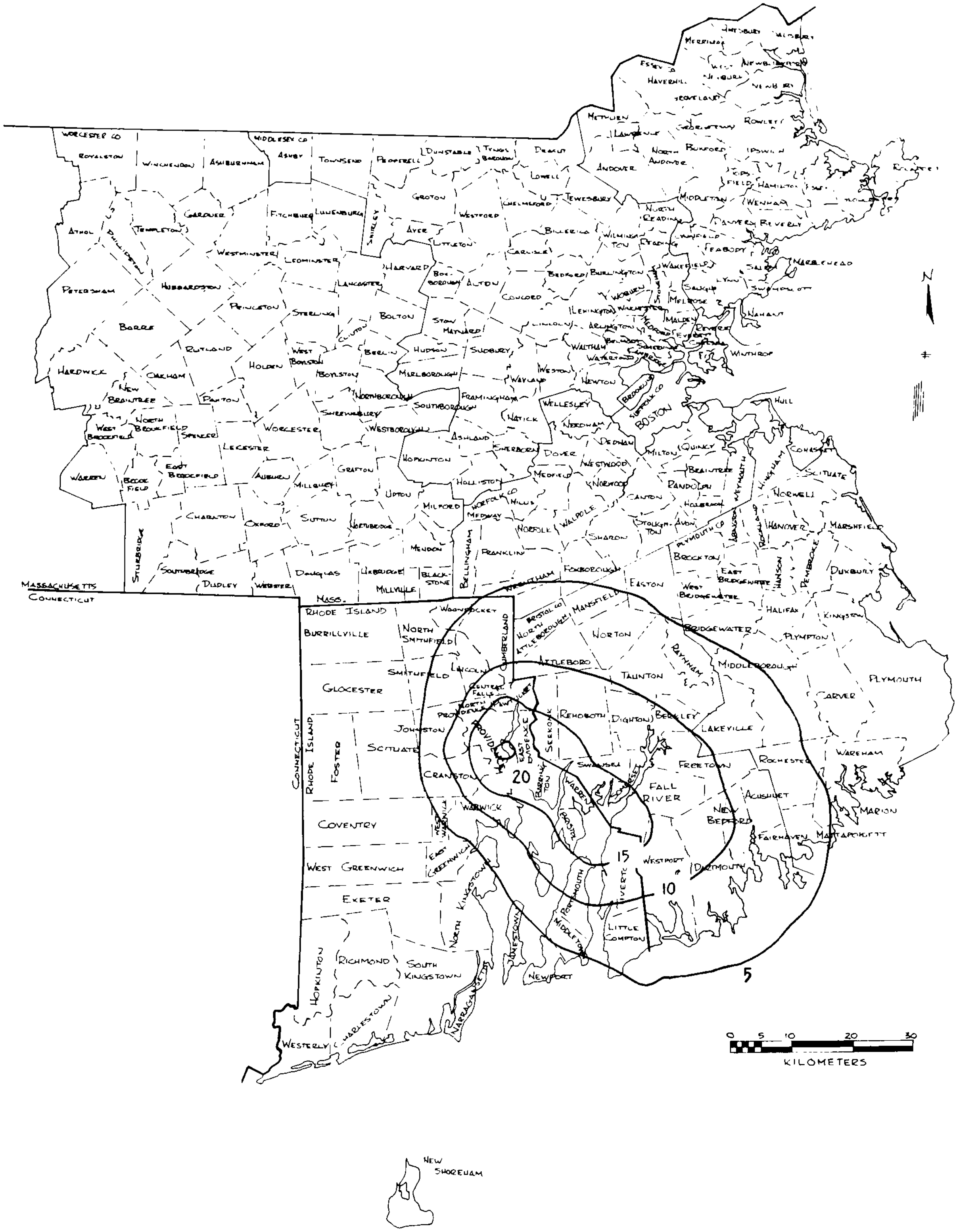


FIGURE 10. THEORETICAL SUSPENDED PARTICULATE CONCENTRATIONS IN $\mu g/m^3$, WINTER AVERAGE.

in and near Providence. Pollutant dispersion toward the east and northeast is significant so that large areas of eastern Massachusetts serve as receptors of particulate pollution from source areas in Rhode Island or close to the Rhode Island border.

Figure 11 shows predicted carbon monoxide concentrations based on summer emissions and meteorology. Greatest CO emissions occur in the summer which result in the greatest predicted CO levels. As anticipated, the theoretical concentrations are highest in and surrounding the city of Providence where vehicular traffic density is greatest. Figure A-1 (Appendix A) indicates that the predominant summer winds are from the southwest and northwest quadrants. This is reflected in the dispersion pattern which indicates predominant CO transport from the urban core areas to the northeast, east, and southeast. An area centered on Providence and extending outward to Fall River, Taunton, and Wrentham in Massachusetts and Woonsocket, Cranston, and Portsmouth in Rhode Island is most significantly affected by CO emissions. The CO concentrations in Figure 11 should not be considered absolute since past applications of the model to studies of this type indicate that actual CO concentrations tend to be underestimated.

SUMMARY

An inventory of pollutant emissions conducted over eastern Rhode Island and a sizeable portion of southeastern Massachusetts (see Figure 3) revealed the existence of an area-wide air pollutant source complex. Emission quantities appear to vary with the intensity of urbanization

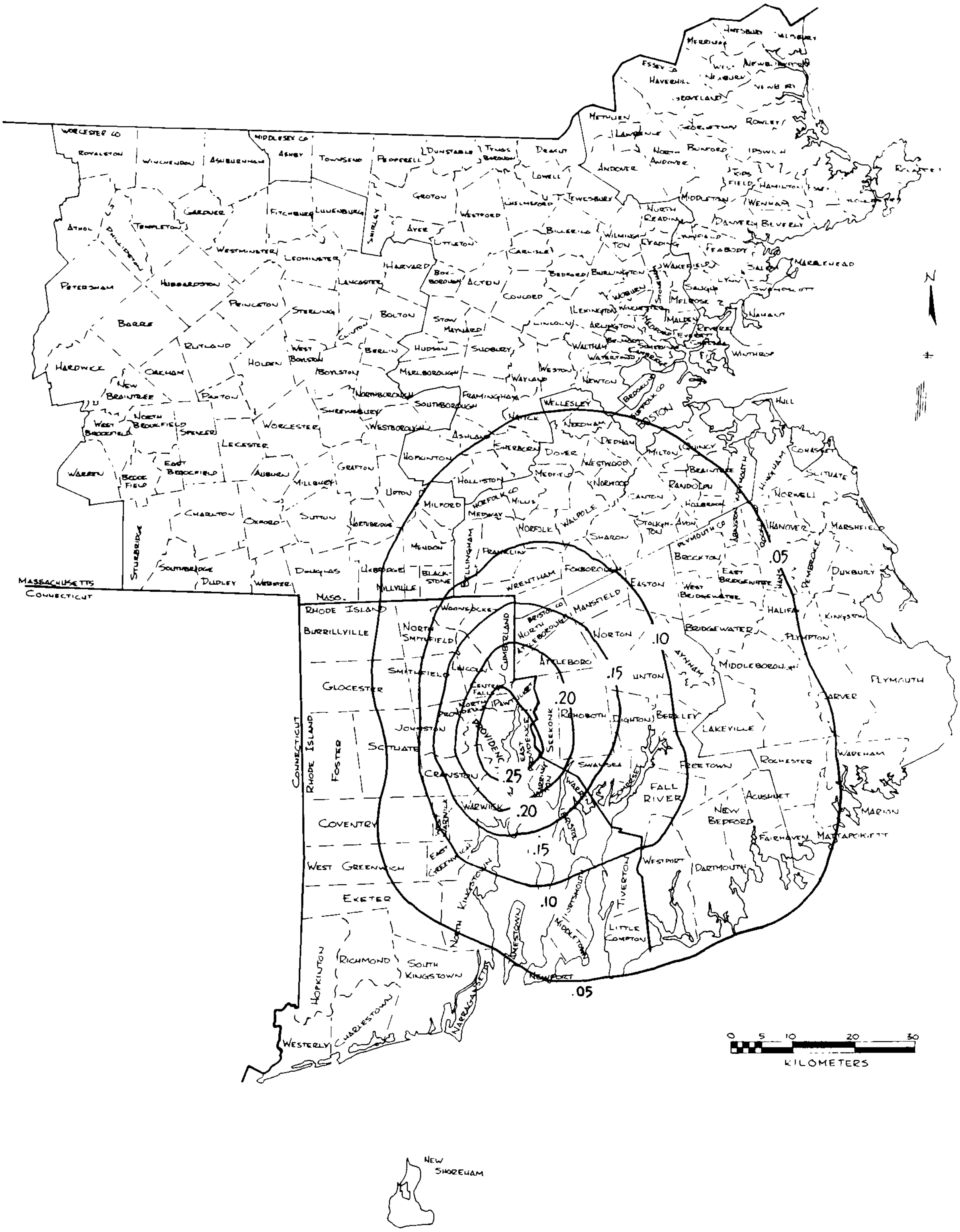


FIGURE 11. THEORETICAL CARBON MONOXIDE CONCENTRATIONS IN PPM, SUMMER AVERAGE.

