To the Graduate Council :

I am submitting herewith a thesis written by Ingrid A. Walker entitled "Temporal and Spatial Allocations of Ozone Precursor Emissions for the Nashville, Tennessee Area." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Environmental Engineering.

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TEMPORAL AND SPATIAL ALLOCATIONS OF OZONE PRECURSOR EMISSIONS IN THE NASHVILLE, TENNESSEE AREA

A Thesis

Presented for the

Master of Science

Degree

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Ingrid A. Walker

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ACRONYMS

CAA	Clean Air Act
CO	carbon monoxide
EIS	Emission Inventory System
EPA	Environmental Protection Agency
HC	hydrocarbons
MAP3S	Multistate Atmospheric Power Production Pollution System
NAAQS	National Ambient Air Quality Standard
NADB	National Air Data Branch
NAPAP	National Acid Precipitation Assessment Program
NEDS	National Emissions Data System
NOx	nitrogen oxide compounds
ppm	parts per million by volume
SAMS	SIP Air Pollution Management System
SIP	State Implementation Plan
SOx	sulfur oxide compounds
TDHE	Tennessee Department of Health and Environment
TDOT	Tennessee Department of Transportation
tpy	tons per year
TSP	total suspended particulate
UAM	Urban Airshed Model
UT	University of Tennessee
UTM	Universal Trans-Mercator

ACRONYMS (cont.)

VOC	volatile organic compounds
VMT	vehicle miles traveled

1.0 INTRODUCTION

The Environmental Protection Agency (EPA) has required Tennessee to revise its State Implementation Plan (SIP) to include a program to meet the National Ambient Air Quality Standard (NAAQS) for ozone because Nashville and Memphis metropolitan areas in Tennessee violated this standard during the period from 1986 to 1988. The Tennessee Department of Health and Environment (TDHE) Division of Air Pollution and the University of Tennessee's (UT) Civil Engineering Department undertook the task of compiling the requisite emission inventory which provided input for air quality modeling necessary in revising the SIP. In addition, UT will perform a modeling study of the air quality planning region using the Urban Airshed Model (UAM) to aid in determining ozone control strategies. The UAM requires inputs of emissions and meteorological data which are then dispersed into a grid system to simulate formation of ozone across a specified region. A conceptual representation of UAM's functions is presented in Figure 1.

The basis of this thesis is to show how emission inventory results can be allocated both spatially and temporally to be used as model inputs for the Nashville air quality planning area. Although UAM is capable of modeling a three-dimensional grid to describe emissions aloft in several different mixing layers, this study will assume that all emissions occur within the first grid layer. Only emissions of non-methane organic hydrocarbons, referred to in this thesis as volatile organic compounds (VOCs), and emissions of nitrogen oxide compounds (NOx) will be considered because they are direct precursors of ozone formation. A discussion of the regulatory background, inventory compilation, and results will be followed by a development of methods used to allocate emissions to grid cells. Spatial and temporal allocation of emissions will be evaluated respectively.

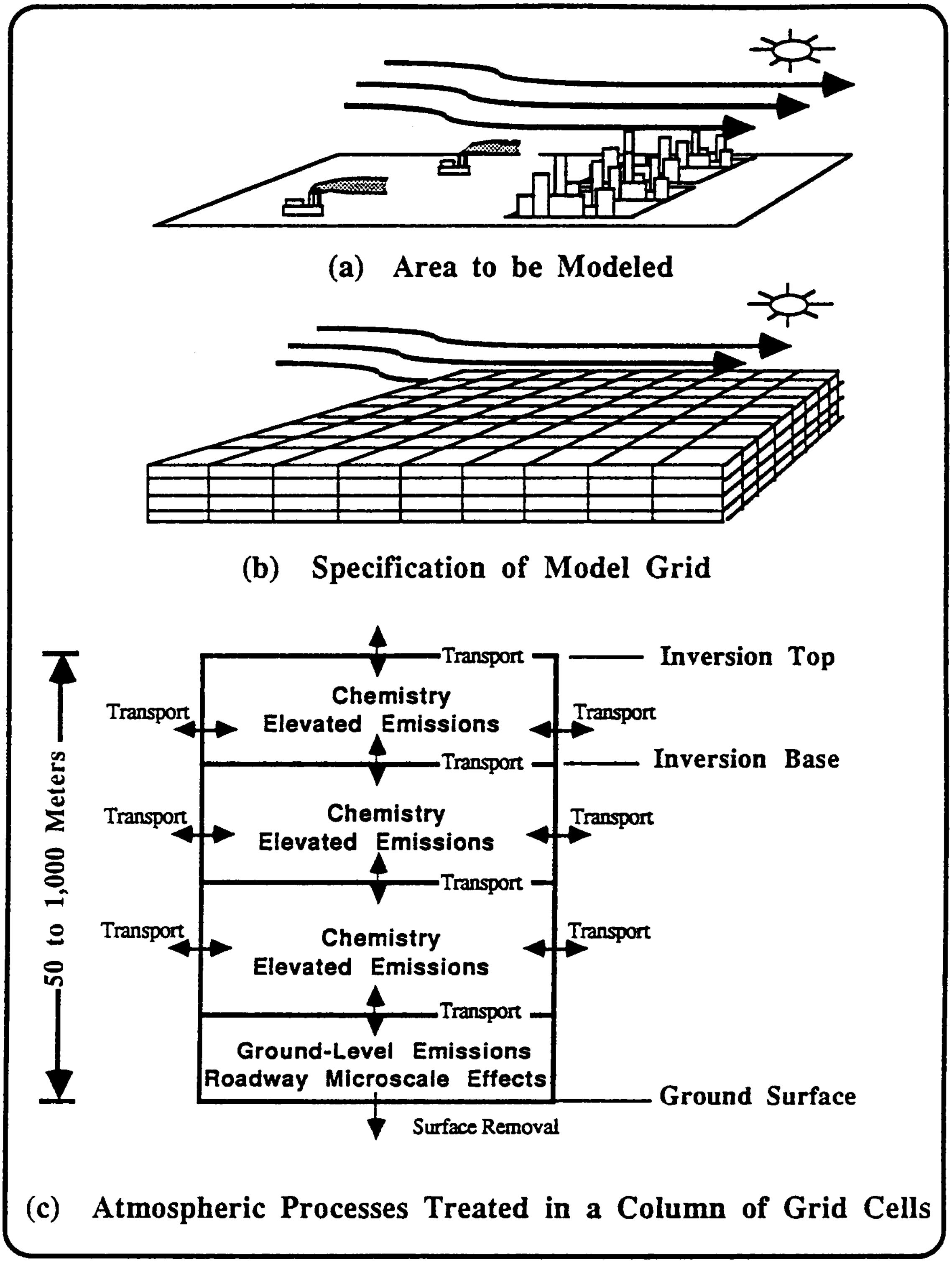


Figure 1. Schematic Illustration of the Grid Used and Treatment of Atmospheric Processes in the SAI Urban Airshed Model

.1.1 Regulatory Background

Post-1987 ozone SIPs are based on the Clean Air Act (CAA) as amended in 1970. The CAA allowed the EPA to set NAAQS's protective of public health with corresponding deadlines for attainment, and called for states to develop SIPs to meet these standards over a three to five year period. In 1977, Congress amended the CAA to extend the ozone and carbon monoxide (CO) NAAQS deadlines to 1982, or in certain special cases 1987. Yet even with the extensions, 68 areas failed to meet ozone standards by 1987, and 59 areas could not attain the CO standard (TDHE, 1989). In an effort to prompt action, the EPA proposed the post-1987 ozone/CO implementation plan in the Federal Register on Nov. 24, 1987. Section 113 of the CAA empowers the EPA to impose civil and criminal penalties for non-compliance with the CAA. Section 120 of the CAA allows each state to submit to the EPA for approval a plan for carrying out non-compliance penalties, and also authorizes EPA to issue fines and sanctions. To forestall such actions, Congress enacted the Mitchell-Conte Amendment to the Budget Reconciliation Act of 1987 which deferred the imposition of EPA sanctions until August 31, 1988. Since the expiration of the Mitchell-Conte deadline, EPA has imposed construction sanctions in counties violating standards in California, Illinois, and Indiana. On May 26, 1988 EPA issued calls for SIP revisions in 43 states, pending final adoption of the post-1987 ozone/CO policy.

The goal of the post-1987 ozone/CO policy is to renovate past regulatory policies and deal with their inadequacies while also providing a realistic regulatory framework within which state agencies can work. The policy requires states to assure full implementation of all previously required control measures, and comply where deficiencies and deviations from the regulations occur. Areas which violate the NAAQS are assigned non-attainment status.

A detailed baseline emission inventory for each state is another cornerstone of the policy. However, it is proposed that each non-attainment area be allowed to adopt flexible attainment deadlines based on the severity of the problem. If an area cannot reach attainment within the requisite time-frame, it must demonstrate an annual emissions reduction of 3 % beyond that achieved by federally implemented measures. The policy expanded the geographic area in which ozone planning for SIPs must be developed from the metropolitan statistical area (MSA) to the entire consolidated metropolitan statistical area (CMSA) (Federal Register, Nov. 24, 1987). The combined MSA and CMSA areas will be referred to as the Standard Metropolitan Statistical Area (SMSA) for the purposes of this thesis.

The revision of SIPs is being promulgated by the EPA because many states could not attain the NAAQS ozone maximum hourly average concentration standard of 0.12 parts per million by volume (ppm) by the December 1987 deadline. States which exceeded the ozone standard more than once in a calender year are are requested to revise their SIPs to include programs which will allow them to meet the standard by 1993. Compilation of an accurate emission inventory is vital to the success of the SIP because it provides a means to assess planning, selection, and implementation of control strategies, as well as providing input for air quality modeling and projected growth (Federal Register, Nov. 24, 1987).

Inventories compiled for ozone SIPs are composed of an estimation of ozone precursor emissions of volatile organic carbons (VOCs), nitrogen oxides (NOx), and carbon monoxide (CO) for Standard Metropolitan Statistical Areas (SMSAs). Areas defined as SMSAs include both non-attainment counties and proposed non-attainment counties. Additionally, any point source within a twenty five mile radius of the SMSA having potential emissions which exceed 100 tons per year (tpy) must be included in the inventory. Inventories should be reported on a countywide basis.

Within the SMSA categories to be included in the inventory are stationary facilities emitting greater than 10 tpy of VOCs (point sources), area sources, and mobile sources. A sample of at least 10 % of point sources emitting between 10-25 tpy must be included in the inventory. Documentation of area source emissions should cover all sources which are too small or too numerous to be included as point sources. The mobile source emission inventory for the SMSA includes a detailed account of emissions from local traffic and traffic on major highways (EPA, 1988a).

1.2 History of Ozone Violations in the Nashville Area

In accordance with the amendments to the CAA, Tennessee submitted a SIP to the EPA demonstrating that by the 1977 deadline, attainment could be achieved for NAAQS for sulfur dioxides (SOx), particulate matter (TSP), CO, ozone, and NOx. EPA found the SIP to be inadequate in demonstrating attainment for CO and ozone for Metropolitan Nashville and Davidson county . EPA required a revised SIP for these areas to be submitted by Jan. 1, 1979 which would demonstrate attainment of the NAAQS by Dec. 31, 1982. The revised SIP was submitted with a contingent five year extension if the demonstration again failed. Metropolitan Nashville and Davidson county requested, and EPA granted the five year extension setting the deadline for attainment of the NAAQS up to Dec. 31, 1987. However, these areas still could not meet the NAAQS by the 1987 deadline. Therefore, EPA proposed to renew Metropolitan Nashville and Davidson county's status as non-attainment in 1988 because of violations the NAAQS for ozone during the period of 1986-1988 (Federal Register, June 6, 1988). Nashville observed violations of the .12 ppm ozone standard ranging from 0.125-0.150 ppm on nineteen separate days during the three year period. The violations occurred during the months of June, July, and August, typically referred to as the "ozone season" months. As part of the revised SIP to demonstrate attainment of the NAAQS by the new 1990 deadline, the SMSA for Metropolitan Nashville and Davidson county submitted an inventory beginning in base year 1988.

The Nashville SMSA consists of the non-attainment county of Davidson where the NAAQS violations occurred along with the adjacent counties of Rutherford, Sumner, Wilson, Williamson ; also included in the SMSA emissions inventory because of proposed non-attainment status are the surrounding counties of Cheatham, Dickson, and Robertson. The twenty five mile extended radius area to be included in the air quality planning for Nashville includes all or parts of the affected counties of Bedford, Benton, Cannon, Clay, Coffee, Dekalb, Franklin, Grundy, Hickman, Houston, Humphreys, Jackson, Lewis, Lincoln, Macon, Marshall, Maury, Montgomery, Moore, Perry, Putnam, Stewart, Trousdale, Warren, and White in Tennessee, and Trigg, Christian, Todd, Logan, Simpson, Allen, Monroe, Barren, Butler, and Muhlenburg in Kentucky. Figure 2 shows the locations and designated status of the counties involved in the emissions inventory.

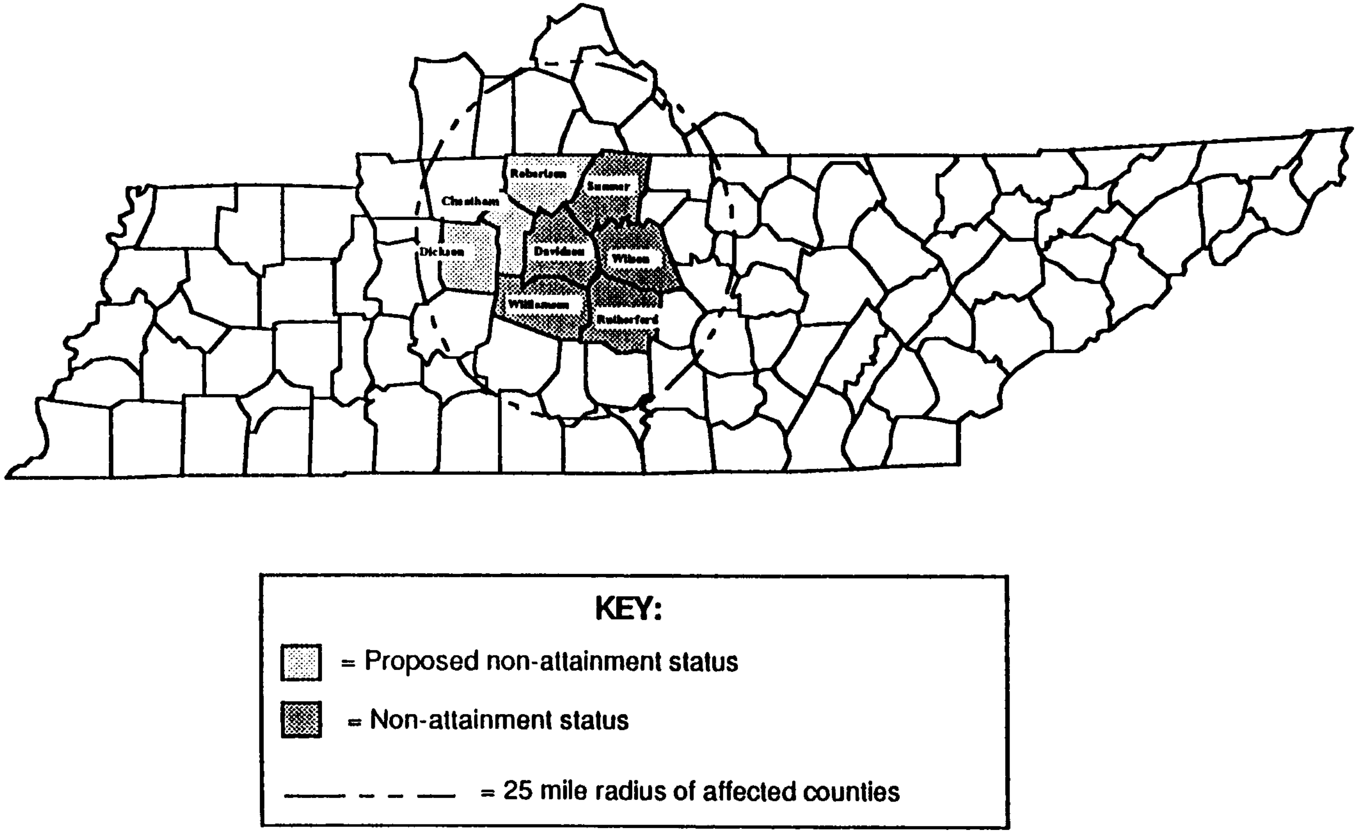


Figure 2. Nashville Air Quality Planning Area

2.0 LITERATURE REVIEW

Anthropogenic emission inventories for nitrogen oxides (NOx) and volatile organic compounds (VOC) use the broad categories of point, area, and mobile sources to define and calculate emissions. Point sources by definition emit more than a defined amount of pollutants per year. Area sources comprise the large number of small stationary and mobile sources with emissions too small to define them as point sources. Because NOx and VOC are precursors of harmful secondary products, their documentation in emission inventories is of paramount importance in developing control strategies for air pollution. This literature review will concentrate on discussions of some of the major emission inventories which have been compiled on regional and national scales.

2.1 The NEDS Emission Inventory

In 1970 the U.S. Congress passed an amendment to the CAA requiring states to compile and maintain annual point source emission inventories for individual sources emitting more than 100 tpy of any one of five criteria pollutants (SOx, NOx, VOC, CO, and TSP). The emission inventory data bases for the five criteria pollutants were to be periodically updated and submitted to the federal government. In 1971 the National Air Data Branch (NADB) of the EPA's Office of Air Quality Planning Standards established a central data base of the emissions inventories submitted by state air pollution agencies. This data base and its management system are part of the National Emissions Data System (NEDS). NEDS groups emissions inventories into point source and area source categories. NEDS point source inventory contents are detailed in the EPA's Guide for Compiling a Comprehensive Emissions Inventory (EPA, 1973a). Additional emission estimation procedures and reporting requirements are documented in EPA's AEROS Manual Series, Vol. 1 (EPA 1976b).

Documentation of individual point sources in NEDS should include the following information:

--- source location (state,county,AQCR, UTM Coordinates)

--- stack parameters

--- normal operation schedule

--- source classification code

--- annual emissions of the 5 primary criteria pollutants

--- emissions control equipment and efficiency information

Annual emissions may be quantified using stack test, process materials balance, process activity x emission factors [(taken from Compilation of Air Pollution Emission Factors (EPA, 1973b)], or an estimation based on personal knowledge and experience.

Although state agencies are required to update the emission inventories annually, a 1979 study indicated that many states' point source emissions data remained essentially at 1973 levels (Clark, 1980). The subsequent National Acid Precipitation Assessment Program (NAPAP) data inventory efforts are estimated to have obtained data for over 80 % of the point source emissions of SOx, NOx, and VOC for 1980 (Toothman, 1985). However, over 80% of the emission values for point sources and all of the area source values were derived using emission factors (QAQPS, 1980).

Area source inventories compiled for each state on an annual basis with spatial resolution at the county level are also stored in NEDS. Each county's area source inventory should contain the following information:

--- location (state, county, AQCR)

--- estimated annual emissions for the five primary criteria pollutants

--- quantity of fuel burned for residential, commercial, and industrial heating and transportation

--- number of vehicle miles traveled (VMT) within the county during the year

--- population data

These data are derived using standard procedures and EPA emission factors (EPA 1973b) along with data compiled by county, state, and federal agencies. The NEDS area source emission inventory is updated annually by NADB based on updated information received from various federal and state agencies.

2.2 The NAPAP Emission Inventory

The NAPAP inventory charged with developing an emissions inventory of acid deposition precursors for anthropogenic sources in the base years 1980 and 1985 has done much to improve the quality of the NEDS data base. The starting point for the development of this inventory was the NEDS 1980 inventory. Updates and additions were made to NEDS to correct known deficiencies and add a larger area and more pollutant species. Improvements were also made in the calculation of area source and highway vehicle emissions.

According to the NAPAP 1980 emission inventory, the annual national tonnages of NOx and VOC emissions are approximately equal. On a national scale, NOx emissions are divided almost equally between major point sources (49%) and area sources (51%), while VOC emissions are predominantly from area sources (79%). NOx point sources are principally stationary fuel combustion sources whereas VOC point sources are composed mainly of a mix of petroleum refineries/storage, and chemical processing plants. Mobile sources account for about 3/4 of the NOx area source emissions and for more than 1/3 of the VOC area source emissions. If cumulative NOx and VOC emissions are converted to molar units of nitrogen dioxide and carbon respectively, the ratio of national emissions in the NAPAP 1980 study is between 3 and 4 (EPA, Dec. 1984).

2.3 The MAP3S Emission Inventory

A key task of the Multistate Atmospheric Power Production Pollution System (MAP3S) study performed in 1981 was to quantify anthropogenic emissions of pollutants to be used in characterizing wet and dry deposition of atmospheric pollutants. The geographic area of interest included all of the continental United States and Canada. NEDS was chosen as the main data source in the United States, and Canadian data were supplied by the Air Pollution Control Directorate of Environment Canada. The NEDS data reflects a base year of 1977-1978 for point sources and a base year of 1975 for area sources. Canadian data could only be obtained for point sources, and reflected a base year of 1974. The original data sets were supplemented by additional information on annual operating and emissions data for power plants in the United States and corrections to NEDS data in the form of emissions, operating schedules, and coordinate location updates. Data were also provided on population demographics for several areas in the United States (Benkovitz, 1982).

Results of the inventory show a total of 20.7 million tons per year of NOx emissions, and 26.7 million tons per year of hydrocarbon (HC) for the United States. The NOx emissions break down into source categories of 52% from point sources and 48% from area sources. Area sources contribute 81% of the total HC emissions in the continental United States, while point sources only contribute 19%. The principal area source contributor of both NOx and HC emissions is the transportation sector. The study found that NOx point source emissions are concentrated on a finite number of emitters. 90% of the NOx point source emissions were accounted for by only 8.3% of the plants inventoried in the study. On the other hand, the same 8.3% of plants accounted for only 43% of all HC emissions, indicating that HC point source emissions are more geographically diverse (Benkovitz, 1982).

2.4 Historical Trends in Emission Inventories

A study compiled by Geschwandtner et al. reports historical annual emission estimates of VOC and NOx for each state of the contiguous United States. Emissions were estimated by apportioning the national estimates for every fifth year according to yearly activity indicators representing major source categories. The major source categories used in the study are 1) transportation sources, 2) external fuel combustion sources, 3) Industrial processes, 4) solid waste disposal, and 5) miscellaneous other sources. Emission values were interpolated for the intervening years (Geschwandtner, 1989).

Historical trends indicate that while NOx and VOC emissions have increased fairly steadily since 1900, NOx emissions are increasing at a faster rate. Since the 1940's transportation and industrial sources have become the main contributors of NOx and VOC emissions. The mass ratio of VOC to NOx has decreased on the national scale from 5.1 in 1900 to about 1.1 in 1980. This decrease is generally attributed to a drop in VOC emissions with a corresponding rise in NOx emissions. Estimates predict the VOC/NOx ratio for the state of Tennessee to be about 1.1 in 1985 (Geschwandtner, 1989). Figure 3 illustrates Geschwandtner's estimations with regard to NOx and VOC emissions for Tennessee and the United States. A comparison of the national ratio to that of Tennessee shown in Figure 3 indicates higher ratios occurring in Tennessee. One possible reason for the higher VOC/NOx ratios in Tennessee may be found in the state's historically low traffic volumes; low traffic volumes imply low mobile source emissions which produce large amounts of NOx emissions that can lower the VOC/NOx ratio.

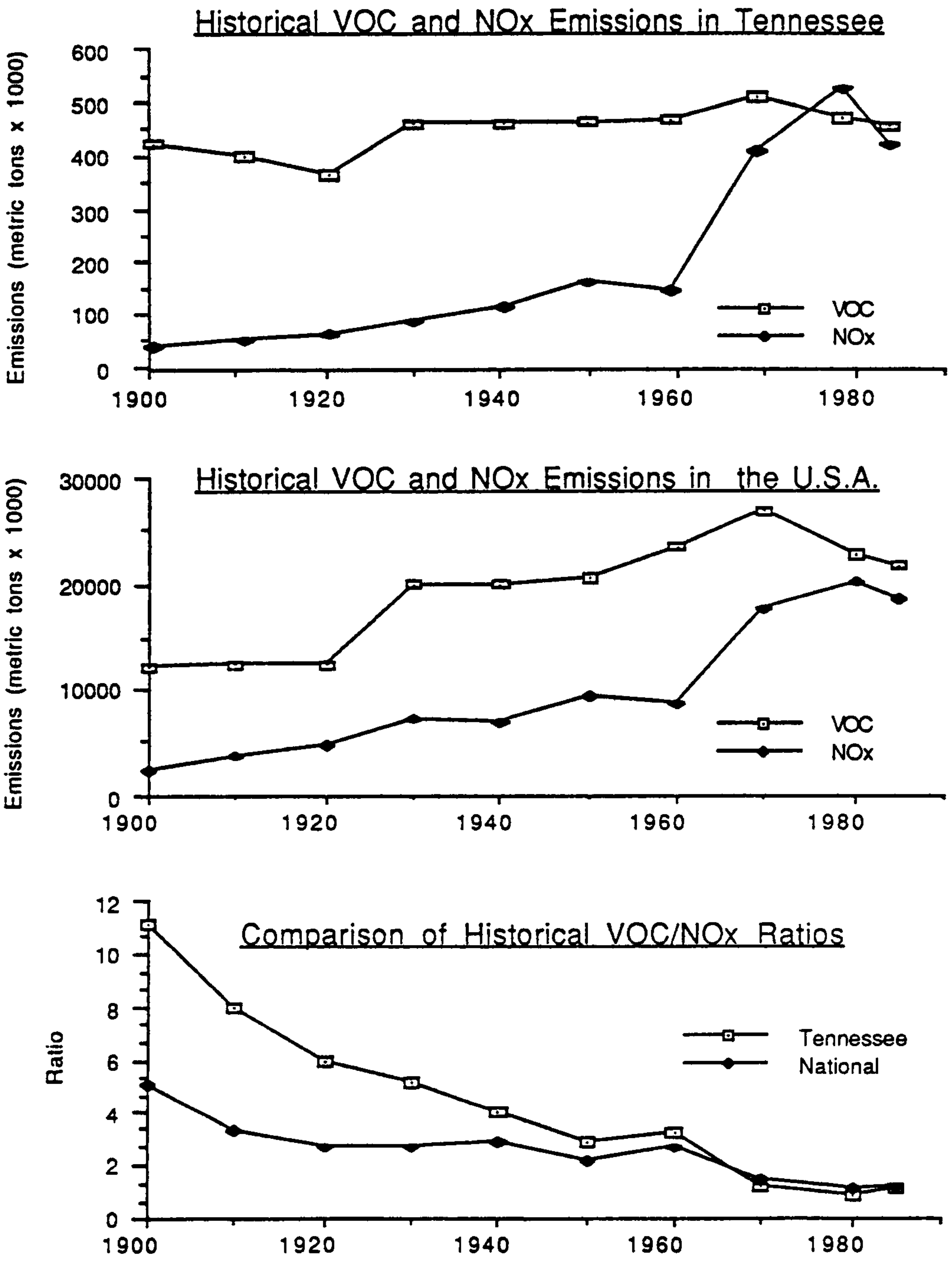


Figure 3. Comparison of Historical Tennessee and National VOC and NOx Emissions and Ratios

2.5 Evaluation of Uncertainties in Emission Inventories

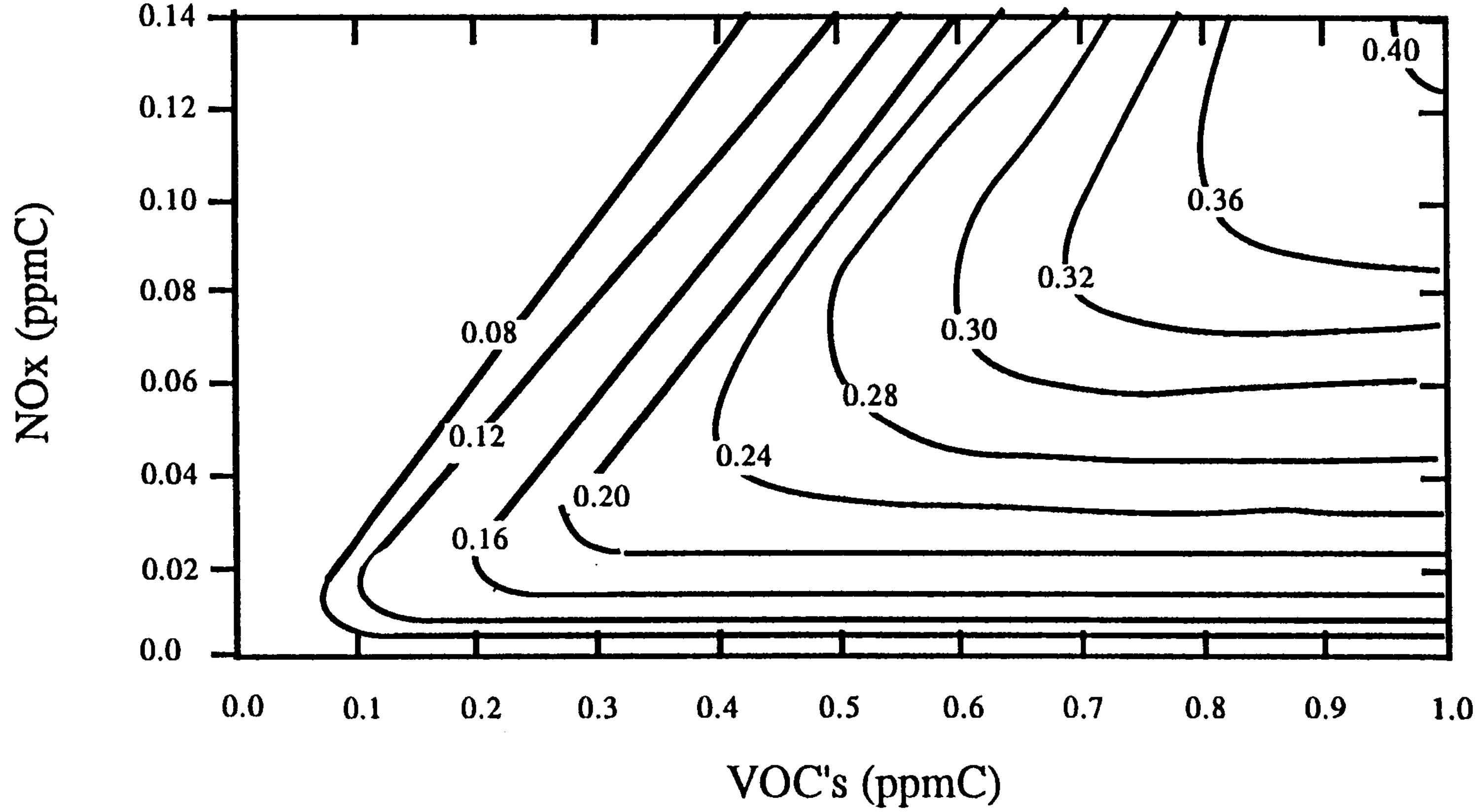
Continuing efforts are helping to identify problem areas creating uncertainties in emission inventories. A study performed by Benkovitz pointed out uncertainties in the inventories by assessing the internal consistency of emission estimates using statistical analysis of the probability distribution of the uncertainty estimate which was processed by expert teams using the Delphi technique. Preliminary results of this method indicate that area source emission factors used in calculating VOC emissions may range in uncertainty up to 100% (Benkovitz, 1985).

An obvious uncertainty in the NEDS emission inventory is the 100 tpy cut-off for point source reporting. Significant quantities of emissions may be emitted from smaller sources which use surrogate indicators to calculate emissions. These smaller sources are considered to be area sources for which NEDS applies county level fuel consumption or activity estimate factors to derive emissions. Such statistically averaged parameters will inherently introduce an element of inaccuracy into the inventory (Ching, et. al., 1987).

Much of the uncertainty in emission inventories is found in the emission factors used for estimations. For example, NOx emission factors for utility and industrial fuel combustion will vary greatly depending on the boiler type, physical condition, and operation conditions. Physical and operating conditions of mobile sources will greatly affect the calculation of corresponding emission factors (Gillani, et. al. 1989).

2.6 Comparison of Ambient Monitoring Data with Emission Inventories

Because the VOC/NOx ratio is critical in determining ozone control strategies, much work has been done to quantify this ratio using ambient monitoring data and emission inventories. Figure 4 demonstrates the role of this ratio in forming ozone along the .12 ppm ozone NAAQS isopleth. The isopleths shown in Figure 4 are the result of



Modified from Dodge, 1984

Figure 4. Ozone Isopleth of Updated Carbon-Bond Mechanism

modeling studies performed using the OZIPM4 (also known as EKMA) photochemical smog simulation model. A high VOC/NOx ratio would indicate ozone concentrations at the far right end of the ozone formation isopleth, implying that VOC concentrations must be reduced to control ozone. A low VOC/NOx ratio would indicate ozone concentrations toward the toe of the isopleth where reductions in NOx may significantly reduce the ozone forming potential of these precursors (Dodge,1984).

