

**CINCINNATI – HAMILTON – MIDDLETON  
AIR POLLUTANT EMISSION  
INVENTORY**

**U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE  
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CINCINNATI - HAMILTON - MIDDLETOWN  
AIR POLLUTANT EMISSION INVENTORY

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## AIR POLLUTANT EMISSION INVENTORY

### INTRODUCTION

This report is a compilation of air pollutant emissions in the Cincinnati - Hamilton - Middletown metropolitan areas. The objectives of this emission inventory were to determine the quantity of the various air pollutants emitted as well as their geographical and seasonal variations. This was done by using a modified form of the rapid survey technique.<sup>1</sup> The Study Area was divided into a grid coordinate system and the emission quantities were reported in terms of tons of pollutant per grid on an average annual day, average summer day, and average winter day.

The pollutants considered in this survey were sulfur oxides, particulates, carbon monoxide, hydrocarbons, and oxides of nitrogen. Data presented herein were gathered mainly by the acknowledged state and local agencies and are representative of 1967 unless otherwise noted.

### STUDY AREA

The Study Area, presented in Figure 1, consists of Cincinnati and the surrounding counties (Boone, Campbell, and Kenton in Kentucky; Dearborn in Indiana; and Warren, Clermont, and the balance of Hamilton in Ohio) as well as the Hamilton - Middletown area which consists of Butler County in Ohio. The area occupies 2,620 square miles and contains an estimated 1967 population of 1,658,880 which is a 13 percent increase over the 1960 population (See Table 1). About 50 percent of the people live in the cities of Cincinnati, Covington, Hamilton, and Middletown; and almost all of the industrial activity



Figure 1. Cincinnati, Hamilton, Middletown study area.

Table 1 POPULATION CHARACTERISTICS FOR THE  
CINCINNATI - HAMILTON - MIDDLETOWN  
STUDY AREA

County	Land Area (Square miles)	Population		1967 Population Density person/sq. mi.
		1960	1967	
Cincinnati SMSA	2,149	1,268,479	1,430,555	665.7
Clermont	458	80,530	105,513	230.4
Hamilton	414	864,121	949,876	2,294.4
Warren	408	65,711	85,266	209.0
Boone	249	21,940	26,300	105.6
Campbell	149	86,803	98,000	657.7
Kenton	165	120,700	135,000	818.2
Dearborn	306	28,674	30,600	100.0
Hamilton - Middletown SMSA				
Butler	471	199,076	228,325	484.8
Total Area	2,620	1,467,555	1,658,880	635.2

is located here.

#### TOPOGRAPHY

The entire Cincinnati Metropolitan area is part of an upland plain about 900 feet above sea level, with the flood plain of the Ohio some 800 feet lower. Downtown Cincinnati is located in the basin formed by the junction of the Mill Creek and Licking River valleys with the flood plain of the Ohio.

The basin area and flood plains are surrounded by steep bluffs rising 200 to 400 feet to the general plateau level. These bluffs are cut frequently by the valleys of small tributary streams which produce a setting of promontories and steep hills.

The Hamilton - Middletown area is located about 25 miles north of the Cincinnati area while the Dayton Standard Metropolitan Statistical Area (SMSA) is 53 miles north of Cincinnati. There are no other large industrial or populated areas within 75 miles.

#### GENERAL CLIMATOLOGY

The climate in the Cincinnati area is basically continental with a wide range in temperature. The Cincinnati area is subjected to frequent changes in weather due to the passage of numerous cyclonic storms in the winter and spring and thunderstorms in the summer. The temperatures range from an all-time high of 109° in the summer to 17° below zero in the winter. On the average, a temperature of 34° could be expected in Cincinnati in the winter.

The prevailing south to southwest winds on the western side of the Bermuda high during the summer carry warm, moist air from the Gulf of

Mexico up the Mississippi and Ohio valleys into the Cincinnati area. This gives the area a high frequency of thunderstorms. The wind speed averages about 11 mph in the winter and about 7.5 mph in the summer.

#### GRID COORDINATE SYSTEM

For the purposes of this survey, the Study Area was divided into 62 grids based on Universal Transverse Mercator Projection (UTM). Three grid sizes of 20,000 meters, 10,000 meters, and 5,000 meters were utilized for delineating emissions of the sulfur oxides, particulates, carbon monoxide, hydrocarbons, and nitrogen oxides (Figure 2).

#### SUMMARY OF RESULTS

The following is a brief summary of pollutant emissions and sources in the Cincinnati - Hamilton - Middletown Study Area:

1. Sulfur oxides (about 428,000 tons per year) are emitted primarily from stationary fuel combustion.

The combustion of coal, mainly from steam electric power plants, contributed 91 percent; industrial processes, 7 percent; and transportation, less than 1 percent.

2. Coal combustion accounted for more than 66 percent of the total particulate emission of 122,470 tons per year. Transportation sources contributed 6.5 percent; industrial processes, 23 percent; and refuse burning, 3.5 percent.