and industrialization within the source-survey area. Greatest quantities of pollutants are emitted from the core cities (Providence, Fall River, and New Bedford) as well as from surrounding cities of high population and industrialization (Woonsocket, Pawtucket, Central Falls, Cranston, and Warwick).

Diffusion model results indicate that the air quality is affected over a receptor area substantially larger than that over which source emissions were inventoried. Wintertime dispersion of suspended particulates and sulfur dioxide is directed primarily toward the east and southeast. This results in the interstate transport of pollutants from the Providence area downwind to the metropolitan Fall River and New Bedford areas. During the summer season carbon monoxide diffusion is directed largely to areas in Massachusetts located to the northeast and east of the source-survey area. The combined results of the emission inventory and the diffusion model application indicates that an interstate air pollution problem exists between Rhode Island and large portions of eastern and southeastern Massachusetts.

An analysis of existing air quality was made in order to determine the geographic variations in air quality over the study area. This particulate analysis is only partially complete, however, since existing air quality data is limited. Available data for the State of Rhode Island indicates a substantial variation in air quality between the rural (Block Island, Exeter) and urban (Providence, Pawtucket) areas. Data for Fall River and New Bedord in Massachusetts indicates that suspended particulate levels in these cities is greater than the expected background level for eastern Massachusetts.

No attempt has been made to define precisely the desired Region boundaries on the basis of engineering factors alone. First, there are limitations on the reliability of predicted levels and dispersion patterns of the various pollutants. Secondly, existing measured air quality data is limited, and cannot be used to determine the outer limits of the Region. Finally, Region boundaries must be drawn on the basis of inclusion or exclusion of geographically small cities and towns in order to preserve administrative unity. The inclusion or exclusion of individual peripheral municipalities in the Region is difficult to determine on the basis of limited technical data. Thus, only a general definition of the extent of the air pollution problem in the Rhode Island and Massachusetts interstate area has been attempted in this analysis.

EVALUATION OF URBAN FACTORS

INTRODUCTION

The Air Quality Act of 1967 calls for the designation of air quality control regions based on "jurisdictional boundaries, urban-industrial concentrations, and other factors" in order to provide for the adequate implementation of air quality standards. 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.

POPULATION DISTRIBUTION

Existing and potential air pollution problems are related geographically to areas of present or anticipated residential and industrial development. For example, air pollution problem areas can generally be identified by studying population statistics since human activity is a basic cause of air pollution. Table II presents 1965 population and population density statistics by city and town for Rhode Island and southeastern Massachusetts. In the State of Rhode Island, the largest cities are Providence, Pawtucket, Warwick and Cranston. More than one-half of the total population of the State resides in Providence and the towns on the periphery of Providence, including the City of Warwick. Woonsocket and Newport, located to the north and to the south of Providence, respectively, are the remaining two cities of significant size in the State. The northeast quadrant of the State generally, and metropolitan Providence specifically, are areas of high population and population densities and intense urban development. Most of the remainder of the State remains undeveloped and rural in nature. This

TABLE II. PRESENT AND PROJECTED POPULATION DATA AND MANUFACTURING EMPLOYMENT BY JURISDICTION

Jurisdiction (Town)	Area (MI.^{2})	1965 Population	1980 Projected Population	1965 Population Density (Persons/MI.^{2})	1980 Projected Population Density (Persons/MI.^{2})	Additional Residents Per Square Mile 1965-1980	1967 Manufacturing Employment	1967 Manufacturing Employment Density (Persons/MI.^{2})
Rhode Island								
Barrington	8.9	16,800	23,150	1,890	2,600	710	513	58
Bristol	10.2	15,500	20,310	1,520	1,990	470	3,466	340
Burrillville	55.8	9,340	10,000	167	179	12	749	13
Central Falls	1.2	18,960	17,870	15,800	14,900	-900	4,022	3,350
Charlestown	36.3	2,260	3,370	62	93	31	N.A.	---
Coventry	62.2	18,670	27,740	300	446	146	2,048	33
Cranston	28.6	72,500	90,110	2,540	3,160	620	6,637	232
Cumberland	27.1	22,120	34,400	815	1,270	455	2,065	76
E. Greenwich	16.6	7,050	12,000	425	723	298	N.A.	---
E. Providence	13.3	45,390	56,720	3,420	4,260	840	5,216	392
Exeter	57.6	2,600	3,640	45	63	18	N.A.	---
Foster	51.4	2,420	3,630	47	70	23	N.A.	---
Glocester	55.3	3,850	5,470	70	99	29	N.A.	---
Hopkinton	43.0	4,530	5,960	105	139	34	429	10
Jamestown	9.7	2,420	3,010	250	310	60	N.A.	---
Johnston	23.7	19,300	26,000	813	1,096	383	1,179	50
Lincoln	18.6	14,530	18,090	782	971	189	2,643	142
Little Compton	21.6	1,800	2,180	83	101	18	N.A.	---
Middletown	12.9	15,180	24,470	1,178	1,900	722	129	10
Narragansett	13.9	4,170	6,600	300	475	175	N.A.	---
Newport	7.7	47,450	50,170	6,160	6,520	360	738	96
New Shoreham	10.0	440	380	44	38	- 6	N.A.	---
N. Kingstown	43.5	21,380	28,260	490	650	190	3,019	69
N. Providence	5.7	20,240	25,650	3,550	4,550	950	1,763	309
N. Smithfield	24.5	8,790	12,800	358	522	162	2,512	1,025
Pawtucket	8.8	79,880	77,650	9,070	8,830	-240	18,996	2,160
Portsmouth	23.3	9,340	12,920	401	554	153	2,234	96
Providence	18.1	193,800	177,800	10,700	9,800	-900	43,549	2,405
Richmond	40.4	2,150	2,720	53	67	14	834	21
Scituate	48.8	6,050	9,020	124	185	61	N.A.	---

