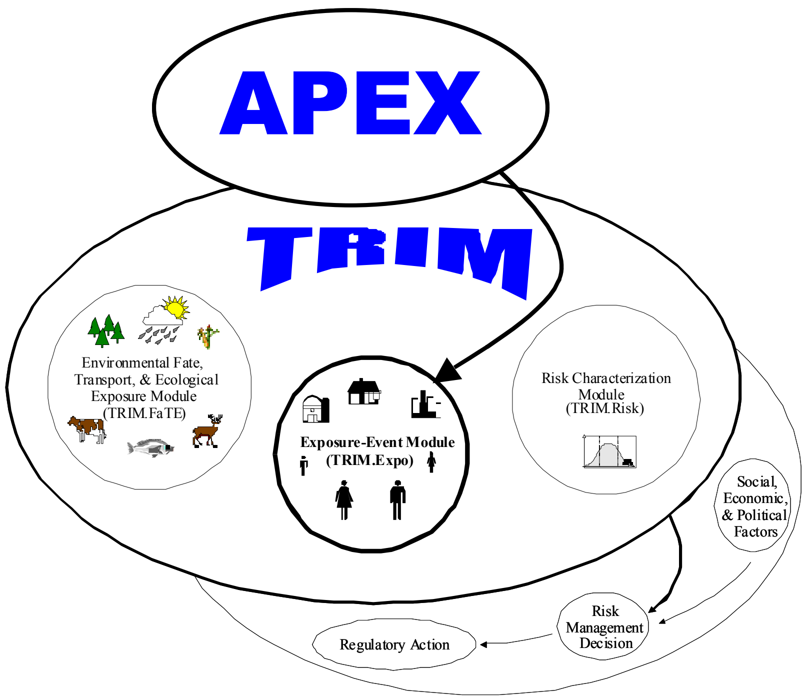
Total Risk Integrated Methodology
TRIM.Expo$_{Inhalation}$ User's Document

Volume I: Air Pollutants Exposure Model (APEX, version 3) User's Guide



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

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Total Risk Integrated Methodology TRIM.Expo$_{\text{Inhalation}}$ User's Document

Volume I: Air Pollutants Exposure Model (APEX, version 3) User's Guide

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Disclaimer

Preface

This document, the APEX User's Guide, is part of a series of documentation for the overall Total Risk Integrated Methodology (TRIM) modeling system, in particular the inhalation component of the exposure module ($TRIM.Expo_{Inhalation}$). The detailed documentation of TRIM's logic, assumptions, algorithms, equations, and input parameters is provided in comprehensive technical support documents (TSDs) and/or user's guidance for each of the TRIM modules. One of those documents is this user's guide, which is designed primarily to assist exposure analysts with running the Air Pollutants Exposure model (APEX), a personal computer (PC)-based program designed to estimate human exposure to criteria and air toxic pollutants at the local, urban, and consolidated metropolitan level. The guide currently is divided into four volumes. Volume I, User's Guide (this volume) is the first volume to be released. It describes the scientific basis of the APEX model (version 3) and describes the steps involved in running APEX for both basic and more advanced applications. Volume II, Programmer's Guide describes the model and computer code in more detail and thus provides advanced users with a greater understanding of the model. Volume III, Criteria Air Pollutants Case Study and Volume IV, Hazardous Air Pollutants Case Study illustrate the use of APEX by applying it to carbon monoxide (criteria air pollutant) and benzene and chromium (hazardous air pollutants), respectively. Additional volumes or revisions to these volumes may be developed as the model is upgraded, example applications are developed, or other needs arise.

Model enhancements, bug fixes, and other changes are occasionally made to APEX, and thus users are encouraged to revisit the download website for notices of these changes, including those listed in a *readme.txt* file. Also, although APEX has been tested during development, the number of available computer configuration options preclude the possibility of testing all possible scenario configurations. Thus, it is possible that bugs remain in the code for some configurations. The current version of APEX is a draft release and users should be considered beta-testers.

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Contents

Tables

Figures

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1. INTRODUCTION

The Air Pollutants Exposure model (APEX) is part of EPA's overall Total Risk Integrated Methodology (TRIM) model framework (EPA, 1999), in particular the inhalation exposure component ($\text{TRIM.Expo}_{\text{Inhalation}}$). TRIM is a time series modeling system with multimedia capabilities for assessing human health and ecological risks from hazardous and criteria air pollutants; it is being developed to support evaluations with a scientifically sound, flexible, and user-friendly methodology. The TRIM design includes three modules:

- Environmental Fate, Transport, and Ecological Exposure module (TRIM.FaTE);
- Human Exposure-Event module (TRIM.Expo); and
- Risk Characterization module (TRIM.Risk).

> **Nomenclature** used throughout this User's Guide for key model components (defined later in this guide):
>
> - Tips to users and other useful information appear throughout in a shaded text box (such as this one).
> - Key terms are underlined for emphasis.
> - *Input file names* and *file types* are in Italics.
> - Model ***Variables*** or parameters are in regular bold italics, especially when first used in a section. ***KEYWORDS***, which are how the variable and parameter names appear in the input files, are in uppercase bold italics.
> - `Input and output data` are in a single lined box, indicating that the text inside the box is shown exactly as it exists in its electronic form.
> - **Computer program and module names** are in all bold, non-italic.

APEX, a personal computer (PC)-based program, is one of the tools being developed to estimate human exposure via inhalation for criteria and air toxic pollutants. APEX is designed to estimate human exposure to criteria and air toxic pollutants at the local, urban, and consolidated metropolitan level.

The $\text{TRIM.Expo}_{\text{Inhalation}}$ user's document currently is divided into four volumes. Volume I, User's Guide (this volume) is the first to be released. It describes the scientific basis of the APEX model and describes the steps involved in running APEX for both basic and more advanced applications. Volume II, Programmer's Guide describes the model and computer code in more detail and thus provides users with a greater understanding of the model. Volume III, Criteria Air Pollutants Case Study and Volume IV, Hazardous Air Pollutants Case Study illustrate the use of APEX by applying it to carbon monoxide (criteria air pollutant) and benzene and chromium (hazardous air pollutants), respectively. Additional volumes or revisions to these volumes may be developed as the model is upgraded, example applications are developed, or other needs arise. Users are encouraged to revisit the download website (http://www.epa.gov/ttn/fera) for notices of these changes, including those listed in a *readme.txt*.

Note that APEX has been extensively reviewed. Any changes to the computer code may lead to results that cannot be supported by this documentation.

1.1 Organization of Volume I

This User's Guide is designed for all levels of expertise, from novice to advanced, and focuses on how to run the APEX computer model, develop the appropriate input files, and utilize the range of options. Volume I is organized into six chapters, plus a reference section at the end:

- *Chapter 1, Introduction*—Describes the nomenclature used in this guide (see above box), provides a brief overview of the conceptual model, discusses the model's strengths, limitations, and applicability, and provides a brief history of the model.
- *Chapter 2, Overview of Model Design And Algorithms*—Describes the key modeling steps, databases, logic processes, and exposure and other equations used in APEX.
- *Chapter 3, Installing APEX*—Describes the hardware requirements and provides instructions for installing APEX on a PC.
- *Chapter 4, Running APEX*—Provides step-by-step instructions and an overview of the basic information needed to run the model and use the available model options.
- *Chapter 5, Input Files*—Provides a description of the format, data, and options for each of the APEX input files.
- *Chapter 6, Output Files*—Provides a description of the format and data associated with each of the APEX output files.

1.2 Background and Overview

This section describes some of the key terms used in this guide (see box below) and provides a brief conceptual description of the model—additional detail is provided in Chapter 2.

APEX estimates human exposure to criteria and toxic air pollutants at the local, urban, and consolidated metropolitan area level using a stochastic, "microenvironmental" approach. That is, the model randomly selects data on a sample of hypothetical individuals in an actual population database and simulates each individual's movements through time and space (e.g., at home, in vehicles) to estimate their exposure to and, optionally, dose of the subject pollutant. APEX can assume people live and work in the same general area (i.e., that the ambient air quality is the same at home and at work) or optionally can model commuting and thus exposure at the work location for individuals who work. One caveat is that this option only applies to people who both live and work in the study area—people who work inside the study area but live outside of it are not modeled under this option, nor are people who live in the study area but work outside of it.

APEX can be thought of as a simulation of a field study that would involve selecting an actual sample of specific individuals who live in (or work and live in) a geographic area and then continuously monitoring their activities and subsequent inhalation exposure to a specific air

Key terms used throughout this User's Guide:

- Diary—a set of events or activities (e.g., cooking, sleeping) for an individual in a given time frame (e.g., a day).
- District—the geographical area represented by a given set of ambient air quality data (either based on a fixed-site monitor or output from an air quality model).
- Event—an activity (e.g., cooking) with a known starting time, duration, microenvironment, and location (usually home or work).
- Microenvironment—a three-dimensional space in which human contact with an environmental pollutant takes place.
- Profile—a set of characteristics that describe the person being simulated (e.g., age, gender, height, weight, employment status, whether an owner of a gas stove or air conditioner).
- Sector—the basic geographical unit for estimating exposure to the study population (e.g., census tract).
- Study Area—the geographical area to be modeled (e.g., metropolitan region).
- Study Area Population—total population of persons who live in the study area; when the commuting option is used, the study area population does not include those who work outside the study area.
- Zone—similar to district, but for ambient temperature data.

pollutant during a specific period of time. The main differences between the model and an actual field study are that in the model:

- The sample of individuals is a "virtual" sample, created by the model according to various demographic variables and census data of relative frequencies, in order to obtain a representative sample (to the extent possible) of the actual people in the study area;
- The activity patterns of the sampled individuals (e.g., the specification of indoor and other microenvironments, the duration of time spent in each) are assumed by the model to be the same as for individuals with similar demographic characteristics, according to activity data such as diaries compiled in EPA's Consolidated Human Activities Database (CHAD) (EPA, 2002c; McCurdy et al., 2000);
- The pollutant exposure concentrations and doses are estimated by the model using a set of user-input ambient outdoor concentrations and information on the behavior of the pollutant in various microenvironments; and
- Various reductions in ambient air quality levels can be simulated by either adjusting air quality concentrations to just attain alternative ambient standards under consideration or by reducing source emissions and obtaining resulting air quality modeling outputs that reflect these potential emission reductions.

Thus, the model attempts to account for the most significant factors contributing to inhalation exposure—the temporal and spatial distribution of people and pollutant concentrations throughout the study area and among the microenvironments—while also allowing the flexibility to adjust some of these factors for regulatory assessment and other reasons.

The basic steps simulated by APEX for estimating exposure of each individual in the sample are: (1) adjust the study area based on sectors (e.g., census tracts) and the availability of air quality and weather data; (2) generate simulated individuals in the study area using census-derived frequency (probability) distributions of demographic and other variables (age, gender, home location, work location) to randomly select and develop a personal profile for each individual; (3) construct a sequence of activity events for each profile, taking into consideration the demographic variables (e.g., child, adult) and day type (e.g., weekday or weekend, temperature) being modeled; (4) calculate hourly concentrations in the microenvironments by determining the pollutant concentration for each hour of the profile diary using ambient outdoor concentration data supplied by the user and information on outdoor-microenvironment relationships or dynamics supplied in data input files and incorporated into the model; (5) estimate the pollutant exposure for each activity in the diary and then average the concentrations by hour to obtain an hourly exposure time series; and (6) estimate the dose, which is an optional step and one that can be conducted only for carbon monoxide currently.

After the specified number of individuals are sampled and exposures and/or doses estimated, APEX produces a set of summary tables that indicate the distributions of exposure and dose (if the dose option was selected) across all the profiles.

1.3 Strengths and Limitations of APEX

All models have strengths and limitations. Therefore, for each application, it is important to carefully select the model that has the desired attributes. With this in mind, it is equally important to understand the strengths and weaknesses of the chosen model. The following sections provide a summary of the strengths and potential limitations of APEX.

1.3.1 Strengths

APEX simulates the movement of individuals through time and space to estimate their exposure to a given pollutant in indoor, outdoor, and in-vehicle microenvironments. Compared to conducting a field study that would involve identifying, interviewing, and monitoring specific individuals in a study area, APEX provides a vastly less expensive, more timely, and more flexible approach. Compared to other air exposure models, APEX provides a good balance in terms of precision and resource expenditure between the more narrowly focused site-specific model and the broadly applicable national screening-level models.

The model also allows different air quality data, exposure scenarios, and other inputs and thus is very useful for decision making.

Another important feature of APEX is its versatility. The model is designed with a great deal of flexibility so that detailed input data can be applied to specific applications. For example, the supplied input data sets for this model contain information for numerous microenvironments. Another example is that the air quality data needed by the model can be in the form of monitoring or modeling data. The data can be for specific locations, or political units such as counties, or census units such as tracts, or even grid points used as air dispersion models receptors. Furthermore, both criteria and hazardous air pollutants can be modeled.

A key strength of APEX is its ability to estimate hourly exposures and doses for all simulated individuals in the sample population from the study area. This ability allows for powerful statistical analysis of a number of exposure characteristics (e.g., acute versus chronic exposure, correlations with activities and demographics), many of which are provided automatically by APEX in output tables.

APEX also estimates the exposures of workers in the geographic area where they work, in addition to the geographic area where they live. The pollutant concentrations in these respective locations may be very different from each other.

APEX incorporates stochastic processes representing the natural variability of personal profile characteristics, activity patterns, and microenvironment parameters. In this way, APEX is able to represent much of the variability in the exposure estimates resulting from the variability of the factors effecting human exposure.

Exposure analysis with APEX has also been facilitated by the development of supplied input files derived from the databases discussed above: national U.S. Census population and commuting information; CHAD activity data; and microenvironment variables.

1.3.2 Limitations

A limitation of APEX is that uncertainty in the predicted distributions is not currently addressed. Some of the uncertainties are as follows.

- The population activity pattern data supplied with APEX (CHAD activity data) are compiled from a number of studies in different areas, and for different seasons and years. Therefore, the combined data set may not constitute a representative sample. Nevertheless, the largest portion of CHAD (about 40 percent) is from a study of national scope (which could be extracted by the user if desired to create a representative sample). Also, research has shown that activity patterns are generally similar once you take into account age, gender, day of week, and season/temperature.

- Commuting pattern data were derived from the 1990 U.S. Census, and these data have been updated to 2000 proportionally based on 2000 Census data. Therefore, the commuting pattern data may not accurately reflect current commuting patterns. Moreover, the commuting data address only home-to-work travel. The population not employed outside the home is assumed to always remain in the residential census tract. Furthermore, although several of the APEX microenvironments account for time spent in travel, the travel is assumed to always occur in basically a composite of the home and work tract. No other provision is made for the possibility of passing through other tracts during travel.

- APEX creates seasonal or year long sequences for a simulated individual by sampling human activity data from more than one subject. Thus, uncertainty exists about season-long exposure event sequences. This approach also tends to underestimate the variability from person to person, because each simulated person essentially becomes a composite or an "average" of several actual people in the underlying activity data (which tends to dampen the variability). At the same time, this approach may overestimate the day to day variability for any individual because each simulated person is represented by a sequence of potentially dissimilar activities from different people rather than more similar activities from one person.

- The model currently does not capture certain correlations among human activities that can impact microenvironmental concentrations (e.g., cigarette smoking leading to an individual opening a window, which in turn affects the amount of outdoor air penetrating the residence).

Also, certain aspects of the personal profiles are held constant, though in reality they change every year (e.g., age). This is generally only an issue for simulations with long timeframes.

Other data and model limitations exist besides those identified above, including physiological, meteorological, and those associated with estimating concentrations in microenvironments. EPA will continue to refine the model and data to reduce these limitations to the extent possible.

1.4 Applicability

APEX is a moderate to advanced tier air exposure model for local, urban, and consolidated metropolitan areas. As part of TRIM, for risk assessments it generally would be used after a simpler, more conservative model or analysis has been applied that prioritizes exposure factors (area, scenarios, pollutants) for further investigation. APEX will provide more detailed estimates of exposure for scenarios identified in screening activities as high priority and/or for regulatory analyses supporting national decisions (e.g., NAAQS reviews).

APEX is appropriate for assessing both average long-term and hourly short- and long-term inhalation exposures of the general population or a specific sub-population. The model is designed to look at the range of inhalation exposures of different groups of people across a population.

Notwithstanding the ability of APEX to assess hourly exposure, however, the model should not be used to quantify episodic "high-end" inhalation exposure that results from highly localized pollutant concentrations and/or activities that, by their nature, could result in potentially high exposures (e.g., emergency releases, occupational exposures). Furthermore, APEX cannot address cumulative exposure from multiple pollutants nor pollutant mixtures.

1.5 Brief History of APEX

The APEX series of models derive from the probabilistic National Ambient Air Quality Standards (NAAQS) Exposure Model for Carbon Monoxide (pNEM/CO). The evolution of these models has been towards greater flexibility and accuracy. The NEM series was developed to estimate exposure to the criteria pollutants (e.g., CO, ozone). In 1979, EPA began to develop NEM by assembling a database of human activity patterns that could be used to estimate exposures to outdoor pollutants (Roddin et al., 1979). The data were then combined with measured outdoor concentrations in NEM to estimate exposures to CO (Biller et al., 1981; Johnson and Paul, 1983). In 1988, OAQPS began to incorporate probabilistic elements into the NEM methodology and using activity pattern data based on various human activity diary studies in an early version of probabilistic NEM for ozone (i.e., pNEM/O_3). In 1991, a probabilistic version of NEM was developed for CO (pNEM/CO) that included a one compartment mass-balance model to estimate CO concentrations in indoor microenvironments and the application of this model to Denver, Colorado has been documented (Johnson et al., 1992). Several newer versions of pNEM/O_3 were developed in the early to mid-1990's including applications to nine urban areas for the general population, outdoor children, and outdoor workers (Johnson et al., 1996a,b,c). During 1999-2001, updated versions of pNEM/CO (versions 2.0 and 2.1) were developed that rely on activity diary data from CHAD and enhanced algorithms for simulating gas stove usage, estimating alveolar ventilation rate (a measure of human respiration), and modeling home-to-work commuting patterns.

The first version of APEX was essentially identical to pNEM/CO (version 2.0) except that it ran on a PC instead of a mainframe. The APEX2 model was substantially different, particularly in the use of a personal profile approach rather than a cohort simulation approach. APEX3 introduced a number of new features including automatic site selection from large (e.g., national) databases, a series of new output tables providing summary statistics, and a thoroughly reorganized method of describing microenvironments and their parameters. Most of the spatial and temporal constraints were removed or relaxed in APEX3.

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2. OVERVIEW OF MODEL DESIGN AND ALGORITHMS

This chapter describes the key modeling steps, logic processes, and equations, and data bases used in APEX3. It is written primarily to give exposure assessors an overview of the model from a technical perspective and an understanding of the scientific basis of the core elements; it is not a comprehensive description of all algorithms. See Volume II for additional detail on the algorithms and how they are incorporated into the model, and see Johnson (2002) for additional detail regarding the derivation and scientific basis of these and other algorithms used in exposure modeling.

APEX is designed to simulate population exposure to criteria and air toxic pollutants at local, urban, and regional scales. The user specifies the geographic area to be modeled and the number of individuals to be simulated to represent this population. APEX then generates a personal profile for each simulated person that specifies various parameter values required by the model. The model next uses diary-derived time/activity data matched to each personal profile to generate an exposure event sequence (also referred to as “activity pattern” or “composite diary”) for the modeled individual that spans a specified time period, such as one year. Each event in the sequence specifies a start time, an exposure duration, a geographic location, a microenvironment, and an activity. Probabilistic algorithms are used to estimate the pollutant concentration and ventilation (respiration) rate associated with each exposure event. The estimated pollutant concentrations account for the effects of ambient (outdoor) pollutant concentration, penetration factor, air exchange rate, decay/deposition rate, and proximity to emission sources, depending on the microenvironment, available data, and the estimation method selected by the user. The ventilation rate is derived from an energy expenditure rate estimated for the specified activity. Because the modeled individuals represent a random sample of the population of interest, the distribution of modeled individual exposures can be extrapolated to the larger population. The model simulation includes up to six steps:

1. Characterize the study area - APEX selects sectors (e.g., census tracts) within a study area—and thus identifies the potentially exposed population—based on the user-defined center and radius of the study area and availability of air quality and weather input data for the area.

2. Generate simulated individuals - APEX stochastically generates a sample of simulated individuals based on the census data for the study area and human profile distribution data (such as age-specific employment probabilities). The user can specify the size of the sample. The larger the sample, the more representative it is of the population in the study area (but also the longer the computing time).

3. Construct a sequence of activity events - APEX constructs an exposure event sequence (activity pattern) spanning the period of simulation for each of the simulated persons (based on the supplied Consolidated Human Activity Database (CHAD) data, although other data could be used).

4. Calculate hourly concentrations in microenvironments - APEX enables the user to define microenvironments that people in a study area would visit (e.g., by grouping location codes included in the supplied CHAD database). The model then calculates hourly concentrations of a pollutant in each of the microenvironments for the period of simulation,

based on the user-provided hourly ambient air quality data. All the hourly concentrations in the microenvironments are re-calculated for each of simulated individuals.

5. Determine exposures - APEX assigns a concentration to each exposure event based on the microenvironment occupied during the event and the person's activity. These values are averaged by clock hour to produce a sequence of hourly-average exposures spanning the specified exposure period (typically one year). These hourly values may be further aggregated to produce daily, monthly, and annual average exposure values.

6. Determine doses - APEX optionally calculates hourly, daily, monthly, and annual average dose values for each of the simulated individuals. This option currently is available only for CO.

The model simulation continues until exposures are determined for the user-specified number of simulated individuals. Figure 2-1 presents these steps within a schematic of the APEX model design. The following sections provide addition detail on the key algorithms used in each of the above simulation steps.

2.1 Characterize the Study Area

A study area in an APEX analysis consists of a set of basic geographic units called sectors (typically defined as census tracts). The user generally provides the geographic center (latitude/longitude) and radius of the study area. APEX calculates the distances to the center of the study area of all the sectors included in the sector location database, and then selects the sectors within the radius of the study area. APEX then maps the user-provided hourly air district and daily temperature zone data to the selected sectors. The sectors identified as having acceptable air and temperature data within the radius of the study area are selected to comprise a final study area for the APEX simulation analysis.

The following sections describe in more detail how a study area is defined in an APEX simulation analysis.

2.1.1 Study Area

The APEX study area has traditionally been on the scale of a city or slightly larger metropolitan area, although it is now possible to model larger areas such as consolidated metropolitan statistical areas (CMSAs). Even larger study areas may be possible, depending primarily on computing capabilities, available data, and the desired precision of the run.

The user defines an initial study area by specifying the latitude and longitude of a central point, together with a radius. The user also has the option of providing a list of counties to be modeled. If present, this list further restricts the area to the countries to be modeled which are within the specified study area radius. The final study area is a function of the availability of the user-supplied demographic data, pollutant concentration data, and the location temperature data within the initial or intermediate study area, as determined respectively by population sectors, air data districts, and temperature zones. Figure 2-2 and the subsections below provide additional details about these geographical units.

