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COMPARISON OF AIR POLLUTION FROM AIRCRAFT AND AUTOMOBILES (PROJECT EAGLE)

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FINAL REPORT

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16. Abstract

This investigation into the environmental aspects of establishing an urban air transportation system for the tri-state area of Connecticut, New Jersey, and New York for daily commuting demonstrates that air pollution and its associated physiological effects, which are created by automobile engine emissions, can be drastically reduced. Similar results pertain when STOL air transportation is substituted for automobiles to provide service for the same area to the three major airports around New York City. Further, the study shows that air pollution at a STOLport in Manhattan supporting such a system would be less than the normal background concentration, even during peak travel periods.

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PREFACE

In a study entitled Project Eagle, it has been determined that urban air transportation in the tri-state area of Connecticut, New Jersey, and New York could be provided for daily commuters at passenger fares competitive with travel by automobile, train, and bus. The Assistant Administrator for Plans of the Federal Aviation Administration (FAA) in Washington, D.C. directed this air pollution study to be conducted for determining the extent that air pollution could be reduced by carrying those automobile passengers who would prefer aircraft travel in a city-to-city air service.

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COMPARISON OF AIR POLLUTION FROM AIRCRAFT AND AUTOMOBILES

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COMPARISON OF AIR POLLUTION FROM AIRCRAFT AND AUTOMOBILES

CHAPTER I
INTRODUCTION

In this report of an ongoing study, it is demonstrated that air pollution and its associated physiological effects, which are created by automobile engine emissions, can be drastically reduced by providing urban air transportation for those daily commuters who now travel by automobile but would prefer journey by aircraft. As one example in the same four hour period, 67 tons of pollutants emitted by automobiles can be reduced to five tons employing aircraft in 1970. The number of commuters who would change from automobiles to aircraft has been determined in an ongoing study called "Project Eagle".[1] The Project Eagle Study, which is being conducted at the Center for Transportation Studies of the Eagleton Institute of Politics at Rutgers University, considers aircraft operating below 3500 feet over the tri-state area of Connecticut, New Jersey and New York. In "Project Eagle", it is shown that approximately thirty per cent of the commuters who now travel by ground transportation would change to aircraft when traveling daily between Manhattan and the 11 satellite city transportation centers and their surrounding eight mile catchment areas in Connecticut, (Bridgeport, New Haven and Stamford), in New Jersey (Linden/Rahway, New Brunswick, Paterson and Newark) and in New York (Farmingdale, Hempstead, Mt. Vernon and White Plains). (See Figure I-1.) "Project Eagle" considers a total of 117,000 commuters traveling from these 11 satellite city transportation centers to work in Manhattan during each 7-9A.M. and 4:30-6:30P.M. peak hour travel period.[2] These population concentrations, scattered about the New York Metropolitan Area, can be termed "satellites" in that they are tied to the New York City sphere of influence.

This air pollution study considers engine emissions of hydrocarbons, particulates, carbon monoxide and nitrogen oxides established by the U.S. Department of Health, Education and Welfare.[3] Consideration of this new concept in urban air transportation is in accordance with the National Environmental Policy Act of 1969[4], which directs consideration of new and expanding technological advances in reducing air pollution.

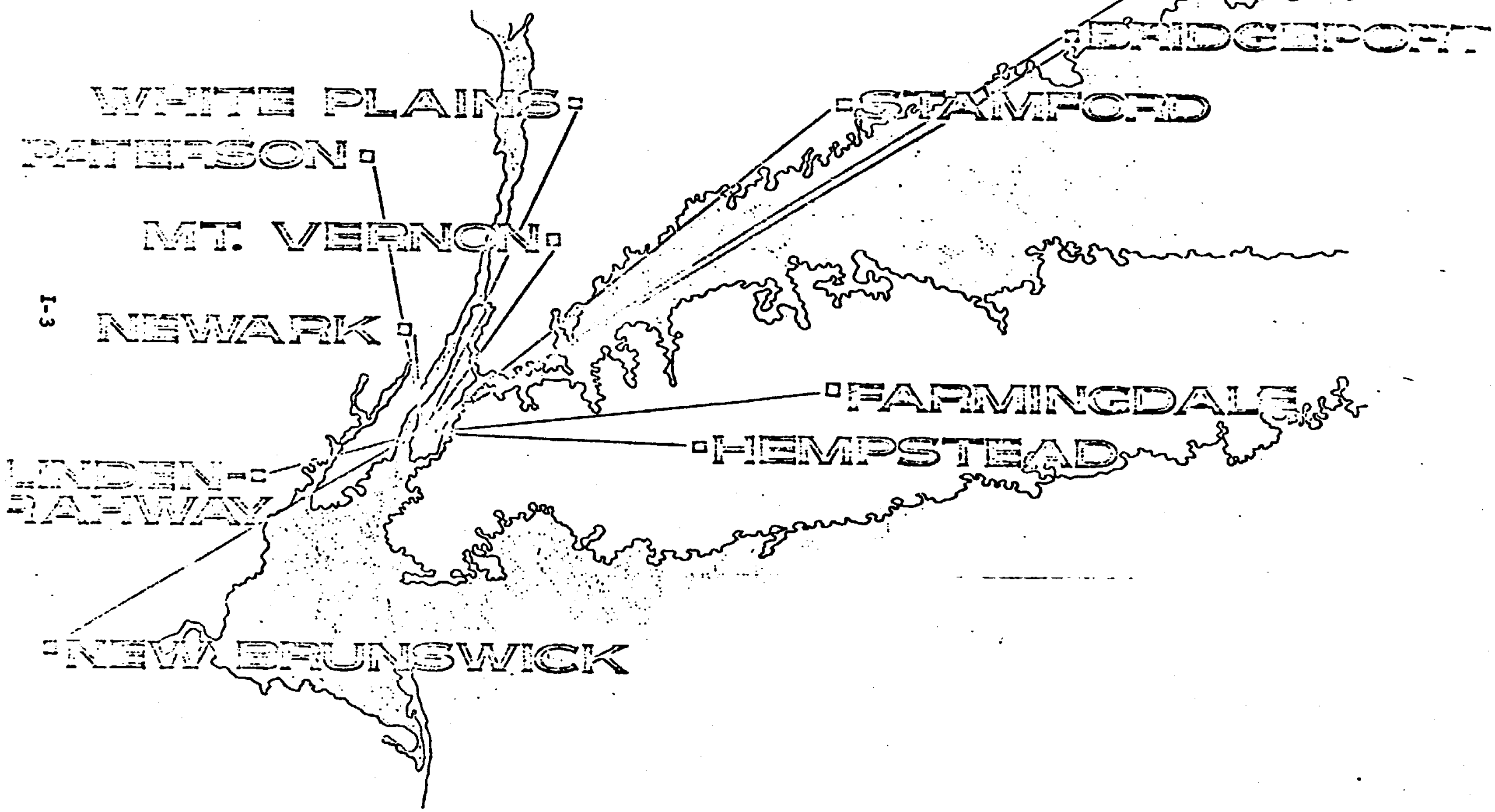
Study Directive and Objectives

This air pollution study is being conducted at the request of Mr. Oscar Bakke, Associate Administrator for Plans, Federal Aviation Administration (FAA) of the U.S. Department of Transportation (DOT). He directed that the FAA support this study of air pollution, comparing automobile and aircraft engine emissions of hydrocarbons, carbon monoxide, nitrogen oxides and particulates. Employing the Project Eagle Study as the basis for the analysis of air pollution, the following objectives were established:

1. Establish the decrease in air pollution from engine emissions that

Figure I-1

SATELLITE CITIES



will occur by transporting daily commuters traveling currently by automobiles from 11 satellite city transportation centers located throughout the tri-state area into and from Manhattan in aircraft powered by turbofan engines.

2. Determine the concentration of pollutants and from these concentrations establish the resulting physiological effects that would be created by aircraft operating at a STOLport located in the Hudson River along the Manhattan shoreline during peak travel operations of a tri-state urban air transportation system. This is to include comparison of aircraft and automobile engine emissions.

3. Estimate the decrease in air pollution levels that can be realized throughout the tri-state area by providing air transportation for daily travelers who now use automobiles to move to Newark, La Guardia and J.F. Kennedy Airports.

4. Develop models and procedures that will permit determining pollution concentrations that would occur in the vicinity of STOLports and along highways providing access into these STOLports.

In establishing the objectives for this study, the lack of information and the incompleteness of data is recognized. But at the same time, this study makes a case for determining findings based on available information.

Future studies will greatly improve our understanding of the way in which various design approaches affect pollution levels. Eventually, it may be possible to develop guidelines containing detailed recommendations on various alternatives and specifying minimum distances and other parameters to help reduce the pollution problem in the airport and street environment.

"The absence of a general body of such information, however, does not prevent us from acting promptly within the context of what we already suspect."[5]

Summary of Conclusions

1. The 67 tons of pollutants emitted by automobiles carrying 29,000 commuters between Manhattan and the 11 satellite city transportation centers within the tri-state area during the hours of 7 A.M. to 9 A.M. and 4:30 P.M. to 6:30 P.M. can be reduced to five tons by carrying them in aircraft powered by turbofan engines.

2. High density aircraft operations on the flight deck of a circular shaped Rutgers Aquadrome generate carbon monoxide levels of 1.2 ppm at a distance of 100 m. off the flight deck compared with a 3-6 ppm ambient rooftop or background level in Manhattan.

3. Pollutants emitted each day by automobile and aircraft transporting the same number of passengers to Newark, La Guardia and J.F. Kennedy Airports from N.Y. County and the counties containing the II satellite city transportation centers are as follows:

	Automobiles	Aircraft
1970	13.34 tons /day	1.03 tons/day
1975	9.01 tons/day	1.03 tons/day
1980	3.73 tons/day	1.03 tons/day

4. Pollutants emitted yearly by automobile and aircraft transporting the same number of passengers to Newark, LaGuardia and J.F. Kennedy Airports from New York County and the counties containing the II satellite city transp...'ation centers are as follows:

	Automobiles	Aircraft
1970	4869 tons/year	380 tons/year
1980	1365 tons/year	380 tons/year

5. The combination of mathematical meterorological models of atmospheric dispersion for determining concentrations of carbon monoxide and procedures for determining the physiological effects of varying carboxyhemoglobin (COHb) levels in the blood caused by these concentrations are applicable for determining air pollution exposure forecasts for airports and highway segments.

6. High density aircraft operations on the decks of oblong shaped and circular shaped Rutgers Aquadromes located at Manhattan would create carboxyhemoglobin (COHb) levels of less than one per cent at a distance of 100m. off the deck which have no known physiological effects on humans.

7. Air pollution concentrations along a highway that would provide access for automobiles to a city center airport located in New Brunswick, N.J. can produce physiological effects which are in violation of the Air Pollution Alert Standards of the New Jersey Air Pollution Control Code.

8. The drastic reduction in air pollution that is possible in providing air transportation in the tri-state area for daily commuters and the major airport users warrants establishing a demonstration air service.

Background

This study begins from an initial analysis of air pollution conducted at the suggestion of Dr. Patrick Moynihan, Counselor to the President, following his review of the Project Eagle Study given at the White House on November 20, 1969.

This analysis for Dr. Moynihan[6] establishes that the high concentrations of pollutants emitted by motor vehicles, which constitute about 58 per cent of the U.S. National total air pollution,[7] could be drastically reduced in urban areas throughout the nation. The significant reductions in air pollution that will occur is shown in the following tabulations which are based upon round trips made by both automobiles and aircraft.

	Number of Commuters	Number of Vehicles	Total Pollution 7 A.M. to 9 A.M. and 4:30 P.M. to 6:30 P.M.
Automobiles	8,700	7,276	15,028 lb. or 8 tons
Aircraft	8,700	74	455 lb. or 1/4 ton

In considering the analysis for Dr. Moynihan, the Assistant Commissioner of Program Development in the National Air Pollution Control Administration of the U.S. Department of Health, Education and Welfare (HEW) suggested that additional analysis be conducted comparing hydrocarbons, carbon monoxide, nitrogen oxides and particulates emitted from automobile and aircraft engines. In this second analysis,[8] new automobile engines were considered to be fitted with devices that would meet pollution standards established by the HEW for 1971, 1975 and 1980[9] as shown in Figure I-2.

These two analyses established that drastic reductions in air pollution will result by providing air transportation for commuters now traveling by automobile.

The comparison of engine emissions from automobile and aircraft are shown in Figure I-3. The comparison for 53 passenger aircraft considering 50% and 100% load factors are shown by the dotted lines. The two solid lines represent automobile engine emission values computed using two different Federal Test Cycles. The 1970 Federal Test Cycle using a 7 mode dynamometer procedure and deriving pollution values by mathematical formula established a 60.34 grams per passenger mile in 1980. The revised 1972 Federal Test Cycle gives a true mass measurement of emissions and avoids estimation of emissions by mathematical formula. The initial value of 91.75 grams per passenger mile in 1970 decreases to 25.69 grams per passenger mile in 1980.

The values represented by the solid lines are based on a methodology considering automobile age and vehicle useage currently being used by the National Air Pollution Control Administration.[10] (refer to appendix A) The automobile pollution values based on these Federal Test Cycles plotted as solid lines and aircraft pollution values at 50% and 100% load factors plotted as dotted lines represent the range of values that can be used in comparing automobile and aircraft engine emissions.

No decrease is shown to occur in the aircraft values for the 53 passenger aircraft.[11] It is recognized, however, that meaningful improvements have been made to the JT 8D engine since February, 1970, which further reduced the pollution level. These improvements were not considered in this interim report as the computer printouts were not available. The pollution values shown for the 53 passenger aircraft in this study have been computed considering two JE 8D engines. The standards employed in this study are shown in Figure I-3.

Figure I-2
PROPOSED AUTOMOBILE ENGINE EMISSION STANDARDS OF H.E.W.

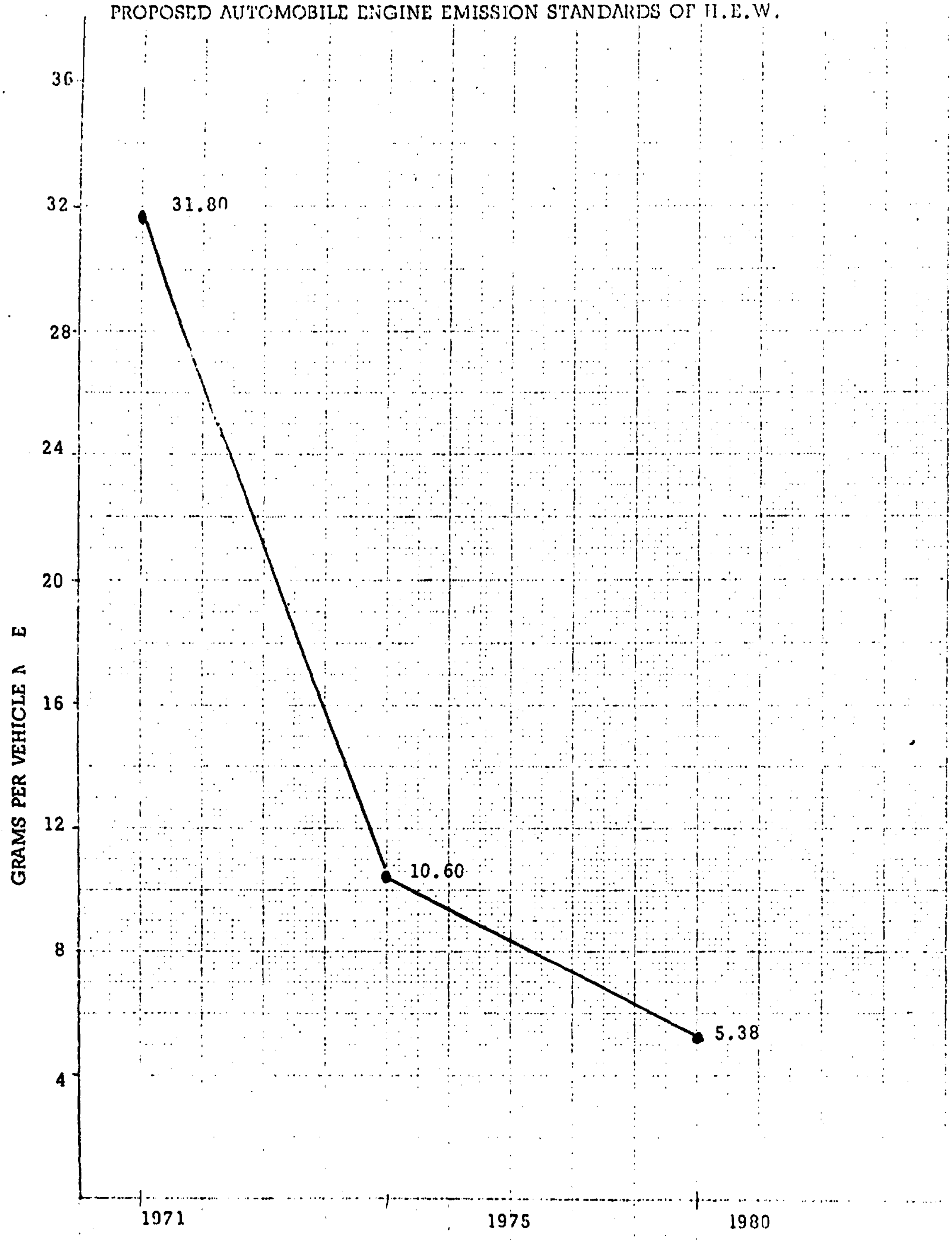
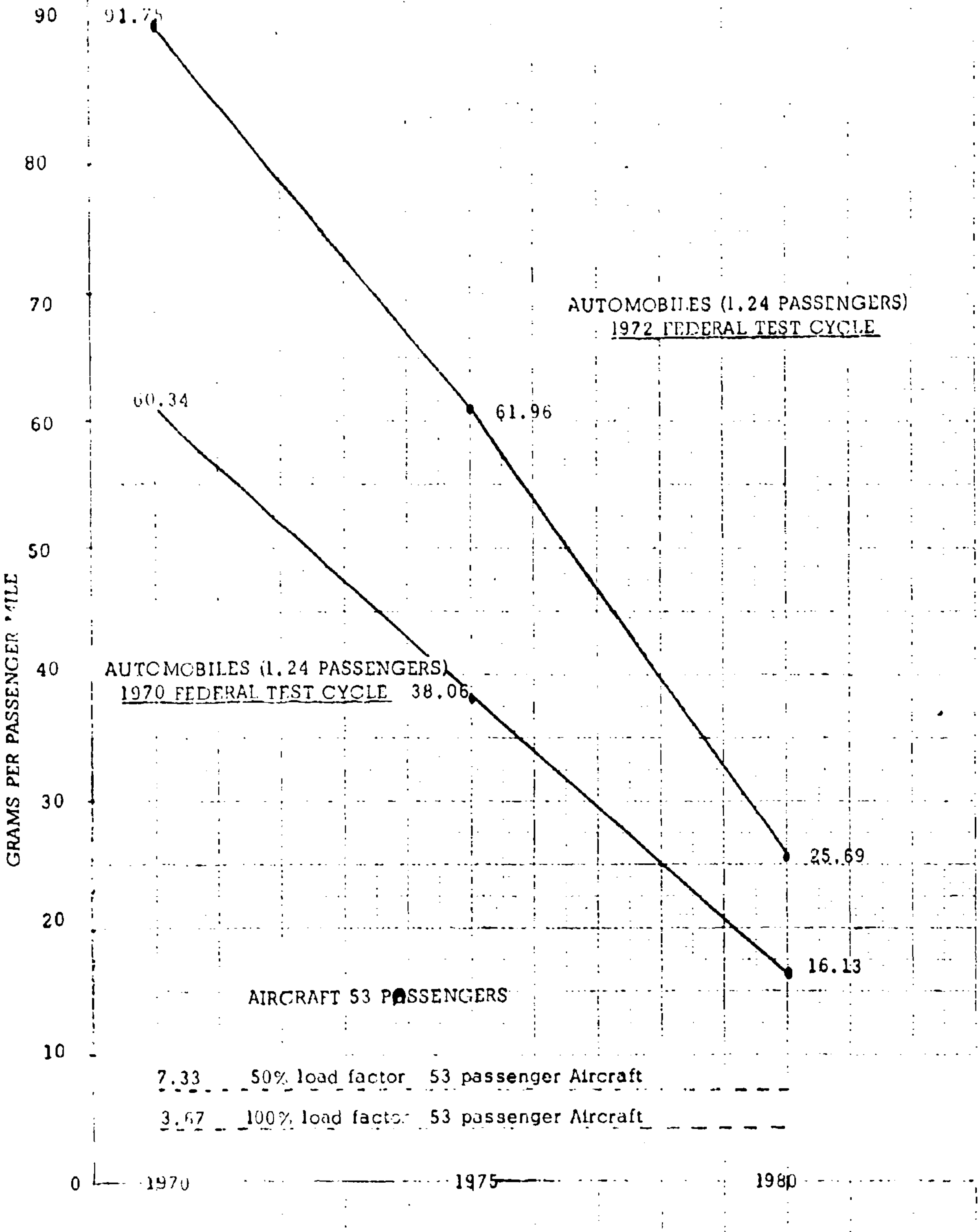


Figure I-3

AIR POLLUTION EMITTED FROM AUTOMOBILE AND AIRCRAFT ENGINES (CARBON MONOXIDE NITROGEN OXIDES, PARTICULATES AND HYDRO-CARBONS)



Two JT 8D engines theoretically sized to produce thrust equivalent to two T-64 turbo-prop engines would produce an 18.6% reduction in the air pollution emitted from the JT 8D emission shown in Figure I-2. The grams of pollution per passenger mile for aircraft powered by two scaled down JT 8D engines at 50% load factor and 100% load factor are 5.97 and 2.99 respectively. These pollution emissions in Figure I-3 consist of the total carbon monoxide, nitrogen oxides, particulates and hydrocarbons emitted by aircraft and automobiles.

The values for both automobile and aircraft engine emissions in gram per vehicle mile, considered in establishing these standards, are contained in Appendix A.

It has been established by HEW that the largest single source of carbon monoxide is from the engine exhaust of passenger cars, light duty trucks and three classes of heavy duty trucks.[13] The annual carbon monoxide emission estimates from the four sources of transportation, solid waste, industrial and stationary fuel consumption for the New York Metropolitan area and 10 other metropolitan areas in 1968 are shown in Figure I-4.

In the case of New York City it is shown that 95.5 per cent of the carbon monoxide pollution was generated in 1968 by motor vehicles, aircraft, ships, railroads and other highway use of motor fuels. (See Figure I-4) By applying the national averages for automobile and truck emissions to New York City, it shows that automobiles and trucks create about 90 per cent of the total carbon monoxide pollution caused by the burning of motor fuels.[14]

By decreasing the number of automobiles used in urban transportation by carrying the passengers in aircraft, the major source of serious carbon monoxide contamination will be reduced.

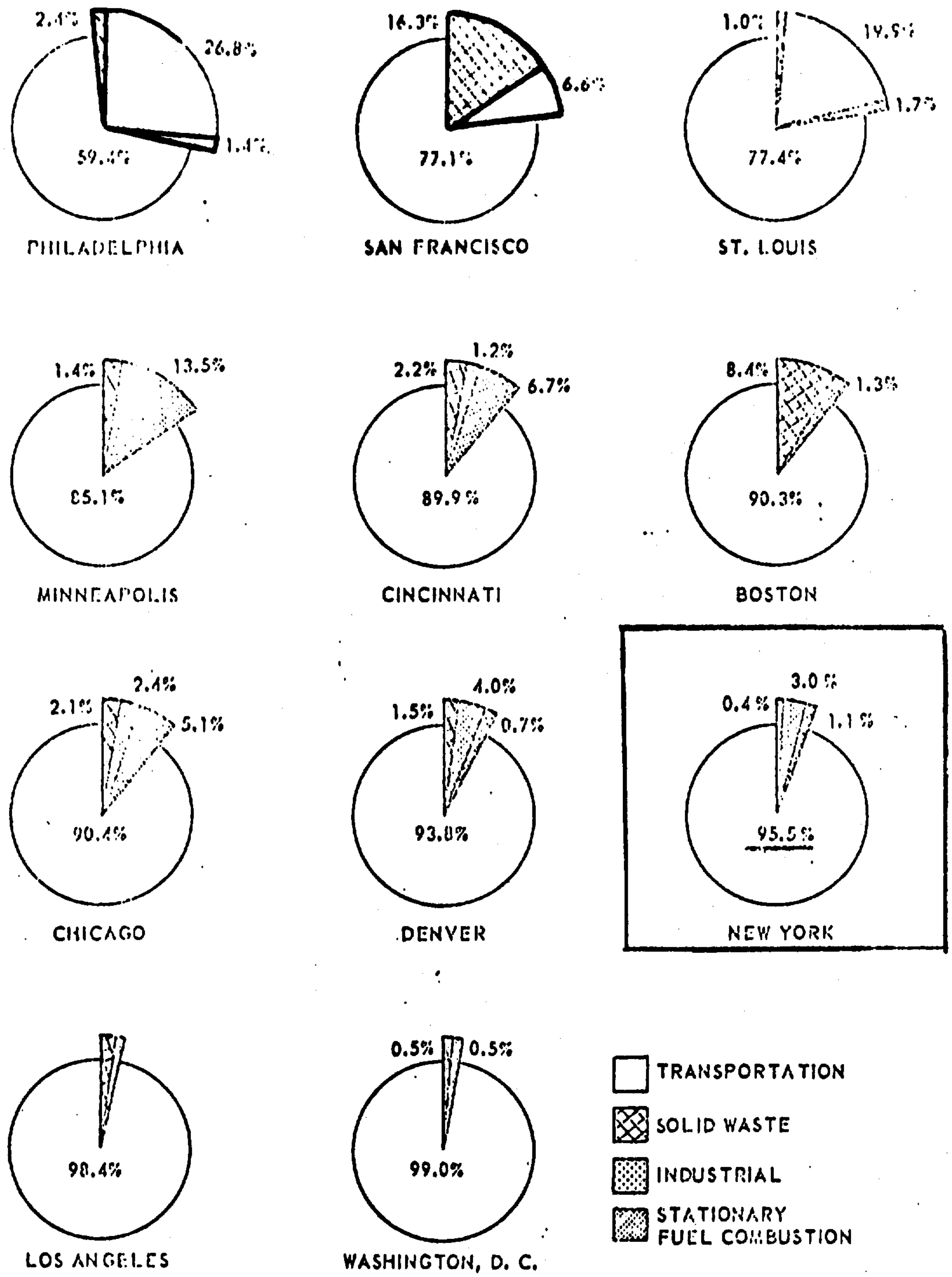


Figure I-4 Carbon monoxide emissions by source category for various U.S. metropolitan areas in 1968.

Source: U.S. Department of Health, Education and Welfare, Air Quality Criteria for Carbon Monoxide, National Air Pollution Control Administration Publication No. AP-62, (Washington, D.C.: U.S. Government Printing Office, 1970), p. 4-6.

FOOTNOTES

CHAPTER I

[1]Rutgers University, Center for Transportation Studies of the Eagleton Institute of Politics, Project Eagle-A Study of Urban Mass Air Transportation for Connecticut, New Jersey and New York, (November, 1969), pp. VII-1 through VII-38.

[2]Ibid., p. V-15.

[3]Automobile Emissions Data for 1971, 1975 and 1980, provided by Raymond Smith, Assistant Commissioner of Program Development, National Air Pollution Control Administration, U.S. Department of HEW, in a personal interview on December 15, 1969.

[4]Statutes, No. 83: 852, National Environmental Policy Act of 1969.

[5]John T. Middleton and Wayne Ott, "Air Pollution and Transportation," Traffic Quarterly, (April, 1968), p. 184.

[6]Letter from Rutgers University, Center for Transportation Studies of the Eagleton Institute of Politics, to Dr. Patrick Moynihan, Counselor to President Nixon on December 1, 1969.

[7]U.S. Department of Health, Education and Welfare, Air Quality Criteria for Carbon Monoxide, National Air Pollution Control Administration Publication No. AP-62, (Washington, D.C.: U.S. Government Printing Office, 1970), pp. 4-1 and 4-2.

[8]Letter from Rutgers University, Center for Transportation Studies of the Eagleton Institute of Politics to Mr. Raymond Smith, Assistant Commissioner of Program Development, National Air Pollution Control Administration on December 23, 1969.

[9]Smith interview on December 15, 1969, op. cit.

[10]Dr. Robert Kirk, Office of Program Development, National Air Pollution Control Administration in a personal interview on January 20, 1969.

George Kittredge, Division of Motor Vehicle Research and Development, National Air Pollution Control Administration in a conference during January, 1970.

James Beaty, Inventory Emissions, National Air Pollution Control Association, Durham, N.C. in a conference during August, 1970.

[11] Joseph Hobbs, Supervisor-Installation Design Requirements, Pratt and Whitney Aircraft, in a conference on November 21, 1969.

The contaminant values of two JT 8D turbofan engines, each of 14,000 lb. thrust, at sea level conditions are based upon a 1969 IBM Computer Print-Out, by Pratt and Whitney Aircraft.

[12] Joseph Hobbs, Supervisor-Installation Design Requirements, Pratt and Whitney Aircraft, in a conference during December, 1969.

[13] U.S. Department of Health, Education and Welfare, Air Quality Criteria for Carbon Monoxide, op. cit., pp. 4-1 and 4-2.

[14] Ibid., pp. 4-2 and 4-6.

CHAPTER II
AIR POLLUTION THROUGHOUT THE TRI-STATE AREA OF CONNECTICUT, NEW JERSEY AND NEW YORK

It is demonstrated that drastic decreases in air pollution will occur by transporting daily commuters in aircraft, who now travel in automobiles from the 11 satellite cities located throughout the tri-state area into and from Manhattan during the peak travel hours of 7 A.M. to 9 A.M. and 4:30 P.M. to 6:30 P.M. These decreases are due to the low level of air pollution from turbofan powered aircraft which carry many passengers compared to automobiles which carry an average of less than two passengers.

This is recognized by the N.J. Clean Air Council in its report on The Status of Air Pollution from Mobile Sources. This report states "the indicated reduction of today's mobile source emissions of carbon monoxide and hydrocarbons will be temporary unless (1) low pollution vehicles are available well before 1980 and (2) mass public transportation systems displace large numbers of cars." [1]

These reductions are arrived at by employing four different methods for determining the numbers of daily commuters who could change from automobile to aircraft travel. Such analysis has been conducted in the Project Eagle Study.[2] In each of these four methods, the basic factor in determining choice between bus, trains, automobiles and aircraft is costs of commuter travel. Costs of commuter travel are computed to include out-of-pocket costs and the dollar value of both travel time and waiting time. In all four methods, the transportation mode having lowest costs receives the highest preference, and the mode having the highest costs receives the lowest preference. These four methods for determining the numbers of daily commuters who could change from automobile to aircraft are:

Method No. 1 considers out-of-pocket costs per passenger between terminals in a satellite city transportation center and the Manhattan Central Business District South of 60th Street.

Method No. 2 considers:

a. Out-of-pocket costs for the trip from the commuter's home to the terminal in the satellite city transportation center.

b. Out-of-pocket costs for the trip between terminals in the satellite city transportation center and the Manhattan Central Business District South of 60th Street.

c. Out-of-pocket costs for the trip from terminal in Manhattan to the commuter's place of work.

Method No. 3 considers out-of-pocket costs and, in addition, the dollar value of travel time and waiting time of the commuter traveling between terminals in the satellite city transportation center and the Manhattan Central Business District South of 60th Street. The specific location for a STOLport employed in this analysis is between 23rd and 34th Streets.

Method No. 4 considers:

a. Out-of-pocket cost for the trip from the commuter's home to terminal in the satellite city transportation center.

b. Out-of-pocket cost and, in addition, the dollar value of travel time and waiting time for the trip between terminals in a satellite city transportation center and the Manhattan Central Business District.

c. Out-of-pocket cost for the trip from terminal in Manhattan to the commuter's place of work.

The number of passengers who occupied each automobile travelling to Manhattan during the peak travel hours varies among counties in which satellite city transportation centers are located. Passengers per automobile ranged from one occupant from New Brunswick, New Jersey to two occupants from Paterson, New Jersey.[3] An example of how these four methods compare considering aircraft travel between New Brunswick, New Jersey and Manhattan in New York City is shown in Figure II-1.[4]

Employing these four methods, the reductions in air pollution achieved by transporting daily commuters by air instead of by automobile from the 11 satellite cities in the tri-state area and into and out of Manhattan are shown in Figure II-2. Method 3, which shows the comparison of total pollution for automobile and aircraft carrying 28,596 passengers, is shown graphically in Figure II-3. These values are for aircraft operating at 100 per cent load factor. Appendix B shows values based on aircraft load factors of both 100 and 50 per cent for carbon monoxide, nitrogen oxides, hydrocarbons and particulates. An example of how these comparative values were obtained is also in Appendix B, which illustrates the four basic steps developed to compare the pollution generated by aircraft and automobiles. These steps determine:

1. The passenger preference for automobile, bus and rail transportation between the 11 satellite city transportation centers and Manhattan.

Figure II-1

AIRCRAFT TRAVEL: NEW BRUNSWICK, N.J. TO MANHATTAN, N.Y.

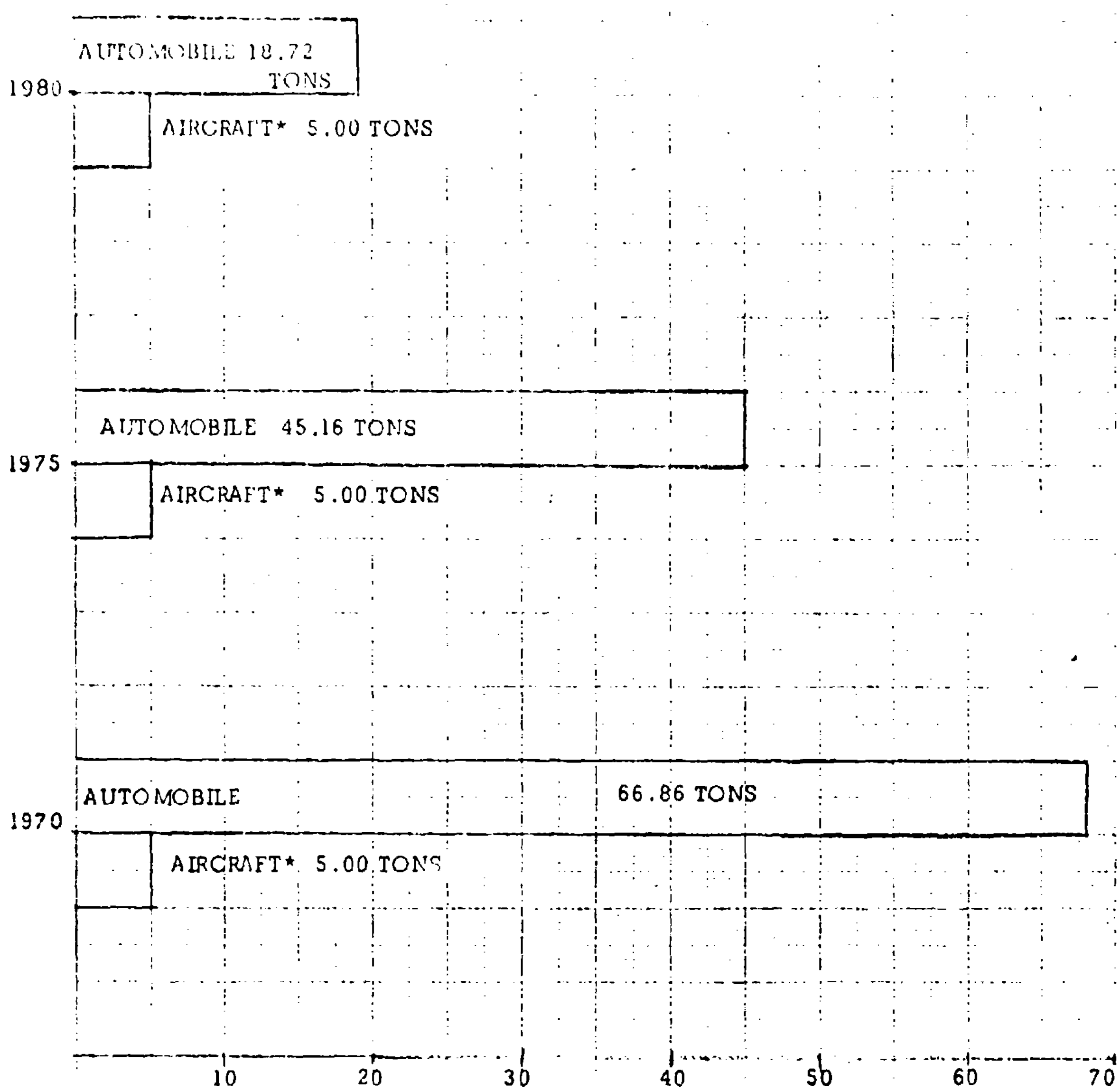
METHOD	COST VARIABLES				
	Out-of-Pocket Cost for Travel from Commuter's Home to Satellite City Transportation Center in New Brunswick	Out-of-Pocket Cost for the Trip between Terminals in New Brunswick and Manhattan	Dollar Value of Travel Time and Waiting Time between Terminals in New Brunswick and Manhattan	Out-of-Pocket Cost from Terminal in Manhattan to Commuter's Place of Work	Total Costs per Passenger
#1		$2.60			$2.60
#2	$ .15	$2.60		$ .15	$2.90
#3		$2.60	$3.53		$6.13
#4	$ .15	$2.60	$3.53	$ .15	$6.43

Figure II-2

COMPARISON OF AUTOMOBILE AND AIRCRAFT POLLUTION

Method	Total Passengers Using Automobiles and Aircraft	Total Pollution (Tons/Day): 7A.M.-9A.M. and 4:30P.M.-6:30P.M.		
		1970	1975	1980
I. Automobile Aircraft (100% Load Factor)	20,290 20,290	48.06 3.64	32.46 3.64	13.47 3.64
II. Automobile Aircraft (100% Load Factor)	17,362 17,362	35.64 2.89	24.08 2.89	9.97 2.89
III. Automobile (100% Load Factor)	28,596 28,596	66.86 5.00	45.16 5.00	18.72 5.00
IV. Automobile Aircraft (100% Load Factor)	25,580 25,580	61.16 4.91	41.29 4.91	17.14 4.91

Figure II-3
COMPARISON OF AUTOMOBILE AND AIRCRAFT POLLUTION PER DAY - (METHOD III)



* AIRCRAFT POLLUTION BASED ON 100% LOAD FACTOR

2. The passenger preference for automobile, bus and rail transportation with the introduction of aircraft service.

3. The automobile passengers that would change to aircraft service.

4. The total tonnages of carbon monoxide, hydrocarbons, particulates and nitrogen oxides produced by aircraft transporting the same passengers who previously traveled by automobile.

