OMSAPC-78-1
II-A-3

Attachment II

An Assessment

of

The Potential Air Quality Impact

of

General Aviation Aircraft Emissions

Prepared by

Bruce C. Jordan

June 17, 1977

Office of Air Quality Planning and Standards

Environmental Protection Agency

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INTRODUCTION

A number of studies have been conducted to assess the impact of aircraft emission on air quality. Most of these studies have been oriented toward the larger airports where the air traffic is heavily dominated by transport (airline) type aircraft. An important segment of the air transportation system is the group of aircraft often referred to as general aviation. This latter group includes a wide variety of aircraft which are used for business, training and pleasure flying.

Emission standards for general aviation aircraft were promulgated in 1973 and will become effective in 1979. Therefore, it is prudent, at this time, to review any new information which has developed since 1973 to determine if current emission standards are adequate to protect the health and welfare of the general public or if any changes in these standards are needed.

In this paper, an attempt is made to place into perspective the emissions from general aviation aircraft, and their potential impact on air quality. Two approaches are used in this assessment. General aviation aircraft emissions are compared on a national, regional and local basis, with emissions from other categories of aircraft. Historical studies are used to relate the potential impact of emissions from general aviation aircraft to that noted from studies oriented around other types of aircraft. Mathematical modeling of a busy general aviation airport is then used to more specifically assess the impact of general aviation aircraft on air quality in the vicinity of the airport.

AIRCRAFT EMISSIONS

On a nationwide basis, aircraft are estimated* to contribute the following percentages of the emission of various air pollutants:

Particulates	1.00%
Carbon Monoxide	0.86%
Hydrocarbons	2.04%
Nitrogen Oxides	0.72%

The above percentages are for all aircraft including transport (airline, etc.), military, and general aviation. Similar percentages for general aviation aircraft alone are shown below:

Particulates	0.07%
Carbon Monoxide	0.27%
Hydrocarbons	0.20%
Nitrogen Oxide	0.04%

The above figures are indicative that on a nationwide basis, aircraft contribute a relatively small percentage of the total emissions, and that general aviation aircraft emissions constitute only a small portion of the total aircraft emissions. With these small percentages, it is not meaningful (or possible within the accuracy of any existing air quality models) to discuss the impact of aircraft emissions from a nationwide standpoint.

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* National Emissions Data System (NEDS), Research Triangle Park, North Carolina.

Table 1 provides an estimate of the contribution of total emissions by aircraft for several air pollutants in ten selected air quality control regions (AQCR's). These ten regions provide a representative sample of areas which experience a large amount of aircraft traffic. The data displayed in Table 1 indicates that even on an AQCR basis, aircraft emissions, especially those from general aviation aircraft, constitute a very small percentage of the total emissions.

Thus, on both a national and an AQCR-wide basis, aircraft emissions are relatively small compared to total emissions. Therefore, the most significant air quality impacts of aircraft emissions must occur in more localized areas where aircraft concentrations are higher. Such areas, frequently called terminal areas, are found in the general vicinity of airports.

REVIEW OF HISTORICAL STUDIES AROUND AIRPORTS

As stated in the introduction, a number of studies have been conducted around major airports to assess the impact of aircraft emissions on air quality. A review of the findings from these studies will be beneficial in subsequent discussions on the impact of general aviation aircraft.

Northern Research and Engineering Corporation Study

One of the earliest comprehensive airport studies was performed in 1971 by the Northern Research and Engineering Corporation[1/] for the Environmental Protection Agency. During this study a mathematical dispersion model was developed and utilized to study air quality impacts

Table 1

Percentage of Total Emissions of
Various Air Pollutants from Aircraft Operations
1975

AQCR	Carbon Monoxide All Aircraft	Carbon Monoxide General Aviation	Hydrocarbons All Aircraft	Hydrocarbons General Aviation	Nitrogen Oxides All Aircraft	Nitrogen Oxides General Aviation	Particulates All Aircraft	Particulates General Aviation
Los Angeles	0.72%	0.30%	1.30%	0.20%	0.81%	0.07%	2.70%	0.33%
San Francisco	0.87%	0.39%	1.60%	0.30%	1.20%	0.10%	2.10%	0.47%
NY-NJ-Conn	0.44%	0.11%	0.70%	0.08%	0.50%	0.02%	0.27%	0.08%
Chicago	0.39%	0.07%	0.70%	0.05%	0.59%	0.06%	0.14%	0.02%
St. Louis	0.76%	0.11%	1.80%	0.07%	0.45%	0.01%	0.85%	0.03%
Cincinnati	0.11%	0.06%	0.40%	0.14%	0.30%	0.03%	0.05%	0.03%
Baltimore	0.59%	0.10%	0.80%	0.04%	0.73%	0.02%	0.87%	0.05%
Boston	0.58%	0.21%	0.84%	0.13%	0.71%	0.02%	0.67%	0.21%
Houston	1.15%	0.58%	0.80%	0.20%	0.65%	0.07%	1.30%	0.30%
S.E. Wisc.	0.37%	0.15%	0.30%	0.05%	0.40%	0.03%	0.12%	0.06%

of several major airports; including Los Angeles International, Chicago O'Hare, New York JFK, and Washington National. Also some limited modeling was performed at two general aviation airports, Van Nuys in Los Angeles and Tamiami in Florida. The model developed by Northern Engineering is frequently referred to as the NREC model.

In the NREC model, aircraft emissions were separated from other sources located on or in the vicinity of the airport so that the impact on air quality from aircraft emissions could be assessed and compared to the impact caused by other source categories.

The NREC model had no capability to account for the reactive nature of several of the pollutants emitted from aircraft and in the initial study no attempt was made to verify the model through comparison with monitoring data.

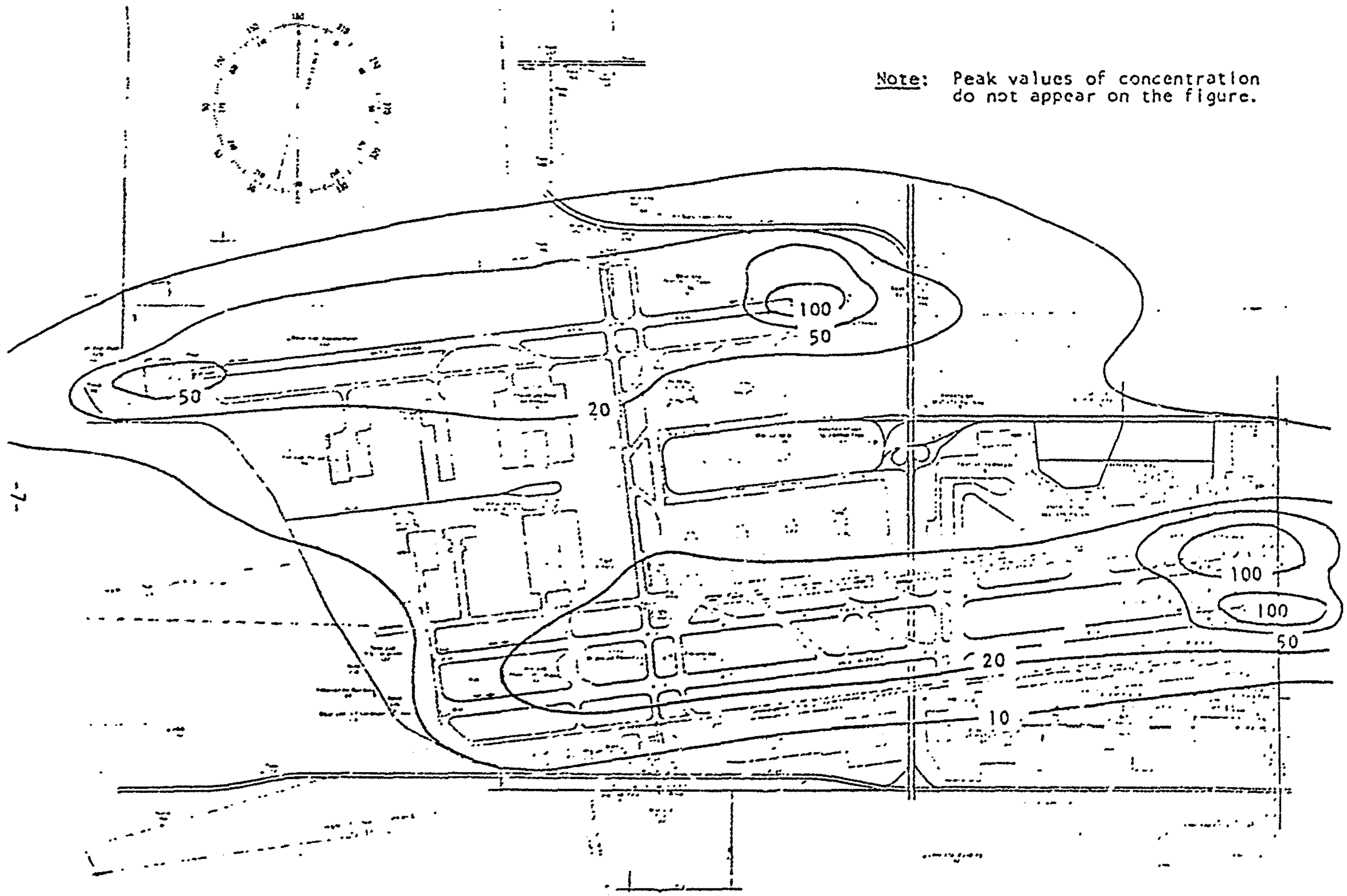
The general findings from the NREC study are perhaps best discussed by the individual pollutants. For carbon monoxide, aircraft emissions were calculated to be sufficiently high to cause violations of the national CO standard in several locations. Most of these violations were found to occur on (or very near) the airport property. The calculated concentrations of CO from aircraft emissions dispersed very rapidly in areas surrounding the airport. Generally, at distances in excess of a few kilometers from the airport, contributions of CO by aircraft emissions were found to be less than 10 percent of the national CO standards.