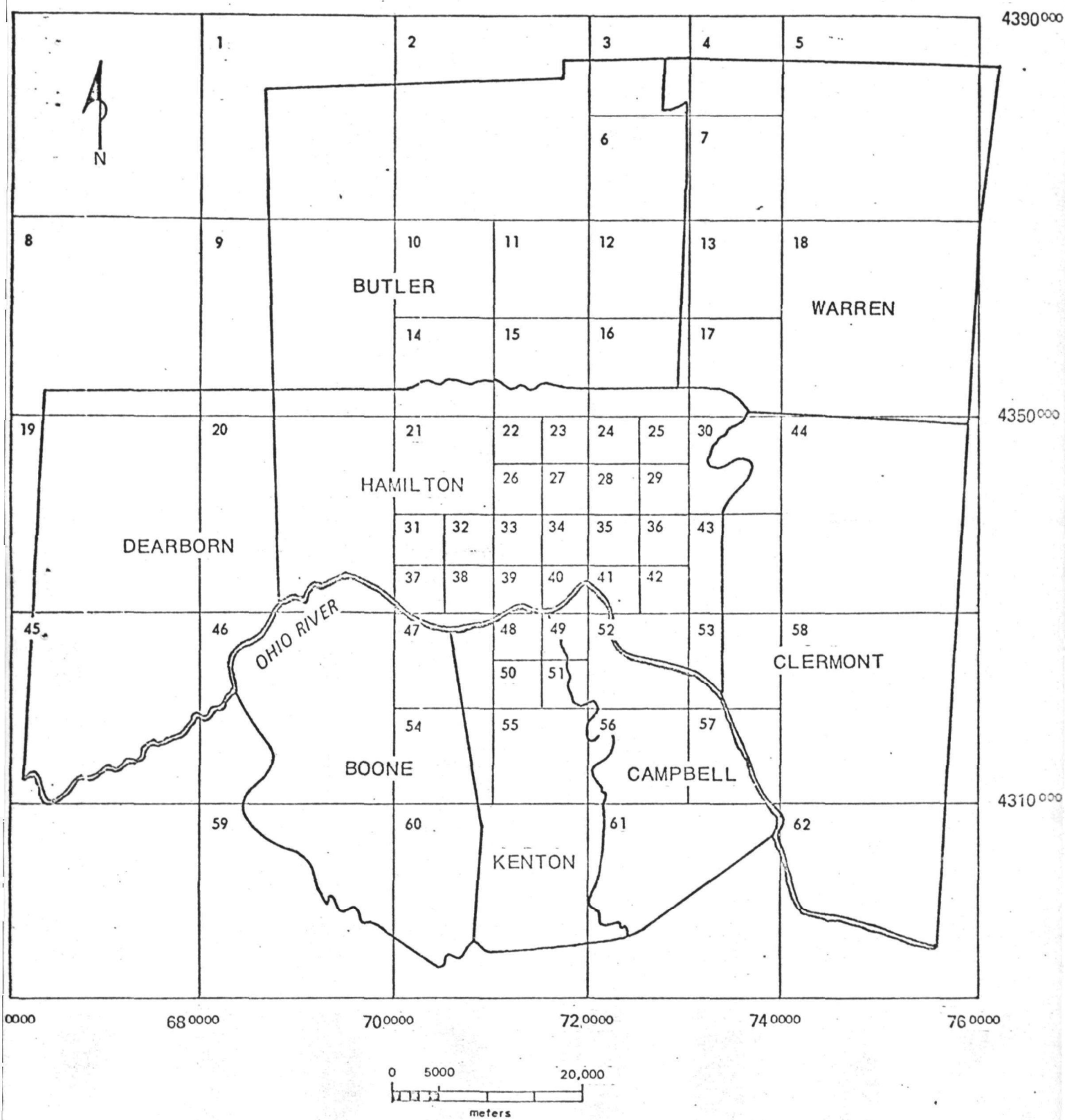


Figure 2 Cincinnati-Hamilton-Middletown grid coordinate map.

Table 2 SUMMARY OF AIR POLLUTANT EMISSIONS IN THE  
CINCINNATI-HAMILTON-MIDDLETOWN STUDY AREA, 1967 (Tons/Year)

Source	SO <sub>x</sub>	Part.	CO	HC	NO <sub>x</sub>
Transportation					
Auto	1,720	2,290	472,800	35,820	24,370
Trucks & Buses	1,240	3,400	1,860	4,200	6,860
Trains	440	1,220	670	1,510	2,480
Planes	Neg.	780	7,130	1,420	810
Total	3,400	7,690	482,460	42,950	34,520
Stationary Fuel Combustion					
Industry	34,500	35,300	3,500	2,450	21,000
Steam-Electric	332,000	18,500	1,500	600	61,000
Residential	6,950	6,780	7,710	1,650	4,030
Commercial & Institutional	19,000	21,800	23,000	5,500	6,550
Total	392,450	82,380	35,710	10,200	92,580
Solid Waste					
Incineration	470	1,790	240	70	470
Open Burning	Neg.	2,610	12,000	620	1,200
Total	470	4,400	12,240	690	1,670
Industrial Process	31,000	28,000	6,600	1,500	1,050
Total	427,520	122,470	537,000	55,340	129,820

Neg. = Negligible

3. The major source of carbon monoxide (537,000 tons per year) was the operation of gasoline powered motor vehicles which emitted 90 percent of the total emissions. Coal combustion in commercial and institutional buildings accounted for another 4 percent. Sources such as refuse burning, industrial process and fuel combustion in stationary sources accounted for the remaining 6 percent.
4. Oxides of nitrogen (129,820 tons per year) were discharged primarily from coal combustion in steam electric utilities (45 percent) and in industrial plants (13 percent). Transportation sources account for 27 percent.
5. Motor vehicles account for approximately 65 percent of the 55,340 tons of hydrocarbons emitted. Stationary fuel combustion accounted for 18 percent of the total hydrocarbons included in this survey (solvent evaporation was not included).

The emissions of pollutants discharged to the air in the Study Area are summarized in Table 2. The validity of these results are dependent on the accuracy and applicability of the emission factors used.<sup>2</sup> These factors, for the most part, represent average emission rates for a particular industry or fuel type. Because of the inherent differences in type of equipment, operating rates, control equipment, and efficiency of operation among the plants and fuel users within

a given category, the application of the emission factors to any individual plant or even a smaller number of similar plants or processes may result in a discrepancy between the actual and the estimated emissions. However, the estimates of total pollutants from all sources in the study area should be fairly accurate since the emission factors are based on average conditions.

Some of the estimates in this report are reported to five significant figures, but because of the limitation of the data involved, they should be considered accurate to no more than two.

