Vol. 3

United States
Environmental Protection
Agency

Office of Air Quality
Planning and Standards
Research Triangle Park NC 27711

EPA-450/4-81-026c c.2
September 1981

Air

EPA

Procedures for Emission Inventory Preparation

Volume III: Area Sources

NOTICE

The Procedures for Emission Inventory Preparation consists of these five volumes.

Volume I - Emission Inventory Fundamentals
Volume II - Point Sources
Volume III - Area Sources
Volume IV - Mobile Sources
Volume V - Bibliography

They are intended to present emission inventory procedures and techniques applicable in State and local air programs, and for contractors and other selected users. The object is to provide the best available and "state of the art" information. For some areas, however, the available source information and data either may allow more precise procedures and more accurate estimation of emissions or may not be amenable to the use of these procedures. Therefore, the user is asked to share his knowledge and experience by providing comments, successfully applied alternative methods or other emission inventory information useful to other users of these volumes. Please forward comments to the U.S. Environmental Protection Agency, Air Management Technology Branch, (MD-14), Research Triangle Park, NC 27711. Such responses will provide guidance for revisions and supplements to these volumes.

Other U.S. EPA emission inventory procedures publications:

Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds, Volume I, Second Edition, EPA-450/2-77-028, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1980.

Procedures for the Preparation of Emission Inventories of Volatile Organic Compounds, Volume II: Emission Inventory Requirements for Photochemical Air Quality Simulation Models, EPA-450/4-79-018, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1979.

EPA-450/4-81-026c

Procedures for Emission Inventory Preparation

Volume III: Area Sources

by

Monitoring and Data Analysis Division
Office of Air Quality Planning and Standards

U S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

September 1981

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Publication No. EPA-450/4-81-026c

Environmental Protection Agency

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1.0 INTRODUCTION

Methods and procedures for preparing and maintaining an inventory of emissions from area sources are presented in this document. The inventory of area source emissions, together with the inventories of point and mobile source emissions, provide a complete representation of pollutant emissions within a given geographical area. A complete and reliable emission inventory serves as the basic tool for the effective development of air quality management plans and programs.

This volume is the third of a multivolume series designed to assist control agency personnel in preparing an emission inventory of air pollutants and deals specifically with preparing the area source inventory. The other volumes of the series are: Volume I which presents the fundamentals of preparing an emission inventory and is intended to serve as a basic managment tool for planning and maintaining the inventory; Volumes II and IV which provide procedures for preparing inventories of point and mobile sources, respectively; and Volume V which is a bibliography of pertinent emission inventory literature.

1.1 DEFINITION OF AN AREA SOURCE

Stationary area sources represent a collection of many small, unidentified points of air pollution emissions within a specified geographical area, all emitting less than the minimum level prescribed for point sources.* Stationary area sources are defined in Reference 1 as (1) those activities for which collective source and emissions information is maintained in the emission inventory, and (2) sources not considered as point sources by the agency. Because these sources are too small and/or too numerous to be surveyed and characterized individually, all area source activities must be identified and emissions from these activities collectively estimated.

The county is usually the geographical area for which emissions from area sources are compiled, primarily because counties are the smallest areas for which data used for estimating emissions are readily available. In states where counties are not the principal political jurisdiction below the state level, county equivalents such as cities, census divisions, parishes, or towns

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*Federal regulations (40 CFR 51) have required state agencies to identify as point sources any facility which emits more than 90.7 metric tons (100 tons) per year of particulate matter, sulfur oxides, nitrogen oxides, hydrocarbons, or carbon monoxide. Any source that emits more than 4.54 metric tons (5 tons) per year of lead must also be identified as a point source. Annual emissions of point sources subject to the reporting provisions of Subpart 51.321 are identical to those above with the exception that for carbon monoxide only sources emitting 907 metric tons (1,000 tons) per year are subject to the annual report requirements. No submission of area source data is required by 40 CFR 51. An agency will usually determine the cut point between a point source and an area source based on its applicable regulations for source categories and pollutants. Generally, when considering hazardous pollutants, point sources would be identified as all known emitters.

can be used. Certain applications of the emission inventory will require more detailed spatial resolution than that provided at the county level. In such cases, county emissions must be apportioned to square grid zones of appropriate size using techniques that will be described in this volume.

1.2 AREA SOURCE CATEGORIES

The agency must establish area source category definitions by identifying activities possessing similar operating and emission characteristics that can be grouped together and handled collectively. Area sources can be grouped into four types of general activity categories:

Fuel combustion sources,

Solid waste incineration and open burning sources,

Fugitive dust sources, and

Volatile organic compound sources.

These major groupings can be further divided into subcategories to facilitate the accurate estimate of emissions based on the application of emission factors to activity level information.

Table 1-1 lists a number of area source categories within each of the four major activity areas listed above. These area source categories are listed for example only, and do not represent all potential area source categories. An agency will want to prepare its own working list based on sources within its jurisdiction and the level of detail desired. Some of the categories listed may not exist in a given area; others may be prohibited by regulation; and some categories may be missing from the examples in Table 1-1. Mobile sources have not been included in this table. Methods for developing an inventory of mobile source emissions are presented in Volume IV.

The area source categories that are used by EPA's National Air Data Branch (NADB) to compile and report area source data are also shown in Table 1-1. An agency may wish to use these categories because of the computer programs available from EPA to apportion and report area source emissions. The agency should obtain a description of available computer programs and reports by contacting the U.S. Environmental Protection Agency, National Air Data Branch, Mail Drop 14, Research Triangle Park, North Carolina 27711.

Many of the source categories in Table 1-1 will be handled strictly as area sources. However, some source categories will consist of both point and area sources. Care must be taken to avoid inclusion of emissions from point sources in the agency's area source emission data file.

The selection and structuring of area source categories are important aspects of the planning process that affect the resources required for compilation and maintenance of an emission inventory. Because an important use of the inventory is to study the effects of applying various control measures, the area source categories should be defined so that emission reduction from anticipated controls can be readily summarized from the data maintained in the area source files. For example, if the effect of vapor recovery of gasoline tank truck unloading emissions at service stations

TABLE 1-1 LISTING OF AREA SOURCE CATEGORIES

- Combustion by Fuel (all criteria pollutants)[a]
  - Residential
  - Commercial/Institutional
  - Industrial
  - Stationary Engines
- Solid Waste Incineration (all criteria pollutants) and Open Burning Sources (all criteria pollutants--primarily particulates, carbon monoxide, and volatile organic compounds)
  - Residential Incineration and Open Burning[a]
  - Commercial/Institutional Incineration and Open Burning[a]
  - Industrial Incineration and Open Burning[a]
  - Governmental Incineration and Open Burning
  - Prescribed Burning
    - Slash Burning[a]
    - Agricultural Burning[a]
    - Leaf Burning[a]
    - Frost Control (orchard heaters)[a]
  - Forest Wildfires[a]
  - Structural Fires[a]
- Fugitive Dust (particulates)
  - Unpaved Roads[a]
  - Unpaved Airstrips[a]
  - Paved Roads

(continued)

TABLE 1-1 (continued)

Construction Site Activity[a]
Land Tilling[a]
Tilled Land
Harvesting
Feed Lots
Pesticide Residues
Miscellaneous Wind Erosion[a]
Miscellaneous Sources
County Grain Elevators
Fertilizer Mixing
Feed Grain Preparation
Sawmills
Scrap Metal Salvage
Metal Melting and Casting
Aggregate Storage/Handling
Structural and Dimensional Stone Preparation
Woodworking Operations
Evaporative Loss of Volatile Organic Compounds (VOC)
Solvent Purchased (consumed)[a]
Gasoline Marketing[a]
Fuel Storage/Handling
Surface Coating
Print Shops

(continued)

TABLE 1-1 (continued)

Degreasing
Dry Cleaning
Cutback Asphalt
Natural Gas and Petroleum Field Operations
Pesticides
Household Products
Miscellaneous Sources
Fermented Beverages
Auto Body Shops
Plastics Processing

[a]Categories included in the NADB file of area source categories.[2]

(Stage I control) is to be evaluated, then these operations should be distinguished from vehicle fuel tank loading (Stage II control) emissions.[3] As another example, in order to estimate the effect of RACT on dry cleaning plants, those systems using perchloroethylene must be maintained in the emission inventory separate from those using petroleum (Stoddard) solvents because of the different control technologies that may be applied to each solvent system.

Nationwide emissions (1977) from major stationary area source categories, plus national totals of point and mobile source emissions, are shown in Table 1-2. This table was developed from information shown in Reference 4 and is presented here to provide some perspective to the agency in its allocation of resources for preparing inventories of area sources. Because the totals are nationwide totals, the agency should recognize that the relative contributions of the source categories shown may differ greatly at the local level. The miscellaneous category, solvent evaporation loss, accounts for about 70 percent of hydrocarbon (or VOC) emissions from stationary area sources; the agency should develop a subcategory breakdown of this category and maintain the subcategories in the inventory. Procedures for doing so are discussed in Chapter 5.

1.3 AREA SOURCE ACTIVITY LEVELS

Area source emissions are estimated by multiplying an emission factor by some known indicator of collective activity for each source category within the inventory area. An indicator is any parameter associated with the activity level of a source, such as production, employment, or population, that can be correlated with the air pollutant emissions from that source. For example, emissions of volatile organic compounds from dry cleaning facilities in an area correlate well with population; thus, it is possible to develop a per capita emission factor which can be used to estimate emissions. As another example, the total amount of gasoline handled by service stations in an area can be used to estimate collective evaporative losses from gasoline handling.

Several methods are available for estimating area source activity levels and emissions. Estimates can be derived by (1) treating area sources as point sources, (2) surveying local activity levels, (3) apportioning national or statewide activity totals to local inventory areas, (4) using per capita emission factors, or (5) by using emissions-per-employee factors. Each method has distinct advantages and disadvantages when used for developing area source emissions estimates. The merits of these methods must be evaluated on a source category-specific basis.

1.4 OVERVIEW OF THE AREA SOURCE INVENTORY

The importance of developing a reliable inventory of area source emissions cannot be overemphasized. The contribution of area source emissions within a given locality can be very significant. In many locations, area

TABLE 1-2 CONTRIBUTION OF AREA SOURCE CATEGORIES TO NATIONWIDE EMISSION TOTALS, 1977

Area source category	Pollutant, tons/year				
	Particulate	SO_x	NO_x	Hydrocarbons	Carbon monoxide
Fuel combustion[a]	61,953	1,558,650	1,033,618	76,700	606,975
Residential	119,676	321,898	385,689	52,953	522,439
Commercial/Institutional	72,411	457,459	313,418	12,644	44,385
Industrial	418,866	799,203	334,511	11,133	40,151
Solid Waste Disposal[b]	366,430	21,805	90,711	786,540	2,280,612
Residential	326,624	13,867	75,889	740,192	2,158,837
Commercial/Institutional	24,375	4,989	9,059	27,527	71,656
Industrial	15,431	2,949	3,713	18,821	50,119
Miscellaneous	38,660,170	4,381	139,382	8,508,278	5,035,395
Forest Wildfires	366,704	3,066	86,277	517,643	3,019,615
Structural Fires	57,793	65	6,728	43,155	234,817
Forest Managed Burning	147,307	1,250	34,659	207,971	1,231,178
Agricultural Burning	99,621	0	11,718	117,206	585,985
Solvent Evaporation Loss	0	0	0	6,485,596	0
Gasoline Station Evaporation Loss	0	0	0	1,136,707	0
Unpaved Roads	37,979,453	0	0	0	0
Unpaved Airstrips	9,292	0	0	0	0
All Stationary Area Sources	39,637,553	1,584,836	1,263,711	9,371,568	7,941,182
All Point Sources	7,692,760	29,036,487	11,057,129	5,593,039	8,607,254
Mobile Sources	6,094,037	856,434	9,415,763	12,772,620	97,166,875
Total All Sources	53,424,350	31,477,757	21,736,603	27,737,227	113,715,311

[a]External combustion only; no area source emissions from internal combustion sources are identified in Reference 4.

[b]Incineration and open burning.

Source: Reference 4.

source emissions are the principal cause of nonattainment of National Ambient Air Quality Standards (NAAQS), thus requiring significant and special attention by the agency if air quality standards are to be met and maintained.

The development of a complete and reliable inventory of area source emissions requires careful planning and documentation of the data and procedures used to compile the inventory. A flow chart depicting an overview of the activities involved in compiling emissions from area sources is provided in Figure 1-1. As a first step in the inventory development, the agency planners must identify the objectives of the inventory and the resolution necessary to achieve those objectives. The area to be inventoried, the inventory base year, and the extent of the spatial and temporal resolution required should be established. The status of the existing inventory should also be evaluated, because of its impact upon the effort needed to compile the new inventory. The existing inventory must be examined to determine whether or not all appropriate area sources have been included and to see if the emission data therein are representative of current conditions. Information concerning data sources, specific emission factors, and the use of activity indicators are generally applicable to inventory effort maintenance activities.

Planning is also necessary to define the area/point source cutoff level and identify the area source categories of significance within the area to be inventoried. These actions will enable the planner of the inventory to specify: data needs and sources of information; methods for apportioning activity levels and calculating and projecting emissions; and data handling, analysis, and reporting procedures. Further definition of manpower and time requirements will also be provided as a result of the above activities.

The actual conduct of an area source emission inventory is generally accomplished in five steps. These are:

1. Collection of data on national, state, and local area source activity levels;

2. Collection of demographic, economic, and other data to be used to apportion activity levels and emission factor parameters;

3. Apportionment of the areawide (typically a state) activity levels to area sources (typically a county) using the appropriate apportioning factors;

4. Calculation of estimated area source emissions by applying emission factors to the apportioned area source activity levels; and

5. Converting the source information and emissions to a formal formatted record and placing the formatted record into the file (manual or automatic).

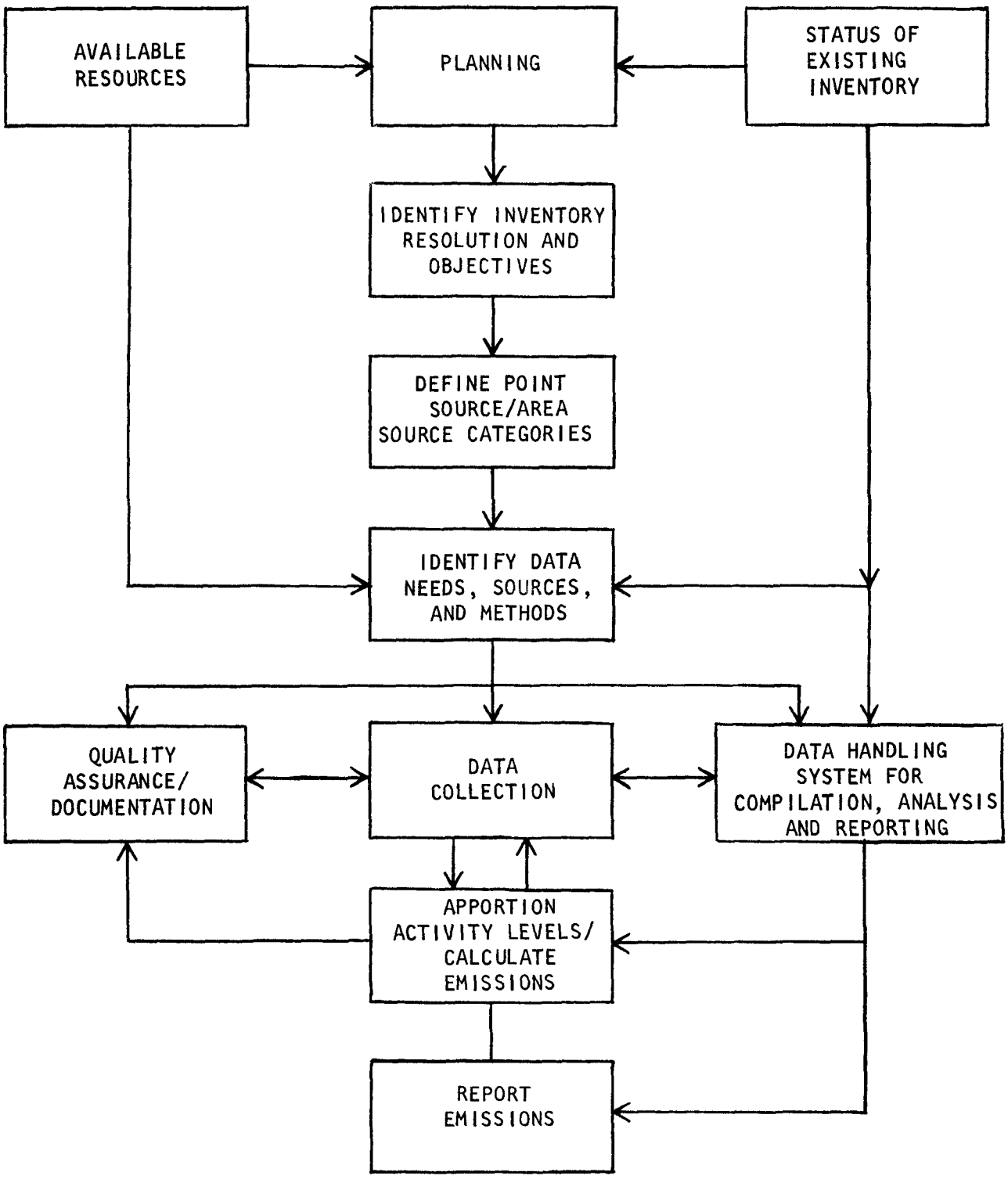

Figure 1-1. Activities for preparation of an inventory of area sources.

It is essential to document data and procedures used in compiling the inventory. Documentation will allow the agency to identify sources of raw data and data handling methods used to estimate emissions. Documented procedures must be followed when conducting quality assurance checks and when updating the inventory as new data are added. Quality assurance checks of the type described in Volume I, Chapter 2, of this series are necessary to ensure that all area source data have been correctly entered into the file.

Full documentation requires the preparation of in-house manuals of methods and procedures for use by agency personnel in developing and maintaining the emission inventory. Adhering to agency procedures, to a large degree, documents the inventory. The agency procedures should include standard forms for recording calculations and data transformations and conversions. Records of all communications that pertain to estimating emissions; data conversions and calculations, including assumptions, emission factors, and correlative parameters used; and copies of all reports should be maintained in identified and accessible files for review, verification, and update of the inventory.

A computerized inventory system is advantageous from a quality assurance standpoint. A computer can perform calculations and conduct error checks much faster than can be done manually. The computerized inventory is necessary if dispersion models are to be utilized. The added complexity involved in developing spatially and temporally resolved emission estimates will generally be too time consuming to complete manually. The agency should give consideration to using EPA's inventory data handling systems [National Emissions Data System (NEDS) or the Emission Inventory System/Area Source (EIS/AS)] or to developing a compatible system. Numerous summary routines and various computer modeling programs have been designed to operate on these EPA data bases.[3]

The EIS/AS, developed by EPA represents the current state-of-the-art in computerized systems. Figure 1-2 is an example load sheet used with the EIS/AS system to input area source emissions information by geographical area. Figure 1-3 is an EIS/AS load sheet used to enter emission data by source category. Once all data is entered into the inventory file, the file itself will serve as a permanent record of the area source emissions data. If the inventory is compiled manually, the emission data sheets will serve as a permanent record of the data.

The EIS/AS programs are modularized by function; i.e., each program performs a complete function. When several functions are needed for a given process (such as file maintenance), the separate programs that perform the component functions are performed in a single procedure. For example, program A maintains the emission factor file transactions, program B maintains the emission factor file, and program C prints the emission factor file and summary reports. Specific instructions for using the EIS/AS system can be found in "The Emission Inventory/Area Source Users Guide."[5]

AGENCY_____

EMISSIONS INVENTORY SYSTEM/AREA SOURCE (EIS/AS)
COMPREHENSIVE DATA HANDLING SYSTEM (CDHS)
DESCRIPTION TRANSACTIONS 1-6

BY _____
DATE _____
PAGE ___ OF _____

STATE	COUNTY	AQCR	SUBALLOC NBR
1	3	7	10 14

DATE YR	DATE DAY	AIR BASIN	SMSA	GEOGRAPHIC NAME	MAJOR ACTIVITY	ASSOC PLANT ID	SIP BASE YR	PROJ YR	% RUR	C/S	NBR	ACTION
15	17	20	23	27	47	67	71	73	75	77	78 79	80
											G 1	

POPULATION	AQCR NAME	C/S	NBR	ACTION
15	23	77	78 79	80
			G 2	

SUB TECH	SUBALLOCATION TECHNIQUE DESCRIPTION	DEF AREA CODE	SULFUR CONTENTS ANTH COAL	SULFUR CONTENTS BITM COAL	SULFUR CONTENTS DIST OIL	SULFUR CONTENTS RESID OIL	ASH CONTENTS ANTH COAL	ASH CONTENTS BITUM COAL	UTM COORDINATES ZONE 1	HORIZ 1	VERT 1	ZONE 2	HORIZ 2	VERT 2	C/S	NBR	ACTION
15	17	37	40	42	44	46	48	51	54	56	60	65	67	71	77	78 79	80
																G 3	

UTM COORDINATES ZONE 3	HORIZ 3	VERT 3	ZONE 4	HORIZ 4	VERT 4	ZONE 5	HORIZ 5	VERT 5	ZONE 6	HORIZ 6	VERT 6	SOURCE	LENGTH OF LINE, LINK, OR AREA	LLA UNITS CODE		C/S	NBR	ACTION
15	17	21	26	28	32	37	39	43	48	50	54	59	60	67		77	78 79	80
																	G 4	

SIP ESTIMATES TSP	SO2	NOX	HC	CO		C/S	NBR	ACTION
15	20	24	28	33 37		77	78 79	80
							G 5	

SUB CD	POP CD	LIGHT VEHICLE GAS	HEAVY VEHICLE GAS	HEAVY VEHICLE DIESEL	LIMITED ACCESS ROADS/MVM	RURAL ROADS MVM	SUBURBAN ROADS/MVM	URBAN ROADS MVM		C/S	NBR	ACTION
15	16	17	24	30	36	42	48	54 66		77	78 79	80
											G 6	

Figure 1-2. Example area source load sheet - description transactions.

