LAND USE AND ENVIRONMENTAL ASSESSMENT IN THE CENTRAL ATLANTIC REGION

L-14

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ABSTRACT

Data from high altitude aircraft, LANDSAT and SKYLAB have been used in a comprehensive regional survey of land use and its associated environmental impact in the Central Atlantic Regional Ecological Test Site (CARETS). Each sensor system has advantages that were demonstrated by producing experimental land use maps and other data products, applying them to typical problems encountered in regional planning and environmental impact assessment, and presenting the results to prospective users for evaluation. An archival collection of imagery, maps, data summaries, and technical reports has been assembled, constituting an environmental profile of the central Atlantic region. The investigation was organized into four closely-related modules, a land use information module, an environmental impact module, a user interaction and evaluation module, and a geographic information systems module. Results revealed a heterogeneous user community with diverse information needs, tending, however, definitely toward the higher-resolution sensor data and the larger-scale land use maps and related information products. Among project recommendations are greater efforts toward improving compatibility of Federal, State, and local land use information programs, and greater efforts toward a broader exchange of imagery, computer tapes, and land use information derived therefrom.

INTRODUCTION

The Central Atlantic Regional Ecological Test Site (CARETS) is a multidisciplinary, multiagency experiment examining the three-component system "people--land use--environmental quality." The CARETS project has been funded cooperatively by the National Aeronautics and Space Administration (NASA) and the U.S. Geological Survey (USGS), agencies that are jointly seeking improved applications of space technology to the solution of environmental problems. The CARETS project approach has been the development of an experimental regional land use information system.

Land use and land cover data from high-altitude aircraft, LANDSAT, and SKYLAB are the primary inputs to the experimental information system. The intent of the experiment has been to build linkages between the technology and the users by assembling comparable data sets on land use, socio-economic factors relevant to land use planning, and environmental quality parameters. System design called for the flexibility of either aggregating basic data components to larger geographic areas, or presenting data elements in the most detailed form possible for smaller geographic areas. The test region was designed to be large enough to serve as a prototype for testing certain design and functional concepts that would be applicable to follow-on operational systems.

The purpose of this paper is to summarize on the occasion of the NASA Earth Resources Symposium, June 1975, the results of the CARETS project, just prior to the assembly of the products into final report format. This report thus serves both as a brief compendium of the 4-year project, and as a guide to the collection of detailed reports, maps, and other data products that will constitute the final reports of the CARETS project.

Characteristics of the Test Region

The CARETS region consists of the heavily-urbanized portion of the eastern seaboard, roughly the southern half of the region that has been called "Megalopolis" (1). The major cities of the test region include Philadelphia, Baltimore, Washington, Richmond, and Norfolk. Thus the region's character is both coastal and metropolitan, and extrapolation of results to other areas is considered most appropriate where one or both of those characteristics are present.

The size of the test region, 74,712 km^2 (28,846 mi^2) would place it between 40th and 41st in rank among the 50 states in area, and its population (13,404,558 in 1970) would place it between 2nd and 3rd in rank among the States in population. The experience gained in assembling land use and related environmental information for CARETS may be expected to be applicable to a populous State with a small area.

AREAS OF CARETS AND SELECTED STATES

State	Total Area Km^2	Rank
Indiana	93,491	38
Maine	86,027	39
South Carolina	78,283	40
CARETS	74,712	
West Virginia	62,341	41
Maryland	31,865	42

POPULATION OF CARETS AND SELECTED STATES, 1970

State	Population	Rank
California	19,953,134	1
New York	18,190,740	2
CARETS	13,404,558	
Pennsylvania	11,793,909	3
Texas	11,196,730	4
Illinois	11,113,796	5

Even in this highly urbanized region, the amount of land devoted directly to urban uses (residential, commercial, industrial, etc.) is small, though significant in its intensity of use and its impact on the surrounding land and water resources. Significant agricultural activity is present in the test region, especially in the Delmarva Peninsula east of Chesapeake Bay, in south-central New Jersey, in southern Maryland and in counties to the north of the Washington-Baltimore corridor, and in southeastern Pennsylvania. Vegetable farming, dairying, poultry, corn and hay are important agricultural activities and products.

Forest land is the dominant cover type in CARETS. In this region of heavy, but unequally distributed population, the significance of forest land is perhaps counted as much for watershed protection, wildlife preservation, recreation, and second-home developments as for supply of timber. Beaches, wetlands, and other coastal environmental types, though relatively small in area covered, are critical arenas of conflict among competing demands for residential, commercial, transportation, industrial, and recreational uses; and for conflict between all the above uses and preservation in the natural state.

Project Design and Organization

The CARETS investigation has been organized into four closely-related and integrated experiment modules: land use information module, environmental impact module, user interaction and evaluation module, and geographic information systems module.

The land use information module has employed three systems for organizing and quantifying remote sensor data for application to the environmental problems associated with land use in the test region. The first such system is complete land use and land cover mapping of the test region applying uniform classification criteria and common map scales for each coverage. Complete map coverages were produced for land use derived from high-altitude aircraft photography for 1970 at a scale of 1:100,000; for 1:100,000 land use change, 1970-1972, derived from high-altitude aircraft photography; and for land use derived from LANDSAT, mapped at 1:250,000. The second system employed consisted of the selected mapping of portions of the test region, using a variety of scales and levels of classification detail. The third system was spatial sampling for statistical assessments of accuracy and costs.

The environmental impact module was based upon linkages among land utilization processes and resulting effects on land, water, and air quality systems. Demonstrations representing selected portions of the test region employed measures of land use and measures of covariant phenomena such as air quality, streamflow characteristics, surface temperature and other components of the surface net radiation balance. Other demonstrated applications include the assessment of land use changes in coastal ecosystems, and the conducting of environmental impact studies.

The user interaction and evaluation module established and maintained contact with selected user institutions within the region. Conferences, workshops, and questionnaire interviews were employed to familiarize potential users with the range of products and services available or potentially available from such a system, and to receive feedback on usefulness with respect to agency functions. Data display and technical assistance were available at a regional information center for the CARETS investigation.

The geographic information systems module sought improved computer techniques for handling and quantifying the large amounts of information necessary for the land use and environmental impact modules. Since the system employed for extracting land use information from remote sensor data was a manual one, the intermediate products for further transferring the information were "line" or "polygon" maps. The project therefore sought a "polygon" system of digitizing and computer handling of these maps. Researchers used a USGS system, which was developing during the latter stages of the CARETS investigation, for testing the various software and hardware requirements. Volume digitizing and processing of the major CARETS maps, including overlay calculations, were performed by the Canada Geographic Information System, through a cooperative arrangement between the two governments.

The interrelations among the four experiment modules can be illustrated by reference to figure 1, the CARETS concept diagram. The land use information module consists of the four boxes in the upper left-hand portion of the diagram: the functions "remote sensor data input" and "land use data extraction," and the products "raw data, mosaics, indexes, and summaries," and "land use maps and area measurements." The environmental impact module is represented by the two lower left-hand boxes: the function "environmental impact assessment" and the products "other thematic maps, environmental impact analyses, and regional planning applications." Examples of the latter include reports showing relationships among land use and the various environmental quality factors studied. The user interaction and evaluation module is represented by the box on the right-hand side of the diagram.

The geographic information systems module is schematically represented in figure 1 by the arrows connecting the various functions and products. The topmost arrow, leading from the user module back to the remote sensing data input, represents the desired feedback to the design and operation of future remote sensing data-gathering systems--feedback that should result from this report and the reports of other investigators conducting similar studies of Earth resources applications of remote sensor data.

LAND USE INFORMATION MODULE

Remote Sensing Data Input

Remote sensing data from low-altitude aircraft, high-altitude aircraft, LANDSAT, and Skylab were acquired for periods of time ranging from 1959 to 1975. These data served as the basis for the extraction of systematic, quantified data sets on land use and land cover, by processes of manual photo and image interpretation, and subsequent transferring of the interpreted units to a map or photomosaic base. CARETS interpreters used the remote sensing data mostly in the form of color or color infrared transparencies. Throughout its duration the project maintained the entire image or "raw data" collection, which served as a reference source for users and members of the research team alike. At the end of the CARETS project, these basic remote sensor data materials and the various maps derived therefrom will be transferred to an appropriate unit, in accordance with the recommendations to be made by the two sponsoring agencies. These basic data materials, along with the mission reports, index maps, and technical reports resulting from the efforts of this investigation, are expected to constitute a valuable environmental profile of the central Atlantic region, that will serve as a data base for future applications and research.

Basic Data Set: Land Use Mapping from High-Altitude Photography

In preparation for the basic mapping, researchers partitioned the region into 48 map sheets, each measuring 50 km on a side and keyed to coordinates of UTM Zone 18. They selected a basic mapping scale of 1:100,000 as one deemed economically feasible, given the size of the test region and the capabilities of the high-altitude aircraft photography.

The project initially produced a series of 1:100,000 geometrically rectified photomosaics as mapping bases on which to key remote sensor data to locations on the Earth's surface. Figure 2 presents an index to the location and names of the mosaics and the land use maps and overlays keyed to them. The USGS Topographic Division compiled these photomosaics from high-altitude aerial photography flown by NASA in October, 1970. To facilitate the location of features and keying to a computer storage system, the photomosaics are presented with a 1-km overlay grid. Figure 3 shows a reduced specimen of one of the photomosaic sheets. When researchers performed horizontal accuracy checks on these photomosaics, they found a conformance to within national map accuracy standards for 90 percent of the points checked.

The photomosaics and other map series have been placed on "Open File," the normal method of releasing reports and maps prior to or in place of final publication. Copies of these sheets are available for inspection at the USGS Public Inquiries Office, Room 1028, GSA Building, 19th and F Streets, N.W., Washington, D.C. 20240. There also, one can obtain the names of commercial firms that can make reproductions of these sheets.

CARETS interpreters employed a prototype land use classification scheme (table I), which was later slightly modified into the USGS Circular 671 classification (2). USGS Geography Program researchers also developed a Level III classification for possible use with remote sensor data, whose capabilities were tested during the CARETS investigation.

Using a manual photointerpretation process, a team of photo interpreters produced land use maps derived from the 1970 photography for each of the 48 sheets. These basic land use maps constituted one of the primary data sets for the experiment, both for user evaluation and for comparison with results to be obtained from LANDSAT and Skylab sensors. A reduced specimen of one of these land use maps, corresponding to the area of the photomosaic, is shown in figure 4.

Complete high-altitude aerial photo coverage was obtained again in 1972 for the test region. Comparing the 1972 photography with 1970 photography and 1970 land use maps, interpreters prepared a complete set of 1970-1972 land use change maps for all 48 CARETS sheets. They then labeled with two numbers each polygon identified as having changed. The first number represented the land use category before the change and the second the land use category after the change. A specimen of one of the maps showing land use change is presented in figure 5.

To facilitate the use of the land use data, the CARETS project produced a series of overlay maps for the region. To allow the association of land use information with drainage areas, maps of major drainage basins for the 48 sheets were compiled, keyed to the mosaics at a scale of 1:100,000. Figure 6 shows a reduced specimen of one of these sheets.

To test the usefulness of surficial geological information in association with land use data, researchers preapred a set of maps depicting land-forms and surface materials for the Washington, D. C. and Norfolk-Portsmouth Standard Metropolitan Statistical Areas (SMSA's) and for five additional sheets in the southeastern Virginia area. A reduced specimen of one of these maps is shown in figure 7, and a key to the classification used is shown in table II.

Another regional data set for which land use comparisons were desired was the location and boundaries of geographic areas used by the Bureau of the Census for reporting population statistics. For all SMSA's within the test site the project compiled census tract maps keyed to the 1:100,000 scale photomosaics. For portions of the test region not inside SMSA's, sheets showing the location of county boundaries, also keyed to the basic map scale, were prepared. A reduction of a specimen sheet of one of the census tract maps is shown in figure 8.

Finally, overlays showing cultural features, place names, and transportation lines such as highways and railroads were prepared for each of the 48 sheets to provide locational cues for users of the land use and other data sets keyed to the same base map. Figure 9 presents a reduced specimen sheet of one of the cultural features maps.

Maps Derived from LANDSAT

For the land use mapping from LANDSAT imagery, investigators selected a scale of 1:250,000, based on a determination of geometric fidelity and spatial resolution of the imagery in the formats being used.

In the LANDSAT compilation, interpreters used color composite transparencies and existing USGS 1:250,000 scale topographic sheets as base maps. Figure 10 indicates the location and names of the 8-sheet series. A reduced specimen of one of the LANDSAT-derived land use maps is shown in figure 11. Although primarily mapped using Level I categories, the LANDSAT series includes 19 Level II and 4 Level III categories that could be identified from LANDSAT imagery.

Maps Derived from Skylab

The CARETS Skylab experiment utilized data obtained from the passing of Skylab 3 over a portion of the test region on August 5, 1973. These include photographic data from multispectral cameras (S190A) and from the Earth Terrain Camera (S190B). Of most interest to the investigators and the users of CARETS land use information were photographs from the S190B experiment, which were of sufficient spatial resolution to allow the identification of most of the Level II categories, and approached in capability the high-altitude aircraft photography. To assess the value of Skylab photographic data (S190B) as a land use mapping source, CARETS investigators compiled land use maps of the city of Fairfax, Virginia, both from high-altitude color infrared photography and from Skylab color photography. Researchers field checked and corrected the map derived from aircraft data to enable the measurement of the relative accuracy of the Skylab map by direct comparison. Using a systematic aligned sample they found the Skylab map to have an accuracy of 83 percent. Researchers found the S190B photography to provide relatively high-resolution data, which can be valuable for land use mapping and inventorying in urban as well as non-urban areas. Experience with various remote-sensor data users indicates that photography of the caliber of S190B could be of considerable value in the work of planning agencies at the State or regional level.

To allow a comparison of Skylab, LANDSAT, and high altitude aircraft photography data and CARETS map products, figures 12 to 21 present sample portions of imagery and maps at a consistent scale (1:100,000) that cover the same site, the Bowie, Maryland area of suburban Washington, D.C. Most of the maps are at their original scale. The imagery and some maps have been enlarged.