#### EMISSIONS BY CATEGORY

For the purposes of compiling the basic data and emission estimates, the air pollutant sources were classified into the following four categories:

1. Fuel combustion in stationary sources
2. Transportation
3. Solid-waste disposal
4. Industrial process losses

#### Fuel Combustion in Stationary Sources

All three major fuels are consumed within the Study Area with coal being the most significant. In 1967, coal accounted for  $2.77 \times 10^{14}$  Btu's or 72 percent of the total energy input while natural gas accounted for 24 percent and fuel oil the remaining 4 percent. Approximately 10,667,000 tons of coal, 104.8 million gallons of fuel oil and 92.2 billion cubic feet of natural gas were consumed in the Study Area (Table 3).

Table 3 SUMMARY OF FUEL CONSUMPTION BY  
STATIONARY SOURCES FOR THE  
STUDY AREA, 1967

Source	Coal (1,000's tons)	Residual Fuel Oil (10 <sup>6</sup> gal.)	Distillate Fuel Oil (10 <sup>6</sup> gal.)	Natural Gas (10 <sup>6</sup> ft <sup>3</sup> )
Steam-electric	5,920	0.75	0.60	8,730
Industry	3,437	13.95	7.5	22,270
Residential	310	Neg.	77.0	41,200
Commercial & Institutional	1,000	Neg.	5.0	20,000
Total	10,667	14.7	90.1	92,200

Neg. = Negligible

The seven steam-electric power plants consumed 56 percent of the total coal utilized by all sources as shown in Table 4. All of the power plants are either equipped with air pollution control equipment or use natural gas. Industry was the other prime user of coal consuming 32 percent of the total.

Fuel oil was consumed primarily in industrial operations (20 percent) and for residential heating (74 percent), approximately 86 percent of this fuel oil was distillate with a sulfur content ranging from 0.15 - 0.20 percent (See Table 5).

Over 44 percent of the natural gas consumed in the Study Area was used for residential purposes while 24 percent was used in industrial operations. Steam-electric utilities used 9.5 percent of the total mainly at Cincinnati, Gas and Electric's West End facility in the city of Cincinnati.

#### Area and Point Sources

Fuel consumption in area and point sources is summarized by county in Table 6. For the entire Study Area, 82 percent of the total coal usage has been accounted for in point sources. (A point source for the purpose of this study was any industry, commercial or institutional establishment, steam-electric power plant, incinerator, open dump, or airport that emitted more than 0.5 tons of any of the five surveyed pollutants per day.) For fuel oil, less than 3 percent was consumed in point sources, but fuel oil only accounts for 4 percent of the total energy input as expressed in Btu's. For natural gas, no point sources

Table 4 SUMMARY OF FUEL CONSUMPTION BY  
STEAM-ELECTRIC UTILITIES FOR THE  
STUDY AREA, 1967

Plant	Coal (1000's Tons)	Natural Gas (10 <sup>6</sup> Ft <sup>3</sup> )	Fuel Oil (1,000's Gal)	Controls*
W.C. Beckjord	1,975	0	250	ESP
Miami Fort	881	0	250	1/2 ESP 1/2 Mech.
West End <sup>a</sup>	0	8,400	0	None
Tanners Creek	2,900	0	750	ESP
Hamilton	138	0	0	Mech.
Reading	24	0	0	Mech.
Butler	0	330	0	None
Total	5,920	8,730	1,250	

\* ESP = Electrostatic precipitator  
Mech. = Mechanical collectors; consists of cyclone collectors or baffles,  
separately or in combination.

<sup>a</sup>West End plant used 351,000 tons of coal in 1967 but switched to gas in 1968.

Table 5 SULFUR AND ASH CONTENTS OF FUELS  
CONSUMED IN THE  
CINCINNATI - HAMILTON - MIDDLETOWN  
STUDY AREA<sup>3</sup>

Fuel	% Sulfur	% Ash
Coal (everything except C.G.&E.)*	1.0	8.0
Coal (C.C.&E)*	3.0	15.0
Residual Fuel Oil	0.9-1.0	-
Distillate Fuel Oil	0.15-0.20	-
Natural Gas	0.0008	-

\*Cincinnati Gas & Electric Company

were identified since emissions from this fuel are relatively low.

Approximately 71 percent of the total dwelling units in the Study Area used natural gas as the heating fuel. Coal was used in 11 percent, fuel oil in 17 percent, and other type of fuel were used in the remaining 1 percent as shown in Table 7.

The areal variation in the home heating fuel use can be seen from Table 8. Natural gas is used mostly in the heavily populated areas of Cincinnati - Covington - Newport and Hamilton - Middletown. Coal is used mainly in the older sections of the City of Cincinnati, while fuel oil is used more in the rural areas. Some dwellings in the Study Area are heated by electricity or wood but these account for less than 1 percent of the total.

The sulfur and ash contents of the fuels in the Study Area are summarized in Table 5. The sulfur content of coal is relatively low being only 1 percent compared to an Ohio State average of 2.7 percent while that of fuel oil is about average.

#### Emissions from Fuel Combustion in Stationary Sources

Air pollutant emissions resulting from fuel combustion in stationary sources are listed in Table 9 and by jurisdiction in Table 10. Although coal accounts for only 72 percent of the total fuel energy, it is responsible for 99.8 percent of the sulfur oxides, 98 percent of the particulates, 99.9 percent of the carbon monoxide, 99.9 percent of the hydrocarbons, and 89 percent of the nitrogen oxides emitted from stationary sources in the Study Area.