Jurisdiction (Town)	Area (MI.^{2})	1965 Population	1980 Projected Population	1965 Population Density (Persons/MI.^{2})	1980 Projected Population Density (Persons/MI.^{2})	Additional Residents Per Square Mile 1965-1980	1967 Manufacturing Employment	1967 Manufacturing Employment Density (Persons/MI.^{2})
Rhode Island (cont'd.)								
Smithfield	26.7	10,880	15,300	407	572	165	1,605	60
S. Kingstown	56.8	15,500	20,200	273	356	83	433	8
Tiverton	29.7	11,570	17,600	389	592	203	75	3
Warren	5.8	8,910	9,500	1,539	1,640	101	2,170	374
Warwick	34.9	76,240	92,880	2,185	2,665	480	6,844	196
Westerly	29.7	15,260	19,000	513	639	126	1,832	62
W. Greenwich	50.6	1,380	2,190	27	43	16	N.A.	---
W. Warwick	8.3	22,450	25,590	2,705	3,085	380	3,061	369
Woonsocket	7.9	46,400	45,750	5,870	5,790	-80	8,100	1,027
Massachusetts								
Acushnet	18.4	6,717	12,000	365	652	287	823	45
Attleboro	27.0	28,690	45,100	1,062	1,670	608	15,946	590
Bellingham	18.0	10,604	20,700	589	1,150	561	165	9
Berkeley	16.6	1,769	3,400	107	204	97	18	1
Blackstone	11.2	6,025	8,162	537	729	192	65	6
Bourne	40.4	6,376	N.A.	158	---	---	196	5
Carver	37.4	2,147	5,000	57	134	77	0	Neg.
Dartmouth	61.0	17,187	30,000	282	491	209	350	6
Dighton	22.2	4,131	8,700	186	392	206	1,546	70
Fairhaven	12.1	15,642	22,000	1,292	1,820	528	569	47
Fall River	33.0	98,053	115,000	2,975	3,480	505	20,922	633
Franklin	26.4	14,721	28,800	557	1,090	533	858	33
Freetown	34.4	3,337	6,200	970	1,800	830	259	8
Halifax	15.9	2,637	7,800	166	490	324	1	Neg.
Kingston	18.5	4,946	11,500	267	622	355	282	15
Lakeville	29.4	3,773	7,300	128	248	120	0	0
Mansfield	20.5	8,620	12,300	421	599	178	1,129	55
Marion	13.7	3,480	6,000	254	438	184	225	16
Mattapoisett	17.2	3,942	7,000	230	407	177	69	4
Middleborough	69.4	11,726	25,500	169	368	199	1,424	21

Jurisdiction (Town)	Area (MI.^{2})	1965 Population	1980 Projected Population	1965 Population Density (Persons/MI.^{2})	1980 Projected Population Density (Persons/MI.^{2})	Additional Residents Per Square Mile 1965-1980	1967 Manufacturing Employment	1967 Manufacturing Employment Density (Persons/MI.^{2})
Massachusetts (cont'd.)								
Millville	4.9	1,706	2,154	348	440	92	175	36
New Bedford	19.5	100,176	100,500	5,140	5,150	10	25,005	1,281
N. Attleborough	18.9	15,682	27,400	829	1,450	621	2,367	125
Norton	28.1	6,737	15,700	240	558	318	860	31
Plainville	10.9	4,252	11,900	390	1,091	801	1,126	103
Plymouth	96.1	15,424	30,500	161	317	156	537	6
Plympton	14.6	1,060	2,500	72	172	100	22	1
Raynham	20.7	5,937	10,015	287	483	196	78	4
Rehoboth	47.3	5,489	9,900	116	209	93	105	2
Rochester	33.2	1,693	2,900	51	87	36	59	2
Sandwich	42.7	2,438	N.A.	57	---	---	3	Neg.
Seekonk	18.6	9,880	21,400	532	1,150	618	558	30
Somerset	8.0	15,080	24,700	1,882	3,080	1,198	148	18
Swansea	22.7	11,767	20,600	517	906	389	236	10
Taunton	47.0	42,018	52,800	895	1,125	230	6,605	140
Wareham	34.4	10,406	18,000	302	523	221	314	9
Westport	49.3	8,200	15,100	166	306	140	158	3
Wrentham	21.6	7,517	20,000	348	925	577	448	21

*Projected Populations for Massachusetts cities and towns are for the year 1990, therefore, calculations for additional residents per square mile reflects population change between 1965 and 1990.

is particularly true of the western half of Rhode Island. Nevertheless, Rhode Island, taken as a whole, is one of the most densely populated States in the nation.

Nineteen-eighty Projected population statistics for the State of Rhode Island are also presented in Table II. Cities that are densely populated at the present time--including Providence, Pawtucket, Central Falls and Woonsocket--are expected to experience a decline in populaton. Conversely, the less densely populated cities and the rural areas are projected to absorb the State's future population growth. Cranston, Cumberland, East and North Providence, Johnston, Middletown, and Warwick are expected to undergo significant increases in population.

In southeastern Massachusetts, the most highly populated cities and towns are Fall River, New Bedford, Taunton, Attleboro, Dartmouth, North Attleborough, Fairhaven, and Plymouth. Fall River and New Bedford are the core cities for surrounding towns whose populations densities are relatively high. In general, a highly urbanized strip of land exists, stretching along the coast from Wareham westward to Dartmouth and northward along the Rhode Island border to Wrentham and Franklin. The cities and towns bordering the northeast corner of Rhode Island are considered an integral part of metropolitan Providence. This urbanized strip of land encompasses the Fall River and New Bedford Standard Metropolitan Statistical Areas (SMSA's) as well as most of the Massachusetts portion of the Providence SMSA (see Figure 12).

Greatest absolute growth in southeastern Massachusetts to the year 1990 is projected to occur in Fall River. The towns of Swansea and Somerset, located close to Fall River, are expected to undergo considerable growth. New Bedford's population is projected to remain approximately at its present level. Significant growth will occur, however, in the towns of Acushnet, Fairhaven, and Darthmouth, all of which are contiguous to the city of New Bedford. To the east, considerable growth, in terms of absolute population increases, will take place in Plymouth, Wareham, and Middleborough. Population densities in these towns will remain relatively low, however. The cities and towns in Massachusetts that are part of the Providence SMSA are expected to undergo substantial increases in population.

INDUSTRY

The location of industrial 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, when specified by city and town, serve as an indicator of the geographic distribution of industrial activity. Such manufacturing employment data is presented in Table II. The statistics reveal that Providence has, by far, the greatest number of manufacturing employees in the study area. These number approximately 43,500 based on 1967 estimates. Pawtucket ranks second to Providence in the State of Rhode Island. Approximately 19,000 manufacturing employees work in the city of Pawtucket. Other important industrial cities within Rhode Island are Woonsocket, Warwick, Cranston, East Providence, and Central Falls. The major industries in Rhode Island are textile mill products, jewelry, non-electrical machinery, primary metal industries, and fabricated metal products.

In southeastern Massachusetts the leading industrial cities are New Bedford, Fall River, and Attleboro, with approximately 25,000, 21,000, and 16,000 manufacturing employees, respectively. The leading industrial types in this area are the apparel industry, textile products, primary metals and rubber and plastic products.

The point source map (Figure 5) presented previously is useful in depicting the geographic locations of industrial point sources. This figure indicated that the major industrial point sources are concentrated in New Bedford and Fall River, Massachusetts, and Providence, Pawtucket, Cranston, Warwick, and Woonsocket in Rhode Island.

EXISTING REGIONAL ARRANGEMENTS

The existence of regional councils, planning agencies, State-defined planning and economic development districts, and region-wide geographic bases over which statistical data gathering is conducted are important determinations affecting the location of proposed air quality control region boundaries. Consideration of these factors permits the identification of that combination of jurisdictions which has been integrated through social and economic interdependence, and further provides some indication of the degree of existing cooperation among those jurisdictions. The designation of an air quality control region compatible with these existing regional arrangements is desirable since the implementation of a regional air pollution control plan is dependent upon cooperation at the various levels of government. In addition, the regional councils and planning agencies may be capable of providing assistance in the development of air quality standards and implementation plans in a designated air quality control region.

The prerequisite for being designated a Standard Metropolitan Statistical Area (SMSA) is that an area contain a core city of at least 50,000 persons as well as adjacent cities and towns which are found to be metropolitan in character and are economically and socially integrated with the central city or cities. In accordance with this definition, it would be logical to consider SMSA's either singly or in combination with neighboring SMSA's as the minimal geographic area over which a regional air resource management program should operate. Figure 12 shows the boundaries of the several SMSA's located in Rhode Island and eastern Massachusetts. Also shown are the 1969 estimated populations of each of these areas. The Providence-Pawtucket-Warwick SMSA is interstate in nature. Within its bounds are 10 cities and towns in the State of Massachusetts. This SMSA encompasses the majority of the eastern portion of the State, and in addition reaches to the extreme western and southern borders of Rhode Island. The Providence Standard Metropolitan Statistical Area is contiguous to the Boston and Fall River SMSA's.

