H. Viebrock

ESSA RESEARCH LABORATORIES

Air Resources Laboratory
Cincinnati, Ohio
March 1969

Fiscal Year 1968 Summary Report of Division of Meteorology Support to the National Air Pollution Control Administration U.S. Department of Health, Education, and Welfare

Technical Memorandum ERLTM-ARL 12

U.S. DEPARTMENT OF COMMERCE / ENVIRONMENTAL SCIENCE SERVICES ADMINISTRATION

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U.S. DEPARTMENT OF COMMERCE
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FISCAL YEAR 1968 SUMMARY REPORT OF DIVISION OF METEOROLOGY SUPPORT TO THE NATIONAL AIR POLLUTION CONTROL ADMINISTRATION U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

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PREFACE

Effective communication between individuals or groups is a difficult activity. This is especially true of communications about new problems and new research, since much must be left unsaid and many questions unanswered. Nevertheless, periodic summaries of work performed constitute a valuable information source as well as a management "how goes it" tool.

The work reported herein is funded by the National Air Pollution Control Administration (NAPCA) and is accomplished under agreement between the NAPCA and the Environmental Science Services Administration (ESSA), dated January 29, 1968.

Any inquiry on the research being performed should be directed to Mr. R. A. McCormick, Director, Division of Meteorology, National Air Pollution Control Administration, 5710 Wooster Pike, Cincinnati, Ohio, 45227.

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FISCAL YEAR 1968 SUMMARY REPORT OF DIVISION OF METEOROLOGY SUPPORT TO THE NATIONAL AIR POLLUTION CONTROL ADMINISTRATION DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE

The following brief summaries of meteorological research and other activities attempt to convey the present status of a variety of projects being conducted by the Air Resources Cincinnati Laboratory for the National Air Pollution Control Administration.

Key Words: Air Pollution potential (APP) forecasting and climatology, dispersion, transport, diffusion, dilution, urban diffusion modelling, turbidity, radiation, lidar, tall stack, large power plant, urban heat island, mixing depth, inversion, stagnation, air quality control region, urban boundary layer.

1.0 HIGHLIGHTS

Initial attempts to quantify air pollution potential (APP) forecasts have employed a simple box model, based on mixing depth and wind speed values, to yield an average normalized concentration. The mixing depth concept is most applicable in regions of light winds (stagnation) and, fortunately, it is in such regions that forecasts of mixing depth and wind speed verify best.

A comprehensive investigation of the transport and dispersion of plumes from tall stacks (800 ft), constituting the Large Power Plant Effluent Study (LAPPES), was initiated at a coal burning power station complex in Western Pennsylvania. Plume rise, plume geometry, dispersion, and SO_2 concentration measurements have been obtained, using instrumented helicopters and a mobile lidar, both under contract. Peak ground-level SO_2 concentrations

as high as 1.4 ppm (parts per million), about 1 km from the stack source, have been measured; a 30-min average concentration of 0.3 ppm has been measured at a distance of 10 km.

Field investigations of the urban heat island have been conducted in Cincinnati to describe the nocturnal urban temperature and wind structure under selected weather conditions. Studies have shown a pronounced modification of the vertical temperature structure over the urban area; this modified layer of air over the city, designated as an "urban boundary layer", was about 150 to 300 ft deep when a strong inversion existed upwind of the city. Within the urban boundary layer the lapse rate was superadiabatic in the central business district and isothermal to weak inversion in the downwind suburban areas; a strong inversion was maintained above the modified urban boundary layer.

An analysis of low-level tracer experimental data, obtained during the St. Louis Dispersion Study, indicates that the urban area enhances the initial horizontal and vertical dispersion of a plume, compared to plume dispersion over relatively flat non-urban terrain.

Tabulations by the National Weather Records Center, ESSA, of morning and afternoon mixing depths and the vertically averaged wind speeds through each corresponding depth, have been prepared for 41 Weather Bureau upper air stations. These data are being analyzed to prepare an air pollution potential climatology of the contiguous States.

As a prelude to the designation by NAPCA of Air Quality Control Regions (AQCR), required by the Air Quality Act of 1967, a geographical delineation

of eight Atmospheric Areas for the 48 contiguous States was accomplished. Each Area represents a region of dilution climate homogeneity based on professional judgment and documented studies of certain relevant meteorological experience. Meteorological descriptions of AQCR's provide estimates of the geographical distribution of mean annual ground-level concentrations of SO_x, CO, and suspended particulates, based on pollutant source inventories provided by NAPCA.

Measurements of turbidity in Cincinnati indicate that the total number of particles suspended in the atmosphere is less in winter, with a higher proportion of large particles, than in summer. The wavelength variation of turbidity indicates absorption in the spectral region of 0.59μ, which may be due to ozone. Measurements of ultraviolet radiation (UV) show a marked reduction of UV received at the ground on days of heavy air pollution.

2.0 TRANSPORT AND DIFFUSION OF AIR POLLUTANTS

2.1 Air Pollution Potential (APP) Forecasting

In November 1967, an optional narrative section was added to the Air Pollution Potential (APP) Advisory message that is transmitted over teletype by the National Meteorological Center (NMC, ESSA). This narrative is intended to supplement the APP forecasts by specifying possible geographical areas of reduced ventilation that do not meet the spatial or meteorological criteria defining an area of high APP. During the period July 1967-June 1968, 10 episodes of high APP were forecast, 8 in the East and 2 in the West.

It has been found that forecasts of mixing depth and transport wind speed verify best in regions of weak circulation (stagnation). Hence, a study was undertaken (using microfilm of meteorological surface and upper air charts of past high APP episodes) to identify such stagnation areas in terms of various parameters that are readily forecast by the Weather Bureau. The parameters considered included wind speed (u) at 850 mb (at 700 mb over higher terrain), absolute vorticity (V) at 500 mb, and the 12-hr absolute change of temperature (ΔT) at 850 mb (at 700 mb over higher terrain). These parameters were examined for the high APP areas forecast during 1965-1967. It was concluded that stagnation areas defined by u less than 20 kt, v less than 10^{-4} s^{-1}, and ΔT less than $5^{o}C$ generally agreed well with the APP forecast areas. As an example, figure 1 shows the areas of weak circulation (hatched) based on data for 12 GMT, November 24, 1966 (Thanksgiving Day). The small areas of stagnation (hatched) in the middle and western part of the country were of insufficient duration to be important. The large region of stagnation in the east persisted for about 2-1/2 days. This technique, when applied to episodes of high APP between 1965 and 1967, adequately delineated the major stagnation zones and generally coincided with the episode forecast areas.

When stagnation is forecast to persist for at least about 36 hr, a quantitative assessment of the situation is made, based on mixing depth and wind speed. This assessment employs a simple box model to obtain values of average concentration over the city of specified linear dimension (C)

$$\chi/Q = 1/2 \frac{C}{LU}$$

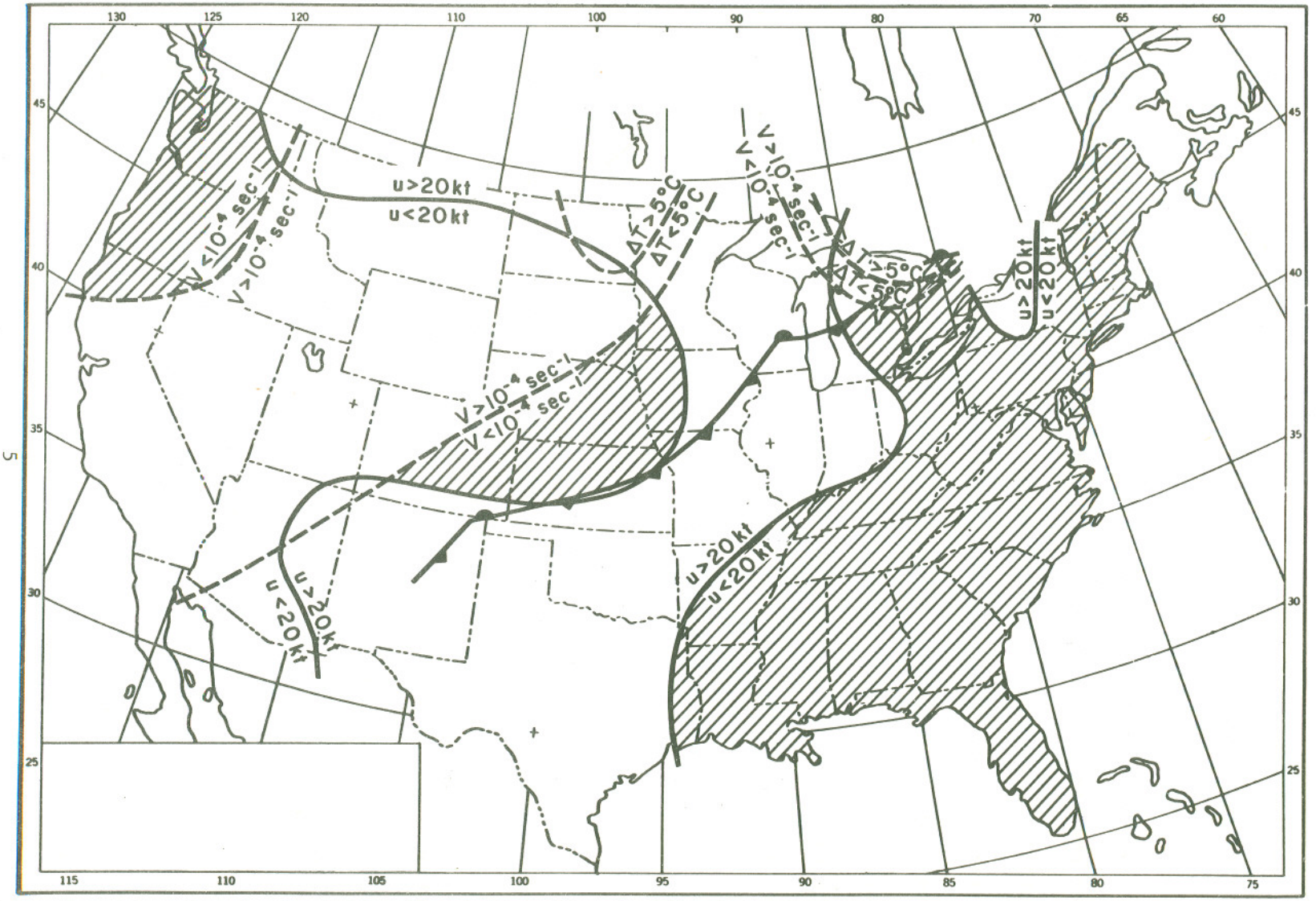

Figure 1. Area of weak circulation (hatched) on November 24, 1966, based on 1200 GMT data and the criteria: (a) winds (u) at 850 mb (700 mb over higher terrain) less than 20 kt ; (b) absolute vorticity (V) less than 10^{-4} s^{-1}; (c) 12-hr temperature change (ΔT) at 850 mb over higher terrain) less than 5°C.

where C = city size (m)

L = mixing depth (m)

U = wind speed (m/s)

χ = concentration (g/m^3)

Q = area source strength ($g/m^2/s$).

Since the normalized concentration (χ/Q) is a linear function of city size, to obtain an average concentration for over the city the term 1/2 is applied. Figures 2 and 3 show the respective morning and afternoon average normalized concentration values (χ/Q) for November 24, 1966, based on the observed meteorological data and for a city size C = 50,000 m. Note the large diurnal variation of χ/Q. The heavily stippled area represents the forecast area of high APP.

2.2 Large Power Plant Effluent Study (LAPPES)

In July 1967, a study was initiated in Western Pennsylvania to evaluate the effects of air pollution resulting from the largest complex of coal burning power plants in the United States. Three power stations, each of which will eventually generate approximately 2000 MW of electrical power, are to be supplied 2.5 percent sulfur-bearing coal directly from nearby mines and will emit daily more than 2000 tons of sulfur dioxide gas into the atmosphere. The three stations are about equally spaced along a line (orientated northwest-southeast) 25 mi long about 50 mi east of Pittsburgh, Pennsylvania. Questions raised by health and air pollution control agencies regarding the potential effects of the airborne effluents from these plants cannot be answered in a definitive

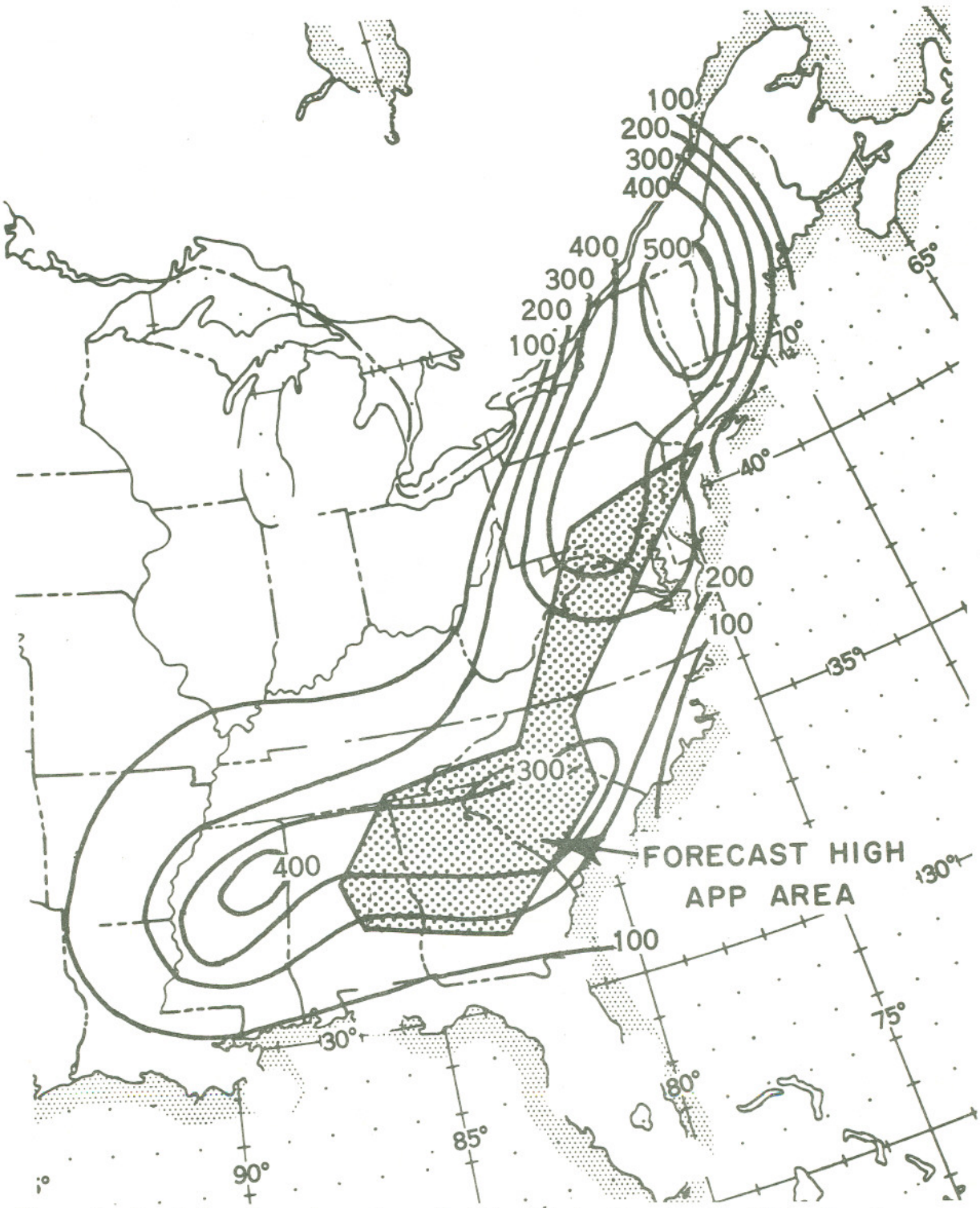

Figure 2. Isopleths of morning values of $\chi/Q(s\ m^{-1})$ for November 24, 1966. Heavily stippled area represents forecast area of high air pollution potential.