Figure 2-1a. Overview of APEX

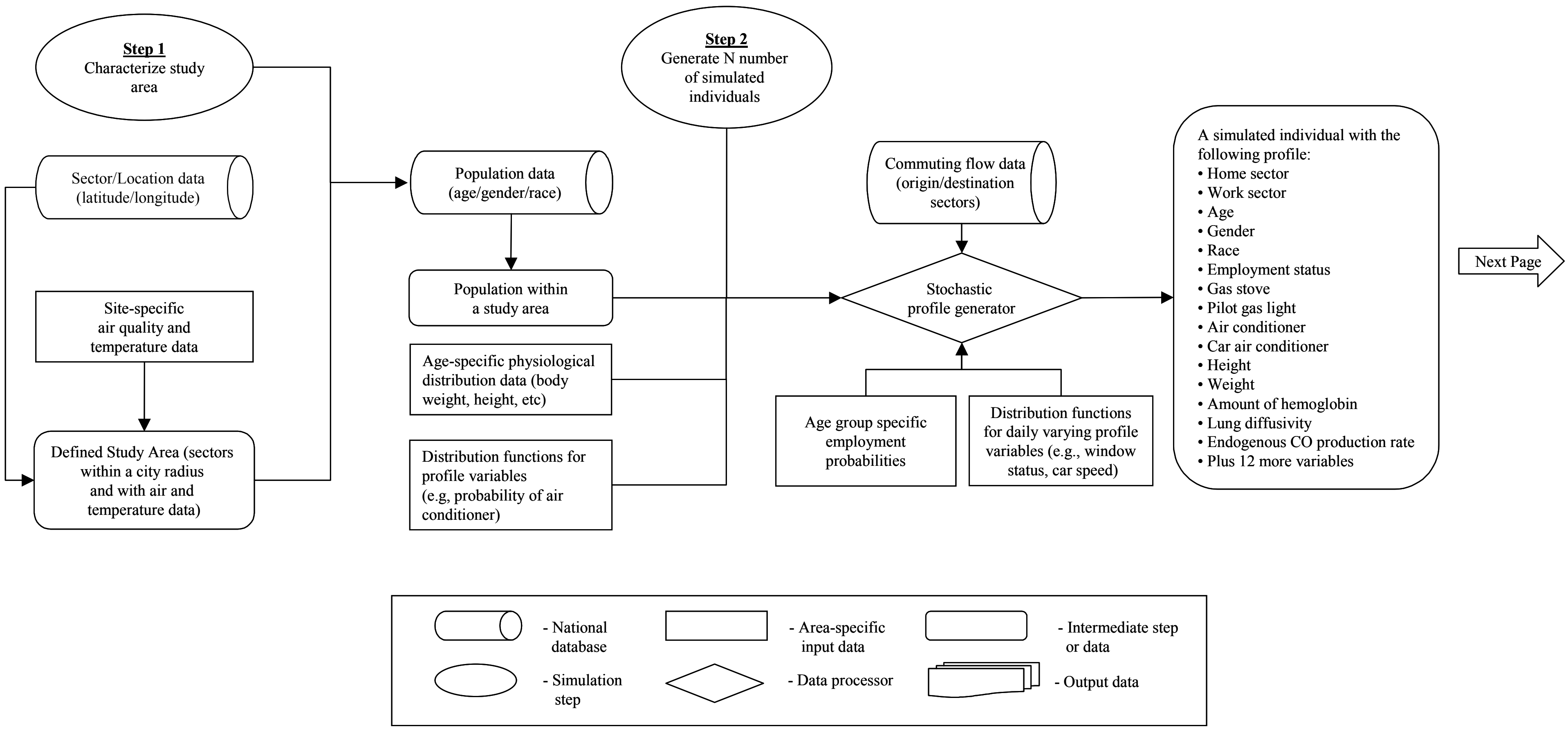


Figure 2-1b. Overview of APEX

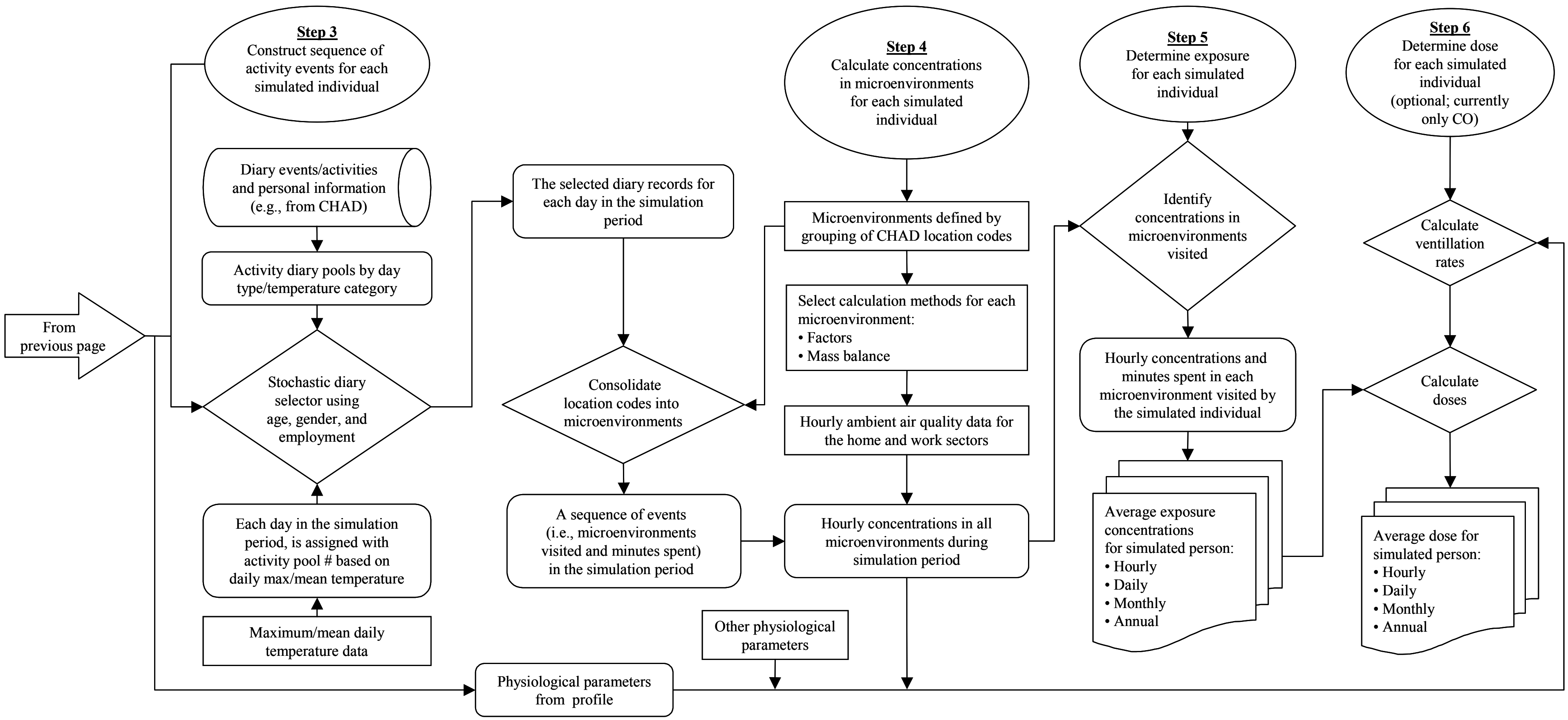
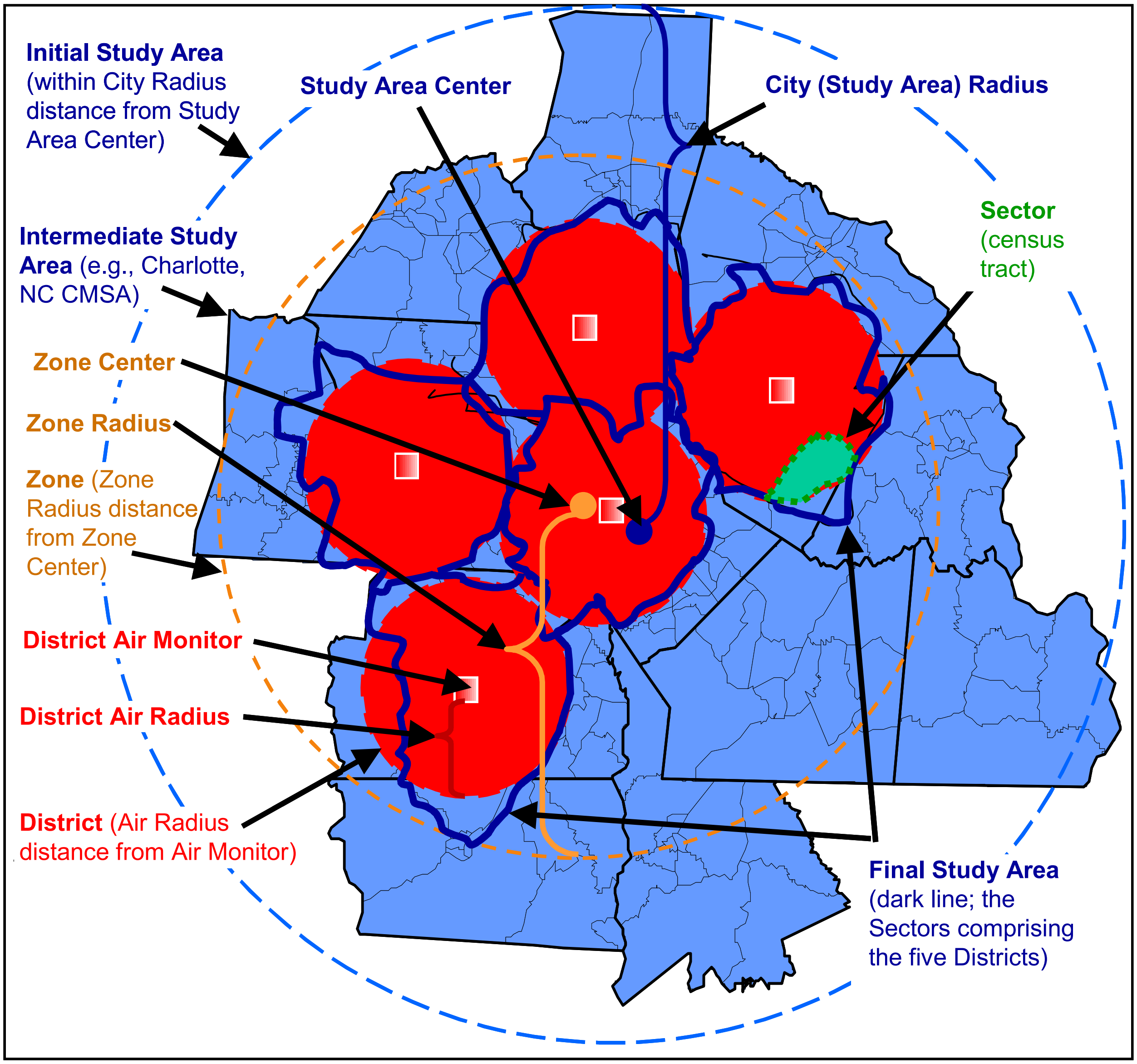


Figure 2-2. Example of Study Areas, Districts, Zones, and Sectors



2.1.2 Sectors

The fundamental spatial unit in APEX is called a sector. The demographic data used by the model to create personal profiles is provided at the sector level. For each sector the model requires demographic information representing the distribution of age, gender, race, and work status within the study population. Each sector must have a location specified by latitude and longitude for some representative point (e.g., geographic center). The current release of APEX includes input files that already contain this demographic and location data for all census tracts in the 50 United States based on the 2000 Census. This database enables the user to model any study area in the country without having to make any changes to these input files. Finer scales, such as census block groups, could be used if the user provided suitable population data files. If fewer (thus larger) sectors were desired, the existing population data files could be aggregated to larger regions such as counties.

For each model run, APEX selects the sectors that meet the following conditions. First, the sector location must be within the specified distance (city radius) of the designated study area center (see initial study area in Figure 2-2). Second, if the user provided a specific list of counties, then the sector must belong to one of these counties (see intermediate study area in Figure 2-2). If no county list is provided, the initial study area is roughly circular, consisting of all sectors with indicated locations within the specified radius. The final study area consists of the subset of sectors in the initial study area that have suitable air quality and temperature zone data, as described in the next two subsections.

2.1.3 Districts

The spatial units for ambient air quality data are called districts. The districts are used to assign pollutant concentrations to the sectors and microenvironments being modeled. The ambient outdoor air quality data must be provided by the user as an hourly time series for one location within each district. The locations could be monitoring sites, the geographic centers of political units such as counties, the centers of census units such as tracts, or even grid points used as receptors by an air quality model. As with sectors, each district has a representative location consisting of a latitude and a longitude. The user designates the effective radius of the districts (see air radius in Figure 2-2). In APEX, all districts have the same effective radius. Districts can reside outside of the study area.

APEX calculates the distance from each sector to each district center, and assigns the sector to the nearest district, provided the sector's representative location point (e.g., geographic center) is in the district. Each sector is assigned to only one district. If the sector does not fall within any district, the sector is deleted from the study area and is not modeled.

2.1.4 Zones

The final spatial unit in APEX is the temperature zone. At a minimum, the daily maximum 1-hour temperature is needed. Optionally, the average or other temperature for the day also can be provided. Either or both temperature variables can be used for modeling functions such as assigning activity diaries to personal profiles and assigning conditional probability distributions to microenvironmental parameters. As with air quality districts, each zone has a location (latitude and longitude), an effective radius, and start and stop dates.

As with districts, APEX calculates the distance from each sector to each zone center and assigns each sector to the nearest zone. If the sector is not in any zone, the sector is deleted from the study area and is not modeled.

Thus, for the population in a given sector to be modeled, the central location of the sector must be within a circular district, within a circular temperature zone, within the circular initial study area, and in a county an the county list (if specified).

2.2 Generate Simulated Individuals

APEX stochastically generates a user-specified number of simulated persons to represent the population in the study area. Each simulated person is represented by a "personal profile." APEX generates the simulated person or profile by probabilistically selecting values for a set of profile variables (Table 2-1). The profile variables include:

- Demographic variables, which are generated based on the census data;
- Residential variables, which are generated based on sets of distribution data;
- Physiological variables, which are generated based on age group-specific distribution data; and
- Daily varying variables, which are generated based on distribution data that change daily during the simulation period.

APEX first selects and calculates demographic, residential, and physiological variables (except for daily values) for all the specified number of simulated individuals, and then determines exposures and optionally doses for each simulated person. The following subsections describe these variables in more detail.

2.2.1 Demographic variables

The values of demographic variables (gender, age, etc.) for a simulated profile are selected probabilistically according to the following steps:

1. Calculate fraction of people in each of the gender/race combinations in the study area and then use the fractions as probabilities to randomly select a gender/race type for a simulated individual.
2. Calculate fraction of the selected gender/race type of people in each sector within a study area and then use the fractions as probabilities to randomly select a home tract for the simulated person.
3. Calculate fraction of people in each age group in the selected sector/gender/race combination and use the fractions as probabilities to randomly select an age group for the simulated person.
4. Randomly select a specific age within the selected age group, assuming a uniform distribution.
5. Use the user-provided employment probability for the selected age group to randomly determine whether a simulated person will work.
6. If the commuting option is used and a simulated person works, use the fractions of people commuting to each of the work sectors for the selected home sector to randomly select a work sector that a simulated person will commute to. Discard the profile if the work sector cannot be assigned air quality or temperature data (e.g., because the sector is outside the study area) If the commuting option is not used, assume a person who works does so in their home sector.

Table 2-1. Profile Variables in APEX

Variable Type	Profile Variables	Description
Demographic variable	Gender	Male or Female
	Race	White, Black, Native American, Asian, and Other
	Age	Age (Years)
	Home sector	Sector in which a simulated person lives
	Work sector	Sector in which a simulated person works
	Employment status	Indicates employment outside home
Residential variables	Gas stove	Indicates presence of gas stove
	Gas pilot	Indicates presence of gas pilot light
	Air conditioner	Indicates presence of air conditioning at home
	Car air conditioner	Indicates presence of air conditioning in the car
Daily varying variables	Window position	Daily window position (open or closed) during the simulation period
	Daily average car speed	Daily average car speed during the simulation period
	Daily endogenous CO production rate	Daily endogenous CO production rate in the simulation period
Physiological variables	Height	Height of a simulated person (in)
	Weight	Body weight of a simulated person (lbs)
	Blood volume	Blood volume of a simulated person (ml)
	Lung diffusivity	Lung diffusivity parameter used in COHb calculation (ml/min/torr)
	Endogenous CO production rate #1	Endogenous (internally produced) CO production rate #1 (ml/min)
	Endogenous CO production rate #2	Endogenous CO production rate #2 (ml/min) used only for women between ages of 12 and 50 for half the menstrual cycle
	Hemoglobin in the blood	Amount of hemoglobin in the blood (g/ml)
	Resting metabolic rate	Resting metabolic activity rate (kcal/min)
	Energy conversion factor	Oxygen uptake per unit of energy expanded (liters/kcal)
	Maximum permitted MET value	Maximum metabolic activity level that can sustained for about five minutes (dimensionless)
	Starting day of menstrual cycle	The day during the first 28 days of the simulation period that menstruation begins; used for determining endogenous CO

2.2.2 Residential Variables

The residential variables (gas stove, air conditioner, etc.) are categorical variables, that are used to indicate whether a residence or a car associated with a simulated person has the specified appliance or component. APEX randomly determines the result based on user-specified probabilities. For example, a user could specify probabilities of 0.3 for not having an air conditioner and 0.7 for having an air conditioner. APEX randomly generates a value in the range of 0 to 1, assuming a uniform distribution. If this value is larger than 0.3, the simulated person will own an air conditioner. If the value is less than 0.3, the person will not own an air conditioner.

2.2.3 Physiological Profile Variables

The physiological variables (volume of blood, height etc.) are used primarily for calculating dose (as described in Section 2.6). APEX provides gender- and age-specific normal distribution data for lung capacity (maximum oxygen uptake), body mass, resting metabolic rate, and blood volume. APEX randomly selects a value for each of these four variables based on the distribution data of pre-determined age and gender for the simulated person. The energy conversion factor is randomly selected, assuming that it is uniformly distributed in the range of 0.20-0.21 liters of oxygen per kcal. The other physiological variables are calculated from the randomly selected values of lung capacity, body mass, resting metabolic rate, blood volume, and demographic variables such as gender and age.

2.2.4 Daily Varying Variables

The daily varying variables are generated based on user-supplied rules and distribution data. For example, the probabilities for the values of window position may depend on the value for home air conditioner and zone temperatures (average and maximum), while the speed category is determined randomly from a set distribution for each simulation day and does not depend on any other variables. Endogenous CO production, which is used in the evaluation of the blood COHb level, depends on age, gender, and menstrual phase. Thus, for males it always has the same value from day to day, while for females it may have one of two values depending on the phase of the menstrual cycle (pre- or post-menstrual).

2.3 Construct a Sequence of Activity Events

APEX probabilistically creates a composite diary for each of the simulated persons by selecting a 24-hour diary record—or diary day—from an activity database for each day of the simulation period. CHAD data have been supplied with APEX for this purpose. A composite diary is a sequence of events that simulate the movement of a modeled person through geographical locations and microenvironments during the simulation period. Each event is defined by geographic location, start time, duration, microenvironment visited, and an activity performed.

For the activity database, APEX currently provides a personal information file and an events file to summarize the CHAD data. The personal information file contains the following variables:

- CHAD ID
- Day type (e.g., Monday)
- Gender

- Race
- Status of employment
- Maximum temperature
- Age
- Occupation
- Count of missing time (when activity and/or location codes are missing from the activity file)
- Number of events

The events file contains the following variables:

- CHAD ID
- Start time (of the event)
- Duration
- Activity code
- Location code

The events file contains a record for each of the events indicated by the number of events in the personal information file. Note that while CHAD data are provided with APEX, other activity data could be used instead, as long as the input file format restrictions are met and the CHAD coding conventions are used.

APEX develops a composite diary for each of the simulated individuals according to the following steps:

1. Divide diary days in the CHAD database into user-defined activity pools, based on day type and temperature.

2. Assign an activity pool number to each day of the simulation period, based on the user-provided daily maximum/average temperature data.

3. Calculate a selection probability for each of the diary days in each of the activity pools, based on age/gender/employment similarity of a simulated person to a diary day.

4. Probabilistically select a diary day from diary days in the activity pool assigned to each day of the simulation period.

5. Evaluate a MET value for each activity performed while in a CHAD location, based on the activity-specific MET distribution data. (MET is a dimensionless ratio of the activity-dependent energy expenditure rate to the basal or resting expenditure rate. It is used to calculate a ventilation rate for a simulated person performing a certain activity. See Section 2.6.1 for details.)

6. Map the location codes in the selected diary to user-defined microenvironments.

7. Concatenate the selected diary days into a composite diary for a simulated individual.

These composite diaries are then used to calculate exposure concentrations, as described below.

2.4 Calculate Concentrations in Microenvironments

APEX calculates air concentrations in the various microenvironments visited by the simulated person by using the ambient air data for the relevant sectors and the user-specified method and parameters that are specific to each microenvironment. The subsections below describe the technical basis and algorithms for this approach.

2.4.1 Define Microenvironments

APEX defines microenvironments by grouping the more than 100 location codes defined in the activity (CHAD) database into a smaller subset of user-defined microenvironments amenable to modeling. The user has control over how many microenvironments will be modeled and which need to be defined and what CHAD (or other activity database) locations should be grouped into each of microenvironment. Table 2-2 lists the 115 CHAD location codes included in APEX and the microenvironment to which each currently is assigned.

2.4.2 Calculating Concentrations in Microenvironments

APEX calculates hourly concentrations of the subject air pollutant in all the microenvironments at each hour of the simulation period for each of the simulated individuals, based on the user-provided hourly ambient air quality data specific to the geographic locations visited by the individual. APEX provides two methods for calculating microenvironmental concentrations: the mass balance method and the factors method. The user is required to specify a calculation method for each of the microenvironments; some microenvironments can use one method while the rest use the other, without restrictions. The parameters, algorithms, and stochastic elements used in each of the methods are explained below.

2.4.2.1 Microenvironment Parameters

Table 2-3 lists and defines the parameters required by the mass balance and factors methods (described in the next two subsections) to calculate concentrations in a microenvironment. Note that the proximity factor is used to account for differences in ambient concentrations between the geographic location represented by the ambient air quality data (e.g., a regional fixed-site monitor) and the geographic location of the microenvironment (e.g., near a roadway). This factor could take a value either greater than or less than 1. The penetration factor represents the fraction of a pollutant entering a microenvironment via air exchange.

> **Tip.** During exploratory analyses, you can examine how a microenvironment affects overall exposure by setting the microenvironment's proximity or penetration factor to zero, thus effectively eliminating the microenvironment

Note that concentrations in Table 2-3 and throughout the equations in the following sections must be in the same units as the ambient air quality data, i.e., either ppm or $\mu g/m^3$ (in the equations only the latter is shown).

Table 2-2. Example of CHAD Location Codes Mapped to Microenvironments

CHAD Location Code	Description	Microenvironment code[a]	CHAD Location Code	Description	Microenvironment code[a]
X	No data	-1	31210	Walk	4
U	Uncertain of correct code	-1	31230	In stroller or carried by adult	4
30000	Residence, general	1	31300	Waiting for travel	4
30010	Your residence	1	31310	..., bus or train stop	4
30020	Other residence	1	31320	..., indoors	3
30100	Residence, indoor	1	31900	Travel, other	2
30120	Your residence, indoor	1	31910	..., other vehicle	2
30121	..., kitchen	1	32000	Non-residence indoor, general	3
30122	..., living room or family room	1	32100	Office building/ bank/ post office	3
30123	..., dining room	1	32200	Industrial/ factory/ warehouse	3
30124	..., bathroom	1	32300	Grocery store/ convenience store	3
30125	..., bedroom	1	32400	Shopping mall/ non-grocery store	3
30126	..., study or office	1	32500	Bar/ night club/ bowling alley	3
30127	..., basement	1	32510	Bar or night club	3
30128	..., utility or laundry room	1	32520	Bowling alley	3
30129	..., other indoor	1	32600	Repair shop	3
30130	Other residence, indoor	1	32610	Auto repair shop/ gas station	2
30131	..., kitchen	1	32620	Other repair shop	3
30132	..., living room or family room	1	32700	Indoor gym /health club	3
30133	..., dining room	1	32800	Childcare facility	3
30134	..., bathroom	1	32810	..., house	3
30135	..., bedroom	1	32820	..., commercial	3
30136	..., study or office	1	32900	Large public building	3
30137	..., basement	1	32910	Auditorium/ arena/ concert hall	3
30138	..., utility or laundry room	1	32920	Library/ courtroom/ museum/ theater	3
30139	..., other indoor	1	33100	Laundromat	3
30200	Residence, outdoor	4	33200	Hospital/ medical care facility	3
30210	Your residence, outdoor	4	33300	Barber/ hair dresser/ beauty parlor	3
30211	..., pool or spa	4	33400	Indoors, moving among locations	3
30219	..., other outdoor	4	33500	School	3
30220	Other residence, outdoor	4	33600	Restaurant	3
30221	..., pool or spa	4	33700	Church	3
30229	..., other outdoor	4	33800	Hotel/ motel	3
30300	Residential garage or carport	4	33900	Dry cleaners	3
30310	..., indoor	4	34100	Indoor parking garage	2
30320	..., outdoor	4	34200	Laboratory	3
30330	Your garage or carport	4	34300	Indoor, none of the above	3
30331	..., indoor	4	35000	Non-residence outdoor, general	3
30332	..., outdoor	4	35100	Sidewalk, street	2
30340	Other residential garage or carport	4	35110	Within 10 yards of street	2
30341	..., indoor	4	35200	Outdoor public parking lot /garage	2
30342	..., outdoor	4	35210	..., public garage	2
30400	Residence, none of the above	1	35220	..., parking lot	2
31000	Travel, general	2	35300	Service station/ gas station	2
31100	Motorized travel	2	35400	Construction site	4
31110	Car	2	35500	Amusement park	4
31120	Truck	2	35600	Playground	4
31121	Truck (pickup or van)	2	35610	..., school grounds	4
31122	Truck (not pickup or van)	2	35620	..., public or park	4
31130	Motorcycle or moped	2	35700	Stadium or amphitheater	4
31140	Bus	2	35800	Park/ golf course	4
31150	Train or subway	2	35810	Park	4
31160	Airplane	0	35820	Golf course	4
31170	Boat	2	35900	Pool/ river/ lake	4
31171	Boat, motorized	2	36100	Outdoor restaurant/ picnic	4
31172	Boat, other	2	36200	Farm	4
31200	Non-motorized travel	4	36300	Outdoor, none of the above	4

[a] -1 = continue using the same microenvironment as appears previously in time in the full composite diary; 0 = concentration of zero; 1 = indoor (residence); 2 = in or near vehicle; 3 = indoor(other); 4= outdoor.

Table 2-3. Parameters Required by Mass Balance and Factors Method

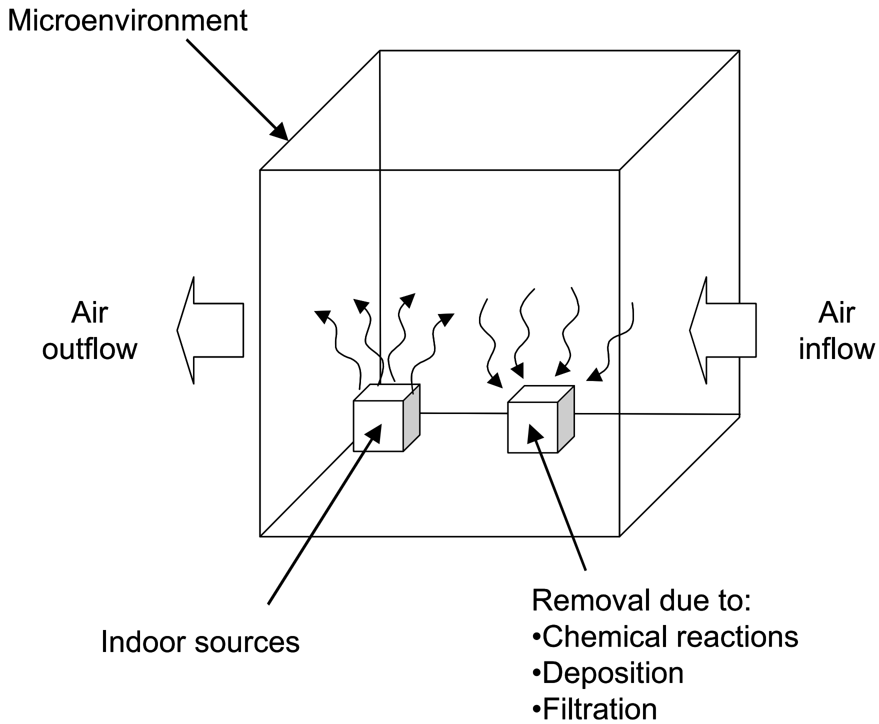
Method	Variable	Definition	Units	Value Range	Default/ Supplied Value
Mass Balance	$f_{proximity}$	Proximity factor	unitless	$f_{proximity} \geq 0$	1
	$f_{penetration}$	Penetration factor	unitless	$0 \leq f_{penetration} \leq 1$	1
	CS	Concentration source	μg/m^3 or ppm	$CS \geq 0$	0
	ES	Emission source	μg/hr	$ES \geq 0$	0
	$R_{removal}$	Removal rate due to deposition, filtration, and chemical reaction	1/hr	$R_{removal} \geq 0$	0
	$R_{air\ exchange}$	Air exchange rate	1/hr	$R_{air\ exchange} \geq 0$	none
	R_{mean}	$R_{removal} + R_{air\ exchange}$	1/hr	$R_{mean} \geq 0$	$R_{removal} + R_{air\ exchange}$
	V	Volume of microenvironment	m^3	$V > 0$	none
Factors	$f_{proximity}$	Proximity factor	unitless	$f_{proximity} \geq 0$	1
	$f_{penetration}$	Penetration factor	unitless	$0 \leq f_{penetration} \leq 1$	1
	CS	Concentration source	μg/m^3 or ppm	$CS \geq 0$	0

2.4.2.2 Mass Balance Method

The mass balance method assumes that an enclosed microenvironment (e.g., a residence) is a single well-mixed box in which the air concentration is spatially uniform at any time at any location within the box. The concentration of an air pollutant in such a microenvironment is estimated using the following four processes (as illustrated in Figure 2-3):

- Inflow of air into the microenvironment;
- Outflow of air from the microenvironment;
- Removal of a pollutant from the microenvironment due to deposition, filtration, and chemical degradation; and
- Emissions from sources of a pollutant inside the microenvironment.