Table 7 SUMMARY OF DOMESTIC HEATING UNITS  
BY FUEL TYPE FOR THE STUDY AREA, 1967

County	Total Dwelling Units	Coal	Oil	Gas
Clermont	26,300	4,940	15,760	4,700
Hamilton	289,000	26,800	30,100	230,500
Cincinnati	159,400	19,000	8,600	130,500
Balance of Hamilton	129,600	7,800	21,500	100,000
Warren	23,000	4,000	9,900	8,600
Boone	7,200	7,840	2,700	2,600
Campbell	28,800	3,430	1,300	23,800
Kenton	41,100	3,320	4,000	33,100
Dearborn	8,800	3,100	2,600	2,500
Total Cincinnati SMSA	424,200	47,430	66,360	305,800
Butler	67,200	8,730	18,900	39,300
Total Study Area	491,400	56,160	85,260	345,100

**Table 9 SUMMARY OF AIR POLLUTANT EMISSIONS FROM  
FUEL CONSUMPTION IN STATIONARY SOURCES  
FOR THE STUDY AREA, 1967 (Ton/Year)**

Source	SO <sub>x</sub>	Part.	CO	HC	NO <sub>x</sub>
Industry					
Coal	34,140	34,790	3,470	2,420	16,860
Fuel Oil	360	230	30	30	820
Natural Gas	Neg.	280	Neg.	Neg.	3,320
Total	34,500	35,300	3,500	2,450	21,000
Residential					
Coal	5,800	6,100	7,620	1,530	1,230
Fuel Oil	1,140	290	80	120	430
Natural Gas	10	390	10	Neg.	2,370
Total	6,950	6,780	7,710	1,650	4,030
Commercial & Institutional					
Coal	18,920	21,440	23,000	5,500	5,210
Fuel Oil	80	60	Neg.	Neg.	180
Natural Gas	Neg.	300	Neg.	Neg.	1,160
Total	19,000	21,800	23,000	5,500	6,550
Steam-electric					
Coal	331,970	18,430	1,500	600	59,230
Fuel Oil	30	10	Neg.	Neg.	70
Natural Gas	Neg.	60	Neg.	Neg.	1,700
Total	332,000	18,500	1,500	600	61,000
Total					
Coal	390,830	80,760	35,590	10,050	82,530
Fuel Oil	1,610	590	110	150	1,500
Natural Gas	10	1,030	10	Neg.	8,550
Total	392,450	82,380	35,710	10,200	92,580

Neg = Negligible

Fuel burning in industrial plants accounted for 8.7 percent of the sulfur oxides and 42.5 percent of the particulates while steam-electric power plants contributed 85 percent of the sulfur oxides and 22.5 percent of the particulates. Commercial and institutional establishments accounted for 26 percent of the particulates from coal combustion.

#### Data Sources

Fuel consumption data for the Study Area were obtained from diverse sources. Natural gas numbers were obtained from the gas companies in the area and are the most accurate. They were provided on a county basis with a breakdown by industry, residential, commercial and institutional source categories.

Residual fuel oil figures were obtained from the Bureau of Census<sup>4</sup> for 1962 and were updated by the increase in manufacturing employment. All residual oil was assumed to be used in industrial operations. Residual fuel was distributed on a county basis by manufacturing employment and on a grid basis by means of land use maps.

Most of the distillate fuel oil (86 percent) was used for residential purposes. The remainder of the distillate fuel oil was apportioned by county using population figures and on a grid basis by land use. Distillate fuel oil totals were also obtained from the Bureau of Census.

Coal consumption in industrial, commercial and institutional facilities was determined by personal contact by the aforementioned local and state agencies. One steam-electric plant, the West End plant in Cincinnati, used 351,000 tons of coal in 1967 but switched to gas

in March 1968. Thus, for this report the emissions for the West End plant were determined by its gas usage.

Residential coal by county was found from the number of dwelling units using coal and the total number of degree days. This method is described in detail in the Rapid Survey Technique publication.<sup>5</sup>

The remaining coal consumption, i.e., area sources consisting of industrial, commercial and institutional zones are estimates made by subtracting current point source data in these zones from the estimate of the total fuel consumption for the jurisdiction involved.

#### Transportation

Three types of transportation sources of air pollution are considered in this survey - road vehicles, aircraft, and railroads. Road vehicles which are by far the most important source of air pollution in this category are further subdivided according to type of fuel - gasoline or diesel.

Emissions from road vehicles were determined from a transportation study done by the Ohio - Kentucky - Indiana Regional Transportation Commission (OKI) in 1965. Vehicle mile totals were obtained by county for automobiles on major arteries from traffic flow maps. This was estimated to be 85 percent of the total vehicle miles on all roads in the 8-county area.

The adjusted totals were then updated to 1967 by the increase in automobile registration since 1965. An average of 14.0 miles/gallon was used to determine gasoline consumption.<sup>6</sup> Since only total truck

trips for the entire eight county area was available, it was assumed that truck trips in each county were proportional to automobile vehicle miles by county. An average truck trip was 6 miles and a truck consumed 1/6 of a gallon of diesel fuel per mile.<sup>7</sup> (See Table 11).

#### Aircraft and Railroads

Total aircraft operations were supplied by the Federal Aviation Administration. A breakdown is given by itinerant operations and local operation.<sup>8</sup> An operation is defined as a combination of a landing and takeoff (See Table 12).

Railroads consume 1.8 million gallons of diesel fuel per year in the Study Area. These figures were obtained from the various railroads in the Study Area.

#### Emissions from Transportation Sources

The quantities of pollutants attributed to transportation sources is summarized in Tables 13 and 14. More than 482,000 tons of carbon monoxide, 43,000 tons of hydrocarbons, and over 34,000 tons of oxides of nitrogen were emitted in the Study Area.

Motor vehicles account for over 98 percent of the total carbon monoxide, 84 percent of the total hydrocarbons, and 70 percent of the total nitrogen oxides.

Aircraft account for a small percentage of the total transportation emissions. However, because of their limited land area, the emission density is high and thus, they become an important point source.