The Fall River SMSA is interstate in nature, including four cities and towns in Massachusetts and one town in Rhode Island. The New Bedford SMSA includes six Massachusetts cities and towns. Each of these two areas contains approximately 150,000 persons. A strip of land several towns wide, at some points, is sandwiched between the New Bedford, Fall River and Providence SMSA's to the south and west, and the Boston and Brockton SMSA's to the north. At the present time, these several cities and towns, including Taunton, Middleborough, and Plymouth, are not included within any SMSA's.

Figure 13 defines the boundaries of the various regional planning districts in the study area. The figure indicates that the two major regional planning groups in the State of Rhode Island have jurisdiction over the entire State. These two groups are the Rhode Island Development Council and the Statewide Comprehensive Transportation and Land Use Planning Program. The Statewide Planning Program is an inter-agency program sponsored in part by the Rhode Island Development Council. Together these agencies are responsible for conducting planning functions throughout the State, including the production of a comprehensive plan to guide the future development of the

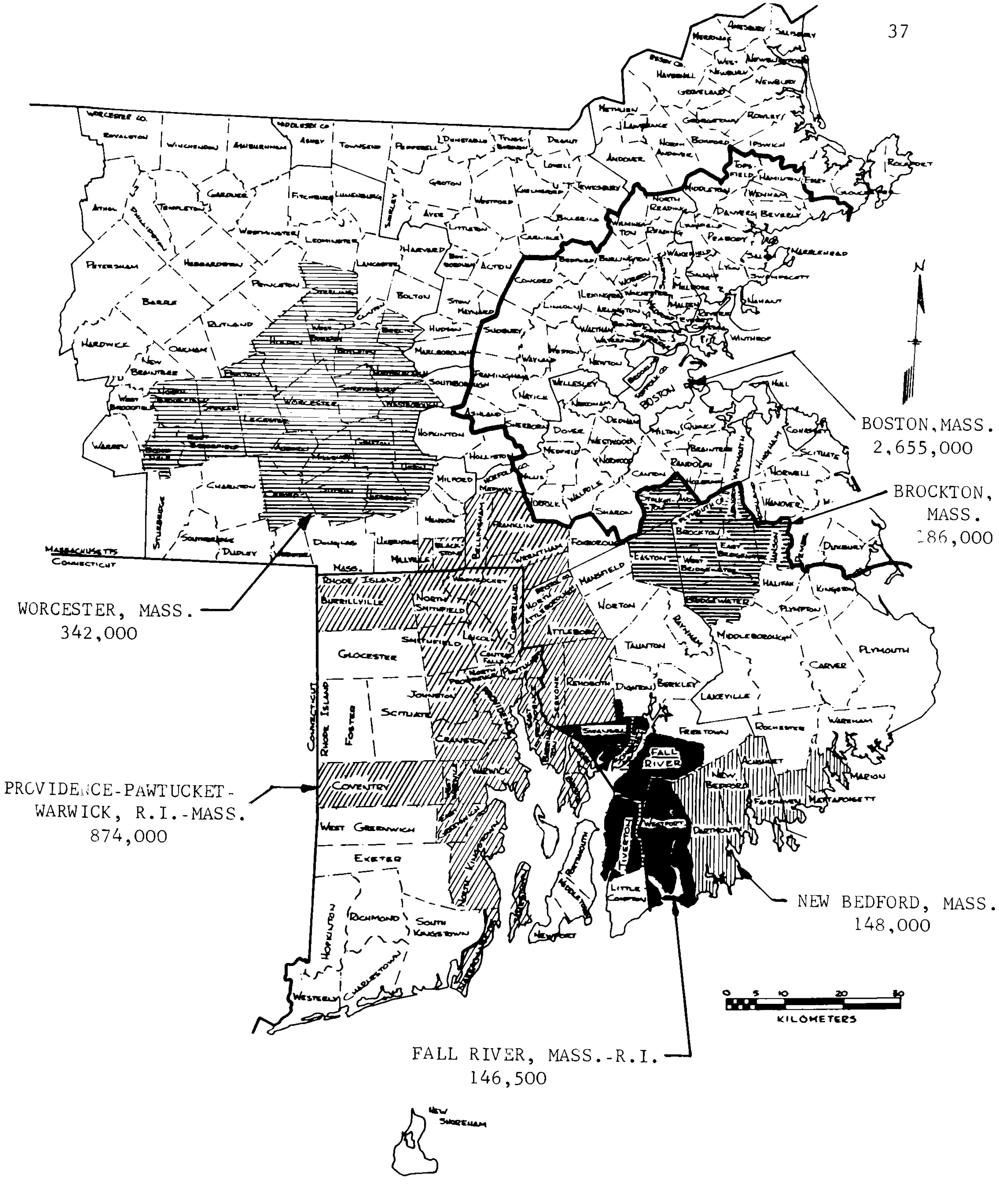


FIGURE 12. STANDARD METROPOLITAN STATISTICAL AREAS IN RHODE ISLAND AND EASTERN MASSACHUSETTS.

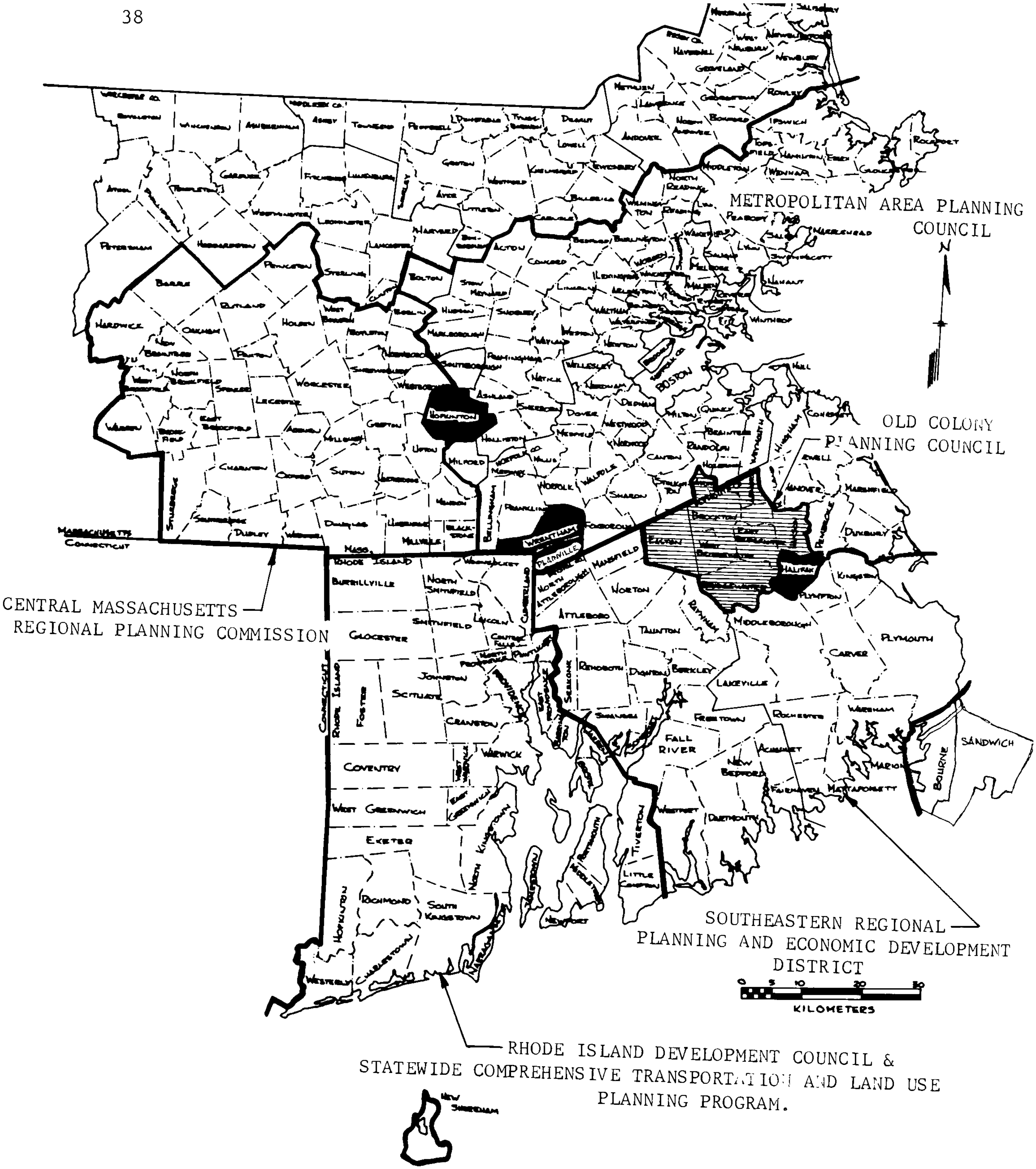


FIGURE 13. BOUNDARIES OF REGIONAL PLANNING AGENCIES IN RHODE ISLAND AND EASTERN MASSACHUSETTS.