Other Maps at Various Scales

Researchers performed several mapping experiments using a variety of scales, to test procedures not employed in the standardized mapping of the entire test region. For example, a 1:1,000,000 scale map of "photomorphic regions" as derived from an uncontrolled LANDSAT black-and-white mosaic, produced a partitioning of the area into subregions of similar tones and textures. These "photomorphic regions" bore close resemblance to the categories mapped in the land use map in the National Atlas at a scale of 1:7,500,000 from data obtained many years before LANDSAT. If other environmental variables mapped at scales of 1:1,000,000 or smaller show similarity with patterns visible on LANDSAT imagery, LANDSAT may have additional value as a source of subregions for spatial sampling (3).

The large size of the CARETS area has limited other experimental mapping efforts to smaller test sites within the region. Foremost of these was the Norfolk test site, defined as the 1970 Norfolk-Portsmouth SMSA. Of great value in conveying to users the potential of remote sensing was a set of maps showing land use change from 1959 to 1970 in the Norfolk SMSA. Planners in particular were interested in seeing the display of the areas that had undergone change because of the greater environmental stresses placed on these areas of change. During the 11-year period, 184 km^2 (nearly 10 percent of the total test site area) changed from one Level I category to another. Of this change, 44 percent involved conversion from agricultural to urban uses.

In another Norfolk test site experiment, interpreters used 1:100,000 land use maps and LANDSAT color composite transparencies to detect 1970-1972 land use change at both Level I and Level II. In using 1972 high-altitude aircraft photography to verify the changes detected, investigators found instances of "false changes," those detected but not actually occurring. Many of these "false changes" can be accounted for by the different appearance of the terrain under different seasonal conditions (4).

A third Norfolk test site experiment involved the Level III land use mapping of the test site using high-altitude aerial photography at a scale of 1:100,000. The preparation of this map followed suggestions of users and of studies of the environmental impact of land use change, which indicated the requirement for greater detail than that provided by Level II.

The results of these and other experiments in the Norfolk test site have been compiled into one of the major reports of the CARETS project. This report will become part of the CARETS project final report.

Spatial Sampling for Accuracy Studies

The CARETS project exerted considerable effort in developing methods of measuring the accuracy of the various remote sensor-derived data sets that it evaluated. One way of assessing the accuracy of a new map is to compare it visually with another map of the same area accepted as "accurate." This visual comparison method is effective because the human eye and brain combine to make a very rapid and efficient processor of 2-dimensional data. But CARETS researchers desired a more objective and quantifiable method of comparing land use maps and assessing relative accuracy.

One method employed was to partition the land use map derived from remote sensor data into two categories: (1) areas where the interpreter had a high degree of confidence in his interpretation accuracy and (2) areas where the interpreter was unsure of the interpretation and that he marked as "questionable." Field checking determined that the areas of high interpreter confidence were also highly accurate in their classification. Areas of low interpreter confidence, on the other hand, were found to be inaccurate, 50 percent or more of the time. For the land use data set derived from high-altitude aircraft photography, researchers determined the correct classification of "questionable areas" by direct field verification to enable the use of this data set as a correct base against which to measure the accuracy of LANDSAT and Skylab interpretations.

The CARETS project also employed a comparison of classifications of sample points selected from each of two maps being compared, or from one map and ground or field observations from low-altitude aircraft.

A third method the project employed was a comparison of areas of each land or water category, as measured from each of the source data sets being compared. The use of this method, however, is contingent upon one's ability to measure satisfactorily the areas involved.

Major problems identified in the earlier CARETS accuracy assessments include:

(1) the mixture of different land use categories within a small area, which is the minimum-size mapping unit;

(2) the generalization of land surface types into units covering larger areas, as in lower-resolution sensors such as LANDSAT;

(3) errors due to imperfect registration of boundaries between categories on the maps being compared;

(4) errors due to generalization from larger map scales to smaller map scales;

(5) errors due to differences in interpreter applications of the classification system;

(6) residual errors due to interpreter misclassification;

(7) errors due to change between the times of the gathering of the two data sets.

After conducting the preliminary accuracy research, investigators undertook a comprehensive accuracy study using a stratified random sampling technique to select and obtain a variety of accuracy measurements. They used a 1-percent sample of the entire CARETS region, including 28, 5 x 5-km sample sites in non-urban areas and 15, 2 x 2-km sample sites from within urbanized areas as defined by the Bureau of the Census. The stratification into urban and non-urban categories resulted from the earlier studies that suggested different accuracy problems with the two kinds of areas.

CARETS investigators assessed the effect of generalization to smaller map scales using land use maps compiled at 1:24,000, 1:100,000, and 1:250,000, from the same remote sensing source (high-altitude aircraft photography), and field verification by ground or low-altitude aircraft observation or both. Preliminary results indicated lower accuracies than expected for a point-by-point comparison using a 1-km sample grid overlay on all the sample sites.

ACCURACY OF LAND USE CLASSIFICATION AT SAMPLE POINTS

FOR THREE SCALES, USING SAME SOURCE MATERIAL

Scale	Accuracy
1:24,000	85%
1:100,000	77%
1:250,000	73%

The above figures obscure the dependency of accuracy on the type of land use--the Level I categories at the three test scales.

COMPARISON OF ACCURACY OF LEVEL I INTERPRETATIONS AT THREE SCALES

Scale	Level I Category, Percent Correct Identification				
	1	2	4	5	6
1:24,000	79	88	91	98	72
1:100,000	80	83	83	88	67
1:250,000	69	75	79	78	72

Investigators also compared samples derived from Level I interpretations of LANDSAT imagery and Level I interpretations of high-altitude aircraft imagery at the same scale. They identified the Level I land use at the center points of each 1-km cell within each sample site on the LANDSAT- and aircraft-derived maps, and found the LANDSAT maps to have an overall accuracy of 70 percent as compared to the 77 percent accuracy for the maps from high-altitude photography at a scale of 1:250,000. The major land use types in discrepancy between the two maps were found to be in the urban and built-up area (Category 1). The following table illustrates accuracy as a function of Level I land use categories:

COMPARISON OF ACCURACY OF ERTS AND AIRCRAFT INTERPRETATIONS,

LEVEL I POINT SAMPLE

	Level I Categories, Percent Correct				
	1	2	4	5	6
Aircraft	69	75	79	78	72
LANDSAT	34	67	77	82	61

The results cited above are examples taken from a study not yet completed. The final results will be reported in one of the major sections of the final report.

Cost Factors

One of the desires of the CARETS investigation was to produce cost documentation and calculations so that the results could be quantitatively compared with those of other investigators, and so that cost factors could be available for use in planning and budgeting follow-on operational efforts. The difficulties of assessing and evaluating costs arise because of the complexity of the processes of extracting land use information, compiling maps, and delivering information products derived therefrom to users (a process that involved many intricately interwoven steps, most highly dependent on other steps in a sequence). Moreover, the monetary inflation occurring throughout the period of performance of the CARETS project increased costs in different proportions for different aspects of the labor and materials inputs. Nevertheless, the CARETS project has exerted considerable effort to present the cost information in as detailed a breakdown as possible, in anticipating the usefulness of at least some components of these cost data to readers of the final report. When comparing the accuracy of various data sets derived from different remote sensor systems, one should realize that different costs are associated with different levels of accuracy. Therefore a prospective user or developer of an operational land use information system should take careful account of tradeoffs between cost and accuracy. Greater accuracy can be obtained, up to a point, by greater investment in detailed data-collection and interpretation activities and in improved technology for obtaining and processing such data.

Two illustrations of documentation of costs of the CARETS project are presented in tables III and IV. Complete documentation of the effort will be presented in a cost section of the final report. Table III compares mapping costs (derived from sampling procedures described previously so that comparisons between cost and accuracy could be made) at each of the three scales tested: 1:24,000, 1:100,000, and 1:250,000. The costs to produce maps at these three scales from high-altitude photography are functions of several processes in the compilation, including acquiring the data, interpretation, preparations for reproduction, and reproduction and publication. Recognizing that actual operational experiences may be quite different from those of mapping 1 percent sample sites, investigators attempted to combine the operational and sampling figures through the experience obtained in mapping the entire CARETS region at a scale of 1:100,000, and using that experience to interpolate between costs of sample mapping at 1:24,000 and 1:250,000. The costs for data acquisition are those presently listed by the EROS Data Center at Sioux Falls.

The interpretation costs are based on an average per hour cost of $20.00. Table III shows that the cost of interpretation using the same source data at 1:24,000 is approximately 2 times that at 1:100,000, which in turn is approximately 1.2 times that of interpretation at 1:250,000. The cost of interpretation, however, is only a portion of the total cost to produce a land use map product.

Table IV summarizes cost estimates per km^2 for deriving land use maps at 1:250,000 from high-altitude aircraft photography and LANDSAT imagery. In this example, interpreters mapped land use using USGS topographic sheet, black and blue line color separation plates, as mapping bases. The project acquired imagery for each sensor at the mapping scale. The costs that differ for the two involved those to acquire the aircraft photography and LANDSAT imagery, those to set up the mapping base, and those to complete the compilation. Table IV also lists standardized labor costs as $20.00 per hour. The time for compilation and cartography is based on the experience of the CARETS project, and the costs of reproduction and publication are estimated from other USGS experience. Table IV reveals that the cost to produce a Level I land use map from high-altitude aircraft photography amounts to approximately $0.48 per km^2. The cost to produce a comparable Level I map from aircraft photography is approximately four times the cost to produce a land use map from the lower-resolution LANDSAT imagery. The difference in the two, results primarily from the greater interpreter time needed to analyze the greater amount of detail on the aircraft photography.

A comparison of costs of producing the maps with accuracy percentages reveals that the range in accuracy difference is relatively small. The high cost of producing a land use map at 1:24,000 ($11.93/km^2) is not offset by the increased accuracy. Mapping at a scale of 1:100,000 in the rural areas is approximately twice as expensive as mapping at 1:250,000 using the same source materials. The accuracy at the larger scale is only slightly improved over the accuracy at the smaller scale. The decision to map at either 1:100,000 or 1:250,000, therefore, should depend upon the intended utilization of the maps.

ENVIRONMENTAL IMPACT MODULE

The environmental impact module of the CARETS investigation consists of several demonstrations illustrating the relationships among land use and various environmental factors or environmental quality measures. Results of these studies are presented in separate reports, which will be compiled as portions of the CARETS final report.

Air Quality

In the Norfolk test site the CARETS project conducted a study of the impact of land use patterns and area source control strategies on air quality. Compiling an estimated average of the annual winter area source emission from CARETS Level II land use categories (Level III was required for residential areas) and placing this inventory into a diffusion model, the investigators estimated sulfur dioxide emissions in the Norfolk-Portsmouth SMSA for 1972. Then using the Southeastern Virginia Planning District Commission's map of projected land use for 1985, they predicted sulfur dioxide emissions for 1985. The researchers predicted a measurable deterioration in sulfur dioxide levels if expected land use changes with their attendant expansion in area sources of air pollutants occur.

Predictions of Streamflow Characteristics

In research designed to evaluate the effectiveness of CARETS land use data in improving estimates of streamflow characteristics in selected drainage basins in Maryland, Delaware, and Virginia, investigators tested Level I and Level II land use categories from both aircraft and LANDSAT data. For this study researchers selected 39 small drainage basins where stream gaging records were available. Portions of two of these basins (designated 5945 and 6495) are shown in figure 21. Comparison of figure 21 with figures 14, 15, 16, and 17 indicates the variety of types of land use within these particular basins. Other stations in the sample were less affected by urban development, and served as control stations to indicate stream behavior under more natural vegetation coverage. The investigators compared streamflow predictions made using a standard USGS multiple regression technique, with predictions made by adding regression terms incorporating area covered by the various land use types within the drainage basins. Preliminary results have indicated that significant improvements in the estimation of streamflow characteristics are obtained by adding the information from the land use measurements. These improvements result from use of data derived from both high-altitude aircraft photography and LANDSAT imagery. Implications of this work are that better information on streamflow characteristics might be made available to water resource planners and others, and at the same time costs reduced by reducing the number of gaging stations, if quantitative information on land use and land cover were available. Examples of results obtained in this study are shown in the following table:

PERCENT IMPROVEMENT OF PREDICTION OF STREAMFLOW CHARACTERISTICS,

USING LEVEL I LAND USE DATA FROM HIGH-ALTITUDE AIRCRAFT

Streamflow characteristic	Percent Improvement
Mean discharge, June	14
Mean discharge, July	20
Mean discharge, September	11
Mean discharge, November	17
7-day, 2-year low flow	13
3-day, 2-year flood volume	15
50 percentile discharge	26

Coastal Zone Management

Two studies illustrated applications of remote sensing and land use information to coastal zone management. In one, investigators examined the Atlantic coastal zone of CARETS with respect to the various land use and land cover categories identified, and illustrated how the natural processes in foreshore, dune, and back bay environments bring about differing responses to man's modification of these ecologically delicate landscapes (5). Investigators recommended more detailed land classification categories to improve the characterization of the various coastal types in terms of their stability or vulnerability to processes of man and nature.

The work of these researchers has already contributed to a major management decision by one of the agencies with coastal zone responsibilities. The National Park Service has decided to discontinue "protection" of seaward sides of barrier beaches from wave erosion, realizing that the protective actions formerly taken interfered with the natural process of sand overwash and replenishment on the landward or lagoon side of the barrier islands. The land use and land cover information provided by CARETS indicates not only present locations of the man-modified types, but also serves as a data base to assess the effects of future modifications by nature and man.

A second study investigated certain environmental problems arising from land use changes in the city of Virginia Beach, Virginia. By examples from field observations, land use information derived from CARETS remote sensing sources, and other information provided by local planners, researchers explained how environmental problems such as barrier beach stabilization, beach replenishment in the commercial and hotel zone, and sewage disposal in urbanized areas have resulted from decisions made in the absence of full understanding of the coastal and wetland ecosystems that are vital to the well-being of the city

Compatibility with Geological Conditions

Researchers prepared a number of experimental surficial geologic maps, designated "landform and surface materials maps," to assist in the relating of land use to relevant surficial conditions such as the engineering characteristics of the near-surface materials. CARETS investigators expected that such information, keyed to the same mapping system as the land use maps, would aid planners in identifying characteristics most suitable from a geological and hydrological standpoint for future development of various land use types. Figure 7 presents a reduced specimen of one of these sheets in the coordination jurisdiction of the Metropolitan Washington Council of Governments (Washington SMSA). The key to the mapped categories is presented in table II.