Ratios of VOCs to NOx may be studied from the perspective of ambient monitoring concentrations as well as results from emission inventories. Ambient monitoring data yields information on volumetric ratios of VOCs and NOx in units of ppm. This concentration data is representative only of air quality in the direct vicinity of the monitor, and may reflect pollutant concentrations affected by meteorological events and photochemical reactions (APCA Critical Reviews, 1988). On the other hand, emission inventories describe mass ratios of VOCs and NOx in units of mass per time, and are usually reported in terms of the characterization of an entire region. Ratios of VOC to NOx calculated from emission inventories describe amounts of these pollutants at their source, and will be affected by operating conditions at the source rather than meteorological conditions or photochemistry.

Although ambient monitoring and emission inventory ratios differ in their fundamental definition, they are both indicators of air quality, and as such it may be useful to compare them. A conversion of ambient monitoring volumetric concentration ratios to mass ratios is necessary for comparison with inventory results given in mass ratios. Volumetric ratios are converted to mass ratios by multiplying the ratio by the inverse of the respective molecular weights. Assuming NOx compounds are reported as nitrogen dioxide, their molecular weight is 46. If the default value of the average species of VOC taken from the OZIPM4 model is used, the total VOC compounds have an average molecular weight of 17. Therefore, a volumetric ratio should be multiplied by 17/46, or a factor of .34, to obtain the corresponding mass ratio. The impact in terms of lowering the ratio when converting from volume to mass is readily apparent in the data shown in Figure 5. Ambient monitoring volumetric ratios shown in Figure 5 were measured in various cities in a study conducted in 1984 (Baugues, 1986). These volumetric ratios have been converted using the previously described method, and the newly derived mass ratios are shown beside their counterparts in Figure 5.

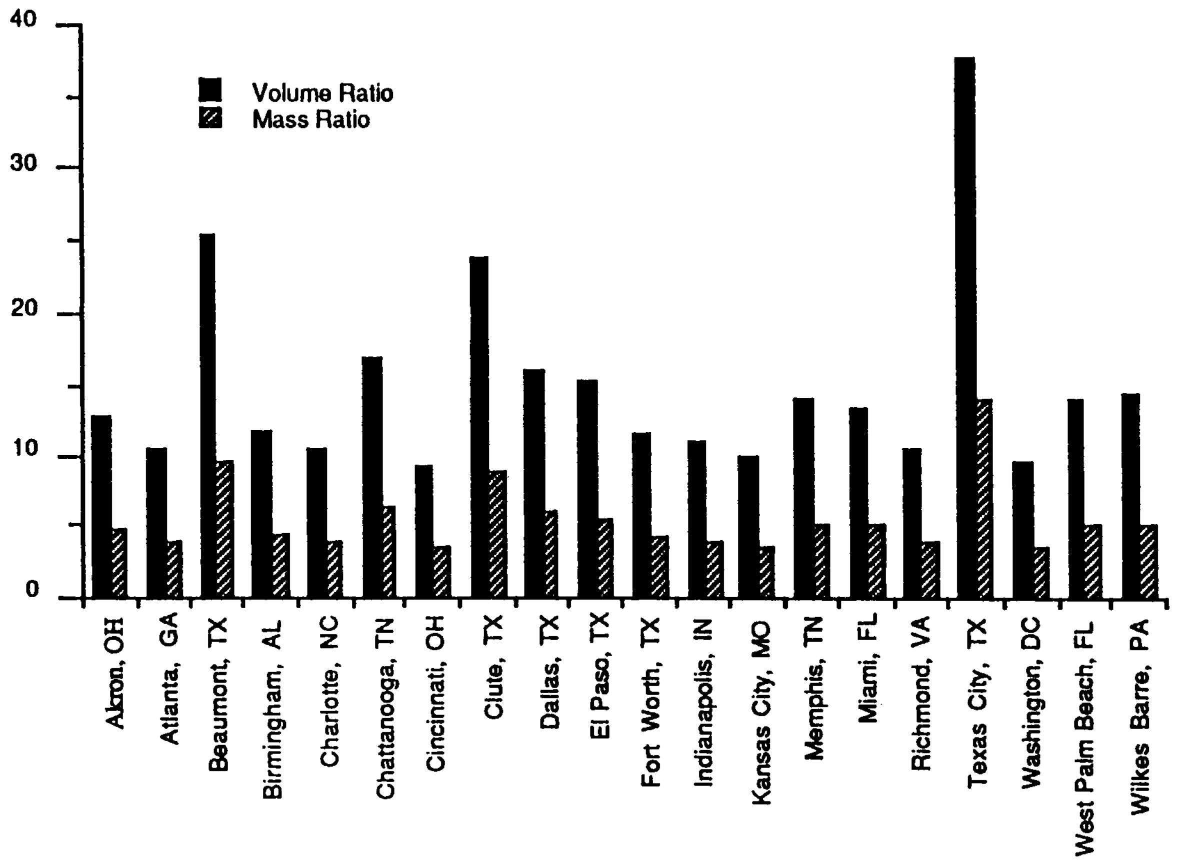


Figure 5. Comparison of Ambient Volumetric and Mass VOC/NOx Ratios for Selected Cities

3.0 EMISSION INVENTORY

The TDHE's Division of Air Pollution Control is responsible for developing the revised SIP and the compulsory emissions inventory. The metropolitan government of Nashville and Davidson county's Department of Health compiled the emission inventory for the Metropolitan Nashville and Davidson county areas.The Civil Engineering Department of the University of Tennessee was sub-contracted to complete the emission inventory for the seven counties included in the SMSA adjacent to Davidson county, as well as to compile the inventory for point sources emitting more than 100 tpy in the affected twenty five mile radius around the SMSA.

The following sections will discuss methods used to compile the emission inventory for point, area, and mobile sources respectively. Methods used in compiling the Davidson county inventory differ from those used for the rest of the air quality planning area because these were compiled by two different agencies. The Davidson county emission inventory will be discussed separately to clarify differences in its methodology.

3.1 The SIP Air Pollution Inventory Management System

All emissions inventory information was entered into the EPA's SIP Air Pollution Inventory Management System (SAMS) which was written using DBASE III for use on IBM PCs. EPA believes SAMS will assist agencies in compiling the proper information as well as providing a standardized data format to aid EPA in assessing data. SAMS provides data entry areas for storing information for point, area, and mobile sources for baseline and projected inventories. In the point source data area of SAMS specific data can be entered for point sources that include plant data, point data, point emissions data, process data, process base year emissions data, and process projection year data. Area and mobile source data are stored in specific categories on a large summary spreadsheet in SAMS (EPA, 1989).

The SAMS database presents unique opportunities for data management. It is compatible with the IBM PC software DBASE III which may be utilized outside of the SAMS program to manipulate data files. SAMS also provides built-in utilities which sum point source emissions, upload computer generated NEDS data, and generate reports.

3.2 Surrounding Counties Inventory Point Source Data

Point source data for the seven counties in the SMSA surrounding Davidson county was compiled from three different sources, namely: NEDS and EIS databases, and questionnaires. All point source information was entered into SAMS either manually or by using utilities module within SAMS allows the import of NEDS data. The methods used to compile and manipulate data are described here in detail because of the complexity of the various systems used to obtain information. Although future efforts may improve and revise these processes, this research would be difficult to duplicate without such detailed insights.

Region IV EPA supplied point source information from NEDS for point sources emitting VOCs or NOx in quantities greater than or equal to 100 tpy. These data were used to collect information on point sources in the affected areas of Kentucky. The data were down-loaded from a main-frame computer onto IBM floppy diskettes, and then it was imported directly into the SAMS database using its "NEDS transaction" utility (University of Tennessee, 1990).

A second source of information was provided by the TDHE's Emission Inventory System (EIS) database. The data were transferred from the EPA Region IV main-frame computer to the VAX main-frame computer at UT using BITNET telecommunications. The data were downloaded from the VAX to an IBM PC computer using a modem and UT's Procomm software. The EIS data files prepared by the TDHE for this study were in an abbreviated format with character headings suppressed. An on-screen editor was used to remove commas from the files so that subsequent computer processor programs could read the data. Then a program called EIS-NEDS.BAS was run on the converted NEDS file to generate a summary table of emissions of VOC's, NOx, and CO for each point source facility. The NEDS formatted data could then be uploaded into the SAMS program using it's built-in "NEDS transaction" utility. Once data were converted to the SAMS format, DBASE III could be used to compile summary tables for each point source facility. In this way, each step of the transferral process could be checked for completeness by comparing the DBASE III and EIS-SUM tables and the hard copies of the EIS files. Any sources that were omitted during conversion from EIS to SAMS were added into SAMS manually using DBASE III utilities (University of Tennessee, 1990).

Detailed point source information reports generated using a SAMS utility were sent to major point source facilities which were requested to verify the accuracy of this information. In addition, these facilities were asked to provide projections on industrial growth which might affect their emissions. Approximately two months after the initial mailing, a second mailing was sent out to illicit responses from facilities which had not returned the initial mailed report (University of Tennessee, 1990).

A third means of compiling point source emissions information was through the use of questionnaires sent to individual facilities. A target mailing list was formed by checking the Tennessee Manufacturer's Directory for facilities. The chamber of commerce of each county was also contacted and asked to provide a list of manufacturers. Any facility with a potential to emit VOCs, NOx, or CO which was not already included in the EIS database was sent a questionnaire (University of Tennessee, 1990). The questionnaire, based on EPA guidance, was designed to provide information on the type of operation, materials used, production rates, and projected growth each facility (EPA, 1978).

Information from the returned questionnaires was evaluated in terms of emissions per through-put for each type of process. Sources which indicated that they weren't VOC, NOx, or Co emitters, or which emitted insignificant quantities of these pollutants (e.g. did not meet the criteria for identification as a point source) were eliminated from the database. Types of processes were identified by description or source classification code. Emission factors for each process were derived from the EPA guidance. The resulting data were entered manually into SAMS in the 10-25 tpy Small Plant Information module (University of Tennessee, 1990).

Point source data compiled in SAMS on a tons per year emissions basis were converted to a pounds per day basis for a typical ozone season summer day. Although SAMS allows the manual entry of emissions for a typical ozone season day, the conversion was performed using a DBASE III program to increase the speed and accuracy of the data entry. The DBASE III program called O3-SEAS.ADJ served the dual purpose of calculating emissions and transferring data to the proper areas in the SAMS database so that an emissions summary tables could be generated using a SAMS utility. The program O3-SEAS.ADJ adjusted annual ozone emissions given in tons per year to emissions in pounds per day occurring on a typical ozone season day by taking into account 1) conversion from tons to pounds and years to days, 2) percentage of operation during the summer months, 3) number of weeks of operation during the year, 4) days of operation during the week, and 5) percentage of space heating. The following formula describes this adjustment in terms of the variable names assigned in the SAMS program:

$$O3EMIS = (2000/365) \times (ESTIMATED) \times (JUNAUG/25) \times (52/WEEKSYEAR) \times (7/DAYSWEEK) \times (1 - SPACEHEAT/100)$$

where,

O3EMIS	=	ozone season emissions in pounds per day
2000	=	conversion from tons to pounds
365	=	conversion from years to days
ESTIMATED	=	estimated annual emissions in tons per year
JUNAUG	=	The percentage of plant operation during the summer months
WEEKSYEAR	=	the number of weeks during the year in which the facility is in operation
DAYSWEEK	=	the number of days during the week during which the facility is in operation, and
SPACEHEAT	=	the annual percentage of boiler operation attributable to space heating.

All variable names used in the above calculation were defined by the SAMS database. Figure 6 presents a flow chart of point source data management and data entry into SAMS (University of Tennessee, 1990).

3.3 Surrounding Counties Area Source Emission Calculations

Area sources for the seven counties in the SMSA surrounding Davidson were calculated using EPA emission estimating procedures for small point and mobile sources. The procedures use emission factors multiplied by surrogate activity indicators to derive emissions for various source categories. In most cases the relevant activity indicators were county data on population, harvested acres, number of employees, and registered boats. If such information was available for a year other than that of the base line year for the inventory (1988), the data were normalized to reflect estimated values for the base line year. Likewise, where data were only available on the state level, they were normalized to reflect estimates for the county level. Seasonal adjustments to correct the annual data to obtain emissions for an average ozone season summer day were taken from table 6.8 of the EPA guidance document on procedures for the preparation of emission inventories for

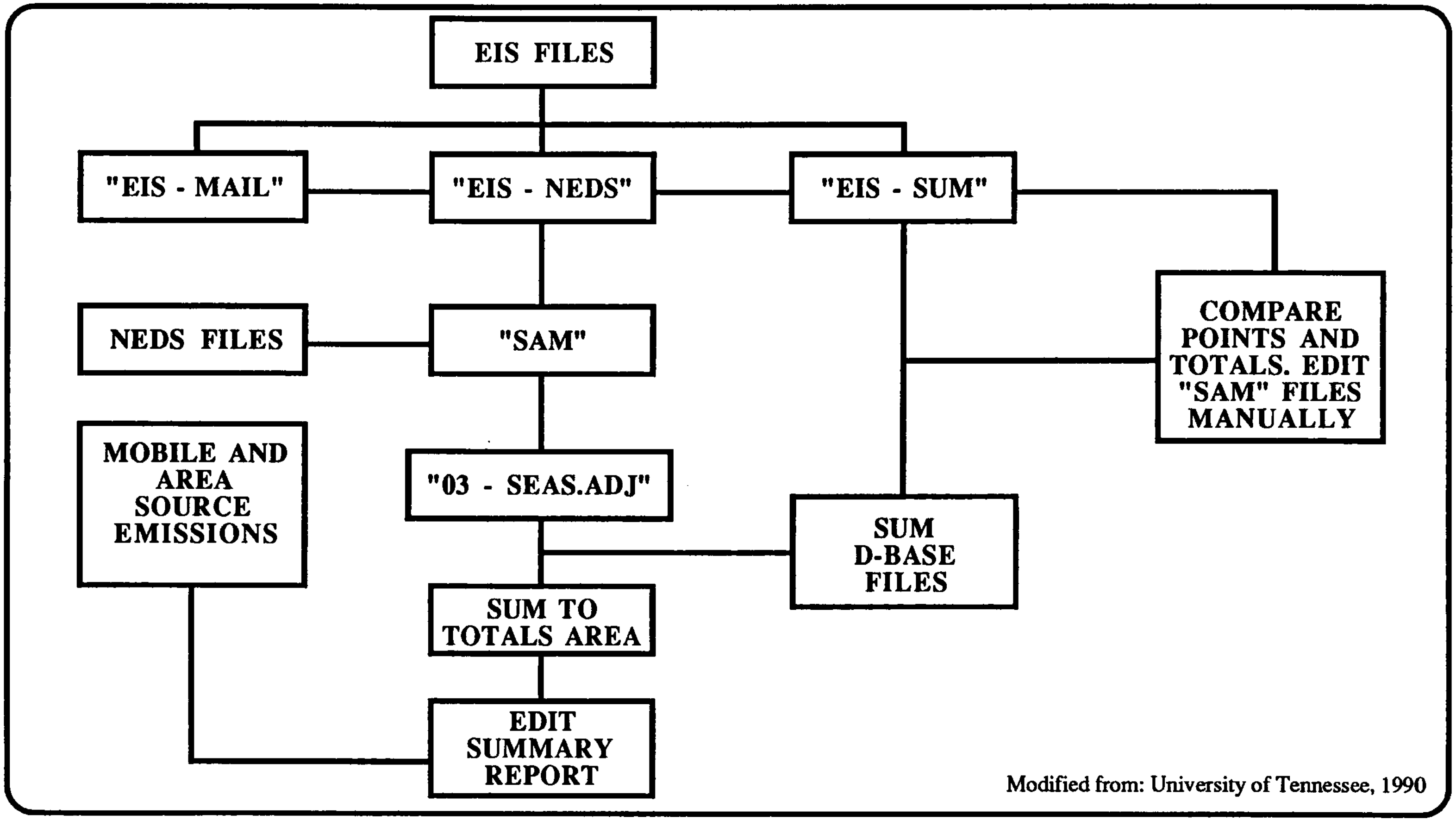


Figure 6. Point Source Data-Handling Procedures

precursors of ozone (EPA, 1988b). Area source categories and emissions for VOCs and NOx are listed in Tables 1 and 2 (University of Tennessee, 1990).

3.4 Surrounding County Mobile Source Emissions

Mobile source emissions for cars and trucks traveling on highways in the seven SMSA counties surrounding Davidson were calculated by using the output from the EPA's Mobile 4 computerized mobile source emissions model along with other IBM PC computer programs developed by the University of Tennessee. The output of Mobile 4 yields emission factors which are defined as grams of emissions per vehicle miles traveled. Different emission factors were calculated using Mobile 4 for the typical ozone season summer day and for the average annual case. The most important inputs were vehicle age, vehicle speed, percentage of heavy duty trucks included in the total traffic volume, and the ambient temperature (University of Tennessee, 1990).

UT developed a few simple programs using BASIC language to compile the vehicle miles traveled (VMT), roadway type, and geographical classification for each grid needed as input to Mobile 4. To obtain the VMT, highway maps were digitized using the AutoCAD software package. Then UTM coordinates and mileage were calculated for each roadway link. Average daily traffic volumes obtained from the Tennessee Department of Transportation were then multiplied by the mileage of each roadway link to obtain VMT for each grid cell using the program VMT-GRID.TOT. Roadway type and geographical classification were assigned to the VMT's of each grid using the program VMT-CLAS.TOT (University of Tennessee, 1990).

Composite average emission factors for each road type and geographic area were calculated using the program MB4-CLAS which used Mobile 4 emission factors and traffic volumes as input. These factors were then applied to the appropriate classification of

Table 1. VOC Area Source Emission Summary

	COUNTY										COUNTY			
	Cheatham		Dickson		Robertson		Rutherford		Sumner		Williamson		Wilson	
SOURCE	Annual Emissions (Tons)	Daily Emissions (Tons)	Annual Emissions (Tons)	Daily Emissions (Tons)	Annual Emissions (Tons)	Daily Emissions (Tons)	Annual Emissions (Tons)	Daily Emissions (Tons)	Annual Emissions (Tons)	Daily Emissions (Tons)	Annual Emissions (Tons)	Daily Emissions (Tons)	Annual Emissions (Tons)	Daily Emissions (Tons)
TANK TRUCK UNLOADING	99.467	0.319	130.375	0.418	161.658	0.518	413.978	1.327	384.007	1.231	292.220	0.937	256.629	0.823
UNDERGROUND TANK BREATHING	8.649	0.028	11.337	0.036	14.057	0.045	35.998	0.115	33.392	0.107	25.410	0.081	22.316	0.072
GAS TRUCKS IN TRANSIT	2.422	0.008	3.174	0.010	3.936	0.013	10.079	0.032	9.350	0.030	7.115	0.023	6.248	0.020
COMMERCIAL DRY CLEANING	17.420	0.067	22.556	0.087	28.145	0.108	72.865	0.280	66.625	0.256	51.350	0.198	44.850	0.173
COIN OP DRY CLEANING	5.360	0.021	6.940	0.027	8.660	0.033	22.420	0.086	20.500	0.079	15.800	0.061	13.800	0.053
DEGREASING-COLD CLEANING	40.200	0.129	52.050	0.167	64.950	0.208	168.150	0.539	153.750	0.493	118.500	0.380	103.500	0.332
ARCHITECTURAL SURFACE COATING	61.640	0.220	79.810	0.285	99.590	0.356	257.830	0.921	235.750	0.842	181.700	0.649	158.700	0.567
AUTO REFINISHING	25.460	0.098	32.965	0.127	41.136	0.158	106.495	0.410	97.375	0.375	75.050	0.289	65.550	0.252
GRAPHIC ARTS	10.720	0.041	13.880	0.053	17.320	0.067	44.840	0.172	41.000	0.158	31.600	0.122	27.600	0.106
CUTBACK ASPHALT	8.576	0.000	11.104	0.000	13.856	0.000	35.872	0.000	32.800	0.000	25.280	0.000	22.080	0.000
PESTICIDE APPLICATION	13.954	0.058	25.798	0.107	118.111	0.492	60.555	0.252	65.635	0.273	56.993	0.237	39.972	0.167
COMMERCIAL/CONSUMER SOLVENT USE	84.420	0.232	109.306	0.300	136.395	0.375	353.115	0.970	322.875	0.887	248.850	0.684	217.350	0.597
MUNICIPAL SOLID WASTE LANDFILL	0.444	0.001	1.290	0.004	0.275	0.001	3.888	0.011	0.118	0.000	0.433	0.001	0.893	0.002
PUBLIC WATER TREATMENT WORKS	2.024	0.008	5.878	0.023	12.912	0.050	32.005	0.123	14.904	0.057	8.030	0.031	15.803	0.061
NATURAL GAS-RESIDENTIAL	0.637	0.001	0.824	0.001	1.028	0.001	2.662	0.002	2.434	0.002	1.876	0.002	1.639	0.001
COAL-RESIDENTIAL	0.612	0.001	0.793	0.001	0.989	0.001	2.561	0.002	2.342	0.002	1.805	0.001	1.577	0.001
DISTILLATE OIL AND KEROSENE-RESIDENTIAL	0.058	0.000	0.075	0.000	0.093	0.000	0.241	0.000	0.220	0.000	0.170	0.000	0.148	0.000
RESIDUAL OIL-RESIDENTIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG-RESIDENTIAL	0.080	0.000	0.104	0.000	0.130	0.000	0.336	0.000	0.308	0.000	0.237	0.000	0.207	0.000
NATURAL GAS-COMMERCIAL	0.115	0.000	0.440	0.001	0.380	0.001	2.252	0.004	1.352	0.002	1.898	0.003	0.930	0.002
COAL-COMMERCIAL	0.012	0.000	0.048	0.000	0.041	0.000	0.244	0.000	0.146	0.000	0.208	0.000	0.101	0.000
DISTILLATE OIL AND KEROSENE-COMMERCIAL	0.012	0.000	0.044	0.000	0.038	0.000	0.227	0.000	0.136	0.000	0.191	0.000	0.094	0.000
RESIDUAL OIL-COMMERCIAL	0.003	0.000	0.012	0.000	0.011	0.000	0.063	0.000	0.038	0.000	0.053	0.000	0.026	0.000
LPG-COMMERCIAL	0.003	0.000	0.011	0.000	0.010	0.000	0.059	0.000	0.035	0.000	0.049	0.000	0.024	0.000
NATURAL GAS-INDUSTRIAL	0.504	0.001	0.560	0.002	0.974	0.003	4.252	0.012	2.327	0.006	1.526	0.004	1.622	0.004
COAL-INDUSTRIAL	3.789	0.010	4.216	0.012	7.330	0.020	31.990	0.088	17.508	0.048	11.479	0.032	12.201	0.034
DISTILLATE OIL AND KEROSENE-INDUSTRIAL	0.020	0.000	0.023	0.000	0.039	0.000	0.172	0.000	0.094	0.000	0.062	0.000	0.066	0.000
RESIDUAL OIL-INDUSTRIAL	0.010	0.000	0.012	0.000	0.020	0.000	0.088	0.000	0.048	0.000	0.031	0.000	0.033	0.000
LPG-INDUSTRIAL	0.015	0.000	0.017	0.000	0.029	0.000	0.128	0.000	0.070	0.000	0.046	0.000	0.049	0.000
RAILROAD	46.309	0.127	51.747	0.142	42.683	0.117	56.444	0.155	82.400	0.226	74.819	0.206	60.152	0.165
RECREATIONAL BOATS	80.512	0.460	84.918	0.485	76.650	0.437	223.203	1.274	295.011	1.684	149.437	0.853	218.090	1.245
MOTORCYCLES	2.312	0.008	2.843	0.010	2.895	0.010	16.054	0.067	9.222	0.033	6.622	0.024	5.928	0.021
FARM EQUIPMENT	29.158	0.088	53.909	0.163	246.815	0.746	126.412	0.382	137.156	0.414	119.096	0.360	83.527	0.252
CONSTRUCTION EQUIPMENT	0.000	0.000	0.000	0.000	0.000	0.000	58.699	0.188	18.181	0.058	106.624	0.342	34.897	0.112
INDUSTRIAL EQUIPMENT	5.272	0.020	6.212	0.024	11.255	0.043	47.093	0.181	25.643	0.099	18.858	0.073	17.826	0.069
LAWN AND GARDEN EQUIPMENT	40.200	0.220	52.050	0.284	64.950	0.355	168.150	0.919	153.750	0.840	118.500	0.648	103.500	0.566
AIRCRAFT	0.000	0.000	2.930	0.008	2.930	0.008	179.000	0.484	5.860	0.016	2.930	0.008	0.000	0.000
ON-SITE INCINERATION-RESIDENTIAL	5.360	0.015	6.940	0.019	8.660	0.024	22.420	0.062	20.500	0.056	15.800	0.043	13.800	0.038
ON-SITE INCINERATION-COMMERCIAL	0.925	0.003	1.197	0.003	1.494	0.004	3.867	0.011	3.536	0.010	2.726	0.007	2.381	0.007
ON-SITE INCINERATION-INDUSTRIAL	1.120	0.003	1.246	0.003	2.166	0.006	9.430	0.026	5.174	0.014	3.392	0.009	3.605	0.010
FOREST FIRES	7.128	0.077	8.856	0.096	15.876	0.173	30.240	0.329	38.880	0.423	0.648	0.007	24.084	0.262
NON-FOREST FIRES	1.109	0.012	1.742	0.019	5.371	0.058	2.045	0.022	2.650	0.029	0.317	0.003	4.334	0.047
OPEN BURNING-RESIDENTIAL	36.180	0.099	46.845	0.129	58.455	0.161	151.335	0.416	138.375	0.380	106.650	0.293	93.150	0.256
OPEN BURNING-COMMERCIAL	0.836	0.002	1.083	0.003	1.351	0.004	3.498	0.010	3.198	0.009	2.465	0.007	2.153	0.006
OPEN BURNING-INDUSTRIAL	0.398	0.001	0.453	0.001	0.778	0.002	3.309	0.009	1.874	0.005	1.187	0.003	1.279	0.004

Table 2. NOx Area Source Emission Summary

SOURCE	Cheatham Annual Emissions (Tons)	Cheatham Daily Emissions Tons	Dickson Annual Emissions (Tons)	Dickson Daily Emissions Tons	Robertson Annual Emissions (Tons)	Robertson Daily Emissions Tons	Rutherford Annual Emissions (Tons)	Rutherford Daily Emissions Tons	Sumner Annual Emissions (Tons)	Sumner Daily Emissions Tons	Williamson Annual Emissions (Tons)	Williamson Daily Emissions Tons	Wilson Annual Emissions (Tons)	Wilson Daily Emissions Tons
	COUNTY								COUNTY					
NATURAL GAS-RESIDENTIAL	2.399	0.0020	3.106	0.0026	3.876	0.0032	10.033	0.0083	9.174	0.0076	7.071	0.0058	6.176	0.0051
COAL-RESIDENTIAL	5.481	0.0045	7.096	0.0058	8.855	0.0073	22.924	0.0189	20.961	0.0173	16.156	0.0133	14.111	0.0116
DISTILLATE OIL AND KEROSENE-RESIDENTIAL	0.405	0.0003	0.524	0.0004	0.654	0.0005	1.693	0.0014	1.548	0.0013	1.193	0.0010	1.042	0.0009
RESIDUAL OIL-RESIDENTIAL	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000	0.000	0.0000
LPG-RESIDENTIAL	0.327	0.0003	0.423	0.0003	0.528	0.0004	1.368	0.0011	1.251	0.0010	0.964	0.0008	0.842	0.0007
NATURAL GAS-COMMERCIAL	0.432	0.0007	1.657	0.0027	1.434	0.0024	8.485	0.0140	5.094	0.0084	7.154	0.0118	3.506	0.0058
COAL-COMMERCIAL	0.189	0.0003	0.725	0.0012	0.627	0.0010	3.712	0.0061	2.228	0.0037	3.130	0.0052	1.534	0.0025
DISTILLATE OIL AND KEROSENE-COMMERCIAL	0.170	0.0003	0.651	0.0011	0.563	0.0009	3.331	0.0055	1.999	0.0033	2.808	0.0046	1.376	0.0023
RESIDUAL OIL-COMMERCIAL	0.014	0.0000	0.054	0.0001	0.047	0.0001	0.277	0.0005	0.166	0.0003	0.234	0.0004	0.115	0.0002
LPG-COMMERCIAL	0.012	0.0000	0.047	0.0001	0.040	0.0001	0.230	0.0004	0.143	0.0002	0.201	0.0003	0.098	0.0002
NATURAL GAS-INDUSTRIAL	6.294	0.0173	7.002	0.0192	12.174	0.0334	53.130	0.1460	29.078	0.0799	19.065	0.0524	20.284	0.0557
COAL-INDUSTRIAL	57.740	0.1586	64.235	0.1765	111.690	0.3068	487.422	1.3391	266.771	0.7329	174.906	0.4805	185.902	0.5107
DISTILLATE OIL AND KEROSENE-INDUSTRIAL	0.510	0.0014	0.568	0.0016	0.987	0.0027	4.308	0.0118	2.360	0.0065	1.546	0.0042	1.643	0.0045
RESIDUAL OIL-INDUSTRIAL	0.184	0.0005	0.205	0.0006	0.358	0.0010	1.556	0.0043	0.851	0.0023	0.558	0.0015	0.593	0.0016
LPG-INDUSTRIAL	0.188	0.0005	0.207	0.0006	0.360	0.0010	1.572	0.0043	0.860	0.0024	0.564	0.0015	0.599	0.0016
RAILROAD	64.040	0.1759	71.561	0.1966	59.028	0.1622	78.056	0.2144	113.950	0.3130	103.467	0.2842	83.184	0.2285
RECREATIONAL BOATS	250.120	1.4276	263.809	1.5058	238.121	1.3591	693.407	3.9578	916.487	5.2311	464.243	2.6498	677.521	3.8671
MOTORCYCLES	8.437	0.0301	10.373	0.0370	10.564	0.0377	58.579	0.2092	33.661	0.1202	24.163	0.0863	21.630	0.0772
FARM EQUIPMENT	67.641	0.1742	108.571	0.3221	487.016	1.4745	249.897	0.7562	271.136	0.8194	235.436	0.7115	165.121	0.4990
CONSTRUCTION EQUIPMENT	0.000	0.0000	0.000	0.0000	0.000	0.0000	872.160	2.7964	270.140	0.8658	1584.229	5.0777	518.499	1.6619
INDUSTRIAL EQUIPMENT	132.889	0.5111	156.593	0.6023	283.709	1.0912	1187.099	4.5658	646.406	2.4862	475.365	1.8283	449.350	1.7283
LAWN AND GARDEN EQUIPMENT	372.520	2.0356	482.330	2.6357	601.870	3.2889	1656.190	8.5147	1424.750	7.7855	1098.100	6.0006	959.100	5.2410
AIRCRAFT	0.000	0.000	73.800	0.2030	73.800	0.2030	385.000	0.7770	147.600	0.4060	73.800	0.2030	0.000	0.0000
ON-SITE INCINERATION-RESIDENTIAL	16.080	0.0442	20.820	0.0572	25.980	0.0714	67.260	0.1848	61.500	0.1690	47.400	0.1302	41.400	0.1137
ON-SITE INCINERATION-COMMERCIAL	3.082	0.0085	3.991	0.0110	4.980	0.0137	12.892	0.0354	11.788	0.0324	9.085	0.0250	7.935	0.0218
ON-SITE INCINERATION-INDUSTRIAL	3.733	0.0103	4.153	0.0114	7.221	0.0198	31.433	0.0864	17.246	0.0474	11.307	0.0311	12.018	0.0330
FOREST FIRES	41.680	0.4520	51.660	0.5615	92.610	1.0066	176.400	1.9174	226.800	2.4652	3.780	0.0411	140.490	1.5271
NON-FOREST FIRES	1.584	0.0172	1.968	0.0214	3.528	0.0383	6.720	0.0730	8.640	0.0939	0.144	0.0016	5.352	0.0582
OPEN BURNING-RESIDENTIAL	20.502	0.056	132.7275	0.3646	165.6225	0.4550	428.7825	1.1780	392.0625	1.0771	302.1750	0.8302	263.9250	0.7251
OPEN BURNING COMMERCIAL	1.093	0.003	7.0788	0.0194	8.8332	0.0243	22.8684	0.0628	20.9100	0.0574	16.1160	0.0443	14.0760	0.0387
OPEN BURNING-INDUSTRIAL	0.521	0.001	2.9643	0.0081	5.0868	0.0140	21.6383	0.0594	12.2530	0.0337	7.7628	0.0213	8.3650	0.0230

VMT's for each grid to obtain emissions for each grid cell by using the program MOB-EMIS.TOT. A flow chart of the seven different computer programs used to process data is shown in Figure 7 (University of Tennessee, 1990).

3.5 Davidson County Point Source Data

The Davidson county point source inventory for VOC and NOx ozone precursors was taken from the existing permit database for the county and entered into the correct areas in SAMS. The cutoff limit for inventorying point sources emitting VOCs was 10 tpy of actual emissions, while the cutoff for the NOx inventory was greater than or equal to 100 tpy (Metropolitan Health Department, 1989).