Conclusions

1. The 67 tons of pollutants emitted by automobiles carrying 29,000 commuters between Manhattan and the 11 satellite city transportation centers within the tri-state area during the hours of 7 A.M. to 9 A.M. and 4:30 P.M. to 6:30 P.M. in 1970 can be reduced to five tons by carrying them in aircraft powered by turbofan engines operating at a 100 per cent load factor.

2. With aircraft operating at a 50 percent load factor, the 67 tons of pollutants emitted in 1970 by automobiles carrying 29,000 commuters between Manhattan and the 11 satellites during the peak travel hours in 1970 can be reduced to ten tons.

3. The drastic reduction in air pollution that is possible in providing air transportation for daily commuters between 11 satellite city transportation centers located in the tri-state area of Connecticut, New Jersey and New York and Manhattan warrants establishment of a demonstration air service.

4. The drastic reduction in pollution that is possible by carrying daily commuters in aircraft supports the recommendation of the New Jersey Clean Air Council that the pressing need is for mass transit.

FOOTNOTES

CHAPTER II

[1]New Jersey Clean Air Council, Department of Environmental Protection, Status of Air Pollution from Mobile Sources, (July 1970), p. 9.

[2]Rutgers University, Center for Transportation Studies of the Eagleton Institute of Politics, Project Eagle - A Study of Urban Mass Air Transportation for Connecticut, New Jersey and New York. (November, 1969), pp. VII-1 through VII-38.

[3]Tri-State Transportation Commission, Automobile Occupancy Print-Out for Rutgers University utilizing the 1963 Home Interview Survey, February, 1969.

[4]All cost variables based upon the base year of 1963 which represents the latest year for which complete information on passenger preference including peak hour automobile occupancies for the journey-to-work is available.

CHAPTER III
AIRCRAFT POLLUTION LEVELS AND PHYSIOLOGICAL EFFECTS CREATED AT A MANHATTAN STOLPORT

A new STOLport concept of employing a floating concrete airport called a Rutgers Aquadrome, has been developed in "Project Eagle."[1] In this concept the Aquadrome will be located alongside the bulkhead of the Hudson River with direct connections to ground transportation systems now existing in New York City. It is planned to employ a site in the waterfront areas now occupied by abandoned piers. This type of floating airport was selected after conducting an operations analysis of heliports, rooftop landing areas and runways supported on pilings.

Types of Aquadromes

Two types of Aquadromes are considered in this analysis of air pollution levels at a Manhattan STOLport. One is an oblong configuration 2040 feet long and 420 feet wide, which satisfies the INTERIM DESIGN CRITERIA FOR METROPOLITAN STOLPORTS AND STOL RUNWAYS,[2] established by the Federal Aviation Administration (FAA) of the U.S. Department of Transportation. It is established in "Project Eagle" that this oblong shaped airport could accommodate 60 flights using 53 passenger aircraft between 7 A.M. to 9 A.M. These aircraft could accommodate 3,180 commuters from the 11 satellite city transportation centers to Manhattan.[3] Location of such an Aquadrome, parallel to the shoreline and within the established pier line in the Hudson River, conforms to the port regulations established by the U.S. Army Corps of Engineers. The location selected for this air pollution analysis is between 23rd and 34th Streets, as shown in Figure III-1.

The other Aquadrome is circular in shape and 1,000 feet in diameter (see Figure III-2). It does not meet the INTERIM DESIGN CRITERIA of the FAA. It would, however, accomodate vertical and short takeoff and landing (V/STOL) aircraft which operate with greatly reduced runway requirements. In computing air pollution emission value's for aircraft, the highest density air operations which could occur during the peak hours of commuter air transportation operating from one Rutgers Aquadrome was considered. The present state of the art in guidance equipment and the flight capabilities of currently operating V/STOL aircraft makes it possible to conduct about 514 daily flights between 7 A.M. to 9 A.M. These flights would operate under visibility flight rules with a landing interval of about 28 seconds. Such air operations are current standard practice in the U.S. Navy Amphibious forces employing VTOL aircraft from both LPH and LPD type ships. It should be noted that by allowing for a 28 second landing interval sufficient time is allowed for unforseen delays in passengers leaving the aircraft, aborted flights, etc. Employing 53 passenger aircraft, a total of 27,242 daily commuters could be accomodated. The diameter of the circular shaped aquadrome considered in these calculations is 1,000 feet. Two aircraft would take off and land from each side of the aquadrome either simultaneously or at 14 second intervals. This method of air operations is in accordance with the present practice in U.S. Navy fleet doctrine where two or four aircraft take off and land simultaneously from a flight deck about 500 feet long and 100 feet wide.

Flight operations under instrument flight rules (IFR) were not considered as the total number of flights occurring from 7 A.M. to 9 A.M. would be considerably less than under VFR. This is primarily because of the greater time interval required for landing. For V/STOL aircraft now operating in the fleet to establish a landing interval of 30 seconds under IFR would require improvement in current technology in air traffic control which includes IFR automatic landing systems or comparable control methods.

Atmospheric Dispersion Estimates of Aircraft Operating from an Aquadrome Located in Manhattan

These air pollution estimates are computed separately for the landing maneuver, operations on the flight deck and the takeoff maneuver. The diffusion of pollution generated by aircraft operating on the Aquadrome flight deck is determined by using the area source model of atmospheric dispersion.[4]

The diffusion of pollutant emissions from aircraft into the surrounding airspace during in-flight landing and takeoff maneuvers differs fundamentally from calculations for diffusion from the flight deck area of the Aquadrome. The plume of pollutants generated by the aircraft in flight was not considered to be a continuously emitting source. Rather, it is considered to be a quasi-instantaneous line source that has a finite time limit for pollutant emissions over a finite distance. In addition, there are further complications created by the extraneous variables of an aircraft in flight, such as the heat content of the pollutants, the atmospheric turbulence created by the aircraft itself and the initial momentum of the pollutant in aircraft engine exhaust. Review of pertinent literature indicates there has been little success in dealing with diffusion from such a complicated source as aircraft in flight.

The need for determining the pollution levels of aircraft in the landing and takeoff maneuver and the resulting effects on the community dictated the choice of a mathematical model that is dependent upon the following qualifying assumptions:

1. Variables arising from in-flight aircraft exhaust emissions, such as heat content, atmospheric turbulence and pollutant momentum, enhance the mixing of the pollutants with the ambient air.

2. Concentrations arrived at without considering the above variables at a distance of 100 meters must be greater than the actual concentrations that would exist at 100 meters.

3. The exhaust plume is such that for small segments (e.g., 1 meter) the plume may be considered to be an effective line source, which is emitted over a small period of time.

By making these assumptions, it is possible to apply the quasi-instantaneous line source model to calculate the concentration of pollutants at distances from aircraft in flight. For the equation and actual calculations, refer to Appendix D.

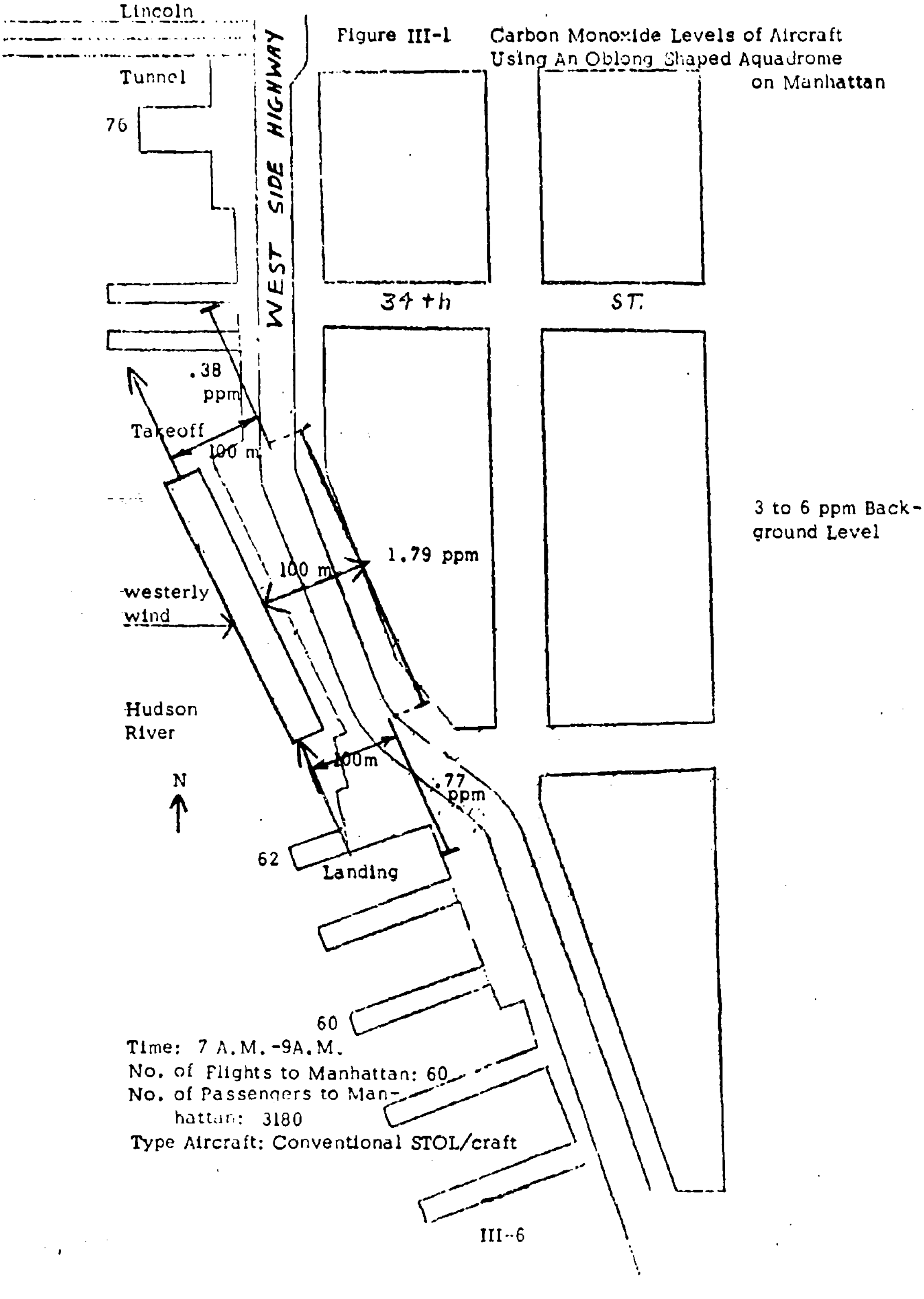
The atmospheric dispersion estimates at a downwind receptor distance of 100 meters from aircraft using an oblong shaped Aquadrome and a circular Aquadrome based on the area source and quasi-instantaneous line source models are shown in Figures III-1 and III-2. These are compared with the ambient rooftop or background level of 3-6 ppm existing on Manhattan Island.[5] The pollution from aircraft adds to this 3-6 ppm background level.

Comparative Unit Area Emission on an Aquadrome and Manhattan Island

Aircraft operations on the flight deck of an oblong Rutgers Aquadrome produces 887 pounds of carbon monoxide between 7 to 9 A.M. and 4:30 to 6:30 P.M. This compares to total carbon monoxide emissions of 16,800 pounds emitted during the same four hours over an area of .2 square miles adjacent to the Aquadrome.[6] Aircraft operations on the flight deck of a circular shaped Aquadrome yield 312 pounds of carbon monoxide between 7 to 9 A.M. and 4:30 to 6:30 P.M. This compares to the 16,800 pounds emitted from the .2 square mile area of Manhattan (see Appendix E).

A comparison of unit area emissions per second (Q) from the oblong shaped Aquadrome, the circular shaped Aquadrome and the adjacent .2 square mile land area is then made predicated on the pounds of carbon monoxide emitted between 7 to 9 A.M. and 4:30 to 6:30 P.M. Such a comparison shows that the emission rate (Q) of aircraft operating on an oblong shaped Aquadrome is 1/2 the emission rate of the land adjacent to the Aquadrome (Figure III-4). Calculation of these emission rates are contained in Appendix E.

Figure III-1 Carbon Monoxide Levels of Aircraft Using An Oblong Shaped Aquadrome on Manhattan



Time: 7 A.M.-9A.M.
No. of Flights to Manhattan: 60
No. of Passengers to Manhattan: 3180
Type Aircraft: Conventional STOL/craft

Figure III-2 Carbon Monoxide Levels of Aircraft Flying from a Circular Shaped Aquadrome on Manhattan

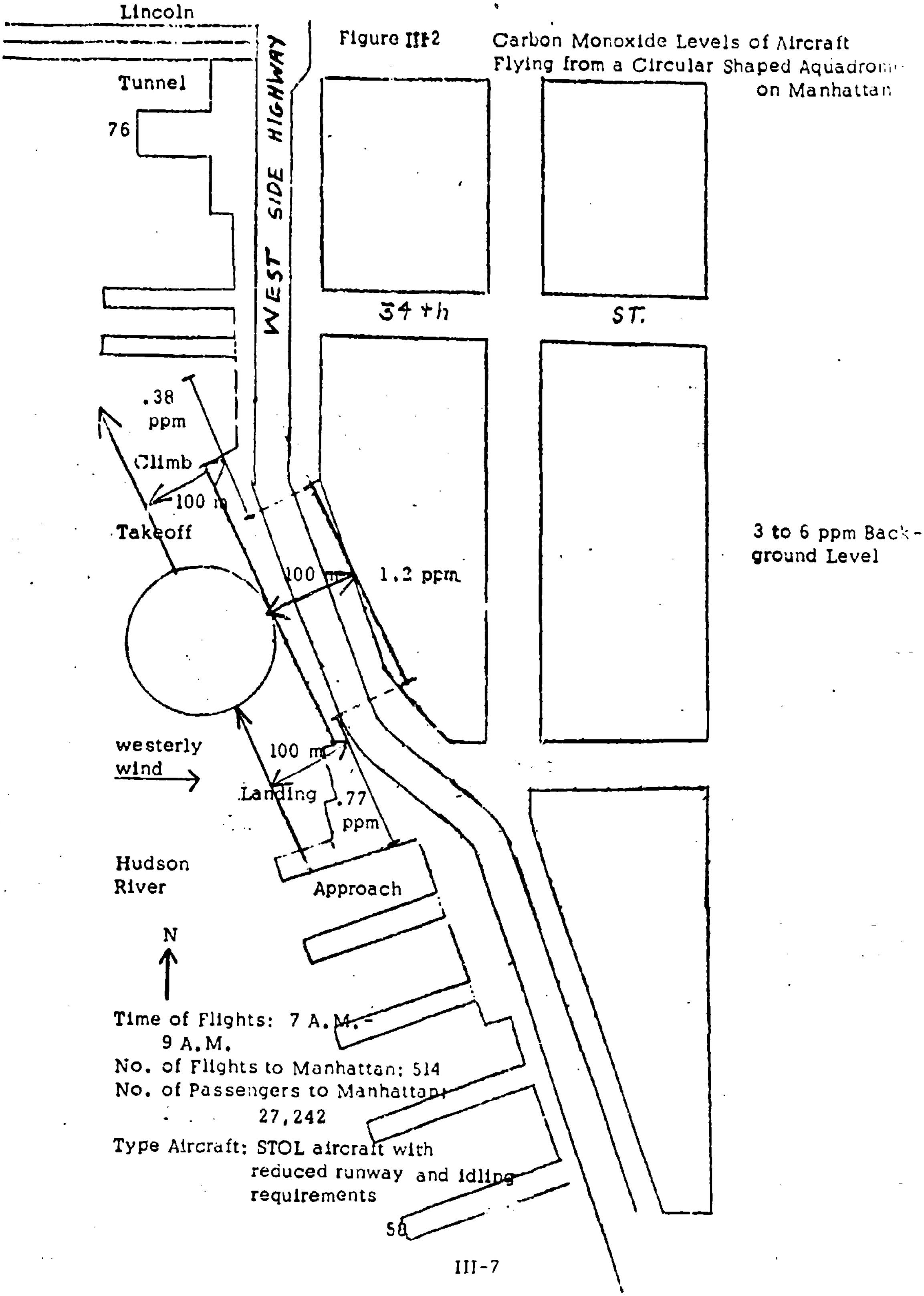


Figure III-3 Unit Area Carbon Monoxide Emissions Per Second on Oblong Shaped Aquadrome

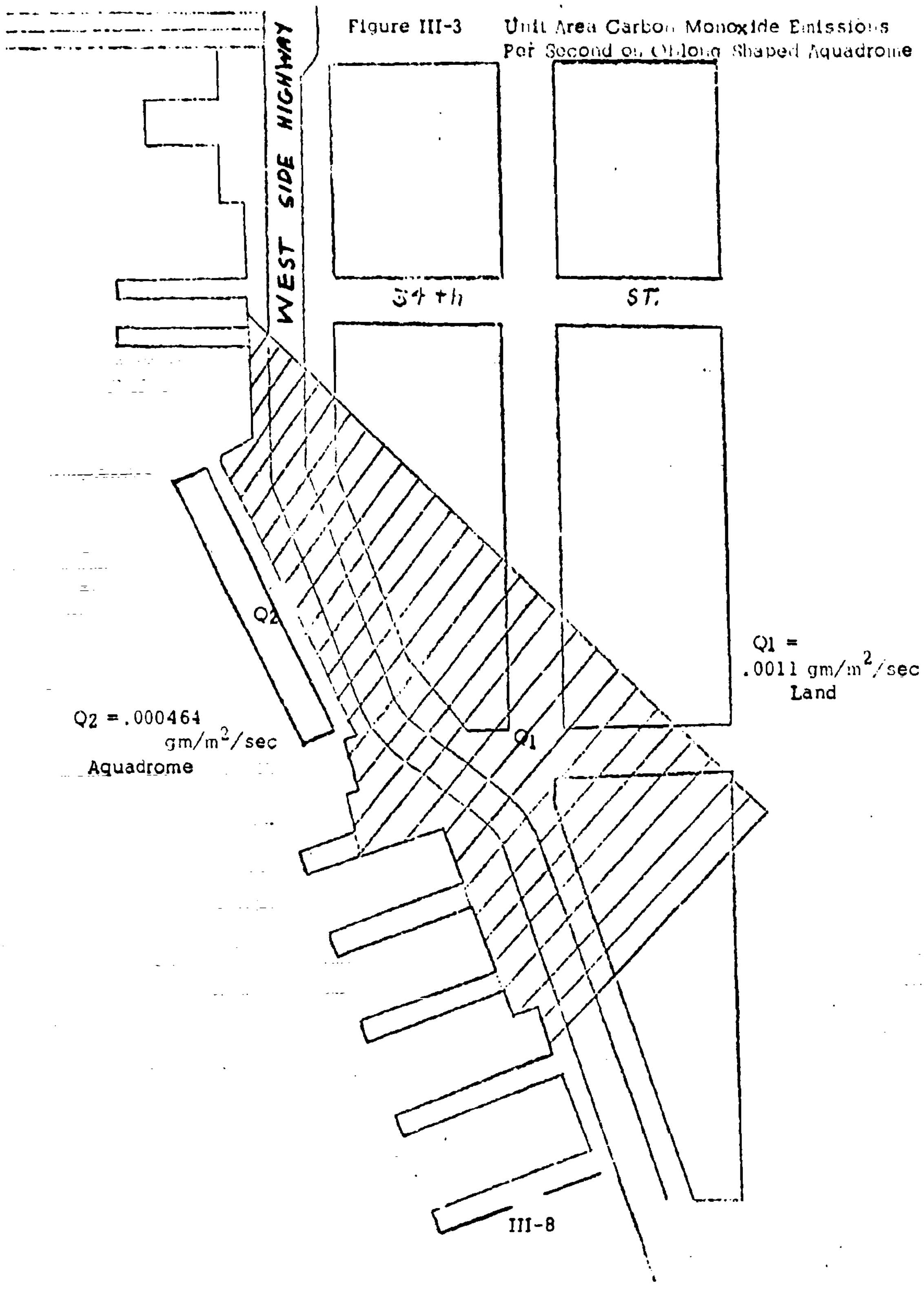
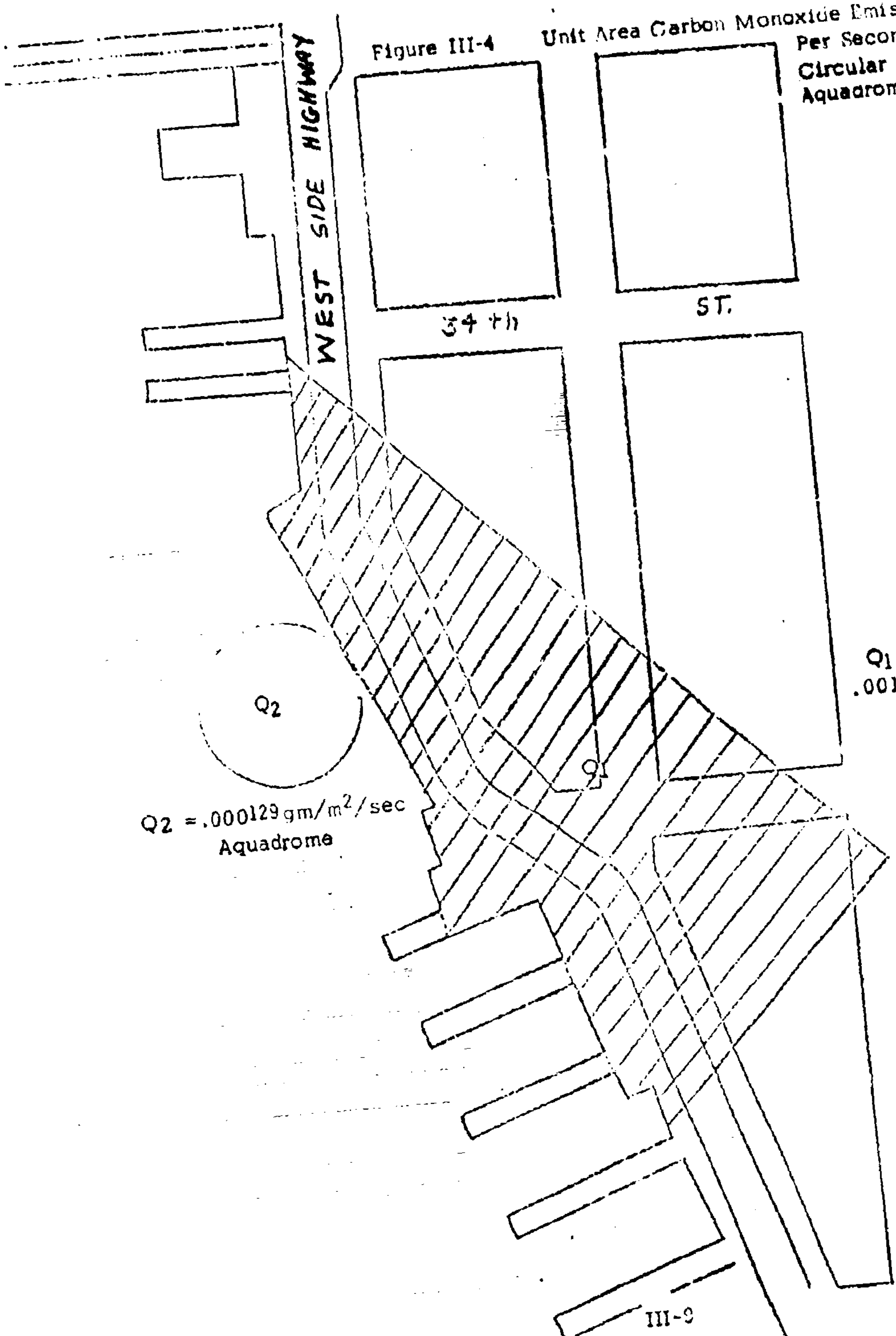


Figure III-4 Unit Area Carbon Monoxide Emissions Per Second on Circular Shaped Aquadrome



Conclusions

1. High density aircraft operations on the flight deck of a circular shaped Rutgers Aquadrome generate carbon monoxide levels of 1.2 ppm at a distance of 100 m. off the flight deck compared with a 3-6 ppm ambient rooftop or background level on Manhattan.

2. The quasi-instantaneous line source model devised to obtain maximum values for CO concentrations at 100 meters from aircraft during the take-off and landing maneuvers shows that such values do not exceed .77 ppm, as compared with a 3-6 ppm ambient rooftop or background level on Manhattan.

3. The carbon monoxide levels in parts per million (ppm) from aircraft operating from an Aquadrome compared to the background or ambient levels on Manhattan are supported by employing the unit area method which finds Aquadrome emission rates to range from 1/2 to 1/9 the rate of emission from the adjacent land segment.

FOOTNOTES

CHAPTER III

[1]Rutgers University, Center for Transportation Studies of the Eagleton Institute of Politics, Project Eagle - A Study of Mass Air Transportation for Connecticut, New Jersey and New York. (November, 1969), pp. V-1 through V-28.

[2]Department of Transportation, Federal Aviation Administration, Interim Design Criteria for Metropolitan STOLports and STOL Runways - Notice 5325.20, (January 1, 1969).

[3]Rutgers University, Project Eagle, op. cit., p. V-16.

[4]Northern Research and Engineering Corporation, Nature and Control of Aircraft Engine Emissions, (Washington, D.C.: National Air Pollution Control Administration, Department of Health, Education and Welfare, 1968), p. 143.

[5]C. Simon, Manager of Data and Meteorology, New York City Department of Air Resources, in a conference on January 15, 1970. The ambient rooftop concentrations were taken at an elevation of 100 feet above street level.

[6]U.S. Department of Health, Education and Welfare, New York-New Jersey Air Pollution Abatement Activity-Sulfur Compounds and Carbon Monoxide, (Cincinnati, Ohio: National Center for Air Pollution Control, 1967), p. 143.

CHAPTER IV
AIR POLLUTION REDUCTIONS BY SUBSTITUTING AIRCRAFT FOR AUTOMOBILES IN PROVIDING TRANSPORTATION TO NEWARK, LA GUARDIA AND J.F. KENNEDY AIRPORTS

By providing air transportation to the three metropolitan airports in New York and New Jersey for travelers who now use automobiles, the total daily reduction in air pollution would be about 12 tons. Automobiles now making these trips create about 13 tons of pollution; whereas the aircraft that would replace them would generate about 1 ton. This pollution consists of carbon monoxide, hydrocarbons, particulates and nitrogen oxide. Comparisons of the yearly amounts of pollution added to the atmosphere by automobiles and the aircraft that would replace them are:

	Automobiles	Aircraft
1970	4869 tons	380 tons
1980	1365 tons	380 tons

Passenger Volume

About 9,000 individuals travel by automobile daily to La Guardia, J. F. Kennedy International and Newark Airports for domestic aircraft flights.[1] The daily automobile travel from eight counties to each airport is summarized in Figure IV-1. These passengers originate from the counties containing the satellite cities of Paterson, Linden-Rahway, New Brunswick, White Plains, Mt. Vernon, Hempstead, Farmingdale, Stamford, Bridgeport and New Haven and New York County (Manhattan).

Figure IV-1

Daily Automobile Passengers
(1963 - 1964)

County (Satellite)	Kennedy International	Newark	La Guardia
Union (Linden/Rahway)	55	361	
Middlesex (New Brunswick)		115	
Passaic (Paterson)	55	132	
Essex (Newark)	55		
Westchester (Mt. Vernon)	222	30	87
Nassau (Hempstead)	701		305
Fairfield (Stamford)	115		60
Westchester (White Plains)	221	31	
Nassau (Farmingdale)	132		66
New York County (Manhattan)	2632	1230	1793
Fairfield (Bridgeport)	117		39
TOTAL	4302	1899	2457

The number of daily automobile passengers was determined from the total number of yearly passengers to each airport using all modes of transportation. The number of yearly automobile passengers is first determined from the modal split by year for each mode of travel. This yearly travel by automobile is then divided by the number of days shown in the yearly survey to yield daily automobile travel.[2] The following steps were followed to determine the total automobile mileages traveled between the satellite city transportation centers and each of the three major airports:

1. Multiply the number of automobiles traveling from the satellite city transportation center and Manhattan to the three airports by distance traveled.

2. Add the total automobile distance traveled between the 11 satellite city transportation centers and Manhattan to each of the three major airports. The total distances to each of the airports from the satellite city transportation centers and Manhattan are:

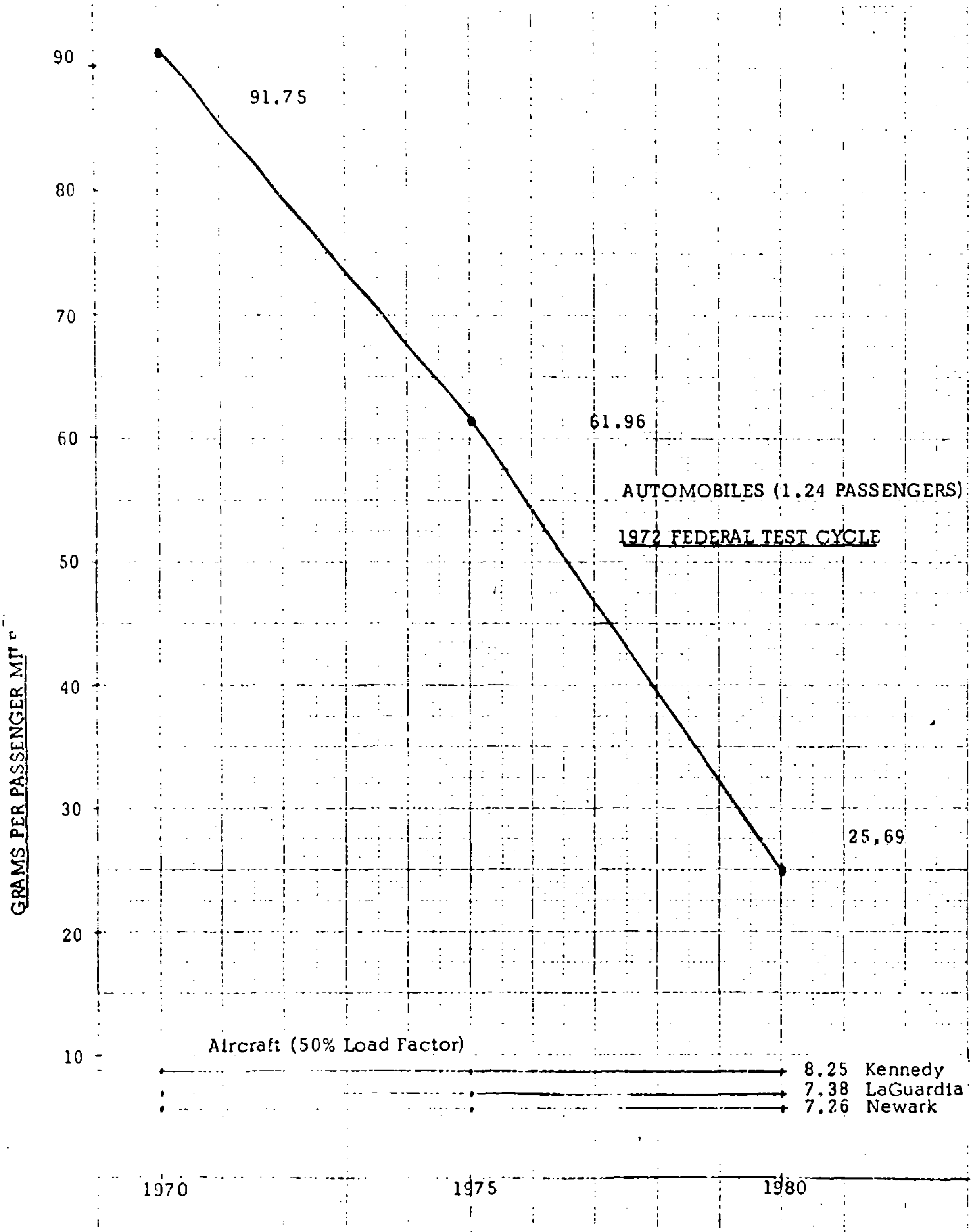
JFK	82,708 passenger miles per day
Newark	21,768 passenger miles per day
LaGuardia	28,393 passenger miles per day

3. Multiply the total distance to each of the airports by the automobile engine emission standards shown in Figure IV-2.[3]

Automobile Travel

The following tabulation summarizes the daily total pollution generayed when 9000 daily passengers travel to the three metropolitan airports by

AIR POLLUTION EMITTED FROM AUTOMOBILE AND AIRCRAFT ENGINES



automobiles in 1970, 1975 and 1980.[4]

Year	Carbon Monoxide		Hydrocarbons & Particulates		Nitrogen Oxides		Total Pollution	
	Pounds	Tons	Pounds	Tons	Pounds	Tons	Pounds	Tons
1970	21,036	10.52	3,655	1,83	1,989	.99	26,679	13.34
1975	13,154	6.58	2,584	1.29	2,279	1.14	18,017	9.01
1980	5,486	2.74	954	.48	1,024	.51	7,464	3.73

Aircraft Pollution

The pollution created by aircraft carrying the 9000 passengers who formerly traveled by automobile was determined by the following steps:

1. Estimate the aircraft passenger miles for flights from each satellite city transportation center and Manhattan to each of the three major airports.

