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Biogenic Sources Preferred and Alternative Methods

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emission inventory
improvement program

PREFACE

As a result of the more prominent role given to emission inventories in the 1990 Clean Air Act Amendments (CAAA), inventories are receiving heightened priority and resources from the U.S. Environmental Protection Agency (EPA), state/local agencies, and industry. More than accountings of emission sources, inventory data are now providing the prime basis for operating permit fee systems, State Implementation Plan (SIP) development (including attainment strategy demonstrations), regional air quality dispersion modeling assessments, and control strategy development. This new emphasis on the use of emissions data will require significantly increased effort by state/local agencies to provide adequate, accurate, and transferrable information to meet various agency and regional program needs.

Existing emission inventory data collection, calculation, management, and reporting procedures are not sufficient or of high enough quality to meet all of these needs into the next century. To address these concerns, the Emission Inventory Improvement Program (EIIP) was created. The EIIP is a jointly sponsored endeavor of the State and Territorial Air Pollution Program Administrators/Association of Local Air Pollution Control Officials (STAPPA/ALAPCO) and the U.S. EPA, and is an outgrowth of recommendations put forth by the Standing Air Emissions Work Group (SAEWG) of STAPPA/ALAPCO. The EIIP Steering Committee and technical committees are composed of state/local agency, EPA, industry, consultant, and academic representatives. In general, technical committee participation is open to anyone.

The EIIP is defined as a program to develop and use standard procedures to collect, calculate, store, and report emissions data. Its ultimate goal is to provide cost-effective, reliable, and consistent inventories through the achievement of the following objectives:

- Produce a coordinated system of data measurement/calculation methods as a guide for estimating current and future source emissions;
- Produce consistent quality assurance/quality control (QA/QC) procedures applicable to all phases of all inventory programs;
- Improve the EPA/state/local agency/industry system of data collection, reporting, and transfer; and
- Produce an integrated source data reporting procedure that consolidates the many current reporting requirements;

EIIP goals and objectives are being addressed through the production of seven guidance and methodology volumes. These seven are:

- Volume I: Introduction and Use of EIIP Guidance for Emissions Inventory Development
- Volume II: Point Sources Preferred and Alternative Methods
- Volume III: Area Sources Preferred and Alternative Methods
- Volume IV: Mobile Sources Preferred and Alternative Methods
- Volume V: Biogenics Sources Preferred and Alternative Methods
- Volume VI: Quality Assurance Procedures
- Volume VII: Data Management Procedures

The purpose of each volume is to evaluate the existing guidance on emissions estimation techniques, and, where applicable, to identify the preferred and alternative emission estimation procedures. Another important objective in each volume is to identify gaps in existing methods, and to recommend activities necessary to fill the gaps. The preferred and alternative method findings are summarized in clear, consistent procedures so that both experienced and entry-level inventory personnel can execute them with a reasonable amount of time and effort. Sufficiently detailed references are provided to enable the reader to identify any supplementary information. Users should note that the number of source categories or topics covered in any volume is constantly expanding as a function of EIIP implementation and availability of new information.

It is anticipated that the EIIP materials will become the guidance standard for the emission inventory community. For this reason, the production of EIIP volumes will be a dynamic, iterative process where documents are updated over time as better data and scientific understanding support improved estimation, QA, and data management methods. The number of individual source categories addressed by the guidance will grow as well over time. The EIIP welcomes input and suggestion from all groups and individuals on how the volumes could be improved.

VOLUME V

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BIOGENIC SOURCES PREFERRED METHODS

Final Report

May 1996

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DISCLAIMER

As the Environmental Protection Agency has indicated in Emission Inventory Improvement Program (EIIP) documents, the choice of methods to be used to estimate emissions depends on how the estimates will be used and the degree of accuracy required. Methods using site-specific data are preferred over other methods. These documents are non-binding guidance and not rules. EPA, the States, and others retain the discretion to employ or to require other approaches that meet the requirements of the applicable statutory or regulatory requirements in individual circumstances.

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ABBREVIATIONS AND SYMBOLS

ABBREVIATIONS

BEIS	--Biogenic Emissions Inventory System
BEIS-2	--Biogenic Emissions Inventory System (updated version)
CBM-IV	--Carbon Bond IV Mechanism
EKMA	--Empirical Kinetic Modeling Approach
EPA	--U. S. Environmental Protection Agency
EPS	--Emission Preprocessor System
FIPS	--Federal Information Placement System
NMHC	--nonmethane hydrocarbons
PC	--personal computer
PC-BEIS	--Personal Computer version of BEIS
SIP	--State Implementation Plan
QA/QC	--quality assurance/quality control
UAM	--Urban Airshed Model
UAM BEIS-2 (updated version)	--Urban Airshed Model's Biogenic Emissions Inventory System
VOC	--volatile organic compounds

SYMBOLS

CH_4	--methane
CO	--carbon monoxide
CO_2	--carbon dioxide
N_2O	--nitrous oxide
NH_3	--ammonia
NO	--nitric oxide
NO_2	--nitrogen dioxide
NO_X	--nitrogen oxides
PFC	--perchlorofluorocarbon

1

INTRODUCTION

1.1 BACKGROUND

Natural source emissions can make a significant contribution to total volatile organic compound (VOC) and oxides of nitrogen (NO_x) emissions. Estimating emissions of VOC and NO_x from natural sources is an essential part of preparing an inventory of ozone precursors. This document presents a standard approach to developing biogenic emission estimates for ozone inventories, and VOC and NO_x emission estimates from the natural sources of lightning and oil and gas seeps.

In the past, the impacts of biogenic VOC were not considered when ozone control strategies to limit emissions of either NO_x or VOC were developed. However, the importance of biogenic VOC emissions in an ozone inventory became apparent in some regions when the biogenic VOC emission estimates were compared to the anthropogenic VOC emission estimates (Chameides *et al.*, 1988).

Biogenic emission estimates for the United States have been reported at 30,860,000 tons of VOC per year and 346,000 tons of NO_x per year (Novak *et al.*, 1993). This is in comparison to estimates of 21,090,000 tons of anthropogenic VOC and 23,550,000 tons of anthropogenic NO_x, estimated for 1990 (EPA, 1994). Isoprene, one of the major constituents of biogenic emissions, is very photoreactive, making biogenic emissions an even more important source of VOC. Because of the interaction between NO_x and VOC in terms of atmospheric ozone levels, biogenic emissions should be included in any inventory which will be used to predict or to monitor atmospheric ozone levels. Inclusion of biogenic emissions is essential for photochemical air quality modeling.

Other sources of natural VOC and NO_x emissions, lightning and oil and gas seeps, are currently assumed to be less significant as potential sources, but within a particular area may need to be considered.

1.2 NATURAL SOURCE EMISSIONS VS. BIOGENIC SOURCE EMISSIONS

Natural source air emissions include VOC, NO_x, and greenhouse gases such as methane (CH_4), nitrous oxide (N_2O), ozone (O_3) and carbon dioxide (CO_2). Emission sources for all of these gases are natural processes occurring in vegetation and soils, in marine ecosystems,

as a result of geological activity in the form of geysers or volcanoes, as a result of meteorological activity such as lightning, and from fauna, such as ruminants and termites. Emissions resulting from anthropogenic activities such as those associated with the agriculture industry are also included in this definition; these activities include fertilizer use which triggers emissions from microbial activity, and agricultural biomass burning.

Biogenic sources, a subset of natural sources, include only those sources that result from some sort of biological activity. Biogenic emissions represent a significant portion of the natural source emissions, and VOC, NO_x, and the greenhouse gases discussed above can all be emitted from biogenic sources.

Vegetation is the predominant biogenic source of VOC and is typically the only source that is used to estimate biogenic VOC emissions. Microbial activity is responsible for the emission of NO_x and the greenhouse gases of CO_2, CH_4, and N_2O. Soil microbial activity is responsible for NO_x and N_2O emissions from agricultural lands and grasslands. CH_4 is emitted through microbial action in waterlogged soils or in other anaerobic microenvironments. CO_2 is released through the aerobic decay of biomass (EPA, 1993; EPA, 1990a).

Natural sources that are not biogenic sources include lightning, a source of nitric oxide (NO) and oil and gas seeps, which are sources of VOC, CH_4 and hazardous air pollutants (HAPs). The estimated contributions of these sources may be significant when a modeling domain extends into areas that do not have a high anthropogenic contribution.

2

SOURCE CATEGORY DEFINITION

The goals of this document are to define certain natural sources of ozone precursors (biogenic sources of VOC and NO_x, lightning as a source of NO_x, and natural oil or gas seeps as sources of VOC) and to provide preferred and alternative methodologies for estimating emissions from those sources. The sources of natural ozone precursors that can be estimated are further limited by the practical consideration of which sources have been studied sufficiently to provide a mechanism for emission calculations. The widespread and complex nature of natural sources means that there is considerable uncertainty in the emission estimates from these sources.

2.1 POLLUTANTS AND SOURCES

2.1.1 VOLATILE ORGANIC COMPOUNDS

The dominant natural source of VOC as nonmethane hydrocarbons (NMHC) is vegetation. For the United States, natural source VOC is estimated to be higher than anthropogenic source VOC, and the Southeastern and South Central portions of the United States account for approximately 43 percent of the national natural NMHC estimate. Forests and agriculture contribute the largest share of biogenic VOC (Novak and Pierce, 1993).

Less significant sources of VOC are the geogenic processes of oil and gas seeps. Natural hydrocarbon seeps occur only in certain parts of the United States and would be important to consider as a source category when they are near by.

Biomass burning (i.e., forest fires, burning of agricultural wastes and other prescribed burning) is sometimes included as a natural source of VOC emissions. However, many of the biomass burning processes are anthropogenic activities and, thus, are better grouped with area sources.

2.1.2 OXIDES OF NITROGEN

There are four source categories for natural NO_x emissions: soils, lightning, stratospheric injection, and oceans. All of these processes produce NO, which is oxidized to NO_2 in the presence of ozone or in a photochemically reactive atmosphere. Emissions from soils are the only biogenic source of NO_x.

Soils emit NO_x through biological and abiological pathways, and emission rates can be categorized by land use. Most of the NO_x emitted by soils is in the form of NO. Agricultural lands and grasslands are the most significant emitters within this category. The quantity of NO_x emissions from agricultural land is dependant on the rate of fertilizer application and the subsequent microbial nitrogen processing in the soil. Microbial nitrogen processing occurs naturally in soil, but the rates are greater when soil has been fertilized with chemical fertilizers. Emissions of NO_x from soils are estimated to be as much as 16 percent of the global budget of NO_x in the troposphere, and as much as 8 percent of the NO_x in North America (EPA, 1993).

Lightning converts atmospheric nitrogen and oxygen to NO through extremely high temperatures. Lightning may contribute as much as 14 percent of the global budget of NO_x in the troposphere, and 4 percent of the NO_x in North America (EPA, 1993).

A smaller source of NO in the troposphere is the NO produced through the photodissociation or oxidation of stratospheric N_2O, which then subsides into the troposphere. This source is estimated to contribute only 2 percent of the global budget of NO_x in the troposphere and a minimal proportion of the NO_x in North America (EPA, 1993). Estimating emissions from this source will not be discussed in this volume.

The photolysis of nitrate dissolved in seawater is responsible for NO_x emissions from oceans. Since NO_x has a short lifetime in the atmosphere, this source is not considered to be a significant source for continental areas such as North America. The global contribution of NO_x to the troposphere by oceans is estimated to be 2 percent (EPA, 1993). Estimating emissions from this source will not be discussed in this volume.

An indirect source of NO_x is the oxidation of ammonia (NH_3) which, besides being emitted by anthropogenic sources, is emitted by the decomposition of nitrogenous matter in natural ecosystems and from animal wastes (particularly from dense populations of livestock). The oxidation of NH_3 is estimated to be as much as 8 percent of the global budget of NO_x in the troposphere (EPA, 1993). Estimating emissions from this source will not be discussed in this volume.

3

AVAILABLE METHODS

This section will present the preferred and alternative methods for estimating biogenic VOC and NO_x emissions, NO_x emissions from lightning, and emissions from natural oil and gas seeps.

3.1 METHODS FOR ESTIMATING BIOGENIC EMISSIONS

Air quality modeling studies have highlighted the need to include biogenic emissions of hydrocarbons in the prediction of ground-level ozone. The appropriateness of any estimation method for biogenic emissions will depend on the ultimate use of the emission estimates. Biogenic emission estimation models will typically output emission information in a format specific to an air quality model. The input needs of the air quality models will determine the choice of the biogenic emission estimation model. Other criteria for selection of a method will depend on whether the model or system has land use and emission information that is suitable for the inventory area. These factors will determine the most appropriate method to use for a particular area.

There are three computer models that can be used to estimate biogenic emissions:

- Biogenic Emission Inventory System-2 (BEIS-2), which will estimate speciated VOC and NO_x emissions from vegetation and soils, respectively. BEIS-2 is adapted to be used with the following quality models: Regional Oxidant Model (ROM), the Regional Acid Deposition Model (RADM) and the Urban Airshed Model (UAM).

- The Personal Computer version of the Biogenic Emission Inventory System-2.2 (PCBEIS2.2), estimates speciated VOC from vegetation and NO_x from soils. Output from this model can be used in an inventory report, as text, or in the Empirical Kinetic Modeling Approach (EKMA) model.

- Biogenic Model for Emissions (BIOME), which will estimate speciated VOC from vegetation. Default output from this model can be used with Geocoded Emissions Modeling and Projections (GEMAP) or in an inventory document.

An alternative to the above models involves collecting local information to substitute for defaults in any of the above models. The most commonly used options are more recent or

more detailed land use or meteorological data and updated or additional emission factors and leaf biomass.

In addition to the computer models, there is a method for biogenic NO_x from soils developed by Yienger and Levy (1995) which can be used. This method was developed in order to estimate global soil NO_x emissions, but no computerized version is available at this time. Using this approach will require data collection for the necessary meteorology and land use data, and computing resources for the calculations. If the necessary data and resources are available, then this method should produce the most accurate results.

The BEIS-2 is the preferred method for air quality models using biogenic estimates, because it is the most scientifically advanced model for estimating biogenic ozone precursors. It can be used with several air quality models, and it estimates emissions of soil NO_x, which can be an important source in many rural areas. The PCBEIS2.2 is the preferred method when an emission estimate is needed for reporting purposes only. The BIOME model, the collection of local data for use in any of these models, and BEIS, the precursor of BEIS-2, are alternative methods.

The BEIS-2 is available in several versions that can be used with the ROM, RADM, and UAM models. The different BEIS-2 models are adaptations of the algorithm and land use files to the meteorology and grid cell sizes used in their respective air quality models. The most important issue in the use of a particular version of BEIS-2 is to match the meteorology and gridding to the air quality model that it will be used with. Aside from these differences, the scientific background of the BEIS-2 and PCBEIS2.2 models are the same, and will be discussed below.