3.6 Davidson County Area Source Emissions

The area source emissions for Davidson county were calculated using procedures similar to those for the seven surrounding SMSA counties (Metropolitan Health Department,1989). This entailed using the same EPA emission factors utilized by the UT group, as well as cooperative efforts between the two agencies in determining appropriate surrogate activity indicators.

3.7 Davidson County Mobile Source Data

Davidson county mobile source emissions were calculated based on local traffic counts, Tennessee Department of Transportation (TDOT) data, and the Mobile 4 emission factor model. Average daily traffic counts at specific points on major radials within Davidson county were multiplied by the distance between these points to obtain the daily vehicle miles traveled for a certain day. The daily vehicle miles traveled were then allocated by street classification to fifteen analysis zones covering Davidson county. Default input

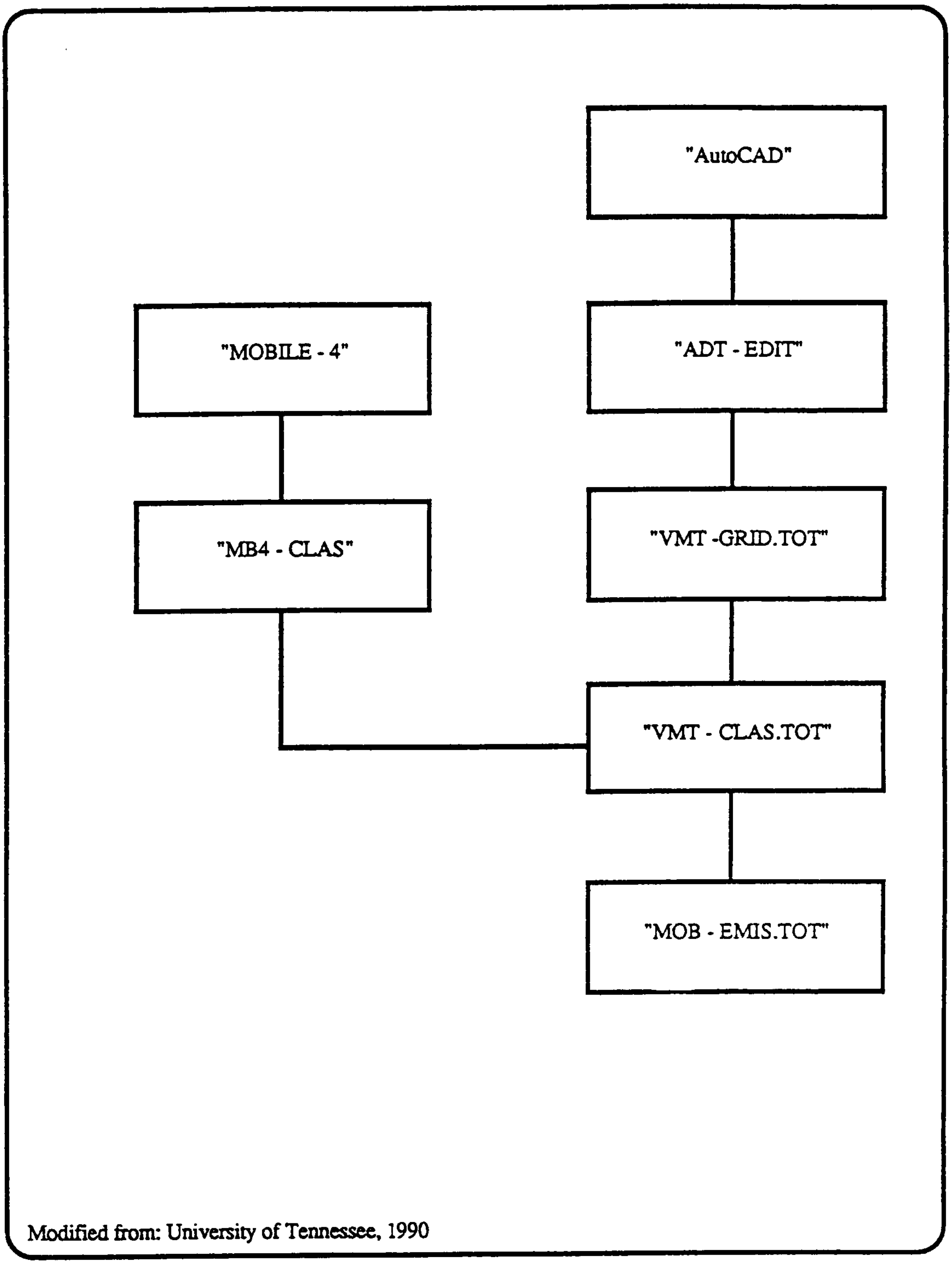


Figure 7. Mobile Source Data-Handling Procedures

values and data supplied by TDOT were used in the Mobile 4 emission model to calculate emission factors. These factors were then multiplied by the daily traffic load to obtain daily emissions in each of the fifteen analysis zones (Metropolitan Health Department,1989).

4.0 EMISSION INVENTORY RESULTS

The results of the 1988 emission inventory for the Nashville area show which pollutants are emitted in the greatest quantities, as well as indicating which sources contribute the most pollution. Detailed inventories of area and mobile sources were conducted only for the Nashville SMSA. Point sources emitting greater or equal to ten tpy of VOC or NOx were documented in the SMSA, and those emitting greater or equal to one hundred tpy were documented in the surrounding twenty five mile radius. Results are shown in Table 3 and Figures 8 through 15. Total emissions of NOx contributed 538 tons per day, and VOC's added 344 tons per day to the inventory (University of Tennessee, 1990).

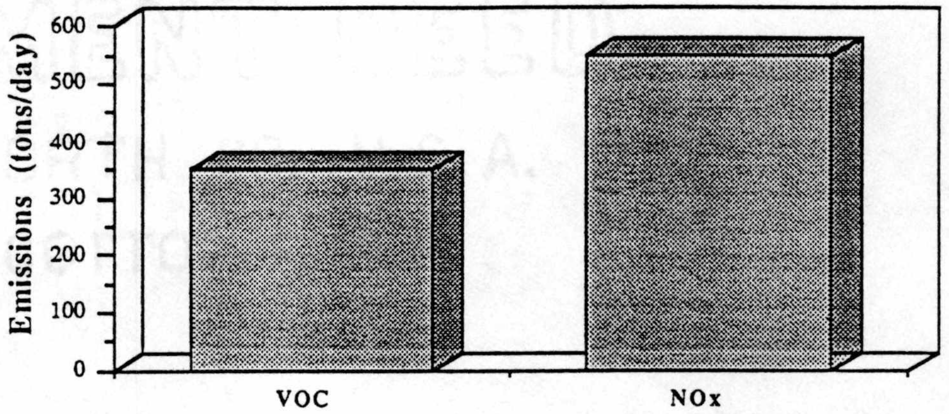
NOx emissions produced predominantly by point sources, with mobile sources contributing less, and area sources contributing still less to the total. Point source emissions make up 64 % (344 tons per day) of the total NOx inventory. Mobile sources contribute 26 % (140 tons per day) of the total NOx inventory. Area sources make up only 10 % (54 tons per day) of the total NOx inventory. It is interesting to note that more than three quarters of the point source emissions of NOx are located outside of Davidson county. A full 50 % of these emissions are contributed by the burning of fossil fuels at power plants located in the affected counties of Stewart and Humphreys. Another 28 % of the point source contributors are located throughout the seven SMSA counties surrounding Davidson county, while only 22 % of the point sources are actually found within Davidson county. Yet NOx concentrations, and hence NOx emissions, play a crucial part in the formation of the ozone for which Davidson county is experiencing non-attainment (University of Tennessee, 1990).

Table 3. Summary of Nashville Area Emissions (Tons/Day)

	Davidson County	Seven County*	Affected Counties**	Total
Hydrocarbons				
Point	20	41	21	82
Mobile	90	84	-	174
Area	46	42	-	88
Total	156	167	21	344
Carbon Monoxide				
Point	10	4	151	165
Mobile	305	364	-	669
Area	103	106	-	209
Total	418	474	151	1043
Nitrogen Oxide				
Point	13	64	269	346
Mobile	80	57	-	137
Area	24	31	-	55
Total	117	152	269	538

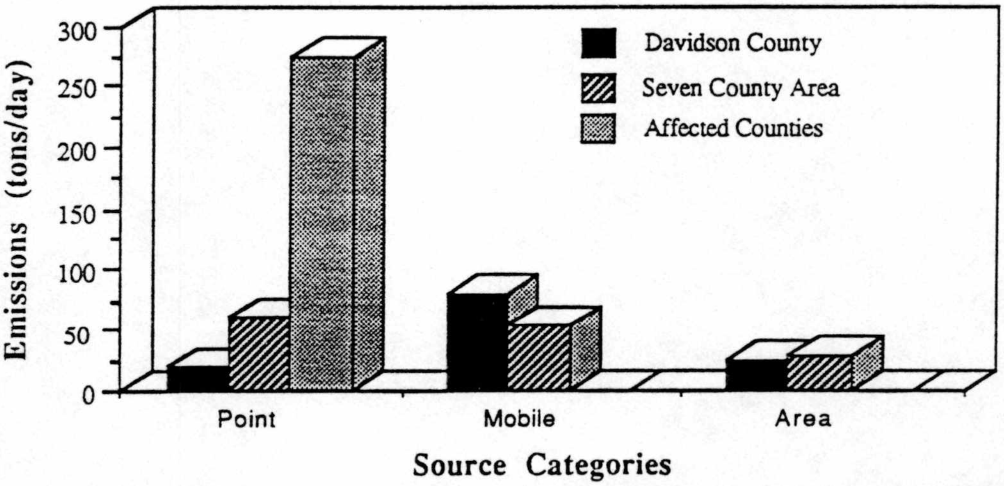
* - Seven counties surrounding Davidson (Rutherford, Cheatham, Sumner, Dickson, Robertson, Williamson, and Wilson)

** - Counties within 25 mile extension of the SMSA



Modified from: University of Tennessee, 1990

Figure 8. Total Daily VOC and NOx Emissions for the Nashville Study Area



Modified from: University of Tennessee, 1990

Figure 9. Comparison of NOx Emissions by Source Category and Location

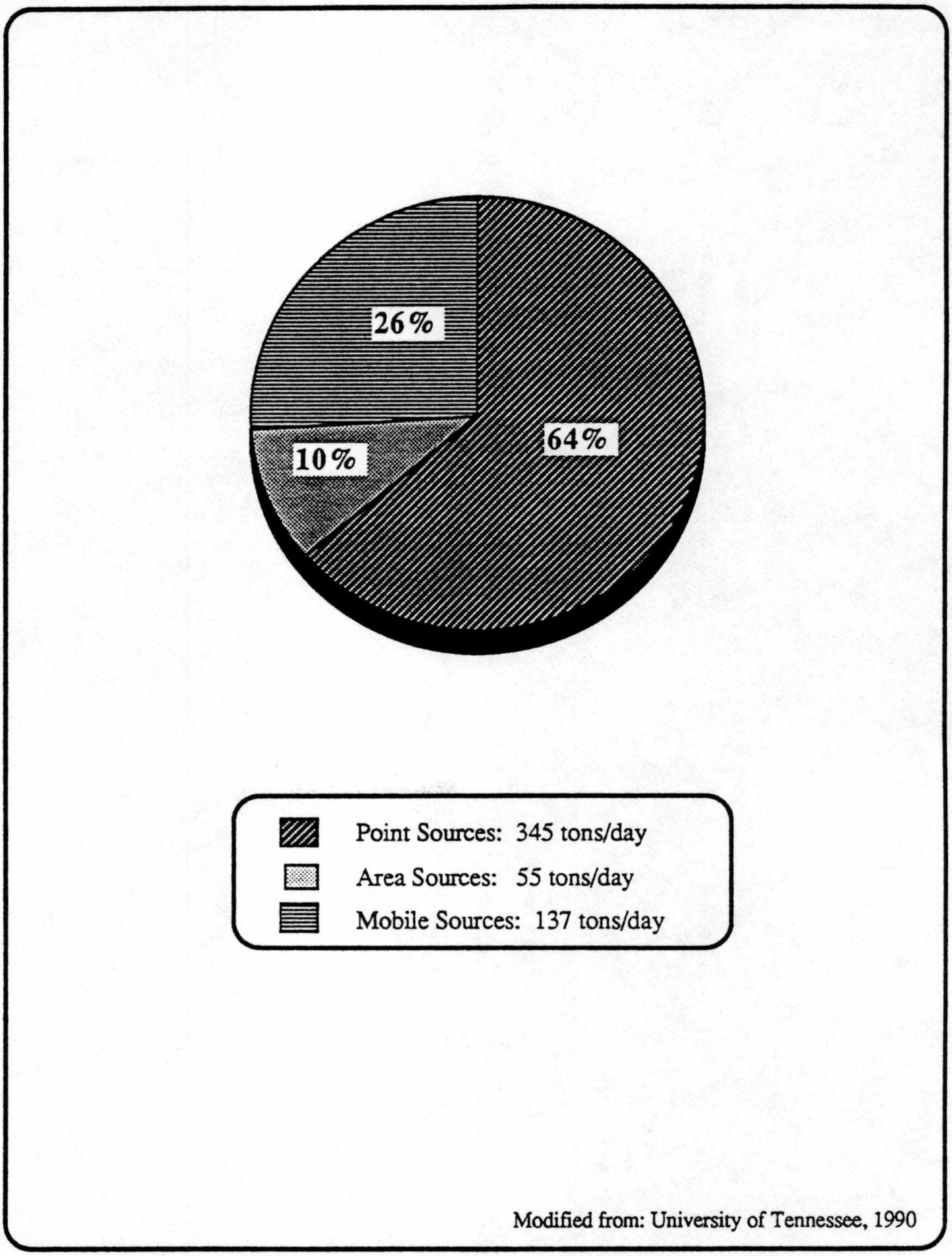


Figure 10. Source Contributions of NOx Emissions

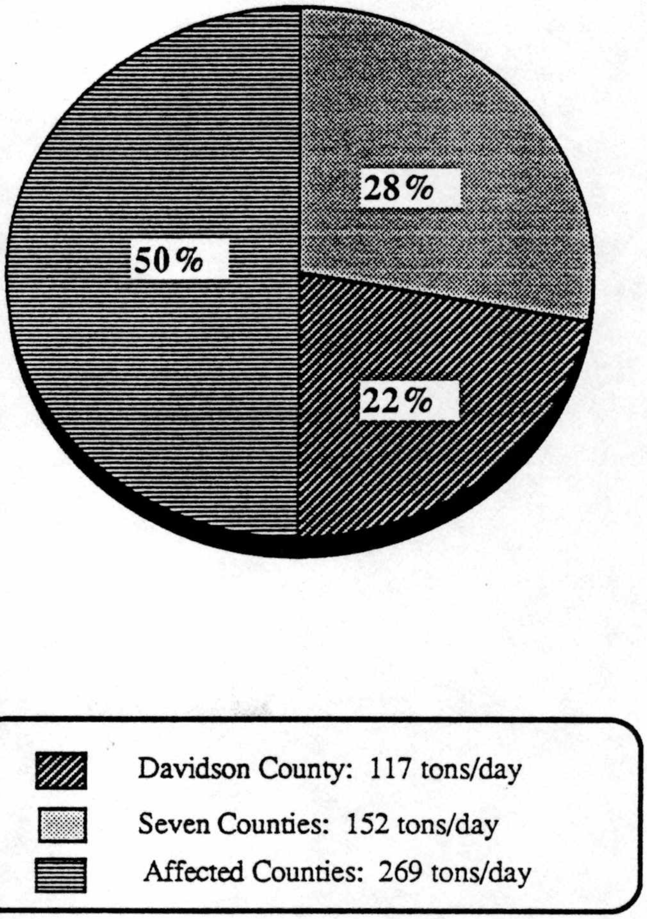


Figure 11. Geographic Contributions of NOx Emissions

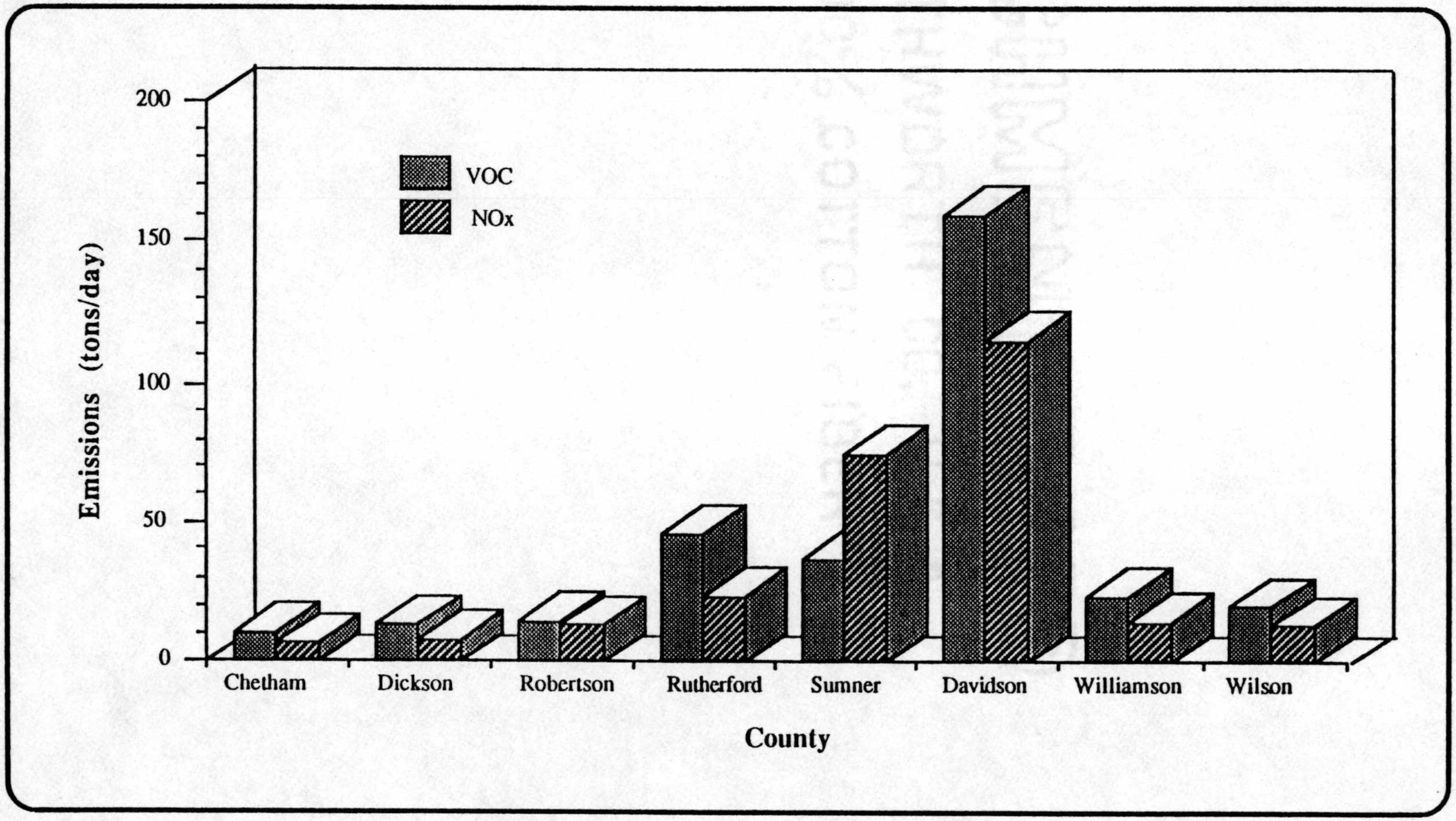


Figure 12. Comparison of VOC and NOx Emissions by County

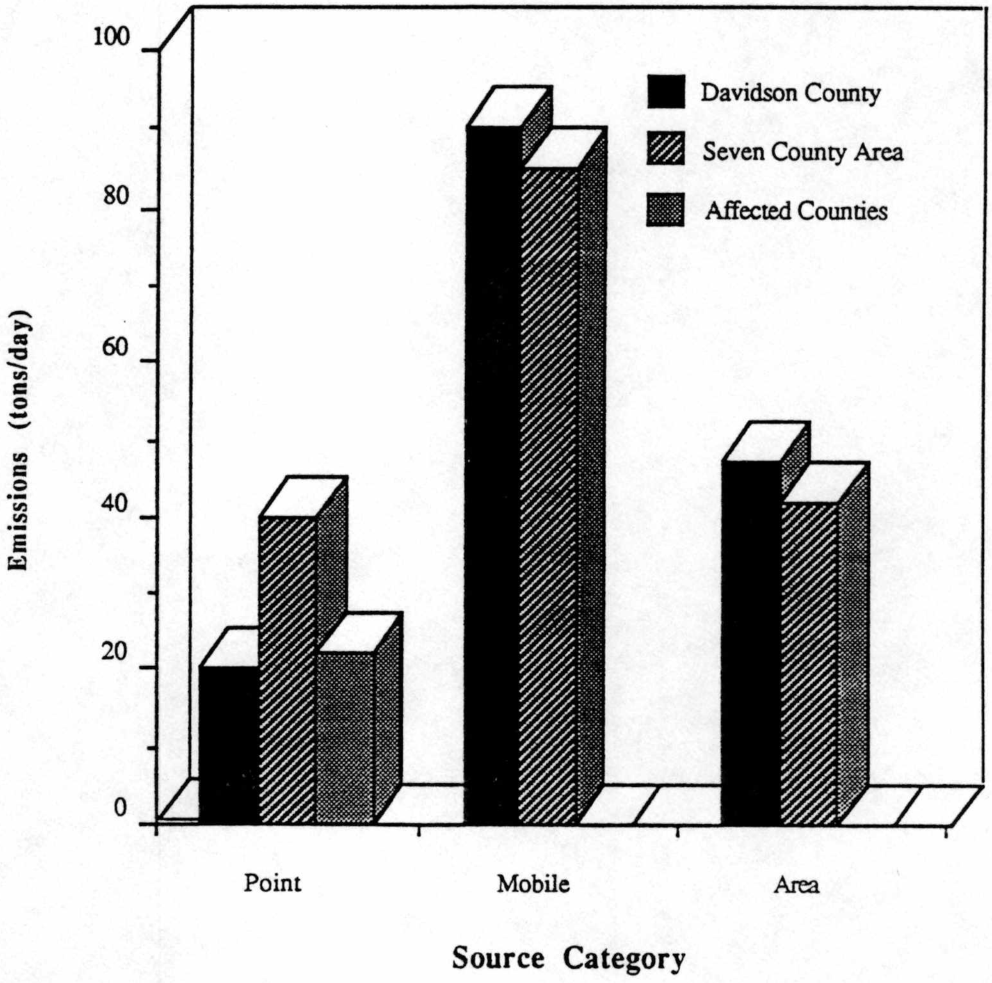
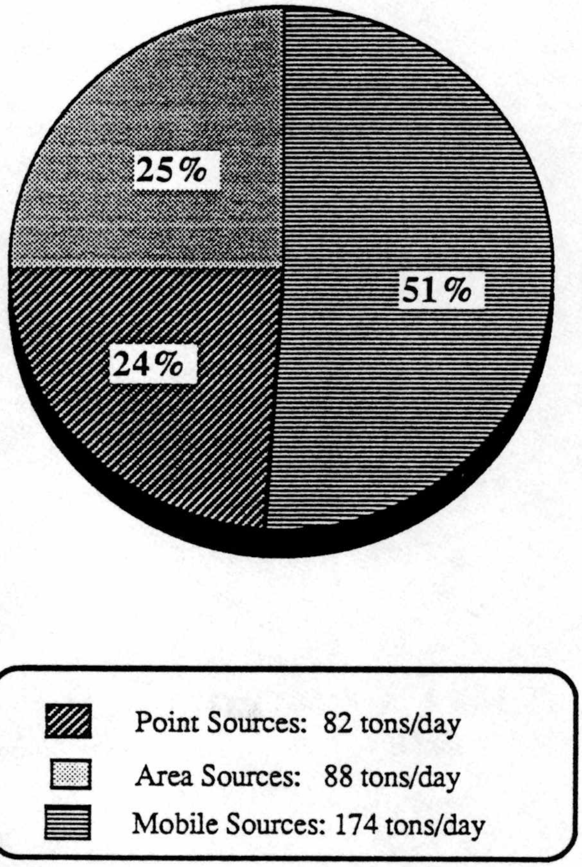


Figure 13. Comparison of VOC Emissions by Source Category and Location



Modified from: University of Tennessee, 1990

Figure 14. Source Contributions of VOC Emissions

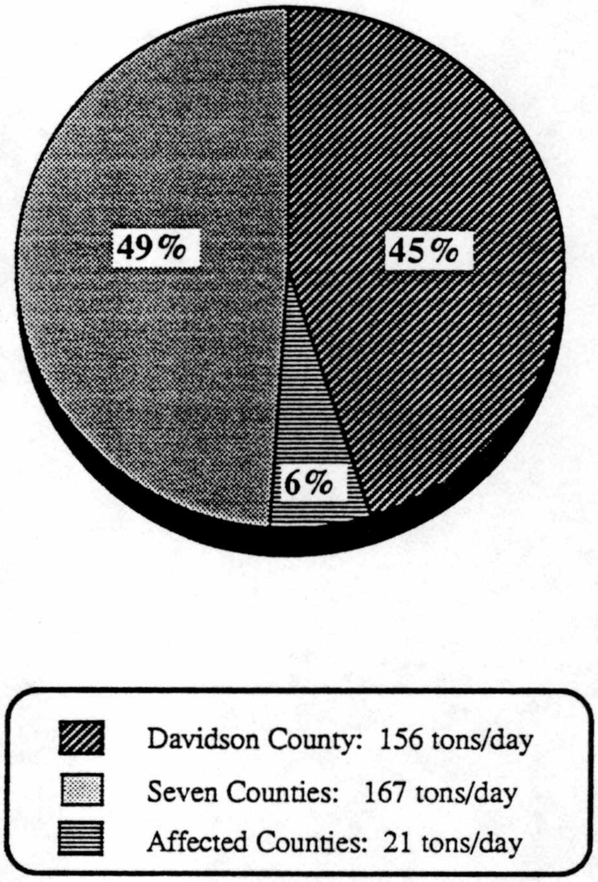


Figure 15. Geographic Contributions of VOC Emissions

The main contributor of VOC emissions in the overall inventory was mobile sources, with area sources and point sources contributing almost equal, but lesser amounts. Mobile sources contributed account for 51 % (175 tons per day) of the total VOC emissions. Area sources and point source contribute 25% (89 tons per day) and 24 % (82 tons per day) respectively. More than half of the total inventoried VOC mobile source emissions are concentrated in Davidson county (90 tons per day), while the rest (84 tons per day) are distributed throughout the seven surrounding SMSA counties (University of Tennessee, 1990).

5.0 ASSIGNING EMISSIONS TO GRID CELLS

To gain an understanding of the spatial distribution of emissions inventory, emissions of VOCs and NOx occurring on a typical ozone season day were assigned to the individual cells of a grid matrix which covered the whole geographic study area. The individual grid cell resolution was five square kilometers, and was based on the typical input for the Urban Airshed air quality model. An initial 41 x 41 grid matrix system was used to define the entire air quality planning region consisting of the SMSA and the twenty five mile surrounding radius.However, for the purposes of this thesis, the gridded study area concentrates on the SMSA where point, area, and mobile source emissions were analyzed in detail. The study area pictured in Figure 16 consists of a 23 x 25 grid matrix covering 575 square kilometers with its lower left Universal Transverse Mercator (UTM) coordinates beginning at approximately 447,000 meters East of the 87th meridian and 3,940,000 meters North of the equator.

Spatial allocation of emissions will be discussed separately for Davidson county and the surrounding counties because of the differing methods used by the two agencies involved in this project. The Metropolitan Nashville and Davidson county Department of Health submitted an allocation of emissions to grid cells in its 1988 baseline emissions inventory report. The Davidson County study used a scheme of dividing emissions into residential, industrial, and mobile categories to allocate them to grid cells. These allocations are based on local knowledge and experience, and have been incorporated into the overall spatial allocations scheme wherever appropriate. Categories used in spatial allocation of emissions for Davidson county and the surrounding SMSA are discussed in order of point, area, and finally mobile sources.

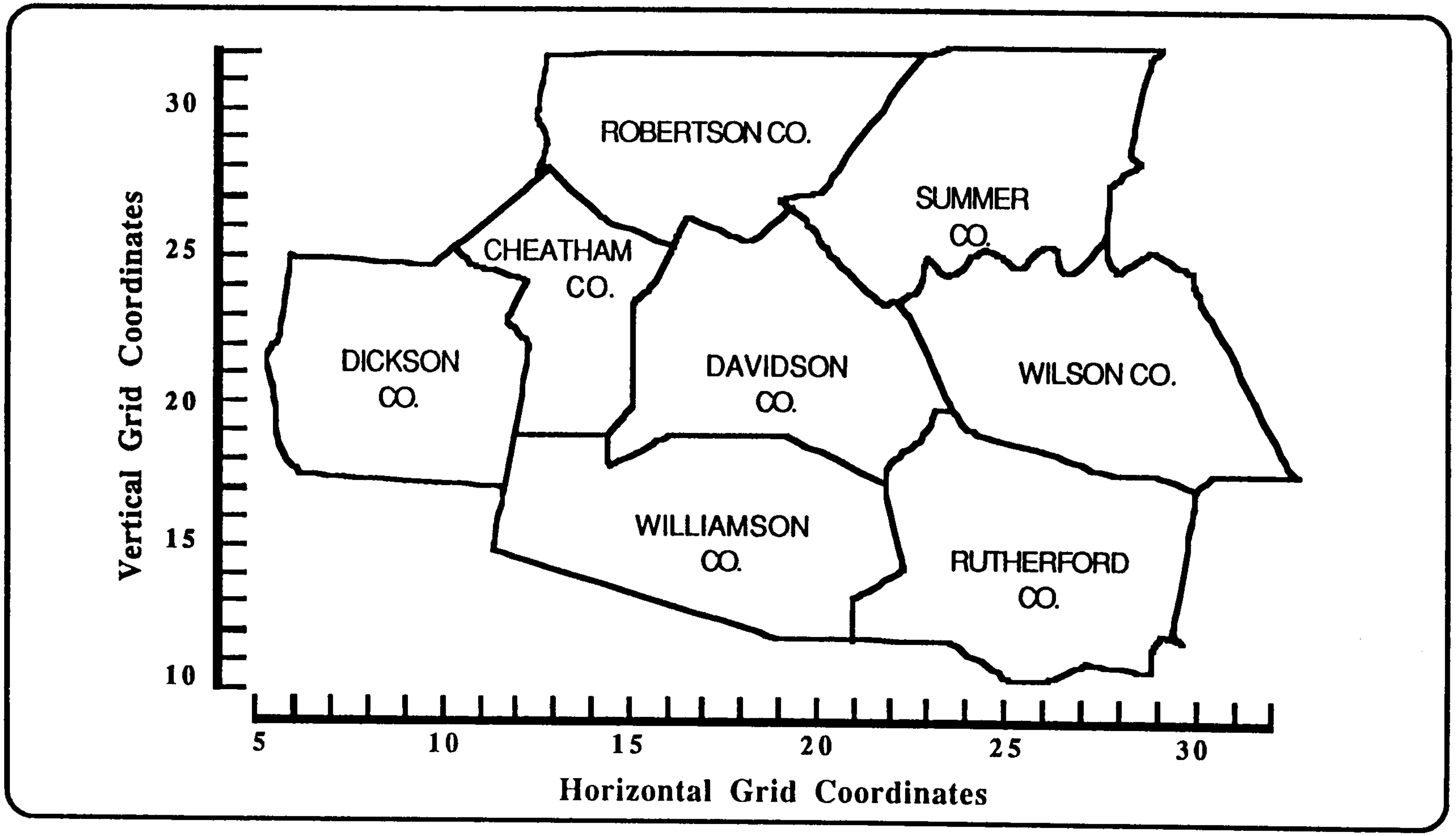


Figure 16. Grid Coordinate System for the Nashville Study Area

5.1 Point Source Allocations

Point sources for both Davidson and the surrounding counties were assigned to grids on the basis of their UTM coordinates which were provided in the NEDS, EIS and county permit data files.The metropolitan Nashville and Davidson county Department of Health had devised a system for assigning industrial sources to grids within Davidson county, but this approach was not used. The Davidson county approach was not used because the data were presented simply as emissions, and could not be directly traced back to point sources from which they originated. Information on each point source emitting pollutants was necessary for future temporal allocation of emissions. Therefore, a consistent approach was taken by using only point source emission data provided in the SAMS data base for all counties rather than using the grid system point source allocations developed by the local agency.

Point source grid locations were assigned only on the cell level, and not on the basis of an actual UTM coordinate position. The UTM coordinates were translated to I,J grid coordinates subtracting the UTM coordinate of the 1,1 (I,J) grid coordinate from the point source coordinate by the formula:

$$I = INT(((UTMEAST - 432)/5)+1)$$

$$J = INT(((UTMNORTH - 3900)/5)+1)$$

Then point source emissions which were located within the same grid (e.g. having the same I,J grid coordinates) were summed to obtain total point source emissions for VOCs and NOx for each grid.

