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USING COMPUTER ASSISTED CARTOGRAPHY TO MAP THE U.S. ENERGY SYSTEM

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ABSTRACT

Most descriptions of the United States energy system are aggregated to the state or national level, and are usually in prose, tabular, or flow-chart form. To improve our understanding as to where fuels are produced and used, and the effects of the U.S. energy system a computer generated atlas of several energy related variables was produced for the country using the county as the basic mapping unit. Existing computer mapping software was used by users new to the computer center as well as the software to produce color maps vividly displaying the heterogeneity of the U.S. energy system.

DOE Contract No. W-74505-eng-48

BACKGROUND

Since 1974 the Biomedical and Environmental Assessment Division of Brookhaven National Laboratory has been assessing the environmental and health impacts of energy related activities at the national level. The primary reasons for this work are to relate specific health and environmental impacts to specific energy activities, particularly the stages of various electricity generation fuel cycles, and to create an adequate foundation for the analysis of impacts associated with alternative fuel mixes in the U. S. energy system.

During the early phases of our work we became somewhat dissatisfied with using values solely aggreggated to the national level, because there was so much heterogeneity and lack of randomness that national averages were misleading. We could perceive this, but we could not document it. We concluded that what was needed to adequately address the problem was a fine-grain geographical approach.

METHOD

The general features of our method to create a fine-grain rendition of the U. S. energy system and its impacts, included:

1. Define the basic unit for presentation, the county;
2. Collect and record to cards as much county and state energy data as we could find;
3. Write and continually modify a rather detailed accounting program, COENBU, which would:
   a. in the absence of county-level data redistribute state-level variables to counties;
   b. calculate air pollutant emissions in each county;
   c. reaggregate county-level calculations to the Water Resources Councils sub-region, state, and national levels,
4. Develop a method for presenting our results, an atlas, with tables, graphs, and maps.

Initially, we made several hand-drawn maps. These were fun (and therapeutic), but uneven in quality, often contained errors, and very time consuming. We needed a better way. A program named CARTE was perfect for our purposes (see sample map).

CARTE was developed for a Department of Labor project by the Computer Science and Applied Mathematics Department of Lawrence Berkeley Laboratory in 1972, and has been used

in numerous projects since. The version used in our application ran on a CDC 7600 computer with output going to a Stromberg-Carlson 4460 black and white film recorder with 4096 x 4096 resolution to produce 35 mm microfilm.

Simply stated, CARTE takes a geographical base file and combines statistical data to produce shaded maps. Map shading can be cross-hatch textures, or, as in this application, be color separation negatives which are subsequently combined in the printing process to produce multi-color maps. Points, lines, or areas can be symbolized. Use of the program requires minimal computer expertise. See Figure 1.

New users, as Drysdale and Calef, learned to use the LBL system, CARTE, and produced 40 maps in less than one week. The average computer cost (time, output, and aborted runs) was about $7.00 per map. The average central processor time for a standard shaded U. S. by county map was about 19 seconds.

Mass production of computer-generated maps has both a computer phase and printing phase.

A. Steps using the computer (compilation of the map) (SLIDE)

   1. Select are a and characteristics to be mapped
   2. Prepare the data set

3. Prepare the base map
4. Design the map
5. Prepare directives to CARTE
6. Execute the program
7. If necessary, repeat steps 4 to 6 until satisfied with map.

B. Steps in map printing (reproduction of the map)

1. Make enlarged printers' negatives
2. Select color scheme and percent screening
3. Make printers' plates
4. Print maps
5. Combine with text
6. Distribute.

The printing steps require a tremendous amount of care and skill. Professional printers can do high quality work to transform the computer output to final products ready for distribution.

We will only elaborate on the computer mapping steps.

First, the data has to put into an appropriate format. For CARTE this format is basically a series of card images with "keys." The keys are geographic identifiers that link the data to the map base file. In this case the Federal Information Processing Standard (FIPS) codes were used as the keys.

