02

III
Vol. 3

TOWARD A NATIONAL LAND USE INFORMATION SYSTEM

77-10015
CR-148985

By

Edward A Ackerman
Robert H Alexander

U.S. Geological Survey

(E77-10015) CARETS: A PROTOTYPE REGIONAL ENVIRONMENTAL INFORMATION SYSTEM. VOLUME 3: TOWARD A NATIONAL LAND USE INFORMATION SYSTEM Final Report (Geological Survey, Reston, Va.) 76 p HC A05/MF A01 CSCL 08B G3/43 N77-10597 Unclas 00015

FINAL REPORT—VOLUME 3
CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE (CARETS) PROJECT

1125A

SPONSORED BY
National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771
and
U S Geological Survey
Reston, Virginia 22092
1975

TOWARD A NATIONAL LAND USE INFORMATION SYSTEM

By Edward A. Ackerman and Robert H. Alexander

U.S. Geological Survey
Reston, Virginia

September 1975

Volume 3 of Final Report For:

Goddard Space Flight Center
Greenbelt, Maryland 20771

Interagency Memorandum of Understanding No. S-70243-AG
Earth Resources Technology Satellite, Investigation SR-125 (IN-002),
"Central Atlantic Regional Ecological Test Site: A Prototype Regional
Environmental Information System."

TECHNICAL REPORT STANDARD TITLE PAGE

1 Report No	2 Government Accession No	3 Recipient's Catalog No
	-	

4 Title and Subtitle CARETS--A Prototype Regional Environmental Information System (SR-125) (v. 3) Toward a National Land Use Information System	5 Report Date 9/30/75
	6 Performing Organization Code
7 Author(s) Edward A. Ackerman and Robert H. Alexander	8 Performing Organization Report No
9 Performing Organization Name and Address U.S. Geological Survey Geography Program Mail Stop 710 Reston, VA 22092	10 Work Unit No
	11 Contract or Grant No S-70243-AG
12 Sponsoring Agency Name and Address Frederick Gordon NASA Goddard Space Flight Center Greenbelt, MD 20771	13 Type of Report and Period Covered Type III Final Report 1975
	14 Sponsoring Agency Code

15 Supplementary Notes

Sponsored jointly by the National Aeronautics and Space Administration and the U.S. Geological Survey

16 Abstract

See attached pages 1-2

17 Key Words Suggested by Author	18 Distribution Statement
Land use mapping Land use information system Remote sensing Central Atlantic region Norfolk, Virginia SMSA	-

19 Security Classif (of this report)	20 Security Classif (of this page)	21 No of Pages	22 Price
Unclassified	Not Applicable	68	

Figure 2A Technical Report Standard Title Page This page provides the data elements required by DoD Form DD-1473, HEW Form OE-6000 (ERIC), and similar forms

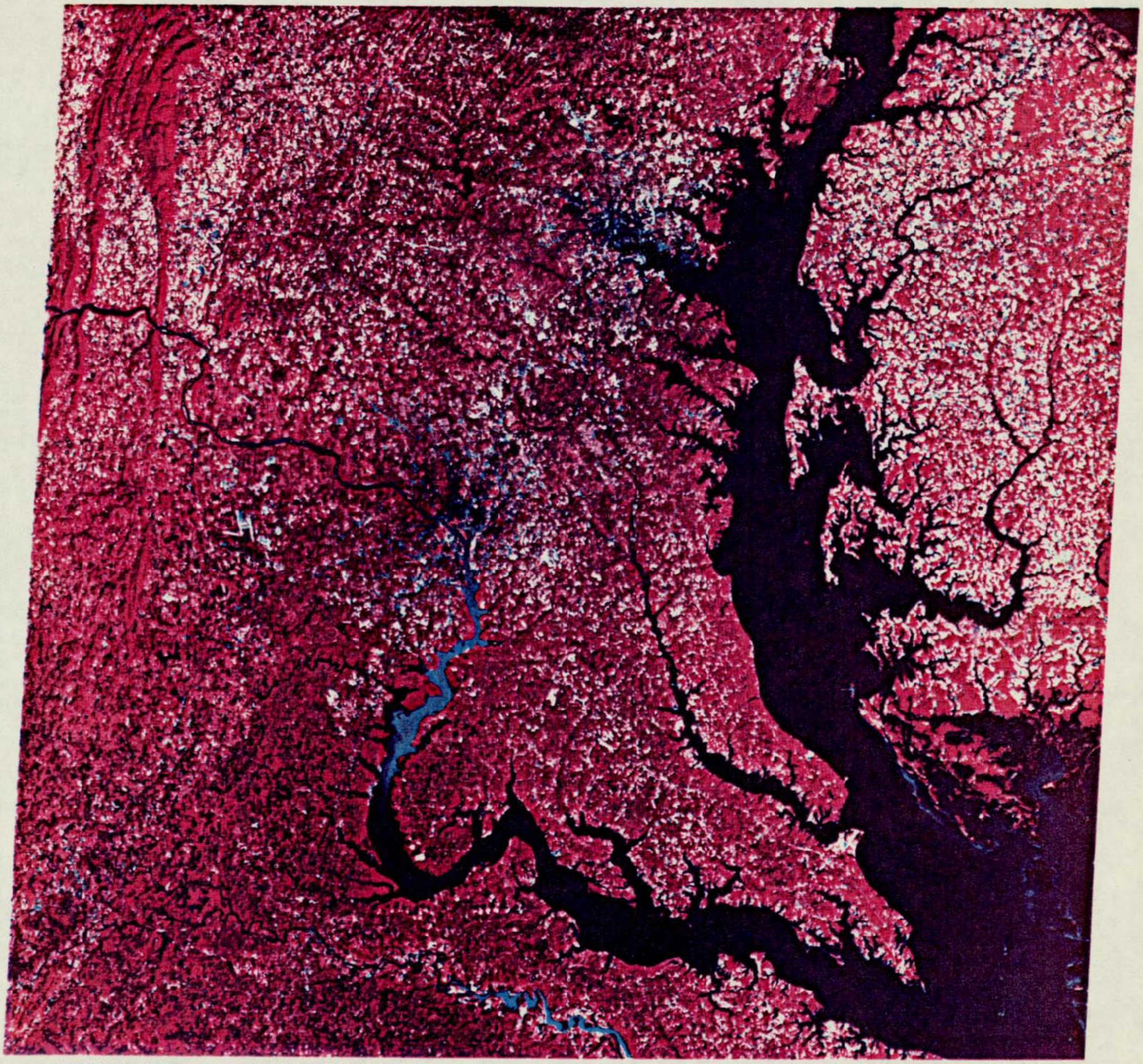
INT 7070-72

ORIGINAL PAGE IS
OF POOR QUALITY

NASA (ERTS-1)

EARTH RESOURCES TECHNOLOGY SATELLITE

NATION'S CAPITAL AREA



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION IMAGE

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D.C.—1972

W077-301 W076-3011 N038-00

11OCT72 C N38-54/W076-48 N N38-52/W076-43 MSS 4 5 7 D SUN EL38 AZ149 191-1114-N-I-N-D-IL NASA ERTS E-1080-15192-7 01

5 0 10 20 30 40 MILE

Scale approximately 1:1,000,000

The Washington-Baltimore metropolitan region from an altitude of 915 km (569 mi). Photo copy of reconstituted multispectral scanner image, telemetered to Earth from the Earth Resources Technology Satellite, ERTS-1 (later renamed Landsat-1), October 11, 1972.

Experimental printed image produced from a color-separated color transparency.
By U.S. Geological Survey

C

LIST OF FINAL REPORT VOLUMES

CARETS/LANDSAT INVESTIGATION SR-125 (IN-002)

Robert H. Alexander, 1975, Principal Investigator

Volume 1. CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE A PROTOTYPE REGIONAL ENVIRONMENTAL INFORMATION SYSTEM by Robert H. Alexander

2. NORFOLK AND ENVIRONS: A LAND USE PERSPECTIVE by Robert H. Alexander, Peter J. Buzzanell, Katherine A. Fitzpatrick, Harry F. Lins, Jr., and Herbert K. McGinty III

3. TOWARD A NATIONAL LAND USE INFORMATION SYSTEM by Edward A. Ackerman and Robert H. Alexander

4. GEOGRAPHIC INFORMATION SYSTEM DEVELOPMENTS ASSOCIATED WITH THE CARETS PROJECT by Robin G. Fegeas, Katherine A. Fitzpatrick Cheryl A. Hallam, and William B. Mitchell

5. INTERPRETATION, COMPILATION AND FIELD VERIFICATION PROCEDURES IN THE CARETS PROJECT by Robert H. Alexander, Peter W. DeForth, Katherine A. Fitzpatrick, Harry F. Lins, Jr., and Herbert K. McGinty III

6. COST-ACCURACY-CONSISTENCY COMPARISONS OF LAND USE MAPS MADE FROM HIGH-ALTITUDE AIRCRAFT PHOTOGRAPHY AND ERTS IMAGERY by Katherine A. Fitzpatrick

7. LAND USE INFORMATION AND AIR QUALITY PLANNING· AN EXAMPLE OF ENVIRONMENTAL ANALYSIS USING A PILOT NATIONAL LAND USE INFORMATION SYSTEM by Wallace E. Reed and John E Lewis

8. REMOTELY-SENSED LAND USE INFORMATION APPLIED TO IMPROVED ESTIMATES OF STREAMFLOW CHARACTERISTICS by Edward J. Pluhowski

9. SHORE ZONE LAND USE AND LAND COVER CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE by R. Dolan, B. P. Hayden, C. L. Vincent

10. ENVIRONMENTAL PROBLEMS IN THE COASTAL AND WETLANDS ECOSYSTEMS OF VIRGINIA BEACH, VIRGINIA by Peter J. Buzzanell and Herbert K. McGinty III

11. POTENTIAL USEFULNESS OF CARETS DATA FOR ENVIRONMENTAL IMPACT ASSESSMENT by Peter J. Buzzanell

12. USER EVALUATION OF EXPERIMENTAL LAND USE MAPS AND RELATED PRODUCTS FROM THE CENTRAL ATLANTIC TEST SITE by Herbert K. McGinty III

13. UTILITY OF CARETS PRODUCTS TO LOCAL PLANNERS: AN EVALUATION by Stuart W. Bendelow and Franklin F. Goodyear (Metropolitan Washington Council of Governments)

Contents

Page

Illustrations

Plates

Tables

TOWARD A NATIONAL LAND USE INFORMATION SYSTEM

By Edward A. Ackerman* and Robert H. Alexander

Abstract

It is recommended that a national land use information system be established by an agency of the Federal Government. This recommendation comes at a time of increasing demand for scientific information in support of environmentally relevant land use planning and management at all levels of government. It is also a time when new airborne and spaceborne remote sensors, tested in cooperation with the National Aeronautics and Space Administration (NASA) and the Earth Resources Observation Systems (EROS) Program of the Department of the Interior, make possible the gathering of land use information rapidly and on an unprecedented scale. Furthermore, information-handling technology is developing toward a capability to receive, store, and disseminate the huge quantities of data that would be involved.