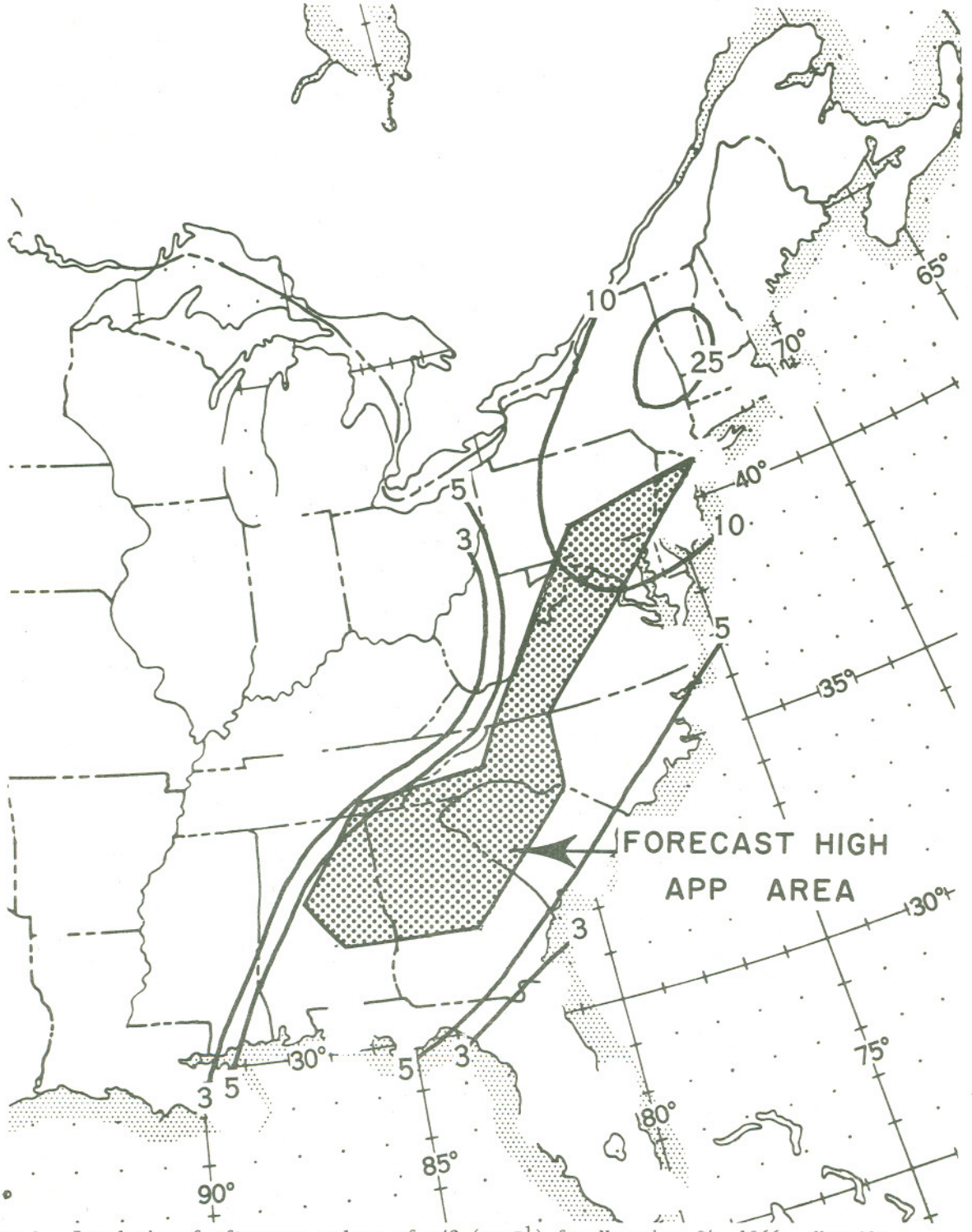

Figure 3. Isopleths of afternoon values of χ/Q (s m^{-1}) for November 24, 1966. Heavily stippled area represents forecast area of high air pollution potential.

way by simple extrapolation of experience from the existing smaller capacity installations. Accordingly, NAPCA is conducting or sponsoring comprehensive field studies to resolve some of the more pressing questions regarding tall stack dispersion from large power plants. Specifically, three objectives are being pursued at the Western Pennsylvania site:

1. To develop and validate transport and diffusion models which give calculations of expected ground-level concentrations of effluents from large power plants.

2. To measure the magnitude, frequency, and spatial distribution of ground-level concentrations from large power plants and tall stacks, singly and in combination, and to compare the observed data with calculated predictions.

3. To evaluate the deleterious effects of sulfur compounds and other effluents from a large power plant complex on vegetation in the region of the installations.

Observations to meet these objectives consist of: (1) direct measurements of the plume aloft and at the earth's surface with a specially instrumented helicopter including a fast response sulfur dioxide detector system; (2) plume rise measurements by helicopter and by ground-based lidar; (3) sulfur dioxide measurements at fixed network stations and at random mobile locations when the plume was fumigating; (4) radiosonde, rabal, and double-theodolite pibal observations; (5) monitoring of selected plots of trees to determine the rate of sulfur assimilation.

During the past year four field studies were conducted. The initial 30-day study was performed in October 1967, and subsequent studies were

conducted in March, May, and June-July 1968. One plant is currently in operation; the Keystone Plant near Indiana, Pennsylvania, went into commercial operation August 1967 at half capacity and reached full capacity in June 1968. The remaining two plants will be completed by 1972. Aerometric sampling of the Keystone plume was carried out on 56 days during the periods scheduled for field experiments. On 66 days it was not possible to fly into the plume due to the following factors: 24 days of adverse weather conditions; power plant breakdowns on 34 days; helicopter malfunction on 8 days. However, 250 hr of helicopter time were used to make measurements in the plume and beneath the plume when it was fumigating.

In addition to observations taken by Program personnel, two contractors to Project LAPPES provided data of interest. A team of scientists from Stanford Research Institute used a Mark V neodymium lidar to measure plume rise and define the geometry of the Keystone plume. This was accomplished by a vertical scanning technique with increments of 1/3° to 5° depending upon the vertical extent of the plume. Such scans were obtained by locating to the side of the plume about 4 km downwind and scanning perpendicular to the plume mean centerline and at 45° on either side of the perpendicular. Three cross sections were obtained at approximate distances of 2, 4, and 6 km from the stack. Figure 4 presents an example of a basic lidar observation, and figure 5 presents a vertical cross section of the Keystone plume taken with the lidar. Several general features of the plume are apparent: a horizontal spreading and tilting of the plume due to vertical directional shear, and a central clear cavity on the bottom of the plume, evidently associated with the bifurcation process. Preliminary results

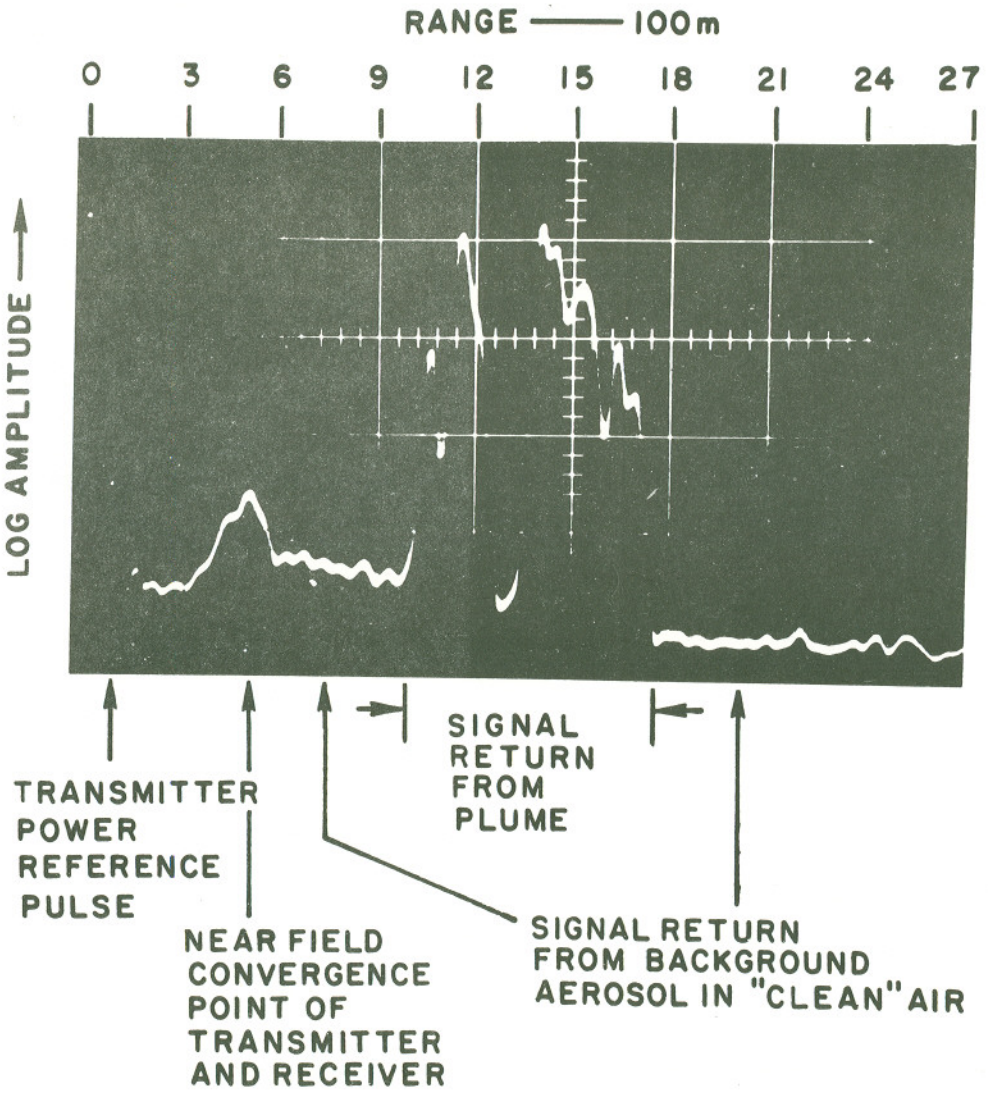

Figure 4. Example of an oscilloscope photograph of a typical lidar shot showing a smoke plume observation (courtesy of Stanford Research Institute).

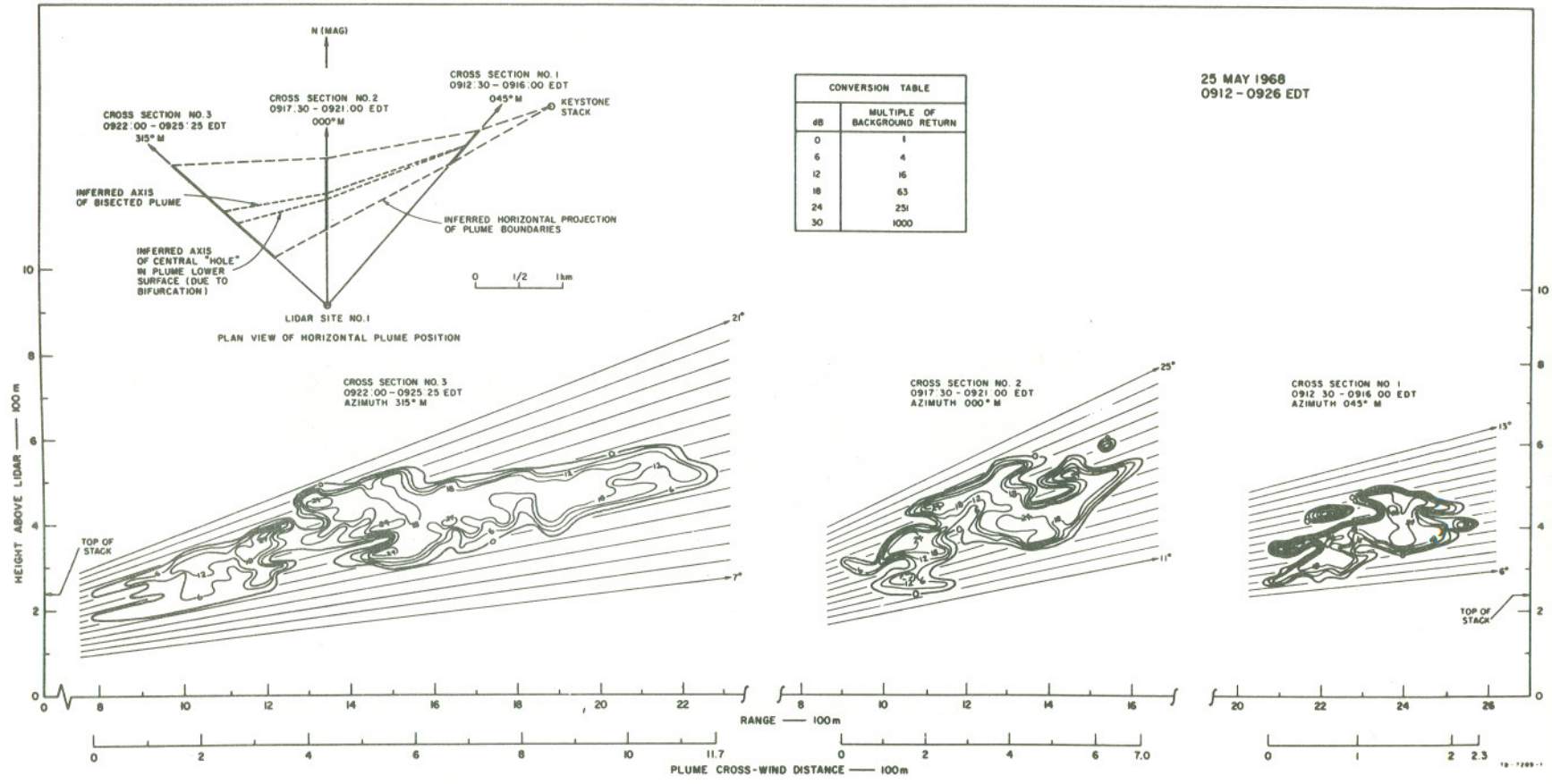

Figure 5. Vertical cross section of plume obtained by means of serial lidar observations in Western Pennsylvania under NAPCA's Project LAPPES (courtesy of Stanford Research Institute).

indicate that lidar cross sections reveal many fine details of plume configuration.

A second contractor also observed plume rise. The Sign X Corp. used an instrumented helicopter to measure SO_2 concentrations, to obtain cross sections, and to perform vertical ascents and descents through the plume within a distance of 6 km from the stack. The Sign X helicopter was instrumented the same as the LAPPES helicopter with one exception: in addition to SO_2, pressure height, temperature, and wet bulb sensors, a space charge derivative unit was used to detect charged particulates in the plume, this enabled simultaneous comparisons with measurements of SO_2 and provided estimates of plume dimension for each plume traverse of both particulates and SO_2.

SO_2 concentrations obtained with the LAPPES helicopter have been analyzed in time and space for the October 1967 and March 1968 series. May and June-July 1968 series data are now being reduced. The available data have indicated peak SO_2 concentrations of 1.4 ppm at ground-level within 1 km of the 800-ft chimney; at 16 km peak concentrations of 0.2 ppm have been measured. A 30-min average concentration of 0.3 ppm at 10 km has been observed from ground based bubbler samples. These concentrations were measured while the plant was operating at about one-half capacity (900 MW).

Future plans call for three field experimental series to be conducted during fiscal year 1969. The first series is scheduled for October-November 1968 and will be the most comprehensive experiment attempted thus far. In addition to our in-house effort we will use subcontractors to obtain plume

rise, turbulence, and dispersion measurements by instrumented aircraft, helicopter, and lidar.

2.3 Urban Diffusion Modelling

A dispersion model adopted for St. Louis (previously described in ESSA Technical Memorandum RLTM - ARL 4, 1968, to calculate 2-hr sulfur dioxide (SO_2) emissions and the resulting 2-hr SO_2 concentrations, was completed and tested. After the initial test runs had been calculated without error, production runs for 89 consecutive days of historical data were completed.

Comparisons were made between calculated 24-hr concentrations and measured concentrations for 40 locations for all 89 days for the same locations. One comparison was by contingency table (fig,6). Skill scores were calculated from each table; the skill score from the data in figure 6 is 0.15. A similar table comparing the observations against estimates using 24-hour persistence, yielded a skill score of 0.12, which indicates that the model is only slightly better than persistence.

Another statistic, using all stations and days, consisted of the fraction of calculated concentrations that was either within $\pm$ 50 percent of observed concentrations, or within $\pm$ 25 μgm^{-3} of observed concentrations (for observed values less than 50 μgm^{-3}); this was determined to be 0.506 for calculated and 0.519 for 24-hr persistence. This statistical comparison indicates that the model and persistence are nearly the same.

The fraction of stations whose concentration was within the above range of observed was determined for each day for both the model and persistence.

24-HOUR CALCULATED CONCENTRATION, μgm^{-3}

24-HOUR OBSERVED CONCENTRATION, μgm^{-3}	0-49	50-99	100-199	200-299	300-399	400-499	≥500	TOTALS
0-49	361	212	132	27	6	2	0	740
50-99	217	241	319	130	36	8	2	953
100-199	105	179	425	258	92	33	12	1104
200-299	9	40	146	110	67	24	8	404
300-399	1	12	33	25	21	4	4	100
400-499	1	1	8	10	2	0	2	24
≥500	0	2	5	4	3	0	2	16
TOTALS	694	687	1068	564	227	71	30	3341

$$\text{SKILL SCORE} = \frac{\text{CORRECT - CHANCE}}{\text{TOTAL - CHANCE}} = \frac{1160 - 778}{3341 - 778} = 0.15$$

Figure 6. Contingency table and skill scores comparing observed 24-hr mean SO_2 concentrations to calculated 24-hr concentrations for St. Louis data.

The model fraction was higher than persistence on 44 days; the persistence fraction was higher than the model on 44 days. They were the same on the remaining day.

The fraction of days for each station with calculated concentrations that were either within $\pm$ 50 percent of observed concentrations or within $\pm$ 25 μgm^{-3} of observed concentrations (for observed values less than 50 μgm^{-3}) was determined; this is the same criterion applied earlier. For 22 of the 40 stations, more than 0.5 of the calculated concentrations were within the designated range. Two-hr measurements were made at 10 of the 40 stations. For all 10 stations for the 89 day period, 0.45 of the calculated 2-hr concentrations were within the above range of observed 2-hr concentrations.