Next, the base map is prepared. In this case the states of Alaska and Hawaii were repositioned on the base map. This permitted use of a standard 8½ x 11 inch page size.

The design of the map involves two steps. First, a layout is made of the map titles and legends on a grid. Usually this requires judgments by the user and CARTE permits wide flexibility in layout. Second, this layout has to be communicated to CARTE by a set of directives. There are directives for those elements common to all maps in a run, as well as directives specific to individual maps. For example, the layout of all map titles will probably be the same, while the words in the title will be different for each map.

The job is then submitted and executed. If the negatives look good, the job goes to the printing stage.

PROBLEMS

No major problems have been encountered using CARTE.

RESULTS

Using slides we will show the results of using CARTE to produce an energy atlas of the United States.

Important features to note in each map include:

1. The intensity of the activity or release;
2. The spatial distribution of the activity or release;

3. The relative abundance of high and low intensity areas.

BENEFITS

A concise publication of maps of energy activities that readily communicate to the viewer where activities occur, who might be effected by the activity, the relative importance of the activity between areas, and a baseline that can be used in comparing future maps and models of energy related activities, emissions, health effects, environmental impacts, and other county-level data.

MANAGEMENT REACTIONS

Management reaction to the production of a county-level energy data base and atlas was initially mixed ranging from outright resistance to helpful support. However, with production of an easily used data base and the energy atlas there seems to be unanimous recognition that the work is worthwhile and has wide application and utility.

TECHNICAL STAFF REACTION

Researchers in the health effects of air pollutants field realized that the county-level energy and pollution data could be easily coupled to their county-level mortality data. And, we are happy that we have a data set and methodology that will permit an adequate assessment of the environmental

impacts associated with energy related activities.

HINDSIGHT

The most important lesson learned was that a large-scale project requiring a wide variety of skills and information can be seen through to completion even though the utility of such an undertaking may not be perceived by management until it is completed.

We also learned that people inexperienced with CARTE and computers in general can, if motivated, easily learn to make computer generated maps. The difficulties encountered by the users of CARTE have stimulated improvements to the program.

IMPROVEMENTS

The energy atlas was never intended to be perfect, and it isn't; rather it was intended to stimulate the exchange of energy information, to document energy related activities for the period approximating 1972-1973, and to form a fine-grain basis for assessing the health and environmental impacts of the U. S. energy system. We think the present work meets these requirements. The next edition of the atlas will compare two time periods and look at basic trends in the U. S. energy system, as well as relate the health and environmental impacts of the U. S. energy system.

The problems with CARTE were encountered during data preparation or stemmed from the nature of batch operation. Most aborted runs were a result of poor user comprehension, or over-looking minor details. This, combined with the iterative nature of map design, stimulated the development of an interactive version of CARTE, as opposed to the batch version used in this work. The interactive version gives the user a preview of his map and makes error correction easy. Program development that emphasizes continued and wide use is more desirable than a program tailored to one specific project. The improvements to CARTE are along the lines of making CARTE more flexible and usable by non-programmers.

POTENTIAL FOR TRANSFER

Both CARTE techniques and the energy atlas materials are high transferable.

DOCUMENTATION

There is a program user's guide - SEEDIS WORKBOOK III, LBL-6439, B. Burkhart and P. M. Wood, May 1977; and technical documentation - "CARTE - A Thematic Mapping Program" by P. M. Wood and D. M. Austin (1974), LBL-3073 (also in Computers & Graphics, Vol. 1, No. 1). This documentation is available from Lawrence Berkeley Laboratory, Berkeley, California 94720.

"The Energetics of the United States of America: An Atlas" by Frank R. Drysdale and Charles E. Calef (1977), BNL-50501R. This is available from the National Technical Information Service, U. S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161. The cost is $14.00 printed, $3.00 microfiche.