The recommendation for the national land use information system is based upon careful analysis of the results of remote sensing experiments funded by NASA, EROS, and the Geography Program of the Geological Survey, with specific examples drawn from the demonstration project known as the Central Atlantic Regional Ecological Test Site (CARETS). CARETS is cast in the framework of a regional land use

*Deceased

information system, channeling the flow of information generated in response to users' declaration of their needs, through stages dealing with remote sensing data gathering systems, data processing and land mensuration, calibration in terms of environmental impact, and evaluation with feedback from users.

The proposed system would develop and implement a unified approach to the description and interpretation of the changing uses of the nation's land resources, building upon the base of interagency and intergovernmental cooperation already achieved in the experimental work to date. The land use data base that is being derived from high-altitude aerial color infrared photography would be the initial component of the recommended system. High-altitude photographic coverage would immediately be extended to as much of the nation as possible as technological developments and economic considerations permit. The system would later expand to include multiple-sensor, multiple-platform data sources. Six system characteristics are recommended: (1) High capacity storage of data available for quick retrieval, inexpensive processing, and update, (2) provision of accuracy appropriate to the scale of survey or to the level of detail dictated by different types of management and decision requirements; (3) permanent, publicly accessible sensor records for historical interpretation; (4) compatibility of the recording, storage, and retrieval system with all types of inputs, from ground observer to satellite; (5) products of diverse formats and scales, responsive to user feedback; (6) and standardization of formats, scales, and storage inputs to permit nationwide comparability.

INTRODUCTION

This report was completed in draft form, very nearly as presented here, a week before Dr. Ackerman died in March 1973. For several years before his death, Dr Ackerman advised and assisted in the development of the Geography Program of the U.S. Geological Survey (USGS). He provided guidance for program efforts in 1971 and 1972, aimed at consolidating the various experiments and program elements that involved the application of data from airborne and spaceborne remote sensors to land use analysis. He felt strongly that the promising results of the remote sensor experiments, coupled with the information systems technology becoming available and the heightened public awareness of land use as a policy issue, pointed toward a need for leadership at the Federal level in certain technical matters concerning land use. One such matter was the systematization of information on land use and land use change, to provide access for Federal policymakers to consistent data on land use trends across the nation and to provide local and regional decisionmakers with information technically equivalent to that needed at the Federal level, on which to base crucial decisions affecting land use change.

The manuscript "Toward a National Land Use Information System" was planned for release as a USGS Circular, containing a blueprint or justification statement for a proposed land use information program in the USGS. The actual program developments in the USGS took a different direction in the years 1973-75, and the manuscript was laid aside. In mid-1975, however, the coauthor found much of the material still relevant to the summarization of results and recommendations of 4 years of research conducted for NASA and the Geological Survey, and the manuscript is here presented with only minor changes, most of which involve changing of items formerly presented as program descriptions to recommendations.

Although many of the recommendations were made before carrying out the detailed user study in the Central Atlantic Regional Ecological Test Site (CARETS), the results of that user study are in many cases remarkably in agreement with the earlier recommendations. Furthermore, the Land Use Data and Analysis (LUDA) program, which could be a first step toward realization of the recommendations presented here, has been established in the USGS with the goal of producing land use maps of the entire country at a scale of 1:100,000, with associated computerized processing along the lines referred to in this report. Another reason for making the manuscript available to a wider readership is that it represents the last geographical writing of Edward A. Ackerman's long and distinguished career as geographer, science administrator, and adviser to government agencies.

Many people assisted and supported the work that made possible the preparation of this report. Program administration and guidance throughout the research were provided by the USGS Chief Geographers, first the late Arch C. Gerlach, and then James R. Anderson. Dr. Anderson is the senior author of the two-level land use classification system for use with remote sensor data, which is the starting point for the recommendations contained herein. USGS colleagues John L. Place and James R. Wray contributed to both the research and the program development. Peter Buzzanell, Peter DeForth, Ivan Hardin, Katherine Fitzpatrick, Harry Lins,

and Herbert K. McGinty were members of the CARETS core team which produced the original maps and data summaries used here as illustrations of products of a land use information system. Robert Dolan of the University of Virginia advised at several stages of program development.

Particular thanks and acknowledgement are given to Wallace E. Reed of the University of Virginia, who gathered and organized much of the background material, designed the key illustrations showing examples of input and output of a proposed land use information system, and prepared the analysis of three levels of land use classification as presented in tables 1 and 2.

A final caveat is necessary to state what this report does not do. It does not examine in detail the problem of how information on land use and other land characteristics is applied in land use management decisions. Appropriate attention to this problem would be an essential companion effort to the development of a land use information system at any level of government. Also, this report does not present the specific calculations on manpower and funding requirements that would be necessary for submitting any program recommendation to the appropriate agencies and to the Congress for consideration. Rather, the report provides discussion and documentation intended to support the argument that a beginning could and should be made toward eventual realization of a national land use information system.

LAND USE INFORMATION--PRESENT NEEDS AND ATTEMPTS TO MEET THEM

NEEDS FOR A LAND USE INFORMATION SYSTEM

Within the last 20 years the United States has undergone some of the most striking changes in its history. The word "revolution" has been used frequently in recent years, not always appropriately. But changes in the places where people live and the manner in which they live and move about have been truly revolutionary. So have been the changes in their attitudes toward the use of resources that form the environment in which they live--land, water, and air. Perhaps better than at any other time in our history the importance of decisions affecting the future of those resources has become popularly understood.

That all resources are interconnected and some resources serve multiple uses has been appreciated for some years. Development of the art and engineering of water management has extensively employed the multiple-use concept for at least 40 years. More recently the critical importance of multiple use for both land and air resources also has come to be appreciated, along with the realization that man and nature are not separate, opposed entities but rather are interdependent and integral parts of complex ecosystems that are as yet poorly understood. Increasingly, the role of land as a natural resource--a part of nature's life cycle rather than simply a private commodity--is also being more widely realized (Madden, 1974).

Management for multiple use thus has become a critical question of the day on all geographical scales from neighborhood to nation. Multiple use means in these cases not only management for different purposes, like industrial, transportation, residential, or other, but also management for clienteles from several geographical sources: local, immediate regional, larger regional, or national. More and more decisions at all levels of responsibility, from private individuals and corporations to Federal Government are being made on the allocation and dedication of our land and other resources to future uses. More and more these decisions are realized as having chain effects extending beyond the resource for which the decision is made. Information on the nature of these linkages--decisions concerning land use, resulting land use patterns or changes, resulting impact on the environment and on the economics or esthetics of man's changed habitat--is becoming more necessary in our attempts to allocate our land resources to new or changed uses.

The conflict among uses of land and the foreclosing of the future by current decisions are most visible within the great metropolitan regions that have developed rapidly since the end of the Second World War. The number of these regions in the United States measure in the thousands of square miles. For example, the greater metropolitan region that includes the Washington and Baltimore metropolitan areas now exceeds 30,000 square miles (Ackerman and others, 1973). The rapidity of land use change in these regions must be a matter of major concern for the inhabitants of a region as well as for the nation as a whole. No part of the country, however, from arctic Alaska to the rain forest of Hawaii, is now remote enough to escape land use conflicts.

In the web of tens of thousands of decisions on land and other resource use made yearly in the United States, no decision is better than the data or assumptions on which it is based. If data are not at hand, then assumptions must be made. It is therefore important to find out how we obtain our data today on the use of land and other resources and whether or not there are practical, economical means of improving the existing system, if it can be called a system as yet.

SOURCES OF LAND USE DECISIONS

In the great complex of land use and resource use decisions within the United States, some decisions are more far reaching than others, and some types of data and information therefore have greater significance than others. For example, the information (or assumptions) used in preparing a Federal executive agency decision of national scope, or preparation for Congressional legislation may be of more far-reaching significance than that needed for an individual private corporate decision. But local and private decisions are very numerous, and numerically make up the bulk of decisions affecting land use where change is now most important. From a national point of view, cumulative knowledge of the total results of these thousands of smaller decisions is essential. The collection and employment of land and related resource use information for these decisions is undertaken, now by the Federal Government, by State governments, by municipalities, counties and groupings of municipalities and counties, and by private organizations or individuals.

Federal operations in which land use and resource use information is essential include those for highways, parks, defense installations, harbors, airports, forest reserves, watershed reserves, fish and wildlife preserves, dams, reservoirs, flood control works, and office buildings. Information is needed for planning, environmental impact studies, land purchase programs, land and facilities disposal, regulation, legislation and litigation, and frontier surveillance and control.

State governments have somewhat parallel interests with the Federal Government in land use and resource use information. Among other things, they especially need information for their collaborative operations with the Federal Government on Federal projects, for public facilities planning and operation, for utilities regulation and planning, for land and related resource use regulation for urban management responsibilities, and for highway planning and operation.

Decisions of particular interest to municipalities and counties include planning for utilities and their operation, development of residential areas, planning and operation of schools, redevelopment of obsolete settlements, amenities planning and operation, traffic control, street and road administration, property tax system review and administration, and negotiation with neighboring jurisdictions and with State governments.

Land and related resource use information is in wide use by private organizations and individuals including those interested in land purchase and sale, in subdivision construction and management, in housing services, in plant location and future operating capacity and in marketing studies for product and service sales.

EXISTING METHODS OF SUPPLYING LAND USE AND RESOURCE USE DATA

The distinguishing characteristic of current methods of collecting data on land use and other resource use is its single-purpose objective. When all the sources and all the existing users are taken into account, an enormous amount of information is collected every year. In almost all cases, however, including that for most Federal agencies, data collection is pointed heavily or exclusively to the particular purpose of the corporation, municipal agency, State agency, or Federal agency. The outstanding exceptions, where comprehensive data are sought, are in the operations of urban, regional, or State planning agencies.