BEIS-2 calculates VOC from vegetation and NO_x from soils. Emissions from vegetation are calculated using vegetation types divided into 75 tree genera, 17 agricultural crops, and urban grasses. BEIS-2 calculates three groups of VOC emissions: isoprene, monoterpenes, and other NMHCs for the tree genera types, agricultural crops, and urban grasses (Pierce, 1994a). Further carbon bond speciation can be done through air quality model speciation routines, such as the UAM Emission Preprocessor System (EPS) (EPA, 1990b). The mainframe versions of the BEIS-2, those used for air quality modeling, provide a file of gridded hourly data, which can be converted to input for the particular air quality model for which it was prepared.

Soil emissions of NO_x are dependant on the crop type and fertilization rate (EPA, 1993), and on a multitude of other factors. BEIS-2 calculates emissions of NO_x as NO based on crop type and fertilizer use. Emission factors have also been updated in BEIS-2.

PCBEIS2.2 generates biogenic emissions by county in kilograms per hour for NO_x and each major VOC species: isoprene, monoterpenes, and other NMHCs. Land use files and

emission factors for biogenic VOC and NO_x emissions are the same as those used in BEIS-2. Output files are at a level of detail suitable for use in State Inventory Plans (SIPs) and input into the air quality model EKMA. In addition to these primary uses, PCBEIS2.2 can be used for any application where biogenic VOC and NO_x emission estimates at this level of detail are needed.

The BIOME was developed for the Lake Michigan Ozone Study (LMOS) as the biogenic component of a comprehensive emission modeling system used to estimate emissions for air quality modeling (Mayenkar, 1993). Other approaches have been taken to estimate emissions for Southern California (CARB, 1983 and Nowak, 1991), and the Houston/Galveston and Beaumont/Port Arthur/Orange areas of Texas (TNRCC, 1993). The approaches taken for the BIOME and the California and Texas estimates will be discussed in Chapter 5, "Using Alternative Methods for Estimating Biogenic Emissions."

Methods to determine biogenic emissions and the scientific background that they are based on may change in the future. For example, algorithms for calculating isoprene emission rates may be based on leaf area. This will be made possible if remote sensing techniques become available that permit a better characterization of the vegetation in a study area.

3.1.1 Overview of the Biogenic Emission Inventory System

The following description of BEIS-2 and PCBEIS2.2 are drawn from the user's guides and U. S. Environmental Protection Agency (EPA) guidance for these models (EPA, 1991a; EPA, 1990b; Birth, 1995), and communications with Chris Geron, Air and Energy Engineering Research Laboratory (AEERL)/EPA (Geron, 1994) and Tom Pierce, Atmospheric Research and Exposure Assessment Laboratory (AREAL)/EPA (Pierce, 1994).

In a collaborative effort, researchers at Washington State University, The National Center for Atmospheric Research, and the EPA have developed a computerized system to estimate hourly gridded biogenic emissions. Until the development of the BEIS, no tool had been readily available for making these estimates of biogenic emissions. The original version of BEIS, released in 1991, has been updated to BEIS-2. At this time, BEIS-2 is not being used for regulatory purposes. However, BEIS-2 will be presented here as the preferred method, and differences between BEIS-2 and BEIS will be noted.

This section describes the basic algorithm used in both the BEIS-2 and PCBEIS2.2. These models are based on the same algorithm, but differ in the level of detail of the input used to run them, the platform that they run on, and the use of their results. BIOME and BEIS also use the same equation (EQ 3-1), but with different land use, emission factors and environmental corrections. BIOME was developed as a Geographical Information System

(GIS)-based system. In general, all of the versions of BEIS-2 estimate biogenic NMHC emissions based on various biomass, emission, and environmental factors.

The basic emission rate equation for forested areas can be expressed as:

$$ER_i = \sum_{j=1}^{n} [A_j \cdot FF_j \cdot EF_{ij} \cdot F(S,T)] \quad (3\text{-}1)$$

where:

ER_i	=	Emission rate of each chemical species (i), (μg) ($hour^{-1}$)
A_j	=	Area of vegetation for each vegetation type (j), $meters^2$
FF_j	=	Foliar density factor for each vegetation type (j), (g leaf biomass) ($meters^{-2}$)
EF_{ij}	=	Emission factor for each chemical species (i) and vegetation type (j), (μg) (g leaf $biomass^{-1}$) ($hour^{-1}$)
F(S,T)	=	Environmental factor accounting for solar radiation (S) and leaf temperature (T), unitless

For nonforested areas, the basic emission rate equation for a county can be expressed by the following:

$$ER_i = \sum_{j=1}^{n} \{ A_j \cdot EF_{ij} \cdot F_{ij}(S,T) \} \quad (3\text{-}2)$$

where:

ER_i	=	Emission rate of each chemical species (i), (μg) ($hour^{-1}$)
A_j	=	Area of each land use type (j), $meters^2$
EF_{ij}	=	Emission flux factor for each chemical species (i), and each land use type (j), (μg) ($meters^{-2}$) ($hour^{-1}$)
$F_{ij}(S,T)$	=	Environmental factor account for solar radiation (S) and leaf temperature (T), unitless

The BEIS-2 estimates NO emissions for forests, agricultural crops, urban trees, and grasslands. Soil moisture and soil temperature are known to influence NO emissions from soil. Nitrate loading can be used as an indicator of the nitrogen processing that is occurring in the soil. BEIS-2 calculates a range of emission flux rates based on information on the fertilizer use for certain crops.

The basis of the BEIS-2 calculation for soil NO emissions originates with the following equation (Williams, *et. al.*, 1992):

$$F_{NO} = A \cdot \exp(0.071\ T_s) \tag{3-3}$$

where:

F_{NO}	=	NO flux, (ng nitrogen) (meters^{-2}) (second^{-1})
T_s	=	Soil temperature, degrees Celsius
A	=	Experimentally derived constant for the land use types of grasslands and pasture, forests and urban trees, and the individual agricultural categories

The reader should note that in this equation, the rate is expressed in seconds rather than in hours. In the BEIS-2 computer code, the calculations for soil NO and forest VOC have been rewritten to take the form of Equation 3-2.

Each of the variables in Equations 3-1, 3-2 and 3-3 are discussed below, followed by a brief description of the processing methodology employed by the BEIS-2.

The UAM BEIS-2 produces one output file, a binary UAM-format low-level emissions file. This file contains hourly gridded biogenic emission rates (which have been corrected for episode-specific environmental conditions) for monoterpenes, isoprene, NMHCs, and NO. This file may be used directly as input to UAM or merged with the UAM low-level anthropogenic emissions file using the UAM EPS Version 2.0. Other versions of BEIS-2, such as those for the RADM and ROM models, produce output files appropriate for their respective air quality modeling system.

The UAM BEIS produces a similar output file, which can also be used in UAM. PCBEIS2.2 produces an ASCII output file. In this file, hourly, county-level emissions for isoprene, monoterpene, and other NMHCs are presented.

Emission Factors

The BEIS-2 estimates VOC and NO_x emissions from canopy vegetation types (forests and trees) and noncanopy vegetation types (primarily agricultural crops). Forests and agricultural crops are the primary emitters of biogenic VOC. Emissions from canopy vegetation types are based largely on Guenther's study of biogenic emission rates (Guenther *et al.*, 1994 and Geron *et al.*, 1994). The emissions for canopy vegetation are broken down into factors for 75 major tree genera, and are listed in Table 3-1. Emissions for nonforest vegetation types are estimated from areal coverage by land use type using the emission rates given in Table 3-1. All Table 3-1 emission rates are expressed in (μg)(m^{-2})(h^{-1}), and have been standardized

to 30°C and bright sunlight. The VOC and NO emissions from corn fields as they were originally used in BEIS were re-evaluated by Pierce and Van Meter, and were subsequently changed in BEIS-2 (Pierce *et al.*, 1992).

VOC emissions are calculated for three groups: isoprene, monoterpenes, and other NMHCs. The Carbon Bond IV (CBM-IV) speciations assumed for these three species are shown in Table 3-2.

The BEIS-2 seasonally adjusts biomass based on the frost dates for each county using a simple step function (Geron, 1994). For each month, deciduous vegetation within a county is assumed to have either full biomass or no biomass. Since most high-ozone episodes occur during the summer months, this is not usually a critical assumption.

Land Use Definitions

Emission factors for forests are multiplied by a foliar density factor recorded in the land use input file. The foliar density of forests is calculated in the BEIS-2 by applying allometric equations, which relate diameter-at-breast-height measurements to foliar mass for groups of tree species. The emission factors in Table 3-1 have already accounted for foliar density in fully-stocked stands. The emission factors for agricultural crops are based on the crop acreage and do not require a calculation of leaf biomass. Agricultural crop types modeled by the BEIS-2 have been presented with their emission rates in Table 3-1.

The default foliar density database provided with the BEIS-2 is derived from land use data compiled from U. S. Forest Service Forest Inventory and Analysis data, U. S. Census 1990 Urbanized Boundary data, U. S. Census of Agriculture data, and EROS Data Center (EDC) 1 km landcover satellite land classification data (Loveland *et al.*, 1991). The land use database contains gridded coverage for forests, agricultural crops, and other areas such as grasslands and water (Geron *et al.*, 1994; Pierce, 1994a; Geron, 1994).

TABLE 3-1

EMISSION RATES AND CHEMICAL SPECIATION EMPLOYED BY BEIS-2 FOR CANOPY AND NONCANOPY LAND USE TYPES

Vegetation ID	Isoprene Flux (µg)(m^{-2})(h^{-1})	Monoterpenes Flux (µg)(m^{-2})(h^{-1})	Other VOC Flux (µg)(m^{-2})(h^{-1})	NO Flux (µg)(m^{-2})(h^{-1})	Vegetation ID Description
Abie	170	5100	2775	4.5	Abies (fir)
Acac	79	2380	1295	4.5	Acacia
Acer	43	680	694	4.5	Acer (maple)
Aesc	43	43	694	4.5	Aesculus (buckeye)
Aila	43	43	694	4.5	Ailanthus
Aleu	43	43	694	4.5	Aleurites (tung oil)
Alfa	19	8	11	13	Alfalfa
Alnu	43	43	694	4.5	Alnus (European alder)
Amel	43	43	694	4.5	Amelanchier, serviceberry
Asim	43	43	694	4.5	Asimina (pawpaw)
Avic	43	43	694	4.5	Avicennia (blk mangrove)
Barl	8	19	11	257	Barley
Barr	0	0	0	0	Barren
Betu	43	85	694	4.5	Betula (birch)
Borf	910	713	755	4.5	Boreal forest (G94)
Bume	43	43	694	4.5	Bumelia (gum bumelia)
Carp	43	680	694	4.5	Carpinus (hornbean)
Cary	43	680	694	4.5	Carya (hickory)

TABLE 3-1

(CONTINUED)

Vegetation ID	Isoprene Flux (µg)(m^{-2})(h^{-1})	Monoterpenes Flux (µg)(m^{-2})(h^{-1})	Other VOC Flux (µg)(m^{-2})(h^{-1})	NO Flux (µg)(m^{-2})(h^{-1})	Vegetation ID Description
Casp	43	43	694	4.5	Castanopsis (chinkapin)
Cast	43	43	694	4.5	Castanea (chestnut)
Casu	29750	43	694	4.5	Casuarina (Austl pine)
Cata	43	43	694	4.5	Catalpa
Cedr	79	1269	1295	4.5	Cedrus (Deodar cedar)
Celt	43	85	694	4.5	Celtis (hackberry)
Cerc	43	43	694	4.5	Cercis (redbud)
Cham	170	340	2775	4.5	Chamaecyparis (p-o cedar)
Citr	43	680	694	4.5	Citrus (orange)
Cnif	745	1367	994	4.5	BEIS conifer forest
Conf	1550	1564	1036	4.5	Conifer forest (G94)
Corn	0.5	0	0	578	Corn
Coru	43	680	694	4.5	Cornus (dogwood)
Coti	43	43	694	4.5	Cotinus (smoke tree)
Cott	8	19	11	257	Cotton
Crat	43	43	694	4.5	Crataegus (hawthorn)
Cswt	1050	660	770	0.2	Herbaceous Wetl (G94)

TABLE 3-1

(CONTINUED)

Vegetation ID	Isoprene Flux (µg)(m^{-2})(h^{-1})	Monoterpenes Flux (µg)(m^{-2})(h^{-1})	Other VOC Flux (µg)(m^{-2})(h^{-1})	NO Flux (µg)(m^{-2})(h^{-1})	Vegetation ID Description
Desh	65	95	57	58	Desert shrub (G94)
Dios	43	43	694	4.5	Diospyros (persimmon)
Euca	29750	1275	694	4.5	Eucalyptus
Fagu	43	255	694	4.5	Fagus (american beech)
Frax	43	43	694	4.5	Fraxinus (ash)
Gled	43	43	694	4.5	Gleditsia (honeylocust)
Gord	43	43	694	4.5	Gordonia (loblolly-bay)
Gras	56	141	84	58	Grass
Gymn	43	43	694	4.5	Gymnocaldus, KY coftree
Hale	43	43	694	4.5	Halesia (silverbell)
Harf	8730	436	882	4.5	Hardwood forest (G94)
Hay	38	95	57	13	Hay
Ilex	43	85	694	4.5	Ilex (holly)
Jugl	43	1275	694	4.5	Juglans (black walnut)
Juni	79	476	1295	4.5	Juniperus (E red cedar)
Lagu	43	43	694	4.5	Laguncularia, w mangrove
Lari	43	43	694	4.5	Larix (larch)

TABLE 3-1

(CONTINUED)

Vegetation ID	Isoprene Flux (µg)(m^{-2})(h^{-1})	Monoterpenes Flux (µg)(m^{-2})(h^{-1})	Other VOC Flux (µg)(m^{-2})(h^{-1})	NO Flux (µg)(m^{-2})(h^{-1})	Vegetation ID Description
Liqu	29750	1275	694	4.5	Liquidambar (sweetgum)
Liri	43	85	694	4.5	Liriodendron (y poplar)
Macl	43	43	694	4.5	Maclura (osage-orange)
Magn	43	1275	694	4.5	Magnolia
Malu	43	43	694	4.5	Malus (apple)
Meli	43	43	694	4.5	Melia (chinaberry)
Mixf	11450	1134	1140	4.5	Mixed forest (G94)
Moru	43	85	694	4.5	Morus (mulberry)
Mscp	8	19	11	13	Misc crops
Nmxf	10150	1100	850	4.5	N Mixed Forest (G94)
Nyss	5950	255	694	4.5	Nyssa (blackgum)
Oak	3108	256	894	4.5	BEIS oak forest
Oats	8	19	11	257	Oats
Odcd	2112	369	872	4.5	BEIS deci forest
Ofor	56	141	84	4.5	Open forest
Oksv	7350	100	600	4.5	Oak Savannah (G94)
Ostr	43	43	694	4.5	Ostrya (hophornbeam)
Othe	56	141	84	58	Other (assume grass)
Oxyd	43	255	694	4.5	Oxydendrum (sourwood)

TABLE 3-1

(CONTINUED)