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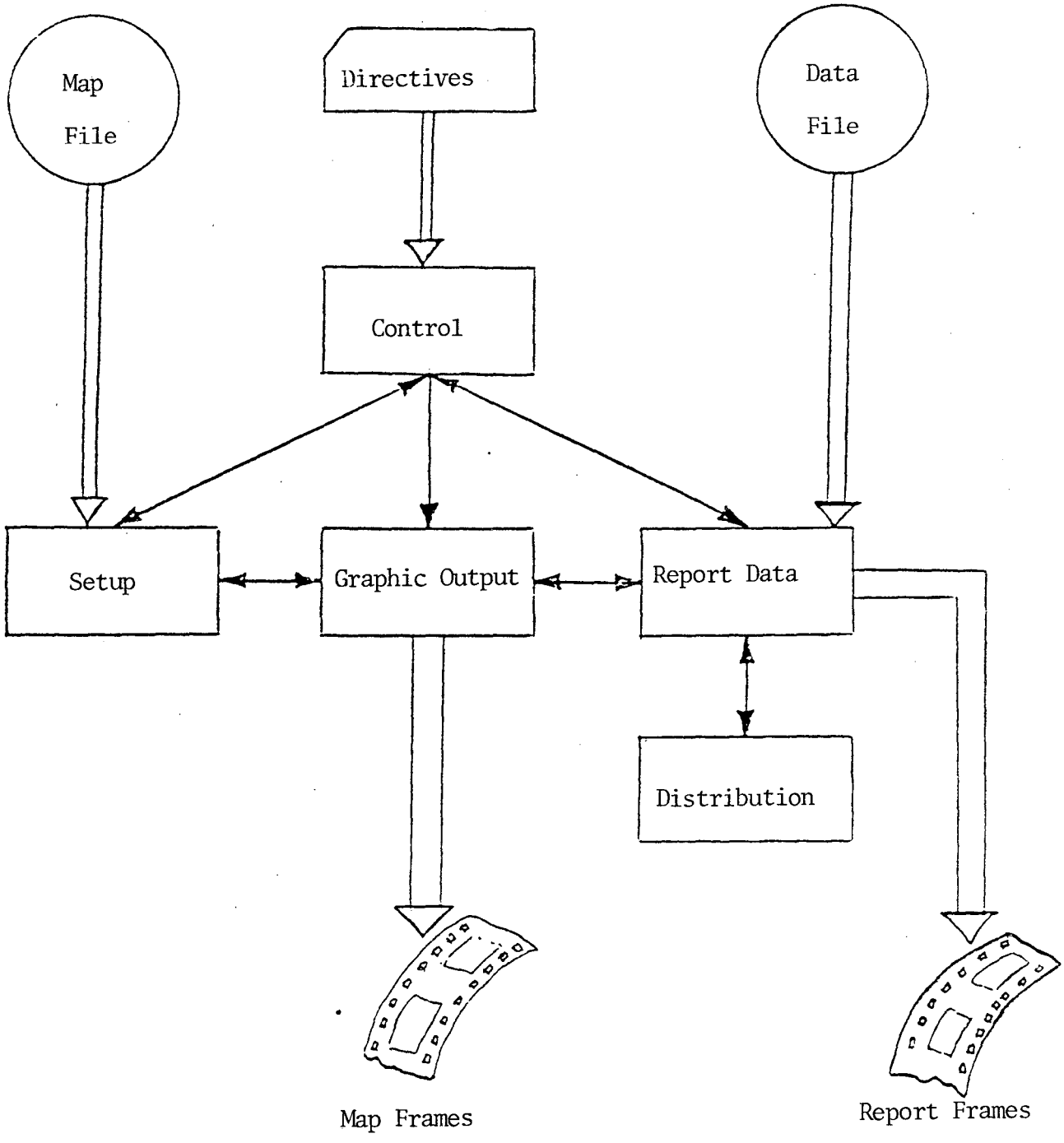
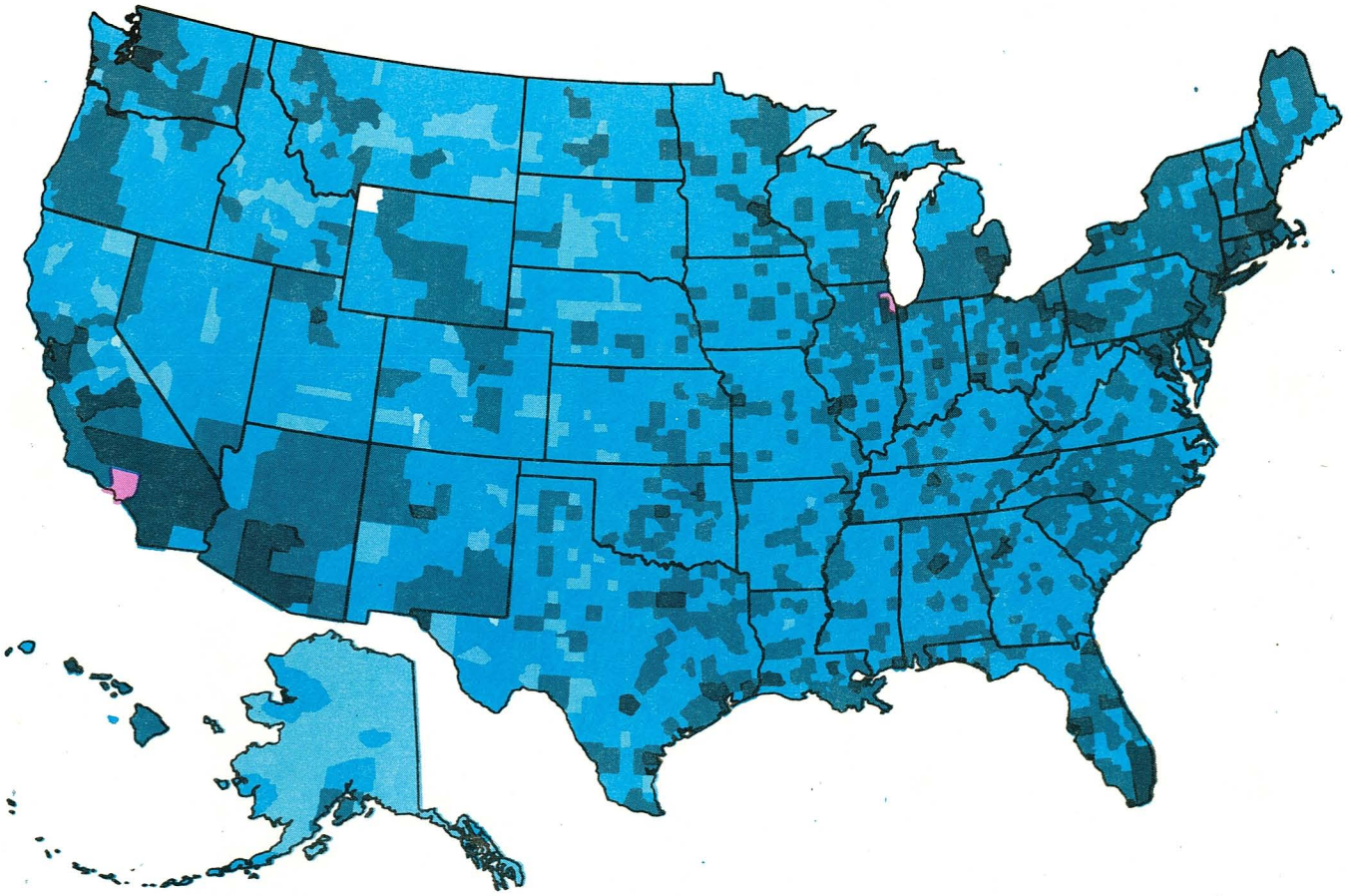


Figure 1. DIAGRAM OF PROGRAM STRUCTURE AND FLOW OF CONTROL

ANNUAL HYDROCARBON EMMISSIONS



THOUSANDS OF KILOGRAMS

BELOW 1 | 1 - 9 | 10 - 99 | 100 - 999 | 1,000 - 9,999 | 10,000 - 100,000 | ABOVE 100,000

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