5.2 Surrounding County Area Source Allocations

Because area source emissions in the emission inventory were only calculated on a county-wide basis, a method was developed to assign them to individual grid cells. Initial calculations of area source emissions involved multiplying a surrogate activity indicator by an emission factor to obtain emissions. In breaking county wide emissions down to assign them to individual grids, it was necessary to group emission factors into categories for which activity indicators could be obtained on the grid cell level. Not only would this method provide a systematic way to assign area sources to grids, but it would also give a more realistic reflection of emission densities than a simple averaging technique. Although land use and employment factors were frequently used in county wide calculations, these factors couldn't be applied on the grid cell level because land use maps and employment distribution have not been developed at this resolution for the Nashville area. Readily available information consisted of topographic, traffic, and census tract maps, and these formed the basis for developing the method to assign area source emissions to grids.

Most emission factors were multiplied by a per capita based activity indicator. The population of each county had already been apportioned to individual grids on the basis of census tracts. An overall population-based emission factor was therefore proposed to conveniently assign emissions to grids. In practice, a population-based emission factor for both VOC and NOx would be back-calculated using total county population and total county emissions. This emissions per population factor would be multiplied by the population assigned to each grid to obtain area source emissions for that grid cell.

A regression analysis was performed plotting total VOC and NOx emissions against total county population to test the appropriateness of the emissions per population logic. The results of the analysis are shown in Figure 17. The analysis showed a very good correlation between total emissions and population for VOC ($R^2 = 0.847$), but poor

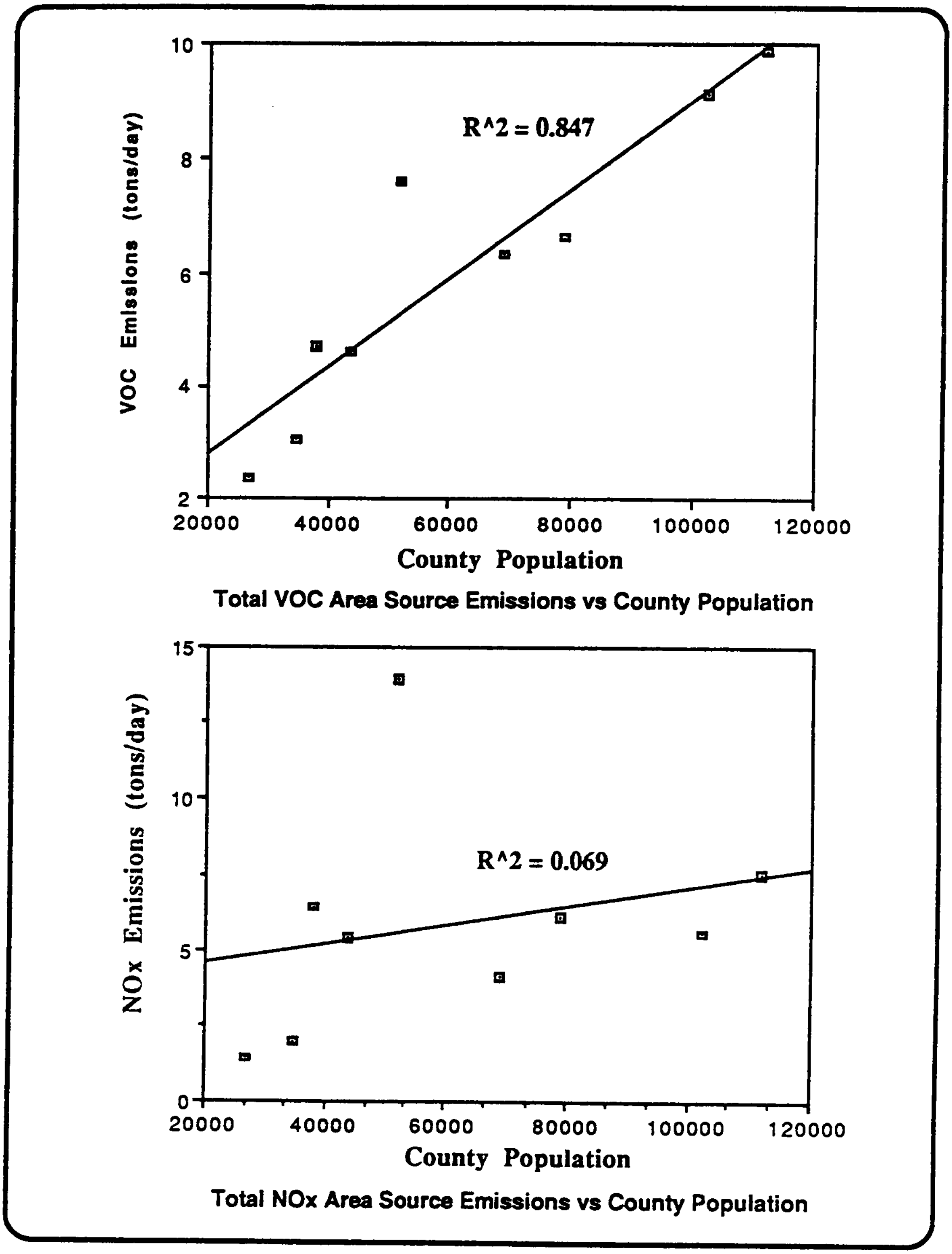


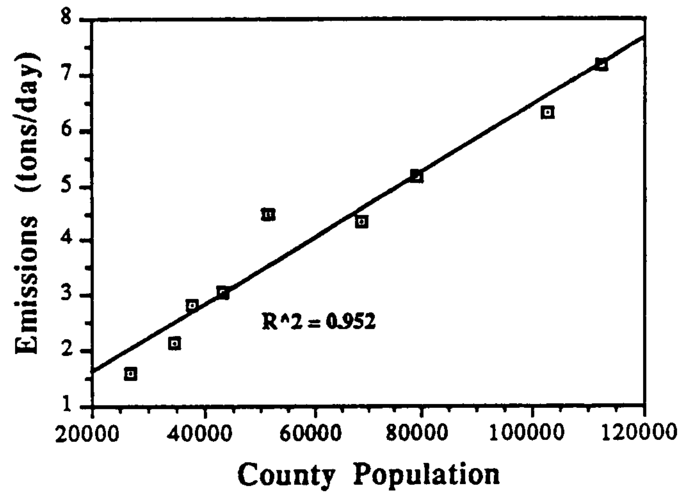
Figure 17. Comparison of Plots of Total VOC and NOx Area Source Emissions vs. County Populations

correlation ($R^2 = 0.069$) for the same variables for NOx. The reason for the poor NOx correlation is that farm equipment emissions based on harvested farm acreage make up a significant portion of the NOx emissions.

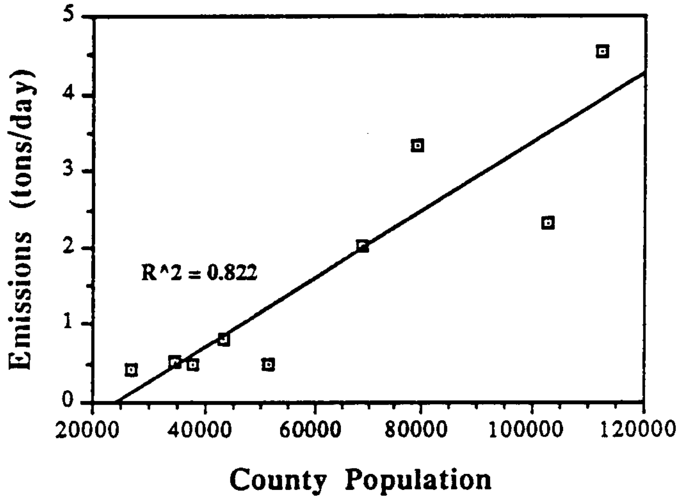
However, if farm equipment emissions were subtracted from the total NOx emission and the regression of total emissions verses population was run, the correlation was relatively good ($R^2 = 0.822$). Figure 18 shows the regression analysis for VOC and NOx when only population based emissions are plotted against total population for each county. The population based emissions group included all emissions derived directly from, or associated,with population. Realizing that a direct correlation of emissions with population would yield an R^2 factor of 1.0, the lower correlations shown in Figure 18 indicate the extent to which emissions are not based directly on population. Population based area source emissions for VOCs and NOx are listed in Tables 4 and 5.

Regression analysis made it obvious that a universal emission factor couldn't be applied to estimated grid cell emissions. On the other hand, the analysis suggested that two emission factor categories, population based and farm equipment based emission factors, could sufficiently characterize a county's area source emissions. Since current EPA methodology assigns area source emissions on an estimation basis, the use of these two simple categories could save a great deal of time when compared to collecting the data and performing the calculations necessary to estimate emissions for each individual EPA recommended emission factor.

However, since it had been demonstrated that at least two specific factors must be used to apportion area source emissions to grids, a more rigorous approach was used to develop logical emission factor categories. In this approach, area source emissions were divided into two broad groups: population based emissions, and source specific emissions. Population based emissions are defined as those area source emissions derived by



Population-Based Area Source VOC Emissions vs County Population
(Excluding Emissions for Davidson County)



Population Based Area Source NOx Emissions vs County Population
(Excluding Emissions for Davidson County)

Figure 18. Comparison of Plots of Population-Based Total VOC and NOx Emissions vs. County Populations

Table 4. VOC Area Source Emissions Grouped by Category (Tons/Day)

	COUNTY						
Population Based Categories	**Cheatam**	**Diskson**	**Robertson**	**Rutherford**	**Sumner**	**Williamson**	**Wilson**
TANK TRUCK UNLOADING	0.319	0.418	0.518	1.327	1.231	0.937	0.823
UNDERGROUND TANK BREATHING	0.028	0.036	0.045	0.115	0.107	0.081	0.072
GAS TRUCKS IN TRANSIT	0.008	0.010	0.013	0.032	0.030	0.023	0.020
COMMERCIAL DRY CLEANING	0.067	0.087	0.108	0.280	0.256	0.198	0.173
COIN OP DRY CLEANING	0.021	0.027	0.033	0.086	0.079	0.061	0.053
DEGREASING-COLD CLEANING	0.129	0.167	0.208	0.539	0.493	0.380	0.332
ARCHITECTURAL SURFACE COATING	0.220	0.285	0.356	0.921	0.842	0.649	0.567
AUTO REFINISHING	0.098	0.127	0.158	0.410	0.375	0.289	0.252
GRAPHIC ARTS	0.041	0.053	0.067	0.172	0.158	0.122	0.106
CUTBACK ASPHALT	0.000	0.000	0.000	0.000	0.000	0.000	0.000
COMMERCIAL/CONSUMER SOLVENT USE	0.232	0.300	0.375	0.970	0.887	0.684	0.597
MUNICIPAL SOLID WASTE LANDFILL	0.001	0.004	0.001	0.011	0.000	0.001	0.002
PUBLIC WATER TREATMENT WORKS	0.008	0.023	0.050	0.123	0.057	0.031	0.061
NATURAL GAS-RESIDENTIAL	0.001	0.001	0.001	0.002	0.002	0.002	0.001
COAL-RESIDENTIAL	0.001	0.001	0.001	0.002	0.002	0.001	0.001
DISTILLATE OIL AND KEROSENE-RESIDENTIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RESIDUAL OIL-RESIDENTIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG-RESIDENTIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NATURAL GAS-COMMERCIAL	0.000	0.001	0.001	0.004	0.002	0.003	0.002
COAL-COMMERCIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DISTILLATE OIL AND KEROSENE-COMMERCIAl	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RESIDUAL OIL-COMMERCIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG-COMMERCIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
NATURAL GAS-INDUSTRIAL	0.001	0.002	0.003	0.012	0.006	0.004	0.004
COAL-INDUSTRIAL	0.010	0.012	0.020	0.088	0.048	0.032	0.034
DISTILLATE OIL AND KEROSENE-INDUSTRIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RESIDUAL OIL-INDUSTRIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
LPG-INDUSTRIAL	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CONSTRUCTION EQUIPMENT	0.000	0.000	0.000	0.188	0.058	0.342	0.112
INDUSTRIAL EQUIPMENT	0.020	0.024	0.043	0.181	0.099	0.073	0.069
LAWN AND GARDEN EQUIPMENT	0.220	0.284	0.355	0.919	0.840	0.648	0.566
ON-SITE INCINERATION-RESIDENTIAL	0.015	0.019	0.024	0.062	0.056	0.043	0.038
ON-SITE INCINERATION-COMMERCIAL	0.003	0.003	0.004	0.011	0.010	0.007	0.007
ON-SITE INCINERATION-INDUSTRIAL	0.003	0.003	0.006	0.026	0.014	0.009	0.010
OPEN BURNING-RESIDENTIAL	0.099	0.129	0.161	0.416	0.380	0.293	0.256
OPEN BURNING-COMMERCIAL	0.002	0.003	0.004	0.010	0.009	0.007	0.006
OPEN BURNING-INDUSTRIAL	0.001	0.001	0.002	0.009	0.005	0.003	0.004
Totals:	**1.55**	**2.02**	**2.56**	**6.92**	**6.05**	**4.92**	**4.17**
Source Specific Categories:							
RAILROAD	0.127	0.142	0.117	0.155	0.226	0.206	0.165
RECREATIONAL BOATS	0.460	0.485	0.437	1.274	1.684	0.853	1.245
MOTORCYCLES	0.008	0.010	0.010	0.057	0.033	0.024	0.021
PESTICIDE APPLICATION + FARM EQUIPMENT	0.146	0.270	1.238	0.634	0.688	0.597	0.419
AIRCRAFT	0.000	0.008	0.008	0.484	0.016	0.008	0.000
FOREST FIRES	0.077	0.096	0.173	0.329	0.423	0.007	0.262
NON-FOREST FIRES	0.012	0.019	0.058	0.022	0.029	0.003	0.047
Totals:	**0.83**	**1.03**	**2.04**	**2.96**	**3.10**	**1.70**	**2.16**

Table 5. NOx Area Source Emissions Grouped by Category (Tons/Day)

	COUNTY						
Population Based Categories	**Cheatam**	**Diskson**	**Robertson**	**Rutherford**	**Sumner**	**Williamson**	**Wilson**
NATURAL GAS-RESIDENTIAL	0.0099	0.0128	0.0160	0.0414	0.0378	0.0292	0.0255
COAL-RESIDENTIAL	0.0004	0.0006	0.0007	0.0018	0.0017	0.0013	0.0011
DISTILLATE OIL AND KEROSENE-RESIDENTIAL	0.0012	0.0016	0.0019	0.0050	0.0046	0.0035	0.0031
RESIDUAL OIL-RESIDENTIAL	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LPG-RESIDENTIAL	0.0013	0.0017	0.0021	0.0054	0.0049	0.0038	0.0033
NATURAL GAS-COMMERCIAL	0.0036	0.0137	0.0118	0.0699	0.0420	0.0590	0.0289
COAL-COMMERCIAL	0.0004	0.0017	0.0015	0.0086	0.0052	0.0073	0.0036
DISTILLATE OIL AND KEROSENE-COMMERCIAL	0.0011	0.0043	0.0037	0.0219	0.0132	0.0185	0.0091
RESIDUAL OIL-COMMERCIAL	0.0003	0.0010	0.0008	0.0050	0.0030	0.0042	0.0021
LPG-COMMERCIAL	0.0001	0.0004	0.0003	0.0019	0.0011	0.0016	0.0008
NATURAL GAS-INDUSTRIAL	0.0693	0.0771	0.1341	0.5852	0.3203	0.2100	0.2232
COAL-INDUSTRIAL	0.2237	0.2488	0.4326	1.8881	1.0334	0.6775	0.7201
DISTILLATE OIL AND KEROSENE-INDUSTRIAL	0.0056	0.0062	0.0108	0.0473	0.0259	0.0170	0.0181
RESIDUAL OIL-INDUSTRIAL	0.0056	0.0062	0.0107	0.0469	0.0257	0.0168	0.0179
LPG-INDUSTRIAL	0.0020	0.0023	0.0040	0.0172	0.0094	0.0062	0.0066
CONSTRUCTION EQUIPMENT	0.0000	0.0000	0.0000	1.0671	0.3305	1.9383	0.6344
INDUSTRIAL EQUIPMENT	0.0561	0.0661	0.1197	0.5010	0.2728	0.2006	0.1896
LAWN AND GARDEN EQUIPMENT	0.0220	0.0284	0.0355	0.0919	0.0840	0.0648	0.0566
ON-SITE INCINERATION-RESIDENTIAL	0.0001	0.0002	0.0002	0.0006	0.0006	0.0004	0.0004
ON-SITE INCINERATION-COMMERCIAL	0.0025	0.0033	0.0041	0.0106	0.0097	0.0075	0.0065
ON-SITE INCINERATION-INDUSTRIAL	0.0031	0.0034	0.0060	0.0259	0.0142	0.0093	0.0099
OPEN BURNING-RESIDENTIAL	0.0199	0.0257	0.0321	0.0832	0.0760	0.0586	0.0512
OPEN BURNING-COMMERCIAL	0.0011	0.0014	0.0017	0.0044	0.0041	0.0031	0.0027
OPEN BURNING-INDUSTRIAL	0.0005	0.0006	0.0010	0.0042	0.0024	0.0015	0.0016
Totals:	**0.43**	**0.51**	**0.83**	**4.53**	**2.32**	**3.34**	**2.02**
Source-Specific Categories							
RAILROAD	0.5007	0.5595	0.4615	0.6103	0.8910	0.8090	0.6504
RECREATIONAL BOATS	0.0133	0.0141	0.0127	0.0370	0.0489	0.0248	0.0362
MOTORCYCLES	0.0002	0.0002	0.0002	0.0013	0.0007	0.0005	0.0005
FARM EQUIPMENT	0.4854	0.8975	4.1092	2.1046	2.2835	1.9828	1.3906
AIRCRAFT	0.000	0.0030	0.0030	0.1730	0.0060	0.0030	0.0000
FOREST FIRES	0.0129	0.0160	0.0288	0.0548	0.0704	0.0012	0.0436
NON-FOREST FIRES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Totals:	**1.01**	**1.49**	**4.62**	**2.98**	**3.30**	**2.82**	**2.12**

multiplying an emission factor by a a per capita related activity indicator. Source specific emissions are defined as area source emissions derived by multiplying an emission factor by a specific activity indicator. Emissions were allocated to grids using the mapped characteristics for these categories, and the total emissions for each grid cell were summed to distribute total area source emissions over the entire grid matrix.

The spatial allocation of emissions for population based emissions was determined by population allocated to each grid cell. This allocation was determined by overlaying grid cell matrices on census tract maps, and estimating population within each cell. The sum of population based emissions per total county population was calculated to yield an emissions per population factor. This factor was then multiplied by the population in each cell to obtain population based emissions per cell. Area source population based emission factors used in allocations are shown in Table 6.

Source specific categories were defined by emission factors which were not logically associated with population, and which could be tied to specific geographic areas. Although various area source emission factors clearly indicate their application to distinct areas such as farm land or forest, the lack of available information limited such assignments. However, topographic and traffic maps did allow the general designation of rural areas, and the locations of railroads, airports, and major water bodies. These designated areas became the basis of source specific area source emission allocations. Area source emissions allocated to rural areas were motorbikes, pesticide application, forest fires, and grass fires. Tables 4 and 5 show the emission factors which were grouped to determine source specific VOC and NOx emissions.

Spatial allocation of source specific emissions was determined on the basis of actual or estimated map locations of factors. Railroads, airports, and lakes map locations in terms of grid cells were used to assign emissions for railroads, airports, and recreational boats on

Table 6. Summary of Population Based Area Source Emission Factors

County	Population	NOX		VOC	
		Emissions (tons/day)	Emission Factor per 1000 people	Emissions (tons/day)	Emission Factor per 1000 people
Cheatham	26,800	0.43	0.016	1.55	0.058
Robertson	43,300	0.83	0.019	2.56	0.059
Rutherford	112,100	4.53	0.040	6.92	0.062
Sumner	102,500	2.32	0.023	6.05	0.059
Williamson	79,000	3.34	0.042	4.92	0.062
Wilson	69,000	2.02	0.029	4.17	0.060
Dickson	34,700	0.51	0.015	2.02	0.058

the basis of their respective individual emission factors. Rural areas were determined as all areas that weren't shaded on traffic maps in which shading indicated dense population. Emissions for each source specific category were calculated by dividing the total county emissions for the category by the number of grid cells assigned to this category. The emissions were then simply allocated to the proper cells. Emissions for specific area sources are shown in Tables 7, 8, and 9.

5.3 Affected County Mobile Source Emission Allocations

Mobile source emissions were allocated to grids as they were calculated as discussed previously. Data were compiled as inputs to the Mobile 4 program on a grid-by-grid basis. Mobile 4 output yielded emission factors for VOCs and NOx which were applied to the information for each grid to obtain emissions per grid.

5.4 Davidson County Area Source Emission Allocations

The Davidson county Department of Health developed a residential category to allocate a group of area source emissions in the Davidson county to grids. Although this residential category is analogous to the area source category used in allocating emissions in the surrounding counties, it contains only selected area sources which are logically associated with residential areas. Therefore, the Davidson county allocation of residential sources does not include area source emissions from railroads, motorcycles, industrial equipment, lawn and garden equipment, vessels, airplanes, or farm equipment. Instead, the sources omitted from the residential category were allocated as mobile source emissions. This shift proved to have a significant impact on emission densities in terms of source categories since research indicates that railroads, boats, and lawn, garden, farm and industrial equipment are some of the major producers of area source emissions of VOCs

Table 7. Source Specific VOC Emission Factors for Area Sources

County	Total Railroad Emissions (tons/day)	Railroad Grid Cells	Railroad Emissions per Grid Cell (tons/day)	Total Rural Based Emissions (a) (tons/day)	Rural Grid Cells	Rural Emissions per Grid Cell (tons/day)	Airport Emissions	Airport Grid Cells	Airport Emissions per Grid Cell (tons/day)
Cheatham	0.1272	6	0.02120	0.2442	31	0.0079	0.000	0	0.0000
Robertson	0.1173	7	0.01676	1.4793	52	0.0284	0.008	3	0.0027
Rutherford	0.1551	9	0.01723	1.0425	59	0.0177	0.484	1	0.4840
Sumner	0.2264	17	0.01332	1.1723	46	0.0255	0.016	1	0.0160
Williamson	0.2055	9	0.02283	0.6315	47	0.0134	0.008	1	0.0080
Wilson	0.1653	8	0.02066	0.7491	65	0.0115	0.000	1	0.0000
Dickson	0.1422	9	0.01580	0.3958	52	0.0076	0.008	1	0.0080

Table 8. Source Specific NOx Emission Factors for Area Sources

County	Total Railroad Emissions (tons/day)	Railroad Grid Cells	Railroad Emissions per Grid Cell (tons/day)	Total Rural Based Emissions (a) (tons/day)	Rural Grid Cells	Rural Emissions per Grid Cell (tons/day)	Airport Emissions	Airport Grid Cells	Airport Emissions per Grid Cell (tons/day)
Cheatham	0.5007	6	0.08345	0.5003	31	0.0161	0.000	0	0.000
Robertson	0.4615	7	0.06593	4.1382	52	0.0796	0.003	3	0.001
Rutherford	0.6103	9	0.06781	2.1607	59	0.0366	0.173	1	0.173
Sumner	0.8910	17	0.05241	2.3546	46	0.0512	0.006	1	0.006
Williamson	0.8090	9	0.08989	1.9845	47	0.0422	0.003	0	0.000
Wilson	0.6504	8	0.08130	1.4347	65	0.0221	0.000	1	0.003
Dickson	0.5595	9	0.06217	0.9137	52	0.0176	0.003	1	0.003

Table 9. Recreational Boat Emission Factors

Pollutant	Total Recreational Boat Emissions (tons/day)	Grid Cells Containing Major Water Bodies	Recreational Boat Emissions per Grid Cell (tons/day)
NOX	0.221	16	0.014
VOC	7.588	16	0.474

and NOx (University of Tennessee, 1990). The remaining area source emissions, termed as residential emissions, and were allocated on the basis of expert knowledge of Davidson county.

5.5 Davidson County Mobile Source Emissions

Davidson county mobile source allocations were performed using the same method which was described for the Davidson county residential source emissions. As discussed previously, the Davidson county mobile source group included other emissions which are considered by the EPA and the surrounding counties study to be area sources. Most of these additional emissions, termed collectively as off-highway emissions, were equally assigned to each grid cell in the Davidson county study area. Industrial equipment emissions were distributed equally over 16 grid cells centrally located in Davidson county where most of the point sources are found. Vessel emissions were assigned to grid cells containing navigable waters (Metropolitan Health Department, 1989).

5.6 Analysis of Spatial Allocations

An analysis of spatial allocations of emission inventory results by grids is best accomplished using maps of these emissions densities for the various source categories. The Macintosh software Map II was used to develop emission density maps from files containing grid coordinates and corresponding summed emissions for each grid. Although the mapped ranges of VOC and NOx show a lower limit of zero, the following discussion of emission ranges sets the lower limit at 0.5 kg/day because emissions lower than this value are exceptions in the bulk of the data. This lower limit is also useful in realistically depicting VOC/NOx ratios where negligible contributions of NOx may lead to a ratio which approaches infinity.

Because UT and the Davidson county Department of Health used different methods to apportion area and mobile sources to grids, it is not appropriate to directly compare the pollutant distribution results of the two agencies for these sources. Accordingly, emission densities for area and mobile sources will be discussed separately for Davidson county and the counties in the surrounding SMSA. Because Davidson county Department of Health chose to group off-highway area sources into the mobile source category, thus subtracting from the cumulative area source emissions, cumulative mobile source emissions in Davidson county experienced a gain while residential source emissions dropped in comparison to the emissions in the surrounding counties. UT considered the area source category as a whole without subtracting out off-highway emissions, so the relative cumulative area source emissions distributed to each grid in the SMSA was on the whole greater than in Davidson county. Nevertheless, the total of VOC and NOx area and mobile source emissions apportioned by grid in Davidson county is approximately equal to the emissions reported in these categories in the Davidson county emission inventory. This mass balance performed for Davidson county indicates that although emissions have been shifted into different categories, none have been lost.

Figure 19 shows residential NOx and VOC emission densities and VOC/NOx residential emission ratios for Davidson county. NOx emissions range from 1 - 300 kg/day, while VOC emissions range from 100 - 1400 kg/day. The high ratio (> 60) of VOC to NOx residential emissions which dominates the county indicates that NOx emissions were most affected by the subtraction of off-highway area source emissions.

Just as the amounts of area sources allocated to each grid in Davidson county were affected by subtraction of certain sources, the corresponding gain of these emissions in the mobile source category elevated the amount of mobile source emissions apportioned to each grid in Davidson county. Figure 20 shows mobile source NOx and VOC emission densities

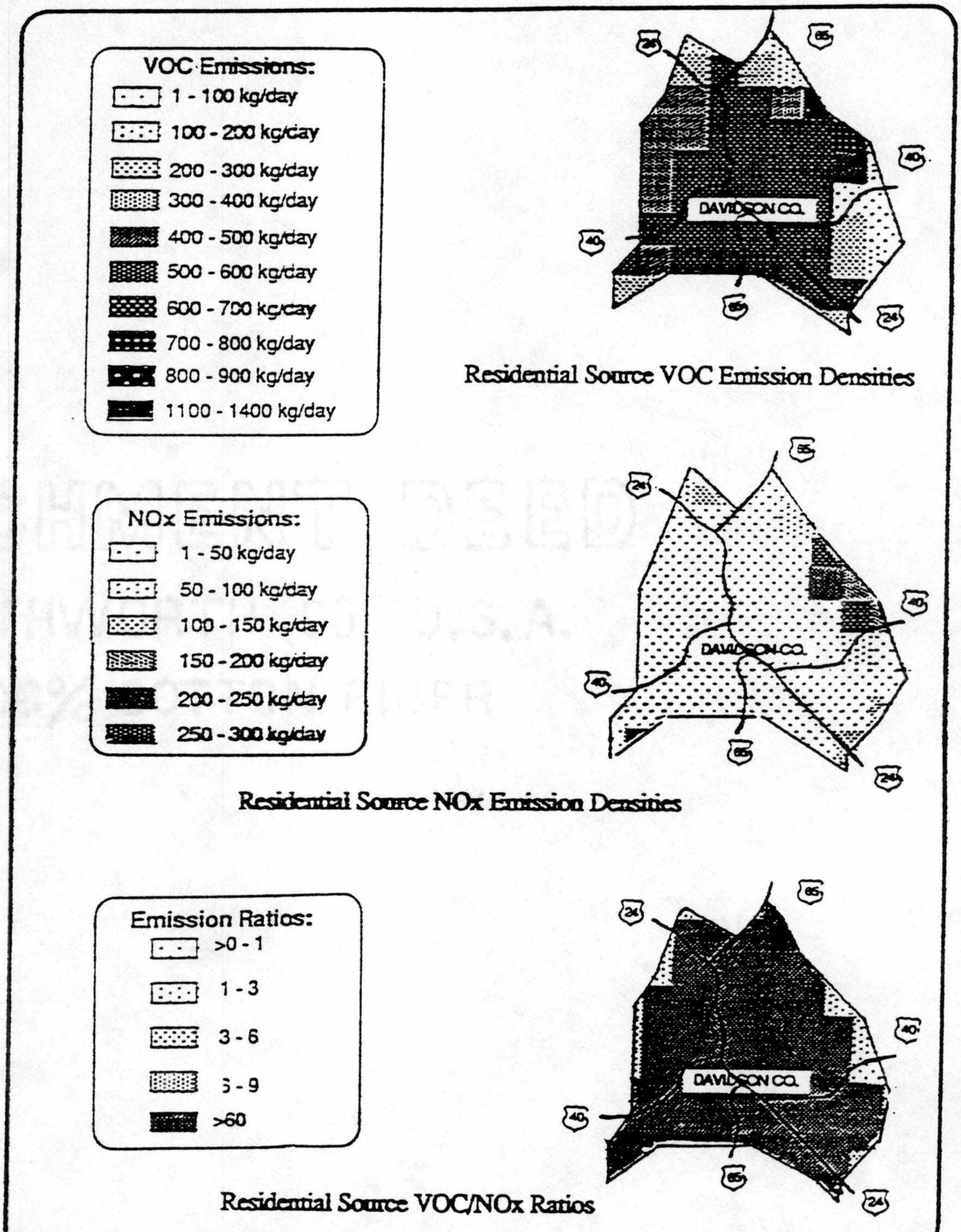
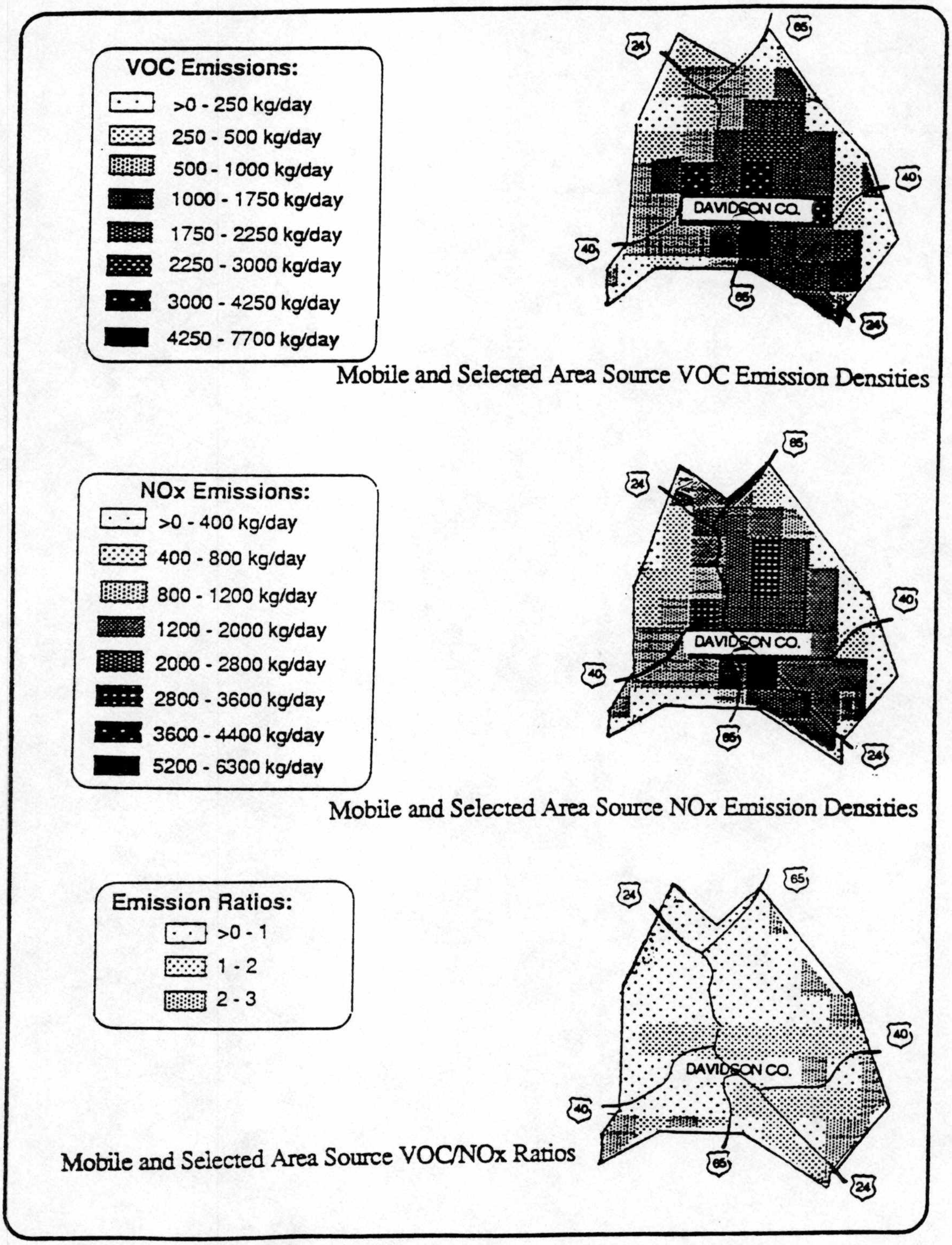


Figure 19. Residential Emission Densities in Davidson County



Mobile and Selected Area Source VOC Emission Densities

Mobile and Selected Area Source NOx Emission Densities

Mobile and Selected Area Source VOC/NOx Ratios

Figure 20. Mobile and Selected Area Source Emission Densities in Davidson County

and emission ratios for Davidson county. NOx mobile source emissions covering the county range from 0.5 - 6300 kg/day, and VOC emissions range from 0.5 - 7700 kg/day. Especially high densities are located at the confluence of major highway routes in the center of Nashville.The ratio of the mobile source VOC/NOx emissions in Davidson county shows a fairly even distribution ranging from 0.5 - 3.