Quality of Ground Water

A study conducted at the request of the Environmental Protection Agency investigated the uses of remote sensing for identifying the causes of man-made ground water pollution. Using examples of remote sensing data from the Norfolk test site, the investigators cite the complex chain of events that may lead to the pollution of ground water by man's activities, and the visible phenomena that can be observed by the remote sensors in a search for pollution indicators. Among the latter are the actual pollutants themselves, producers and activities that generate actual or potential pollutants, conditions associated with those activities, and surface cover types where one might expect to find detrimental activities, conditions, or pollutants. As a part of this study, researchers developed a special-purpose Level III land use classification and used it to map the Norfolk test site at a scale of 1:100,000.

Environmental Impact Statements

To inquire into ways in which CARETS products might be used to assist in estimating environmental impacts of proposed projects, as required by law, investigators reviewed the 150 environmental impact statements filed in the

CARETS region during a 4-year period. These statements fall into seven categories:

(1) construction of transportation and communication facilities;

(2) construction of power plants and power lines;

(3) urban renewal, new town development, and multi-story building construction;

(4) construction of watershed protection and development facilities;

(5) construction of waste treatment disposal facilities;

(6) navigation improvement and beach erosion control projects;

(7) establishment of conservation areas.

Land use data of the type produced by the CARETS project can be of assistance in developing portions of many of these impact statements. For such information to be of continuing value, it should be available operationally, in quick response to queries from the agency responsible for the environmental impact statement. Also, the existence of such a land use information system should be made widely known, as environmental impact statements are often written by consultants working under short deadlines and requiring quick access to whatever input data are required.

Land Use Climatology

The major CARETS project effort in studying the environmental impact of land use, and one that preceded the CARETS project as a NASA-funded investigation in the USGS, is a study of the surface energy balance and consequent climatological effects of man's local modifications of the land surface, as measured with the assistance of remote sensors. Although the concentration of effort has been the study of the urban heat island and other aspects of the climates of cities, the results have application as well to other types of land use, and the project has been given the generalized name of "land use climatology."

An integral part of this research effort has been the development and testing of an urban climate simulation model based upon the energy conservation equation (6). Each of the terms in this equation, net radiation, soil heat flux, sensible heat flux, and latent heat flux, is a complex function of certain environmental variables. Several of these variables (albedo, soil thermal properties, wet fraction, and aerodynamic roughness) are amenable to measurement and spatial analysis using remote sensor data. In this light, the CARETS Skylab investigation and its precursor aircraft mission have employed analysis of calibrated multispectral scanner data in constructing radiation maps of an urban area (the Baltimore test site) and in coupling this information with the operation of the urban climate simulator.

The precursor mission to the CARETS Skylab climatology investigation was flown by the Environmental Research Institute of Michigan aircraft, under contract to NASA as support to this USGS project, over the Baltimore test site in May 1972. Researchers produced isorithmic maps of radiation temperatures derived from multispectral scanner data, which successfully showed the development of the urban heat island from sunrise to early afternoon. Also this research produced net radiation maps based in part on albedos determined from the scanner data. These maps, reflecting a single set of synoptic conditions, provided a base of observed environmental information against which the simulator was compared to see how well it could predict the climatic condition that occurred at that time. Results showed the simulator capable of providing close approximations to the energy balance conditions for specific land uses. In similar fashion, investigators analyzed thermal data obtained from the Skylab 3 mission. The results will appear in the final report of the Skylab portion of the CARETS project.

Using a modified version of the gray window model developed by R. W. Pease and applied during earlier NASA aircraft missions, researchers calibrated thermal data from the S192 multispectral scanner. The gray window model converts a radiant energy signal received at the scanner in space to its value when emitted by the Earth's surface by compensating for atmospheric attenuation (turbidity and water vapor) and for upward emitted radiant energy from the atmosphere. Researchers also used the scanner data to produce a map of thermal radiance values for the Baltimore-Washington area. A hand-colored version of this map is presented in figure 22. Preliminary results from this experiment indicate that land use-related components of urban climate can be measured and modeled with the aid of input data from spaceborne remote sensors. These results may have applications to urban land use planning, in making information on the climatological consequences of land use patterns in and around cities, available to input to future urban design. With energy shortages looming, opportunities to conserve energy inputs to urban heating and cooling systems may be welcome.

USER INTERACTION AND EVALUATION MODULE

The user interaction and evaluation module of the CARETS project was designed to obtain the input of local, regional, State, and Federal agencies and university and private research community users of land resource information into the development of a regional information system; to provide users with assistance and data resulting from CARETS research; and to have user organizations evaluate how well the CARETS products meet their needs.

On June 11, 1971, the USGS conducted a conference of potential users of land use data products at the National Academy of Sciences in Washington, D. C. This conference introduced the CARETS project to the user community, helped establish contacts with users, and provided insight into the land use data needs of agencies interested in land resources. User responses at this conference combined with results of prior technical evaluations led to the decision to establish the CARETS regional mapping scale at 1:100,000.

As the CARETS project progressed, CARETS investigators established an experimental regional information center in the Geography Program office to organize the user services role of the project and to maintain contacts with the user community. At the CARETS Information Center (CIC), visitors had access to remote sensor data and project products. The lack of funds and personnel to provide such services as imagery reproduction, search and retrieval assistance and imagery interpretation assistance resulted in a reduction in the center's intended functions. The USGS's Public Inquiries Office's "Open File" system took on the responsibility of making map products available to users, but the complexity of the system discouraged many users from obtaining copies of the maps. Nevertheless, the CIC and the Public Inquiries Office provided services to numerous user agencies.

When most CARETS products were completed, investigators began the user evaluation phase of the project. In cooperation with the Metropolitan Washington Council of Governments (MWCOG) the CARETS project conducted an initial user evaluation workshop in March, 1974. At this workshop planners from MWCOG member agencies were introduced to the project and received a packet of sample products to be evaluated. The CARETS research group held a similar workshop for State and regional agencies and for Federal agencies in the fall of 1974. Approximately 2 months following the workshop, investigators conducted evaluation interviews with the representatives of the organizations attending the workshop.

The evaluation of CARETS land use and related products revealed that most user agencies interviewed at all governmental levels require more detailed data than those provided by the CARETS project. Table V presents the number of agencies (by major function) reporting utility in higher detailed Level III data. Level II data, though reported useful in support of agency functions by a majority of users interviewed and considered of high value by several user agencies, were generally considered of secondary utility by most users. Although such organizations as the Maryland Department of State Planning, the Virginia Division of State Planning and Community Affairs, the New Jersey Department of Natural Resources and Environmental Control, the Baltimore District of the Army Corps of Engineers, and several county, regional, and private organizations used the Level II land use maps in support of their functions, the greatest use for such data has been for display purposes or for providing a generalized view of land use.

Table VI summarizes the responses of user agencies toward products evaluated, revealing a highly positive response toward NASA-flown high-altitude aircraft photography and the USGS 7.5 minute orthophotoquads. Few agencies, however, found utility for the Level I LANDSAT-derived land use maps.

Recommendations resulting from the evaluation reflect the need to establish a flexible and reliable system for providing more detailed raw and processed land resource information as well as the need to improve the methods of making information available to users. Furthermore, some users expressed the need for the USGS to devote more effort toward educating potential users in the use of new data products.

GEOGRAPHIC INFORMATION SYSTEMS MODULE

The decision to develop a computer capability as an essential part of the CARETS project was based upon four considerations:

(1) Large amounts of land use information were needed in quantitative form for the environmental modeling and monitoring applications envisioned at the start of the project. This conclusion was derived from a number of studies, including one conducted for feasibility test and system design recommendations prior to the formal beginning of the CARETS project.

(2) A need existed for flexibility in land use information retrieval, by a variety of geographic areas and user jurisdictions.

(3) A need existed for area measurements and summaries for a variety of uses, including the previously cited work on stream basin charactistics.

(4) A need existed for quantitative comparisons between LANDSAT- and aircraft-derived land use data sets, according to the original project design.

All of these considerations led to the requirement that the data portrayed on CARETS maps be quantified for input to, processing, and output from, a computerized information system.

Selection of the Polygon System

CARETS project investigators obtained the advice of a group of consultants, the International Geographical Union Commission on Geographical Data Sensing and Processing. This group has wide knowledge and experience in the area of geographic information systems, including those having the capability of incorporating map or spatial data and retaining location on the earth's surface as an essential identifier for each data element. Investigators surveyed the available systems, hardware, and software and concluded that a grid system, though simpler to handle with present computer processing capabilities, would be too costly for handling the large amounts of input data, given the size of the CARETS region and the mapping scale and minimum mapping unit (4 hectares at 1:100,000). Therefore they decided to use a "polygon" type input system, in which the boundaries between land use categories, as drawn by the original interpreters, would be digitized directly and input to the system with as little loss in information as possible.

Since no capability existed within the USGS for volume digitizing of the number of maps required for CARETS, external digitizing capability was sought. After the issuing of a request for proposal and a thorough evaluation of proposals and capabilities, investigators decided to use the already operational capability of the Canada Geographic Information System (CGIS), Department of the Environment, Government of Canada. As of this writing, digitizing and processing of the CARETS data are approximately half completed by CGIS.

CARETS Tests in USGS as Part of In-House Information System Development

Shortly after the CARETS project began, investigators decided to develop an operational geographic information system for handling land use and related data in the Geography Program, USGS. In collaboration with the CARETS investigation, researchers conducted early tests contributing to the development of this new operational capability and making use of CARETS data and results of preliminary surveys of equipment and systems capabilities. Many of the information-handling capabilities desired as part of the CARETS project are being developed by the Geographic Information Systems Branch of the Geography Program for support of the new national land use mapping effort (Land Use Data and Analysis Program).

CARETS Information Systems Developments to Date

The CARETS project information systems effort was subject to a number of unavoidable delays, largely related to lengthy computer-services procurement actions, including contract negotiations between the governments of the United States and Canada. Work is proceeding satisfactorily, however, on digitizing (by means of the CGIS drum scanner) and data processing, including the capability of overlaying one polygon map with another, and calculating the areas of categories depicted on one of the maps compared to those on the other. At the time of the presentation at the NASA Earth Resources Survey Symposium, June 1975, CGIS has already delivered to USGS the complete results of processing land use data derived from LANDSAT maps for the entire test site, overlayed on county boundaries. This data set, which will be made available as a portion of the final report, contains measurements of each land use type as mapped by the interpreters, summed for each county and independent city within the CARETS region. Table VII presents sample Level I land use area summaries and percentages for the District of Columbia and for States or portions of States within the CARETS region.

Other processing will be performed on data from aircraft photography-derived land use maps for the Washington, D.C. and Norfolk-Portsmouth SMSA's and selected additional sheets. Other maps to be digitized for the two SMSA's include the 1970-1972 land use change, census tract, and landforms and surface materials maps, thus making possible the automatic correlations of data from the basic land use data set (1970) with those from these other data sets. Illustrations of these correlations and their applications will be presented in the final report.

In addition to the major digitizing and data-processing tasks, investigators are performing an experiment in interaction via computer graphics terminal, linked to the CGIS system at a remote location. Experimental output from this system is illustrated in the map (taken directly from CRT display) shown in figure 20. Derived from aircraft data, this map resulted from a query for location and amount of one type of land use only--in this case urban residential (category 11). Such a system is capable of a large number of possibilities of data processing and quick retrieval. Investigators believe that this capability will greatly enhance the value to many users of products derived from aircraft and satellite remote sensor sources.

CONCLUSION AND REOMMENDATIONS

In the CARETS project, each sensor system tested had advantages, which were demonstrated by producing experimental land use maps and other data products, applying them to typical problems encountered in regional planning and environmental impact assessment, and presenting the results to prospective users for evaluation. An archival collection of imagery, maps, data summaries, and technical reports has been assembled, constituting an environmental profile of the central Atlantic region, which will serve as a data base for future applications and research. Such products will also serve as a guidepost for investigating the design criteria of future operational land use information systems.

Responses of users revealed the heterogeneity of the user community and hence the difficulty of finding standardized products such as land use maps that were broadly applicable to user needs. LANDSAT data and 1:250,000 maps derived therefrom satisfied few of the users, but the relatively low cost for the regional-scale land use overview suggests the appropriateness of LANDSAT products for users with that particular need. Low-cost methods for user access to LANDSAT computer-compatible tapes would have increased user interest. Skylab high-resolution (S190B) photography was closer to aircraft photography than to LANDSAT imagery in capability and would have satisfied a number of potential users, but its one-time and limited areal coverage was a handicap in securing adequate user response.

The preliminary recommendations are summarized as follows:

(1) The most useful single product for CARETS users of land resource information is the high-altitude aircraft color infrared photography. Its potential for supplying the diversity of information required by users far exceeds the use made in the standard CARETS maps at 1:100,000. In the CARETS metropolitan areas, 1:100,000 maps are marginal for many users at the land use decision-making level. They are also of marginal value for those who need to evaluate specific environmental impacts. Such users need maps at a scale no smaller than 1:24,000, a scale well within the capability of the high-altitude photography. Therefore such imagery and maps should be included in a metropolitan land use information system if present users' needs are to be met.

(2) Lower-resolution imagery and smaller-scale maps are useful for certain users who are engaged in large-area overview surveys, not requiring information input at the land parcel or household unit. Speed and cost factors may justify use of such products in addition to the more detailed products needed in metropolitan areas.

(3) Value of remote sensing data and maps at all levels of detail would be increased if such information could be provided operationally on a regular basis.

(4) Archival imagery and computer-compatible tapes should be made easily available to users at a variety of levels of sophistication.

(5) A post-Skylab thermal capability is needed, along with improved methods of processing and mapping multispectral data, to capitalize on the promising prospects, indicated by the Skylab experiment, for delimiting urban heat island and other ramifications of altered surface energy regimes resulting from changing land use and land cover patterns.