Table 11 MOTOR VEHICLE FUEL CONSUMPTION  
AND REGISTRATIONS FOR THE STUDY  
AREA, 1967

County	Gasoline (10 <sup>6</sup> gal)	Diesel (10 <sup>6</sup> gal)	Automobile Registration	Truck and Bus Registration
Clermont	18.1	2.6	4,600	3,150
Hamilton	242.8	37.6	370,000	28,000
Warren	28.9	4.1	36,000	3,100
Boone	9.8	1.4	14,600	1,600
Campbell	13.4	1.9	36,800	3,200
Kenton	29.5	4.2	52,800	5,000
Dearborn	10.4	1.5	12,200	3,400
Total Cincinnati SMSA	352.9	53.3	527,000	47,450
Butler	56.5	8.1	95,000	8,000
Total Study Area	409.4	61.4	622,000	55,450

TABLE 12  
AIRPORT FLIGHTS IN THE CINCINNATI - HAMILTON - MIDDLETOWN STUDY AREA,  
(1967)

Airport	Total Flights*	Air Carrier	General Aviation	Military
Greater Cincinnati	73,488	44,186	28,498	803
Lunken	94,379	7	93,859	514
Total	167,867	44,193	122,357	1,317

\* A Flight is defined as a combination of a Landing and a Take off

Table 14 AIR POLLUTANT EMISSIONS FROM  
AIRPORTS IN THE CINCINNATI -  
HAMILTON - MIDDLETOWN STUDY AREA, 1967 (Tons/Year)

Airport	Type of Carrier	SO <sub>x</sub>	Part.	CO	HC	NO <sub>x</sub>
Lunken	Air Carrier	Neg.	0.1	0.1	0.0	0.1
	General Aviation and Military					
	Itinerant	Neg.	14	3,000	560	140
	Local	Neg.	8	1,660	320	80
	Total	Neg.	22	4,660	880	220
Greater Cincinnati	Air Carrier	Neg.	750	770	220	510
	General Aviation and Military					
	Itinerant	Neg.	8	1,430	270	70
	Local	Neg.	2	270	50	10
	Total	Neg.	760	2,470	540	590
Total Cincinnati Hamilton - Middletown Study Area	Air Carrier	Neg.	750	770	220	510
	General Aviation and Military					
	Itinerant	Neg.	22	4,430	830	210
	Local	Neg.	10	1,930	370	90
	Total	Neg.	782	7,130	1,420	810

Neg = Negligible

### Solid Waste Disposal

Approximately 1.52 million tons of refuse were generated during 1967 in the Study Area. This was determined by assuming a per capita disposal rate of five pounds of refuse per day.<sup>9</sup> The disposal of this refuse is divided fairly evenly between landfills, municipal incineration, and open dumps (See Table 15). Any balance was assumed to be backyard burning.

Landfills accounted for 30 percent; municipal incineration, 31 percent; open dumps, 30 percent; and backyard burning, 9 percent of the total refuse disposed.

At landfills no burning occurred. The amount of refuse burned at the 40 dumps varied. Some burned 100 percent of the refuse collected while others did not burn at all. A total of over 12,000 tons of carbon monoxide, 4,400 tons of particulate matter, and 1,600 tons of nitrogen oxides were emitted from solid waste disposal practices in the Study Area. These totals and a breakdown by jurisdiction are presented in Table 16.

### Industrial Process Losses

The Cincinnati - Hamilton - Middletown Study Area is for the most part void of heavy industry and thus emissions from this category did not constitute a major portion of the total. As is the case in any emission inventory, the lack of emission factors for some industrial processes did not allow for a complete estimation of process emissions e.g. soap manufacture.

Table 16. AIR POLLUTANT EMISSIONS BY  
JURISDICTION FROM SOLID WASTE DISPOSAL  
FOR THE CINCINNATI-HAMILTON-MIDDLETOWN  
Study Area, 1967 (Ton/year)

County	Type of Disposal	SOx	Part	CO	HC	NOx
Clermont	incineration	0	0	0	0	0
	open dump	0	0	0	0	0
	on-site	0	60	205	7	7
	TOTAL	0	60	205	7	7
Hamilton	incineration	400	1470	200	60	400
	open dump	0	1140	6,070	360	790
	on-site	0	90	330	10	10
	TOTAL	400	2700	6,600	430	1200
Warren	incineration	0	0	0	0	0
	open dump	0	0	0	0	0
	on-site	0	45	155	5	5
	TOTAL	0	45	155	5	5
Boone	incineration	neg	neg	neg	neg	neg
	open dump	0	0	0	0	0
	on-site	0	100	360	10	10
	TOTAL	0	100	360	10	10
Campbell	incineration	20	150	10	3	20
	open dump	0	80	425	25	25
	on-site	0	250	885	30	30
	TOTAL	20	480	1,320	58	105
Kenton	incineration	16	55	8	3	16
	open dump	0	120	640	40	85
	on-site	0	365	1,290	45	45
	TOTAL	16	540	1,938	88	146

Table 16 AIR POLLUTANT EMISSIONS BY  
JURISDICTION FROM SOLID WASTE DISPOSAL  
FOR THE CINCINNATI-HAMILTON-MIDDLETOWN  
Study Area, 1967 (Ton/year) Cont'd

County	Type of Disposal	SOx	Part	CO	HC	NOx
Dearborn	incineration	0	0	0	0	0
	open dump	0	0	0	0	0
	on-site	0	20	30	3	3
	TOTAL	0	20	30	3	3
Cinc. SMSA	incineration	436	1675	218	66	436
	open dump	0	1340	7,135	425	930
	on-site	0	930	3,305	110	110
	TOTAL	436	3945	10,658	601	1476
Butler	incineration	35	115	20	5	35
	open dump	0	200	1,060	65	140
	on-site	0	140	500	20	20
	TOTAL	35	455	1,580	90	195
Study Area	incineration	471	1790	238	71	471
	open dump	0	1540	8,195	490	1070
	on-site	0	1070	3,805	130	130
	TOTAL	471	4400	12,238	691	1671

Neg = Negligible

There are over 30 foundries in the Study Area which were considered, most of which did not have any air pollution control equipment. However, with the exception of one foundry in Cincinnati which did have control equipment, the others were small ranging from 20 to 7,000 tons per year of production. In addition there are 10 concrete batching plants all of which are small (production ranges from 17,000 to 140,000 cubic yards per year), 7 asphalt batching plants, one refinery which has a carbon monoxide waste heat boiler, one sulfuric acid plant and two steel mills. Air pollutant emissions from steel mills emanate primarily from the process use of coal and coke.