2. Add the total aircraft passenger miles traveled between the 11 satellite city transportation centers and Manhattan to each of the three airports. The total distances to each airport from the satellite city transportation centers and Manhattan are:

JFK	73,173 miles
Newark	19,268 miles
LaGuardia	23,879 miles

3. Multiply the aircraft passenger miles by the aircraft emission standards, shown in Figure IV-2.[5] These pollution values are average emissions for takeoff, cruise and landing over varying stage lengths to each airport. (APPENDIX F)

The total pollution generated by aircraft in transporting passengers to three metropolitan airports each day are:

Year	Carbon Monoxide		Hydrocarbons & Particulates		Nitrogen Oxides		Total Pollution	
	Pounds	Tons	Pounds	Tons	Pounds	Tons	Pounds	Tons
1970	837	.42	780	.39	451	.23	2,068	1.03
1975	837	.42	780	.39	451	.23	2,068	1.03
1980	837	.42	780	.39	451	.23	2,068	1.03

Comparison of Aircraft and Automobile Air Pollution

Comparative pollution values of carbon monoxide, particulates, hydrocarbons and nitrogen oxides for automobile and aircraft providing transportation from the eleven satellite city transportation centers and Manhattan are tabulated in Appendix F. The tabulations are for Newark Airport, LaGuardia Airport and J.F. Kennedy Airport. Comparative values for travel to all three airports is also summarized in Appendix F. Yearly pollution emitted by automobile and aircraft travel are shown in the following figures:

Figure IV-3 Bargraph Newark Airport

Figure IV-4 Bargraph LaGuardia Airport

Figure IV-5 Bargraph J.F. Kennedy Airport

Figure IV-6 Bargraph all three metropolitan airports

Figure IV-3

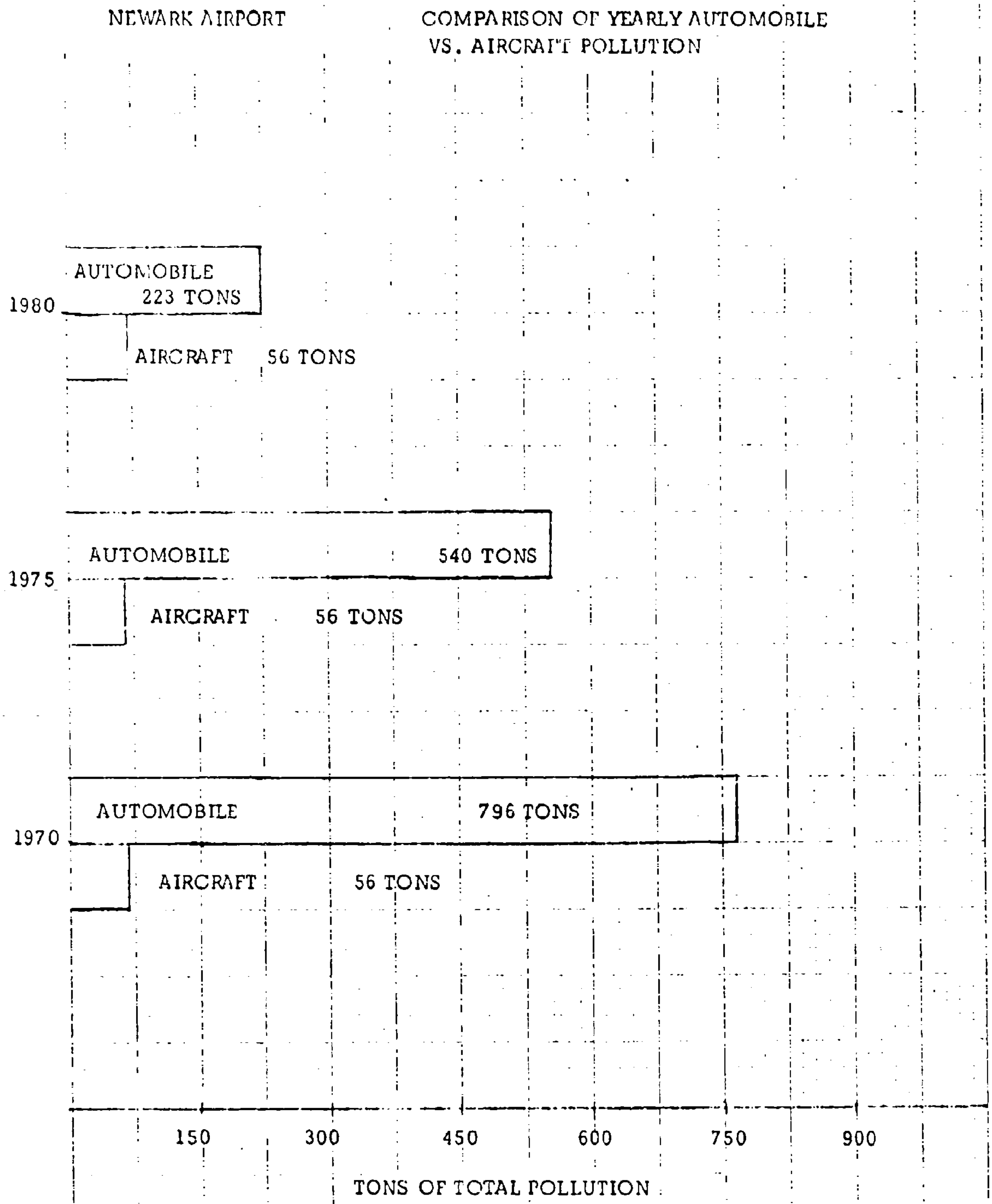
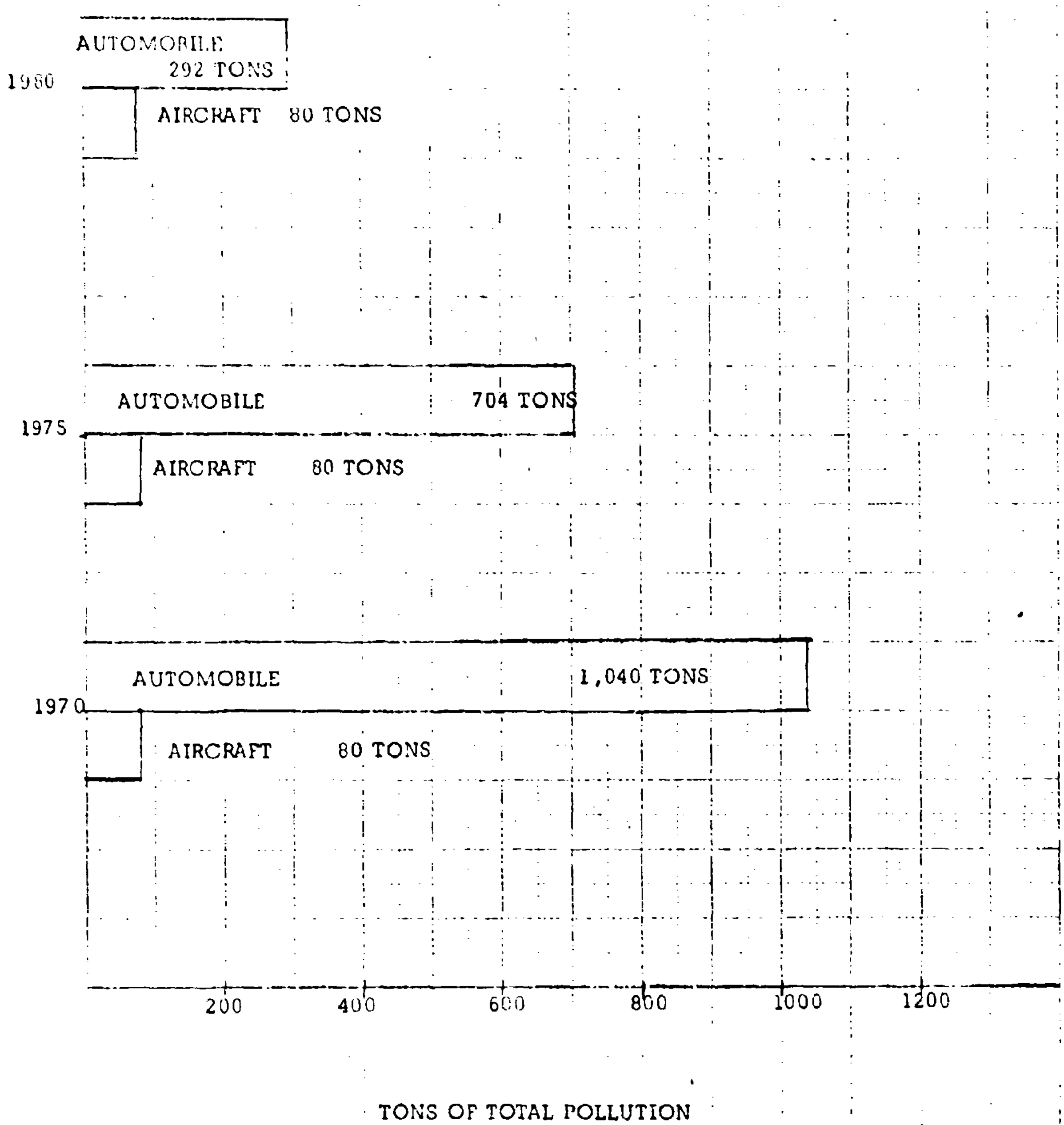

NEWARK AIRPORT
COMPARISON OF YEARLY AUTOMOBILE VS. AIRCRAFT POLLUTION
1980
AUTOMOBILE 223 TONS
AIRCRAFT 56 TONS
1975
AUTOMOBILE 540 TONS
AIRCRAFT 56 TONS
1970
AUTOMOBILE 796 TONS
AIRCRAFT 56 TONS
150
300
450
600
750
900
TONS OF TOTAL POLLUTION

Figure IV-4

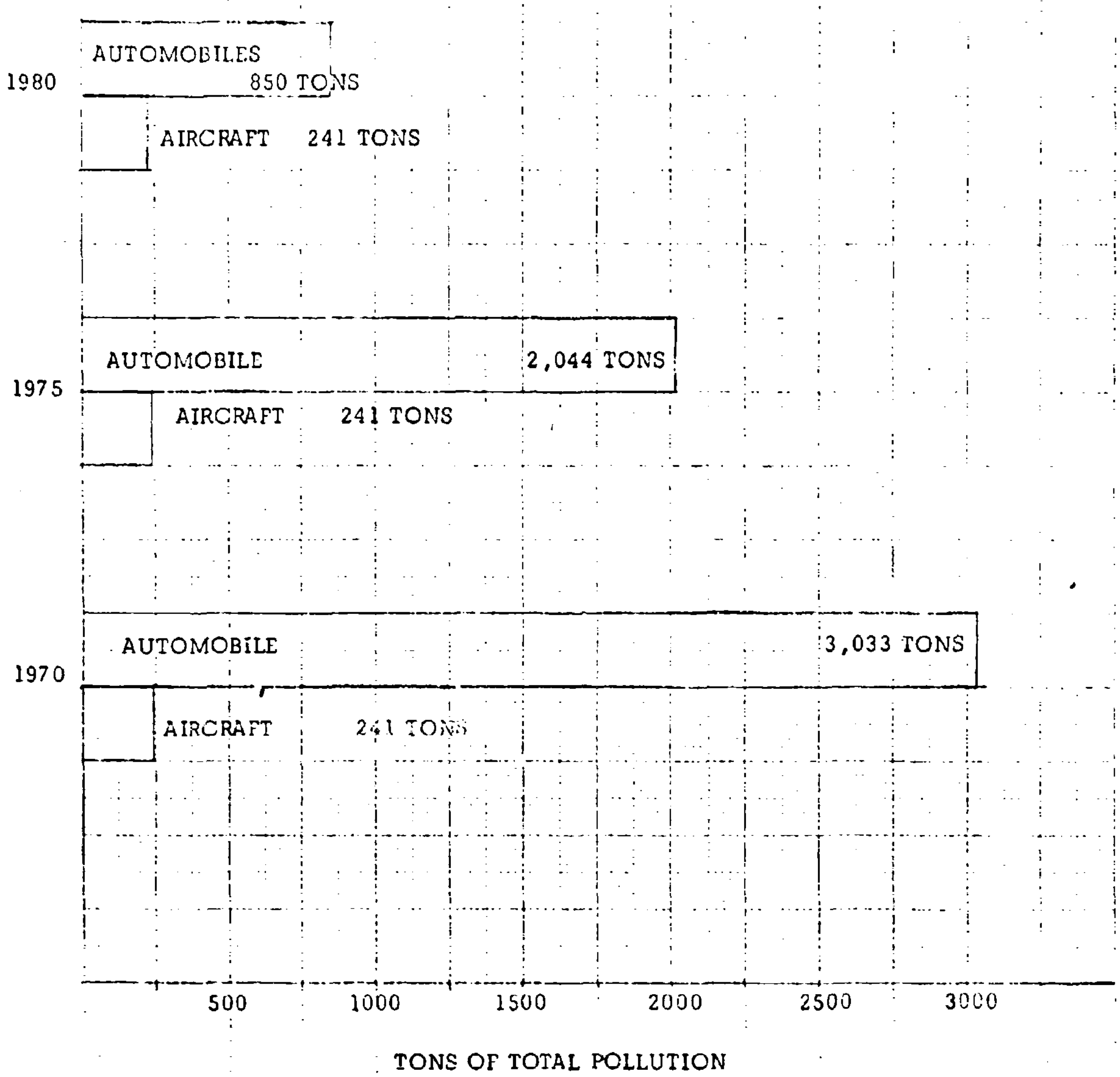
LA GUARDIA AIRPORT

COMPARISON OF YEARLY AUTOMOBILE VS. AIRCRAFT POLLUTION



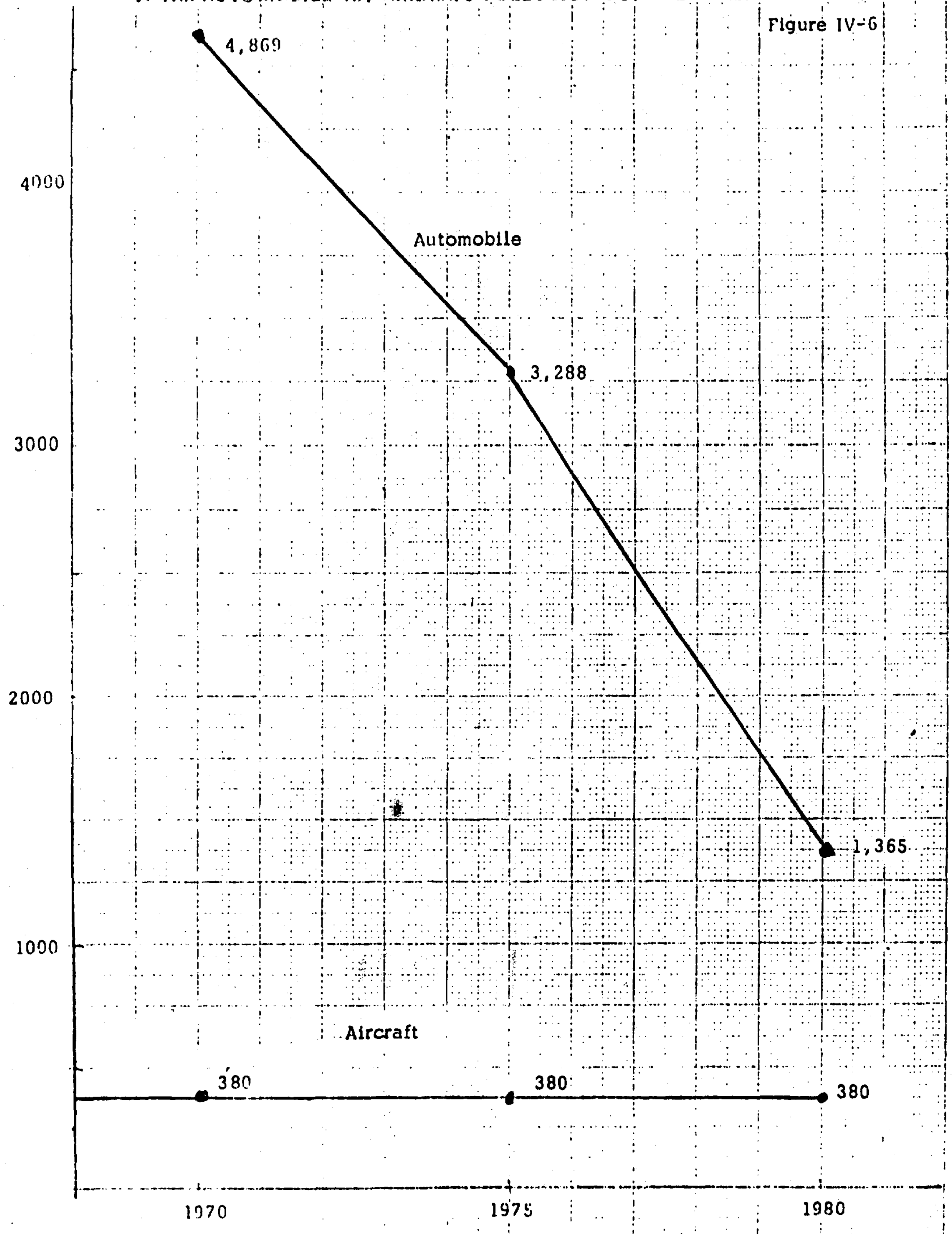
J.F. KENNEDY AIRPORT

COMPARISON OF YEARLY AUTOMOBILE VS. AIRCRAFT POLLUTION



TOTAL AUTOMOBILE VS. AIRCRAFT POLLUTION FOR ALL THREE AIRPORTS

Figure IV-6



Conclusions

1. Daily pollutants emitted by automobile and aircraft transporting the same number of passengers to Newark, LaGuardia and J. F. Kennedy Airports from N. Y. County and the counties in which the 11 satellite city transportation centers are located are as follows:

	Automobiles	Aircraft
1970	13.34 tons/day	1.03 tons/day
1975	9.01 tons/day	1.03 tons/day
1980	3.73 tons/day	1.03 tons/day

2. Pollutants emitted yearly by automobile and aircraft transporting the same number of passengers to Newark, LaGuardia and J. F. Kennedy Airports from N. Y. County and the counties in which the 11 satellite city transportation centers are located are as follows:

	Automobiles	Aircraft
1970	4,869 tons/year	380 tons/year
1980	1,365 tons/year	380 tons/year

3. The drastic reduction in air pollution that is possible by providing air transportation in the tri-state area of Connecticut, New Jersey and New York to the three major airports warrants establishing a demonstration air service.

FOOTNOTES

CHAPTER IV

[1]The Port of New York Authority, New York's Domestic Air Passenger Market, April 1963 through March, 1964, (New York: Aviation Economics Division, The Port of New York Authority, 1965), pp. 21-23 and 87-91.

[2]*Ibid*.

[3]Automobile Emissions Data for 1971, 1975 and 1980, provided by Raymond Smith, Assistant Commissioner of Program Development, National Air Pollution Control Administration, U.S. Department of HEW, in a personal interview on December 15, 1969.

[4]Smith interview on December 15, 1969, *op.cit.*

[5]Joseph Hobbs, Supervisor-Installation Design Requirements, Pratt and Whitney Aircraft, in a conference on November 21, 1969.

The contaminant values of two JT8D turbofan engines, each of 14,000 lb. thrust, at sea level conditions are based upon a 1969 IBM Computer Print-Out, by Pratt and Whitney Aircraft.

CHAPTER V

ATMOSPHERIC DISPERSION MODELS FOR DETERMINING THE PHYSIOLOGICAL EFFECTS OF AIR POLLUTION CREATED BY AIR-CRAFT AND AUTOMOBILE ENGINES

Having established the comparative amounts of air pollution emitted by aircraft and automobile engines, atmospheric dispersion models for determining ambient concentrations have been employed to show on the basis of the physiological effects the degrees of "Imminent Endangerment" under the Air Quality Act of 1967.[1] Both the floating airport concept (Rutgers Aquadrome) and the center city highway access analyses contained in the Project Eagle Study have been selected for evaluation as to the physiological effects on people subjected to engine emission pollution.

The analysis of the air pollution that would occur from aircraft operating on two types of Rutgers Aquadromes are shown in Figures III-1 and III-2. The Physiological effects of these air pollution levels are determined in this chapter.

The highway segment used as a model for determining the varying traffic volumes and the physiological effects is the proposed N.J. State Highway Route 18 Extension (Figures V-1 and V-2).

This particular highway segment was selected as it has been the subject of extensive traffic and cost analysis in the Project Eagle Study and extensive planning data is available.

The highway segment would run from a Stol/port proposed for location in the Central Business District (CBD) of New Brunswick, N.J. across the Raritan River to Alternate Route 18.[2] This highway segment, shown in Figure V-1 is also

Figure V-1
Top View of Proposed N. J. Route 18 Extension

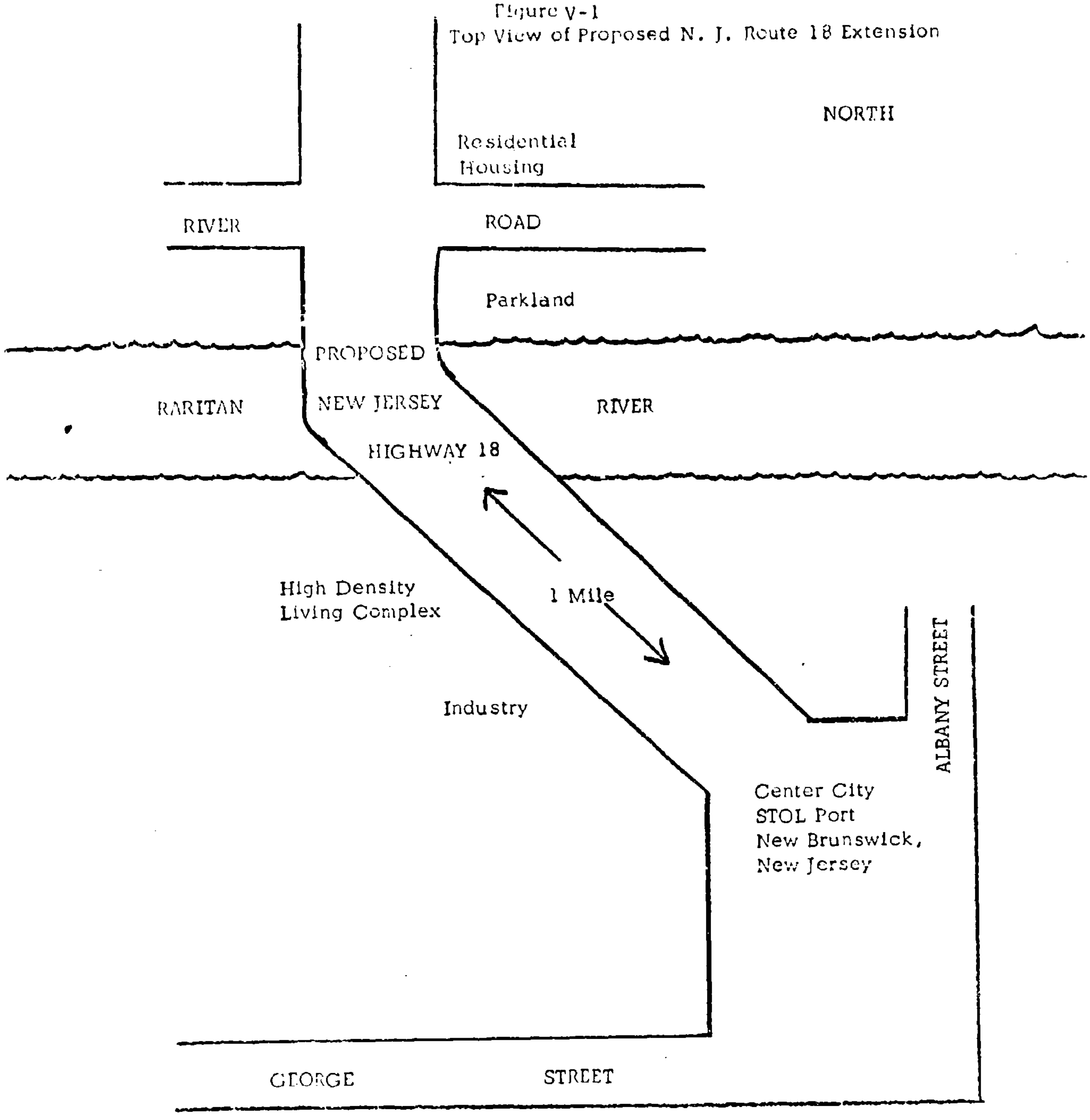
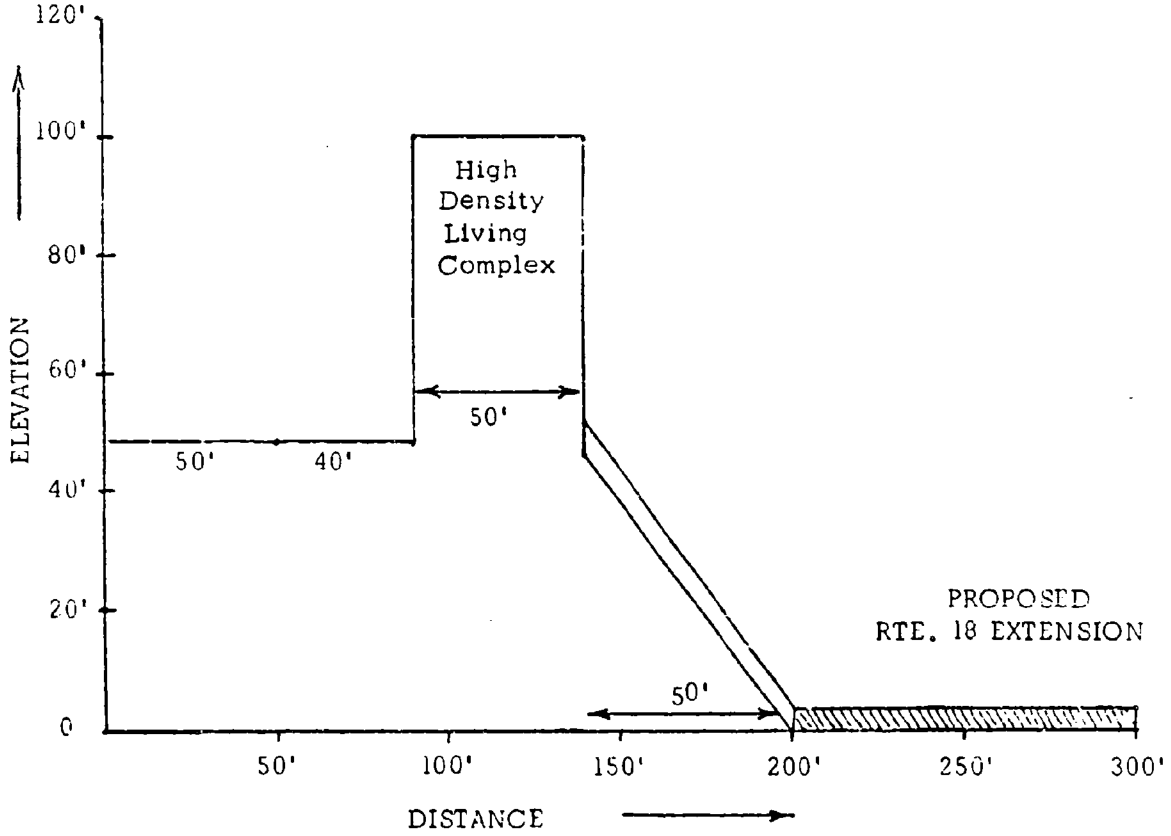


Figure V-2

CROSS SECTION OF PROPOSED

N.J. ROUTE 18 EXTENSION WITH HIGH DENSITY LIVING

COMPLEX



particularly well adapted to a study of physiological effects, as a high density living complex, industry, parkland and a residential area are contiguous to the highway. Figure V-2 is a cross section of the high density living complex located along the proposed New Jersey Route 18 Extension. The pollution models that have been applied to the total peak hour highway traffic are also valid for any fraction of highway traffic such as the additional number of travelers utilizing a STOLport. These models can be applied to the highway networks serving other center city STOLports.

Atmospheric Dispersion Models

Emissions data for automobiles and aircraft provide a general idea of the presence of certain pollutants in a given area and may be thought of as showing the potential of atmospheric concentrations. Whether this potential is realized depends strongly on meteorological factors.

The mathematical-meteorological models used in this analysis consider CO concentration distributions to be largely dependent on wind speed and wind direction relative to building and topographical configuration. The wind direction and wind velocity information employed in this analysis were obtained from the U.S. Department of Commerce, Environmental Data Service, National Weather Records Center, Asheville, North Carolina. The data consists of a series of special computer print-outs provided to Rutgers University. This data has been compiled in terms of wind direction vs. wind speed for varying time intervals during the 1956-65 period.[3]

The calculations obtained from these models are in the form of pollutant concentrations at specific locations. Gaussian distribution functions are used to model the area source and line source emmissions patterns assumed in this comparative study of aircraft and automobile pollution. These models yield pollution values in parts per million (ppm). (The equations and calculated carbon monoxide concentrations are given in Appendices C, D, and H.)

Time Concentration Problem for Carbon Monoxide Uptake in the Bloodstream

The carboxyhemoglobin (COHb) in the bloodstream is determined considering carbon monoxide concentration in ppm and time of exposure. Experimental data has established the relationship between these two variables[4] to be --

$$\text{Log \% COHb} = .85753 \text{ Log CO} + .62995 \text{ Log } t - 2.29519$$

where: CO is measured in ppm and t is the duration of exposure in minutes.

This relationship is shown in Figure V-3.[5]

In determining the effect of carbon monoxide on humans, the results of the major experiments reported to date are summarized in Figure V-4. Because some of these experiments give information on carbon monoxide (ppm) and length of exposure and do not give per cent COHb, these latter values, where missing, were determined by applying the procedures contained in Figure V-3. In determining the effects or standards listed in Figure V-4, it is recognized that at present very little definitive information is available. The effects from both COHb as well as the standards of state

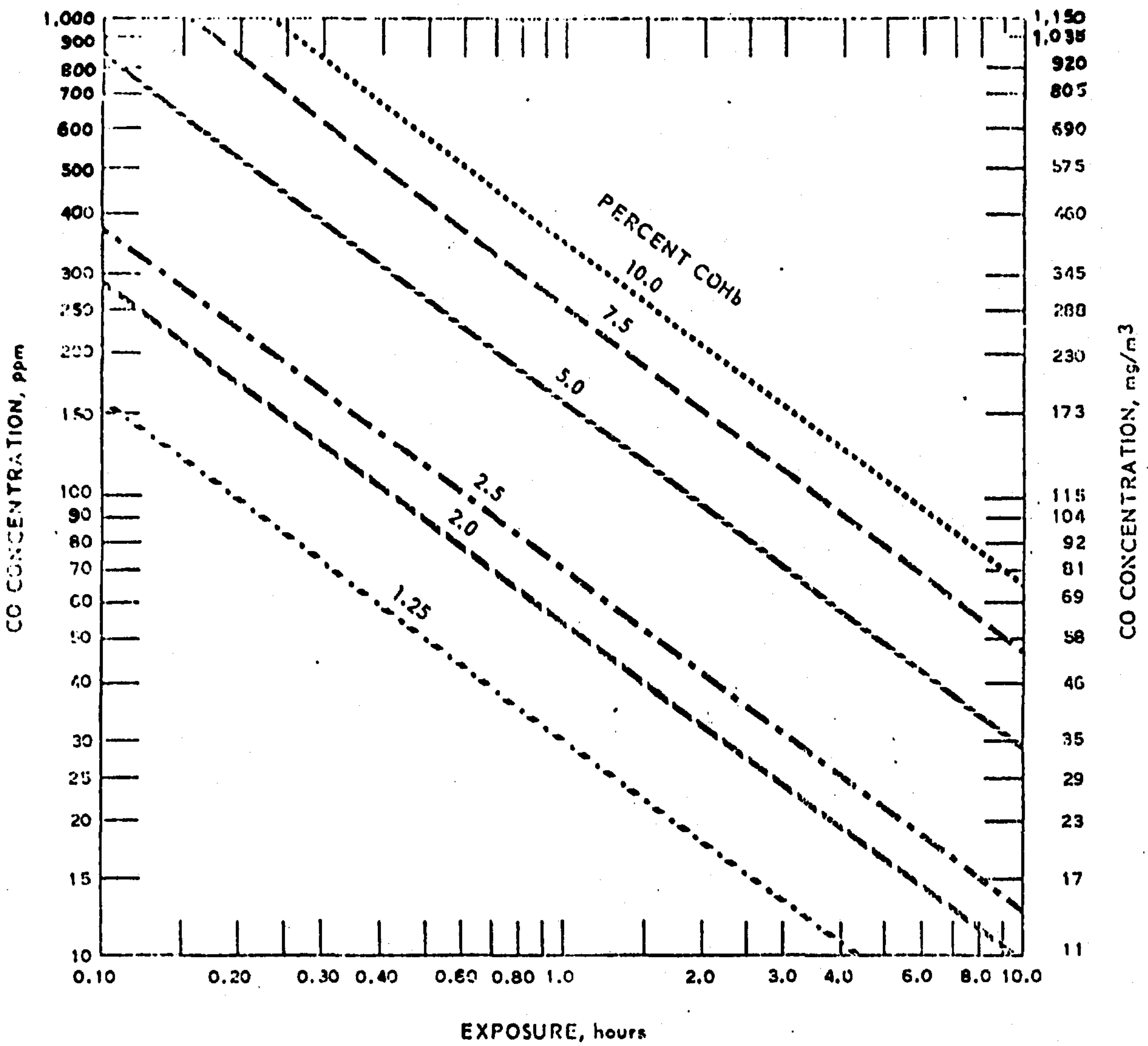


Figure V-3. Concentration and duration of continuous CO exposure required to produce blood COHb concentrations of 1.25, 2.0, 2.5, 5.0, 7.5, and 10 percent in healthy male subjects engaging in sedentary activity.

Source: U.S. Department of Health, Education and Welfare, Air Quality Criteria for Carbon Monoxide, National Air Pollution Control Administration Publication No. AP-62, (Washington, D.C.: U.S. Government Printing Office, 1970), p. 8-11.

Figure V-4

Effects of Carbon Monoxide in Humans

CO Level (ppm)	Length of Exposure	COHb %	Effect or Standard
More than 8	7 Days	------	1. Increased fatality rate among hospitalized heart attack patients.[6]
10	1 Hour	Less than 1	1. Maximum residential level used in highway location considering office and public buildings (N.J. Dept. of Transportation).[7]
10	24 Hours	About 2.5	1. Increased risk of automobile accidents.[8] 2. Impairment in performance of psychomotor tests.[9] 3. Increase in cases in heart fatality.[10] 4. Errors in arithmetic.[11]
14	7 Days	------	1. Headaches; 2. Nausea.[12]
15	8 Hours	2.5	1. Tentative 8 hour average not to be exceeded more than 15 per cent of the time on an annual basis (New York State Air Pollution Control Board).[13]
30 (Average)	6 Hours	3.5	1. Air Pollution Alert--New Jersey State Department of Health.[14]
30	8-12 Hours	About 5.0	1. Tentative 8 hour average not to be exceeded at any time (New York State Air Pollution Control Board).[15] 2. Errors in response to color stimulus.[16] 3. Visual discrimination of brightness.[17]

(continued on p. V-11)

Figure V-4 continued

CO Level (ppm)	Length of Exposure	COHb(%)	Effect or Standard
50	50 Minutes	1.6	1. Impairment in 3 of 4 parameters of visual function.[18]
50	90 Minutes	2.0	1. Impairment in judging differences in time intervals.[19] 2. Errors in auditory duration determination.[20]
50 (Average)	6 Hours	5.6	1. Air Pollution Emergency--New Jersey State Department of Health.[21]
60	1 Hour	2.25	1. Tentative 1 hour average not to be exceeded more than 1 per cent of the time on an annual basis (New York State Air Pollution Control Board).[22]
100	2 Hours	5.0	1. Shortness of breath and tissue hypoxia.[23]
200	2 Hours	10.0	1. Shortness of breath; 2. Headaches.[24]
300	2 Hours	Over 10.0	1. Headaches; 2. Fatigue; 3. Dizziness; 4. Dimness of vision.[25]
400	2 Hours	Over 10.0	1. Headaches; 2. Collapse; 3. Death, if exposure is continued.[26]

governments are listed together. In this manner, it is possible to establish a rationale for understanding state standards in terms of the effects of COHb.

Physiological Effects at a Manhattan STOLport

The following air pollution levels in ppm's have been established in this study. Values for all Aquadrome operations are given for concentrations existing at 100 meters from the flight deck and 100 meters from the landing and take-off flight paths.

	CO (ppm)			
	Landing	Flight Deck	Takeoff	Background[27]
Oblong Shaped Aquadrome	.77	1.79	.38	3-6
Circular Shaped Aquadrome	.77	1.2	.38	3-6

Applying these air pollution values assuming duration periods of two hours to Figure V-3 establishes the COHb levels resulting from aircraft operations are below 1 percent. The U.S. Department of Health, Education and Welfare states, "no human health effects have been demonstrated nor have they been observed for COHb levels of 0 to 1 percent, since endogenous CO production makes this a physiological range."[28] Even when considering the total pollution created by aircraft being added to the existing background level of air pollution, the COHb level remains below 1 percent. This analysis demonstrates that no threat to the environment occurs from high density aircraft operations on oblong shaped and circular shaped Rutgers Aquadromes located on Manhattan. To determine the air pollution that would occur with high density automobile traffic, which could be compared to high density air traffic, the segment of highway contained in "Project Eagle" is selected for analysis.

Physiological Effects from High Density Automobile Traffic

The standards employed in this automobile air pollution analysis are those established by HEW for 1970, 1975 and 1980.[29] The COHb levels are determined from carbon monoxide concentrations (ppm) and time of exposure for the years 1970, 1975 and 1980. In addition, other variables are considered, i.e., topography, atmospheric dispersion conditions, background carbon monoxide levels, peak hour traffic volumes, wind velocity and wind speed.

In determining the physiological effects from high density automobile traffic, the proposed N.J. State Highway Route 18 Extension analyzed in "Project Eagle" is used for this analysis.

Topography

This highway segment is located in the valley of the Raritan River. The Watchung Mountains to the north and west contribute to the stability of the air in the lowest hundred meters due to air drainage of dense, cold air into the areas of lowest relief. The cold off-shore waters of the Atlantic Ocean act to moderate temperatures under conditions of easterly winds throughout the year except during the winter months. These two potential sources of atmospheric stability enhance the possibilities of high pollution concentrations in the New Brunswick area.

Dome Condition

When a layer of warm air flows over a stagnant layer of cold air, a temperature inversion develops. A temperature inversion creates stable conditions that can produce a dome which limits the vertical diffusion of pollutants emitted under it. Dome condition implies an elevated inversion layer with a slightly unstable surface layer below. Over time, a general increase in concentration results, as pollutants are slowly spread towards the top of the dome and, then recirculate downwards. Since low-level temperature inversions in the New Brunswick area tend to occur during the peak travel hours, the automobile generated pollution can be expected to have its maximum impact. This local condition can result in concentrations of carbon monoxide which have a direct effect on public health.

Typical variations in temperature and wind speeds with height for surface inversions are shown in Figure V-5[30]. Under surface based inversions, the ver tical dispersion of pollutants from an area or line source is minimal. Automobile generated turbulence however, might create a shallow turbulent layer which enhances the vertical dispersion of pollutants from a highway segment.