Figure 2-3. Mass Balance Model



Change in microenvironmental concentration due to influx of air is represented by the following equation:

$$\Delta C_{in} = \frac{dC(t)}{dt} = C_{ambient} \times f_{proximity} \times f_{penetration} \times R_{air\ exchange} \qquad (2\text{-}1)$$

where:

ΔC_{in}	=	Change in microenvironmental concentration due to influx of air (µg/m^3/hour)
$C(t)$	=	Concentration in a microenvironment at time t (µg/m^3)
t	=	Time
$C_{ambient}$	=	Ambient hourly concentration (µg/m^3)
$f_{proximity}$	=	Proximity factor (unitless)
$f_{penetration}$	=	Penetration factor (unitless)
$R_{air\ exchange}$	=	Air exchange rate (1/hour)

Change in microenvironmental concentration due to outflux of air is described by:

$$\Delta C_{out} = \frac{dC(t)}{dt} = R_{air\ exchange} \times C(t) \qquad (2\text{-}2)$$

where:

ΔC_{out} = Change in microenvironmental concentration due to outflux of air (μg/m^3/hour)

Change in concentration due to deposition, filtration, and chemical degradation in a microenvironment is simulated based on the first-order equation:

$$\Delta C_{removal} = \frac{dC(t)}{dt} = (R_{deposition} + R_{filtration} + R_{chemical})\ C(t) = R_{removal} \times C(t) \qquad (2\text{-}3)$$

where:

$\Delta C_{removal}$ = Change in microenvironmental concentration due to removal processes (μg/m^3/hour)

$R_{deposition}$ = Removal rate of a pollutant from a microenvironment due to deposition (1/hour)

$R_{filtration}$ = Removal rate of a pollutant from a microenvironment due to filtration (1/hour)

$R_{chemical}$ = Removal rate of a pollutant from a microenvironment due to chemical degradation (1/hour)

$R_{removal}$ = Removal rate of a pollutant from a microenvironment due to overall removal (1/hour)

Sources of a pollutant from inside the microenvironment is described by the following equation:

$$\Delta C_{source} = \frac{1}{V} \sum_{i=1}^{n_e} ES_i + R_{mean} \sum_{i=1}^{n_c} CS_i \qquad (2\text{-}4)$$

where:

$\Delta C_{removal}$ = Change in microenvironmental concentration due to source emission inside a microenvironment (μg/m^3/hour)

V = Volume of a microenvironment (m^3)

ES_i = Emission rate for emission source *I* (μg/hour)

CS_i = Emission rate for concentration source *I* (μg/m^3)

R_{mean} = $R_{air\ exchange} + R_{Removal}$ (1/hour)

n_e = Number of emission sources in the microenvironment

n_c = Number of concentration sources in the microenvironment

(Note that concentration must be in the same units as the ambient air quality data, i.e., either ppm or μg/m^3, although throughout these equations concentration is shown only in μg/m^3. The above equation, 2-4, is the only one that needs modification if the units are switched. Specifically, *1/V* would be replaced by *f/V*, where *f = 1/ppmFact.* The value of ppmFact is a user-supplied input parameter that expresses the number of μg/m^3 that equate to 1 ppm. For CO, ppmFact=1,145.) Thus, the mass balance equation for a pollutant in a microenvironment is described by:

$$\frac{dC(t)}{dt} = \Delta C_{source} + \Delta C_{in} - \Delta C_{out} - \Delta C_{removal} \tag{2-5}$$

where:

$C(t)$ = Concentration in a microenvironment at time t ($\mu g/m^3$)

Within the time period of an hour, ΔC_{source} and ΔC_{in} can be assumed to be constant. Using $\Delta C_{combined} = \Delta C_{source} + \Delta C_{in}$, Eq. (2-2), and Eq (2-3) in Eq. (2-5) leads to:

$$\begin{aligned}\frac{dC(t)}{dt} &= \Delta C_{combined} - R_{air\ exchange} C(t) - R_{removal} C(t) \\ &= \Delta C_{combined} - R_{mean} C(t)\end{aligned} \tag{2-6}$$

Solving the differential equation Eq. (2-6) leads to:

$$C(t) = \frac{\Delta C_{combined}}{R_{mean}} + \left(C(0) - \frac{\Delta C_{combined}}{R_{mean}} \right) exp\,(-R_{mean}\, t) \tag{2-7}$$

where:

$C(0)$ = Concentration of a pollutant in a microenvironment at the beginning of a hour ($\mu g/m^3$)

$C(t)$ = Concentration of a pollutant in a microenvironment at time t within the time period of a hour ($\mu g/m^3$).

Based on Eq. (2-7), the following three hourly concentrations in a microenvironment are calculated:

$$C_{equil} = C(t \rightarrow \infty) = \frac{\Delta C combined}{R_{mean}} = \frac{\Delta C_{source} + \Delta C_{in}}{R_{air\ exchange} + R_{removal}} \tag{2-8}$$

$$C_{hourly\ end} = C_{equil} - \left(C(0) - C_{equil} \right) exp\ (-R_{mean}) \tag{2-9}$$

$$C_{hourly\ mean} = \frac{\int_0^1 C(t)dt}{\int_0^1 dt} = C_{equil} + (C(0) - C_{equil})\ \frac{1 - exp(-R_{mean})}{R_{mean}} \tag{2-10}$$

where:

C_{equil} = Equilibrium concentration in a microenvironment ($\mu g/m^3$)

$C(0)$ = Concentration in a microenvironment at the beginning of each hour ($\mu g/m^3$)

$C_{hourly\ end}$ = Concentration in a microenvironment at the end of each hour ($\mu g/m^3$)

$C_{hourly\ mean}$	=	Hourly mean concentration in a microenvironment (µg/m^3)
R_{mean}	=	$R_{air\ exchange} + R_{removal}$ (1/hour)

At each hour time step of the simulation period, APEX uses Eq. (2-8), Eq. (2-9), and Eq. (2-10) to calculate the hourly equilibrium, hourly ending, and hourly mean concentrations. APEX reports hourly mean concentration as hourly concentration for a specific hour. The calculation continues to the next hour by using $C_{hourly\ end}$ for the previous hour as *C(0)*.

2.4.2.3 Factors Method

The factors method is simpler than the mass balance method. It does not calculate concentration in a microenvironment from the concentration in the previous hour, and it has many fewer parameters. The factors method uses the following equation to calculate hourly concentration in a microenvironment from the user-provided hourly air quality data:

$$C_{hourly} = C_{ambient}\, f_{proximity}\, f_{penetration} + \sum_{i=1}^{n_c} CS_i \qquad (2\text{-}11)$$

where:

C_{hourly}	=	Hourly concentration in a microenvironment (µg/m^3)
$C_{ambient}$	=	Hourly concentration in ambient environment (µg/m^3)
$f_{proximity}$	=	Proximity factor (unitless)
$f_{penetration}$	=	Penetration factor (unitless)
CS_i	=	Mean air concentration resulting from source *I* (µg/m^3)
n_c	=	number of concentration sources in the microenvironment

2.4.2.4 Stochastic Elements

To account for temporal and spatial variability of the microenvironment parameters required to calculate an hourly microenvironmental concentration APEX allows, the user to provide distribution data to randomly select a value for each of the parameters. The following distribution types can be specified for each model-parameter:

- Single point
- Uniform
- Normal
- Log-normal
- Triangle
- Exponential
- Off/on
- Discrete
- Histogram

Also, the user can provide distribution data for any combination of the following temporal, spatial, and conditional variables:

- Hour in a day
- Day in a week
- Month in a year (i.e., season)

- Air district
- Three conditional variables selected from the following profile variables:
  - Gender
  - Race
  - Employment status
  - Gas stove
  - Gas pilot light
  - Air conditioner
  - Car air conditioner
  - Window position
  - Maximum temperature categories
  - Average temperature categories
  - Car speed categories

APEX also allows the user to decide whether a new random value should be selected for a microenvironmental factor from the same distribution data at every hour in a time block of a day or every day in a simulation period.

2.5 Determine Exposure

APEX calculates exposure as a time series of exposure concentrations that a simulated individual experiences during the simulation period. APEX determines the exposure by identifying hourly concentrations and minutes spent in a sequence of microenvironments visited according to the composite diary. The hourly exposure concentration at any clock hour during the simulation period is determined using the following equation:

$$C_i = \frac{\sum_{j=1}^{N} \left(C_{hourly\ (j)} t_{(j)} \right)}{T} \qquad (2\text{-}12)$$

where:

C_i	=	Hourly exposure concentration at clock hour *I* of the simulation period (µg/m^3 or ppm)
N	=	Number of events (i.e., microenvironments visited) in clock hour *I* of the simulation period.
$C_{hourly\ (j)}$	=	Hourly concentration in microenvironment *j* (µg/m^3 or ppm)
$t_{(j)}$	=	Time spent in microenvironment *j* (minutes)
T	=	60 minutes

From the hourly exposures, APEX calculates time series of 8-hour and daily average exposure concentrations that a simulated individual would experience during the simulation period. APEX then statistically summarizes and tabulates the hourly, 8-hour, and daily exposures.

2.6 Determine Dose

For some pollutants, such as CO, the toxicokinetics are sufficiently understood such that dose can be modeled in addition to the exposure concentration. Dose may be more useful or accurate than exposure for evaluating the effects of air pollutants because it accounts better for differences in pollutant uptake resulting from (1) the variation in physiology and activities across populations and (2) the variation in physiological responses to activities within an individual. Therefore, APEX has been designed to allow the user the option of calculating either exposure concentration, as described in the preceding section, or also calculating dose, as described in this section. APEX currently has been designed to calculate dose for CO. To estimate dose for other pollutants, the development of pollutant-specific dose algorithms is required.

As seen by the box to the right, dose can have many definitions. In APEX, dose can be calculated for CO, in particular the delivered dose of CO as measured by the biotransformation product carboxyhemoglobin (COHb)—specifically %COHb—in the blood. The estimated %COHb, in addition to being a more refined measure of exposure compared to exposure concentration, is useful for comparing to health-based benchmarks of %COHb.

Conceptually, APEX uses a number of factors, in particular a time series estimate of alveolar ventilation rate (which is activity and physiology dependent) and a time series estimate of exposure (which indicates the pollutant concentration in the inhaled air for specific moments in time), to calculate %COHb. The ventilation rate algorithm is discussed in Section 2.6.1 and the %COHb algorithm is discussed in Section 2.6.2. For other factors and additional detail, see Johnson (2002).

Definitions of dose. The term dose is often defined as the administered or delivered amount of a substance to the body and generally is stated as the total mass of the chemical or the mass per unit body weight or related denominator. But dose actually can be subdivided as follows:

- Potential dose is the amount of chemical contained in material ingested, air breathed, or bulk material applied to the skin.
- Applied dose is the amount of the chemical in contact with the major absorption boundaries, such as the skin, lungs, and gastrointestinal tract, and available for absorption.
- Absorbed dose is the amount of a chemical penetrating across the absorption barrier. For the respiratory route, the internal dose is the amount of the chemical absorbed via the lung.
- Internal dose is a more general term denoting the amount absorbed without respect to specific absorption barriers or exchange boundaries.
- Delivered dose is the amount of the chemical available for interaction with any particular organ or cell.

2.6.1 Ventilation Rate

Ventilation is a general term for the movement of air into and out of the lungs. Minute or total ventilation is the amount of air moved in or out of the lungs per minute. Quantitatively, the amount of air breathed in per minute (V_I) is slightly greater than the amount expired per minute (V_E). Clinically, however, this difference is not important, and by convention minute ventilation is always measured on an expired sample, V_E. Alveolar ventilation (V_A) is the volume of air breathed in per minute that (1) reaches the alveoli and (2) takes part in gas exchange. The ventilation rate needed for the %COHb determination is this ventilation rate, V_A, and is derived for use in APEX based on work by Adams (1998), Astrand and Rodahl (1977), Burmaster and Crouch (1997), Esmail et al. (1995), Galetti (1959), Johnson (1998), Joumard et al. (1981), McCurdy (2000), McCurdy et al. (2000), Schofield (1985), and many others. Only a brief description of V_A is described below; for the complete derivation, see Johnson (2002).

Total or expired ventilation rate, V_E, also can be calculated from V_{O2}. In fact, APEX currently contains the equations for calculating V_E in case they are needed for other pollutants. See Johnson (2002) for additional information on the derivation of V_E.

Conceptually, V_A can be related to the oxygen ventilation rate of the individual at any given moment. This relationship can be described as follows for a given activity event and personal profile:

$$V_A = V_{O2} \times CF_{O2,A} \tag{2-13}$$

where

V_A	=	Alveolar ventilation rate (ml of air/min)
V_{O2}	=	Oxygen ventilation rate (l of O_2/min)
$CF_{O2,A}$	=	Oxygen to air conversion factor (19,530 ml of air/l of O_2).

V_{O2} in turn is related to the energy expenditure rate for the given event activity and the given profile's physiology in terms of oxygen ventilation per unit energy expenditure, or:

$$V_{O2} = EE \times ECF \tag{2-14}$$

where

EE	=	Energy expenditure (kcal/min)
ECF	=	Energy conversion factor (l of O_2/kcal).

ECF is based on the physiology of the individual being modeled and is described in Section 2.2. *EE* is related to the activity-specific energy expenditure rate and the basal or resting energy expenditure (metabolic) rate of the given profile, or:

$$EE = MET \times RMR \tag{2-15}$$

where

MET	=	Metabolic equivalent (dimensionless)
RMR	=	Resting metabolic rate (kcal/min).

RMR is based on the physiology of the individual being modeled and is described in Section 2.2. *MET*—which comes from "metabolic equivalents of task"—is a dimensionless ratio of the activity-specific energy expenditure rate to the basal or resting energy expenditure rate. While different people have very different basal metabolic rates, it is generally found that the *MET* ratios do not exhibit as much variability. Thus, standing still might require two times the basal energy expenditure, or two *MET*, for most people, with relatively little variation. Since the basal rate is constant for each profile, it only has to be determined once and the activity-specific *MET* ratio can be used to determine the absolute energy expenditure rate, *EE*, for each activity. *MET* is discussed in more detail below as well as in Section 2.2.

The overall equation for V_A for activity *I* of day *j* for person *k* is:

$$V_A(i,j,k) = MET(i,j,k) \times RMR(k) \times ECF(k) \times CF_{O2,A} \tag{2-16}$$

APEX incorporates these concepts using a variety of other parameters, limits, and probabilistic data and algorithms. For example, before *MET* can be used in APEX for a given activity and profile combination, it must be evaluated for whether it satisfies the condition that the average level of metabolic activity over long time intervals cannot remain as high as it can for short intervals. That is, the nominal value for the maximum *MET* for any individual, MET_{max}, represents the maximum activity level that can sustained for about five minutes. Shorter bursts of activity can exceed this level, in part because a substantial non-aerobic contribution is usually present. However, for longer time periods, the average *MET* cannot remain as high as the nominal value for MET_{max}. In particular, over one hour the average *MET* cannot exceed about 64% of MET_{max} for any person. The average *MET* over a two hour time interval cannot exceed about 54% of MET_{max}. Similar limits exist for periods up to nine hours (33% of MET_{max}). Therefore, after first determining the time series for hourly mean MET values for the entire simulation period—which may require aggregation across several diary events or microenvironments within each hour—APEX calculates running averages from 1 to 9 hours for the entire simulation period. Each set of 9 averages then are compared to the respective limits on the maximum sustainable MET averages. If the limit is exceeded, the preceding MET values are adjusted downwards sufficiently to place the average at the limit.

See Volume II of the User's Guide and the above references—especially Johnson (2002)—for additional details regarding the incorporation of this and other limits, other parameters, and probabilistic data and algorithms used in APEX.

2.6.2 Carboxyhemoglobin (COHb) Determination

The %COHb calculation in APEX uses the time series for exposure (CO concentration in the air) and the time series for alveolar ventilation rate, V_A, as inputs (among other factors). The dose calculation is based on the solution to the non-linear Coburn, Forster, Kane (CFK) equation, as detailed in Johnson (2002). As pointed out by that report, the CFK equation does not have an explicit solution, so an iterative solution or approximation is needed to determine the %COHb. An iterative solution, however, was determined to be unsuitable because of the model execution time necessary (a typical model run of one calendar year represents roughly 14,000 events per person and several thousand people, or tens of millions of diary events). Therefore, the CFK equation is solved using a modified Taylor's series method in which the event duration is restricted in time (if necessary) to ensure convergence with only a few terms. This method avoids the dangers of non-convergence that arise in some other methods.

As the mathematical derivation in the above report is very detailed, only the main results are presented here. First, it should be noted that the literature discusses two forms of the CFK equation, namely a linear and a non-linear form. The linear form itself is an approximation that allows an explicit solution, but is not accurate under all conditions. The non-linear form is considered to be more correct and is the one being discussed here.

Restricting %COHb(t) to between 0 and 100 (percent), the CFK equation takes the form of the following differential equation:

$$\%COHb'(t) = C_o - C_1 \times \frac{\%COHb(t)}{100 - \%COHb(t)} \qquad (2\text{-}17)$$

where C_0 and C_1 are constants over the duration of one event that depend on physical and physiological parameters, including V_A, and on the CO concentration in the air.

Time zero represents the start of the current event. The concentration *%COHb(0)* (at time zero) is assumed to be known. The first derivative, *%COHb(0)*, can easily be found from the above equation. The solution *%COHb(t)* is a smoothly varying function of time without sudden discontinuities or changes in slope. It therefore can be expanded in a Taylor's series about

t = 0, which should converge fairly rapidly. One simplification is to rescale the time variable to the unitless parameter z:

$$z = \frac{(C_0 + C_1) \times t}{(100 \times D_0 \times D_0)} \tag{2-18}$$

where

$$D_0 = \frac{1 - \%COHb(0)}{100} \tag{2-19}$$

The Taylor's series up to the fourth order term is:

$$T_4(z) = \%COHb(0) + 100 \times D_0 \times Dz - \frac{100 \times A_1 \times D_0 \times Dz^2}{2} + \frac{100 \times A_1 \times D_0 \times D \times (A_1 - 2D) \times z^3}{6} - \frac{100 \times A_1 \times D_0 \times D \times (A_1^2 - 8DA_1 + 6D^2) \times z^4}{24} \tag{2-20}$$

where

$$A_1 = \frac{C_1}{C_0 + C_1} \tag{2-21}$$

$$D = D_0 - A_1 \tag{2-22}$$

For typical values for the constants C_0, C_1, and *%COHb(0)*, convergence occurs for z<1. For z values below this limit but still close to one, the convergence is slow, so the terms beyond fourth order would be needed if high accuracy were desired. It is found that z<1 generally corresponds to *%COHb(0)* values below 40 to 50% for one-hour events.

The z value is proportional to t. In APEX, an event can have a duration of no more than one hour. For one hour events there are conditions where z is close to one and convergence of the Taylor's series may require more than four terms. However, it is not necessary to evaluate the entire hour in one step. By dividing the event into shorter subevents, each will have a smaller z value. For example, if a one-hour activity diary event has initial conditions that correspond to z=0.9, then by dividing this into three 20 minute subevents, each will have a z value around 0.3. Actually, the first subevent will have exactly z=0.3. The others will be slightly different as the initial conditions for those subevents will have changed slightly. Thus, dose accumulates the average %COHb level over the subevents. At the end of all subevents, the average dose is the accumulated dose divided by the number of subevents, while the final value of the dose is simply the final value of COHb itself. These values are saved and the next diary event is processed.

3. INSTALLING APEX

This chapter provides the requirements and instructions for installing APEX on a personal computer (PC). Section 3.1 describes the hardware and software requirements for installing APEX. Section 3.2 describes the steps involved in a typical installation of APEX with the Multimedia Integrated Modeling System (MIMS) graphical user interface (GUI). Section 3.3 describes the steps involved in installing APEX to run in DOS batch mode.

3.1 Hardware and Software Requirements

To use APEX, the user's PC should be equipped with at least:

- 256 MB of RAM;
- 600 MHz or faster processor; and
- 450 MB of available hard drive space.

PCs with less RAM and slower processors will also work, but performance (e.g., model run time) will be less than optimal.

APEX is compatible with the following computer operating systems:

- Windows XP
- Windows 2000
- Windows NT
- Windows 95/98

However, Windows XP, Windows 2000, and Windows NT are the recommended operating systems for running APEX because they best meet the memory requirements of the model. As APEX was developed using Java, it can be run under a number of other operating systems, such as Linux and Solaris; however, APEX has not been fully implemented in any non-Windows-based operating systems to date.

3.2 Installing APEX to Run in MIMS

The installation of APEX with the MIMS GUI consists of the following six steps. Note that the first five steps can be completed in any order; however, Step 6 must be completed after Step (5).

1. Download and unzip the APEX project file

Users should download the MIMS project for APEX from the internet (http://www.epa.gov/ttn/fera) to their hard drive. This zip file, which contains a single file in BIN format, should then be unzipped into the directory in which APEX will be installed (e.g., C:\APEX) using extraction software (e.g., WinZip). This directory will be referred to as the "Default Directory."

2. Install the Java Runtime Environment

The Java Runtime Environment (JRE) is installed by completing the following steps.

- Download the JRE file from http://java.sun.com/j2se/1.3/download.html (select the appropriate Windows download from the “JRE” column). Important note: During testing, several issues have been identified with running APEX in MIMS using JRE version 1.4. If you encounter problems and are using JRE version 1.4, consider switching to JRE version 1.3.

- Close all open applications.

- Run the downloaded JRE file (e.g., j2re-1_3_1_04-windows-i586.exe) and follow the instructions on the screen.

- Reboot the computer.

- To free up hard drive space, delete the downloaded JRE file.

3. Download and unzip the APEX executable

Users should download the APEX executable from the internet (http://www.epa.gov/ttn/fera) to their hard drive. This zip file should then be unzipped into the Default Directory using extraction software (e.g., WinZip).

4. Download and unzip the APEX national input databases

Users should download the following national input databases from the internet (http://www.epa.gov/ttn/fera) to their hard drive.

- Consolidated Human Activity Database Files (4 MB zipped). This database contains activity diaries, as well as metabolic and physiological parameter data.

- Population Files (28 MB zipped). This databases contains 2000 tract-level U.S. Census counts, tract locations, and national employment probabilities by age.

- Commuting Database (36 MB zipped). This database contains adult commuting patterns based on the 1990 U.S. Census, updated to year 2000 population.

These zip files should then be unzipped into the Default Directory using extraction software (e.g., WinZip). These databases can be used for most applications in the United States; however, users can optionally use alternative databases (e.g., if the user wishes to model a subpopulation). More details on these databases can be found in Chapter 5.

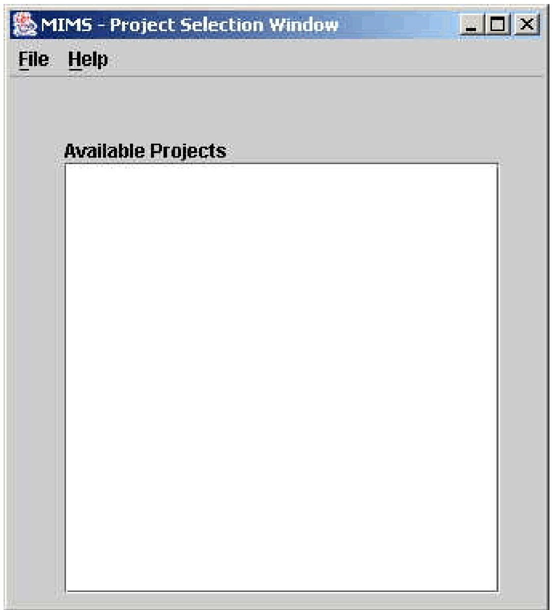
5. Install MIMS

Users must install the Multimedia Integrated Modeling System (MIMS) to run APEX in MIMS. For instructions on installing MIMS, refer to http://www.epa.gov/ttn/fera.

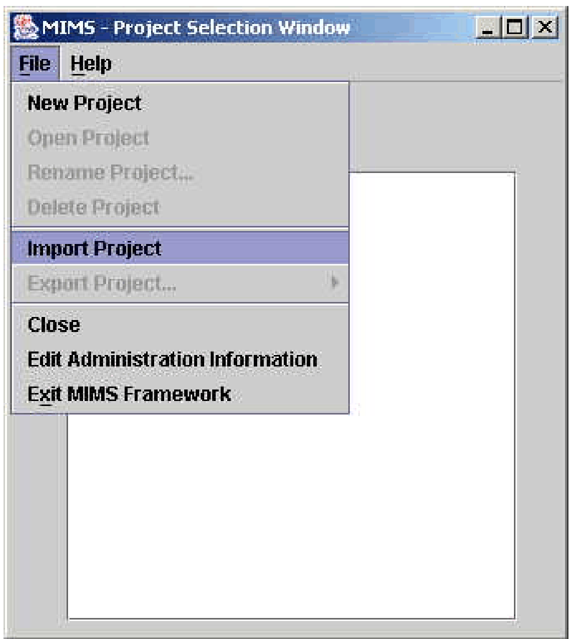
6. *Import the APEX project file into MIMS*

To import the APEX project file into MIMS, the user must complete the following steps.

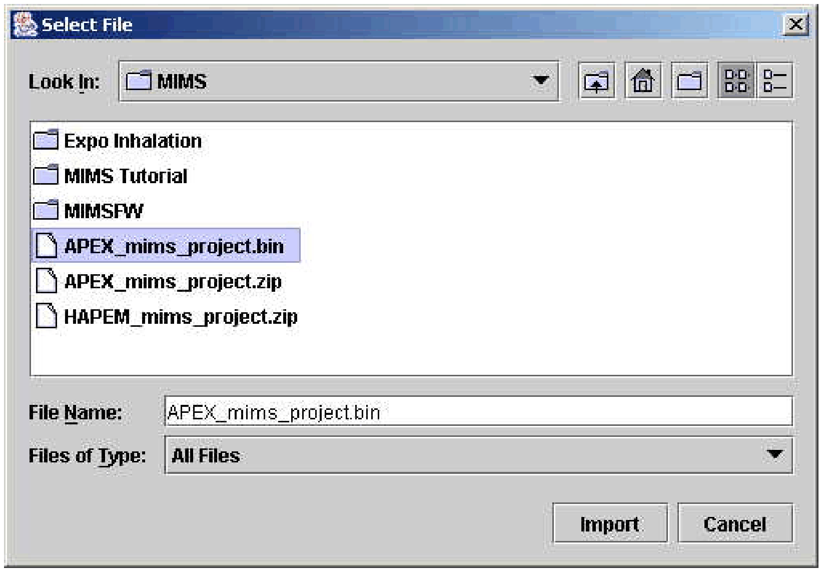
- Start MIMS as described in the MIMS installation instructions. The “Project Selection Window” will open.



- From Project Selection Window, select “Import Project” from the File menu.

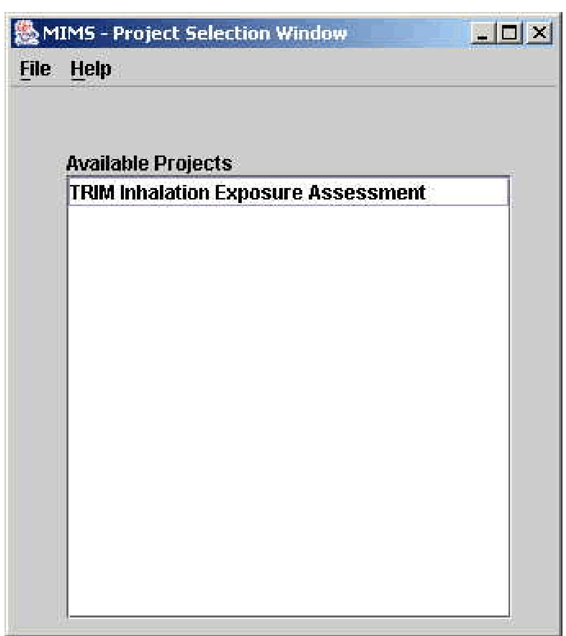


- After selecting "Import Project," a file browser will appear. Use this browser to select the APEX project file (with extension ".BIN"). After selecting the file, click "Import."



- In the "Import Project" window, enter a name for APEX project (e.g., "TRIM Inhalation Exposure Assessment") and click "OK."

- After importing the project, the Project Selection Window will include the new APEX project. To open the model, double-click on the project name.



3.3 Installing APEX to Run in DOS Batch Mode

To install APEX to run in DOS batch model, the user must download the zip files containing the APEX executable and national input database files from http://www.epa.gov/ttn/fera. After downloading these four zip files (i.e., one zip file containing the executable and three zip files containing the national input databases and other supplied data), the user must unzip them using extraction software (e.g., WinZip). These files can be unzipped anywhere on the hard drive; however, the user must ensure that there is at least 450 MB of available hard drive space in the target location for the national input database files. The user should note the name and location of all of the unzipped files for later reference.

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4. RUNNING APEX

This chapter describes the steps involved in setting up and running an APEX simulation, the purpose and content of the input and output files, and the available model options. This chapter is organized as follows:

Chapters 5 and 6 provide a detailed description of the input and output files, respectively.

What's a "unit number"? The APEX computer code uses a unit number to refer to a specific input or output file. For example, Unit 10 is the *Params* file (which specifies the overall settings, or parameters, for an APEX simulation—see Chapter 5). Thus, if a unit number is requested during an APEX run, then that means that one of the input files could not be found. The user should consult the appropriate section of this user's guide. Unit numbers have been included in section headings for easy reference.

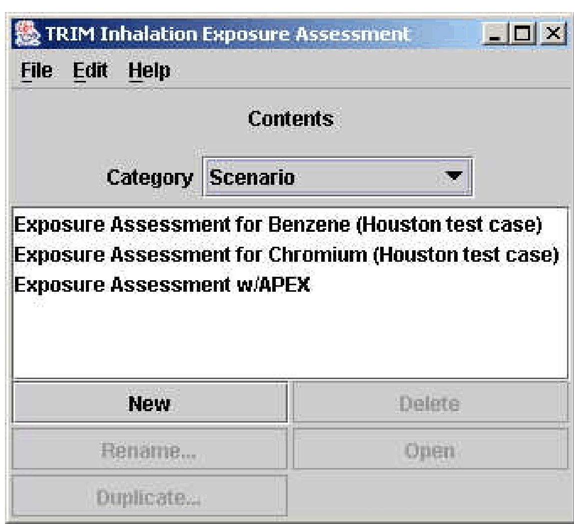
4.1 Running APEX in MIMS

After installing APEX in MIMS as described in Section 3.2, the user can run the model by starting MIMS and either:

- Selecting the APEX project from the "Available Projects" list in the "Project Selection Window" and then selecting "Open Project" from the File menu, or

- Double-clicking on the APEX project in the "Available Projects" list in the "Project Selection Window."