Although the NREC model did not have the capability to treat the reactive pollutants, very high levels of nitrogen oxide (NO_x) concentrations were estimated at several locations on the airport property such as near the departure end of runways, etc. Assuming that a high percentage of the NO_x was in the form of nitrogen dioxide (NO_2), aircraft operations were predicted to cause violations of the national NO_2 standard at several locations on the airport property. Figures 1 and 2 which have been extracted from Reference 1, provide some idea of how annual average NO_2 levels were estimated to vary at points in the vicinity of Los Angeles International Airport, and the contribution of aircraft emissions to these concentrations.

As can be seen by comparing these two figures, aircraft emissions were estimated to account for approximately 50 percent of the total NO_2 near the ends of the runway, but only about 10 percent of the NO_2 levels at locations near the airport fence line (except where the fence line is near the end of the runway).

Concentrations of hydrocarbons were also calculated assuming no reactivity. The results provided indications that during the early morning hours (6:00 to 9:00 AM) high levels of hydrocarbon concentrations from aircraft emissions could be expected to occur both on the aircraft surface, and at distances considerably downwind of the airport property. It is generally believed that hydrocarbons emitted during the early morning hours are one of the primary pollutants that lead to ozone and other photochemical oxidant formation during the afternoon hours.

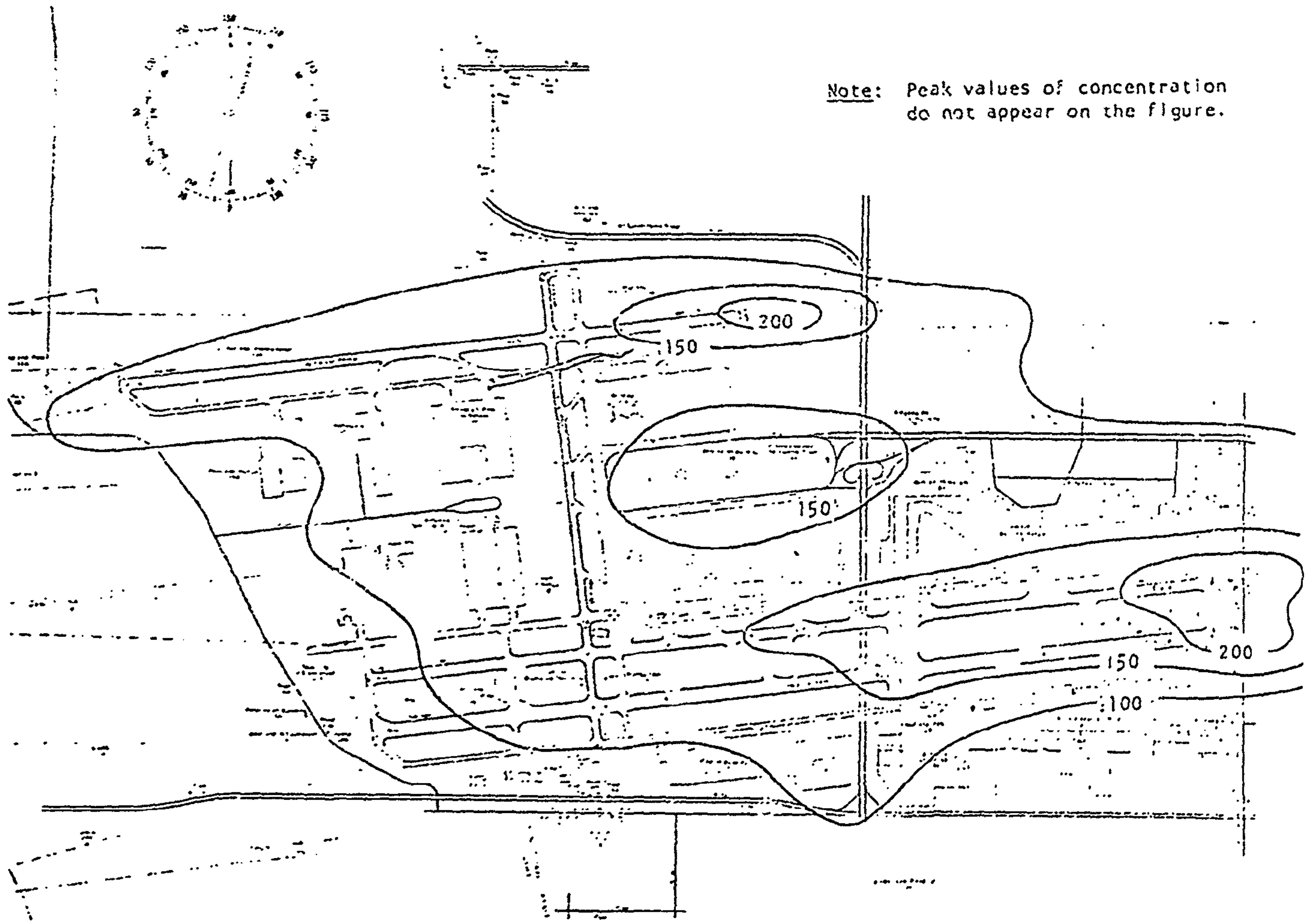
Other pollutants were also investigated, however since the purpose of the present paper is to focus on general aviation aircraft, and the



(numbers in $\mu g/m^3$)

FIGURE 1 - NO_2 ISOPLETHS AT LOS ANGELES INTERNATIONAL: AIRCRAFT SOURCES

Annual average for 1970 as estimated in Reference 1.



(numbers in $\mu g/m^3$)

FIGURE 2 - NO_2 ISOPLETHS AT LOS ANGELES INTERNATIONAL: TOTAL EMISSION SOURCES

Annual average for 1970 as estimated in Reference 1.

above three pollutants are of primary concern for this category of aircraft, no discussion of other pollutants will be presented.

Environmental Protection Agency Study

In Support of Aircraft Emission Standards

Following the above work by NREC, the EPA conducted an analysis to determine if emission standards on aircraft were needed. The results of this study are contained in Reference 2. Briefly, the EPA found that at some of the larger airports, CO emissions from aircraft could cause or significantly contribute to violations of the CO standard at locations where the general public could be exposed. While highest CO levels were found on the airport property, the EPA estimated that aircraft emissions could cause (or significantly contribute) to violations of the CO standard in nearby residential areas. Figure 3 (from Reference 2) contains isopleths of the percent contribution to CO levels by aircraft in the vicinity of Los Angeles International Airport. This figure indicates that under some conditions up to 70 percent of the CO in some residential areas near the airport could be attributed to aircraft emissions. Monitoring data was used to show that in such areas violations of the 8-hour CO standard could be expected to occur several times per year unless CO emissions from aircraft were controlled.

The EPA study also concluded that at the larger airports, concentrations of NO_2 as the result of aircraft emissions could contribute substantially to NO_2 levels in areas near the airport property. Figures 4 and 5 are isopleths of predicted annual NO_x concentrations for 1970 and 1980