The second important characteristic of present methods is the lack of timely replication. Even types of land occupancy and regions of survey where rapid change does not prevail show problems of obsolescent data. For example, the most recent nationwide map compilation of land use information, published in the National Atlas in 1970 at a scale of 1:7,500,000, used source materials ranging in date from 1955 to 1967.

The third major shortcoming of the present methods of survey follows from the other two: a lack of standardization and comparability for data gathered. Single purpose approaches that do not have definite targets for replication encourage specialized, unrelated, and unstandardized methods It is doubtful that a replicatable general survey of land and related resource use could be achieved in anything but the roughest form from present data sources and methods.

Land use data are generated by specific registration, licensing, and census programs; by economic analyses, traffic, utility, and local planning activities; and by other types of information gathering procedures serving local management needs. These data, however, are compiled in categories, for areal units, and for time periods related to the specific needs of the data gathering agency. These data are seldom aggregated to areal units appropriate for the generalized Federal and State program planning review activities. Except for some continuously updated registration systems, most land use data are assembled through slow and costly ground survey processes and augmented by ad hoc reference to large-scale aerial photographs. Urban, transportation, environmental, and other information systems are making progress, yet land use data are most frequently presented in map or tabular form and are seldom digitized for rapid analysis, or standardized so that they can be exchanged or widely used.

COSTS OF THE PRESENT METHODS

The costs of the present system are high, both in terms of the monetary costs of obtaining the data and in terms of the benefits foregone because of the lack of data that cannot be obtained at all from the present methods.

For the nation as a whole, an uncoordinated system highly dependent on "handwork" of ground observers is extremely expensive, even for the data that are obtained. Familiar examples are the land use data for community or county plans in most densely settled sections of the country. The costs of the present system have been vividly illustrated by the national needs that have arisen in recent years in areas where the system is weakest--data on overlapping or conflicting uses, and data on connections between planned uses and environmental consequences. In the absence of a rational, technically sophisticated system of providing easily replicatable data on the relation of land and other resource uses, a very cumbersome and expensive process--the drafting of environmental impact statements--was set up to meet political and policy needs. The impact of the costs of this process has been reverberating through the nation and among the Federal and State agencies for some time.

Perhaps the greatest weakness, and therefore cost, of the present methods results from a lack of comprehensive information that will allow the anticipation of overlapping interests and conflicts sufficiently ahead of their occurrence. The environmental impact statements are at best a "spot" method that only samples problems, sometimes after crisis conditions have been allowed to arise. Policy formation at both State and Federal levels, regional planning, balanced provision of resource allocation for all economic and social needs, and a great variety of other public and private actions are being carried out with the serious handicap of proceeding from assumptions rather than knowledge. Despite sincere efforts to cover the more critical situations, we are muddling along in a state of costly ignorance where land use decisions are concerned.

DESIGN OF AN IMPROVED SYSTEM

EXPERIENCE OF OTHER COUNTRIES

Several other technically advanced nations for many years have had more sophisticated land use survey systems than those of the United States. Among them are Japan, United Kingdom, France, Western Germany, and Switzerland. The 1968 United Kingdom Land Use Survey at a scale of 1:25,000 is a notable example. In all cases the survey and needed graphics are responsibilities of a unit of the central government. Until very recently, however, none of these nations has been faced with the impact of land use change of a magnitude and rate comparable to what occurred in the United States within the last two decades. Also, these land use survey systems, though further along in their development than counterparts in the United States, have not necessarily been designed to respond to the kinds of needs now present in the United States, nor have they developed the kinds of user orientation required here. For these reasons, the technical problems of achieving economical, frequent replication of survey have not been solved by any of these countries, in a way that could provide a realistic model for the United States. They may have had better organized surveys and better records than we, but their past methods provide no analog for meeting the situation with which the United States is faced at the present time. Canada has had a more modern survey, begun in 1963, but it does not yet have an operational updating capability based on remote sensing inputs.

ALTERNATIVES FOR THE UNITED STATES

Only an agency of the Federal Government has the requisite authority and scope of operation to initiate and maintain an improved national land and related resource use information system. The Federal Government has three alternatives for such a system. (1) Continue the status quo, that is, multiple sources of specialized information for the multiple points of decision making, (2) continue its technical experiment with potentially revolutionary instruments like Landsat but postpone establishing a national system until the capacities of new technology are further proven; or (3) establish a national system of land and related resource use survey at an early date on the basis of existing technology, so designed that it can accept all types of land use data inputs, including those of later satellite sensors.

An increasingly vocal opinion seems to be rapidly developing that the status quo is no longer acceptable, not only because of the great costs for uncoordinated, duplicating collection of information on land use, but also because of widespread demand for action to alleviate the increasing environmental stresses resulting from uncoordinated and unplanned land use changes. Evidence of the latter can be seen in the introduction of major legislation on land use policy into every session of the U.S. Congress since 1970.

The second alternative, awaiting the results of further experiments with new technology, characterizes the situation of the past several years in the community of agencies and individuals involved in remote sensing research in support of Earth observation activities. With the support and collaboration of the NASA Earth Observation Program and the EROS Program of the Department of the Interior, the USGS Geography Program has conducted a thorough research and evaluation effort on the applications of remote sensor and related computer technology to land use analysis. The results of this research indicate that although further experiments are called for to improve or refine the technology, e.g. the use of satellites, the technological capability for developing a national land use information system is already at hand.

Therefore, the third alternative is the recommendation of this report, beginning immediately with a land use data base that is being derived from color infrared photography from high-altitude aircraft, and later expanding to multiple-sensor, multiple-platform data sources as technological developments and economic considerations permit.

Recent progress in computer storage and remote sensing technology has overcome some of the major technical constraints on the development of such a system. Computer technology now permits the rapid digitizing of land use information taken from maps, tables, registration systems, or photographic sources. Also possible are rapid retrieval and exchange of data among information systems, and rapid manipulation of data for analyses and graphic or tabular output. Therefore, although the basic framework of the proposed national land use information system would be provided by remote sensing data sources, the system could also be linked, through appropriate geographical referencing of the data items, with land use information derived from other than remote sensing sources.

DESIGN CRITERIA FOR THE SYSTEM

A system having wide application must have certain design characteristics, including: (1) high capacity storage of data available for quick retrieval and inexpensive processing; (2) capacity for inexpensive updating and other replication to survey at large or small scale; (3) provision of accuracy appropriate to the scale of survey or the level of comprehensiveness and detail required by different types of management and decision (namely, urban fringe areas with housing and industrial development as compared to forest and rangeland areas); (4) capacity to provide a spatial image or a sensor record capable of providing information on points, lines, and two-dimensional surfaces of all shapes, (5) statistical-graphic interconvertibility, whether through digital tape, holographic, or other means; (6) permanent, publicly accessible records of survey data and programs for historical interpretation; (7) compatability and adaptability of the recording, storage, and retrieval system with all types of inputs, from ground observer to satellite, and adaptability to different combinations of sensors as required by different needs or as made possible by technical improvements; (8) products of diverse formats, scales, and precision and responsiveness of product to user feedback; and (9) standardization of formats, scales and storage inputs to permit nationwide comparability.

It is recommended that the proposed national land use information service be developed from a technical design that incorporates the above-listed design criteria. The design should consider optimum scale or size of the operation, so that efficiency of operation can be combined with widest possible application. Careful records of costs of the various component activities and instrumentation should be kept by demonstration projects. Accurate descriptions of the needs of users and their acceptance of products likely to be available from a national land use information system should be inputs to the design and developmental phases of the program. Finally, in communications concerning the new land use information system, demonstrations of its application to Federal, regional, State and local level activities should be cited.

DEVELOPMENTS IN THE FIELD OF REMOTE SENSING

For many years before the term "remote sensing" came into being to define a broader field, the use of aerial photographs as sources of information on land use was well established. Marschner's (1959) classic work on rural land use was specifically built around the availability of aerial photography, which, as he explained, "...furnishes documentary evidence of local settings that could not be obtained with the same completeness and speed as ground observations...Of the many purposes aerial photography may serve, recording the major distinctions in the use of land is a main objective." (p. 99)

Wray (1960) summarized aerial photographic applications in identifying and analyzing urban land use, as one portion of an ambitious synthesis undertaken by the American Society of Photogrammetry in the late 1950's. That synthesis contained treatises on all major applications of aerial photography, a compendium that stood as a standard reference in the field until being expanded and updated 15 years later (American Society of Photogrammetry, 1975).

The early 1960's saw the introduction of increased coordination in research and development encompassing techniques of nonphotographic as well as photographic sensing and associated data processing, spurred by the needs of Federal agencies. Remote sensing symposia, workshops, conferences, publications, and technical sessions at professional meetings flourished. Recent texts contain bibliographic sections citing key references (Holz, 1973; Estes and Senger, 1974).

Several committees of the National Academy of Sciences-National Research Council (NAS-NRC) have concerned themselves with activities intended to foster appropriate uses of remote sensing technology, including those that would make land use information more readily available (National Academy of Sciences, 1966, 1970; 1974). These efforts have recognized the global potential of applications from remote sensors operated from Earth-orbitting satellites. At this writing (mid-1975) the newly-formed NAS-NRC Committee on Remote Sensing and Development is looking at potential applications for resource surveying and environmental monitoring in developing countries.

RESULTS OF EXPERIMENTATION BY USGS AND OTHERS

From its beginnings in the mid-1960's, the USGS Geography Program has participated in test site or pilot project experiments to determine the validity of various remote sensing data-gathering and data-handling techniques and their use in different environmental situations.

The Geography Program has tested certain procedures for rapid data acquisition by remote sensing. It has conducted field observations to verify remote sensing interpretations; it has experimented with software and hardware components to digitize, store, retrieve, and interpret land use information; and it has experimented with methods to provide such information to Federal, State, regional and local users.

It also has investigated the possibility of interpreting elements of the land use system thus described with respect to probable environmental impact consequences such as effects on runoff, sedimentation, water quality, microclimate, and air pollution. The experimentation has been conducted in cooperation with NASA, the EROS Program of the Department of the Interior, other units of the Geological Survey, and other bureaus of the Department of the Interior. Observations and tests have been conducted in several types of environments, throughout the conterminous United States and Puerto Rico, including both urban and rural regions.

Results of this experimentation have been reported in numerous published and unpublished works (Gerlach and others, 1971).

In addition to conducting and directly sponsoring the research, USGS geographers have kept abreast of the results obtained by colleagues in other organizations performing similar research.