AGENCY _____

EMISSIONS INVENTORY SYSTEM/AREA SOURCE (EIS/AS)
COMPREHENSIVE DATA HANDLING SYSTEM (CDHS)
DESCRIPTION TRANSACTION 7

BY _____
DATE _____
PAGE ___ OF _____

STATE	COUNTY	AQCR	SUBALLOC NBR
1	3	7	10 14

POLLUTANT ID	POLLUTANT NAME	ATTN	AQMA NUMBER	POLLUTANT ID	POLLUTANT NAME	ATTN	AQMA NUMBER		C/S		NBR	ACTION
15	20	35	36 41	43	48	63	64 69		77	78	79	80
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	
										G	7	

Figure 1-2 (continued)

AGENCY _____

EMISSIONS INVENTORY SYSTEM/AREA SOURCE (EIS/AS)
COMPREHENSIVE DATA HANDLING SYSTEM (CDHS)
CATEGORY TRANSACTIONS

BY _____
DATE _____
PAGE ___ OF _____

FE	COUNTY	AQCR	SUBALLOC NBR	CATEG NBR	DISAG NBR
1	3	7	10	15	18

CATEGORY DESCRIPTION	YEAR	PROCESS RATE	CATEGORY ADJUSTMENT	UNIT CODE	UNITS CODE DESCRIPTION	C/S	A/D	M/N	ACTION
20	46	47	56	63	65	77	78	79	80

UNIFM	MONTHLY THRUPUT PERCENTAGE JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	WRS PER DAY	DAYS	WKS PER YR	THRUPUT RATIO	MAXIMUM HOURLY THRUPUT	CONF	NITRO CONT	SULF CONT	ASH CONT	HEAT CONTENT	C/S	A/D	M/N	ACTION
20	21	23	25	27	29	31	33	35	37	39	41	43	45	47	48	50	54	64	65	68	70	73	77	78	79	80

UNIFM	HOURLY THRUPUT PERCENTAGE 0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	C/S	A/D	M/N	ACTION
20	21	23	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61	63	65	67	77	78	79	80

NEDS A7 COMMENT	SOURCE	SOURCE OF INFORMATION NARRATIVE	C/S	A/D	M/N	ACTION
20	54	55 74	77	78	79	80

POLLUTANT ID	EMISSION FACTOR	CONF	ORG	SRC	POLLUTANT SPECIFIC DATA	NEDS A7 EMISSION	POLLUTANT NAME	C/S	A/D	M/N	ACTION
20	25	35	36	37	38	48	55 69	77	78	79	80

Figure 1-3. Example area source load sheet - category transactions.

The conduct of the activities depicted in Figure 1-1 is an iterative one. The output of the data handling system, whether manual or computerized, must be examined by the agency to ensure that the outputs are sound and consistent with state and local conditions. Serious discrepancies or questionable outputs will require the agency to re-examine the data sources and/or methods of apportioning and calculating emissions.

In general, emission inventory methods that use locally available data (such as survey questionnaires or data from local distributors) result in the most accurate emission estimates. The five-step procedure previously outlined is usually required because adequate source data are often not available for counties or smaller geographic units. Thus, for many source categories, areawide totals, often state totals, must be used to apportion totals to counties. Once county totals are obtained, similar procedures can then be used to apportion these totals to grids, if desired.

The use of statistical data (e.g., population) as apportioning factors presumes a relationship between the available data and the desired area source pollutant. For some area source categories, reasonably accurate predictions of area source quantities can be obtained using this method. For other area source categories, it is difficult to obtain any literature data that can be correlated with emissions. New data must be developed or existing data modified to provide a better indicator of area source activity levels. In addition, existing emission factors for many area source categories are based on limited and often site-specific data; e.g., silt content of soils and roadways. Thus, the development of an accurate inventory of area sources will require the use of many sources of information, and the application of sound judgment by local agency personnel in their selection of apportioning methods and emission factors.

1.5 PURPOSE AND ORGANIZATION OF THE VOLUME

The purpose of this volume is to assist the user in identifying area source categories and relevant sources of data that can be used to estimate emissions from these categories. Methods for the development of the inventory of area sources are provided in Chapters 2, 3, 4, and 5, respectively, for the following major source categories:

Combustion Sources,

Solid Waste Incineration and Open Burning Sources,

Fugitive Dust Sources, and

Volatile Organic Compound (VOC) Sources.

In each chapter, the data requirements for establishing emission levels are presented along with the available data sources. Validation methods and cross checks which are available to assess data accuracy and to establish the reliability of the inventory are also delineated. Chapter 6 deals with the

presentation of the inventory of area source emissions. Volume I of this series and References such as Nos. 3, 6, and 7 should be consulted for further information concerning planning, preparing and documenting the emission inventory.

References for Chapter 1.0

1. Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds, Volume I, First Edition, EPA-450/2-77-028, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1977.

2. AEROS Manual Series, Volume I, AEROS Overview, EPA 450/2-76-001, U.S. Environmental Protection Agency, Research Triangle Park, NC, February 1976.

3. Procedures for the Preparation of Emission Inventories for Volatile Organic Compounds, Volume I, Second Edition, EPA-450/2-77-028, U.S. Environmental Protection Agency, Research Triangle Park, NC, September 1980.

4. 1977 National Emissions Report, EPA-450/1-80-005, U.S. Environmental Protection Agency, Research Triangle Park, NC, March 1980.

5. The Emission Inventory System/Area Source User's Guide, EPA-450/4-80-009, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1980.

6. Development of the Area Source Emission Inventory for the 1982 Ozone State Implementation Plan for the Chicago Metropolitan Region of Illinois and Indiana, Contract No. 81C-279, Northeastern Illinois Planning Commission, Chicago, IL, 1981.

7. Final Emission Inventory Requirements for 1982 Ozone State Implementation Plans, EPA 450/4-80-016, U.S. Environmental Protection Agency, Research Triangle Park, NC, December 1980.

2.0 COMBUSTION SOURCES

Stationary fuel combustion sources that emit less than the minimum level of pollutants prescribed for point sources are included in the inventory of emissions from area sources. External combustion sources used for space heating and other functions, and internal combustion turbines and reciprocating engines used for the pumping and compression of fluids and electricity generation, are included in this major area source category. An emission rate of less than 100 tons per year of any criteria pollutant is characteristic of uncontrolled combustion systems which are smaller than the following thermal input capacities.[1]

Bituminous Coal	4×10^6 Btu/hr
Residual Oil	13×10^6 Btu/hr
Distillate Oil	55×10^6 Btu/hr
Natural Gas	110×10^6 Btu/hr
Internal Combustion	10×10^6 Btu/hr

These maximum area source capacities vary with type of combustion unit, fuel, ash and sulfur content, operating hours and load. The value for internal combustion units is subject to the greatest uncertainty due to the pronounced effect of engine type (i.e., turbine or reciprocating engine), operating parameters, and fuel on emissions of nitrogen oxides, carbon monoxide and hydrocarbons.[2] Lead emissions from area combustion sources are not significant, amounting to about 100 tons per year.[1] This is less than 1 percent of estimated lead emissions from all stationary sources.

2.1 EXTERNAL COMBUSTION SOURCES

All criteria pollutants are emitted during fuel combustion. Each source may emit only small quantities of pollutants but, because of their great number, their collective contribution can be significant. Therefore, it is necessary to obtain an accurate estimate of this collective contribution to total emissions.

2.1.1 EXTERNAL COMBUSTION SOURCE CATEGORIES

External combustion sources are grouped by fuel into the following three categories, representing the use of the fuel burning equipment.[3]

Residential--Structures containing fewer than 20 dwelling units.

Commercial/Institutional--Establishments, not classified as point sources, engaging in retail and wholesale trade, schools, hospitals, government facilities and apartment complexes with 20 or more dwelling

units. The commercial/institutional sector covers all establishments defined by Standard Industrial Classification (SIC)[4] groups 50 through 99.

Industrial--All manufacturing establishments not classified as point sources. Included are those establishments defined by SIC groups 20 through 39.

Collectively, these three use categories account for the predominance of nonpoint combustion source emissions.[3] The breakdown of fuel use into three categories provides the basis for apportioning emissions to county and subcounty levels and is useful for the formulation of strategies to achieve air quality goals.

2.1.2 FUEL USE

Area source emissions from the three use categories are reported for each major fuel. The subdivision by fuel, in addition to providing valuable information to the agency, is needed to relate activity levels to AP-42 emission factors.[5] The seven major fuels that are used by area combustion sources are:

Anthracite Coal--Anthracite coal is mined almost exclusively in Pennsylvania. It is used mainly by residential sources in states that are within economical shipping distance of Pennsylvania.

Bituminous Coal--Bituminous coal, including sub-bituminous and lignite coals, is available in most areas of the country. It is used primarily by the commercial/institutional and industrial source categories.

Distillate Oil--Fuel oil grades 1, 2 and 4 and diesel fuel and kerosene are considered distillate type oils. Residential and commercial/institutional sources are the largest consumers.

Residual Oil--Residual oils include fuel oil grades 5 and 6. These fuel grades are not used by residential sources.

Natural Gas--Natural gas is used by all three source categories.

Liquified Petroleum Gas (LPG)--LPG may be used in some areas by all categories.

Wood--Wood is primarily a residential fuel, although it may be used by all source categories.

In addition to the above major fuels, some coke and process gas may be used by area sources. Although area source usage of these fuels is low, activity levels should be determined by the agency.

2.1.3 DATA REQUIREMENTS AND SOURCES

Emissions from external combustion area sources must be determined at the spatial and temporal levels of resolution required by the agency. Fuel used in the inventory area by the source category, minus the fuel used by point sources within the inventory area, is multiplied by the appropriate emission factors in AP-42 to obtain criteria pollutant emissions before control.

2.1.3.1 Activity Levels

Fuel use data should be obtained from local sources of information if possible. Many state and local environmental agencies charged with compiling inventories of area sources use data from local fuel dealers, agency permit registrations, and other state and local agencies involved in such functions as energy policy, commerce, taxation and land use planning. Local natural gas suppliers are generally reliable sources of usable information. Data obtained from coal, wood and oil distributors are generally less reliable; distributors are much more numerous and care must be exercised to insure that all dealers are included. Activity levels derived from dealers must also take into account shipments into and out of the area.

If local data sources are inadequate then literature sources must be used. Table 2-1 lists the literature sources which can be used to determine the factors necessary for estimating activity levels. Department of Energy (DOE) reports provide accurate state fuel use totals for oil, natural gas, and LPG. Consumption of bituminous coal and lignite is reported for most states. Information regarding anthracite shipments to some states is also available from DOE and can be used to estimate state anthracite fuel use.

The DOE reporting techniques vary for each fuel, and adjustments of the reported values are required to allocate state fuel totals to the residential, commercial/institutional, and industrial categories. Accepted techniques for assigning fuel use to categories are those used by the U.S. EPA in the National Emissions Data System (NEDS). Most states that do not rely on local information sources use these techniques, which are based on correlative relationships among demographic, socioeconomic, and local climatological data and fuel usage. Department of Commerce Publications are the primary sources of correlative information. Much of the data are updated annually. Other data must be updated by the agency using state or local sources of information or information from fuel trade associations.

2.1.3.2 Spatial Resolution

Apportionment of state totals to county or subcounty levels by NADB relies on techniques and correlative relationships which are similar to those used for allocating fuel use to source categories. Combustion source data compiled at the county level are generally sufficient for most applications of this inventory. However, certain inventory applications; e.g., dispersion modeling, will require finer spatial resolution in which counties must be subdivided into grid squares. Instructions for apportioning fuel use to grid squares are given in Section 2.1.6.

TABLE 2-1. STATISTICAL DATA SOURCES FOR ESTIMATING FUEL USE

Information/source	Reference No.	Comments
Fuel Use by State		
Energy Data Reports (Annual), DOE/EIA		
Sales of Fuel Oil and Kerosene	6	Reporting classifications are different for all fuels, thus requiring use of slightly different methods to allocate fuel to the three source categories.
Natural Gas Production and Consumption	7	
Sales of Liquified Petroleum Gas and Ethane	8	
Coal-Bituminous and Lignite	9	
Coal-Pennsylvania Anthracite	10	
Bureau of Census: Statistical Abstract of the United States	11	Fuel use by category; employment by SIC; annual publication.
National Emissions Data System, Fuel Use Report	12	Fuel use by source category; contact reference for updates.
Residential Fuel Use		
1970 Census of Housing, Advanced Report	13	Housing characteristics and fuel use by function (e.g., heating, hot water and cooking); data must be updated.
1970 Census of Housing, Detailed Housing Characteristics	14	
Local Climatological Data, Annual Summary with Comparative Data	15	Degree-day data.
Gas Facts, American Gas Association	16	Update of housing/fuel characteristics--available annually.
Gas House Heating Survey, American Gas Association	17	
Fuel Oil and Oil Heat, Industry Publications	18	Update of fuel use--available annually in October.
Commercial/Institutional and Industrial Fuel Use		
Standard Industrial Classification Manual, 1972	4	Identification of SIC groups.
County Business Patterns (Annual)	19	Employment by SIC

2.1.3.3 Temporal Resolution

A comprehensive inventory of area combustion sources is designed to estimate emissions for any time period. Most inventories are planned to provide annual data. In preparing more detailed temporal inventories, it is generally assumed that the temporal distribution of residential, commercial/institutional, and industrial fuel use (for area source space heating) is identical. The agency should verify this assumption by obtaining hourly natural gas flow data for various customer classifications from local gas dealers. Natural gas consumption data adjusted for nonheating uses can be correlated with local temperature data to show the relationship between outdoor temperature and fuel use for space heating. This relationship can be applied to all fuel types to estimate seasonal consumption for space heating. Monthly billing records, obtained from local fuel dealers, will also provide an estimate of monthly and seasonal fuel consumption patterns.

2.1.3.4 Emission Factors

Criteria pollutant emission factors can be found in AP-42 and its supplements for all fuels. The AP-42 emission factor parameters (sulfur content of fuel oil and ash and sulfur content of coal) needed for calculation of particulate and sulfur oxide emissions are usually available at the state agency or from local data sources. Information can be obtained from such sources as permit registrations, local fuel dealers or, if necessary, DOE data for states. Local point source information or agency regulations can also be used. It is usually acceptable to assume that the sulfur and ash contents of a fuel used within a county are similar for the residential, commercial/institutional, and industrial source categories.

Lead emissions from area source combustion categories will be negligible for normal fuels.[1,20] The use of used automotive lubricating oils for space heating, however, may result in locally significant lead emissions due to the generally high lead content of such oils.[20]

For coal-fired sources some care must be exercised by the agency in selecting furnace types and their associated AP-42 emission factors for use in calculating emissions. Pulverized units, cyclones and spreader stokers, because of their size, would almost invariably be reported as point sources. Most residential units would be hand-fired overfeed stokers. Under-fired stokers account for over 80 percent of commercial/institutional units of less than 10×10^6 Btu/hr thermal input. However, some overfeed and other stoker types could be used. The particulate emission factors for bituminous underfeed and overfeed stokers are 2A (A = ash content in percent) and 5A, respectively. Significant error in the combustion source particulate emission estimate could result in locations burning large amounts of coal, if overfeed stokers predominate, and the emission factor for underfeed stokers is used.

2.1.4 DETERMINATION OF STATE FUEL USE BY SOURCE CATEGORY

As noted above, accurate state fuel consumption figures are available in most instances from DOE publications. These state totals include fuel used by point sources. Nonpoint or area source fuel consumption must be allocated to the three area source categories and, subsequently, to the geographical area of the inventory. The following is a description of the procedures used by the NADB to allocate DOE state fuel use data to the three source categories. The procedure is diagrammed in Figure 2-1 for fuel oil.

2.1.4.1 Residential

Residential fuel use is calculated for each fuel type using the following empirical equations. The correlative relationships and their constants shown below were developed in the early 1970's and, because of present day emphasis on fuel conservation, may tend to overestimate residential fuel use.

Distillate Oil (gal/yr)--

$$F_{DO} = \left(\frac{0.01288D + 30.41R - 79.54}{0.14}\right) S_{DO} + 250\ W_{DO} \qquad (2\text{-}1)$$

Residual Oil (gal/yr)--

$$F_{RO} = 0 \qquad (2\text{-}2)$$

Natural Gas (therms*/yr)--

$$F_{NG} = 47.5 \times A \times D^{0.367} \times \left(\frac{S_{NG}}{W_{NG}}\right)^{0.588} \times R^{0.125} \qquad (2\text{-}3)$$

LPG (therms/yr)--

$$F_{LPG} = (376 + 0.209D)\ S_{LPG} + H_C + H_W \qquad (2\text{-}4)$$

Coal (tons/yr)--

$$F_C = 0.003874\ e^{\left(7.6414 - \frac{1000}{D}\right)} \qquad (2\text{-}5)$$

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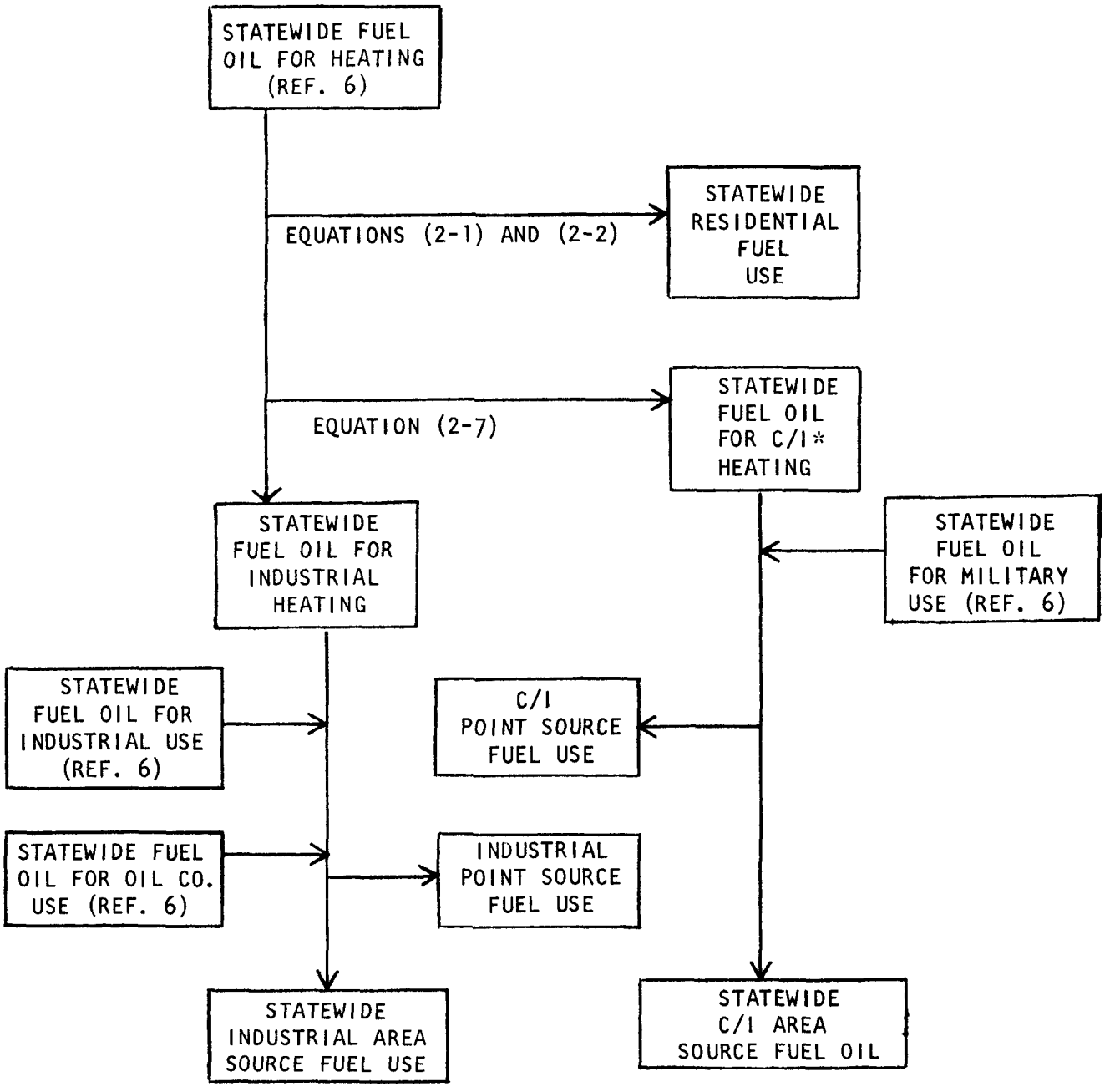
*1 therm = 10^5 Btu.



*C/I = COMMERCIAL/INSTITUTIONAL

Figure 2-1. Procedure for determination of state area source fuel oil use by source category.

Wood (tons/yr)--

$$F_W = 0.0017 \times S_W \times D \times \frac{R}{5} \qquad (2\text{-}6)$$

where F = fuel use, in units shown;

A = total number of natural gas customers, obtained from American Gas Association[17] or local suppliers;

D = degree-days, obtained from Reference 15;*

H_C = therms of LPG used for cooking, regional average therms obtained from the American Gas Association[16] or NADB[21];

H_W = therms of LPG used for water heating, regional average therms obtained from the American Gas Association[16] or NADB[21];

R = number of rooms, obtained from Reference 14;

S = number of housing units using fuel for space heating, obtained from Reference 14;

W_{DO} = number of housing units using fuel for water heating; and

W_{NG} = the larger of the number of housing units using natural gas for water heating or cooking, obtained from Reference 14 and 17.

Updating of the Census of Housing data base is necessary to determine S, R, W, and A for the year of the inventory. Information concerning housing characteristics, including the net increase in combustion units, can be obtained from local sources or trade associations and journals.[16-18] A sharp rise in the use of coal and wood units for space heating in some locations should be monitored closely by agencies in those locations.