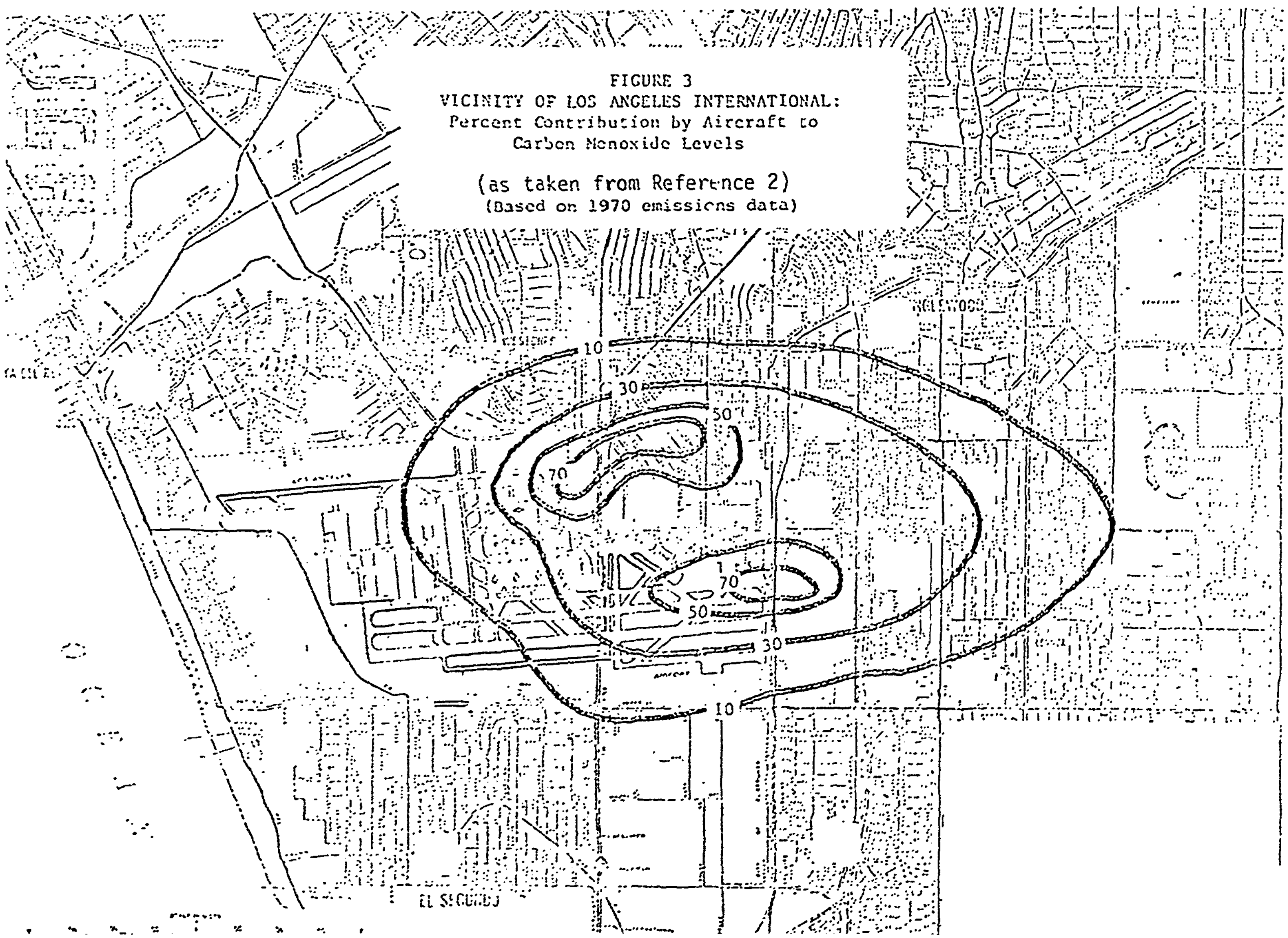
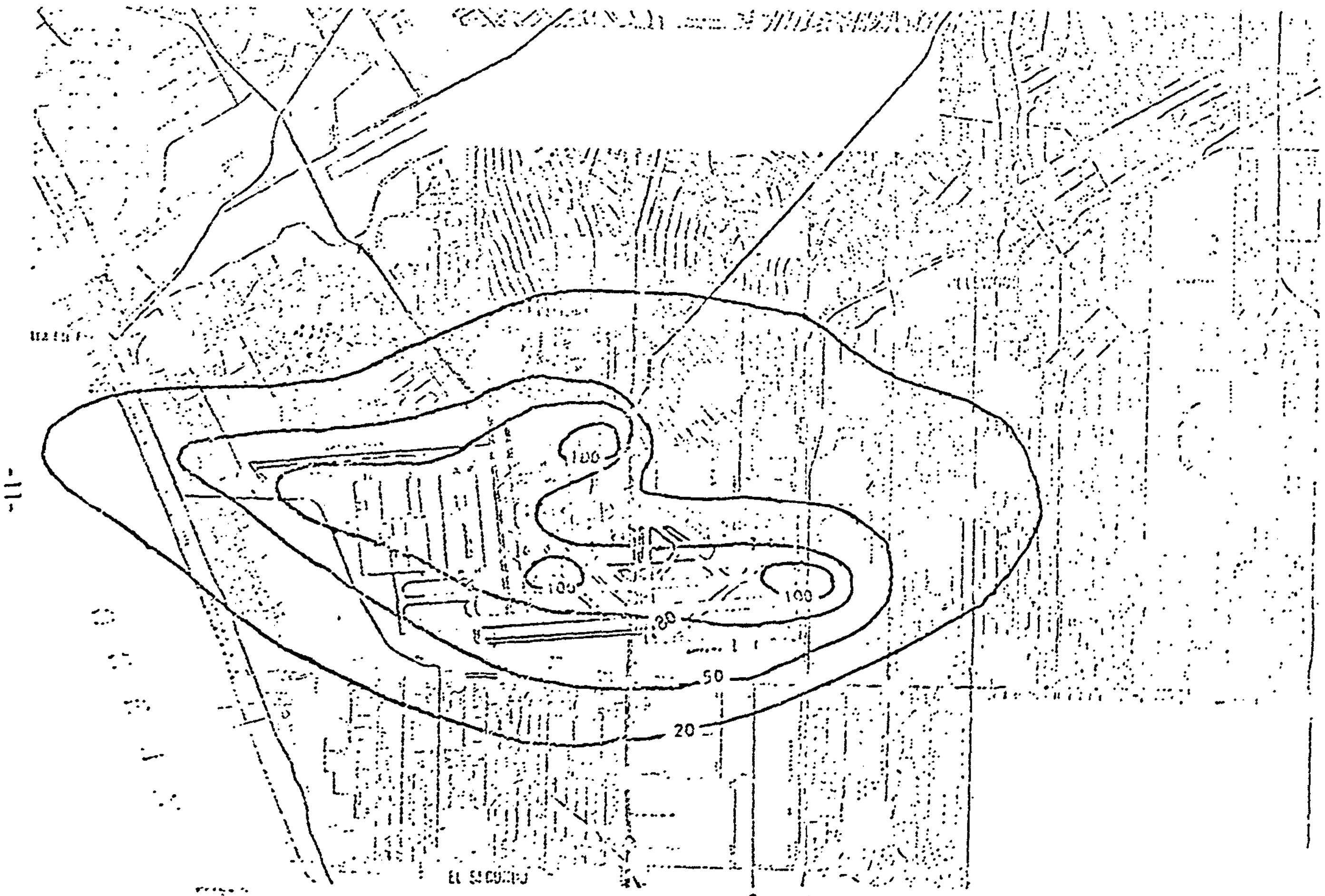


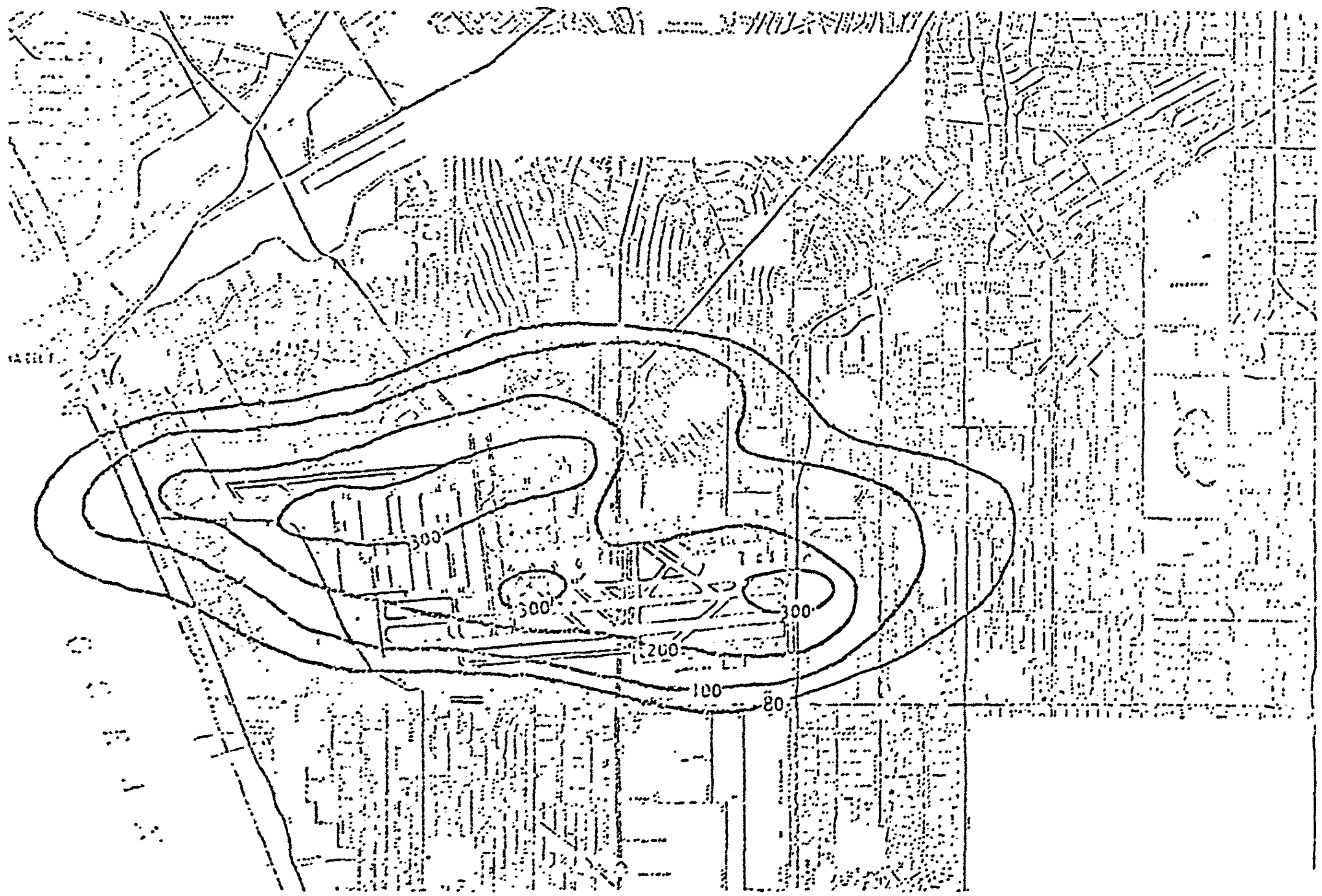
FIGURE 3
VICINITY OF LOS ANGELES INTERNATIONAL:
Percent Contribution by Aircraft to
Carbon Monoxide Levels

(as taken from Reference 2)
(Based on 1970 emissions data)



(numbers in $\mu g/m^3$)

FIGURE 4 NO_x ISOPLETHS IN THE VICINITY OF LOS ANGELES INTERNATIONAL: AIRCRAFT SOURCES
Annual Average for 1970



(numbers in $\mu g/m^3$)

FIGURE 5 NO ISOPLETHS IN THE VICINITY OF LOS ANGELES INTERNATIONAL: AIRCRAFT SOURCES
Annual Average for 1980

around Los Angeles International Airport as estimated in the above EPA study. Note that the isopleths are for NO_x concentrations while the air quality standard is for NO_2. However, the above study indicated that high levels of NO_x concentrations as a result of aircraft emissions extend well into the residential area around the airport. Projected growth indicated a sharp increase in NO_x concentrations between 1970 and 1980. Similar conclusions were reached for other large airports as shown in Figure 6.