Areas where SO_2 concentrations exceeded 200 μgm^{-3} were determined for each day for calculated and observed concentrations from an analysis of concentration isopleths. A score called the "threat score" relating the calculated and observed areas and the area where both calculated and observed are greater than or equal to 200 μgm^{-3} (the area common to both) was calculated for each day for the model and for persistence; the areas were measured by planimeter. The threat score is C/(Cal + Obs - C) where C is the common area, Cal is the calculated area, and Obs is the observed area. The threat score for the model was higher than persistence on 55 of the 89 days, the same as persistence on 4 days, and lower than persistence on 30 days. An overall threat score, determined by summing the respective areas for all days and then calculating the score, was 0.26 for the model and 0.18 for persistence.

Concentrations were also averaged for each day for three geographical areas: upwind, downwind, and central areas for both calculated and observed concentrations, with the stations in the upwind and downwind areas determined by the 24-hr resultant wind. Calculated area concentrations were within ± 50 percent of observed area concentrations on 69 of 89 days for upwind areas, 64 of 89 days for downwind areas. Seasonal (89 day) average concentrations for each station were determined for both calculated and observed concentrations. Calculated seasonal concentrations were within ± 50 percent of observed at 29 of the 40 stations.

Analysis of the results of the model indicates the following areas of difficulty: inadequate source emission inventory; errors inherent in the grid spacing; assumption of a single 6-hr half-life for SO_2 definition of plume rise for a 2-hr period; definition of a single stability category for a 2-hr period; wind speed and direction shear in the vertical; possible non-Gaussian horizontal distribution of plume over a 2-hr period. Despite these limitations, this model provides slightly more accurate calculated SO_2 concentrations than would be obtained from using 24-hr persistence. Efforts to improve the model are continuing.

2.4 Urban Heat Island Study

It is well known that the atmospheric structure over a city differs from that in an upwind rural area. The modification results from: (1) mechanical turbulence generated by the movement of air over the large roughness elements of the urban area; and (2) thermal turbulence generated by heat produced in the combustion of fossil fuels and by heat stored in

urban structures. The horizontal surface extent of the nocturnal urban-induced modification is well documented in the many "heat island" studies reported in the literature. Considerably less is known, however, about the vertical extent of the urban-induced modification, hereafter referred to as the "urban boundary layer".

Additional knowledge of the urban boundary layer is essential, particularly for further development of comprehensive models of atmospheric dispersion in urban areas. The development and application of such models require that the temporal and spatial variation of the turbulence and wind profiles, both above and within the boundary layer, be defined. Toward this end the Meteorology Division of NAPCA has undertaken a program of field investigations in the Cincinnati, Ohio, metropolitan area. The study consists of: (1) temperature measurements across the city obtained by sensors mounted on automobiles; (2) temperature measurements aloft based on coordinated helicopter soundings obtained along the automobile route; and, (3) pilot balloon observations in both urban and rural areas.

Fifteen urban boundary layer field investigations have been conducted in the Cincinnati metropolitan area. The depth of the nocturnal urban boundary layer was found to be related to the stability of the planetary boundary layer upwind of the city. Figure 7 (looking to the west) is a typical example of the urban boundary layer with a strong inversion upwind (south) of the city. The urban boundary layer originated on the Kentucky side (to the left of the downtown area in fig. 7) of the Ohio River and extended through the suburban areas downwind (northward) from the city. In the central business district the urban boundary layer consisted of a

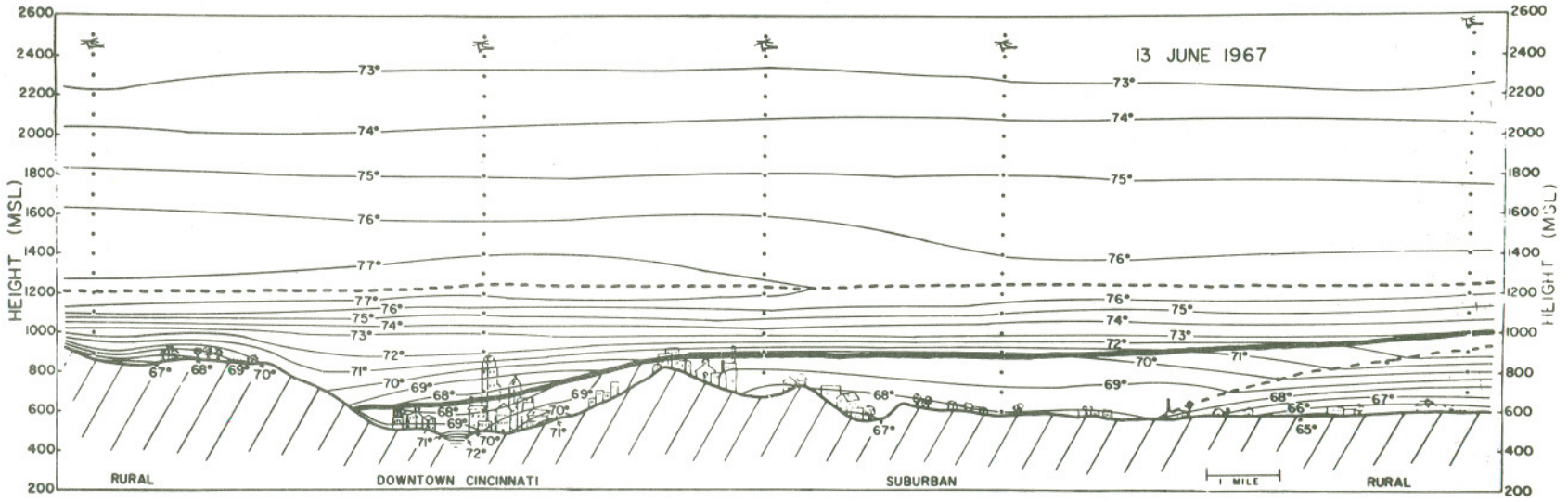

Figure 7. Cross section of temperature structure of the Cincinnati area, June 13, 1967. Isolines are ^{o}F.

superadiabatic layer extending to about 150 ft above the surface. In the downwind suburban areas the boundary layer consisted of weak inversion that generally increased in height with downwind distance. The lowest vertical extent (above ground) of the boundary layer was on the ridge north (to the right, fig. 7) of the central business district. Although the boundary layer tended to follow the contour of the land on the windward side of the ridge, it did not do so on the leeward side. A moderate to strong inversion, similar to that at the same height in the upwind rural area, existed above the entire length of the urban boundary layer.

Temperature profiles in the vicinity of downtown Cincinnati and associated wind profiles for four additional "stable" experiments are presented in figure 8. The wind speed within the urban boundary layer was generally light and exhibited little vertical shear. It is not known whether this type of wind profile is characteristic of the urban boundary layer or if such a profile is in part due to shielding by the surrounding ridges. Above the boundary layer the wind speed increased to a low-level maximum near the top of the inversion.

The urban boundary layer was sufficiently low during the "stable" cases that two distinct urban dispersion regimes could be recognized: the relatively unstable regimes within the urban boundary layer (i.e., adjacent to the surface) and the stable stratum immediately above. Current knowledge of atmospheric diffusion suggests that pollutants emitted within the boundary layer will be dispersed through and essentially contained within the boundary layer. This study, however, has demonstrated a spatial variation of the temperature profiles within the urban boundary layer and

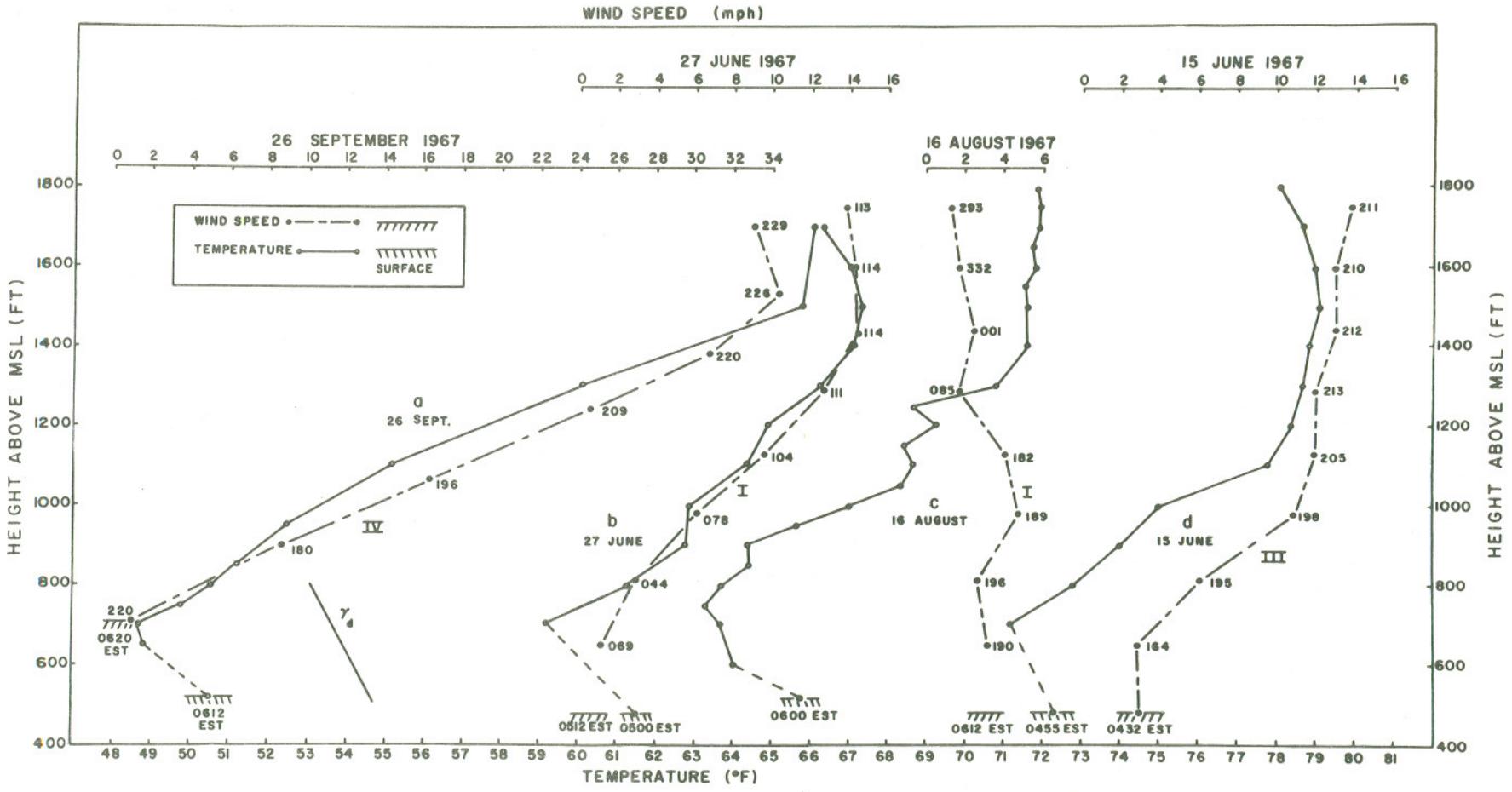

Figure 8. Vertical temperature and wind profiles obtained in the vicinity of Cincinnati's central business district. Wind direction is given in degrees at each level. That portion of the temperature profile interpolated from automobile temperature traverses is indicated by a dashed line.

consequently a spatial variation of the dispersion rate. Pollutants emitted from tall stacks into the stable stratum above the boundary layer will experience little vertical dispersion. They will not contribute significantly to the ground-level concentrations at a nearby receptor, and possibly not anywhere over the urban area, until the fumigation or inversion breakup period that typically occurs after sunrise.

To study the atmospheric structure over a city located in less complicated terrain, a series of urban boundary layer field investigations were conducted in the Columbus, Ohio, metropolitan area from 10 to 14 June 1968. Seventy-two helicopter temperature soundings were obtained, including wet bulb temperature measurements on 28 of the soundings. Over 400 double-theodolite pilot balloon soundings were made. The surface temperature of the city was mapped on two occasions using a Barnes infrared radiometer. In addition, the horizontal spatial extent of the heat island was obtained by a sensor mounted on an automobile. An experimental program to collect turbulence data from building platforms and at various ground sites in the cities was made. Bivanes and anemometer bidirectional vanes were used as sensors. The analysis of these data and similar field investigations under selected weather conditions in Columbus, Ohio, are planned for the coming months.

2.5 St. Louis Dispersion Study

In the spring of 1963 a 2-yr experimental program was initiated in St. Louis, Missouri, to study the diffusion of tracer material (zinc

cadmium sulfide) over an urban area and to relate that diffusion to measured meteorological parameters and to the diffusion of tracer material from past experimental studies, especially those conducted over relatively "open" country. Details of the tracer equipment, experimental operating procedures, diffusion parameter computations, and supplementary meteorological data were given in ESSA Technical Memorandum RLTM-ARL 4, 1968.

Diffusion parameters determined from the experimental data were cross-wind standard deviation of tracer material, σ_y, peak or axial concentration, $(\chi/Q)_p$, peak concentration normalized by mean transport wind speed, $(\chi/Q)_p u$, and "effective" vertical standard deviation of tracer material, σ_z. Measurements of tracer material in the vertical were too limited to permit direct computation of parameter values or to provide definitive information concerning concentration distributions.

The computed values of diffusion parameters were related to several readily measured or derived meteorological indices of turbulence. These indices in terms of increasing sophistication were: Pasquill-Turner stability classes (Pasquill, 1961; Turner, 1964) based on net radiation and wind speed; modified "Brookhaven" gustiness classes (Singer and Smith, 1953) based on the general range and rapidity of horizontal wind direction fluctuations; and the standard deviation of horizontal wind direction fluctuations, σ_θ, and conditions of vertical stability expressed as a Bulk Richardson Number (Lettau, 1957), Ri_B. Values of indices were determined for semi-rural and periphery sites as well as for urban sites to allow qualitative inferences concerning the applicability of station locales in describing diffusion over urban areas. Although the basic

Brookhaven gustiness classes were used, different class limits on ranges of wind direction fluctuations were climatologically derived, since the wind sensors in St. Louis were located near larger roughness elements and usually nearer the ground than those at Brookhaven. The Ri_B was derived from temperature and wind measurements at the 39- and 140- m levels of a downtown TV tower. Originally, $\bar{u}$ was incorporated with σ_θ and Ri_B as a joint index; however, its use as an additional parameter or in the form $\sigma_\theta \bar{u}$, generally increased data scatter. Diffusion in the cross-wind direction and the vertical and axial concentration distributions were better described by σ_θ and Ri_B, jointly, than alone.

Values of σ_y, σ_z, $(\chi/Q)_p$, and $(\chi/Q)_p \bar{u}$ were plotted against downwind distance, x, and travel time, t. Diffusion data points were grouped according to the meteorological indices determined for each urban, peripheral, and semi-rural location. In view of the small sample sizes, best-fit lines approximated by eye were placed through data groupings. The following features were apparent in the resulting plots: (1) the ordering of data was poorest for the close-in sampling arcs, on which multi-peaked or otherwise complex distributions in the cross-wind occurred in greater proportion than on more distant arcs; (2) the scatter of data points about best-fit lines was greatest in σ_z correlograms as expected, since the actual vertical distributions of tracer material were largely unknown; (3) values of σ_z and $(\chi/Q)_p$, that were considered to be significantly affected by a restrictive mixing depth were usually smaller and larger, respectively, than their non-affected counterparts under similar meteorological conditions; (4) in terms of these meteorological indices the data,

except for σ_z, were best ordered according to x; σ_z was about as well ordered by t as by x; (5) greater scatter about best-fit lines was observed in Pasquill-Turner classes than in the more detailed indices, and in the meteorological indices computed at peripheral and semi-rural sites than in corresponding indices at urban sites.