Vegetation ID	Isoprene Flux (µg)(m^{-2})(h^{-1})	Monoterpenes Flux (µg)(m^{-2})(h^{-1})	Other VOC Flux (µg)(m^{-2})(h^{-1})	NO Flux (µg)(m^{-2})(h^{-1})	Vegetation ID Description
Pacp	55	80	48	35	Pasture cropland (G94)
Past	56	141	84	58	Pasture
Paul	43	43	694	4.5	Paulownia
Pean	102	255	153	13	Peanuts
Pers	43	255	694	4.5	Persea (redbay)
Pice	23800	5100	2775	4.5	Picea (spruce)
Pinu	79	2380	1295	4.5	Pinus (pine)
Plan	43	43	694	4.5	Planera (water elm)
Plat	14875	43	694	4.5	Platanus (sycamore)
Popu	29750	43	694	4.5	Populus (aspen)
Pota	10	24	14	193	Potato
Pros	43	43	694	4.5	Prosopis (mesquite)
Prun	43	43	694	4.5	Prunus (cherry)
Pseu	170	2720	2775	4.5	Pseudotsuga (doug fir)
Quer	29750	85	694	4.5	Quercus (oak)
Rang	38	95	57	58	Range
Rhiz	43	43	694	4.5	Rhizophora (r mangrove)
Rice	102	255	153	0.2	Rice
Robi	5950	85	694	4.5	Robinia (black locust)
Rye	8	19	11	13	Rye

TABLE 3-1

(CONTINUED)

Vegetation ID	Isoprene Flux (µg)(m^{-2})(h^{-1})	Monoterpenes Flux (µg)(m^{-2})(h^{-1})	Other VOC Flux (µg)(m^{-2})(h^{-1})	NO Flux (µg)(m^{-2})(h^{-1})	Vegetation ID Description
Sabl	5950	43	694	4.5	Sabal (cabbage palmetto)
Sali	14875	43	694	4.5	Salix (willow)
Sapi	43	43	694	4.5	Sapium (chinese tallow)
Sass	43	43	694	4.5	Sassafras
Scru	38	95	57	58	Scrub
Scwd	2700	349	651	31	Scrub woodland (G94)
Sere	14875	43	694	4.5	Serenoa (saw palmetto)
Shrf	10750	530	910	4.5	SE/W Decid Forest (G94)
Smxf	17000	1500	1250	4.5	SE Mixed Forest (G94)
Snow	0	0	0	0	Snow
Sorb	43	43	694	4.5	Sorbus (mountain ash)
Sorg	8	20	12	578	Sorghum
Soyb	22	0	0	13	Soybean
Spin	1460	1983	1252	4.5	S pine (G94)
Swie	43	43	694	4.5	Swietenia (mahogany)
Taxo	43	1275	694	4.5	Taxodium (cypress)
Thuj	170	1020	2775	4.5	Thuja (W. red cedar)
Tili	43	43	694	4.5	Tilia (basswood)
Toba	0	59	235	257	Tobacco

TABLE 3-1

(CONTINUED)

Vegetation ID	Isoprene Flux (µg)(m^{-2})(h^{-1})	Monoterpenes Flux (µg)(m^{-2})(h^{-1})	Other VOC Flux (µg)(m^{-2})(h^{-1})	NO Flux (µg)(m^{-2})(h^{-1})	Vegetation ID Description
Tsug	79	159	1295	4.5	Tsuga (Eastern hemlock)
Tund	2412	121	151	0.2	Tundra
Ufor	1989	664	920	4.5	BEIS urban forest
Ugra	56	141	84	58	BEIS urban grass
Ulmu	43	43	694	4.5	Ulmus (American elm)
Uoth	11	28	17	12	BEIS2 other urban (20% grass)
Urba	408.6	161.9	200.5	12.5	BEIS urban, .2 grs/.2 for
Utre	5140	1000	959	5	Urban trees (50% hardwood, 50% coniferous)
Vacc	43	43	694	4.5	Vaccinium (blueberry)
Wash	5950	43	694	4.5	Washingtonia (fan palm)
Wate	0	0	0	0	Water
Wcnf	4270	1120	1320	4.5	W Conifer Forest (G94)
Wdcp	2550	663	2053	9	Woodland/ cropland (G94)
Wetf	3820	923	1232	0.2	Wetland forest (G94)
Whea	15	6	9	193	Wheat
Wmxf	5720	620	530	4.5	W Mixed Forest (G94)
Wwdl	525	250	360	4.5	Western Woodlands (G94)

TABLE 3-2

CARBON BOND IV MECHANISM SPECIATION FOR BEIS-2 BIOGENIC SPECIES

Chemical Species	Moles CMB-IV Species per Mole of Chemical Species				
	Ole	PAR	ALD2	ISOP	Non-Reactive
Isoprene	--	--	--	1	--
Monoterpene	0.5	6	1.5	--	--
Unidentified	0.5	8.5	--	--	0.5

Environmental Correction Factors

Studies indicate that biogenic emissions from most plant species are strongly temperature-dependent; isoprene emissions also vary with solar intensity. The emission factors used by BEIS-2 are standardized for full sunlight and 30° C. The BEIS-2 adjusts these emission factors to account for the effects of variations in ambient conditions.

BEIS-2 also simulates the vertical variation of leaf temperature and sunlight within the forest canopy. The canopy model employed by BEIS-2 assumes that sunlight decreases exponentially through the hypothetical forest canopy; the rate of attenuation depends on the assumed leaf area index. Moisture stress is thought to have an important effect on emissions, but has not been quantified. The effect is not included in the BEIS-2 model.

3.1.2 ALTERNATIVE METHODS FOR ESTIMATING BIOGENIC EMISSIONS

Of the five alternative methods available for estimating biogenic emissions, three are computer models: PCBEIS2.2, BIOME and BEIS. The Yienger and Levy (1995) method has not been made into a computer model. PCBEIS2.2 has been discussed with BEIS-2, since they are based on the same scientific principals. BEIS uses the same algorithm as BEIS-2, but contains older land use data, less detailed emission factors for forests, and an older environmental correction factor; the BEIS-2 represents upgrades from BEIS for all of those factors.

BIOME is a GIS-based system that calculates gridded, hourly, chemical species-specific biogenic emission estimates for VOC. The emission rate equation is the same as the one used in the BEIS-2 and BEIS, but it uses different factors. Although the system is built to allow the users flexibility in using biomass and emission factors of their own choosing for

plant types, and their own environmental adjustment factors, the model also provides defaults. BIOME allows users to enter their own land use and land cover data as GIS coverages. Enhancements include QA capabilities for the analysis of input and output. BIOME is designed with a scheme for gridding biomass distribution that provides a higher level of detail than the BEIS model. The choice of using BIOME as opposed to the BEIS-2 models will depend on the final uses of the results, the hardware and software available for conducting the work, and access to and availability of the information needed to run the models.

The fourth alternative method is only for computing NO_x for soils, and is the approach used by Yienger and Levy (1995) for global soil NO_x emissions. This method is the most advanced method available but its use as a regional inventory method may be limited by the data and computational needs required by the model.

The final alternative method uses any of the previously mentioned computer models, but substitutes locally collected and/or more detailed information for factors like emissions or land use. In some cases, this may be the approach that will give the most reliable emission estimates. Strategies and resources that may be useful will be discussed in Section 5, "Using Alternative Methods for Estimating Biogenic Emissions."

3.2 METHODS FOR ESTIMATING EMISSIONS FROM LIGHTNING

Lightning forms NO through a high-temperature reaction from the energy released during a lightning flash. Lightning can release about 10^5 Joules per meter (J/m), and produce temperatures of about 30,000°K. NO is in thermodynamic equilibrium with N_2 and O_2 at temperatures above 2300°K, and as the heated air rapidly cools below 2000°K, NO "freezes out" as a stable species (Levine *et al.*, 1984).

Experimental work shows that NO production in air surrounding a lightning flash is a linear function of the energy released in the flash (Branvold and Martinez, 1988). Thus, simplifying the process to assume a single value for energy released and estimating the frequency of lightning flashes allows for an estimate of NO formed by lightning. Global estimates of NO formed by lightning have ranged from 2 to 90 Teragrams (Tg) of nitrogen (N)/yr (Levine *et al.*, 1984)(1 Tg=10^{12}g). The basis for these estimates is a combination of atmospheric measurements, laboratory experiments, and theoretical calculations. When constraints based on the global NO_x budget are applied to these estimates, a narrower range of 2 to 20 Tg N/yr for the global estimate is reached (Logan, 1983). Lightning is estimated to be responsible for about 5 percent of the total NO_x produced in the United States, and may contribute to oxidant chemistry in NO_x-limited rural areas (Novak and Pierce, 1993).

There are two available methods for estimating NO_x emissions from lightning. The preferred method uses a method discussed in Pierce and Novak (1991) and used in the ROM; the alternative method uses emission factors and lightning strike data from other sources.

3.2.1 OVERVIEW OF THE PREFERRED METHOD

The preferred method estimates production of NO by assuming the frequency and type of lightning strikes, and the amount of energy released. The method derives emission estimates for cloud to ground (CG) flashes and intra-cloud (IC) flashes. The method relies on four assumptions:

- Global production of NO by lightning is 6 Tg N/yr;
- Global flash rate is 100 flashes/sec;
- IC flashes occur approximately 4 times more frequently than CG flashes, a number which varies with latitude; and
- CG flashes are approximately 10 times more energetic than IC flashes.

Emission factors have been developed using an equation from Borucki and Chameides (1984) for CG flashes and the previous assumptions:

- CG flashes: $2.9 * 10^{26}$ molecules NO per flash; and
- IC flashes: $2.9 * 10^{25}$ molecules NO per flash.

In order to calculate emissions estimates for this source, the emission factors are applied to activity for the inventory area, taking into account any corrections to the activity measurements. This correction factor compensates for lightning flash detection network efficiency, including a lack of detection of IC flashes by the network. Other correction factors correct for changes in air density as a function of height, and correct for seasonal variations in activity. Values for these correction factors and a detailed methodology are presented in Chapter 4, "Preferred Methods for Estimating Natural Source Emissions."

3.2.2 OVERVIEW OF THE ALTERNATIVE METHOD

The alternative method, the use of alternative emission factors and lightning strike data, would be used only if more recent or better-constrained information becomes available.

3.2.3 METHOD UNCERTAINTY

Although there have been several studies of emissions from lightning, there are practical limitations to the development of reliable estimates from this source. Any direct measurement of this source is dependant on remote sensing techniques applied to the unpredictable occurrence of lightning. Laboratory experiments, although they are well controlled, do not simulate the large discharge associated with an actual lightning stroke. As a result, all of the parameters used to estimate emissions from lightning carry a certain amount of uncertainty. The preferred method uses an NO production factor that has an uncertainty of as much as 10. The vertical distribution of emissions in the atmosphere is not well defined. Activity in this method uses observations that are corrected, but still represent an estimate. The estimate for cloud-to-ground lightning strike data is plus or minus 20 percent. (Personal communication, T. Pierce, 1994)

3.3 METHODS FOR ESTIMATING EMISSIONS FROM OIL AND GAS SEEPS

Oil and gas seeps occur in many locations in the U.S., and emission rates and constituents vary widely. These seeps have not been extensively studied as sources of VOC. Estimates for this source depend upon a wide range of variables, as do other source categories in this volume. A viable method must simplify this variability in order to be practical. The variables that have primary importance are the amount of material or gas seeping or escaping from the ground into the air (flow rate), and the volatile fraction of the material. Variables that could cause similar seeps to have different emission rates include surface area of the seep, local meteorology such as temperature and wind speed, and variability in the rate of seepage. Seeps may become more active or new seeps may appear after seismic activity (earthquakes) or during warmer weather.

The preferred method for this category is to develop a local emission factor based on study of the oil or gas seeps in the inventory area. Emission calculations for this method take into account the volatile fraction of the seep, the volume and exposed area of the seep, and the local meteorology. The alternative method uses an approach tentatively offered by the California Air Resources Board (CARB), suitable for the estimation of emissions over a large area, such as a nonattainment area.

3.3.1 PREFERRED METHODS

The preferred method for this source category is to develop a local emission factor based on a study of the conditions in the inventory area. The level of detail in data collection will depend on the needs of the inventory and the estimated magnitude of emissions from this source category. Individual measurements of flow rate, volatile constituents, vapor pressure

of constituents, and surface area, as well as local meteorological observations would be necessary to determine the most reliable estimate.
Locating seeps in an area, estimating their flow rates and other physical qualities are the most labor intensive steps. Areas without any past or current oil or gas extraction activity probably do not need to consider emissions from seeps in any air pollution inventories. Areas with an oil or gas extraction history should have usable information available in the form of exploration records and state or local surveys of seep occurrences. More detailed information about individual sites may be available from local universities or oil or gas exploration companies.

3.3.2 ALTERNATIVE METHODS

The alternative method for estimating emissions from this source is based on a number of assumptions:

- Oil seeps and gas seeps can be characterized by one emission factor for either oil or gas;
- Seeps have a steady flow rate year-round, with no seasonal variation; and
- All oil seeps are composed of the same material, and all gas seeps emit the same type of gas.

These simplifying assumptions are necessary in order to provide a practical estimation method for sources that are typically left unstudied, and that do not have a significant body of supporting literature.

The method is summarized thus:

- Gather information about the location of oil or gas seeps;
- Estimate the number of barrels (42 gal) of oil or million cubic feet of gas emitted by the seep in 1 year; and
- Multiply the annual flow rate of the seep in either barrels or million cubic feet by the oil or gas emission factor.

3.4 UNCERTAINTY OF BIOGENIC EMISSIONS ESTIMATES

The major sources of uncertainty associated with biogenic emissions estimates have been discussed in detail for a national inventory of biogenic emissions prepared with BEIS by

Lamb *et al.* (1993); other authors have also discussed some aspects of uncertainty (Gaudioso *et al.*, 1993; Geron *et al.*, 1994). The sources of uncertainty discussed by these authors are:

- The composition of hydrocarbons classified as "other" in the original data set used to develop some emission factors;
- The possible disturbance of vegetation by the sampling process, resulting in erroneously high monoterpene emissions;
- The use of canisters for storage may cause artifacts in the data resulting in an under-estimate of emissions;
- The results of use of geometric mean rather than arithmetic mean;
- In the original BEIS, specification of emission rate factors for hydrocarbons other than isoprene and the monotepenes and for agricultural crops is very uncertain; and
- The canopy model is a highly simplified representation of a complex system, and feedback mechanisms are neglected.

A thorough assessment of biogenic emissions uncertainties requires an evaluation of emissions model (or factors) and the biomass data set. With respect to the latter, Gaudioso *et al.* (1993) noted that estimates on coverage of forests can vary by a factor of 2 between inventories for some countries. They cited another study where biomass estimates varied by 20 to 40 percent.

In the U. S., land use and biomass density for Idaho obtained from satellite imagery and the Geoecology Data Base have been compared (Cheung *et al.*, 1991). For the dominant land use types -- coniferous forests, scrublands and agricultural lands -- the differences in coverage between data sets were less than 20 percent. However, very large variations were found for the more rare land use types. Despite these differences in coverage estimates, emission estimates based on the two datasets were within 10 percent of each other. In the same study, an independent estimate of biomass density for coniferous forests was obtained. In comparison to the standard inventory biomass density factors, the alternative produced emission estimates 14 percent lower.