State. Also, it is hoped that their efforts will lead to the establishment of a permanent administrative and technical framework for inter-governmental planning and cooperation on a continuing basis.

In southeastern Massachusetts, the Southeastern Regional Planning and Economic Development District is the agency responsible for the preparation of comprehensive regional plans and economic development programs. The District was formed in 1968 by legislative enactment. It encompasses all of the New Bedford SMSA as well as the entire Massachusetts portion of the Fall River SMSA. In addition, it includes within its jurisdiction four Massachusetts cities and towns which are also in the Providence SMSA, and all those remaining jurisdictions in southeastern Massachusetts (excepting Halifax) which are not included in any SMSA's. The District has been directed to conduct studies of the resources, problems and needs of the region and to make recommendations for the physical, social and economic improvement of the region. The District is further required to conduct research and surveys for the purpose of formulating regional goals related to the comprehensive physical, social and economic improvement of the region.

Contiguous to the Southeastern Regional Planning and Economic Development District are the Old Colony Planning Council (OCPC) and the Metropolitan Area Planning Council (MAPC). To the north of Rhode Island, and contiguous to the MAPC, is the Central Massachusetts Regional Planning Commission. Together these regional planning districts include all the communities in the area of concern with the exception of Wrentham and Plainville at the northeast corner of Rhode Island, and the town of Halifax located to the northwest of Plymouth.

Figure 14 shows the boundary of the recently established Metropolitan Boston Intrastate Air Quality Control Region. The boundaries of the

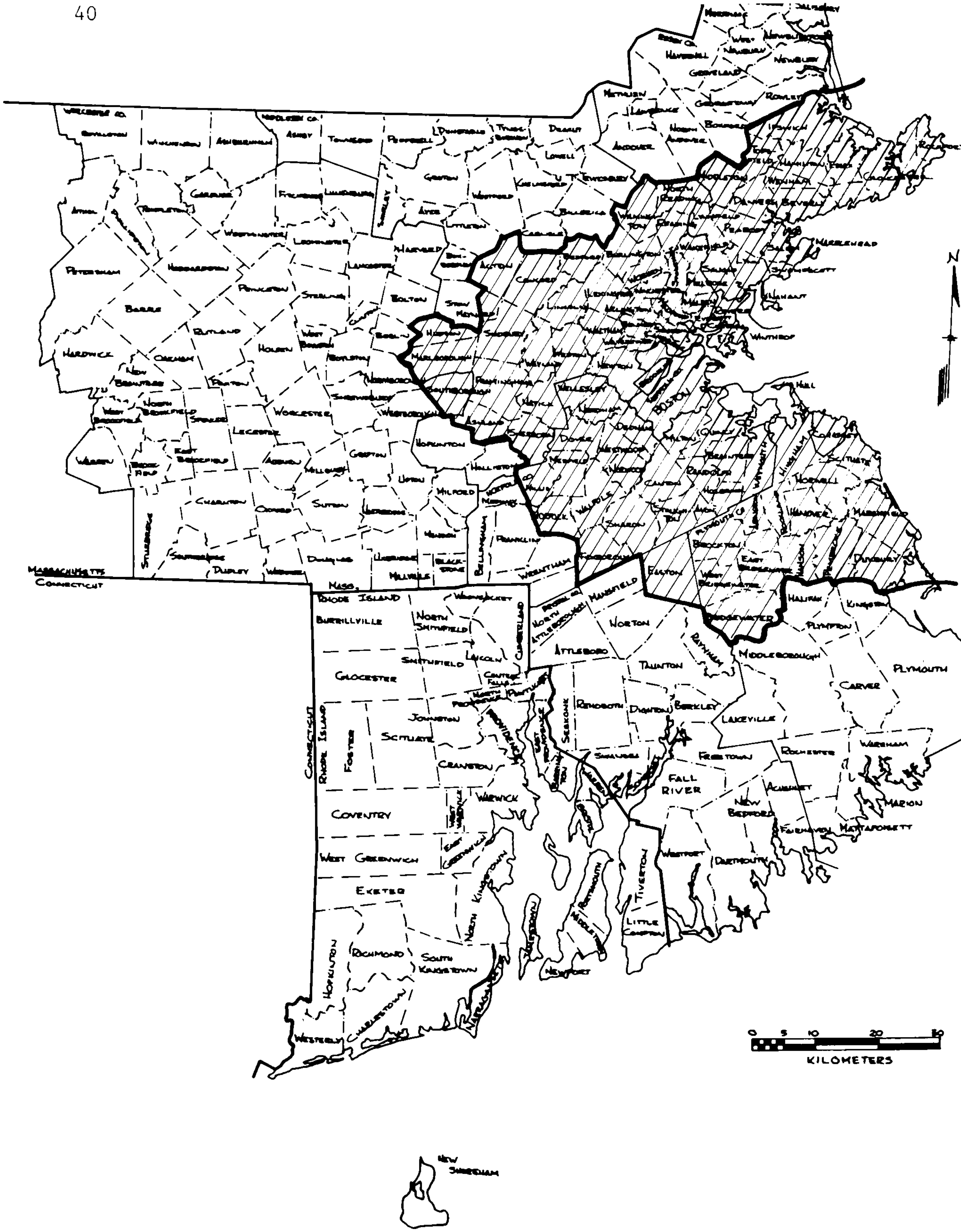


FIGURE 14. METROPOLITAN BOSTON INTRASTATE AIR QUALITY CONTROL REGION.

Metropolitan Boston Region closely approximate the combined boundaries of the MAPC and the OCPC. The Southeastern Regional Planning and Economic Development District is contiguous to the entire southern border of the Boston Air Quality Control Region with the exception of the border around the town of Halifax. Also, the towns of Plainville, Wrentham, and Franklin, which are members of the Providence SMSA, are contiguous to the Metropolitan Boston Region. Any effort to establish boundaries for the Providence Region should take into account the boundary locations of the Boston Air Quality Control Region.

EXISTING AIR POLLUTION CONTROL PROGRAMS AND LEGISLATION

In the process of defining the bounds of an air quality control region it becomes important to consider the role of existing State and local air pollution control programs. It is also important to review pertinent legislation which allows for the promulgation of air pollutant control regulations and which grants enforcement powers to agencies at the State and local levels. Such analysis is critical since the ultimate responsibility for implementing region-wide air quality standards rests upon State and local programs.

Responsibility for the control of air pollution in Massachusetts rests with the State Department of Public Health. The State Legislature has authorized the Department to adopt (minimum) State-wide air pollution regulations. The application of such regulations was intended for air pollutant emissions arising from State institutions, mobile sources, sources causing inter-municipal pollution effects, and sources which could and should be controlled by other agencies, but are not. The Department has the authority to approve rules and regulations promulgated by local control bodies, and are further authorized to advise local control bodies in all matters of atmospheric pollution. Existing law gives local boards of health the authority to adopt and enforce air pollution rules and regulations (subject to the approval of the State Department of Public Health).

The State Department of Public Health may, upon request of the board of health of a town adversely affected by atmospheric pollution from another town, assume joint jurisdiction to regulate or control such cause of air pollution. Enabling legislation passed in 1960 authorizes the Department of Public Health, upon request of two or more contiguous municipalities within the State, to establish multi-municipal regional air pollution control districts. Such districts have been established in the Boston and Springfield metropolitan areas in accordance with this legislation. Rules and regulations to prevent and control pollution within these districts have been adopted by the Department. The Department has the authority to order the cessation or abatement of any violations of these regulations, subject to penalty.

