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IMPROVED MANAGEMENT AND ANALYSIS OF INDUSTRIAL AIR EMISSIONS USING A GEOGRAPHIC INFORMATION SYSTEM

Abstract: As air quality regulations become more demanding, geographic information system (GIS) technology presents itself as a valuable tool. GIS can aid in managing and analyzing the large amounts of data generated by environmental managers. A PC-based system, pcAir-1, has been developed which combines GIS, air dispersion models, and industrial data bases into a desktop air toxics management package.

INTRODUCTION

As air quality regulations become more demanding, evaluating impacts from air emissions at an industrial complex is becoming increasingly difficult. A geographic information system (GIS) is one tool that helps to manage the large amounts of data that must be analyzed and reported. A GIS is a data management system with maps and graphics linked directly to data bases. For this specific application, a GIS is a suitable data manager for tracking emissions and for using computerized air dispersion models to estimate downwind impacts. Since the data needed to perform such procedures are geographically referenced, these data can be easily incorporated into a GIS (1). In addition, data from different sources, such as computer-aided design (CAD) drawings (2) and census data (3), can be incorporated as long as the data have a geographic reference.

This paper introduces the reader to a PC application called pcAir-1, a GIS-based air toxics management system. The first section provides background into input and output parameters used in air dispersion modeling. The second section explains the reasons for using GIS as the platform for pcAir-1. The third section describes how the data are stored, accessed, and analyzed within the framework of pcAir-1 and GIS. The final section summarizes the major goals and features of the system.

BACKGROUND TO AIR DISPERSION MODELING

Air dispersion modeling is one method of estimating downwind impacts from an emission source. These impacts are dependent on the characteristics of the source, local meteorology, and surrounding terrain. Source characteristics include source height and width, relationships to surrounding buildings, and the rate and temperature that emissions leave the source. One source may have multiple emissions, meaning that more than one pollutant is involved.

Meteorological conditions and terrain both influence plume direction and magnitude. On a day with light winds, a plume will not disperse very far in any direction. On a day with persistent winds, aplume vill disperse over a wide area in the direction of the wind. Terrain can influence the dispersion of a plume as well. For example, in a valley, winds will often drain parallel to the valley. Also, if the terrain is higher than the plume, the plume will tend to follow the contour of the terrain.

Based on source characteristics, meteorological conditions, and terrain, a plume's height and dispersion can be mathematically simulated through the use of computer models available from the U.S. Environmental Protection Agency. Downwind impacts from the plume are estimated at discrete points on the ground called receptors. As shown in Figure 1, the impact at a receptor is based on plume characteristics and is dependent upon the receptor's geometrical relationship with the source. Calculations for the single source/single receptor analysis are relatively straightforward; however, at many industrial sites the situation is far more complex, with model input consisting of hundreds of emission sources and receptors (Figure 2). Data management is greatly aided through the use of a GIS.

GIS AS A DATA BASE ORGANIZER

The pcAir-1 system architecture is based on off-the-shelf GIS technology. GIS manages pcAir-1 data by storing information on the emission sources, the model receptors, and other necessary data as separate map "layers." The layers share a common reference of X and Y coordinates so that they may be overlaid upon each other (as seen in Figure 3). The greatest advantage of using GIS, however, is that each map layer can be directly linked to data bases containing characteristics pertaining to the features in that layer. Figure 4 illustrates this concept with a map of emission sources linked to data base files of emission concentrations and stack physical parameters.

The GIS foundation of the system acts as a shell that, through the use of a "point-and-click" menu interface, connects the system's various operating functions (see Figure 5). Such operations include:

Figure 1. Single-source/single-receptor modeling scenario.