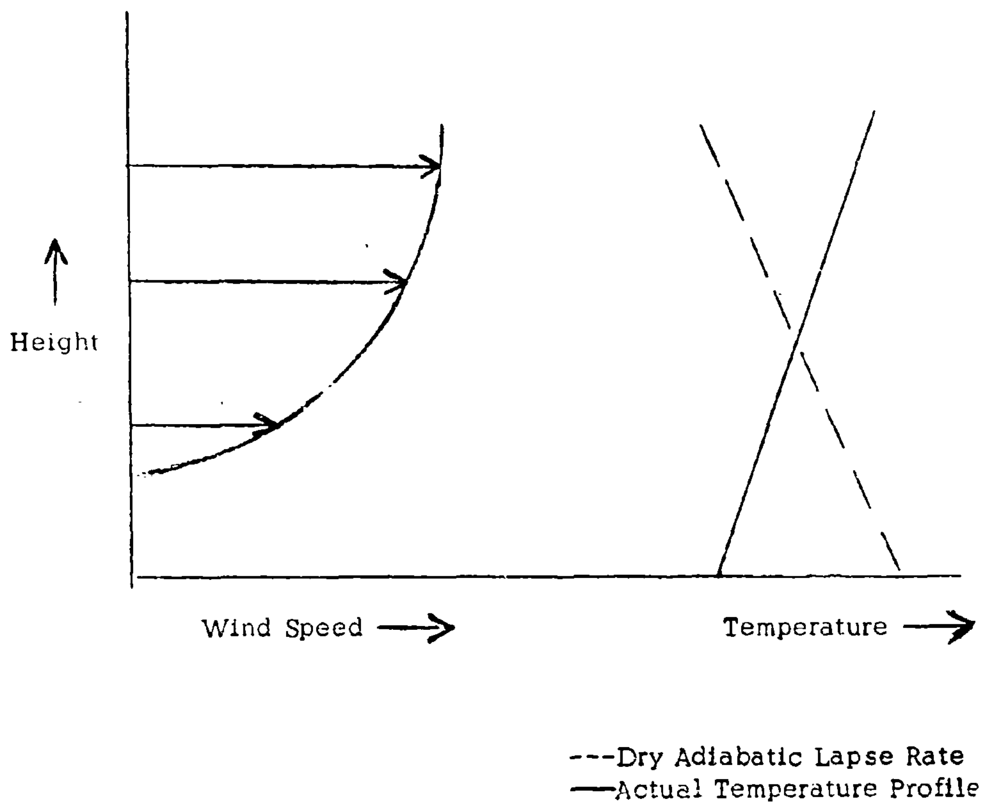
This dome condition is perhaps analogous to a box model of diffusion. The exponential decrease of pollutants in the vertical is not really much different from the horizontal decrease found with the area source model except wind speed (u) is replaced with a vertical dilution factor.[31] No computations for the dome were attempted in this study.

Plume Condition

A plume condition exists when winds continually transport pollution in organized flow away from the local generating area. High local pollution is

Figure V-5

Variation in Temperature and Wind Speed for Surface Inversions



Source: American Society of Mechanical Engineers, Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, (New York: American Society of Mechanical Engineers, 1968), p. 18.

prevented from occurring, as pollutants are dispersed over a wide region.

Important parameters in this study are the velocity, direction and time of occurrence of the winds in relation to the highway and the high density living complex. During the four hour morning and afternoon periods of automobile traffic considered, north, northeast or east winds produce the highest pollution levels under plume conditions. The low wind conditions of 0 to 3 miles per hour, would create the most dangerous human impairments, along the highway. This 0-3 mph wind speed is the lowest wind category used by the National Weather Records Center. Appendix G tabulates wind direction and velocity by month and annually for 10 hours of the day (5, 6, 7, 8, 9, 10 A.M. and 2, 3, 4, 5, 6, 7 P.M.). The Appendix also contains tabulations of occurrences of continuous winds from the quadrant N, NNE, NE, ENE, and E for four consecutive hours. The 6-10 A.M. and 3-7 P.M. periods were considered in January, February, March, April, November and December. To make the time intervals comparable because of Daylight Savings Time (DST), 5 to 9 A.M. and 2 to 6 P.M. periods are used for May, June, July, August, September and October. This was necessary as wind information is recorded using Eastern Standard Time (EST). The above two summaries which are for 10 years were prepared for Rutgers University by the U.S. Department of Commerce, Environmental Science Services Administration, Environmental Data Service, National Weather Records Center, Asheville, North Carolina. The data base employed for the computer runs is the Climatological Summary 1956-1965.

Background Carbon Monoxide Levels

Daily and peak travel hour background levels of carbon monoxide in the New Brunswick area were obtained from Station No. 5 of the National Center for Air Pollution Control, HEW, located at the Raritan Depot in Edison, New Jersey. The average daily level of carbon monoxide from September, 1968 through September, 1969 was 2.0 ppm. The peak travel hour concentration of carbon monoxide was 14 ppm during the same monitoring period.[32]

Automobile Emissions: 1972 Revised Federal Test Cycle

The 1970, 1975 and 1980 carbon monoxide emissions from automobiles were adjusted to reflect the revised 1972 Federal Test Cycle. This cycle gives a true mass measurement of emissions and avoids estimation of emissions by mathematical formula used in the 1970 Federal Test Cycle.[33] (Refer Figure I-3)

Automobile Traffic Volumes between 6 to 10 A.M. and 3 to 7 P.M.

The range of automobile traffic volumes during the 6 to 10 A.M. and 3 to 7 P.M. hours considered in the analysis are:[34]

AUTOMOBILE TRAFFIC VOLUMES

	6 to 10 A.M.	3 to 7 P.M.
1970	4,950-14,256	7,825-22,536
1975	5,940-14,256	9,390-22,536
1980	7,151-14,256	11,305-22,536

The two basic highway traffic projections used in this analysis were developed by the New Jersey Department of Transportation[35] and the Tri-State Transportation Commission.[36]

Figures V-6 through V-9 summarize the automobile pollution levels and resultant physiological effects that would exist along the highway segment. Human impairments were identified that would occur from carbon monoxide concentrations caused by automobiles during the time periods of 6 to 10 A.M. and 3 to 7 P.M. Concentration computations were performed using an area source model with a receptor distance of 15 meters under stability Class D conditions, considering northeast winds at 4 mph and 6 mph, and automobile emission rates for 1970, 1975 and 1980. The detailed calculations supporting the results shown in Figures V-6 through V-9 are contained in Appendix H. This Appendix contains calculations employing the line source model.

Carboxyhemoglobin levels for varying concentrations of carbon monoxide in Appendix H have been derived by employing two methods. Method 1 employs the time-concentration graph shown in Figure V-3. In this method concentrations below the 10 ppm level over 4 hour durations are not considered to produce human impairments because of the lack of toxicological studies at low level concentrations. Method 2 considers the human effects of carbon monoxide levels below 10 ppm over 4 hour durations, which requires extending the mathematical relationship of percent COHb to CO concentrations over time, to the region of lower concentrations (refer page V-5).

Figure V-6
HUMAN IMPAIRMENTS FROM AUTOMOBILE EMISSIONS

Plume Condition: Northeast Wind, 6 mph
Method 2
Diffusion from area - source; Time, 3-7 P.m.

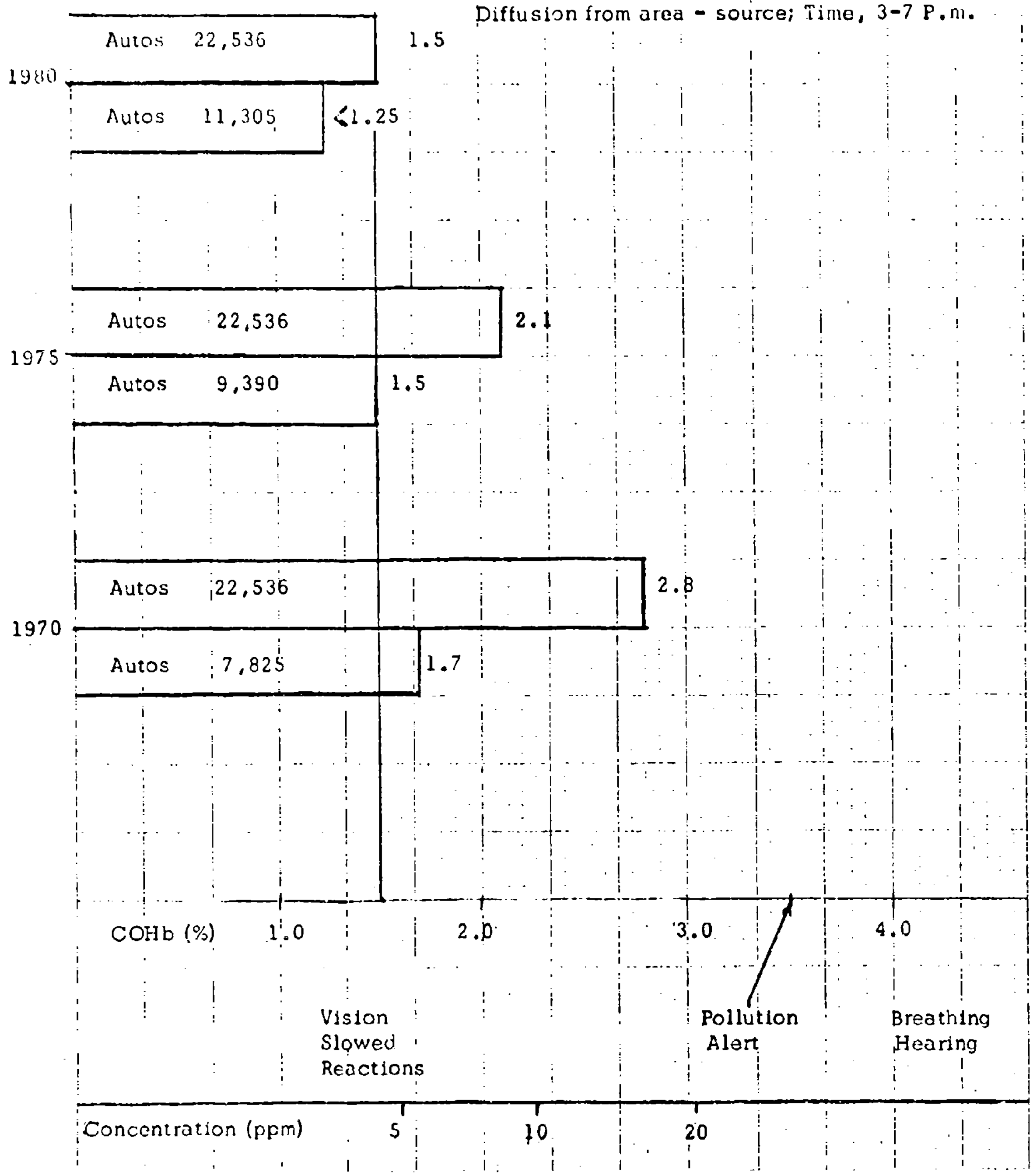


Figure V-7
HUMAN IMPAIRMENTS FROM AUTOMOBILE EMISSIONS

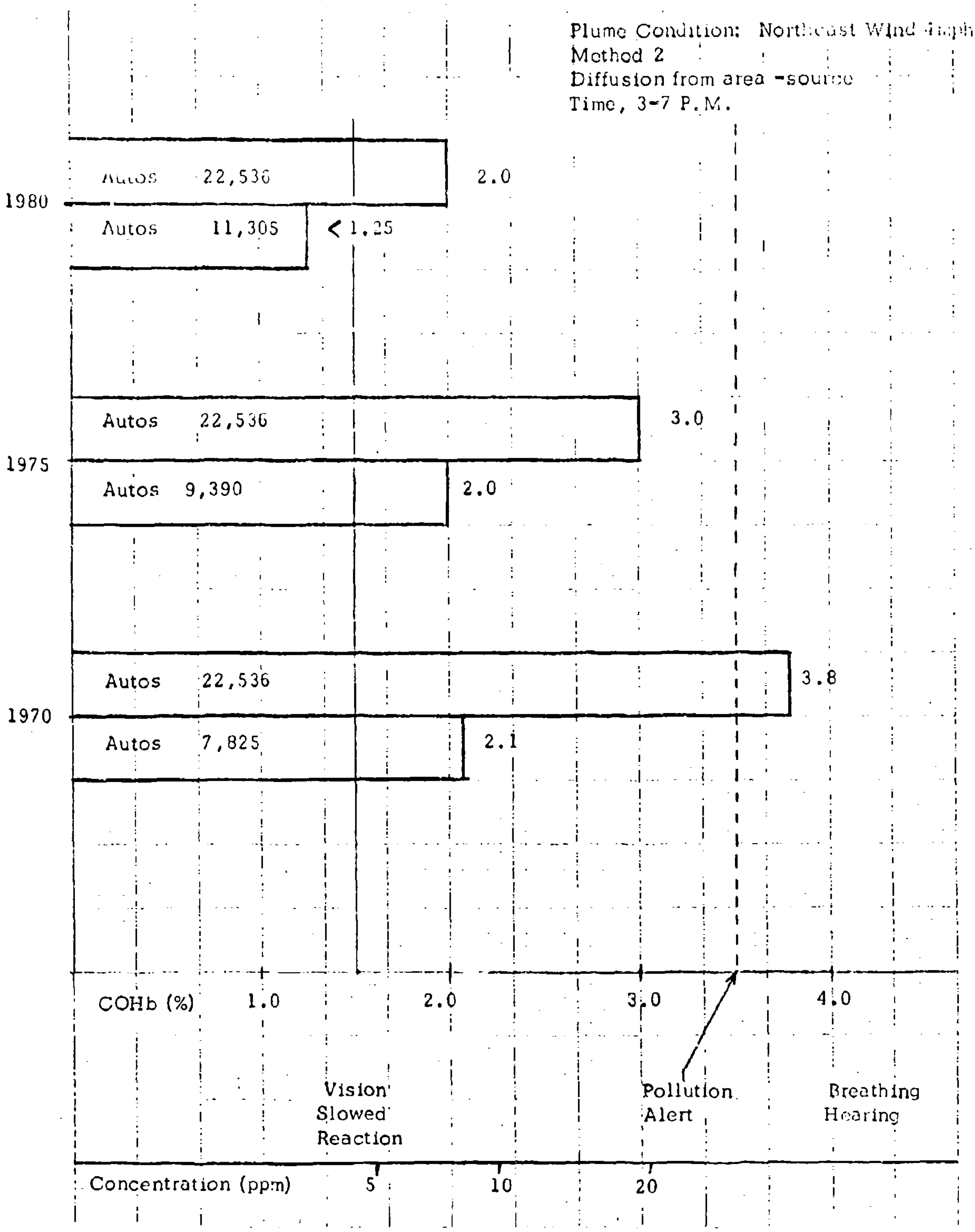


Figure V-8

HUMAN IMPAIRMENTS FROM AUTOMOBILE EMISSIONS

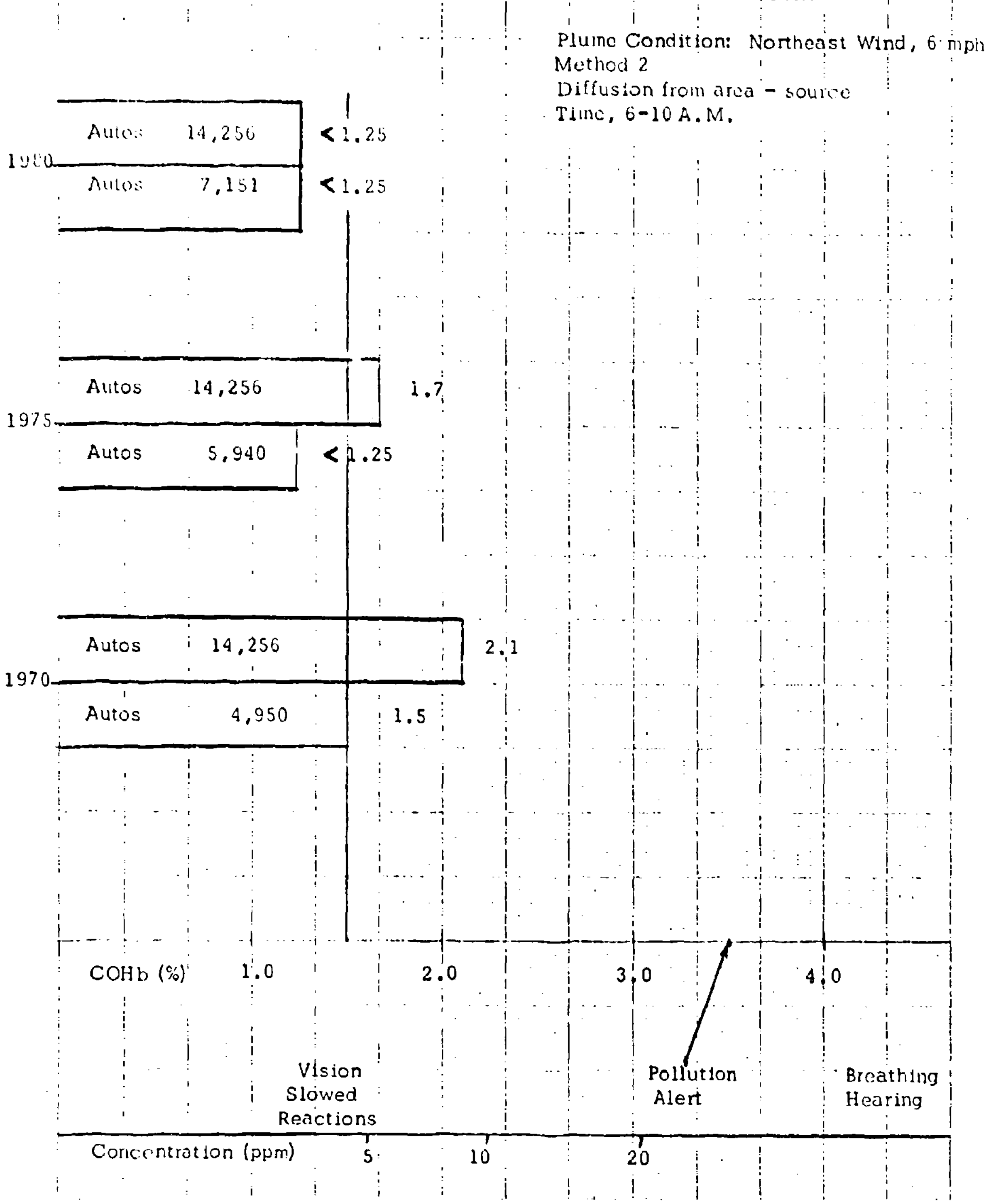
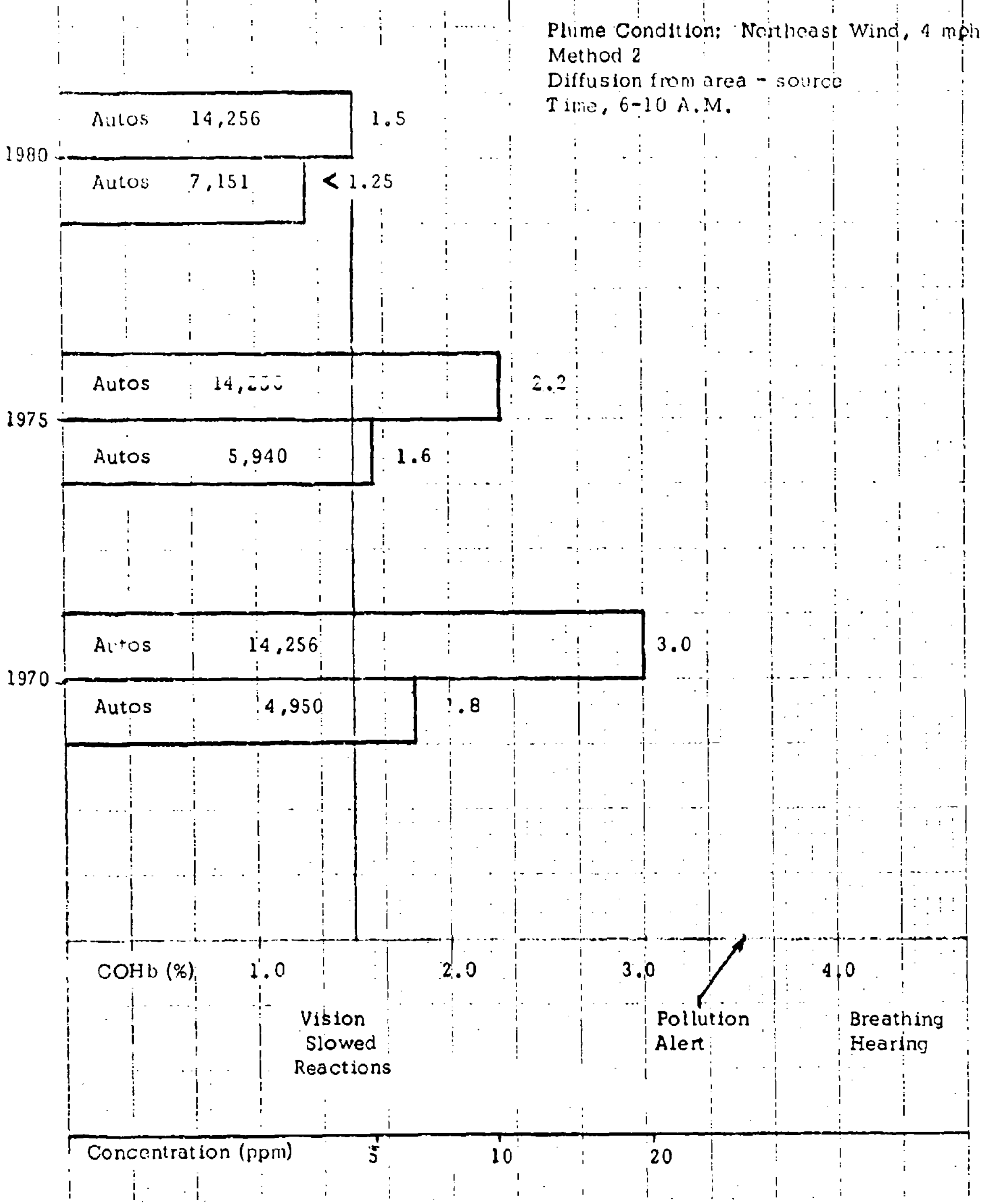


Figure V-9

HUMAN IMPAIRMENTS FROM AUTOMOBILE EMISSIONS



Air Pollution Alert

The first two figures, V-6 and V-7 (Method 2), which cover the 3 to 7 P.M. period accounting for about 30 percent of total daily traffic, indicate that in one out of twelve cases, the COHb levels exceed the Air Pollution Alert standard established by the New Jersey State Department of Health. A case is defined as each COHb (%) level derived by using traffic volumes, automobile emission standards by year and northeast winds at 4 mph or 6 mph. An Air Pollution Alert is declared when in "any consecutive six hours in the immediately preceeding twelve hours, the carbon monoxide dosage is equal to or exceeds 180 parts per million-hours."[37] This Air Pollution Alert level of an average 30 ppm over six hours converts to a value of 3.5 percent COHb as shown in Figure V-3. Human impairments of vision and slowed reactions (1.5 percent COHb) result in 10 of the 12 afternoon cases.

The pollution on this highway segment during 3 to 7 P.M. also violates the Air Quality Act of 1967 (Imminent Endangerment) by creating a "direct effect on public health."[38] Under this violation the Secretary of the U.S. Department of Health, Education and Welfare has "authority to proceed immediately to court for abatement of any pollution that creates substantial and imminent public health endangerment anywhere in the country."[39] The Committee on Public Works, United States Senate,

> "...feels this far reaching authority is necessary during the standards development period, due to the passage of time which will occur prior to establishment of enforcible standards. And we cannot allow time to justify a continued danger to anybody anywhere in the country whether it is an interstate or intrastate pollution situation.

> This provision directs itself to the control of pollution sources which are contributing to air pollution under conditions resulting in an imminent and substantial endangerment to public health. Under this provision the Secretary would have absolute authority to take the required control steps to avert disaster episodes such as occurred in the heavily industrialized Meuse Valley of Belgium in 1930; in Donora, Pa., in 1948; in New York City in 1953 [and 1962]; and in London in 1952 and 1962. Such incidents are obvious, dramatic, and tragic."[40]

Figures V-8 and V-9 (Method 2) show the human impairments which will occur during the 6-10 A.M. period when almost 20 percent of the total daily traffic occurs on the highway segment. Of the 12 cases occurring during the morning period, no cases exceed the Air Pollution Alert criteria established for N.J. Human impairments of vision and slowed reactions occur in 8 out of the 12 morning cases. The automobile traffic pollution occurring in the morning also creates a "direct effect on public health" as prohibited by the Air Quality Act of 1967.[41] Figure V-10 (Method 1) and Figure V-11 (Method 2) identify the range of occurrences of Air Pollution Alert and human impairments for both the 6-10 A.M. and 3-7 P.M. hours which can be expected to occur between 1970 and 1980.[42] These occurrences are based upon an analysis of special computer print-outs of wind speeds and directions, provided to Rutgers University by the U.S. Department of Commerce, Environmental Science Services Administration, Enviornmental Data Service, National Weather Records Center in Asheville, North Carolina. These print-outs contain the hourly wind speeds and directions compiled over a 10 year period at Newark, New Jersey.

FIGURE V - 10

Occurrences of Air Pollution Alert and Human Impairments: 1970 through 1980 (Method 1)

Time	Air Pollution Alert (≥3.5% COHb)	Human Impairments* (≥ 1.5% COHb)
6 A.M. to 10 A.M.	0	40
3 P.M. to 7 P.M.	5	15

*Air Pollution alerts are counted in occurrences of human impairments.

FIGURE V-11

Occurrences of Air Pollution Alert and Human Impairments: 1970 through 1980 (Method 2)

Time	Air Pollution Alert ($\geq$ 3.5% COHb)	Human Impairments* ($\geq$ 1.5% COHb)
6 A.M. to 10 A.M.	0	100
3 P.M. to 7 P.M.	5	25

*Air Pollution Alerts are counted in occurrences of human impairments.

Air Pollution Emergency

The laws of the State of New Jersey define an air pollution emergency as "any consecutive six hours in the immediately preceeding twelve hours, the carbon monoxide dosage is equal to or exceeds 300 parts per million-hours."[43] This carbon monoxide dosage of an average 50 ppm over six hours to a COHb of 6 percent when using Figure V-3. This COHb level will cause breathing impairments among humans. During any Air Pollution Emergency condition, the Govemor of New Jersey has the power "to prohibit, restrict or condition motor vehicle travel of every kind, including trucks and buses, in the area."[44]

Air Pollution Dispersion under Stable and Unstable Atmospheric Conditions

A neutral atmospheric stability condition (Class D) has been assumed in the foregoing analysis when determining dosage effects of air pollution. This section, however, deals with occurrences during periods of atmospheric instability.

Factors affecting the determination of atmospheric stability include the turbulence generated by solar radiation. One technique of evaluating solar radiation is to use an "Aerovane" type of wind system, and to record actual directional fluctuations in the wind pattern experimentally.[45] When dealing with a localized area, such as a roadway or airport, actual on-site measurement is the principal way to obtain steady and non-steady wind flow data. Another approach in evaluating the influence of solar radiation involves the determination of cloud cover over a specific geographic area. Cloud cover is an additional factor in formulating basic rules about atmospheric stability.

When solar insolation is high (e.g., during the day under clear skies), the lower atmosphere can be expected to be unstable. On the other hand, when solar insolation is low, as in the evening or during overcast conditions, the atmosphere will be relatively stable. These rules are the basis in this analysis for calculating values of the vertical deviation of the plume (σ_z). Categories can be devised, such as Turner's A,B,C,D and E categories,[46] which determine patterns of turbulence, which are related to the standard deviation of the azimuthal wind direction (σ_θ).[47] These standard deviations may be expressed mathematically as functions of travel time or travel distance on the basis of experimental measurements.[48]

In certain cases over a large, open area of even terrain, solar radiation can be the only significant factor affecting stability. In the case of the proposed extension to the New Jersey Route 18 Highway, however, the terrain is uneven. This highway passes between the Raritan River and a 50 foot embankment . Automobiles moving along this highway would generate turbulence in the vicinity of the high density living complex. This turbulence generated by automobiles, effects of uneven terrain, and solar radiation are considered in the dosage effects of air pollution. Because no accepted rules are presently available for introducing these additional factors into the analysis and actual atmospheric measurements are lacking, assumptions are made of their likely influence on the diffusion of pollutants.

The use of a neutral stability category (Class D) during the four hour daytime exposure periods reduces the number of times these conditions will occur annually when compared to Class D occurrences at hourly intervals. Class C would occur under these same four hour periods a greater number of times than is the case with Class D, because of daytime solar insolation which produces greater instability.

Employing an unstable category (Class C) reduces the CO concentrations (ppm) to 70 per cent of the values shown in the preceding analysis conducted under conditions of neutral stability (Class D). In this unstable case, increased atmospheric turbulence enhances the diffusion of the pollutants by creating a larger vertical deviation at the living complex. This comparison of one case in 1970 which considers the same traffic volume and wind velocity under stability categories C and D is shown in Appendix I.

The movement of automobiles along the highway which creates unstable atmospheric conditions presents a special problem of atmospheric dispersion.[49] Mathematical analysis of this effect has not been published to date. Consequently, a number of assumptions are made, which both enhance and impede the diffusion of pollutants. The amount of mechanical turbulence generated is dependent primarily upon automobile speed and the spacing interval between automobiles. Such localized turbulence produced by the movement of automobiles can be considered to promote diffusion by increasing the vertical plume height over the roadway above the ground level emission previously considered under neutral conditions ($\sigma_{z_o} = 0$).

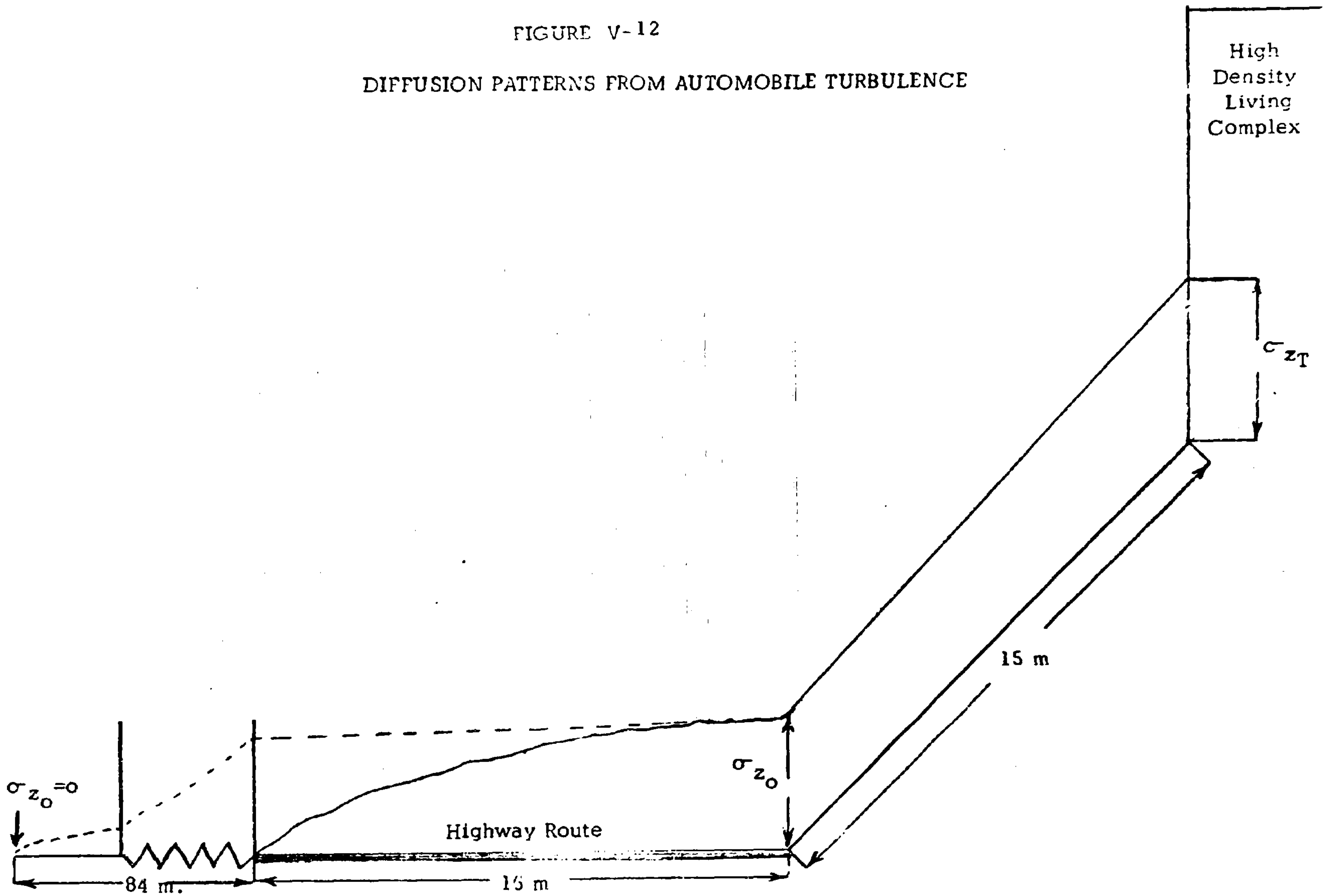
In evaluating this unstable condition created by automobile movement, a two-step method has been devised at the Center for Transportation Studies to account for the total vertical deviation (σ_{zT}). Step one involves the calculation of the initial vertical deviation (σ_{z_o}) of the plume over the roadway. A very unstable category is assumed, where $\sigma_{z_o} = .40\ X^{.91}$, where X is the width of the roadway (16 meters).[50] The value of σ_{z_o} becomes five meters.

The second step involves the determination of the virtual distance, X_z. This virtual distance is the distance at which the emissions are considered to be released at ground level. This distance (X_z) can be calculated for the Class C (unstable) category by considering the approximate equation that relates the standard vertical deviation (σ_{z_o}) with the downwind distance (X_z). Solving the equation ($\sigma_{z_o} = .17\ X_z^{.75}$; σ_{z_o} = 5 meters) yields a value for the virtual distance (X_z) equal to 100 meters. To achieve a five meter value for σ_{z_o} under stability Class C requires that the roadway be considered a virtual source existing 100 meters away from and parallel to its present proposed site. (See Figure V-12) This procedure enables the area source calculation to be made considering ground level emissions ($\sigma_{z_o} = o$). Using the theoretical 100 meters distance of the roadway from the proposed site plus the 15 meter distance from the embankment to the high density living complex, the standard vertical deviation is calculated (σ_{z_T}). Recalculation of the area source model resulted in CO levels (in ppm) equal to or about 15 per cent of the CO levels previously arrived at under neutral stability Class D conditions, (See Appendix I).

In using the area source models for concentration calculations on the highway segment, the wind velocity component ($\bar{U}$) has been orientated at a right

FIGURE V-12

DIFFUSION PATTERNS FROM AUTOMOBILE TURBULENCE



angle to the roadway. In most cases the wind will not be found at such a perpendicular orientation. In the case of the highway segment, which is boarded on one side by a relatively steep (45°) embankment, there will be channeling of pollutants along the roadway cut. There has been no attempt made at computing concentration values for this channeling condition, but it is expected that these concentrations would generally be lower than those values obtained for a perpendicular wind orientation.

The results of this study allows considering the CO concentrations ranging between 15 - 100 per cent of the previously calculated values using the neutral atmospheric conditions (Class D). This range considers both stable and unstable categories of atmospheric conditions. Certainly, more diffusion research and atmospheric sampling are required to determine the effects of automobile turbulence on atmospheric dispersion.

Federal Air Pollution Laws

Major federal laws dealing with the problem of air pollution are found in 42 United States Code ("Health and Welfare"), Chapter 15B ("Air Pollution Control"), Section 1857 through 1857(L). These statutes represent the cumulative air pollution legislation from 1955, (when Congress responded to "growing public concern with legislation authorizing a federal program of research in air pollution and technical assistance to state and local governments." [51] through the Clean Air Act of 1963 and the Air Quality Act of 1967.

The first subchapter of Chapter 15B entitled "Air Pollution Prevention and Control", is divided into sections dealing with Research and Development, air quality standards and designation of "air quality control regions."

Research and Development-The Secretary of Health, Education and Welfare (HEW) shall, "Establish a national research and development program."

Coinciding with this, the Secretary shall as well, "conduct and promote the coordination and acceleration of research, investigations, experiments, training, demonstrations, surveys and studies related to the causes, effects, extent, prevention and control of air pollution; encourage, cooperate with, and render technical services and provide financial assistance to air pollution control agencies, and other appropriate public or private agencies, institutions and organizations and individuals in the conduct of such activities."[52]

In carrying out these provisions, the Secretary of HEW is authorized to make information readily available to all agencies and parties concerned, by collection, publication and "other appropriate means." He is also authorized to encourage cooperation between governmental agencies and between such agencies and those outside the sphere of government, in the conduct of research and "other activities." Moreover, the Secretary can "make grants to air pollution control agencies, to other public or non-profit private agencies, institutions, and organizations and individuals" for purposes relating to the prevention and control of air pollution. The Secretary, in order to facilitate research related to fuels and vehicles, shall conduct and accelerate programs related to combustion and use of fuel byproducts, furnish grants for such research to appropriate organizations, and construct and operate facilities.[53]

Under the same section (1857b), the Secretary shall review scientific studies on "the harmful effects on the health and welfare of persons by the various known air pollution agents (or combinations of agents). He can also construct facilities and grant funds for the training of personnel (such as the maintenance of research fellowships), public, or non-profit private educational institutions or research organizations.

Law Enforcement-In the event, by his own judgement, the Secretary determines that a discharge, or discharges, are likely to pose a threat of potential air pollution, he may convene a conference, to be held near the area of potential pollution. If the findings of the conference show that potential air pollution is imminent, he is to send such findings to the parties concerned (that is, the potential polluters, and the appropriate state or interstate or local agency with jurisdiction in the area).[54]

Such air pollution or potential air pollution is subject to abatement under Section 1857d of the title. States are entitled to set their own standards of ambient air quality; if such action is not forthcoming, the Secretary of HEW shall prepare regulations "setting forth standards of air quality and recommended control techniques issued pursuant to Section 1857c-2 of this title to be applicable to such air quality control region or portions thereof." The section cited refers to that requiring the Secretary to establish, no later than one year after November 21, 1967, arbitrary air quality control regions, based on jurisdictional boundaries, urban industrial concentrations, and other factors." The Secretary shall, after consultation with appropriate advisory committees and federal departments and agencies...develop and issue to the States such criteria of air quality as in his judgement may be requisite for the protection of the public welfare. The criteria will reflect the latest scientific knowledge, and those variable factors which may alter public health.