The first Geography Program test sites in urban, rural, and wilderness environments, respectively, were in the Chicago metropolitan area, the eastern portion of the Tennessee Valley Authority region in the Asheville, North Carolina area, and the North Cascade Range of Washington State (Marble and Thomas, 1966; Marble and others, 1971, Peplies, 1970; Meier and others, 1966). Other test sites were soon added in southern California, Florida, Arizona, Kansas, and other areas where cooperative activities were also being carried on and aircraft and spacecraft data were being made available through the NASA facilities (Simonett, 1969; Thrower and others, 1970, Rudd, 1971; Horton, 1972). Early emphasis was on broad investigations of the potential of the remote sensing observations to geographic science, and a great deal of the work was conducted through contracts with university scientists.

Based on the results of the early test site studies, program emphasis shifted to a concentration on land use analysis and applications to urban and regional planning, with an increased staff effort within the USGS. Program direction was aimed toward a proposed operational capability of supplying standardized land use data and integrating those data with other environmental and socioeconomic data for urban and regional planning (Alexander, 1970). This effort developed into the integrated program of geographic pilot projects (see below) that served as the foundation upon which the recommendations of this report are based.

As demonstrated in portions of the pilot projects mentioned below, a series of activities drawn from components of the research effort can be arrayed in a logical sequence and blended into a coherent program. These include: (1) integration of appropriate sensor systems into a common data-producing survey, including ground-based observers and more traditional map and other library sources; (2) development and testing of a standardized (or nationally compatible) land use classification system (Anderson and others, 1972); (3) computer storage and manipulation, including quantification of land use descriptions, graphic and statistical portrayal, with flexibility of retrieval, subject classification, and scale; (4) sample field analyses, including coordination with geologic, hydrologic, and other environmental mapping and analysis; (5) assessment of user reactions through individual interviews, conferences, and field study collaboration; (6) establishment of experimental data distribution services for potential users.

Experiments to date have demonstrated that imagery obtained from high-altitude aircraft (NASA RB-57s and U-2s) can provide a source of resource data that has many uses and advantages. Such imagery can be rapidly interpreted and verified with selected ground checking. It can also be integrated with information provided by local programs of land use monitoring, like those for building inspection, crop reports, or crop subsidy applications. Remote sensing imagery provides a stable record that can be reinterpreted for verification at any time. High-altitude imagery can provide synoptic records of processes operating over large areas regardless of jurisdictional or enumerational boundaries. Providing coverage extending over large areas in a relatively short time, precision mapping cameras and high-quality color infrared film in the high-altitude aircraft also producephotographic images of sufficient ground resolution to distinguish and identify considerable detail in the land use patterns. With such flexible and versatile records, comprehensive national, regional, and local resource use and change patterns can be identified.

In our opinion, the utility of the high-altitude aerial photography provided by the NASA Earth Observations Program as a source of needed land use data has been proven conclusively, and no further research to estbalish its general utility is called for. Rather, extended high-altitude aircraft coverage should be obtained for as much of the country as possible. Associated studies should focus on the refinement of procedures for deriving replicable and verifiable data sets from such photography taken over the various environmental types that would be encountered in a national land use information service. Such studies might include determining seasonal variations suggesting different optimum data collection times in different environments. High-altitude coverage would become an invaluable basic source, immediately useful throughout the community of persons and organizations who need land resources information. It would further serve as a source for building a standardized system for describing land use as would be essential for a national land use information system, and in addition would be available as the source of essential calibration information for testing and evaluating more advanced sensor systems such as the multi-spectral scanners of Landsat and Skylab.

URBAN AND REGIONAL PILOT PROJECTS

Among the USGS Geography Program test sites or pilot projects, some are of region-wide scope and some are primarily concentrated on urban areas. Locations of these sites are indicated in figure 1. They are grouped into four projects: the Urban or "Census Cities" project; Arizona; Ozarks; and CARETS. These particular sites were selected for a variety of reasons, including the existence of other agency collaborative activities and the benefits from sharing data provided by NASA test aircraft and satellites.

The city locations represented by dots in figure 1 are a sample of 27 urban places, including San Juan, Puerto Rico, designated by the Geography Program in 1970 as the "Census Cities" project. The name "Census Cities" derives from the time of high-altitude aircraft data collection (approximately that of the 1970 Census of Population), and the plan to compare systematically land use data obtained from the air with data derived from the 1970 census. Experimentation with Landsat-1 data is also part of the Census Cities project.

The Arizona and Ozarks projects involve experiments with land use mapping at a scale of 1:250,000. Data from these sites are being digitized, stored, and automatically printed out in map form, first by 1 km x 1 km-grid cells, and later by actual "line" boundaries of land use types. Arizona is also the site of a Landsat-1 experiment.

URBAN AND REGIONAL TEST SITES

Figure 1

These projects have tested different technical approaches, and different combinations of inputs, interpretation, and graphic portrayal in a system. Each has supplied distinctive contributions to the development of the Geography Program at its present stage. More detailed descriptions and reports of progress on these projects are available elsewhere (Wray, 1970, 1972; Place, 1972). The fourth project, CARETS, has been selected for more detailed discussion in the following sections.

CARETS AS A TEST PROJECT AND REGIONAL DEMONSTRATION

The Central Atlantic Regional Ecological Test Site covers an area of some 74,000 square kilometres (28,000 square miles) on the eastern seaboard (figure 2). It falls within portions of five States at the southern end of a group of urban regions that collectively have been called Megalopolis (Gottmann, 1961). It also includes two of the largest estuarine systems in the United States, the Chesapeake and Delaware Bays.

Because of these natural conditions and its heavily urbanized hinterland, the region has a geographic unity that enhances its value as a test site for a national land and related resource use information system. The test site has other favorable attributes. (1) environmental systems and resource problems that cross State boundaries; (2) great diversity of resource use, (3) a large population, and (4) a rapid rate of change in land occupance and resource use. The site thus includes some of the more sensitive environmental types in the country and some of the more aggressive agents for change.

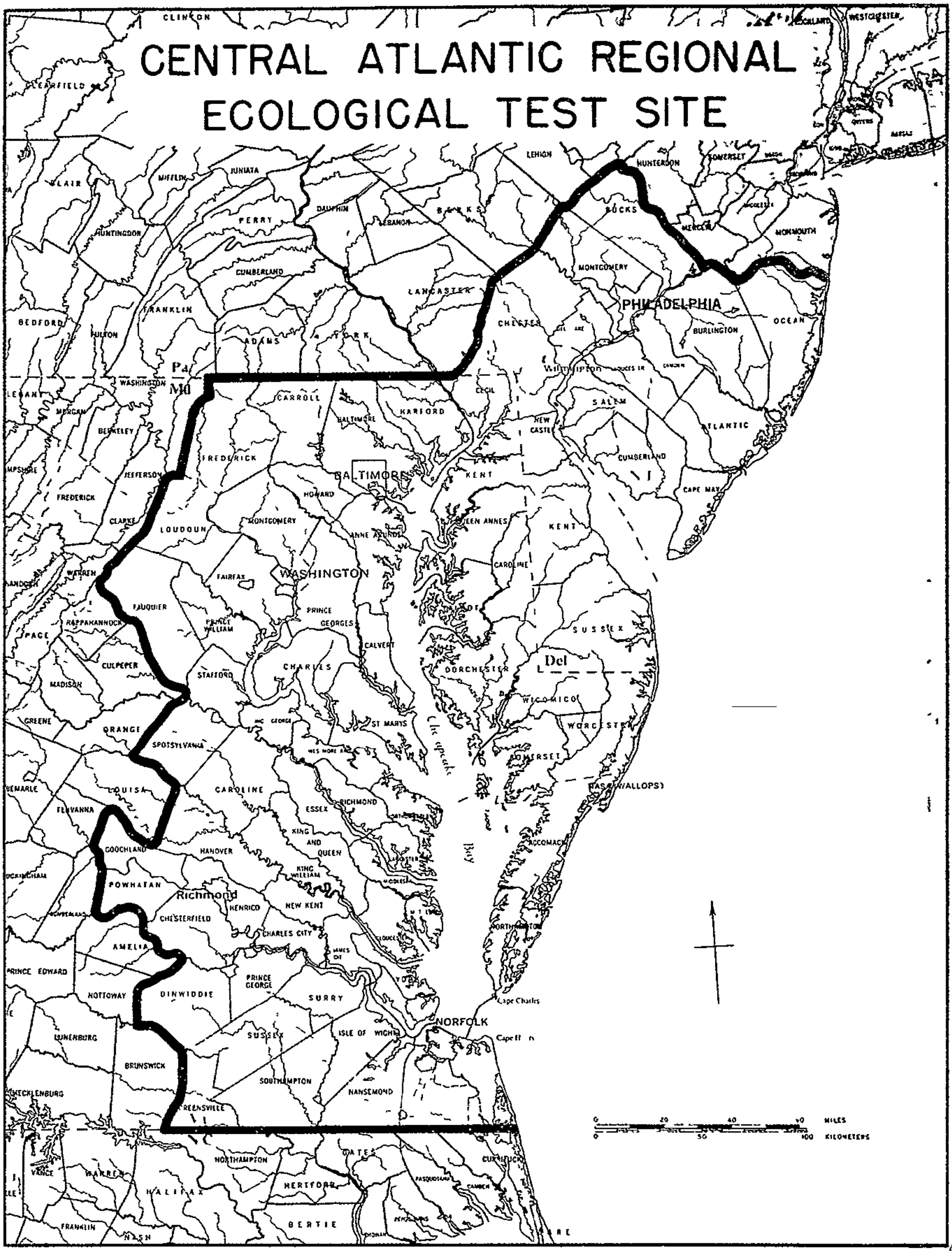

CENTRAL ATLANTIC REGIONAL
ECOLOGICAL TEST SITE
PHILADELPHIA
BALTIMORE
WASHINGTON
Richmond
NORFOLK
Wilmington
Pa
Md
Del
Chesapeake
Bay
Cape Charles
LEHIGH
HUNTERDON
SOMERSET
BUCKS
MERCER
MONMOUTH
MONTGOMERY
OCEAN
BURLINGTON
JUNIATA
MIFFLIN
BLAIR
PERRY
DAUPHIN
LEBANON
BERKS
HUNTINGDON
CUMBERLAND
LANCASTER
FRANKLIN
CHESTER
BEDFORD
FULTON
ADAMS
YORK
WASHINGTON
CECIL
CARROLL
HARFORD
BALTIMORE
SALEM
ATLANTIC
NEW CASTLE
MORGAN
BERKELEY
FREDERICK
CUMBERLAND
JEFFERSON
KENT
CAPE MAY
HOWARD
FREDERICK
CLARKE
LOUDOUN
MONTGOMERY
ANNE ARUNDEL
QUEEN ANNES
KENT
WARREN
FAIRFAX
CAROLINE
FAUQUIER
PRINCE WILLIAM
PRINCE GEORGES
RAPPAHANNOCK
PAGE
SUSSEX
CALVERT
CULPEPER
MADISON
STAFFORD
CHARLES
DORCHESTER
WICOMICO
GREENE
ORANGE
ST MARYS
WORCESTER
SPOTSYLVANIA
SOMERSET
LOUISA
CAROLINE
ALBEMARLE
FLUVANNA
ESSEX
RICHMOND
KING AND QUEEN
GOOCHLAND
HANOVER
ACCOMACK
KING WILLIAM
POWHATAN
HENRICO
NEW KENT
CHESTERFIELD
NORTHAMPTON
AMELIA
CHARLES CITY
PRINCE EDWARD
PRINCE GEORGE
NOTTOWAY
DINWIDDIE
SURRY
LUNENBURG
SUSSEX
ISLE OF WIGHT
BRUNSWICK
SOUTHAMPTON
NANSEMOND
MECKLENBURG
GREENSVILLE
NORTHAMPTON
GATES
CURRITUCK
VANCE
WARREN
HALIFAX
HERTFORD
CAMDEN
FRANKLIN
NASH
BERTIE
MILES
KILOMETERS