It will be necessary in many areas to determine residential consumption of both anthracite and bituminous coals. To do so, compare the calculated residential consumption of coal to anthracite deliveries minus all anthracite point source use. If the calculated consumption is greater than the available area source anthracite the difference is assigned to bituminous. If calculated consumption is less than the available anthracite the remaining anthracite is assigned to the commercial/institutional and industrial sectors.

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*Each degree of declination below 65°F in mean outdoor temperature, averaged over a 24-hour period, is a degree-day.

2.1.4.2 Commercial/Institutional

The procedure for determining state area source fuel consumption by the commercial/institutional source category is to (1) obtain fuel use data from DOE publications, (2) subtract calculated residential fuel use from DOE total, (3) allocate a fraction of the remaining fuel to the commercial/institutional category, and (4) subtract commercial/institutional point source fuel use. Because of DOE reporting methods, allocation procedures will differ depending upon the fuel used. The procedure for fuel oil is shown in Figure 2-1. Specific step-by-step procedures for each major fuel are presented below.

Fuel Oil--

1. Calculate residential fuel oil consumption for state using Equations (2-1) and (2-2).

2. Subtract residential fuel oil from fuel used for heating in Reference 6 to obtain commercial/institutional and industrial fuel total.

3. Allocate remaining fuel oil to the category using the following expression:

$$F_{C/I} = \left(F_{C/I} + F_{Ind}\right) \frac{\text{State employment in SIC groups 50-99}}{\text{State employment in SIC groups 20-39 and 50-99}} \qquad (2\text{-}7)$$

4. Subtract point source commercial/institutional fuel oil.

Natural Gas--

1. Allocate commercial/institutional and industrial state fuel use total provided in Reference 7 to their respective categories using Equation (2-7).

2. Subtract point source commercial/institutional natural gas fuel use from allocated commercial/institutional fuel above to obtain state area source fuel use.

LPG--

1. Subtract calculated residential fuel use from residential and commercial/institutional fuel use total provided in Reference 8 to obtain state commercial/institutional fuel use.

2. Subtract point source commercial/institutional LPG fuel use to obtain state area source fuel use.

Bituminous Coal--

1. Assign bituminous coal from "retail sales category" in Reference 9 to the residential category if needed to make up the difference between calculated coal consumption (Equation 2-5) and available area source anthracite.

2. The remaining bituminous fuel used for "retail sales" is assigned to the commercial/institutional category.

3. Subtract point source commercial/institutional fuel use to obtain state area source bituminous coal.

Anthracite Coal--

1. Allocate available anthracite (total anthracite minus residential area source and point source anthracite used by utilities) to the commercial/institutional category using Equation (2-7).

2. Subtract point source commercial/institutional fuel use from result above to obtain area source fuel use.

Wood--

Wood is not generally used by the commercial/institutional category unless there is evidence at the local agency level to indicate otherwise.

2.1.4.3 Industrial

State area source industrial fuel use is determined as follows for the major fuels.

Fuel Oil--

Industrial fuel used for heating (total fuel oil used for heating minus the fuel used for residential and commercial/institutional heating as determined above), plus fuel oil for industrial and oil company use,* from Reference 6, represents the total industrial fuel oil use within the state (see Figure 2-1). Subtract point source fuel use to obtain state area source industrial fuel consumption.

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*The agency should note that oil companies burn a substantial quantity of fuel oil in oil tank heaters to control residual oil viscosity. Whether or not these sources will be included in the area source inventory depends on the source size and the point/area source size cut-off set by the agency.

Natural Gas--

State industrial area source natural gas use is obtained by subtraction of the sum of the total commercial/institutional gas use and industrial point source gas use from the combined commercial/institutional and industrial total given in Reference 7.

LPG--

State industrial area source LPG use is the industrial use total given in Reference 8 minus LPG used by industrial point sources.

Bituminous Coal--

State industrial fuel use, plus coal used by coke plants, are provided in Reference 9. Point source use should be subtracted from the total to obtain the state area source total for the industrial category.

Anthracite Coal--

Anthracite coal use by the industrial source category is the difference between the total fuel available for allocation minus the fuel used by the commercial/institutional category, as calculated by Equation 2-7. Subtract industrial point source use to obtain area source use by the industrial category.

Wood--

Industrial area source wood consumption is considered to be negligible. However, some wood-related industries will burn wood waste. A survey of potential sources is necessary in certain locations.

2.1.5 DETERMINATION OF COUNTY FUEL USE BY SOURCE CATEGORY

If fuel use data for counties are not available at the local level the same general procedures described above can be used to calculate county totals or to apportion state fuel use to the county. The methods described below are adequate for almost all purposes of the inventory and are much simpler to apply than the procedures now used by NADB.

2.1.5.1 Residential

Residential fuel use is calculated for each county and fuel using Equations (2-1) through (2-6) shown in Section 2.1.4.1. It is worth noting that the equations may tend to overestimate residential fuel consumption because of fuel conservation practices and, thus, underestimate fuel use by the commercial/institutional and industrial categories.

2.1.5.2 Commercial/Institutional

The NADB procedures for estimating fuel consumption by the commercial/institutional category are complex. They are based on correlative relationships between employment and fuel use for five subcategories; hospitals, hotels, laundries, schools and universities. Because fuel use by the commercial/institutional category is less than that for the residential and industrial categories, and because the five categories account for only a modest percentage of total commercial/institutional fuel use, the NADB procedures are not recommended, except for the most detailed inventory. To determine county fuel use, apportion state commercial/institutional fuel to the county by population using the following expression:

$$\begin{matrix}\text{county}\\ \text{area source}\\ \text{fuel use}\end{matrix} = \begin{matrix}\text{state}\\ \text{area source}\\ \text{fuel use}\end{matrix} \left(\frac{\text{population of county}}{\text{population of state}}\right) \qquad (2\text{-}8)$$

The use of Equation (2-8) for all fuels consumed within the state assumes that the distribution of fuel use is similar for each county and the state as a whole. If the agency has reason to question this assumption, a procedure which assumes that residential fuel distribution is equivalent to that of the commercial/institution category can be followed. In this case, county commercial/institutional fuel use for each fuel is calculated as follows:

$$\begin{matrix}\text{county}\\ \text{area source}\\ \text{fuel use}\end{matrix} = \begin{matrix}\text{state}\\ \text{area source}\\ \text{fuel use}\end{matrix} \left(\frac{\text{residential county fuel use}}{\text{residential state fuel use}}\right) \qquad (2\text{-}9)$$

2.1.5.3 Industrial

The following steps should be followed to apportion state industrial fuel use to each county.

1. Subtract county industrial (SIC 20 to 39) point source employment from total county industrial employment. Employment data are found in Reference 19.

2. Subtract state industrial point source employment from total state industrial employment (Reference 19).

3. Calculate county industrial area source fuel use as follows:

$$\begin{matrix}\text{County area source}\\ \text{industrial fuel use}\end{matrix} =$$

$$\begin{matrix}\text{state industrial area}\\ \text{source fuel use}\end{matrix} \left(\frac{\text{county area source industrial employment}}{\text{state area source industrial employment}}\right) \qquad (2\text{-}10)$$

The NADB procedures are similar, but rely on adjustment of employment figures within each two digit SIC, using point source employment data and fuel intensity factors developed for each two-digit SIC. The procedures, while useful for estimating total industrial fuel consumption, are of questionable merit for industrial area sources.

2.1.6 APPORTIONING FUEL CONSUMPTION TO SUBCOUNTY LEVELS

Techniques for apportioning countywide fuel consumption to smaller areas, thus showing more clearly the areas of high emission density and their origin, are similar to those discussed above for apportioning state totals to the county level. Fuel consumption, and subsequently emissions, are apportioned to a map of the study area on which grids are superimposed, as shown in Figure 2-2. The UTM Coordinate System is used to define the grid area and its boundaries. The required level of resolution of the inventory will determine grid size. Usually, as shown in Figure 2-2, the grid sizes used will be smallest in urban areas and largest in rural areas, thus providing greater emphasis to areas of high population density, while limiting the number of grids and the attendant level of effort to a practical limit.

2.1.6.1 Apportioning Population to Grids

As a first step in the apportioning of fuel consumption, information on population and housing distribution in counties by census tract is obtained from the U.S. Bureau of Census. Contact with local planning agencies or the Chamber of Commerce will usually be necessary to ensure that information is current and complete.

Estimates of population within each grid are made using census tract maps suitably adjusted to reflect current conditions. The assumption is made that population is uniformly distributed over each tract. The populations for each grid is computed as follows:

1. Using an overlay of the grid system, estimate the fraction of a census tract in a grid zone.

2. Multiply this fraction by the total population of the census tract to obtain census tract population within the grid.

3. Sum the contribution of each census tract within the grid to obtain total grid population.

After apportioning, the population in all grids are totaled to ensure that the sum is identical, or nearly so, to the total population of all census tracts within the study area.

2.1.6.2 Apportioning Fuel Consumption

For residential fuel use, assume housing distribution is similar to the population distribution previously determined. The type of fuel used by

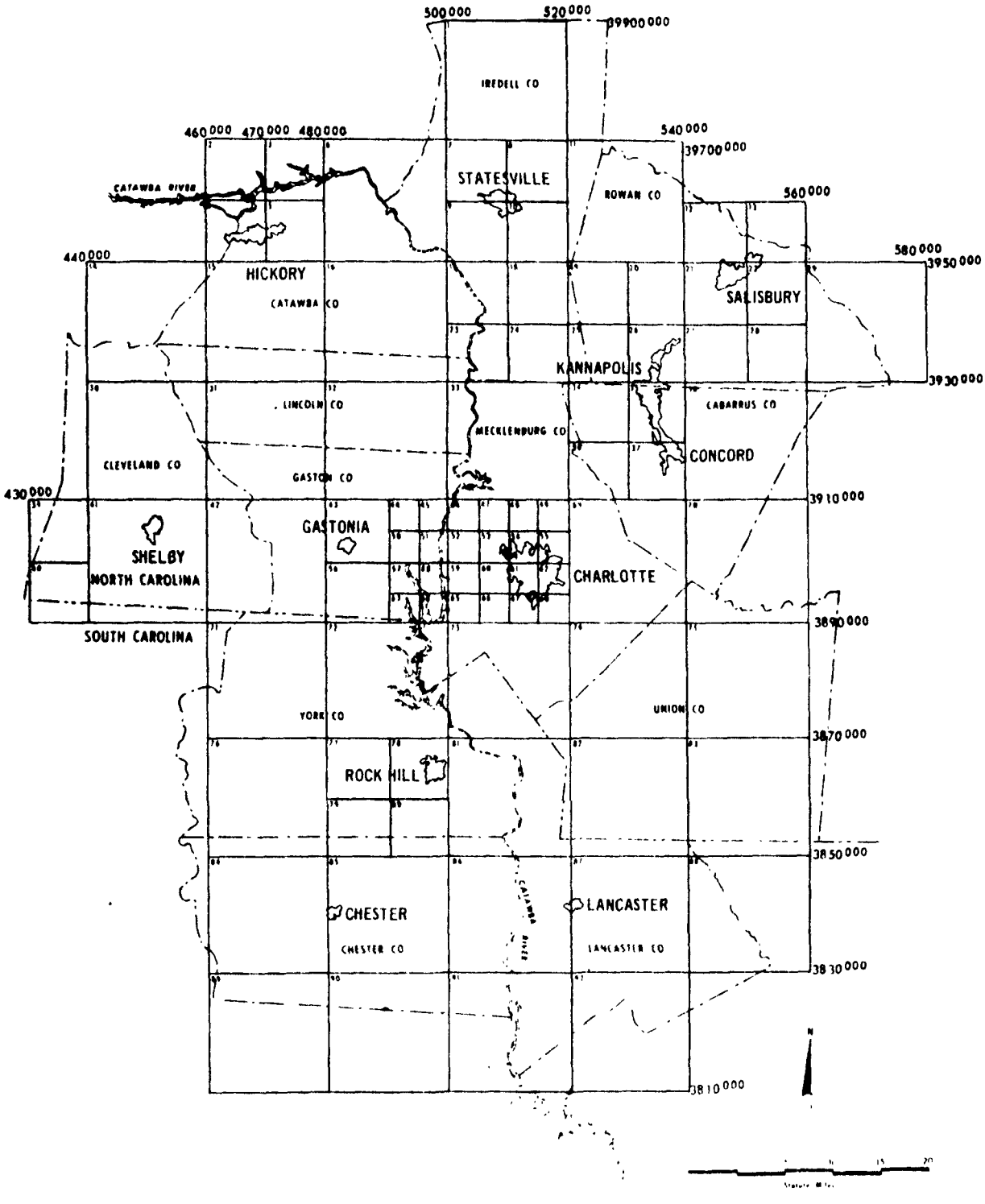

Figure 2-2. Grid coordinate system example.

housing within a grid is assumed to be identical to the county distribution of fuel use. The fuel is allocated to the grid by multiplying county fuel use by the ratio of grid population to county population.

For commercial/institutional fuel use, the same procedure as that used for residential fuel can be applied. If local planning agencies compile commercial/institutional employment data on a subcounty level, fuel can be allocated to the grid by multiplying county commercial/institutional fuel use by the ratio of grid commercial/institutional employment to county commercial/institutional employment. If employment data are not available, zoning maps, obtained from local planning agencies, can be used. These maps indicate the total land area utilized for a given purpose (e.g., residential, commercial/institutional, industrial). To use the zoning map, the agency grid must be plotted to the same scale as the zoning map. The grid is then overlayed onto the zoning map so that the total area zoned for commercial/institutional structures within each grid square can be visually estimated. Fuel use is then allocated to the grid by multiplying commercial/institutional county fuel use by the ratio of grid commercial/institutional zoned area to county commercial/institutional zoned area.

Local zoning maps should be used for apportioning industrial fuel. The agency grid (adjusted to the zoning map scale) is overlayed onto the zoning map and the total area of industrial zoning in each grid square is determined. Fuel is apportioned to the grid by multiplying industrial county fuel use by the ratio of grid industrial zoned area to county industrial zoned area.

2.1.7 CALCULATING EMISSIONS

Emissions of criteria pollutants are estimated by multiplying the emission factors given in AP-42 by fuel consumption. Emission factor parameters (ash content of coal and the sulfur content of all fuels) must be known by the agency in order to use the AP-42 emission factors. The use of average ash and sulfur content for fuels used within the county is adequate. This information should be available within the agency, if not, local fuel dealers or DOE publications should be consulted.

As noted previously, combustion units with heat inputs greater than a certain size will be in the point source inventory. Coal-fired units of pulverized, cyclone or spreader stoker design are almost invariably included in the point source inventory. As a guide to the agency, over 80 percent of commercial size stokers are of underfeed design. This is probably true also for the smaller size industrial furnaces. Most coal-fired residential units will be hand-fired, although new units are generally equipped with overfeed stokers.

2.1.8 SAMPLE CALCULATIONS

To assist agency personnel in applying the methods described above for estimating emissions from area external combustion sources two sample calculations are given below.

EXAMPLE 1. Allocation of fuel use to categories and counties

Given: Data for year of inventory

Population: County--300,000; State--3,000,000

Dwelling units (DU) in county number 100,000. Of these: 10,000 DU use coal for space heating
40,000 DU use oil for space heating (20,000 use oil for water heating)
35,000 DU use gas for space heating (30,000 use gas for cooking, 20,000 for water heating)
15,000 DU use electricity for space heating
Median unit size is 5.5 rooms per unit

Employment in SIC Groups 20-39:
County--20,000; State--300,000
Employment in SIC Groups 50-99:
County--30,000; State-200,000

DOE State fuel oil use data (Reference 6)
Distillate oil used for heating: 15,000,000 barrels or 630,000,000 gallons
Residual oil used for heating: 30,000,000 barrels or 1,260,000,000 gallons
Distillate oil for industrial and oil company use: 4,000,000 barrels or 168,000,000 gallons
Residual oil for industrial and oil company use: 25,000,000 barrels or 1,050,000,000 gallons
Distillate oil for military use: 1,000,000 barrels or 42,000,000 gallons
Residual oil for military use: 500,000 barrels or 21,000,000 gallons

DOE state natural gas use data (Reference 7)
Natural gas used by the residential category: 72,000 x 10^6 ft^3
Natural gas used by the commercial and industrial categories: 150,000 x 10^6 ft^3

DOE state bituminous coal use data (Reference 9)
Bituminous coal for retail sales: 330,000 tons
Bituminous coal for industrial: 480,000 tons

DOE state anthracite shipments data (Reference 10)
Anthracite shipments to state: 150,000 tons

Annual degree days: 5000

Calculations:

Step I Calculate county residential fuel consumption using Equations 2-1, 2-2, 2-3, and 2-5.

A. Distillate oil (Equation 2-1)

$$\left(\frac{0.01288\ (5000\ \text{degree-days}) + 30.41\ (5.5\ \text{rooms/DU}) - 79.54}{0.14}\right)$$

$$40{,}000 + 250\ (20{,}000\ \text{DU using oil for water heating}) =$$

$$43{,}461{,}000 + 5{,}000{,}000 = 48{,}461{,}000\ \text{gallons}$$

B. Residual oil (Equation 2-2)

Residual oil = 0 for the residential category

C. Natural gas (Equation 2-3)

$$47.5\ (35{,}000\ \text{DU}) \times (5000\ \text{degree-days})^{0.367} \times$$

$$\left(\frac{35{,}000\ \text{DU}}{30{,}000\ \text{DU for cooking}}\right)^{0.588} \times (5.5)^{0.125}$$

$$= 1{,}662{,}500 \times 22.8 \times 1.09 \times 1.24 = 51{,}232{,}398\ \text{therms or}$$

$$5{,}123{,}240 \times 10^6\ \text{Btu or}\ \ 5.12 \times 10^9\ \text{ft}^3$$

D. Coal (Equation 2-5)

$$0.00387 \times 10{,}000\ \text{DU} \times e^{\left(7.64 - \frac{1000}{5000\ \text{Degree-days}}\right)}$$

$$= 38.7 \times 1702 = 65{,}896\ \text{tons of coal}$$

Step II Sum residential fuel totals for all counties to obtain state residential fuel consumption. Hypothetical results are:

Distillate Oil--500,000,000 gallons

Residual Oil--0 gallons

Natural Gas--76 x 10^9 ft^3

Coal--300,000 tons

Step III Determine state commercial/institutional and industrial area source fuel consumption

A. Distillate fuel oil

1. Subtract residential distillate oil from DOE distillate oil used for heating (Reference 6)

630,000,000 - 500,000,000 = 130,000,000 gallons

2. Allocate fuel to commercial/institutional and industrial sector using Equation 2-7

$$130{,}000{,}000 \text{ gallons} \times \left(\frac{300{,}000 \text{ employees SIC 50-99}}{500{,}000 \text{ employees SIC 20-39 and 50-99}}\right)$$

= 78,000,000 gallons for state commercial/institutional use and

52,000,000 gallons for state idustrial use

3. To commercial/institutional fuel above add distillate oil for military use

78,000,000 + 42,000,000 = 120,000,000 gallons

4. Subtract state point source distillate oil use by the commercial/institutional category (assumed 10,000,000 gallons) to obtain state commercial/institutional area source distillate oil use: 110,000,000 gallons

5. To industrial fuel above add distillate oil used for industrial and oil company use

52,000,000 + 168,000,000 = 220,000,000 gallons

6. Subtract state point source industrial fuel use (assumed 100,000,000 gallons) to obtain area source distillate oil fuel use:

220,000,000 - 100,000,000 = 120,000,000 gallons

B. Residual Fuel Oil

1. Because residual fuel oil use by the residential category is 0 allocate state residual oil used for heating in Reference 6 to commercial/institutional and industrial categories using Equation 2-7.

$$1{,}260{,}000{,}000 \text{ gallons} \times \left(\frac{\text{State employment in SIC Groups 50-99}}{\text{State employment in SIC Groups 20-39 and 50-99}}\right)$$

= 760,000,000 gallons for commercial/institutional

and 504,000,000 gallons for industrial use

2. To commercial/institutional fuel above add residual oil for military use

756,000,000 + 21,000,000 = 777,000,000 gallons

3. Subtract state point source residual oil use by the commercial/institutional category (assumed 500,000,000 gallons) to obtain state commercial/ institutional area source residual oil use

777,000,000 - 500,000,000 = 277,000,000 gallons

4. To industrial fuel above, add residual oil used for industrial and oil company use

504,000,000 + 1,050,000,000 = 1,554,000,000 gallons

5. Subtract state point source residual oil use by the industrial category (assumed 1,054,000,000 gallons) to obtain state industrial area source residual oil use: 500,000,000 gallons

C. Natural Gas

1. State use of natural gas by the residential category is given in Reference 7 as 72 x 10^9 ft^3. This is slightly lower than calculated state total of 76 x 10^9 ft^3. Use Reference 7 value and reduce calculated county totals to (72)/76 or 0.947 of calculated values.

2. Allocate commercial and industrial total of 150,000,000,000 ft^3 from Reference 7 using Equation 2-7 to give

90×10^9 ft^3 commercial/institutional, and

60×10^9 ft^3 industrial.

3. Subtract state point source natural gas use by the commercial/institutional and industrial categories from the respective values above to obtain state area source natural gas totals (assumed 50 percent in point source inventory)

   State area source totals are

   45×10^9 ft^3 commercial/institutional, and

   30×10^9 ft^3 industrial

D. Anthracite Coal

1. Calculated state residential coal consumption is 300,000 tons. This is greater than the 150,000 tons of anthracite shipped to state.

2. Assign all anthracite to residential after subtracting point source anthracite (20,000 tons by industry). State residential anthracite fuel use is 130,000 tons. Commercial and industrial area source totals are 0.

E. Bituminous Coal

1. Assign difference between calculated state area source residential coal and area source anthracite residential coal to bituminous coal.

   300,000 - 130,000 = 170,000 tons

2. The difference between state bituminous retail sales in tons from Reference 9 and the 170,000 tons of residential coal or 160,000 tons is assigned to the commercial category.