The techniques, which will be determined capable of achieving the level of air quality set forth in the criteria, will appear in the Federal Register.[55]

When the Secretary finds that the ambient air quality of any air quality control region, or portion thereof, is below the air quality standards established, and that such is the fault of a State's non-enforcement of such standards, the Secretary is to bring such information to the attention of all parties concerned. If the pollution is endangering the health and welfare of persons in a state other than that in which the pollution originates and is not then properly regulated, the Secretary may request the Attorney General of the United States to bring suit in the appropriate Federal district court. This suit brought on behalf of the United States will immediately enjoin any contributor to the alleged pollution to stop the emission of contaminents causing such pollution or to take any other action as may be necessary. If the pollution is occurring on an intrastate basis, the Secretary, on request of the Governor of the affected State, shall provide technical and other assistance necessary to assist the State in judicial proceedings to secure abatement of the pollution under state or local law, or, on request of the Governor, the Secretary shall request the Attorney General to bring suit on behalf of the United States in the appropriate Federal district court to secure abatement of the pollution.[56]

In cases of "imminent and substantial endangerment" to the health of persons from a particular pollution source, the Secretary may request the Attorney General to seek injunction against any contribution, to stop emission of such contaminents causing the pollution.

The last two sections of the subchapter deal with the creation of an Air Quality Advisory Board in the Department of HEW, and the regulation of pollution from Federal facilities. The members of the Board shall consist of fifteen members and a Chairman, appointed by the President, none of whom shall be Federal officers or employees. Made up of representatives of various state, interstate and local government agencies, and of public or private interests related directly to problems of air pollution, the Board shall, "advise and consult with the Secretary on matters of policy...and make such recommendations as it deems necessary to the President." [57]

In order to prevent air pollution from any Federal facilities, the Secretary of HEW shall establish classes of potential pollution sources under which Federally controlled facilities must qualify before being issued a certificate of permission for an atmospheric discharge. [58]

Air Pollution Standards-The second subchapter of Chapter 153 refers to Motor Vehicle Emission Standards. The Secretary of HEW shall, "giving appropriate consideration to technological feasibility and economic costs," as soon as practicable, establish standards," applicable to the emission of any kind of substance, from any class or classes of new motor vehicles, or new motor vehicle engines, which in his judgement cause or contribute to, or are likely to cause or contribute to, air pollution, which endangers the health or welfare of any persons. Prohibited acts under this subchapter include manufacture, sale or importation of vehicles or engines not in conformity with regulations, failure to make reports or provide information to the Secretary regarding specifications, or removal of anti-pollution devices, once installed, prior to its sale or delivery to the ultimate purchaser.[59]

Jurisdiction over such illegal acts, as in Subchapter 1, is given to the United States District Courts.[60]

Engine Emission Standards Testing-The Secretary shall determine the manner of testing of automobiles and/or engines, and upon conformity with established regulations, the Secretary shall issue a certificate of conformity. Similar regulations are provided concerning fuels; the manufacturers are required to register such fuels with the Secretary, giving the commercial name and the physical makeup of the fuel, including fuel additions, and their chemical composition. (All information acquired, regarding trade secrets, will be kept in confidence.) Any violation of this section is punishable by fine.[61]

In addition to this, the Secretary of HEW shall initiate, in no later than two years after November 21, 1967, a comprehensive report on the need for and effect of national emission standards for stationery sources, as well as conducting an investigation into the controlling of emissions from jet and piston aircraft as well.[62] Under Subchapter III ("General Provisions") the Secretary of HEW is authorized to prescribe such regulations as are necessary to carry out his functions under these laws. He may also delegate to any officer or employee of the Department of HEW such of his powers and duties as he may deem necessary or expedient, except those of prescribing regulations.[63]

Pending Legislation-Regarding Federal legislation a set of amendments have been prepared in regard to the existing statutes cited. Besides extending and increasing the financial expenditure provisions for two years past fiscal year 1971, these "Clean Air Act Amendments of 1970"[64] would do away with the "Air Quality Control Regions." The Secretary would then establish National Air Quality Standards; that is, after consultation with appropriate advisory committees and Federal departments and agencies, (and no later than six months after enactment,) he shall publish in the Federal Register proposed regulations establishing nationally applicable standards of ambient air quality and recommended control techniques.

The amendments also provide for the establishment by states or interstate air pollution control agencies mandatory plans for the implementation, maintenance and enforcement of such standards of air quality. Such plans must include adequate emission standards, provisions for inter-governmental cooperation, adequate means of enforcement and provision for revision from time to time. If any particular state or agency does not file a letter of intent to adopt such a plan, the Secretary is authorized to develop a plan <u>for</u> the state or agency. The amendments provide enforcement of the plans through the U.S. District courts, and conferences, in the same manner as the statutes.

Other major provisions of the 1970 Amendment Bill concern motor vehicle emission standards, specifically, "compliance testing and certification." The Secretary would be able to test any vehicle or engine produced by any manufacturer. The amendments also provide for revocation of the certificate of conformity if any of these vehicles do not conform with regulations.

The Secretary, or those delegated authority by him would, under the amended form, be permitted to enter any factory business or establishment, in order to inspect and test vehicles or engines coming off the assembly lines as well as records, files, papers, processes, controls and facilities.

Regulations regarding fuels would be amended to designate fuel additives as well.

A Senate bill, entitled the "Air Quality Improvement Act"[65] includes the changes made in the House bill, as well as extending federal regulations to cover vessels and aircraft. The Senate Amendments would also call for Federal assistance in developing vehicle inspection programs and the development of low emission vehicles.

Air Pollution Laws in New Jersey

The "Air Pollution Control Act (1954)"[66] provides for a nine-member Air Pollution Control Commission to be established in the State's Department of Health. Membership will include representatives from the Department of Labor and Industry and the Department of Agriculture.[67] The Commission retains the power to promulgate, formulate, amend and repeal "codes and rules and regulations controlling and prohibiting air pollution throughout the State...provided, however, that no such code, rule or regulation and no such amendment or repeal shall be adopted except after public hearing..." of which appropriate prior notice shall be given to the public.[68]

The State Department of Health, in accordance with codes, rules and regulations promulgated by the Commission, shall have the power to conduct research programs related to the air pollution problem, prepare and distribute information relating to the problem, require the registration of all potential sources of emission, and enter any building or place in order to investigate compliance or non-compliance of a potential polluter with rules, etc., promulgated by the Commission. In addition to this, the Department shall have the power to institute legal proceedings in relation to complaints of air pollution. The Department of Health can also cooperate with, and receive money from, the Federal Government and the State Government for the study and control of air pollution.[69]

The Commission shall organize county air pollution control associations in each county, which shall investigate all air pollution problems in their respective counties. These county associations shall also have the power to pass on all rules, etc., which apply to strictly local (that is, county) pollution problems, before enactment by the State's Commission.[70]

In case any written complaint is filed with the State Department of Health, an investigation of the complaint shall follow, and, if necessary, the Department shall "immediately endeavor to eliminate any source or cause of air pollution "by conference conciliation and persuasion."[71] If the pollution situation remains unaltered, the person complained against will have to appear before a hearing to answer charges of non-compliance. If, after the hearing, the party complained against, has not remedied the situation within a reasonable amount of time, the New Jersey Department of Health is empowered to "institute a civil action in any court of competent jurisdiction, for injunctive relief to prevent any further violation of such code, rule or regulation."

The court shall be given such injunctive power and the power to authorize a weekly penalty of $100 for non-compliance.[72] The Air Pollution Emergency Control Act (1967),[73] which supplements the Air Pollution Control Act, provides emergency powers in order to "prevent or minimize disasters of unforseeable proportions." Upon recommendation of the New Jersey Commissioner of Health, the Governor may declare any area of the State to be an area of "air pollution emergency." In such an emergency, the Governor may, by order(s), prohibit, restrict or condition motor vehicle travel of every kind (including trucks and buses), commercial activities, operation of incinerators, burning or other consumption of fuels, or any other activity which may contribute to air pollution emergency in the area.[74] Any orders promulgated by the Governor in any case of air pollution emergency shall be enforcible by the Departments of Health, Defense, and the State and local police and air pollution enforcement personnel forces. They may use such reasonable force as is required to enforce the orders, by means of entering any property or establishment believed to be in violation, by stopping, detouring, rerouting and prohibiting motor vehicle travel and traffic or "by closing down or restricting the use of any business, commercial, retail, manufacturing, industries or other establishment."[75] Any willful violation of the Governor's orders can be penalized by "a fine of not more than $100,000 or by imprisonment for not more than ten years, or both."[76]

The 1967 Act also provides for hearings to be held if any party is aggrieved by such orders issued by the Governor. The hearings shall determine whether or not the orders are unreasonable.[77] The State Commissioner of Health shall also prepare a set of stand-by orders which the Governor may choose to use in the case of any air pollution emergency.[78]

Chapter 12 ("Emergencies") of the New Jersey Air Pollution Control Code[79] sets forth the specific pollution levels by which to control air pollution in New Jersey. This code consists of a "group of administrative regulations published as chapters," which have the force and effect of law. This code ennunciates emergency criteria necessary for the declaration of an Air Pollution Alert, Warning or Emergency. Such a condition shall exist whenever the State Commissioner of Health determines that the accumulation of contaminants "in any place, locality, county, or other area in the State is attaining or has attained levels which could, if such levels are sustained or exceeded, lead to a threat to the health of the public."[80]

The State Department of Health, in conjunction with the United States Weather Bureau, shall conduct an internal watch, and prepare an "Air Pollution Forecast," which will determine whether a high air pollution potential will exist for the next thirty-six hours.[81] If, for any consecutive six hours the carbon monoxide dosage is equal to, or exceeds, 180 parts per million-hours, the Status will be one of "Air Pollution Alert."[82] If the dosage rises to 300 parts, the Status will alter to "Air Pollution Warning."[83] The Air Pollution Warning Standards for carbon monoxide are also the "Air Pollution Emergency" Standards.[84] Sulfur dioxide dosages are also outlined for Alert Warning and Emergency conditions.

All persons responsible for the operation of any source of air contamination (including power-generating facilities, manufacturing industries, refuse disposal operations, etc.) shall have prepared standby plans, consistant with good industrial practice, for reducing emission of air contaminants into the outdoor atmosphere during periods of Air Pollution Alert, Warning and Emergency. In the event of Alerts and Warnings, guidelines for such standby plans are set forth in the code regulating open burning of wastes, use of incinerators, use of fuel-burning equipment, etc. In the case of an Air Pollution Emergency, far more drastic measures may be taken, such as the closing of schools, businesses and government offices, and the prohibition of the use of any (except emergency) motor vehicles.[85]

Conclusions

1. The combination of mathematical meteorological models of atmospheric dispersion and procedures for determining the physiological effects of varying COHb levels developed in this analysis is applicable for determining air pollution exposure forecasts for airports and highway segments.

2. Air pollution concentrations along a highway segment estimated by mathematical meteorological models produce physiological effects which violate the Imminent Endangerment Section of the Air Quality Act of 1967.

3. Air pollution concentrations along a highway that would produce access for automobiles to a city center airport located in New Brunswick, New Jersey can produce physiological effects which are in violation of the Air Pollution Alert Standard of the New Jersey Air Pollution Control Code.

4. High density aircraft operations on the decks of oblong shaped and circular shaped Rutgers Aquadromes located at Manhattan create carboxyhemoglobin (COHb) levels of less than one percent which have no known physiological effects on humans.

5. The mathematical meteorological models for determining the physiological effects from air pollution are applicable to other highway networks including evaluation of alternate routes for proposed highway locations.

6. Calculations indicate that automobile emissions along the proposed New Jersey Highway Extension to Route 18 produce human impairments [illegible] ision, slowed reactions, breathing and hearing.

7. More diffusion research and atmospheric sampling is necessary to support a mathematical analysis of the effects of atmospheric stability con-

ditions and turbulence generated by transportation vehicles on the atmospheric dispersion of pollutants.

FOOTNOTES
CHAPTER V

[1] United States Senate, Committee on Public Works, Air Quality Act of 1967 Amending the Clean Air Act as Amended, Report to accompany S. 780, (July 13, 1967).

[2] Rutgers University, Center for Transportation Studies of the Eagleton Institute of Politics, Project Eagle - A Study of Urban Mass Air Transportation for Connecticut, New Jersey and New York, (November, 1969), pp. III-7 through III-18.

[3] U.S. Department of Commerce, Environmental Science Services Administration, Environmental Data Service, National Weather Records Center, Asheville, N.C., Computer Print-outs of Wind Speed vs. Wind Direction, for Rutgers University utilizing Jan. 1, 1956 to Dec. 21, 1965 data from Vol. 26 of the Climatological Summaries, (May, 1970).

[4] U.S. Department of Health, Education and Welfare, Air Quality Criteria for Carbon Monoxide, National Air Pollution Control Administration Publication No. AP-62, (Washington, D.C.: U.S. Government Printing Office, 1970), p. 8-10.

[5] Ibid., p. 9-11.

[6] J.R. Goldsmith and S.R. Landaw, "Carbon Monoxide and Human Health", Science, Vol. 162 (1968), pp. 1352-1359.

[7]New Jersey Department of Transportation, Air-Rights Potentials in Major Highways-Criteria for Joint Development, (New York: Tippetts-Abbett-McCarthy-Stratton Engineers and Architects, 1969), p. 24.

[8]P. Chevin, "Carbon Monoxide: Analysis of Exhaust Gas Investigations in Paris," Environmental Research, Vol. 1 (1967), pp. 185-206, quoted by National Academy of Sciences, Effects of Chronic Exposure to Low Levels of Carbon Monoxide on Human Health, Behavior and Performance, (Washington, D.C.: National Academy of Sciences, 1969), p. 45.

[9] R.R. Beard and G.A. Wertheim, "Behavioral Impairment Associated with Small Doses of Carbon Monoxide," American Journal Public Health, Vol. 57 (1967), 11, 2011-2022, quoted by J.R. Goldsmith, Head Environmental Epidemiology Unit, California Department of Public Health in a letter dated Dec. 10, 1968, to Mr. Kenneth Johnson, U.S. Public Health Region II, National Air Pollution Control Administration, N.Y., N.Y.

[10]J.R. Goldsmith and S.A. Lundaw, op. cit., pp. 1352-1359.

[11]J.H. Schulte, "Effects of Mild Carbon Monoxide Intoxications," Archives Environmental Health, Vol. 7 (1963), pp. 524-530, quoted by A.M. Ray and T.H. Rockwell, An Exploratory Study of Automobile Driving Performance Under the Influence of Low Levels of Carboxyhemoglobin, paper presented at the New York Academy of Sciences' Conference on Biological Effects of Carbon Monoxide on January 24, 1970, p. 11.

[12] Mr. Steven D. Ittel, Assistant Director of Station 5 at Raritan Depot in Edison, N.J., Eastern Regional Air Pollution Control Activity, U.S. Department of Health, Education and Welfare in a conference during March, 1970.

[13] New York State Air Pollution Control Board Standards quoted by the Secretary of Health, Education and Welfare in Senate Resolution 159, 90th Congress, 1st Session, (1967), p. 11.

[14] New Jersey State Department of Health, New Jersey Air Pollution Control Code, Chapter 12, Emergencies, (October 24, 1969).

[15] New York State Air Pollution Control Board Standards quoted by the Secretary of Health, Education and Welfare, op. cit., p. 11.

[16]J. H. Schulte quoted by A.M. Ray and T.H. Rockwell, op. cit., p. 11.

[17] R. A. McFarland, F.J.W. Roughton, M.H. Halperin and J. I. Niven, "The Effects of Carbon Monoxide and Altitude on Visual Thresholds," Journal of Aviation Medicine, Vol. 15 (1944, pp. 381-394, quoted by A.M. Ray and T. H. Rockwell, op. cit., p. 11.

[18] R. R. Beard and N. Grandstaff, CO Exposure and Cerebral Function, paper presented at The New York Academy of Sciences Conference on Biological Effects of Carbon Monoxide on January 14, 1970, pp. 6-8.

[19] R. R. Beard and G. A. Wertheim, "Behavioral Impairment Associated with Small Doses of Carbon Monoxide," American Journal Public Health, Vol. 57 (1967), pp. 2011-2022, quoted by U.S. Department of Health, Education and Welfare, Air Quality Criteria for Carbon Monoxide, National Air Pollution Control Administration Publication No. AP-62, (Washington, D.C.: U.S. Government Printing Office, 1970), p. 8-49.

[20] R. R. Beard and N. Grandstaff, op. cit., p. 5.

[21] Mr. William Munroe, Chief, Air Pollution Control Program, New Jersey State Department of Health, in a conference on April 7, 1970, stated the Air Pollution Warning standards for carbon monoxide in the New Jersey Air Pollution Control Code, Chapter 12-Emergencies (October 24, 1969) are also the Air Pollution Emergency Standards.

[22] New York State Air Pollution Control Board Standards quoted by Senate Resolution 159, 90th Congress, 1st Session, (1967), p. 11, op. cit., p. 11.

[23] National Academy of Sciences, Effects of Chronic Exposure to Low Levels of Carbon Monoxide on Human Health, Behavior and Performance, (Washington, D.C.: National Academy of Sciences, 1969), pp. 18-24.

[24] I. B. S. Hadane, "Carbon Monoxide as a Tissue Poison," Biochemical Journal, (1927), quoted by A. M. Ray and T. H. Rockwell, op. cit., p. 8.

[25] Ibid.

[26] Ibid.

[27] C. Simon, Manager of Data and Meteorology, New York City Department of Air Resources, in a conference on January 15, 1970.

[28] U.S. Department of Health, Education and Welfare, Air Quality Criteria for Carbon Monoxide, op. cit., p. 8-51.

[29] Automobile Emissions Data for 1971, 1975 and 1980, provided by Raymond Smith, Assistant Commissioner of Program Development, National Air Pollution Control Administration, U.S. Department of Health, Education and Welfare, in a personal interview on December 15, 1969.

[30] The American Society of Mechanical Engineers, Recommended Guide for the Prediction of the Dispersion of Airborne Effluents, (New York: The American Society of Mechanical Engineers, 1968), p. 18.

[31] C. Simon, Manager of Data and Meteorology, and Harold Nudelman, Senior Meteorologist, New York City Department of Air Resources, in a review of a first draft of this report dated April 21, 1970.

[32] Ittel interview during March, 1970, op. cit.

[33] N. Cernansky, Engineer, Office of Criteria and Standards, National Air Pollution Control Administration, Durham, N.C. in a conference on July 16, 1970. Emission correction factors for the revise 1972 Federal Test Cycle were identified as:

Pollutant (1970 Cycle)	Emission Correction Factor (1972 Cycle)
Carbon Monoxide	2.09
Hydrocarbons	2.2
Oxides of Nitrogen	1.9
Particulates	1.0

The 1970 and 1972 Federal Test Cycle Procedures are explained in the following documents:

(a) Federal Register, Vol. 33, No. 108, Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines

(b) Federal Register, Vol. 34, No. 125, Control of Air Pollution from New Motor Vehicles and New Motor Vehicle Engines

(c) U.S. Department of Health, Education and Welfare, National Air Pollution Control Administration, Preliminary Draft of Test Procedures for True Mass Measurement of Exhaust Emissions Applicable to 1972 and Subsequent Model Year Light-Duty Vehicles and Engines, April 22, 1970.

(d) U.S. Department of Health, Education and Welfare, National Air Pollution Control Administration, History of Federal Procedures and Standards, NPC/RDW/6-10-70.

34 Percentage trips by hour of day based upon Tri-State Transportation Commission, Travel Time Comparisons to Manhattan Central Business District, Interim Technical Report 4175-5250, March, 1970, p. 2.

35 New Jersey Department of Transportation, Map-Route 18 Freeway, 1985 ADT/DHV, #1110-1, September 10, 1965.

36 James N. Wilson, Manager, Highway Planning Unit, Tri-State Transportation Commission, N.Y., N.Y., in a letter dated June 19, 1969 to the Middlesex County Planning Board.

37 New Jersey State Department of Health, New Jersey Air Pollution Control Code, Chapter 12, Emergencies, (October 24, 1969), op. cit.

38 U.S. Senate, Committee on Public Works, Air Quality Act of 1967, op. cit., p. 31.

39 Ibid.

40 Ibid.

41 Ibid.

42 U.S. Department of Commerce, National Weather Records Center, Asheville, North Carolina, op. cit.

43 New Jersey State Department of Health, New Jersey Air Pollution Control Code, Chapter 12, Emergencies, (October 24, 1969), op. cit., p. 2.

44 New Jersey Air Pollution Control Act (1967), Chapter 108, Public Laws of 1967, Title 26, 2C: 26-36.

45 David H. Slade, op. cit., p. 5.

46 D. Bruce Turner, op. cit., p. 6.

KEY TO STABILITY CATEGORIES

Surface Wind Speed (at 10 m), m sec⁻¹	Day: Incoming Solar Radiation			Night	
	Strong	Moderate	Slight	Thinly Overcast or ≥4/8 Low Cloud	≤3/8 Cloud
< 2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

The neutral class, D, should be assumed for overcast conditions during day or night.

[47] David H. Slade, op. cit., p. 4.

[48] The American Society of Mechanical Engineers, op. cit., p. 45.

[49] C. Simon, Manager of Data and Meteorology, New York City Department of Air Resources, in a conference on April 30, 1970.

[50] The American Society of Mechanical Engineers, op. cit., p. 45.

[51] Senate Document No. 92, 90th Congress, 2d Session. "Progress in the Prevention and Control of Air Pollution," (1968).

[52] 42 U.S.C. 1857b.

[53] Ibid.

[54] 42 U.S.C. 1857d.

[55] 42 U.S.C. 1857c-2.

[56] 42 U.S.C. 1857d.

[57] 42 U.S.C. 1857e.

[58] 42 U.S.C. 1857f.

[59] 42 U.S.C. 1857f-5.

[60] 42 U.S.C. 1857f-1.

[61] 42 U.S.C. 1857f-3.

[62] 42 U.S.C. 1857f-6d.

[63] 42 U.S.C. 1857g.

[64] H.R. 15848, 91st Congress, 2d Session, (1970).

[65] S. 3229, 91st Congress, 1st Session, (1969).

[66] New Jersey, Air Pollution Control Act (1954), Chapter 122, Public Laws of 1954, pp. 780-787.

[67] Ibid., p. 781.

[68] Ibid., p. 782.

[69] Ibid., pp. 783-784.

[70] Ibid., p. 784.

[71] Ibid., p. 785.

[72] Ibid., p. 786.

[73] New Jersey, Air Pollution Control Act (1967), Chapter 108, Public Laws of 1967, Title 26, 2C: 26-36.

[74] Ibid., Title 26, 2C-29.

[75] Ibid., Title 26, 2C-32.

[76] Ibid., Title 26, 2C-33.

[77] Ibid., Title 26, 2C-35.

[78] Ibid., Title 26, 2C-36.

[79] New Jersey State Department of Health, New Jersey Air Pollution Control Code, Chapter 12, Emergencies, (October 24, 1969).

[80] Ibid., Section 2.

[81] Ibid., Section 2.1.

[82] Ibid., Section 2.2.

[83] Ibid., Section 2.3.

[84] Munroe conference on April 7, 1970, op. cit.

[85] New Jersey State Department of Health, op. cit., Section 4.2.

APPENDIX A

Motor Vehicle Emissions
(Grams per Passenger Mile)

	1970[1] Emissions	1970[2] Actual	1975[1] Goals	1975[2] Actual	1980[1] Goals	1980[2] Actual
Hydrocarbons	8.81	12.10	0.40	8.51	0.20	3.11
Carbon Monoxide	38.95	72.35	8.87	45.24	3.79	18.87
Nitrogen Oxides	10.35	6.84	0.73	7.84	0.32	3.52
Particulates	.40	.47	0.08	0.38	0.02	0.17

Total Aircraft Vehicle Emissions: Approach, Cruise, Take-Off at 100% Load Factor
(Grams per Passenger Mile)

	1970	1975	1980
Hydrocarbons	.3696	.3696	.3696
Particulates	1.0107	1.0107	1.0107
Carbon Monoxide	1.4717	1.4717	1.4717
Nitrogen Oxides	.8151	.8151	.8151

[1] Based on HEW estimates of emission-controlled vehicles that will be in production at that date.

In converting the grams per vehicle mile to grams per passenger mile, an average automobile passenger occupancy of 1.24 persons is used. In the case of aircraft, occupancy load factors of both 100 per cent and 50 per cent were considered. The 100 per cent load factor was demonstrated to be feasible in the Project Eagle Study. As shown in the tabulation above, the values for aircraft in grams per passenger mile is computed allowing separate emission rates for approach, cruise and takeoff. In converting the grams per vehicle mile to grams per passenger mile, a trip length of 20.8 miles is used for the 53 passenger aircraft. This 20.8 mile trip length represents the average air passenger distance traveled in an urban air transportation system during 7 A.M. to 9 A.M. and 4:30 P.M. to 6:30 P.M. between Manhattan and the 11 transportation centers in Connecticut (Bridgeport, New Haven, and Stanford), New Jersey (Linden/Rahway, New Brunswick, Paterson and Newark) and New York (Farmingdale, Hempstead, Mt. Vernon, and White Plains).

APPENDIX A -- continued

[2]Based on a methodology considering automobile age and vehicle useage corresponding to automobile age (refer to following tabulation). This procedure is currently being used by the National Air Pollution Control Administration, Durham, North Carolina.

Automobile Population Average

Automobile Age (Years)	Per Cent of Total Automobiles	Average Annual Mileage		Use Factor (X)	Per Cent Useage Factor $\frac{X}{\Sigma}$
0 (new)	10.9%	(13,200)	=	1,439	15.7%
1	10.4	(12,000)	=	1,248	13.7
2	10.0	(11,000)	=	1,100	12.0
3	09.6	(9,600)	=	922	10.1
4	9.1	(9,400	=	855	9.4
5	8.6	(8,700)	=	748	8.2
6	8.0	(8,600)	=	688	7.5
7	7.4	(8,100)	=	599	6.6
8	6.6	(7,300)	=	482	5.3
9	5.6	(7,000)	=	392	4.3
10	4.5	(5,700)	=	257	2.8
11	3.2	(4,900)	=	157	1.7
12	1.7	(4,300)	=	73	0.8
12	4.2	(4,300)	=	181	2.0
			Σ =	9,141	100.1%

APPENDIX B

COMPARISON OF AUTOMOBILE & AIRCRAFT POLLUTION – 19[illegible]

Method	Automobile Passengers Preferring Aircraft	Carbon Monoxide (Tons)	Hydrocarbons & Particulates (Tons)	Nitrogen Oxides (Tons)	Total (Tons)
I. Automobile	12,872	24.08	4.18	2.28	30.54
Aircraft (50% load factor)	12,872	2.00	1.88	1.11	4.99
Reduction		22.08	2.30	1.17	25.55
Automobile	20,290	37.90	6.58	3.58	48.06
Aircraft (100% load factor)	20,290	1. 46	1 .37	.81	3 .64
Reduction		36.44	5.21	2.77	44.42
II. Automobile	7,706	11.31	1.96	1.07	14.34
Aircraft (50% load factor)	7,706	1. 42	1.33	.79	3.54
Reduction		9.89	.63	.28	10.80
Automobile	17,362	28.10	4.88	2.66	35.64
Aircraft (100% load factor)	17,362	1.16	1 . 09	.64	2.39
Reduction		26.94	3.79	2.02	32.75
III. Automobile	23,098	42.43	7.37	4.01	53.81
Aircraft (50% load factor)	23,098	3.59	3.37	1.87	8.83
Reduction		38.84	4.00	2.14	44.98
Automobile	28,596	52.72	9.16	4.98	66.86
Aircraft (100% load factor)	28,596	2. 01	1. 88	1. 11	[illegible]. 00
Reduction		50.71	7.28	3.87	61.86
IV. Automobile	22,042	40.17	6.98	3.80	50.95
Aircraft (50% load factor)	22,042	3.22	3.02	1.77	8.01
Reduction		36.95	3.96	2.03	42.94
Automobile	25,580	48.22	8.37	4.56	61.15
Aircraft (100% load factor)	25,580	1.97	1.85	1.09	4.91
Reduction		46.25	6.52	3.47	56.24

APPENDIX B

COMPARISON OF AUTOMOBILE & AIRCRAFT POLLUTION - 1975

Method	Automobile Passengers Preferring Aircraft	Carbon Monoxide (Tons)	Hydro-carbons & Particulates (Tons)	Nitrogen Oxides (Tons)	Total (Tons)
I. Automobile	12,872	15.06.	2.96	2.61	20.63
Aircraft (50% load factor)	12,872	2.00	1..88	1.11	4.99
Reduction		13.06	1.08.	1.50	15.64
Automobile	20,290	23.70	4.66	4.11	32.47
Aircraft (100% load factor)	20,290	1 .46	1.37	.81	3 . 64
Reduction		22.24	3.29	3.30	28.83
II. Automobile	7,706	7.07	1.39	1.22	9.68
Aircraft (50% load factor)	7,706	1.42	1.33	.79.	3.54
Reduction		5.65	.06	.43	6.14
Automobile	17,362	17.57	3.45	3.05	24.07
Aircraft (100% load factor)	17,362	1.16	1.09	.64	2.89
Reduction		16.41	2.36	2.41	21.18
III. Automobile	23,098	26.53	5.21	4.60	36.34
Aircraft (50% load factor)	23,098	3.59	3.37	1.87	8.83
Reduction		22.94	1.84	2.73	27.51
Automobile	28,596	32.97	6.47	5.71	45.15
Aircraft (100% load factor)	28,596	2.01	1.88	1.11	5. 00
Reduction		30.96	4.59	4.60	40.15
IV. Automobile	22,042	25.12	4.93	4.35	34.40
Aircraft (50% load factor)	22,042	3.22	3.02	1.77	8.01
Reduction		21.90	1.91	2.58	26.39
Automobile	25,580	30.16	5.92	5.22	41.30
Aircraft (100% load factor)	25,580	1. 97	1.85	1.09	4. 91
Reduction		28.19	4.07	4.13	36.39

APPENDIX B

COMPARISON OF AUTOMOBILE & AIRCRAFT POLLUTION - 1970

Method	Automobile Passengers Preferring Aircraft	Carbon Monoxide (Tons)	Hydrocarbons & Particulates (Tons)	Nitrogen Oxides (Tons)	Total (Tons)
I. Automobile	12,872	6.28	1.09	1.17	8.54
Aircraft (50% load factor)	12,872	2.00	1.88	1.11	4.99
Reduction		4.28	- .79	.06	3.55
Automobile	20,290	9.89	1.72	1.76	13.37
Aircraft (100% load factor)	20,290	1.46	1.37	.81	3.54
Reduction		8.43	.35	.95	9.73
II. Automobile	7,706	2.95	.51	.55	4.01
Aircraft (50% load factor)	7,706	1.42	1.33	.79	2.54
Reduction		1.53	- .82	- .24	.47
Automobile	17,362	7.33	1.28	1.37	9.98
Aircraft (100% load factor)	17,362	1.16	1.09	.64	2.39
Reduction		6.17	.19	.73	7.09
III. Automobile	23,098	11.07	1.93	2.07	15.07
Aircraft (50% load factor)	23,098	3.59	3.37	1.87	8.83
Reduction		7.48	- 1.44	.20	6.24
Automobile	28,596	13.75	2.39	2.57	18.71
Aircraft (100% load factor)	28,596	2.01	1.88	1.11	5.00
Reduction		11.74	.51	1.46	13.71
IV. Automobile	22,042	10.48	1.82	1.96	14.26
Aircraft (50% load factor)	22,012	3.22	3.02	1.77	8.01
Reduction		7.26	- 1.20	.19	6.25
Automobile	25,580	12.58	2.19	2.35	17.12
Aircraft (100% load factor)	25,580	1.97	1.85	1.09	4.91
Reduction		10.61	.34	1.26	12.21

The following example of Method No. 3 illustrates the four basic steps developed in the Project Eagle Study which compares the pollution generated by aircraft and automobiles. In this case, aircraft operate at 100% load factor.

Step 1 determines the passenger preference for automobile, bus, and rail transportation from satellite cities to Manhattan. The first table summarizes the 1963 costs for determining passenger preference for each mode of travel including aircraft. The next table computes the actual passenger preference for auto, bus, and rail travel.

APPENDIX B
SUMMARY OF COSTS

Satellite	Mode	Cost Variables Out of Pocket ($)	Value of Travel Time ($)	Value of Waiting Time ($)	Total Cost ($)
Newark	Auto	1.86	2.40	.00	4.26
	Bus	.43	2.40	.38	3.21
	Rail	.44	.90	.36	1.70
	Aircraft	1.69	.83	1.50	4.02
Hempstead	Auto	1.78	8.55	.00	10.33
	Bus				
	Rail	.92	4.05	1.80	6.77
	Aircraft	2.11	1.47	2.70	6.28
Paterson	Auto	1.23	3.85	.00	5.08
	Bus	.70	3.50	.63	4.83
	Rail				
	Aircraft	1.69	1.01	2.10	4.80
Linden/ Rahway	Auto	1.65	6.00	.00	7.65
	Bus	.65	5.50	3.00	9.15
	Rail	.78	3.25	1.38	5.41
	Aircraft	2.11	1.61	3.00	6.72
Farmingdale	Auto	1.88	11.25	.00	13.13
	Bus				
	Rail	.99	5.40	2.88	9.27
	Aircraft	2.11	1.59	2.79	6.49
Mt. Vernon	Auto	1.74	7.60	.00	9.34
	Bus				
	Rail	.63	2.08	1.20	3.91
	Aircraft	1.16	1.14	2.40	4.70
White Plains	Auto	2.07	12.10	.00	14.17
	Bus				
	Rail	.81	4.40	1.43	6.64
	Aircraft	2.11	1.80	3.30	7.21

APPENDIX B
SUMMARY OF COSTS

Satellite	Mode	Cost Variables Out of Pocket ($)	Value of Travel Time ($)	Value of Waiting Time ($)	Total Cost ($)
New Brunswick	Auto	3.63	4.55	.00	8.18
	Bus	.90	4.55	.84	6.29
	Rail	.95	3.85	.98	5.78
	Aircraft	2.60	1.29	2.24	6.13
Bridgeport	Auto	2.94	7.35	.00	10.29
	Bus				
	Rail	1.37	4.90	2.45	8.72
	Aircraft	2.81	1.63	2.80	7.24
New Haven	Auto	4.56	8.40	.00	12.96
	Bus	2.50	8.40	7.00	17.90
	Rail	1.66	6.30	4.69	12.65
	Aircraft	3.37	1.88	4.20	9.45
Stamford	Auto	2.54	7.80	.00	10.34
	Bus				
	Rail	.94	5.40	1.44	7.78
	Aircraft	2.60	2.26	4.80	9.66

APPENDIX E

ACTUAL PASSENGER PREFERENCE FOR BUS, RAIL, AND AUTOMOBILE

Satellite City		Total Cost ($)	Ratio	Preference (%)
Newark	Auto	4.26	1	20.74
	Bus	3.21	1.32	27.37
	Rail	1.70	2.50	51.85
Hempstead	Auto			39.00
	Bus			
	Rail			61.00
Paterson	Auto	5.08	1	48.78
	Bus	4.83	1.05	51.21
	Rail			
Linden/Rahway	Auto	7.65	1.19	30.73
	Bus	9.15	1.00	25.83
	Rail	5.41	1.68	43.39
Farmingdale	Auto			35.00
	Bus			
	Rail			65.00
Mt. Vernon	Auto			29.00
	Bus			
	Rail			69.00
White Plains	Auto			28.00
	Bus			
	Rail			71.00
New Brunswick	Auto			33.20
	Bus			34.40
	Rail			32.40
Bridgeport	Auto	10.29	1.00	46.09
	Bus			
	Rail	8.72	1.17	53.91

APPENDIX B

ACTUAL PASSENGER PREFERENCE FOR BUS, RAIL, AND AUTOMOBILE

Satellite City		Total Cost ($)	Ratio	Preference (%)
New Haven	Auto	12.96	1.38	36.40
	Bus	17,90	1.00	26.38
	Rail	12.65	1.41	37.20
Stamford	Auto	10.34	1.00	43.10
	Bus			
	Rail	7.78	1.32	56.89

Step 2 determines the passenger preference for automobile, bus, and rail transportation with the introduction of aircraft service.