Much of the uncertainty described by Lamb *et al.* (1993) is the result of the emissions data used for BEIS. The addition of more new data in BEIS-2 has reduced or at least allowed some quantification of that uncertainty. The emissions predicted by BEIS-2 have been compared to measured values for some sites, and generally performed well (Geron *et al.*,

1994). The uncertainty for the genus level emission rates used in BEIS-2 are estimated to be approximately ±50 percent (Guenther *et al.*, 1994).

3.4.1 SENSITIVITY ANALYSIS

The emission of isoprene and monoterpenes is sensitive to light and leaf temperature (Guenther *et al.*, 1993). The biogenic models use light and temperature levels to adjust the empirical emission rate factors. Leaf temperatures are strongly dependent on light intensity as well as other environmental factors.

The sensitivity of BEIS emission estimates to several environmental parameters was analyzed by Lamb *et al.* (1993). The effect of the canopy model was found to be very important, especially in deciduous forests. Without the canopy correction, peak hourly and daily average emissions from deciduous forests were 50 percent higher than baseline. Similar results were found for coniferous forests. The canopy both attenuates light reaching the leaves and reduces mean leaf temperature. It is believed and almost certain that the BEIS canopy model underestimated leaf temperatures in the lower portion of coniferous canopies. However, there is a lack of rigorous datasets to test the canopy model. BEIS-2 computes light attenuation within the canopy, but assumes ambient temperature throughout. As a result, when sunlight attenuation is allowed to occur, but leaf temperatures are set equal to above-canopy ambient temperatures, coniferous forest emissions increase by 28 percent. Deciduous forest emissions increase by only 3 percent.

The canopy model is not directly under the control of BEIS users. However, if BIOME or other alternative methods are used, the ability of the model to incorporate canopy effects needs to be carefully evaluated.

In addition to temperature sensitivity, other user-supplied (or user-controlled) input data such as solar radiation, relative humidity, and wind speed may affect emissions. Isoprene emissions were relatively sensitive to changes in solar radiation and relative humidity, but wind speed had only a small effect. The BEIS-2 canopy model does not use relative humidity or wind speed. Wind speed had no effect on monoterpene emissions, while solar radiation and relative humidity had small effects relative to isoprene. Figure 3-1 (redrawn from Lamb *et al.*, 1993) shows the results. In the figure, predicted isoprene is shown as a solid line and total monoterpene is shown as a dashed line for situations of increasing solar radiation, relative humidity and wind speed. Figure 3-2 (also from Lamb *et al.*, 1993) shows predicted leaf temperatures for an oak forest (solid line) and a coniferous forest (dashed line) for cases with (a) 10% and (b) 50% relative humidity with 1 $ly \cdot min^{-1}$ solar radiation, 4 $m \cdot s^{-1}$ wind speed and 30°C ambient temperature (dotted line) at the canopy top. Other studies have stressed the importance of temperature effects on biogenic VOC emissions (Gaudioso *et al.*, 1993, Guenther *et al.*, 1994), particularly isoprene, and the role of moisture stress.

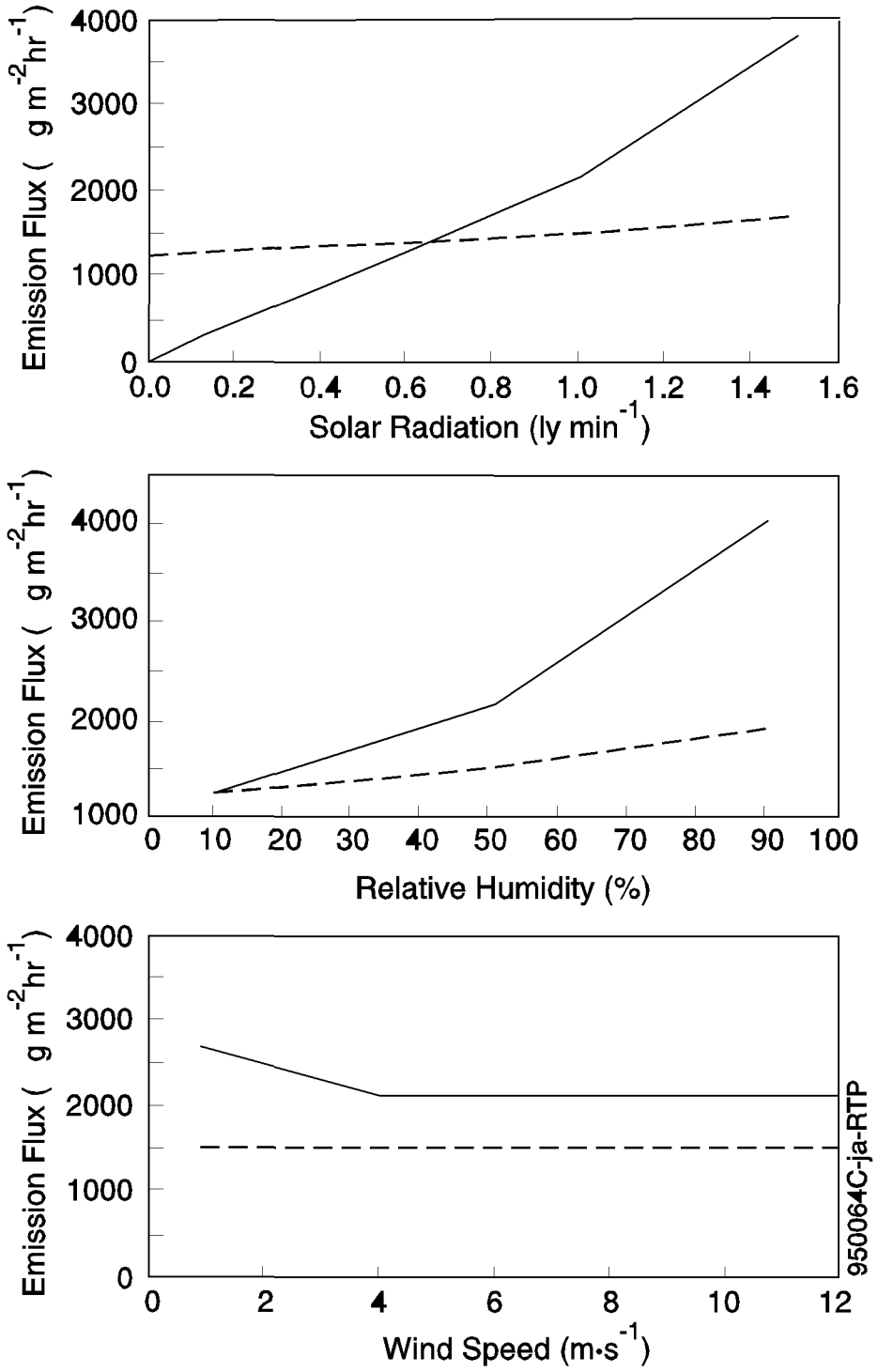

FIGURE 3-1. EFFECT OF SOLAR RADIATION, RELATIVE HUMIDITY AND WIND SPEED UPON PREDICTED ISOPRENE

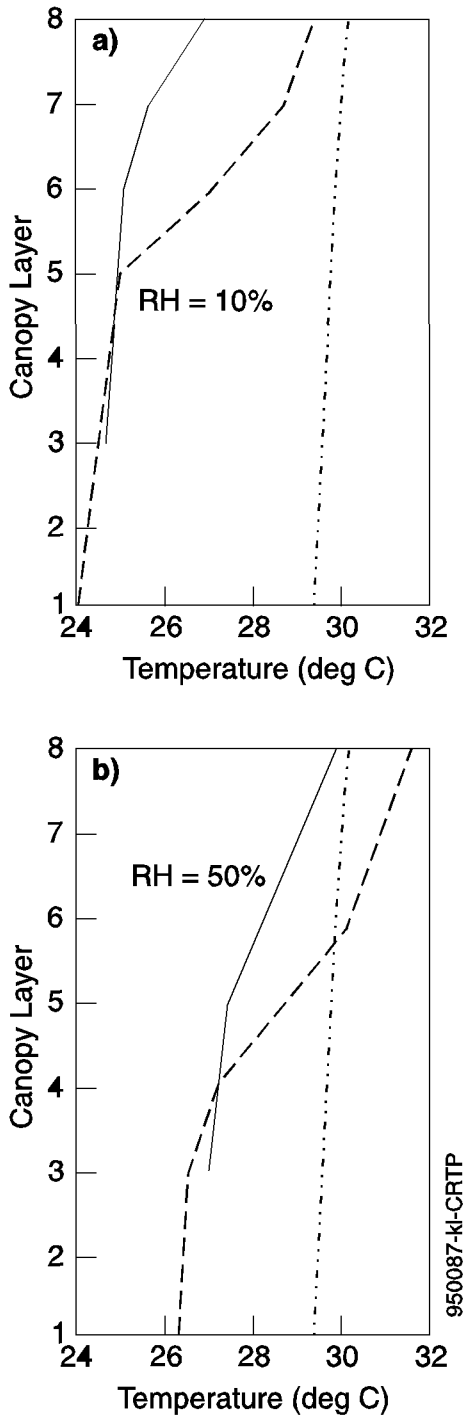

FIGURE 3-2. TEMPERATURE RELATIONSHIPS WITHIN FOREST CANOPIES WITH 10% (A) AND 50% (B) RELATIVE HUMIDITY.

Inventory emissions are also sensitive to land-use and biomass density data. With the exception of the Idaho database comparison described in the previous section, very little has been published on this topic. However, it is safe to say that the correct allocation of land use/plant types can have significant impacts on emissions of specific pollutants. An extreme example would be incorrectly identifying a forest type as coniferous when it was deciduous; isoprene emissions would be underestimated and monoterpenes over-estimated.

3.5 QUALITY ASSURANCE/QUALITY CONTROL

As with any inventory development process, QA/QC procedures should be planned and scheduled in advance. The level of effort spent on QA and on QC will depend on the importance of biogenic sources in the overall inventory and the degree to which the user plans to modify the defaults or use of an alternative land use dataset.

Details on specific QA/QC methods can be found in the QA Source Document, Volume VI of this series.

At a minimum, the QA program should include:

- Peer review of input data and results;
- Quality control checks of data transcription (i.e., written or keyed into computer); and
- Review (at QC or QA level) of any calculations, analyses (e.g., choice of ozone days to model), or data conversions (e.g., conversion of units of measure).

These minimum QA/QC elements may be adequate where biogenic emissions are not a significant component of the inventory and the default data in BEIS-2 are used. However, more extensive procedures may be warranted in some cases. Specific aspects of QA/QC procedures are described for key inventory components in the following sections.

3.5.1 LAND USE/BIOMASS DENSITY

If BEIS-2 is being used with default land use and biomass data sets, the amount of additional QA/QC of these datasets will depend on the importance of the biogenic emissions to the overall inventory. At a minimum, the receiver should check the FIPS code to verify that the correct county data were used. The reviewer may also want to perform a reality check on the genus/land use proportions; if any of the data look unreasonable, other data sources or local experts should be consulted for comparison values. A local university, for example,

may be able to supply independent estimates of forest biomass, land use patterns, or other relevant information. If the user is modifying the land use data or is using an entirely different dataset, then performing an uncertainty analysis is more critical. At a minimum, the results using the default and the new data should be compared.

There are no hard and fast rules on how well such comparisons need to agree, or even how to choose the correct dataset. If the source category is a significant one, and if these are competing datasets of similar quality, the user is advised to conduct a detailed assessment. The assessment could include an uncertainty analysis whereby the model is run with each dataset in turn. If the emissions estimated for each pollutant are not markedly different (i.e., within the source order of magnitude), the results could be averaged. In this situation, the rationale and the approach need to be clearly documented, and the uncertainty of the estimate should be quantified using a standard statistic such as the standard error or the coefficient of variation. If one dataset is chosen over others, the reasons for the choice need to be clearly documented.

3.5.2 METEOROLOGICAL DATA

As the discussion of model sensitivity described, certain meteorological variables can have significant effects on emission estimates. Therefore, the days chosen for modeling will have an impact on the results; higher temperatures, in particular, will produce higher emissions. Verification that the modeling days were chosen correctly should be a primary objective of the QA program.

Another potential source of error lies in selecting the meteorological dataset. Generally, data from the closest airport weather station is used, but terrain will influence meteorology considerably. If the nearest meteorological station is at a much higher or lower elevation, or if there are major differences in the characteristics of the landscape (e.g., mountains, large bodies of water) alternative meteorological data may be needed. The discussion on using PCBEIS2.2 in Section 4 of this volume describes sources of meteorological data.

3.5.3 ALTERNATIVE METHODS

If a model other than BEIS-2 is used, all of the above QA/QC procedures are still relevant. Furthermore, sensitivity and uncertainty analyses should be conducted to provide a good understanding of the model. These analyses should cover the key variables (temperature, light) and critical model components (such as the canopy model).

If the results are to be used for any sort of regulatory purposes, the BEIS-2 results (using the default datasets) should be provided as a benchmark. Differences in the results from the two models should be explained and the reasons for using the alternative model results needs to

be justified. Thoroughly documented QA/QC procedures are especially important when using a new or non-standard approach.

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4

PREFERRED METHOD FOR ESTIMATING NATURAL SOURCE EMISSIONS

In this volume, emissions of VOC and NO_x from biogenic sources (vegetation and soils), lightning, and geogenic sources (oil and gas seeps) are discussed. In this section, the preferred emission estimation methods for these sources and pollutants will be described.

4.1 BIOGENIC SOURCES

4.1.1 USING BEIS

When an inventory requires air quality analysis using a photochemical grid model, biogenic VOC and NO_x need to be included with the modeled emissions. Under the Clean Air Act Amendments of 1990 (CAAA), the use of photochemical grid models is required for areas designated as serious, severe, and extreme ozone nonattainment areas, and for multistate moderate ozone nonattainment areas in the preparation of their SIPs. For these instances, the UAM should be used for photochemical pollutant modeling applications involving entire urban areas.

The BEIS-2 is adapted to use with the UAM, RADM, and ROM air quality models, although RADM and ROM are used for regional modeling and are not as widely used as UAM. RADMBEIS-2 and ROMBEIS-2 use the same types of parameters as UAMBEIS-2 but they apply different adaptations of the algorithm and land use files to the meteorology and grid cell sizes. The primary differences between all of the different versions of BEIS-2, including PCBEIS2.2, are in the treatment of the cloud cover and in the raw meteorology data used to calculate the environmental correction factor.

For instance, PCBEIS2.2 uses a single value for sky cover. In the mainframe versions, more detailed information for cloud cover is used. Cloud cover in these versions is defined by thickness, level, and percent of load per level. This may provide a more accurate measure of the reduction of solar radiation through clouds.

There are two preferred methods for estimating biogenic emissions of VOC and NO_x, either BEIS-2 or PCBEIS2.2. The following sections will describe how to use the UAMBEIS-2 and PCBEIS2.2.

4.1.2 BEIS AND UAM

The UAM is a three-dimensional photochemical grid model designed to calculate concentrations of both inert and chemically reactive pollutants by simulating physical and chemical processes which occur in the atmosphere. As of this writing, a stand-alone version of BEIS-2 is planned to provide biogenic emission estimates that can be input to the UAM. Inputs to BEIS-2 for the UAM are discussed in this section.