The EPA study further found that hydrocarbons emitted by aircraft at large airports could cause significant build up of this pollutant during the earlier morning hours. This build up could lead to high levels of photochemical oxidant later during the day after the air has moved into areas where large numbers of people live or work. The 1980 projected average hydrocarbon concentrations during the 6:00 to 9:00 AM time period on worst days at Los Angeles International Airport are shown on Figure 7.

Geomet Validation Study

The NREC study was criticized for not having validation data to support its conclusions. Since much of the above EPA study was based on the NREC results, it too was highly criticized. Consequently, in 1974, Geomet, Incorporated, conducted a study[3/] to validate the NREC model. This study was conducted using monitoring data collected during a six month period at Washington National Airport.

Geomet found that the results of the NREC model did not correlate very well with the monitoring data. The NREC model was found to generally under predict emissions, in some cases by a factor of 10 or more. An

(ıs taken from Reference 2)

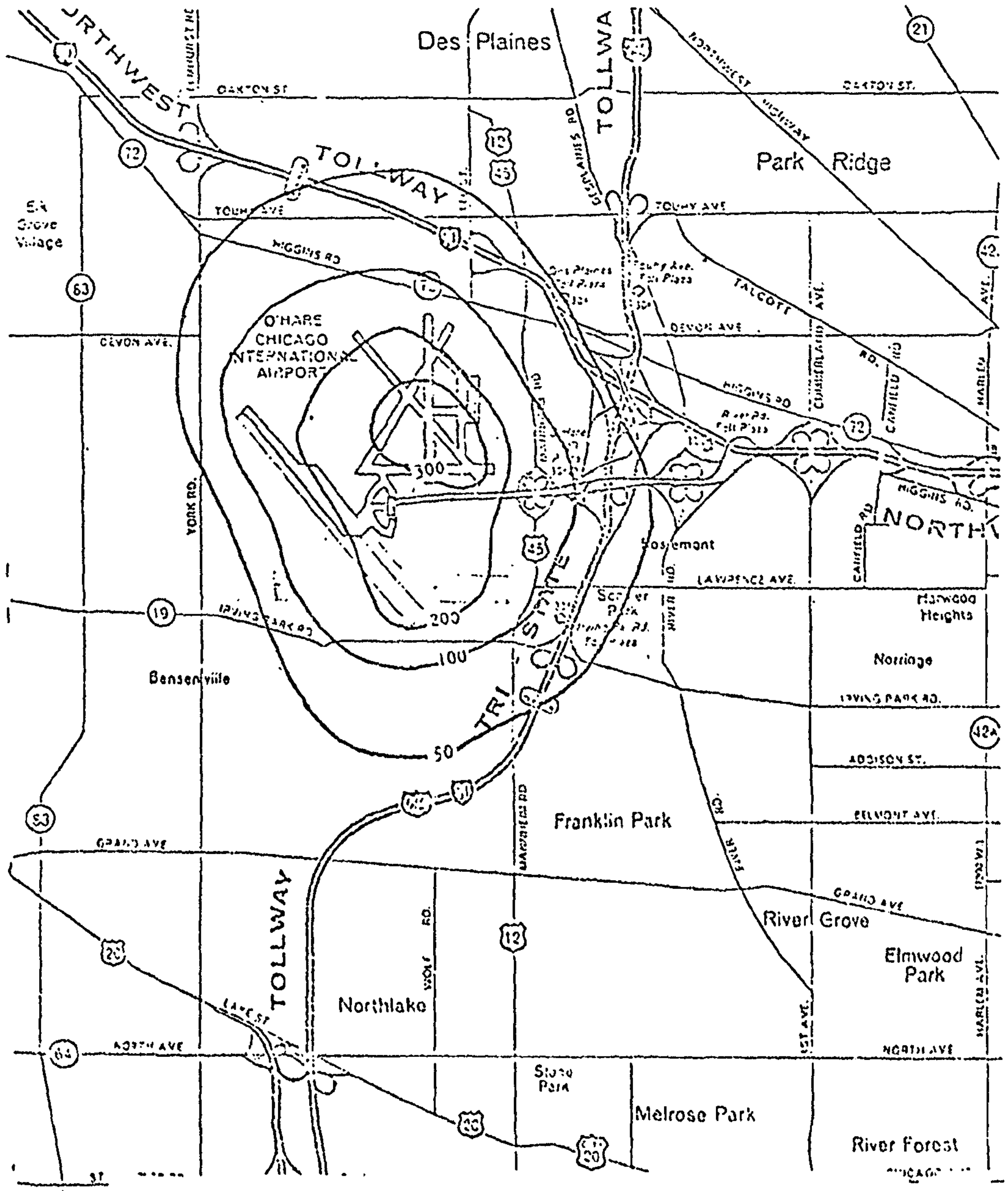
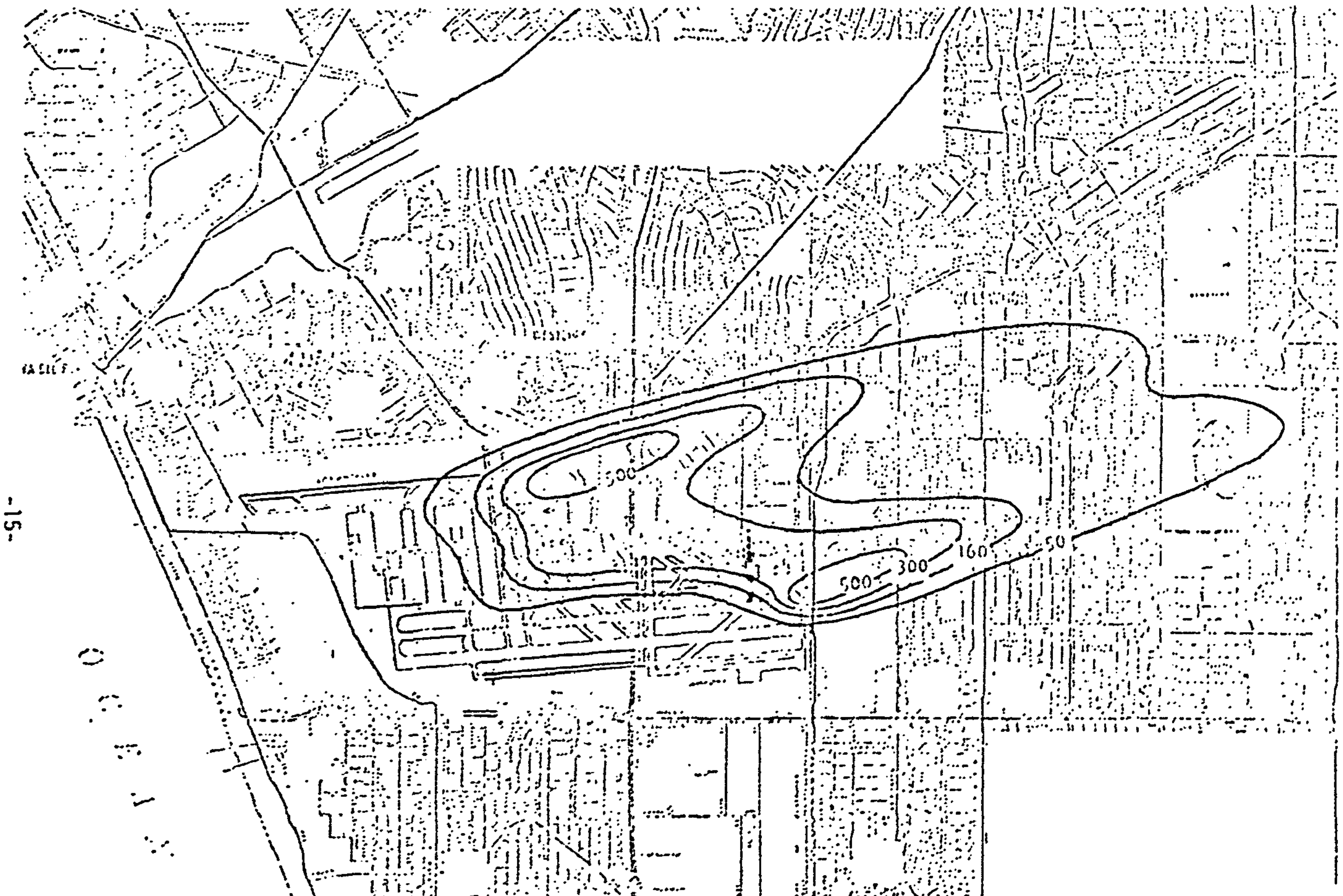


FIGURE 6 (numbers in µg/m³)

NO_x ISOPLETHS IN THE VICINITY OF CHICAGO-O'HARE INTERNATIONAL: AIRCRAFT SOURCES

Projected Annual Average for 1980



(numbers in $\mu g/m^3$)

FIGURE 7 HYDROCARBON ISOPLETHS IN THE VICINITY OF LOS ANGELES INTERNATIONAL: AIRCRAFT SOURCES

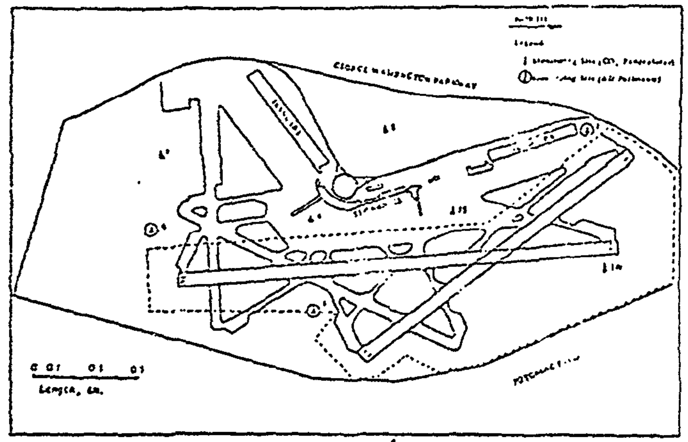
Projected 3-Hr Average f(. 1980 (6 - 9AM) on worst days
(as taken from Reference 2)

improved version of the NREC model was developed by Geomet and was used to demonstrate that reasonable correlation between airport dispersion models and monitoring data could be obtained. The monitoring data collected and used in the Geomet study is summarized in Table 2. Corresponding locations of the monitoring sites are indicated on the insert of the table.