3. Subtract state point source commercial/ institutional bituminous to obtain state area source commercial/institutional bituminous use.

4. Subtract state point source industrial bituminous use from total industrial sales in tons given in Reference 9 to obtain state area source industrial bituminous use.

Step IV Apportion state area source fuel use to counties

A. Residential fuel use by county is based on calculations as described above.

B. State area source commercial/institutional fuel is apportioned to counties on the basis of population

County C/I area source fuel use =

$$\text{State C/I area source fuel} \times \left(\frac{\text{County population}}{\text{State population}}\right)$$

For Natural Gas; county commercial/institutional area source natural gas use is:

$$45 \times 10^9 \times \left(\frac{300{,}000}{3{,}000{,}000}\right)$$

$$= 4.5 \times 10^9 \text{ ft}^3$$

C. State area source industrial fuel is apportioned to counties on the basis of area source employment in SIC Groups 20-39. Assumed 10,000 and 100,000 point source employees in county and state SIC Groups 20-39, respectively.

For natural gas; county industrial area source natural gas use is:

$$30 \times 10^9 \text{ ft}^3 \times \left(\frac{20{,}000 - 10{,}000 \text{ county employees}}{300{,}000 - 100{,}000 \text{ state employees}}\right)$$

$$= 1.5 \times 10^9 \text{ ft}^3$$

EXAMPLE 2. Updating and estimating residential fuel consumption by grid.

Given:

County and census-tract data for 1978 have been distributed onto grids. The following population and dwelling units (DU) data are available for one grid in the country:

	County A	Grid 4
1978 population	300,000	10,000
1978 DU	100,000	4,000
1978 DU using coal	10,000	500

1978 DU using oil	40,000	1,300
1978 DU using gas	35,000	1,800
1978 DU using electricity	15,000	400

Local planning commission population and housing estimates for County A in 1981 are as follows:

1981 population: 315,000

1981 DU: 105,000

Since 1978, according to the local gas company:

10 percent of the dwelling units using coal have switched to gas.

5 percent of the dwelling units using oil have switched to gas.

80 percent of the homes built since 1978 are heated with gas and 20 percent with electricity.

Total residential gas sales for 1981 are 9.1×10^9 ft^3.

Other:

In 1981, 20 percent of coal burned was anthracite and 80 percent was bituminous.

1981 degree-days (°day) = 5,000 °day.

Average number of rooms per dwelling unit, 1981 = 5.5 rooms.

Dwelling units in County A using oil for water heating, 1978 = 20,000 DU or 50 percent; 25,000 dwelling units use natural gas for water heating and cooling (1981).

<u>Calculations:</u>

Step I Update grid population from 1978 to 1981.

$$\frac{315,000}{300,000} (10,000 \text{ pop.}) = 10,500 \text{ population in grid 4}$$

Step II Update grid housing data from 1978 to 1981

$$\frac{10,500}{10,000} (4,000 \text{ DU}) = 4,200 \text{ DU in grid 4}$$

Step III Estimate 1981 coal usage for space heating in grid 4.

A. Dwelling units:

$$500 - (0.1)(500) = 450 \text{ DU using coal}$$

B. Usage in Tons:

$$(0.00387)(450) \exp\left(7.64 - \frac{1000}{5000}\right) = 2970 \text{ (Equation 2-5)}$$

1. Anthracite coal burned = (2,970 tons) (0.2) = 594 tons

2. Bituminous coal burned = (2,970 tons - 594 tons) = 2376 tons

Step IV Estimate 1981 oil use for space heating and water heating in grid 4. All oil is assumed to be distillate oil.

A. Dwelling units:

40,000 - (0.05) (40,000) = 38,000 DU using oil, County A

1,300 - (0.05) (1,300) = 1,235 DU using oil, grid 4

B. Usage in Gallons

$$\left(\frac{(0.01288)(5000\ ^\circ\text{day}) + 30.41\ (5.5 \text{ rooms}) - 79.54}{0.14}\right)(1,235 \text{ DU}) +$$

$$250\ (1,235 \text{ DU})\ (0.5) = 1,496,291 \text{ gallons fuel oil (Equation 2-1)}$$

Step V Estimate 1981 natural gas use for space heating and other purposes (water heating, cooking, etc.)

A. Dwelling units:

The following formula is used in this example for updating:

1978 DU gas users + converted from coal + converted from oil + new DU using gas = 1981 DU gas users.

County: 35,000 + 1,000 + 2,000 + 5,000 (0.80) = 42,000 DU

Grid: 1,800 + 50 + 65 + 200 (0.80) = 2,075 DU

B. Gas used in 1981.

County: 47.5 x 42,000 DU x $5000^{0.367}$ x $(42,000/25,000)^{0.588}$ x $5.5^{0.125}$ = 42.3 x 10^6 therms (Equation 2-3)

42.3 x 10^6 therms x 95 ft^3 gas/therm = 4.1x 10^9 ft^3 gas used in County A.

Grid: (2,075 DU/42,000 DU) 4.1 x 10^9 ft^3 = 203 x 10^6 ft^3 gas used in Grid 4.

Emissions estimates can now be obtained by multiplying fuel use totals by appropriate emission factors.

2.2 STATIONARY INTERNAL COMBUSTION ENGINES

Internal combustion sources for electricity generation, industrial, and commercial/institutional applications are grouped into two types: gas turbines and reciprocating engines. A basic gas turbine consists of a compressor, a combustor and a turbine. High pressure air is supplied by the compressor to the combustor. Fuel is mixed with the air in the combustor and burned. Combustion products are then expanded through the turbine to drive a rotor and generate power. A variety of advanced models have evolved from the simple gas turbine, and are classified into three general operating cycles: simple open cycle, regenerative open cycle and combined cycle. In the simple open cycle, the hot gas discharged from the turbine is exhausted to the atmosphere. In the regenerative open cycle the gases are passed through a heat exchanger to preheat the combustion air. Preheating the air increases the efficiency of the turbine. In the combined cycle, the gas discharged from the turbine is used as auxiliary heat for a steam cycle. The combined cycle system offers a great increase in the combined efficiency of the overall system. Gas turbines use gas or liquids, such as distillate oil and kerosene, as fuel. In open cycle gas turbines, where the products of combustion come in direct contact with the turbine blades, combustion gases must be free of corrosive ash and large particulates ($\geq$2 μm) which cause erosion.

Reciprocating internal combustion engines may be classified according to the method of ignition into spark ignition and compression ignition engines. The spark ignition engines use gas or volatile liquids such as gasoline as fuel, whereas the compression ignition engines use liquid fuels of low volatility such as low-grade kerosene and distillate oil (diesel fuel). All distillate oil reciprocating engines are compression ignited, and all gasoline reciprocating engines are spark ignited. Spark ignited gasoline engines have very limited use for electricity generation and industrial applications, because of their poor part-load economy and demand for premium fuel. Gas-fired reciprocating engines are mostly spark ignited, but gas can also be used in a compression ignition engine if a small amount of diesel fuel is injected

into the compressed air/gas mixture to initiate combustion. Such compression ignition engines are known as dual-fuel engines, and are normally designed to burn any mixture ratio of gas and diesel fuel. Most of the large bore, high power engines for utility and industrial applications are four-stroke cycle compression ignition engines designed to operate on diesel fuel or dual-fuel, and either two-stroke cycle or four-stroke cycle spark ignited gas engines.

2.2.1 POPULATION OF INTERNAL COMBUSTION SOURCES

Gas turbine and reciprocating engine capacity in 1978, and areas of application, are shown in Tables 2-2 and 2-3, respectively.[2] Utility systems are included in these tables for reference. However, they are not area sources and should appear in the point source inventory, as should many of the larger units in excess of 1000 hp (746 kw) output in size used for electricity generation and heavy-duty compressor and pump drive applications. Commercial/ institutional internal combustion sources are generally reciprocating engines burning either natural gas or fuel oil. There are approximately 4000 engines currently in use by municipalities for water and sewage pumping. Average size is 400 hp or approximately 0.3 megawatts (MW).* At an average thermal input rate of about 7,500 Btu/hp-hr for reciprocating engines, these units consume about 3×10^6 Btu/hr and emit less than 100 ton/year of any criteria pollutant. They generally should be considered as area sources, as should a larger number of smaller units used for light-duty applications and emergency power generation.

The lack of data concerning the number, size, areas of application, and hours of operation of small to medium size internal combustion systems presents serious problems to the agency interested in compiling an inventory of emissions from this source category. Although stationary internal combustion sources consume a relatively small percentage (~10 percent) of all fuel consumed by stationary combustion sources, it has been estimated that they account for approximately 20 percent of NO_x and 9 percent of hydrocarbon stationary source combustion emissions. The preponderance of emissions are from the industrial sector, with 80 percent of industrial emissions attributed to reciprocating engines.[2]

2.2.2 ESTIMATING FUEL CONSUMPTION

There are no literature sources that can be used to estimate fuel use by small and medium size stationary internal combustion sources. A survey by the agency of manufacturers, oil and gas companies (the principal industrial users of such systems), and municipalities will be required. A survey is particularly important in states that have oil and gas transmission pipelines and oil and gas production activities.

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*1000 horsepower (hp) = 746 kw; 1 MW = 1341 hp.

TABLE 2-2. CURRENT AND PROJECTED GAS TURBINE INSTALLED CAPACITY FOR UTILITY AND INDUSTRIAL APPLICATIONS

Application area (average capacity)[a,b]	Installed capacity (MW)[a] 1978	1985
Utilities (30 MW)		
Oil-fueled combustion turbine	41,500	49,100
Gas-fueled combustion turbine	3,410	2,910
Oil-fueled combined cycle	3,760	8,770
Gas-fueled combined cycle	2,130	1,580
Oil and gas industry (2.2 MW)	5,390	5,950
Private industry electricity generation		
Oil and gas industry	490	540
Other industry	2,400	3,600
Other industrial applications	1,080	1,620
Total	60,160	74,070

[a]1 MW = 1,000 kW = 1,341 hp.

[b]Gas turbines larger than 0.745 MW may be point sources. This depends on the fuel composition, usage rate and point source size cut-off chosen by the agency.

TABLE 2-3. RECIPROCATING ENGINE INSTALLED CAPACITY FOR UTILITY, INDUSTRIAL, AND COMMERCIAL/INSTITUTIONAL APPLICATIONS

Application area (average capacity)	1978 installed capacity (MW)
Utilities (1.9 MW)	
Diesel, dual fuel, and gas engine	5,300
Oil and gas transmission (1.5 MW)	
Diesel engine	780
Gas engine	9,380
Natural gas processing	
Gas engine	2,350
Oil and gas exploration	
Diesel engine	840
Gas engine	840
Crude oil and natural gas production	
Gas engine	4,000
Industrial processes	
Gas engine	940
Onsite power generation	
Gas engine	350
Municipal water and sewage (0.3 MW)	1,200
Total	25,980

2.2.3 CALCULATING EMISSIONS

Emissions from internal combustion sources are estimated by multiplying fuel consumption by an emission factor. Emission factors are given in AP-42 for pipeline compressor engines firing natural gas, and for gas- and oil-fired electric utility turbines. The EPA Regional Office should be contacted for information concerning emission factors for smaller area source internal combustion sources. Recent information may now be available as a result of EPA-sponsored NSPS and emissions assessment programs.

References for Chapter 2.0

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3.0 SOLID WASTE INCINERATION AND OPEN BURNING

The areas of solid waste incineration and open burning have changed substantially since the 1970's because of the enactment of air pollution regulations. There has been a marked decrease in the number of operating incinerators and open burning has been banned in many states and municipalities. Due to this reduction in activity level, procedures based on correlative relationships used previously to compile an inventory of emissions from these sources are for the most part outdated. This section outlines procedures for inventorying these sources using the best available and most current information. Agency personnel must exercise judgment in assessing the quantitative value of these procedures as applied to the agency's inventory jurisdiction.

3.1 SOURCE CATEGORIES

Source categories falling under the major heading of solid waste incineration and open burning include those listed in Table 3-1. Prescribed burning and wildfires are distinct categories, and are distinguished from the incineration and open burning categories that burn wastes generated by residential, commercial and industrial sources.

Many facilities in the source categories listed in Table 3-1, such as municipal incinerators and many industrial incinerators, will be point sources or located at a major facility included in the point source inventory. Emissions from those facilities accounted for in the inventory of point sources must not be included in the inventory of area sources.

3.2 INCINERATION

Incineration (and open burning) sources are classified according to origin into residential, commercial/institutional and industrial categories. Criteria pollutant emissions from incineration are affected by the type of waste burned, incinerator design, and the presence of stack gas control equipment. The type of waste incinerated will affect emissions due to variations in such factors as: moisture content, heating value, chemical composition and ash content. However, the effect of these factors on emissions from urban wastes have not been quantified. The emission factors given in AP-42 are average values; i.e., all urban refuse wastes are assumed to be homogeneous.

Incinerator design has a direct bearing on emissions. Consequently, area source emission calculations are based on the design mix of area source incinerators. The area source incineration population is classified according to incinerator design as follows:

TABLE 3-1. SOLID WASTE INCINERATION AND OPEN BURNING SOURCE CATEGORIES

Incineration
Residential
Commercial/Institutional
Industrial
Open Burning
Residential
Commercial/Institutional
Industrial
Prescribed Burning
Agricultural
Slash
Frost Control
Leaf
Forest Fires
Structural Fires

Single Chamber--the earliest and simplest design, consisting of one combustion chamber. These constitute approximately 25 percent of all incineration units currently operating.

Multichamber--equipped with an ignition as well as a combustion chamber. These units have a much lower emission rate than single chamber units of comparable size. Their primary use is in commercial and industrial applications. Multichamber units comprise approximately 68 percent of all area source incinerators.

Controlled Air--they combine tight combustion air controls with a built-in afterburner. The relatively sophisticated design and controls built into controlled air units result in substantially lower emission rates. The majority of these units are currently used to incinerate pathological wastes. Recent documents indicate that controlled air incinerators make up 2 percent of the total incinerator population. However, this percentage is likely to increase as more stringent emission controls become mandatory.

The breakdown of incinerator design for residential, commercial/institutional, and industrial incinerators has been determined by EPA for the year 1975. This distribution is shown in Table 3-2. As shown in Table 3-2, all residential incinerators are assumed to be single chamber units. However, the residential single chamber units are further classified as:

Flue-fed (modified) for urban-residential

Single chamber without primary burner for rural-residential

TABLE 3-2. INCINERATOR DESIGN DISTRIBUTION[2]

	Residential	Commercial/institutional	Industrial
Single Chamber	100%	25%	38%
Multiple Chamber	0	73%	58%
Controlled Air	0	2%	4%
Total	100%	100%	100%

In an inventory of area source incinerators, it is assumed that the sources are not equipped with stack gas control equipment. Generally, incinerators that are equipped with emission control systems to achieve emission standards are point source incinerators.

3.2.1 PROCEDURES FOR INCINERATOR EMISSION INVENTORY PREPARATION

Emissions from area source incinerators are estimated by identifying the activity level of each incinerator subcategory (i.e., residential, commercial/ institutional and industrial) and then applying an appropriate emission factor to obtain subcategory emissions. The agency will need to maintain separate records in the inventory for each subcategory. A separate subcategory record permits changes in this record as specific subcategory source changes occur, such as the outlawing of open burning or the outlawing of single chamber incinerators.

3.2.1.1 Determination of Activity Level

The quantities of waste disposed of by onsite incineration are shown in Table 3-3. The estimates are provided by EPA region, as a function of population or employment. The factors, in conjunction with population and employment data obtained from Department of Commerce publications,[3,4] can be used, if necessary, to estimate emissions from incineration. However, the data shown in Table 3-3 are 1975 data and subject to large local variations. Thus, the agency must make use of local surveys, permit and registration files and regulatory statutes to estimate activity levels, if a defensible inventory of onsite incineration emissions is to be maintained in the area source file.

The agency should conduct a survey of a representative sector of the inventory region for the purpose of developing or modifying the waste generation factors presented in Table 3-3. Additional data sources that may provide assistance are:

Air Quality Agency Data

- Source registrations
- Construction and operating permits
- Source inspection reports
- Existing emission inventory
- Special solid waste studies

Solid Waste Agency Data

- Waste generation rates
- Solid waste categorization studies

TABLE 3-3. FACTORS TO ESTIMATE TONS OF SOLID WASTE BURNED IN ONSITE INCINERATION[a,b]

EPA Region	Residential (ton/1000 population/yr)	Commercial/ institutional (ton/1000 population/yr)	Industrial (ton/1000 mfg employees/yr)
I	52	64	125
II	11	65	180
III	4	54	560
IV	4	23	395
V	61	87	420
VI	23	33	345
VII	75	37	325
VIII	87	49	430
IX	90	5	80
X	90	29	170
National Average Incineration	41	50	335

[a]References 2 through 6.

[b]These factors are based on 1975 data and should be updated to the inventory base year.

- Waste disposal studies

Waste Disposal Firms

- Waste generation rates by industry sector
- Population served by service
- Trends in waste generation rates and onsite disposal techniques

Incinerator Manufacturers

- Facilities with new installations
- Trends in onsite incineration

County/Local Fire Marshals

- Structural fires
- Trends in onsite incineration

Fuel Suppliers/Gas Company

- Customers utilizing auxiliary fuel for incinerators

3.2.1.2 Emission Factors for Incineration

Emission factors for onsite incineration are presented in EPA publication AP-42.[1] These emission factors are for refuse incinerators without emission controls. As previously stated, it is assumed that area source incinerators are not equipped with control equipment. Consequently, the emission factors in AP-42 can be used directly. (AP-42 emission factors are being updated continuously; the agency should verify that the factors are current).

The emission factors for incinerators are expressed in terms of pounds of pollutant per ton of waste charged. When multiplied by the appropriate activity levels (tons of waste incinerated), they will yield uncontrolled emission rates.

3.2.2 EXAMPLE CALCULATION: EMISSIONS FROM INCINERATORS

The following example is presented to illustrate the general procedures for evaluating emissions generated by area source incinerators.

Given: The inventory region is located in EPA Region V.

Step I Determine the Activity Level

From Table 3-3 the waste generation factors to estimate onsite incineration are:

Residential: 61 tons/1000 population

Commercial/Institutional: 87 tons/1000 population

Industrial: 420 tons/1000 manufacturing employees

A survey of a representative sector of the inventory region (group of counties of the state) shows that the above waste generation factors are high by roughly 35 percent for each category. The modified activity level factors are then calculated to be:

Residential: 40 tons/1000 population

Commercial/Institutional: 56 tons/1000 population

Industrial: 273 tons/1000 manufacturing employees

A review of the point source incinerator file shows that Agency personnel involved in the point source inventory have determined 50 percent of all commercial/institutional wastes and 85 percent of all industrial wastes are accounted for in the point source inventory. The activity levels are modified to represent only area source incinerators:

Residential: 40 tons/1000 population

Commercial/Institutional: (56)(0.5) = 28 tons/1000 population

Industrial: 273 (0.15) = 41 tons/1000 manufacturing employees

Step II Determine Activity Levels as a Function of Incinerator Design

The activity levels for each category can now be proportioned among incinerator design types (i.e., single chamber, multiple chamber, and controlled air) from Table 3-2.

Residential (given the inventory region is 25 percent urban and 75 percent rural):
Flue fed modified: 40 (0.25) = 10 tons/1000 population/year;
Single chamber: 40 (0.75) = 30 tons/1000 population/year.

Commercial/Institutional:
Single chamber: 28 (0.25) = 7 tons/1000 population/year
Multiple chamber: 28 (0.73) = 20 tons/1000 population/year
Controlled air: 28 (0.02) = 0.6 tons/1000 population/year

Industrial:
Single chamber: 41 (0.38) = 16 tons/1000 manufacturing employees/year

Multiple chamber: 41 (0.58) = 24 tons/1000 manufacturing employees/year
Controlled air: 41 (0.04) = 1.6 tons/1000 manufacturing employees/year

Step III Obtain Population and Manufacturing Employee Statistics

From published data:[3,4]

Population of inventory region: 5,500,000
No. of manufacturing employees: 550,000

Step IV Obtain Particulate Emission Factors (AP-42)

Residential:
Flue fed: 6 lb/ton
Single chamber: 35 lb/ton

Commercial/Institutional:
Single chamber: 15 lb/ton
Multiple chamber: 7 lb/ton
Controlled air: 1.4 lb/ton

Industrial:
Single chamber: 15 lb/ton
Multiple chamber: 7 lb/ton
Controlled air: 1.4 lb/ton

Step V Calculate Emissions

Emission Estimate = Activity Data x Population Employment x Emission Factor

Residential:
Flue fed modified: 10 tons/1000 population/yr x 5,500 x 6 lb/ton = 330,000 lb/yr
Single chamber no primary burner: 30 tons/1000 population/yr x 5,500 x 35 lb/ton = 5,775,000 lb/yr.

Commercial/Institutional:
Single chamber: 7 tons/1000 population/yr x 5,500 x 15 lb/ton = 577,500 lb/yr
Multiple chamber: 20 tons/1000 population/yr x 5,500 x 7 lb/ton = 770,000 lb/yr
Controlled air: 0.6 tons/1000 population/yr x 5,500 x 1.4 lb/ton = 4,620 lb/yr

Industrial:
Single chamber: 16 tons/1000 manufacturing employees/yr x 550 x 15 lb/ton = 132,000 lb/yr

Multiple chamber: 24 tons/1000 manufacturing employees/yr x 550 x 7 lb/ton = 92,400 lb/yr

Controlled air: 1.6 tons/1000 manufacturing employees/yr x 550 x 1.4 lb/ton = 1,232 lb/yr.

If desired, total emissions may be calculated by summing total residential, commercial/institutional and industrial emissions as follows:

$$\begin{aligned} \text{Emissions} &= 339{,}000 + 5{,}775{,}000 + 577{,}500 + 770{,}000 + 4{,}620 \\ &\quad + 132{,}000 + 92{,}400 + 1{,}232 \\ &= 7{,}682{,}752 \text{ lb/yr } (3{,}841 \text{ tons/yr}) \end{aligned}$$

3.3 OPEN BURNING

As stated in Section 3.1 the agency should be aware that prescribed burning and wildfire emission sources are distinct categories. Consequently, these categories should not be included in the open burning category.