Readers should note that as of May 1996, a regulatory version of UAM BEIS-2 was not available. As an alternative, modelers have been using emissions data extracted from ROM BEIS-2. For regulatory purposes, readers are advised to look to the U.S. EPA Office of Air Quality Planning and Standards (OAQPS) Technology Transfer Network (TTN)[a] for updates on the status of BEIS2, or call Chet Wayland of the Emissions, Monitoring, and Analysis Division at (919) 541-4603.

The UAM simulates the hour-by-hour photochemistry occurring for each grid cell in the modeling domain; as a result, the input emission data from BEIS must contain a comparable level of resolution. Total VOC and NO_x emission estimates must be chemically speciated into the chemical classes employed by the model. In addition to the temporal and chemical allocation necessary to prepare emission information for the UAM, the data must be spatially allocated by grid cell for each hour of the modeling episode. Chemical speciation and temporal and spatial allocation are discussed in EPA guidance for UAM and procedures for modeling inventories (EPA, 1991b; EPA, 1990b).

4.1.3 PROCESSING METHODOLOGY

The BEIS-2 calculates the emission rates of monoterpenes, isoprene, and other NMHCs by multiplying foliar density for each forest type by the appropriate emission factors. The calculated emission rates are then adjusted for the specific environmental conditions of the modeling episode using data from the user-supplied meteorology file and the UAM temperature preprocessor (TPBIN). Corrections are performed for each grid cell of the modeling domain using the hourly gridded temperature and solar radiation data contained in these input files.

For forested areas, land use data for each county are multiplied by an emission flux value for each tree genus. Emission flux represents the forest species emission factor and species foliar density. The EPA provides a default land use data file for use with BEIS-2 which contains county-level land use data for each of the tree genera and for the noncanopy vegetation types listed in Table 3-1.

The calculated county-level vegetation coverages are gridded using a county allocation file, which indicates the percentage of each grid cell occupied by a particular county. If more current land use data are available, the user may include these data by using the optional gridded land use data file or the optional county-level land use data file.

The next step in processing forested areas involves adjusting the emission rates for temperature and solar energy changes within the forest canopy. The adjusted emission rates are then grouped into categories for five CBM-IV species (olefins, paraffins, isoprene, aldehydes, and nonreactives) and NO. Although UAM BEIS-2 calculates emission rates for nonreactive hydrocarbons, it does not report this information because it is not used by UAM.

Nonforested areas, or noncanopy areas (including agricultural areas and urban trees), are handled in a slightly different way than forested areas. The principal difference is that a canopy model is not used. Noncanopy areas use either a winter or summer emission factor table to reflect seasonal variations in biomass. Next, the data are gridded using the county allocation file. Land use is then multiplied directly by the emission factor for that land use type to produce emission rates. Speciation and environmental adjustments are handled the same as for forested areas, except that the nonforest emission rates are not adjusted for canopy effects.

4.1.4 INPUT REQUIREMENTS

BEIS-2 is a stand-alone processor that prepares biogenic emission estimates so they can be used as input to the UAM or other models such as ROM or RADM. As indicated above, the BEIS-2 uses three types of data files: UAM preprocessor data, user-supplied data, and data supplied to the user by EPA. Figure 4-1 shows a flow chart of the BEIS-2 and BEIS (discussed in Section 5) flow of information. Each of the input data files is briefly described below. Differences between BEIS-2 and BEIS will be noted. The *User's Guide for the Urban Airshed Model, Volume IV: User's Manual for the Emissions Preprocessor System 2.0, Part A: Core FORTRAN System* (EPA, 1990b) contains detailed format descriptions of the various input files.

The information that must be supplied by the user for the BEIS-2 is information that will be needed for running the UAM as well; this information includes scenario definition and control flags, hourly meteorology information, and the Federal Information Placement System

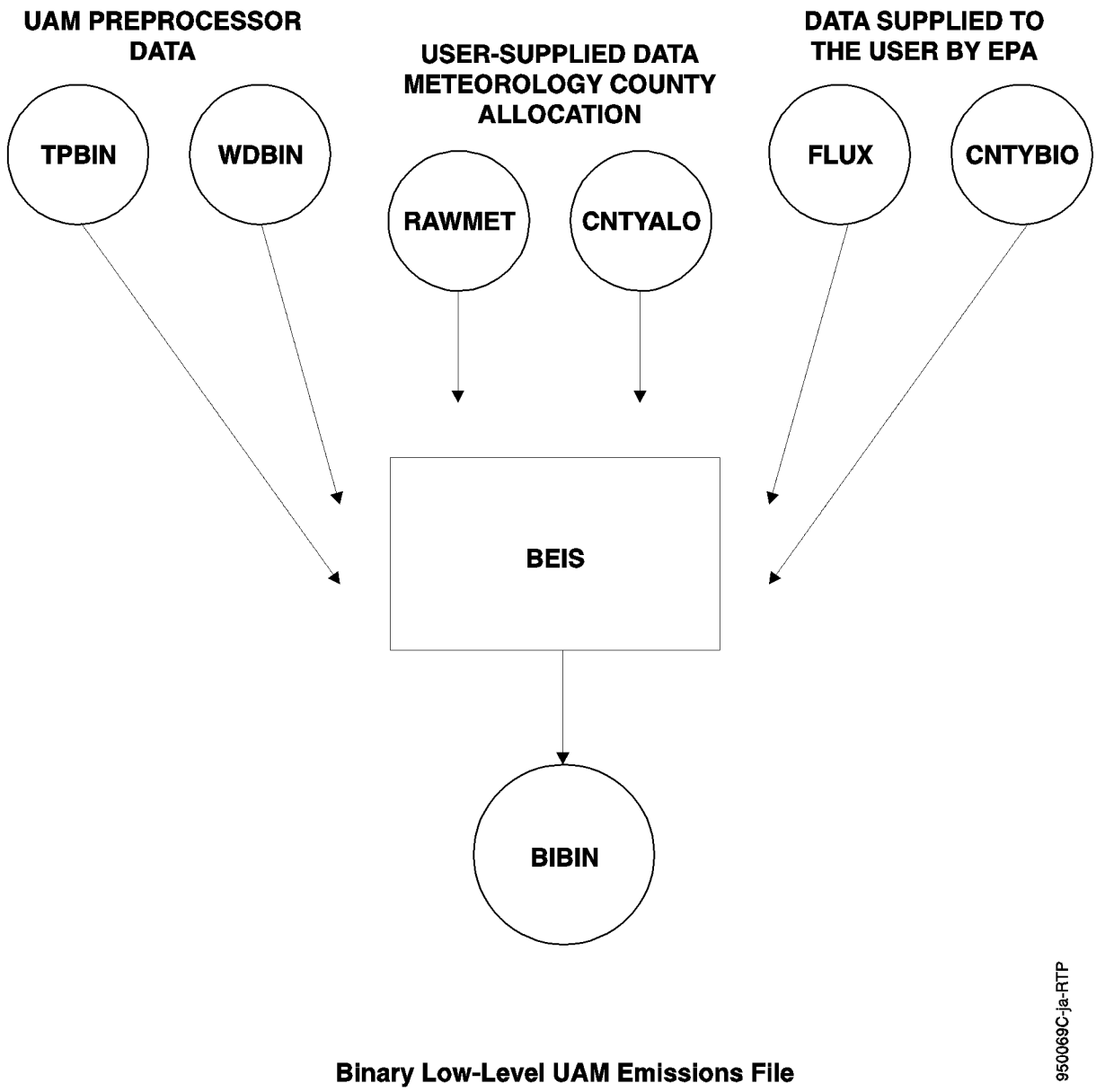

FIGURE 4-1. UAM STAND-ALONE BIOGENICS PROCESSOR. OVERVIEW OF THE BIOGENIC EMISSION INVENTORY SYSTEM (BEIS)

(FIPS) code of the counties being modeled. BEIS-2 calculates emission estimates for speciated VOC from forests and agricultural crops, and NO from soil processes.

It should be noted that when a projected year is being modeled, biogenic emissions need to be estimated for the projected year in addition to other projected emissions. However, unless there are anticipated changes in land use or vegetation patterns for the modeling area, it is appropriate to assume that biogenic emissions will remain the same between base and projected years.

UAM Preprocessor Data

Two of the UAM preprocessor files are also used by BEIS and one for BEIS-2. The WDBIN file is used by BEIS, is produced by the UAM winds preprocessor and contains hourly gridded surface wind speed data. The second file is the TPBIN file, which is produced by the UAM temperature preprocessor program. This file contains hourly gridded temperature data and is used by BEIS and BEIS-2. These files should be available from the photochemical modeler.

User-Supplied Data

The user must supply two types of data: meteorological and county allocation data for both BEIS and BEIS-2. In addition, BEIS allows the user to specify land use data, either county-level or for each grid cell of the modeling domain. Each of these files is described briefly below.

RAWMET. The meteorology file RAWMET contains hourly surface meteorological information on cloud cover, and cloud height for one station in the user's UAM domain. The file is created by the user with data that may be obtained from the National Weather Service.

CNTYALO. The county allocation file contains the percentage of each grid cell that a given county occupies. To speed processing, this file should be sorted by FIPS code. The CNTYALO file may be created by the user; however, the EPA has a Gridded Surrogate/County Allocation Utility which will create the file given the UAM domain coordinates and grid cell size. To request this data, contact the nearest EPA Regional Office.

GRBIO. If the user wishes to use more up-to-date land use data which are already gridded, the optional gridded land use file, GRBIO, may be used. For each grid cell, the user must input values in hectares for all of the land use types used by BEIS.

UCBIO. If the user has more up-to-date land use data on a county level, the optional county land use file, UCBIO, may be used. For each FIPS code, the user must input values in hectares for all of the land use types used by BEIS.

In addition to the user-supplied data files listed above, the user must supply certain input control data required by BEIS-2, consisting of domain and scenario-specific information along with control option flags. The user must input start date and hour, end date and hour, month of scenario, number of columns and rows, number of hours from Greenwich mean time to local time, number of counties, and a list of counties. Three flags which control several options in BEIS-2 must also be set by the user. The first flag, called GIFLAG, must be set to TRUE if the user wishes to input his own gridded land use data using the optional GRBIO file. The second flag, called CFLAG, must be set to TRUE if the optional UCBIO file is being used to input the user's own county land use data. The third flag, called GROWFLAG, must be set if the user inputs gridded land use data. This flag is set to TRUE to indicate that vegetation is growing and FALSE if only coniferous vegetation is growing, which might be the case in a cold season like late fall or winter.

EPA-Supplied Data

The EPA provides two data files for use with the BEIS-2. The first of these files contains county land use in hectares for canopy, noncanopy and urban tree areas. The second file contains visible solar energy ($\mu E\ m^{-2}s^{-1}$) data.

4.2 USING PCBEIS2.2

4.2.1 INTRODUCTION

In addition to emission modeling and projection inventory preparation where a version of the mainframe-based BEIS-2 would be used, other emission inventories may require biogenic emission estimates. Where the speciated and spatially allocated output of BEIS-2 is not necessary, or where a PC-based model is a more practical choice, PCBEIS2.2 is the recommended option.

The model documentation, executable file, source code, and necessary data files are available on EPA's CHIEF (Clearinghouse for Inventories and Emission Factors)

The following discussion of PCBEIS2.2 is drawn primarily from the model documentation (Birth, 1995).

PCBEIS2.2 provides outputs for two specific uses:

- An estimate of biogenic VOC and NO emissions required for baseline emission inventories mandated by the CAAA; and

- Hourly estimates of biogenic VOC emissions needed for use with EKMA.

For the first item, PCBEIS2.2 gives an estimate in tons per day. In order to meet EKMA's needs, biogenic emissions are output on a kilograms per square kilometer per hour basis for each major species (isoprene, monoterpenes, NO_x, and VOC). In addition to these primary uses, PCBEIS2.2 can be used for any application where biogenic VOC emission estimates at this level of detail are needed. A discussion of the model's technical background, computer aspects and a model run example can be found in the model documentation (Birth, 1995).

4.2.2 PROCESSING METHODOLOGY

The following methodology is for using PCBEIS2.2. The PCBEIS2.2 interface has been designed to resemble that of PC-BEIS, its predecessor, and the steps taken to run PC-BEIS should be very similar to those described for PCBEIS2.2.

Modeling Day Selection

Modeling day selection will be partly determined by the intended application of the results, or the reason for the emission estimate. A SIP base year inventory may need a total biogenic VOC estimate for a single typical ozone day. The day selection procedure below describes the steps in selecting such a day for use in the PCBEIS2.2. If results from PCBEIS2.2 are intended for use with an air quality model such as EKMA, a number of days will need to be simulated with PCBEIS2.2. These will correspond to the days which will be modeled.

The procedure for selecting the typical ozone day for modeling by PCBEIS2.2 is fully described in the documentation for the model, and involves selecting the day with the fourth-highest temperature out of the ten highest ozone days from a 3-year period. This procedure allows the user to use a day that is certain to have resulted in high ozone levels without using meteorology that may have been uncharacteristic of the area. Note that the selection of the typical ozone day for running this model may not be the same as the selection of typical ozone days for other purposes in a base year inventory (e.g., modeling mobile emissions), and those days do not need to be the same.

For a baseline inventory the following steps should be followed:

- Select the top ten days with the highest hourly ozone readings over the most recent three years of monitoring data;

- Obtain National Weather Service data for daily maximum temperature for each of the ten days;
- Rank maximum daily temperatures from highest to lowest;
- Select fourth highest based upon maximum daily temperature; and
- Use hourly meteorological data (cloud cover, relative humidity, wind speed, and temperature) for this day as input to PCBEIS2.2.

The following example illustrates the application of this procedure.

Example 4-1

The top ten ozone exceedances during the 3-year period, 1987-89, for a hypothetical area are shown in Table 4-1. After the values are ranked by temperature, the fourth highest is selected. In this case, it is June 30, 1987. Meteorological values for that day should be input to PCBEIS2.2. In the event that two days have the same maximum temperature which would be the fourth highest, the one with the lowest average daily wind speed should be selected.

Data Requirements

The data requirements for PCBEIS2.2 are modest since the detailed land use and emission factor information is supplied with the model. The user needs to obtain geographic information on the county of interest and hourly meteorological data. To run PC-BEIS, the following data are required:

Site Information

- County Federal Information Processing System (FIPS) code
- Latitude, longitude (decimal degrees, tenths)

TABLE 4-1

EXAMPLE OF DAY SELECTION FOR PCBEIS2.2

Date	Ozone Level (ppm)	Maximum Temperature (°F)
Ranked by Date		
30/06/87	0.147	90
10/08/87	0.155	87
06/06/88	0.138	85
15/06/88	0.162	93
26/06/88	0.159	88
17/07/88	0.144	87
05/08/88	0.145	88
12/08/88	0.144	84
04/09/88	0.152	91
03/07/89	0.157	92
Ranked by Temperature		
15/06/88	0.162	93
03/07/89	0.157	92
04/09/88	0.152	91
30/06/87	0.147	90
10/08/87	0.155	87
26/06/88	0.159	88
05/08/88	0.145	88
17/07/88	0.144	87
06/06/88	0.138	85
12/08/88	0.144	84

- Time zone (5=EST, 6=CST, etc.)
- Month, day, year, hour(s)

Meteorological Data (hourly)

- Ambient air temperature (°C)
- Photosynthetically Active Radiation (PAR)--not required if you are using cloud cover data
- Opaque sky cover (fraction)--not required if you provide PAR data

Meteorological data can be obtained from several sources. Locally, airport weather stations record temperature and cloud cover throughout the day. The National Climatic Data Center in Asheville, North Carolina, also is a resource for meteorological data. As noted above, either PAR or opaque sky cover is needed. Usually, only opaque sky cover information will be available. Either of the two can be used.