In connection with the third stated objective of the diffusion program, the results (i.e., the derived diffusion relationships based on meteorological indices) were compared with those of "open-country" studies for which the diffusion parameters were described by comparable meteorological indices. The St. Louis results according to Pasquill-Turner stability classes are related in figure 9 to those of several programs as summarized by Pasquill (1961), and modified slightly by Gifford (1961). In figure 9 note that values of best-fit lines for σ_y and σ_z in St. Louis are everywhere larger than those for the open-country counterparts. When extrapolated to longer downwind distances, best-fit lines for σ_y approach their counterparts; those for σ_z generally approach counterparts of stability one class higher. In figure 10, the difference in the normalized dilution factor $(\chi/Q)_{p\bar{u}}$ in St. Louis compared to that for over open country is greatest near the source, and this difference is greater for stable than for unstable meteorological conditions. The composite results indicate that a large initial dimension of the tracer plume in the cross-wind occurs over urban areas. Presumably, this enhancement of plume size decreases as the cloud grows and disappears when the cloud becomes larger than the aerodynamically induced eddies. A large initial dimension of the cloud and considerably enhanced diffusion are indicated in the vertical; the

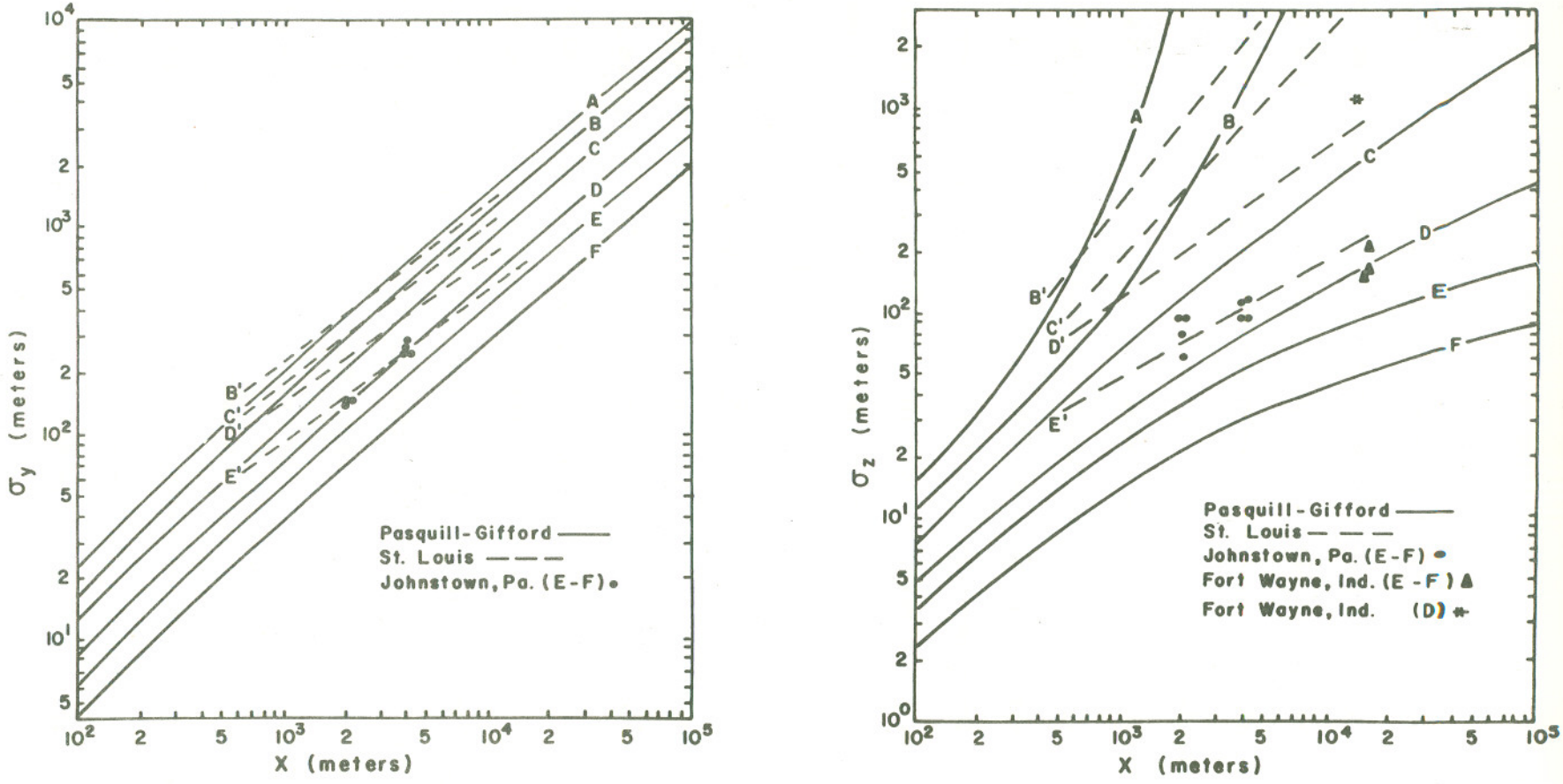

Figure 9. Comparison of σ_y and σ_z values as a function of distance, x, for St. Louis and other urban tracer experiments with those summarized by Pasquill (1961) and Gifford (1961). The solid curves as presented by Gifford are based upon data ordered by the Pasquill stability classes. The grouping of the St. Louis, Johnstown, and Ft. Wayne data herein was by the Pasquill-Turner stability classes (Turner, 1964), which are more objective expressions of the Pasquill classes in terms of readily available meteorological variables.

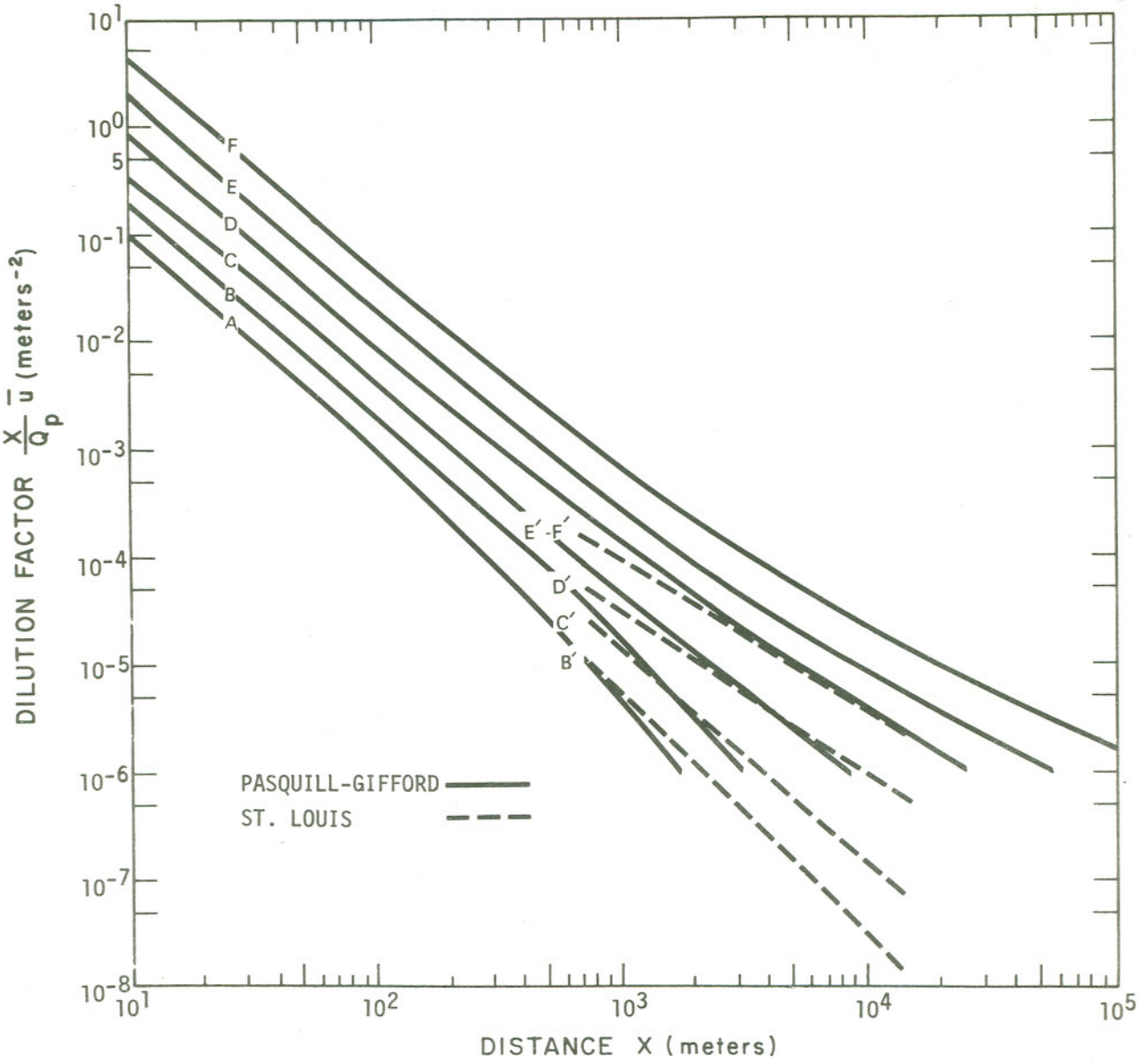

Figure 10. Comparison of the normalized dilution factor ($\chi\bar{u}/Q_p$) as a function of distance (χ), for St. Louis with the Pasquill-Gifford curves.

enhancement appears greater for stable than for unstable meteorological conditions and is presumably largely due to increased convective activity over the urban environment.

Results of the comparisons of the St. Louis data with those of other experimental programs were generally similar to those of figure 9. Values of diffusion parameters obtained in fluorescent particle tracer experiments in Johnstown, Pennsylvania (Smith, 1967), and Fort Wayne, Indiana (Csanady et al., 1967), are also shown in figure 9. Their values are similar to those obtained in St. Louis under the same meteorological conditions. In Johnstown, disseminations were from a low-level point source in the urban area. In Fort Wayne, they were from a cross-wind line source located 1.6 km upwind of the urban area; values of σ_z for this elevated (90-m) line source reported at the upwind edge of the urban area are not shown here.

A special study (Vaughn and McMullen, 1968) was conducted to assess the magnitude of fallout and deposition that occurred during the St. Louis tracer experiments under various meteorological and ambient air pollution conditions. The assessment was based on statistical comparisons of percentages of fluorescent particles in class-size groupings between samples collected at the various downwind distances and between these collected samples and the standard "lot" disseminated. The findings indicated that in general significant losses in particular size ranges did not occur in transit. An apparent loss of small particles in the size range less than 1.5μ did occur with downwind distance under stable meteorological conditions. This loss seemingly resulted from background obstruction of collected

particles during prolonged sampling times at greater distances, and not from deposition or fallout. In the St. Louis study, particles with less than 1.5μ diameters constituted about 20 to 30 percent of the total mass released during each experiment. However, an absolute determination of deposition losses could not be made from the sampling network available since lack of sufficient vertical profiles prevented mass flux calculations.

A two-volume report describing the experiments, "The St. Louis Dispersion Study", has been written. "Volume I - Instrumentation, Procedures, and Data Tabulations" and "Volume II - Analysis" are being prepared for publication by NAPCA.

3.0 AIR POLLUTION CLIMATOLOGY

3.1 Air Pollution Potential Climatology

Tabulations by the National Weather Records Center (NWRC) of morning and afternoon mixing depths and the corresponding averaged wind speeds were prepared for 41 Weather Bureau upper air stations for 5 yr of rawinsonde data. NWRC will provide tabulations for 21 additional stations. All (62) stations are located in the contiguous United States.

One of the studies, using these tabulations, has been to determine the frequency of episodes of high air pollution potential (APP). Such episodes are defined as:

1. No morning or afternoon mixing depth greater than 1500 m.
2. No morning or afternoon vertically averaged wind speed greater than 4.0 m/s.
3. No significant precipitation.

4. All of the preceding must persist for at least 2 days (i.e., 5 consective observation times; each observation occurring every 12 hr).

Significant precipitation is defined according to its intensity in regular observations taken on the hour during the periods, 2200-0900 LST for morning and 1000-2100 LST for afternoon; two or more occurrences (hourly observations) of light or one or more occurrences of moderate or heavy precipitation are considered as significant precipitation. Table 1 shows preliminary data for selected stations, arranged in order of increasing total episode-days. The climatological frequency of high APP episodes is commensurate with the total number of forecast days of high APP predicted by the National APP Forecasting Program over the past 8 years.

During the coming year an air pollution potential climatology will be prepared for the United States, based on the mixing depth and wind speed tabulations received from NWRC.

3.2 Air Quality Control Region Climatology

The Air Quality Act of 1967, signed into law on November 21, 1967, is a mandate for clean air; this Act provides a time schedule for the completion by NAPCA of certain tasks. One task under Title I, Section 107 (a) (1) calls for the definition of "...atmospheric areas of the Nation on the basis of those conditions, including, but not limited to, climate, meteorology, and topography, which affect the interchange and diffusion of pollutants in the atmosphere". Further guidelines stated that Atmospheric Areas would represent only a gross definition of meteorological conditions, to serve as

Table 1. Potential episodes of at least 2 days duration during which morning and afternoon mixing depths were 1500 m or less and average wind speeds were 4.0 m/s or less without significant precipitation, based on 5 yr of records, 1960-1964.

	Frequency of Episodes (number)	Total Number Episode-Days (days)	Episode of Longest Duration (days)	(season)
Oklahoma City, Okl.	0	0	0	--
San Antonio, Texas	2	5 1/2	3 1/2	Winter
New York, N. Y.	4	9	3	Autumn
Bismarck, N. D.	8	19	3	Spring
Tampa, Fla.	9	22 1/2	4 1/2	Summer
Flint, Mich.	10	30	4	Autumn
Peoria, Ill.	15	36 1/2	4	Autumn
Pittsburgh, Pa.	16	38 1/2	4	Winter
Washington, D. C.[a]	18[a]	39 1/2[a]	3	Autumn
Nashville, Tenn.	17	40	3 1/2	Autumn
Denver, Colo.	16	40 1/2	4 1/2	Winter
Charleston, S. C.	18	41 1/2	3 1/2	Autumn
Greensboro, N. C.	17	47	5	Autumn
Tucson, Ariz.	19	47	4	Winter
Little Rock, Ark.	23	59	4	Winter
Seattle, Wash.[b]	27[b]	66[b]	4	Autumn
Montgomery, Ala.	28	70 1/2	4 1/2	Autumn
Spokane, Wash.	34	101 1/2	6	Autumn
Huntington, W. Va.[c]	40[c]	103[c]	5	Autumn
Boise, Idaho	36	134	12	Winter, Autumn
Salt Lake City, Utah	49	178	12	Winter
Grand Junction, Colo.	43	192 1/2	15	Winter
Oakland, Calif.	54	204 1/2	12	Winter
Medford, Ore.	55	213 1/2	15	Winter
Los Angeles, Calif.	82	247 1/2	10	Winter

[a]Pro-rated from 4 years, 1961-1964.
[b]Pro-rated from 3 years, 1959-1961.
[c]Pro-rated from 3 years, 1962-1964.

a prelude to the more exacting task of defining Air Quality Control Regions; furthermore, these areas were to be defined solely on the basis of meteorological and topographical conditions already well documented.

A geographical delineation of eight Atmospheric Areas for the contiguous 48 States was made and documented in the January 16, 1968, Federal Register (Vol. 33, No. 10, p 548). These areas, shown in figure 11, were described on the basis of documented annual averages or frequencies of (a) low-level inversions, (b) vertical mixing depths, (c) wind speed, and (d) results of the high Air Pollution Potential (APP) Advisory Program, initiated by NAPCA in the early 1960's and now administered by ESSA; the dilution climate studies used for the description of these areas have been documented by Hosler (1961, 1964), Holzworth (1964, 1967), and Korshover (1967). Other factors, including geographic and topographic influences, were also considered.

The boundaries drawn to delineate the various areas (fig. 11) are not based entirely on precise quantitative measurements, nor are the dilution climate criteria absolute. At best, the Atmospheric Areas represent a delineation of dilution climate homogeneity, based on professional judgment and documented studies of certain relevant meteorological experience. Consequently, the area boundaries can be considered as transition zones that may be displaced according to the variation of prevailing weather regimes.

Designation of Air Quality Control Regions (AQCR), under the Air Quality Act of 1967, is a fundamental step leading toward action by State governments responsible for adopting and enforcing standards to control

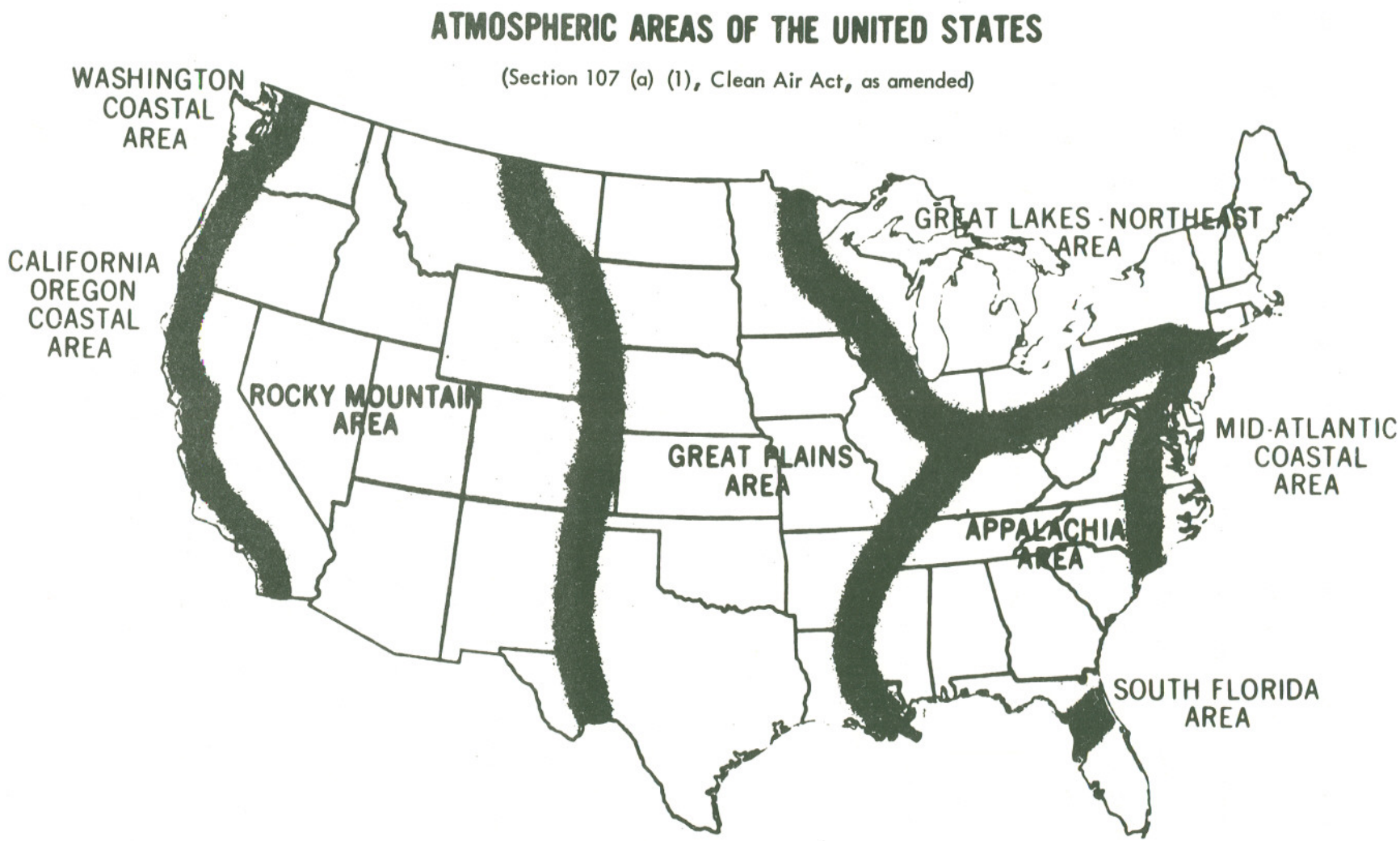

Figure 11. Atmospheric Areas of the United States.

air pollution on regional scales. Regional boundaries will be drawn on the basis of meteorological and topographic factors, the extent of urban-industrial development, and political jurisdictional factors including existing arrangements for regional action. Before AQCR's are actually designated, State and local officials in the areas involved will be consulted.