Either of these methods will bring up a window named with the name of the project (e.g., "TRIM Inhalation Exposure Assessment"). This window is comprised of a drop-down menu of "Category" types, a list of the items associated with the selected type, and five buttons that correspond to the actions that can be performed on these items. There are three "Category" types listed in the drop-down menu: Scenario, Domain Object, and Default External Module. The user should refer to the MIMS guidance for detailed descriptions of these "Category" types.

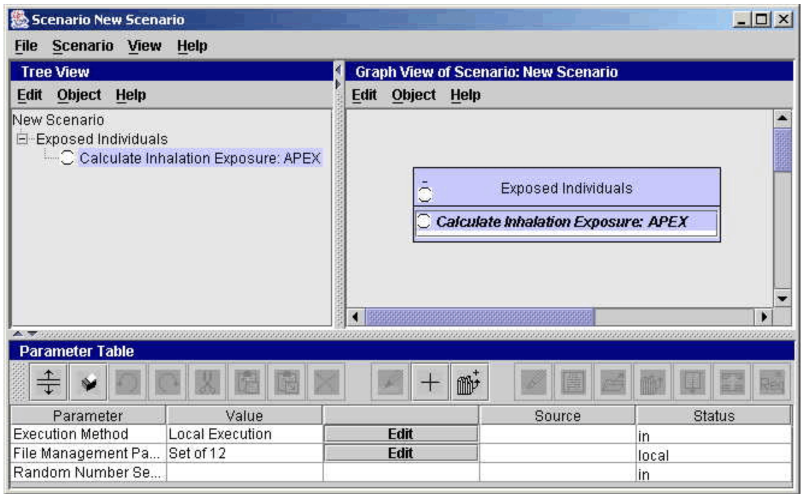


To configure and run an application using APEX in MIMS, the user must complete the following steps.

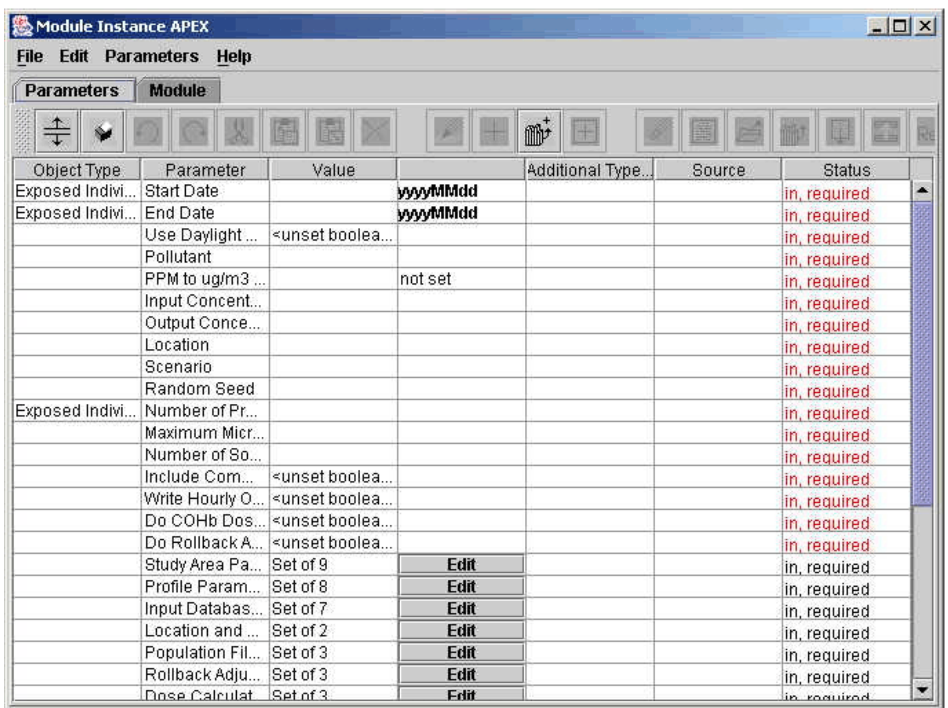
1. Select “Scenario” from the “Category” drop-down menu. The list of scenarios included in the project will appear in the space below the drop-down menu. Initially, this list will include a generic scenario for U.S. locations (i.e., “Exposure Assessment w/APEX”) that can be used to develop a new scenario specific to a user’s application and two example application scenarios (i.e., “Exposure Assessment for Benzene (Houston test case)” and “Exposure Assessment for Chromium (Houston test case)”). Users wishing to run either of the example applications should open the example scenario (by either double-clicking on the scenario name or selecting the scenario name and clicking the “Open” button) and then skip to Step (3). Users wishing to configure a new application should proceed to Step (2).

2. Select the “Exposure Assessment w/APEX” scenario and click the “Duplicate” button. The “Rename Library Member” pop-up window will appear. Enter a name for the application scenario (e.g., “New Scenario”) and click “OK.” The new scenario will then appear in the list of scenarios. Open the new scenario by either double-clicking on the scenario name or selecting the scenario name and clicking the “Open” button.

3. Select “Expand All” from the “Object” drop-down menu in the “Graph View of Scenario: <Scenario Name>” panel. Select “Calculate Inhalation Exposure: APEX” in the “Graph View of Scenario: <Scenario Name>” panel. When selected, the text will change to bold italics.

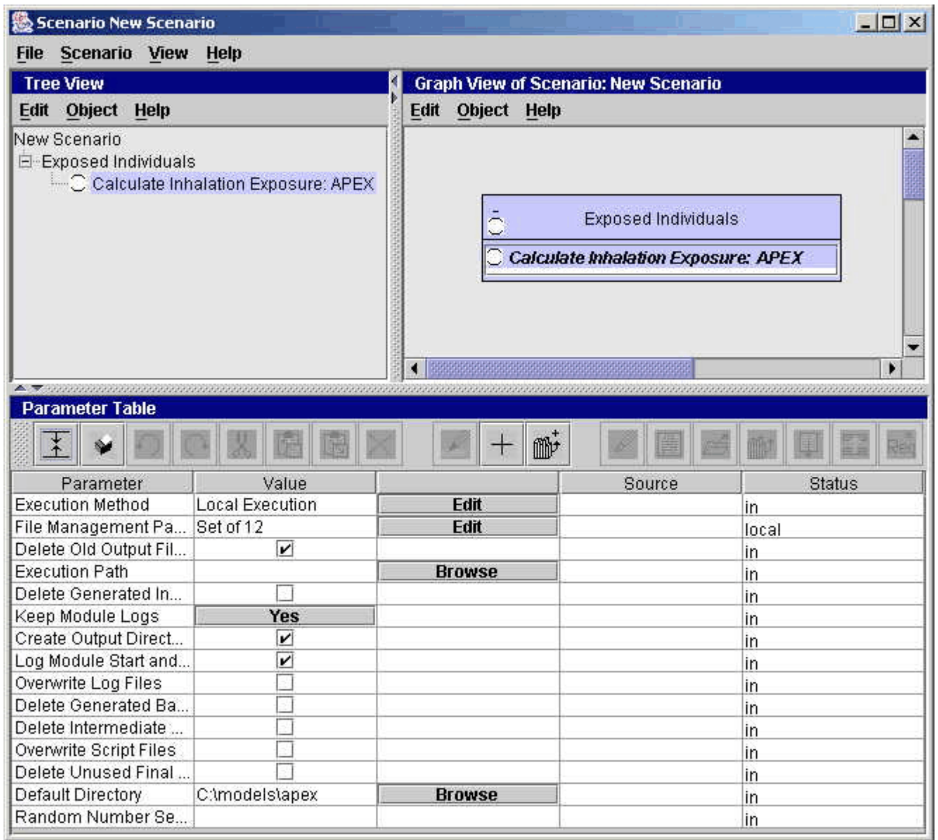


4. Double-click on “Calculate Inhalation Exposure: APEX" in the “Graph View of Scenario: <Scenario Name>” panel. The “Module Instance” window will appear.



5. Set the necessary parameter values in the “Module Instance” window. These parameters correspond to the variables in the *Params* file (described in Chapter 5). The mapping between the parameter names in the “Module Instance” window and the variable names in the *Params* file is provided in Tables 5-1 through 5-4 in Chapter 5. After setting the necessary parameter values, close the Module Instance window by clicking on the “X” in the upper right-hand corner of the window.

6. In the “Parameter Table” at the bottom of the Scenario Window, press the left-most button to expand the list of parameters. If necessary, check the “Create Output Directories” parameter. When selected, the option allows MIMS to create any required output directories if they do not exist when the simulation starts. If the user specifies an output directory that already exists, this option does not need to be selected. Set the “Default Directory” to correspond to directory containing the APEX executable (i.e., the Default Directory from the installation). Set the remaining scenario settings as desired. Refer to the MIMS User Guide for more details about these parameters.



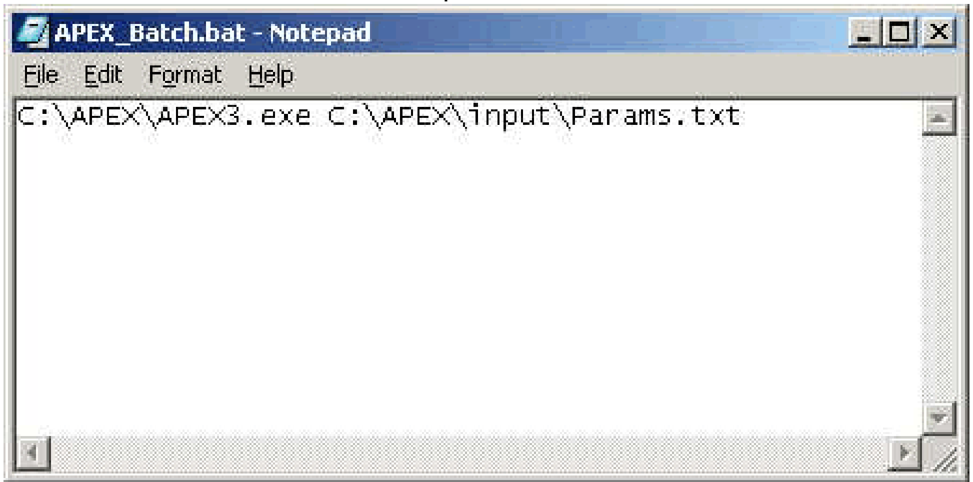
7. To start the simulation, select “Execute All” from the Scenario drop-down menu of the Scenario window.

4.2 Running APEX in DOS Batch Mode

The APEX executable can be run in DOS batch mode, meaning that the model’s executable (.exe) and *Params* files are specified in a single user-created file (referred to as a “batch” file) that is submitted to the operating system for job execution. When running APEX in DOS batch mode, there is no GUI. To run APEX in DOS batch mode, the user must complete the following steps.

1. Create the APEX batch file

To create an APEX batch file, open a new file in a text editor (e.g., Notepad). On the first line of this file, enter the file path and name of the APEX executable followed by a space and the file path and name of the *Params* file. For example,



In this example the APEX executable (i.e., APEX3.exe) is located in the "C:\APEX" directory and the *Params* file (i.e., Params.txt) is located in the "C:\APEX\input" directory. After entering this line, save the file. The file can be named anything, provided it ends with the extension ".bat" (e.g., APEX_Batch.bat).

2. Run the APEX batch file

APEX can be run using the batch file in any of the following ways.

- Double-clicking on the batch file in Explorer
- Typing the batch file name in a DOS window
- Selecting "Run" from the Start menu and entering the file path and name of the batch file
- Creating a shortcut to the batch file on the desktop by selecting the batch file in Explorer, right-clicking the mouse, and selecting "Create Shortcut" from the menu. A shortcut file will be created and this file can be dragged onto the desktop and optionally renamed. To run APEX, double-click on this shortcut.

In addition to running in DOS batch mode, there are several other ways to run APEX outside of the MIMS framework (described in the text box below). Refer to MS-DOS documentation for additional information on these alternative options.

Additional Options for Running APEX Outside of MIMS or DOS Batch Mode

1. *Typing the file name of the APEX executable at the prompt in a DOS window*. APEX will prompt the user for the "Unit(10)" file, at which time the user would input the location and name of the *Params* file.

2. *Double-clicking on the APEX executable in Explorer*. APEX will prompt the user for the "Unit(10)" file, at which time the user would input the location and name of the *Params* file.

3. Typing the file names of the APEX executable and *Params* file at the prompt in a DOS window.

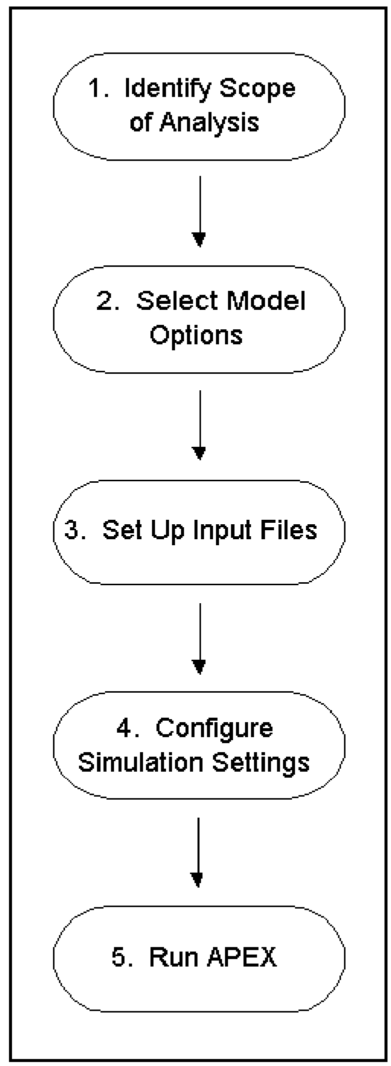
4.3 Setting Up an APEX Simulation

This section describes the steps involved in performing an APEX simulation. In particular, this section provides an overview of these steps followed by more detailed descriptions.

4.3.1 Overview

Figure 4-1 lists the five general steps involved in configuring and performing an APEX simulation. These steps are described below. Because each of these steps builds on the previous one, the user should proceed through these steps in this order.

Figure 4-1. General Steps to Configure and Conduct an APEX Simulation



1. Identify the Scope of the Analysis

The first step in configuring an APEX simulation is to identify the scope of the analysis. This step involves selecting the study area, modeling period, pollutant, and populations of interest for the analysis.

2. Select Model Options

After identifying the scope of the analysis, the user must decide which options to select. To determine the appropriate options for the application, the user must answer questions such as the following.

- Do I want to model worker commuting?
- How many profiles (or what percentage of the population) do I want to model?
- How many microenvironments do I want to model?
- How should I define my microenvironments?
- Which model settings should I select (e.g., model Daylight Savings Time? use air quality controls, or “rollbacks”?)
- What types of outputs do I want from the model?

Each of these options is described in more detail in Section 4.4.

3. Set Up Input Files

After deciding which model options to use and how to configure them, the next step in configuring an APEX simulation is to set up the input data files with the necessary data. There are 16 types of input data files required by APEX. With the exception of the population data file type, there is only one input file per input data file type. One of these files, the *Params* file (see next step), is used to specify input and output file names and locations and simulation settings. However, when running APEX in MIMS, the *Params* file is generated by the model (see next step), as opposed to being supplied by the user (as is the case when APEX is run in DOS batch mode). The remaining files contain the input data necessary to run APEX. The data contained in these remaining files varies depending on the options selected and the data contained in the other input files. The relationships between the input files (e.g., if you change one input file, does it impact any of the others?) is described in Table 4-3 in Section 4.5 and Chapter 5.

4. Configure the Simulation Settings

The final step before starting an APEX simulation is to configure the *Params* input file. This file contains five sections:

- Input file names and locations (other than population files);
- Population file descriptions, names, and locations;
- Output file names and locations;
- Parameter settings; and
- Output table levels.

A detailed description of each of the sections of the *Params* file is provided in Chapter 5.

When running APEX using the DOS batch mode, the *Params* file must be created by the user. When running APEX in MIMS, this information is specified by the user within the GUI and then the model uses it to create the *Params* file automatically. The steps involved is specifying these settings in the MIMS GUI are described in Section 4.1.

***5. Running* APEX**

The final step in configuring and performing an APEX simulation is running the model. If APEX is run in DOS batch mode, this step involves running the APEX executable. If APEX is run using MIMS, it involves completing Step (7) in Section 4.1.

4.3.2 Detailed Steps

The usual manner for preparing an APEX model run is to start with an existing application and modify it as necessary (e.g., change simulation settings, input file content, or output file names). Because there are many different ways to run APEX, there is no single list of steps that will work for every analysis. Users should always review the *Params* file (when running APEX in DOS batch mode) or the settings in the MIMS scenario (when running APEX in MIMS) to ensure the file locations and simulation settings are correct. The key factor in determining the effort required to prepare an analysis, however, is the degree to which the remaining input files need to be modified. In light of this, APEX applications can be grouped into two categories: standard and advanced.

Standard applications are designed to use the national-scale input database files accompanying APEX, to the extent possible. That is, these applications define sectors as census tracts, define the age groupings as in the accompanying data files, and use the profile functions, commuting data, population data, dose input data (if dose is modeled), microenvironment mapping, and CHAD activity data provided with APEX. These settings are defined in the following input files:

- *Sector Location* file;
- *Population Data* files*;*
- *Employment by Age Group* file;
- *Commuting* file;
- *Activity-specific MET* file;

- *Physiological Parameter* file;
- *Profile Functions* file
- *Microenvironment Mapping* file;
- *Personal Info* file; and
- *Diary Events* file.

Thus, for the first run of a standard application for a given study area, pollutant, etc., the user generally would only need to edit or create the following input files (in addition to the *Params* file or settings in the MIMS scenario):

- *District Location* file;
- *Temperature Zone Location* file;
- *Temperature Data* file;
- *Air Quality Data* file;
- *Profile Functions* file;
- *Micro Mapping* file; and
- *Microenvironment Descriptions* file.

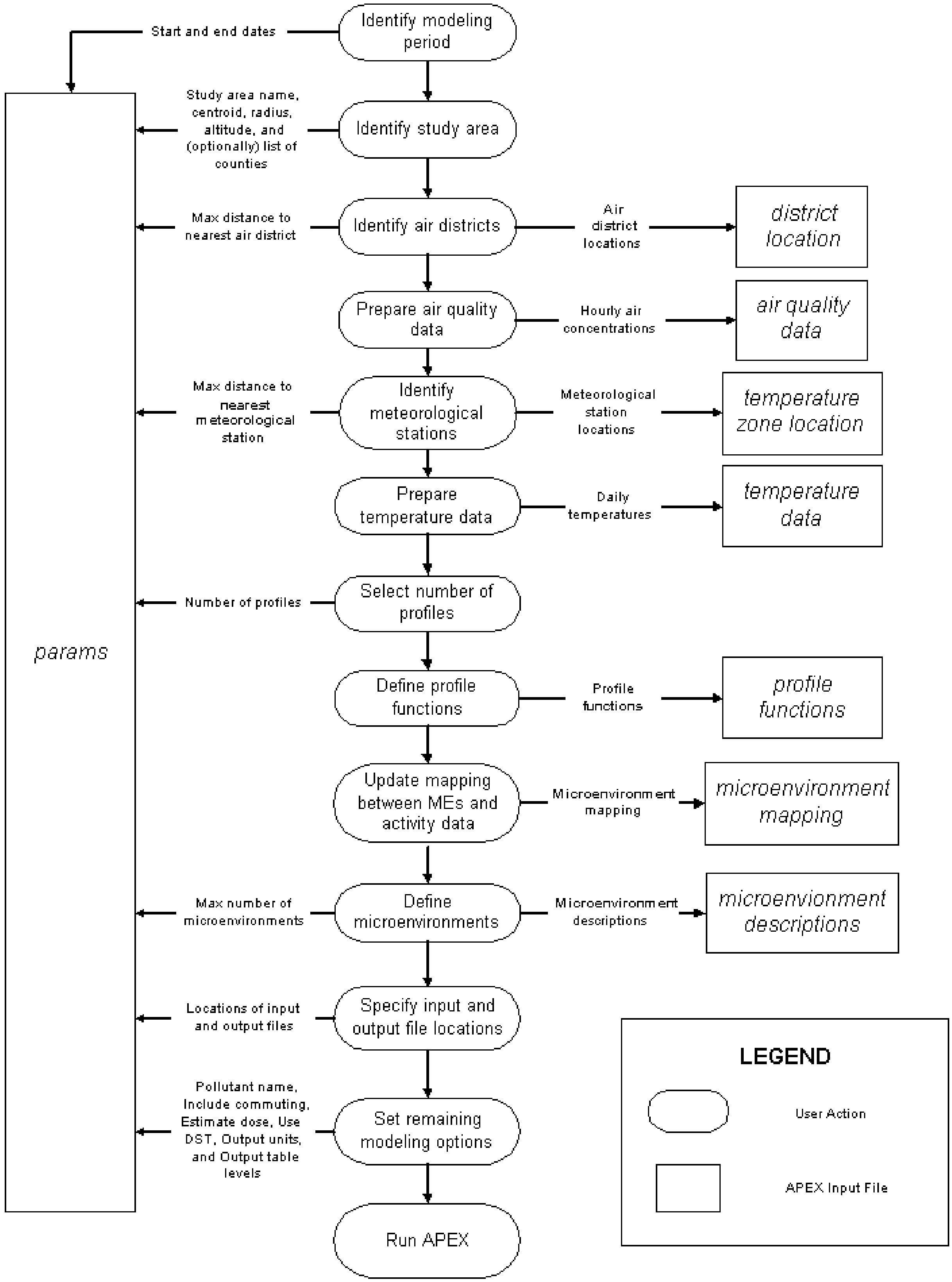
Subsequent runs for the same study area, pollutant, etc. could involve as little as a single parameter change (e.g., the simulation start or stop dates) in the *Params* file (when running APEX in DOS batch mode) or in the MIMS GUI (when running APEX in MIMS) – the most basic standard application – or could involve changes in all of the same input files edited as indicated above for the first run. Figure 4-2 contains a flow chart that describes each of the steps a user must complete to configure and perform a standard APEX simulation.

Advanced applications involve modifying or replacing the national-scale input database files accompanying APEX. These types of applications allow the user to perform analyses that are specifically tailored to unique needs, such as use in a country other than the U.S. or using a finer (or coarser) spatial resolution. Depending on the application, the user may need to edit or replace all of the input data files. The steps required for an advanced application depend on how much the application deviates from a standard application. Users should be aware that advanced applications can require significantly more time to develop input data.

4.4 Overview of Input and Output Files

This section provides a brief overview of the input and output files associated with APEX. (For more detailed descriptions of the input and output files, refer to Chapters 5 and 6, respectively.) All of the input and output files used by APEX are ASCII text files, which allows them to be read and/or modified by the user using any text editor. Note, however, that certain files, such as the commuting input file and possibly the exposure and dose output files, may be very large (over 100 megabytes) and difficult for some text editors to handle.

Figure 4-2. Steps for Setting up a "Standard" APEX Simulation



4.4.1 Input Files

There are 16 types of input data files required by APEX. Table 4-1 lists each file type and a brief description of the content of the file. With the exception of the population data file type, there is only one input file per input data type. When APEX is run in DOS batch mode, the *Params* file will typically be edited prior to each simulation. When running APEX in MIMS, the user will edit the inputs and settings for each simulation in the MIMS GUI and the model will create the *Params* file based on the provided information. The remaining input data files may need to be edited for a particular simulation depending on the type of application (i.e., standard or advanced) and the options selected for the simulation (e.g., commuting, dose estimates). (Table 4-3 in Section 4.5 provides an explanation of the input data file changes required with changes to the different model options.)

Note that several of the APEX input files use a "keyword" approach. APEX processes these files and searches for particular keywords followed by an equal sign and one or more values for the keyword. Chapter 5 provides a detailed description of the keyword approach and its syntax.

4.4.2 Output Files

There are seven types of output files from APEX. Table 4-2 lists each of the output data files and a description of the content of the file. The names and locations, as well as the output table levels (e.g., output percentiles, cut-points) for these output files, are specified by the user in the *Params* file (when running APEX in DOS batch mode) or in the MIMS GUI (when running APEX in MIMS). <u>If an output file is specified with the same name and location as an existing file, the old files are overwritten</u>. Therefore, if the user wishes to conduct a series of model runs, the output files for each run should be named differently or the output should be copied elsewhere before the next model run is submitted.

4.5 Overview of Model Settings and Options

This section describes the settings and options available in APEX. There are five general categories of settings and options in APEX:

- General Model Settings and Options;
- Study Area Location;
- Profiles;
- Microenvironments; and
- Outputs.

Table 4-3 describes all of the settings and options in each of these categories, how the settings and options are selected or changed, and the impact of changing a setting or option on the other input files. <u>Note that the impact of these settings and options on input files should be distinguished from the changes in certain input files that may significantly affect other input files (e.g., the effect that changes in *Population Data* would have on *Commuting Flow*)</u>. As many of the settings and options impact multiple APEX input files, it is important for the user to pay close attention to the impacts that changing the various settings and options can have on the different input files. The table includes the settings and selected options in the input data files accompanying APEX to help the user understand the settings for a standard application and

Table 4-1. Overview of APEX Input Files

Input File Name	Description
Params	Specifies the overall settings (or parameters) for an APEX simulation (i.e., input file names, population data file names, output file names, job parameter settings, and output table levels). This file is the simulation control file and is the input file most often changed by the user.
*Sector Location**	Contains the sector IDs and locations (in degrees latitude and longitude) for each sector.
*Population Data**	Contain the number of people in each age range for each sector ID. There must be one *Population Data* file for each gender/race combination included in the simulation.
District Location	Includes the site ID and location (in degrees latitude and longitude) for each air quality monitoring/modeling location included in the simulation.
Temperature Zone Location	Includes the site ID and location (in degrees latitude and longitude) for each meteorological station included in the simulation.
*Employment by Age Group**	Specifies the age group ranges included in the population files and the probability of employment associated with each age group.
*Commuting Flow**	Contains the probabilities of a worker commuting to different destination sectors from any given home sector. This file is only required when worker commuting is modeled.
Temperature Data	Contains the daily maximum and optionally average (or other) temperature data for the meteorological stations and dates indicated in the *Temperature Zone Location* file.
Air Quality Data	Contains the hourly air concentrations for the modeled pollutant for the monitoring/modeling locations and dates indicated in the *District Location* file.
*Activity-specific MET**	Provides distributional shapes and parameters for calculating a metabolic (MET) value for each activity code in the *Diary Events* file.
*Physiological Parameters**	Provides tables of physiological parameters (e.g., body mass) used in calculating dose.
Profile Functions	Contains user-defined functions that define probabilities that simulated individuals will have particular characteristics (e.g., probability a simulated individual will have air conditioning at home).
Microenvironment Mapping	Links the diary events location codes to the APEX microenvironments in the *Micro Descriptions* file.
*Personal Info**	Contains information relating to each 24-hour activity diary (e.g., day type, gender, age, race, occupation) from the *Diary Events* file.
*Diary Events**	Contains the event descriptions (i.e., start time, duration, activity, and location) for all of the diary days in the activity database (e.g., CHAD).
Microenvironment Descriptions	Contains the definitions of the APEX microenvironments referenced in the *Micro Mapping* file.

* The input file of this type that accompanies APEX contains data that can be applied to any study area in the United States and would only be edited or replaced for an Advanced application.