When the meteorological measurements have been recorded at a frequency of less than 1 hour, modelers will need to approximate the intermediate hours by averaging between the 2 hours that have data.

User data requirements for PCBEIS2.2 are minimal, but the model employs several data files that are critical to its operation, which are supplied with the model. These files are stored with the model executable in a file labeled B2DATA.EXE. B2DATA.EXE is a self-extracting executable that contains land use files (cc_LU.DAT, where cc is the 2-character state postal code), a FIPS code lookup table (FIPSCODE.DAT), and the emission factor lookup table (BEIS2.TAB). Descriptions of the parameters in these files are given in Tables 4-2 through 4-4. An example of the data in a land use file for one example county can be seen in Figure 4-2.

In Figure 4-2, the first line of the cc_LU.DAT file contains the FIPS code for the state and county, the county latitude and longitude, the two-letter state abbreviation, and the county name. Below that, the area of each land use or vegetation type is given; the total for a broad category is given first, followed by specific genera. For example, the example in Figure 4-2 shows 438,701.312 hectares (ha) of forest areas, with 27 different genera represented. The predominate genera are maples (Acer, 97,233.508 ha) and beech (Fagus, 37,127.871 ha). Also, note that 8,901.898 ha of the county are water (shown at bottom of column). A reality check of the genera and land use types should be performed as part of the QA program to verify that the data look reasonable.

```
36089  44.50  75.07  NY St Lawrence
                438701.312        27
Abie             11377.75
Acer             97233.508
Betu             28381.52
Carp               600.761
Cary              1293.441
Coru                31.115
Crat              4696.688
Fagu             37127.871
Frax             12950.65
Gled                57.673
Jugl              1053.291
Juni               255.826
Lari              2462.424
Malu               910.761
Ofor            108310.203
Ostr             10004.05
Pice             22084.51
Pinu             12330.27
Popu             17781.27
Prun             20458.48
Quer              4255.675
Robi               172.084
Sali              2432.601
Thuj             15177.44
Tili              4551.643
Tsug             10038.79
Ulmu             12670.88
                        0         0
                 98456.492         5
Hay              57555.641
Corn             13776.610
Pota                 8.499
Oats               751.113
Mscp             26364.631
                190270.812         2
Othe            181368.906
Wate              8901.898
```

FIGURE 4-2. EXAMPLE OF THE COUNTY LAND USE DATA FILE FOR PCBEIS2.2 FOR ST. LAWRENCE COUNTY, NEW YORK

TABLE 4-2

DESCRIPTION OF THE FIPS CODE FILE FIPSCOD.DAT

Variable Name	Format	Description
sfips	I2	State FIPS Code
cfips	I3	County FIPS Code
county	C30	County Name
state	C2	Abbreviated State Name

TABLE 4-3

DESCRIPTION OF THE LAND USE DATA FILE CC_LU.DAT[a]

Variable Name	Format	Description[b]
cfips	I5	State and County FIPS Code
lat	F5.2	Latitude
long	F6.2	Longitude
staid	A2	State Abbreviation
ctyid	C24	County Name
forar	Floating Point	Forest Area
fnvg	Integer	Number of Forest data records
forgen	Character	Forest Genera
crnar	Floating Point	Crown Area for the specific Genera
uforar	Floating Point	Urban Forest Area
ufnvg	Integer	Number of Urban Forest data records
uforgn	Character	Urban Forest Genera
ucrar	Floating Point	Crown Area for the specific Urban Forest Genera
agar	Floating Point	Agriculture Area
agnvg	Integer	Number of Agriculture data records

TABLE 4-3

(CONTINUED)

Variable Name	Format	Description[b]
agid	Character	Agriculture type identifier
aidar	Floating Point	Area of the specific type of agriculture
othar	Floating Point	Area of all other vegetation
onvg	Integer	Number of records of other vegetation
othid	Character	Other vegetation identifier
oidar	Floating Point	Area of specific other type of vegetation

[a] There is one file for each state; number of records for each county depends on number of specific vegetation types and consequently varies from county to county.
[b] All areas are recorded in hectares (ha).

TABLE 4-4

DESCRIPTION OF THE EMISSION FACTOR LOOKUP TABLE BEIS2.TAB

Variable Name	Format	Description	Units
vegid	C4	Vegetation Identification Code	Unitless
factrs(1)	F7.1	Isoprene Emission Factor	$\mu g\ m^{-2}\ h^{-2}$
factrs(2)	F6.1	Monoterpene Emission Factor	$\mu g\ m^{-2}\ h^{-2}$
factrs(3)	F6.1	Other VOCs Emission Factor	$\mu g\ m^{-2}\ h^{-2}$
factrs(4)	F5.1	NO Emission Factor	$\mu g\ m^{-2}\ h^{-1}$
lai	I1	Leaf Area Index	$m^2 m^{-2}$
genus	C30	Genus and Common Name[a]	unitless

[a] The data from the FIA database are aggregated to the genus level to be consistent with the emission factor database of Guenther *et al.* (1994). Other entries are common names for agriculture or generalized terms such as Boreal Forest for the AVHRR data source.

Optional data files that can be prepared by the model user are the meteorological file and a file containing the site information. The model also allows the user to enter this information directly into the model, but preparing the files before the model run should allow for input QA/QC and should be less cumbersome. Table 4-5 provides a description of the meteorological data input file. The file format for the site information file is simply the input information separated by commas. Site input parameters are listed in Table 4-6. Both of these input files are named by the user. Entering the meteorological and site information during the model run is described in the following section, *Running the Model*.

TABLE 4-5

OPTIONAL METEOROLOGICAL DATA FILE[a]

Variable Name	Format	Description
IHR	I3	Hour, local standard time (e.g., 12)
ACLDCV	Floating Point	Opaque sky cover - optional (fraction)
ATMPSR	Floating Point	Ambient temperature (°C)
UPAR	Floating Point	PAR (µE/m^2-sec)-optional (if PAR is not supplied, it wil be calculated from sky cover)

[a] Up to 24 records (hours) are allowed.

TABLE 4-6

OPTIONAL SITE INFORMATION DATA FILE

- FIPS
- Site Description
- Latitude
- Longitude
- Day
- Month
- Year
- Time Zone
- Begin Hour
- End Hour

Running the Model

PCBEIS2.2 is a simple to use PC-based model that provides the user with default values for all parameters except the location and meteorological data, which were discussed above.

PCBEIS2.2 is written to conform with the FORTRAN 77 standard and has been compiled on the PC with Microsoft FORTRAN version 5.0. PCBEIS2.2 has been compiled to allow its use on IBM-compatible personal computers. The executable, source code and necessary data files needed to run PCBEIS2.2 will take up approximately 3.16 MB of memory. In order for the menu interface to function properly, ANSI.SYS must be installed on your PC. ANSI.SYS is available with MS-DOS. It is recommended that PCBEIS2.2 users have a math co-processor.

Example 4-2

In this example, biogenic emissions for Wake County, North Carolina, are estimated for a 24-hour period. There are 7 basic steps for running the model:

(1) Start PCBEIS2.2 program;
(2) Identify the location of any input files;
(3) Identify any input and output files;
(4) Review, edit and save site information;
(5) Select, edit and save meteorology file;
(6) Calculate emissions; and
(7) End program.

Meteorological data were obtained from the National Climatic Data Center for the weather reporting station at Raleigh-Durham airport. The day chosen for simulation, August 19, 1988, had a maximum temperature of 103°F (313°K) and light to moderate winds.

Before beginning the model simulation, the user should assemble the data required. Site information includes the county FIPS code and the latitude and longitude of Wake County (35.8°N, 78.6°W).

Step 1

The user begins the model simulation by typing the command "PCBEIS."

Step 2

The first question that the program asks is:

```
Please enter the drive and directory where input files are located:
```

Enter the appropriate drive and directory.

Step 3

The next query is:

```
If you have a default input file, enter the name:
```

Enter the file name of the input file, or press the RETURN key if not. The next question is:

```
Please enter the output filename for this run:
```

For this example, enter "TEST.OUT."

Step 4

The site Input Screen appears as follows:

```
PCBEIS version 2.2

Site Input Screen

 1. FIPS              :  37183
 2. Site description :
 3. Latitude          :  35.80
 4. Longitude         :  78.60
 5. Day               :  19
 6. Month             :   8
 7. Year              :  88
 8. Time Zone         :   5
 9. Begin Hour        :   1
10. End Hour          :  24
11. Continue
12. Quit

Enter selection number to change and hit RETURN
```

Note that the default values listed above are for the Wake County example, so there is no need to modify any of the values. If the user wishes to modify a value, however, they would select the variable number (e.g., enter an "8" for the Time Zone). The program will position the cursor in the appropriate location, whereupon the user may enter a new value. Once the "Site Input Screen" is finalized, the user should enter "11" to continue.

When the site information is complete, the next screen asks:

```
If you want your input information saved, enter the file name here:
```

Enter the file name, or press the RETURN key.

Step 5

The next screen asks:

```
Do you wish to use a MET file for hourly met parameters:
```

If the user has already created a meteorological file, answer "YES." The next screen will ask for the name of the meteorological file:

```
Enter the MET filename:
```

Enter "TEST.MET" for example, and the following screen is shown.

```
PCBEIS version 2.2
Hourly Met Input Screen

      Hour     CldCvr   TpSf     PAR      Hour    CldCvr   TpSf     PAR
      1         .30     26.70    0.0      13      .10      35.60    0.0
      2         .50     26.10    0.0      14      .10      37.20    0.0
      3         .60     25.60    0.0      15      .30      38.90    0.0
      4        1.00     26.10    0.0      16      .40      38.30    0.0
      5        1.00     26.70    0.0      17      .40      37.80    0.0
      6         .80     25.60    0.0      18      .30      35.60    0.0
      7         .80     25.60    0.0      19      .30      35.00    0.0
      8         .50     25.60    0.0      20      .30      33.30    0.0
      9         .00     28.30    0.0      21      .30      30.60    0.0
      10        .10     30.60    0.0      22      .30      30.00    0.0
      11        .10     32.80    0.0      23      .60      29.40    0.0
      12        .10     35.00    0.0      24      .60      28.30    0.0

 OPTIONS
CLDCVR : "C"    DUP Hour  : "D"          Cloud cover (Fraction 50% = .50)
TPSF   : "T"    NEXT HOUR : "N"          Surface Temp.   (Degrees C)
PAR    : "P"                             PAR (µe/m²-hr)
GO     : "G"    QUIT      : "Q"

  Hit RETURN to continue
```

Initially, only one line of meteorological data is displayed. One line at a time may be modified with the options in the left-hand corner of the screen. Enter a "C" and RETURN to enter a different cloud cover value, or a "T" for temperature, or a "P" for PAR. Proceed to the next hour with an "N" for NEXT or the "D" to DUPLICATE the previous line. If no

changes are desired, the "G" for GO should be used to fill in the entire meteorological file; then enter RETURN to continue the program.

If PCBEIS2.2 is to be used to build the meteorological file from scratch, answer "no" to "Do you wish to use a MET file for hourly met parameters?" One line of default meteorological data will be displayed. The values may be modified using the options in the left-hand corner. New values may be entered until the file is complete. Enter RETURN to continue the program.

Preparation of a meteorological file is cumbersome using the procedure in PCBEIS2.2. These files can also be built outside of PCBEIS2.2 using a text editor, word processing, or spreadsheet program. The format consists of four columns of data which include: hour, sky cover (fraction), temperature (°C), and PAR (μ E/m_2-sec). Columns should be separated by a space and must be in ASCII format. This file does not require any header information. If PAR is recorded as 0.0, the value of PAR will be calculated based on the parameters previously provided for latitude, longitude, month and hour. The format for these parameters is illustrated below:

Hour	Sky Cover	Temp	PAR
1	0.3	26.7	0.0
2	0.5	26.1	0.0
3	0.6	25.6	0.0
4	1.0	26.1	0.0
5	1.0	26.7	0.0
6	1.0	25.6	0.0
7	0.8	25.6	0.0
8	0.5	25.6	0.0
9	0.0	28.3	0.0
10	0.1	30.6	0.0
11	0.1	32.8	0.0
12	0.1	35.0	0.0
13	0.1	35.6	0.0
14	0.1	37.2	0.0
15	0.3	38.9	0.0
16	0.4	38.3	0.0
17	0.4	37.8	0.0
18	0.3	35.6	0.0
19	0.3	35.0	0.0
20	0.3	33.3	0.0
21	0.3	30.6	0.0
22	0.3	30.0	0.0
23	0.6	29.4	0.0
24	0.6	28.3	0.0

Next, there is the option of saving the meteorological data file as the following is displayed:

```
Do you want to save the MET file for later use?:
```

In this example, the answer is "NO" because the data file was not modified. If the user had answered "YES," the following command would have been displayed:

```
Enter the MET filename:
```

Step 6

The PCBEIS2.2 now begins its computations and displays a status line like the following:

```
Processing HOUR:  3
```

Step 7

The last query from the program is as follows:

```
Do you wish to make another selection? (Y/N):
```

Answer "NO" and the final screen is displayed:

```
Program output is located in TEST.OUT
Program finished.
```

A listing of this output file is shown in Figure 4-3. This file is automatically saved using the user file name specified at the outset. For this example, it is TEST.OUT. The viewer can use the DOS TYPE command to view the data on the screen. The PRINT command can be

PCBEIS2.2 EMISSION RATES CORRECTED FOR MET INPUTS

*****Wake Co NC*****

Simulation Date : 8/19/88
Latitude : 35.80
Longitude : 78.60
Time Zone : 5

HR	CLD frac	TMPSRF C	ISOPRENE kg/h	ISO FLUX mg-C/m2-h	MONOTERP kg/h	MON FLUX mg/m2-h	OVOC kg/h	OVO FLUX mg-C/m2-h	NO kg/h	NO FLUX mg/m2-h
1	0.3	26	0	0	798.98	0.317	702.39	0.279	41.48	0.019
2	0.5	26	0	0	798.98	0.317	702.39	0.279	41.48	0.019
3	0.6	25	0	0	730.21	0.29	641.94	0.255	39.43	0.018
4	1	26	0	0	798.98	0.317	702.39	0.279	41.48	0.019
5	1	26	0	0	798.98	0.317	702.39	0.279	41.48	0.019
6	0.8	25	172.5	0.068	730.21	0.29	641.94	0.255	39.43	0.018
7	0.8	25	2216.02	0.879	730.21	0.29	641.94	0.255	39.43	0.018
8	0.5	25	4179.68	1.659	730.21	0.29	641.94	0.255	39.43	0.018
9	0	28	7103.62	2.819	956.55	0.38	840.92	0.334	45.89	0.021
10	0.1	30	9525.36	3.78	1145.2	0.455	1006.76	0.4	50.79	0.023
11	0.1	32	12173.92	4.832	1371.05	0.544	1205.31	0.478	56.21	0.025
12	0.1	35	16127.6	6.401	1796.03	0.713	1578.92	0.627	65.45	0.029
13	0.1	35	16083.4	6.383	1796.03	0.713	1578.92	0.627	65.45	0.029
14	0.1	37	17858.75	7.088	2150.24	0.853	1890.31	0.75	72.45	0.033
15	0.1	38	17819.05	7.072	2352.73	0.934	2068.33	0.821	76.23	0.034
16	0.3	38	16363.9	6.495	2352.73	0.934	2068.33	0.821	76.23	0.034
17	0.4	37	12944.72	5.138	2150.24	0.853	1890.31	0.75	72.45	0.033
18	0.4	35	6042.26	2.398	1796.03	0.713	1578.92	0.627	65.45	0.029
19	0.3	35	0	0	1796.03	0.713	1578.92	0.627	65.45	0.029
20	0.3	33	0	0	1500.17	0.595	1318.82	0.523	59.13	0.027
21	0.3	30	0	0	1145.2	0.455	1006.76	0.4	50.79	0.023
22	0.3	30	0	0	1145.2	0.455	1006.76	0.4	50.79	0.023
23	0.6	29	0	0	1046.63	0.415	920.11	0.365	48.28	0.022
24	0.6	28	0	0	956.55	.38	840.92	0.334	45.89	0.021

FIGURE 4-3. PCBEIS2.2 OUTPUT FILE LISTING

used to print a hard copy of the results. Note that the output results exceed 80 characters in width. The user must refer to a DOS manual to make the appropriate modifications for either screen viewing or printing for their particular system. The output can also be viewed or printed through use of a text editor or through a word processing or spreadsheet program.