Area source emissions densities for VOC and NOx for the SMSA counties surrounding Davidson county are shown in Figures 21 and 22. The NOx emission density map indicates that typical densities in rural areas range from 1 - 200 kg/day (kg/day), with the highest density ranges of 200 - 925 kg/day being located in or near urban centers. The VOC emission density map indicate a range of 1 - 100 kg/day in the rural SMSA area, while densities in turban area of the SMSA surrounding Davidson county fall mainly in the range of 200 - 700 kg/day. Both NOx and VOC area source emission density maps indicate highest emissions occurring along major highways and in urban areas. The map of VOC/NOx area source emission ratios in the SMSA surrounding Davidson county shown in Figure 23 indicates area source emission ratios falling in the range of 0.5 - 4.0.

Mobile source emission density maps for the SMSA counties surrounding Davidson are shown for VOCs, NOx and their ratios in Figures 24, 25, and 26 respectively. Spatial concentrations of emissions clearly define the routes of major highways, with emissions of NOx ranging from 400 - 2000 kg/day, and VOCs ranging from 250 - 2250 kg/day along these routes. Emissions densities in non-highway grids in the surrounding counties fall in the range of 0.5 - 400 kg/day for NOx, and 0.5 - 250 kg/day for VOCs. The ratios of VOC and NOx in non-highway grids vary from .5 - 4, and are influenced by fluctuations in traffic and mixes of vehicles. Emission ratios along the major highway routes tend to range from 0.5 - 1.

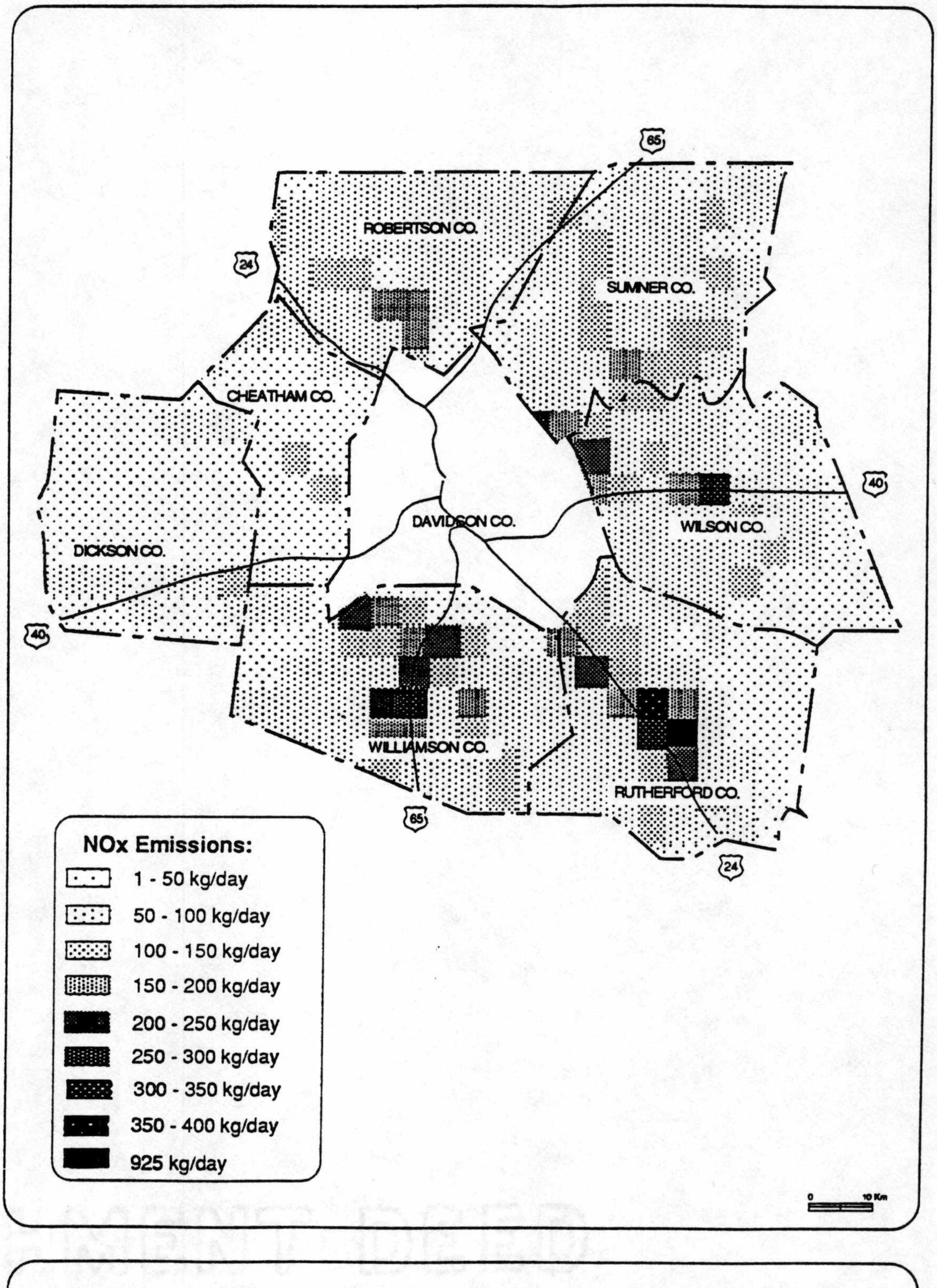


Figure 21. Area Source NOx Emission Densities in the SMSA Surrounding Davidson County

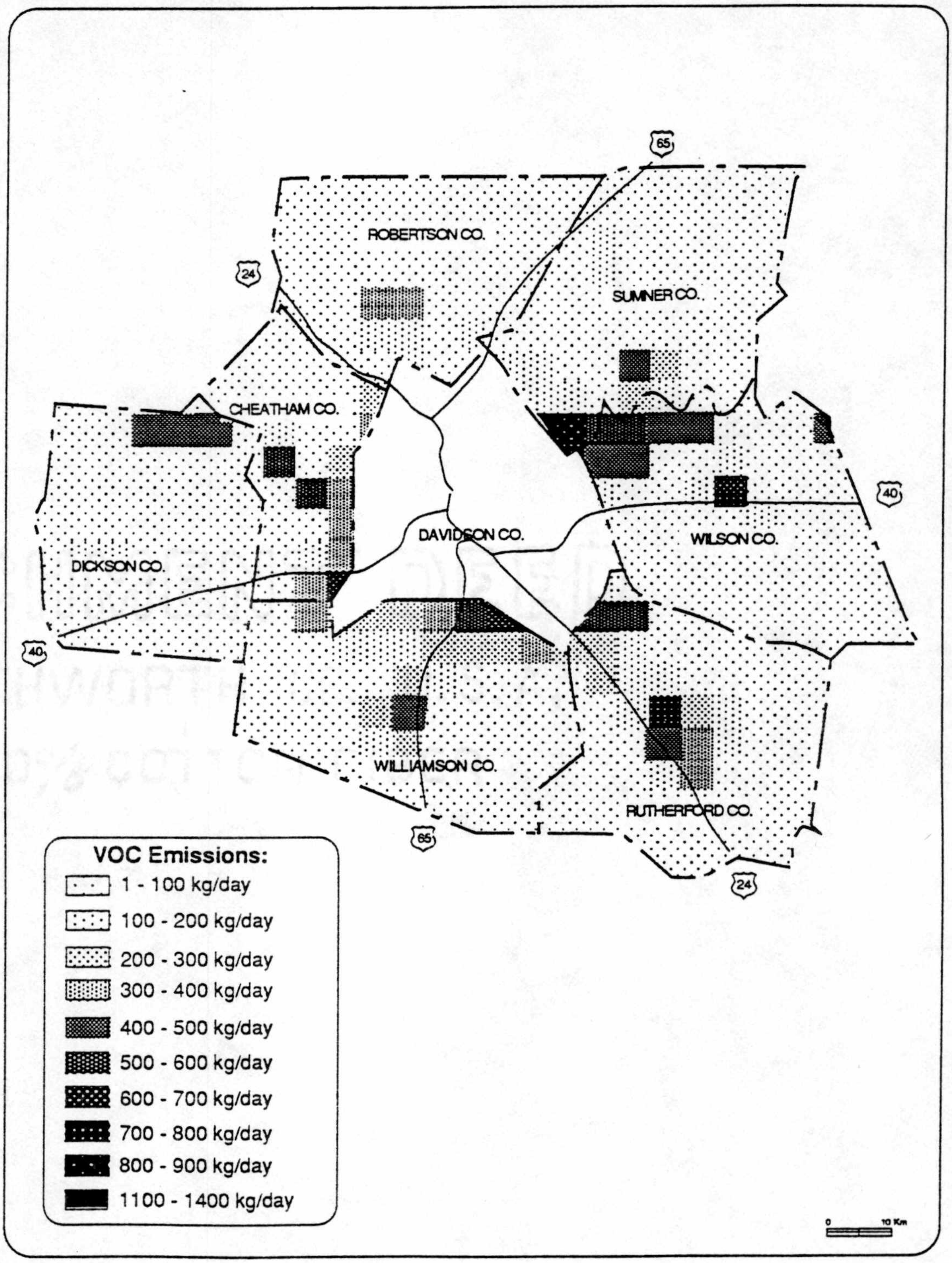


Figure 22. Area Source VOC Emission Densities in the SMSA Surrounding Davidson County

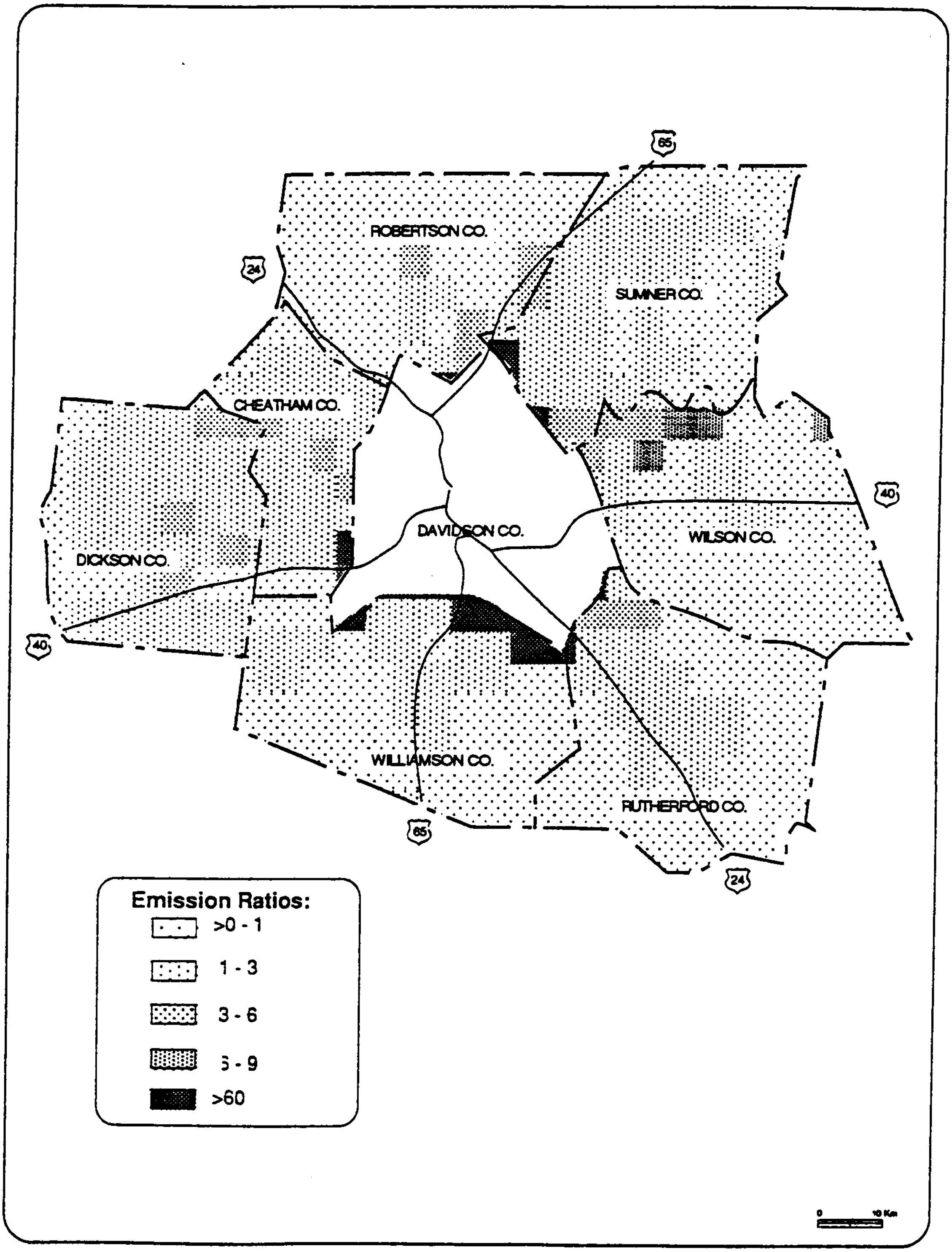


Figure 23. Area Source VOC/NOx Ratios in the SMSA Surrounding Davidson County

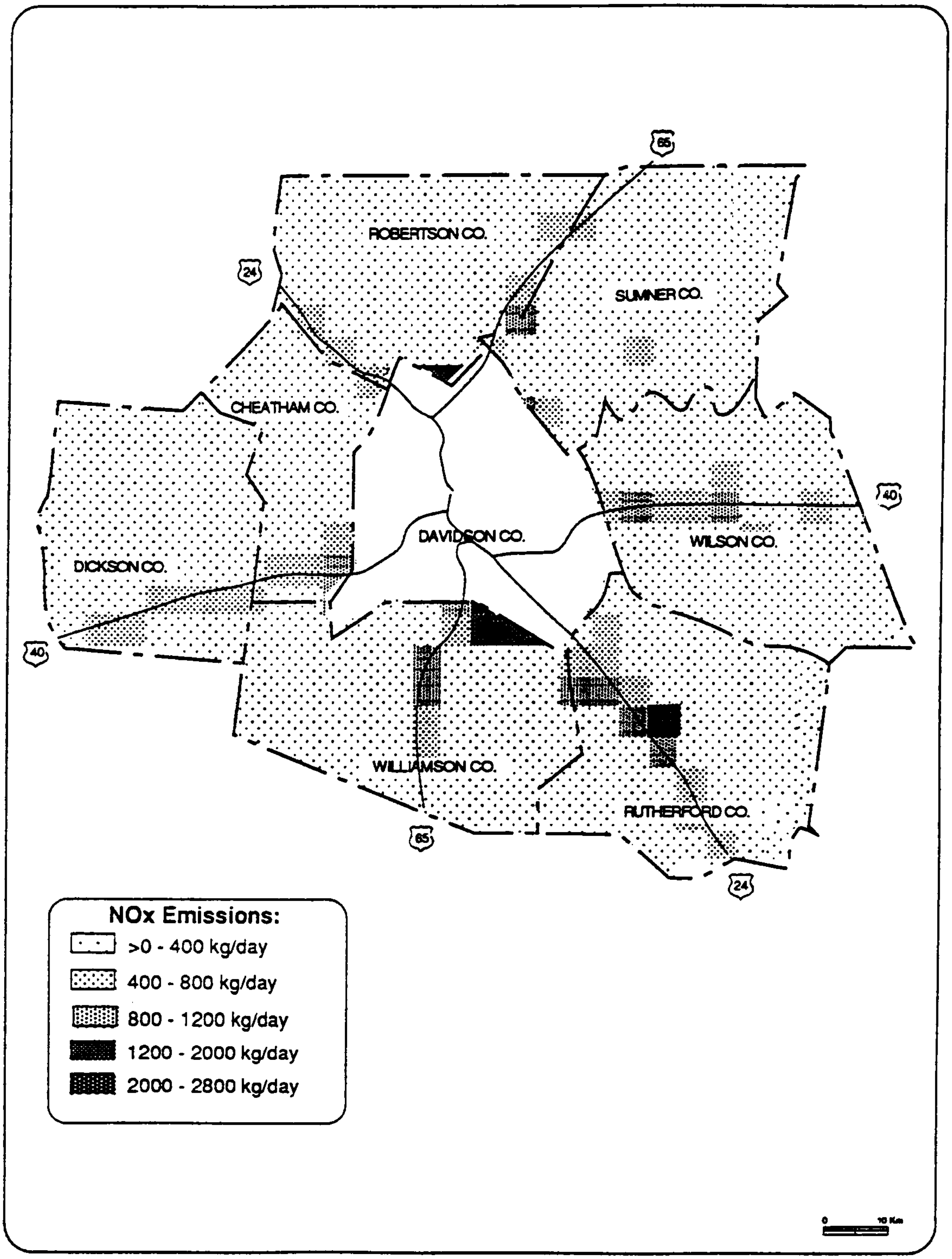


Figure 24. Mobile Source NOx Emission Densities in the SMSA Surrounding Davidson County

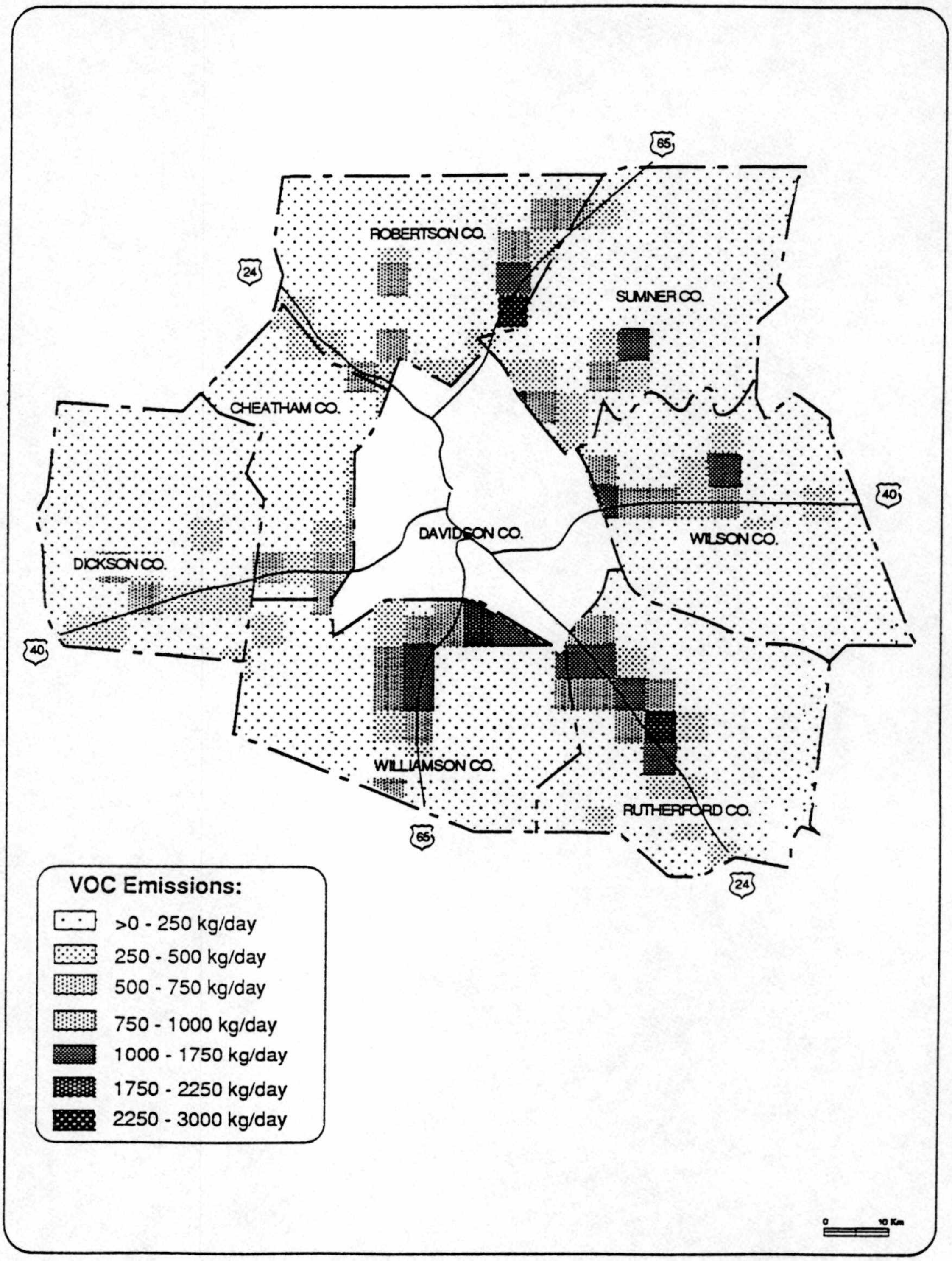


Figure 25. Mobile Source VOC Emission Densities in the SMSA Surrounding Davidson County

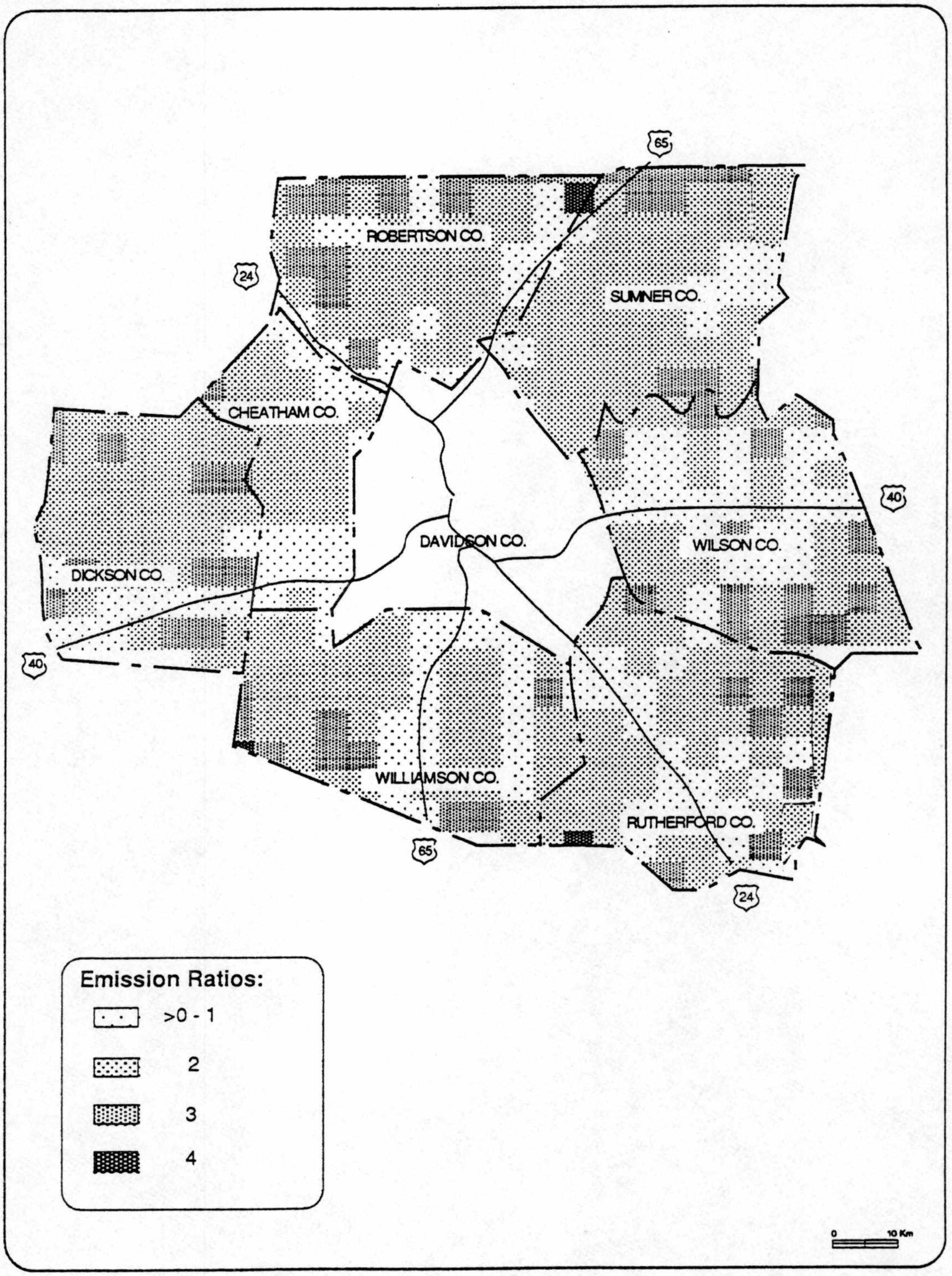


Figure 26. Mobile Source VOC/NOx Ratios in the SMSA Surrounding Davidson County

The resulting cumulative emission density maps for VOCs, NOx, and their ratios when the effects of the point source emissions are added to those of area and mobile source emissions for all counties in the SMSA are shown in Figures 27, 28, and 29. These maps still show a dominance of mobile source emissions which outline the highways. However the contribution of NOx emissions by the TVA Gallatin Steam Plant in Sumner county is also significant. The immediate Nashville area shows elevated cumulative emission densities of NOx ranging from 1500 - 9500 kg/day, while the surrounding counties show much lower densities ranging from 1 - 500 kg/day. The cumulative VOC emission densities in the immediate Nashville vicinity range from 2000 - 13500 kg/day, while rural areas in the surrounding county show VOC densities ranging from 1 - 500 kg/day. The cumulative ratios for the entire area indicate that ranges from 0.5 - 3 are most typical of the region.

Cumulative mass ratios may be assessed in terms of their position on the OZIPM4 ozone isopleth plot. The top end of the most common cumulative mass ratio range is 1, which corresponds to the volumetric ratio of 3 when multiplied by the inverse of the molecular ratio conversion factor of .34. Cumulative mass ratios along the major highways and in scattered pockets throughout the region range typically from 2 - 5; applying the conversion calculation, the volumetric ratio corresponding to the top end of this range is about 15. Both of the volumetric ratios derived from mass emission ratios would plot in the toe region of the OZIPM4 0.15 ppm ozone isopleth. This isopleth concentration is equal to the highest ozone concentration observed during violations of the ozone NAAQS in the Nashville area. In this region of the isopleths, reductions in VOCs will reduce ozone concentrations whereas reductions in NOx may actually increase it.