Figure 2

Much, if not all, of CARETS is made up of three extended metropolitan regions, or "urban fields," i.e., Philadelphia in the north, the Washington-Baltimore metropolitan region in the center, and the Richmond-Norfolk region in the south. Within these metropolitan regions are important segments of heavy industry, the nation's political capital, some of its more important defense establishments, the oldest continuously occupied land surfaces, some of the most important recreational areas on the east coast, and agricultural areas of regional significance. If an information system can be designed that will be useful in the further development and management of this region, it should also have the capacity for application to many other parts of the United States.

OBJECTIVES AND GOALS OF CARETS

The principal objective of CARETS is to test the extent to which various remote sensor data systems, including Landsat and the high-altitude aircraft systems made available by NASA, can be used as input to a regional land resources information system (Alexander, 1974). Two corollary objectives are included so that CARETS can serve as a pilot project or prototype in the development of a national capability to provide up-to-date information on changing land uses. The first is to develop a unified land use survey in both graphic and statistical form for the entire region. The second is to test and verify the use of information obtained in the land use survey in planning and managing for environmentally-sound uses of the land. The project has been jointly funded by NASA and the EROS Program of the Department of the Interior.

CARETS is one of a class of Federal projects aimed at achieving a better balance between growth and environmental quality through improved allocation of land to new and existing uses. The goal of improved land use planning in an advanced industrialized nation is complex, reaching all levels of government, commerce, and industry. It requires the integration of expert knowledge on a wide variety of phenomena, including the physical environment, transportation, agriculture, mining, manufacturing, public health, and other social and economic considerations. The CARETS project addresses the need for better and more timely information on land use, its changes, and its environmental consequences. Because the implications of new technology are not immediately apparent to those who make decisions on land use change the "démonstration project," "pilot project," or "test site" approach is used, somewhat analogous to the U.S. Department of Agriculture's test demonstrations so successfully used to introduce new technology into agriculture.

PROJECT DESIGN AND CONCEPTUAL BASIS

The conceptual basis for the CARETS demonstration project is a particular kind of sampling strategy for deriving from remote sensing sources measurements of the land surface and converting those measurements into elements of a land use information system. Since the visible land surface or landscape results from a number of interacting environmental and socioeconomic processes, the elements of the information system should be meaningfully relatable to those processes.

The project design takes advantage of the two-way linkage between land use and the processes and responses of the environment. According to this linkage, land use evolves under constraints set by processes of the physical environment, and socioeconomic processes determine the particulars of how a given land use pattern develops within environmental limits.

Certain environmental responses are functions of land use and land use change. Such responses include runoff, sediment yield, microclimate, water quality, and air quality. If the land use that is mapped can be properly "calibrated" in terms of its probable environmental impact, then a land use data base might be a powerful tool of inference, concerning for example, environmental quality. Such a data base would not replace direct measurement of critical environmental parameters but would rather provide a basis for extrapolating those measurements region-wide for more rapid early determination of environmental impact of proposed new development in time to assist in the critical decisions as to how and where that development should occur.

The CARETS research design contains a sequence of three interrelated program steps or subtasks. (1) land use analysis; (2) environmental impact assessment; and (3) user evaluation. Data and data products from remote sensor sources are used to extract land use information, which is produced first in the form of maps, then measured and summarized with computer assistance, and made available to users. The land use information, along with other data sets (geologic, hydrologic, political boundary, and socioeconomic) is used for environmental impact analysis and other regional planning and management applications. These analyses are also presented to users for evaluation and use in problem solving. User feedback should govern the types of data and products produced in later phases of the information system development.

Answers to certain questions about the design and operation of a land use information system are to be sought. The more important questions are. (1) What uses can a land use information system be put to in the region? (2) What resource use situations have compelling requirements for comprehensive land use information? (3) What are the costs of providing information under the proposed system as compared to current sources of information? (4) What basic field studies are required for proper interpretation under the proposed system? (5) Where are frequent replications of survey required? Can a model schedule of such replications be devised? (6) How should cooperation and communications be organized between the land use information agency and users?

CARETS project designers decided that the basic sensor inputs would be sought from NASA U-2 or RB-57 overflights for the entire region, to be replicated as much as possible with satellite overflights as determined by the Landsat-1 experiment. The U-2 or RB-57 overflights were to provide photographs that would be keyed to a UTM grid, so that all derived data would have known location referents on the Earth's surface. Answers to the questions are to be sought not only in an interpretation of the aerial survey data but also in field studies to be provided through outside contracts and by cooperation from other units of the Geological Survey. Interviews and organized conferences were planned to supplement the above measures. Development of the classification needed for mapping at Levels I, II, and III was to be provided by the Geography Program staff.

Project designers further decided that completion of study of the CARETS area would proceed on a mosaic pattern, beginning with the Norfolk, Virginia and Washington, D.C. Standard Metropolitan Statistical Areas (SMSAs). They felt that meaningful answers to the questions facing the program could best be obtained in this way.

REMOTE SENSOR INPUTS, CLASSIFICATION, AND MAPPING

The first stage of the CARETS project included obtaining basic remote sensor coverage for the entire region, supplemented by sample or specialized types of coverage for smaller portions of the test region. Most of the basic coverage was supplied by the NASA Earth Observation Program. high-altitude aircraft color infrared photography of the type already mentioned, and photographically-reconstituted multispectral scanner imagery from Landsat-1. Aircraft photography was obtained in 1970, to be as nearly contemporaneous as possible with the census of population, and again in 1972 and 1973, to allow the determination of land use change during that period. Landsat imagery was obtained continuously from launch in July 1972 for all cloud-free observation passes of the satellite, which has a potential observation period over each ground site every 18 days. Coverage over portions of the test region was also obtained from Skylab sensors, from NASA-sponsored flights of an Environmental Research Institute of Michigan aircraft, and from archival aerial photography from the U.S. Air Force and the U.S. Department of Agriculture.

This collection of basic remote sensor data, brought together in the information center set up as part of the CARETS project, constitutes a regional data bank of considerable richness. To reduce this vast store of data to a manageable package to allow a quantifiable input to a land use information system, the data had to pass through spatial filters in the forms of different levels of a land use classification system and of various other sampling schemes.

The classification system used was one developed by a special interagency committee, later slightly modified into the USGS Land Use Classification System for use with Remote Sensor Data, Circular 671 (Anderson and others, 1972). This is a multilevel, hierarchical classification system, which specifies the first two levels and leaves the more detailed levels for later determination. Level I contains generalized categories deemed suitable for derivation from Landsat. In the CARETS area these generalized categories are urban and built-up, agriculture, forest, water, nonforested wetlands, and barren land. Level II gives somewhat greater detail within each of the Level I categories (table 2), and was thought suitable for use with high-altitude aerial photography as a source.

Level III and higher levels would provide still greater detail, as would be provided by low-altitude aircraft data, supplemented by information from other than remote sensor sources (plate 1 and tables 1 and 2). The higher the spatial resolution of the remote sensor source material, the greater the number of categories or classes that can be distinguished.

and related resource use information system

Characteristics \ Level	Level I	Level II	Level III and Greater Detail
A. Initial Remote Sensor Inputs	Satellite (ERTS), high altitude, B/W, color IR	High altitude, B/W, color IR	High and low altitude, B/W, color IR
B. Typical Spatial Resolution of Imagery	30 to 100 meters (100 - 300 feet)	1.5 to 10 meters (5 - 30 feet)	.15 to 1.5 meters (.5 - 5 feet)
C. Typical Areal Recording Unit For System Input	4 hectares (10 acres)	.04 hectares (.10 acres) to 4 hectares (10 acres)	.004 hectares (.01 acres) to .04 hectares (.10 acres)
D. Typical Map Scale	1.100,000 to 1:1,000,000	1:24,000 to 1:100,000	1:1000 to 1:24,000
E. Common Uses			
land use planning	National, State, regional land use plans, environmental impact statements, definition of critical environmental area and zones	State, regional, metropolitan, local land use plans and design, definition of critical environmental areas, development and review of environmental impact statements	local land use planning and design at land parcel detail, specific definitions of critical environmental areas, historic sites, open space, scenic easements
land use regulation and review of change	National and State review of land use regulations and planning, review of proposals for change such as wetland conversion	State, regional, local registration and permits for pollution, change in wetlands, area franchises	local zoning, taxation, property aquisition, easements, licensing registration, and activity permits
economic forecasting	National, State, and regional forecasts by major economic sector	State, regional, local forecasts by detailed sectors	local area forecasts by detailed activity classes
agricultural and forest productivity	National, State, and regional production forecasts by crop and timber types	State, regional, local design of soil, cropping, and forest management programs	local designation of soil conservation, cropping and timber management areas

Table 1--Continued

Characteristics \ Level	Level I	Level II	Level III and Greater Detail
transportation planning and design	demand analysis and general network layout	network location and design	engineering design and implementation
outdoor recreation planning	National, State inventories, resource comparison	National, State and local inventories, analysis of access and demand, facility planning and design	State, regional, local facility design and management
F. Decision Makers primarily Concerned	Federal and State planning and regulatory agencies, large private utilities, and land management firms--legislative overview, program planning, funding, review, surveillance, implementation	Federal, State, regional, county, municipal planning, development and regulatory agencies, private utilities, all sizes of land management firms--program and project planning, implementation, land parcel management	Federal, through local planning and development and regulatory agencies, private utilities, all sizes of land management firms including individuals--program planning, funding, review, surveillance, project planning, engineering design, implementation, land parcel management.