(6) Much more effort is needed to improve compatibility of Federal, State, and local land use information programs and to facilitate exchange of imagery, computer tapes, and land use information derived therefrom. This recommendation arises from the observation that many different land use data collection and mapping programs are being conducted simultaneously, given the present near-autonomy of most land use user agencies.

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TABLE I --LAND USE CATEGORIES IN THE CENTRAL ATLANTIC REGIONAL

ECOLOGICAL TEST SITE DATA BASE

Level I Categories and Map Notation Used	Level II Categories and Map Notation Used
1 - URBAN & BUILT UP	11-Residential 12-Commercial and services 13-Industrial 14-Extractive 15-Transportation, communications, and utilities 16-Institutional 17-Strip and clustered settlement 18-Mixed 19-Open and other
2 - AGRICULTURAL	21-Cropland and pasture 22-Orchards, groves, bush fruits, vineyards, and horticultural areas 23-Feeding operations 24-Other
4 - FORESTLAND	41-Heavy crown cover (over 40%) 42-Light crown cover (10% to 40%)
5 - WATER	51-Streams and waterways 52-Lakes 53-Reservoirs 54-Bays and estuaries 55-Other
6 - NON-FORESTED WETLAND	61-Vegetated 62-Bare
7 - BARREN LAND	72-Sand other than beaches 73-Bare 74-Beaches 75-Other

TABLE II--LANDFORMS AND SURFACE MATERIALS CLASSIFICATION LEGEND

LANDFORMS-Digits 1 and 2

No Slope, No Relief	Water	00
	Marsh, swamp	01
	Bogs	02
	Beaches	03
Little Slope, Small Relief	Flats, undissected	11
	Flats, dissected	12
	Flood plains	13
	Terraces	14
Gentle to Steep Slope, Moderate Relief	Sand dunes	21
	Hills	22
	Low Ridges	23
	Valley sides	24
	Gulley sides	25
Steep Slope, High Relief	Ridges	31
Negative Relief	Sinkholes	62
	Crater lands	64
	Vertical pits	66
Man-Made Features	Made land (fill)	81
	Sanitary landfill	82
	Waste (mine)	83
	Quarries, pits	84
Miscellaneous	Mined-out areas	91
	Unstable slopes	92

LITHOGRAPHY-Digits 3 and 4
(Bedrock more than 9 feet below the surface)

Unconsolidated Deposits	Water	00
	Clay, silt	01
	Sand	02
	Gravel	03
	Boulders	04
	Colluvium	05
	Talus	06
	Organic	07
Igneous Rocks	Granite	11
	Gabbro, diorite	12
	Basalt, diabase, felsite, rhyolite	13
Metamorphic Rocks	Phyllite	21
	Schist	22
	Gneiss	23
	Quartzite	24
	Metabasalt	25
	Marble	26
	Slate	27
	Serpentine	28
Sedimentary Rocks	Shale, siltstone, mudstone	30
	Sandstone	31
	Conglomerate	32
	Limestone, dolomite	35

MISCELLANEOUS DESCRIPTORS-Digits 5 and 6

High water table	01
Shallow soil (bedrock less than 9 feet below surface)	11

TABLE III-- PRODUCTION COSTS* PER KM^2 FOR LEVEL II LAND USE MAPS** AT THREE SCALES

	1:24,000	1:100,000	1:250,000	
Data Acquisition[1]	$.14	$.06	$.05	[1]Based on 50 frames for 10,000 km^2 1:24,000 ea. frame $28.00 1:100,000 ea. frame $12.00 1:250,000 ea. frame $10.00
Mosaic Construction[2]	$6.00	$.70	$.16	[2]Based on average estimate for mosaic construction by the Topographic Division (Interview with Bernard Kelley, USGS Topographic Division, 4/11/75)
Interpretation & Edit[3] ($20/hr)	600 hrs/ 10,000 km^2 $1.20	300 hr/ 10,000 km^2 $.60	250 hr/ 10,000 km^2 $.50	[3]Actual time from interpreting at 1:100,000 - estimates at 1:250,000 and 1:24,000 interpolated from sample site interpretation. Cost estimates based on USGS Topographic Division per hour rates, 1975.
Cartographic[4] ($12/hr)	200 hr/ 10,000 km^2 $.24	100 hr/ 10,000 km^2 $.12	80 hr/ 10,000 km^2 $.096	[4]Based on actual time for cartographic work at 1:100,000 interpolated to 1:24,000 and 1:250,000, and assumed to be 1/3 the interpretation time
Marginalia[5]	$1.25	$.08	$.010	[5]Based on actual costs to compile collars for CARETS maps at 1:100,000, and assumed to be the same per map at each scale
Reproduction[6]	$.10	$.01	$.002	[6]USGS cost to produce positive film transparencies at scale
Publication Cost[7]	$3.00	$.18	$.06	[7]Cost of publication by the USGS (Interview with Bernard Kelly, USGS Topographic Division, 4/11/75)
TOTAL	$11.93	$1.75	$.88	

*1975 dollars

**At scales and formats conforming to the USGS 1:24,000 and 1:250,000 topographic map series and CARETS 50 x 50 km 1:100,000 photomosaics.

TABLE IV--COMPILATION AND PUBLICATION COSTS* PER KM^2 FOR A LEVEL I LAND USE MAP**

	High-Altitude Photography 1:250,000	LANDSAT 1:250,000	
Data Acquisition from EROS D.C.[1]	$.05	$.01	[1]Based on 50 frames of high-altitude photography for 10,000 km^2 1:250,000 (4" x 5") at $10 ea. and a Cibachrome transparency from commercial firm at $41.50 (20" x 24") of LANDSAT
Mapping Base/ no mosaic[2]	$.15	$.01	[2]Based on rectified high-altitude photography with a transparency of the black and blue line plate at 1:1250,000, and on LANDSAT Cibachrome print with a transparency of the black and blue line plate: 5 1:250,000 high-altitude prints $10 ea. $10,000/50,000$km^2$=$.05/km^2 5 frames rectification $20 ea. $100/10,000 km^2=$10/km^2 1 line base map $20 ea. $20/20,000 km^2=$.001/km^2
Interpretation $20/hr[3]	80 hr/10,000 km^2 $.16	15 hr/10,000 km^2 $.03	[3]Interpretation time, estimated for interpretation from high-altitude photography and actual time for LANDSAT interpretation
Cartographic $12/hr[4]	40 hr/10,000 km^2 $.05	8 hr/10,000 km^2 $.01	[4]Cartographic time considered to be half the interpretation time, at Level I mapping
Marginalia[5]	$.01	$.01	[5]Based on the actual costs to compile collars for CARETS maps at 1:100,000 and assumed to be the same per map at each scale
Reproduction[6]	($18/sheet) $.01	($18/sheet) $.01	[6]USGS cost to produce positive film transparencies at scale
Publication Cost[7]	$.06	$.06	[7]Cost of publication by the USGS (interview with Bernard Kelley, USGS Topographic Division, 4/11/75)
TOTAL	$.48	$.12	

* 1975 dollars
** conforming to the USGS 1:250,000 map series

TABLE V--CARETS USER AGENCY LAND USE DATA GENERALIZATION REQUIREMENTS

MAJOR AGENCY FUNCTIONS	Number of Agencies								
	Level I			Level II			Level III		
	Primary Utility	Secondary Utility	Tertiary Utility	Primary Utility	Secondary Utility	Tertiary Utility	Primary Utility	Secondary Utility	Tertiary Utility
Land Use Planning (20)	0	1	4	3	12	0	18	0	0
Transportation Planning (5)	0	0	0	0	2	0	4	0	0
Environmental Protection	0	0	0	1	4	0	4	0	0
Mineral/Energy Survey (3)	0	0	0	0	1	0	3	0	0
Disaster Warning Assessment (2)	0	0	0	0	0	0	2	0	0
Water Resource Planning (2)	1	0	0	0	2	0	2	0	0
Fish & Wildlife Management (2)	0	0	0	0	2	0	2	0	0
Agricultrual Management (2)	0	0	0	1	1	0	2	0	0
Socio-Economic Data Collection (1)	0	0	1	0	1	0	7	0	0
Utility Planning (1)	0	0	0	0	1	0	1	0	0
Economic & Community Development (2)	0	0	0	1	1	0	2	0	0
Multi-Purpose Resource Managment (2)	1	0	0	0	1	0	1	0	0
Total (47)	2	1	5	6	28	0	43	0	0

*Excludes organizations primarily engaged in research and agencies not having an actual need for such data.

Numbers in parentheses indicate number of agencies participating.

TABLE VI --PRODUCTS REPORTED USEFUL IN SUPPORT OF AGENCY FUNCTIONS

Number of Agencies Finding Products Useful

	High-Altitude Photography	Skylab Photography	LANDSAT Imagery	Photomosaic	Level II Land Use Map, 1:100,000	1970-72 Land Use Change, 1:100,000	Census Tract & Political Boundary Overlay	Cultural & Locational Features Overlay	Level I Land Use, LANDSAT-Derived, 1:250,000	Landforms & Surface Material Map	USGS Orthophotoquads	Orthophotoquad Land Use Overlay	LANDSAT Gridded Image	Computer Plots of Land Use	Computer Data Listings
Washington Area Local Planning Agencies (11)	11	*	1	7	10	10	3	3	1	9	11	*	*	9	9
Regional Planning Agencies (5)	5	0	4	3	4	4	3	3	4	4	2	1	1	1	3
State Agencies (22)	12	7	9	11	14	12	8	6	4	8	11	10	6	10	10
Federal Agencies (21)	17	7	6	7	12	12	5	4	2	7	13	4	1	4	11
Research and University Community (6)	5	3	3	2	2	3	1	1	0	2	2	2	0	1	2
TOTAL	50	17	22	23	32	31	17	14	10	21	28	17	8	16	27

*Products not evaluated by local planners.

Numbers in parentheses indicate number of agencies participating.

TABLE VII--CENTRAL ATLANTIC REGION LEVEL I 1972 LAND USE AREA SUMMARIES DERIVED FROM LANDSAT IMAGERY DIGITIZED BY THE CANADA GEOGRAPHIC INFORMATION SYSTEM

		1 Urban	2 Agriculture	4 Forest	6 Wetland	7 Barren	Total Land	Total Water	Total Land & Water
Delaware	Km^2	321.6	2846.7	1599.7	322.6	.7	5091.3	1102.2	6193.5
	% Land Area	6.3	55.9	31.4	6.3	0			
D.C.	Km^2	138.0	0	20.6	0	0	158.7	10.3	168.9
	% Land Area	87.0	0	13.0	0	0			
Maryland*	Km^2	1844.3	10170.0	8767.4	612.0	18.7	21412.5	6054.5	27466.9
	% Land Area	8.6	47.5	40.9	2.9	.1			
New Jersey*	Km^2	1150.2	2830.7	4666.5	851.6	0	9499.0	1682.5	11181.4
	% Land Area	12.1	29.8	49.1	9.0	0			
Pennsylvania *	Km^2	1279.1	3150.3	1203.1	0	0	5632.5	59.5	5692.0
	% Land Area	22.7	55.9	21.4					
Virginia*	Km^2	1840.0	9459.3	20485.3	637.0	54.5	32476.0	6782.5	39258.5
	% Land Area	5.7	29.1	63.1	2.0	.2			
TOTAL	Km^2	6573.2	28457.0	36742.5	2423.2	74.0	74269.9	15691.4	89961.3
	% Land Area	8.9	38.3	49.5	3.2	.1			

* Includes only portion of State within CARETS region.