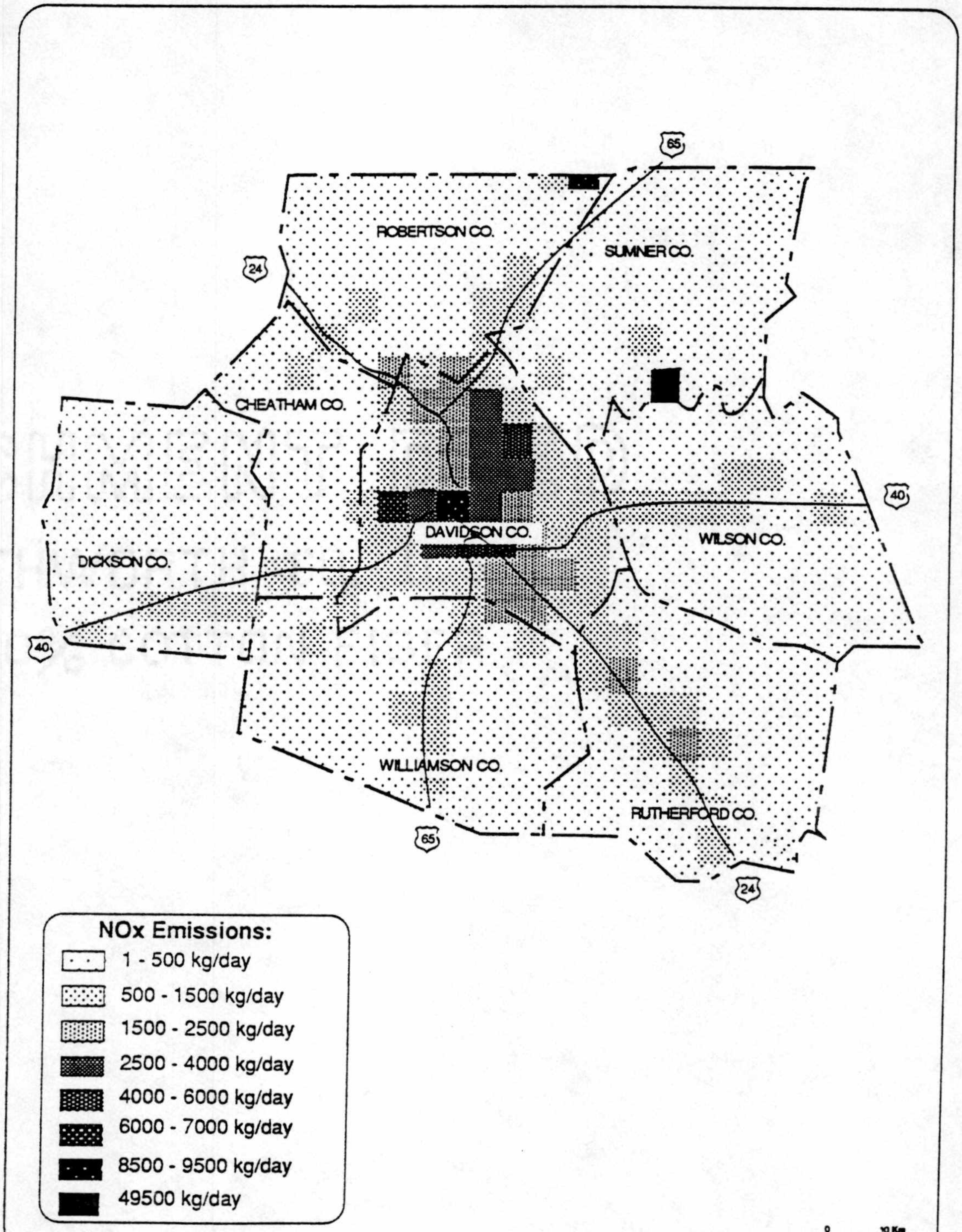


Figure 27. Cumulative NOx Emission Densities in the Nashville Study Area

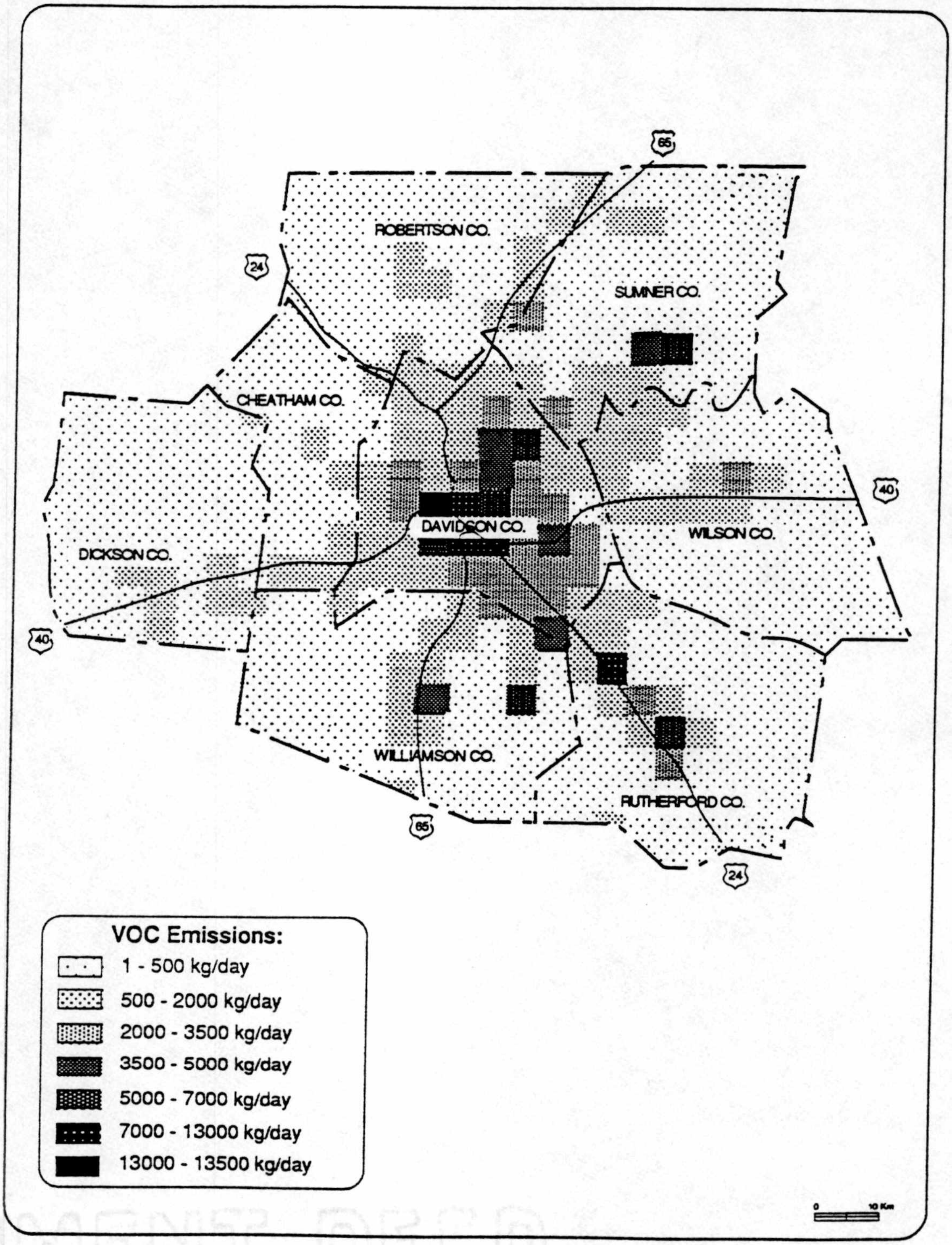


Figure 28. Cumulative VOC Emission Densities in the Nashville Study Area

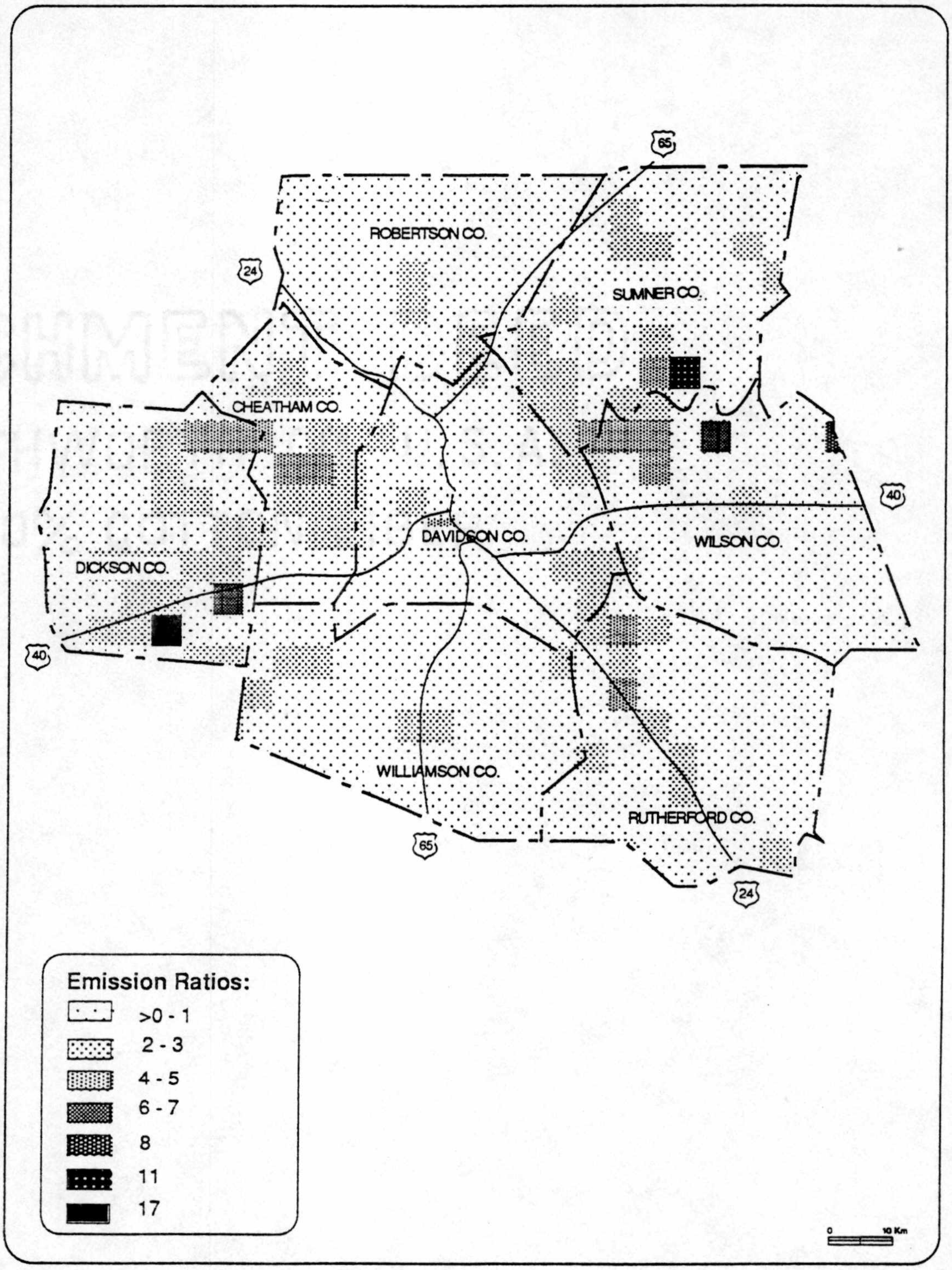


Figure 29. Cumulative VOC/NOx Ratios in the Nashville Study Area

6.0 TEMPORAL ALLOCATION OF EMISSIONS

Point, mobile, and area source emissions inventory values were allocated temporally in hour increments both to assess the impact of emissions throughout the typical ozone season day, and to serve as inputs for air quality modeling. A separate temporal allocation method was developed for each emissions source group to conform to the distinct characteristics of each group. Temporal allocations will be discussed in order of the treatment of point, area, and finally mobile sources. Because no previous hourly emission data for Davidson county existed, the same methods were used to derive these emissions as were applied to the data from the surrounding counties. Therefore, it is not necessary in this case to discuss the handling of Davidson county data separately, and methods discussed will apply to all counties in the Nashville air quality planning area.

6.1 Point Source Temporal Allocations

In general, point source emissions were allocated to hours of the day based upon permit information recorded in the EIS database. Hours of daily operation provided in facility permits ranged from 1 to 24 hours. When hourly operation schedules were missing from permit data, a 24 hour operating schedule was assumed. Total recorded emissions were divided by the hours of operation in the permit data, and assigned to separate hours of the day. All operation shifts were assumed to begin at 8:00 am. No adjustment was made to describe variations in the rate of emissions during daily operation.

6.2 Area Source Temporal Allocations

A central factor in determining the temporal allocation of area sources is their general definition as small industries or activities associated with typical urban activities. With a few notable exceptions, this definition implies that most emissions will occur on an 8 hour schedule which makes up the average working day. The assumption that most area source emissions occur in this time frame is doubly appropriate since it allows the most conservative (e.g. largest amount) estimate of emissions to be used in air quality modeling. Emissions derived using this assumption are calculated by dividing the total emissions allocated to each grid cell by 8. The assumed operating schedule and associated emissions allocation begins at 8:00 am and continues for 8 consecutive hours up to 4:00 pm.

The notable exceptions to the 8 hour allocation scheme are the forest and grass fire and railroad emissions which could not logically be predicted to occur in this time frame. These area source emissions were allocated on a 24 hour basis by dividing the total emissions for each category assigned to each grid by 24 and assigning this value to each hour of the day.

6.3 Mobile Source Temporal Allocations

Allocation of hourly mobile source emissions was performed using data supplied from the Quick Response Urban Travel Estimation Techniques and Transferable Parameters User's Guide in the form of percentages of average daily traffic volumes for each hour of the day on a typical July weekday (National Research Council, Report 187). The percentages for each hour were multiplied by the daily total for each grid square calculated previously using Mobile 4 emissions factors and VMTs. This process resulted in twenty four hourly data files for all grids containing mobile sources. Quick Response User's Guide traffic volume percentages and resulting total tons per hour for the surrounding counties data is presented in Table 10. The same percentages were applied in a like manner to the Davidson county mobile source data, and these data were added into the appropriate hourly mobile source files compiled for the seven surrounding SMSA counties.

6.4 Temporal Allocation Analysis

A synthesis of both temporal and spatial allocations of emissions resulted in twenty four files representing the VOC and NOx ozone precursor emissions for the entire gridded study area at each hour of a typical ozone season day. Table 11 shows the summary of cumulative emissions for each of these hourly files. These data files were compared to the total daily emission files from which they were derive to assure that no emissions were lost during the process of refining daily emissions to an hourly gridded scale; the agreement between the totals in Table 11 and the daily emission totals indicate that data was not lost.

A trend in total regional VOC and NOx emissions by hour given in Table 11 show a peak of emissions at 8:00 am remaining relative high during the day until 4:00 pm after which emissions decline steadily until 4:00 am. Regional mobile source emissions closely follow this pattern indicating that they strongly influence regional emissions. Another factor responsible for the sharp peak of regional emissions at 8:00 am is found in the area source emission trends. Comparison of area source emissions by hour show an increase in area source emissions between 7:00 am and 8:00 am. This increase is caused by the introduction of all the Davidson county area source emissions which run on an 8 hour schedule beginning at 8:00 am. In addition, the scheme used in spatial allocation of point sources in which the starting time for all operating schedules was assumed to be 8:00 am with sources "turning off" according to operating schedules sequentially thereafter also contributes to the regional trend. On the other hand, neither area nor point sources show a marked variation

Table 10. Allocation of Mobile Source Emissions by Hour (Tons/Hour)

Hour of the Day	VOC Emissions for the Surrounding Counties		NOx Emissions for the Surrounding Counties	
	tons per hour	% of Total	tons per hour	% of Total
1	0.92	1.09	1.21	2.15
2	0.48	0.57	0.89	1.59
3	0.41	0.48	0.79	1.41
4	0.39	0.47	0.78	1.40
5	0.53	0.62	0.86	1.53
6	1.23	1.46	1.47	2.63
7	3.72	4.40	2.76	4.94
8	4.60	5.44	3.29	5.88
9	3.53	4.18	2.98	5.33
10	3.67	4.34	2.91	5.19
11	4.19	4.95	3.03	5.41
12	4.85	5.74	2.91	5.19
13	5.25	6.21	3.07	5.48
14	5.24	6.20	3.00	5.35
15	5.93	7.01	3.19	5.70
16	7.30	8.64	3.30	5.89
17	7.78	9.20	3.25	5.81
18	6.92	8.18	3.26	5.82
19	4.95	5.85	2.82	5.03
20	3.94	4.66	2.60	4.65
21	3.05	3.61	2.27	4.05
22	2.46	2.90	2.05	3.66
23	1.82	2.15	1.83	3.27
24	1.39	1.64	1.46	2.61

Table 11. Summary of Hourly Emissions in Tons

Time of Day	Area Sources		Mobile Sources		Point Sources		Total Emissions	
	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX
1:00	0.1	0.2	3.2	3.5	1.6	14.8	4.9	18.5
2:00	0.1	0.2	1.0	2.6	1.6	14.8	2.7	17.6
3:00	0.1	0.2	0.9	2.3	1.6	14.8	2.5	17.3
4:00	0.1	0.2	0.9	2.3	1.5	14.8	2.5	17.3
5:00	0.1	0.2	1.1	2.5	1.5	14.8	2.8	17.5
6:00	0.1	0.2	2.6	4.2	1.5	14.4	4.3	18.8
7:00	0.1	0.2	7.9	7.9	1.5	14.4	9.5	22.5
8:00	9.1	4.0	9.7	9.4	8.2	25.4	27.0	38.8
9:00	9.1	4.0	7.5	8.6	8.2	25.1	24.8	37.7
10:00	9.1	4.0	7.8	7.4	8.0	25.1	24.9	36.5
11:00	9.1	4.0	8.9	8.7	7.8	23.6	25.8	36.3
12:00 PM	9.1	4.0	10.3	8.4	6.0	23.5	25.4	35.9
1:00	9.1	4.0	11.2	8.8	5.9	23.5	26.1	36.3
2:00	9.1	4.0	11.2	8.6	5.7	23.5	25.9	36.1
3:00	9.1	4.0	12.6	9.2	5.5	23.5	27.2	36.7
4:00	0.1	0.2	15.5	9.5	3.6	22.9	19.3	32.6
5:00	0.1	0.2	16.5	9.3	3.5	22.9	20.1	32.5
6:00	0.1	0.2	14.7	9.4	3.2	22.9	18.0	32.5
7:00	0.1	0.2	10.5	8.1	3.3	22.9	13.9	31.2
8:00	0.1	0.2	8.4	7.5	3.1	22.9	11.6	30.6
9:00	0.1	0.2	6.5	6.5	3.1	14.9	9.7	21.6
10:00	0.1	0.2	5.2	5.9	3.0	14.9	8.4	21.0
11:00	0.1	0.2	3.9	5.3	3.0	14.9	7.0	20.4
12:00 AM	0.1	0.2	2.6	4.1	1.6	15.3	4.3	19.6
24 Hour Total	**74.5**	**35.2**	**180.7**	**160.0**	**93.6**	**470.7**	**348.7**	**665.9**

in the early morning hours indicating that the regional trend is most strongly influenced by a fluctuations in traffic loads at this time.

The variation in temporal emissions over the region acts in conjunction with the spatial allocation of emissions to create locally variable emissions for each hour throughout the region. The trends of VOC and NOx emissions over time shown for three different geographic settings in Figure 30 demonstrate the necessity of considering temporal and spatial resolution when characterizing emission trends. Figure 30 shows these trends over time for a grid cell (grid cell coordinates are 18,21) located in the center of Nashville which proved to have some of the highest emissions of NOx and VOCs for the entire region. Figure 30 also compares this grid cell's variations in VOCs and NOx emissions over time to those of the entire Nashville SMSA region. Finally, Figure 30 depicts data for an air quality study performed in 1979 for the Philadelphia air quality planning region which provides comparable material for analysis. The local cell plot shows VOC emissions at higher levels than NOx emissions while both regional plots indicate that NOx emissions are higher than VOC emissions. This local phenomenon is caused by the presence of a point source in the grid cell which emits more VOCs than NOx. However, each graph indicates a rise in emissions in the early morning with high rates of emissions continuing throughout the day, and dropping off steadily after 5:00 pm.

VOC/NOx ratios for all three settings graphed in Figure 30 are shown in Figure 31. Ratios tend to be lowest for the Nashville SMSA, and much higher for grid cell 18,21 and the Philadelphia region. The higher ratios experienced in the center city grid cell and the Philadelphia region may be attributed to the greater contributions of VOCs produced in urban settings. Since much of the Nashville SMSA is rural, and doesn't experience increased VOC emissions associated with urban settings, its overall ratio is lower.

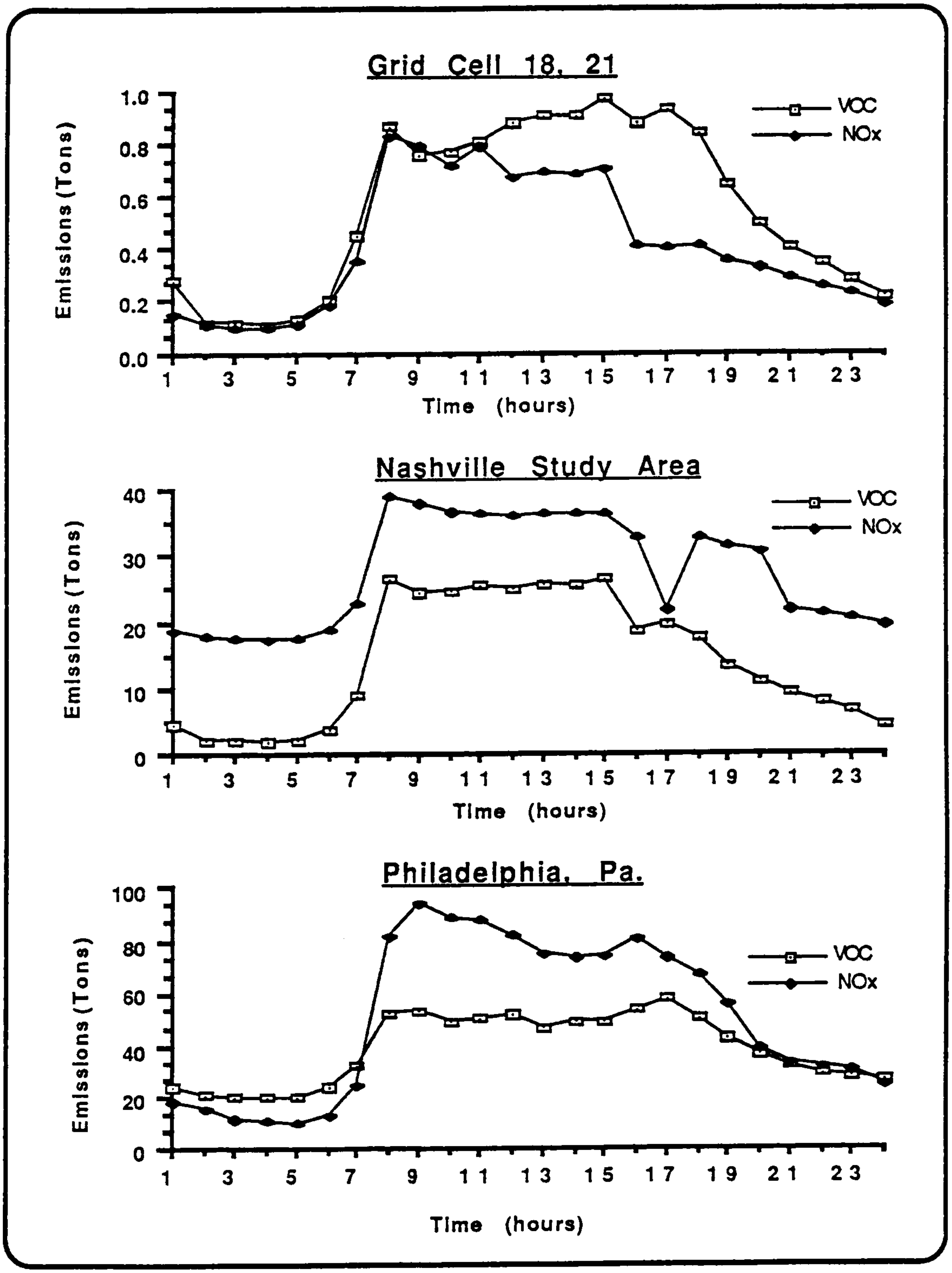


Figure 30 VOC and NOx Emissions for Three Geographic Settings

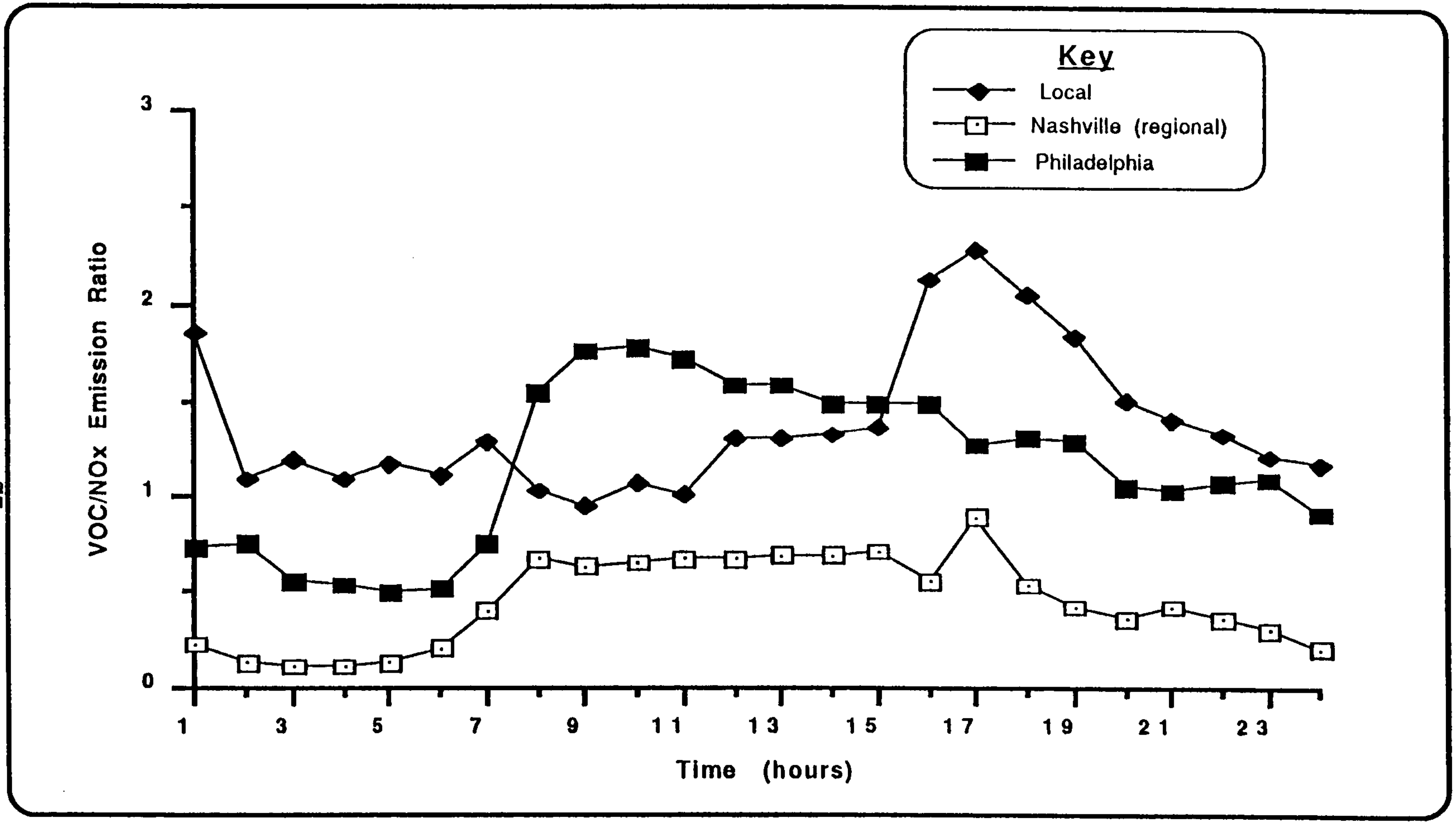


Figure 31. Comparison of VOC/NOx Ratios for a Representative Cell and Two Regional Areas

It is useful to analyze these regional VOC/NOx ratios in terms of their relationship to the ozone formation isopleths plotted for VOC and NOx concentrations using the OZIPM4 photochemical smog simulation model. To directly compare the mass VOC/NOx emission ratios for the Nashville study area with volumetric ratios derived using OZIPM4, the inverse of the molecular ratio conversion factor of .34 is multiplied by the mass emission ratio. Applying this calculation to the temporal distribution graph of mass ratios for the region graphed shown in Figure 31, the volumetric ratio corresponding to the highest mass ratio which occurs in cell 18,21 is about 7.3. This volumetric VOC/NOx ratio would plot in the toe region of the OZIPM4 0.15 ppm ozone isopleth. Ozone control strategies for volumetric ratios which plot in the toe region of the OZIPM4 ozone isopleths should concentrate on reducing VOC concentrations, since a reduction in NOx concentrations may actually increase ozone.

7.0 CONCLUSIONS

The temporal and spatial analysis of VOC and NOx emissions performed in this study indicate a wide amount of variation. Cumulative temporal distributions of VOC and NOx for the entire ozone season day ranged in individual grid cells from >1 kg/day to 13,500 kg/day, and >1 kg/day to 49,500 kg/day respectively. Spatial distibutions of cumulative VOC and NOx emissions for the entire region for each hour of the day ranged from 2,268 kg/hr to 24,675 kg/hr, and 15,694 kg/hr to 34,4201 kg/hr respectively. However, the distributions of ozone precursor emissions indicated that the high densities stretched along major highway routes and in urban settings, with some significant input from large point sources. It is also clear that mobile source emissions along major highway routes are the dominant sources of emissions in the study area.

Despite the wide variation of VOC and NOx emissions for each gird cell throughout the ozone season day, the cumulative ratios of VOC to NOx were largely grouped in a smaller range. With a few exceptions, the cumulative temporal mass ratios ranged from >0 to 5. Cumulative spatial VOC/NOx ratios for each hour of the ozone season day ranged from >0 to 2.5. Since the 0.15 ppm ozone isopleth developed using the OZIPM4 model is the upper range of the ozone violation concentrations observed in the Nashville study area, this isopleth is appropriate for use in relating VOC and NOx emissions to ozone control strategies for the Nashville area. The upper ends of the spatial and temporal ratio ranges, when converted to their volumetric ratio equivalents of 7.3 and 15 respectively, appear to plot in the toe region of the 0.15 ppm ozone isopleth. In this region of the isopleth, a reduction in VOC emissions may reduce ozone concentrations, while a reduction in NOx emissions may actually increase it.

Because of the great degree of variation in emissions, it is apparent that ambient monitoring data may only characterize the air quality in the immediate vicinity of the monitor. Spatial and temporal distribution of emissions indicate that attempts to quantify emissions directly using localized ambient monitoring data may lead to errors if these data are extrapolated to represent an entire region. Computer modeling will be required to better understand the impact of the varying VOC and NOx emissions on area-wide ozone air pollution concentrations in the Nashville study area.

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APPENDICES

Appendix A.1 Area Source Emission Data for the Nashville Study Area

Area Source Emission Data for the Nashville Study Area

GRID COORDINATES		1990 POULATION	COUNTY	AIRPORT EMISSIONS (kg/day)		RAILROAD EMISSIONS (kg/day)		RECREATIONAL BOAT EMISSIONS (kg/day)		RURAL BASED EMISSIONS (kg/day)		POPULATION BASED EMISSIONS (kg/day)		TOTAL EMISSIONS (kg/day)		
Horizontal	Vertical			NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	VOC/NOX Ratio
4	17	16	DICKSON							15.94	6.91	0.21	0.84	16.2	7.7	0.48
4	18	48	DICKSON							15.94	6.91	0.64	2.53	16.58	9.43	0.57
4	19	48	DICKSON							15.94	6.91	0.64	2.53	16.58	9.43	0.57
4	20	64	DICKSON							15.94	6.91	0.85	3.37	16.79	10.27	0.61
4	21	95	DICKSON							15.94	6.91	1.26	5.00	17.20	11.90	0.69
4	22	31	DICKSON							15.94	6.91	0.41	1.63	16.35	8.54	0.52
5	17	159	DICKSON							15.94	6.91	2.11	8.37	18.05	15.27	0.85
5	18	319	DICKSON							15.94	6.91	4.23	16.78	20.17	23.69	1.17
5	19	319	DICKSON			56.40	14.33			15.94	6.91	4.23	16.78	76.56	38.02	0.50
5	20	318	DICKSON							15.94	6.91	4.21	16.73	20.15	23.64	1.17
5	21	269	DICKSON							15.94	6.91	3.56	14.15	19.50	21.06	1.08
5	22	290	DICKSON							15.94	6.91	3.84	15.26	19.78	22.16	1.12
5	23	214	DICKSON							15.94	6.91	2.83	11.26	18.77	18.17	0.97
5	24	152	DICKSON							15.94	6.91	2.01	8.00	17.95	14.90	0.83
5	25	31	DICKSON							15.94	6.91	0.41	1.63	16.35	8.54	0.52
6	17	259	DICKSON							15.94	6.91	3.43	13.63	19.37	20.53	1.06
6	18	719	DICKSON							15.94	6.91	9.52	37.83	25.46	44.74	1.76
6	19	1019	DICKSON			56.40	14.33			15.94	6.91	13.50	53.62	85.83	74.86	0.87
6	20	519	DICKSON	2.72	7.26					15.94	6.91	6.87	27.31	25.54	41.47	1.62
6	21	315	DICKSON							15.94	6.91	4.17	16.57	20.11	23.48	1.17
6	22	305	DICKSON							15.94	6.91	4.04	16.05	19.98	22.95	1.15
6	23	305	DICKSON							15.94	6.91	4.04	16.05	19.98	22.95	1.15
6	24	305	DICKSON							15.94	6.91	4.04	16.05	19.98	22.95	1.15
6	25	15	DICKSON							15.94	6.91	0.20	0.79	16.14	7.69	0.48
7	17	1055	DICKSON							15.94	6.91	13.97	55.51	29.91	62.42	2.09
7	18	1319	DICKSON							15.94	6.91	17.47	69.40	33.41	76.31	2.28
7	19	1623	DICKSON			56.40	14.33					21.50	85.40	77.89	99.73	1.28
7	20	2120	DICKSON							15.94	6.91	28.08	111.55	44.02	118.45	2.69
7	21	700	DICKSON							15.94	6.91	9.27	36.83	25.21	43.74	1.73
7	22	319	DICKSON							15.94	6.91	4.23	16.78	20.17	23.69	1.17
7	23	305	DICKSON							15.94	6.91	4.04	16.05	19.98	22.95	1.15
7	24	275	DICKSON							15.94	6.91	3.64	14.47	19.58	21.37	1.09
8	17	1127	DICKSON							15.94	6.91	14.93	59.30	30.87	66.20	2.14
8	18	1079	DICKSON			56.40	14.33					14.29	56.77	70.69	71.11	1.01
8	19	1615	DICKSON									21.39	84.98	21.39	84.98	3.97
8	20	2047	DICKSON							15.94	6.91	27.11	107.71	43.05	114.61	2.66
8	21	444	DICKSON									5.88	23.36	5.88	23.36	3.97
8	22	430	DICKSON							15.94	6.91	5.70	22.63	21.64	29.53	1.36
8	23	333	DICKSON							15.94	6.91	4.41	17.52	20.35	24.43	1.20
8	24	259	DICKSON							15.94	6.91	3.43	13.63	19.37	20.53	1.06
9	17	720	DICKSON							15.94	6.91	9.54	37.88	25.48	44.79	1.76
9	18	719	DICKSON							15.94	6.91	9.52	37.83	25.46	44.74	1.76
9	19	835	DICKSON			56.40	14.33			15.94	6.91	11.06	43.94	83.40	65.17	0.78
9	20	1118	DICKSON							15.94	6.91	14.81	58.83	30.75	65.73	2.14
9	21	492	DICKSON							15.94	6.91	6.52	25.89	22.46	32.79	1.46
9	22	444	DICKSON							15.94	6.91	5.88	23.36	21.82	30.27	1.39
9	23	444	DICKSON							15.94	6.91	5.88	23.36	21.82	30.27	1.39
9	24	331	DICKSON			56.40	14.33	12.50	430.24	15.94	6.91	4.38	17.42	89.22	468.89	5.26
9	25	103	CHEATHAM							14.64	7.15	1.50	5.39	16.14	12.54	0.78
10	14	20	WILLIAMSON							38.30	12.19	0.77	1.13	39.07	13.32	0.34
10	17	719	DICKSON							15.94	6.91	9.52	37.83	25.46	44.74	1.76
10	18	720	DICKSON							15.94	6.91	9.54	37.88	25.48	44.79	1.76
10	19	739	DICKSON			56.40	14.33			15.94	6.91	9.79	38.88	82.13	60.12	0.73