Table 2--Characteristics of hierarchical land use classification with increasing detail in activities and processes identified

Level I	Level II	Examples of Level III and Greater Detail
1. Urban and Built-up		
	11 Residential	111 High density
	12 Commercial and services	112 Medium density
	13 Industrial	113 Low density
	14 Extractive	
	15 Transportation, communication, and utilities	
	16 Institutional	
	17 Strip and cluster settlement	
	18 Mixed	
	19 Open and other	
2. Agriculture		
	21 Cropland and pasture	211 Cropland
	22 Orhards, vineyards, bush fruit, groves, horticulture	212 Pasture
	23 Feeding, operations	
	24 Other	
3. Rangeland		
	31 Grass	311 Tall
	32 Savanna	312 Short
	33 Chaparral	313 Bunch
	34 Desert Shrub	314 Desert
4. Forest Land		
	41 Forest, 40-100% crown closure	411 Conifers
		412 Deciduous
	42 Foresting, bushland, 10-39% crown closure	
5. Water		
	51 Streams waterways	521 Fresh
	52 Lakes	522 Brackish
	53 Reservoir	
	54 Coastal estuary	
	55 Other	
6. Nonforested Wetlands		
	61 Vegetated	621 Tidal
	62 Bare	622 Fresh
7. Barren Land		
	71 Salt flats	721 Sand
	72 Beaches	722 Clays
	73 Sand other than beaches	723 Other
	74 Exposed Rock	
	75 Other	

Table 2--Continued

Level I	Level II	Examples of Level III and Greater Detail
8. Tundra	81 Tundra	811 Arctic 812 Tundra 813 Shrub
9. Permanent Snow and Ice Fields	91 Permanent snow and ice fields	911 Glacier 912 Snow field 913 Ice pack 914 Other

The land use mapping was performed by manual photo and image interpretation by trained geographer-interpreters. The first mapping effort produced the base line data set for the entire project, a land use map at a scale of 1:100,000, to a Level II classification detail, using the NASA high-altitude photography flown in 1970. At this scale the smallest area depictable is about 4 hectares (10 acres), or the equivalent of a square 200 metres on a side. The mapping base was a controlled photomosaic made from the same NASA photography, enlarged slightly from its original scale of approximately 1:120,000. The USGS issued an experimental CARETS map series, requiring 48 sheets or portions thereof, to contain the land use and related information at a scale of 1:100,000. Another complete coverage of CARETS was that of the land use change that was detected by comparing the original photography and maps with similar photography flown 2 years later. Additional overlay maps were prepared for each of the 48 sheets to assist in interpretation and use of the land use maps. These overlay maps depict major drainage basin boundaries, census tracts, and county boundaries, and place names and other cultural information to aid in locating the land use information elements.

Landsat-1 data, which became available in 1972, was source material for another complete mapping coverage of the CARETS region. Because of its lower spatial resolution and geometric fidelity, a smaller scale, 1:250,000, was selected for this mapping effort. The smallest area depictable at this scale is 25 hectares (about 62 acres), or the equivalent of a square 500 metres on a side. After digitizing and associated data processing activities are carried out, comparisons of the relative accuracy of the aircraft and Landsat data, as sources of land use information, can be performed. Although when using Landsat imagery one can only obtain uniform mapping coverage at Level I detail, investigators discovered that some Level II and even Level III detail could be discerned. Likewise, the high-altitude aircraft photography was found to be usable for greater than Level II detail. It is expected that, as the technology improves, the different levels will be defined by user needs and classification logic rather than by the altitude of the remote sensor platforms.

STUDY OF THE NORFOLK, VIRGINIA METROPOLITAN AREA

An analysis of land use and related problems in the 1970 Norfolk-Portsmouth SMSA was undertaken to develop and test procedures in detail before applying them to the larger CARETS area. The results of this analysis will be described briefly because they illustrate clearly the situations in which land use information is most needed at the level of a metropolitan region.

The Norfolk SMSA is strategically situated on the southern side of the entrance to Chesapeake Bay (figure 2), a location making the area an almost obligatory choice for the siting of some important national defense installations, particularly for the Navy. It also has a strategic commercial location, with a hinterland extending far south into the Carolina piedmont and westward across the Appalachians. It has one of the most important coal-handling ports in the world. Norfolk's port and commercial situation favor industrial and urban expansion.

At the same time large blocks of land in the region are reserved for defense agency uses.

Other resources make the region a favored recreational area. Its 48-km ocean frontage and the wildlife attracted to the wetlands behind the barrier beaches of the southern part of the region encourage recreational visitors. They come from the entire State of Virginia, and other districts to the west, north, and southwest.

All this is in a setting where agriculture has its encouragements too. The light sandy and muck soils found on the outer edges of the Atlantic Coastal Plain and the relatively long frost-free season, averaging 235 days, have favored vegetable growing and other intensive farming.

Land use, land ownership, and human activities in the region thus have become a mosaic of these uses: Federal defense agencies, commercial port, other transportation, and other commercial functions, farming, family residences, and State or Federal reserves for ecological purposes.

The Norfolk SMSA exists in a situation where land use not only is intensive but land uses are in competition. Industry, defense installations, commercial port facilities, and land transport facilities compete with residence, recreation, agriculture, and fish and wildlife. At the same time recreational developments conflict with some resources on which they partly depend, such as fish and wildlife. Recreation may also be considered in competition with general urban residence needed to support industry, defense, and commerce. Recreation also may be assumed to compete with certain defense installations on the ocean side, and even with the beach itself. Encroachment of both recreational and general residential development onto beach erosion areas has been pronounced.

The most aggressive elements in the situation are the residential developments based on recreation, on defense installations, or on commerce and industry, and the land transportation needed to serve them. The uses in retreat are agriculture and "ecological" reserves on public lands. Unfavorable change also affects water resources, which have deteriorated from industrial, commercial, recreational, and even agricultural effluents. The biota dependent on the water, of course, have deteriorated with the water.

Different types of activities thus are in conflict not only on the land but also in the water. They are also in conflict in the atmosphere, where pollutants from industrial plants and land transportation facilities conflict with almost every other form of occupance. The patterns of conflict, furthermore, are not regular, they differ for land, water, and air.

The Norfolk metropolitan area, then, is in a dynamic state, but hardly one of equilibrium. It has aggressive and defensive components in its resource use, both of which have notable economic and social values. A great variety of decisions on land and other resource use is required, many of which are decisions by default at the present time. What can a comprehensive land use information system do to guide these decisions?

The Norfolk situation, though having an unusual number and variety of land use and resource use components, may be assumed to be typical of the regions where most of the people of this country live today-- the extended metropolitan regions. It is certainly typical of the CARETS area.

The reasons for interest in better comprehensive information about the dynamics of land use involve interests related to the "defensive" forms of occupance, whose existence is being threatened by the "aggressive" forms of land use. "Agressive" forms are expanding and preempting air, water, and land, in the absence of balanced decisions made in the public interest. The pattern of "aggressive" and "defensive" interests, however, is confused. Some forms of occupance, like recreation, urban residential development, and even agriculture, are on both sides.

Comprehensive information therefore is needed by every agency or interest operating above a neighborhood or local community level. It is needed to achieve the proper balance between the aggressive and defensive elements through public action.

A quarterly or semiannual survey that easily conveyed information on land, water, and air use could be employed by anyone having responsibilities for planning, regulation, or management of resource use in the region, including those within industrial corporations. On the whole, the processes that have been set up for achieving this balance have been too cumbersome, too selective, and too expensive to be effective. The efforts to protect the interests of the land and resource uses that are on the defensive, like the environmental impact statements, are stop-gap measures, applied at whatever point a problem or crisis has arisen. Even if the environmental impact procedure is to be continued, it could be made much more efficient in the Norfolk region with a satisfactory background of general survey data that permitted policy formation aided by comprehensive land use information, in both graphic and statistical formats. Examples of input and output of a possible system for supplying such information are displayed in plate 1.

Comprehensive information has been demonstrated to be useful for air pollution determination and monitoring. Although they cannot record all water quality changes, comprehensive surveys would be useful in the many situations in the region where sediment movement causes shoreline changes, biotic destruction, sediment deposition problems, and associated phenomena. Sensor systems for these surveys are sensitive to almost all land use, land quality, and vegetational changes. Although information at a Level III degree of detail can be used by all agencies needing comprehensive surveys, the more easily composed Level II has also been shown to be useful.

REPLICATIONS OF SURVEY

The NASA high-altitude overflights for the CARETS area in October 1970 were repeated in 1972/1973. It is hoped that further replications can be made at intervals of not more than 1 year.

The eventual schedule of survey replication will certainly be a compromise between cost and user needs. In the Norfolk metropolitan area a quarterly survey of the entire region would be useful, a semiannual survey would be adequate, and an annual survey less adequate but preferable to the existing sources of information.

As long as aircraft platforms must be depended on for the major sensor inputs, however, anything more frequent than an annual survey may be too costly. Replication at such an interval will be welcomed, if summary graphic and statistical interpretations can be made available to users. Graphic and statistical comparisons of intervals longer than a year also will be useful, like those undertaken experimentally for the years 1959 and 1970 in the Norfolk metropolitan region.

Changes in terms of the 1959 and 1970 land use categories, respectively, are shown in figures 3 and 4. These maps show dramatic increase in urbanization at the expense of agriculture and forest. Structural components of the change for the whole SMSA are displayed in the transition matrix, figure 5, showing the types and amounts of change, both out of and into each Level I category. The matrix shows transitions among all categories, with the diagonal representing land that did not change in this period. About 91 percent of the total land area had no change in use at Level I. This means that even in this rapidly changing, highly urbanized region, only 9 percent of the total land area showed change in Level I categories in 11 years.

Admittedly, this analysis may be insensitive to many kinds of land use change at Levels II and III. Land use data at Levels II and III should also be analyzed to test the sensitivity of these more detailed measures to the detection of change. There are some indications, however, that even changes at Level I may be indicative of those changes having the most critical environmental impact, especially the relatively irreversible changes from any category into the "urban and

Areas of Level I Land Use Change, 1959-1970

Figure 3--This map depicts areas for which Level I land use change occurred in the period 1959-1970. EDC-010108.