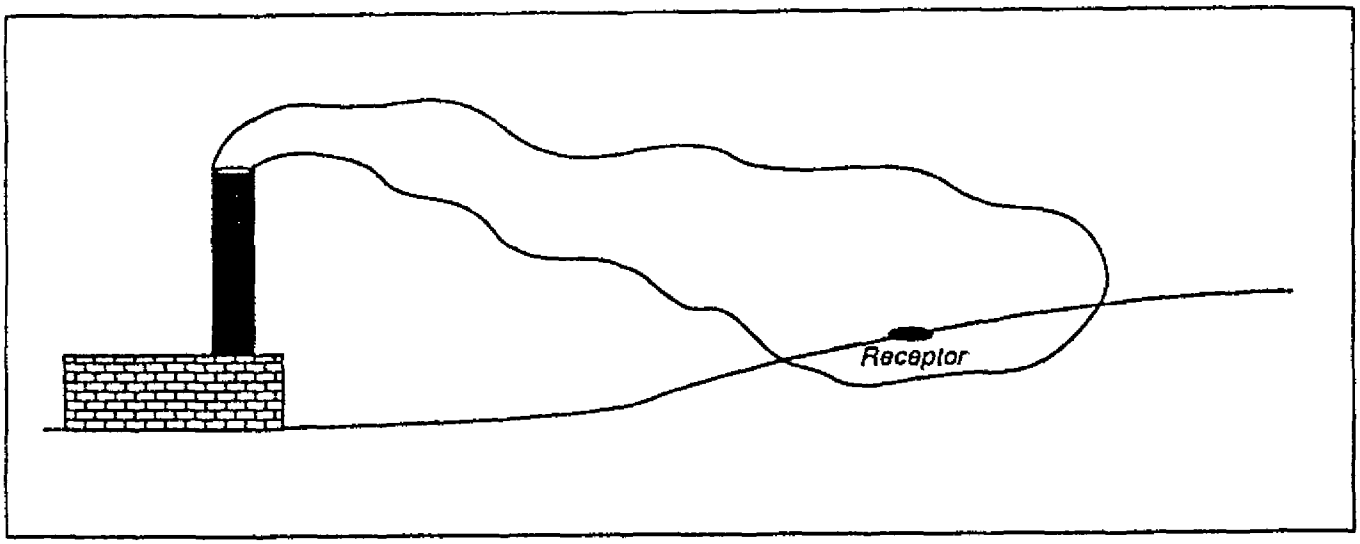


Figure 2. Multi-source/multi-receptor modeling scenario.