Recently, the Governor of Massachusetts proposed legislative action which would enable the State Department of Public Health to meet more easily the requirements of the Federal Air Quality Act. The proposed legislation would enable the Department of Public Health to establish additional air pollution control districts and further, would allow for the alteration of existing districts in the State so that they would be compatible with Federally designated air quality control regions. Proposed legislation would also authorize air pollution inspections and would provide for the issuance of warrants for such inspections when consent is refused. In addition, the Department of Public Health would be given greater enforcement powers to prevent and control air pollution from other public agencies. Legislation has also been proposed with respect to fuel additives, open burning and solid waste disposal, and emission control devices on automobiles.

The Rhode Island Clean Air Act, which formed the Division of Air Pollution Control within the State Department of Health, went into effect on January 1, 1967. Under this Act the new Division was given sole responsibility for achieving air quality throughout the entire State of Rhode Island. All existing municipal air pollution control agencies ceased to operate. The law created a 5 member Advisory Air Pollution Board whose duty is to advise the Director of the State Department of Health concerning policies, plans, and goals in relation to the administration of the law, and to submit recommendations to the Director. The Director is required to exercise general supervision of the administration and enforcement of the law and all rules and regulations promulgated under the law. He is directed to develop programs for the prevention, control, and abatement of atmospheric pollution and to promulgate air quality standards for the State or any region or district of the State. It is the Director's duty to advise, consult, and cooperate with the cities and towns and other agencies of the State, Federal Government, and other States and interstate agencies in carrying out air pollution control. The Director is also given authority to promulgate rules and regulations for the control of air pollution, to inspect public and private property, to conduct hearings, to require the prior submission of plans relating to pollutant producing facilities, and to determine the emission of air contaminants from premises through means of testing.

Six basic regulations have been established which apply on a uniform State-wide basis. Among these regulations are included control of visual emissions, dusts and fumes, particulate matter, and other airborne nuisances.

SUMMARY

The metropolitan Providence and southeastern Massachusetts study area includes several core cities--Providence, Rhode Island, and Fall River and New Bedford, Massachusetts--as well as the surrounding developed areas associated with each of these core cities. The combined urban area encompasses most of eastern Rhode Island as well as a broad area in Massachusetts bordering the coast and the State of Rhode Island. Much of western Rhode Island remains non-urban. Similarly a band of Massachusetts communities stretching eastward from Mansfield to Plymouth remains only moderately developed. These Massachusetts communities are not related directly to any surrounding core cities. They are included within the jurisdiction of the Southeastern Regional Planning and Economic Development District, however, along with those cities and towns in the Fall River and New Bedford metropolitan areas. In addition the Southeastern Planning District includes many of those Massachusetts cities and towns considered as part of metropolitan Providence.

In Rhode Island, existing regional planning groups have jurisdiction over the entire State. In addition, air pollution control in Rhode Island is effected solely at the State level.

The minimum desirable extent of the Region based on a consideration of urban factors would be the combined area of the Providence, New Bedford, and Fall River SMSA's. However, existing regional planning is conducted by several agencies for the entire southeastern Massachusetts region as well as for the entire State of Rhode Island. The boundaries of these planning regions serve as better guides for the Region boundaries if long-range air quality goals are considered.

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 Providence, Rhode Island and Southeastern Massachusetts interstate area. The proposed Region consists of the following jurisdictions:

The Entire State of Rhode Island

In the State of Massachusetts:

Cities	Towns	
Attleboro	Acushnet	Mattapoisett
Fall River	Bellingham	Middleborough
New Bedford	Berkley	Millville
Taunton	Blackstone	North Attleborough
	Bourne	Norton
	Carver	Plainville
	Dartmouth	Plymouth
	Dighton	Plympton
	Fairhaven	Raynham
	Franklin	Rehoboth
	Freetown	Rochester
	Halifax	Sandwich
	Kingston	Seekonk
	Lakeville	Somerset
	Mansfield	Swansea
	Marion	Wareham
		Westport
		Wrentham

As so proposed, the Metropolitan Providence Interstate 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, 42 U.S.C. 1857h(f). Figure 15 shows the boundaries of the proposed Region while Figure 16 indicates the geographic relationship of the Region to surrounding areas.

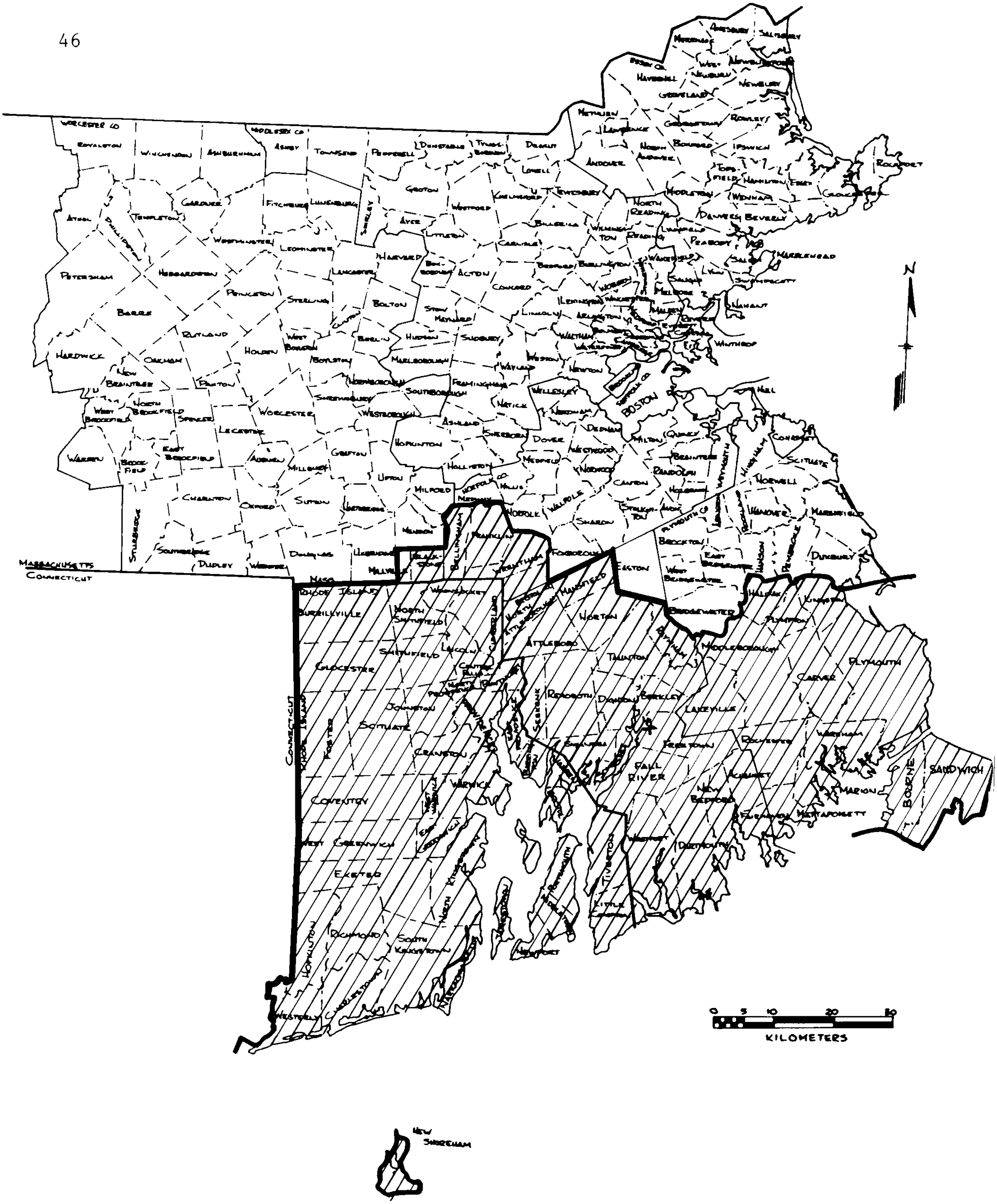
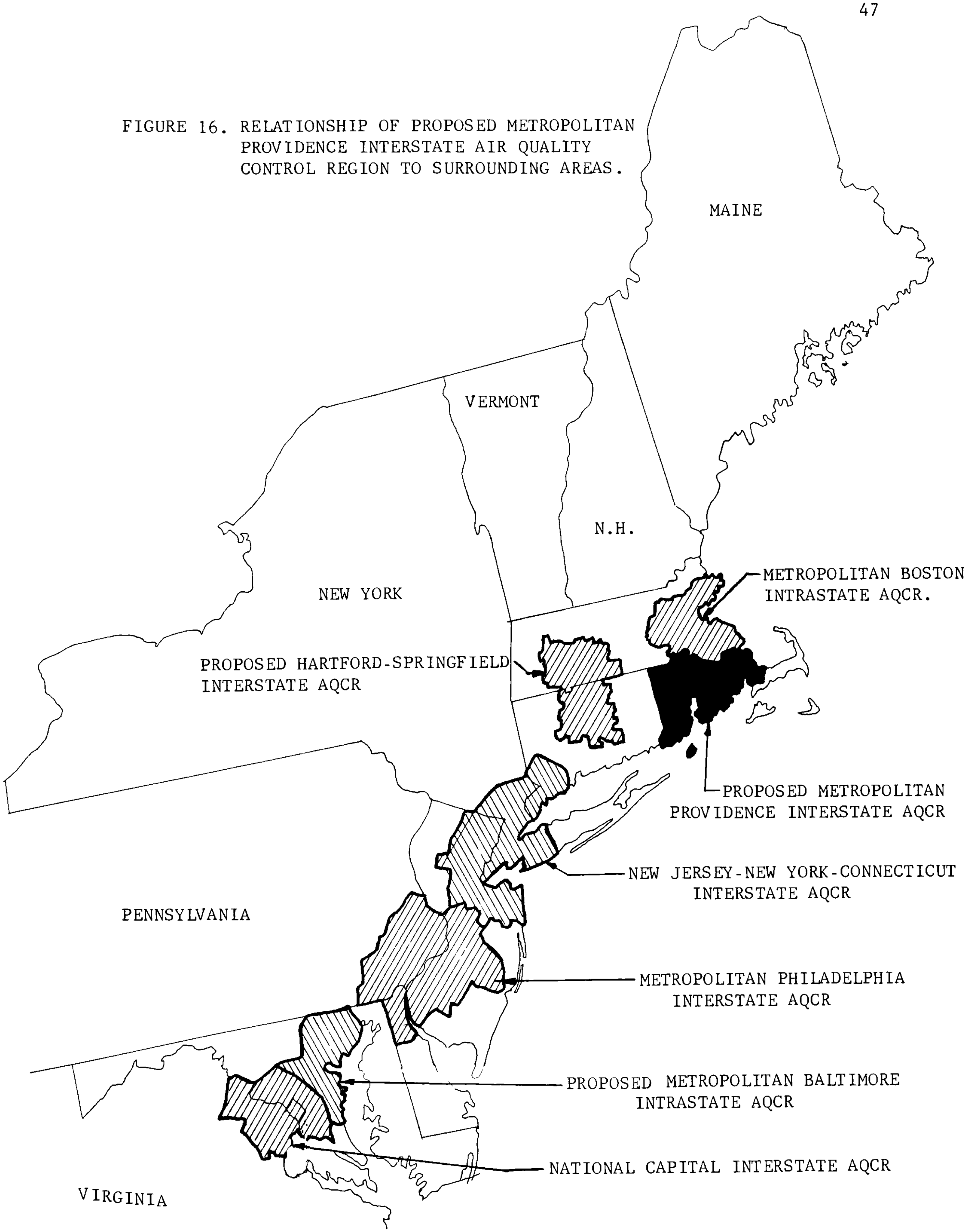