Table 4-2. Overview of APEX Output Files

Output File Name	Description
Log	The *Log* file contains the record of the APEX model simulation as it progresses. If the simulation completes successfully, the log file indicates the input files and parameter settings used for the simulation and reports on a number of different factors. If the simulation ends prematurely, the log file contains error messages describing the critical errors that caused the simulation to end.
Hourly Exposure	The *Hourly Exposure* file provides an hour-by-hour time series of exposure estimates for each modeled profile.
Hourly Dose	The *Hourly Dose* file provides an hour-by-hour time series of dose estimates for each modeled profile, if doses are modeled.
Profile Summary	The *Profile Summary* file provides a summary of each profile modeled in the simulation.
Microenvironment Summary	The *Microenvironment Summary* file provides a summary of the time and exposure by microenvironment for each profile modeled in the simulation.
Sites	The *Sites* file lists the sectors, districts, and zones in the study area, and identifies the mapping between them.
Output Tables	The *Output Tables* file contains a series of tables summarizing the results of the simulation. The percentiles and cut-off points used in these tables are defined in the *Params* file.

how deviating from these settings can significantly increase the effort required to setup the required input files. Throughout this table, “keywords” (or variables or parameters) are referenced in indicating how different options can be selected. See Chapters 5 and 6 for additional details on the keywords and input files, how to change them, and how they interact with other keywords and files. Also, see Section 1.3.2 for limitations on the use of this model, especially in terms of the number of setting options it has available.

Table 4-3. Description of Steps and Implications Involved in Changes to APEX Settings and Options

Setting/Option	How Option is Selected	Impact of Changing Default Setting on Other Input Files
GENERAL MODEL SETTINGS AND OPTIONS		
Simulation start/end dates	Specified in YYYYMMDD format (e.g., 19960704 is July 4, 1996) using the ***START_DATE*** and ***END_DATE*** keywords in the *Params* file. The user must define the appropriate start and end dates for an application.	The indicated start and end dates must be included in the date ranges included in the *District Location*, *Temperature Zone Location, Temperature Data*, and *Air Quality Data* files. These files may contain additional data before and/or after the start and end dates, but must contain data for the entire period between the specified start and end dates.
Adjust for Daylight Saving Time (DST)	Specified using the ***DSTADJUST*** keyword in the *Params* file. If this parameter is set to “YES”, then the *Air Quality Data* file will be adjusted for DST in the summer; if it is set to “NO”, no adjustment is made. This keyword should be set to “YES” if the *Air Quality Data* file is based on Standard Time yet the activity data are based on DST.	Changing this setting means that the *Air Quality Data* file is based on DST (it typically is in Standard Time) or that the activity data are based on Standard Time (the supplied CHAD data are based on DST). Regardless of this setting, the output (hourly exposure and dose) for all simulated days will contain exactly 24 hours, and all input activity diaries must contain exactly 24 hours.
Model worker commuting	Specified using the ***COMMUTING*** keyword in the *Params* file. If this keyword is set to “YES”, commuting to work is allowed and the user must provide a *Commuting Flow* file in the appropriate format and employment status must be specified in the *Employment by Age Group* file; if it is set to “NO”, all workers are assumed to work at home and the user is not required to provide a *Commuting Flow* file. If employment status is not specified in the *Employment by Age Group* file, commuting will not be modeled, regardless of the ***COMMUTING*** keyword setting in the *Params* file. The *Commuting Flow* file accompanying APEX contains commuting flows between all census tracts from the 2000 Census. These commuting data are sufficient for all applications where the sectors are defined as census tracts.	If the user changes the value of the ***COMMUTING*** keyword to “NO”, there are no additional changes required. If the user chooses to use sectors other than census tracts, a new *Commuting Flow* file(in addition to a number of other input files) must be created corresponding to the new sectors.

Table 4-3. Description of Steps and Implications Involved in Changes to APEX Settings and Options (continued)

Setting/Option	How Option is Selected	Impact of Changing Default Setting on Other Input Files
Model exposure dose	Specified using the ***DODOSE*** keyword in the *Params* file. If this keyword is set to "YES", the model will create the hourly dose file; if it is set to "NO", the dose calculations will be suppressed and the hourly dose file will not be created. If ***DODOSE*** is set to "YES", the user must specify the correct values for the ***ALTITUDE***, ***COHBFACT***, and ***COTHRESH*** keywords in the *Params* file. Regardless of the setting for ***DODOSE***, the user must provide the *Activity-specific MET* and *Physiology Data* files; however, if ***DODOSE*** is set to "NO," the content of these files does not impact the results.	The *Activity-specific MET* file accompanying APEX must be changed if (1) the underlying MET distributions in the CHAD database are changed or (2) activity data other than that provided in the CHAD database are used. The user may edit or replace the *Physiology Data* file provided with APEX, provided the new or revised file is in the appropriate format.
Air quality rollback adjustment (for estimating exposure in hypothetical control scenarios)	Specified using the ***ROLLBACK*** keyword in the *Params* file. If this keyword is set to "YES", the user must specify appropriate values for the ***RBTARGET***, ***RBBACKGND*** , and ***RBMAX*** keywords in the *Params* file; if it is set to "NO", values are not required for these keywords (and any present will be ignored).	If the ***ROLLBACK*** keyword is changed to "YES" in the *Params* file accompanying APEX, the ***RBTARGET***, ***RBBACKGND*** , and ***RBMAX*** keywords must be set to appropriate values.
STUDY AREA LOCATION		
Center of study area	Specified as the latitude and longitude of the center of the study area in decimal degrees using the ***LATITUDE*** and ***LONGITUDE*** keywords in the *Params* file. The user must always define the appropriate study area center for an application.	If the study area is changed, the user must ensure that the following files contain appropriate data for the new location: *Sector Location* file (unless the included file is used), *District Location* file, *Temperature Zone Location* file, *Temperature Data* file, and *Air Quality Data* file.
Radius of study area	Specified as the distance (in km) from the center to the edge of the study area using the ***CITYRADIUS*** keyword in the *Params* file. The user must always define the appropriate study area radius for an application.	If the study area is changed, the user must ensure that the following files contain appropriate data for the new location: *Sector Location* file (unless the included file is used), *District Location* file, *Temperature Zone Location* file, *Temperature Data* file, and *Air Quality Data* file.

Table 4-3. Description of Steps and Implications Involved in Changes to APEX Settings and Options (continued)

Setting/Option	How Option is Selected	Impact of Changing Default Setting on Other Input Files
Restrict study area to selected counties	Specified using the ***COUNTYLIST*** keyword in the *Params* file. If the value of this keyword is set to "YES", the user must list the FIPS code (or other relevant portion of the sector ID if the supplied sector files are not used) for the counties to which the study area will be restricted using the ***COUNTY*** keyword in the *Params* file. The county IDs for all census tracts in the 2000 Census are included in the *Sector Location* file accompanying APEX, thus allowing the user to select counties in the *Params* file without making changes to the included *Sector Location* file.	If the user does not use the included *Sector Location* file, they must ensure that the new *Sector Location* file provides the county ID for each sector as part of the sector ID in the appropriate format.
Locations of sectors	Specified as sector IDs and locations (latitude and longitude) in the *Sector Location* file. The *Sector Location* file accompanying APEX use the census tracts from the 2000 Census as sectors. This file also specifies the county associated with each sector (via the first five characters of the sector ID, which are the county FIPS codes in the supplied data), which allows the user to restrict the study area to selected counties. In most cases, the user will not need to change this setting as it provides sectors with the necessary population and commuting data for the entire United States.	Sectors identified in *Sector Location* file must match the sectors identified in *Population Data* files. If the user wishes to use census tracts from the 2000 Census, the *Sector Location* file accompanying APEX will be sufficient. All of the sectors used in the commuting file must be included in the *Sector Location* file and the *Population Data* files; if sectors other than 2000 Census tracts are used, the user must provide a *Commuting* file compatible with these sectors. In addition, if the user wants to restrict the study area to selected counties, the *Sector Location* file must include the county IDs associated with sector as part of the sector IDs in the proper format (as in the supplied file).
Locations of air districts	Specified in the *District Location* file. The user must always define the appropriate air districts for an application. The user must always define the appropriate air districts for an application.	The locations of the air districts must be selected such that they can provide reasonable estimates of air quality for the sectors and study period included in the analysis.
Radius of air district	Using the ***AIRRADIUS*** keyword in the *Params* file, the user can specify the maximum distance (in km) that a sector can be from the nearest air district to remain in the study. If all district centers are further than ***AIRRADIUS*** from the sector center, the sector is removed from the study area and is not modeled. Users must always define an appropriate value for this keyword based on their application.	The radius of the air districts must be selected such that they will include the sectors the user would like to include in the analysis.

Table 4-3. Description of Steps and Implications Involved in Changes to APEX Settings and Options (continued)

Setting/Option	How Option is Selected	Impact of Changing Default Setting on Other Input Files
Location of meteorological data stations	Specified as zone IDs and locations (latitude and longitude) in the *Temperature Zone Location* file. In the absence of a national database of temperature data, the user must always define the location(s) of meteorological stations for an application.	Temperature data for each meteorological data station specified in the *Temperature Zone Location* file must be provided in the *Temperature Data* file.
Radius of meteorological station coverage	Using the ***ZONERADIUS*** keyword in the *Params* file, the user can specify the maximum distance (in km) from a sector to the nearest meteorological station. If all zone centers are further than ***ZONERADIUS*** from the sector center, the sector is removed from the study area and is not modeled. Users must define an appropriate value for this keyword based on their application.	The radius of the zones must be selected such that they will include the sectors the user would like to include in the analysis.
PROFILES		
Number of profiles	Set to an integer using the ***#PROFILES*** keyword in the *Params* file. Users must define an appropriate value for this keyword based on their application.	None.
Modeled populations	Specified in the *Params* file following the specification of the file names. The user must provide a population file for each population to be modeled and indicate the gender and race associated with the file. All gender/race combinations without specified population files are assumed to have zero populations. Users can select from the sets of available *Population Data* files accompanying APEX (i.e., the national population files or the files specific to the Houston example applications), or generate their own.	If the user wishes to model a subpopulation, the user must supply alternative *Population Data* files with the appropriate counts. The sector IDs in these population files must correspond to sector IDs provided in the *Sector Location* file.
Profile function options	The existing profile functions can be edited by the user in the *Profile Functions* file. This file can also be edited by the user to add new functions. The *Profile Functions* file accompanying APEX contains nine functions that can be edited by the user as necessary for an application.	None, if the user edits one of the existing functions.
Employment status	Specified in the *Employment by Age Group* file for implementation of commuting. The *Employment by Age Group* file accompanying APEX should be sufficient for all applications where sectors are defined as census tracts.	None.

Table 4-3. Description of Steps and Implications Involved in Changes to APEX Settings and Options (continued)

Setting/Option	How Option is Selected	Impact of Changing Default Setting on Other Input Files
Minimum and maximum ages for simulated profiles	Specified using the ***AGEMIN*** and ***AGEMAX*** keywords in the *Params* file.	None.
Modeled age groups	Specified in the *Employment by Age Group* file. The *Employment by Age Group* file accompanying APEX defines the age groups as single years up to 99 and three groups beyond, and thus should be sufficient for all applications where sectors are defined as census tracts.	The age groups specified in the *Employment by Age Group* file must match the age groups used in the *Population Data* files. If the user wishes to change the age groups in the *Employment by Age Group* file, the associated changes must also be made to the *Population Data* files.
Size of age window	The ***AGECUTPCT*** and ***AGE2PROBAB*** keywords in the *Params* file are used to specify the window around the assigned age of a profile from which activity data can be selected.	None.
Probabilities for selecting diaries with missing characteristics	Using the ***MISSGENDER***, ***MISSEMPL***, and ***MISSAGE*** keywords in the *Params* file, the user can specify the probability that activity diary data with missing gender, employment status, or age will selected.	None.
MICROENVIRONMENTS		
Maximum number of micro-environments	Set to an integer using the ***#MICRO*** keyword in the *Params* file; must not exceed 127.	Number of APEX microenvironments in the *Microenvironment Mapping* and *Microenvironment Descriptions* files must not exceed the specified value in the *Params* file
Microenvironment definitions	Specified in the *Microenvironment Descriptions* file. The user must develop data relevant to a particular application prior to performing an APEX simulation.	Each location referenced in the activity database (e.g., CHAD) must be mapped to one of the microenvironments specified in the *Microenvironment Descriptions* file using the *Microenvironment Mapping* file.
OUTPUTS		
Produce hourly outputs	Specified using the ***HOURLYOUT*** keyword in the *Params* file. If this keyword is set to "YES", the hourly exposure and dose (if applicable) output files are created; if it is set to "NO", these files are not created.	None.

Table 4-3. Description of Steps and Implications Involved in Changes to APEX Settings and Options (continued)

Setting/Option	How Option is Selected	Impact of Changing Default Setting on Other Input Files
Output table levels	Specified using the following keywords in the *Params* file: ***PERCENTILES***, ***EXPTIME***, ***DM1HEXP***, ***DM8HEXP***, ***DAVGEXP***, ***ANNEXP***, ***DM1HDOSE***, ***DM8HDOSE***, ***H_EHDOSE***, ***DMEHDOSE***, ***DAVGDOSE***, ***ANNDOSE***, and ***DOSETIME***. These keywords are described in detail in Chapter 5.	None.

5. INPUT FILES

This chapter provides the details necessary for accessing, creating, and modifying, as needed, the APEX input files. Addressed are input file format, the *Params* (or control) input file, and the population and other input files. The user should have a general understanding of how the APEX model works (from Chapter 2) and a clear understanding of the relationships between the various input files (from Chapter 4—in particular Table 4-3) before using this chapter.

5.1 Input File Formats

APEX requires the following input files to run:

- A parameters file;
- 14 other input files; and
- A population file for each combination of gender/race to be modeled.

All input files are "ASCII text" files that can be edited on a text editor such as Notepad. Each input line of these files is categorized into one of four types:

1. Keyword (or variable or parameter) line: Keywords are used in the *Params* file to indicate to APEX where the input files are located and what values should be assigned to certain variables. A keyword line always contains an "=" sign. The part of the line to the left of "=" is called the "keyword" and the part to the right is called the "value." The keyword must start with a letter and must match the spelling sought by the program code, after which the keyword may contain other letters, blanks, or commas. APEX uses the keyword to locate and set the input values. The values may be character, logical, or numeric values, or file names.

2. Numeric line: Any line beginning with a digit (0-9) is recognized as a numerical data line by APEX. Non-digits may appear later in a numeric line.

3. Character line: A line that begins with a character but does not contain an "=" sign is recognized as a character data line.

4. Comment line: Any blank lines and any lines beginning with "!" generally are regarded as comment lines by APEX and used only by the user to help document the input file data. Comment lines inserted in the middle of a block of data, however, can be unpredictable. That is, if the computer code is expecting to read a long series of numbers without a break, then comments may break the flow. If in doubt, use comments only where they are used in the supplied input files.

The keywords and input values are not case sensitive. Also, each line on an input file is processed independently by APEX. Continuation of data values across multiple lines is not permitted unless specifically noted for a particular file. APEX uses "list" (or "free") format for most input values (the *Physiological Parameters* input file—Section 5.11—is the exception). This means that the values or data do not have to be fixed in specific positions on an input line. Multiple items on an input line can be separated by either a blank or comma. The various site names and similar inputs, however, should not contain internal blanks, as these will be interpreted as delimiters between input fields. This does not apply to keyword lines, as those lines have only two fields (separated by the "=" sign), so either or both sides may contain internal blanks.

The following sections discuss the details of APEX input files and provide several examples. Note that these example files in this and the next chapter are provided for illustration only! They have been developed solely for the purpose of highlighting various aspects and options of APEX. These example files are not necessarily related to each other nor to the supplied data files that can be downloaded separately from this user's guide. In many cases these examples are only portions of the necessary input files. Thus, these example files will not work as an actual set of input files. Users are encouraged to view the EPA-supplied input files (downloaded separately) for a complete and related set of input files. Also, Volumes III and IV—which provide APEX case studies—are associated with complete and related sets of input (and output) files.

5.2 *Params* File (Unit 10)

> **Tip.** Keep a copy of the *Params* file associated with each simulation to provide a record of the input and output files and model settings associated with the simulation and to make it easier to run the model again based on different input data.

The parameter, or *Params*, file is APEX's simulation control file. The *Params* file names input and output files, sets model parameters, and controls formats of output files. APEX only processes keyword lines in this file. Any other types of input lines are ignored. As described in Chapter 4, the *Params* file is created or modified directly by the user when running APEX in DOS batch mode. Conversely, when running $\text{TRIM.Expo}_{\text{Inhalation}}$, the *Params* file is created or modified automatically based on the parameter settings provided by the user in the $\text{TRIM.Expo}_{\text{Inhalation}}$ GUI. Although the remainder of this section is written from the perspective of a user configuring a *Params* file to run APEX in DOS batch mode, users can refer to the keyword tables in this section (i.e., Tables 5-1 through 5-4) for a description of how the $\text{TRIM.Expo}_{\text{Inhalation}}$ parameters relate to the keywords in the *Params* file. That is, each of these tables contain a column titled "TRIM.Expo-Inh Parameter Name" that indicates the parameter name in $\text{TRIM.Expo}_{\text{Inhalation}}$ that corresponds to the keyword in the *Params* file. With this information, users can determine how to set the parameter values in the $\text{TRIM.Expo}_{\text{Inhalation}}$ GUI.

When accessing in DOS batch mode, the following rules should be used:

- Keywords (or parameters or variable names) are placed to the left of the equal sign in a keyword line;
- Parameter values are to the right of the equal sign;
- Lines may appear in any order;
- Lines may be omitted if defaults are acceptable;
- Only one equal sign allowed per keyword line;
- Anything after an exclamation mark in a line is ignored; and
- Any line without an equal sign is ignored.

To ensure that the keywords are input properly, the user may want to use the example file as a template. The user only needs to change values to the right of the "=" sign on the key word line. An example of the *Params* file is provided in Figure 5-1.

Figure 5-1. Example of *Params* File[a]

```
INPUT FILES:
  sectors file      = C:\APEX3\input\tp_geo.txt
  districts file    = C:\APEX3\input\districts_houston61.txt
  zones file        = C:\APEX3\input\zones_houston.txt
  employment file   = C:\APEX3\input\employment.txt
  commuting file    = c:\APEX3\input\comm2000.txt
  temperature file  = C:\APEX3\input\temperatures_houston.txt
  air quality file  = C:\APEX3\input\APEXHoustonAir61.txt
  metabolic file    = C:\APEX3\input\CHADMets.txt
  physiology file   = C:\APEX3\input\Physiology.txt
  distribution file = C:\APEX3\input\distrib_houston.txt
  microenv. file    = C:\APEX3\input\MP_houston.txt
  diaryevent file   = C:\APEX3\input\CHADEvents.txt
  diarysum file     = C:\APEX3\input\CHADQuest.txt
  diarymap file     = C:\APEX3\input\micromap34.txt

POPULATION FILES:
  pop file, Female, White = C:\APEX3\input\tp_FW.txt
  pop file, Female, Black = C:\APEX3\input\tp_FB.txt
  pop file, Female, Asian = C:\APEX3\input\tp_FA.txt
  pop file, Female, NatAm = C:\APEX3\input\tp_FN.txt
  pop file, Female, Other = C:\APEX3\input\tp_FO.txt
  pop file, Male,   White = C:\APEX3\input\tp_MW.txt
  pop file, Male,   Black = C:\APEX3\input\tp_MB.txt
  pop file, Male,   Asian = C:\APEX3\input\tp_MA.txt
  pop file, Male,   NatAm = C:\APEX3\input\tp_MN.txt
  pop file, Male,   Other = C:\APEX3\input\tp_MO.txt

OUTPUT FILES:
  log file          = C:\APEX3\output\log.txt
  exposure file     = C:\APEX3\output\exp.txt
  dose file         = C:\APEX3\output\dose.txt
  persons file      = C:\APEX3\output\psum.txt
  microsum file     = C:\APEX3\output\msum.txt
  tables file       = C:\APEX3\output\tablesb.txt
  sites file        = C:\APEX3\output\sites.txt

PARAMETER SETTINGS:
  pollutant   = Benzene
  inputunit   = ppm
  outputunit  = ppm
  location    = Houston
  scenario    = test
  #profiles   = 20
  #micros     = 4
  #sources    = 3
  start_date  = 19960101
  end_date    = 19961231
  Latitude    = 29.75533
  Longitude   = -95.18716
  CityRadius  = 20
  AirRadius   = 0.5
  ZoneRadius  = 300.
```

Figure 5-1. Example of *Params* File (continued)

```
  CountyList  = YES
  County      = 48201
  County      = 48157
  Commuting   = YES
  AgeMin      = 0
  AgeMax      = 99
  DSTadjust   = YES
  HourlyOut   = NO
  DoDose      = NO
  rollback    = NO
  RBtarget    =  5.0
  RBbackgnd   =  0.0
  RBmax       = 10.0
  PPMFact     = 1145.
  MissGender  =  0.1
  MissEmpl    =  0.1
  MissAge     =  0.1
  AgeCutPct   = 25.0
  Age2Probab  =  0.1
  Altitude    = 90
  COHbFact    = 2.5
  COThresh    = 100.
  DebugLevel  = 0
  RandomSeed  = 547862400

OUTPUT TABLE LEVELS:
 Percentiles = 10, 25, 50, 75, 90, 95, 99
 TimeEXP     = 2, 4, 6, 8, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60
 DM1HExp     = 5, 10, 20, 30, 40, 50, 75
 DM8HExp     = 3, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 18, 20, 25
 DAvgExp     = 2, 4, 5, 6, 7, 8, 9, 10, 11, 12, 14, 16, 18, 20
 SavgExp     = 0.5, 1, 1.25, 1.5, 1.75, 2, 2.5, 3, 4, 5, 6, 8, 10
 DM1HDose    = 0.5, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 4.0, 5.0, 6.0
 DM8HDose    = 0.5, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 4.0, 5.0, 6.0
 H_EHDose    = 0.5, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 4.0, 5.0, 6.0
 DMEHDose    = 0.5, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 4.0, 5.0, 6.0
 DAvgDose    = 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 4.0, 5.0
 SavgDose    = 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.0, 1.2, 1.4, 1.6, 1.8, 2.0, 2.5
 TimeDose    = 0.5, 1.0, 1.25, 1.5, 1.75, 2.0, 2.25, 2.5, 2.75, 3.0, 4.0, 5.0, 6.0
```

[a] Note that COHbFact and COthresh parameters are needed only for CO dose calculation. For other pollutants, DoDose should be set to NO. APEX currently only includes dose algorithms for CO.

There are five sections in this example (these same sections are recommended for all *Params* files): input file, population files, output files, parameter settings, and output table levels. The details of each section are discussed below.

5.2.1 Input and Output File List Sections of *Params* File

In the Input File section of the parameter file, the user needs to specify the names and path names of 14 non-population input files. Table 5-1 provides a brief description of these files. For a new scenario or standard application, the user needs to modify or replace the files of units 12, 13, 16, and 17. (See the introduction to Chapter 4 for a description of “Unit number”

Table 5-1. Input Files for APEX Model[a]

Input File	Keyword	APEX in MIMS Parameter Name	Unit #	Uses
Sector Location	***SECTOR***	**Input File - Sector Locations**	11	Provides the IDs and locations (in degrees latitude and longitude) of sectors (e.g., census tracts). The file is used along with the user-defined ***CityRadius*** and other data to select the sectors within the modeled area.
District Location	***DISTRICT***	**Input File - District Locations**	12	Provides the site IDs and locations (degrees latitude and longitude) of air quality monitoring or modeling locations. The file is used along with the user-defined ***AirRadius*** to define the geographical area covered by the air quality data. The air quality data from a monitoring or modeling location are used for the sectors (e.g., census tracts) within its covered area. Start and end dates indicate the dates during which the data for a particular location are valid.
Temperature Zone Location	***ZONE***	**Input File - Meteorological Zone Locations**	13	Provides the site IDs and locations (degrees latitude and longitude) of the meteorological stations. The file is used along with the user-defined ***ZoneRadius*** to determine the area covered by the temperature data. Start and end dates indicate the dates during which the data for a particular location are valid.
Employment by Age Group	***EMPLOYMENT*** (or ***AGEGROUP***)	**Input File - Employment**	14	Provides a list of probabilities of employment for each age group in the *Population Data Input* files. The probabilities are used to determine if a simulated person (i.e., a profile) will commute to another census tract to work.
Commuting Flow	***COMMUT***	**Input File - Census Commuting Flow**	15	Provides probabilities of a worker commuting to various destination census tracts from any given home tract. This file is only required when worker commuting is modeled.
Temperature Data	***TEMPERAT***	**Input File - Temperature Data**	16	Contains the daily maximum and optionally average (or other) temperature data for the meteorological stations and dates indicated in the *Temperature Zone Location* file. Temperature is used to determine window positions and group activity pattern pools in APEX.
Air Quality Data	***QUALITY***	**Input File - Air Quality Data**	17	Provides the hourly air quality data for the modeled pollutant for each air monitoring/modeling location listed in the *District Location* file.

Table 5-1. Input Files for APEX Model[a] (continued)

Input File	Keyword	APEX in MIMS Parameter Name	Unit #	Uses
Activity-specific MET	***METABOL***	**Input File - Activity Specific METS**	18	Provides distribution types and parameters for calculating the metabolic (MET) value for each activity code in the *Diary Events* file. A MET value is a dimensionless ratio of the activity-dependent energy expenditure rate to the basal or resting energy expenditure (metabolic) rate. This file is used for calculating dose, not exposure concentrations. It is needed for running APEX even if the dose calculation is turned off.
Physiological Parameters	***PHYSIOL***	**Input File - Physiological Parameters**	19	Provides tables of certain physiological parameters (e.g., body mass) by age and gender. The file is used for calculating dose, not exposure concentrations. It is needed for running APEX even if the dose calculation is turned off.
Profile Functions	***DISTRIB***	**Input File - Profile Functions**	20	Provides the definitions of the following user-definable functions: ***MaxTempCat*** - Binning daily 1-hour maximum temperatures into categories ***AvgTempCat*** - Binning daily mean temperatures into categories ***DiaryPools*** - Assigning diary pools using day of week, MaxTempCat, and AvgTempCat ***IDGRP*** - Group number for output labeling not used in internal calculation ***HasGasStove*** - Define probability of having gas stove in a residence ***HasPilot*** - Probability of having a pilot light, based on HasGasStove ***AC_Home*** - Probability of having air conditioning at home ***AC_Car*** - Probability of having air conditioning in a car ***WindowPos*** - Probability of windows open or closed, based on ***AC_Home***, ***MaxTempCat***, and ***AvgTempCat*** ***SpeedCat*** - Probability of average car speed categories
Microenvironment Mapping	***DIARYMAP***	**Input File - Microenvironment Mapping**	21	Provides the mapping from activity location codes in *Diary Events* (e.g., from CHAD) to user-defined microenvironments in *Micro Descriptions*.
Personal Info	***DIARYSUM***	**Input File - Personal Info**	22	Provides personal and other information (e.g., day type, gender, age, race, occupation) relating to each 24 hour activity record from the original activity database (e.g., CHAD).

Table 5-1. Input Files for APEX Model[a] (continued)

Input File	Keyword	APEX in MIMS Parameter Name	Unit #	Uses
Diary Events	***DIARYEVE***	**Input File - Diary Events**	23	Provides the 24 hour event descriptions (i.e., start time, duration, activity, and location) for all the diary days in the original activity database (e.g., CHAD). This file contains the same list of diary IDs as the *Personal Info* file, in the same order.
Microenvironment Descriptions	***MICROENV***	**Input File - Microenvironm ent Descriptions**	24	Contains the definitions of the microenvironments and the microenvironment factors used to determine the exposure concentrations in user-defined microenvironments.

[a] Other than *Params* and *Population Data* files.

and how it is used by APEX; see the tables below for which input and output files have been assigned which unit number.) If the user wants to redefine the set of microenvironments, the files of units 21 and 24 should also be changed. Similarly, the user may want to redefine the various distributions used in APEX (unit 20). The details of these input files are provided in the subsequent sections of this chapter.