From Table 2 it can be seen that violations of both the 1-hour (40 ug/m^3) and 8-hour (10 ug/m^3) CO standard were recorded at several of the monitoring sites. Unfortunately, the monitoring data cannot be differentiated into aircraft and other source category emissions. However, by examining the monitoring site locations (see Table 2), it would appear that the monitoring data tends to support the general findings of both the NREC and EPA studies. That is, emissions from aircraft can cause high levels of CO at locations on the airport property. It is particularly interesting that some of the highest recorded CO concentrations were found in the ramp area where passengers embark and disembark. This is probably due to a combination of the concentration of slow moving aircraft, operation of ground power units, and operation of auxilary equipment such as baggage tow trucks. Also it is interesting that both the peak and highest mean CO levels were found in the maintenance area at the southern end of the field. Finally, it would appear that monitoring site number 3 (see Table 2) was somewhat isolated from sources other than aircraft. The highest recorded value for this particular monitoring site was 71 percent of the 8-hour CO standard and 27 percent of the 1-hour standard.

Table 2 Summary of Six Months of Air Quality Observations at Washington National Airport

Pollutant	Number of Observations	Median Value	Mean Value	99th Percentile Value	Maximum Value
Carbon Monoxide - 1-hour values, mg/m³					
Station					
1	2221	1.72	2.48	12.2	[illegible]
2	3272	1.33	1.52	5.46	16.3
3	2913	1.42	2.12	4.26	13.5
4	2975	3.45	4.43	17.1	42.1
5	4137	2.22	2.95	5.20	19.4
6	3283	1.29	1.37	4.00	9.25
7	4004	2.02	4.97	18.5	25.1
8	1974	1.75	[illegible]	4.20	11.4
Total Obs.	27,266				
Carbon Monoxide - 8-hour values, mg/m³					
Station					
1	293	2.14	2.56	9.17	12.0
2	478	1.12	1.52	5.33	9.63
3	613	1.45	2.10	5.24	7.06
4	503	3.26	4.50	12.5	21.6
5	1024	2.45	3.2	7.76	12.6
6	381	1.22	1.53	4.44	7.25
7	572	3.16	5.19	22.0	83.3
8	312	1.64	1.87	6.10	8.10
Total Obs.	4,342				
Non-Methane Hydrocarbons - 3-hour values, µg/m³					
Station					
2	1222	455	1258	7740	9564
3	2129	366	321	1828	4443
6	1672	1223	1256	2461	6213
Total Obs.	5,237				
Non-Methane Hydrocarbons - 6-9 a.m. values, µg/m³					
Station					
2	104	465	553	8637	5643
3	73	311	329	2258	2834
6	73	1229	1187	7371	1834
Total Obs.	255				
Nitrogen Dioxide - 1-hour values, µg/m³					
Station					
2	3428	145	152	428	631
3	2214	104	149	545	629
6	2012	83.6	127	427	623
Total Obs.	[illegible]				
Particulates - 24-hour values, µg/m³					
Station					
1	77	42.8	44.4	130	141
2	173	81.9	82.3	180	272
3	149	45.1	54.2	105	144
4	325	93.7	97.9	160	153
5	175	73.6	77.5	149	159
6	152	64.9	68.9	137	267
7	134	128	132	286	435
8	75	63.1	65.6	126	122
Total Obs.	1,175				



For nitrogen dioxide, only three monitoring sites were used (sites 2, 3 and 6 on Table 2). As noted in Table 2, all three recorded mean values in excess of 100 ug/m^3 during the six month period (the ambient standard is 100 ug/m^3 annual average concentration). At least one of these monitoring locations (site 2) could have been strongly influenced by automobile traffic from a nearby heavily traveled highway.

Both the 1-hour and the 6:00 to 9:00 AM average concentration of non-methane hydrocarbons were recorded at three monitoring sites (sites 2, 3 and 6 on Table 2). Very high levels of hydrocarbons were recorded at all three monitoring sites with average concentrations between 6 and 9 AM ranging from 320 to 1187 ug/m^3. Although ozone levels were not measured, the ratio of non-methane hydrocarbons to NO_2 indicates that the atmosphere around the airport is quite conducive to the formation of ozone.

The primary purpose of the Geomet study was to validate model results, consequently little effort was expended to separate the impact of aircraft emissions from that caused by other sources However, it is interesting that Geomet does point out that except for a few occassions, aircraft emissions appear to contribute a relatively small percentage to the total air pollution around Washington National Airport, with the majority of the burden being imposed by the surrounding major highways and environ area sources (see page 6 of reference 3).

Other Studies Using Geomet Model

As mentioned above, the Geomet study conducted at Washington National Airport lead to the development of a mathematical model frequently referred to as the Geomet model. Versions of this model have been used in several other studies, the bulk of which have been air quality assessments associated with the preparation of Environmental Impact Statements (References 4, 5 and 6). One such analysis was performed to predict the impact that a proposed expansion of Salt Lake City Airport would have on future air quality (see Reference 4). This analysis revealed that with the current levels of aircraft emissions, violations of the CO 8-hour standard could be expected to occur as the result of emissions from airport sources. These violations, however, would be confined to the immediate airport surroundings and the impact of CO emitted by airport sources would have negligible impact on areas outside the airport. Assuming that applicable aircraft emission standards for both aircraft and other sources were implemented, no violations of the CO standard were projected to occur in 1985 even with the projected increase in aircraft traffic.

Figure 8 provides a summary of the results of the Salt Lake City Airport analysis for nitrogen oxide emissions. This figure is interesting in that it provides a means of comparing the predicted impact on air quality of a medium size airport to that previously found for a larger airport. Also it provides a means of comparing, at various locations, the contribution to predicted NO_x concentration levels by both aircraft

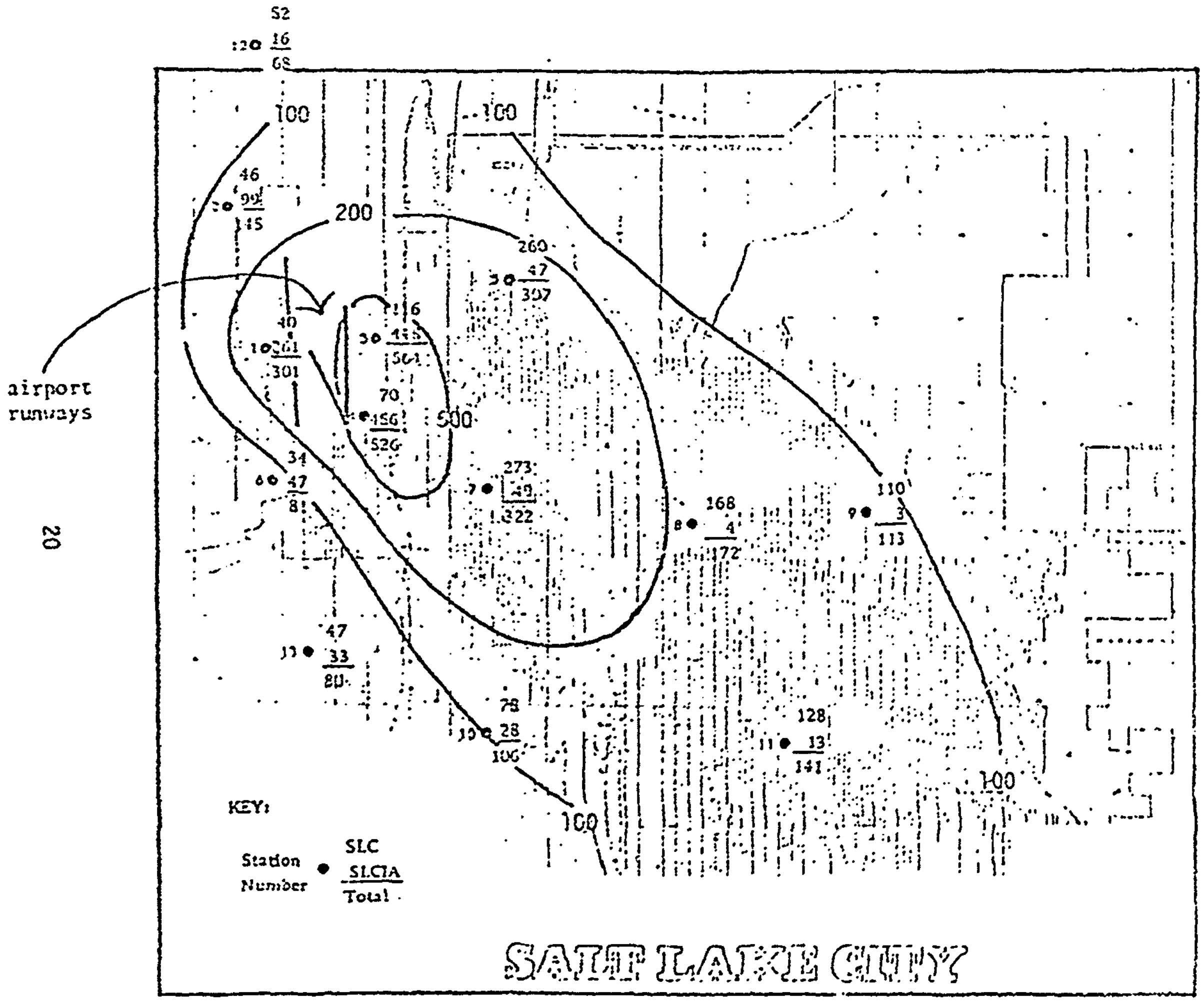


Figure 8 Mean Annual Predicted Values of NO_x showing contributions for airport sources (SLCIA) and non-airport sources (SLC), and totals, in micrograms/cu. m. Contour lines are drawn for totals.