APPENDIX B

PREDICTED PASSENGER PREFERENCE FOR BUS, RAIL, AUTOMOBILE, AND AIRCRAFT

Satellite City		Total Cost ($)	Ratio	Preference (%)
Newark	Auto	4.26	1.00	17.03
	Bus	3.21	1.32	22.48
	Rail	1.70	2.50	42.58
	Aircraft	4.07	1.05	17.88
Hempstead	Auto	10.33	1.00	24.03
	Bus			
	Rail	6.77	1.52	36.52
	Aircraft	6.28	1.64	39.40
Paterson	Auto	5.08	1.00	32.25
	Bus	4.83	1.05	33.86
	Rail			
	Aircraft	4.80	1.05	33.86
Linden/Rahway	Auto	7.65	1.19	22.75
	Bus	9.15	1.00	19.12
	Rail	5.41	1.68	32.12
	Aircraft	6.72	1.36	26.00
Farmingdale	Auto	13.13	1.00	22.57
	Bus			
	Rail	927	1.41	31.82
	Aircraft	6.49	2.02	45.59
Mt. Vernon	Auto	934	1.00	18.65
	Bus			
	Rail	391	2.38	44.39
	Aircraft	470	1.98	36.93
White Plains	Auto	14.17	1.00	19.64
	Bus			
	Rail	6.64	2.13	41.83
	Aircraft	721	1.96	38.49

APPENDIX B

PREDICTED PASSENGER PREFERENCE FOR BUS, RAIL, AUTOMOBILE, AND AIRCRAFT

Satellite City		Total Cost ($)	Ratio	Preference (%)
New Brunswick	Auto	8.18	1.00	19.84
	Bus	6.29	1.30	25.79
	Rail	5.78	1.41	27.97
	Aircraft	6.13	1.33	26.39
Bridgeport	Auto	10.29	1.00	27.77
	Bus			
	Rail	8.72	1.18	32.77
	Aircraft	7.24	1.42	39.43
New Haven	Auto	12.96	1.38	24.29
	Bus	17.90	1.00	17.60
	Rail	12.65	1.41	24.82
	Aircraft	9.45	1.89	33.26
Stamford	Auto	10.34	1.00	29.49
	Bus			
	Rail	7.78	1.32	38.93
	Aircraft	9.66	1.07	31.55

Step 3 determines the automobile passengers who would change to aircraft travel. The procedure followed in Step 3 is first to estimate the automobile, bus, and railroad passengers in terms of percentages preferring aircraft travel. The decrease in number of automobiles and automobile passengers travelling to Manhattan who would change to aircraft travel from each satellite city is then established. It is shown that a total of 14,298 automobile passengers travelling in 10,861 automobiles from the 11 satellite cities into Manhattan would change to aircraft travel.

APPENDIX B

AUTOMOBILE, BUS, AND RAILROAD PASSENGERS PREFERRING AIRCRAFT TRAVEL

Satellite City	Mode	Actual Split(%)	Projected Split With Aircraft Service (%)	% Commuters Preferring Aircraft Service
Newark	Auto	20.74	17.03	-3.71
	Bus	27.37	22.48	-4.89
	Rail	51.85	42.58	-9.27
	Aircraft		17.88	+17.88
Hempstead	Auto	39.00	24.03	-14.97
	Bus			
	Rail	61.00	36.52	-24.48
	Aircraft		39.40	+39.40
Paterson	Auto	48.78	32.25	-16.55
	Bus	51.21	33.86	-17.35
	Rail			
	Aircraft		33.86	+33.86
Linden/Rahway	Auto	30.73	22.75	-7.98
	Bus	25.83	19.12	-6.71
	Rail	43.39	32.12	-11.27
	Aircraft		26.00	+26.00
Farmingdale	Auto	35.00	22.57	-12.43
	Bus			
	Rail	65.00	31.82	-33.18
	Aircraft		45.59	+45.59
Mt. Vernon	Auto	29.00	18.65	-10.35
	Bus			
	Rail	69.00	44.39	-24.61
	Aircraft		36.93	+36.93
White Plains	Auto	28.00	19.64	-8.36
	Bus			
	Rail	71.00	41.83	-29.17
	Aircraft		38.49	+38.49

APPENDIX B

AUTOMOBILE, BUS, AND RAILROAD PASSENGERS PREFERRING AIRCRAFT TRAVEL

Satellite City	Mode	Actual Split (%)	Projected S Split With Aircraft Service (%)	% Commuters Preferring Aircraft Service
New Brunswick	Auto	33.20	19.84	-13.36
	Bus	34.40	25.79	-8.61
	Rail	32.40	27.97	-4.43
	Aircraft		26.39	+26.39
Bridgeport	Auto	46.09	27.77	-18.32
	Bus			
	Rail	53.91	32.77	-21.14
	Aircraft		39.43	+39.43
New Haven	Auto	36.40	24.29	-12.11
	Bus	26.38	17.60	-8.78
	Rail	37.20	24.82	-12.38
	Aircraft		33.26	+33.26
Stamford	Auto	43.10	29.49	-13.61
	Bus			
	Rail	56.89	38.93	-17.96
	Aircraft		31.55	+31.55

APPENDIX B

REDUCTION IN AUTOMOBILE TRAVEL WITH THE INTRODUCTION OF AIRCRAFT TRAVEL

Satellite City	Total Commuters	% Automobile Passengers Change. Aircraft Service	Decrease in Number of Automobile Passengers Travelling to Manhattan	7am-9am Auto Occupancy	Decrease in Number of Automobiles Travelling to Manhattan
Newark	8,632	-3.71	320	1.00	320
Hempstead	32,167	-14.97	4,815	1.25	3,852
Paterson	17,931	-16.55	2,987	2.04	1,454
Linden/Rahway	3,892	-7.98	311	1.33	234
Farmingdale	13,335	-12.43	1,658	1.25	1,326
Mt. Vernon	18,394	-10.35	1,904	1.15	1,656
White Plains	14,847	-8.36	1,241	1.15	1,079
New Brunswick	1,876	-13.36	251	1.00	251
Bridgeport	1,179	-18.32	216	1.25	173
New Haven	171	-12.11	21	1.29	16
Stamford	4,934	-13.61	672	1.25	538
Total			14,376		10,899

Step 4 compares the total tonnages of carbon monoxide, hydrocarbons, particulates and nitrogen oxides produced by 53 passenger aircraft and automobiles each transporting 14,298 passengers. These commuters represent the automobile riders who would change to air transportation. To transport 14,298 people requires 10,861 automobiles which travel a total distance of 268,503 miles.

A total of 536 aircraft flights travelling 623,333 passenger air miles would be required in transporting the same total of 14,298 passengers.

Total pollution created by 14,298 passengers travelling by automobile is determined by multiplying the 268,503 automobile vehicle miles by the 1970 engine emission values per vehicle mile for carbon monoxide, nitrogen oxides, hydrocarbons and particulates. The daily pollution generated by automobile travel equals 66.86 tons.

The total pollution created by 14,298 passengers travelling by aircraft is determined by multiplying the 623,333 passenger air miles by the aircraft engine emission value per air mile for carbon monoxide, nitrogen oxides, hydrocarbons and particulates. This aircraft travel produces 1.67 tons per day.

APPENDIX B

VEHICLE MILES OF 14,298 PASSENGERS TRAVELING FROM SATELLITE CITIES TO MANHATTAN 10,899 AUTOMOBILES

Satellite City	Number of Automobiles	Ground Mileage	Total Automobile Mileage
Newark	320	12	3,840
Hempstead	3,852	24	92,448
Paterson	1,454	20	29,080
Linden/Rahway	234	21	4,914
Farmindale	1,326	32	42,432
Mt. Vernon	1,656	17	28,152
White Plains	1,079	26	28,054
New Brunswick	251	38	9,538
Bridgeport	173	55	9,515
New Haven	16	76	1,216
Stamford	538	36	19,368
TOTAL	10,899		268,557

APPENDIX B

AIRCRAFT TRIPS REQUIRED IN SERVING 14,398 PASSENGERS FROM SATELLITE CITIES TO MANHATTAN

Satellite City	Number of Passengers	Total Passenger Capacity of One Aircraft [1] (7 am-9 am)	Trips per Aircraft [2] (7 am-9 am)	Total Aircraft Required	Total Trips Required
Newark	320	265	10	1	10
Hempstead	4,815	212	8	23	184
Paterson	2,967	265	10	11	110
Linden/Rahway	311	212	8	2	16
Farmingdale	1,658	212	8	8	64
Mt. Vernon	1,904	265	10	7	70
White Plains	1,241	212	8	6	48
New Brunswick	251	212	7	1	7
Bridgeport	216	159	6	1	6
New Haven	21	---	--	--	---
Stamford	672	212	7	3	21
TOTAL	14,376				536

1. The aircraft employed has a 53 passenger seating capacity.

2. This includes the trips to Manhattan from the satellite cities at a 100% load factor and the trips from Manhattan to the satellite cities carrying a 100% load factor. Thus 10 trips for one aircraft between 7 A.M. - 9 A.M. is equal to 5 round trip flights between Manhattan and a satellite city. Only five of these flights carry passengers to Manhattan. The same total of 14,376 can be carried from Manhattan during the 7 A.M. - 9 A.M. period.

APPENDIX B

AIRCRAFT PASSENGER MILES OF 14,298 PASSENGERS TRAVELLING FROM SATELLITE CITIES TO MANHATTAN

Satellite City	Total Trips Required	x	Air Miles	x	Passengers	=	Aircraft Passenger Miles
Newark	10		11		53		5,830
Hempstead	184		20		53		195,040
Paterson	110		14		53		81,620
Linden/Rahway	16		19		53		16,112
Farmingdale	64		26		53		88,192
Mt. Vernon	70		30		53		111,300
White Plains	48		13		53		33,072
New Brunswick	7		20		53		7,420
Bridgeport	6		32		53		10,176
New Haven	--		--		--		---
Stamford	21		67		53		74,571
Total							623,333

APPENDIX B

TOTAL POLLUTION OF 11,298 PASSENGERS TRAVELLING FROM SATELLITE CITIES TO MANHATTAN BETWEEN 7AM – 9AM

1970 Automobile Travel

	Passenger Miles	x gm Passenger Mile	Total Pollution
Carbon Monoxide	268,557 (1.24) = 333,010	72.35	24,093,273 gm. 52,720 lb.
Hydrocarbons and Particulates	268,557 (1.24) = 333,010	12.57	4,185,935 gm. 9,159 lb.
Nitrogen Oxides	268,557 (1.24) = 333,010	6.84	2,277,788 gm. 4,984 lb.

Aircraft Travel

	Passenger Miles	x gm /Passenger Mile =	Total Pollution
Carbon Monoxide	623,333	1.4717	917,359 gm. 2,007 lb.
Hydrocarbons and Particulates	623,333	1.3803	860,387 gm. 1,883 lb.
Nitrogen Oxides	623,333	.8151	508,079 gm. 1,112 lb.

APPENDIX B

DAILY POLLUTION OF 14,298 PASSENGERS TRAVELLING BETWEEN SATELLITE CITIES AND MANHATTAN (7AM-9AM, 4:30PM-6:30PM)

Mode	Carbon Monoxide	Hydrocarbons & Particulates	Nitrogen Oxides	Total Pollution
	Tons of Pollution			
1970 Automobile Travel	52.72	9.16	4.98	66.86
Aircraft Travel	2.01	1.88	1.11	5.00

APPENDIX C

AREA-SOURCE MODEL:

Concentrations can be estimated at a downwind receptor by employing an area-source model for both the circular and oblong aquadromes, and for the highway segment. Emissions from either aquadrome or roadway areas are considered to constitute a surface of randomly distributed multiple sources. This surface is assumed to be a uniform area source with respect to a receptor located a variable distance downwind from the edge of the aquadrome or highway segment. The prevailing wind is orientated along one side of the area under investigation.

Each infinitesimal strip of the area normal to the wind direction is an effective line source. The integration of the concentrations found in all such strips, from the windward to the down wind edge, establishes a relationship for the concentration from the area source that will be found at the downwind receptor.

From Slade, the line source formula is given as:

$$X = \left(\frac{2}{\pi}\right)^{1/2} \frac{Q_L}{\sigma_z\ U} \quad \exp.\left(-\frac{h^2}{2\sigma_z{}^2}\right)$$

Where X is the concentration (grams / meter^3), σ_z is the vertical deviation of the plume (meters), U is the wind speed (meters / second), h is thestack height, and Q_L is the rate of mass emissions per unit length (grams/meter/second).

For ground level emissions:

$$\exp.\left(-\frac{h^2}{2\ \sigma_z{}^2}\right) = 1$$

The equation can be rewritten as:

$$X = \left(\frac{2}{\pi}\right)^{1/2} \frac{Q\,L}{\sigma_z\ U}$$

Because another dimension besides length is involved in area calculations, this dimension (width = S) must be introduced into the equation. This is done by considering infinitesimal strips of width dS. Thus, the relationship of each infinitesimal strip to the concentrations is written as:

$$dX\ (S) = -\frac{2}{\sqrt{2\pi}} \ \frac{Q}{U} \ \frac{dS}{\sigma_z}$$

The integral for a receptor a distance (T) from the downwind edge becomes:

$$X = \frac{2}{\sqrt{2\pi}} \ \frac{Q_a}{U} \int_{T}^{T+L} \frac{d\,S}{\sigma_z}$$

Where X is the concentration, Q_a is the strength of the area source (rate of mass emissions per unit area), U is the wind speed, S is the distance of the receptor from any infinitesimal strip source, σ_z is the standard deviation of the plume along the vertical, L is the along-wind dimension of the area considered, and T is the distance of the receptor from the downwind edge.

To evaluate the integral, it is useful to note that σ_z can be expressed as a function of travel distance from any infinitesimal strip to the receptor (S).

For a stable condition of neutral stability:

$$\sigma_z = .12\ S^{3/4}$$

Inserting this value of σ_z into the integral leaves:

$$X = \frac{2}{\sqrt{2\pi}} \ \frac{Q_a}{U} \int_{T}^{T+L} \frac{dS}{.12\ S^{3/4}}$$

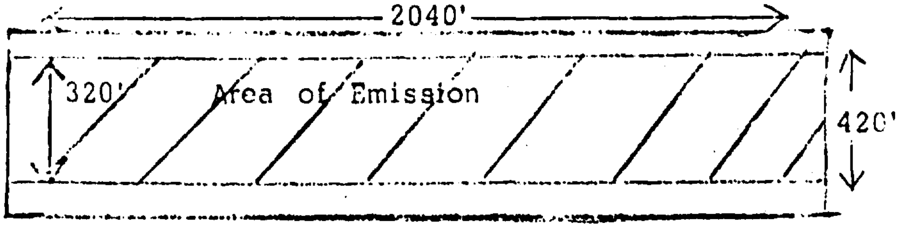
Integrating further yields:

$$X = \frac{8}{\sqrt{2\pi}} \ \frac{Q_a}{.12\ U} \left[(T + L)^{1/4} - L^{1/4} \right]$$

REFERENCE: Northern Research and Engineering Corporation; Nature and Control of Aircraft Engine Exhaust Emissions (Washington, D.C.: National Air Pollution Control Administration, U.S. Dept., of Health, Education and Welfare, 1968), p. 142.

OBLONG SHAPED
ATMOSPHERIC DISPERSION ESTIMATES FROM AQUADROME FLIGHT DECK
AREA CONSIDERING 6 AIRCRAFT ON THE DECK SIMULTANEOUSLY

AREA-SOURCE:
2000' AQUADROME



CONVERSIONS:

320' = 97.5 m   2040' = 622 m

AREA = 60,645 m^2

FORMULA:

$$X = \frac{8}{\sqrt{2\pi}} \quad \frac{Q}{.12u} \quad \left[(T + L)^{\frac{1}{4}} - T^{\frac{1}{4}} \right]$$

X = Concentration (Grams/m^3)
Q = Source Strength (Grams/m^2/sec)

u = Wind Velocity (2.5 m/sec.)
L = 97.5 m
T = Distance of the aquadrome from the receptor (100 meters)

CALCULATIONS:

Q:

Over 1 Hour (3600 sec.), there are 101,337 grams of CO emitted from the aircraft.

Q = 101,337 grams/60,645 m^2/3600 sec.
Q = .000464 gm/m^2/sec.

$$X = 2.51 \frac{(.000464)}{(.12)(2.5)} \left[(100 + 97.5)^{\frac{1}{4}} - (100)^{\frac{1}{4}} \right]$$

$$X = \frac{.001165}{.30} \left[(100 + 97.5)^{\frac{1}{4}} - (100)^{\frac{1}{4}} \right]$$

$197.5^{\frac{1}{4}} = x$

$\log x = \frac{1}{4} \log 197.5 = \frac{1}{4} (2.29557)$

$\log x = .57389$ or $x = 3.749$

$100^{\frac{1}{4}} = y$

$\log y = \frac{1}{4} \log 100 = \frac{1}{4} (2.00000)$

$\log y = .50000$ or $y = 3.162$

$x - y = .587$

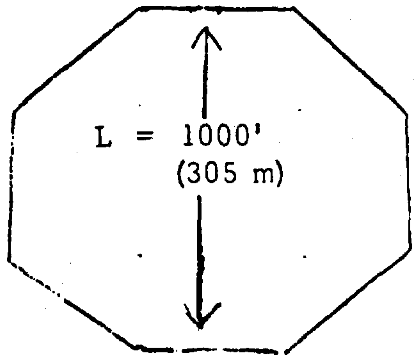
$$X = \frac{.001165\ (.587)}{.30} = \frac{.000684}{.30} = .0023$$

$X = .0023$ gm $/m^3$

$$\frac{.0023}{44.6} = .00005 \text{ gm /vol. 22.4 liters}$$

$$\frac{.00005}{28} = .00000179 = 1.79 \text{ ppm}$$

AREA-SOURCE:
CIRCULAR AQUADROME



AREA = $76,641\ m^2$

FORMULA:

$$X = \frac{8}{\sqrt{2\pi}} \frac{Q}{.12u} \left[(T + L)^{\frac{1}{4}} - T^{\frac{1}{4}} \right]$$

X = Concentration (grams/m^3)
Q = Source Strength (grams/m^2/sec.)

u = Wind Velocity (2.5 m /sec.)
L = 305 m
T = Distance of the aquadrome from the receptor (100 Meters)

CALCULATIONS:

Q:
over 1 hour (3600 sec.), there are 35,615 grams of CO emitted from the aircraft.
Q = 35,615 grams/76,641 m^2/3600 sec.
Q = .000129 gm /m^2/sec.

$$X = \frac{2.51\ (.000129\ )}{(.12)\ (2.5)} \left[(100 + 305)^{\frac{1}{4}} - 100^{\frac{1}{4}} \right]$$

$$X = \frac{.000324}{.30} \left[(405)^{\frac{1}{4}} - 100^{\frac{1}{4}} \right]$$

$405^{\frac{1}{4}} = x$

$\log x = \frac{1}{4} \log 405 = \frac{1}{4}(2.60746\ )$

$\log x = .65187$ or $x = 4.486$

$100^{\frac{1}{4}} = y \qquad y = 3.162$

$x - y = 1.324$

$$X = \frac{.000324}{.30}(1.324) = \frac{.000429 \text{ Grams/ } m^2}{.30 \text{ m}}$$

$X = .00143 \text{ gm/ } m^3$

$$\frac{.00143}{44.6} = .0000321 \text{ /vol. } 22.4 \text{ liter}$$

44.6 (num. grams vol. 22.4 liters at STP)

$$\frac{.0000321}{28} = .00000115 = 1.2 \text{ ppm}$$

Engine Emission Rates Used on Flight Deck Area :

Aircraft Operation	Engine Emission Rate
Landing Ground Roll	Take-off
Taxi	Idle
Open Door	Idle
Close Door	Idle
Take-off Ground Run	Take-off

Fuel Consumption Rates - JT8D

Idle 920 lbs. per hour per engine

Take-off 7765 lbs. per hour per engine

Carbon Monoxide Emissions - One JT8D

Idle .0499 Lbs. CO/Lb. Fuel

Take-off .00123 Lbs. CO/Lb. Fuel

APPENDIX D

Atmospheric Dispersion Estimates During Takeoff and Landing Maneuvers

The following assumptions are made in conducting a study of the maximum atmospheric dispersion estimates that would occur during takeoff and landing aboard a Rutgers Aquadrome:

1. Variables arising from in-flight aircraft exhaust emissions, such as heat content, atmospheric turbulence and pollutant momentum, enhance the mixing of the pollutants with the ambient air.

2. Concentrations arrived at without considering the above variables at a distance of 100 meters must be greater than the actual concentrations that would exist at 100 meters.

3. The emission of pollutants from the aircraft is carried out such that the plume can, for small segments, be considered an effective line source, where lateral movement of pollutants in one small segment is compensated for by the lateral movement of pollutants in another small segment. In this manner, uniformity of concentrations is preserved and the lateral deviation of pollutants (σ_y) is effectively 0.

By making these assumptions, it is possible to apply the quasi-instantaneous line source model to calculate the concentration of pollutants at distances from aircraft in flight. The formula* for this model is:

$$X = \frac{Q_L}{\pi \sigma_x \sigma_z} \exp\left\{-\left[\frac{(x-ut)^2}{2\sigma_x^2} + \frac{h^2}{2\sigma_z^2}\right]\right\}$$

where: X = Concentration (gm/m^3)
Q_L = Source strength (gm/m)
σ_x = Standard deviation of the downwind direction of a plume concentration distribution (4m at 100m distance from source)
σ_z = The standard deviation in the vertical of the plume concentration distribution (3.8m at 100m distance from source)

The next step was to consider the exponent:

$$\exp\left\{-\left[\frac{(x-ut)^2}{2\sigma_x^2} + \frac{h^2}{2\sigma_z^2}\right]\right\}$$

*Slade, D.H., Estimates of dispersion from pollutant releases of a few seconds to 8 hours in duration, Tech. note 39-ARL-3, April, 1966

In order to avoid complications arising from the emission time rate (t) and the calculation of effective stack height (h), an assumption is made that effectively maximizes the concentrations by considering the exponent to achieve the maximum value, or:

$$\exp - \left[\frac{(x-ut)^2}{2\,\sigma_x^{\,2}} + \frac{h^2}{2\,\sigma_z^{\,2}} \right] = 1$$

thus:

$$X = \frac{Q_L}{\pi \sigma_x \, \sigma_z} \quad (1)$$

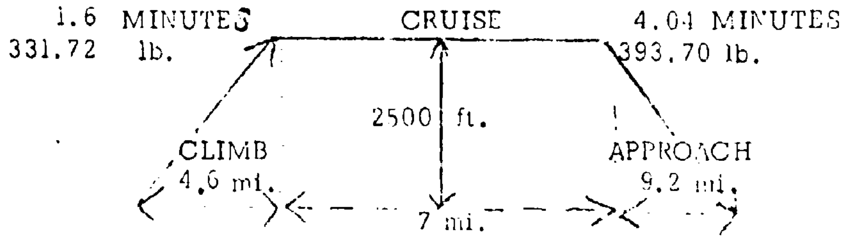
: calculated value for a maximum of concentrations.

The following values are used in determining emission estimates during take-off and landing maneuvers:

Fuel Consumption Rates During Take-off and Approach for the JT8D

Take-off	7765 lbs. per hour per engine
Approach	2925 lbs. per hour per engine
Cruise	5000 lbs. per hour per engine

BUFFALO [ISA + 15° C]



POLLUTANT EMISSION RATES

CLIMB 2 JT 8D Engines	APPROACH 2 JT 8D Engines
1 LB. FUEL =.00123 LB. CO	1 LB. FUEL =.006558 LB. CO

HEIGHT CALCULATION AT 1000':

CLIMB:

$\angle \theta = \angle$ of ascent

$\text{Tan}\,\theta = \frac{2500}{24,288} = .10293$

$\theta = 5^\circ\ 53'$ $.10293 = \frac{X}{1000}$ where X is the height.

X = 102.9' or 31.4 meters

APPROACH:

$\angle \theta = \angle$ of descent

$\text{Tan}\,\theta = \frac{2500}{48,576} = .05146$

$\theta = 2^\circ\ 57'$

X = 51.5' or 15.7 meters $.05146 = \frac{X}{1000}$ where X is the height.

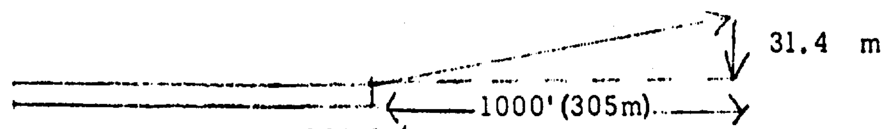
CLIMB: INSTANTANEOUS RELEASE MODEL:

Continuous acceleration yields a value of:

A (acceleration) = 2.7 ft/sec^2

$V_i \approx 135$ ft/sec.
$V_F \approx 295$ ft/sec.

FOR 1000' SEGMENT:



$V_{av} = V_i + V_F = \frac{135 \text{ ft/sec.} + V_F}{2}$

$V_F = AT$

$V_F - V_i = \Delta V = 295 - 135 = 160$ ft/sec.

$24.288 \overline{)160 \text{ ft/sec.}} = 6.6$ ft/sec. over 1000 feet.

$V_{av} = \frac{135 + 141.6}{2} = \frac{276.6}{2} = 138.3$

$V_{av} = 138.3$ ft/sec

$D = ST = (138.3 \text{ ft/sec.})\ T$

$\frac{1000 \text{ ft}}{138.3 \text{ ft/sec.}} = T = 7.23$ sec

$\frac{7.23 \text{ sec. (1000' Climb)}}{96 \text{ sec. (Total Climb)}} = .075$

.075 (331.72 lbs) = 24.88 lbs. Fuel consumed in 1000' Ft.

$\frac{24.88 \text{ lbs } (.00123)\ 457 \text{ gm/lb}}{305 \text{ m}}$ (Rate of Mass Emissions per unit length)

$\frac{13.9842}{305 \text{ m}} = .04585$ gm/m

SIMPLIFY PLUME TO BECOME AN APPLICATION OF INSTANTANEOUS INFINITE, CROSS WIND LINE SOURCE:

$$X = \frac{Q_L}{\pi \sigma_x \sigma_z} \exp \left\{ - \left[\frac{(x-\bar{u}t)^2}{2\sigma_x^2} + \frac{h^2}{2\sigma_z^2} \right] \right\}$$

MAXIMIZE EXPONENT:

$$\exp \left\{ - \left[\frac{(x-\bar{u}t)^2}{2\sigma_x^2} + \frac{h^2}{2\sigma_z^2} \right] \right\} = 1$$

THUS:

$$X \max = \frac{Q_L}{\pi \sigma_x \sigma_z}$$

where variables:

σ_x = 4 m (Slade - neutral stability)
σ_z = 3.8 m (Slade - neutral stability)
Q_L = .04585 gm/m

$$X \max = \frac{.04585}{(3.14)(4)(3.8)} = \frac{.04585}{47.73} \frac{GM/m}{m^2}$$

$$\frac{.04585}{47.73} = .00096$$

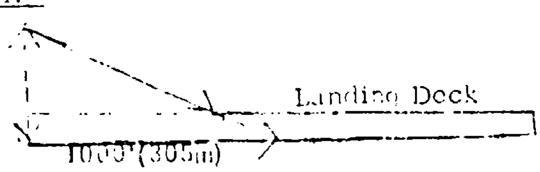
X max = .00096 gm/m^3

$$\text{ppm (CO) max} = \frac{.00096}{44.6 \text{ (num. of 22.4 liter vol.)}} = .0000215 \ \frac{\text{Grams CO}}{\text{Vol. 22.4 liter}}$$

$$\text{ppm (CO) max} = \frac{.0000215}{28 \text{ (num G in vol. 22.4 liters at STP)}} = .000000768$$

ppm (CO) max = .77 ppm
at 100 meters

APPROACH:



APPROACH VELOCITY IN THE LAST 1000' SHOULD BE EQUIVALENT TO 1.3 V_S, WHERE V_S IS THE VELOCITY AT LIFT-OFF.

V_s = 135 ft./sec (D-3)
(135 ft./sec.) 1.3 = Approach Velocity
175.5 ft./sec = Approach Velocity

$$\frac{1000 \text{ ft.}}{175.5 \text{ ft./sec}} = T$$

$$5.70 \text{ sec.} = T$$

$$\frac{5.70 \text{ sec.}}{242.4 \text{ sec.}} = .0235$$

(393.70 lbs. fuel) (.0235) = 9.252 lbs. fuel used in last 1000'

$$\frac{9.252 \text{ lbs. } (.006658)\ 457\text{gm/lb.}}{305 \text{ meters}} = .0923\text{gm/meter}$$

USING ASSUMPTIONS OF CLIMB, HAVE:

$$X \text{ max.} = \frac{Q_L}{\pi \cdot \sigma_x \ \sigma_z}$$

where variables:

σ_x = 4 m (Slade- neutral stability)
σ_z = 3.8 m (Slade- neutral stability)
Q_L = .0923 gm/m

$$X \text{ max.} = \frac{.0923}{(3.14)\ (4)\ (3.8)} = \frac{.0923}{47.73}$$

$$\frac{.0923}{47.73} = .00193$$

X max = .00193 gm/m^3

$$\text{ppm (CO) max} = \frac{.00193}{44.6 \text{ (num. 22.4 liter vol. 1 m}^3)} = .0000433 \ \frac{\text{Grams CO}}{\text{Vol. 22.4 liters}}$$

$$\text{ppm (C O) max} = \frac{.0000433}{28 \text{ (num. grams vol. 22.4 liter at STP)}} = .00000155$$

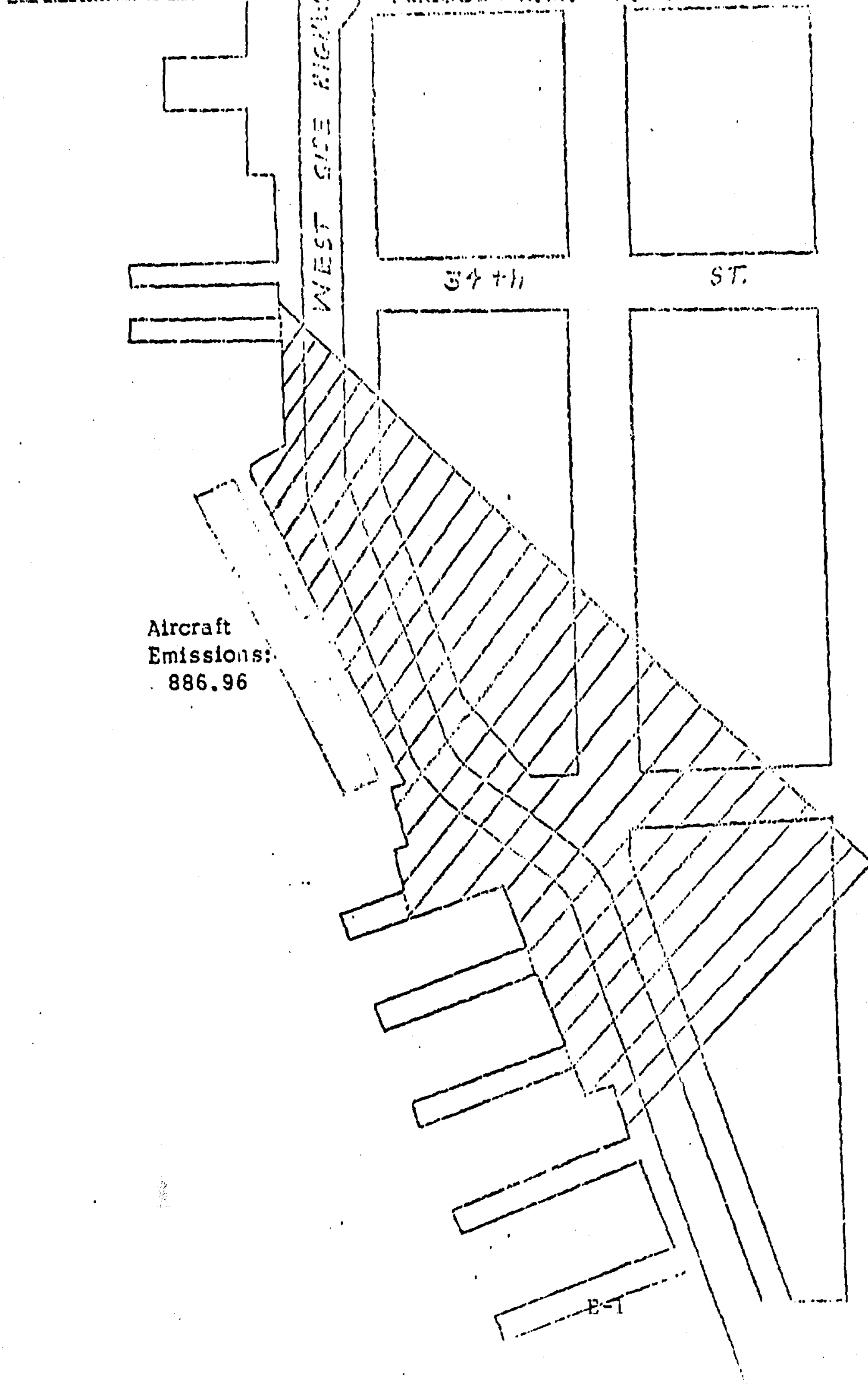
ppm (CO) max = 1.55 ppm
at 100 meters

CONSIDERING 1 ENGINE, HAVE 1/2 Q FOR CALCULATIONS, THUS:

Climb = .38 ppm
Approach = .77 ppm

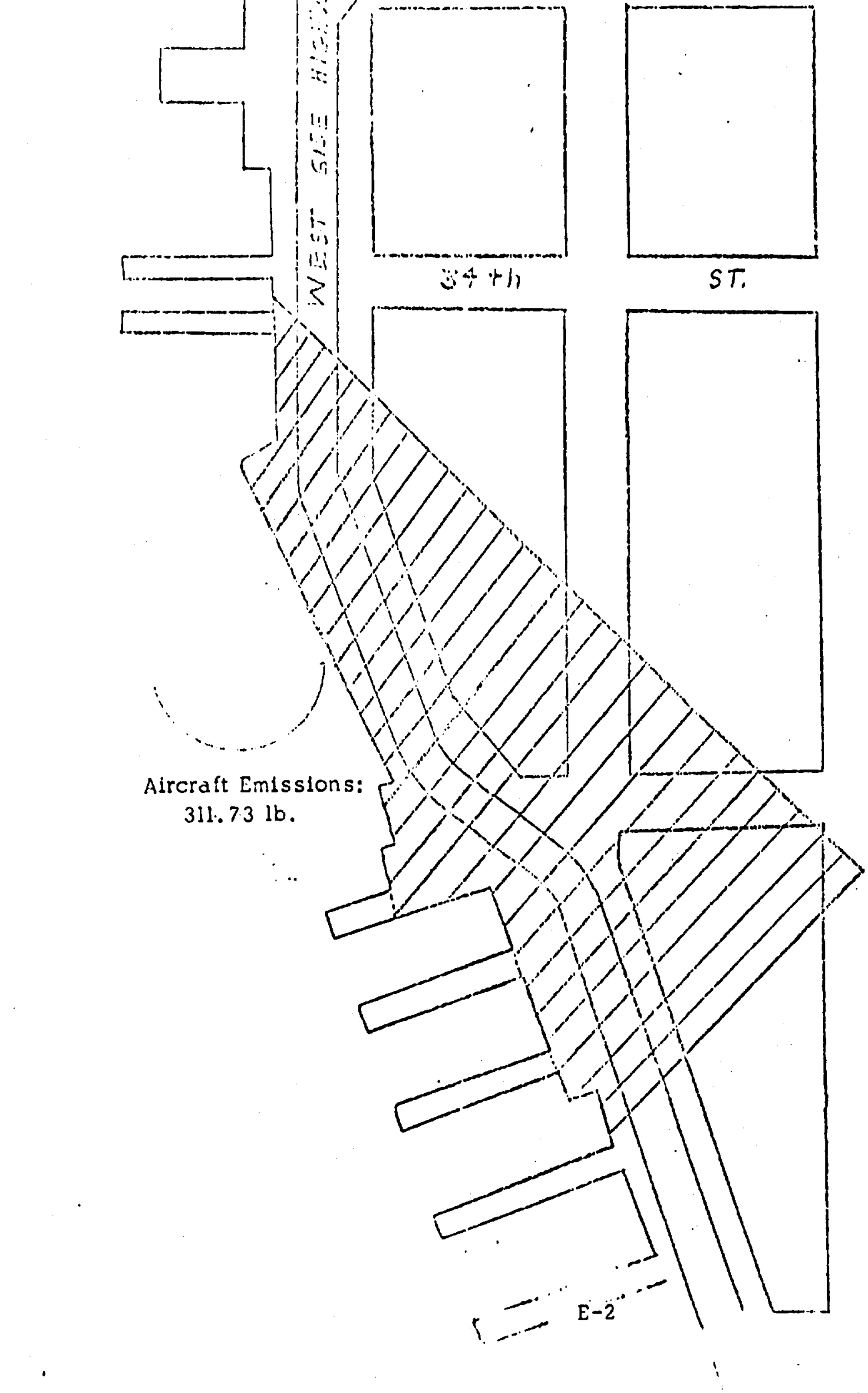
Calculations have been made considering combined emission from <u>two</u> JT-8D aircraft engines. Each engine in flight, under the three previously stated assumptions, will create two separate emission trails. The emission trails are considered to initially have a height and width of 0 ($\sigma_z = 0$; $\sigma_x = 0$) under the assumption that each trail is a quasi-instantaneous line source, where σ_z and σ_x must be equal to 0. σ_z and σ_x values after engine emission can be derived over time or distance. In this case it was possible to consider the spread of pollutants to be achieved over distance, as Slade has derived experimental values for σ_z and σ_x over a distance of 100 meters. From these experimental values, and given an actual horizontal separation distance between the JT - 8D engines of 20 meters, it becomes evident that the two emission trails of pollutants will not spread enough so that the two separate trails will mix. Each trail will undergo a horizontal spread (σ_x) of 4 meters over the 100 meter distance, so the two trails will still be separated from one another by more than 12 meters. For this reason, concentrations derived for an emission rate (Q) that combines emissions for both engines must be reduced by a factor of 1/2.