For the meteorological description of AQCR's, a long period diffusion equation with appropriate wind rose data is used to provide a geographical distribution of annual and seasonal (winter or summer) mean ground-level concentrations of SO_x (sulphur oxides), CO, and suspended particulates, based on respective pollutant source inventories provided by the Air Quality and Emission Data Program of NAPCA.

Essentially, the diffusion model (Martin and Tikvart, 1968) sums the effect averaged over a year, of a number of sources (area and point) for a specified number of receptors; the receptor points are at distances of 20, 30, 40, 50, 70, and 100 km from a defined central grid point, for each of 16 compass directions. To maintain simplicity, the CO and particulate sources are assumed to originate at ground level and no decay or removal factors are applied; for SO_x, "half-lives" are sometimes considered for comparative purposes. The limitations inherent in the diffusion model are recognized in that its strict application is limited to relatively uncomplicated geographic and topographic areas.

The model has been shown to provide reasonable spatial distributions of long-term average pollutant concentrations. The final analyses are in the form of isolines of pollutant concentration as shown in figure 12 which

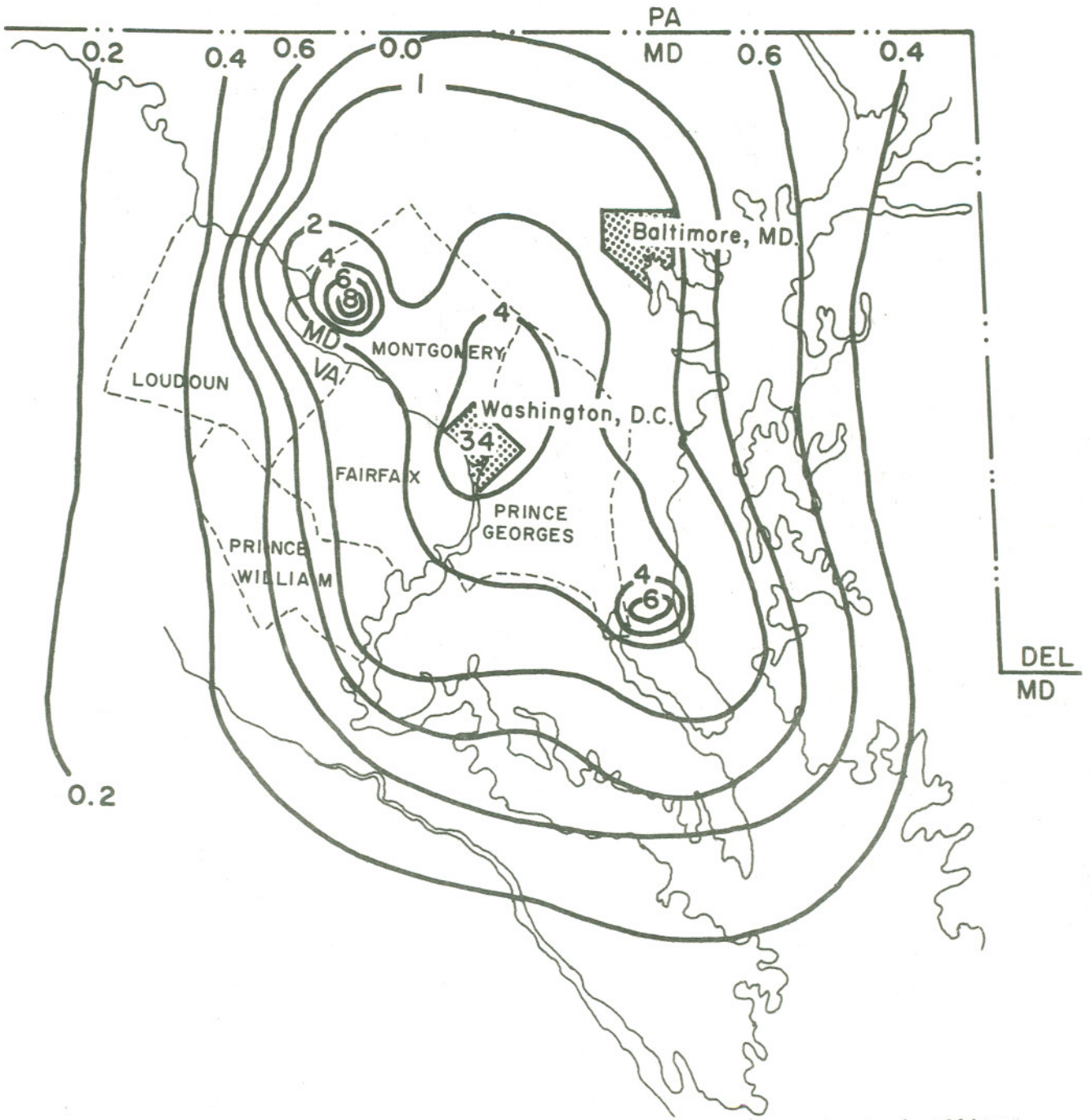

Figure 12. Calculated mean winter SO_x concentration (in parts per hundred million, pphm) distribution for the Washington, D. C. metropolitan area, resulting from metropolitan area source emission inventory provided by NAPCA. No decay has been applied; all releases assumed at ground level.

indicates the expected mean winter SO_x concentration distribution originating from the Washington, D. C., metropolitan source inventory area; for this example no decay was considered.

3.3 Atmospheric Turbidity and Radiation

This project was begun in 1960 to obtain a turbidity climatology for the United States and to use the measurements as quantitative indicators of the aerosol content of urban atmospheres. About 40 stations are maintained in the continental United States and in addition, observations are received from Mauna Loa, Hawaii, and Poona, India. Each station uses the Volz sunphotometer to measure the turbidity coefficient (B) at 0.50μ wavelength. An improved sunphotometer has been developed utilizing an interference filter and minature DC amplifier. Six of the new instruments will soon be used in the network. The summary of 5 to 6 years of network turbidity measurements has been completed and will be published soon.

One year of measurements in Cincinnati of turbidity made with an Eppley pyrheliometer equipped with Schott glass filters has given values of turbidity (B) and Angstrom's wavelength exponent (α) as illustrated in figure 13; α is a wavelength factor that is proported to be inversely proportional to particle size. The relationship of these terms can be expressed by

$$P(\lambda) = \exp - \beta/\lambda^{\alpha}$$

$$P(\lambda) = 10^{-B},$$

where $P(\lambda)$ is the solar transmission factor whose values range from 0 to 1 in accordance with the degree of scattering and absorption of solar radiation

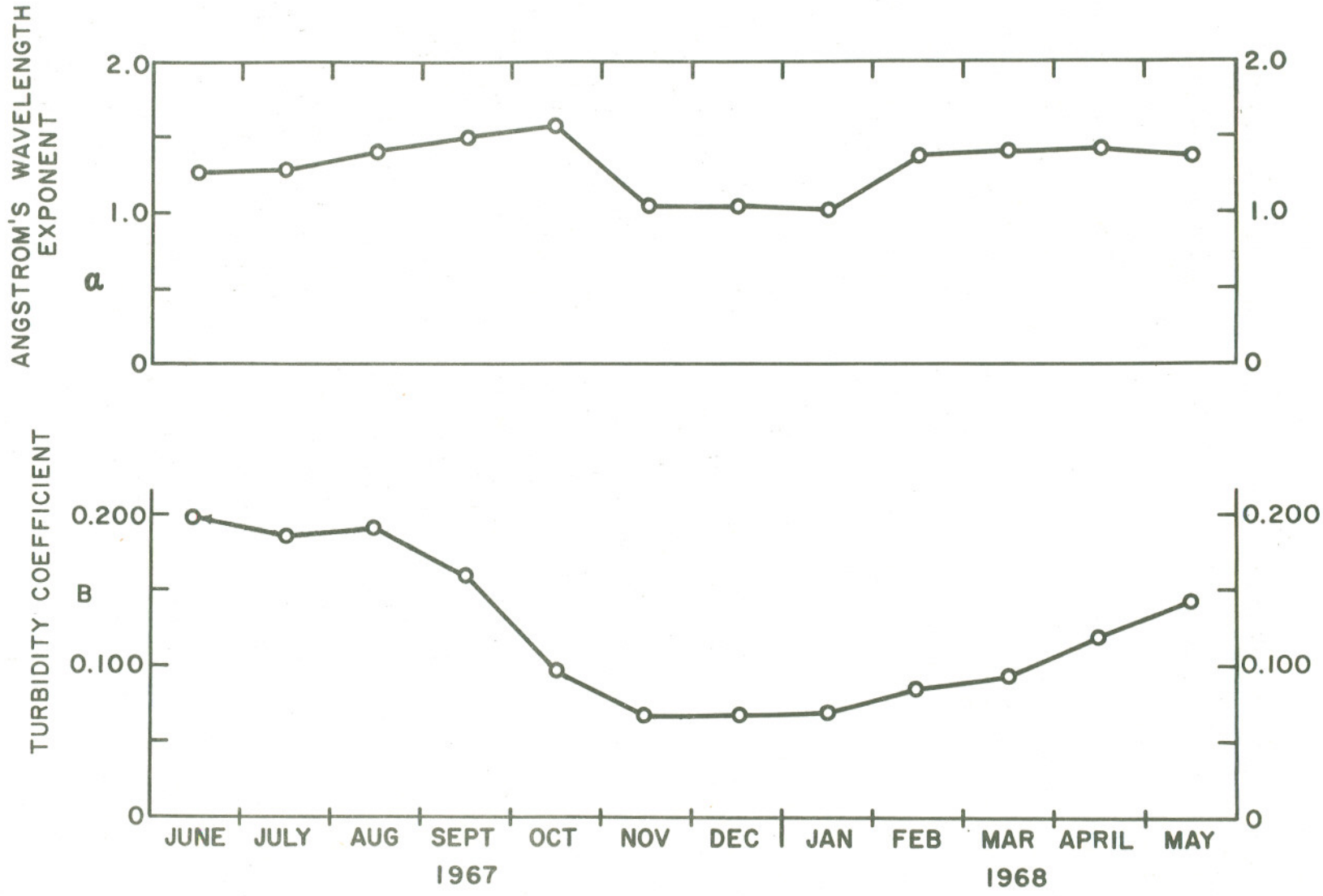

Figure 13. Monthly mean turbidity, B, ($\sim$0.435μ) and Angstrom's wavelength exponent (α) measurements in Cincinnati, June 1967 to May 1968.

by atmospheric aerosol, and β is the Angstrom turbidity coefficient, with limiting values between ∞ and 0, related to the "dust" loading of the atmosphere. The measurements with the pyrheliometer and sunphotometer have two basic differences: 1) the pyrheliometer aperture is 5.75° and the sunphotometer aperture is 3.75°; and 2) the pyrheliometer measurements are for broad spectral intervals of several hundred millimicrons while the sunphotometer is essentially monochromatic. Angstrom's wavelength exponent (α) is useful as an indication of the relative populations of large and small particles. A large α indicates a high proportion of small particles and small α, a high proportion of large particles. The data in figure 13 thus indicate that the total number of particles is less in winter with a higher proportion of large particles than in summer. The wavelength variation of turbidity is also useful to indicate spectral intervals where anomalous scattering may have occurred. At wavelengths shorter than .70μ, if scattering is the only extinction factor (other than ozone absorption, which is assumed known and constant for any wavelength), Angstrom's wavelength exponent should be constant for any particular measurement and a plot of B versus wavelength should give a straight line whose slope is α. Figure 14 is such a plot of average values for January 1968 for Cincinnati, Ohio, using both pyrheliometer and sunphotometer measured turbidities. These data indicate anomalous extinction (absorption) in the spectral region at .59μ, which may be due to ozone. This feature, which appears nearly every month in the Cincinnati measurements, will be investigated further using additional wavelength filters for both the pyrheliometer and the sunphotometer.

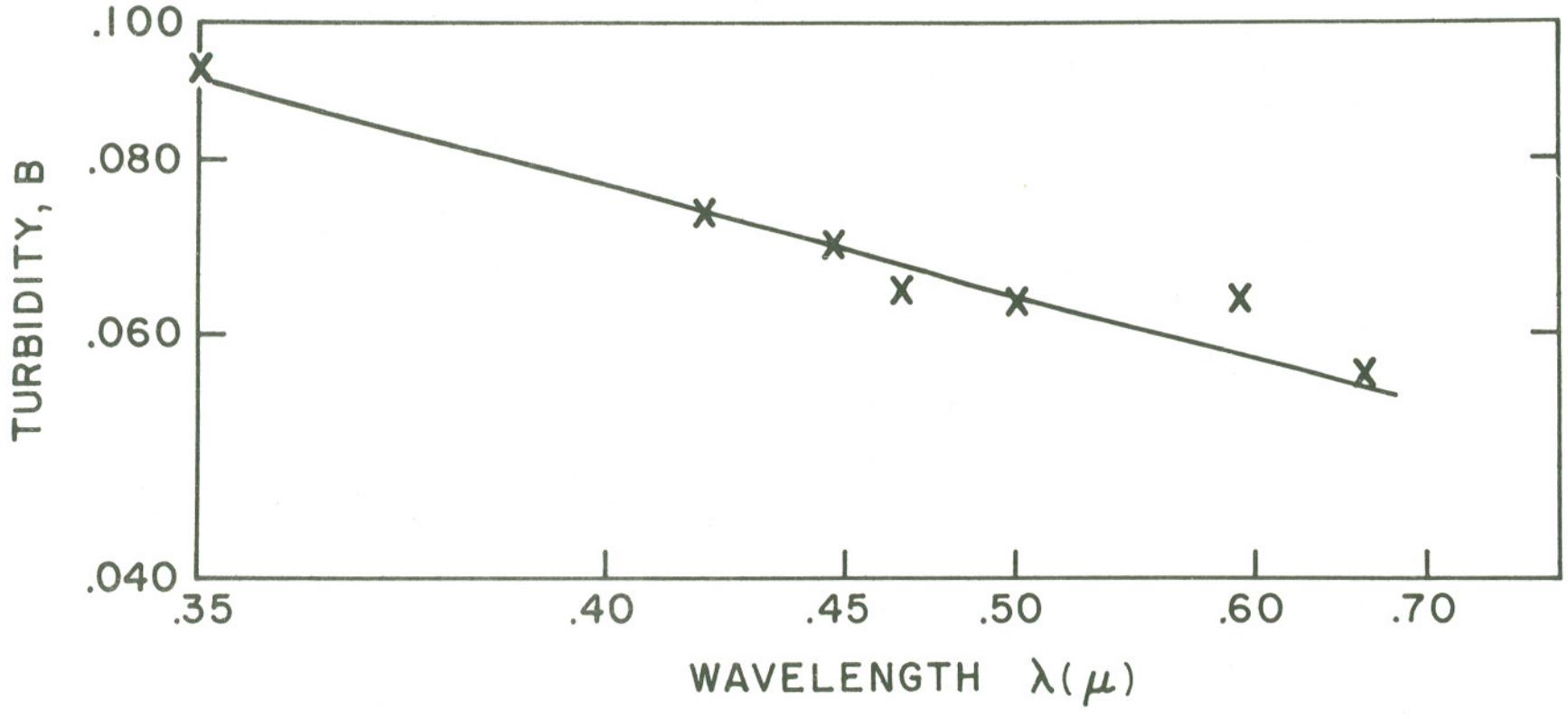

Figure 14. Turbidity (B) measurements for various wavelengths (λ) by pyreheliometer and photometer, Cincinnati, January 1968.

The intensity of the ultraviolet radiation (.30-.385μ) from the sun and sky on a horizontal surface has been measured continuously since September 1967 in downtown Cincinnati. On days of high air pollution this intensity is sharply reduced. Figure 15 illustrates 2 days in February 1968 which had relatively heavy and light air pollution with essentially cloudless skies. The effect of heavy pollution on the 6th is quite evident and resulted in a depletion of UV energy of about 45 percent at 1400 TST (true solar time) as compared to the day with light pollution. Similar measurements are planned for a rural location about 30 miles east of Cincinnati and for periodic measurements from an airplane above the pollution layer.