Area Source Emission Data for the Nashville Study Area

GRID COORDINATES		1990 POULATION	COUNTY	AIRPORT EMISSIONS (kg/day)		RAILROAD EMISSIONS (kg/day)		RECREATIONAL BOAT EMISSIONS (kg/day)		RURAL BASED EMISSIONS (kg/day)		POPULATION BASED EMISSIONS (kg/day)		TOTAL EMISSIONS (kg/day)		
Horizontal	Vertical			NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	VOC/NOX Ratio
10	20	761	DICKSON									10.08	40.04	10.08	40.04	3.97
10	21	746	DICKSON							15.94	6.91	9.88	39.25	25.82	46.16	1.79
10	22	509	DICKSON							15.94	6.91	6.74	26.78	22.68	33.69	1.49
10	23	444	DICKSON							15.94	6.91	5.88	23.36	21.82	30.27	1.39
10	24	494	DICKSON			56.40	14.33	12.50	430.24	15.94	6.91	6.54	25.99	91.38	477.47	5.22
10	25	656	CHEATHAM							14.64	7.15	9.52	34.34	24.16	41.48	1.72
10	26	241	CHEATHAM			75.71	19.23			14.64	7.15	3.50	12.62	93.84	38.99	0.42
11	14	333	WILLIAMSON							38.30	12.19	12.77	18.82	51.07	31.01	0.61
11	15	515	WILLIAMSON							38.30	12.19	19.75	29.11	58.05	41.30	0.71
11	16	762	WILLIAMSON									29.22	43.07	29.22	43.07	1.47
11	17	785	WILLIAMSON									30.10	44.37	30.10	44.37	1.47
11	18	758	WILLIAMSON							38.30	12.19	29.07	42.84	67.37	55.03	0.82
11	19	740	CHEATHAM			75.71	19.23			14.64	7.15	10.74	38.74	101.09	65.11	0.64
11	20	746	CHEATHAM							14.64	7.15	10.83	39.05	25.47	46.20	1.81
11	21	752	DICKSON							15.94	6.91	9.96	39.57	25.90	46.47	1.79
11	22	659	CHEATHAM							14.64	7.15	9.57	34.50	24.21	41.64	1.72
11	23	519	CHEATHAM							14.64	7.15	7.53	27.17	22.17	34.31	1.55
11	24	528	DICKSON			56.40	14.33	12.50	430.24	15.94	6.91	6.99	27.78	91.83	479.26	5.22
11	25	690	CHEATHAM							14.64	7.15	10.02	36.12	24.66	43.26	1.75
11	26	621	CHEATHAM							14.64	7.15	9.01	32.51	23.65	39.65	1.68
11	27	35	ROBERTSON							72.20	25.81	0.61	1.87	72.80	27.68	0.38
12	13	59	WILLIAMSON							38.30	12.19	2.26	3.33	40.57	15.52	0.38
12	14	392	WILLIAMSON							38.30	12.19	15.03	22.16	53.34	34.34	0.64
12	15	719	WILLIAMSON							38.30	12.19	27.57	40.64	65.88	52.83	0.80
12	16	802	WILLIAMSON									30.75	45.33	30.75	45.33	1.47
12	17	802	WILLIAMSON									30.75	45.33	30.75	45.33	1.47
12	18	769	WILLIAMSON							38.30	12.19	29.49	43.46	67.79	55.65	0.82
12	19	694	CHEATHAM			75.71	19.23			14.64	7.15	10.07	36.33	100.42	62.71	0.62
12	20	694	CHEATHAM							14.64	7.15	10.07	36.33	24.71	43.47	1.76
12	21	693	CHEATHAM							14.64	7.15	10.06	36.28	24.70	43.42	1.76
12	22	735	CHEATHAM							14.64	7.15	10.67	38.47	25.31	45.62	1.80
12	23	852	CHEATHAM							14.64	7.15	12.37	44.60	27.01	51.74	1.92
12	24	784	CHEATHAM							14.64	7.15	11.38	41.04	26.02	48.18	1.85
12	25	690	CHEATHAM							14.64	7.15	10.02	36.12	24.66	43.26	1.75
12	26	690	CHEATHAM							14.64	7.15	10.02	36.12	24.66	43.26	1.75
12	27	485	ROBERTSON							72.20	25.81	8.45	25.96	80.64	51.77	0.64
12	28	179	ROBERTSON							72.20	25.81	3.12	9.58	75.31	35.39	0.47
12	29	97	ROBERTSON							72.20	25.81	1.69	5.19	73.88	31.00	0.42
12	30	172	ROBERTSON			59.81	15.20			72.20	25.81	3.00	9.21	135.00	50.22	0.37
12	31	115	ROBERTSON			59.81	15.20			72.20	25.81	2.00	6.16	134.01	47.17	0.35
13	13	353	WILLIAMSON							38.30	12.19	13.54	19.95	51.84	32.14	0.62
13	14	392	WILLIAMSON							38.30	12.19	15.03	22.16	53.34	34.34	0.64
13	15	741	WILLIAMSON							38.30	12.19	28.42	41.88	66.72	54.07	0.81
13	16	802	WILLIAMSON							38.30	12.19	30.75	45.33	69.06	57.52	0.83
13	17	802	WILLIAMSON									30.75	45.33	30.75	45.33	1.47
13	18	791	WILLIAMSON							38.30	12.19	30.33	44.71	68.64	56.90	0.83
13	19	694	CHEATHAM			75.71	19.23			14.64	7.15	10.07	36.33	100.42	62.71	0.62
13	20	700	CHEATHAM							14.64	7.15	10.16	36.64	24.80	43.79	1.77
13	21	799	CHEATHAM							14.64	7.15	11.60	41.82	26.24	48.97	1.87
13	22	895	CHEATHAM							14.64	7.15	12.99	46.85	27.63	54.00	1.95
13	23	1712	CHEATHAM			75.71	19.23	12.50	430.24	14.64	7.15	24.85	89.61	127.70	546.23	4.28
13	24	1814	CHEATHAM							14.64	7.15	26.33	94.95	40.97	102.10	2.49
13	25	696	CHEATHAM							14.64	7.15	10.10	36.43	24.74	43.58	1.76

Area Source Emission Data for the Nashville Study Area

GRID COORDINATES		1990 POULATION	COUNTY	AIRPORT EMISSIONS (kg/day)		RAILROAD EMISSIONS (kg/day)		RECREATIONAL BOAT EMISSIONS (kg/day)		RURAL BASED EMISSIONS (kg/day)		POPULATION BASED EMISSIONS (kg/day)		TOTAL EMISSIONS (kg/day)		
Horizontal	Vertical			NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	VOC/NOX Ratio
13	26	683	CHEATHAM							14.64	7.15	9.91	35.75	24.55	42.90	1.75
13	27	441	ROBERTSON							72.20	25.81	7.68	23.60	79.88	49.41	0.62
13	28	359	ROBERTSON							72.20	25.81	6.25	19.22	78.45	45.02	0.57
13	29	308	ROBERTSON							72.20	25.81	5.36	16.49	77.56	42.29	0.55
13	30	287	ROBERTSON			59.81	15.20					5.00	15.36	64.81	30.56	0.47
13	31	287	ROBERTSON							72.20	25.81	5.00	15.36	77.19	41.17	0.53
14	12	39	WILLIAMSON							38.30	12.19	1.50	2.20	39.80	14.39	0.36
14	13	353	WILLIAMSON							38.30	12.19	13.54	19.95	51.84	32.14	0.62
14	14	391	WILLIAMSON							38.30	12.19	14.99	22.10	53.30	34.29	0.64
14	15	678	WILLIAMSON							38.30	12.19	26.00	38.32	64.30	50.51	0.79
14	16	802	WILLIAMSON							38.30	12.19	30.75	45.33	69.06	57.52	0.83
14	17	1128	WILLIAMSON							38.30	12.19	43.26	63.75	81.56	75.94	0.93
14	21	915	CHEATHAM							14.64	7.15	13.28	47.90	27.92	55.04	1.97
14	22	905	CHEATHAM			75.71	19.23	12.50	430.24	14.64	7.15	13.14	47.37	115.98	503.99	4.35
14	23	1040	CHEATHAM							14.64	7.15	15.10	54.44	29.74	61.59	2.07
14	24	1444	CHEATHAM							14.64	7.15	20.96	75.59	35.60	82.73	2.32
14	25	819	CHEATHAM							14.64	7.15	11.89	42.87	26.53	50.02	1.89
14	26	524	ROBERTSON							72.20	25.81	9.13	28.05	81.32	53.85	0.66
14	27	359	ROBERTSON	0.91	2.45					72.20	25.81	6.25	19.22	79.36	47.47	0.60
14	28	358	ROBERTSON							72.20	25.81	6.24	19.16	78.43	44.97	0.57
14	29	294	ROBERTSON			59.81	15.20			72.20	25.81	5.12	15.74	137.13	56.75	0.41
14	30	287	ROBERTSON							72.20	25.81	5.00	15.36	77.19	41.17	0.53
14	31	287	ROBERTSON							72.20	25.81	5.00	15.36	77.19	41.17	0.53
14	32	14	ROBERTSON							72.20	25.81	0.24	0.75	72.44	26.56	0.37
15	12	59	WILLIAMSON									2.26	3.33	2.26	3.33	1.47
15	13	392	WILLIAMSON							38.30	12.19	15.03	22.16	53.34	34.34	0.64
15	14	414	WILLIAMSON							38.30	12.19	15.88	23.40	54.18	35.59	0.66
15	15	1245	WILLIAMSON							38.30	12.19	47.74	70.37	86.05	82.55	0.96
15	16	1271	WILLIAMSON							38.30	12.19	48.74	71.83	87.04	84.02	0.97
15	17	2044	WILLIAMSON							38.30	12.19	78.38	115.52	116.69	127.71	1.09
15	18	5078	WILLIAMSON							38.30	12.19	194.73	287.00	233.03	299.19	1.28
15	24	815	CHEATHAM							14.64	7.15	11.83	42.66	26.47	49.81	1.88
15	25	883	CHEATHAM							14.64	7.15	12.82	46.22	27.46	53.37	1.94
15	26	413	ROBERTSON							72.20	25.81	7.19	22.11	79.39	47.91	0.60
15	27	358	ROBERTSON							72.20	25.81	6.24	19.16	78.43	44.97	0.57
15	28	486	ROBERTSON							72.20	25.81	8.47	26.01	80.66	51.82	0.64
15	29	466	ROBERTSON	0.91	2.45	59.81	15.20			72.20	25.81	8.12	24.94	141.03	68.40	0.49
15	30	287	ROBERTSON							72.20	25.81	5.00	15.36	77.19	41.17	0.53
15	31	287	ROBERTSON							72.20	25.81	5.00	15.36	77.19	41.17	0.53
15	32	29	ROBERTSON							72.20	25.81	0.51	1.55	72.70	27.36	0.38
16	12	294	WILLIAMSON									11.27	16.62	11.27	16.62	1.47
16	13	392	WILLIAMSON			81.55	20.71			38.30	12.19	15.03	22.16	134.88	55.06	0.41
16	14	1717	WILLIAMSON			81.55	20.71			38.30	12.19	65.84	97.04	185.69	129.95	0.70
16	15	4677	WILLIAMSON			81.55	20.71					179.35	264.34	260.90	285.05	1.09
16	16	1784	WILLIAMSON									68.41	100.83	68.41	100.83	1.47
16	17	2340	WILLIAMSON							38.30	12.19	89.73	132.25	128.04	144.44	1.13
16	18	3691	WILLIAMSON							38.30	12.19	141.54	208.61	179.84	220.80	1.23
16	26	1176	ROBERTSON							72.20	25.81	20.48	62.94	92.68	88.75	0.96
16	27	1626	ROBERTSON							72.20	25.81	28.32	87.03	100.52	112.84	1.12
16	28	6223	ROBERTSON			59.81	15.20					108.39	333.08	168.20	348.28	2.07
16	29	1568	ROBERTSON									27.31	83.93	27.31	83.93	3.07
16	30	291	ROBERTSON	0.91	2.45					72.20	25.81	5.07	15.58	78.17	43.83	0.56
16	31	287	ROBERTSON							72.20	25.81	5.00	15.36	77.19	41.17	0.53

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Horizontal	Vertical			NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	VOC/NOX Ratio
16	32	43	ROBERTSON							72.20	25.81	0.75	2.30	72.94	28.11	0.39
17	11	153	WILLIAMSON							38.30	12.19	5.87	8.65	44.17	20.84	0.47
17	12	492	WILLIAMSON							38.30	12.19	18.87	27.81	57.17	40.00	0.70
17	13	1221	WILLIAMSON							38.30	12.19	46.82	69.01	85.13	81.20	0.95
17	14	3434	WILLIAMSON							38.30	12.19	131.68	194.08	169.99	206.27	1.21
17	15	8673	WILLIAMSON									332.58	490.18	332.58	490.18	1.47
17	16	3892	WILLIAMSON			81.55	20.71					149.25	219.97	230.79	240.68	1.04
17	17	2835	WILLIAMSON			81.55	20.71					108.71	160.23	190.26	180.94	0.95
17	18	3752	WILLIAMSON									143.88	212.06	143.88	212.06	1.47
17	26	1772	ROBERTSON							72.20	25.81	30.86	94.85	103.06	120.65	1.17
17	27	1766	ROBERTSON			59.81	15.20			72.20	25.81	30.76	94.52	162.77	135.53	0.83
17	28	5939	ROBERTSON							72.20	25.81	103.45	317.88	175.64	343.69	1.96
17	29	881	ROBERTSON							72.20	25.81	15.35	47.16	87.54	72.96	0.83
17	30	326	ROBERTSON							72.20	25.81	5.68	17.45	77.87	43.26	0.56
17	31	295	ROBERTSON							72.20	25.81	5.14	15.79	77.33	41.60	0.54
17	32	76	ROBERTSON							72.20	25.81	1.32	4.07	73.52	29.88	0.41
18	11	407	WILLIAMSON							38.30	12.19	15.61	23.00	53.91	35.19	0.65
18	12	509	WILLIAMSON							38.30	12.19	19.52	28.77	57.82	40.96	0.71
18	13	544	WILLIAMSON							38.30	12.19	20.86	30.75	59.17	42.94	0.73
18	14	582	WILLIAMSON							38.30	12.19	22.32	32.89	60.62	45.08	0.74
18	15	588	WILLIAMSON							38.30	12.19	22.55	33.23	60.85	45.42	0.75
18	16	2864	WILLIAMSON									109.83	161.87	109.83	161.87	1.47
18	17	3462	WILLIAMSON			81.55	20.71					132.76	195.67	214.30	216.38	1.01
18	26	1758	ROBERTSON									30.62	94.10	30.62	94.10	3.07
18	27	1766	ROBERTSON									30.76	94.52	30.76	94.52	3.07
18	28	890	ROBERTSON							72.20	25.81	15.50	47.64	87.70	73.44	0.84
18	29	482	ROBERTSON							72.20	25.81	8.40	25.80	80.59	51.61	0.64
18	30	381	ROBERTSON							72.20	25.81	6.64	20.39	78.83	46.20	0.59
18	31	514	ROBERTSON							72.20	25.81	8.95	27.51	81.15	53.32	0.66
18	32	166	ROBERTSON							72.20	25.81	2.89	8.89	75.09	34.69	0.46
19	11	435	WILLIAMSON							38.30	12.19	16.68	24.59	54.99	36.77	0.67
19	12	509	WILLIAMSON							38.30	12.19	19.52	28.77	57.82	40.96	0.71
19	13	510	WILLIAMSON							38.30	12.19	19.56	28.82	57.86	41.01	0.71
19	14	644	WILLIAMSON			81.55	20.71			38.30	12.19	24.70	36.40	144.55	69.30	0.48
19	15	820	WILLIAMSON			81.55	20.71			38.30	12.19	31.44	46.34	151.30	79.25	0.52
19	16	1430	WILLIAMSON							38.30	12.19	54.84	80.82	93.14	93.01	1.00
19	17	3805	WILLIAMSON									145.91	215.05	145.91	215.05	1.47
19	27	1497	ROBERTSON							72.20	25.81	26.07	80.13	98.27	105.93	1.08
19	28	664	ROBERTSON							72.20	25.81	11.57	35.54	83.76	61.35	0.73
19	29	664	ROBERTSON							72.20	25.81	11.57	35.54	83.76	61.35	0.73
19	30	664	ROBERTSON							72.20	25.81	11.57	35.54	83.76	61.35	0.73
19	31	665	ROBERTSON							72.20	25.81	11.58	35.59	83.78	61.40	0.73
19	32	199	ROBERTSON							72.20	25.81	3.47	10.65	75.66	36.46	0.48
20	11	489	RUTHERFORD							33.22	16.03	17.94	27.37	51.17	43.40	0.85
20	12	524	RUTHERFORD			61.52	15.63			33.22	16.03	19.23	29.33	113.97	60.99	0.54
20	13	509	WILLIAMSON			81.55	20.71			38.30	12.19	19.52	28.77	139.37	61.67	0.44
20	14	779	WILLIAMSON							38.30	12.19	29.87	44.03	68.18	56.22	0.82
20	15	846	WILLIAMSON							38.30	12.19	32.44	47.81	70.75 6	35985	0.85
20	16	846	WILLIAMSON							38.30	12.19	32.44	47.81	70.75 6	35985	0.85
20	25	2603	SUMNER							46.44	23.12	53.37	139.32	99.80	162.44	1.63
20	26	2001	SUMNER									41.03	107.10	41.03	107.10	2.61
20	27	974	SUMNER									19.97	52.13	19.97	52.13	2.61
20	28	664	ROBERTSON									11.57	35.54	11.57	35.54	3.07

Area Source Emission Data for the Nashville Study Area

GRID COORDINATES		1990 POULATION	COUNTY	AIRPORT EMISSIONS (kg/day)		RAILROAD EMISSIONS (kg/day)		RECREATIONAL BOAT EMISSIONS (kg/day)		RURAL BASED EMISSIONS (kg/day)		POPULATION BASED EMISSIONS (kg/day)		TOTAL EMISSIONS (kg/day)		
Horizontal	Vertical			NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	VOC/NOX Ratio
20	29	664	ROBERTSON									11.57	35.54	11.57	35.54	3.07
20	30	665	ROBERTSON							72.20	25.81	11.58	35.59	83.78	61.40	0.73
20	31	287	ROBERTSON							72.20	25.81	5.00	15.36	77.19	41.17	0.53
20	32	233	ROBERTSON							72.20	25.81	4.06	12.47	76.25	38.28	0.50
21	11	524	RUTHERFORD							33.22	16.03	19.23	29.33	52.45	45.36	0.86
21	12	552	RUTHERFORD							33.22	16.03	20.26	30.90	53.48	46.93	0.88
21	13	538	RUTHERFORD							33.22	16.03	19.74	30.11	52.97	46.14	0.87
21	14	806	RUTHERFORD							33.22	16.03	29.58	45.11	62.80	61.14	0.97
21	15	757	RUTHERFORD							33.22	16.03	27.78	42.37	61.00	58.40	0.96
21	16	757	RUTHERFORD							33.22	16.03	27.78	42.37	61.00	58.40	0.96
21	23	11886	SUMNER									243.69	636.19	243.69	636.19	2.61
21	24	12777	SUMNER			47.55	12.08	12.50	430.24			261.96	683.88	322.01	1126.20	3.50
21	25	2609	SUMNER									53.49	139.65	53.49	139.65	2.61
21	26	1916	SUMNER							46.44	23.12	39.28	102.55	85.72	125.67	1.47
21	27	1235	SUMNER							46.44	23.12	25.32	66.10	71.76	89.22	1.24
21	28	1041	SUMNER									21.34	55.72	21.34	55.72	2.61
21	29	930	SUMNER							46.44	23.12	19.07	49.78	65.50	72.90	1.11
21	30	709	ROBERTSON							72.20	25.81	12.35	37.95	84.54	63.76	0.75
21	31	288	ROBERTSON							72.20	25.81	5.02	15.42	77.21	41.22	0.53
21	32	232	ROBERTSON							72.20	25.81	4.04	12.42	76.24	38.23	0.50
22	11	552	RUTHERFORD							33.22	16.03	20.26	30.90	53.48	46.93	0.88
22	12	552	RUTHERFORD							33.22	16.03	20.26	30.90	53.48	46.93	0.88
22	13	552	RUTHERFORD							33.22	16.03	20.26	30.90	53.48	46.93	0.88
22	14	552	RUTHERFORD							33.22	16.03	20.26	30.90	53.48	46.93	0.88
22	15	552	RUTHERFORD							33.22	16.03	20.26	30.90	53.48	46.93	0.88
22	16	1464	RUTHERFORD							33.22	16.03	53.72	81.95	86.95	97.98	1.13
22	17	3613	RUTHERFORD			61.52	15.63					132.58	202.23	194.10	217.87	1.12
22	18	3551	RUTHERFORD					12.50	430.24			130.31	198.76	142.81	629.00	4.40
22	21	822	WILSON							38.30	10.46	21.63	45.02	59.93	55.47	0.93
22	22	7736	WILSON			73.75	18.74			38.30	10.46	203.52	423.68	315.58	452.88	1.44
22	23	5630	WILSON					12.50	430.24	38.30	10.46	148.12	308.34	198.92	749.03	3.77
22	24	7295	SUMNER					12.50	430.24			149.57	390.46	162.07	820.70	5.06
22	25	2015	SUMNER			47.55	12.08					41.31	107.85	88.86	119.93	1.35
22	26	1403	SUMNER							46.44	23.12	28.77	75.09	75.20	98.21	1.31
22	27	1165	SUMNER							46.44	23.12	23.89	62.36	70.32	85.48	1.22
22	28	1107	SUMNER							46.44	23.12	22.70	59.25	69.13	82.37	1.19
22	29	1059	SUMNER							46.44	23.12	21.71	56.68	68.15	79.80	1.17
22	30	690	SUMNER							46.44	23.12	14.15	36.93	60.58	60.05	0.99
22	31	718	SUMNER			47.55	12.08			46.44	23.12	14.72	38.43	108.70	73.63	0.68
22	32	100	SUMNER			47.55	12.08			46.44	23.12	2.05	5.35	96.03	40.55	0.42
23	10	230	RUTHERFORD							33.22	16.03	8.44	12.87	41.66	28.90	0.69
23	11	528	RUTHERFORD							33.22	16.03	19.38	29.55	52.60	45.58	0.87
23	12	552	RUTHERFORD							33.22	16.03	20.26	30.90	53.48	46.93	0.88
23	13	552	RUTHERFORD							33.22	16.03	20.26	30.90	53.48	46.93	0.88
23	14	551	RUTHERFORD							33.22	16.03	20.22	30.84	53.44	46.87	0.88
23	15	1464	RUTHERFORD							33.22	16.03	53.72	81.95	86.95	97.98	1.13
23	16	4518	RUTHERFORD			61.52	15.63					165.79	252.89	227.31	268.52	1.18
23	17	4056	RUTHERFORD									148.84	227.03	148.84	227.03	1.53
23	18	2897	RUTHERFORD					12.50	430.24			106.31	162.16	118.81	592.39	4.99
23	19	2131	RUTHERFORD							33.22	16.03	78.20	119.28	111.42	135.31	1.21
23	20	426	WILSON							38.30	10.46	11.21	23.33	49.51	33.79	0.68
23	21	1247	WILSON									32.81	68.29	32.81	68.29	2.08
23	22	3033	WILSON			73.75	18.74					79.79	166.11	153.55	184.85	1.20

Area Source Emission Data for the Nashville Study Area

GRID COORDINATES		1990 POULATION	COUNTY	AIRPORT EMISSIONS (kg/day)		RAILROAD EMISSIONS (kg/day)		RECREATIONAL BOAT EMISSIONS (kg/day)		RURAL BASED EMISSIONS (kg/day)		POPULATION BASED EMISSIONS (kg/day)		TOTAL EMISSIONS (kg/day)		
Horizontal	Vertical			NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	VOC/NOX Ratio
23	23	7625	WILSON							38.30	10.46	200.60	417.60	238.91	428.06	1.79
23	24	2792	WILSON					12.50	430.24	38.30	10.46	73.45	152.91	124.26	593.60	4.78
23	25	1266	SUMNER									25.96	67.76	25.96	67.76	2.61
23	26	588	SUMNER			47.55	12.08					12.06	31.47	59.60	43.55	0.73
23	27	653	SUMNER			47.55	12.08			46.44	23.12	13.39	34.95	107.37	70.15	0.65
23	28	974	SUMNER			47.55	12.08			46.44	23.12	19.97	52.13	113.95	87.33	0.77
23	29	1674	SUMNER	5.44	14.52	47.55	12.08			46.44	23.12	34.32	89.60	133.75	139.32	1.04
23	30	3449	SUMNER			47.55	12.08					70.71	184.61	118.26	196.69	1.66
23	31	644	SUMNER									13.20	34.47	13.20	34.47	2.61
23	32	129	SUMNER							46.44	23.12	2.64	6.90	49.08	30.02	0.61
24	10	507	RUTHERFORD							33.22	16.03	18.60	28.38	51.83	44.41	0.86
24	11	514	RUTHERFORD							33.22	16.03	18.86	28.77	52.09	44.80	0.86
24	12	532	RUTHERFORD							33.22	16.03	19.52	29.78	52.75	45.81	0.87
24	13	1176	RUTHERFORD							33.22	16.03	43.15	65.83	76.38	81.85	1.07
24	14	1323	RUTHERFORD							33.22	16.03	48.55	74.05	81.77	90.08	1.10
24	15	3083	RUTHERFORD			61.52	15.63					113.13	172.57	174.65	188.20	1.08
24	16	3180	RUTHERFORD									116.69	178.00	116.69	178.00	1.53
24	17	2292	RUTHERFORD							33.22	16.03	84.11	128.29	117.33	144.32	1.23
24	18	1353	RUTHERFORD					12.50	430.24	33.22	16.03	49.65	75.73	95.38	522.00	5.47
24	19	534	WILSON							38.30	10.46	14.05	29.25	52.35	39.70	0.76
24	20	569	WILSON							38.30	10.46	14.97	31.16	53.27	41.62	0.78
24	21	810	WILSON							38.30	10.46	21.31	44.36	59.61	54.82	0.92
24	22	1180	WILSON			73.75	18.74			38.30	10.46	31.04	64.63	143.10	93.83	0.66
24	23	889	WILSON					12.50	430.24	38.30	10.46	23.39	48.69	74.20	489.38	6.60
24	24	1360	WILSON					12.50	430.24	38.30	10.46	35.78	74.48	86.59	515.18	5.95
24	25	4995	SUMNER									102.41	267.35	102.41	267.35	2.61
24	26	9143	SUMNER									187.46	489.37	187.46	489.37	2.61
24	27	910	SUMNER							46.44	23.12	18.66	48.71	65.09	71.83	1.10
24	28	764	SUMNER							46.44	23.12	15.66	40.89	62.10	64.01	1.03
24	29	839	SUMNER							46.44	23.12	17.20	44.91	63.64	68.03	1.07
24	30	965	SUMNER							46.44	23.12	19.78	51.65	66.22	74.77	1.13
24	31	644	SUMNER							46.44	23.12	13.20	34.47	59.64	57.59	0.97
24	32	225	SUMNER							46.44	23.12	4.61	12.04	51.05	35.16	0.69
25	9	205	RUTHERFORD							33.22	16.03	7.52	11.47	40.75	27.50	0.68
25	10	512	RUTHERFORD							33.22	16.03	18.79	28.66	52.01	44.69	0.86
25	11	512	RUTHERFORD			61.52	15.63			33.22	16.03	18.79	28.66	113.53	60.32	0.53
25	12	544	RUTHERFORD			61.52	15.63			33.22	16.03	19.96	30.45	114.70	62.11	0.54
25	13	2039	RUTHERFORD			61.52	15.63					74.82	114.13	136.34	129.76	0.95
25	14	6896	RUTHERFORD			61.52	15.63					253.06	386.00	314.57	401.63	1.28
25	15	6388	RUTHERFORD	156.94	439.08							234.41	357.56	391.36	796.64	2.04
25	16	1597	RUTHERFORD							33.22	16.03	58.60	89.39	91.83	105.42	1.15
25	17	646	RUTHERFORD							33.22	16.03	23.71	36.16	56.93	52.19	0.92
25	18	501	WILSON							38.30	10.46	13.18	27.44	51.49	37.89	0.74
25	19	569	WILSON							38.30	10.46	14.97	31.16	53.27	41.62	0.78
25	20	576	WILSON							38.30	10.46	15.15	31.55	53.46	42.00	0.79
25	21	586	WILSON							38.30	10.46	15.42	32.09	53.72	42.55	0.79
25	22	889	WILSON							38.30	10.46	23.39	48.69	61.69	59.14	0.96
25	23	889	WILSON			73.75	18.74			38.30	10.46	23.39	48.69	135.45	77.89	0.58
25	24	864	WILSON					12.50	430.24	38.30	10.46	22.73	47.32	73.54	488.01	6.64
25	25	1627	SUMNER			47.55	12.08			46.44	23.12	33.36	87.08	127.34	122.29	0.96
25	26	5581	SUMNER									114.42	298.72	114.42	298.72	2.61
25	27	675	SUMNER			47.55	12.08					13.84	36.13	61.39	48.21	0.79
25	28	519	SUMNER							46.44	23.12	10.64	27.78	57.08	50.90	0.89

Area Source Emission Data for the Nashville Study Area

GRID COORDINATES		1990 POULATION	COUNTY	AIRPORT EMISSIONS (kg/day)		RAILROAD EMISSIONS (kg/day)		RECREATIONAL BOAT EMISSIONS (kg/day)		RURAL BASED EMISSIONS (kg/day)		POPULATION BASED EMISSIONS (kg/day)		TOTAL EMISSIONS (kg/day)		
Horizontal	Vertical			NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	VOC/NOX Ratio
25	29	719	SUMNER							46.44	23.12	14.74	38.48	61.18	61.60	1.01
25	30	938	SUMNER							46.44	23.12	19.23	50.21	65.67	73.33	1.12
25	31	653	SUMNER							46.44	23.12	13.39	34.95	59.82	58.07	0.97
25	32	228	SUMNER							46.44	23.12	4.67	12.20	51.11	35.32	0.69
26	10	409	RUTHERFORD							33.22	16.03	15.01	22.89	48.23	38.92	0.81
26	11	605	RUTHERFORD							33.22	16.03	22.20	33.86	55.42	49.89	0.90
26	12	705	RUTHERFORD							33.22	16.03	25.87	39.46	59.09	55.49	0.94
26	13	5699	RUTHERFORD									209.13	319.00	209.13	319.00	1.53
26	14	25227	RUTHERFORD									925.73	1412.05	925.73	1412.05	1.53
26	15	4437	RUTHERFORD							33.22	16.03	162.82	248.36	196.04	264.39	1.35
26	16	584	RUTHERFORD							33.22	16.03	21.43	32.69	54.65	48.72	0.89
26	17	479	RUTHERFORD							33.22	16.03	17.58	26.81	50.80	42.84	0.84
26	18	566	WILSON							38.30	10.46	14.89	31.00	53.20	41.45	0.78
26	19	568	WILSON							38.30	10.46	14.94	31.11	53.25	41.56	0.78
26	20	621	WILSON							38.30	10.46	16.34	34.01	54.64	44.47	0.81
26	21	633	WILSON							38.30	10.46	16.65	34.67	54.96	45.12	0.82
26	22	2978	WILSON	2.72	7.26	73.75	18.74					78.35	163.10	154.82	189.10	1.22
26	23	1297	WILSON							38.30	10.46	34.12	71.03	72.43	81.49	1.13
26	24	567	WILSON					12.50	430.24	38.30	10.46	14.92	31.05	65.72	471.74	7.18
26	25	557	SUMNER							46.44	23.12	11.42	29.81	57.86	52.93	0.91
26	26	505	SUMNER			47.55	12.08			46.44	23.12	10.35	27.03	104.34	62.23	0.60
26	27	505	SUMNER			47.55	12.08			46.44	23.12	10.35	27.03	104.34	62.23	0.60
26	28	505	SUMNER							46.44	23.12	10.35	27.03	56.79	50.15	0.88
26	29	619	SUMNER							46.44	23.12	12.69	33.13	59.13	56.25	0.95
26	30	696	SUMNER							46.44	23.12	14.27	37.25	60.71	60.37	0.99
26	31	696	SUMNER							46.44	23.12	14.27	37.25	60.71	60.37	0.99
26	32	104	SUMNER							46.44	23.12	2.13	5.57	48.57	28.69	0.59
27	10	442	RUTHERFORD							33.22	16.03	16.22	24.74	49.44	40.77	0.82
27	11	124	RUTHERFORD							33.22	16.03	4.55	6.94	37.77	22.97	0.61
27	12	736	RUTHERFORD			59.00	15.00			33.22	16.03	27.01	41.20	119.24	72.22	0.61
27	13	685	RUTHERFORD							33.22	16.03	25.14	38.34	58.36	54.37	0.93
27	14	1706	RUTHERFORD							33.22	16.03	62.60	95.49	95.83	111.52	1.16
27	15	1824	RUTHERFORD							33.22	16.03	66.93	102.10	100.16	118.13	1.18
27	16	456	RUTHERFORD							33.22	16.03	16.73	25.52	49.96	41.55	0.83
27	17	546	WILSON							38.30	10.46	14.36	29.90	52.67	40.36	0.77
27	18	569	WILSON							38.30	10.46	14.97	31.16	53.27	41.62	0.78
27	19	569	WILSON							38.30	10.46	14.97	31.16	53.27	41.62	0.78
27	20	640	WILSON							38.30	10.46	16.84	35.05	55.14	45.51	0.83
27	21	1139	WILSON							38.30	10.46	29.97	62.38	68.27	72.84	1.07
27	22	12136	WILSON									319.28	664.66	319.28	664.66	2.08
27	23	1856	WILSON							38.30	10.46	48.83	101.65	87.13	112.10	1.29
27	24	567	WILSON							38.30	10.46	14.92	31.05	53.22	41.51	0.78
27	25	471	WILSON							38.30	10.46	12.39	25.80	50.70	36.25	0.72
27	26	455	SUMNER							46.44	23.12	9.33	24.35	55.77	47.47	0.85
27	27	505	SUMNER			47.55	12.08			46.44	23.12	10.35	27.03	104.34	62.23	0.60
27	28	505	SUMNER							46.44	23.12	10.35	27.03	56.79	50.15	0.88
27	29	581	SUMNER			47.55	12.08			46.44	23.12	11.91	31.10	105.90	66.30	0.63
27	30	696	SUMNER									14.27	37.25	14.27	37.25	2.61
27	31	696	SUMNER			47.55	12.08			46.44	23.12	14.27	37.25	108.25	72.45	0.67
27	32	69	SUMNER			47.55	12.08			46.44	23.12	1.41	3.69	95.40	38.89	0.41
28	10	124	RUTHERFORD							33.22	16.03	4.55	6.94	37.77	22.97	0.61
28	12	621	RUTHERFORD							33.22	16.03	22.79	34.76	56.01	50.79	0.91
28	13	621	RUTHERFORD							33.22	16.03	22.79	34.76	56.01	50.79	0.91