Areas of Level I Land Use Change, 1959-1970

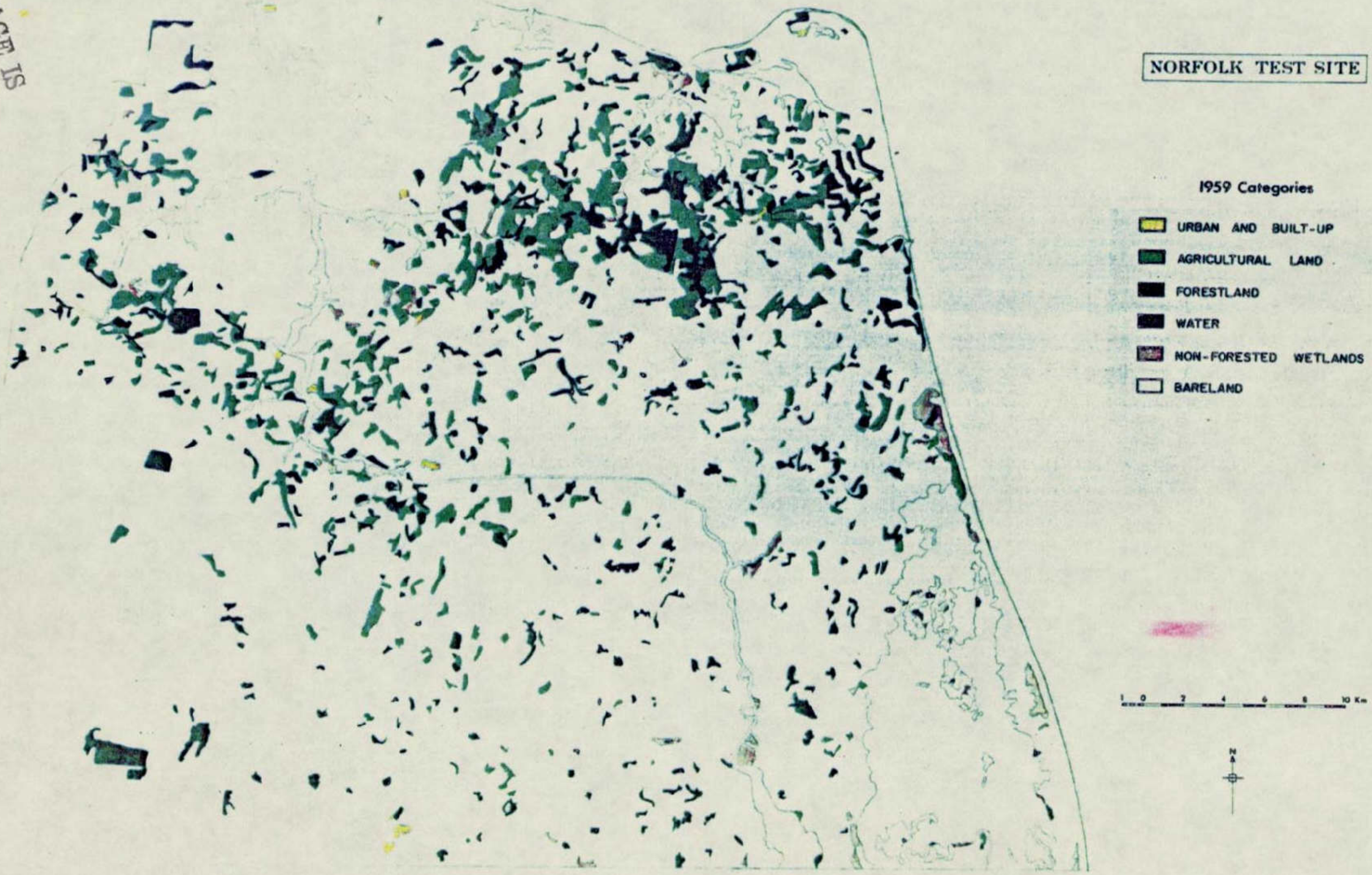


Figure 4—This map depicts areas for which Level I land use change occurred in the period 1959-1970. EDC-010107.

NORFOLK-PORTSMOUTH SMSA
LEVEL I LAND USE CHANGE MATRIX
1959-1970

1970 (*in km²*)

1959 (*in km²*)

From \ To	1	2	4	5	6	Total 1959
1	*286*	*2*	*1*	–	–	*289*
2	*80*	*549*	*19*	*1*	–	*649*
4	*34*	*32*	*495*	2	2	*565*
5	–	–	–	*244*	*3*	*247*
6	2	*1*	5	–	*129*	*137*
Total 1970	*402*	*584*	*520*	*247*	*134*	*1887*

1 Urban and Built-up Land

2 Agricultural Land

4 Forest Land

5 Water

6 Non-forested Wetland

Figure 5

built-up" category. Thus, the relatively small percentage of the total area that has undergone this kind of change in 11 years suggests a sampling strategy of focussing on areas where change is occurring. This method may result in a considerable saving over a survey method that sets out to examine every square kilometre of land surface for change resulting in critical environmental impact. Sample assessments at larger scales, such as 1:24,000, must also be made to see what is missed by smaller scale analysis.

BASIC FIELD STUDIES REQUIRED FOR PROPER INTERPRETATION

Although the bulk of the data inputs to a national land use information system might be from remote sensors, ground checks and other supplementary field studies will be necessary for proper interpretation and analytical use of system products. Air sampling is needed to describe the chemical content of a smog cover or stack exhausts. Water sampling is needed for information on all nonvisible changes in water bodies. Geological study is needed for the analysis of the suitability of land use changes from the point of view of long-term occupance.

Field studies in CARETS have been carried out with two objectives: (1) to verify the photointerpreted land use units, and (2) to make observations pertinent to the estimation of the "environmental impact" of land use.

To verify the photointerpreted land use, field teams visited the Norfolk SMSA. Team members were geographers who had worked on the photo-determined land use mapping. They visited primarily problem areas encountered in the photointerpretation, but also sampled other areas representative of each land use type. Errors of two types were investigated: those arising from incorrect assignment of areas to a classification category and errors of boundary placement between categories. In addition, "mixed" categories in a single mapped unit were investigated; the "mixing" of categories is inherent in the particular classification used at the relatively small scale (1:100,000) of map compilation.

The CARETS project conducted environmental impact investigations to demonstrate the correlation of land use information elements with environmental consequences. Such environmental information is needed whenever and wherever decisions on land use changes are being made. Investigations thus far have included geomorphic effects (erosion and sedimentation); effects on air and water quality, and effects on microclimate. The latter was conducted at a Baltimore test site in conjunction with measurement of the effects of land use types on the surface energy budget.

Data on geology, soils, and air quality were compiled from other sources to demonstrate other factors relevant to land use planning. These data, however, were not field checked. An "earth materials" map for the Norfolk area has been compiled, showing distribution of naturally occurring rock and soil materials and their suitability for various kinds of land use. One demonstration relates land use type in the Norfolk area to typical sources and dissemination of air pollutants. Another study examines the deterioration of the wildlife habitat in the Back Bay National Wildlife Refuge, south of Norfolk, resulting from increased population growth, increased urbanization, increased demand for recreational land, and increased application of chemical fertilizers and pesticides on agricultural land.

COLLABORATION AND COMMUNICATION WITH USERS

Appraisal of the uses of the land and related resources use system also included a user conference of Federal, State, regional and local planners and other potential users in the CARETS area, the initiation of an experimental CARETS information center in the Geography Program's offices, and the initiation of a collaborative program with the Maryland State Department of Planning. The CARETS information center and the collaborative program with the Maryland State Department of Planning will be described briefly here.

The CARETS information center provided for the storage, indexing and processing of aerial and satellite photographs, ground truth information, regional land use maps, environmental research reports, United States census data, and other material considered relevant to the system. It was designed to provide for, or assist in providing, computer analysis and computer graphics, reproduction services, and consultation on the use of data accumulated. Information on user needs and evaluation of usefulness of products from the land use information system were sought from collaborating users.

Collaboration between the Geography Program and the State of Maryland was first suggested by the geographic information requirements for Landsat experiments in the State of Maryland. Cooperative arrangements include coordination and communication between Geography Program staff and staff of the Maryland State Department of Planning in: (1) testing and evaluation of Geological Survey-developed interpretation of high-altitude and satellite imagery; (2) testing, evaluation, and operational revision of land use classifications at Levels I, II, and III; (3) correlation of remote-sensor data with other sources of survey information; (4) investigation and testing of available schemes for the spatial recording of area, line, and point data; (5) specification of thresholds for accuracy levels and scales of aggregation for State, regional, and local community users in Maryland by the department; (6) testing of a preliminary design of a user-interactive computer-based geographic information system; and (7) a mutual investigation into the parameters of systems costs and time requirements for an operational planning agency.

The Maryland State Department of Planning is assigned the responsibility of preparing and updating a "Generalized Land Use Plan" that will recommend the most desirable general pattern of land use within the State, determine the major circulation patterns for routes and terminals of transit and communication within the State and for movement from adjoining areas, and recommend the general location of major public and private facilities.

Although the connection of the programs with forthcoming satellite-derived data has stimulated great interest and some hopes on the part of many users of land and resource use information in the region, programs of technical training will be needed to develop the analytical capacity within the States necessary for effective long-term collaboration among the Federal Government, the States, and communities of the region. No university in the region currently has a research program that could serve as an effective bridge in this respect.

NEXT STEPS IN ESTABLISHING A LAND AND RELATED RESOURCE USE INFORMATION SYSTEM

Considerable further effort would be required for the development of a land and related resource use information system. Nevertheless, the progress to date has brought an atmosphere of optimism about the feasibility and the eventual usefulness of such a system. The next steps will be most important. They should be undertaken with recognition of the most efficient order in which effort should be applied. Otherwise excessive expenditures by the Federal Government are likely to result, along with needless delays in development of a full operational system, and needless user disappointment.

OTHER PLANS FOR RESOURCE USE INFORMATION SYSTEMS

The CARETS experimental land and related resource use information system belongs to a type described in the professional literature as "geographic information systems" (Tomlinson, 1972). A relatively large number of these systems have been experimented with, and a number developed to the point of some utility. Examples are the Minnesota Land Use Information System, the Orstom soil information system and the Urbax urban land use information system in France, the Canada Land Use Inventory and the Canada Geographic Information System, and the FRIS system for land use and other real estate data of the Central Board for Real Estate Data in Sweden. Many experiments for urban or metropolitan areas are underway in the United States (Tomlinson, 1972, p. 1282-1327). With the exception of the Canadian systems, none of the many experiments or operational systems cover anything like the extent and complexity that will have to be dealt with in a national land use information system for the United States as a whole. Nevertheless, progress in the most advanced of these systems should be fully reviewed for results that are relevant to implementation of any United States national system.