4.0 SUPPORT TO NAPCA PROGRAMS

4.1 Air Quality and Emission Data

A report entitled, "The Thanksgiving 1966 Air Pollution Episode in the Eastern United States" will be published by NAPCA by the time of this printing. This report describes the meteorological conditions and air quality measurements obtained during this stagnation period.

Methods of calculating carbon monoxide (CO) concentrations arising from various traffic configurations were provided to a study to relate CO concentrations at street level to traffic volume. Recently, traffic volume, wind, and CO concentrations have been measured simultaneously at three different distances from a roadway in Cincinnati; future measurements of CO at different heights above ground will be obtained in the initial data acquisition phase of this study.

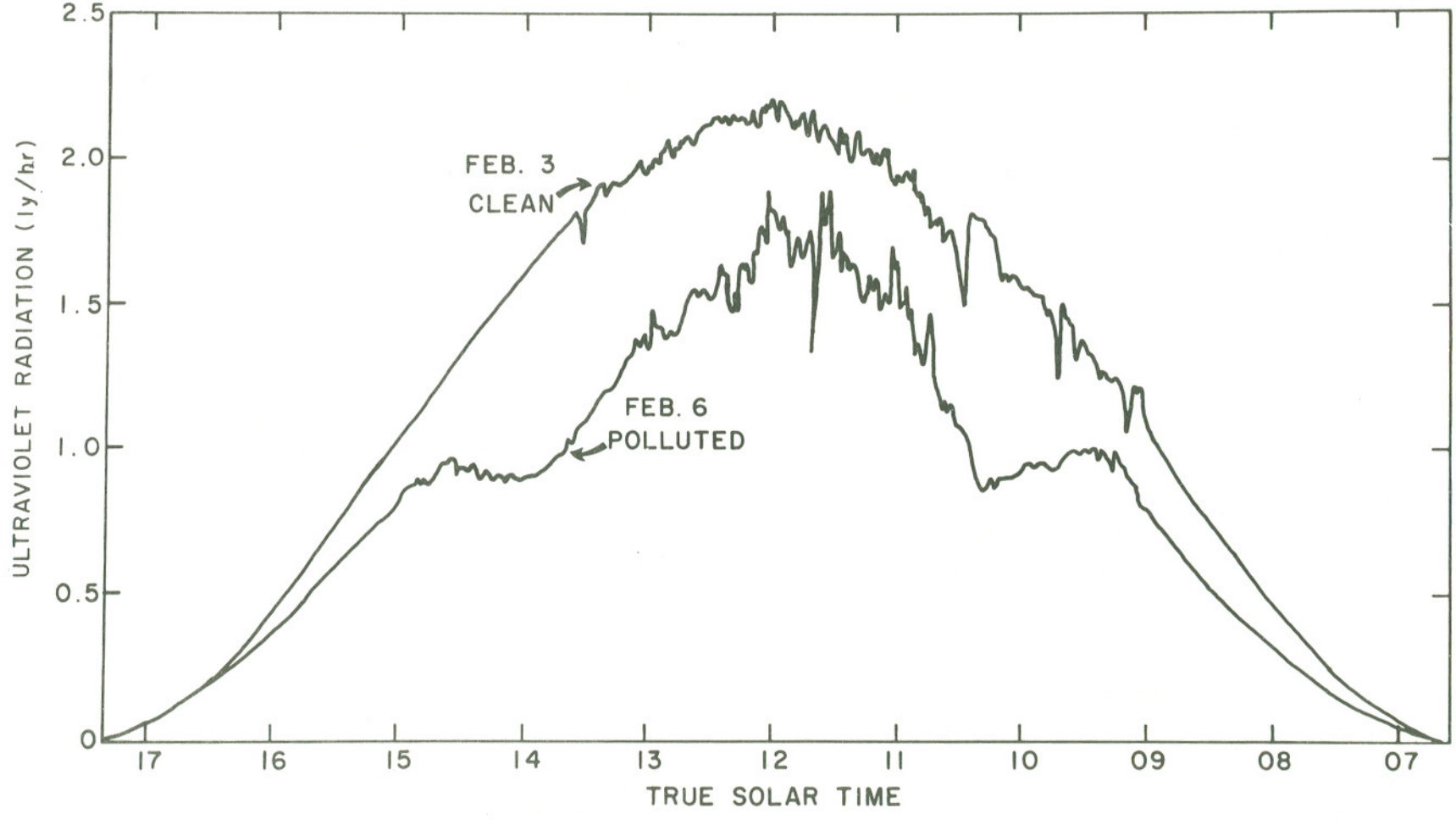

Figure 15. Ultraviolet radiation measurements conducted in Cincinnati on "clean" and "polluted" days in February 1968.

A study was made of possible meteorological differences during the years 1965 and 1966 that might relate to the large drop in the measured value of suspended particulates observed at many cities across the country. In 20 cities, of 65 for which continuous records since 1957 are available, the lowest annual values were recorded in 1966. The investigation is difficult because the data are sparse (a maximum of 26 samples per year per station) and because observations are taken on different days. Considerations of wind speed, degree days, and rainfall produced no conclusive evidence of an effect due to these parameters. In some cases wind direction seemed to affect particulate concentration, but because of the limited number of samples no weight could be assigned to the different directions and so the difference in the years again was obscure. In a further effort to discover the effect of wind direction, data from Chicago for the year 1960 through 1966 were analyzed, providing 168 data points. A pollution rose was constructed, showing the average suspended particulate values associated with each wind direction, based on average daily directions recorded in the Weather Bureau's monthly Local Climatological Data sheet for the respective city and period of interest. The average suspended particulate values were determined for each compass point and adjusted on the basis of a regression line of particulate values which showed the general downward trend of concentration over the 7-year period. As a test of this method, the annual average was reconstructed from these values. The calculated annual average agreed well with the actual averages and predicted the 1967 value within about 4 percent (fig. 16). The same sort of procedure was used with data from Salt Lake City, and the predicted value was exactly the

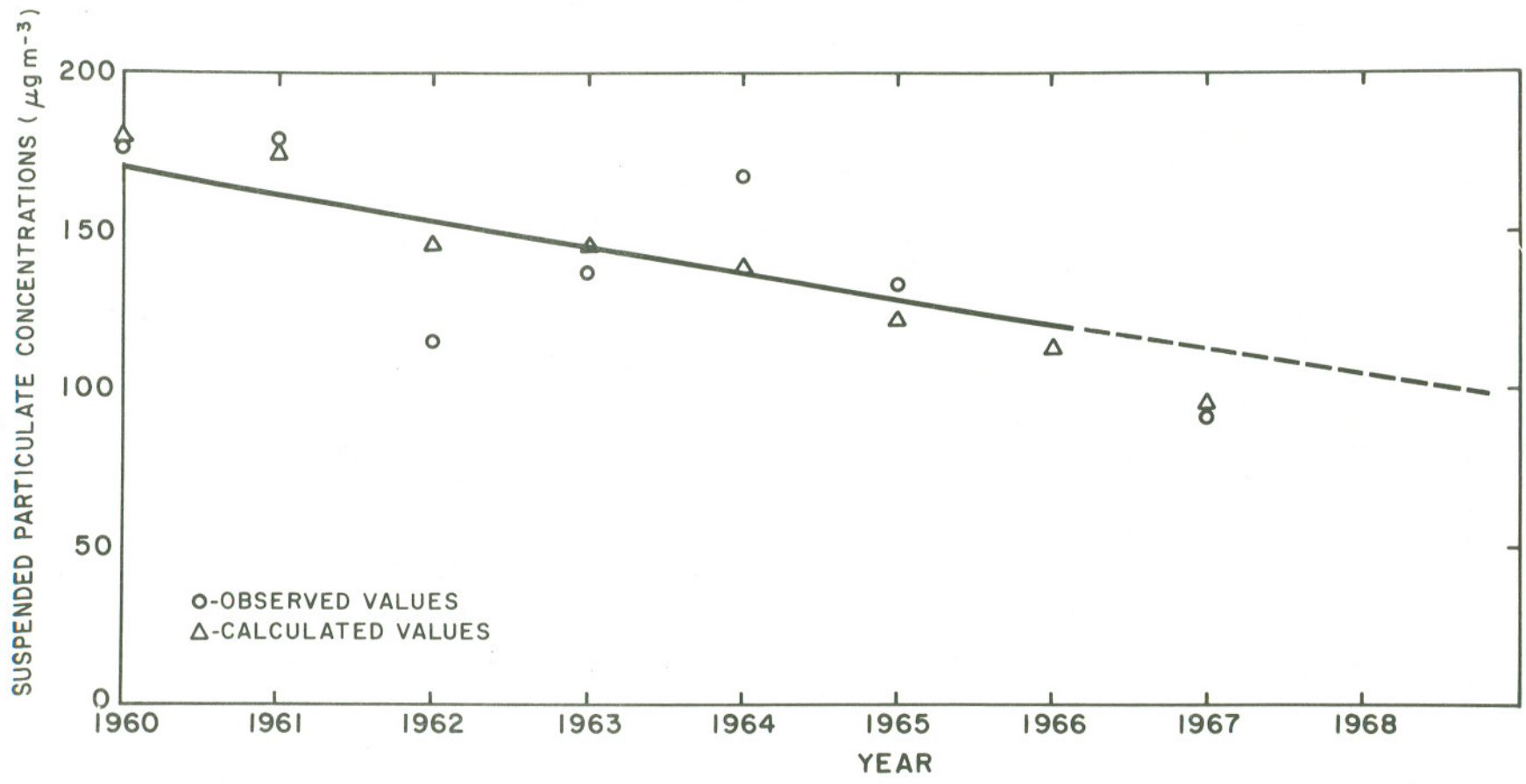

Figure 16. A comparison of calculated and measured average annual concentrations of suspended particulates for Chicago, 1960-1967.

same as the measured value for 1967 (fig. 17). The data were classified according to amounts of precipitation, but for most of the class intervals there were too few data points to give meaningful values.

Suspended particulate samples have been taken daily in some cities. Buffalo has provided 2 yr of such data. We expect to study these data intensively with respect to meteorology and other air quality measurements.

Reasons for the comparatively high values of oxidant on weekends are being considered. Analysis of weekday values of oxidant (Cincinnati) has sonwn that whenever high values of nitric oxide were observed during the morning traffic peaks, high oxidant values usually followed in the afternoon; it is believed that 3 hr or more are required for the assumed chemical reaction to be completed. Since the morning traffic peak does not occur on weekends, the high morning value of nitric oxide is also absent and one might expect low oxidant values. However, some reported laboratory experiments show that the transformation of nitric oxide that results in oxidant goes to more than 50 percent completion in 30 min; this would suggest that the traffic occurring during or shortly preceding the time of the oxidant peak is responsible for the resulting concentration. Traffic counts obtained from the Hamilton County Traffic Engineer show that traffic during times of peak nitric oxide observations is much higher on weekends than on weekdays (fig. 18). Traffic counts in the city area near the Continuous Air Monitoring Program station will be obtained to study this phenomenon further.

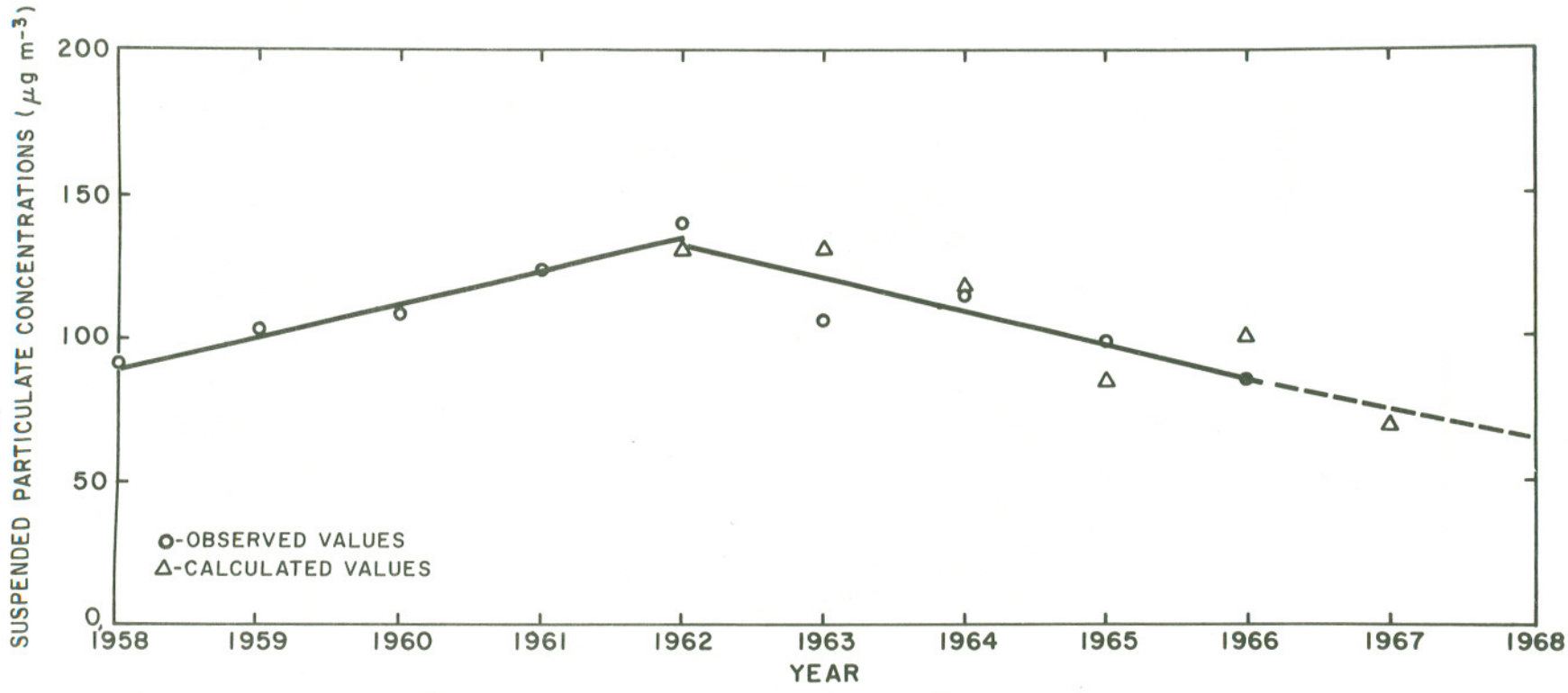

Figure 17. A comparison of calculated (1958-1966) and measured (1962-1967) average annual concentrations of suspended particulates for Salt Lake City.

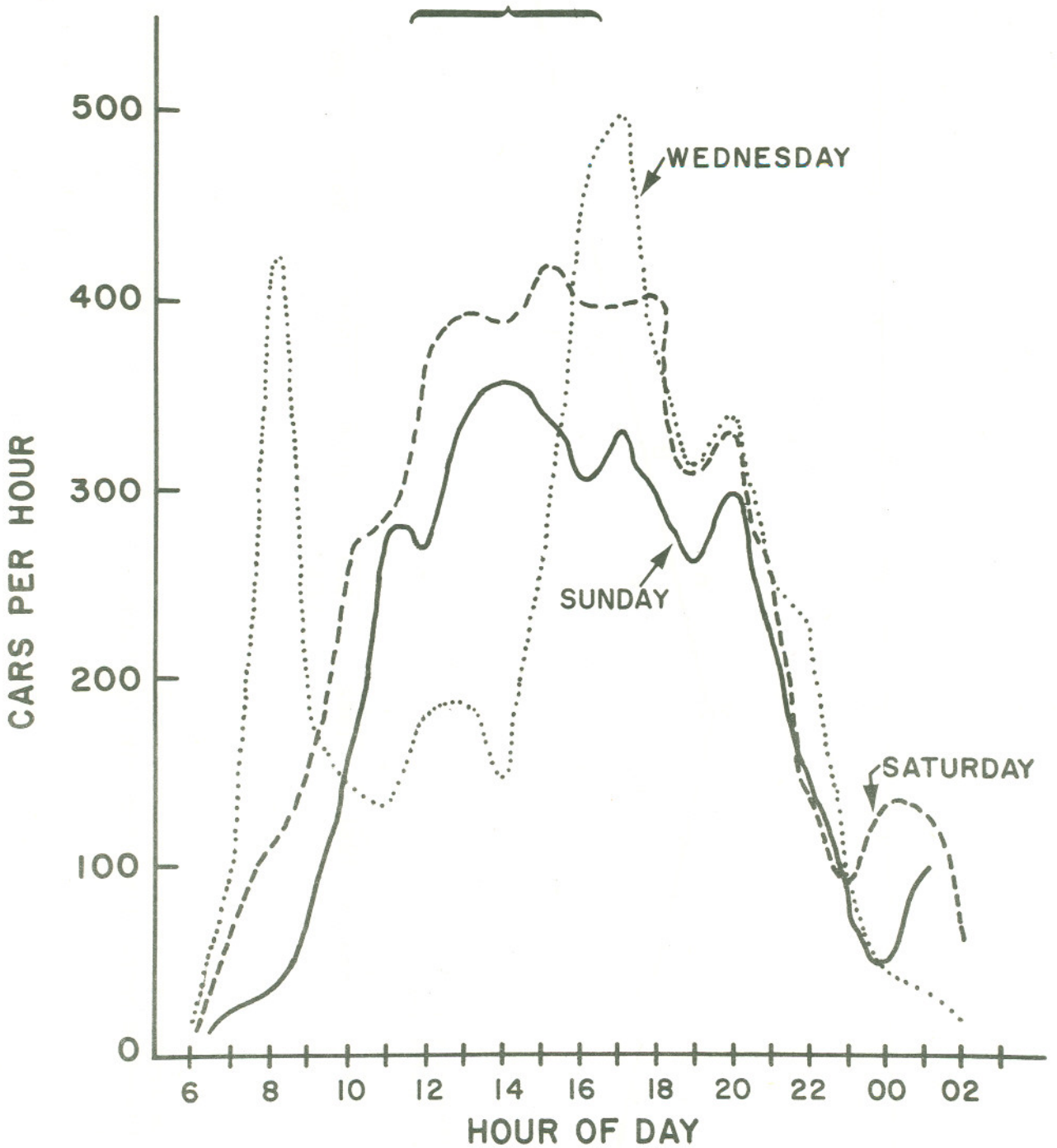

Figure 18. Hourly traffic flow for certain days of the week on a selected Cincinnati highway. (Courtesy of Traffic Engineer, Hamilton County, Ohio.)