CARETS CONCEPT DIAGRAM

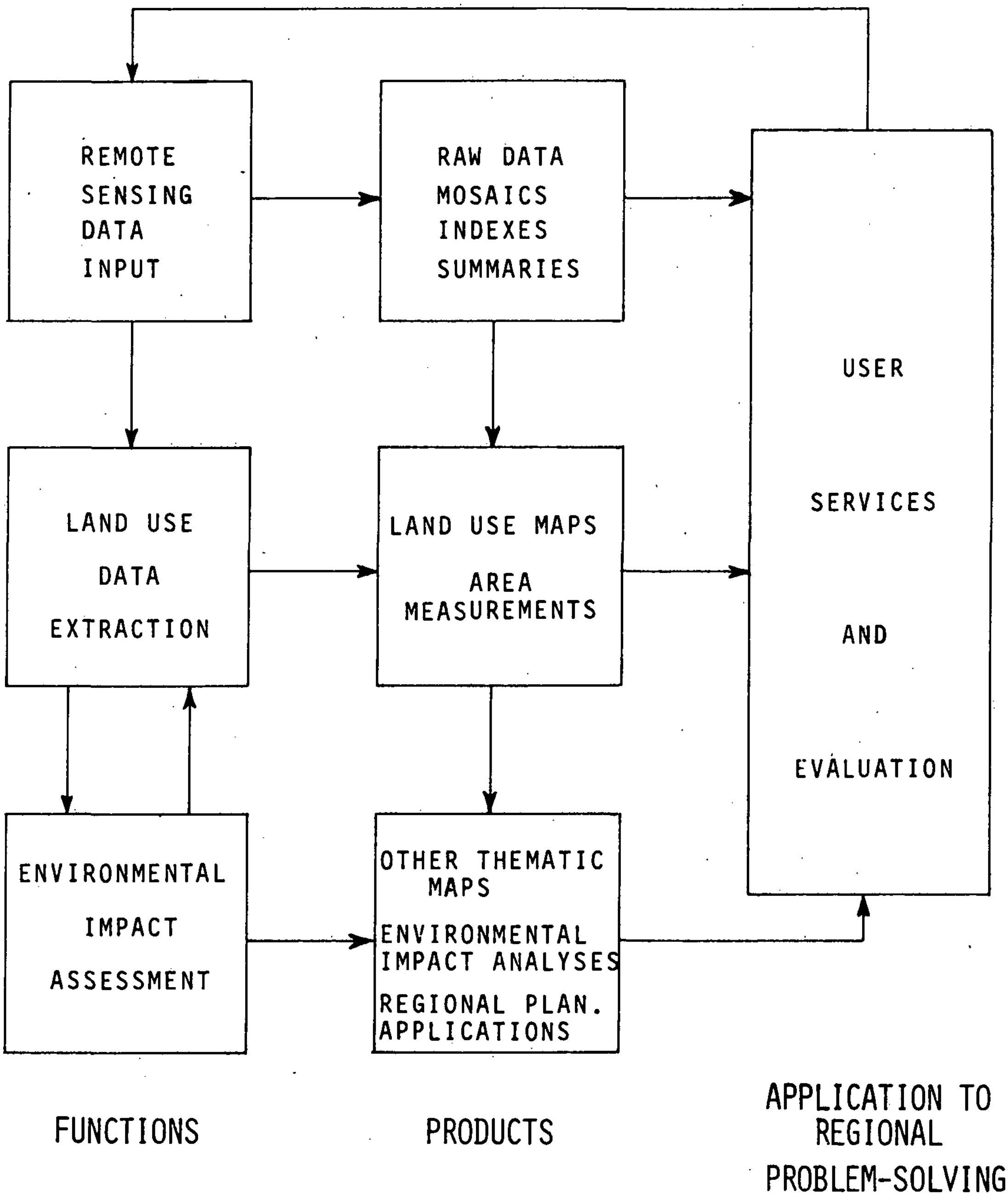


Figure 1

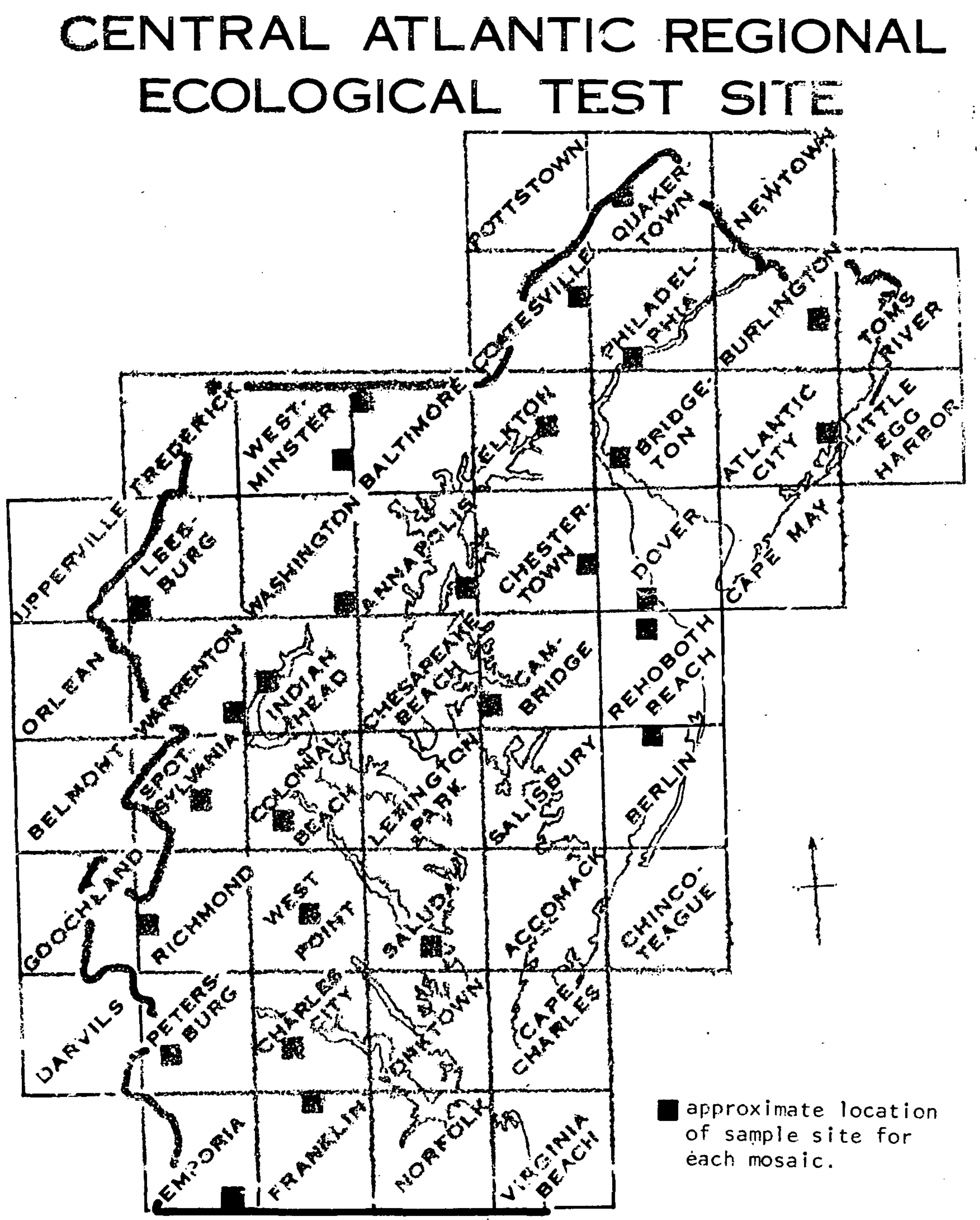
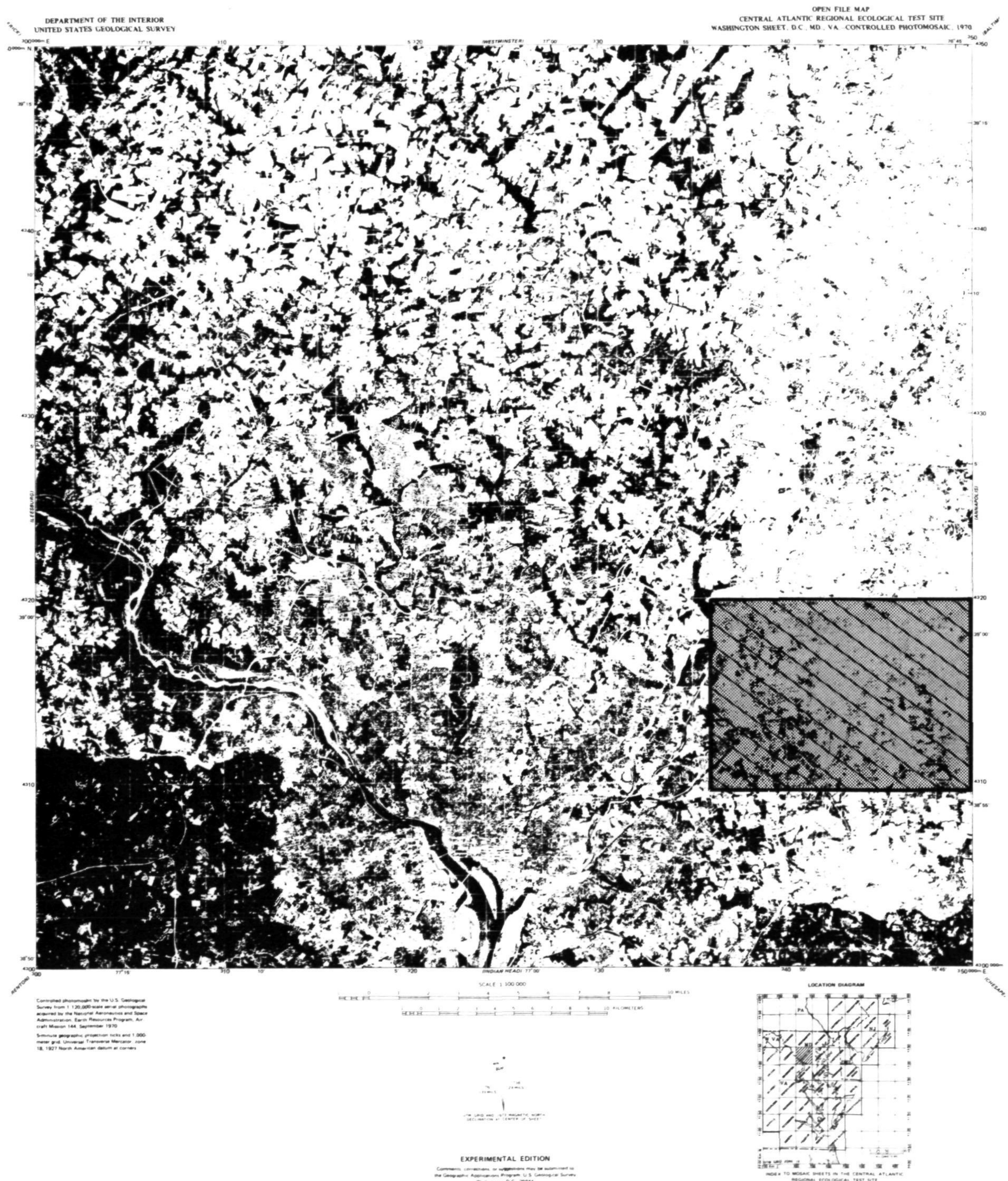


Figure 2.- Index to 48 sheets for CARETS 1:100,000 scale data base.



CONTROLLED PHOTOMOSAIC, 1970, OF THE WASHINGTON SHEET, D.C., MD., VA.
1973

Figure 3. - Reduction of specimen sheet of controlled photomosaic of one of the 48 CARETS sheets. Original sheet 50 x 50 cm at scale 1:100,000. Area outlined is location of detailed coverage in figures 12 through 21.

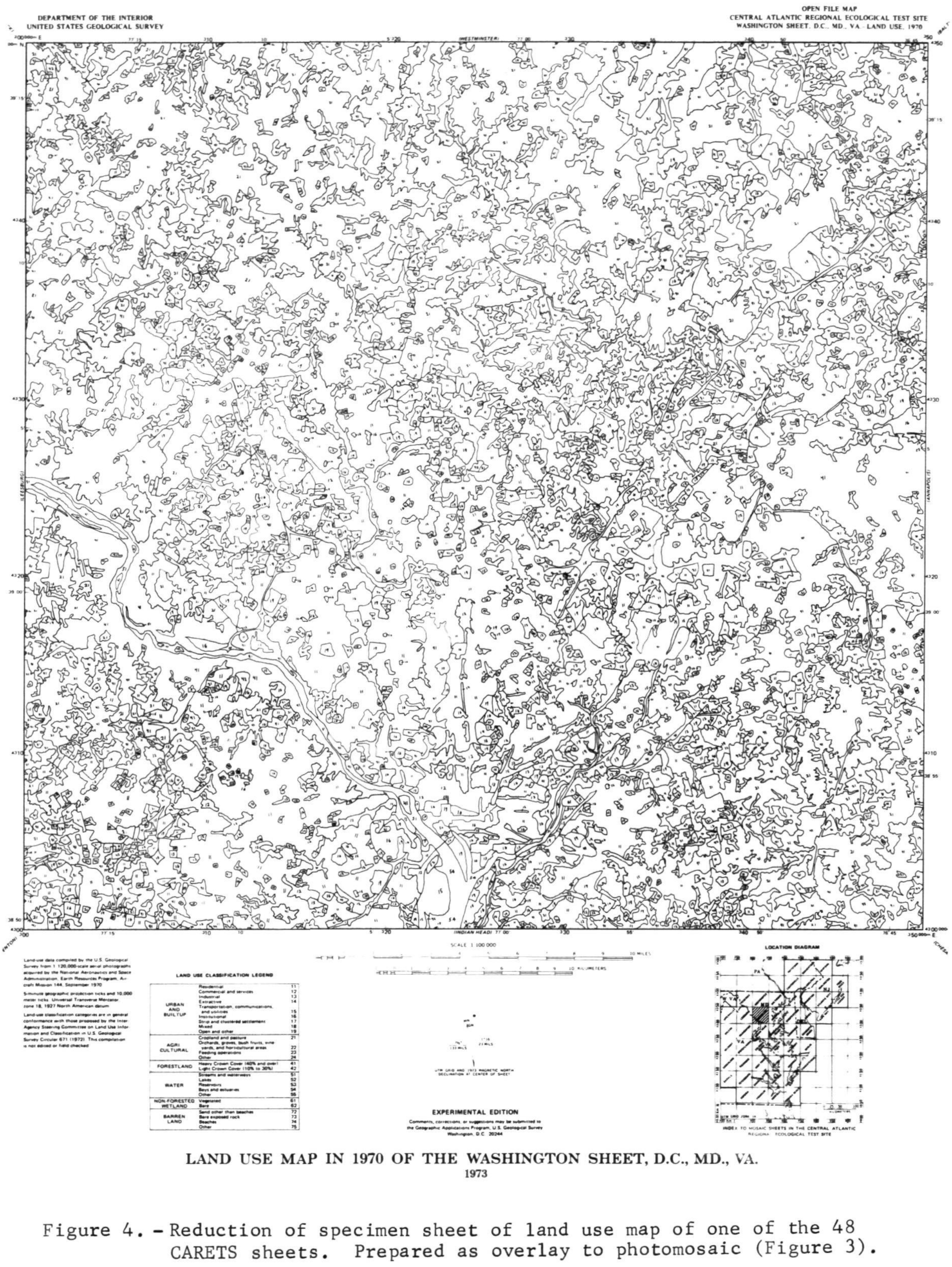


Figure 4. - Reduction of specimen sheet of land use map of one of the 48 CARETS sheets. Prepared as overlay to photomosaic (Figure 3).

Figure 5. - Reduction of specimen sheet of land use change map. Prepared as overlay to photomosaic (figure 3).