(as taken from Reference 4)

and other sources of NO_x. Note that in the immediate vicinity of the airport, calculated levels of NO_x are high and that aircraft emissions account for a large portion of the total concentrations. However, at increasing distances from the airport property, the contribution to NO_x concentrations by aircraft emissions diminishes very rapidly.

High concentration levels of hydrocarbons were also predicted to occur in the near vicinity of the airport as the result of aircraft emissions. However, substantial reductions in these concentration levels were projected to occur by 1985 as the result of current aircraft emission standards.

Another study (References 5 and 6) involving the use of the Geomet model was conducted for an airport proposed to locate in the vicinity of Cleveland, Ohio. The conclusions reached were similar to those discussed above, except that it was found that the location site of the airport could significantly influence the air quality impacts, due to the historical prevailing wind patterns.

Studies Conducted by Argonne National Laboratory

The Argonne National Laboratory has developed two mathematical models for use in determining the impact of aircraft emissions on air quality. These models are referred to as the Airport Vicinity Air Pollution (AVAP) model developed for the Federal Aviation Agency, and the Air Quality Assessment Model (AQAM) developed for the U.S. Air Force. Validation studies for the above two models have been conducted using monitoring data from Washington National Airport.

Several studies have been conducted using the two Argonne developed models. In two such studies using Washington National Airport (References 7 and 8), conclusions similar to those previously discussed were reached. In addition, these Argonne studies noted that under certain conditions the combining of pollutants from the airport and other sources (such as from downtown Washington, D.C.) could cause violations of the national air quality standards for CO, photochemical oxidant, NO_2 and TSP in locations downwind of the airport. These studies expressed concern that any future increases in emissions either from the airport or surrounding areas could possibly lead to significant violations of the national air quality standards, both on the airport property and in the outlying areas.

One of the most extensive efforts to define and assess the impact of aircraft emissions on air quality has been undertaken by the U.S. Air Force. A summary of the results from this effort is contained in Reference 9. Briefly, ten air force bases were modeled to determine what impact aircraft flights might have on air quality in neighborhoods around the base. The findings from these studies tend to indicate that NO_x and CO emissions from air force aircraft have little to no effect on air quality outside the base. Even within the base areas, there were relatively few areas where CO and NO_x concentrations were found to be excessively high as the result of aircraft operations. On the other hand, the build up of hydrocarbon concentrations during the early morning hours as a result of aircraft operations, was found to be sufficiently high to cause concern over the potential for photochemical oxidant generation even in areas considerably downwind of the base.

Studies Conducted by Systems Applications Incorporated

The previously discussed studies have all been severely handicapped in that no capability existed to treat the reactive properties of the hydrocarbon and nitrogen oxide emissions. Consequently, the results do not adequately account for the potential of aircraft emissions to form ozone and other photochemical oxidants.

In reference 10, Systems Applications Incorporated (SAI) attempted to better define the potential role that jet aircraft emissions may play in ozone formation. The SAI study found that the mixture of hydrocarbons and nitrogen oxide emissions from aircraft was quite different than that from automobiles. The ratio of non-methane hydrocarbons to nitrogen oxides emitted from aircraft tends to be relatively high compared to that from automobiles. In isolation from other emission sources air containing jet exhaust was found not to be very conducive to the formation of high levels of ozone (because of the high $NMHC/NO_x$ ratio). However, under conditions where the air containing jet exhaust mixes with air containing automobile exhaust, the net result is to make the air much more conducive to forming ozone than would be the case where the air contained only automobile exhaust. For this reason, the SAI study indicates that around major airports, where there exists a high volume of automobile traffic, emissions from jet engines can significantly affect the levels of ozone generated in the ambient air.

OVERVIEW OF AIRCRAFT STUDIES

The purpose of the preceeding review was primarily to set the stage for the discussion to follow. Therefore, it is prudent to briefly summarize the findings from the historical airport studies. While there are many caveats which need to be placed on each individual airport study, there appears to be some general agreements and conclusions that all studies support. These include:

(1) Emissions from aircraft at major airports are sufficiently high enough to cause the airport to be a local "hot spot" source of CO, HC, and NO_x as well as other pollutants.

(2) Around major airports, CO emissions from aircrafts are high enough to cause violations of the national CO standards. However, the locations which experience CO violations will usually coincide very closely with areas where the concentration of aircraft is high (i.e., parking ramps, departure/delay queues and the ends of runways). Also high CO levels can be experienced when ventilation is poor, or where obstructions to natural dispersion (such as buildings, etc.) occur. The historical studies indicate that the CO from aircraft disperses very rapidly and probably would not by itself cause violations of the standard in locations much beyond the airport perimeter. However, there may be situations where CO from major airports could aggravate a local problem in areas close to the airport.

(3) Some uncertainty exists over the potential impact NO_x emissions from aircraft have on both NO_2 and photochemical oxidant levels. There

are good indications that aircraft emissions at major airports contribute substantially to high NO_2 levels in areas near the ends of runways and possibly at other points on the airport surface. Also some of the studies have shown that aircraft emissions at major airports contribute substantially to high NO_x concentrations in areas around the airport. Other studies indicate that at medium size air terminals (such as the Salt Lake City Airport) NO_x emissions from aircraft have a relatively small impact on NO_x concentrations in the immediate area adjacent to the airport.

(4) There seems to be good agreement between all study efforts that hydrocarbon emissions from aircraft at major and medium size air terminals result in high levels of this pollutant being experienced both on and off the airport property. These levels appear to be high enough to cause violations of the photochemical oxidant standard in situations where sources of NO_x may be present.

Comparison between Emissions from General Aviation Aircraft and Other Aircraft

As previously stated, most of the historical studies have been conducted around major airports where the air traffic is primarily composed of transport type aircraft. While efforts to study the impacts of smaller aircraft could be done using existing models, such efforts would be time consuming and require considerable expense and manpower. This is because most existing models are data intensive, requiring detailed emission inventories both for the aircraft and other sources around the airport. For major airports already modeled, general aviation traffic is only a small portion of the total traffic and it is doubtful that much could be learned by modeling the general aviation traffic separately. Much can be learned, however, by comparing emissions from general aviation aircraft and other types of aircraft and using this comparison to quantitatively extrapolate the results from existing studies to general aviation.

Reference 11 contains perhaps the most up to date compilation of emissions from aircraft at several airports. In this reference, emissions are appropriately accounted for by using distributions of the different type aircraft normally operated at the individual airports. This includes mixtures of jet transport, military, helicopters, business jet and other general aviation aircraft.

Table 3 provides a breakdown of emissions from various aircraft operating at three major airports; John F. Kennedy, Los Angeles International, and Chicago O'Hare. The emission data in Table 3 is divided into three categories of aircraft. Transport (2, 3 and 4 jet-engine airliners), general aviation and air taxi (actually the air taxi and general aviation fleet contain similar type aircraft). Also shown in Table 3 are emissions from auxiliary power units used by the transport aircraft during ground operations. The emissions shown on the table are annual values and include all aircraft operations below 3,000 feet.

Table 3

Estimated Emissions by Various Aircraft
Operations During 1975
(in tons per year)

Type Aircraft	JFK			LAX			ORD		
	HC	CO	NO_x	HC	CO	NO_x	HC	CO	NO_x
Transport	9082	14,513	3141	5739	10,243	3,349	6,799	13,876	4,562
Air Taxi	20	54	3	37	53	7	91	98	14
Gen. Aviation	26	161	5	133	538	45	45	432	9
APU	14	394	315	15	343	346	16	418	429

Two important points can be made from the data contained in Table 3. First, the magnitude of emissions from aircraft at these major air terminals is far in excess of the level normally associated with a major stationary source (a stationary source is normally considered major if it emits 100 tons/year or more of any pollutant). Secondly, nearly all the emissions shown in Table 3 are from transport aircraft. Consequently, the air quality impact of these emissions are primarily due to large jet aircraft.

Table 4 provides aircraft emission data for five airports (two combined in San Jose because of their close proximity) which are heavily dominated by general aviation traffic. The emission data shown in Table 4 are for general aviation aircraft operations only.

Van Nuys Airport in California is the busiest general aviation airport in the U.S. and ranks third in total operations among all airports. For comparison purposes, the total number of aircraft operations at Van Nuys in 1975 exceeded 588,000, while total operations at John F. Kennedy during the same year were approximately 335,000. General aviation accounts for over 90 percent of the total traffic at Van Nuys (VNY). The 1974 HC, CO and NO_x emissions from Van Nuys Airport as the result of general aviation traffic are shown below along with similar emissions from transport aircraft (1975 emissions) operating at John F. Kennedy (JFK), Los Angeles International (LAX), and Chicago O'Hare (ORD).