As with small incinerators, the activity level for open burning can not be accurately correlated to some other easily identifiable factor such as population. The economic and regulatory climate for open burning varies throughout the country, and consequently, any general assumptions concerning open burning activity levels are not practical.

To determine emissions from open burning sources, the agency must develop accurate estimates of the activity levels. Existing regulations and their effectiveness should be considered by the agency in developing these estimates. Because many areas of the country require burning permits, an estimate of the activity level in those areas can be obtained by contacting the local officials responsible for issuing permits. Additional information can often be obtained from state agencies in charge of regulating solid waste disposal. If information cannot be obtained at either the local or state level, then nationally averaged activity level factors must be used. Table 3-4 provides factors for estimating the quantity of waste disposed of by open burning by the residential, commercial/institutional and industrial categories (1975 data). It is important to stress the limitations of these data when applied to specific local areas.

The procedures followed for calculating emissions are generally the same as previously detailed for incinerator sources. The quantities of waste accounted for in the point source open burning file should be subtracted from the factors in Table 3-4 before calculating the area source emissions.

TABLE 3-4. FACTORS TO ESTIMATE TONS OF SOLID WASTE DISPOSAL THROUGH OPEN BURNING[a]

	Residential, tons/1000 population/yr	Commercial/institutional, tons/1000 population/yr	Industrial, tons/1000 mfg. employees/yr
National Average	450[b]	24	160

[a]These factors should be updated to the inventory base year.

[b]For rural population only. Open burning assumed banned in urban areas.

Source: References 3 through 7.

3.4 PRESCRIBED FIRES

The prescribed burning category includes agricultural burning, slash burning, leaf burning and orchard heaters for frost control. These source categories have a seasonal occurrance and therefore a characteristic time when they release emissions. The agency should account for these temporal variations in the emission rate by estimating and recording emissions for the most active month(s) or season in addition to the annual emission totals.

3.4.1 AGRICULTURAL BURNING

Estimates of burning activity can usually be derived from data provided by State Agricultural Departments or extension services. Additional data may be obtained from the U.S. Soil Conservation Service. Emission factors for a variety of agricultural crops are obtained from Section 2.4 of EPA Publication AP-42.[1]

3.4.2 SLASH BURNING

The agency should consult with the U.S. Forest Service and State Forest Departments to obtain data on area and fuel loading of slash burned areas. If fuel loading data are unavailable, a figure of 75 tons per acre burned can be used. Emission factors in Section 2.4 of AP-42[1] can be applied to this loading factor.

3.4.3 FROST CONTROL

Typically, the county or State Department of Agriculture will be able to identify the number, location and type of orchard heaters in use. Grove and orchard operators may also provide such data. These sources will also furnish

the number of nights and the length of time the units were used during the year. From these data, hours of operation can be determined and emissions computed using emission factors given in AP-42.[1]

3.4.4 LEAF BURNING

In order to estimate the activity level, the agency should contact the local or state agency in charge of issuing leaf burning permits. Emission factors, provided by AP-42,[1] are used to calculate emissions.

3.5 FOREST FIRES

Data on forest fires may be available from State Forest Departments. If not, then Wildfire Statistics will provide data on acreage burned on a state-wide basis.[8] Fuel loading, emission factors, and estimates of organic emissions from forest fires in various U.S. Forest Service regions are found in Section 11.1 of EPA Publication AP-42.[1]

3.6 STRUCTURAL FIRES

For information, contact local fire departments or fire protection associations. In the absence of such information, assume an average of four fires/1000 people/year.[9] The EPA Regional Office should be contacted to assist in the selection of appropriate emission factors.

References for Chapter 3.0

1. Compilation of Air Pollution Emission Factors, Third Edition and Subsequent Supplements, AP-42, U.S. Environmental Protection Agency, Research Triangle Park, NC, October 1980.

2. Screening Study to Determine the Need for Standards of Performance for Industrial and Commercial Incinerators, Draft Final Report, EPA Contract No. 68-02-2607, Work Assignment No. 18, October 1978.

3. Census of Population, Bureau of the Census, U.S. Department of Commerce, Washington, DC, Decennial publication.

4. County Business Patterns, U.S. Department of Commerce, Bureau of the Census, Washington, DC, Annual publication.

5. National Survey of Community Solid Waste Practices: Interim Report, U.S. Department of Health, Education and Welfare, Cincinnati, OH, 1978.

6. National Survey of Community Solid Waste Practices: Preliminary Data Analysis, U.S. Department of Health, Education and Welfare, Cincinnati, OH, 1978.

7. OAQPS Data File of Nationwide Emissions, 1971, Monitoring and Data Analysis Division, U.S. Environmental Protection Agency, Research Triangle Park, NC, May 1973. Unpublished report.

8. Wildfire Statistics, Forest Service, U.S. Department of Agriculture, Washington, DC, Annual publication.

9. Statistical Abstract of the United States, Bureau of the Census, U.S. Department of Commerce, Washington, DC, Annual publication.

4.0 FUGITIVE DUST SOURCES

Fugitive dust emissions are particulate matter entrained and suspended by wind, vehicular traffic or other means. The following categories are recognized sources of fugitive dust emissions.

Anthropogenic sources

- Unpaved roads
- Unnpaved airstrip LTOs
- Paved roads
- Agricultural activities
- Construction activities
- Feed lots
- Miscellaneous industrial area sources

Natural sources

- Wind erosion of miscellaneous open areas.

It should be noted that fugitive dust emissions from all of the above anthropogenic sources, with the exception of the feed lot category, are associated, at least in part, with the operation of mobile sources, i.e., fugitive dust emissions are primarily the result of vehicle related traffic and LTOs. These fugitive dust categories are maintained separately in the area source file distinct from the inventory of mobile source tailpipe (combustion related) and crankcase and evaporative loss emissions which are the subject of Volume IV, Mobile Sources. The distinction between the fugitive dust and mobile source categories is maintained because of significant differences in inventorying procedures, the pollutants emitted and methods of control. Mobile sources, although significant emitters of suspended particulates, including inhalable particulates and lead, are the major emitters of NO_x, VOC, and CO in urban areas. Fugitive dust sources emit only particulates. As shown in Table 1-1, nationwide fugitive emissions from unpaved roads are six times greater than particulate emissions from mobile sources (combustion related) and over 20 times greater than all other area sources of particulate matter, including the previously discussed combustion and incineration area sources.

Historically, due to the difficulty in measuring fugitive dust emissions, little attention has been given to these sources. However, in view of the widespread failure to attain the NAAQS for particulate matter in many AQCRs,

these sources are currently undergoing rigorous examination. It now appears that fugitive dust emissions (principally from unpaved roads) are the major cause of nonattainment of NAAQS in many areas, and that a thorough inventory of such sources is mandatory for the development of an accurate inventory of particulate emissions.

A 1978 EPA report[1] stated that ambient air quality standards for total, suspended particulates (TSP) were not being met in 60 percent of the nations 247 air quality control regions (AQCRs). Estimated fugitive particulate emissions exceeded particulate emissions from point sources in over 90 percent of the 150 AQCRs that were out of compliance. In nearly 40 percent of the AQCRs, fugitive dust emissions exceeded point source particulate emissions by a factor of 10.[1] In AQCRs where industrial activity is absent, fugitive dusts are probably responsible for observed TSP standard violations. However, fugitive dusts also contribute significantly to ambient TSP levels in highly industrialized urban areas. The annual open source contribution to TSP levels in industrialized urban areas may be greater than 25 $\mu g/m^3$, or in excess of one-third of the primary NAAQS of 75 $\mu g/m^3$ (annual geometric mean).[2]

As a result of the past lack of attention given to fugitive dust emissions, the data base describing emission rates has not been been adequately defined. Although fugitive emission factors for many open source categories have been published in AP-42[3] and other EPA publications, the reliability rating for the majority of these factors is not high. Engineering judgment and extrapolation from related sources have played a large part in fugitive dust emission factor development, and few of the emission factors are supported by extensive test data. However, several programs are now ongoing to further refine existing emission factors and develop emission factors for other fugitive dust sources. New developments must be closely followed by the agency to update fugitive dust emission factors, and, thus, improve the accuracy of this important segment of the total particulate matter inventory.

Emission factors for fugitive dust sources are, in most cases, specific to a given geographical area. They are often dependent upon a number of parameters, including soil characteristics and climate. Sound professional judgment must be exercised by agency personnel in adjusting existing emission factors to reflect local conditions.

4.1 DATA REQUIREMENTS

Prior to the collection and validation of the data required for the estimation of emissions from fugitive dust sources, the agency must prepare the following:

1. A list of all fugitive dust source categories which exist within the agency's jurisdiction. This includes potential industrial-related area sources.

2. A list of the parameters necessary for the calculation of emissions, including activity levels and emission factors and their associated parameters.

3. A list, if necessary, of the data needed for the spatial and temporal resolution of emissions and for projection of emissions.

The list of fugitive dust sources should be as complete as possible to establish the impact of all source categories on the total inventory. Although considerable effort may be required initially to establish the impact of all potential source categories, this effort will contribute to the reliability of the inventory and will simplify future inventory efforts and updates.

Data requirements for the calculation of emissions are best identified by examination of the equations used to calculate emissions from open fugitive dust sources. As noted previously, formulae have been developed which provide for the application of correction factors which reflect the effect of local transportation, soil and climatic conditions. Emissions from industry-related sources will require careful consideration, but in most cases can be estimated using techniques developed for identical or related point sources.

Equations for uncontrolled emission rates from major open fugitive dust emission sources are given in Table 4-1. As shown, a number of factors influence emissions from certain source categories. These factors are often difficult to quantify. As a result, estimated values or simplified equations are often used. Miscellaneous industrial processes such as small grain elevators and woodworking operations are not listed in Table 4-1. Emission estimates from these industrial sources must be based on estimated activity levels determined through association with the number of employees, production rates or other statistical indicators, and emission factors based on, or extrapolated from, similar or related point sources and/or engineering judgment.

A definition of data requirements for all area source categories logically precedes the collection of data for purposes of estimating activity levels, deriving emission factors, and apportioning, as necessary, emissions from each source category to the geographical area of interest. This is particularly true of fugitive dust area sources because of the large number of corrective factors that are used to adjust emission factors.

4.2 DATA SOURCES

Having defined the data requirements for preparing an inventory of area source fugitive dust emissions, agency personnel will be required to collect the data necessary for estimating emissions of fugitive dust. As shown in Table 4-1, data related to transportation, climate, and agriculture are common requirements for estimating emissions from most fugitive dust sources. State and local agencies associated with such activities should be able to supply the information required.

TABLE 4-1. FUGITIVE DUST SOURCE EMISSION FACTORS (UNCONTROLLED)[a]

Source	Uncontrolled emission rate	Units	Equation symbols
1. Unpaved roads	$E = \frac{VMT}{yr}\left[5.9\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.8}\left(\frac{d}{365}\right)\right]$	Pounds/yr	VMT - Vehicle miles traveled
2. Unpaved airstrips	$E = \frac{LTO}{yr} \times 2.0\left[0.49s\left(\frac{S}{30}\right)\ \frac{d}{365}\right]$	Pounds/yr	s - Material silt content (%) S - Vehicle speed (mph)
3. Paved roads	$E = \frac{VMT}{yr}\left[0.45\left(\frac{s}{10}\right)\left(\frac{L}{5000}\right)\left(\frac{W}{3}\right)^{0.8}\right]$		W - Vehicle weight (tons) d - Number of dry days per year
4. Agricultural tilling	E = Acres of farmland x $1.1s\ [(S/5.5)/(PE/50)^2]$	Pounds/yr	L - Surface dust loading on paved road (pounds/mile)
5. Wind erosion of fallow fields	E = Acres of fallow field x $3400\left[\frac{\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)}{(PE/50)^2}\right]$	Pounds/yr	PE - Thornthwaites Precipitation Evaporation Index e - Surface erodibility (tons/acre-year)
6. Construction activities	E = 1.2 Active acres	Tons/month	f - Percentage of time wind speed exceed 12 mph
7. Cattle feed lots	$E = \frac{1000 \text{ head of cattle}}{\text{year}} \times 8$	Tons/yr	E - Emissions (given units)
	or		
	E = Feed lot acres x 3	Tons/yr	

Source: References 4 through 8

[a]These emission factors will soon be updated in AP-42 at which time Table 4-1 will be out of date. The agency should therefore obtain emission factors from the most recent edition of AP-42.

It is emphasized that data sources cannot always be precisely defined due to differences in state and county government structure. Data not available at the state or county level may be available from a specialized commission charged, for example, with defining transportation and land use requirements. Generally, information not available at the local level may be obtained from a state agency.

When the desired data are not available at the state and local level, the agency has the option of conducting a survey or a study of its own to develop the data. The importance of the needed data may warrant doing so. If such a study is not possible, the agency should derive an estimated value in as sound a fashion as is possible. Although an estimate will not be as accurate as data derived from actual measurement, the error can generally be estimated by calculating the variance in emissions within a reasonable choice of boundary conditions. The impact of the error on the total emissions inventory of particulates can also be estimated by relating the emissions from the area source category of interest to the emissions from the total inventory.

4.3 SOURCE CATEGORIES

4.3.1 UNPAVED ROADS

Unpaved roads, nationally, are the largest source of fugitive dust emissions. According to one estimate, emissions from unpaved roads represent almost 75 percent of the total national anthropogenic area and point source particulate emissions combined.[1] Road length; vehicle traffic, mix and speed; type of surface; and road moisture content are the principal determinants of the amount of dust generated by vehicle traffic on unpaved roads.

In order to determine the length of unpaved roads and vehicle miles traveled (VMT), the State Department of Highways or State Department of Public Works should be contacted. These agencies will, in most cases, have very accurate figures relative to the miles and type (e.g., gravel, silt) of unpaved roads in the study area. They should also have a good estimate of the average daily traffic, and thus VMT, for each segment of the study area. If the number and length of unpaved roads within a study area are not known, an alternative method of measuring road distances is to trace over the dirt roads shown on Department of Highway maps with a curvimeter. This device reads distance in either centimeters or inches which can be converted to road miles using the map scale. Depending on the size of the area being inventoried, this can be a quick and fairly accurate procedure.

Emissions data based on VMT data from previous years, given no change in the miles of unpaved roads in the area, may be updated by using recent census population figures for the area (usually county figures) and ratioing the VMT accordingly. This is accomplished by the following equation:

$$VMT_2 = VMT_1 \times \frac{population_2}{population_1}$$

where: VMT_2 = vehicle miles traveled in year y,

VMT_1 = vehicle miles traveled in year x,

$population_2$ = population, year y, and

$population_1$ = population, year x.

Some emission source parameters needed for estimating fugitive dust emissions from unpaved roadways, along with the primary and most reliable sources of information concerning these parameters, are listed in Table 4-2.

TABLE 4-2. EMISSION SOURCE PARAMETERS AND SOURCES OF INFORMATION

Source parameter	Data source
Length of unpaved road	1. Department of Highways 2. Department of Public Works 3. Highway Map Measurement
Vehicle miles traveled--VMT (average daily traffic x miles of unpaved road)	1. Sources 1 and 2 above 2. Old data updated by census ratio
Road base silt content	1. U.S.D.A. Soil Conservation Service 2. State or County Agricultural Agency 3. State or County Geological Agency

Once these parameters have been defined they can be applied to Equation 1 of Table 4-1. Equation 1 is expressed as:

$$E = \frac{VMT}{yr}\left[5.9\left(\frac{s}{12}\right)\left(\frac{S}{30}\right)\left(\frac{W}{3}\right)^{0.8}\left(\frac{d}{365}\right)\right]$$

where E = emissions (in pounds/yr),

VMT = vehicle miles traveled,

s = road silt content (%),

S = vehicle speed (mph),

W = vehicle weight (tons), and

d = number of dry days per year.

Fugitive emissions can be considered insignificant on days when rainfall exceeds 0.01 inches. Consequently, dry days are defined as those days in which rainfall is less than 0.01 inches. Vehicle speed (S) and weight (W) can be estimated with the assistance of personnel associated with one or more of the state agencies listed as data sources in Table 4-2.

4.3.2 UNPAVED AIRSTRIPS

Reference information needed to calculate fugitive dust emissions from unpaved airstrips can be obtained from the Federal Aviation Administration (FAA). A computer tape with data on any U.S. airport can be obtained from the Washington offices of the FAA.* Data include the following information: site number, city, state, airport name, county code, latitude, longitude, airport type, number of total based aircraft, runway pavement, runway length, population served, ownership and usage type. Local FAA officials or airstrips can also provide landing/takeoff (LTO) cycle estimates.

The following parameters are used in the calculation of fugitive particulate emissions from unpaved airstrips:[5]

the surface texture, measured as percent silt content;

the average LTO speed, (can be estimated to be 40 mph);

the surface soil moisture as determined by annual number of dry days; and

a wind-erosion multiplier, estimated to be equal to 2.

Once these parameters have been defined, emissions can be calculated (for a runway 1 mile in length) using Equation 2 of Table 4-1 which is:

$$E = \frac{LTO}{yr} \times 2.0 \left[0.49s \left(\frac{S}{30}\right)\left(\frac{d}{365}\right)\right]$$

where LTO = landing/takeoff cycles,

s = surface silt content (%),

S = average LTO speed, and

d = number of dry days per year.

4.3.3 PAVED ROADS

Emissions of dust from paved roads result from traffic or wind re-entrainment of dust deposited on the road by mud carryout (e.g., trucks

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*Aircraft Services Tape, Federal Aviation Administration, Public Information Center, AIS 230, Washington, D.C., 20541.

leaving construction sites), soil erosion, sanding and salting of roads, tire wear, etc. To quantify emissions, the agency personnel will need to quantify surface dust loading, in addition to many of the other parameters used to estimate emissions from unpaved roads.

One source of surface dust loading information is Reference 8, which presents minimum, maximum and average dust loading values for paved roads in residential, industrial and commercial areas. Once the appropriate variables have been determined they can be applied to Equation 3 of Table 4-1 which is:

$$E = \frac{VMT}{yr}\left[0.45\left(\frac{s}{10}\right)\left(\frac{L}{5000}\right)\left(\frac{W}{3}\right)^{0.8}\right]$$

where E = emissions (pounds/yr),

VMT = vehicle miles traveled,

s = silt content of surface dust (%),

L = surface dust loading (pounds/mile), and

W = vehicle weight (tons).

A simplified emission factor is provided in EPA publication AP-42 and shows average emissions to be 0.012 pounds/VMT. This emission factor can be used if the above parameters cannot be readily determined by the agency.

4.3.4 AGRICULTURAL ACTIVITIES

Fugitive dust emissions from agricultural activity occur during agricultural tilling and from fields exposed to wind erosion. Emissions from this category can range in magnitude from nonexistent to large depending on whether the area inventoried is mostly urban or rural. Much of the reference information required to perform an inventory of these sources can be obtained from EPA publications (AP-42, and Reference 5) and the U.S. Soil Conservation Service publication entitled "Guide for Wind Erosion Control in the United States." This information includes:

Thornthwaite's precipitation-evaporation (PE) index (see Figure 4-1)

Silt content of surface soil

Climatic factor (see Figure 4-2).

Surface erodibility--An estimate of the particulates per acre eroded from the exposed field. Erodibility factors are given for general areas, usually by county.

Other needed information which is best obtained at either the state (State Department of Agriculture) or local (county) level includes:

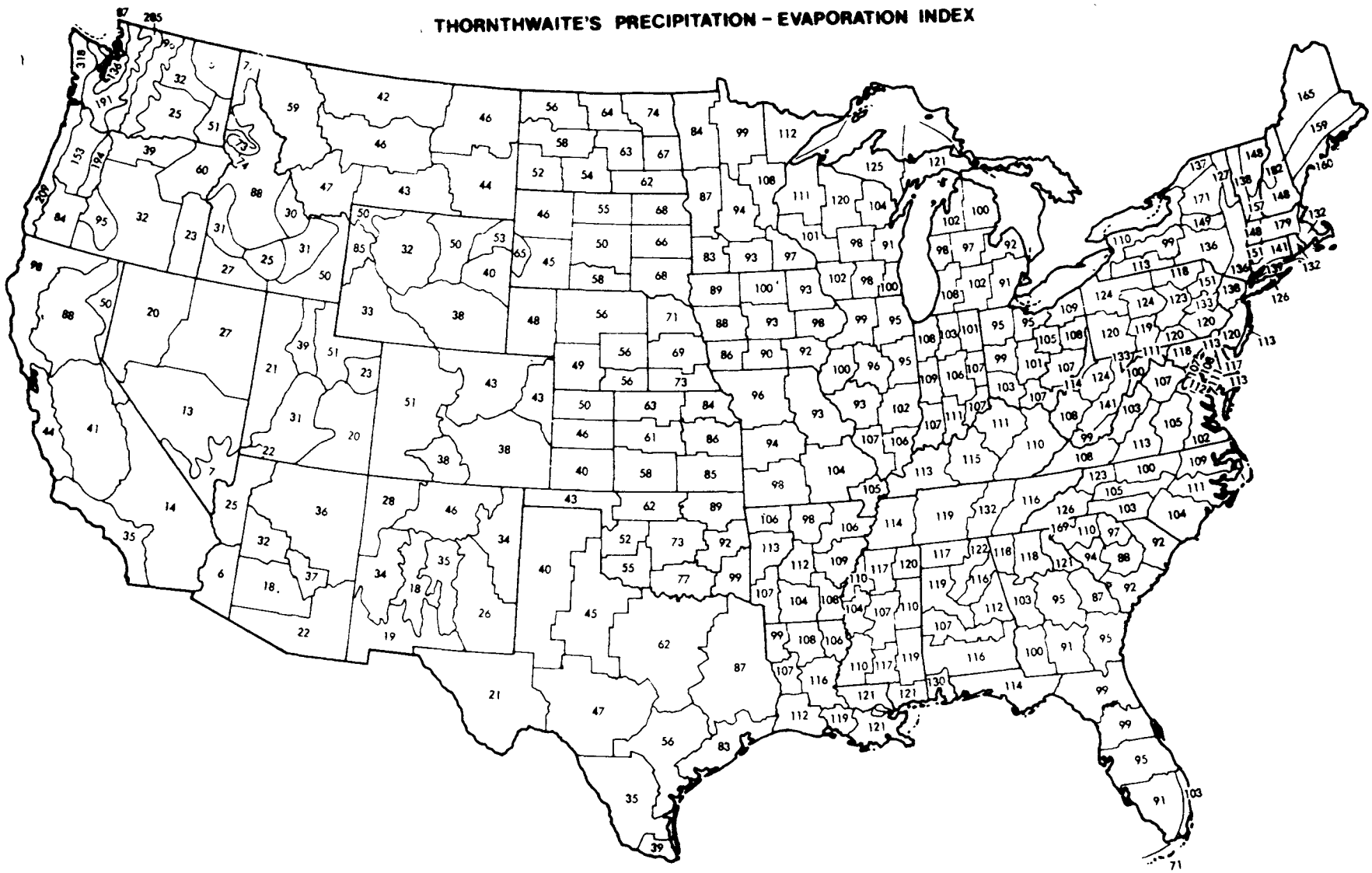

Figure 4-1. Map of Thornthwaite's Precipitation-Evaporation Index[3] values for state climatic divisions.