4.3 ESTIMATING EMISSIONS FROM LIGHTNING

The preferred method for estimating emissions from lightning requires the collection of activity level data (cloud-to-ground [CG] lightning flashes) and determination of the study area's latitude. Activity for intra-cloud (IC) flashes are calculated from the CG activity. It is assumed that IC flashes occur about 4 times more frequently than CG flashes, and this ratio varies with latitude (Pierce and Novak, 1991). Readers should check with their regulatory representative to determine whether calculation of lightning NO is required. Lightning NO calculations are not performed routinely with regional models because of their relatively small contribution and the difficulty in obtaining lightning strike data.

The equation to calculate emissions from lightning is:

$$LNO = (N_{CG} \cdot E_{CG} \cdot EF_{CG}) + [(N_{CG} \cdot E_{CG}) \cdot (10/(1 + (\Phi/30)^2) - 1)] \cdot EF_{IC} \quad (4\text{-}1)$$

where:

LNO	=	NO emissions for lightning flashes in study area, molecules NO
N_{CG}	=	Number of CG flashes recorded by detection network in study area
E_{CG}	=	Efficiency of the CG network
EF_{CG}	=	Emission factor of NO for each CG lightning flash
Φ	=	Latitude of the study area in degrees
EF_{IC}	=	Emission factor of NO for each IC lightning flash

Activity for this emission equation can be collected either from the East Coast lightning detection network (Orville *et al.*, 1983), satellite data, or from the lightning strike data archive from Global Atmospherics, Inc. in Tucson, AZ. Global Atmospherics is the only known nationally available database for lightning strikes.

The efficiency of the East Coast CG detection network is approximately 0.7, making the efficiency factor 1.43. This efficiency factor may vary with the data source. The emission factors for CG and IC flashes are:

- CG flashes: $2.9 * 10^{26}$ molecules NO per flash; and
- IC flashes: $2.9 * 10^{25}$ molecules NO per flash.

Air models such as ROM or RADM require emission estimates to be separated into layers as well as grid cells. Emissions from IC flashes should be added to a 5-km layer above the CG flash, which will vary in height from 7 km (north of 35 N) to 10 km (south of 25 N), varying in a linear fashion between the two latitudes. The distribution of NO emitted is assumed to decrease with altitude as a function of density (Novak and Pierce, 1993).

4.4 Estimating Emissions from Oil and Gas Seeps

The preferred method for estimating emissions from any source category is the one that provides the most reliable emission estimate and also can be practically accomplished. In the case of oil and gas seeps, the most reliable emission estimate is developed through site-specific measurements of all of the sites or development of a local emission factor based on a detailed study of a representative sample. Since this method is very resource-intensive, it is recommended that it be used only when the source is potentially an important part of the inventory, either as a contributor to total emissions, as a source emissions that is close to the population, or as one that needs thorough definition for the sake of inventory completeness.

Parameters that will affect emissions from this source category are: flow rate, volatile constituents, vapor pressure of constituents, surface area, and local meteorology. Collecting information about flow rate, volatile constituents, or vapor pressure of constituents will allow more detailed local activity estimates and emission factors to be developed. Additional information about the seep's surface area, in the case of an oil seep, and local meteorology should be enough to calculate the emissions for a specific seep, or to develop a local emission factor for similar seeps.

Approaches to developing local emission factors would include categorizing the material in the seeps, and defining the volatile constituents and their physical properties for each type of categorized seep. Three categories of materials that might be emitted at an oil seep are:

- Asphaltum: A brownish-black solid or semisolid mixture of bitumens with a density of 8.4 to 9.9 lb/gal;
- Oil: Crude oil with a density of 7.08 to 7.3 lb/gal; and

- Tar: A dark, oily, viscid mixture, consisting mainly of hydrocarbons. Produced by the destructive distillation of organic substances such as wood, coal, or other organic substance with a density of 7.08 to 7.3 lb/gal.

Individual gas seeps may also vent different mixtures of gases.

Seeps can also be categorized by flow rate. A difficulty in determining this rate will be in how the oil or gas reaches the surface; seeps are often diffuse, and may exist over a widespread area. Any estimate of flow rate will need to be based on several measurements over that area and on an estimate of the extent of the area. It may be useful to classify seepage rates by vent size. Table 4-7 is a copy of the guidelines used to do a visual categorization of seepage rates in a study of off-shore oil and gas seeps. As an indicator of the scale of seepage rate categories, flow rates for two gas vents characterized as being light-moderate seeps were measured as being 1.08 and 0.89 cubic feet per hour (cfh). A small oil seep was visually estimated as having a flow rate of 40 milliliters per hour (Nekton, 1982).

The approach for either a detailed site-specific study or the development of local emission factors uses the following steps:

- Locate the occurance of all seeps in the inventory area;
- Determine the type of material that is emitted: gas, oil, asphalt or tar;
- Identify a suitable emission factor for the types of materials emitted, and the pollutants being inventoried;
- Estimate the amount of material emitted at the seep during the inventory interval (day, season or year) or the surface area of the material; and
- Collect the meteorological parameters that could affect emissions such as temperature and average local wind speed.

If the site-specific approach is used, it may be necessary to identify how the emissions may vary through time. If a local emission factor is developed, variability of the seep flow time and variability of physical qualities of seeps from one site to another should be considered. There are a number of factors that effect emissions from this source.

TABLE 4-7

EXAMPLE CATEGORIZATION OF UNDERWATER GAS SEEPAGE

Symbol	Assessment Term	Definition
VL	Very Light	An intermittent single stream of gas bubbles from undisturbed sediment or from a small vent hole.
L	Light	A continuous single stream of gas bubbles from a small vent hole. Bubbles generally have the same diameter.
LM	Light Moderate	A continuous gas flow of bubbles of various diameters and forming a dispersed stream of bubbles which emanate from a shallow pock-mark in the sediment.
M	Moderate	Multiple streams of gas bubbles flowing continuously from a basin-sized pock-mark in the sediment.
MH	Moderately Heavy	Multiple gas flows from the same conduit which has formed a large pock or dug a small crater.
H	Heavy	Large steady gas flows forming a rising column of gas, associated with a crater larger than a bathtub in the sediment.
VH	Very Heavy	Pulsating heavy seepage.

Some of the factors affecting emissions temporally are meteorology and seismic activity. Emissions from different seep sites can vary by: seep flow rate, volatile constituents in the seep material, vapor pressure of constituents, and seep surface area. Inventory preparers may want to consider including these factors in the data collection and in the emission estimation calculation.

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5

USING ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS

5.1 ALTERNATIVE METHODS FOR ESTIMATING BIOGENIC EMISSIONS

There are four alternate methods for estimating emissions of VOC or NO_x from biogenic sources. When investigating alternative methods, the Yienger and Levy method, for soil NO_x emissions should be considered first, if it is practical. The next alternatives are the BIOME and the use of alternate land use files with the BEIS-2. The fourth method is using a version of the BEIS, the earlier version of the BEIS-2. The last three of these methods estimate gridded, hourly, chemical species-specific VOC emissions. At the time of this writing, BIOME does not estimate NO_x emissions from soils, but the BEIS-2 and BEIS models do.

5.1.1 YIENGER/LEVY METHOD FOR SOIL NO_x

This approach has been developed to estimate a world-wide level of soil NO_x emissions. Yienger and Levy associate the variation of soil NO_x emissions with the following factors:

- Biomass burning;
- History of soil moisture (pulsing);
- Temperature;
- Soil moisture;
- Vegetation cover type (biome);
- Canopy reductions; and
- Fertilization rate.

Biomass burning

Biomass burning is recognized as a factor in soil NO_x, but is included only for tropical biomes in Yienger and Levy's approach. Emissions for tropical grasslands and tropical woodlands are simply increased by a factor of 3 during the dry to wet season transition period.

Pulsing

Pulsing is an increase of emissions that occurs when a dry soil is moistened. Pulsing is believed to have its greatest impact in the tropics, but the range of emissions increase ranges from 10 to 100 times more than background for any environment. Estimating the emissions resulting from a pulsing event requires a record of the rainfall in the study area for the past two weeks. When an area receives rain after two dry weeks, emissions will increase for a period of time. The increase in emissions and the duration of the increase will depend on the amount of rainfall.

This parameter could be used in US inventories, if the inventory preparers have access to records of rainfall that extend over the inventory period, and are prepared to do the calculations required. This parameter has been recognized as being important, but has not been addressed in previous models.

Temperature, moisture, biome

The equation used to calculate the effect of these parameters takes into account the following assumptions:

- Emissions from temperate biomes vary similarly in response to temperature. If one biome has emissions one order of magnitude greater than another at a given temperature, it will have proportionately larger emissions at a higher temperature. Yienger and Levy refer to this as "stratified" emissions. Biome parameters have been developed to fit emissions to a particular biome's emission range, and are based on literature reviews of field work;

- In moist soils, emissions increase exponentially with temperature within the temperature range of 10 to 30 degrees C;

    - Inundated soils suppress nitrifying bacteria, and thus, emissions.

    - Above the "optimal" soil temperature of 30 degrees C, temperature dependance of emissions disappears.

- Below the soil temperature of 10 degrees, moist soil emissions increase linearly with temperature.

- In dry soils, rather than an exponential increase, emissions tend to increase with temperature, in a weak linear relationship.

In temperate regions, the relationship between soil moisture and temperature may not be as important in areas such as the tropics where there can be large fluctuations in soil moisture. Soil moisture is determined using the same process of recording rainfall over a period of time before the time period of emission estimation.

Temperature is calculated from air temperatures using the same empirical relationships used by Williams *et al.* (1992), for wet soils, and by adding 5 degrees C to dry soils, based on observations of Johansson *et al.* (1988).

Biomes used in the Yienger and Levy study were identified as those that could be matched to the supporting data, such as a satellite-derived vegetation index and the empirically-derived factors. In this case, biomes are vegetation and land cover types. Biomes that are assumed to not have any emissions include water, ice, desert, and scrubland. Tundra, grassland, woodland, deciduous forests, coniferous forests, drought-deciduous forests, rain forests and agricultural lands are biomes that are assumed to have emissions.

Canopy Reduction

Canopy reduction is the loss of NO_x from soil by diffusion of NO_2 through plant stomata and deposition of NO_2 onto and through the cuticle. Although the dominant component of soil NO_x emissions is NO, and these processes absorb only NO_2, the process is accentuated by the conversion of NO to NO_2 by O_3 in the canopy. Canopy reduction is estimated for each biome, from leaf area index (LAI) and stomatal area index (SAI), and is included in the development of a biome parameter. However, although the biome canopy reduction is based on SAI and LAI specific to each biome, other constants used in the equation to calculate the canopy reduction are set to values measured in a Brazilian rain forest.

Fertilization Rate

Fertilizing soils with nitrogen fertilizers results in increased NO_x emissions, through the biological nitrification and denitrification of the fertilizer (depending on whether ammonium or nitrate fertilizer has been applied). Increased emissions can be 1 to 10% of the added nitrogen in the fertilizers.

Emissions are calculated using the equation:

$$\text{Flux} = f_{w/d}\,(\text{soil temperature}, A_{w/d}(\text{biome})) * P\,(\text{precipitation}) * CR(LAI, SAI) \quad (5\text{-}1)$$

where:

$f_{w/d}$	=	Function that is either constant, linear or exponential, depending on whether the soil is wet or dry ($_{w/d}$).
soil temperature	=	Function that is based on air temperature, varying according to soil moisture.
$A_{w/d}$(biome)	=	Function dependant on soil moisture, vegetation type, and latitude. Agricultural soils have a separate set of functions using the monthly fertilizer rate.
P (precipitation)	=	Function based on precipitation over the past two weeks.
CR(LAI, SAI)	=	Canopy reduction factors specific to each biome that describe the absorption by the plant canopy. Canopy reduction is roughly dependant on the leaf area index (LAI) and the stomatal area to leaf area, defined as the stomatal area index (SAI).

Data necessary to use this approach are:

- Rainfall--Yienger and Levy used six-hour resolution rainfall data. Emissions are dependant on rainfall during the previous two weeks;
- Air temperature;
- Biome; and
- Monthly fertilizer application rate for agricultural soils.

5.1.2 BIOME

BIOME is a GIS-based system that calculates gridded, hourly, chemical species-specific biogenic emission estimates for VOC. BIOME has been developed to be compatible with the GEMAP system, an emissions processing system, which has been developed to estimate emissions from biogenic sources, point, and area sources, and motor vehicles.

The emission rate equation used in BIOME is the same as that used in BEIS-2 and BEIS. BIOME, however, is designed to be flexible in terms of the parameters used in the equation. The model has recently been used to estimate emissions using 18 land use classes, and using

the environmental adjustment factors, leaf biomass factor, and similar emission factors to those that are used in the BEIS (Mayenkar, 1993).

The greatest distinction between the BIOME and the BEIS-2 or BEIS is that BIOME allows the user to change any of its parameters and the destination of the model's output files. BIOME allows input of biomass and emission factors for plant types and input of environmental adjustment factors. Land use and land cover can be entered as GIS coverages. BIOME also provides flexibility with output format, but is set up to create input files ready for GEMAP.

Enhancements to the model include quality assurance (QA) capabilities for the analysis of input and output. BIOME is designed with a scheme for gridding biomass distribution, which provides a higher level of detail than the BEIS model.

Disadvantages to using this model as opposed to the BEIS-2 are the greater amount of data collection and handling required for the BIOME, and the potential loss of consistency between areas, based on different choices being made while running the model. The advantage of locally collected land use types and up-to-date specific emission factors is that the result should be a higher quality emission estimate. Since biogenic VOC can be a significant contributor to the overall total, the effort required for more detailed input data may be justified.