Area Source Emission Data for the Nashville Study Area

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Horizontal	Vertical			NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	NOX	VOC	VOC/NOX Ratio
28	14	621	RUTHERFORD							33.22	16.03	22.79	34.76	56.01	50.79	0.91
28	15	481	RUTHERFORD							33.22	16.03	17.65	26.92	50.87	42.95	0.84
28	16	452	RUTHERFORD							33.22	16.03	16.59	25.30	49.81	41.33	0.83
28	17	437	WILSON							38.30	10.46	11.50	23.93	49.80	34.39	0.69
28	18	461	WILSON							38.30	10.46	12.13	25.25	50.43	35.70	0.71
28	19	461	WILSON							38.30	10.46	12.13	25.25	50.43	35.70	0.71
28	20	608	WILSON			73.75	18.74			38.30	10.46	16.00	33.30	128.06	62.50	0.49
28	21	645	WILSON							38.30	10.46	16.97	35.32	55.27	45.78	0.83
28	22	2523	WILSON							38.30	10.46	66.38	138.18	104.68	148.63	1.42
28	23	583	WILSON							38.30	10.46	15.34	31.93	53.64	42.38	0.79
28	24	466	WILSON							38.30	10.46	12.26	25.52	50.56	35.98	0.71
28	25	146	WILSON							38.30	10.46	3.84	8.00	42.15	18.45	0.44
28	27	76	SUMNER							46.44	23.12	1.56	4.07	47.99	27.19	0.57
28	28	404	SUMNER							46.44	23.12	8.28	21.62	54.72	44.74	0.82
28	29	633	SUMNER							46.44	23.12	12.98	33.88	59.41	57.00	0.96
28	30	591	SUMNER									12.12	31.63	12.12	31.63	2.61
28	31	695	SUMNER							46.44	23.12	14.25	37.20	60.69	60.32	0.99
28	32	35	SUMNER							46.44	23.12	0.72	1.87	47.15	24.99	0.53
29	12	248	RUTHERFORD							33.22	16.03	9.10	13.88	42.32	29.91	0.71
29	13	435	RUTHERFORD							33.22	16.03	15.96	24.35	49.19	40.38	0.82
29	14	377	RUTHERFORD							33.22	16.03	13.83	21.10	47.06	37.13	0.79
29	15	456	RUTHERFORD							33.22	16.03	16.73	25.52	49.96	41.55	0.83
29	16	452	RUTHERFORD							33.22	16.03	16.59	25.30	49.81	41.33	0.83
29	17	354	WILSON							38.30	10.46	9.31	19.39	47.62	29.84	0.63
29	18	354	WILSON							38.30	10.46	9.31	19.39	47.62	29.84	0.63
29	19	353	WILSON							38.30	10.46	9.29	19.33	47.59	29.79	0.63
29	20	412	WILSON			73.75	18.74			38.30	10.46	10.84	22.56	122.90	51.76	0.42
29	21	587	WILSON							38.30	10.46	15.44	32.15	53.75	42.60	0.79
29	22	585	WILSON							38.30	10.46	15.39	32.04	53.70	42.49	0.79
29	23	583	WILSON							38.30	10.46	15.34	31.93	53.64	42.38	0.79
29	24	524	WILSON							38.30	10.46	13.79	28.70	52.09	39.15	0.75
29	25	58	WILSON							38.30	10.46	1.53	3.18	39.83	13.63	0.34
29	31	696	SUMNER							46.44	23.12	14.27	37.25	60.71	60.37	0.99
30	15	137	RUTHERFORD							33.22	16.03	5.03	7.67	38.25	23.70	0.62
30	16	81	RUTHERFORD							33.22	16.03	2.97	4.53	36.20	20.56	0.57
30	17	354	WILSON							38.30	10.46	9.31	19.39	47.62	29.84	0.63
30	18	353	WILSON							38.30	10.46	9.29	19.33	47.59	29.79	0.63
30	19	353	WILSON							38.30	10.46	9.29	19.33	47.59	29.79	0.63
30	20	354	WILSON			73.75	18.74					9.31	19.39	83.07	38.13	0.46
30	21	533	WILSON							38.30	10.46	14.02	29.19	52.33	39.65	0.76
30	22	554	WILSON							38.30	10.46	14.57	30.34	52.88	40.80	0.77
30	23	466	WILSON							38.30	10.46	12.26	25.52	50.56	35.98	0.71
30	24	175	WILSON					12.50	430.24	38.30	10.46	4.60	9.58	55.41	450.28	8.13
31	17	354	WILSON							38.30	10.46	9.31	19.39	47.62	29.84	0.63
31	18	354	WILSON							38.30	10.46	9.31	19.39	47.62	29.84	0.63
31	19	283	WILSON							38.30	10.46	7.45	15.50	45.75	25.95	0.57
31	20	247	WILSON							38.30	10.46	6.50	13.53	44.80	23.98	0.54
31	21	178	WILSON							38.30	10.46	4.68	9.75	42.99	20.20	0.47
31	22	58	WILSON							38.30	10.46	1.53	3.18	39.83	13.63	0.34
32	17	177	WILSON							38.30	10.46	4.66	9.69	42.96	20.15	0.47
32	18	71	WILSON							38.30	10.46	1.87	3.89	40.17	14.34	0.36

Appendix A.2 Mobile Source Emissions for Affected Counties in the Nashville Study Area

Appendix A.2. Mobile Source Emissions for Affected Counties in the Nashville Study Area

GRID COORDINATE		EMISSIONS (kg/day)		
Horizontal	Vertical	VOC	NOx	VOC/NOx Ratios
4	17	0.7	0.2	3.5
4	19	17.6	10	1.76
4	20	1.9	0.6	3.17
4	21	6.2	2	3.10
4	22	1.4	0.4	3.50
5	17	112.2	151.2	0.74
5	18	16	5.2	3.08
5	19	97.5	53.7	1.82
5	20	35.8	12.5	2.86
5	21	34.2	11.7	2.92
5	22	17.4	5.9	2.95
5	23	21.3	7.1	3.00
5	24	5.6	1.7	3.29
5	25	1.1	0.4	2.75
6	17	333.6	514.8	0.65
6	18	40.5	13.9	2.91
6	19	9.8	3.2	3.06
6	20	92.7	32	2.90
6	21	38.9	13.2	2.95
6	22	41.2	14.1	2.92
6	23	41.1	14.2	2.89
6	24	25.4	8.7	2.92
6	25	0.8	0.3	2.67
7	17	264.2	403	0.66
7	18	133.7	144.2	0.93
7	19	728	348.7	2.09
7	20	64.7	22.4	2.89
7	21	30.1	10.1	2.98
7	22	20	6.8	2.94
7	23	15.8	5.2	3.04
7	24	26.4	8.9	2.97
8	17	97.3	47.7	2.04
8	18	810.8	462.3	1.75
8	19	290.2	144.3	2.01
8	20	87.1	30	2.90
8	21	186.8	86.9	2.15
8	22	105.7	36.6	2.89
8	23	82.6	28.5	2.90
8	24	34.9	11.9	2.93
9	17	24.7	8.1	3.05
9	18	450.6	562.6	0.80
9	19	74.8	36	2.08
9	20	91.4	44.4	2.06
9	21	26	9.9	2.63
9	22	42.3	14.4	2.94
9	23	19.2	6.5	2.95
9	24	20.1	6.8	2.96
9	25	4.5	1.3	3.46

Appendix A.2. Mobile Source Emissions for Affected Counties in the Nashville Study Area

GRID COORDINATE		EMISSIONS (kg/day)		
Horizontal	Vertical	VOC	NOx	VOC/NOx Ratios
10	14	2.2	0.7	3.14
10	15	4	1.3	3.08
10	16	60.6	28.2	2.15
10	17	27.6	9.1	3.03
10	18	477.6	596.6	0.80
10	19	6.6	2	3.30
10	20	261.6	128	2.04
10	21	36.6	12.6	2.90
10	22	12.3	4.1	3.00
10	23	55.2	25.7	2.15
10	24	23.3	7.9	2.95
10	25	17.1	5.6	3.05
10	26	23.2	11.1	2.09
11	13	0.4	0.1	4.00
11	14	14.3	4.7	3.04
11	15	25.2	8.3	3.04
11	16	381.9	170.4	2.24
11	17	65.6	28.7	2.29
11	18	487.5	655.1	0.74
11	19	12.1	3.7	3.27
11	20	117.3	64.8	1.81
11	21	48.1	16.7	2.88
11	22	13.2	4.4	3.00
11	23	20.1	9.3	2.16
11	24	53	25.3	2.09
11	25	86.8	40	2.17
11	26	37.2	17	2.19
11	27	4	1.3	3.08
12	13	2.8	0.9	3.11
12	14	20.1	6.8	2.96
12	15	30.2	10.4	2.90
12	16	31.5	13	2.42
12	17	426.6	190.4	2.24
12	18	98.7	140.5	0.70
12	19	555.8	777.7	0.71
12	20	123.6	68.2	1.81
12	21	16.6	5.7	2.91
12	22	20.8	7.1	2.93
12	23	89.4	41.6	2.15
12	24	100.2	48.6	2.06
12	25	26.5	8.9	2.98
12	26	50.6	17.3	2.92
12	27	256.5	353.1	0.73
12	28	83.7	122.6	0.68
12	29	7.2	3	2.40
12	30	17.1	8.2	2.09
12	31	18.1	8.6	2.10
13	13	22.2	7.5	2.96

Appendix A.2. Mobile Source Emissions for Affected Counties in the Nashville Study Area

GRID COORDINATE		EMISSIONS (kg/day)		
Horizontal	Vertical	VOC	NOx	VOC/NOx Ratios
13	14	41	14.1	2.91
13	15	57.5	19.9	2.89
13	16	23.3	8	2.91
13	17	215.8	96.3	2.24
13	18	6.4	3	2.13
13	19	439.1	652.1	0.67
13	20	117.8	59.5	1.98
13	21	28.7	9.9	2.90
13	22	58.4	20	2.92
13	23	241.5	114.7	2.11
13	24	196.9	95	2.07
13	25	112.3	50.3	2.23
13	26	265.4	257.2	1.03
13	27	339	497.1	0.68
13	28	23.8	8	2.98
13	29	26.3	8.7	3.02
13	30	72.3	35.7	2.03
13	31	16	4.8	3.33
14	12	3.5	1.2	2.92
14	13	10.7	3.2	3.34
14	14	8.1	2.5	3.24
14	15	84.8	29.3	2.89
14	16	23.4	8	2.93
14	17	86.2	43.2	2.00
14	21	25.1	8.7	2.89
14	22	159.7	72.5	2.20
14	23	77.5	34.9	2.22
14	24	80.9	27.8	2.91
14	25	62.6	40.6	1.54
14	26	376.6	547.6	0.69
14	27	51.5	22.8	2.26
14	28	21.3	7.1	3.00
14	29	19.5	6.5	3.00
14	30	65.3	34.8	1.88
14	31	17.9	5.5	3.25
14	32	1	0.3	3.33
15	12	123.5	61.7	2.00
15	13	15.1	4.8	3.15
15	14	47.3	16.2	2.92
15	15	85.4	29.6	2.89
15	16	175	79.8	2.19
15	17	44.3	15.1	2.93
15	18	97.6	33.6	2.90
15	24	36.9	12.6	2.93
15	25	569.5	689.9	0.83
15	26	21.4	7.1	3.01
15	27	94.1	41.1	2.29
15	28	79.6	36.8	2.16

Appendix A.2. Mobile Source Emissions for Affected Counties in the Nashville Study Area

GRID COORDINATE		EMISSIONS (kg/day)		
Horizontal	Vertical	VOC	NOx	VOC/NOx Ratios
15	29	54.9	24.7	2.22
15	30	39.8	20.1	1.98
15	31	31.1	10.5	2.96
16	11	11.2	17.6	0.64
16	12	563.7	343.6	1.64
16	13	235.8	140.9	1.67
16	14	298.8	157.7	1.89
16	15	556.8	273	2.04
16	16	687.6	333.4	2.06
16	17	351.9	168.1	2.09
16	18	260.3	132.9	1.96
16	26	511.9	287.1	1.78
16	27	145.1	71.1	2.04
16	28	585.3	287.4	2.04
16	29	442.4	212.8	2.08
16	30	55.3	19.1	2.90
16	31	21.3	7	3.04
16	32	0.3	0.1	3.00
17	11	12.4	6.4	1.94
17	12	63.5	30.3	2.10
17	13	390.8	511.7	0.76
17	14	511.6	554.7	0.92
17	15	1720.3	902.1	1.91
17	16	1358.6	801.2	1.70
17	17	584	307.4	1.90
17	18	17.4	6.3	2.76
17	26	34.5	11.7	2.95
17	27	132.7	71.7	1.85
17	28	202.7	97.1	2.09
17	29	118.1	54.3	2.17
17	30	91.9	47.6	1.93
17	31	55.8	30.9	1.81
17	32	5.4	2.9	1.86
18	11	2.1	0.6	3.50
18	12	37.4	12.8	2.92
18	13	41.3	14.1	2.93
18	14	53.2	18	2.96
18	15	235.7	109.6	2.15
18	16	88.1	41.7	2.11
18	17	979.9	606.7	1.62
18	26	200.4	100.1	2.00
18	27	154.6	75.7	2.04
18	28	79.2	27.4	2.89
18	29	46.2	17.6	2.63
18	30	49.2	23.3	2.11
18	31	11.7	3.8	3.08
18	32	3.2	1	3.20
19	11	10.8	3.6	3.00

Appendix A.2. Mobile Source Emissions for Affected Counties in the Nashville Study Area

GRID COORDINATE		EMISSIONS (kg/day)		
Horizontal	Vertical	VOC	NOx	VOC/NOx Ratios
19	13	35.8	12.2	2.93
19	14	134	61.1	2.19
19	15	79.1	35.8	2.21
19	16	36	12.3	2.93
19	17	63.7	28.5	2.24
19	27	414.8	603.5	0.69
19	28	97.5	33.7	2.89
19	29	54.6	24.3	2.25
19	30	19.6	7.5	2.61
19	31	31	12.2	2.54
19	32	3.3	1.3	2.54
20	10	46.6	16.3	2.86
20	11	57.8	28.5	2.03
20	12	107.8	57.8	1.87
20	13	127.3	67.3	1.89
20	14	173.4	92.7	1.87
20	15	68	39.1	1.74
20	16	115	58.1	1.98
20	25	338.7	117.6	2.88
20	26	193.1	97.7	1.98
20	27	2458.4	909.9	2.70
20	28	1101.2	651.4	1.69
20	29	583.3	339.7	1.72
20	30	37.3	12.5	2.98
20	31	28.9	9.7	2.98
20	32	2.4	0.7	3.43
21	11	78.5	34.2	2.30
21	12	20.3	7	2.90
21	13	23.3	7.8	2.99
21	14	84.9	42.1	2.02
21	15	18.4	5.9	3.12
21	16	53.6	18.7	2.87
21	23	88.2	41.7	2.12
21	24	874.7	432	2.02
21	25	267	125	2.14
21	26	221.1	76.8	2.88
21	27	16.4	5.5	2.98
21	28	133.5	63.7	2.10
21	29	305.1	339.7	0.90
21	30	602	794.4	0.76
21	31	105.8	128.5	0.82
21	32	3.8	1.1	3.45
22	10	0.4	0.1	4.00
22	12	38.9	13.4	2.90
22	13	16.3	5.5	2.96
22	14	115.8	53.3	2.17
22	15	98	33.9	2.89
22	16	679.9	854.2	0.80

Appendix A.2. Mobile Source Emissions for Affected Counties in the Nashville Study Area

GRID COORDINATE		EMISSIONS (kg/day)		
Horizontal	Vertical	VOC	NOx	VOC/NOx Ratios
22	17	1119.9	664	1.69
22	18	710	354.8	2.00
22	21	347	508.6	0.68
22	22	416.7	219.7	1.90
22	23	203.4	70.5	2.89
22	24	381.3	175.4	2.17
22	25	491.8	245	2.01
22	26	136.3	47.3	2.88
22	27	28.8	12.7	2.27
22	28	46.2	20.8	2.22
22	29	72.4	25.2	2.87
22	30	107.5	50.7	2.12
22	31	507.4	550.8	0.92
22	32	0.4	0.1	4.00
23	10	21.4	7.3	2.93
23	11	467.8	159	2.94
23	12	54.6	18.8	2.90
23	13	60.3	21	2.87
23	14	42.4	14.4	2.94
23	15	554.8	818.7	0.68
23	16	1465.1	768.9	1.91
23	17	866.1	421.2	2.06
23	18	67.1	31.3	2.14
23	19	46.5	16.1	2.89
23	20	248	86.2	2.88
23	21	1083.2	652.1	1.66
23	22	675.4	328.3	2.06
23	23	94.8	30.4	3.12
23	24	65.9	22.6	2.92
23	25	687.7	343.7	2.00
23	26	284.6	137.8	2.07
23	27	37.3	17.8	2.10
23	28	110.7	54.3	2.04
23	29	157.8	72.3	2.18
23	30	476.5	213.4	2.23
23	31	97.3	44.3	2.20
23	32	4.6	1.4	3.29
24	9	1.8	0.6	3.00
24	10	81.2	42.6	1.91
24	11	17.4	9.8	1.78
24	12	46	15.9	2.89
24	13	173.4	60.4	2.87
24	14	969.3	1114.8	0.87
24	15	1184.4	621.5	1.91
24	16	311.6	155.7	2.00
24	17	102.6	35.3	2.91
24	18	16	5.3	3.02
24	19	27.7	9.3	2.98

Appendix A.2. Mobile Source Emissions for Affected Counties in the Nashville Study Area

GRID COORDINATE		EMISSIONS (kg/day)		
Horizontal	Vertical	VOC	NOx	VOC/NOx Ratios
24	20	55.5	19.2	2.89
24	21	557.1	816.2	0.68
24	22	212.8	111.7	1.91
24	23	153.3	77.3	1.98
24	24	176.6	85.5	2.07
24	25	300.6	139.2	2.16
24	26	1139.3	538.5	2.12
24	27	219.1	100.8	2.17
24	28	83.4	32.8	2.54
24	29	44.6	14.9	2.99
24	30	79.7	35.6	2.24
24	31	24	7.9	3.04
24	32	4	1.2	3.33
25	9	4.7	1.5	3.13
25	10	102.4	41	2.50
25	11	213.8	115.2	1.86
25	12	342.3	293.5	1.17
25	13	1632.1	915.8	1.78
25	14	2591.4	1258.6	2.06
25	15	554.7	277.2	2.00
25	16	230.3	120.8	1.91
25	17	139.2	67.3	2.07
25	18	11.2	3.8	2.95
25	19	33.9	11.7	2.90
25	20	63.6	21.7	2.93
25	21	547.5	721.7	0.76
25	22	153	81.6	1.88
25	23	105.9	54.8	1.93
25	24	41.9	14.3	2.93
25	25	0.6	0.2	3.00
25	26	222.7	101.4	2.20
25	27	188.5	94.2	2.00
25	28	23.6	7.9	2.99
25	29	29.4	9.9	2.97
25	30	98.7	40.8	2.42
25	31	24.1	7.9	3.05
25	32	5.6	1.8	3.11
26	10	27.7	9.3	2.98
26	11	340.2	464.1	0.73
26	12	352.1	463.7	0.76
26	13	159.1	76.8	2.07
26	14	488.3	236	2.07
26	15	235.5	110.4	2.13
26	16	65.7	22.9	2.87
26	17	38.7	20.4	1.90
26	18	86.5	50.7	1.71
26	19	133.4	65.2	2.05
26	20	182.3	103.5	1.76

Appendix A.2. Mobile Source Emissions for Affected Counties in the Nashville Study Area

GRID COORDINATE		EMISSIONS (kg/day)		
Horizontal	Vertical	VOC	NOx	VOC/NOx Ratios
26	21	466.9	660.7	0.71
26	22	447	206.9	2.16
26	23	87.8	30	2.93
26	24	7.5	2.2	3.41
26	25	11.3	3.6	3.14
26	26	120.7	59.5	2.03
26	27	63.1	33.2	1.90
26	28	116.4	64.5	1.80
26	29	29.6	10	2.96
26	30	62.5	27.7	2.26
26	31	44.5	15	2.97
26	32	4.7	1.4	3.36
27	9	118.8	47.7	2.49
27	10	465	720.5	0.65
27	11	120	157.8	0.76
27	12	58.2	20	2.91
27	13	136.8	74.7	1.83
27	14	86.6	33.3	2.60
27	15	41.4	13.8	3.00
27	16	108.3	47.3	2.29
27	17	8.3	2.6	3.19
27	18	11.2	3.4	3.29
27	19	15.6	16.7	0.93
27	20	12.4	4.1	3.02
27	21	899.4	871.7	1.03
27	22	1206.5	612.4	1.97
27	23	354.9	198	1.79
27	24	27.5	9.3	2.96
27	25	3.5	1.2	2.92
27	26	80.4	39.8	2.02
27	27	13.3	4.7	2.83
27	28	101.9	55.7	1.83
27	29	98.7	52.6	1.88
27	30	102.2	46.4	2.20
27	31	53.4	18.3	2.92
27	32	4.9	1.6	3.06
28	9	121.3	180.3	0.67
28	11	8.8	2.9	3.03
28	12	24.7	8.4	2.94
28	13	143	83.2	1.72
28	14	27.5	9.4	2.93
28	15	14.6	4.6	3.17
28	16	60.8	28	2.17
28	18	19.1	6.4	2.98
28	19	27.1	9.3	2.91
28	20	116.6	58.3	2.00
28	21	132.4	75.6	1.75
28	22	373.7	503.6	0.74

Appendix A.2. Mobile Source Emissions for Affected Counties in the Nashville Study Area

GRID COORDINATE		EMISSIONS (kg/day)		
Horizontal	Vertical	VOC	NOx	VOC/NOx Ratios
28	23	48.4	16.7	2.90
28	24	15.2	5.1	2.98
28	25	1.3	0.4	3.25
28	27	0.2	0.1	2.00
28	28	2.6	0.8	3.25
28	29	47.5	27.1	1.75
28	30	187.2	90.3	2.07
28	31	62.1	33.3	1.86
28	32	12.8	6.7	1.91
29	12	4.6	1.4	3.29
29	13	54.3	31.7	1.71
29	14	12.5	4.2	2.98
29	15	11.6	3.8	3.05
29	16	47.4	22.5	2.11
29	17	9.1	3	3.03
29	18	6.7	2.1	3.19
29	19	85.9	47.8	1.80
29	20	66.5	35.2	1.89
29	21	163.7	231.3	0.71
29	22	223.5	297.6	0.75
29	23	55.4	28.3	1.96
29	24	24.6	8.3	2.96
29	25	1.6	0.6	2.67
30	17	2.4	0.8	3.00
30	18	23.2	7.9	2.94
30	19	105.7	51.6	2.05
30	20	47.4	21.5	2.20
30	21	348.1	521.7	0.67
30	22	17.4	6	2.90
30	23	27.4	15.1	1.81
30	24	0.3	0.1	3.00
31	17	40.3	19.2	2.10
31	18	4.5	1.4	3.21
31	19	79.6	34.6	2.30
31	20	1.8	0.5	3.60
31	21	55.6	87.2	0.64
32	17	10.7	5.3	2.02

Appendix A.3 Cummulative Point Source NOx and VOC Emissions for Ozone Season Day

Appendix A.3 Cummulative Point Source NOX and VOC Emmissions for Ozone Season Day

Grid Coordinate		Emmissions (kg/day)			Grid Coordinate		Emmissions (kg/day)		
Horizontal	Vertical	NOX	VOC	Ratio	Horizontal	Vertical	NOX	VOC	Ratio
-4	18	156,842	347	0.00	17	16	4	212	58.62
-3	18	75		0.00	17	21		9,576	
-3	19	181	11	0.06	17	28	124		0.00
-1	29		859		17	38	4		0.00
0	13	5,369	462	0.09	18	5	429	1,902	4.44
0	18	58		0.00	18	6		507	
1	18		68		18	19		424	
2	26	177,358	1,077	0.01	18	20		1,777	
5	31	0			18	21	2,327	3,583	1.54
6	14	3,408	147	0.04	18	22		171	
6	31	103	70	0.68	19	19		551	
6	36	41	3,491	84.18	19	20		1,100	
7	19	25	725	28.62	19	21		668	
7	28	205	232	1.13	19	24		778	
7	30		1,104		19	25		54	
8	9	6,098	163	0.03	19	27	55	25	0.45
8	17	22	1,598	71.44	20	19		42	
8	18		672		20	20		375	
8	19	0	210		20	23	3,459	4,277	1.24
8	20	134		0.00	20	24		28	
9	9	0		0.00	21	17	82	2,039	24.84
9	30	79	348	4.42	21	18		793	
10	7	840	20	0.02	21	19		88	
10	19		458		21	23		141	
10	31	37	273	7.33	21	24	32	309	9.74
12	23		264		22	14		94	
13	9	542	2,115	3.90	22	17	90	94	1.04
13	10	15		0.00	22	18	16	8	0.53
13	23	126	876	6.97	22	24	7	196	27.12
16	14	47	231	4.89	22	26	224	17	0.08
16	15	16	323	19.86	22	28	124		0.00
16	21	5,841	450	0.08	22	31	8,538	263	0.03
16	22		1,705		22	32	938	2	0.00
16	28	30	562	18.65	22	34		977	
16	29	31	407	12.98	23	15	6		0.00
16	36		5,287		23	16	782	5,393	6.90
16	37	73		0.00	23	17	7	534	74.43
17	15	47	2,455	52.19	23	18		0	
23	26		30		25	26	257	5,092	19.82
23	30	12	524	45.04	25	36	16		0.00
24	5	0	0		26	14	31	17	0.56

Appendix A.3 Cummulative Point Source NOX and VOC Emmissions
for Ozone Season Day

Grid Coordinate		Emmissions (kg/day)			Grid Coordinate		Emmissions (kg/day)		
Horizontal	Vertical	NOX	VOC	Ratio	Horizontal	Vertical	NOX	VOC	Ratio
24	6	70	1,669	23.92	26	20	3	17	6.81
24	15	64	1,992	31.17	27	16	0		
24	16		9		27	21		543	
24	18	100	5	0.05	27	22		276	
24	26	72	1,965	27.45	28	22	13	81	6.38
24	27		80		31	3	349	29	0.08
24	30	152	395	2.61	31	4	1,325	114	0.09
24	35	4	1,632	451.00	31	6	4	1,674	462.69
24	39	0			33	7	21	337	16.32
25	13	0	481	96803.34	33	21	15	1,073	71.14
25	14	50	2,257	45.23	35	16	29	438	15.12
25	15	39	0	0.01	35	17		30	
25	24	49,507	620	0.01	36	10	40	6	0.16

Appendix A.4 Davidson County Area Source and Mobile Source Emission Summary (kg/day)

Davidson County Area and Moble NOX and VOC Emission Summary
(kg/day)

Grid Coordinates		Area Sources			Mobile Sources			Grid Coordinates		Area Sources			Mobile Sources		
Horizontal	Vertical	VOC	NOX	Ratio	VOC	NOX	Ratio	Horizontal	Vertical	VOC	NOX	Ratio	VOC	NOX	Ratio
14	18	307.5	4.5	67.800	808.3	907.2	0.891	18	24	647.7	9.1	71.400	556.1	2,380.5	0.234
14	19	323.9	4.5	71.400	808.3	907.2	0.891	18	25	647.7	9.1	71.400	444.5	1,905.1	0.233
14	20	162.4	2.7	59.667	425.5	477.2	0.892	19	18	583.3	8.2	71.444	1,921.4	1,903.3	1.010
15	19	647.7	9.1	71.400	850.9	954.4	0.892	19	19	647.7	9.1	71.400	2,075.7	2,148.2	0.966
15	20	323.9	4.5	71.400	789.3	900.8	0.876	19	20	647.7	9.1	71.400	6,730.5	5,481.3	1.228
15	21	323.9	4.5	71.400	605.1	737.5	0.820	19	21	647.7	9.1	71.400	4,168.6	3,517.2	1.185
15	22	323.9	4.5	71.400	328.4	494.4	0.664	19	22	647.7	9.1	71.400	3,220.5	2,792.3	1.153
15	23	243.1	3.6	67.000	165.1	289.4	0.571	19	23	647.7	9.1	71.400	2,902.1	3,252.3	0.892
16	19	323.9	4.5	71.400	901.8	1,095.9	0.823	19	24	647.7	9.1	71.400	1,843.4	2,894.9	0.637
16	20	647.7	9.1	71.400	780.2	991.6	0.787	19	25	259.5	3.6	71.500	434.5	1,360.8	0.319
16	21	323.9	4.5	71.400	1,267.4	1,076.8	1.177	19	26	97.1	1.8	53.500	138.8	595.1	0.233
16	22	323.9	4.5	71.400	349.3	612.4	0.570	20	17	243.1	3.6	67.000	1,259.2	1,202.0	1.048
16	23	323.9	4.5	71.400	235.9	412.8	0.571	20	18	615.1	9.1	67.800	2,023.0	2,003.1	1.010
16	24	323.9	4.5	71.400	284.0	708.5	0.401	20	19	647.7	9.1	71.400	1,933.2	1,931.4	1.001
16	25	259.5	3.6	71.500	484.4	2,043.9	0.237	20	20	647.7	9.1	71.400	1,723.7	1,736.4	0.993
17	19	647.7	9.1	71.400	868.2	1,029.7	0.843	20	21	647.7	9.1	71.400	2,074.8	2,007.6	1.033
17	20	647.7	9.1	71.400	3,527.2	3,609.7	0.977	20	22	647.7	9.1	71.400	2,718.9	2,774.2	0.980
17	21	647.7	9.1	71.400	3,004.6	2,854.0	1.053	20	23	647.7	9.1	71.400	2,035.7	2,239.9	0.909
17	22	647.7	9.1	71.400	961.6	966.2	0.995	20	24	388.3	5.4	71.333	1,067.8	1,173.9	0.910
17	23	323.9	4.5	71.400	363.8	1,201.1	0.303	21	17	323.9	4.5	71.400	1,314.5	1,302.7	1.009
17	24	323.9	4.5	71.400	523.5	2,183.6	0.240	21	18	647.7	9.1	71.400	1,846.1	1,859.7	0.993
17	25	243.1	3.6	67.000	333.8	1,427.9	0.234	21	19	647.7	9.1	71.400	1,478.7	1,373.5	1.077
18	18	323.9	4.5	71.400	906.3	861.8	1.052	21	20	647.7	9.1	71.400	3,019.1	1,405.2	2.148
18	19	647.7	9.1	71.400	1,281.0	1,353.5	0.946	21	21	647.7	9.1	71.400	1,641.1	1,316.3	1.247
18	20	647.7	9.1	71.400	4,945.1	4,231.2	1.169	21	22	647.7	9.1	71.400	1,183.0	1,292.8	0.915
18	21	647.7	9.1	71.400	7,738.4	6,371.2	1.215	22	19	243.1	3.6	67.000	2,602.7	1,135.8	2.292
18	22	647.7	9.1	71.400	1,542.2	2,415.9	0.638	22	20	291.2	4.5	64.200	2,378.7	1,241.9	1.915
18	23	647.7	9.1	71.400	684.9	2,432.2	0.282								

VITA

Ingrid A. Walker was born in Oak Ridge, Tennessee, the second daughter of Dr. Charles Gurney and his wife Gerda Gurney. She graduated from Oak Ridge High School and Methodist Ladies College in Kew, Austrailia which she attended for one year during an a American Field Service student exchange program. Upon her return to this country, Ms. Walker attended Rhodes College in Memphis Tennessee where she was introduced to the subject of geology. She subsequently transferred to the University of Tennessee where she earned a BA in Geology. While at the University of Tennessee, she participated in an exchange program to study geology at the Freidrich Wilhelm Rheinische Universitat in Bonn, West Germany. Ms. Walker completed one year of graduate studies in hydrology at Ohio University in Athens, Ohio before leaving to gain practical working experience with Geraghty and Miller, Ground-water Consultants, Inc. in Oak Ridge, Tennessee. Ms. Walker married Jeffrey Walker of San Antonio, Texas, and finished her degree in Environmental Engineering at the University of Tennessee.