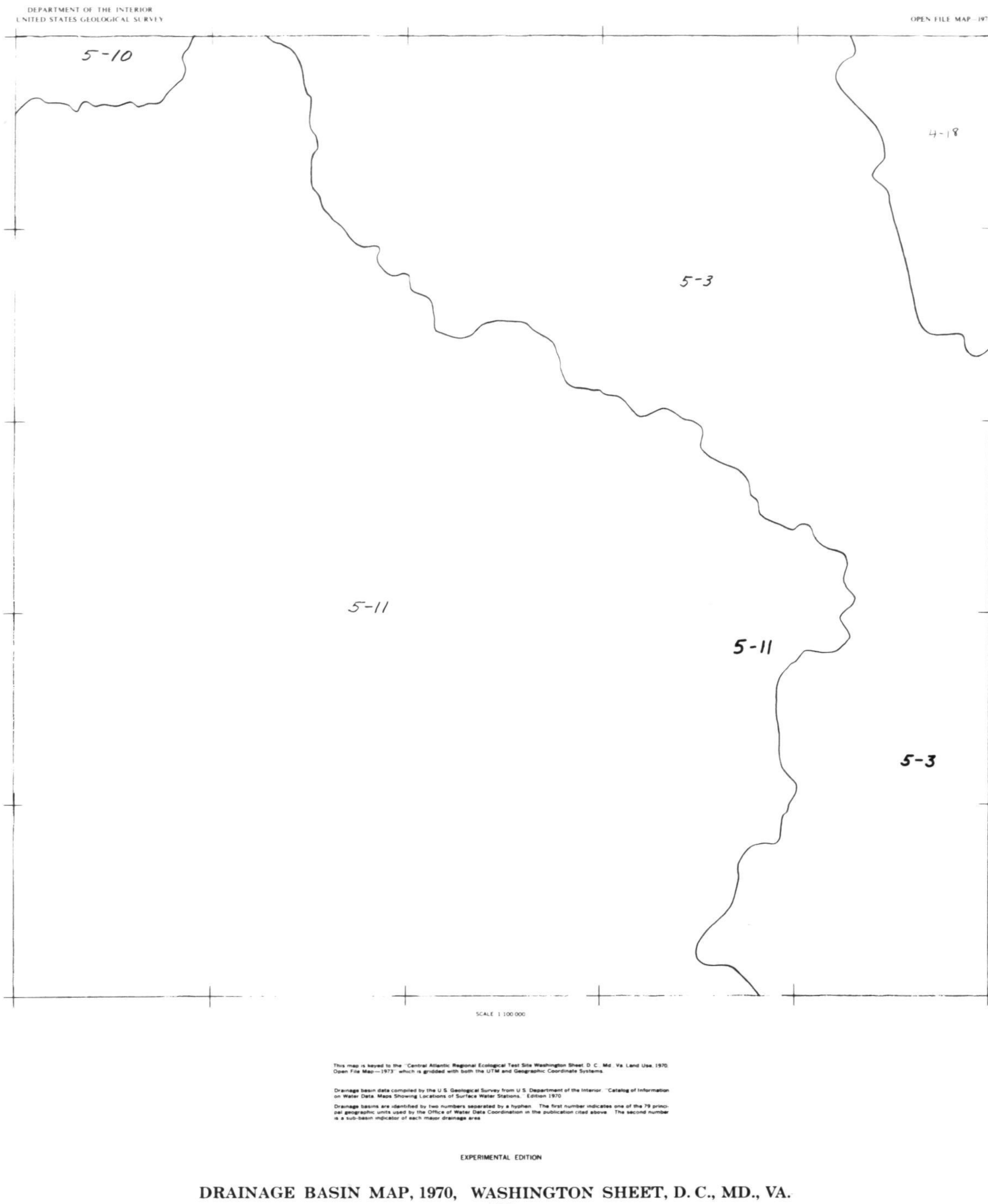
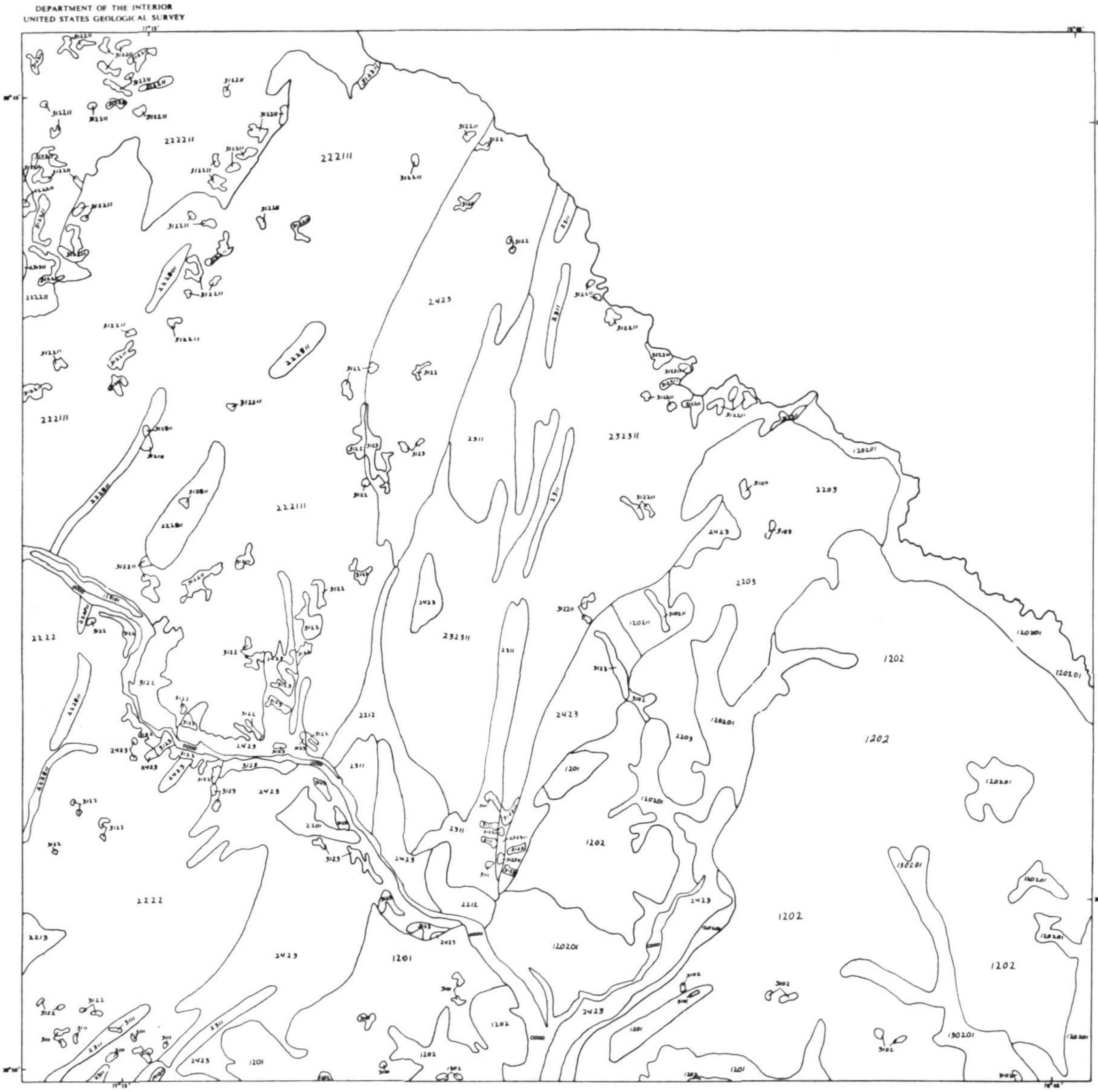


Figure 6. - Reduction of specimen sheet of drainage basin map. Prepared as overlay to photomosaic (figure 3).



LANDFORMS AND SURFACE MATERIALS MAP, WASHINGTON SHEET, D.C., MD., VA.

Reduced from 1:100,000 scale

Figure 7.- Reduction of specimen sheet of landforms and surface materials map, Washington, D.C., Md., Va. Sheet. Prepared as overlay to photomosaic (figure 3). Key to numbered categories is presented in table II.

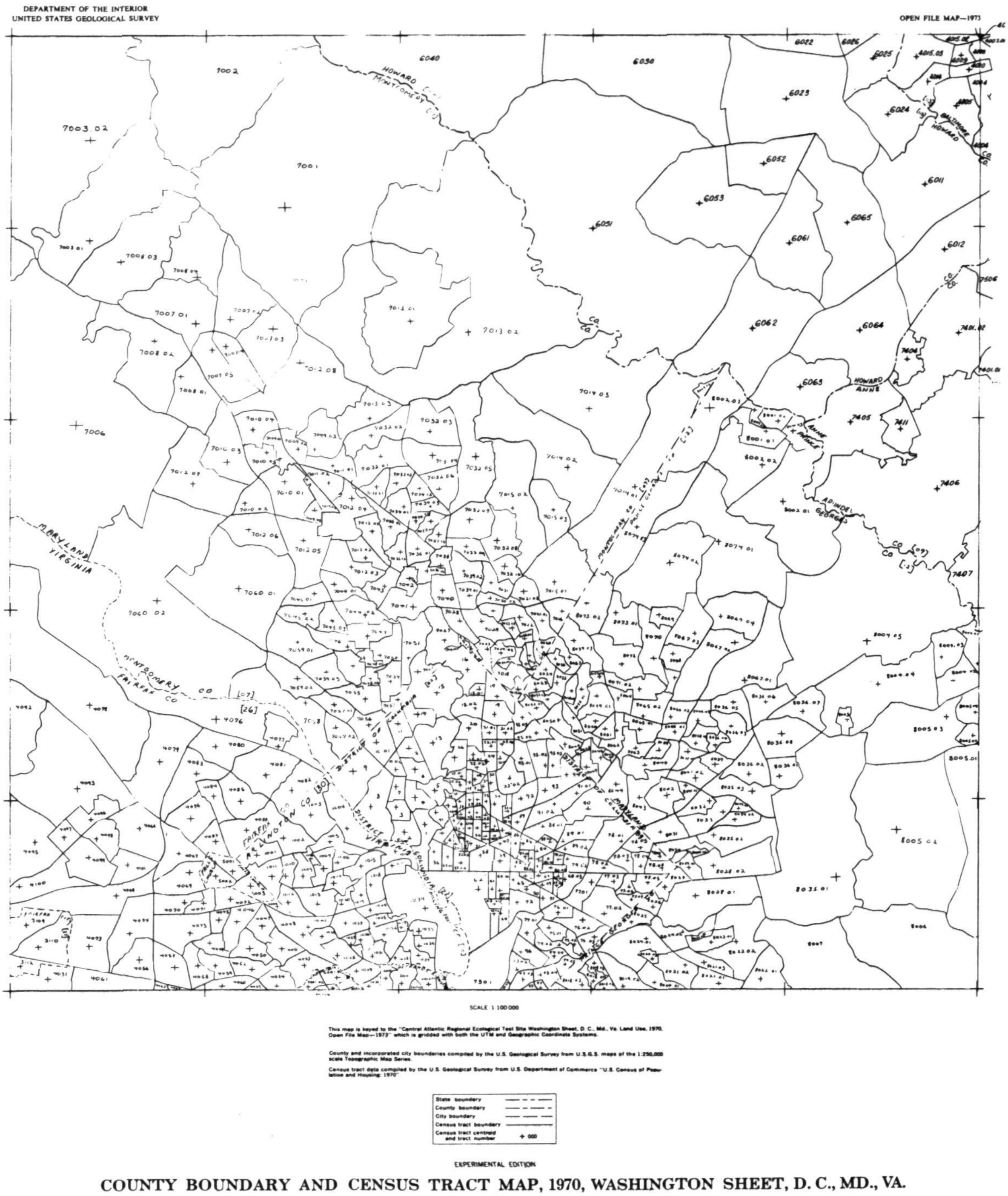
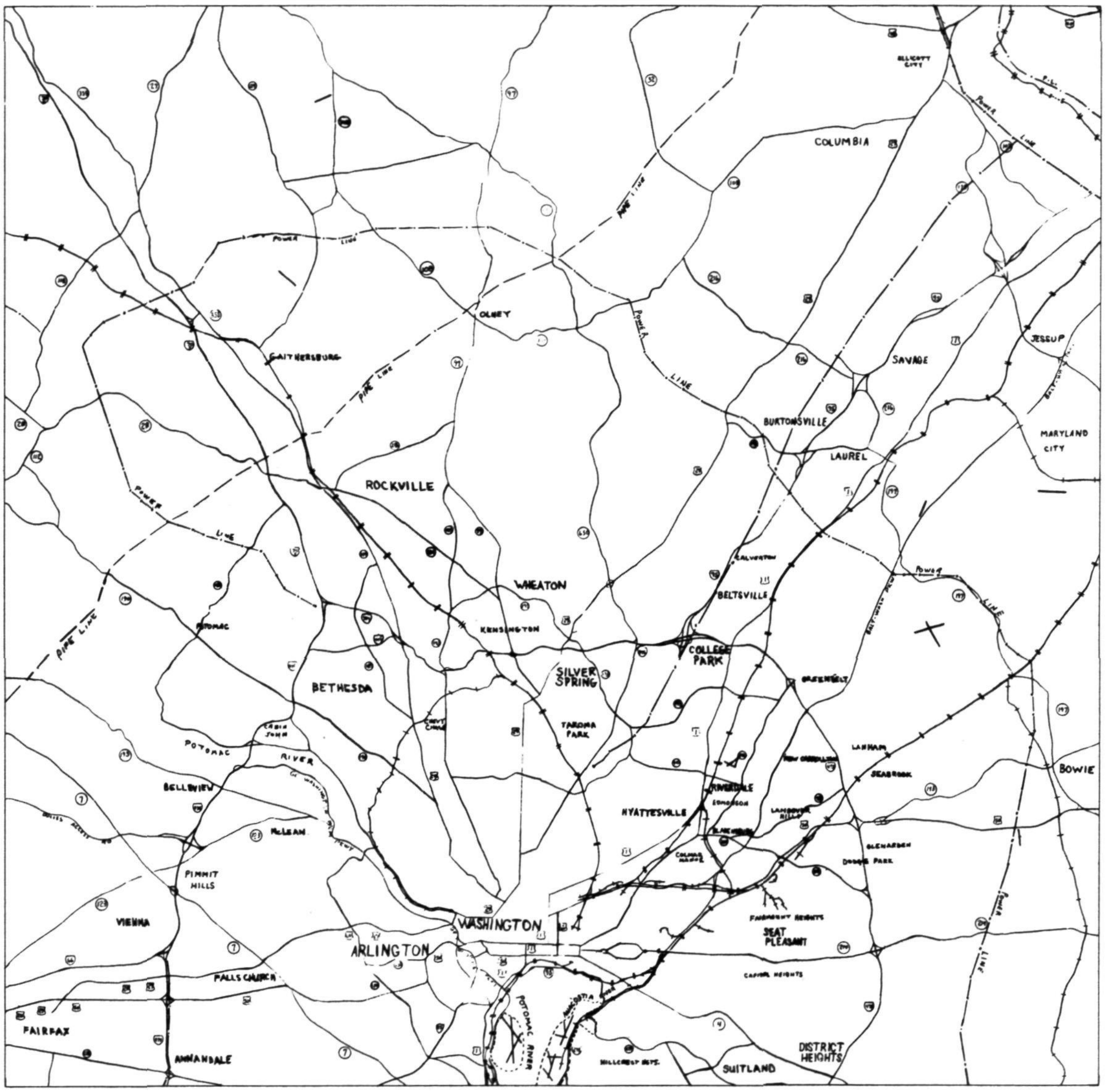


Figure 8.- Reduction of specimen sheet of county boundary and census tract map. Prepared as overlay to photomosaic (figure 3).