The information that should be collected when using the BIOME without any of the model's default values are listed below with some potential information sources:

- Biomass: derived from literature review of field sampling;
- Emission factors: existing data, literature review, researcher contact, and assignment of surrogate factors;
- Land use: local records, aerial photos, state agricultural information, U.S. Census Bureau agricultural information, satellite images; and
- Meteorology: National Weather Service, local airports, other weather stations.

Also, in addition to collecting emission factors and other relevant data, users of the BIOME need to decide whether the default environmental adjustments, biomass adjustments, or leaf canopy models should be used or if substitutions for those adjustment models should be made. Users may consider the adjustments used in BEIS-2 as substitutes.

At this time, BIOME does not calculate emission estimates for NO_x from soils, as BEIS-2 and BEIS do. However, BIOME may include a soil NO_x module in the future. General

issues surrounding the development of alternate land use files or emission factors for soil NO_x and biogenic VOC, which are discussed below, apply to BIOME and the BEIS models.

5.1.3 USING ALTERNATE LAND USE FILES WITH BEIS

There are several advantages to using the BEIS-2 for biogenic emission estimates. Upgrades to the model are planned to incorporate updates to the algorithm and data files, based on new research and improved land use categorization. The model provides a nationally consistent emission estimation tool that provides results comparable to those from any other area that has used the same method. The most recent version of the BEIS-2 should provide a reliable emission estimate in most cases. However, the model's land use files are based on the most readily available national data, and more recent and detailed local information might provide better results. In such a case, BEIS-2 allows the user to alter land use files. There will also be cases when detailed local information gathering may be most effectively used with another biogenics emission estimation model, such as BEIS and BIOME, or with other methodologies that use the same algorithms as BEIS-2, but not the same data or the automated features of BEIS-2.

In Section 3 of this volume, the sources used to develop the BEIS-2 default land use files are listed. In many cases, this default file will be appropriate to use with BEIS-2. However, a user will need to consider using an alternate file in certain situations. Those situations are when:

- There has been a change in land use from that in the current default land use file;
- The land use file needs to be updated to reflect changes for use in a projected inventory; and
- It is necessary to provide more detailed and accurate land use data for modeling of urban areas.

When BEIS-2 is being used to create biogenic emission estimates for a projection inventory, the land use file may need to be changed. Changes to the land use file are necessary if significant changes in land use are projected to take place (e.g., if a major new development is planned, or population density is expected to increase in a previously rural area). This sort of local information should be uncovered during the development of projections for mobile and area sources. Use of BEIS-2 for projected biogenic emissions should rely on the same meteorology that is used for other projected emissions in the air quality model being used.

The BEIS-2 land use file is derived from land use data compiled from U. S. Forest Service, U. S. Census of Agriculture data, U. S. Census 1990 Urbanized Boundary data, and satellite

land classification data. The BEIS land use file is derived from land use data compiled from the Oak Ridge National Laboratory's Geoecology data set (Olsen, *et. al,* 1980). The land use data bases for both BEIS and BEIS-2 consist of gridded coverage for forests, agricultural crops, and other areas such as grasslands and water, with other areas being interpreted from satellite images. The satellite data covers areas in the west and arid ecosystems where there are gaps in the other datasets; however, because it does not have the kind of control that the Forest Service and the Agricultural Census data have, it is less reliable. Therefore, detailed land use information may need to be added for those areas, as well as for urban areas, which may also not be well covered. The default land use data is suitable for estimating biogenic emissions for the ROM, but should be examined before use with the UAM. PCBEIS2.2 users that are modeling urban areas should also review the land use data in the default land use data files before running the model.

Preparing Alternate Land Use Files

The data collection task for preparing alternate land use files for use in any of the biogenic models (BEIS-2, BEIS or BIOME) should be planned and defined before beginning the task itself. The major steps in the process are as follows:

- Assess agency resources and data needs;
- Determine the level of quality assurance/quality control (QA/QC) that will be performed;
- Define QA/QC procedures;
- Conduct inventory of available information;
- Determine what can be reasonably collected, converted, and compiled into land use files;
- Collect information;
- Convert into forms that can be used in the model's land use files (match spatial qualities and land use types); and
- Create data files.

All inventory processes require oversight and review. The QA/QC measures will be implemented more efficiently if they are planned as part of the entire process.

The agency should begin by assessing the time and resources available to gather, interpret, and arrange the information needed to prepare alternate land use files. The agency should also assess the level of detail needed. If time and money are available, the agency should inventory the available information and the review format. State and local agencies that can provide information are:

- Planning departments;
- Revenue departments;
- Parks and recreational services;
- Cooperative extension services;
- Engineering departments;
- Soil and water conservation services; and
- Geographic information services.

Other resources may be found at universities with geography, forestry, or agricultural departments; they may be able to provide detailed studies of small areas that could be extrapolated to larger areas.

While investigating potential sources of information, keep the model's data format requirements in mind. For example, if gridded land use is required, paper maps or county-level statistics may not be useful. However, many governments are storing information in GIS, and these digital files may be useful. In addition to the spatial characteristics of the data, determine if the land use types available from the local resources can be directly transferred to match the land use types used by the model. If they are not, some method for interpreting land use types from the available resources will need to be devised. Also, some method of determining the quality of the data should be devised. Old or unreliable data should be flagged and discarded. Land use files for BEIS-2 or BEIS can be created using the formats described in the sections that follow.

Using BEIS or BEIS-2 with Alternate Land Use Files

In order to input alternate land use information to BEIS or BEIS-2, one of two optional land use files must be generated. This section provides descriptions of these two optional land use files and the user-input control data necessary to use them. The discussion and descriptions in this section will use BEIS as the primary example.

Table 5-1 shows the variables and format of the optional gridded land use file, GRBIO for BEIS. For each grid cell, the user must input values in hectares for the 25 land use types used by BEIS. The BEIS-2 version of GRBIO has 94 land use types.

If alternate land use data is on a county level, the optional county land use file, UCBIO, may be used. For each FIPS code, the user must input values in hectares of the amount of area covered by the 25 land use types used by BEIS, or the 94 land use types used by BEIS-2. The variables and format of the county land use file for BEIS are specified in Table 5-2.

In order to trigger the use of the alternate land use files, control option flags must be set in the BEIS. The user must enter a number of variables to specify the domain and scenario-specific information, and control option flags. Three flags which control several options in BEIS must be set by the user. The first flag, called GIFLAG, must be set to TRUE if the user wishes to input his own gridded land use GRBIO file. The second flag, called CFLAG, must be set to TRUE if the optional UCBIO file is being used to input the user's own county land use data. The third flag, called GROWFLAG, must be set if the user inputs gridded land-use data; this flag is set to TRUE to indicate that vegetation is growing and FALSE to indicate only coniferous vegetation is growing, which might be the case in a cold season like late fall or winter. A listing of the user-input control data is found in Table 5-3.

Using PCBEIS2.2 with Alternate Land Use Files

Using an alternate land use file with PCBEIS2.2 can be done in order to provide more accurate or recent data to the model, or to model a partial county area. PCBEIS2.2 uses the file cc_LU.DAT to define the area and land use types of each county. By altering the contents of the file, the land use types used by the model for the county can be changed. The procedure is to:

- Make a copy of the original cc_LU.DAT file on a disk or some other safe place;

TABLE 5-1

BEIS GRBIO VARIABLES

Record No.	Variable Name	Data Type	Description
1	COL	I*4	Column
	ROW	I*4	Row
	Land Use (ha)		
	VEGA(1)	R*4	Oak forest area
	VEGA(2)	R*4	Deciduous forest area
	VEGA(3)	R*4	Coniferous forest area
	VEGA(4)	R*4	Urban oak forest area
	VEGA(5)	R*4	Urban deciduous forest area
	VEGA(6)	R*4	Urban coniferous forest area
	VEGA(7)	R*4	Alfalfa area
	VEGA(8)	R*4	Sorghum area
	VEGA(9)	R*4	Hay area
	VEGA(10)	R*4	Soybean area
	VEGA(11)	R*4	Corn area
	VEGA(12)	R*4	Potato area
	VEGA(13)	R*4	Tobacco area
	VEGA(14)	R*4	Wheat area
	VEGA(15)	R*4	Cotton area
	VEGA(16)	R*4	Rye area
	VEGA(17)	R*4	Rice area
	VEGA(18)	R*4	Peanut area
	VEGA(19)	R*4	Barley area
	VEGA(20)	R*4	Oats area
	VEGA(21)	R*4	Scrub area
	VEGA(22)	R*4	Grass area
	VEGA(23)	R*4	Urban grass area
	VEGA(24)	R*4	Miscellaneous crops area
	VEGA(25)	R*4	Water area

TABLE 5-2

BEIS UCBIO VARIABLES

Record No.	Variable Name	Data Type	Description
1	UCTID	I*4	FIPS county code
	Land Use (ha)		
	VEGA(1)	R*4	Oak forest area
	VEGA(2)	R*4	Deciduous forest area
	VEGA(3)	R*4	Coniferous forest area
	VEGA(4)	R*4	Urban oak forest area
	VEGA(5)	R*4	Urban deciduous forest area
	VEGA(6)	R*4	Urban coniferous forest area
	VEGA(7)	R*4	Alfalfa area
	VEGA(8)	R*4	Sorghum area
	VEGA(9)	R*4	Hay area
	VEGA(10)	R*4	Soybean area
	VEGA(11)	R*4	Corn area
	VEGA(12)	R*4	Potato area
	VEGA(13)	R*4	Tobacco area
	VEGA(14)	R*4	Wheat area
	VEGA(15)	R*4	Cotton area
	VEGA(16)	R*4	Rye area
	VEGA(17)	R*4	Rice area
	VEGA(18)	R*4	Peanut area
	VEGA(19)	R*4	Barley area
	VEGA(20)	R*4	Oats area
	VEGA(21)	R*4	Scrub area
	VEGA(22)	R*4	Grass area
	VEGA(23)	R*4	Urban grass area
	VEGA(24)	R*4	Miscellaneous crops area
	VEGA(25)	R*4	Water area

TABLE 5-3

USER-INPUT CONTROL VARIABLES

Record No.	Control Variable	Description
1	SDATE	Scenario starting date (Julian)
	SHOUR	Scenario starting hour
	EDATE	Scenario ending date (Julian)
	EHOUR	Scenario ending hour
	MONTH	Month of scenario
	NCOLS1	Number of columns
	NROWS1	Number of rows
	GMT	Number of hours from GMT to local
2	GIFLAG	TRUE/FALSE flag to show if user-supplied gridded land use data is being used TRUE if using user-supplied data FALSE if not
	CFLAG	TRUE/FALSE flag to show if user-supplied county land used data is being used. TRUE if vegetation is growing FALSE if not
	GROWFLAG	TRUE/FALSE flag to show if vegetation is growing or not. TRUE if vegetation is growing FALSE if only coniferous vegetation is growing (late fall and winter)
3	NUMCNTY	Number of counties to be processed
4	COUNTY(NUMCNTY)	FIPS codes of counties to be processed
	-9999	Indicates end of list of FIPS codes

NOTE: The control variables data is unformatted; values are separated by commas.

- Use an ASCII text editor to find and alter the listing for the county of interest. Counties are sorted by FIPS code. The format of the individual records can be found in the user's guide for PCBEIS2.2 (Birth, 1995);

- Check the accuracy of the land use types in the county. If a partial county is being modeled, set the value for the area of the partial county, and area (all areas are in hectares) of land use types in the partial county. Make sure the land use types add up to the area being modeled;

- Run PCBEIS2.2. The output will be the value for the corrected county. This version's output and copies of altered the land use file should be kept in a separate directory or on a disk that is clearly labeled; and

- Include the print-out of the modified cc_LU.DAT file in the inventory documentation, along with a justification of the data and methods used.

When using this method, it is important to remember these warnings in order to avoid pitfalls:

- Back up the original land use file;

- Convert acres to hectares (1 acre = 0.405 hectares); and

- The new land use record should add up to the county area.

5.2 USING ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS FROM LIGHTNING

Any method for estimating emissions from this source carries with it a high amount of uncertainty. Estimates of NO_x emissions per lightning stroke require calculations involving the length of the stroke, the number of strokes per flash, the estimated energy discharge, and the amount of NO_x produced per Joule, all of which are uncertain.

The alternative to the preferred method for this source is to define more reliable values for the factors listed above, or to use a more accurate lightning activity estimate than that used in the preferred method if one becomes available. Either of these alternatives would depend on advances reported in journal articles and technical reports.

5.3 USING ALTERNATIVE METHODS FOR ESTIMATING EMISSIONS FROM OIL AND GAS SEEPS

Very little work has been done to measure emissions from this source because it occurs infrequently and because measuring emissions from this source can be difficult. Because the more detailed site-specific approach is very resource intensive, an alternative method for estimating emissions from oil and gas seeps is to collect local data about the location and volume of the seeps, and multiply by an emission factor. This method is based on the CARB's "Area Source Methodologies" Section 1.11, Oil and Gas Seeps. Information that should be collected for this method includes:

- Location of oil or gas seeps: information should be available from the U. S. Geological Survey, state or local geological surveys, universities, local chapters of petroleum exploration trade organizations, or petroleum exploration companies exploring or extracting in the area; and

- Flow rate from the seeps: information should be available from the same resources as for location of seeps.

Assumptions that must be made at this point are that the seeps identified in the location step represent the main portion of existing seeps in the area, and that measurements or estimates of flow rate at a particular time can be scaled up to represent annual flow. Flow rate estimates may need to be made from qualitative descriptions of seeps. Whenever possible try to match these descriptions with descriptions that include a quantitative estimate of flow and use that estimate. Emission factors for total organic gas (TOG) for oil and gas seeps are presented in Table 5-4.

TABLE 5-4

EMISSION FACTORS FOR OIL AND GAS SEEPS

Type of Seep	Emission Factor TOG[a]	Units
Oil	105	pounds/barrel[b]
Gas	48,648.65	pounds/million cubic feet

[a] Total Organic Gas
[b] 1 barrel = 42 gallons

Seep emissions can be further speciated by using the speciation profiles in Table 5-5 and Table 5-6.

TABLE 5-5

VOC SPECIES PROFILE--OIL SEEPS, VOLATILE FRACTION

Species	Weight Fraction
Benzene	0.0100
n-Butane	0.0700
Ethane	0.0100
Isomers of Decane	0.1200
Isomers of Dodecane	0.1200
Isomers of Heptane	0.1200
Isomers of Hexane	0.0800
Isomers of Nonane	0.1200
Isomers of Octane	0.1200
Isomers of Pentane	0.0700
Isomers of Undecane	0.1200
Propane	0.0300
Toluene	0.0100
TOTAL	1.0000

TABLE 5-6

VOC SPECIES PROFILE--GAS SEEPS

Species	Weight Fraction
n-Butane	0.0700
Ethane	0.0600
Isomers of Heptane	0.0100
Isomers of Hexane	0.0100
Isomers of Pentane	0.0300
Methane	0.7500
Propane	0.0700
TOTAL	1.0000

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