Emissions from industrial process losses accounted for less than 8 percent of the total sulfur oxides, 22 percent of the particulates, 1.2 percent of the carbon monoxides, 3 percent of the hydrocarbons, and less than 1 percent of the nitrogen oxides (See Table 2).

The major industrial process source was a steel mill in Butler County which was estimated to account for 96 percent of the sulfur oxides and 89 percent of the particulates from industrial process emissions.

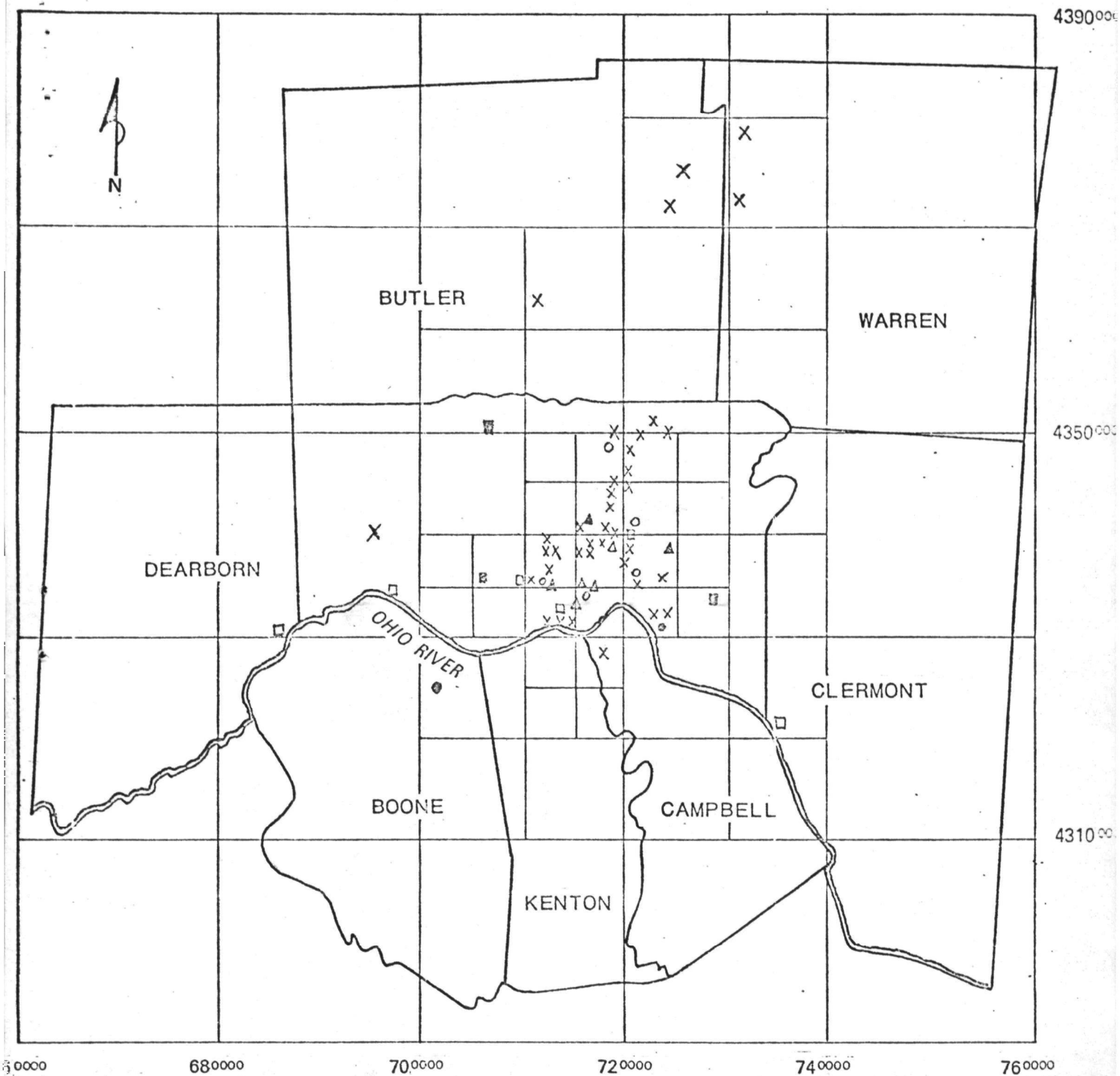
Locations of all point sources are shown in Figure 3 which indicates that the majority of large industries are located in Hamilton County.

#### Emissions by Grid

For the purpose of modeling the air pollutant emissions in the Study Area the resulting emissions were apportioned on the grid coordinate

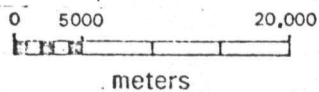
Figure 3

Point Source Location for Cincinnati - Hamilton - Middletown Study Area, 1967



LEGEND

- |                 |                |
|-----------------|----------------|
| X Industrial    | ● Airport      |
| O Commercial    | ▴ Incineration |
| Δ Institutional | □ Power Plant  |
| □ Power Plant   | ▢ Pump         |



system shown in Figure 2.

An immediate need for the apportionment by grid is for the purpose of designating Air Quality Control Regions.

The emissions of each pollutant were divided into two source subgroups - point and area sources. The 62 point sources were identified by source category, and horizontal and vertical coordinates. They are presented in Table 17, along with emissions for the five pollutants for an average annual, winter, and summer day. The appendix presents the method for calculating these three averages since it differs from the Rapid Survey Technique.

The emissions for area sources on the annual, winter and summer average bases are shown in Table 18. The calculation of these averages is similar to that presented in the appendix for point sources.