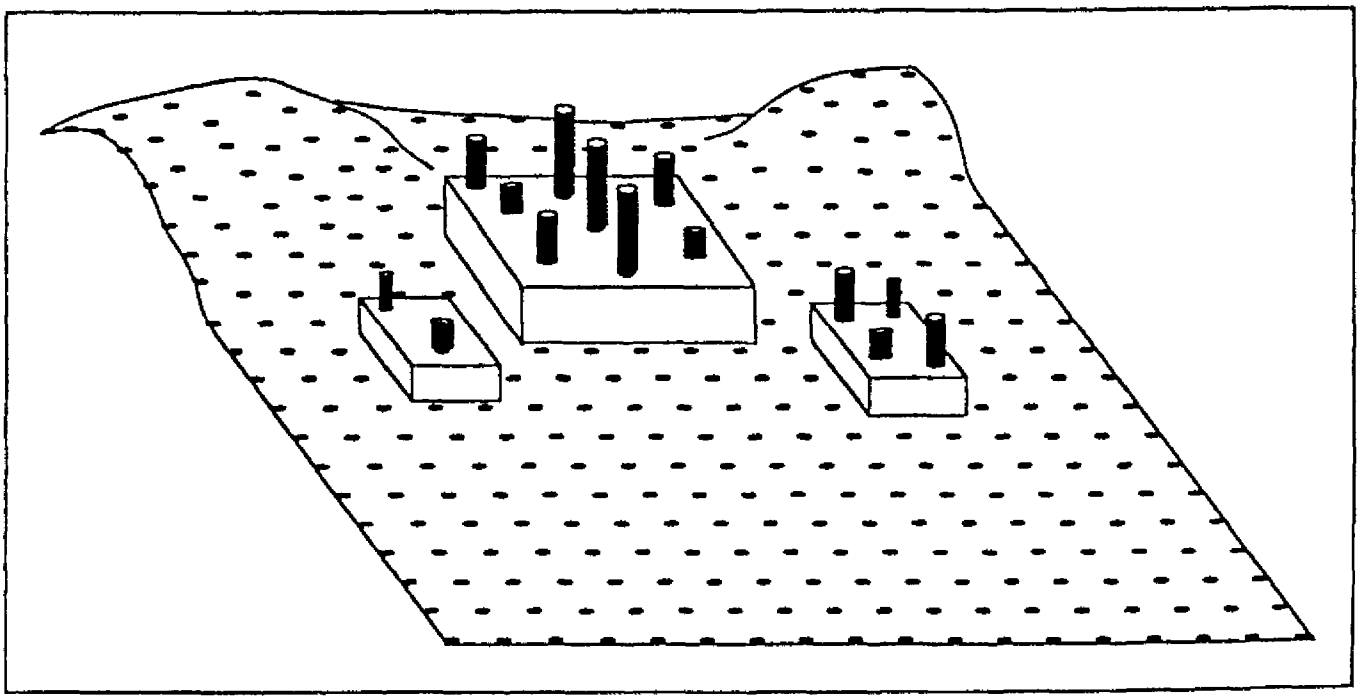


Figure 3. Map "layers" share a common X-Y coordinate system.