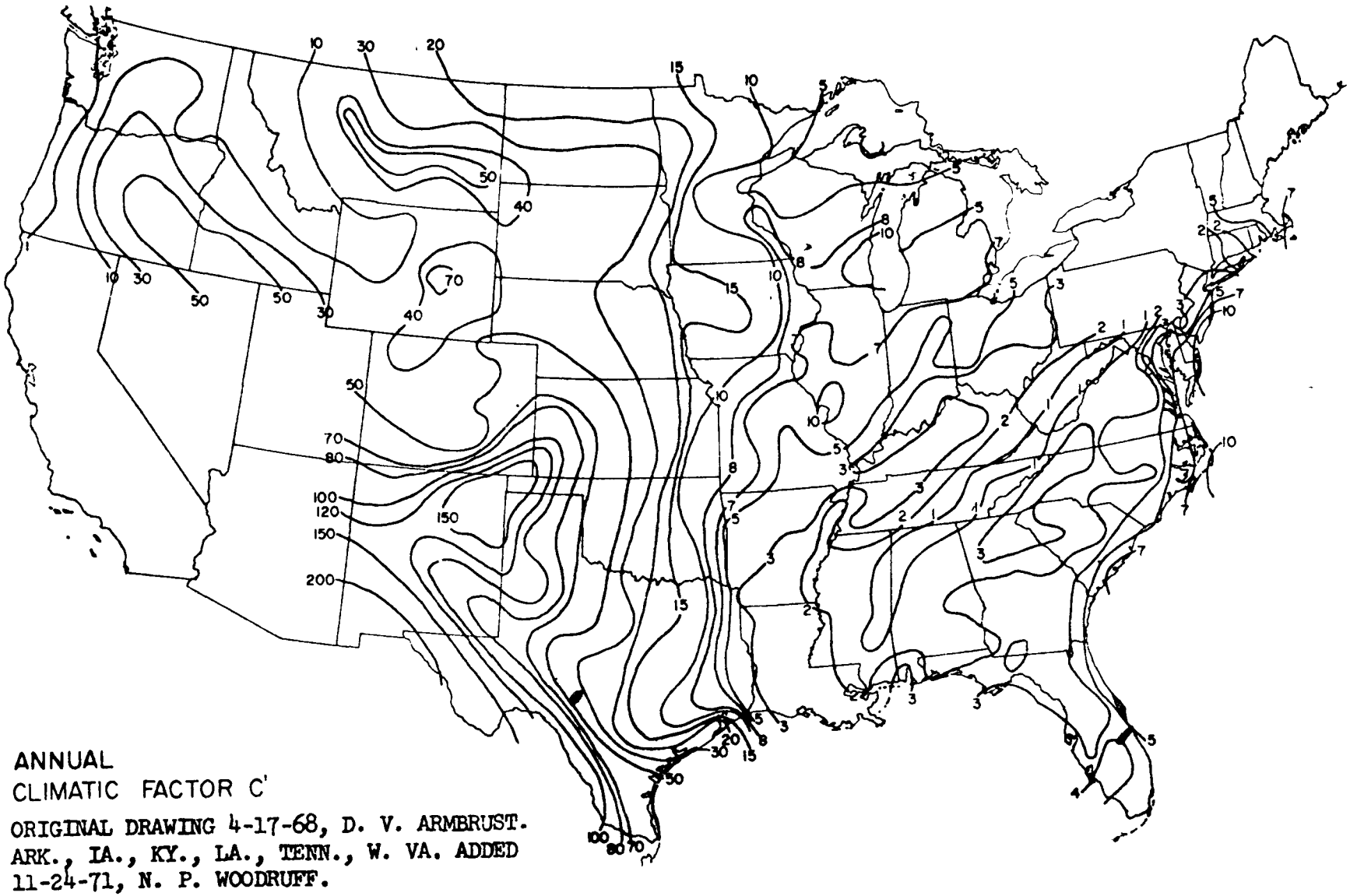

Figure 4-2. Climatic factor used in wind erosion equation.

Acres of agricultural land in the area

Average percentage of time during a given year when fields are fallow and the percentage of fields that are fallow. Fallow, in this context, means agricultural land which is not under cultivation. Fallow fields are not always bare soil, often having a vegetative cover of crop residue consisting of either stubble or residue mulched into the ground. This vegetative cover will significantly affect particulate emissions due to wind erosion.

Type of crops planted--The residue (vegetative cover) left on a field is closely related to the type of crops planted.

Average tractor speed during tilling.

Percentage of time that wind speed exceeds 12 mph (data obtained from local U.S. Weather Bureau).

Once these variables have been determined, they can be applied to Equations 4 and 5 of Table 4-1 to calculate fugitive dust emissions from agricultural tilling operations and wind erosion of fallow fields. Equation 4, for agricultural tilling emissions is presented as:

$$E = \text{Acres of farmland} \times 1.1s \left[\frac{(S/5.5)}{(PE/50)^2}\right]$$

while Equation 5, for wind erosion emissions of fallow fields is represented by:

$$E = \text{Acres of fallow field} \times 3400 \left[\frac{\left(\frac{e}{50}\right)\left(\frac{s}{15}\right)\left(\frac{f}{25}\right)}{(PE/50)^2}\right]$$

where E = emissions (pounds/yr),

s = soil silt content (%),

S = vehicle speed (mph),

PE = precipitation-evaporation index (see Figure 4-1),

e = surface erodibility (tons/acre-year), and

f = percentage of time wind speed exceeds 12 mph.

An alternative version of the wind erosion equation is given by:

$$E_s = AIKCL'V'$$

where E_s = suspended particulate fraction of wind erosion losses of tilled fields, tons/acre-year,

A = portion of total wind erosion losses that would be measured as suspended particulate, estimated to be 0.025,

I = soil erodibility, tons/acre-year,

K = surface roughness factor, dimensionless,

C = climatic factor, dimensionless,

L' = unsheltered field width factor, dimensionless, and

V' = vegetative cover factor, dimensionless.

As an aid in understanding the meaning of this equation, "I" may be thought of as the basic erodibility of a flat, very large, bare field in a climate highly conducive to wind erosion (i.e., high wind speed and temperature with little precipitation), and K, C, L' and V' as reduction factors for a ridged surface, a climate less conducive to wind erosion, smaller-sized fields, and vegetative cover, respectively. A more in-depth explanation of each term is presented in Reference 4.

4.3.5 CONSTRUCTION ACTIVITIES

Construction activity can be divided into residential, industrial and highway construction. A composite emission factor for these categories has been developed which can be multiplied by the total area of active construction to yield an estimation of fugitive construction emissions. The State Highway Department or Department of Public Works should be able to estimate the area (in acres or square miles) of highway and building construction active during a given month of the year. Additional information sources are:

Land Use Commissions

County Engineers

Local Assessors

Construction Associations

Once the active area of construction has been determined, emissions can be estimated using Equation 6 of Table 4-1 which is:

$$E = 1.2 \text{ (active acres)}$$

The emissions in tons per month can be summed for the months during which construction activities occur to obtain yearly emissions.

4.3.6 CATTLE FEED LOTS

Cattle feed lot emissions are of concern to agencies preparing inventories in the Midwest and Great Plain States. Emissions from cattle feed lots are based either on cattle feed lot area or the number of cattle in feed lots (yearly throughput) in the survey area. Personnel at the State Department of Agriculture should be able to provide accurate estimates of the number and size of feed lots in the study area as well as their throughput (number of cattle per year).

Once either of these parameters has been determined, emissions can be estimated using Equation 7 of Table 4-1:

$$E = \frac{1000 \text{ head of cattle}}{\text{yr}} \times 8, \text{ or}$$

$$E = \text{feed lot acres} \times 3$$

where E = emissions in tons/yr.

4.3.7 MISCELLANEOUS SOURCES

Miscellaneous anthropogenic and natural sources of fugitive particulate emissions include blasting and demolition activities, and small industrial process operations such as sawmills, auto body paint shops, wood and stone working operations, small grain elevators, secondary metal, and fertilizer mixing operations that are too small to be classified as point sources. Agencies must prepare their own list of such miscellaneous sources. It is essential that a careful determination be made by the agency as to the magnitude and significance of any of these source activities in the agency's jurisdiction. Emission estimates can then be made on the basis of existing emission factor data for larger point sources, or by extrapolation of emission data from related sources using best engineering judgment. For either method, the agency must establish standard procedures for identifying and inventorying these sources.

4.4 EMISSION CONTROLS

Several methods are used to control emissions from various area sources of fugitive dust. Periodic wet suppression, oiling or the application of chemical stabilizers are methods sometimes used to control unpaved roadway emissions. Paving is, in most cases, the most cost-effective control method and reduces fugitive particulate emissions by an order of magnitude or greater. Fugitive dust emissions from paved roads can be effectively controlled by sweeping, flushing, resurfacing and coating. Agricultural emissions are controlled in some instances using vegetative stabilization, wind brakes and/or wet suppression. Wet suppression and stabilization with chemical binders are methods sometimes used to control emissions in construction areas.[6-8]

Many area emission sources will be partially controlled. In such cases engineering judgment must be relied upon to estimate the degree of control. An estimate of control efficiency can then be incorporated into the appropriate equation for calculating emissions.

Table 4-1 lists emission rates along with the variables (correction factors) used in computing those factors. The emission rate, E, represents uncontrolled emissions for the given fugitive dust source. To determine controlled emission rates, the agency must estimate the extent to which control is applied. For example, assuming that for county A:

Potential unpaved road emissions = 1000 tons/yr

Percent of total unpaved roadway controlled = 10 percent

Control efficiency = 70 percent

Then:

Controlled Emissions = (Uncontrolled Emissions) (1-XY)

where X = percent of roads controlled and

Y = control efficiency

and Controlled Emissons = (1000) (1 - (0.1) (0.7)) = 930 tons/year

As another example of calculation of emissions from unpaved roads, assume that the following data have been obtained by the agency from the data sources shown in Table 4-2.

EXAMPLE CALCULATION

Emission inventory for: County X

Unpaved Road Data

- Miles	- 210
- Average daily traffic (ADT)	- 700 vehicles/road mile/day
- VMT = Miles of road x ADT	- 210 x 700 = 147,000 VMT/day
- Silt content(s)	- 12 percent
- Average vehicle speed (S)	- 35 mph
- Average vehicle weight (W)	- 2.5 tons
- Dry days per year (d)	- 230 days

Control--10 percent of roads are controlled (70 percent efficiency).

$$E = \frac{VMT}{yr} \left[5.9 \left(\frac{s}{12}\right) \left(\frac{S}{30}\right) \left(\frac{W}{3}\right)^{0.8} \left(\frac{d}{365}\right) \right] (1 - \text{control})$$

$$E = (147{,}000)\ (365) \left[(5.9) \left(\frac{12}{12}\right) \left(\frac{35}{30}\right) \left(\frac{W}{3}\right)^{0.8} \left(\frac{230}{365}\right) \right] \ 1 - (0.10)\ (0.70)$$

$$= 187{,}060{,}428 \text{ pounds per year } (93{,}530 \text{ tons per year})$$

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5.0 VOLATILE ORGANIC COMPOUND (VOC) SOURCES

5.1 INTRODUCTION

This category includes operations/industries such as gasoline marketing, dry cleaning, numerous types of surface coating, degreasing, pesticide use, cutback asphalt, and solvents in household products.

This section presents general procedures for inventorying VOC sources and provides specific guidance on the eight major categories of evaporative VOC sources listed in Table 5-1. All area sources in these evaporative VOC categories must be inventoried. However, the number of subcategories an agency chooses to include in its inventory will depend on the needs of the agency and inventory users. Special attention should be given to those subcategories which are covered by existing or proposed regulations; e.g., ozone State Implementation Plans[1].

Each area source category listed in Table 5-1 will be described in more detail later in this section. In some of these source categories, all of the sources will meet the agency's definition of an area source. However, other area source categories may include sources already in the point source inventory file. Emissions from sources in the point source file must be subtracted from the area source emission estimate to avoid "double-counting" these facilities.

Additional sources of areawide VOC emissions not shown in Table 5-1. include the fuel combustion and solid waste categories discussed previously. Mobile source emissions of VOC, generally the largest VOC emitting category (see Table 1-2), are fully treated in Volume IV and are not addressed in this volume.

5.2 GENERAL PROCEDURES

Five general procedures for inventorying evaporative VOC area source categories are available. Each approach has distinct advantages and disadvantages when inventorying area sources. The five procedures are (1) use of point source inventorying methods, (2) use of local activity level data, (3) apportioning state or national data, (4) per capita emission factors, and (5) emissions-per-employee factors.[2]

5.2.1 USE OF POINT SOURCE INVENTORYING METHODS

There are several reasons for using point source methods to inventory small sources that are maintained in the area source inventory. First, there may be only a few sources within the geographical area being inventoried, making it practical to inventory each source individually. Second, it may be very difficult to correlate available activity level data for the sources to their evaporative VOC emissions. Some bulk gasoline storage plants are a good

TABLE 5-1. EVAPORATIVE VOC AREA SOURCE CATEGORIES

Source category	Emissions[a]	Procedure recommended
Petroleum marketing	5	Use local activity level data Point source methods
Tank truck unloading Vehicle fueling Storage tank losses Tank truck transit losses		
Degreasing	5	Point source methods Survey Emissions per employee
Dry cleaning	2	Survey Per capita emission factor
Surface coating	10	Use local activity level data Survey Per capita emission factor
Industrial Nonindustrial Architectural coating Auto body refinishing		
Graphic arts	2	Per capita emission factor
Commercial/consumer solvent use	5	Per capita emission factor
Cutback asphalt	1	Local activity level data
Pesticides	1	Local activity level data Apportion statewide data

[a]Emissions are indicated by an approximate relative scale. Ten is the category with largest VOC emissions, 1 is the category(ies) with smallest emissions, and the remaining numbers indicate the relative quantities of emissions on a linear scale. The ratings are based on information contained in References 2-4.

example of small sources (emissions of about 10 to 70 tons/yr) that are small in number and can readily be inventoried individually. The available activity level indicator for the source category is gasoline sales which cannot be easily correlated to the amount of gasoline throughput required to calculate emissions for bulk plants. Therefore, agencies should contact the bulk plants individually to obtain gasoline throughput data.

Another reason for using point source methods would be the availability of sufficient data on individual small sources to directly calculate VOC emissions. For example, records may be available from another agency which show the location and amount of solvent handled by each dry cleaner within the inventory area. At this point, the agency may decide whether an individual point source record will be coded and maintained for each facility or whether the resulting individual activity levels and emission estimates will be collectively handled in the area source inventory.

Direct plant contact is also the best way to identify the type of VOC used by a facility. Because many solvents, particularly those used for degreasing,[4] are considered nonreactive under atmospheric conditions, the agency will want to identify those solvents and maintain them separately within the inventory.

5.2.2 USE OF LOCAL ACTIVITY LEVEL DATA

Sometimes, local surveys have been performed that provide activity level data. For example, local trade associations may have data on the amount and types of architectural surface coating, or the amount and types of dry cleaning or degreasing solvents used in an area. Tax, highway, and energy departments or other state or local agency records may provide activity level estimates for other area source categories, including gasoline sales or cutback asphalt use. Hence, the inventorying agency should survey various local trade associations and agencies to determine the availability of information that can be used for compiling an inventory of area sources.

5.2.3 APPORTIONING STATE OR NATIONAL DATA

If local data are not available, state or national data can be apportioned to local areas. This may be done by indicators such as population, number of employees or number of facilities. For example, if pesticide application data are available only on a statewide basis from the agricultural department, this data could be apportioned to counties by the number of acres of agricultural land or the number of agricultural employees.

Major drawbacks of this approach are that additional data and resources are needed to apportion activity level estimates to the local level, and accuracy is lost in the process. If state and local data are not available, then national data may have to be apportioned to the local inventory area. Apportioning national data to the local level is less accurate than most available methods and should be done only when absolutely necessary.

The National Air Data Branch of EPA uses state and national totals from various available publications to estimate area source emissions at the county level for NEDS. Those interested in obtaining NEDS emission estimates for particular area sources in specific counties should contact their EPA Regional Office or the National Air Data Branch, MD-14, U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. There are only two evaporative area source emission categories in NEDS: solvent purchased and gasoline marketing. The NEDS area source estimates will not be as reliable and as useful as estimates made by an agency using locale-specific information and a much more extensive number of VOC categories.

5.2.4 PER CAPITA EMISSION FACTORS

Population per capita emission factors can be applied to some area source categories that cannot be inventoried using one of the above procedures. As an example, solvent evaporation from consumer and commercial products, such as waxes, aerosol products and window cleaners, cannot be routinely determined by the local agency from any local sources, nor will surveys generally yield such information. The use of per capita factors is based on the assumption that, in a given area, emissions can be reasonably associated with population. This assumption is valid over broad areas for certain activities such as drycleaning, architectural surface coating, and solvent evaporation from household and commercial products. Per capita factors should not be developed and used indiscriminately for sources whose emissions do not correlate well with population.

5.2.5 EMISSIONS-PER-EMPLOYEE FACTORS

This procedure is similar to using population per capita emission factors, except that emissions are correlated to the number of employees in the source category. Emissions-per-employee factors are usually used to estimate emissions from small industrial source categories for which an SIC code has been assigned and for which employment data (typically by SIC) at the local level are available. Because many facilities within the industrial classifications of interest will be point sources of VOC emissions, it will be possible to develop emissions-per-employee factors by SIC from data in the point source inventory, to account for emissions from small area sources. This approach may also be used where the agency surveys a fraction of the area sources within a given category. In this case, employment is used as an indicator to "scale up" the inventory to account collectively for missing sources and emissions in the area source file. Parameters other than employment, such as sales data or number of facilities, can be used to develop emission estimates.[3] However, employment is generally the most readily available parameter.

5.3 SPECIFIC METHODS AND TECHNIQUES

Specific methods and techniques for inventorying eight major evaporative VOC area source categories are presented below. These source categories

include most but not all possible VOC sources. The inventorying agency should inventory all area sources categories that may have significant VOC emissions by applying the methods and techniques discussed in this chapter.

5.3.1 PETROLEUM LIQUIDS MARKETING AND STORAGE

The petroleum liquids marketing and storage area source category must be carefully separated from the point source category of the same name. The area source category usually covers VOC emissions from tank truck unloading and service station operations; while bulk plants may be included under either an area or a point source category. Gasoline is the petroleum liquid of primary concern; however, aviation and marine fuels should also be considered. Diesel fuel is not usually included because of its low volatility. The relative magnitude of emissions from the marketing of gasoline is given in Table 5-2. Emission factors for VOCs from gasoline loading operations and other petroleum products are given in Section 4.4 of AP-42.[5]

TABLE 5-2. GASOLINE MARKETING AND STORAGE

Emission point	Emission factor,[a] $lb/10^3$ gal
Filling underground tank	
Splash fill	11.5
Submerged fill	7.3
Stage I	0.3
Tank breathing losses	1.0
Vehicle refueling	9.0
With Stage II	0.9
Spillage	0.7

[a]The user should refer to the current edition of AP-42 to ensure the use of the most up-to-date emission factors.

Source: Reference 5, AP-42, Table 4.4-4.

Gasoline can be purchased from service stations, auto repair garages, parking garages, convenience stores, and similar types of businesses. In addition, gasoline may be distributed to vehicles through various nonretail outlets. Because outlets other than service stations account for roughly a

quarter of all gasoline handled, care should be taken they are covered in the area source inventory.[6,7]

The method for determining emissions from petroleum liquid (gasoline) marketing and storage is as follows:

1. Determine quantity of gasoline sold from tax data or transportation planning agency data.

2. Determine the quantity of gasoline distributed through nonretail outlets from local survey data, or use 30 percent of the quantity of gasoline sold.[6,7]

3. Sum 1 and 2 to obtain total gasoline distributed.

4. Determine the percent of service stations equipped with submerged fill underground storage tanks from local survey data, or use a value of 90 percent, as suggested by recent studies.[8-11]

5. Consider whether Stage I and II vapor controls for tank and vehicle filling, respectively, are required and, if so, determine the percent of facilities with vapor control equipment installed and operating.

6. Based on gasoline throughput determined in steps 1 and 2, above, and emission factors in Table 5-2; determine VOC emissions from tank truck unloading, tank breathing losses, vehicle refueling and spillage.

The emission factors shown in Table 5-2 are AP-42 emission factors. Because they are subject to revision, the agency should check with EPA before using them to determine emissions from petroleum marketing. They are shown here to illustrate the emission estimation procedure presented below.