4.2 Criteria and Standards Development

In calculating concentration distributions for use as a parameter to help delineate Air Quality Control Regions, interest was expressed in the effect of various half-lives upon concentrations of SO_2. Such calculations were made for distributed SO_2 sources within three metropolitan areas, applying annual mean values of meteorology, and half-lives of 12, 6, and 3 hr; in one case 2-hr and 1-hr half-lives were calculated. In addition, for one of the metropolitan areas calculations were also made for the summer season for 12-, 6-, and 3-hr half-lives.

Results of these calculations are presented in tables 2 and 3. In Table 2 averages for the three cities are presented, with the values in percent of calculated values of infinite half-life. Distances are from the centers of the major cities involved in each case. Table 3 shows summer, winter, and annual values for one city, with the annual values extended to the shorter half-lives.

Values at each distance are averages for 16 points equally spaced around the city at that distance. In nearly every case at 100 km, (many cases at 70 km, and some cases at 50 km), the points for which SO_2 concentrations were calculated are outside the source area used. However, in some cases points at as great a distance as 50 km are strongly affected by nearby major point sources, especially under the assumptions used in these calculations. Half-life calculations based on winter data indicate the effect of more widespread domestic heating; this effect is particularly

Table 2. The effect of various half-lives upon calculated concentrations of SO_2 for 3 cities using annual mean meteorology. Values are percent of calculated infinite half-life values.

Distance (km)		Half-life values			
		Infinite	12 hr	6 hr	3 hr
0	High	100	97	94	89
	Average		96	92	86
	Low		94	90	82
20	High	100	91	83	72
	Average		90	81	67
	Low		89	79	63
30	High	100	90	81	68
	Average		87	77	60
	Low		85	73	54
40	High	100	87	73	55
	Average		85	72	54
	Low		83	70	52
50	High	100	83	69	52
	Average		81	67	47
	Low		80	65	43
70	High	100	76	60	39
	Average		73	54	34
	Low		68	46	25
100	High	100	65	47	24
	Average		62	39	19
	Low		56	31	13

Table 3. Effect of decay on SO_2 percent of infinite half-life concentration for one city.

Distance (km)	Half-Life (hr) 12	6	3	2	1
	Summer				
0	94	89	80		
20	90	80	67		
30	87	78	63		
40	81	67	48		
50	80	64	46		
70	72	52	31		
100	53	29	10		
	Winter				
0	96	91	84	78	65
20	92	85	73	65	48
30	91	83	70	61	43
40	88	78	63	50	31
50	86	74	57	45	27
70	77	62	38	27	12
100	66	44	20	10	1
	Annual				
0	94	90	82	75	62
20	91	83	72	63	46
30	90	81	68	59	42
40	85	72	55	43	23
50	83	69	52	39	21
70	76	60	38	26	12
100	65	40	20	10	2

apparent when comparing the winter values with summer and annual values at greater distances for the city.

4.3 Health Effects Research

The Meteorology Division supported an air quality sampling and dustfall study conducted in Cincinnati by maintaining a network of wind sensors and hygrothermographs at four sites; air sampling instrumentation to record SO_2, NO_2, suspended particulates, and dustfall were also maintained at the four observation sites. The network has been in operation since November 1967, when it was initiated to support the Cincinnati School Children Pulmonary Function Study. The network continues in operation as part of a general air quality sampling and dustfall study in the Cincinnati area.

Meteorological support was provided to the New York State Ragweed-Pollen Study, conducted near Saratoga Springs, New York, to assess ragweed pollen concentration distributions during the 1968 summer season (August-September). This effort was a feasibility study to determine the number of samplers and the meteorological data required for an anticipated large-scale sampling study of six cities in New York State in the summer of 1969. The purpose of these studies is to provide background data that will be sufficient to assess the effects of ragweed eradication by tests scheduled for 1970. Wind and temperatures were measured at two sites in the Saratoga Springs area; the meteorological data will be analyzed with respect to helping select the appropriate area for ragweed eradication.

4.4 Abatement and Control

The Abatement Program of NAPCA is responsible for gathering and evaluating air quality data and meteorological information that is required to support abatement actions initiated under Federal legislation.

4.4.1 New York - New Jersey

Meteorological support was given for the preparation of parts of the report on the New York-New Jersey Air Pollution Abatement Activity, Phase II -- Particulate Matter, December 1967. It is the second in a series of reports prepared to describe air pollution in a 17-county metropolitan area of southeastern New York and northeastern New Jersey. The first report, January 1967, on the subject of sulfur compounds and carbon monoxide, discussed the air pollution climatology of the area and interstate transport.

An attempt was made to determine the extent of normality of weather conditions during the New York-New Jersey study period (January - May 1967) in order to evaluate the representativeness of air quality data collected during the study period. It was found that in general weather conditions were near normal during the study period, so that sampled air quality data should have been about average. To ascertain the extent to which any anomalies in the wind speed and wind direction during the study period affected the geographic distribution of pollutants, a model similar to that given by Martin and Tikvart (1968) was used to delineate areas where the maximum pollution impact occurred.

Seven theoretical point sources which were typical of the location of major point sources of particulates were used to determine the areas of major impact. An analysis of these data indicated that, although the dispersive ability of the atmosphere was about normal during the study period, the variations from the normal wind directions should have caused the pattern of contamination to be shifted somewhat to the east. The eastern portions of the metropolitan area should have experienced more contamination than normal, the western and northern portions about average, and the extreme southern portion less than average contamination.

To justify a recommended reduction in the amount of emitted air contaminants, it was necessary to determine whether the proposed emissions reduction would have a significant impact on the air quality. Based on State and local air pollution control regulations, both existing and pending, a significant reduction in particulate emissions was anticipated in portions of the 17-county New York-New Jersey area. To estimate the effect that these reduced emissions would have on air quality throughout the abatement area, theoretical determinations were made of particulate concentrations at selected locations. This was done by utilizing a recent (1966) emission inventory and projected 1971 particulate emissions, and by imposing on the calculations a set of defined meteorological conditions.

Meteorological conditions on a spring day were selected for the calculations. An average wind direction of 215° and an average wind speed of 4.3 m/s were designated. It was assumed that neutral stability existed all day and that an inversion was based at an average height of 500 m above the surface. By use of a Gaussian diffusion

equation (Gifford, 1961) the sum of particulate ground-level concentrations that can be attributed to emissions from all upwind point and area sources was determined for each of 11 representative receptor sites. Concentrations were calculated by assuming continuous emissions from all sources at average yearly rates for both the 1966 emission data and for the projected 1971 data; a background level of 75 $\mu g m^{-3}$ was included at all sites. Isopleths of theoretical estimates of particulate concentration based on the 1966 emission data and on the projected 1971 emission data, respectively, are displayed on maps in figures 19 and 20.

Comparison of the 1971 concentrations with those calculated for 1966 source data revealed the same basic concentration pattern: however, the comparison indicates that when the proposed controls are put into effect, general contaminant levels would be reduced by as much as 30 percent in many areas and by 50 percent in the most polluted areas, i.e., upper Manhattan and northwestern Staten Island.

4.4.2 Washington, D. C.

As part of the support given to the Public Health Service of the Department of Health, Education, and Welfare in preparation for a public conference under the Clean Air Act, the meteorological representativeness of the Washington, D. C., sampling period, January-July 1967, was determined. In addition to the standard meteorological elements, data on vertical temperature differences from towers and radiosonde measurements were available. To determine anomalies in the horizontal distribution of

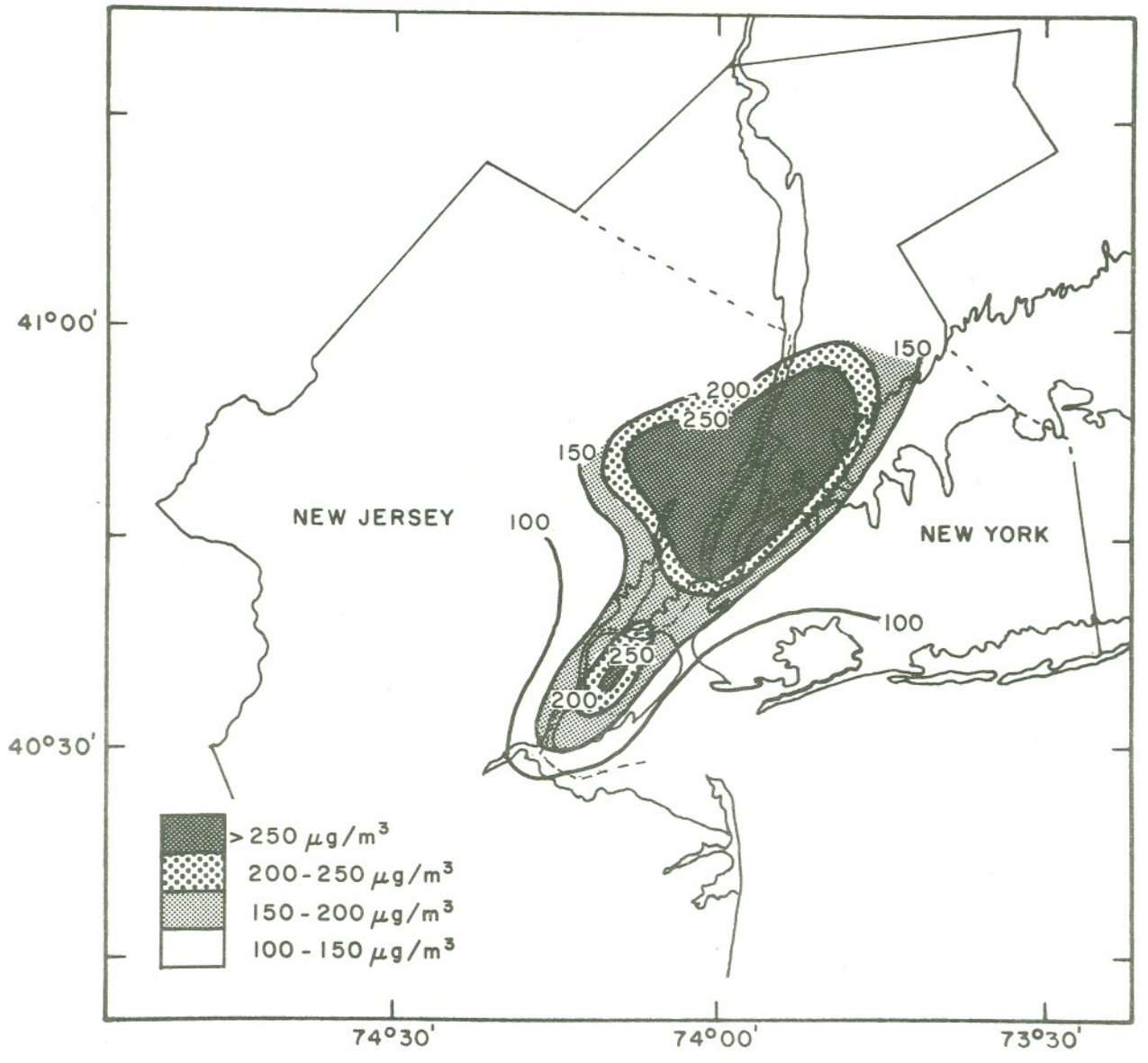

Figure 19. Theoretical distribution of particulate concentrations in the New York City area based on April 2, 1967, weather data and 1966 emission data.

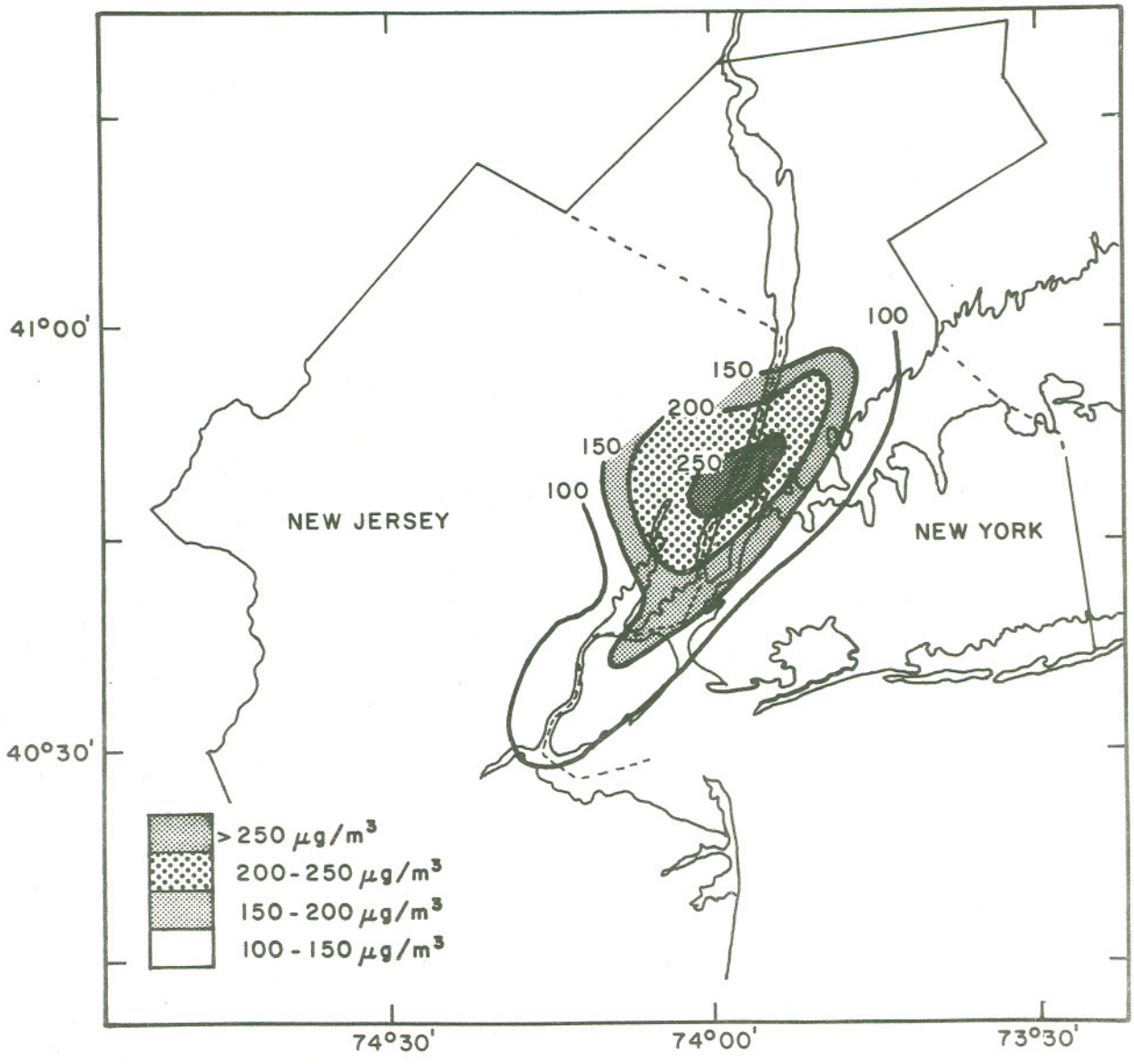

Figure 20. Theoretical distribution of particulate concentrations in the New York City area based on April 2, 1967, weather data and projected 1971 emission data.

pollutants, a diffusion model was applied using NO_x emission and climatological data from the District of Columbia. This analysis suggested that concentrations measured during the first half of 1967 over the Washington, D. C., area may have been higher than the average for the normal January through July period.

Average SO_2 and particulate emission inventory data for the year 1966 were used in a diffusion model to calculate pollutant concentration distributions. The emissions inventory included point and area sources. The meteorological input consisted of a frequency distribution of stability, wind direction, and wind speed based on climatological data from Washington National Airport. The concentrations of both SO_2 and predicted particulates by the model for selected points in the urban area were generally well within a factor of 2 of the available measured concentrations based on existing air quality data after a background level of 50 $\mu g\, m^{-3}$ was added to the calculated particulate concentrations for comparison with observed air quality values.

4.4.3 Kansas City, Kansas-Kansas City, Missouri

The Kansas City, Kansas - Kansas City, Missouri, air pollution abatement activity was conducted in two phases, and two public conferences were held in accordance with the Clear Air Act. The first phase of the investigation, contained in the pre-conference report, January 1967, was concerned with visibility at Municipal and Fairfax Airports, whereas the second phase dealt with the overall air pollution problem in the area. For an air

quality study of Kansas City, besides the usual analysis of topography, climatology, and meteorology of the area, an attempt was made to assess the effects of specific combustion sources on air quality.