#### Emission Densities by Grid

Emission densities on a grid basis were obtained by summing the annual area and point source emissions for each grid. This total, divided by the grid area, gives an emission density in tons per square mile per day. Figures 4 through 8 present the emission density maps for the five surveyed pollutants.

Figure 4 presents the emission density for sulfur oxides. As can be seen the densities are high in a number of grids located in the sparsely populated areas of Boone, Campbell, and Dearborn counties. This is primarily due to the fact that the steam electric

power plants which are the major source of sulfur oxides, are located here.

In Figure 5 the particulate emission density has been delineated. This too is high in the outer areas because of the effect of the power plants.

The carbon monoxide densities are shown in Figure 6. This shows that the emissions are highest in the downtown areas of Cincinnati, Hamilton, Middletown as would be expected. However, as one moves out of the cities the densities are higher in a north-south direction rather than in an east-west. This is due to the predominance of heavily traveled roads in this direction such as the interstate freeway I-75.

Because motor vehicles account for a large percentage of the total hydrocarbons, the same effect is observed for hydrocarbon densities as was found for carbon monoxide, i.e. high in the cities, radiating in a north-south rather than an east-west direction.

Since power plants account for almost half the total of the nitrogen oxides, the high density locations are similar to those of sulfur oxide and particulates, as can be seen from Figure 8.

## REFERENCES

1. Ozolins, G. and Smith, R., Rapid Survey Technique for Estimating Community Air Pollutions, DHEW, PHS, October 1966.
2. Duprey, R. L., Compilation of Air Pollutant Emission Factors, DHEW, PHS, April 1967.
3. Personal Communication with Cincinnati Bureau of Heating and Air Pollution.
4. Fuels and Electric Energy Consumed in Manufacturing Industries, U. S. Bureau of the Census, 1962.
5. op. cit. Ozolins, G.
6. op. cit. Duprey, R. L.
7. Ohio, Kentucky, Indiana Regional Transportation Commission.
8. FAA Air Traffic Activity, Calendar Year 1967, Department of Transportation, Federal Aviation Administration, Feb. 1968.
9. Personal Communication with NCUIH, DHEW, PHS, Cincinnati Ohio.

County	Coal (1000's tons)	Residual Oil (10 <sup>6</sup> gal.)	Distillate Oil (10 <sup>6</sup> gal.)	Gas (10 <sup>6</sup> ft. <sup>3</sup> )
<b>Clermont</b>				
Point Source	1,976	0.0	0.0	0
Area Source	104	0.7	14.8	1,400
<b>Total</b>	<b>2,080</b>	<b>0.7</b>	<b>14.8</b>	<b>1,400</b>
<b>Hamilton</b>				
Point Source	2,110	1.0	0.6	0
Area Source	1,078	7.4	34.7	62,400
<b>Total</b>	<b>3,188</b>	<b>8.4</b>	<b>35.3</b>	<b>62,400</b>
<b>Warren</b>				
Point Source	0	0.0	0.0	0
Area Source	84	0.6	9.5	2,900
<b>Total</b>	<b>84</b>	<b>0.6</b>	<b>9.5</b>	<b>2,900</b>
<b>Boone</b>				
Point Source	0	0.0	0.0	0
Area Source	30	0.1	2.6	900
<b>Total</b>	<b>30</b>	<b>0.1</b>	<b>2.6</b>	<b>900</b>
<b>Campbell</b>				
Point Source	2	0.0	0.0	0
Area Source	108	0.6	1.8	5,100
<b>Total</b>	<b>110</b>	<b>0.6</b>	<b>1.8</b>	<b>5,100</b>
<b>Kenton</b>				
Point Source	3	0.0	0.0	0
Area Source	142	0.8	4.6	6,900
<b>Total</b>	<b>145</b>	<b>0.8</b>	<b>4.6</b>	<b>6,900</b>
<b>Dearborn</b>				
Point Source	2,900	0.8	0.0	0
Area Source	43	0.3	2.7	2,000
<b>Total</b>	<b>2,943</b>	<b>1.1</b>	<b>2.7</b>	<b>2,000</b>
<b>Total Cinc. SMSA</b>				
Point Source	6,991	1.8	0.6	0
Area Source	1,589	10.5	70.7	81,300
<b>Total</b>	<b>8,580</b>	<b>12.3</b>	<b>71.3</b>	<b>81,300</b>
<b>Butler</b>				
Point Source	1,832	0.3	0.0	0
Area Source	255	2.1	18.8	10,900
<b>Total</b>	<b>2,087</b>	<b>2.4</b>	<b>18.8</b>	<b>10,900</b>
<b>Total Study Area</b>				
Point Source	8,823	2.1	0.6	0
Area Source	1,844	12.6	89.5	92,200
<b>Total</b>	<b>10,667</b>	<b>14.7</b>	<b>90.1</b>	<b>92,200</b>

Table 8 SUMMARY OF FUEL CONSUMPTION BY JURISDICTION  
FOR STATIONARY SOURCES IN THE STUDY AREA, 1967

County	Distillate Fuel Oil 10 <sup>6</sup> gal			Residual Fuel Oil 10 <sup>6</sup> gal	Coal 1,000's tons			Natural Gas 10 <sup>6</sup> Ft <sup>3</sup>		
	Res	Ind	C&I		Res	Ind <sup>a</sup>	C&I	Res	Ind <sup>a</sup>	C&I
Clermont	14.2	0.4	0.2	0.7	27	2,011	42	600	500	300
Hamilton	27.3	4.9	3.1	8.4	148	2,386	654	27,000	21,400	14,000
Warren	8.9	0.4	0.2	0.6	22	30	32	1,200	1,000	700
Boone	2.4	0.1	0.1	0.1	10	5	15	500	200	200
Campbell	1.1	0.4	0.3	0.6	20	35	55	3,000	1,100	1,000
Kenton	3.6	0.5	0.5	0.8	18	43	84	4,000	1,600	1,300
Dearborn	2.4	0.2	0.1	1.1	17	2,912	14	400	1,500	100
Total Cincinnati SMSA	59.9	6.9	4.5	12.3	262	7,338	896	36,700	27,300	17,300
Butler	17.1	1.2	0.5	2.4	48	1,935	104	4,500	3,700	2,700
Total Study Area	77.0	8.1	5.0	14.7	310	9,357	1,000	41,200	31,000	20,000

a. Includes steam and electric power plants

Res = Residential

Ind = Industrial

C & I = Commercial and Institutional

Table 10 SUMMARY OF AIR POLLUTANT EMISSIONS FROM  
STATIONARY SOURCES BY JURISDICTION FOR  
THE STUDY AREA, 1967 (Tons/Year)