APPENDIX E - CARBON MONOXIDE EMISSIONS DURING PERIODS 7 A.M.-9 A.M. and 4 P.M.-6 P.M.



*U.S. Dept. of Health, Education & Welfare, Nat'l Center for Air Pollution Control, N.Y.-N.J. Air Pollution Abatement Activity Sulfur Compounds & Carbon Monoxide (1967) p. 143.

APPENDIX E - CARBON MONOXIDE EMISSIONS DURING PERIODS 7 A.M.-9A.M. and 4 P.M.-6 P.M.



Total Emissions
16,800 lb. *

*U.S. Dept. of Health, Education & Welfare, Nat'l Center for Air Pollution Control, N.Y.-N.J. <u>Air Pollution Abatement Activity Sulfur Compounds & Carbon Monoxide</u> (1967) p. 143.

APPENDIX E

Calculation of Emission rates for the oblong shaped Aquadrome, circular shaped Aquadrome and from an adjacent area of .2 square miles is as follows:

Step 1. Percentage of automobiles traveling to Manhattan between

7 A.M. - 9 A.M. and 4 P.M. - 6 P.M.*

7 A.M.	4%	
8 A.M.	8%	
9 A.M.	6%	
	18% ÷ 3	= 6% per hour between 7 A.M. - 9 A.M.
4 P.M.	8%	
5 P.M.	8%	
6 P.M.	8%	
	24% ÷ 3	= 8% per hour between 4 P.M. - 6 P.M.

Total peak hour automobile traffic is--

A.M.	6% x 2	= 12%
P.M.	8% x 2	= 16%
		28%

Step 2. Total emissions over the .2 square mile area between

7 A.M. - 9 A.M. and 4 P.M. - 6 P.M.

60,000 pounds x .28 = 16,800 pounds of carbon monoxide

Step 3. Calculate emission rates (Q) = grams/square meter/second

.2 Square Mile Area

Grams of Carbon Monoxide is--

16,800 pounds x 457 = 7,677,600 gm.

----

*Source: Tri-State Transportation Commission, Travel Time Comparisons to Manhattan Central Business District, Interim Technical Report 4175-5250, March, 1970, p. 2.

$$\text{Area} = 1560 \times 1560 \times .2$$
$$= 486{,}720 \text{ m}^2$$

$$\text{Seconds} = 60 \times 60 \times 4 = 14{,}400$$

$$Q = \frac{7{,}677{,}600 \text{ gm.}}{486{,}720 \text{ m}^2/14{,}400 \text{ sec.}}$$

$$Q = .0011 \text{ gm/m}^2\text{/sec}$$

<u>Oblong Shaped Aquadrome</u>

Grams of Carbon Monoxide are--

$$886.98 \text{ lb} \times 457 = 405{,}350\text{gm.}$$

$$\text{Area} = 622 \times 97.5 = 60{,}645 \text{ m}^2$$

$$\text{Seconds} = 60 \times 60 \times 4 = 14{,}400$$

$$Q = \frac{405{,}350 \text{ gm.}}{60{,}645\text{m}^2/14{,}400 \text{ sec}}$$

$$Q = .000464\text{gm/m}^2\text{/sec.}$$

<u>Circular Shaped Aquadrome</u>

Grams of Carbon Monoxide are--

$$311.73 \text{ lb} \times 457 = 142{,}460\text{gms.}$$

$$\text{Area} = \pi (152)^2$$
$$= 76{,}641 \text{ m}^2$$

$$\text{Seconds} = 60 \times 60 \times 4 = 14{,}400$$

$$Q = \frac{142{,}460\text{gm}}{76{,}641 \text{ m}^2/14{,}400}$$

$$Q = .000129 \text{ gms./m}^2\text{/sec.}$$

Step 4. Ratio of Q rates for aquadrome and adjacent .2 square mile land area.

<u>Oblong Aquadrome</u>

$$\frac{\text{Q Land}}{\text{Q Oblong Aquadrome}} = \frac{.0011}{.000464} = 2.37$$

<u>Circular Aquadrome</u>

$$\frac{\text{Q Land}}{\text{Q Circular Aquadrome}} = \frac{.0011}{.000129} = 8.53$$

The land area thus emits carbon monoxide at a rate 2.37 times greater than the oblong shaped Aquadrome and 8.53 times greater than the circular shaped Aquadrome.

APPENDIX F

DAILY AIR POLLUTION --- NEWARK AIRPORT

	AUTOMOBILE TRAVEL			AIRCRAFT TRAVEL		
YEAR	CARBON MONOXIDE	PARTICULATES & HYDROCARBONS	NITROGEN OXIDES	CARBON MONOXIDE	PARTICULATES & HYDROCARBONS	NITROGEN OXIDES
1970	3,446 (1.72)	599 (.30)	326 (.16)	121 (.06)	117 (.06)	68 (.03)
1975	2,155 (1.08)	423 (.21)	373 (.19)	121 (.06)	117 (.06)	68 (.03)
1980	899 (.45)	156 (.08)	168 (.08)	121 (.06)	117 (.06)	68 (.03)

Figures are in pounds; figures in brackets are the same figures expressed in tons.

APPENDIX F

DAILY AIR POLLUTION -- LA GUARDIA AIRPORT

YEAR	AUTOMOBILE TRAVEL			AIRCRAFT TRAVEL		
	CARBON MONOXIDE	PARTICULATES & HYDROCARBONS	NITROGEN OXIDES	CARBON MONOXIDE	PARTICULATES & HYDROCARBONS	NITROGEN OXIDES
1970	4,495 (2.25)	781 (.39)	425 (.21)	176 (.09)	168 (.08)	97 (.05)
1975	2,811 (1.41)	552 (.28)	487 (.24)	176 (.09)	168 (.08)	97 (.05)
1980	1,172 (.59)	204 (.10)	219 (.11)	176 (.09)	168 (.08)	97 (.05)

Figures are expressed in lbs.; figures in brackets are the same figures expressed in tons.

APPENDIX F

DAILY AIR POLLUTION -- J. F. KENNEDY AIRPORT

YEAR	AUTOMOBILE TRAVEL			AIRCRAFT TRAVEL		
	CARBON MONOXIDE	PARTICULATES & HYDROCARBONS	NITROGEN OXIDES	CARBON MONOXIDE	PARTICULATES & HYDROCARBONS	NITROGEN OXIDES
1970	13,094 (6.55)	2,275 (1.14)	1,238 (.62)	540 (.27)	495 (.25)	286 (.14)
1975	8,188 (4.09)	1,609 (.80)	1,419 (.71)	540 (.27)	495 (.25)	286 (.14)
1980	3,415 (1.71)	594 (.30)	637 (.32)	540 (.27)	495 (.25)	286 (.14)

Numbers are in pounds, numbers in brackets are the same figures expressed in tons.

APPENDIX F

DAILY TOTAL AIR POLLUTION -- THREE METROPOLITAN AIRPORTS

	AUTOMOBILE TRAVEL				AIRCRAFT TRAVEL			
YEAR	CARBON MONOXIDE	HYDROCARBONS & PARTICULATES	NITROGEN OXIDES	TOTAL	CARBON MONOXIDE	HYDROCARBONS & PARTICULATES	NITROGEN OXIDE	TOTAL
1970	21,035 (10.52)	3,655 (1.86)	1,989 (.99)	26,679	837 (.42)	780 (.39)	451 (.23)	2068
1975	13,154 (6.58)	2,584 (1.29)	2,279 (1.14)	18,017	837 (.42)	780 (.39)	451 (.23)	2068
1980	5,486 (2.74)	954 (.48)	1,024 (.51)	7,464	837 (.42)	780 (.39)	451 (.23)	2058

Total Aircraft Vehicle Emissions: Approach, Cruise, Take-off at 50% Load Factor

	1. Newark Airport	2. LaGuardia Airport	3. J. F. Kennedy Airport
Hydrocarbons & Particulates	2.7748	2.8056	3.0930
Carbon Monoxide	2.8798	2.9478	3.3698
Nitrogen Oxides	1.6108	1.6282	1.7860
Total	7.2654	7.3816	8.2488

1. Average stage length of 10.14 air miles based upon Domestic Air Passenger Market.

2. Average stage length of 9.71 air miles based upon Domestic Air Passenger Market.

3. Average stage length of 17.01 air miles based upon Domestic Air Passenger Market.

APPENDIX G

HOURLY WIND DIRECTION AND VELOCITY DATA

The first section of Appendix G summarizes wind velocity vs. wind direction by hour for Newark Airport, Newark, New Jersey. This data was compiled by the U.S. Department of Commerce, Environmental Science Services Administration, Environmental Data Service, National Weather Records Center, Asheville, North Carolina.

Since wind velocity and direction are the major variables of the mathematical meteorological atmospheric dispersion models used in the study, this data was essential in determining the physiological effects of carbon monoxide.

Hourly-These hourly occurrences can be used to determine carbon monoxide concentrations (ppm) and the resulting physiological effects on humans (% COHb) during 10 separate hours of the day.

Morning and Afternoon Periods-Comparisons of the physiological effects of carbon monoxide between morning hours and afternoon hours can be made from the hourly tabulations. Generally, the larger number of low wind conditions occur in the morning hours.

Month by Month-Monthly variations in carbon monoxide dosages can also be ascertained. For example, on the average, the largest number of low wind conditions occur during the summer months.

APPENDIX G, cont'd.

One month-Examination of the wind patterns for the month of August at 6:00 A.M. shows 300 occurrences of all wind directions and velocities. Of this total 72 occurrences were between 0-3 mph; 145 occurrences were between 4-7 mph; and 43 occurrences were at 8 mph or more than 8 mph. Likewise, it is possible to determine wind directions of the above occurrences at the various wind velocities.

This wind direction and velocity data collected over a 10 year period (1956-1965) provides sufficient information from which it is possible to forecast air pollution levels in the future.

APPENDIX G

6 A.M. - EASTERN STANDARD TIME

	January A - B - C	February A - B - C	March A - B - C	April A - B - C	May A - B - C	June A - B - C
N	3 - 4 - 21	4 - 3 - 8	0 - 6 - 12	2 - 4 - 7	2 - 5 - 7	2 - 5 - 11
NNE	0 - 7 - 24	0 - 9 - 22	1 - 7 - 23	0 - 5 - 25	3 - 10-36	3 - 11 - 22
NE	4 - 4 - 14	2 - 4 - 22	1 - 6 - 26	2 - 8 - 22	1 - 14-20	3 - 7 - 11
ENE	3 - 4 - 4	0 - 3 - 5	0 - 3 - 13	2 - 2 - 10	2 - 3 - 5	1 - 4 - 4
E	2 - 1 - 1	3 - 2 - 3	2 - 4 - 8	2 - 5 - 7	1 - 2 - 4	6 - 3 - 3
ESE	1 - 1 - 0	0 - 0 - 3	1 - 0 - 4	0 - 4 - 5	1 - 4 - 5	0 - 4 - 1
SE	0 - 0 - 1	1 - 1 - 0	0 - 2 - 0	0 - 2 - 1	0 - 0 - 2	0 - 1 - 0
SSE	1 - 1 - 1	3 - 0 - 2	1 - 0 - 0	1 - 3 - 1	1 - 2 - 3	2 - 0 - 1
S	1 - 2 - 2	2 - 0 - 0	3 - 1 - 1	3 - 4 - 1	7 - 5 - 1	4 - 6 - 3
SSW	3 - 8 - 10	2 - 7 - 6	3 - 10-6	3 - 15-9	3 - 14-14	9 - 20 - 14
SW	5 - 24-8	6 - 13-11	3 - 16-8	7 - 11-13	14 - 27-14	17 - 39 - 16
WSW	1 - 11-13	1 - 11-12	1 - 11-8	2 - 8 - 5	2 - 14-8	1 - 9 - 5
W	3 - 9 - 19	0 - 5 - 19	2 - 4 - 10	3 - 6 - 11	1 - 5 - 13	0 - 5 - 6
WNW	0 - 2 - 37	0 - 3 - 32	1 - 4 - 32	0 - 4 - 19	5 - 5 - 6	1 - 5 - 10
NW	0 - 7 - 27	0 - 0 - 29	1 - 5 - 27	0 - 9 - 26	1 - 4 - 7	1 - 3 - 6
NNW	1 - 1 - 16	1 - 4 - 14	0 - 4 - 28	3 - 2 - 12	1 - 0 - 11	2 - 3 - 5
Calm	2	5	1	4	5	5
Total	30 - 83-197	30 - 65-188	21 - 83-206	34 - 92-174	50 -114-146	57 -125 - 118

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G

6 A.M. - EASTERN STANDARD TIME

	July A - B - C	August A - B - C	September A - B - C	October A - B - C	November A - B - C	December A - B - C
N	1 - 9 - 11	6 - 14 - 7	3 - 7 - 19	1 - 8 - 10	2 - 8 - 5	0 - 4 - 11
NNE	3 - 12 - 16	5 - 15 - 21	3 - 15 - 33	1 - 17 - 37	2 - 8 - 22	1 - 6 - 29
NE	4 - 7 - 8	3 - 9 - 10	5 - 7 - 16	4 - 5 - 13	2 - 9 - 10	3 - 9 - 14
ENE	0 - 7 - 1	2 - 0 - 2	2 - 4 - 4	3 - 0 - 6	3 - 1 - 3	2 - 3 - 4
E	2 - 1 - 7	3 - 3 - 0	2 - 2 - 2	1 - 0 - 2	1 - 2 - 1	0 - 2 - 1
ESE	3 - 2 - 0	0 - 1 - 0	0 - 2 - 0	0 - 0 - 0	1 - 2 - 4	0 - 2 - 1
SE	0 - 1 - 0	0 - 1 - 1	0 - 0 - 0	0 - 0 - 2	0 - 0 - 2	2 - 0 - 0
SSE	1 - 0 - 3	1 - 5 - 4	0 - 1 - 0	0 - 1 - 3	1 - 3 - 2	0 - 0 - 1
S	7 - 1 - 3	2 - 7 - 8	2 - 9 - 3	3 - 2 - 1	1 - 6 - 6	1 - 3 - 1
SSW	7 - 17 - 13	5 - 21 - 12	4 - 27 - 10	4 - 15 - 11	4 - 16 - 7	7 - 16 - 4
SW	14 - 52 - 18	21 - 41 - 2	10 - 30 - 7	8 - 23 - 11	3 - 18 - 14	9 - 24 - 9
WSW	6 - 16 - 2	7 - 9 - 4	6 - 10 - 3	5 - 12 - 2	4 - 12 - 10	7 - 16 - 19
W	3 - 4 - 2	8 - 5 - 1	4 - 3 - 4	3 - 12 - 10	5 - 7 - 17	3 - 9 - 20
WNW	3 - 7 - 8	2 - 8 - 5	1 - 2 - 5	2 - 8 - 16	3 - 6 - 21	2 - 6 - 20
NW	1 - 4 - 7	1 - 5 - 5	3 - 0 - 6	2 - 6 - 17	0 - 2 - 20	0 - 6 - 18
NNW	1 - 3 - 7	0 - 6 - 6	2 - 5 - 12	2 - 6 - 10	3 - 2 - 15	2 - 4 - 6
Calm	5	6	5	5	4	3
Total	61 - 143 - 106	72 - 145 - 93	52 - 124 - 124	44 - 115 - 151	38 - 105 - 157	43 - 110 - 157

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G
7 A.M. - EASTERN STANDARD TIME

	January A - B - C	February A - B - C	March A - B - C	April A - B - C	May A - B - C	June A - B - C
N	0 - 6 - 14	0 - 5 - 12	0 - 2 - 16	1 - 3 - 9	1 - 5 - 5	2 - 4 - 12
NNE	2 - 9 - 27	1 - 7 - 23	1 - 4 - 24	2 - 4 - 28	2 - 9 - 31	1 - 15 - 31
NE	3 - 4 - 11	2 - 3 - 24	0 - 4 - 29	1 - 7 - 18	3 - 6 - 26	4 - 9 - 9
ENE	3 - 2 - 2	1 - 3 - 6	3 - 2 - 17	1 - 4 - 15	2 - 3 - 6	1 - 2 - 5
E	2 - 2 - 2	5 - 3 - 2	1 - 1 - 7	4 - 6 - 6	3 - 2 - 6	1 - 5 - 1
ESE	1 - 0 - 0	1 - 1 - 1	1 - 4 - 1	1 - 5 - 4	2 - 4 - 3	2 - 2 - 0
SE	0 - 0 - 1	0 - 0 - 2	1 - 1 - 1	0 - 2 - 0	0 - 3 - 0	0 - 1 - 1
SSE	2 - 2 - 1	0 - 1 - 2	0 - 3 - 0	2 - 0 - 3	2 - 3 - 2	6 - 3 - 1
S	1 - 2 - 2	2 - 2 - 0	2 - 2 - 1	4 - 3 - 4	4 - 4 - 1	5 - 6 - 1
SSW	0 - 7 - 13	2 - 7 - 6	1 - 7 - 5	4 - 7 - 12	5 - 12 - 17	6 - 15 - 17
SW	2 - 22 - 5	6 - 11 - 8	5 - 14 - 10	3 - 10 - 18	6 - 33 - 23	2 - 30 - 15
WSW	3 - 16 - 12	5 - 10 - 14	1 - 14 - 11	1 - 9 - 6	2 - 10 - 13	0 - 18 - 9
W	2 - 9 - 13	1 - 8 - 19	2 - 1 - 7	3 - 0 - 13	2 - 4 - 4	4 - 3 - 3
WNW	1 - 11 - 35	0 - 2 - 29	0 - 6 - 34	0 - 4 - 27	0 - 3 - 8	3 - 2 - 10
NW	0 - 8 - 20	0 - 2 - 24	0 - 3 - 33	1 - 1 - 22	1 - 0 - 13	4 - 1 - 8
NNW	0 - 3 - 25	0 - 4 - 13	0 - 2 - 26	0 - 1 - 16	0 - 2 - 13	1 6 - 6
Calm	2	3	0	5	1	7
Total	24-103-183	29 - 69 - 185	18-70-222	33 - 66-201	36-103-171	49 -122 -129

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at ≥ 8 mph.

APPENDIX G

7 A.M. - EASTERN STANDARD TIME

	July A - B - C	August A - B - C	September A - B - C	October A - B - C	November A - B - C	December A - B - C
N	0 - 1 - 12	2 - 5 - 4	2 - 7 - 19	1 - 6 - 8	1 - 3 - 11	2 - 4 - 11
NNE	1 - 1 - 17	6 - 9 - 36	4 - 20 - 45	3 - 17 - 39	1 - 14 - 20	0 - 13 - 30
NE	2 - 10 - 10	2 - 12 - 6	5 - 5 - 9	6 - 9 - 14	2 - 7 - 7	2 - 7 - 9
ENE	1 - 2 - 6	0 - 4 - 3	1 - 3 - 5	1 - 1 - 6	0 - 3 - 2	2 - 4 - 3
E	2 - 6 - 3	2 - 4 - 1	2 - 3 - 3	4 - 0 - 1	2 - 0 - 2	0 - 5 - 0
ESE	1 - 0 - 1	1 - 1 - 1	1 - 3 - 0	0 - 0 - 1	2 - 4 - 2	1 - 0 - 1
SE	2 - 1 - 0	0 - 0 - 2	0 - 0 - 0	0 - 0 - 1	0 - 0 - 3	2 - 1 - 1
SSE	0 - 1 - 1	2 - 4 - 2	0 - 0 - 1	0 - 0 - 2	2 - 0 - 0	1 - 0 - 2
S	4 - 4 - 6	1 - 8 - 6	1 - 2 - 6	1 - 3 - 3	3 - 7 - 7	1 - 6 - 0
SSW	8 - 18 - 13	8 - 17 - 10	1 - 15 - 13	3 - 12 - 12	1 - 8 - 11	4 - 18 - 9
SW	12 - 30 - 18	9 - 40 - 12	14 - 26 - 10	8 - 23 - 11	9 - 32 - 11	12 - 14 - 10
WSW	4 - 12 - 9	5 - 11 - 4	8 - 13 - 2	2 - 14 - 3	3 - 9 - 14	2 - 15 - 27
W	6 - 8 - 6	5 - 9 - 4	4 - 8 - 4	6 - 10 - 9	0 - 7 - 11	1 - 9 - 15
WNW	1 - 4 - 4	5 - 5 - 6	0 - 1 - 3	2 - 9 - 18	1 - 6 - 27	0 - 5 - 25
NW	2 - 7 - 14	3 - 1 - 7	3 - 0 - 8	1 - 1 - 17	0 - 2 - 22	0 - 3 - 15
NNW	3 - 1 - 5	3 - 2 - 13	1 - 1 - 11	1 - 3 - 11	2 - 2 - 13	2 - 2 - 12
Calm	7	7	7	7	4	2
Total	56 - 129 - 125	61 - 132 - 117	54 - 107 - 139	46 - 108 - 156	33 - 104 - 163	34 - 106 - 170

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G

8 A.M. - EASTERN STANDARD TIME

	January A - B - C	February A - B - C	March A - B - C	April A - B - C	May A - B - C	June A - B - C
N	0 - 2 - 17	0 - 3 - 10	0 - 0 - 14	1 - 1 - 18	2 - 0 - 9	0 - 4 - 9
NNE	1 - 7 - 30	4 - 4 - 25	0 - 3 - 28	2 - 5 - 21	1 - 5 - 26	3 - 8 - 31
NE	2 - 8 - 13	3 - 7 - 23	1 - 6 - 28	0 - 4 - 21	2 - 11 - 18	3 - 7 - 18
ENE	1 - 3 - 0	3 - 4 - 4	1 - 4 - 17	2 - 7 - 18	4 - 3 - 14	1 - 3 - 12
E	0 - 2 - 1	2 - 2 - 4	1 - 4 - 8	2 - 10 - 2	2 - 7 - 6	3 - 5 - 2
ESE	1 - 2 - 1	0 - 1 - 1	0 - 2 - 3	2 - 5 - 6	1 - 2 - 7	2 - 4 - 0
SE	0 - 1 - 0	0 - 0 - 0	0 - 1 - 0	0 - 1 - 3	3 - 0 - 1	2 - 5 - 0
SSE	0 - 1 - 2	0 - 2 - 2	1 - 4 - 1	0 - 2 - 2	0 - 3 - 2	1 - 5 - 2
S	1 - 2 - 1	3 - 4 - 2	0 - 1 - 4	0 - 2 - 6	0 - 2 - 1	0 - 7 - 4
SSW	2 - 8 - 7	2 - 6 - 5	1 - 5 - 8	1 - 7 - 11	6 - 3 - 22	2 - 13 - 15
SW	3 - 19 - 13	2 - 17 - 7	0 - 5 - 13	3 - 7 - 15	4 - 19 - 23	3 - 17 - 16
WSW	0 - 12 - 17	2 - 8 - 14	0 - 6 - 10	0 - 9 - 16	1 - 14 - 13	3 - 10 - 13
W	1 - 10 - 18	0 - 4 - 20	0 - 2 - 12	0 - 1 - 11	0 - 6 - 7	1 - 7 - 9
WNW	0 - 7 - 32	0 - 2 - 33	1 - 0 - 32	1 - 0 - 30	2 - 3 - 14	3 - 5 - 10
NW	0 - 4 - 33	0 - 2 - 25	0 - 4 - 39	0 - 3 - 28	0 - 2 - 18	1 - 3 - 15
NNW	0 - 1 - 22	0 - 2 - 18	0 - 5 - 35	0 - 0 - 11	2 - 2 - 17	0 - 1 - 8
Calm	2	1	0	3	0	4
Total	14 - 89 - 207	22 - 68 - 193	6 - 52 - 252	17 - 64 - 219	30 - 82 - 198	32 - 104 - 164

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G

9 A.M. - EASTERN STANDARD TIME

	January A - B - C	February A - B - C	March A - B - C	April A - B - C	May A - B - C	June A - B - C
N	0 - 3 - 14	0 - 1 - 8	0 - 0 - 13	0 - 2 - 12	0 - 3 - 12	1 - 5 - 3
NNE	2 - 8 - 29	0 - 7 - 28	0 - 4 - 31	0 - 5 - 22	1 - 6 - 29	1 - 10 - 25
NE	0 - 7 - 18	4 - 7 - 19	2 - 6 - 27	0 - 6 - 16	1 - 5 - 15	0 - 10 - 23
ENE	0 - 2 - 4	2 - 3 - 7	0 - 2 - 17	1 - 6 - 16	0 - 6 - 18	1 - 3 - 10
E	3 - 3 - 1	2 - 2 - 6	0 - 2 - 10	0 - 9 - 8	0 - 2 - 11	0 - 6 - 3
ESE	0 - 0 - 1	0 - 0 - 0	0 - 6 - 4	0 - 5 - 11	4 - 8 - 6	1 - 7 - 3
SE	0 - 0 - 0	0 - 0 - 1	1 - 0 - 0	3 - 1 - 0	1 - 3 - 1	2 - 1 - 0
SSE	0 - 2 - 1	1 - 2 - 1	0 - 3 - 4	0 - 2 - 2	0 - 7 - 1	2 - 6 - 0
S	1 - 4 - 3	0 - 1 - 3	0 - 3 - 1	3 - 3 - 5	1 - 2 - 1	5 - 4 - 3
SSW	0 - 14 - 7	1 - 9 - 7	0 - 3 - 8	3 - 2 - 16	2 - 4 - 19	2 - 11 - 18
SW	6 - 11 - 12	0 - 8 - 17	0 - 4 - 12	0 - 6 - 13	1 - 6 - 29	3 - 11 - 16
WSW	1 - 14 - 15	3 - 6 - 17	1 - 2 - 16	0 - 8 - 17	2 - 10 - 15	2 - 7 - 15
W	0 - 3 - 22	0 - 1 - 20	0 - 4 - 8	0 - 4 - 15	1 - 3 - 11	2 - 3 - 9
WNW	0 - 4 - 41	0 - 0 - 32	2 - 3 - 36	1 - 4 - 27	1 - 4 - 12	0 - 5 - 15
NW	0 - 2 - 27	0 - 2 - 34	1 - 3 - 38	0 - 1 - 24	1 - 2 - 17	1 - 4 - 16
NNW	0 - 2 - 22	0 - 0 - 21	0 - 3 - 30	0 - 1 - 19	2 - 0 - 24	3 - 2 - 19
Calm	1	0	0	1	0	1
Total	14-79 -217	13 - 49 -221	7 - 48 - 255	12 - 65-223	18 - 71 -221	27-95 -178

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX C

9 A.M. - EASTERN STANDARD TIME

	January A - B - C	February A - B - C	March A - B - C	April A - B - C	May A - B - C	June A - B - C
N	0 - 3 - 14	0 - 1 - 8	0 - 0 - 13	0 - 2 - 12	0 - 3 - 12	1 - 5 - 3
NNE	2 - 8 - 29	0 - 7 - 28	0 - 4 - 31	0 - 5 - 22	1 - 6 - 29	1 - 19 - 25
NE	0 - 7 - 18	4 - 7 - 19	2 - 6 - 27	0 - 6 - 16	1 - 5 - 15	0 - 10 - 23
ENE	0 - 2 - 4	2 - 3 - 7	0 - 2 - 17	1 - 6 - 16	0 - 6 - 18	1 - 3 - 10
E	3 - 3 - 1	2 - 2 - 6	0 - 2 - 10	0 - 9 - 8	0 - 2 - 11	0 - 6 - 3
ESE	0 - 0 - 1	0 - 0 - 0	0 - 6 - 4	0 - [illegible] - 11	4 - 8 - 6	1 - 7 - 3
SE	0 - 0 - 0	0 - 0 - 1	1 - 0 - 0	3 - 1 - 0	1 - 3 - 1	2 - 1 - 0
SSE	0 - 2 - 1	1 - 2 - 1	0 - 3 - 4	0 - 2 - 2	0 - 7 - 1	2 - 6 - 0
S	1 - 4 - 3	0 - 1 - 3	0 - 3 - 1	3 - 3 - 5	1 - 2 - 1	5 - 4 - 3
SSW	0 - 14 - 7	1 - 9 - 7	0 - 3 - 8	3 - 2 - 16	2 - 4 - 19	2 - 11 - 18
SW	6 - 11 - 12	0 - 8 - 17	0 - 4 - 12	0 - 6 - 13	1 - 6 - 29	3 - 11 - 16
WSW	1 - 14 - 15	3 - 6 - 17	1 - 2 - 16	0 - 8 - 17	2 - 10 - 15	2 - 7 - 15
W	0 - 3 - 22	0 - 1 - 20	0 - 4 - 8	0 - 4 - 15	1 - 3 - 11	2 - 3 - 9
WNW	0 - 4 - 41	0 - 0 - 32	2 - 3 - 36	1 - 4 - 27	1 - 4 - 12	0 - 5 - 15
NW	0 - 2 - 27	0 - 2 - 34	1 - 3 - 33	0 - 1 - 24	1 - 2 - 17	1 - 4 - 16
NNW	0 - 2 - 22	0 - 0 - 21	0 - 3 - 30	0 - 1 - 19	2 - 0 - 24	3 - 2 - [illegible]
Calm	1	0	0	1	0	1
Total	14-79 -217	13 - 49 -221	7 - 48 - 255	12 - 65-223	18 - 71 -221	27-95 -178

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at ≥ 8 mph.

APPENDIX G

9 A.M. - EASTERN STANDARD TIME

	July A - B - C	August A - B - C	September A - B - C	October A - B - C	November A - B - C	December A - B - C
N	2 - 8 - 14	0 - 5 - 16	1 - 5 - 13	1 - 7 - 6	0 - 5 - 11	0 - 5 - 11
NNE	1 - 8 - 22	1 - 8 - 32	2 - 13 - 47	3 - 14 - 42	2 - 5 - 17	0 - 11 - 23
NE	0 - 7 - 19	3 - 6 - 18	1 - 11 - 25	2 - 14 - 15	3 - 7 - 12	1 - 10 - 18
ENE	0 - 7 - 7	0 - 3 - 7	1 - 1 - 8	3 - 3 - 2	3 - 1 - 8	1 - 2 - 2
E	5 - 3 - 6	3 - 8 - 6	2 - 2 - 2	4 - 2 - 2	4 - 1 - 6	3 - 2 - 3
ESE	0 - 3 - 4	1 - 4 - 2	1 - 3 - 5	2 - 0 - 2	0 - 2 - 0	2 - 2 - 2
SE	1 - 2 - 0	2 - 0 - 1	4 - 0 - 1	1 - 0 - 3	1 - 2 - 0	0 - 2 - 0
SSE	2 - 4 - 0	1 - 1 - 2	4 - 0 - 1	0 - 1 - 1	1 - 3 - 2	1 - 1 - 0
S	1 - 5 - 3	2 - 8 - 8	4 - 3 - 4	2 - 0 - 3	3 - 2 - 7	0 - 3 - 6
SSW	3 - 9 - 10	4 - 11 - 23	3 - 11 - 16	5 - 9 - 10	3 - 6 - 17	1 - 6 - 9
SW	3 - 16 - 29	2 - 16 - 18	2 - 15 - 21	0 - 17 - 18	2 - 8 - 19	4 - 14 - 27
WSW	1 - 11 - 15	1 - 9 - 13	0 - 5 - 8	1 - 9 - 8	0 - 9 - 21	2 - 13 - 22
W	1 - 9 - 11	1 - 9 - 7	0 - 4 - 7	0 - 5 - 10	1 - 7 - 15	0 - 3 - 22
WNW	2 - 5 - 13	3 - 3 - 10	1 - 4 - 13	0 - 1 - 26	2 - 2 - 30	1 - 4 - 29
NW	3 - 1 - 14	1 - 1 - 15	1 - 1 - 7	3 - 3 - 21	0 - 3 - 22	1 - 2 - 20
NNW	2 - 4 - 12	1 - 2 - 16	0 - 3 - 14	0 - 6 - 22	0 - 1 - 24	1 - 3 - 15
Calm	2	1	0	1	0	0
Total	29 - 102 - 179	27 - 94 - 188	27 - 81 - 198	28 - 91 - 191	25 - 64 - 211	18 - 83 - 209

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G

10 A.M. - EASTERN STANDARD TIME

	January A - B - C	February A - B - C	March A - B - C	April A - B - C	May A - B - C	June A - B - C
N	2 -1 -15	1 -2 -8	0 -0 -14	0 -2 -18	1 -3 -5	0 -1 -7
NNE	2 -8 -27	1 -2 -29	0 -5 -34	0 -1 -14	0 -3 -20	1 -10 -23
NE	0 -4 -20	1 -7 -18	1 -6 -20	0 -6 -15	0 -1 -17	2 -9 -17
ENE	1 -1 -4	2 -4 -6	0 -5 -22	0 -3 -16	0 -12 -16	3 -0 -13
E	3 -4 -3	4 -4 -6	0 -3 -9	1 -5 -12	1 -2 -11	1 -4 -5
ESE	0 -4 -0	0 -1 -2	0 -5 -9	1 -3 -18	4 -7 -12	2 -4 -5
SE	0 -1 -0	2 -0 -0	0 -0 -0	1 -3 -0	1 -2 -3	3 -3 -4
SSE	0 -2 -1	2 -2 -0	0 -1 -3	2 -2 -6	2 -4 -8	3 -12 -3
S	0 -3 -4	1 -5 -3	1 -2 -3	0 -3 -5	1 -6 -6	1 -6 -5
SSW	2 -5 -12	0 -5 -7	0 -1 -9	0 -3 -18	1 -2 -15	1 -5 -18
SW	3 -8 -21	1 -4 -12	0 -1 -17	3 -5 -11	0 -0 -23	1 -10 -16
WSW	1 -5 -12	0 -7 -22	1 -1 -11	0 -4 -18	0 -7 -25	2 -4 -19
W	0 -4 -20	0 -0 -19	1 -1 -18	0 -1 -15	0 -2 -15	0 -2 -11
WNW	0 -4 -50	1 -2 -41	0 -2 -33	1 -1 -32	0 -3 -19	2 -1 -26
NW	0 -1 -24	0 -0 -27	0 -1 -33	0 -1 -28	1 -3 -15	1 -2 -13
NNW	0 -3 -25	0 -2 -20	0 -4 -33	1 -2 -19	0 -2 -29	0 -2 -16
Calm	0	0	0	0	0	1
Total	14 -58 -238	16 -47 -220	4 -38 -268	10 -45 -245	12 -59 -239	24 -75 -201

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G

10 A.M. - EASTERN STANDARD TIME

	July A - B - C	August A - B - C	September A - B - C	October A - B - C	November A - B - C	December A - B - C
N	[illegible] - 7 - 8	1 - 5 - 11	1 - 7 - 16	3 - 3 - 14	1 - 2 - 8	0 - 0 - 9
NNE	[illegible] - 9 - 15	1 - 5 - [illegible]	1 - 8 - 37	3 - 10 - 32	1 - 4 - 18	4 - 10 - 30
NE	[illegible] - 7 - 23	1 - 5 - 16	1 - 7 - 27	0 - 9 - 32	1 - 8 - 12	2 - 7 - 10
ENE	[illegible] - 11 - 9	[illegible] - 12 - 4	4 - 5 - 12	3 - 7 - 3	0 - 5 - 5	2 - 2 - 6
E	[illegible] - 5 - 5	1 - 2 - 3	0 - 1 - 5	3 - 2 - 3	1 - 5 - 4	1 - 1 - 1
ESE	[illegible] - 6 - [illegible]	2 - 7 - 4	1 - 3 - 8	1 - 2 - 3	2 - 4 - 3	0 - 1 - 2
SE	4 - 5 - 4	1 - 3 - 0	4 - 1 - 1	1 - 0 - 0	2 - 0 - 1	0 - 0 - 0
SSE	[illegible] - 5 - 4	[illegible] - 3 - 4	2 - 3 - 0	2 - 1 - 2	3 - 3 - 3	0 - 2 - 3
S	2 - 5 - 3	0 - 9 - 10	1 - 6 - 6	0 - 2 - 2	1 - 4 - 4	0 - 5 - 3
SSW	[illegible] - 7 - 22	[illegible] - 11 - 16	2 - 4 - 18	3 - 9 - 16	2 - 8 - 21	2 - 6 - 17
SW	[illegible] - 3 - 27	[illegible] - 14 - 16	1 - 11 - 23	2 - 4 - 23	1 - 7 - 23	4 - 10 - 14
WSW	[illegible] - 5 - 19	[illegible] - 5 - 27	0 - 10 - 9	2 - 4 - 9	0 - 5 - 23	6 - 6 - 28
W	[illegible] - 7 - 8	1 - 4 - 12	0 - 2 - 7	1 - 3 - 14	0 - 1 - 23	1 - 3 - 25
WNW	1 - 3 - [illegible]	[illegible] - 1 - 24	0 - 1 - 9	1 - 3 - 15	0 - 2 - 21	1 - 3 - 32
NW	1 - 1 - 22	[illegible] - 3 - 14	0 - 2 - 15	0 - 1 - 24	1 - 1 - 31	0 - 2 - 27
NNW	1 - 0 - 1[illegible]	2 - 6 - 12	0 - 2 - 16	0 - 5 - 27	0 - 1 - 24	1 - 3 - 18
Calm	1	0	0	1	0	0
Total	22 - 86 - 202	10 - 94 - 206	18 - 73 - 209	26 - 65 - 219	16 - 60 - 224	24 - 61 - 225

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at ≥ 8 mph.