Table 4

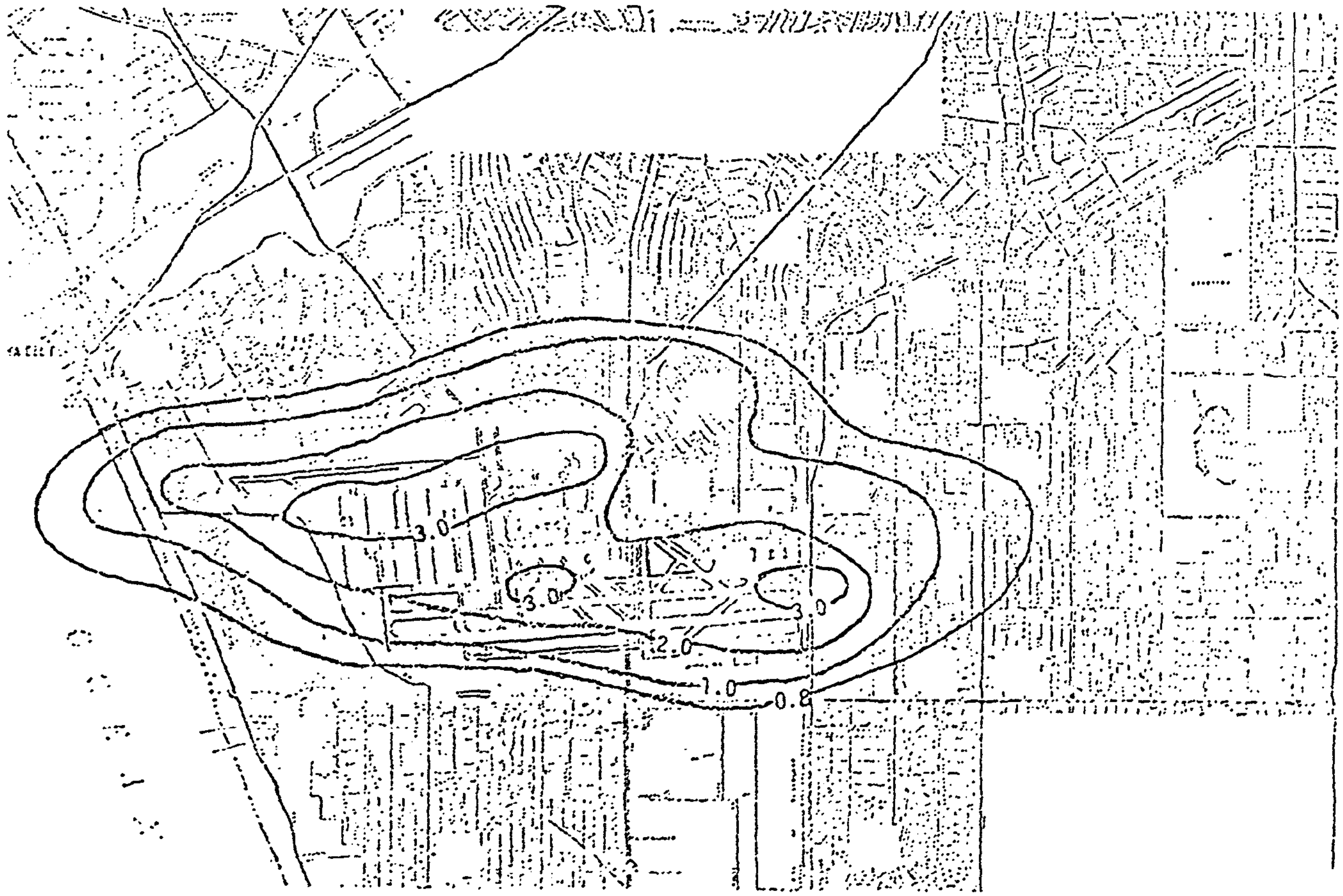
Estimated Emissions During 1974 from
General Aviation Aircraft Operations
(in tons per year)

Airport	Percent of Total Traffic	HC	CO	NO_x
Van Nuys	92	56	2488	10
Tamiami	91	35	1551	6
Phoenix	71	33	1448	6
Fairbanks	86	14	631	3
San Jose Municipal/ San Jose Reid	84	64	2827	12

	Emissions (tons/year)		
Airport	HC	CO	NO_x
VNY	56	2488	10
JFK	9082	14513	3141
LAX	5739	10243	3349
ORD	6799	13876	4562

Recall that even with the large magnitude of HC and NO_x emissions from aircraft at the major airports, there has been some uncertainty in assessing the impact such emissions have on air quality in areas around the airport. Intuitively then, the magnitude of the HC and NO_x emissions from general aviation aircraft at Van Nuys Airport are so small that there is little probability any of the existing models would show any significant impact of such emissions on air quality in the area adjacent to the airport.

As an illustration, consider Los Angeles International where, in Reference 11, it is estimated that by 1980 NO_x emissions from general aviation aircraft will be approximately 53 tons/year or about one percent of the total NO_x emissions from aircraft. Recall that Figure 5 contained estimated NO_x isopleths around Los Angeles International for 1980 as the result of all aircraft traffic. Assuming that the isopleths are composed of NO_x concentrations in direct proportion to the different type aircraft operating at the Los Angeles Airport, similar isopleths can be constructed for each type aircraft. Figure 9 contains estimated NO_x isopleths for 1980 at Los Angeles International as the result of general aviation



(numbers in $\mu g/m^3$)

Figure 9 Estimated NO_x Isopleths In The Vicinity of Los Angeles International
As The Result of General Aviation Aircraft
Annual Average for 1980

traffic only. As can be seen, the NO_x concentrations from general aviation aircraft appear to be very small both on the airport property and in the adjacent area.

The above illustration is not entirely valid since general aviation aircraft operations at Los Angeles International would not be uniformly spread over the same area as emissions from transport aircraft. That is, general aviation aircraft operations would tend to be confined to a smaller area of the airport, and most such operations would be from a single runway. Nevertheless, since the 1980 NO_x emissions from general aviation aircraft at Los Angeles International are projected to be over five times greater than similar emissions currently being experienced at Van Nuys, the illustration does indicate that NO_x emissions from general aviation aircraft at Van Nuys probably have very small air quality impacts.

The magnitude of carbon monoxide emissions at Van Nuys, although considerably smaller than at JFK New York, Los Angeles International and Chicago O'Hare, is sufficiently large enough to warrant further assessment of the potential impact these emission may have on air quality. This analysis will be presented in more detail later.

Hydrocarbon emissions from general aviation aircraft at Van Nuys are considerably below 100 tons per year. Within the accuracy of existing models, complete removal of these emissions would probably not significantly alter projected air quality in the Van Nuys Airport area.

While it cannot be shown with any degree of certainty that the HC emissions at Van Nuys (and other general aviation airports) have any significant impacts on air quality, it must be remembered that a large portion of the hydrocarbon emissions in an urban area come from relatively small and diversely located sources. The additive impact on air quality of these many small sources can be significant in some situations. Nevertheless, except for a relatively few airports which experience a high volume of general aviation traffic, it appears that very small air quality benefits can be expected from the exhaust emission control of HC on general aviation aircrafts. Thus, a more appropriate measure of whether or not such controls should be required is perhaps their cost-effectiveness as compared to the cost-effectiveness of controlling other sources with similar emission magnitudes. Table 5 provides a comparison of the magnitude of HC emissions from several sources in the Baltimore AQCR during 1973.

The HC emissions thus far discussed have all been from aircraft engine exhaust. Very little work has been accomplished to date toward estimating evaporative emissions from gasoline powered aircraft. However, some rough calculations have indicated that the evaporative emissions from such aircraft may be considerably higher than the HC emitted through the exhaust. For example, the San Diego County Air Pollution Control District recently estimated that HC evaporative emissions from general aviation aircraft were over twelve times greater than from exhaust (Reference 12). Also some rough hand calculations indicate that

Table 5

1973 HC Emissions from
Selected Sources in Baltimore AQCR

Sources	Tons of HC
Automobiles and Light Duty Trucks	86,200
Heavy Duty Trucks	16,000
Solvent Evaporative Loss	9,700
Gasoline Handling Loss	8,600
Solid Waste Disposal	3,950
Lawn and Garden Equipment	2,000
Vessels	1,300
Off Highway Vehicles	1,200
Locomotives	1,200
Woodburing Home Heaters	142
General Aviation Aircraft*	122

*Total HC emissions from all aircraft = 2,145 tons gasoline normally drained and poured on the ground during pre-flight inspections, may result in several times more HC emissions than the exhaust of general aviation aircraft. Also, evaporation losses during refueling may be significant.

The above findings, although preliminary at this time, indicate that substantially more benefits may be gained through evaporation loss control than from HC exhaust emission control.

Mathematical Model of CO Impact at Van Nuys Airport

As previously noted, CO emissions from general aviation aircraft at several airports exceeds 2000 tons per year. In Reference 11, such emissions are predicted to sharply increase due to expected growth. For example, even with the current emission standards, CO emissions at Van Nuys Airport are projected to increase to over 3700 tons per year by 1985. By comparison, this level is approximately the same as now being experienced at Washington National Airport. Therefore, it is prudent to further analyze the potential impact of these CO emissions from general aviation aircraft.

The Office of Air Quality Planning and Standards recently used a newly developed dispersion model to make the above assessment. The findings of this study are contained in Reference 13 and will be briefly summarized here.

Using Van Nuys Airport (the busiest general aviation airport in the country and the one having the highest CO emissions from general aviation traffic), actual traffic counts were obtained during the month of August

1976. From this data, the period of highest traffic was selected for modeling. Aircraft activity at Van Nuys was divided into several categories of aircraft and a distribution of various types of aircraft operating at Van Nuys was determined. Emission factors pertinent to these various aircraft were developed.

The aircraft activity at Van Nuys was then modeled using a dispersion model designed for assessing the simultaneous impact of various point, area and line sources in a given area on air quality in that area. The details of the model are contained in Reference 14.

Modeling of the airport consisted of dividing the aircraft activity into various modes of operation such as taxi, parking, take off, approach, etc. Emission factors for each mode of operation was determined for each type aircraft modeled. Consequently, the impact of various types of operations by the aircraft could be assessed.