From local activity level data and survey data determine:

Retail Gasoline:	Retail gasoline consumption (10^3 gal/yr).
Nonretail Gasoline:	Nonretail gasoline consumption (10^3 gal/yr).
Submerged Fill:	Proportion of service stations equipped with submerged fill storage tanks (convert from percent).
Splash Fill:	Proportion of service stations <u>not</u> equipped with submerged fill or Stage I equipment.

Stage I:	Proportion of service stations equipped with Stage I control equipment.
Stage II:	Proportion of service stations equipped with Stage II control equipment.
Bulk Plant:	Bulk Plant throughput, 10^3 gal/yr.

The following equations apply:

Tank Truck Unloading Loss, lb/yr	= (Nonretail gasoline + retail gasoline) (Submerged Fill x 7.3 + Splash Fill x 11.5 + Stage I x 0.3).
Tank Breathing Loss, lb/yr	= (Nonretail gasoline + retail gasoline) x 1.0.
Vehicle Refueling Loss, lb/yr	= (Nonretail gasoline + retail gasoline) [(1-Stage II) x 9 + Stage II x 0.9].
Spillage Loss, lb/yr	= (Nonretail gasoline + retail gasoline) x (0.7).

Area source VOC emissions from other petroleum liquids may be determined using the above method and emission factors provided in Chapter 4.4 of AP-42.

5.3.2 DRY CLEANING

Virtually all commercial and self-service dry cleaning facilities are area sources. Industrial dry cleaning facilities may be either point or area sources. Dry cleaners emit one of three types of solvents: perchloroethylene (70 percent of dry cleaning emissions), petroleum distillates or Stoddard solvent (30 percent of emissions) or trichlorotrifluoroethane (negligible).[12,13] There are several methods of inventorying dry cleaning emissions; two widely applicable methods are given below.

Method 1 -

1. Send survey forms to a representative sample of dry cleaners taken from the yellow pages of telephone directories. The data to be collected are: number of employees, quantity of clothes cleaned (ton/yr), type and the net amount of solvent used (solvent purchased minuts solvent returned for recycle), and normal operating schedule. Assume that all of the solvent used is emitted, and check the survey values with emissions calculated as the product of the AP-42 emission factors and the quantity of clothes cleaned.

2. Project calculated emissions to the dry cleaning area source category by either the number of nonpoint source employees in SICs 7215, 7216, and 7218 (from County Business Patterns)[14] or by number of area source facilities.

Method 2 -

A less accurate method requiring less resources is to use per capita emission factors as follows:[13]

0.36 lb Stoddard/capita-yr from commercial plants

0.84 lb perchloroethylene/capita-yr from commercial plants

0.30 lb perchloroethylene/capita-yr from self service facilities

For this method, it is necessary to subtract out any emissions included in the point source inventory.

5.3.3 DEGREASING (SOLVENT CLEANING OPERATIONS)

There are basically three types of degreasers: small cold cleaners, open top vapor degreasers, and conveyorized degreasers. According to recent estimates, there are about 1,300,000 small cold cleaning units operating in the U.S. Seventy percent of these units are devoted to maintenance of servicing operations, including service stations, auto dealerships, and miscellaneous repair stations, while the remaining 30 percent are devoted to manufacturing operations. A typical cold cleaning unit emits approximately one third metric ton of VOC per year. In contrast, typical open top vapor degreasers and conveyorized degreasing units emit, respectively, 10 and 27 metric tons of VOC per year. These larger units are commonly used in the metal working industry. The design and operation of each of these types of degreasers will vary, as will emissions and the types of control measures used. References 12 and 15 should be consulted for detailed descriptions of processes and emissions from degreasing units.

A broad spectrum of organic liquids including petroleum distillates (special naphthas), chlorinated hydrocarbons, ketones and alcohols are used in solvent cleaning operations. Development of degreasing emission estimates is complicated by a number of factors. First, some degreasers are large enough to be considered point sources, and yet, a large fraction of all degreasers will fall below any reasonable point source cutoff and thus must be accounted for as area sources. Second, degreasing operations are not associated with any particular industrial activity. Instead, degreasing of some sort may be carried out in a wide variety of industries, including (1) metal working facilities (e.g., automotive, electronics, appliances, furniture, jewelry, plumbing, aircraft, refrigeration, business machinery, fasteners), (2) nonmetal working facilities (printing, chemicals, plastics, rubber, textiles, glass, paper, electric power), (3) maintenance cleaning operations (electric motors, fork lift trucks, printing presses), and (4) repair shops (automobile, railroad, bus, aircraft, truck, electric tool). Third, the practice of solvent waste reprocessing at some degreasing facilities complicates the use of material balance estimates of solvent loss. Fourth, the fact that some of the VOC emissions associated with degreasing occurs at the solvent waste disposal site complicates the location of emissions within the inventory

area. Fifth, many of the solvents used for degreasing are considered photochemically nonreactive, and hence, must be excluded from an inventory of reactive VOC emissions.[4,15] Reactivity is defined as a measure of the rate and extent with which a VOC will react in the presence of sunlight and nitrogen oxides to form photochemical oxidants. The nonreactive VOCs are:[2]

Methane
Ethane
1,1,1-Trichloroethane (methyl chloroform)
Methylene chloride
Trichlorofluoromethane (CFC 11)
Dichlorodifluoromethane (CFC 12)
Chlorodifluoromethane (CFC 22)
Trifluoromethane (FC 23)
Trichlorotrifluoroethane (CFC 113)
Dichlorotetrafluoroethane (CFC 114)
Chloropentafluoroethane (CFC 115)

Open top vapor (OTV) cleaners and conveyorized cleaners should be included in the point source inventory whenever possible. These types of equipment tend to be associated with industrial plants that are already included in the point source inventory. Cold cleaners are smaller and will be included primarily in the inventory of area sources. For open top vapor and conveyorized cleaners that are not included in the point source, one of the following methods may be used to project emissions for the category.

Method 1 -

Survey a sample population of facilities in SIC codes 25, 28, 30 and 33 through 39. The relative magnitude of VOC emission by SIC category is shown in Table 5-3. The survey should establish the number of each type of equipment operated; quantity and type of solvent consumed; operating schedule; waste solvent disposal method; and number of employees at the facility. (The inclusion or exclusion of exempt solvent will be a decision of the agency based on the purpose of the inventory.) Calculate an emissions per employee or emissions per facility factor for each SIC code. Multiply these factors by either the number of employees or the number of facilities in each SIC - in each county (from County Business Patterns).[14] Point source emissions are subtracted from the calculated total emissions.

Method 2 -

Instead of establishing a sample population through a survey, the data on OTV and conveyorized cleaners in the point source inventory can be used. The point source data could be used to establish emissions per employee factors for each SIC code. County Business Patterns data is used to project the area source category emissions. This method may produce high estimates due to the

TABLE 5-3. SOLVENT CLEANING EMISSIONS BY SIC CATEGORY[a]

SIC	Group	Release emissions
25	Furniture and Fixtures	1
28	Chemicals and Allied Products	1
30	Rubber and Miscellaneous Plastic Products	1
33	Primary Metal Industry	9
34	Fabricated Metal Products	8
35	Machinery, Except Electric	10
36	Electric and Electronic Equipment	6
37	Transportation Equipment	1
38	Instruments and Related Products	1
39	Miscellaneous Manufacturing	1
75	Auto Repair, Services and Garages	2

[a]Includes point and area source category emissions.

[b]Emissions are indicated by an approximate relative linear scale from 1 to 10; 1 indicating the least emissions and 10 the most.

Source: Reference 16.

potential bias of using data only from facilities large enough to be included in the point source category. All point source emissions should be subtracted from the area source projection.

VOC emissions from cold cleaners can be inventoried either by using Method 1 (SIC 75 should be added) above, or through a per capita estimation procedure. A 3 lb/capita-yr emission factor is used for a reactive VOC emission inventory.[13] Cold cleaner emissions that are in the point source inventory are subtracted out. Total VOC emissions are approximately 4 lb/capita-yr of which 25 percent are 1,1,1-trichloroethane, methylene chloride, and trichlorotrifluoroethane.[15]

5.3.4 SURFACE COATING

Surface coating operations can be separated into two groups, industrial and nonindustrial. Industrial surface coating operations for such products as appliances, automobiles, paper, fabric and cans are usually point sources of volatile organic compounds, although small area sources do exist. Because there are no reliable area source inventory techniques for small industrial surface coating operations, the agency should try to include as many sources as possible in the point source inventory.[2] Nonindustrial surface coating includes refinishing of automobiles and architectural coatings which are better inventoried as area sources.

Architectural surface coatings (trade paints) are primarily used by painting contractors and home owners. Sales and distribution data from wholesale and retail suppliers of solvent-borne paints, varnishes and other surface coatings provide the most accurate activity level data. Distributors should be contacted directly, either through questionnaires or a telephone survey. Necessary information includes quantities of solvent-borne and water-borne coatings sold; and the average solvent content of each type of coating sold. Also the quantity of thinning and cleaning solvents and their densities should be obtained. To convert gallons (volume) of solvent to pounds (mass), densities of 6.5 and 8.6 lb/gal may be assumed for solvent-borne and water-borne coatings, respectively. A density of 7.0 lb/gal may be assumed for thinning solvents. In the absence of solvent content data for coatings, solvent-borne and water-borne coatings may be assumed to be 54 and 8 percent solvent by weight, respectively.[17] However, solvent contents of coatings vary greatly, and local data should be used if available. It is assumed that all solvent in the coatings evaporates upon application. An alternative method for estimating emissions that can be used in the absence of local data, is the application of a national activity level factor of 4.6 lb/capita-yr.[13] Thinning and cleanup emissions are included in this factor.

One approach to inventorying automobile refinishing emissions is to use an emissions-per-employee factor and to apply it to the number of employees in SICs 7531 and 7535. Based on nationwide estimates of solvent loss from automobile refinishing and employment in these two SICs, an average factor of

2.6 ton/employee-year may be applied as an estimate of auto body shop emissions in the area.[18] Employment by SIC code is available at county levels in County Business Patterns.[14]

An alternative is to use a per capita emission factor of 1.9 lb/capita/year.[4] Because auto body refinishing may be generally expected to relate to human activity, such a population based approach will provide reasonable emission estimates. All VOC emissions from auto body refinishing are reactive.[2]

5.3.5 GRAPHIC ARTS

The graphic arts or printing industry consists of approximately 40,000 facilities. About half of these establishments are inhouse printing services in nonprinting industries. Printing of newspapers, books, magazines, fabrics, wall coverings, and other materials is considered to be a graphic arts application.

An emission factor of 0.8 lb/capita/year is recommended for estimating VOC emissions from small graphic arts facilities which emit less than 100 tons per year. Graphic arts facilities which emit more than 100 tons of VOC per year are excluded from this factor and are inventoried by point source procedures. However, emissions from point sources emitting less than 100 ton per year must be subtracted from the per capita derived emission totals.[13] All VOC emissions from this industry are considered reactive.[2]

5.3.6 COMMERCIAL/CONSUMER SOLVENT USE

Certain commercial/consumer uses of products containing VOC are not easily quantified using questionnaires, surveys or other inventory procedures yielding locale-specific emission estimates. Thus, a factor of 6.3 lb/capita/year is recommended for estimating reactive VOC emissions from this category.[2] This factor includes the following commercial/consumer subcategories:

	Reactive VOC
Household products	2.0 lb/capita/year
Toiletries	1.4 lb/capita/year
Aerosol products	0.8 lb/capita/year
Rubbing compounds	0.6 lb/capita/year
Windshield washing	3.4 lb/capita/year
Polishes and waxes	0.3 lb/capita/year
Nonindustrial adhesives	0.3 lb/capita/year

Space deoderants	0.2 lb/capita/year
Moth control	0.1 lb/capita/year
Laundry treatment	0.1 lb/capita/year
Total	6.3 lb/capita/year

These factors are based on national estimates of solvent use in each of these end use categories. Speciation data are available in references 4 and 19. The major organic materials comprising this 6.3 lb/capita/year factor are special naphthas, alcohols, carbonyls and various other organics. Nonreactive halogenated compounds used in aerosols and other products are excluded from this factor.

It should not be inferred that the commercial/consumer factor is a catchall estimate to account for deficiencies in point source or area source inventories. Specifically, the factor does not include: small cold cleaning degreasing operations; dry cleaning plants; auto refinishing shops; architectural surface coating applications; graphic art plants; cutback asphalt applications; and pesticides not used for home and garden applications. These categories must be inventoried by point or area source procedures and be tabulated separately.

5.3.7 CUTBACK ASPHALT PAVING

Cutback asphalt is a type of liquified road surface that is prepared by blending or "cutting back" asphalt cement with various kinds of petroleum distillates. VOCs are emitted to the atmosphere as the cutback asphalt cures and as the petroleum distillate, used as the diluent, evaporates. The diluent content of cutbacks ranges from 25 to 45 percent by volume, averaging 35 percent. Gasoline or naphtha is used as the diluent in "rapid cure" cutback (RC), kerosene is used in "medium cure" cutback (MC), and low volatility fuel oil type solvents are used in "slow cure" road oils (SC).[20]

The two major variables affecting both the quantity of VOC emitted and the time over which emissions occur are (1) the type and (2) the quantity of petroleum distillate used as diluent. As an approximation, long term emissions from cutback asphalts can be estimated by assuming that 95 percent of the diluent evaporates from rapid cure cutback asphalts, 70 percent from medium cure (MC) cutbacks, and about 25 percent from slow cure asphalts, by weight percent. These percentages are applicable in estimating emissions occuring during the ozone season. Some of the diluent appears to be retained permanently in the road surface after application.[20]

Because the use of cutback asphalts varies so much from area to area, local records should be accessed to determine usage in the area of concern. Data should be obtained from the state or local highway department or highway contractors on the quantity of each type of cutback applied, as well as the diluent content of each. From these data, the equations or tables of

AP-42[5] can be used to compute long term solvent evaporation. If the diluent content is not known by the local highway department personnel, default values of 25, 35, and 45 percent can be assumed for slow cure, medium cure, and rapid cure cutbacks, respectively.

5.3.8 PESTICIDES

Pesticides broadly include any substances used to kill or retard the growth of insects, rodents, fungi, weeds, or microorganisms. Pesticides fall into three basic categories: synthetics, nonsynthetics (petroleum products), and inorganics.

Formulations are commonly made by combining synthetic pesticides with various petroleum products. The synthetic pest killing compounds in such formulations are labeled as "active" ingredients, and the petroleum product solvents acting as vehicles for the active ingredients are labeled "inert." Neither of these toxicological designations should be interpreted as indicators of photochemical reactivity. Inorganic pesticides are not of interest in the inventory, since they contain no organic fraction.[21,22]

Local, state and federal departments of agriculture (including branches concerned with forest pests control) should be contacted to determine the quantities and types of pesticides applied within the inventory area. The quantity of inorganics, should first be eliminated from the above total. Then, as a crude estimate, the remaining synthetic and nonsynthetic total should be multiplied by a factor of 0.9 to estimate the amount that evaporates and can be considered photochemically-reactive VOC.[22]

Pesticide application in agricultural areas may range from 2 to 5 lb/yr-harvested acre.[20] This use includes both synthetic and nonsynthetic material in the pesticide formulation. These factors should be applied as a check on the figures determined from local sources.

Pesticide use for nonagricultural applications should be determined by contacting appropriate state or local agencies, including local public health departments, parks departments, highway departments, or private concerns such as utilities, exterminators, and landscapers. These groups will know the extent of pesticide application for insect control and weed killing, in addition to that used in agricultural applications. The same types of data are obtained and the same procedures followed for estimating evaporative VOC as are suggested for agricultural pesticides. Commercial/consumer pesticide use is quantified under the subcategory headings of household products and moth control in Section 5.3.6. Commercial/consumer pesticide usage is reported to be less than 0.25 lb/capita/year.[2]

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6.0 PRESENTATION OF AREA SOURCE EMISSION INVENTORIES

6.1 INTRODUCTION

Area sources, as previously defined, are those stationary facilities too small, and/or too numerous to be surveyed individually. Emission inventory data on these sources are obtained, recorded and presented on a collective basis. Source categories, not individual sources, are therefore the level of concern when reporting emission data. The major area source categories have been discussed in Chapters 2 through 5 of this volume. For data handling and evaluation purposes, these categories are often further subdivided according to the origin of the areawide emissions. Fugitive dust emissions, for example, can be attributed to subcategories such as agricultural activity, construction activity, unpaved roads or natural sources. Specific data presentation techniques will utilize these subcategories in displaying emission levels. Most of the methods of data presentation discussed in Volume I, Chapter 6, are useful in presenting area source data. However, specific techniques that relate the inventory area (county, AQCR, SMSA) to emissions from area source categories type and the pollutant(s) of concern are provided in this section. The specific uses of the emission inventory will determine the data maintained in the file and the focus of data presentation.

6.2 SPECIFIC PRESENTATION TECHNIQUES

Tabulated summaries are the most common method of presenting area source data. Examples of this technique for various area source category/pollutant combinations are presented in Tables 6-1 through 6-4. Table 6-1 is a statewide inventory summary of area and mobile source emissions. Major area source categories are broken down into several subcategories. Overall, this table indicates the source of each pollutant and identifies the level of contribution of each category to emissions. This type of presentation is not only informative to the general public, but is also useful to air quality planners and management by indicating where resources should be concentrated. Table 6-2 presents more specific area source data. These data are only for one AQCR and only for emissions from one subcategory, commercial-institutional incinerators. By displaying emissions on a county basis, this summary facilitates comparisons between counties and identifies potential problem areas associated with incineration. Table 6-3 demonstrates another use of the tabulated summary. This list of reactive organic emissions in an urban area was made to note relative changes in these emissions during the summer months. This type of comparison is useful for pollutants which may exhibit a seasonal variance in emissions due to temperature and/or activity level changes. Table 6-4 illustrates the use of summary tables for comparing base year emissions with projected emissions. Emission projections are made assuming no additional controls (Column 2) and assuming additional regulatory controls adopted as part of the SIP (Column 3).

TABLE 6-1. STATE OF NEW HAMPSHIRE 1985 AREA SOURCE POLLUTANT EMISSIONS (TONS/YEAR)[a]

	Particulate Matter	Sulfur Oxides	Nitrogen Oxides	Hydro-Carbons	Carbon Monoxide
FUEL COMBUSTION					
Residential					
Anthracite Coal	16	35	5	4	143
Bituminous Coal	0	0	0	0	0
Distillate Oil	276	3,180	1,990	110	552
Natural Gas	21	1	172	17	43
Wood	1,760	106	706	1,410	1,410
Commercial-Institutional					
Bituminous Coal	0	0	0	0	0
Distillate Oil	76	1,100	840	38	191
Residual Oil	39	531	111	2	9
Natural Gas	14	1	173	12	29
Industrial					
Bituminous Coal	161	65	13	1	2
Distillate Oil	64	920	703	32	160
Residual Oil	197	2,680	562	9	47
Natural Gas	8	0	143	2	14
Wood	4,360	262	1,740	3,490	3,490
Total Fuel Combustion	6,990	8,880	7,160	5,120	6,090
TRANSPORTATION					
Highway					
Light-duty	2,000	612	5,300	6,330	28,400
Heavy-duty	649	80	3,250	1,410	20,600
Diesel	429	364	2,990	457	2,560
Off-Highway					
Gasoline	147	77	1,670	4,720	53,500
Diesel	334	299	3,700	406	1,040
Rail	0	0	0	0	0
Vessel					
Gasoline	0	5	20	683	2,170
Diesel	1	1	11	3	4
Aircraft					
Commercial	4	6	61	80	166
Civil	58	11	52	255	1,460
Military	270	51	129	625	671
Total Transportation	3,890	1,510	17,200	15,000	111,000
MISCELLANEOUS					
Evaporative Losses					
Retail Gasoline	0	0	0	5,070	0
Solvent Evaporation	0	0	0	46,700	0
Solid Waste Disposal					
All	309	60	74	458	1,290
Fires and Open Burning					
Structure Fires	194	0	17	50	439
Forest Fires	39	0	9	55	318
Fugitive Emissions					
Dirt Roads	613,000	0	0	0	0
Dirt Airstrips	27	0	0	0	0
Construction	78,600	0	0	0	0
Wind Erosion	68	0	0	0	0
Land Tilling	535	0	0	0	0
Total Miscellaneous	693,000	60	100	52,300	2,050
STATE TOTAL	704,000	10,400	24,500	72,400	119,000

[a]This Table is presented to provide a format example. Data contained herein should not necessarily be considered typical.

Source: Reference 1.

TABLE 6-2. SOLID WASTE COMMERCIAL-INSTITUTIONAL INCINERATION EMISSIONS (TONS/YEAR) IN AQCR 70 FOR 1973[a]

County	Part.	SO_x	NO_x	HC	CO
Missouri					
Franklin	3.21	0.38	0.58	2.57	5.13
Jefferson	6.05	0.73	1.09	4.84	9.67
St. Charles	5.47	0.66	0.98	4.37	8.75
St. Louis	50.00	6.00	9.00	40.00	80.00
St. Louis City	29.86	3.58	5.38	23.89	47.78
Illinois					
Bond	0.74	0.09	0.13	0.59	1.18
Clinton	1.52	0.18	0.27	1.22	2.44
Madison	13.30	1.60	2.40	10.68	21.37
Monroe	0.95	0.11	0.17	0.76	1.51
Randolph	1.63	0.20	0.29	1.30	2.61
St. Clair	15.09	1.81	2.72	12.07	24.14
Washington	0.74	0.09	0.13	0.59	1.18

[a]This Table is presented to provide a format example. Data contained herein should not necessarily be considered typical.