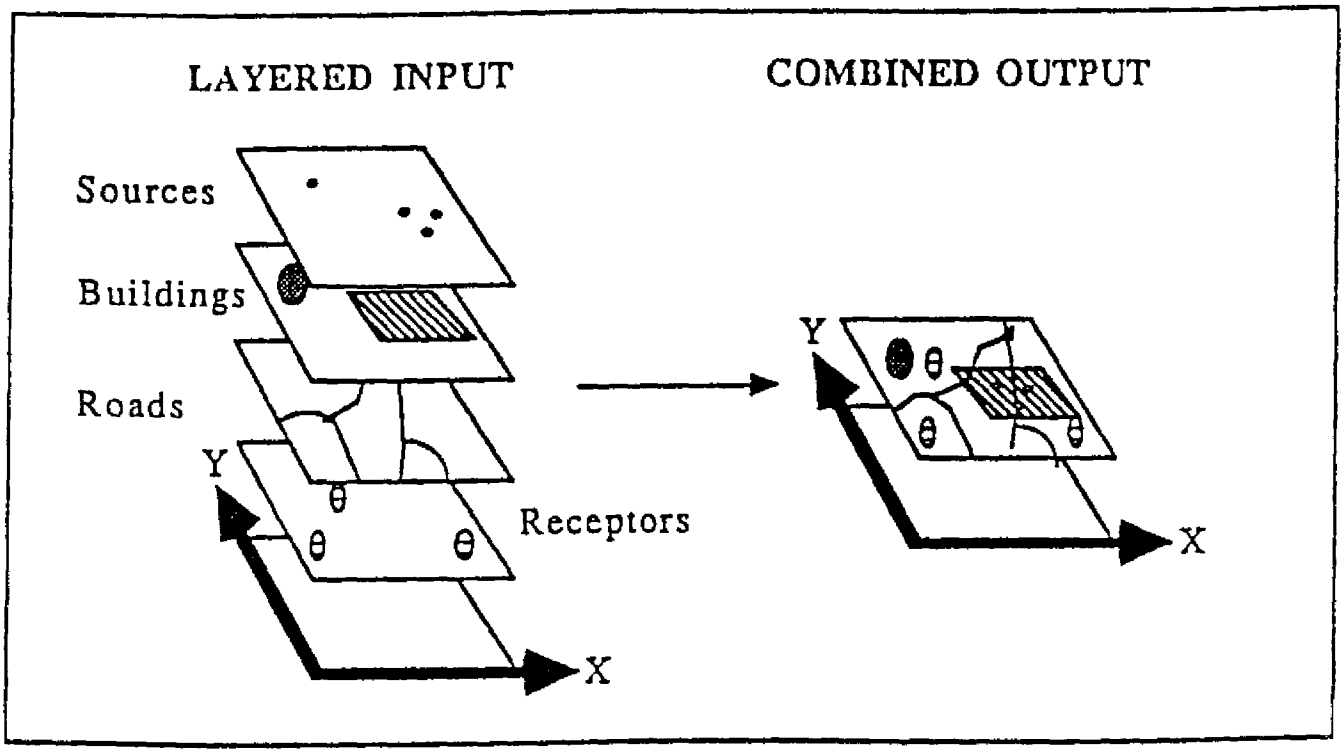


Figure 4. GIS links maps with descriptive data bases.