APPENDIX G
3 P.M. - EASTERN STANDARD TIME

	January A-B-C	February A-B-C	March A-B-C	April A-B-C	May A-B-C	June A-B-C
N	1- 1- 7	0- 0- 8	0- 0- 11	1- 0- 11	0- 0- 4	0- 0- 5
NNE	2- 2- 13	1- 1- 19	0- 4- 12	0- 0- 7	0- 5- 6	0- 0- 9
NE	0- 6- 20	2- 3- 12	0- 3- 23	0- 2- 8	0- 3- 7	0- 2- 5
ENE	1- 4- 4	0- 2- 6	2- 2- 14	0- 2- 11	0- 1- 12	0- 3- 8
E	2- 6- 4	0- 3- 5	2- 2- 10	0- 2- 10	1- 2- 11	1- 5- 9
ESE	2- 1- 3	2- 6- 7	0- 4- 18	0- 6- 31	0- 8- 34	1- 3- 24
SE	0- 0- 1	1- 1- 3	0- 3- 7	0- 1- 22	0- 1- 28	0- 1- 17
SSE	1- 6- 5	1- 1- 5	0- 3- 12	1- 2- 22	0- 3- 29	0- 3- 33
S	1- 2- 4	0- 5- 6	0- 2- 3	1- 1- 5	0- 1- 3	1- 4- 15
SSW	0- 0- 14	0- 1- 16	0- 0- 8	0- 0- 10	1- 0- 18	1- 2- 20
SW	0- 3- 18	0- 1- 14	0- 0- 10	0- 1- 16	1- 0- 23	0- 3- 15
WSW	1- 1- 16	0- 2- 19	0- 1- 16	0- 1- 16	0- 0- 25	0- 4- 16
W	0- 2- 39	0- 1- 27	0- 1- 23	0- 1- 17	0- 0- 20	0- 4- 21
WNW	1- 3- 46	2- 5- 48	0- 5- 45	0- 2- 44	0- 1- 26	0- 2- 23
NW	0- 2- 45	0- 2- 27	0- 0- 38	0- 2- 27	0- 1- 20	0- 1- 25
NNW	0- 2- 28	1- 0- 16	0- 1- 25	0- 1- 16	0- 1- 14	0- 2- 12
Calm	0	1	0	0	0	0
Total	12-41-257	11-34-238	4-31-275	3-24-273	3-27-280	4-39-257

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at ≥ 8 mph.

APPENDIX G

3 P.M. - EASTERN STANDARD TIME

	July A - B - C	August A - B - C	September A - B - C	October A - B - C	November A - B - C	December A - B - C
N	0- 2- 2	0- 0- 3	0- 2- 11	1- 2- 9	0- 1- 11	0- 1- 9
NNE	1- 1- 10	0- 0- 14	0- 2- 18	0- 3- 10	0- 2- 10	0- 2- 24
NE	0- 2- 7	1- 1- 11	1- 3- 9	0- 2- 17	1- 3- 8	3- 3- 12
ENE	0- 2- 7	1- 1- 6	0- 3- 17	0- 4- 11	0- 3- 7	1- 3- 2
E	0- 5- 6	0- 2- 5	0- 0- 13	1- 4- 5	0- 3- 5	3- 5- 4
ESE	0- 1- 20	0- 5- 15	0- 7- 20	1- 4- 20	1- 3- 16	1- 3- 4
SE	0- 3- 17	0- 7- 23	0- 1- 13	0- 5- 8	1- 4- 7	0- 1- 2
SSE	0- 2- 33	1- 3- 27	2- 3- 16	2- 6- 8	1- 2- 10	0- 3- 6
S	0- 3- 17	1- 4- 12	2- 1- 12	2- 2- 7	0- 2- 5	1- 0- 8
SSW	0- 3- 20	0- 4- 25	1- 1- 16	0- 4- 17	1- 2- 18	0- 8- 16
SW	0- 4- 22	0- 0- 16	0- 1- 26	0- 2- 23	2- 3- 20	0- 2- 19
WSW	0- 1- 25	0- 3- 27	0- 3- 17	0- 2- 27	1- 4- 22	2- 7- 24
W	0- 5- 28	0- 2- 19	0- 2- 13	1- 0- 16	0- 5- 27	1- 2- 31
WNW	1- 2- 31	1- 3- 29	0- 4- 23	1- 2- 23	0- 0- 41	0- 3- 31
NW	0- 3- 15	0- 2- 23	0- 2- 13	0- 2- 35	0- 2- 29	0- 1- 36
NNW	1- 2- 5	0- 1- 12	0- 3- 18	0- 2- 19	0- 1- 15	0- 1- 22
Calm	1	0	0	0	1	3
Total	4-41-265	5-38-267	6-39-255	9-46-255	9-40-251	15-45-250

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G
4 P.M. - EASTERN STANDARD TIME

	January A - B - C	February A - B - C	March A - B - C	April A - B - C	May A - B - C	June A - B - C
N	1- 1- 12	0- 1- 7	0- 3- 5	0- 1- 10	0- 1- 5	0- 0- 4
NNE	0- 3- 11	0- 4- 11	0- 2- 9	0- 2- 2	0- 0- 8	0- 3- 7
NE	1- 1- 21	0- 1- 13	0- 1- 24	0- 1- 6	0- 3- 7	0- 2- 6
ENE	0- 2- 5	1- 4- 9	0- 3- 17	0- 0- 10	0- 4- 8	0- 2- 7
E	6- 6- 5	1- 2- 5	1- 2- 10	0- 2- 10	0- 4- 13	0- 5- 11
ESE	0- 6- 1	4- 4- 7	0- 4- 13	0- 4- 29	1- 6- 28	1- 6- 23
SE	0- 1- 1	0- 2- 6	0- 0- 12	0- 8- 22	0- 3- 29	0- 1- 18
SSE	0- 6- 2	1- 1- 10	3- 3- 16	1- 3- 24	0- 2- 32	0- 2- 39
S	0- 4- 3	1- 1- 6	0- 0- 5	1- 2- 9	0- 2- 8	0- 2- 11
SSW	3- 5- 13	1- 2- 13	0- 1- 4	0- 2- 9	0- 0- 9	0- 1- 18
SW	1- 3- 15	2- 4- 11	0- 2- 8	0- 1- 14	0- 0- 23	0- 2- 13
WSW	0- 2- 21	1- 3- 16	1- 4- 17	0- 0- 17	0- 1- 33	1- 3- 22
W	0- 3- 33	1- 1- 28	0- 0- 30	0- 1- 12	0- 0- 17	1- 2- 21
WNW	0- 2- 44	0- 4- 47	0- 0- 47	0- 1- 38	0- 0- 21	0- 3- 28
NW	0- 2- 40	0- 0- 27	0- 1- 35	0- 2- 41	0- 0- 22	1- 1- 20
NNW	0- 0- 22	0- 1- 19	0- 1- 26	0- 0- 15	1- 0- 19	0- 2- 11
Calm	0	0	0	0	0	0
Total	12-47-251	13-35-235	5-27-278	2-30-268	2-26-282	4-37-259

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G

4 P.M. - EASTERN STANDARD TIME

	July A -B-C	August A -B-C	September A -B-C	October A- B-C	November A- B-C	December A- B-C
N	0- 2- 5	0- 1- 0	0- 3- 5	0- 1- 7	0- 1- 10	0- 0- 6
NNE	2- 4- 9	0- 1- 11	0- 3- 13	0- 5- 13	0- 2- 8	0- 9- 22
NE	0- 3- 7	0- 0- 10	0- 1- 8	0- 0- 10	1- 3- 6	1- 4- 9
ENE	0- 0- 8	0- 0- 7	0- 1- 21	0- 4- 11	0- 4- 9	1- 2- 3
E	1- 3- 5	3- 1- 2	0- 4- 10	1- 3- 6	2- 4- 6	4- 1- 4
ESE	1- 3- 17	0- 5- 16	1- 4- 19	0- 5- 23	0- 8- 8	1- 2- 4
SE	0- 4- 26	0- 1- 28	0- 3- 22	0- 3- 10	0- 4- 6	1- 2- 3
SSE	0- 5- 42	0- 4- 35	0- 6- 24	1- 4- 15	0- 6- 13	3- 5- 7
S	0- 2- 14	0- 3- 17	1- 0- 10	0- 3- 7	0- 1- 7	0- 3- 4
SSW	0- 1- 16	0- 6- 20	0- 0- 14	0- 3- 22	0- 7- 17	1- 6- 18
SW	0- 2- 15	0- 4- 20	1- 2- 21	0- 5- 22	0- 3- 25	0- 8- 17
WSW	0- 6- 20	0- 5- 27	0- 2- 20	0- 2- 19	1- 1- 16	1- 6- 24
W	0- 2- 17	0- 2- 20	0- 1- 10	0- 1- 13	0- 3- 29	0- 2- 31
WNW	1- 1- 37	0- 3- 22	0- 6- 25	1- 0- 32	0- 0- 34	1- 2- 34
NW	0- 2- 20	1- 3- 20	0- 1- 17	0- 3- 34	0- 2- 35	0- 2- 36
NNW	0- 1- 5	0- 0- 12	0- 2- 18	0- 1- 20	0- 2- 15	1- 1- 17
Calm	1	0	0	0	1	1
Total	6-41-263	4-39-267	3-39-257	3-43-264	5-51-244	16-55-239

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G

5 P.M. - EASTERN STANDARD TIME

	January A -B-C	February A -B-C	March A -B-C	April A- B-C	May A- B-C	June A- B-C
N	0- 2- 4	0- 2- 7	0- 4- 7	0- 0- 5	0- 0- 6	0- 2- 3
NNE	0- 1- 16	0- 2- 12	0- 2- 15	0- 0- 11	0- 0- 5	0- 1- 5
NE	2- 5- 21	0- 1- 9	0- 2- 18	0- 2- 7	1- 2- 9	0- 2- 4
ENE	0- 2- 4	1- 3- 11	1- 2- 16	0- 0- 5	0- 2- 4	1- 1- 5
E	4- 7- 4	2- 4- 6	2- 4- 9	0- 5- 15	2- 2- 9	1- 2- 7
ESE	0- 4- 2	1- 8- 7	0- 2- 11	1- 4- 20	1- 5- 44	0- 6- 31
SE	0- 0- 2	1- 2- 3	0- 2- 9	0- 5- 17	0- 4- 23	0- 4- 21
SSE	0- 3- 3	0- 5- 6	0- 0- 17	0- 5- 30	0- 1- 39	0- 5- 44
S	0- 6- 4	1- 2- 5	1- 0- 8	0- 2- 11	0- 0- 6	0- 1- 4
SSW	1- 4- 9	0- 2- 7	0- 2- 9	1- 1- 14	0- 0- 8	0- 1- 17
SW	0- 7- 21	1- 5- 16	0- 2- 7	0- 0- 13	0- 1- 22	0- 1- 16
WSW	1- 7- 24	1- 5- 21	1- 2- 20	0- 0- 8	0- 1- 26	0- 5- 14
W	0- 4- 26	0- 5- 25	1- 1- 28	0- 0- 15	0- 0- 16	0- 0- 27
WNW	1- 5- 33	0- 1- 36	0- 0- 33	0- 1- 40	0- 0- 27	0- 0- 37
NW	0- 1- 49	0- 2- 36	0- 2- 46	0- 0- 32	0- 1- 22	0- 1- 16
NNW	1- 1- 18	0- 0- 18	0- 0- 24	0- 0- 29	0- 0- 20	0- 1- 14
Calm	1	0	0	1	1	0
Total	11-59-240	8-49-225	6-27-277	3-25-272	5-19-286	2-33-265

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G
5 P.M. - EASTERN STANDARD TIME

	July A - B - C	August A - B - C	September A - B - C	October A - B - C	November A - B - C	December A - B - C
N	0- 0- 6	0- 0- 2	0- 0- 10	0- 1- 5	0- 1- 10	0- 4- 14
NNE	1- 0- 4	1- 2- 7	1- 2- 9	0- 1- 12	0- 1- 10	1- 2- 15
NE	0- 2- 6	0- 1- 10	0- 2- 13	0- 1- 9	2- 1- 7	1- 4- 16
ENE	0- 2- 7	0- 2- 4	2- 2- 17	1- 2- 15	0- 1- 9	0- 3- 5
E	0- 4- 7	0- 2- 4	0- 4- 5	1- 4- 9	1- 8- 5	3- 5- 0
ESE	1-11- 13	0- 4- 18	0- 4- 18	0- 7- 14	1- 1- 5	0- 5- 3
SE	0- 4- 31	1- 3- 22	0- 3- 26	0- 7- 14	0- 5- 2	2- 1- 1
SSE	0- 4- 40	0- 2- 50	0- 3- 31	0- 5- 18	0- 7- 16	2- 4- 2
S	0- 2- 12	1- 4- 13	0- 3- 8	0- 2- 10	0- 7- 11	1- 4- 4
SSW	0- 2- 17	0- 8- 11	0- 1- 14	0- 1- 22	1- 5- 16	1-10- 15
SW	0- 3- 23	0- 4- 14	0- 5- 14	0- 4- 19	0-11- 14	0- 8- 17
WSW	1- 1- 15	0- 5- 27	0- 2- 16	0- 0- 20	0- 5- 19	1- 8- 22
W	0- 2- 23	0- 1- 22	0- 1- 17	0- 2- 14	0- 3- 23	0-13- 23
WNW	0- 2- 35	0- 3- 36	0- 3- 22	0- 0- 28	0- 3- 33	1- 3- 30
NW	0- 1- 16	1- 0- 14	0- 4- 25	0- 4- 37	0- 3- 28	2- 1- 36
NNW	1- 0- 10	0- 2- 9	0- 0- 12	0- 3- 18	0- 2- 21	1- 2- 13
Calm	1	0		0	2	1
Total	5-40-265	4-43-263	3-39-257	2-44-264	7-64-229	17-77-216

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G

6 P.M. - EASTERN STANDARD TIME

	January A - B - C	February A - B - C	March A - B - C	April A - B - C	May A - B - C	June A - B - C
N	1- 0- 10	0- 4- 5	0- 1- 10	0- 0- 4	0- 1- 3	0- 1- 3
NNE	0- 4- 17	0- 4- 7	0- 0- 15	0- 0- 9	1- 3- 3	0- 0- 5
NE	0- 4- 18	2- 3- 13	0- 7- 17	0- 2- 8	0- 0- 11	0- 2- 5
ENE	0- 0- 1	1- 3- 8	0- 3- 13	0- 1- 7	0- 1- 9	0- 2- 7
E	3- 5- 6	1- 3- 3	1- 4- 9	1- 5- 14	1- 2- 6	2- 6- 11
ESE	1- 3- 2	1-10- 4	0- 2- 12	0-11- 24	0-11- 35	0- 5- 19
SE	2- 0- 0	0- 2- 1	0- 5- 6	0- 1- 15	1- 2- 18	0- 7- 22
SSE	1- 2- 2	1- 5- 7	0- 4- 14	0- 6- 18	0- 6- 45	0- 3- 48
S	1- 5- 7	2- 1- 6	0- 2- 9	1- 1- 13	0- 0- 9	0- 1- 9
SSW	1- 5- 11	0- 7- 10	1- 1- 10	0- 3- 16	0- 0- 8	0- 1- 12
SW	2- 5- 22	1- 8- 12	0- 6- 8	0- 3- 9	0- 2- 21	0- 1- 16
WSW	1- 7- 16	1- 5- 15	1- 2- 13	0- 3- 6	0- 0- 19	0- 3- 16
W	1- 4- 28	1- 7- 23	2- 2- 25	0- 1- 16	0- 1- 27	0- 1- 27
WNW	1- 6- 42	1- 1- 41	0- 3- 34	0- 1- 33	1- 0- 15	0- 3- 22
NW	0- 2- 39	0- 1- 31	0- 1- 46	0- 2- 41	0- 1- 26	1- 3- 19
NNW	0- 2- 17	0- 1- 19	1- 0- 20	0- 0- 25	0- 1- 20	0- 1- 16
Calm	3	1	0	0	0	0
Total	18-54-238	13-65-205	6-43-261	2-40-258	4-31-275	3-40-257

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

APPENDIX G

6P.M. - EASTERN STANDARD TIME

	July A - B - C	August A - B - C	September A - B - C	October A - B - C	November A - B - C	December A - B - C
N	1- 0- 3	0- 1- 2	1- 1- 6	0- 1- 5	0- 0- 10	0- 2- 11
NNE	2- 3- 5	0- 1- 7	0- 1- 14	0- 0- 15	0- 0- 11	0- 3- 23
NE	0- 1- 4	0- 2- 9	0- 1- 11	0- 3- 9	0- 4- 13	0- 8- 13
ENE	0- 1- 7	0- 1- 7	0- 1- 16	0- 1- 11	1- 0- 3	1- 2- 2
E	0- 2- 5	0- 2- 3	0- 5- 5	2- 7- 3	1- 3- 4	1- 3- 2
ESE	2- 5- 11	0- 4- 15	0- 3- 17	1- 8- 12	2- 4- 6	1- 4- 1
SE	0- 1- 27	0- 5- 21	0- 3- 10	2- 6- 7	2- 4- 3	1- 1- 1
SSE	0- 6- 49	1- 6- 52	1- 7- 43	0- 6- 18	3- 9- 9	0- 4- 2
S	0- 2- 26	0- 1- 17	1- 3- 12	2- 7- 13	1- 8- 5	0- 4- 5
SSW	0- 1- 15	0- 2- 19	0- 3- 15	0- 4- 19	1-12- 16	0-13- 14
SW	0- 1- 15	0- 3- 20	0- 0- 15	0- 5- 23	1- 8- 15	7-18- 15
WSW	0- 5- 23	0- 1 - 10	2- 2- 16	0-10- 10	1- 5- 12	2-10- 12
W	0- 2- 21	0- 1- 20	0- 5- 18	0- 5- 14	1-13- 30	0- 8- 22
WNW	1- 3- 26	0- 3- 42	1- 6- 17	0- 2- 22	1- 2- 26	0- 6- 29
NW	1- 1- 24	0- 1- 9	0- 3- 18	0- 3- 39	0- 2- 34	0- 5- 36
NNW	0- 1- 7	0- 1- 11	0- 3- 13	0- 0- 15	0- 1- 13	0- 1 - 15
Calm	0	0	0	0	0	2
Total	7-35-268	1-35-274	6-47-246	7-68-235	15-75-210	15-92-203

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at ≥ 8 mph.

APPENDIX C

7 P.M. - EASTERN STANDARD TIME

	January A - B - C	February A - B - C	March A - B - C	April A - B - C	May A - B - C	June A - B - C
N	0- 1- 7	0- 1- 4	0- 2- 8	0- 4- 7	0- 0- 6	0- 2- 2
NNE	0- 3- 16	0- 4- 11	0- 6- 18	0- 0- 11	0- 1- 1	0- 0- 7
NE	0- 5- 17	0- 1- 11	0- 3- 16	0- 1- 6	0- 4- 13	0- 1- 3
ENE	2- 4- 5	2- 7- 7	1- 6- 12	0- 2- 8	0- 4- 9	1- 3- 3
E	0- 3- 6	2- 1- 4	1- 2- 9	0-11- 12	0- 3- 11	1- 4- 8
ESE	1- 2- 1	3- 3- 7	1- 1- 12	2- 8- 21	0-14- 28	0-11- 16
SE	0- 2- 0	2- 1- 2	0- 3- 4	1- 4- 5	0- 8- 13	1- 3- 14
SSE	0- 4- 1	0- 5- 3	0- 9- 9	2- 4- 19	3- 4- 29	1-11- 41
S	0- 4- 6	1- 3- 8	0- 7- 5	0- 1- 13	0- 0- 20	0- 3- 19
SSW	2- 8- 14	2- 9- 10	0-10- 10	0- 0- 21	0- 2- 15	0- 2- 11
SW	1- 7- 14	1- 8- 10	3- 1- 11	0- 4- 11	1- 1- 19	0- 2- 19
WSW	1-12- 18	0- 9- 6	0- 6- 9	0- 3- 10	0- 2- 17	0- 6- 19
W	1-12- 28	1- 5- 30	1 - 4- 20	0- 3- 9	0- 2- 17	0- 1- 17
WNW	1- 2- 40	0- 7- 32	1- 1- 30	0- 6- 27	0- 1- 13	0- 2- 26
NW	1- 2- 35	0- 1- 32	0- 1- 46	1- 2- 32	0- 0- 22	0- 5- 19
NNW	0- 0- 20	1- 1- 23	0- 1- 20	0- 2- 27	0- 0- 27	0- 2- 14
Calm	1	2	0	0	0	0
Total	11-71-228	17-66-200	8-63-239	6-55-239	4-46-260	4-58-238

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at ≥ 8 mph.

APPENDIX G

7 P.M. - EASTERN STANDARD TIME

	July A - B - C	August A - B - C	September A - B - C	October A - B - C	November A - B - C	December A - B - C
N	0- 0- 4	0- 2- 2	1- 1- 6	0- 2- 2	0- 0- 10	0- 2- 11
NNE	0- 1- 5	0- 2- 10	0- 3- 12	1- 4- 20	0- 0- 11	0- 3- 23
NE	0- 2- 5	0- 2- 8	0- 4- 9	1- 0- 11	0- 4- 13	0- 8- 13
ENE	0- 1- 4	0- 2- 1	0- 0- 14	0- 1- 11	1- 0- 3	1- 2- 2
E	0- 4- 5	0- 1- 4	0- 4- 5	1- 7- 5	1- 3- 4	1- 3- 2
ESE	2- 4- 18	0- 6- 8	1- 7- 10	3- 6- 12	2- 4- 6	1- 4- 1
SE	1- 5- 13	0- 5- 14	1- 3- 10	1- 2- 5	2- 4- 3	1- 1- 2
SSE	0-13- 37	1-11- 42	0-10- 32	1- 7- 7	3- 9- 9	0- 4- 2
S	1- [illegible]- 25	1- 2- 27	0- 6- 26	1- 9- 14	1- 8- 5	0- 4- 5
SSW	1- [illegible]- 14	2- [illegible]- 21	0- 3- 14	1-11- 24	1-12- 16	0-13- 14
SW	0- 2- 17	0- 4- 19	0- 8- 18	1-10- 19	1- 8- 15	7-18- 15
WSW	1- 2- 23	1- 5- 19	1- 7- 8	2- 4- 11	1- 5- 12	2-10- 12
W	0- 1- 23	0- 6- 22	0- 5- 17	2-10- 5	1-13- 30	0- 8- 22
WNW	0- 2- 25	0- 2- 20	0- 9- 13	0- 4- 21	1- 2- 26	0- 6- 29
NW	0- 1- 18	0- 1- 20	1- 2- 15	1- 7- 27	0- 2- 34	0- 5- 36
NNW	0- 3- 16	0- 1- 12	0- 2- 12	0- 3- 12	0- 1- 13	0- 1- 15
Calm	0	1	0	1	0	2
Total	6-17-257	6-55-249	5-74-221	17-87-206	15-75-210	15-92-203

KEY:

Column A is Wind Occurrences at 0-3 mph.
Column B is Wind Occurrences at 4-7 mph.
Column C is Wind Occurrences at $\geq$ 8 mph.

Appendix G: Job #11931

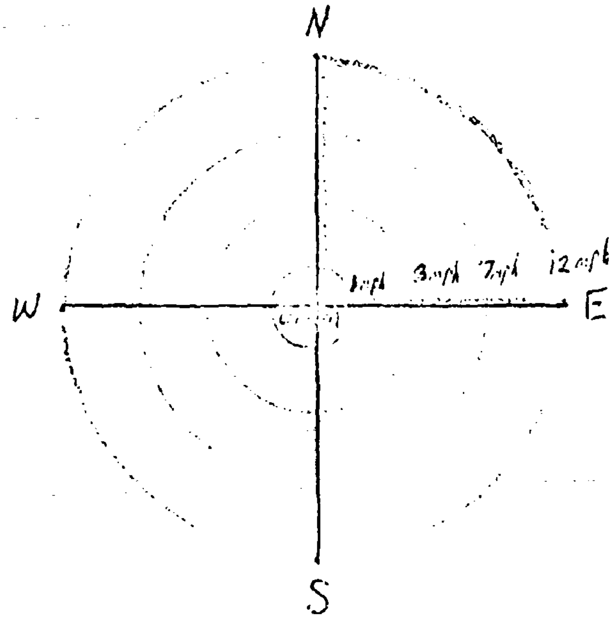
WIND PERSISTENCE TABULATION

Hourly surface wind observations at Newark, N. J. were examined for persistence during the period January 1956 - December 1965.

A persistence is defined as the occurrence, at five consecutive hourly readings of wind directions of calm, N, NNE, NE, ENE or E (in any order) with associated speeds of less than 13 mph. The hours examined were 06-1000 and 15-1900 EST for the months January through April, November and December. For the months May through October the hours were 05-0900 and 14-1800 EST. Calms reported for the five consecutive hours met the criteria of persistence. When a calm was reported within the five hour period a persistence was continued if all other conditions were met.

Four speed classes are presented: 0-3, 4-7, 8-12 and 0-12 mph. If the reported wind speeds for the five consecutive hours fell entirely within either the 0-3, 4-7 or 8-12 mph class, the persistence was assigned to that class. If the reported wind speeds fell in more than one class, the persistence was assigned to the 0-12 mph class.

Incidents occurring in the m[illegible]ing hours were tabulated in the AM class, those in the afternoon hours in the PM class, While those occurring both in the morning and afternoon of the same day were tabulated in all three classes (A.M., P.M., and both).



Wind Persistence Tabulation STN: Newark, N. J. (1956 - 1965)

		WIND VELOCITY (MPH)			
		0-3	4-7	8-12	0-12
JANUARY	A M	0	0	5	32
	P M	0	0	4	20
	BOTH	0	0	0	6
FEBRUARY	A M	0	2	6	39
	P M	0	0	2	13
	BOTH	0	0	0	2
MARCH	A M	0	1	5	30
	P M	0	0	5	15
	BOTH	0	0	1	2
APRIL	A M	0	0	0	26
	P M	0	0	2	8
	BOTH	0	0	0	1
MAY	A M	0	2	6	33
	P M	0	0	1	6
	BOTH	0	0	0	2
JUNE	A M	0	1	5	33
	P M	0	0	2	7
	BOTH	0	0	0	1
JULY	A M	0	1	5	43
	P M	0	2	2	6
	BOTH	0	0	1	2
AUGUST	A M	0	1	4	25
	P M	0	0	0	3
	BOTH	0	0	0	0
SEPTEMBER	A M	0	1	10	49
	P M	0	0	2	13
	BOTH	0	0	0	1
OCTOBER	A M	0	4	6	53
	P M	0	1	1	12
	BOTH	0	0	0	3
NOVEMBER	A M	0	2	2	31
	P M	0	0	3	13
	BOTH	0	0	0	2
DECEMBER	A M	0	5	3	37
	P M	0	2	7	23
	BOTH	0	0	1	6
SUB TOT 1	A M	0	10	21	195
	P M	0	2	23	96
	BOTH	0	0	2	19
SUB TOT 2	A M	0	10	36	256
	P M	0	3	[illegible]	[illegible]
	BOTH	0	0	1	9

Sub Tot 1 January, February, March, April, November, December
Sub Tot 2 May, June, July, August, September, October

Appendix G

Methodology of Figure V-__ (Method 1)

Time of Exposure	Background and Endogenous COHb [1]	Automobile Pollution	Total COHb	Occurences 1970-1980 [2]
6 A.M. to 10 A.M.	1%	≥ 19ppm = ≥ 2%	≥ 3%	20 Alerts (4-7 mph)
6 A.M. to 10 A.M.	1%	≥ 10ppm = ≥ .5%	≥ 1.5%	40 Impairments (0-12 mph)
3P.M. to 7P.M.	1%	≥ 19ppm = ≥ 2%	≥ 3%	10 Alerts (4-7 mph)
3 P.M. to 7 P.M.	1%	≥ 10ppm = ≥ .5%	≥ 1.5%	15 Impairments (0-12 mph)
7 A.M. to 7 P.M.	1%	≥ 10ppm = ≥ .5%	≥ 1.5%	3 Impairments (8-12 mph)
7 A.M. to 7 P.M.	1%	≥ 11ppm = ≥ 2%	≥ 3%	3 Air Pollution Alerts (8 - 12 mph)

1. The Background and endogenous Carbon Monoxide is sufficient to sustain a 1% COHb level. Endogenous CO produces a physiological range of 0 to 1% COHb. The 1% value is probable because background levels averaging 2ppm and peaking at 14ppm add to the endogenous CO in the blood. This background level alone could produce a 1% level.
2. The occurences between 1970-1985 are predicated upon the actual occurences recorded by the National Weather Records Center in the 10 year interval 1956-1965.

APPENDIX H

In the area source model, emissions are assumed to constitute a surface which has randomly distributed uniform sources. The equation for the area source model, from Appendix C, is:

$$X = \frac{8}{\sqrt{2\pi}} \quad \frac{Q}{au} \quad \left[(15 + L)^{\frac{1}{4}} - 15^{\frac{1}{4}} \right]$$

The vertical plume dispersion statistics reported by Slade are approximated by the expression:

$$\sigma_z = .12 \quad S^{3/4} \qquad \text{(meters)}$$

where: σ_z is the standard deviation of the plume concentration distribution in the vertical.

S is the downwind distance of the living complex.

For the area-source model,

- X is the concentration (gm/m^3)
- Q is the strength of the area source (rate of mass emission per unit area) $gm/m^2/sec$.
- L is the along wind dimension of the area source (16 meters)
- u is the wind speed (2.5 meters/sec)
- 15 is the number of meters from the edge of the roadway to the living complex (T = 15 meters)
- a is the numerical coefficient from the expression for σ_z (.12)

The second model estimates concentrations downwind of a continuously emitting infinite line source, when the wind direction is normal to the line. The mathematical expression for the line source model, also from Appendix C, is:

$$X\ (x,\ y,\ o;\ H) = \frac{2\ Q}{\sqrt{2\pi}\ \sigma_z\ u} \quad \exp - \frac{1}{2} \left(\frac{H}{\sigma_z} \right)^2$$

where: X (x, y, o; H) concentration of the point (x, y, o) from an elevated source with effective height of emission H

Q is the emission rate per length of a line source (gm/m/sec)

APPENDIX H

6 A.M. - 10 A.M. Exposure:

Case No.	Year	Traffic Flow	Wind Velocity	Concentrations Line Source (ppm)	Area Source (ppm)
1.	1970	4,950	6	5	4
2.	1970	4,950	4	8	7
3.	1970	14,256	6	14	10
4.	1970	14,256	4	23	19
1.	1975	5,940	6	4	3
2.	1975	5,940	4	7	5
3.	1975	14,256	6	9	6
4.	1975	14,256	4	15	11
1.	1980	7,151	6	2	1
2.	1980	7,151	4	3	2
3.	1980	14,256	6	4	2
4.	1980	14,256	4	7	4

APPENDIX H

6 A.M. - 10 A.M. Exposure: (Method 1)
COHb (%)*

Case No.	1970		1975		1980	
	LINE	AREA	LINE	AREA	LINE	AREA
1.	< 1.25	< 1.25	< 1.25	< 1.25	< 1.25	< 1.25
2.	< 1.25	< 1.25	< 1.25	< 1.25	< 1.25	< 1.25
3.	2.60	< 1.25	< 1.25	< 1.25	< 1.25	< 1.25
4.	3.40	3.00	2.70	< 1.25	< 1.25	< 1.25

*COHb includes a 1% background and endogenous value for carbon monoxide concentrations $\geq$10 ppm.

APPENDIX H

6 A.M. - 10 A.M. Exposure: (Method 2)
COHb (%) *

Case No.	1970 LINE	1970 AREA	1975 LINE	1975 AREA	1980 LINE	1980 AREA
1.	1.6	1.5	1.5	< 1.25	< 1.25	< 1.25
2.	2.0	1.8	1.8	1.6	< 1.25	< 1.25
3.	2.6	2.1	2.0	1.7	1.5	< 1.25
4.	3.4	3.0	2.7	2.2	1.8	1.5

*COHb includes a 1% background and endogenous value for carbon monoxide concentrations $\geq$ 4 ppm.

APPENDIX B

3 P.M. - 7 P.M. Exposure:

Case No.	Year	Traffic Flow	Wind Velocity	Concentrations Line Source (ppm)	Concentrations Area Source (ppm)
1.	1970	7,825	6	8	6
2.	1970	7,825	4	13	10
3.	1970	22,536	6	22	17
4.	1970	22,536	4	38	28
1.	1975	9,390	6	6	4
2.	1975	9,390	4	10	8
3.	1975	22,536	6	14	10
4.	1975	22,536	4	23	19
1.	1980	11,305	6	3	2
2.	1980	11,305	4	5	3
3.	1980	22,536	6	5	4
4.	1980	22,536	4	9	8

APPENDIX H

3 P.M. - 7 P.M. Exposure: (Method 1)

COHb (%) *

CASE No.	1970 LINE	1970 AREA	1975 LINE	1975 AREA	1980 LINE	1980 AREA
1.	< 1.25	< 1.25	< 1.25	< 1.25	< 1.25	< 1.25
2.	1.30	< 1.25	< 1.25	< 1.25	< 1.25	< 1.25
3.	2.30	1.80	1.6	< 1.25	< 1.25	< 1.25
4.	3.60	2.80	2.[illegible]	2.00	< 1.25	< 1.25

*COHb includes a 1% background and endogenous value for carbon monoxide concentrations > 10 ppm.

APPENDIX H

3 P.M. - 7 P.M. Exposure (Method 2)
COHb (%) *

CASE No.	1970 LINE	1970 AREA	1975 LINE	1975 AREA	1980 LINE	1980 AREA
1.	2.0	1.7	1.7	1.5	∠ 1.25	∠ 1.25
2.	2.3	2.1	2.1	2.0	1.6	∠ 1.25
3.	3.3	2.8	2.6	2.1	1.6	1.5
4.	4.6	3.8	3.4	3.0	2.1	2.0

*COHb includes a 1% background and endogenous value for carbon monoxide concentrations $\geq$ 4 ppm.

In evaluating air pollution conditions, previous experience in carbon monoxide monitoring has been considered. Concentrations in tunnels sometimes peak around 200 ppm but average much lower. Concentrations in trench portions of the Brooklyn Queens Expressway in New York City average around 50 ppm with peaks to 100 ppm during rush hours. At night, values drop as low as 1-2 ppm. (Date from Raritan Depot in Edison, N.J., Station No. 5 of Eastern Regional Air Pollution Congrol Activity, U.S. Dept. of HEW.)

Peak hour travel on East River Drive in New York City produces an average of 100 ppm at roadside. A total of 8000 automobiles produce this peak hour level. This concentration falls to 10-12 ppm at a 50 foot height in apartments built over the one-side-open decked section of the East River Drive. (Data from conference on February 5, 1970 with Dr. Simon, Director of Data and Meteorology of the City of New York Department of Air Resources, regarding the monitoring on a one-sided open decked section of the East River Drive.)

Pollutant Calculation for Non-Perpendicular Wind:

Considering a highway 16 meters wide and a 15 meter receptor distance off the highway, the area-source computation predicts an increase of concentrations by a factor of 1.08 when the wind is oriented at 45° to the roadway. The area-source formula is not, however, amenable to adjustment that would enable the application of a directional deviation (e.g. expressed in terms of the sine of the angle between a perpendicular (normal) wind and a non-perpendicular (non-normal) wind.) This type of adjustment is possible using the line-source calculation of Turner.* In the area-source the non-normal wind must be considered through recalculation of cross-wind distance over the roadway and an increased receptor distance. Both roadway and receptor distances increase with non-perpendicular winds. Each area-source calculation must be examined based on specific distance increases, and cannot be predicted through the use of any generalized relationship. In the specific example of the highway case, a deviation of 45° from the normal predicts a 1.08 increase in concentrations. For deviations greater than 45°, the relationship should not be attempted for reasons pertaining to topography and the possibility of a channeling of pollutants along the roadway.

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*D. Bruce Turner, <u>Workbook of Atmospheric Dispersion Estimates</u>, Public Health Service Publication No. 999-AP-26, (Cincinnati, Ohio: National Air Pollution Control Administration, 1969), p. 40.

APPENDIX I

CARBON MONOXIDE CONCENTRATIONS UNDER VARYING CONDITIONS OF STABILITY

YEAR: 1970

WIND VELOCITY: 4 mph

WIND DIRECTION: Northeast

I. PEAK - HOUR VOLUME = 2,500 automobiles

	Stability Class	Concentrations (ppm) 15 meters from roadside
1)	"D" continuous	13
2)	"C" continuous	9
3)	"A" over roadway "C" on embankment	2

II. PEAK-HOUR VOLUME = 7,200 Automobiles

	Stability Class	Concentration (ppm) 15 meters from roadside
1)	"D" continuous	37
2)	"C" continuous	26
3)	"A" over roadway "C" on embankment	6

KEY TO STABILITY CATEGORIES*

Surface Wind Speed (at 10 m), m sec^{-1}	Day: Incoming Solar Radiation			Night	
	Strong	Moderate	Slight	Thinly Overcast or ≥4/8 Low Cloud	≤3/8 Cloud
< 2	A	A-B	B		
2-3	A-B	B	C	E	F
3-5	B	B-C	C	D	E
5-6	C	C-D	D	D	D
> 6	C	D	D	D	D

The neutral class, D, should be assumed for overcast conditions during day or night.

*Source: D. Bruce Turner, Workbook of Atmospheric Dispersion Estimates, Public Health Service Publication No. 999-AP-26 (Cincinnati, Ohio: National Air Pollution Control Administration, 1969), p. 6.

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