Note that the keyword ***FILE*** must appear (with a blank space before it) right after each of the file keywords and before the "=". If any of these 14 files are not found at the specified locations, then APEX will prompt the user for the pathname of the missing file using the unit #.

In the Output File section of the *Params* file, the user needs to specify the names and path names of six and optionally seven output files. If the user turns off the dose calculation, hourly exposure, or dose outputs, the corresponding output files will not be created. Table 5-2 describes the output files. The details of these output files are further explained in Chapter 6.

5.2.2 Population Files Sections of *Params* File

In the Population Files section of the *Params* file, the user needs to specify the names and path names of either the 10 supplied *Population Data* files or any *Population Data* files the user creates. The number of population files could change, depending on how the user classifies the population.

Similar to the other input files, the keywords ***POP*** and ***FILE*** must appear at the beginning of the keyword part of the keyword input line in *Params*, followed by a comma and ***Gender*** and another comma and ***Race***. Gender must be either male or female and it can be shortened to M or F. Currently, to correspond to the supplied data, the races must be White, Black, Asian, NatAm, or Other, which may be shortened to W, B, A, N, or O. It is not necessary to specify all genders and race combinations for APEX to run. However, the model assumes that any missing gender/race combinations have zero population and it does not give any warning messages.

Table 5-2. Output Files for APEX Model

Output file	Keyword	APEX in MIMS Parameter Name	Unit #	Description
Log	***LOG***	**Output File - Log**	25	Contains the record of the APEX model simulation as it progresses. If the simulation completes successfully, the log file indicates the input files and parameter setting used for the simulation, reports the number of diaries available to match each individual simulation, provides the total runtime of the simulation, reports statistical summaries for the simulated individuals, and includes a series of summary tables, identical to those found in the Output Tables file. If the simulation ends prematurely, the log file contains error messages describing the critical errors that caused the simulation to end.
Hourly Exposure	***EXPOSURE***	**Output File - Hourly Exposure Estimates**	26	Provides an hour-by-hour time series of exposure estimates for each modeled profile.
Hourly Dose	***DOSE***	**Output File - Hourly COHb Dose Estimates**	27	Provides an hour-by-hour time series of dose estimates for each modeled profile.
Personal Summary Data	***PERSON***	**Output File - Person Summary**	28	Provides a summary of each profile modeled in the simulation.
Microenvironment Summary	***MICROSUM***	**Output File - Microenvironment Summary**	29	Provides a summary of the time and exposure by microenvironment for each profile modeled in the simulation.
Summary Tables	***TABLE***	**Output File - Tables**	30	Contains a series of tables summarizing the results of the simulation. The percentiles and cut-off points used in these tables are defined in the *Params* file.
Sites	***SITES***	**Output File - Site Mapping**	31	The Sites file lists the sectors, districts, and zones in the study area, and identifies the mapping between them.

Each *Population Data* file used in a model run must have exactly the same format and a record for each sector listed in the sector location file. Each record has the ***Sector ID***, followed by a ***Count*** for each population age group (youngest first). The number of age groups and their age ranges are provided in the *Employment by Age Group* file (Unit 14). The counts are the number of a given age group of people living in the sector.

Ten gender/race specific population data files for all 65,443 Year 2000 Census tracts have been prepared and provided with APEX. These population files should be adequate for most purposes. Figure 5-2 provides an example of a portion of a *Population Data* File. The first column, sector ID, is the census tract FIPS code. The 23 numbers that follow are the population counts for each of the 23 defined age groups starting with the youngest.

Figure 5-2. Example Portion of *Population Data* File ("Wrapped" View)

```
01001020100   44  75   79   52   18   13   7   32   60   61   90   87   68   70   56
   18   23   14   19   23   17   7   15
01001020200   77  86   61   42   25   17   9   47   76   68   60   86   71   73   51
   24   19   19   21   34   21  17   23
01001020300  130 125  141   75   41   12  21   53  117  134  155  139  106   91   80
   32   44   31   35   68   48  46   76
01001020400  129 172  166   87   60   24  21   52  121  144  196  191  145  150  146
   58  114   63   73  115   70  38   39
01001020500  239 281  241  138   57   20  23   84  195  205  394  282  206  188  141
   54   65   33   53   58   54  41   16
```

5.2.3 Job Parameter Settings Section of *Params* File

In the Job Parameter Settings section of the *Params* file, the user can specify a number of different job parameters for APEX runs. Table 5-3 provides a description of the keyword, data type, and uses of these job parameters. As with Input and Output Files, the keyword is the part of the *Params* input line that is necessary to allow APEX to identify the parameter. Data type is either integer (I), real (R), or character (C)). Each character variable has a specified length: input values longer than allowed will be truncated to this length, and values shorter than allowed are simply padded with blanks. In all cases except ***County***, if the same keyword appears more than once, the last occurrence overwrites the others.

Table 5-3. Job Parameters in APEX *Params* File

Variable	Keyword	APEX in MIMS Parameter Name	Type (Length)	Description
Pollutant	***POLL***	**Pollutant**	C(40)	Pollutant name (for output only; not used internally).
InUnits	***INPUTUNIT***	**Input Concentration Units**	C(40)	Pollutant concentration units used for the input data, in ppm or ug/m^3.
OutUnits	***OUPUTUNIT***	**Output Concentration Units**	C(40)	Pollutant concentration units used for the output data, in ppm or ug/m^3.
Location	***LOCATION***	**Location**	C(40)	Study area location (for output only; not used internally).
Scenario	***SCENARIO***	**Scenario**	C(40)	Scenario description (for output only; not used internally).
#Profiles	***PROFILE***	**Number of Profiles**	Integer	Number of profiles to simulate.
#Micros	***MICRO***	**Maximum Microenvironm ent Number**	Integer	Number of microenvironments defined in the *Micro Mapping* file (Unit 21) and on the *Micro Descriptions* file (Unit 24).
#Sources	***SOURCE***	**Number of Sources**	Integer	Largest number of sources in any microenvironment.
Start_Date	***START_***	**Start Date**	Integer	Simulation start date in YYYYMMDD format (e.g., 19960704 for July 4, 1996).

Table 5-3. Job Parameters in APEX *Params* File (continued)

Variable	Keyword	APEX in MIMS Parameter Name	Type (Length)	Description
End_Date	***END_***	**End Date**	Integer	Simulation end date in YYYYMMDD format.
Latitude	***LATIT***	**Latitude**	Real	Latitude in decimal degrees for the center of the study area. Note that latitude south of the equator is negative.
Longitude	***LONGIT***	**Longitude**	Real	Longitude in decimal degrees for the center of study area. Note that longitude west of the primary meridian is negative (e.g., in the United States).
CityRadius	***CITYRAD***	**Study Area Radius**	Real	Radius of study area in km. The sectors (e.g., census tracts) with representative locations within this radius will be automatically selected for modeling.
AirRadius	***AIRRAD***	**Air Quality District Radius**	Real	Maximum application radius (km) of air quality data collected at an air monitoring station or modeled at that location. Air quality data are applied to the sectors within this radius.
ZoneRadius	***ZONERAD***	**Meteorological Zone Radius**	Real	Maximum application radius (km) of daily temperature data collected at a weather station.
CountyList	***COUNTYL***	**Use County List?**	C(1)	Y = the study area is restricted to sectors in the listed counties (next variable) and within ***CityRadius***; N = the study area is restricted to sectors within the specified ***CityRadius*** only. The default value is N.
County	***COUNTY***	**County FIPS Code**	C(5)	FIPS code for listed county (or other relevant portion of the sector ID if the supplied sector files are not used). ***County*** is used only if countylist=Y. Repeat this line for each additional county code.
Commuting	***COMMUT***	**Include Commuting to Work?**	C(1)	Y = allow a simulated profile (or person) to commute to a work sector (or census tract), N = No commuting. If Y, a work sector (e.g., census tract) is randomly selected for each simulated profile based on the probabilities of work sectors a person may travel to from a home sector. If N, then workers are assumed to work in their home sector. The commute database provided with this model is only for Y2000 Census tracts and can only be used with Y2000 population data.
AgeMin	***AGEMIN***	**Minimum Age**	Integer	Minimum age for simulated profiles (persons).

Table 5-3. Job Parameters in APEX *Params* File (continued)

Variable	Keyword	APEX in MIMS Parameter Name	Type (Length)	Description
AgeMax	***AGEMAX***	**Maximum Age**	Integer	Maximum age for simulated profiles (persons).
DSTAdjust	***DST***	**Use Daylight Savings Time?**	C(1)	Y = use Daylight Saving Time (DST) in summer, N = don't use DST. In areas that use DST, one day per year (in April) is only 23 hours long and another (in October) is 25 hours long. However, most air quality data sets are reported in Standard Time throughout the year. If DSTAdjust is set to Y, the first and last days of summer time (using different rules before 1986) are determined, and the concentration from 2-3 a.m. on the short day is duplicated, while the concentration from 2-3 a.m. on the long day is deleted. Regardless of this setting, the output (hourly exposure and dose) for all simulated days will contain exactly 24 hours, and all input activity diaries must contain exactly 24 hours.
HourlyOut	***HOURLY***	**Write Hourly Output?**	C(1)	Y = write hourly exposure and dose files, N = don't write files. If this flag is set to NO, the output files of hourly exposures and doses will not be generated. Note that the hourly exposure or dose file could be as large as 200 megabytes for every 2,000 simulated profiles (or persons).
DoDose	***DODOSE***	**Do COHb Dose Calculations?**	C(1)	Y = perform dose calculations, N = don't perform calculations. If this flag is NO, the dose calculations will be turned off. This saves some job execution time if the user does not need dose calculation. Note that the physiology input file must still be provided, even though physiology is needed exclusively for the dose calculations.
RollBack	***ROLLBACK***	**Do Rollback Adjustments?**	C(1)	Y = use air quality rollback adjustments, N = don't use adjustments. Rollback adjusts the ambient air quality data before the exposure calculations occur. The purpose is to determine exposure in hypothetical scenarios where the ambient concentrations have been reduced by various controls.
RbTarget	***RBTARGET***	**Rollback target concentration**	Real	Rollback target concentration. Use same units as ***InUnits***.
RbBackgnd	***RBBACK***	**Rollback background concentration**	Real	Rollback background concentration. Use same units as ***InUnits***.

Table 5-3. Job Parameters in APEX *Params* File (continued)

Variable	Keyword	APEX in MIMS Parameter Name	Type (Length)	Description
RbMax	***RBMAX***	**Rollback maximum concentration**	Real	Rollback maximum concentration. Use same units as ***InUnits***.
PPMFactor	***PPM***	**PPM to ug/m3 Factor**	Real	Units conversion factor (1 ppm = ppmfact μg/m^3). For CO, ppmfact = 1,145 (i.e., 1 ppm = 1,145 ug/m^3). It is used when source strengths are expressed in micrograms per hour, but concentrations are in parts per million (ppm), and when ***InUnits*** and ***OutUnits*** are in different units.
MissGender	***MISSGEND***	**Missing Gender Diary Probability Factor**	Real	Diary probability factor for missing gender. Some of the supplied CHAD diaries are for persons of unknown gender. All profiles are assigned gender, however, and the CHAD diaries are selected from those of the same gender or from the unknowns. ***MissGender*** is used as a multiplicative factor to reduce the selection probability. If MissGender=0, then diaries with missing gender will never be selected. If MissGender=1, then such diaries are equally likely to be selected as diaries of the correct gender. MissGender can also be set to values between zero and one. Allowing a small but nonzero value for MissGender expands the pool size without permitting very much chance of selecting a diary with missing gender (which would cause APEX to stop prematurely).
MissEmployment	***MISSEMP***	**Missing Employment Diary Probability Factor**	Real	Diary probability factor for missing employment. Some of the supplied CHAD diaries are for persons of unknown employment status. Like ***MissGender***, this factor lowers the selection probability for such diaries. If ***MissEmpl*** = 0, then such diaries will never be selected.
MissAge	***MISSAGE***	**Missing Age Diary Probability Factor**	Real	Diary probability factor for missing age. Some of the supplied CHAD diaries are for persons of unknown age. This factor operates just like ***MissGender*** and ***MissEmpl*** to lower the selection probability for such diaries.

Table 5-3. Job Parameters in APEX *Params* File (continued)

Variable	Keyword	APEX in MIMS Parameter Name	Type (Length)	Description
AgeCutPCT	***AGECUT***	**Primary Age Window Width**	Real	Width of main age window (%). Each simulated profile (person) is assigned a specific year of age. A window is created around this target age, of size equal to ***AgeCutPCT*** percent of the target age. If the target age is 40 and ***AgeCutPCT*** = 25, then the age window is ten years wide (25% of 40) and diaries for persons from 30 to 50 years of age inclusive are permitted to be selected. The age window is always at least 1 year wide.
Age2Probability	***AGE2PROB***	**Shoulder Age Window Width**	Real	Diary probability factor for "shoulder" ages. This parameter allows an optional shoulder window of ages outside the primary age window. The shoulders have the same width in years as the main age window, so in the example under ***AgeCutPCT*** the shoulders are ages 20-29 and 51-60. The ***Age2Probab*** parameter operates like ***MissAge***, by suppressing the selection probability in the shoulders. If ***Age2Probab*** = 0 then shoulder ages are never selected.
Altitude	***ALTITUDE***	**Altitude**	Real	Altitude of study area in feet. The altitude in feet is assumed constant for the study area. It is used in the Coburn-Forster-Kane (CFK) equation for determining blood COHb concentration. Note, however, that the altitude correction that was used in pNEM and earlier versions of APEX was found to be in error and so this factor has been temporarily eliminated from the CFK equations. The use of altitude to adjust for air pressure as a function of altitude still exists.
COHbFactor	***COHBFACT***	**COHb Convergence Factor**	Real	Convergence parameter for COHb algorithm. This is a safety factor that limits the permitted error in determining the solution to the CFK equation. Larger factors mean greater accuracy but slower evaluation. Numerical tests indicate that factors in the range of 2 - 3 are optimal for most purposes.

Table 5-3. Job Parameters in APEX *Params* File (continued)

Variable	Keyword	APEX in MIMS Parameter Name	Type (Length)	Description
COThreshold	***COTHRESH***	**CO Notification Threshold**	Real	CO concentration threshold for user notification. If a simulated individual experiences a concentration above ***COThresh***, then a message is printed both to the screen and to the log file.
DebugLevel	***DEBUG***	**Debug Level**	Integer	A value of one results in more information being written to the log file than for a value of zero.
Randomseed	***RANDOM***	**Random Seed**	Integer	Seed>0 is user preset, Seed=0 gets seed from clock. If ***RandomSeed*** is changed between runs (using 0 for both runs or using two different non-zero numbers), two separate model runs of 100 profiles each time will be equivalent to one model run of 200 profiles. Otherwise, the same 100 profiles will be generated over again. Control of the random number seeds is an important part of using APEX for sensitivity analysis. For example, when performing multiple runs with slightly different inputs, it may be convenient to sample the same set of profiles, activity diaries, and microenvironmental concentrations, in order to prevent stochastic differences between the runs from obscuring the differences due to the changed input.

5.2.4 Output Table Levels Sections of *Params* File

In the Output Table Levels section of the *Params* file, the user could specify the value levels of each of 12 output parameters in the output summary tables. Each parameter is identified by a single keyword and the values are a list of numbers ordered from smallest to largest and separated by a comma. All the values are read as real numbers, although the decimal points are optional if the values happen to be integers. Items in each list must be separated by commas. Except for the ***Percentiles***, all of other parameters are used to bin exposures or doses into categories in order to create output tables. Note that there is always one more bin than there are number of values in the list, since the first bin is below the first value in the list and the last bin is above the last number. The specific meanings of the parameters are explained in Table 5-4.

Table 5-4. Output Parameter Levels in the Output Summary Table

Variable	Keyword	APEX in MIMS Parameter Name	Data Type	Description
Percentiles	***PERCENTILES***	**Table - Percentiles**	Real	This parameter specifies the levels of percentile of the exposed population for exposure or dose in APEX output files. Values can include up to one digit beyond the decimal point (e.g. the 99.5 or 99.9 percentile). Percentiles can only be distinguished from nearby ones if there are enough profiles in the model run. For example, at least 100 profiles are needed to properly determine a 99^{th} percentile, and unless at least 200 profiles are used, the 99.5 and 99.9 percentiles will both report the results for the highest individual profile.
Exposure Cutpoints	***TIMEEXP***	**Table - Exposure Cutpoints**	Real	This parameter specifies the exposure cutpoints (ppm) for summing time spent at various exposure levels. The time is expressed in minutes and is summed across all profiles. ***TimeExp*** is used in two tables. The first table is non-cumulative, meaning that only the time spent at a level between one cutpoint and the next is totaled. The other table is cumulative, meaning that all time spent at levels above the cutpoint is reported, even if it is also above higher cutpoints. For both tables, the second dimension is provided by the microenvironment number.
Daily Max 1-Hour Exposure Cutpoints	***DM1HEXP***	**Table - Daily Max 1-Hour Exposure Cutpoints**	Real	This parameter specifies the daily maximum 1-hour exposure cut-points (ppm) for binning all the person-days in the simulation period.
Daily Max 8-Hour Exposure Cutpoints	***DM8HEXP***	**Table - Daily Max 8-Hour Exposure Cutpoints**	Real	This parameter specifies daily maximum 8-hour average exposure cut-points in ppm for binning all the person days in the simulation period. It is similar to ***DM1HExp*** except for the longer averaging time. Typically, DM8HExp values are about 1/3 of DM1HExp values.
Daily Average Exposure Cutpoints	***DAVGEXP***	**Table - Daily Average Exposure Cutpoints**	Real	This parameter specifies daily average exposure cut-points (ppm) for binning all the person-days in the simulation period.
Simulation Average Exposure Cutpoints	***SAVGEXP***	**Table - Simulation Average Exposure Cutpoints**	Real	This parameter specifies cut-points (ppm) for average exposure over the simulation period. The cut points are used to bin all simulated persons created in a run.
Daily Max 1-Hour Dose Cutpoints	***DM1HDOSE***[a]	**Table - Daily Max 1-Hour COHb Dose Cutpoints**	Real	This parameter specifies cutpoints in %COHb for Daily Maximum 1-Hour Blood Dose. The cut points were used to bin all the person-days in the simulation period.

Table 5-4. Output Parameter Levels in the Output Summary Table (continued)

Variable	Keyword	APEX in MIMS Parameter Name	Data Type	Description
Daily Max 8-Hour Dose Cutpoints	***DM8HDOSE***[a]	**Table - Daily Max 8-Hour COHb Dose Cutpoints**	Real	This parameter specifies cutpoints in %COHb for Daily Maximum 8-Hour Blood Dose. The cut points were used to bin all the person-days in the simulation period.
Daily Max End-of-hour Dose Cutpoints	***DMEHDOSE***[a]	**Table - Daily Max End-of-Hour COHb Dose Cutpoints**	Real	This parameter specifies cutpoints in %COHb for Daily Maximum End-of-Hour Blood Dose. The cut-points are used to bin all the person/days in the simulation period. Note that DMEHDose uses the instantaneous level at the end of each hour, whereas DM1HDose uses the time-averaged level over each hour. These two statistics usually track each other fairly closely. DMEHDose is reported since it is the dose statistic calculated in the pneum. model.
Hourly End-of-hour Dose	***H_EHDOSE***[a]	**Table - Number of Hours End-of-Hour Dose Cutpoints**	Real	Similar to DMEHDose, except that instead of using just the highest single end-of-hour dose on each day, it collects results for all 24 end-of-hour doses on each day. As with the other keywords, the values specified here refer to the cutpoints in %COHb used for tabulating the dose results.
Daily Average Dose Cutpoints	***DAVGDOSE***[a]	**Table - Daily Average COHb Dose Cutpoints**	Real	This parameter specifies cutpoints in %COHb for the Daily Average Blood Dose. The cut-points are used to bin all the person/days in the simulation period.
Simulation Average Dose Cutpoints	***SAVEDOSE***[a]	**Table - Simulation Average COHb Dose Cutpoints**	Real	This parameter specifies cutpoints in %COHb for the Average Blood Dose over the entire simulation. The cut-points are used to bin all the persons (or profiles) created in the APEX run.
Dose Cutpoints	***TIMEDOSE***[a]	**Table - COHb Dose Cutpoints**	Real	This parameter specifies cut-points in %COHb for summing time spent at various blood dose levels. Apart from the statistic, the tables resemble the Time Exp tables.

[a] Note that these variables are used only for summarizing dose results. The current version of APEX can only calculate doses for CO. For other pollutants the dose calculation should be turned off.

5.3 *Sector Location* File (Unit 11)

The *Sector Location* file provides the latitude and longitude of a representative location such as the geographic center of all the sectors (e.g., census tracts) to be included in the *Population Data* files. The file includes only numeric lines. Each line includes a ***Sector ID*** (starting with a digit), ***Latitude***, and ***Longitude***. The sector IDs must match and be in the same order as the sector IDs in the *Population Data* files. In addition, the sector ID must match the sector IDs in the *Commute Flow* file as well (if worker commute is being modeled).

The sector location file is used along with the user-specified ***CityRadius*** to automatically select sectors (or census tracts) within the study area (after also addressing an optional county test and ensuring suitable air district and temperature zone data). APEX calculates the distance between the location of a sector and the center of the study area and then compares it with the ***CityRadius***. All the sectors with a distance less than the city radius will be selected and included in the exposure assessment.

The current default sector location file contains the 11-digit ID and latitudes and longitudes of 65,443 Year 2000 US Census tracts. An example of this file is provided in Figure 5-3. APEX expects that the left most five characters of a sector ID should be the state and county FIPS code or at least whatever county-level code is used in the ***County*** list (if the study area will be limited in that way).

The latitude and longitude should be in decimal degrees. At least three significant digits should be provided after the decimal point to prevent significant rounding error. Note that the longitude west of the primary meridian (e.g., United States locations) should be negative.

Figure 5-3. Example Portion of *Sector Location* File

```
01001020100  32.470986  -86.487033
01001020200  32.466056  -86.472934
01001020300  32.474035  -86.457764
01001020400  32.466794  -86.445569
01001020500  32.454933  -86.425025
```

5.4 *District Location* File (Unit 12)

The *District Location* file provides the ***Site ID***, ***Latitude***, ***Longitude***, air data ***Start Date***, and air data ***End Date*** for all air quality (modeling or monitoring) sites included in the *Air Quality Data* file (Section 5.9). The site ID is stored as a character string (up to length 40). Latitude and longitude are in decimal degrees. The start and end dates are in YYYYMMDD format (for example, 19951231 is December 31, 1995). This file contains only character or comment lines. The order of the listed sites must match the order of the sites in the *Air Quality Data* file. See Figure 5-4 for an example of the *District Location* file.

Figure 5-4. Example of *District Location* File

```
 Site1  29.76112    -95.27645    19960101   19961231
 Site2  29.81707    -95.27897    19960101   19961231
 Site3  29.83677    -95.25692    19960101   19961231
 Site4  29.82384    -95.19532    19960101   19961231
 Site5  29.80085    -95.25586    19960101   19961231
```

APEX uses the *District Location* file to determine the “district” or geographical area represented by the set of ambient air quality data collected at a specified location. APEX first compares the start and end dates for each air quality site with the start and end dates for the APEX exposure simulation. Only the sites with air quality data covering the entire simulation period are accepted. Air quality data before or after the simulation period are simply ignored.

> **Tip.** Not all districts on the air quality input file need sectors assigned to them. Such districts are simply not included in the modeling. This feature allows the user to prepare an input file in the simplest manner, perhaps containing more districts than are necessary. For example, a single input file could be prepared for all districts in a given state. This same input file could then be run on several study areas in the state without having to alter the air quality input file.

APEX also calculates the distance of a district location from the study area center and compares it with the sum of ***CityRadius*** and ***AirRadius***. This allows air quality data to be used from a nearby (and the nearest) district even if the district’s location is outside the study area. Only the sites with a distance less than this sum are used.

APEX then calculates the distances of a site from the locations of sectors (e.g., census tracts). Sectors with distances less than ***AirRadius*** will be mapped to an air site. Based on this mapping, APEX will use each set of air quality data in the *Air Quality* file only for the sectors within its AirRadius. APEX assigns the sector to the nearest district. Each sector is assigned to only one district.

5.5 *Temperature Zone Location* File (Unit 13)

The format and use of the *Temperature Zone Location* file is exactly like that of the *District Location* file. Each record represents one site, and contains five values: ***Site ID***, ***Latitude***, ***Longitude***, ***Start Date***, and ***End Date***. The site selection process is analogous to that described above for the *District Location* file. The file is used to map the set of temperature data collected at a weather station to sectors within its zone radius for exposure calculations. An example file is provided in Figure 5-5. Similar to air quality districts, zones within the sum of ***CityRadius*** and ***ZoneRadius*** are used.

Figure 5-5. Example of *Temperature Zone Location* File

```
TempSite1  39.742   -105.045     19950101        19951231
TempSite2  39.103   -105.521     19950101        19951231
```

5.6 *Employment by Age Group* File (Unit 14)

This file provides employment probabilities for all the age groups included in the *Population Data* files. The file contains only three records: ***Min_Age***, ***Max_Age***, and ***Employ_Prob***. The format for each record is a keyword input line with a keyword, an “=”, and a list of values. APEX only reads the first three letters of each input line as keywords (i.e., ***MIN***, ***MAX***, and ***EMP***), although the user can spell out the record names in full if desired. The Min_Age input line is used to list the minimum ages of each age group from the youngest to the oldest, while the Max_Age input line to list the maximum ages of the corresponding population age groups.

The Employ_Prob input line lists employment probabilities for each population group. The probabilities should be a real value between 0 and 1. See Figure 5-6 for an example of this file.

Figure 5-6. Example of *Employment by Age Group* File ("Wrapped" View)

```
Min_Age = 0   5   10  15  18  20  21  22  25  30  35  40  45  50  55  60  62  65  67
  70  75  80  85
Max_Age = 4   9   14  17  19  20  21  24  29  34  39  44  49  54  59  61  64  66  69
  74  79  84  99
Employ_prob = 0.0 0.0 0.1 0.5 0.6 0.8 0.9 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 1.0 0.8
  0.5 0.5 0.2 0.1 0.0 0.0
```

5.7 *Commuting Flow* File (Unit 15)

This file provides cumulative fractions of the population in a home sector commuting to different work sectors. An example of a portion of this file is provided in Figure 5-7. Each record contains a ***Sector ID*** and a ***Cumulative Fraction*** of the population commuting to this sector. The home sector is indicated by a negative value of -1 for cumulative fraction. The subsequent records provide the ***Work Tract IDs*** and the ***Cumulative Fractions***. The cumulative fraction for the last work sector should always be 1. APEX uses this file to determine which work sector a simulated individual may commute to by using the cumulative fractions as commuting probabilities.

If the sectors used in the simulation are Year 2000 Census tracts, the default commuting flow file provided with APEX should be used. This data base file contains all the 65,443 year 2000 Census tracts and their associated work tracts. The mean number of associated work tracts per home tract is 104, with a minimum of one and a maximum of 829. The flows in the data base file were calculated from the 1994 national commuting database and then mapped to the Year 2000 Census tracts.

5.8 *Temperature Data* File (Unit 16)

This file provides daily maximum and optionally average (or other) temperature data collected at the sites listed in the *Temperature Zone Location* file (Unit 13). Only keyword or numeric input lines are processed and other types of input lines are ignored in this file. The data set from each site begins with a header section with selected site information (see Figure 5-8). The subsequent numeric lines include ***Date***, ***Maximum Temperature*** (Fahrenheit), and other temperature data such as mean or minimum daily temperature (if present).

The date should be in YYYYMMDD format (e.g., 20010507 is May 7, 2001) and the temperature data should be in Fahrenheit. Each data set should cover the exposure simulation period. A data set can include more days than the exposure simulation period. APEX only uses the data within the simulation period. Thus, the user may prepare a file with a full year or many years of data for each site and then use the same temperature file for a series of different simulation periods.