An emission inventory had shown major combustion sources in an area in which SO_3 emissions were much greater in the winter months than in other seasons; this seasonal variation was attributed to large quantities of coal and oil used in winter, whereas natural gas was consumed during the rest of the year. However, several industrial sources in the same area emit SO_3 constantly throughout the year. To determine the impact of these industrial sources on ground-level SO_3 concentrations sampled in the area, seasonal geographic distributions of SO_3 concentrations and seasonal wind roses were determined. These data, shown in figures 21 and 22, indicate that during the winter the highest average SO_3 concentrations were calculated to be over the downtown area, where power plants are located; this area also is affected by a high frequency of northwest winds that transport SO_3 from the nearby industrial sources. For the summer months the areas of maximum SO_3 concentrations are north of the industrial sources, because of the high frequency of southerly winds and the lower SO_3 emission by major combustion sources. This analysis indicated that during the winter season major combustion sources have a marked effect on the SO_3 concentrations observed in the downtown Kansas City area, while the rest of the year they have little or no effect.

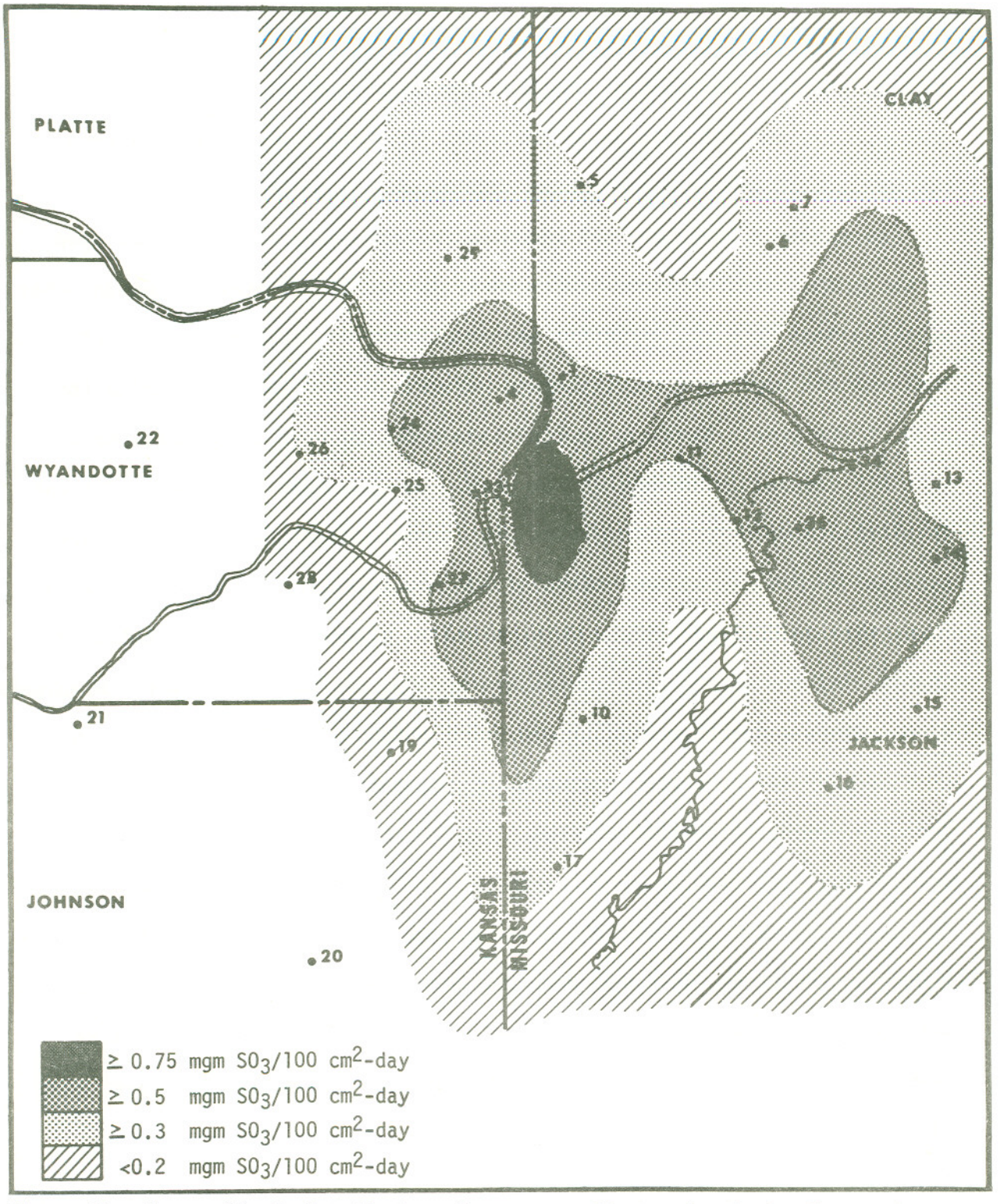

Figure 21. Geographical distribution of average sulfation levels for Kansas City, January-February 1967.

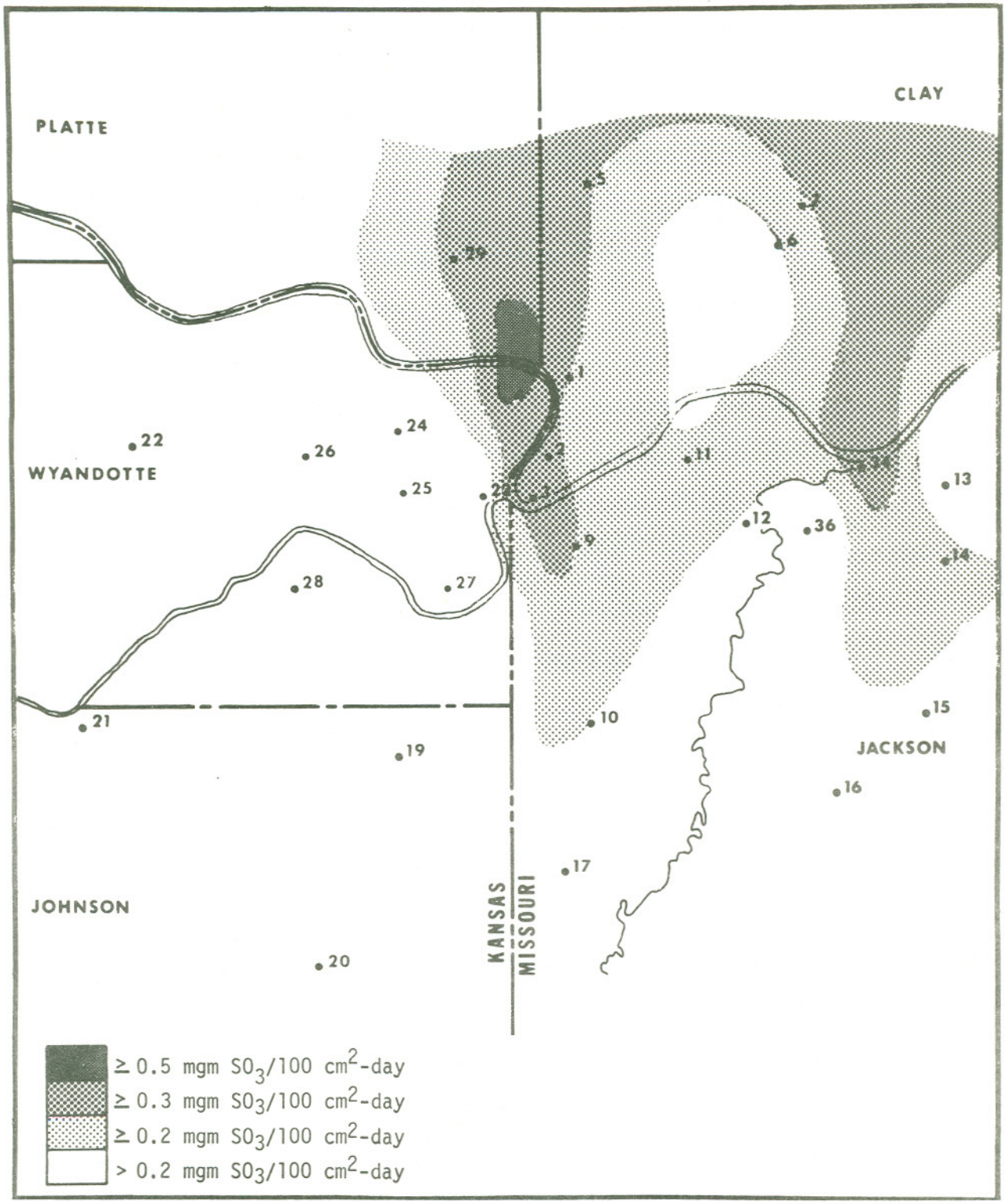

Figure 22. Geographical distribution of average sulfation levels for Kansas City, June-August 1967.

4.4.4 Chattanooga, Tennessee

When a sampling network is set up for an interstate air pollution investigation, it is often done on a subjective basis. Frequently, because of lack of time and political considerations, the network is based on political jurisdictions, the existence of serious complaints, and accessibility. Although these factors should be considered in network design, items that affect the transport and dispersion of contaminants (topography and meteorology) are more important. The air pollution investigation of the Chattanooga, Tennessee, metropolitan area, conducted by the U. S. Public Health Service during October 1967-November 1968, offered an opportunity to establish a network on a scientifically objective basis. The purpose of the investigation is to develop technical information for use by the various air pollution control agencies with responsibilities in the metropolitan area in assessing air pollution problems and in guiding future control activities.

By distribution of the meteorological and air quality sampling stations along a major SSW-NNE axis, parallel to the orientation of the ridges, and also along a minor axis, data on the horizontal distribution of pollutants are obtained. Location of sampling sites on a few of the numerous ridges allows observations pertaining to the vertical distribution of pollutants.

Continuous temperature measurements are being made at selected ridge-top and valley-floor sites by means of thermographs. Analyses of these data will provide information on the frequency, time of occurrence, and intensity of inversions. As an independent check on the adequacy of the

thermograph network to develop inversion data, tethersonde and pilot balloon observations are being made during certain periods.

Concentrations of NO_x, particularly from the Volunteer Army Ammunition Plant, have been measured remotely by means of aerial surveys with a correlation spectrometer. This instrument seems to be particularly suited to making NO_x observations, as much stronger signals are available from these gases than from SO_2. The aerial surveys were obtained by a contract with Barringer Research Limited, Rexdale, Ontario.

4.4.5 Douglas, Arizona, SO_2 Survey

A large copper smelter operates near the U. S. - Mexican border at Douglas, Arizona. When the smelter was shut down by a strike in July 1967, the State of Arizona requested NAPCA to conduct an air pollution survey of the area to assess the impact of the smelter on the environment. In September 1967, an airborne and ground-level survey of the area was made and a lead-peroxide candle network designed and placed in operation. The sulfation (lead-peroxide candle) network was operated continuously from October 1967 to June 1968. The smelter returned to production about April 1, 1968. The second phase of the aerial sampling was scheduled for September 1968, when chances were better for encountering weather essentially identical to the initial sampling period. No detectable concentrations of SO_2 were found in the Douglas area while the smelter was shut down.

The aerial sampling plan and the sulfation-candle array were carefully designed using available climatological data for the area. Expected

areas of frequent contamination were ascertained under various wind and stability conditions. From the frequency of occurrence of these meteorological factors, estimates of the geographical distribution of various frequencies of contamination were developed. The sampling plans were designed to sample in areas where the expectancy of contamination was both high and low.

4.4.6 International Joint Commission Study

An international air pollution study in the vicinities of Detroit and Port Huron, Michigan, and neighboring Canadian communities in Ontario province has been in progress since September 1967. The study is being directed by the International Joint Commission (IJC), a body that will report to the two governments on the extent of transboundary air pollution along the international areas involved. Industrial sources are concentrated along the boundary waterways so that the air monitoring network consists of several lines of samplers paralleling the border. A meteorological survey is being conducted in support of the program consisting primarily of a fixed network of stations to measure the areal and temporal variations of wind and stability parameters. Also, seasonal intensive observations of vertical temperature and wind structure have been accomplished. In addition, aircraft sampling along the boundary was performed in the spring of 1968 for flux determinations of pollutants traversing the boundary.

The aircraft sampling constitutes an important part of the study. The aerial measurements were accomplished during two periods in March and

May 1968. Pollutant sampling consisted of SO_2, CO, CO_2, hydrocarbons, and suspended particulate. Temperature was sensed continuously on vertical ascents to determine stability structure. The particulate measurements should be of particular significance because of the large quantities of the material emitted along the boundary. A Charlsen-Ahlquist nephelometer was used to sample particulate matter. A light-scattering coefficient measured by the device can be related to aerosol mass in a volume of air.

The data gathered during the study will be analyzed and subsequently reported by the IJC following completion of the field investigation in December 1968.

4.4.7 Other Abatement Projects

The Delaware Valley Regional Air Quality Program is being conducted (1) to assess the sources, characteristics, concentrations, transport, and extent of air pollution that may affect health and welfare in the Delaware Valley (PENJERDEL) area, (2) to recommend procedures and techniques for the abatement and prevention of air pollution, (3) to recommend specific air pollution control regulations. A network of surface wind recording stations is being used, plus vertical measurements of wind and temperature from several levels on the WFIL-TV tower, Philadelphia, Pa. The tower data are being obtained by means of a contract with Drexel Institute of Technology.

The air pollution climatology of the Ironton, Ohio - Ashland, Kentucky - Huntington, W. Va., area was presented in a public abatement conference.

The air pollution climatology of a portion of the Ohio River Valley near Steubenville, Ohio, is being studied in preparation for a possible conference to develop local control procedures. The adequacy of a limited air sampling effort is being tested by means of a mathematical urban diffusion model.

A staff report has been prepared on the impact of power generating facilities on air quality in the Lake Powell Area.

A mathematical model has been developed for predicting the percent frequency of occurrence of selected air pollutant concentrations.

Development work on the tethersonde is continuing, with improvements in solid-state circuitry and antenna systems. Recent field performance is generally satisfactory. Also, a vest-pocket-size pibal timer has been developed.

4.5 Training Program

The Air Pollution Training Program offers two 1-week courses in the meteorology of air pollution. The first, "Meteorological Aspects of Air' Pollution," is designed for scientists having no meteorological training and for meteorological technicians. The second course, "Diffusion of Air Pollution - Theory and Application," is planned for meteorologists working in the air pollution field and for graduates of the Meteorological Aspects course. The Meteorology Program supports the Training Program by taking full responsibility for these two courses as well as by furnishing air pollution meteorology lectures which may be required in any of the other 25 courses offered by the Training Program.

During the past year the Meteorological Aspects course was presented once at the Plumbrook Nuclear Reactor Facility near Sandusky, Ohio, and once as a resident course in Cincinnati, Ohio. The combined attendance at these two courses was 71 students, and of this number 44 were engineers. The Diffusion of Air Pollution course was given in Cincinnati to 31 students, including 15 meteorologists of whom six were ESSA employees.

The Weather Bureau has proposed that the Diffusion of Air Pollution course be given in a different Weather Bureau Region every year until all the Regional Directors have had the opportunity to offer the course to selected meteorologists in their regions. Under this program Diffusion of Air Pollution was given as a field course for the first time at the Western Regional Headquarters in Salt Lake City, Utah. Of the 30 enrollees who attended full-time, 26 were meteorologists; 23 were ESSA employees.

The training staff of the Meteorology Program consists of two men. For the resident air pollution meteorology courses these two are assisted by the entire Meteorology Program professional staff who lecture in their specialities. For the courses during the past year ESSA furnished additional speakers from Weather Bureau Western Region Headquarters, Air Resources Idaho Falls Laboratory, Weather Bureau Analysis and Prediction Division, and the Office of the Ohio State Climatologist. Guest lecturers from other governmental agencies, from universities, and from industry also participated in these courses.

The air pollution meteorology taught in the Training Program's non-meteorology courses is usually presented by the Meteorology Program's two-man training staff at the National Air Pollution Control Administration

Headquarters in Cincinnati, Ohio, and at Durham, North Carolina. Staff members also lectured in NAPCA courses given in Elyria, Ohio; Akron, Ohio; Seattle, Washington; Brooks AFB, San Antonio, Texas; Kansas City, Missouri; and Dallas, Texas. Another Meteorology Program staff member lectured in a field course in Philadelphia, Pennsylvania.

Other lecture presentations were given as part of a course in the Department of Occupational Health at the University of Pittsburgh and as part of the lecture series of the American Society of Mechanical Engineers course, "Air Pollution Control," in New York, New York.

Soon the Meteorology Program's training unit will move to North Carolina to join the NAPCA Training Program, which is already established in the Research Triangle Area. Future presentations of the Meteorological Aspects and Diffusion courses will be given in North Carolina. The program of field presentations of Diffusion of Air Pollution in the Weather Bureau Regions will continue with a course scheduled at the Eastern Region Headquarters in September 1968.

Air pollution control personnel express increasing interest in the use of meteorological instruments as part of their programs in cities, counties, and states. These people need current information about instruments for various types of air pollution meteorological studies and about the operation and maintenance of these instruments. To supply this information and offer practical experience in the operation of these instruments, a 1-week course entitled, "Meteorological Instrumentation in Air Pollution," will be presented for the first time in June 1969.

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