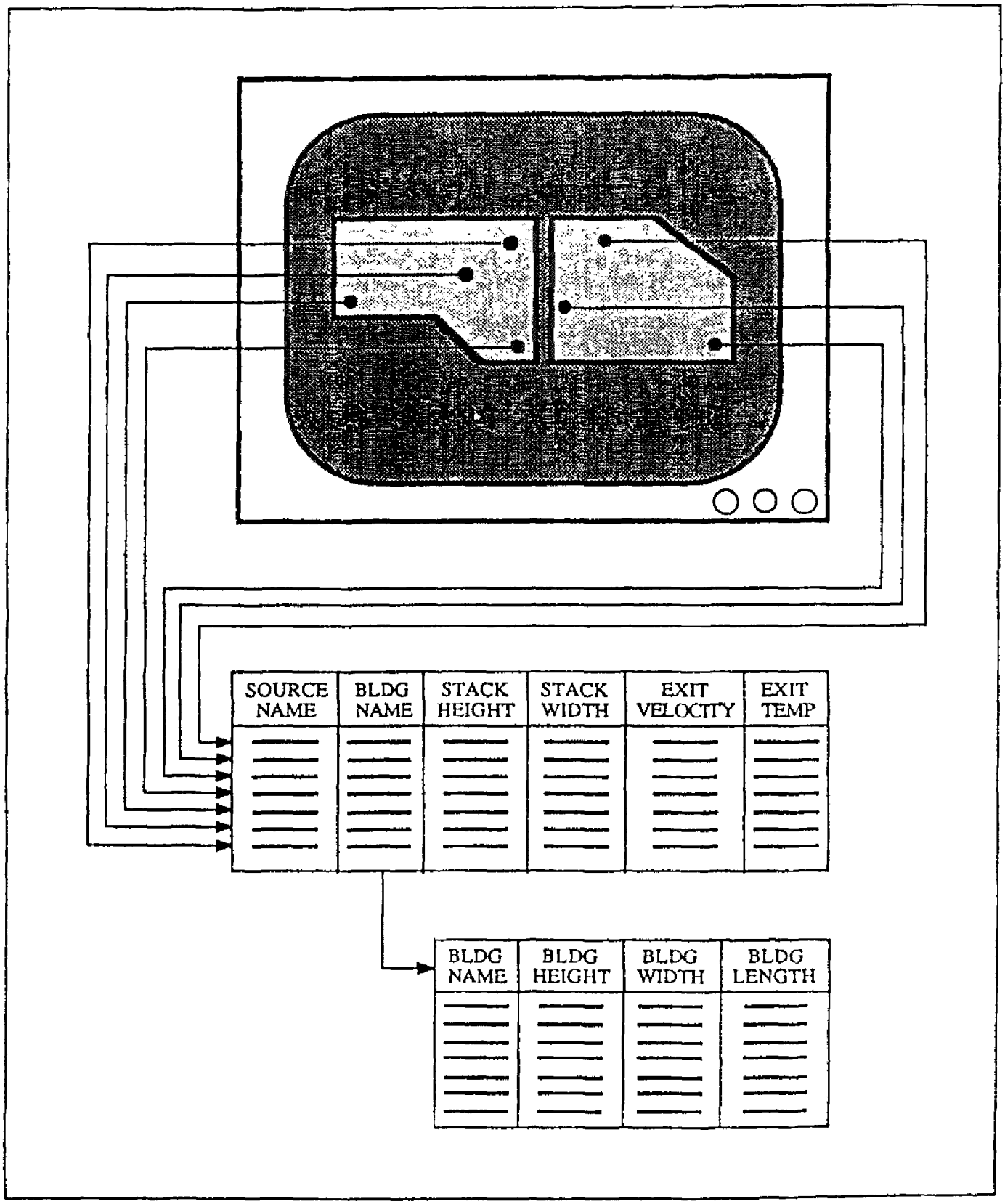
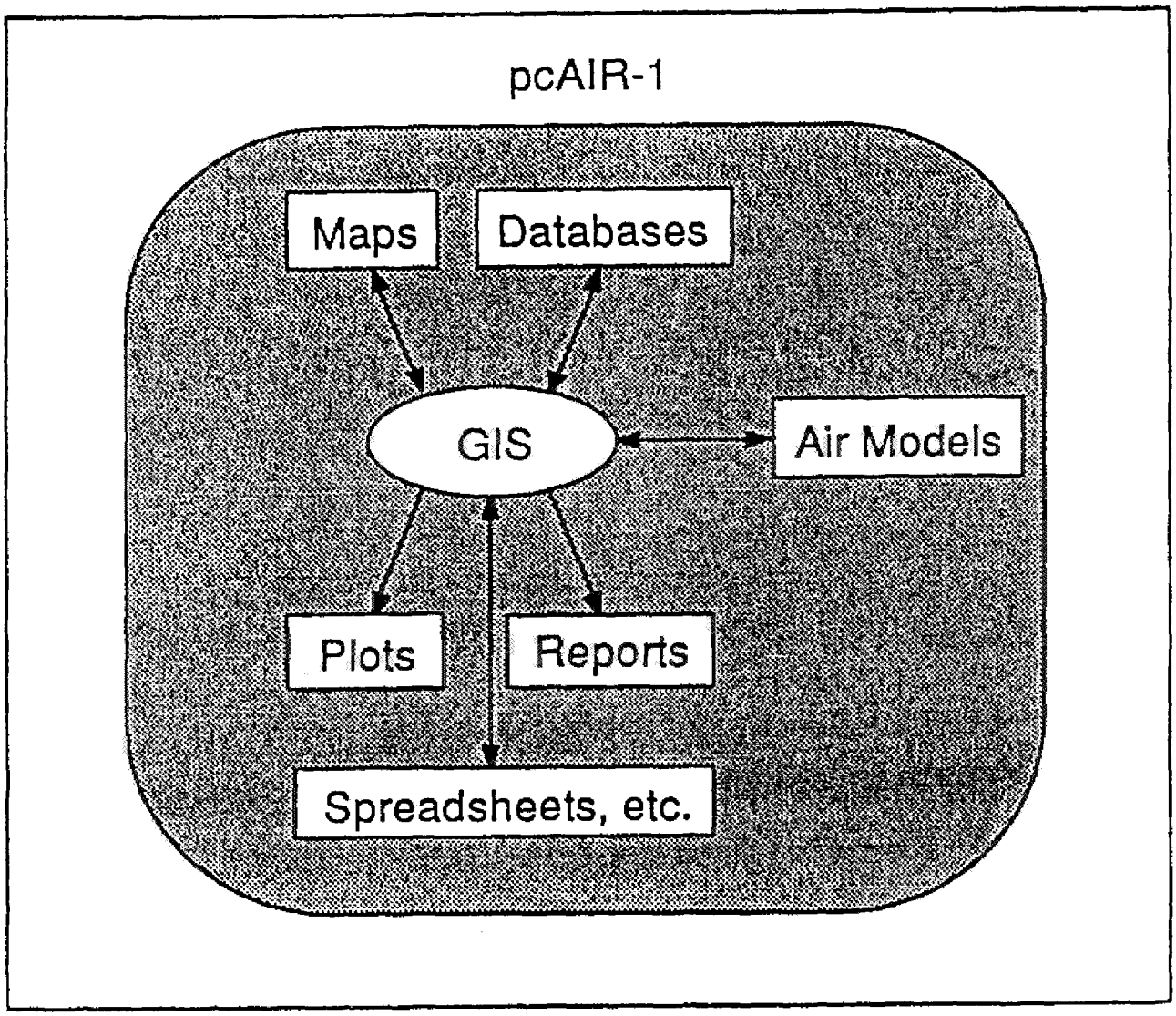