Figure 5-7. Example Portion of *Commuting Flow* File

```
01001020100     -1
01001020100      0.050060
01001020200      0.057040
01001020300      0.097790
01001020500      0.336685
01001020700      0.513635
01001020800      0.544820
01011952200      0.550640
01051031100      0.562280
01073012903      0.570430
01085981000      0.576250
01101000100      0.620490
01101000200      0.694990
01101000300      0.713620
01101000600      0.757860
01101000700      0.770660
01101001000      0.783470
01101001400      0.788130
01101001800      0.810240
01101002000      0.814900
01101002201      0.820666
01101002202      0.821890
01101002400      0.821892
01101002800      0.828872
01101002900      0.852152
01101003000      0.873112
01101003200      0.881262
01101003301      0.887082
01101005301      0.894062
01101005401      0.932482
01101005402      0.947612
01101005403      0.954602
01101005902      0.961580
01101006000      1.000000
01001020200     -1
01001020100      0.065350
01001020200      0.085080
01001020300      0.177560
```

Figure 5-8. Example Portion of *Temperature Data* File

```
Name  = TempSite1
Denver Daily Maximum and Mean Temperatures
Degrees Fahrenheit
Start = 19950101
End   = 19951231
Lat   = 39.742
Lon   = -105.045
19950101   41      17
19950102   25      20
19950103   20      14
19950104   20      10
19950105   36      23
```

The data sets may be in any order. However, each site must begin with the “name” keyword input line. APEX matches a site name in the *Temperature Zone Location* file with the data set site name to locate its data in this file. If desired, the user could add more comment or character lines in the header section of a data set.

This file should contain data sets for the sites and time duration indicated on the *Temperature Zone Location* file (Unit 13). Any missing dates within the simulation period are written to the log file.

5.9 *Air Quality Data* File (Unit 17)

This file provides hourly air concentration data for air sites listed in the *District Location* file. Only keyword or numeric input lines are processed and other types of input lines are ignored in this file. The data set for each site begins with a header section containing selected site information (see Figure 5-9). Each of the subsequent numeric input lines includes 24 ***Hourly Average Air Concentrations*** and a ***Date***. The date should be in YYYYMMDD format (e.g., 20010507 is May 7, 2001). Air quality data should be in units of parts per million (ppm) or ug/m^3. Hourly data could be either comma or space delimited. In the example file, the number of cumulative hours for each day also is included (for quality control)—APEX ignores this column. Note that the length of each data line in air quality file should not exceed 256 characters.

Air data sets can be in any order. APEX locates the air data set by matching a site name in the *District Location* file with the site name in this file. Any missing dates within the simulation period will be written to the log file.

Figure 5-9. Example Portion of *Air Quality Data* File (“Wrapped” View)

```
Name = #48201212100
 Houston TX Modeling Receptor Location #  1
 Units = ppm
 Start Date = 19960101
 End Date   = 19961231
 Lat        =  29.76113
 Lon        = -95.27644
0.00,  0.65,  0.57,  0.45,  0.87,  1.24,  3.46,  3.89,  2.88,  0.00,  1.20,  1.59,  1.89,
  1.04,  1.21,  1.25,  1.08,  1.05,  1.01,  0.86,  0.71,  0.55,  0.58,  0.52    19960101     1
0.29,  0.23,  0.22,  0.17,  0.28,  0.38,  1.00,  1.57,  1.52,  1.14,  1.05,  1.03,  0.96,
  1.20,  1.03,  1.02,  1.53,  3.38,  4.20,  4.30,  2.79,  1.01,  0.52,  0.56    19960102    25
0.25,  0.31,  0.16,  0.29,  0.98,  2.21,  4.76,  6.33,  3.10,  1.45,  1.61,  1.31,  0.54,
  0.59,  1.01,  1.44,  1.08,  0.00,  2.62,  0.00,  3.58,  3.04,  2.64,  2.06    19960103    49
1.53,  1.19,  0.93,  0.00,  0.00,  1.74,  7.25,  6.17,  2.62,  0.59,  0.63,  0.78,  0.37,
  0.79,  0.71,  0.82,  1.00,  0.82,  1.79,  6.20,  3.10,  3.74,  0.00,  3.84    19960104    73
1.68,  0.00,  0.00,  0.00,  0.68,  1.54,  5.81,  5.56,  0.00,  4.00,  4.23,  2.29,  2.83,
  2.63,  3.13,  5.98,  2.35,  1.72,  1.56,  1.98,  1.59,  0.82,  0.52,  0.47    19960105    97
0.60,  0.59,  0.32,  0.23,  0.17,  0.21,  0.56,  0.67,  0.88,  1.07,  1.01,  1.53,  1.35,
  1.24,  0.97,  1.04,  0.97,  0.88,  1.10,  0.74,  0.60,  0.50,  0.75,  0.55    19960106   121
0.70,  0.27,  0.23,  0.23,  0.23,  0.24,  0.41,  0.59,  0.56,  0.69,  0.62,  0.66,  0.97,
  0.91,  1.07,  1.04,  1.05,  1.34,  3.24,  3.87,  5.36,  1.92,  3.00,  3.46    19960107   145
```

5.10 *Activity-specific MET* File (Unit 18)

This file provides distributional shapes and parameters for calculating the MET value for each CHAD (or other) activity code. A MET value is a dimensionless ratio of the activity-dependent energy expenditure rate to the basal or resting energy expenditure (metabolic) rate. The file is inherited from APEX2 unchanged. The user should not change this file unless the MET distribution data in the CHAD database are revised.

Each data line in this file provides the following information in list format:

- ***MET Distribution Number***;
- ***Activity Code*** from supplied CHAD data (see Table 5-5);
- ***Age Category***;
- ***Occupation***;
- ***Distribution Type***;
- ***Mean***;
- ***Median***;
- ***Standard Deviation***;
- ***Minimum***;
- ***Maximum***; and
- ***Description of Activity Type***.

A portion of this file is shown in Figure 5-10.

Figure 5-10. Example Portion of *Activity-Specific MET* File

```
1   10000    0  ADMIN    LogNormal   1.7    1.7    0.3    1.4  2.7    9  Work, general
2   10000    0  ADMSUP   LogNormal   1.7    1.7    0.3    1.4  2.7    9  Work, general
3   10000    0  FARM     LogNormal   7.5    7.0    3.0    3.6  17.0   9  Work, general
4   10000    0  HSHLD    LogNormal   3.6    3.5    0.8    2.5  6.0    9  Work, general
5   10000    0  LABOR    Triangle    8.5    8.4    2.1    3.6  13.8   9  Work, general
```

5.11 *Physiological Parameters* File (Unit 19)

This file provides four tables of age/gender specific data for the following physiological parameters (also see Figure 5-11):

- ***NVO$_2$Max***;
- ***Body Mass***;
- ***Resting Metabolic Rate*** (RMR); and
- ***Blood Volume Factor*** and ***Hemoglobin Content***.

This file requires the data to be in fixed column positions. Each table has three header lines and 202 numerical lines of data. The first table contains age/gender specific distribution data on normalized lung capacity (VO$_2$-max). APEX only reads the Mean NVO$_2$Max in columns 24-30 in F7.1 Fortran format and the NVO$_2$Max standard deviation in columns 31-37 (F7.1).

Table 5-5. CHAD Activity Codes

CHAD Activity Code	Description	CHAD Activity Code	Description
10000	Work and other income producing activities, general	13600	Obtain car services
10100	Work, General	13700	Other repairs
10110	Work, general, for organizational activities	13800	Other services
10111	Work for professional/union organizations	14000	Personal needs and care, general
10112	Work for special interest identity organizations	14100	Shower, bathe, personal hygiene
10113	Work for political party and civic participation	14110	Shower, bathe
10114	Work for volunteer/ helping organizations	14120	Personal hygiene
10115	Work of/for religious groups	14200	Medical care
10116	Work for fraternal organizations	14300	Help and care
10117	Work for child / youth / family organizations	14400	Eat
10118	Work for other organizations	14500	Sleep or nap
10120	Work, income-related only	14600	dress, groom
10130	Work, secondary (income-related)	14700	Other personal needs
10200	Unemployment	15000	General education and professional training
10300	Breaks	15100	Attend full-time school
11000	General household activities	15110	Attend day-care
11100	Prepare food	15120	Attend K-12
11110	Prepare and clean-up food	15130	Attend college or trade school
11200	Indoor chores	15140	Attend adult education and special training
11210	Clean-up food	15200	Attend other classes
11220	Clean house	15300	Do homework
11300	Outdoor chores	15400	Use library
11310	Clean outdoors	15500	Other education
11400	Care of clothes	16000	General entertainment / social activities
11410	Wash clothes	16100	Attend sports events
11500	Build a fire	16200	Participate in social, political, or religious activities
11600	Repair, general	16210	Practice religion
11610	Repair of boat	16300	Watch movie
11620	Paint home / room	16400	Attend theater
11630	Repair / maintain car	16500	Visit museums
11640	Home repairs	16600	Visit
11650	Other repairs	16700	Attend a party
11700	Care of plants	16800	Go to bar / lounge
11800	Care for pets/animals	16900	Other entertainment / social events
11900	Other household	17000	Leisure, general
12000	Child care, general	17100	Participate in sports and active leisure
12100	Care of baby	17110	Participate in sports
12200	Care of child	17111	Hunting, fishing, hiking
12300	Help / teach	17112	Golf
12400	Talk /read	17113	Bowling / pool / ping pong / pinball
12500	Play indoors	17114	Yoga
12600	Play outdoors	17120	Participate in outdoor leisure
12700	Medical care-child	17121	Play, unspecified
12800	Other child care	17122	Passive, sitting
13000	Obtain goods and services, general	17130	Exercise
13100	Dry clean	17131	Walk, bike, or jog (not in transit)
13200	Shop / run errands	17140	Create art, music, participate in hobbies
13210	Shop for food	17141	Participate in hobbies
13220	Shop for clothes or household goods	17142	Create domestic crafts
13230	Run errands	17143	Create art
13300	Obtain personal care service	17144	Perform music / drama / dance
13400	Obtain medical service	17150	Play games
13500	Obtain government / financial services	17160	Use of computers
		17170	Participate in recess and physical education
		17180	Other sports and active leisure

Table 5-5. CHAD Activity Codes (continued)

CHAD Activity Code	Description	CHAD Activity Code	Description
17200	Participate in passive leisure	17242	Write for leisure / pleasure / paperwork
17210	Watch	17250	Think and relax
17211	Watch adult at work	17260	Other passive leisure
17212	Watch someone provide childcare	17300	Other leisure
17213	Watch personal care	18000	Travel, general
17214	Watch education	18100	Travel during work
17215	Watch organizational activities	18200	Travel to/from work
17216	Watch recreation	18300	Travel for child care
17220	Listen to radio/listen to recorded music/watch T.V.	18400	Travel for goods and services
		18500	Travel for personal care
17221	Listen to radio	18600	Travel for education
17222	listen to recorded music	18700	Travel for organizational activity
17223	Watch TV	18800	Travel for event / social activity
17230	Read, general	18900	Travel for leisure
17231	Read books	18910	Travel for active leisure
17232	Read magazines / not ascertained	18920	Travel for passive leisure
17233	Read newspaper	U	Unknown
17240	Converse / write	X	Missing
17241	Converse		

The second table contains age/gender specific body mass (kg) distribution data. APEX only reads the mean body mass in columns 22-30 (F9.1) and the body mass standard deviation in columns 31-38 (F8.3).

The third table contains regression parameters for fitting the resting metabolic rate. APEX reads the slope in columns 30-38 (F9.3), the intercept in columns 39-47 (F9.3), and the residual error in columns 48-54 (F7.3).

The fourth table contains blood parameters. APEX reads the blood factor in columns 7-15 (F9.1), the hemoglobin mean in columns 16-24 (F9.1), and the hemoglobin standard deviation in columns 25-32 (F8.1).

5.12 *Profile Functions* File (Unit 20)

This file provides the user-definable functions required in generating profiles or simulated persons. The profile functions that can be defined in this file are summarized in Table 5-6. Note that all user-definable functions must be included in this file except those identified as not required in Table 5-6. Also, note that when preparing or editing a profile functions file, be careful not to use Tab to separate the items on a line. APEX is explicitly searching for blanks (spaces) as delimiters, and fails to recognize Tabs as such. An example of the user-defined function for ***WindowPos*** is provided in Figure 5-12. The box after this example provides a general description of the procedures for defining a function.

Figure 5-11. Portions of Four Data Tables in *Physiological Parameters* File
(Columns in this view are not in their required positions)

Males age 0-100, then females age 0-100 (last revised 6-11-98)
NVO2max distribution

Age	Source	Distr	Mean	SD	Lower	Upper	Assumptions
0	1	Normal	44.0	5.2	33.7	54.3	2-yr-old mean
1	1	Normal	44.0	5.2	33.7	54.3	2-yr-old mean
2	1	Normal	44.0	5.2	33.7	54.3	CV = 6.9/57.9
3	1	Normal	46.0	5.5	35.3	56.7	CV = 6.9/57.9
4	1	Normal	48.0	5.7	36.8	59.2	CV = 6.9/57.9
5	1	Normal	50.0	6.0	38.3	61.7	CV = 6.9/57.9
6	1	Normal	52.0	6.2	39.9	64.1	CV = 6.9/57.9
7	1	Normal	54.0	6.4	41.4	66.6	CV = 6.9/57.9
8	1	Normal	56.0	6.7	42.9	69.1	CV = 6.9/57.9

Males age 0-100, then females age 0-100 (last revised 6-11-98)
Body mass distribution, kg

Age	Source	Distr	GM	GSD	Lower	Upper	Assumptions
0	4	LN	9.3	1.141	7.2	12.0	
1	4	LN	11.7	1.126	9.3	14.8	
2	4	LN	13.5	1.127	10.7	17.1	
3	4	LN	15.6	1.121	12.5	19.5	
4	4	LN	17.6	1.142	13.6	22.8	
5	4	LN	19.9	1.148	15.2	26.1	
6	4	LN	22.9	1.156	17.2	30.4	
7	4	LN	24.8	1.163	18.4	33.3	
8	4	LN	27.9	1.198	19.6	39.8	

Males age 0-100 then females age 0-100 (last revised 6-11-98)
Regression equation Estimate for RMR

Age	Source	DV	IV	Slope	Interc	SE	Units	med. wgt
0	R47g	BMR	BM	0.244	-0.127	0.290	MJ/day	2.1
1	R47g	BMR	BM	0.244	-0.127	0.290	MJ/day	2.7
2	R47g	BMR	BM	0.244	-0.127	0.280	MJ/day	3.2
3	R47h	BMR	BM	0.095	2.110	0.280	MJ/day	3.6
4	R47h	BMR	BM	0.095	2.110	0.280	MJ/day	3.8
5	R47h	BMR	BM	0.095	2.110	0.280	MJ/day	4.0
6	R47h	BMR	BM	0.095	2.110	0.280	MJ/day	4.3
7	R47h	BMR	BM	0.095	2.110	0.280	MJ/day	4.5
8	R47h	BMR	BM	0.095	2.110	0.280	MJ/day	4.8

Males age 0-100 then females age 0-100
Blood Volume factor and Hemoglobin content

Age	BLDFAC	HGMN	HGSTD
0	17.0	16.0	1.0
1	17.0	16.0	1.0
2	17.0	16.0	1.0
3	17.0	16.0	1.0
4	17.0	16.0	1.0
5	17.0	16.0	1.0
6	17.0	16.0	1.0
7	17.0	16.0	1.0
8	17.0	16.0	1.0

Users may enter additional functions for use with the microenvironmental concentration calculations. These additional functions may be given any names that start with “M” (except for “MaxTempCat”, already used for another purpose). These functions are used if they are referenced on the *Micro Descriptions* input file (unit 24). The user also can define functions in this input file that are not actually referenced by the model. This could be useful if the user has two versions of some function and for convenience would like to store the definitions of both in the same file. One function would then be given the function name expected by APEX and the other would be given some related name. After the model is run, the functions could be interchanged simply by switching function names, and the job run again. This would permit a comparison of the effects of the two versions of the function.

Table 5-6. User-definable Functions in *Profile Functions* File

Function	Purpose
MaxTempCat	Binning daily 1-hour maximum temperatures into categories
AvgTempCat	Binning daily average temperatures into categories
Diary Pools	Assigning diary pools using day of week, MaxTempCat, and AvgTempCat
IDGRP	pneum. group number (for output labeling, not used internally in APEX)
HasGasStove	Probability of having a gas stove
HasPilot	Probability of having a pilot light, based on HasGasStove
AC_Home	Probability of having air conditioning at home
AC_Car	Probability of having air conditioning in car
WindowPos	Probability of windows being open or closed, based on AC_Home, MaxTempCat, and AvgTempCat
SpeedCat	Probability of average speed categories for vehicles
M1S1I2 (not required)	Cigarette emissions micro #1, block #2 in ug/hr
M1S1I1 (not required)	Cigarette emissions micro #1, block #1 in ug/hr
M2S1 (not required)	Cigarette emissions micro #2 in ppm

Figure 5-12. Example of *WindowPos* User-Defined Profile Function

```
WindowPos
! Home windows open(1) or closed (2)
TABLE
INPUT 1 INTVALUE 2        "AC_Home"
1 2
INPUT 2 INTRANGE 3        "MaxTemp"
56 80
INPUT 3 INTRANGE 1        "AvgTemp"
INPUT 4 CONDITIONAL 12
0.2 0.8
0.2 0.8
0.5 0.5
0.7 0.3
0.1 0.9
0.9 0.1
RESULT INTEGER 2
1 2
```

General procedures for defining a profile function:

1. A function definition begins with its name on the first input line.

2. Add as many comment lines as necessary to describe the profile function or units of the involved parameters.

3. A function type—Table or Continuous—is specified on the subsequent input line. At the present time, APEX can only recognize the function type of Table.

4. For the function type Table, the number of subsequent input lines varies with the number of input variable required to define a function. At least two input lines are needed for each input variable of the function. In addition, at least two lines are also needed for the function result. For each input variable (table dimension), the first line starts with the keyword ***INPUT***, followed by the indexing number of ***Input Variable*** in the function, the ***Type of Input Variable***, and the ***Number of Values*** allowed for the input variable. At the end of this input line, the user may add comments in double quotes to explain input variables. The type of input variables must be one of the following six types:

   - conditional,
   - probability,
   - realrange,
   - intrange,
   - intvalue, or
   - intindex.

   "Conditional" refers to conditional probabilities that depend on the values of other input variables. "Probability" means fixed probabilities for each outcome, not dependent on the input data. "Realrange" means a set of discrete categories, each consisting of a range of real numbers. "Intrange" is similar, except each category consists of a range of integers. "Intvalue" means that each possible value that the input variable may take on is listed. "Intindex" means that the input variable is integer and is to be used to index the table directly (*e.g.*, a value of 3 means use the third cell along that dimension). For each input variable, the remaining lines (beyond the first) contain the data.

5. After all the input variables are specified, the next line must contain the keyword ***RESULT***, followed by a type (either integer or real) and the number of possible results.

6. List the results in order in subsequent lines.

7. End the profile function with a new line that has a # sign.

5.13 *Micro Mapping* File (Unit 21)

This file provides the mapping of the ***Location Codes*** (e.g., for CHAD) to ***Microenvironments*** defined in APEX. An example of a portion of this file is provided in Figure 5-13. This file only allows comment lines and keyword input lines, except for the first two header lines. Each keyword input line begins with a location code followed by a short description, an "=", and an integer that designates a microenvironment defined in the *Micro Description* file. APEX only reads the location codes and the code for the APEX microenvironments.

The supplied file contains 115 CHAD location codes. The user must assign each location code to microenvironments defined in the *Micro Description* file by specifying the microenvironment number in the APEX Micro column. The user could place a zero in the APEX Micro column if no exposure occurs in a CHAD microenvironment location, or -1 if the CHAD locations are 'U' or 'X' (unknown). The value of -1 means that APEX should use whichever microenvironment was previously in use in the composite diary time series. See Table 2-2 for a description of the CHAD location codes supplied with APEX and mapped in the *Micro Description* file.

Figure 5-13. Example Portion of *Micro Mapping* File

CHAD	Loc. Description	APEX micro
X	No data	= -1
U	Uncertain of correct code	= -1
30000	Residence, general	= 1
30010	Your residence	= 1
30020	Other residence	= 1
30100	Residence, indoor	= 1
30120	Your residence, indoor	= 1
30121	..., kitchen	= 1
30122	..., living room or family room	= 1
30123	..., dining room	= 1
30124	..., bathroom	= 1
30125	..., bedroom	= 1
30126	..., study or office	= 1
30127	..., basement	= 1
30128	..., utility or laundry room	= 1
30129	..., other indoor	= 1
30130	Other residence, indoor	= 1
30131	..., kitchen	= 1
30132	..., living room or family room	= 1
30133	..., dining room	= 1
30134	..., bathroom	= 1
30135	..., bedroom	= 1
30136	..., study or office	= 1
30137	..., basement	= 1
30138	..., utility or laundry room	= 1
30139	..., other indoor	= 1
30200	Residence, outdoor	= 4
30210	Your residence, outdoor	= 4
30211	..., pool or spa	= 4
30219	..., other outdoor	= 4
30220	Other residence, outdoor	= 4
30221	..., pool or spa	= 4
30229	..., other outdoor	= 4
30300	Residential garage or carport	= 4
30310	..., indoor	= 4
30320	..., outdoor	= 4
30330	Your garage or carport	= 4
30331	..., indoor	= 4
30332	..., outdoor	= 4
30340	Other residential garage or carport	= 4
30341	..., indoor	= 4
30342	..., outdoor	= 4
30400	Residence, none of the above	= 1

5.14 *Personal Info* File (Unit 22)

This file provides the personal information component of each 24-hour activity diary (Figure 5-14). Each record contains values for the following variables:

- ***CHAD ID***;
- ***Day Type*** (MON, TUE, etc., Missing (X));
- ***Gender*** (Male (M), Female (F), Missing (X));
- ***Race*** (White (W), Black (B), Asian (A), Hispanic (H), Other (O), Information not available (X));
- ***Employment Status*** (Yes (Y), No (N), Missing (X));
- ***Maximum Temperature*** (degrees C);

- ***Age*** (Years);
- ***Occupation*** (see Table 5-7);
- ***Count of Missing Time*** (the total number of minutes associated with events in the Diary Events file for which the activity and/or location codes are missing); and
- ***Record Count***.

This file is identical to the Diary Questionnaire file produced by the Access® version of the CHAD database (see next section). The user should not change this input file unless the CHAD database has changed or other activity data are to be used instead. If the latter, the input file format restrictions must be met and the CHAD coding conventions used. Note that this file has only one record per CHAD ID, whereas the CHAD Diary Events file has ***Record Count*** of records per CHAD ID.

Figure 5-14. Example Portion of *Personal Info* File

```
BAL97001A,TUE,F,W,N,      77,   43,X   ,  45,      29
BAL97001B,WED,F,W,N,      77,   51,X   , 135,      28
BAL97001C,THU,F,W,N,      77,   57,X   ,  15,      30
BAL97001D,FRI,F,W,N,      77,   45,X   ,   0,      28
BAL97001E,TUE,F,W,N,      77,   47,X   ,   0,      27
BAL97001F,WED,F,W,N,      77,   36,X   ,   0,      28
BAL97001G,THU,F,W,N,      77,   38,X   ,   0,      26
BAL97001H,FRI,F,W,N,      77,   43,X   ,   0,      28
BAL97001I,TUE,F,W,N,      77,   41,X   ,  15,      28
BAL97001J,WED,F,W,N,      77,   54,X   ,  15,      28
BAL97001K,THU,F,W,N,      77,   48,X   ,   0,      30
BAL97001L,FRI,F,W,N,      77,   42,X   ,  30,      30
BAL97006A,WED,M,W,N,      80,   51,X   ,   0,      31
BAL97006B,THU,M,W,N,      80,   57,X   ,  60,      36
BAL97006C,FRI,M,W,N,      80,   45,X   ,  75,      31
BAL97006D,TUE,M,W,N,      80,   47,X   ,  15,      33
BAL97006E,WED,M,W,N,      80,   36,X   ,  30,      31
BAL97006F,THU,M,W,N,      80,   38,X   , 210,      34
BAL97006G,FRI,M,W,N,      80,   43,X   , 165,      30
BAL97006H,TUE,M,W,N,      80,   41,X   ,  45,      31
BAL97006I,WED,M,W,N,      80,   54,X   ,  60,      34
BAL97006J,THU,M,W,N,      80,   48,X   ,  15,      31
BAL97008A,TUE,F,W,N,      88,   43,X   ,   0,      31
BAL97008B,WED,F,W,N,      88,   51,X   ,  60,      27
BAL97008C,THU,F,W,N,      88,   57,X   , 345,      33
BAL97008D,FRI,F,W,N,      88,   45,X   ,  90,      28
BAL97008E,TUE,F,W,N,      88,   47,X   ,  30,      29
BAL97008F,WED,F,W,N,      88,   36,X   ,  90,      26
```

Table 5-7. CHAD Occupation Codes

Code	Description
ADMIN	Executive, administrative, and managerial
PROF	Professional
TECH	Technicians
SALE	Sales
ADMSUP	Administrative support
HSHLD	Private household
PROTECT	Protective services
SERV	Service
FARM	Farming, forestry, and fishing
PREC	Precision production, craft, and repair
MACH	Machine operators, assemblers, and inspectors
TRANS	Transportation and material moving
LABOR	Handling, equipment cleaners, helpers, and laborers
X	Missing

5.15 *Diary Events* File (Unit 23)

This file provides descriptions of events occurring hourly or in shorter duration in each day for all the diary days in the CHAD database. Each record includes the following variables:

- ***CHAD ID***;
- ***Event Start Time*** (the time the event began; HHMM, with 0000 representing midnight);
- ***Event Duration*** (the duration of the event, in minutes);
- ***Activity Code*** (see Table 5-5); and
- ***Location Code*** (see Table 2-2).

This file should be generated from the CHAD database at the same time as the *Personal Info* (questionnaire) file to ensure that the CHAD IDs are in the same order. Each diary day begins and ends at midnight and there should be exactly twenty-four hours of data per diary. See Figure 5-15 for an example of a portion of this file. And see the previous section on the *Personal Info* file if user-supplied date are to be provided.

Figure 5-15. Example Portion of *Diary Events* File

```
BAL97001A,0000,60,14500,30125,
BAL97001A,0100,60,14500,30125,
BAL97001A,0200,60,14500,30125,
BAL97001A,0300,60,14500,30125,
BAL97001A,0400,60,14500,30125,
BAL97001A,0500,60,14500,30125,
BAL97001A,0600,60,14500,30125,
BAL97001A,0700,30,14500,30125,
BAL97001A,0730,30,14400,30121,
BAL97001A,0800,60,16000,30122,
BAL97001A,0900,60,14500,30125,
BAL97001A,1000,30,14500,30125,
BAL97001A,1030,30,X    ,X    ,
BAL97001A,1100,45,14500,30125,
BAL97001A,1145,15,X    ,X    ,
BAL97001A,1200,60,14500,30125,
BAL97001A,1300,60,14500,30125,
BAL97001A,1400,60,14500,30125,
BAL97001A,1500,60,16000,30122,
BAL97001A,1600,60,14600,30125,
BAL97001A,1700,15,14600,30125,
BAL97001A,1715,45,14400,30123,
BAL97001A,1800,45,14400,30123,
```

5.16 *Micro Descriptions* File (Unit 24)

The *Micro Descriptions* file provides microenvironment definitions and parameters required to calculate pollutant concentrations in microenvironments. As described below, the *Micro Descriptions* file has two sections: Micro Descriptions and Parameter Descriptions. A portion of an example file is provided in Figure 5-16.

5.16.1 Micro Descriptions Section

In the Micro Descriptions section of the *Micro Descriptions* file, the user specifies a ***Microenvironment Number***, a ***Name***, and a ***Calculation Method*** for each microenvironment, as shown in Figure 5-16. The microenvironment number cannot exceed the number of microenvironments specified in the *Params* file and nor can it exceed 127. It also has to correspond with each of the microenvironment numbers in the *Micro Mapping* file. A microenvironment name may be a word up to 12 characters. The calculation method could be either MASSBAL or FACTORS. In the MASSBAL method, the concentration in a microenvironment is calculated using a mass balance approach, while in the FACTORS method the microenvironment concentration is assumed to be a linear function of ambient concentration.