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

OPEN FILE MAP—1973



SCALE 1:100 000

This map is keyed to the "Central Atlantic Regional Ecological Test Site Washington Sheet, D. C., Md., Va. Land Use, 1970, Open File Map—1973" which is gridded with both the UTM and Geographic Coordinate Systems.

Cultural Feature data compiled by the U.S. Geological Survey from U.S.G.S. maps of the 1:250,000 and 1:24,000 scale Topographic Map Series.

Cultural information symbols are the same as those used by the U.S. Geological Survey for topographic maps unless otherwise indicated.

EXPERIMENTAL EDITION

CULTURAL FEATURES MAP, 1970, WASHINGTON SHEET, D. C., MD., VA.
1973

Figure 9.- Reduction of specimen sheet of cultural features map. Prepared as overlay to photomosaic (figure 3).

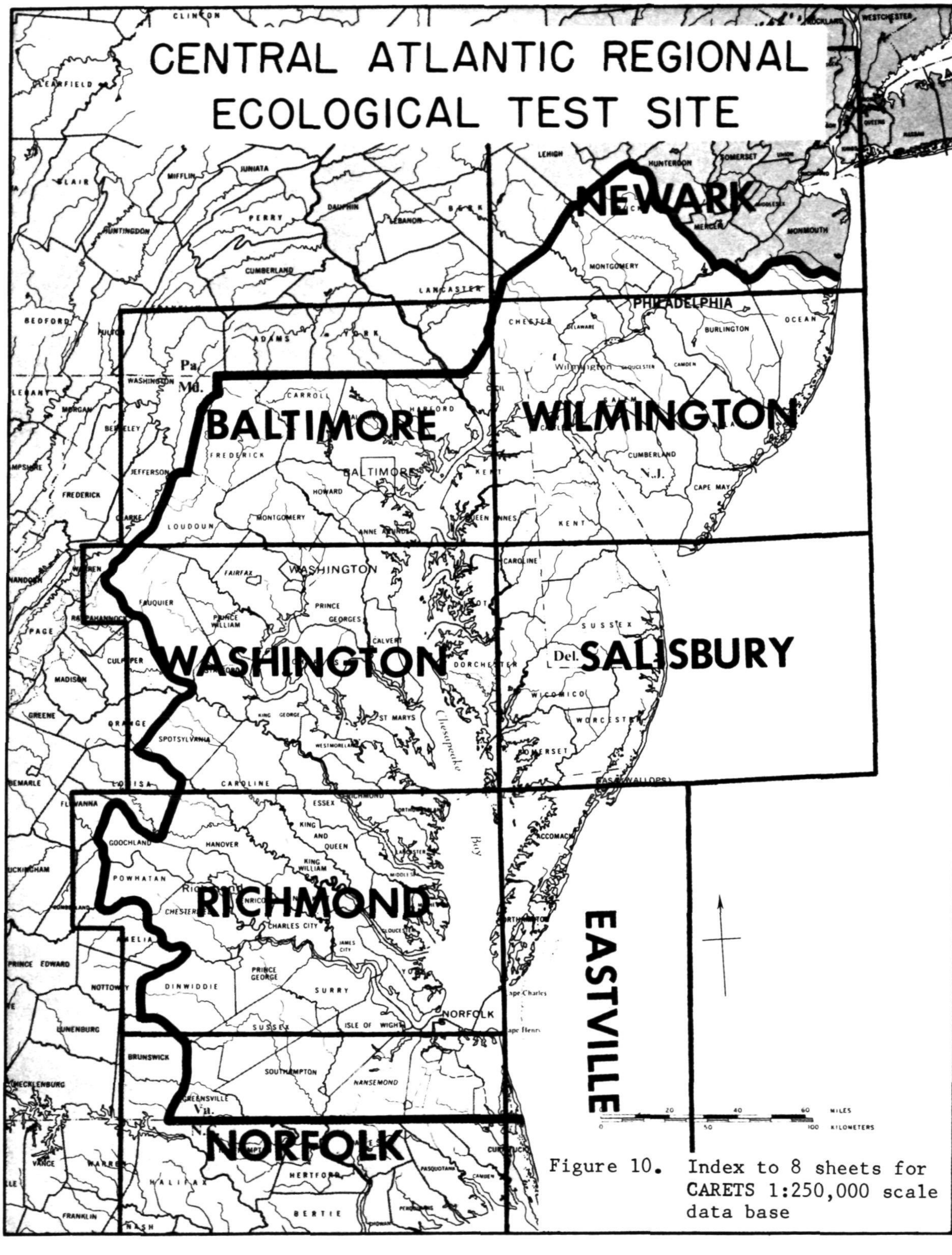


Figure 10. Index to 8 sheets for CARETS 1:250,000 scale data base

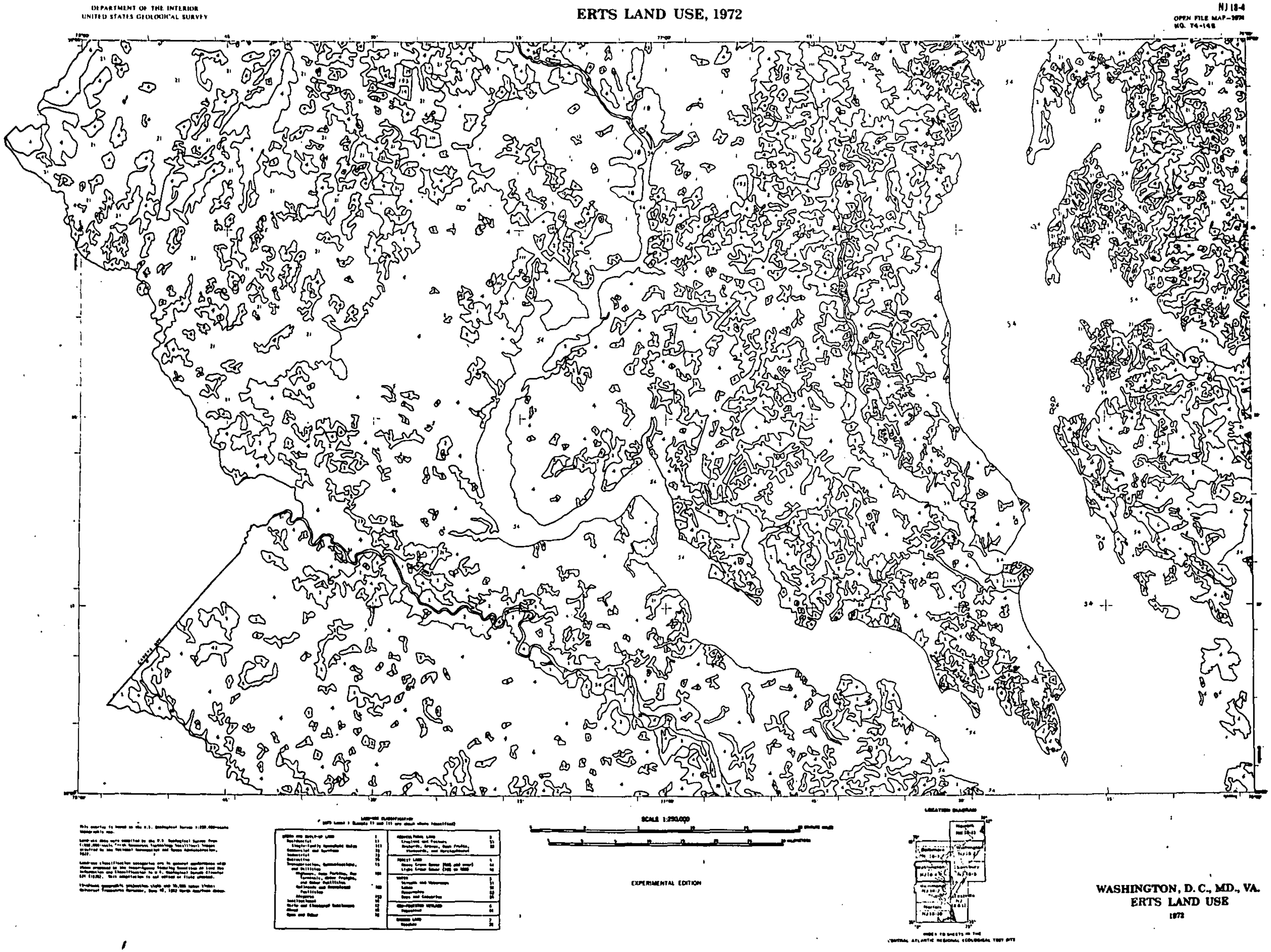


Figure 11.— Reduction of specimen sheet of ERTS-derived land use map. Original at 1:250,000 scale.

Figure 12. - Full-scale (1:100,000) detail of part of photo-mosaic sheet showing Bowie, Md. (area outlined on figure 3). Grid cells 1 km on a side.

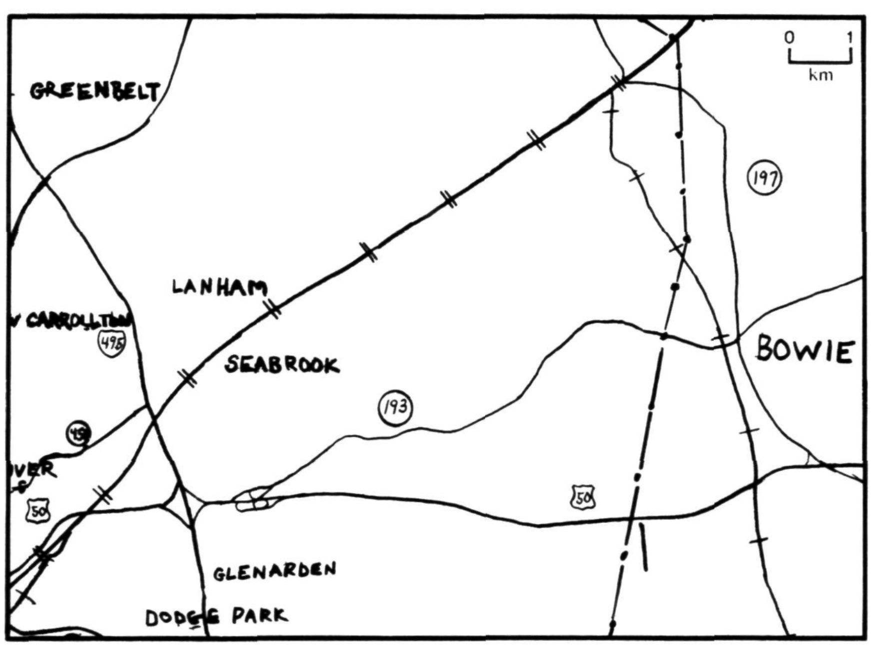


Figure 13. - Full-scale (1:100,000) detail of part of cultural features map, Bowie, Md. (area outlined on figure 3).

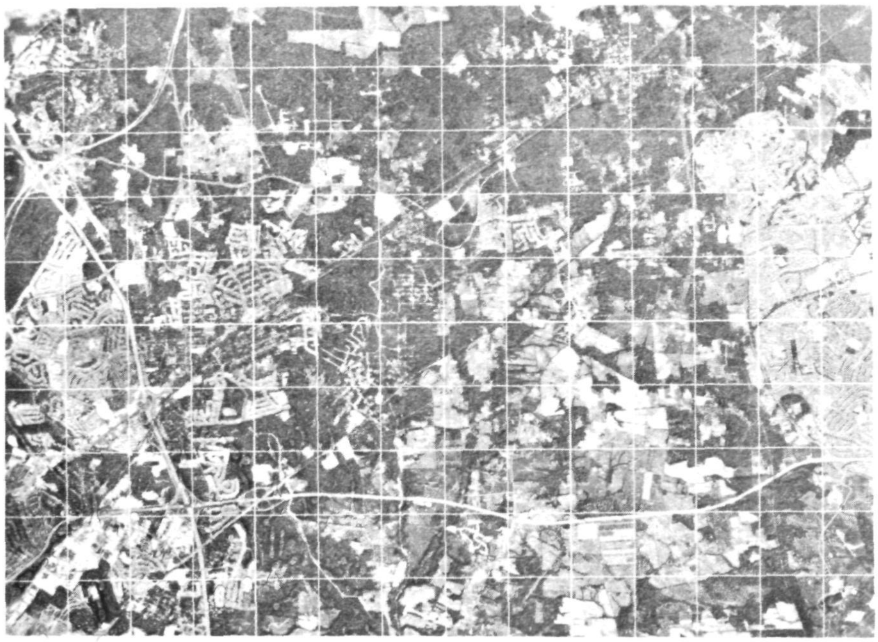


Figure 14. Detail of high-altitude aircraft photo, NASA Mission 144, October 1970, Bowie, Md. (area outlined on figure 3).