Source: Reference 2

TABLE 6-3. REACTIVE ORGANIC EMISSION, TAMPA BAY[a]

Source Category	Emissions			
	Summer		Annual	
	MT/yr	%	MT/yr	%
Gasoline-powered vehicles	42,400	(61)	41,400	(61)
Exhaust emissions	25,400	37	26,500	39
Evaporative emissions	17,000	24	14,900	22
Solvent evaporative losses	8,800	13	8,800	14
Petroleum product evaporation				
Storage and transport	7,100	1	6,100	1
Gasoline station losses	5,800	9	5,400	8
Petroleum refineries	0	0	0	0
Solid waste disposal	500	1	500	1
Manufacturing	2,700	4	2,700	4
Stationary fuel combustion	700	1	700	1
Carbon black production	0	0	0	0
Aircraft	800	1	800	1
Diesel-powered vehicles	1,400	2	1,400	2
Vessels	3,000	5	3,000	5
Remainder unlisted	1,600	2	1,600	2
Total	74,800	100	72,400	100

[a]This Table is presented to provide a format example. Data contained herein should not necessarily be considered typical.

Source: Reference 3.

TABLE 6-4. SUMMARY TABLE OF REACTIVE VOC EMISSIONS FOR GEOGRAPHICAL AREA[a]

	Base Year		Baseline Projection		SIP Strategy	
	1980		Attainment year		Attainment year	
	Point	Area	Point	Area	Point	Area
STORAGE, TRANSPORTATION AND MARKETING OF VOC						
Oil and Gas Production & Processing						
Gasoline and Crude Oil Storage						
Synthetic Organic Chemical Storage & Transfer						
Ship and Barge Transfer of VOC						
Barge and Tanker Cleaning						
Bulk Gasoline Terminals						
Gasoline Bulk Plants						
Service Station Loading (Stage I)						
Service Station Unloading (Stage II)						
Others (Specify)						
INDUSTRIAL PROCESSES						
Petroleum Refineries						
Lube Oil Manufacture						
Organic Chemical Manufacture						
Inorganic Chemical Manufacture						
Fermentation Processes						
Vegetable Oil Processing						
Pharmaceutical Manufacture						
Plastic Products Manufacture						
Rubber Tire Manufacture						
SBR Rubber Manufacture						
Textile Polymers & Resin Manufacture						
Synthetic Fiber Manufacture						
Iron and Steel Manufacture						
Others (Specify)						
INDUSTRIAL SURFACE COATING						
Large Appliances						
Magnet Wire						
Automobiles						
Cans						
Metal Coils						
Paper						
Fabric						
Metal Wood Products						
Miscellaneous Metal Products						
Plastics Parts Painting						
Large Ships						
Large Aircraft						
Others (Specify)						

(continued)

TABLE 6-4 (continued)

	Base Year		Baseline Projection		SIP Strategy	
	1980		Attainment year		Attainment year	
	Point	Area	Point	Area	Point	Area
NONINDUSTRIAL SURFACE COATING						
Architectural Coatings						
Auto Refinishing						
Others (Specify)						
OTHER SOLVENT USE						
Degreasing						
Dry Cleaning						
Graphic Arts						
Adhesives						
Cutback Asphalt						
Solvent Extraction Processes						
Consumer/Commercial Solvent Use						
Others (Specify)						
OTHER MISCELLANEOUS SOURCES						
Fuel Combustion						
Solid Waste Disposal						
Forest, Agricultural, and Other Open Burning						
Pesticide Application						
Waste Solvent Recovery Processes						
Stationary Internal Combustion Engines						
MOBILE SOURCES						
Highway Vehicles						
Light-Duty Automobiles						
Light-Duty Trucks						
Heavy-Duty Gasoline Trucks						
Heavy-Duty Diesel Trucks						
Motorcycles						
Off-Highway Vehicles						
Rail						
Aircraft						
Vessels						
Total						

[a]Kilograms per day (kg/day) for a typical summer weekday.

Source: Reference 4.

Another common presentation technique is the pie chart, shown in Figure 6-1. Pie charts are useful for presenting data to audiences who do not have the time or the expertise to review large amounts of tabulated data. Pie charts summarize data in a direct manner that facilitates quick comparisons. Referring to Figure 6-1, the reader can quickly see that the fugitive particulate emission problem in this survey area is largely attributable to unpaved roads. This type of graphical display would be especially useful, for example, if the agency is presenting emission data at a public hearing, in support of proposed fugitive emission control regulations. For pie charts, absolute quantities of emissions are not as important as relative amounts.

General display techniques of the type identified in Volume I, Chapter 6, may also be used for area source data. Bar charts, line charts and time series charts can all be used to highlight and present data in various ways. Emission density plots of the type shown in Figure 6-2 are useful for a variety of air quality projects. They can be used to pinpoint area source contributions to local air quality problems, help in siting of ambient monitoring stations and serve as a useful tool in air quality maintenance area planning. Area source density maps, when added to similar overlays for point and mobile source densities, graphically display the relative source contributions to local air quality levels.

Display techniques are frequently used by agencies in presenting and analyzing temporal and spatial emissions variations. A plot of relative temporal activity levels as shown in Figure 6-3. This series of time charts presents the hourly, daily, and seasonal activity of one area source subcategory, agricultural tilling. This type of activity level plot is used to temporally resolve annual emission rates and to correlate activity levels with air quality levels.

Zoning maps are often used to spatially allocate area source emissions to grids. A representative urban zoning map is presented in Figure 6-4. These maps are available from local planning and zoning boards. Fuel use, solid waste disposal, fugitive dust and volatile organic compound emissions are all allocated on the basis of land use. Activity levels are allocated by superimposing the grid (adjusted to the proper scale) onto the zoning map to determine the land area being used for a given purpose (i.e., residential, commercial/institutional, industrial) within each grid square. Grid square emissions per category are then calculated using procedures previously outlined in this volume.

Area source emissions data may be presented in any format that is compatible with the end use of the data. All emission inventory summaries can be limited to one page, and no one technique is necessarily better than another. The compiler of the inventory summary should take into account the environmental awareness of the audience before selecting any specific method.

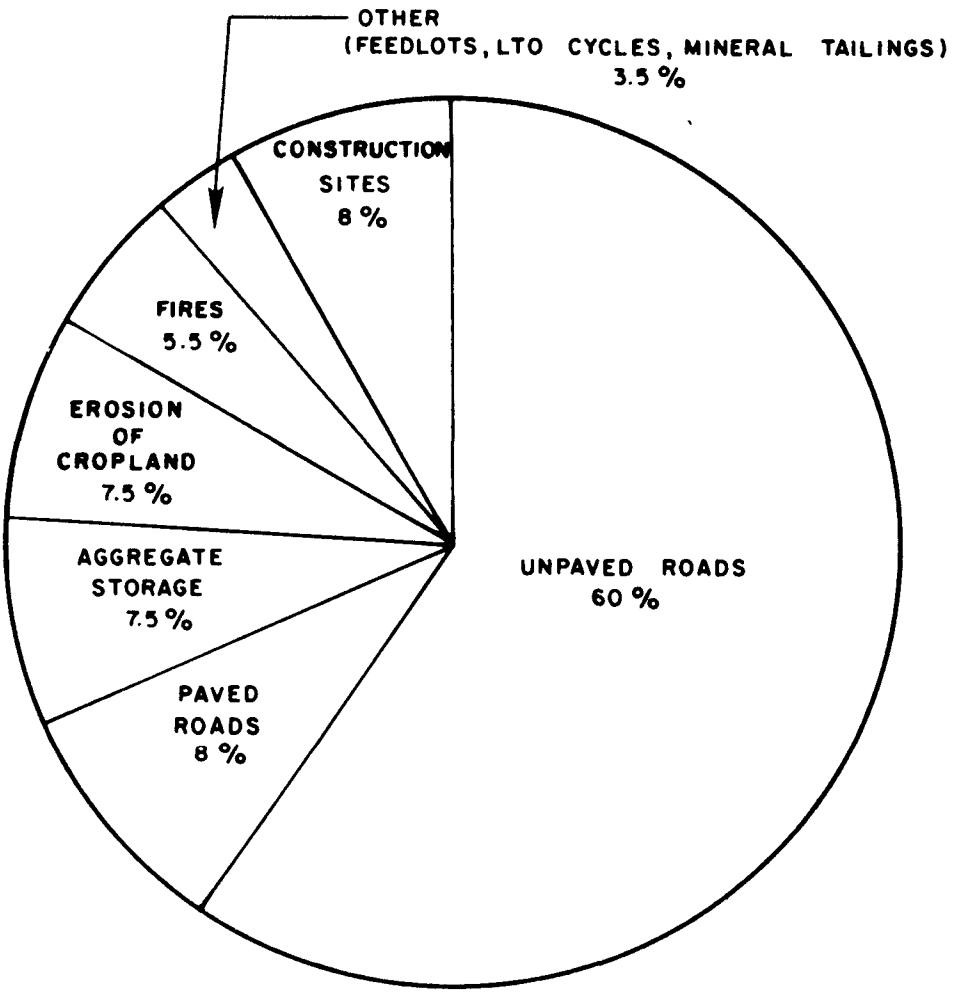


Figure 6-1. The distribution of fugitive particulate emissions in a survey area.

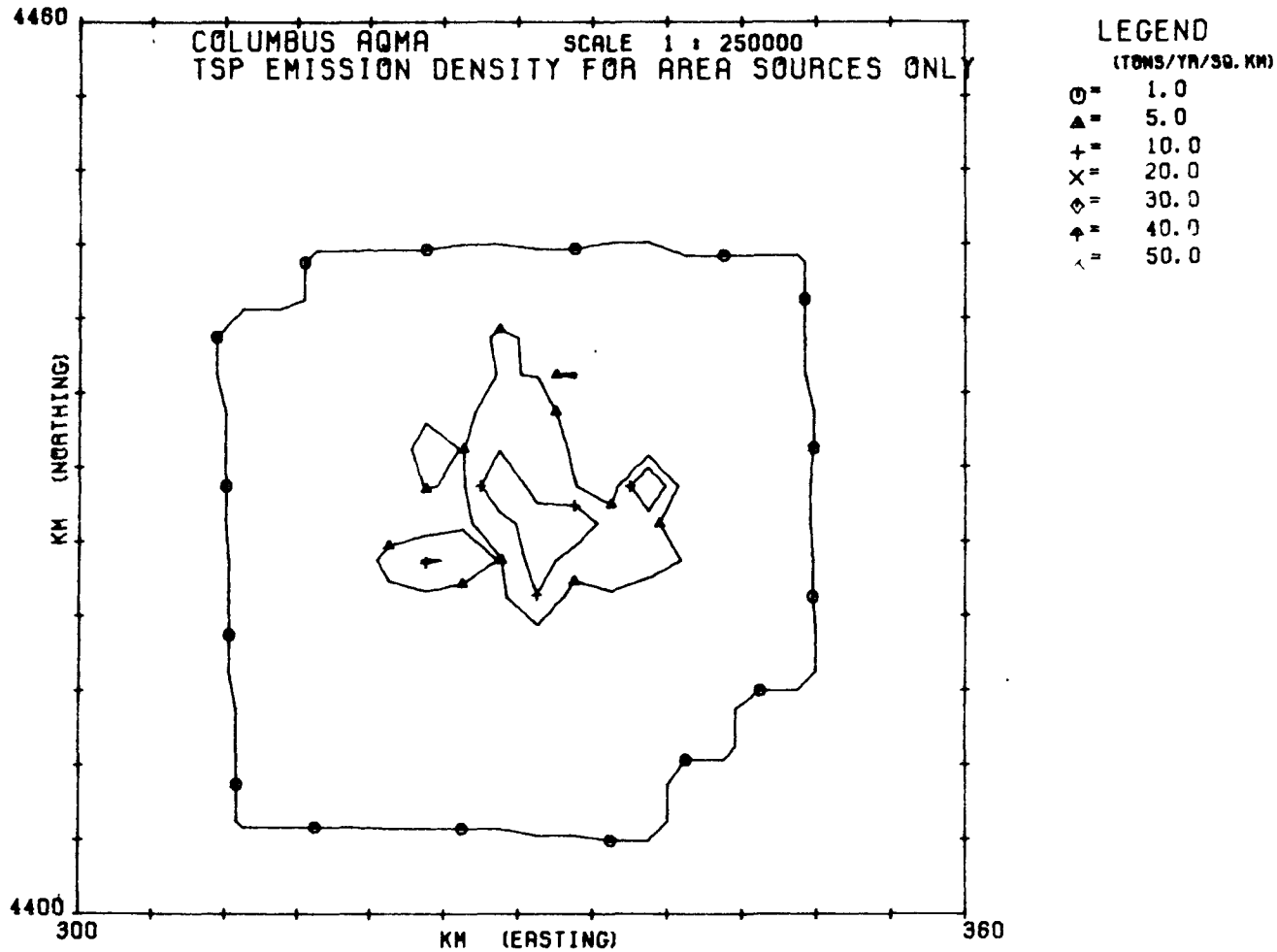
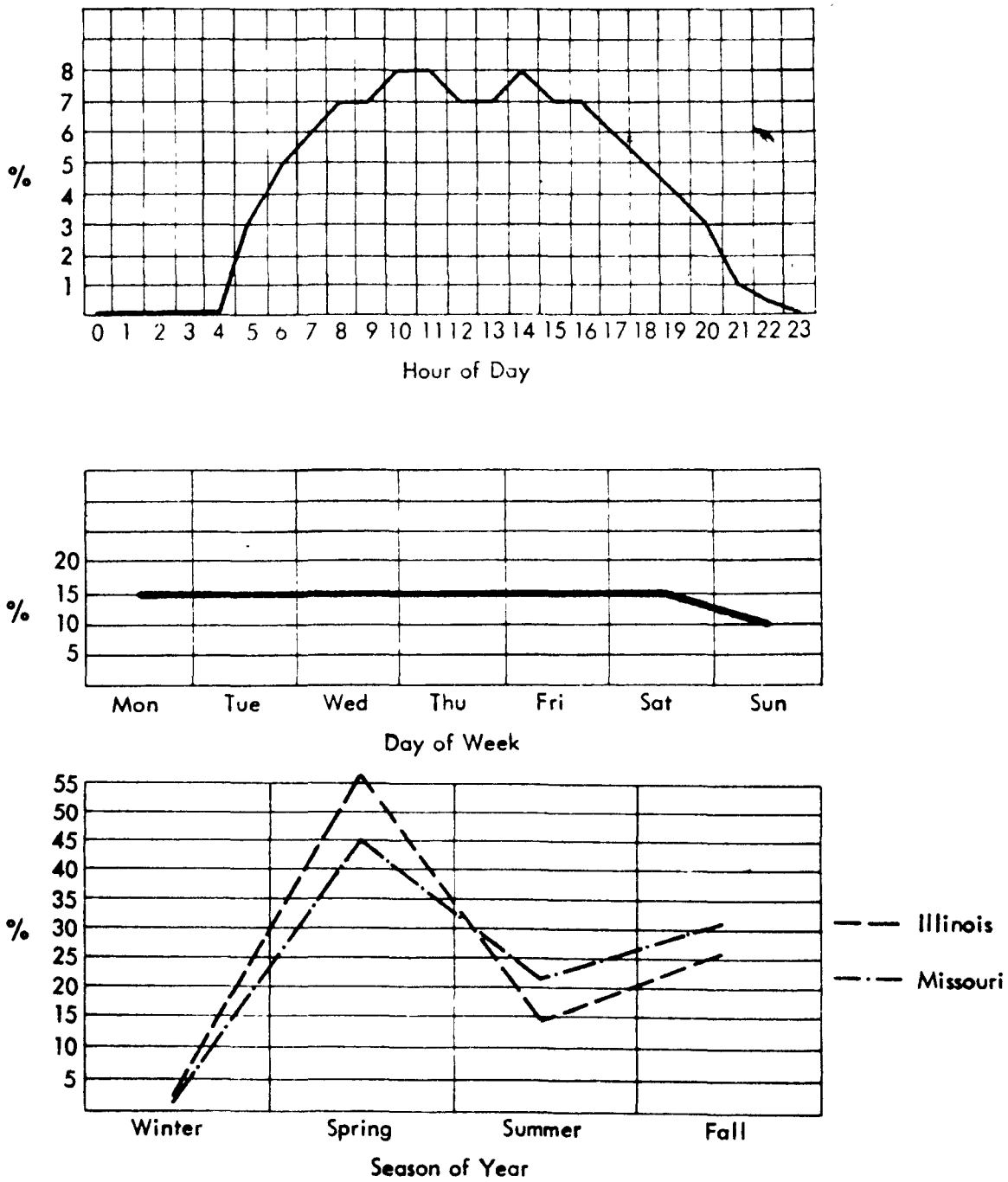


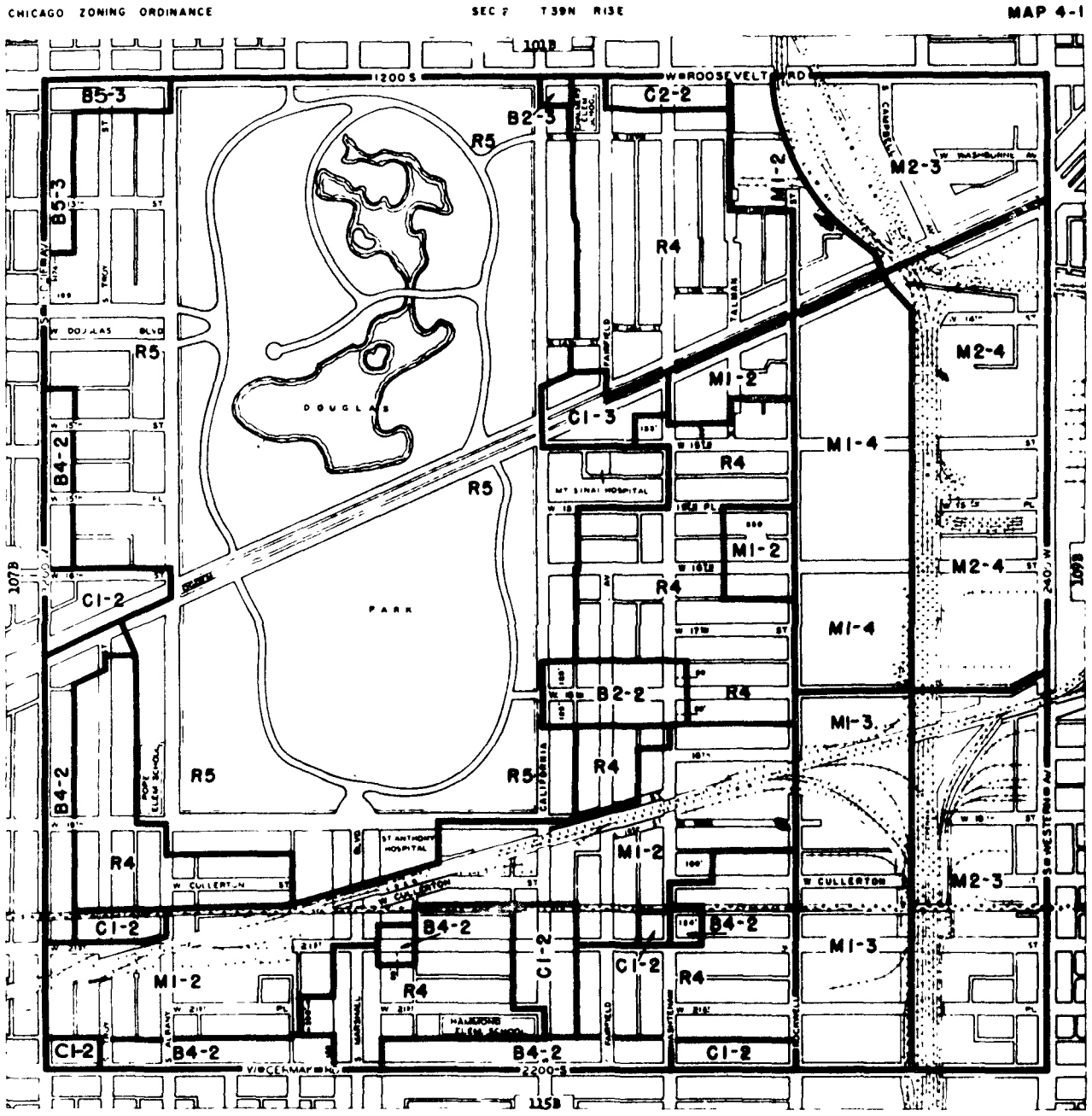
Figure 6-2. Sample emission density plot.[5]

Source Type: Agricultural Tilling



Source: Reference 6.

Figure 6-3. Percentage of total daily, weekly, and annual agricultural tilling.



Source: Reference 5.

Figure 6-4. Example of Complex Zoning (from City of Chicago Zoning Ordinance).

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TECHNICAL REPORT DATA
(Please read Instructions on the reverse before completing)

1. REPORT NO. EPA-450/4-81-026c	2.	3. RECIPIENT'S ACCESSION NO.
4. TITLE AND SUBTITLE Procedures for Emission Inventory Preparation Volume III: Area Sources		5. REPORT DATE September 1981
		6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Monitoring and Data Analysis Division Office of Air Quality Planning and Standards		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS U. S. Environmental Protection Agency Research Triangle Park, NC 27711		10. PROGRAM ELEMENT NO.
		11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS		13. TYPE OF REPORT AND PERIOD COVERED
		14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

EPA Project Officer: A. A. MacQueen

16. ABSTRACT

Procedures are described for compiling the complete comprehensive emission inventory of the criteria pollutants and pollutant sources. These procedures described are for use in the air quality management programs of state and local air pollution control agencies.

Basic emission inventory elements--planning, data collection, emission estimates, inventory file formatting, reporting and maintenance--are described. Prescribed methods are presented; optional methods are provided. The procedures are presented in five (5) volumes:

Volume I, Emission Inventory Fundamentals
Volume II, Point Sources
Volume III, Area Sources
Volume IV, Mobile Sources
Volume V, Bibliography

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Emission Inventory Area Sources Inventory Source Inventory Emissions Source Emissions Files Formatting Questionnaire Air Quality Management		

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS (This Report)	21. NO. OF PAGES 106
	20. SECURITY CLASS (This Page)	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

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