Figure 5. Conceptual diagram of pcAir-1.



- Data Base Management:
  Querying, linking, and editing environmental data bases. Data in a GIS can flow easily in both directions between graphic and data base forms. The data base can be accessed and displayed by choosing map features on the screen; conversely, map features can be highlighted and manipulated by querying on the data base.

- Air Dispersion Modeling/Analyses:
  Access to air dispersion models and the ability to interpret model impacts in relation to criteria values or established guidelines.

- Report Generation:
  Ability to generate standard and special-purpose data reports in both tabular and graphical formats.

- Software Access:
  Access to external software and tools, such as word processors, spreadsheets, and other data base managers.

GIS was chosen as the pcAir-1 platform for several reasons. First, dispersion modeling analyses are dependent upon mapped data such as source location, receptors, and other spatial features (such as terrain). GIS is a computer technology specifically designed to handle such data (4, pp. 6-7).

Second, many advanced graphical and analytical functions, such as layered storage of data, zooming and panning, custom map creation, and on-screen point-and-click queries, are fundamental GIS operations that do not require additional programming.

Third, GIS is adept at handling large data sets and incorporating data from many sources, including output from the dispersion models that run outside of the GIS itself (5). With this capability, it is possible to incorporate existing data bases, thereby avoiding the need to spend time and money to re-enter data the user may already possess. The modular design of pcAir-1 gives the system the flexibility to incorporate other data bases and models without the need for reprogramming existing pcAir-1 functions. For instance, new procedures can be created from air dispersion models, demographic data, and census maps to produce a health risk module which plugs into the existing system. This module would then be available as a menu choice during a pcAir-1 session.

INCORPORATING GIS AND AIR DISPERSION MODELS WITHIN PCAIR-1

The strength of pcAir-1 is its flexibility in querying, storing, analyzing, reporting, and plotting air emissions data. The user has the option to manipulate data either through the menu-driven graphical interface (i.e., pointing and clicking on

on-screen maps) or directly through the data base management system. Figure 6 shows how the data bases interact with analysis/process procedures and output. Hard copy and screen display are available for both reports and plots, and the reporting system is menu-driven with appropriate prompts for data queries.

Data Base Types

In the left-hand column of Figure 6, the different data bases are listed. Data bases supported by pcAir-1 can be divided into three groups: those containing information needed for input to air-dispersion models, those containing output from the models, and those containing reference criteria.

Input to air dispersion models. Data bases holding input parameters include source data, such as building and stack parameters, and receptor data, such as X and Y coordinates and elevations.

Output from air dispersion models. The second type of data base holds model output. In order to model a large number of sources and complex source distributions in a timely fashion, pcAir-1 stores model results as normalized concentrations maintained in a separate data base. The normalized concentrations are based on an emission rate of 1.0 grams/second. The normalized concentrations are then multiplied by the actual emission concentrations during the analysis phase, thereby generating the requested model results. This approach facilitates fast and reliable estimation of ambient impacts when emission rates and/or pollutants change for one or more sources.