FIGURE 15. PROPOSED METROPOLITAN PROVIDENCE INTERSTATE AIR QUALITY CONTROL REGION.

FIGURE 16. RELATIONSHIP OF PROPOSED METROPOLITAN PROVIDENCE INTERSTATE AIR QUALITY CONTROL REGION TO SURROUNDING AREAS.



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 boundaries chosen should be compatible with the existing intentions of the State agencies to effect air pollution control on an areawide basis. The proposed region boundaries should serve to reinforce the exercise of State air pollution control in multi-municipal districts where such districts exist. In addition, the region boundaries selected should serve to strengthen the working relationship of inter-State or State-local governmental jurisdictions. Hopefully too, the proposed region will serve to foster such multi-jurisdictional relationships as a vehicle for cooperative regional governmental administration of the air resource.

The problem of air pollution is one in which harmful pollutants are emitted from identifiable sources and are subsequently transported over large areas to detrimentally affect people and property. The locations of these pollutant sources and receptors are definable. A pollutant source-emissions inventory was conducted over the Providence, Rhode Island, and southeastern Massachusetts interstate area. The majority of the quantities of sulfur dioxide, total particulates, and carbon monoxide emitted were attributable to industrial, power generation, residential, transportation (road vehicles), and open-burning sources. The geographic pattern of pollutant emissions reflected the pattern of urbanization over the study area since these source types themselves are an integral part of the urban pattern. Pollutants were thus emitted in greatest quantities in the major cities of Rhode Island-Providence, Pawtucket, Warwick, and Cranston--and southeastern Massachusetts--Fall River and New Bedford. It is in these cities, or in their immediate vicinities, that population, industry, and dwelling unit concentrations are greatest, and where pollutant producing human activity (e.g., motor vehicle traffic) is most intense.

It is clear that these above-defined urban areas will necessarily bear the heaviest burden of pollutant concentrations in the ambient air. Transport of this pollution affects the air over larger geographic areas, though to a lesser degree, than in the urban core areas. Some means of measuring air quality is thus necessary in order to determine the extent of the area affected.

A meteorological diffusion model, which predicts air quality based on meteorological and emissions input parameters, was used to determine the geographic dispersion patterns of the various pollutants. The importance of the model in this study was to predict <u>spatial distributions</u> of pollutant concentrations in the atmosphere, and to predict <u>relative</u> concentrations. Winter season dispersion patterns for SO_2 and total particulates reveal an elongation of the equal-concentration contours on a northwest-southeast axis. This axis follows a line from Providence to Fall River and New Bedford. The transport of pollutants from the source areas is primarily toward the east. Thus, pollutant transport is greatest from Rhode Island to Massachusetts, while transport from the Fall River and

New Bedford areas affects additional Massachusetts cities and towns to the north and east. This same trend in pollutant dispersion toward the eastern quadrants is typified by the summer season CO diffusion pattern.

Measured air quality data for the study area is limited in the length of time for which sampling has occured, in the variety of pollutants sampled for, and to the geographic extent of sampling networks. As a result, few conclusions regarding the desired outer limits of the Region can be reached from existing air quality data.

In summary, the engineering evaluation indicates that an interstate region-wide air pollution problem, which includes the Providence, Rhode Island, and Fall River and New Bedford, Massachusetts metropolitan areas, exists. Based on pollutant source locations, the smallest logical air pollution control region should include an area approximating the SMSA's of these three cities. A consideration of pollutant receptors requires that this area be enlarged in size, though the limited pollutant emission survey area, the lack of reliable air quality information, and the use of city and town boundaries in defining the region makes this area determination more difficult. As a result, it becomes desirable to find some other bases upon which the Region boundaries may be established.

The procedure of the National Air Pollution Control Administration in designating air quality control regions is to define region boundaries, where feasible, corresponding or at least compatible with State established planning and development regions. The importance of a Federally designated region which is geographically compatible with a State defined region or regions will be realized subsequent to the designation of the air quality control region, when standards of air quality must be set, and an implementation plan must be devised to achieve the air quality goal.

The various regional planning agencies may be capable of providing assistance in the development of air quality standards and implementation plans which recognize the close relationship between air quality management and fields such as transportation, land-use patterns, solid waste disposal, etc.