Modeling was accomplished only for aircraft operations, thus providing a means of determining the impact emissions from the aircraft would have on CO air quality. The results of this modeling effort are summarized in Figures 10 and 11. These figures present the predicted 1-hour and 8-hour CO concentrations as a function of distance from the point of highest concentrations calculated for several locations on the airport. The results shown in Figures 10 and 11 are for a "worst-case" situation, that is unfavorable meteorological conditions, a single runway in used (Van Nuys utilizes two parallel runways) and high traffic causing substantial departure delays.

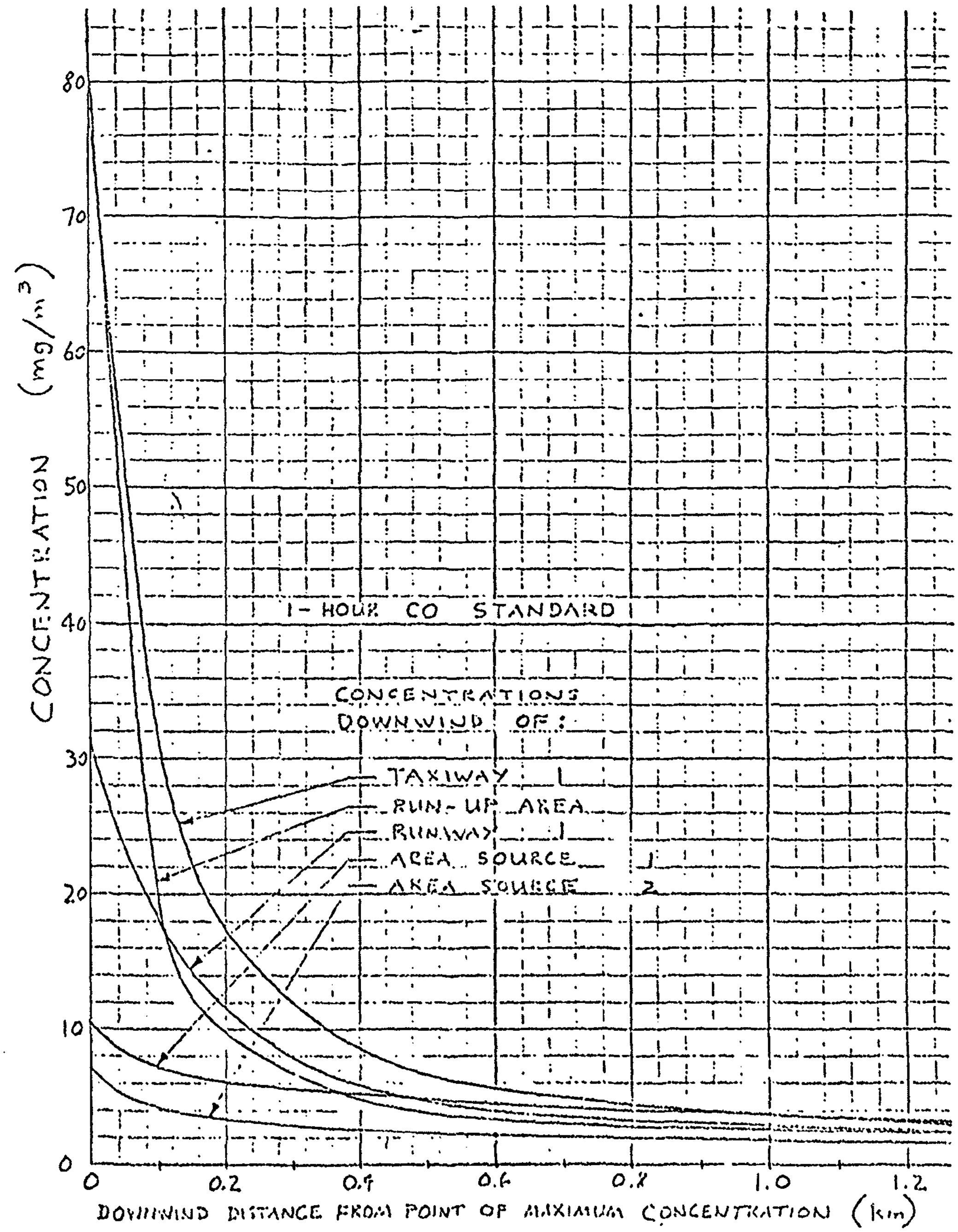


Figure 10 Maximum 1-Hour CO Concentrations as a Function of Downwind Distance (assuming that all aircraft use Runway 1).

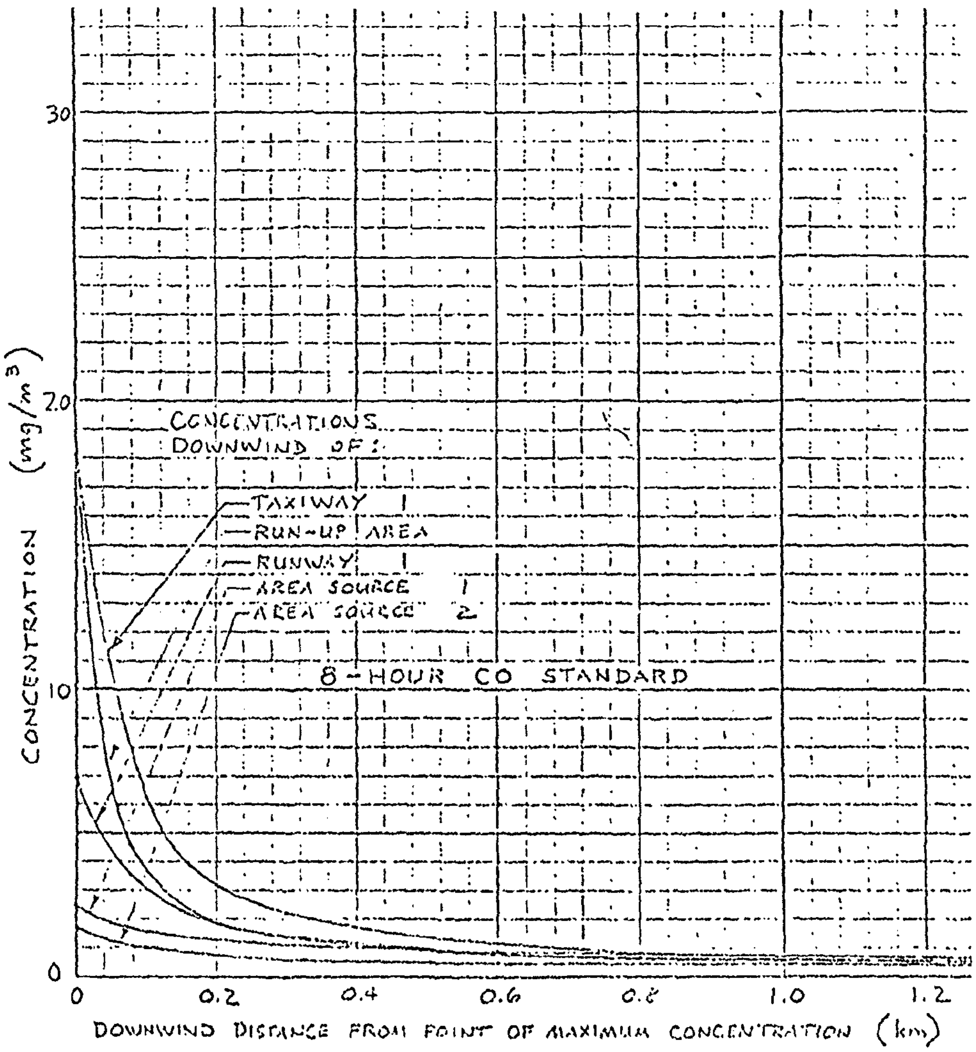


Figure 11 Maximum 8-Hour CO Concentrations as a Function of Downwind Distance (assuming that all aircraft use Runway 1).

As can be seen from Figures 10 and 11, there are locations where both the 1-hour and 8-hour CO standard is predicted to be violated by a factor of over 2. These locations occur just downwind of the active runway and taxiway. (The area sources 1 and 2 shown on the figures are parking areas near the approach end of the active runway.) However, as can be seen from the figures, the CO concentration disperses very rapidly as one moves away from the point of highest concentration. Thus, there appears to be localized CO "hot spots" on the airport property where CO levels are exceedingly high. The contribution of CO by aircraft at Van Nuys appears to be no more than about 10 percent of the standard at locations off the airport property. Similar calculations with both runways in use show that the peak levels of CO near the "hot spots" are reduced by about 25 percent, but that the impact outside the airport property remains about the same as when a single runway is in use. A comparison with the results from the study involving 10 air force bases previously discussed (Reference 9) shows good agreement with the results found for the above Van Nuys study.

CONCLUSIONS

A review of the potential impact of general aviation aircraft emissions indicates:

(1) The level of HC and NO_x emissions from these aircrafts are too small for current mathematical models to accurately assess their impact.

(2) NO_x emissions are probably too low to have any significant impact on air quality except under extreme adverse meteorological conditions, and then only on or near the airport property.

(3) HC emissions from general aviation aircraft fall into a group of sources which are not considered major, but which may eventually require controls to insure the oxidant standard is met. The magnitude of HC emissions from general aviation aircraft exhaust at the most active general aviation airports indicate that relatively small air quality benefits can be expected to be gained through control of these emissions. There are some preliminary indications that substantially more benefits can be gained through evaporative emission control.

(4) CO emissions are sufficiently high to cause excessive levels of CO to be experienced at a few spots on the airport property. Maximum contributions of CO emissions from general aviation traffic to areas outside the airport are estimated not to exceed about 10 percent of the national standards.

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