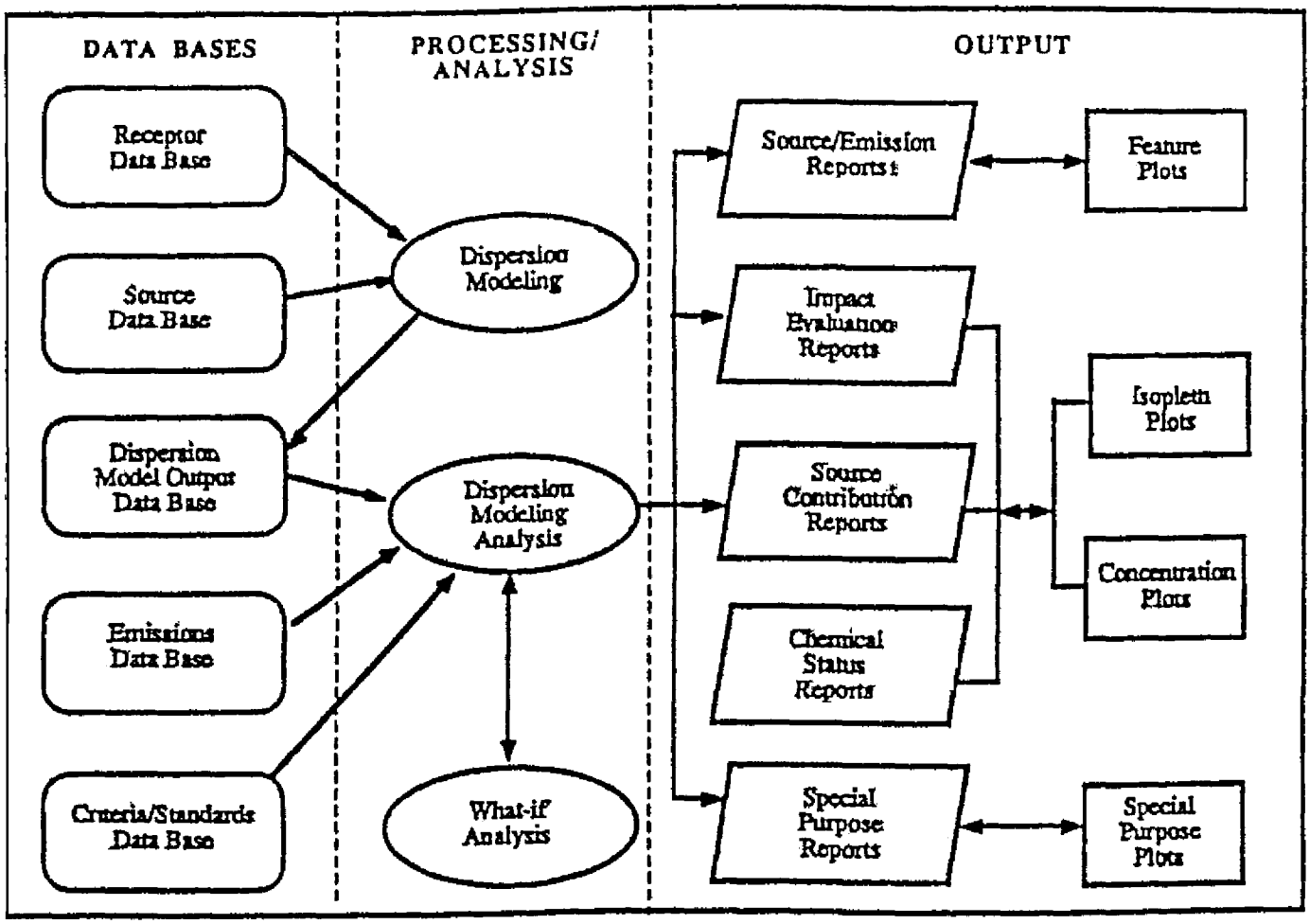
Reference data bases. Two data bases are used for reference. The emissions data base contains data on operating hours, stack characteristics, and pollutant emissions. The criteria/standards data base contains chemical-by-chemical reference criteria used for comparison to federal and state standards.