Figure 5-16. Example Portion of *Micro Description* File

```
! First section - micro descriptions

Micro       Name           Method
1           Residence      MASSBAL
2           Car            MASSBAL
3           InsideOther    FACTORS
4           Outside        FACTORS

! Second section - parameter descriptions

Micro number      = 1
Parameter Type    = PRX
Hours   - Block   = 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1
Weekday - Daytype = 1 1 1 1 1 1 1
Month   - Season  = 1 1 2 2 2 3 3 3 4 4 4 1
District- Area    = 1 1 1 1 1 1
Condition # 1     = 0
Condition # 2     = 0
Condition # 3     = 0
ResampHours       = NO
ResampDays        = YES
ResampWork        = YES
RandomSeed        = 0
Block DType Season Area    C1  C2  C3 Shape      Min    Max    Par1   Par2
1      1      1     1       1   1  1   Normal      0.     2.     1.2   0.4
2      1      1     1       1   1  1   Point       2.      .            .
1      1      2     1       1   1  1   Lognormal   0.     2.     1.2   1.5
2      1      2     1       1   1  1   Exponential 1.      .     2.     .
1      1      3     1       1   1  1   Triangle    0.     3.     2.     .
2      1      3     1       1   1  1   Normal      1.     2.5    1.5   0.5
1      1      4     1       1   1  1   Uniform     0.     1.6     .     .
2      1      4     1       1   1  1   Lognormal   1.      .     3.    1.4

Micro number      = 1
Parameter Type    = AER
Hours   - Block   = 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1
Weekday - Daytype = 1 1 1 1 1 1 1
Month   - Season  = 1 1 1 1 1 1 1 1 1 1 1 1
District- Area    = 1 1 1 1 1 1
Condition # 1     = AC_HOME
Condition # 2     = 0
Condition # 3     = 0
ResampHours       = NO
ResampDays        = NO
ResampWork        = YES
RandomSeed        = 0
Block DType Season Area C1  C2  C3        Shape       Min    Max    Par1   Par2
1      1      1     1   1   1   1         Uniform      0.5    4.     .      .
2      1      1     1   1   1   1         Normal       0.      .    2.5    1.0
1      1      1     1   2   1   1         Point        3.      .     .      .
2      1      1     1   2   1   1         Triangle     1.     5.    2.      .
```

5.16.2 Parameter Description Section

In the Parameter Description section of the *Micro Descriptions* file, the user defines a number of parameters for each microenvironment, depending in the calculation method: three parameters for the FACTORS method and eight parameters for the MASSBAL method. These parameters are required for calculating concentrations in microenvironments. If a default or supplied value (in Table 5-8) is acceptable, the user does not have to define the parameters further. A Parameter Description section is needed for each parameter and consists of keywords and data. The following two sections provide additional details on the parameter keywords and data.

Table 5-8. Micro Parameters Required to Define a Microenvironment

Calculation Method	Parameter Type	Code	Units	Default/Supplied Value
FACTORS	Proximity	PR	None	1
	Penetration	PE	None	1
	Csource	CS	ppm or µg/m^3 (depends on InputUnits)	0
MASSBAL	Proximity	PR	None	1
	Penetration	PE	None	1
	Csource	CS	ppm or µg/m^3 (depends on InputUnits)	0
	DecayRate	DE	1/hr	0
	AIrExRate	AE	Air changes/hr	none
	Volume	VO	m^3	none
	MeanR	MR	1/hr	AirExRate+DecayRate
	ESource	ES	µg/m^3	0

5.16.2.1 Keywords

The user needs to specify values for the 13 parameters on keyword input lines, as shown in Figure 5-16. A brief description of each parameter is provided in Table 5-9. The keyword list needs to end with a character line that is the header line for the data section and begins with the word ***Block***, which APEX recognizes as an indicator for ending of the keyword section. The Esource and Csource terms, unlike the others, may have multiple definitions within the same microenvironment. These terms are then added or multiplied together, depending on the source numbering. If source terms are multiplied, then only the final product must have the proper units. This feature allows the source terms to be expressed in any suitable units, with the units conversion expressed as a multiplicative factor.

Table 5-9. Keyword Definitions for the Parameter Descriptions Section of the *Micro Descriptions* File

Keyword	Description
Micro Number	These numbers must match the micro numbers in the Microenvironment Description section.
Parameter Type	A parameter code such as PR (Proximity) and PE (Penetration) provided in Table 5-8 should be used to specify a parameter type.
Hours - Block	This variable is used to map hours of a day to different time blocks. The input line always contains a list of 24 integers, representing 24 hours a day. The first hour is midnight to 1.a.m. and the 24th is 11 p.m. to midnight. The position of an integer in the input line represents the hour in a day. The integer represents the number of a time block that a hour belongs to. The hours in a time block do not need to be consecutive, nor does a time block have to have the same number of hours. If this line is missing, the default value is that all 24 hours are in a single time block - block #1.
Weekday - Daytype	This variable is used to map days in a week to different day types. Seven integers must be given in this input line. The position of an integer in the input line represents a day, beginning on Sunday and ending on Saturday. The integer represents the day type a day belongs to. If this variable is not defined, all days of a week will belong to daytype #1.
Month - Season	This variable is used to map months of a year to different seasons. Twelve integers must be given in this input line. The position of an integer represents a month of a year, beginning in January and ending in December. The integer represents the season that a month belongs to. If this line is missing, all 12 months belong to season #1.
District - Area	This variable is used to map air quality districts to larger areas. The number of integers in this line must match the number of air quality districts in the study area. This variable is a holdover from APEX2 and should not be used unless really necessary. The user could delete this line or place the same number of 1 in this line as the number of air districts.
Condition # 1	Choice for the first conditional variable. If not used, this line may either be omitted or the value set to zero. APEX accepts the following variables as conditional variable : Gender, Race, Employed, GasStove, GasPilot, AC_Home, AC_Car, WindowPos, , MaxTempCat, AvgTempCat, SpeedCat.
Condition # 2	Choice for the second conditional variable.
Condition # 3	Choice for the third conditional variable.
ResampHours	Either YES or NO. If YES, a random value is selected from distribution for a parameter in each hour within a time block. If NO, a random value is selected for a parameter for a time block and used for every hour within the time block. The default value is NO.
ResampDays	Either YES or NO. If YES, a random value is selected from a distribution for a parameter for each day within a day type. If NO, a random value is selected for a day type and used for every day within the same day type. The default is NO.
ResampWork	Either YES or NO. If YES, a separate set of random values is selected from a distribution for the workplace. If NO, the same set of random values are used (for the same day and hour) both for home and at work. The default is YES.
RandomSeed	Either zero or a positive integer up to about 2.1 billion. If zero, the random number seed for a parameter is determined from the internal clock, and the results will differ from one run to another. If not zero, then Seed = (RandomSeed x 2^{32}) + RandomSeed. Multiple model runs with the same seed will generate the same sequence of random numbers for the parameters (as long as the MP definition is unchanged). The default value is zero.

5.16.2.2 Data

The data are sets of distribution data for all possible combinations of the user-specified cases of the following seven indexing parameters:

- ***Block*** — time block
- ***Daytype*** — day time
- ***Season*** — season
- ***Area*** — area
- ***C1*** — conditional variable # 1
- ***C2*** — conditional variable # 2
- ***C3*** — conditional variable # 3

Note that the cases of each indexing parameter must be represented by integers ranging from 1 to the maximum number of cases for an indexing parameter. The number of cases for a indexing parameter is specified in the keyword section.

In the example file in Figure 5-16, there are two time blocks and four types of seasons for the PRX parameter of microenvironment 1. Thus, the user needs eight data lines in the data section to specify eight sets of distribution data. In the second parameter description section, there are two time blocks and C1 specified as AC-Home. Since AC-Home has two options—off (1) or on (2)—the user needs four data lines to specify distribution data in the data section. The meaning of integers for conditional variables can could be found in the *Profile Function* file (Unit 20).

The user needs to specify the following parameters for a set of distribution data:

- ***Shape*** — distribution type
- ***Min*** — minimum;
- ***Max*** — maximum;
- ***Par1***; and
- ***Par2***.

Shape represents the distribution type. APEX allows the user to specify one of the six standard distribution types—point, uniform, normal, lognormal, triangle, and exponential—plus user-defined functions. APEX only examines the first letter of a distribution type. The user could specify a shape value by using P, U, N, L, T, and E or spelling out the name of a distribution type. The letter M is for the user-defined functions.

A real value must be specified for a required parameter. The parameters that are not used for specifying a distribution should be marked with a period (see Figure 5-16).

The optional <u>Min</u> and <u>Max</u> parameters are used only when the user wants to set the limits to selected random values from a distribution. If the optional parameters are not used, they should be marked with a period as well. Note that the Par1 and Par2 represent different parameters for different distribution types.

Table 5-10 lists the required and optional parameters for specifying each type of distribution.

Table 5-10. Uses of Distribution Parameters for Each Standard Distribution Type

Shape	Min	Max	Par1	Par2
Point	Required	Not used	Not used	Not used
Uniform	Required	Required	Not used	Not used
Normal	Optional	Optional	Mean – Required	Required (Standard Deviation)
Lognormal	Optional	Optional	Geometric Mean – Required	Geometric Standard Deviation – Required
Triangle	Required	Required	Mode – Required	Not used
Exponential	Required	Optional	Mean – Required	No used

6. OUTPUT FILES

APEX produces the following six output files:

1. *Log* file;
2. *Hourly Exposure* file;
3. *Hourly Dose* file;
4. *Profile Summary* file;
5. *Microenvironment Summary* file;
6. *Output Table* file; and
7. *Sites* file.

Most of these output files can be opened and reviewed using a text editor. The larger files, *Hourly Exposure* and *Hourly Dose*, may need a spreadsheet or other program. Details of each of these output files are provided in the following sections. Additional discussion and a description of how these files were set up in the *Params* file can be found in Sections 5.2.1 and 5.2.4.

6.1 *Log* File (Unit 25)

The *Log* file records the following information as a model run progresses:

- Input files used;
- Model parameters used;
- Number of diaries available to match each simulated person (or profile);
- Model execution time (sec.);
- Sectors in the study area;
- Air districts in the study area;
- Temperature zones in the study area:
- Mappings of sectors to air districts and temperature zones;
- Statistical summaries of each simulated person (or profile); and
- Output summary tables.

If a model run stops abnormally, a error message will be written to the log file. The user should review the Log file after a run to ensure that a model run is executed and terminated normally and the output results are valid. Note that output summary tables in this file are exactly the same as the tables in the *Output Table* file.

6.2 *Hourly Exposure* File (Unit 26)

The *Hourly Exposure* file contains hourly time series of exposure concentrations for each simulated person or profile. Each record provides 24 hourly exposure values for a simulation day in the following format:

- Profile number—Sequential index number for simulated individual
- Day number—Sequential index number for the day of the simulation
- Year—Part of the date for the simulated day
- Month—Part of the date for the simulated day
- Day—Part of the date for the simulated day

- Hour 1—Mean exposure concentration from midnight to 1 a.m. for the profile on that day
- Hour 2, etc.—Mean exposure concentration from 1 a.m. to 2 a.m., etc.
- Hour 24—Mean exposure concentration from 11 p.m. to midnight

The units of exposure concentrations are the same as those of the air quality data. Note that the hourly exposure file could be very large if a large number of profiles are simulated. The user could block generation of the hourly exposure file by setting the ***HourlyOut*** parameter to NO in the parameter file.

6.3 *Hourly Dose* File (Unit 27)

The *Hourly Dose* file contains hourly time series of doses for each simulated person or profile. In APEX, dose is defined as the percent of carboxyhemoglobin (%COHB) in the blood. Thus, as currently formulated, APEX calculates dose only for carbon monoxide.

Each record in *Hourly Dose* provides 24 hourly dose values for a simulation day in the same format as the *Hourly Exposure* file, except the hourly values are in dose rather than concentration.

The hourly dose file could be very large if a large number of profiles are simulated. The user could block generation of the hourly dose file by setting the ***HourlyOut*** parameter to NO in the parameter file.

6.4 *Profile Summary* File (Unit 28)

This file provides a summary of profile characteristics and exposure/dose for each simulated person. Each record contains values for the following variables for each simulated individual:

- Profile number—Sequential index number for simulated individual
- HSect—Sector in which the person lives (home)
- WSect—Sector in which the person works (=HSect for non-workers)
- HDis—Air quality district for HSect
- WDis—Air quality district for WSect
- Zone—Temperature zone for HSect
- DGRP—Demographic group # (1-11) as defined in pNEM/CO
- Age—Age (years)
- Gender—Male or female
- Race—Such as White, Black, Asian, Native American (NatAm), Other (depending on pop. files)
- Employed—Indicates employment outside the home
- Stove—Indicates the presence of a gas stove in the home
- Pilot—Indicates the presence of a gas pilot light
- ACHom—Indicates the presence of air conditioning in the home
- ACCar—Indicates the presence of air conditioning in the car
- Height—Person height (inches)
- Weight—Body mass (pounds)
- Hemoglob—The amount of hemoglobin in the blood (g/ml)
- DiffDay—A lung diffusivity parameter used in the COHB calculation (ml/min/torr)
- BloodVol—The volume of blood in the body (ml)
- HemFac—The change in the hemoglobin level with altitude (1/ft)

- Endgn1—Endogenous CO production rate (ml/min)
- Endgn2—Endogenous CO production rate (ml/min) used only for women between ages of 12 and 50 for half the menstrual cycle
- #Events—Number of diary events covering the simulation period
- AvgExp—Mean exposure concentration over the simulation (ppm or µg/m^3, as specified in *Params* file)
- AvgDose—Mean dose over the simulation (blood %COHB level)
- MaxExp—Maximum 1-hour exposure concentration over the simulation (ppm or µg/m^3, as specified in *Params* file)
- MaxDose—Maximum 1-hour average dose over the simulation (blood %COHB level)

The file can be opened using a text editor or imported into a spreadsheet or other file type.

6.5 *Microenvironment Summary* File (Unit 29)

This file provides the amount of time spent, mean exposure concentration, and maximum exposure concentration in each microenvironment during the period of simulation, for each simulated person. Each record in the file contains the following variables:

- Profile number—Sequential index number for simulated individual
- Microenvironment—Sequential index number for each microenvironment
- Minutes—Total time spent in the microenvironment by the profile
- MeanConc—Average (mean) concentration during the time spent in the microenvironment (ppm or µg/m^3, as specified in *Params* file)
- MaxConc—Maximum concentration during the time spent in the microenvironment (ppm or µg/m^3, as specified in *Params* file)

6.6 *Output Tables* File (Unit 30)

This file provides 14 summary tables. The first six are exposure summary tables:

1. Non-cumulative person-minutes at each exposure range by microenvironment
2. Cumulative person-minutes at each exposure level by microenvironment
3. Cumulative person-days of daily max 1-hour exposure levels
4. Cumulative person-days of daily max 8-hour exposure levels
5. Cumulative person-days of daily average exposure levels
6. Cumulative # persons at each overall (simulation) average exposure level

The remaining eight are dose summary tables:

1. Cumulative person-days of daily max end-of-hour dose levels
2. Cumulative person-days of daily max 1-hour average dose levels
3. Cumulative person-days of daily max 8-hour average dose levels
4. Cumulative person-days of daily average dose levels
5. Cumulative # persons at each overall (simulation) average dose level
6. Cumulative person-hours at each end-of-hour dose level
7. Non-cumulative person-minutes at each dose level
8. Cumulative person-minutes at each dose level

There are two types of tables in this file: cumulative and non-cumulative time tables. The cumulative time tables summarize the minutes or days spent by simulated individuals when the exposure concentration in a microenvironment is equal to or greater than various threshold levels. The non-cumulative time tables summarize the minutes or days spent by simulated individuals when exposure is within various ranges.

In the follow sections, each of the 14 summary tables is discussed in more detail.

Table #1—Non-cumulative minutes at each exposure range by microenvironment

This table lists the total minutes spent by all simulated persons in each microenvironment when exposure concentration is within various ranges. The bounds of a range are specified at the top of each column and the top of the next column to the right (Figure 6-1) . For each microenvironment, the table provides three rows of data for the following three variables:

- Minutes—The number of person-minutes summed over all the simulated persons that are spent in the specified microenvironment and that fall within the exposure concentration range bounded by the values indicated at the top of the column and the top of the next column to the right;

- Row_%—The percent of the minutes spent in the specified microenvironment that fall within the exposure concentration range; and

- Tot_%—the percent of the total minutes that are spent in the microenvironment and that fall within the exposure concentration range.

Figure 6-1. Example Portion of Table #1 in Output Table File (“Truncated” View)[a]

```
Non-cumulative minutes at each exposure level by microenvironment, for
N = 2000 Profiles

      Level:        0.0000      2.0000      4.0000      6.0000    8.0000
 Micro  ----------------------------------------------------------------------
   0   Minutes           0.          0.          0.          0.        0.
   0     Row_%          NaN         NaN         NaN         NaN       NaN
   0     Tot_%       0.0000      0.0000      0.0000      0.0000    0.0000
   1   Minutes    37602112.   35900088.   32791732.   26165204. 18736580.
   1     Row_%      21.2988     20.3347     18.5741     14.8206   10.6129
   1     Tot_%       1.2713      1.2138      1.1087      0.8846    0.6335
   2   Minutes     3911714.    2669300.    1258124.     678414.   431163.
   2     Row_%      40.9246     27.9264     13.1626      7.0976    4.5109
   2     Tot_%       0.1323      0.0902      0.0425      0.0229    0.0146
   3   Minutes      951714.     823961.     593331.     397681.   262075.
   3     Row_%      28.5896     24.7519     17.8237     11.9464    7.8728
   3     Tot_%       0.0322      0.0279      0.0201      0.0134    0.0089
```

[a]Because this table is truncated (i.e., it actually extends to the right), not all columns are visible and Row_% does not add to 100%.

Table #2—Cumulative minutes at each exposure level by microenvironment

This table is similar to Table #1, except that it reports the cumulative person-minutes that are spent in a microenvironment with an exposure concentration that equals or exceeds the value indicated at the top of the column.

Tables #3—Cumulative Person-days of Daily Max 1-Hour Exposure levels

This table provides a statistical summary of the cumulative person-days, for both simulated persons and the population in the study area, with a daily maximum 1-hour (hourly) average exposure concentration that equals or exceeds the value indicated at the top of the column (Figure 6-2). The definitions of variables in Table #3 are provided in Table 6-1.

Figure 6-2. Example of Table #3 in Output Table File

```
 Cumulative Person-days of Daily Max 1-Hour Exposure levels for N =    2000 Profiles,
with Area Population =    44732

   Level:             0.000         5.000       10.000       20.000    30.000    40.000
 ----------------------------------------------------------------------------------------
 Counts(Pop):     0.164E+08     0.158E+08    0.803E+07    0.845E+06 0.311E+06 0.155E+06
 #Meet(Pop) :         44732         44732        44732        44732     44732     42741
 %Meet(Pop) :       100.000       100.000      100.000      100.000   100.000    95.550
 Mean       :       366.000       353.592      179.612       18.880     6.945     3.462
 Std.Dev.   :         0.000        28.169      116.865        9.762     4.155     2.572
 CV         :         0.000         0.080        0.651        0.517     0.598     0.743
 Minimum    :       366.000       197.000       27.000        2.000     1.000     0.000
 10.0 %ile  :       366.000       321.000       62.000        9.000     3.000     1.000
 25.0 %ile  :       366.000       360.000       81.000       12.000     4.000     2.000
 50.0 %ile  :       366.000       365.000      127.000       17.000     6.000     3.000
 75.0 %ile  :       366.000       366.000      315.000       23.000     9.000     5.000
 90.0 %ile  :       366.000       366.000      363.000       31.900    12.000     7.000
 95.0 %ile  :       366.000       366.000      365.000       39.000    15.000     9.000
 99.0 %ile  :       366.000       366.000      366.000       52.000    21.000    12.990
 Maximum    :       366.000       366.000      366.000       74.000    27.000    18.000
 Mean  (%)  :       100.000        96.610       49.074        5.158     1.898     0.946
 Min   (%)  :       100.000        53.825        7.377        0.546     0.273     0.000
 Max   (%)  :       100.000       100.000      100.000       20.219     7.377     4.918
 Counts(Sim):     0.732E+06     0.707E+06    0.359E+06    0.378E+05 0.139E+05 0.692E+04
 #Meet(Sim) :          2000          2000         2000         2000    2000       1911
```

Table #4—Cumulative person-days of daily max 8-hour exposure levels

This table provides a statistical summary of the cumulative person-days, for both simulated persons and the population in the study area, with a daily maximum 8-hour average exposure concentration that equals or exceeds specified levels. The table is the same as Table #3 (Figure 6-2) except that the exposure metric is the daily max 8-hour average exposure concentration.

Table 6-1. Definitions of Variables in Summary Tables

Counts(pop)	The number of study area person-days for which the exposure metric is equal to or greater than the level specified at the top of each column of the table.
#Meet(pop)	The number of persons in the study area whose exposure metric is equal to or greater than the level specified at the top of each column at least once during the period of simulation.
%Meet(pop)	The percent of the population in the study area whose exposure metric is equal to or greater than the level specified at the top of each column at least once during the period of simulation.
Mean	The average of the number of days for each simulated person for which the exposure metric is equal to or greater than the level specified at the top of each column.
Std. Dev.	The standard deviation of the number of days for each simulated person for which exposure metric is equal to or greater than the level specified at the top of each column.
CV	The coefficient of variation, which is the ratio of the standard deviation to the mean.
Minimum	The minimum number of days for any simulated person for which the exposure metric is equal to or exceeds the level specified at the top of each column.
<n>%ile	The nth percentile value of the number of days for each simulated person for which the exposure metric is equal to or exceeds the level specified at the top of each column.
Maximum	The maximum number of days for any simulated person for which the exposure metric is equal to or exceeds the level specified at the top of each column.
Mean(%)	The average percent of days during the period of simulation for which a simulated person's exposure metric is equal to or exceeds the level specified at the top of each column. (This variable is calculated by dividing the Mean by the total number of days in the simulation period and then multiplying by 100.)
Minimum(%)	This variable represents the minimum percent of days during the period of simulation, in which a simulated person experience exposure at or above a level specified at the top row of each column of a table. This variable is calculated by dividing the Minimum by the total number of days in the simulation period and then multiplying by 100.
Maximum(%)	The maximum percent of days during the period of simulation for which a simulated person's exposure metric is equal to or exceeds the level specified at the top of each column. (This variable is calculated by dividing the Maximum by the total number of days in the simulation period and then multiplying by 100.)
Counts(Sim)	The number of simulated person-days for which the exposure metric is equal to or exceeds the level specified at the top of each column.
#Meet(Sim)	The number of simulated persons for whom the exposure metric is equal to or exceeds the level specified at the top of each column at least once during the period of simulation.

Table #5—Cumulative person-days of daily average exposure levels

This table provides a statistical summary of the cumulative person-days, for both simulated persons and the population in the study area, with a daily average exposure concentration that equals or exceeds specified levels. The table is the same as Table #3 (Figure 6-2) except that exposure metric is the daily average exposure concentration.

Table #6—Cumulative number of persons at each overall average exposure level

This table provides a statistical summary of cumulative numbers of both simulated persons and people in the study area whose overall average exposure concentrations equal or exceed specified levels. The overall average exposure concentration is the average of hourly exposure concentrations over the whole period of simulation. An example of this table is provided in Figure 6-3. The definitions of the variables in this example can be found in Table 6-1.

Figure 6-3. Example of Table #6 in the Output Table File

```
  Cumulative # Persons at each Overall Average Exposure level for N =    2000 Profiles,
with Area Population =    44732

   Level:              0.000        0.500       1.000       1.250     1.500     1.750
 ---------------------------------------------------------------------------------------
 Counts(Pop):     0.447E+05     0.447E+05   0.447E+05   0.447E+05 0.447E+05 0.447E+05
 #Meet(Pop) :         44732         44732       44732       44732     44732     44732
 %Meet(Pop) :       100.000       100.000     100.000     100.000   100.000   100.000
 Counts(Sim):     0.200E+04     0.200E+04   0.200E+04   0.200E+04 0.200E+04 0.200E+04
 #Meet(Sim) :          2000          2000        2000        2000      2000      2000
 ---------------------------------------------------------------------------------------
```

Table #7—Cumulative person-days of daily max end-of-hour dose levels

This table provides a statistical summary of the cumulative person-days for both simulated persons and the population in the study area, for which the daily maximum end-of-hour dose is equal to or exceeds specified levels. The format of the table is the same as Table #3 (Figure 6-2). The definitions of the variables in this table can be found in Table 6-1.

Note that Table #7 through #13 are produced only for CO dose calculation. For other pollutants, dose calculation should be turned off.

Table #8—Cumulative person-days of daily max 1-hour dose levels

This table provides a statistical summary of the cumulative person-days, for both simulated persons and the population in the study area, for which the daily maximum 1-hour average dose is equal to or exceeds specified levels. The format of the table is the same as Table #3 (Figure 6-2). The definitions of the variables in this table can be found in Table 6-1.

Table #9—Cumulative person-days of daily max 8-hour dose levels

This table provides a statistical summary of the cumulative person-days, for both simulated persons and the population in the study area, for which the daily maximum 8-hour average dose is equal to or exceeds specified levels. The format of the table is the same as Table #3 (Figure 6-2). The definitions of variables in this table can be found in Table 6-1.

Table #10—Cumulative person-days of daily average dose levels

This table provides a statistical summary of the cumulative person-days, for both simulated persons and the population in the study area, for which the daily average dose is equal to or exceeds specified levels. The format of the table is the same as Table #3 (Figure 6-2). The definitions of the variables in the table can be found in Table 6-1.

Table #11—Cumulative # persons at each overall average dose level

This table provides a statistical summary of cumulative numbers of both simulated persons and the people in the study area whose overall average doses are equal to or exceed a specified level. The overall average dose is the average of hourly dose levels over the whole period of simulation. The format of this table is the same as Table #6 (Figure 6-3). The definitions of the variables in this table can be found in Table 6-1.

Table #12—Cumulative person-hours at each end-of-hour dose level

This table provides a statistical summary of the number of person-hours, for both simulated persons and the population in the study area, for which each end-of-hour dose level is equal to or exceeds specified levels. The format of this table is the same as Table #3 (Figure 6-2). The definitions of the variables in the table can be found in Table 6-1, except that the time units are hours rather than days.

Table #13—Non-cumulative minutes at each dose level

This table provides a statistical summary of cumulative person-minutes, for both simulated persons and the population in the study area, for which the dose (i.e., blood %COHb level) is within a specified range. The bounds of the dose range are specified by the levels at the top of each column and the top of the next column to the right. The format of this table is similar to the exposure summary table, Table #3 (Figure 6-2). The definitions of the variables in this table are similar to those found in Table 6-1, except that the time units are minutes rather than days.

Table #14—Cumulative minutes at each dose level

This table provides a statistical summary of cumulative person-minutes spent by both simulated persons and the population in the study area, for which the dose (i.e., blood %COHb level) is equal to or exceeds specified levels. The format of this table is the same as Table #3 (Figure 6-2). The definitions of the variables in this table are similar to those found in Table 6-1, except that the time units are minutes rather than days

6.7 *Sites* File (Unit 31)

The *Sites* output file lists the sectors, districts, and zones in the study area, and identifies the mapping between them. Thus, each record contains the following:

- Sector#—Sector ID
- Latitude—Sector latitude
- Longitude—Sector longitude
- Sectorname—Sector name
- Air#—Air district ID

- Airdistance—Distance from district to sector
- Airlatitude—Air district latitude
- Airlongitude—Air district longitude
- Airname—Air district name
- Tem#—Tempurature zone ID
- Temdistance—Distance from zone to sector
- Temlatitude—Zone latitude
- Temlongitude—Zone longitude
- Temname—Zone name

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