Important, too, is a consideration of State and local air pollution control programs and their approach to a regional management of the air resource. Since the ultimate responsibility for implementing region-wide air quality standards rests with the official State agencies, it is desirable to designate region boundaries compatible with functional State-designated air pollution control districts, where they exist.

In the State of Rhode Island, Planning is conducted on a Statewide basis by the Rhode Island Development Council and the Statewide Comprehensive Transportation and Land Use Planning Program. In addition, air pollution control within Rhode Island exists only at the State level. No municipal control agencies exist. For these reasons, the entire State has been proposed for inclusion in the Region.

In Massachusetts, virtually the entire southeastern portion of the State is under the jurisdiction of the Southeastern Regional Planning and Economic Development District. It would be most sensible to expand the Massachushetts portion of the Providence, and the Fall River and New Bedford SMSA areas to the boundaries of the Southeastern Planning District. The inclusion of this area in the Region provides for additional growth, which will be substantial in the presently moderately developed areas. Such a Region would be contiguous to most of the southern border of the recently established Metropolitan Boston Intrastate Air Quality Control Region. The town of Halifax, which is not in the Boston Air Quality Control Region or in the Southeastern Planning District, has been included in the proposal along with the jurisdictions within the District.

Six towns in Massachusetts (Plainville, Wrentham, Franklin, Bellingham, Blackston, and Millville) are members of the Providence SMSA but are not under the jurisdiction of the Southeastern Regional Planning and Economic Development District. Plainville and Wrentham are not presently included in any regional planning agency. Franklin and Bellingham are members of the Metropolitan Area Planning Council, while Blackstone and Millville are members of the Central Massachusetts Regional Planning Commission. These six towns have been included in the proposal for the Providence Region, however. Bellingham, Franklin, Millville, and Blackstone have been recommended for inclusion since their social and economic relationship to Providence is greater than to the central city--Boston or Worcester--of the planning regions to which they belong. Also, they are closely tied to a common air pollution problem with the remainder of metropolitan Providence, as the engineering evaluation has shown. For similar reasons, the towns of Plainville and Wrentham have been included in the proposal.

The towns of Bourne and Sandwich have been proposed as part of the Region since a power plant is presently located in the town of Sandwich. These towns can at present be considered non-urban. However, the inclusion of these jurisdictions in the Region should help to preserve the air of presently acceptable quality within them.

As is true of most efforts to draw boundaries around an area to differentiate it from its surroundings, there is always a likelihood of boundary conditions existing or developing. In the case of air quality control regions, such a boundary condition would exist where sources of pollution on one side of the region boundary affect in some real way air quality on the other side of the boundary. Relocating the boundary would only rarely provide relief from this condition. The solution is to be found in the way in which control efforts are implemented following the designation of an air quality control region. Consonant with the basic objective of providing desirable air quality within the problem area being designated as an air quality control region, the implementation plan that follows the designation should have provisions for the control of sources located close to but beyond the region boundaries. The level of control for such sources should be a function of, among other factors, the degree to which emissions from sources cause air quality levels to exceed the standards chosen for application within the air quality control region. The boundaries of the Metropolitan Providence Interstate Region were selected so as to minimize the pollutant transport boundary problems mentioned above.

In summary, the Region proposed is considered on the whole to be the most cohesive and yet inclusive area within which an effective regional effort can be mounted to prevent and control air pollution in the Rhode Island and Massachusetts interstate area. Official designation of this Region will follow the consultation with appropriate State and local officials, and after due consideration of comments presented for the record at the consultation or of those 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 assumed 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 source 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 Providence area.* They represent graphically the frequency of occurrence of the wind from the various compass directions. This data, along with effective wind speeds for the respective commpass directions was used as input data to the computerized model. The characteristic prevailing wind directions for each of the averaging times as depicted

*U.S. Weather Bureau Data for T.F. Green Airport, Warwick, Rhode Island, 1951 through 1960.

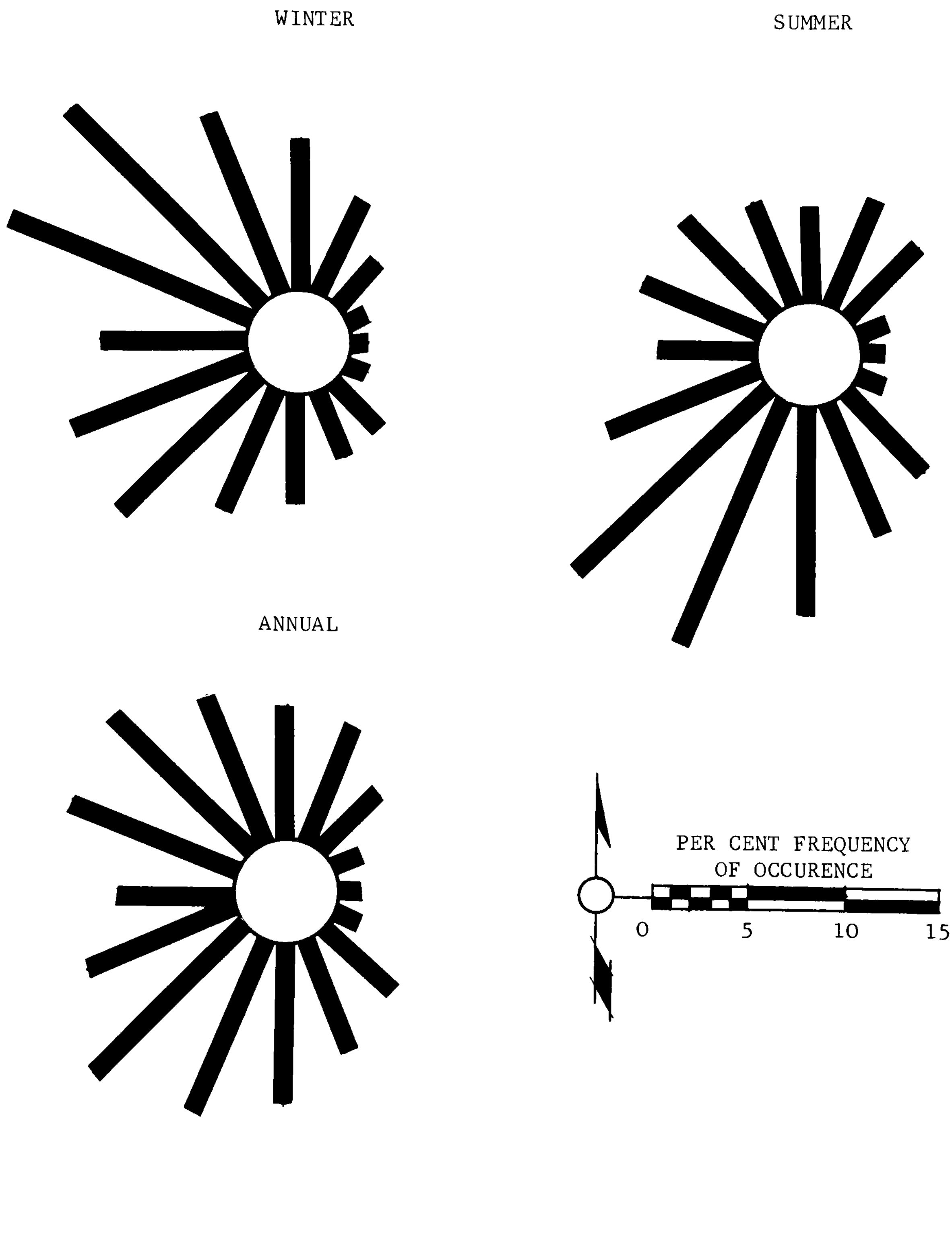


FIGURE 1-A. WIND DIRECTION PER CENT FREQUENCY OF OCCURENCE FOR VARIOUS AVERAGING TIMES.

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 winter, summer, and annual averaging periods.* 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 Providence
by Season and Time of Day (meters)

Season	Morning Average	Afternoon Average	Average, Morning and Afternoon
Winter	705	825	765
Summer	405	1085	745
Annual (four seasons)	572	952	762

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 mest points 15 kilometers apart. This grid, 210 km. on a side, was centered in the City of Providence. 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.

*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.

APPENDIX A. REFERENCES

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