There are three distinct approaches to entering and editing data for pcAir-1. First, in interactive graphic mode, users can display maps of the receptors and sources and then employ a mouse to point-and-click on the map to add or modify feature characteristics. These features can be selected individually or in groups.

Second, in the nongraphic text mode, data input screens are available that have easy-to-follow formats and error-trapping capabilities. These screens are customized to accommodate user preferences for format and style. No maps or graphics are present, for the user is working directly with the database management system.

The third mode is batch processing. For large data sets or intensive calculations, the user may wish to update the data bases

Figure 6. Interaction of pcAIR-1 data bases, dispersion models, and output.



overnight or during slow-use periods. This mode is most useful for extensive modeling, or when importing large data sets such as emission or meteorological data.

Types of Processes and Analyses

In the middle column of Figure 6, the different available processes and analyses are listed. Running the air dispersion models is the primary processing procedure. The models are linked to the system data bases with pre- and post-processors that format the data.

There are two general types of analyses: regular dispersion model analysis and "what if" analysis. When the "what if" mode is used, different scenarios can be investigated without disrupting the permanent data bases. The analysis results can be accessed and queried in one of two ways: either through the interactive graphics mode or directly through the data base management system (text mode). Queries may be made on any user-defined subset of receptors or sources. In the graphics mode, the subset may be chosen from the screen either individually or in groups using the point-and-click method.

Output

The right-hand segment in Figure 6 lists examples of output. Output can be reported in either a tabular or graphical format.

Tabular reports. Standard tabular reports are included as menu options accessed from either the graphics screen or directly from the data base management system, and may be added and deleted from menus as needed. Some examples of standard reports include impact evaluation reports listing all receptor concentrations, and chemical status reports listing maximum concentrations and location compared to ambient guidelines. The user also has the option to create special-purpose reports based on specific queries to the data base. Tabular report data can be saved in a format ready for spreadsheets, word processors, or other software with links to pcAir-1.

Plots. Graphic plots of model results are generated through interactive query. For instance, if the system is queried for receptor concentrations over a threshold value (such as a state guideline), the appropriate receptors are highlighted on the map. The highlighted receptors form the basis for a map composition.

A map composition is a group of map features arranged on the screen in the desired manner. During each query (or series of queries), a map composition is automatically generated, to which annotation and other relevant information may be added. An advantage of this is that if a tabular report is being generated through on-screen graphical query, a map composition representing the table's contents can be generated simultaneously. While composing a map, the user has the ability to access multiple

layers of data (such as buildings, sources, receptors, topography, natural features, and impact isopleths), to zoom and pan, to plot at any scale, and to access annotation with a variety of fonts and colors.

The map compositions can be modified and copied, saved for later retrieval, and sent to a laser printer or plotter. If the same queries are used repeatedly, a menu selection or function key can be designated that will automatically create a standard map composition ready for hardcopy generation.

CONCLUSION

The pcAir-1 system has been developed to provide environmental managers with a tool that helps them maintain regulatory compliance. For ease of use, the software employs a menu-driven point-and-click interface, and provides flexible access to air emissions data, dispersion models, and projected pollutant impacts. The system has been built around a GIS in order to incorporate data handling and display features frequently cited by environmental managers. These features include:

- o High-quality graphics both on-screen and as hard copy,
- o Using digital maps to edit data bases,
- o A method for storing large quantities of data,
- o A flexible query system, especially the ability to focus on specific sources and/or receptors, and
- o Flexible report generation.

By emphasizing the integration of existing software to develop pcAir-1, many of the system's important features are provided without extensive custom programming. In addition, pcAir-1 is designed to be modular. This modularity allows for adding or modifying existing capabilities without significantly altering the system. Planned enhancements include incorporating pcAir-1 into a larger system that includes data bases on hazardous waste and water management needed for SARA Title III compliance and incorporating census data and other attributes needed to perform very detailed health risk assessments.

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