County	Source	SO <sub>x</sub>	Part.	CO	HC	NO <sub>x</sub>
Clermont	Industrial	720	720	50	20	440
	Residential	790	660	760	170	240
	Commercial & Institutional	800	850	1,050	210	190
	Steam-electric	112,630	7,410	500	200	19,770
	Total	114,940	9,640	2,360	600	20,640
Hamilton	Industrial	22,780	19,780	6,400	2,800	13,240
	Residential	2,950	3,060	3,420	720	2,250
	Commercial & Institutional	12,000	14,000	14,000	3,700	4,700
	Steam-electric	59,450	5,280	260	110	12,120
	Total	97,180	42,120	24,080	7,330	32,310
Warren	Industrial	630	620	50	20	440
	Residential	600	520	600	130	220
	Commercial & Institutional	610	650	800	160	180
	Steam-electric	0	0	0	0	0
	Total	1,840	1,790	1,450	310	840
Boone	Industrial	105	100	5	5	90
	Residential	235	220	260	60	70
	Commercial & Institutional	290	300	375	75	75
	Steam-electric	0	0	0	0	0
	Total	630	620	640	140	235

Table 10 SUMMARY OF AIR POLLUTANT EMISSIONS FROM  
STATIONARY SOURCES BY JURISDICTION FOR  
THE STUDY AREA, 1967 (Tons/Year) (cont'd.)

County	Source	SO <sub>x</sub>	Part.	CO	HC	NO <sub>x</sub>
Butler	Industrial	39,400	40,210	4,450	1,060	6,390
	Residential	1,220	1,120	1,290	280	590
	Commercial & Institutional	2,380	2,920	2,950	580	630
	Steam-electric	Neg.	Neg.	Neg.	Neg.	70
	Total	43,000	44,250	8,680	1,920	7,670
Study Area	Industrial	65,495	63,300	10,100	3,950	22,050
	Residential	6,955	6,780	7,710	1,650	4,030
	Commercial & Institutional	19,000	21,800	23,000	5,500	6,550
	Steam-electric	332,000	18,500	1,500	600	61,000
	Total	423,450	110,390	42,310	11,700	93,630

Neg = Negligible

**Table 13 AIR POLLUTANT EMISSIONS FROM  
TRANSPORTATION SOURCES BY JURISDICTION  
FOR STUDY AREA, 1967 (Ton/Year)  
(EXCLUDING AIRPORTS)**

County	Category	SO <sub>x</sub>	Part	CO	HC	NO <sub>x</sub>
Clermont	<u>Motor Vehicles</u>					
	Gasoline	75	100	20,950	1,590	1,080
	Diesel	50	145	80	180	290
	Trains	25	70	40	90	150
	Total	160	315	21,070	1,860	1,520
Hamilton	<u>Motor Vehicles</u>					
	Gasoline	1,020	1,360	280,400	21,240	14,450
	Diesel	750	2,060	1,130	2,550	4,160
	Trains	230	630	350	780	1,280
	Total	2,000	4,050	281,880	24,570	19,890
Warren	<u>Motor Vehicles</u>					
	Gasoline	120	160	33,400	2,530	1,730
	Diesel	85	230	125	280	460
	Trains	Neg.	Neg.	Neg.	Neg.	Neg.
	Total	205	390	33,525	2,810	2,190
Boone	<u>Motor Vehicles</u>					
	Gasoline	40	55	11,250	850	580
	Diesel	30	75	40	95	160
	Trains	30	80	50	100	170
	Total	100	210	11,340	1,045	910
Campbell	<u>Motor Vehicles</u>					
	Gasoline	55	75	15,500	1,170	800
	Diesel	40	105	60	130	215
	Trains	80	230	120	280	460
	Total	175	410	15,680	1,580	1,475
Kenton	<u>Motor Vehicles</u>					
	Gasoline	125	165	34,000	2,580	1,750
	Diesel	85	230	125	285	470
	Trains	65	180	100	220	360
	Total	275	575	34,225	3,085	2,580
Dearborn	<u>Motor Vehicles</u>					
	Gasoline	45	60	12,100	920	620
	Diesel	30	80	45	100	165
	Trains	Neg.	Neg.	Neg.	Neg.	Neg.
	Total	75	140	12,145	1,020	785
Total Cincinnati SMSA	<u>Motor Vehicles</u>					
	Gasoline	1,480	1,975	407,600	30,880	21,010
	Diesel	1,070	2,925	1,600	3,620	5,915
	Trains	430	1,190	650	1,470	2,420
	Total	2,980	6,090	409,850	35,970	29,345
Butler	<u>Motor Vehicles</u>					
	Gasoline	240	315	65,200	4,940	3,360
	Diesel	170	470	255	580	940
	Trains	10	30	20	40	60
	Total	420	815	65,475	5,560	4,360
Total Study Area	<u>Motor Vehicles</u>					
	Gasoline	1,720	2,290	472,800	35,820	24,570
	Diesel	1,240	3,395	1,855	4,200	6,835
	Trains	440	1,220	770	1,510	2,480
	Total	3,400	6,905	475,325	41,530	33,785

Neg = Negligible