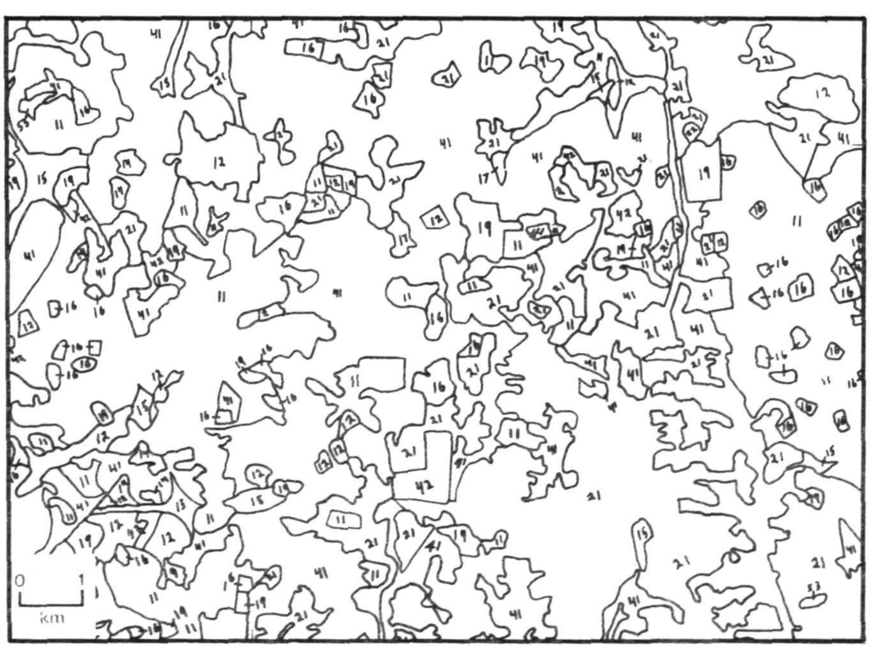


Figure 15. Full-scale (1:100,000) detail of part of land use map, Bowie, Md. (area outlined on figure 3). Key to land use classification categories in table I.

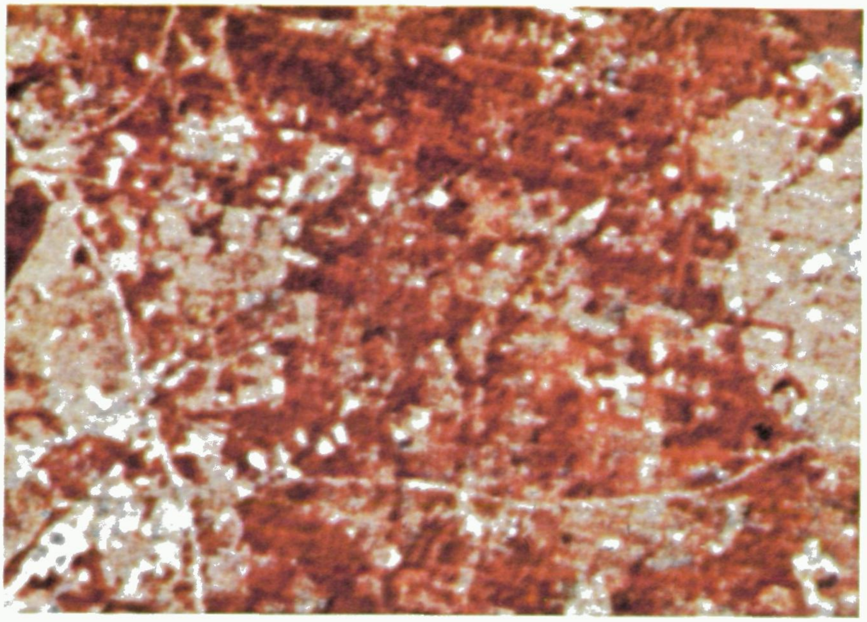


Figure 16. Detail of LANDSAT image E1080-15192, Oct. 11, 1972, color composite of bands 4, 5, and 7, Bowie, Md. (area outlined on figure 3).

Figure 17. Detail of land use map derived from LANDSAT imagery, enlarged to 1:100,000 from original scale of 1:250,000, Bowie, Md. (area outlined on figure 3). Category iii = single-family residential; 1 = urban and built up; 21 = cropland and pasture; 4 = forest.

Figure 18. Detail of Skylab 3 S190B photo, August 5, 1973, Bowie, Md. (area outlined on figure 3).

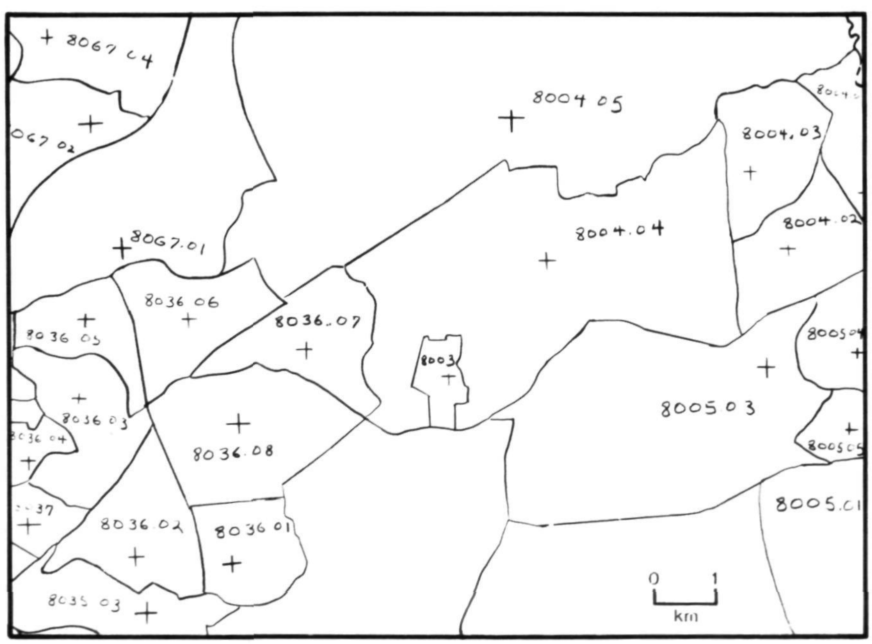


Figure 19. Full-scale (1:100,000) detail of part of census tract and county boundary map, Bowie, Md. (area outlined on figure 3).

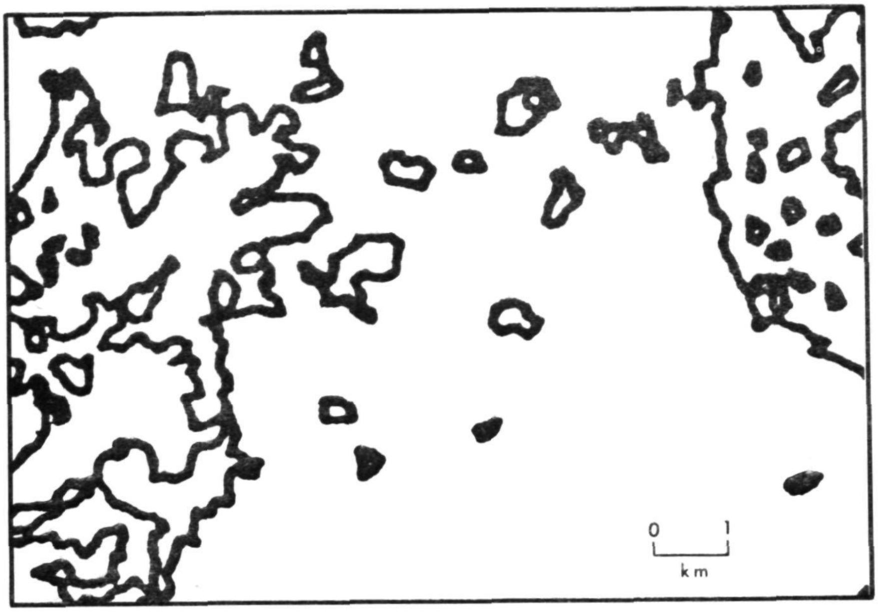


Figure 20. Experimental printout from digitized land use map, Canada Geographic Information System, computer graphics terminal. Callout of urban residential (11) category only, Bowie, Md. (area outlined in figure 3).

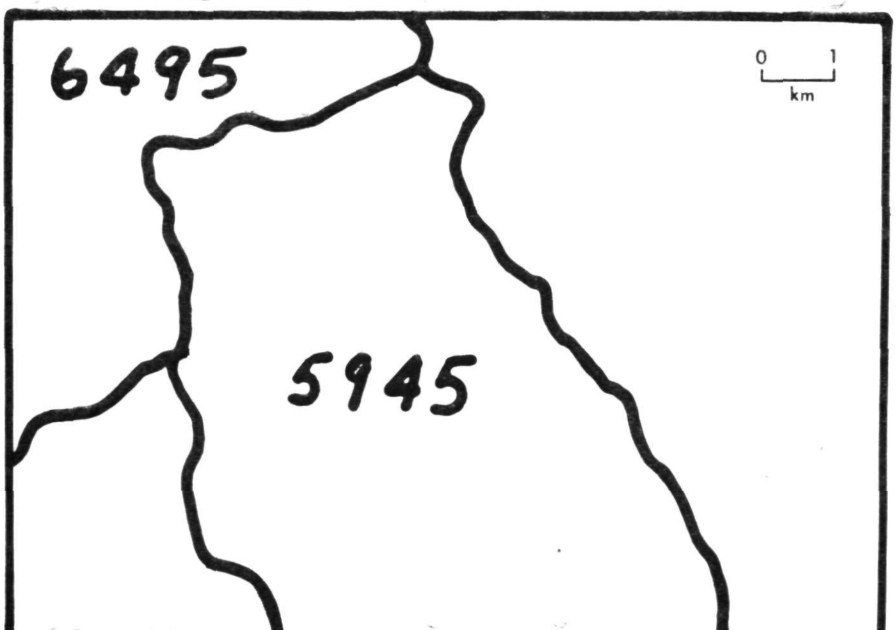
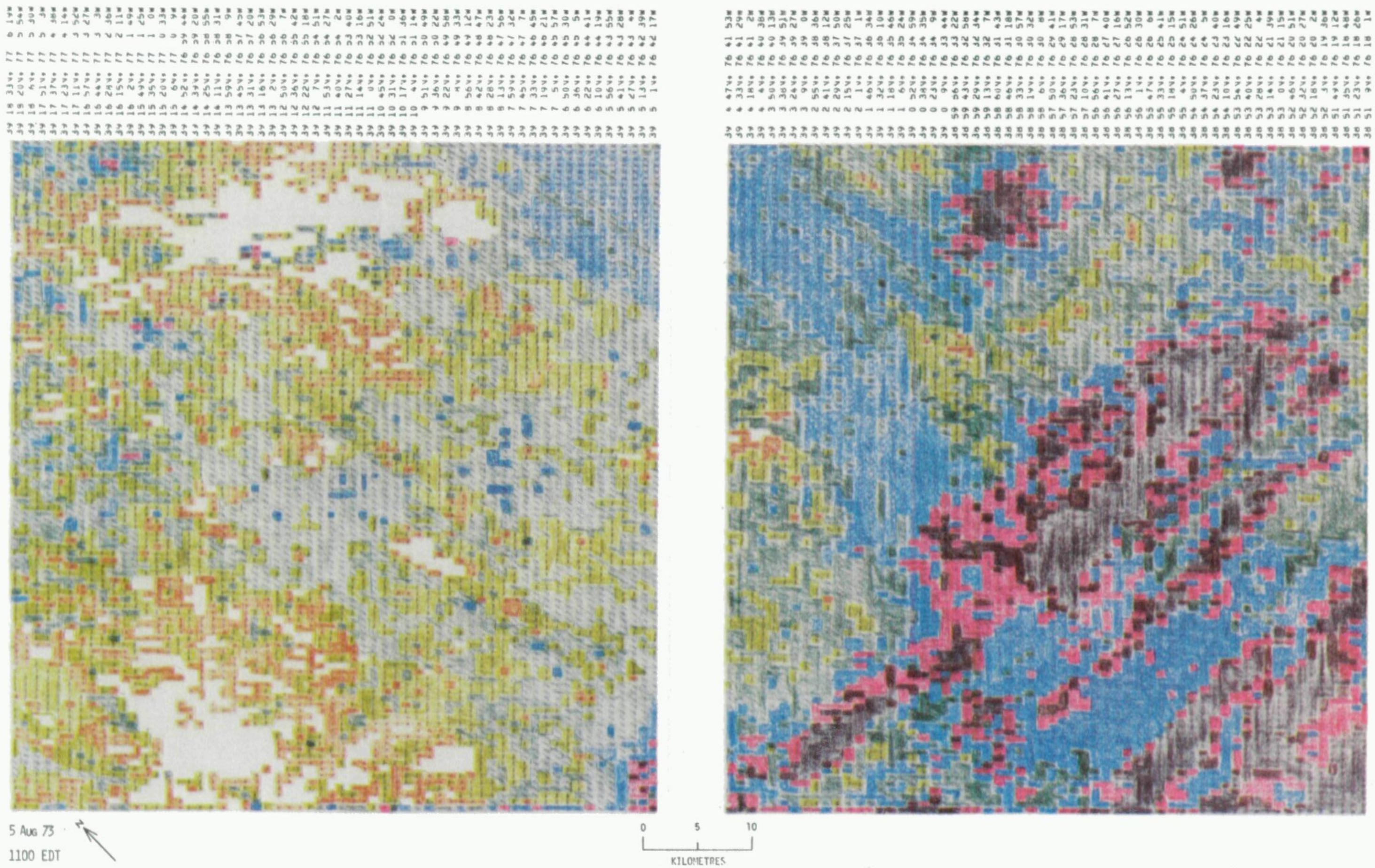


Figure 21. Location of small drainage basins, used in study of the effects of land use on stream runoff characteristics, Bowie, Md. (area outlined on figure 3). Numerical designations used by USGS Water Resources Division.



LEGEND

white	$> 36.1^{\circ}$C.
orange	= 33.6-35.6°C.
light green	= 31.1-33.1°C.
dark green	= 28.5-30.6°C.
blue	= 25.9-28.0°C.
purple	= 23.1-25.3°C.
brown	= 20.3-22.6°C.
gray	$< 20.3^{\circ}$C.

Figure 22. Hand-colored printout of Skylab S192 thermal data, channel 13, smoothed with 10 pixel by 10 pixel block filter, and calibrated to surface radiometric temperature