RECOMMENDATIONS FOR EVOLUTIONARY DEVELOPMENT OF AN OPERATIONAL PROGRAM

It is recommended that work on CARETS and the other demonstration projects be coordinated and concluded in such a way that the resulting products and institutional bases can provide the best possible technical preparation for a national land and related resource use system. These considerations suggest that the term "CARETS" be dropped and the boundaries of CARETS and the other demonstration projects be redefined in preparation for appropriate regionalization of a nationwide effort; that a systematic user survey be undertaken, that further technical development be pressed; that a methodical cost-benefit study be started; and that the information center and its user contacts be further developed.

MERGE THE CARETS AREA INTO A MID-ATLANTIC REGION

The CARETS area originally was chosen and defined in terms of Chesapeake Bay and the watersheds associated with it. The first contacts with possible users of the information system, however, indicated that a broadening of the boundaries of the area along State lines would provide information in a form more welcome to State agencies that might be conmted among the users. Delaware and part of four other States are included within the CARETS region as now defined. The presentation of land and related resource use information from CARETS on only parts of their jurisdictions obviously limits usefulness for Virginia, Maryland, New Jersey, and Pennsylvania. The already accepted arrangements of the Geography Program with the State of Maryland alone make such an extension desirable. Furthermore, the existing boundaries of CARETS do not include all of the two most important metropolitan regions, or metropolitan fields, centered within the region, those of Washington-Baltimore and Philadelphia. Presentation of the most meaningful land use data for these metropolitan fields would include all of the counties that may be considered part of a broadly defined metropolitan region in each case.

Also, since a part of eastern West Virginia is included in the effective Washington-Baltimore metropolitan region, an "operational region" for the redefinition of the CARETS land use information system would therefore most likely include all of the mid-Atlantic States and West Virginia.

CONTINUATION OF USER ANALYSIS

The systematics of establishing any geographical information system have been described a number of times. For such a system, or for any information system, a systematic user analysis is a critical part of procedure (figure 6). This user analysis was begun in the manner described above.

The next steps in an analysis of user demands should be. (1) a methodical operations research type study of a structured sample of users in the various regions among Federal and State government agencies, and (2) a special supplementary study of the relation of the proposed land and related resource use information system to the environmental impact statement requirement of the National Environmental Policy Act of 1969 (NEPA).

The operations research study will compile and analyze as methodically as possible detailed user requirements. The sort of information to be sought in the study is illustrated in figure 7. A great variety of information needed for future development of the system can be acquired from such a study with important bearing on hardware and software design, operation of sensors, design of products, operation of the land use information center or centers, and communication with users. The use of such a study in interim evaluations of the developing system is illustrated by figure 8.

The special analysis of relation to environmental impact statements should review the section 102 of NEPA requirements and the OMB Circular, A-95, Revised, requirements and analyze the proposed system design for

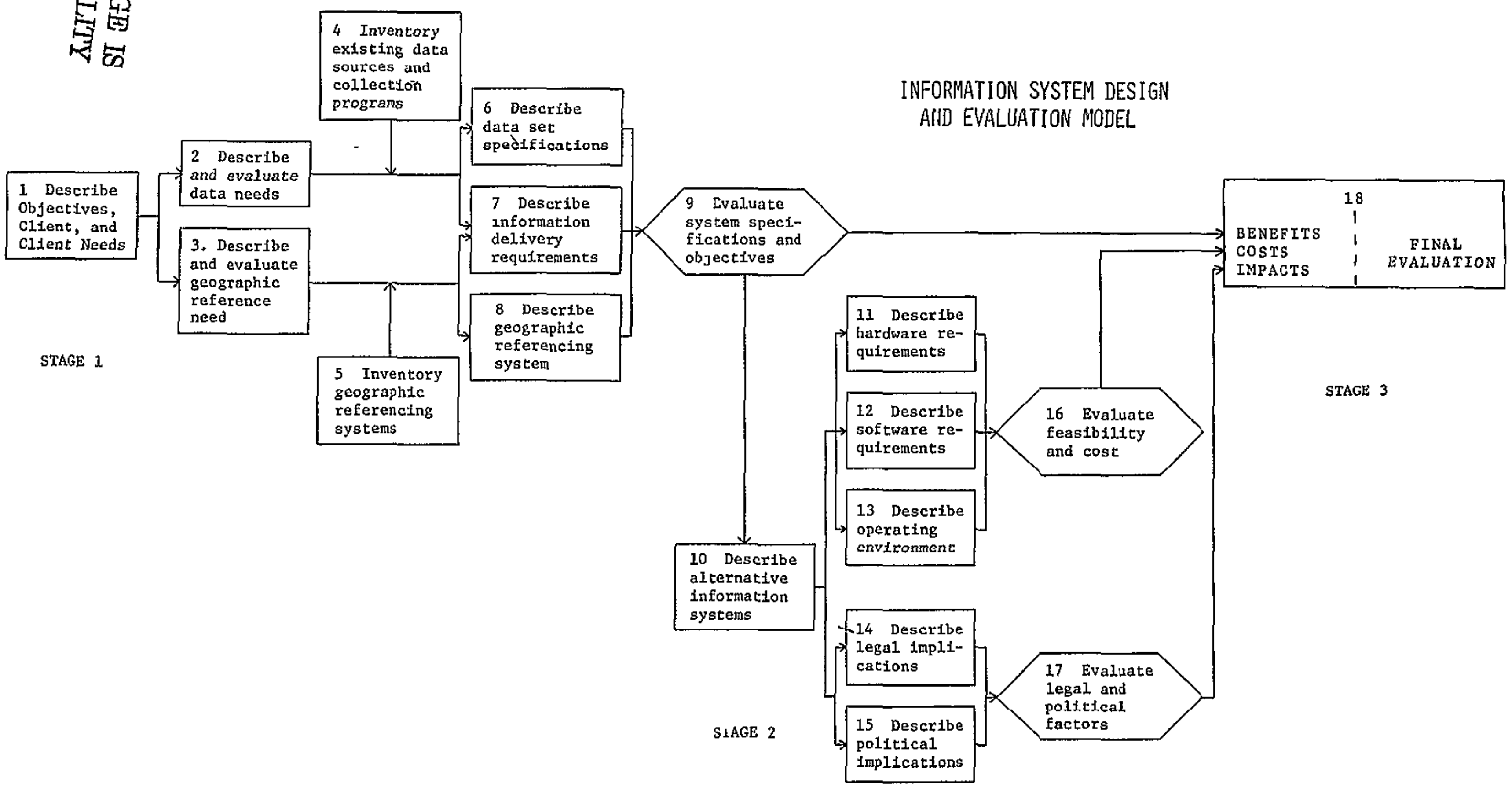


Figure 6

Source: Tomlinson, 1972, p. 1211

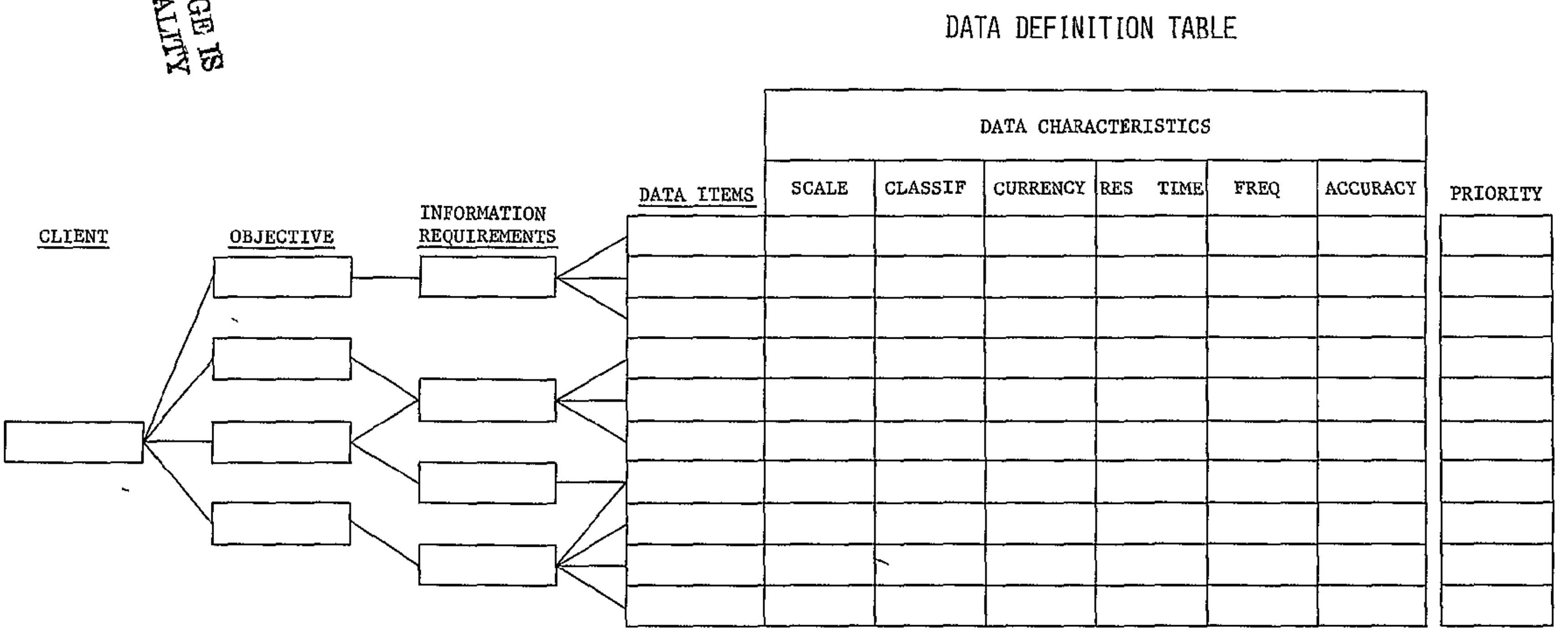


Figure 7

Source: Tomlinson, 1972, p. 1220

INTERNAL STRUCTURE OF EFFECTIVENESS MODEL

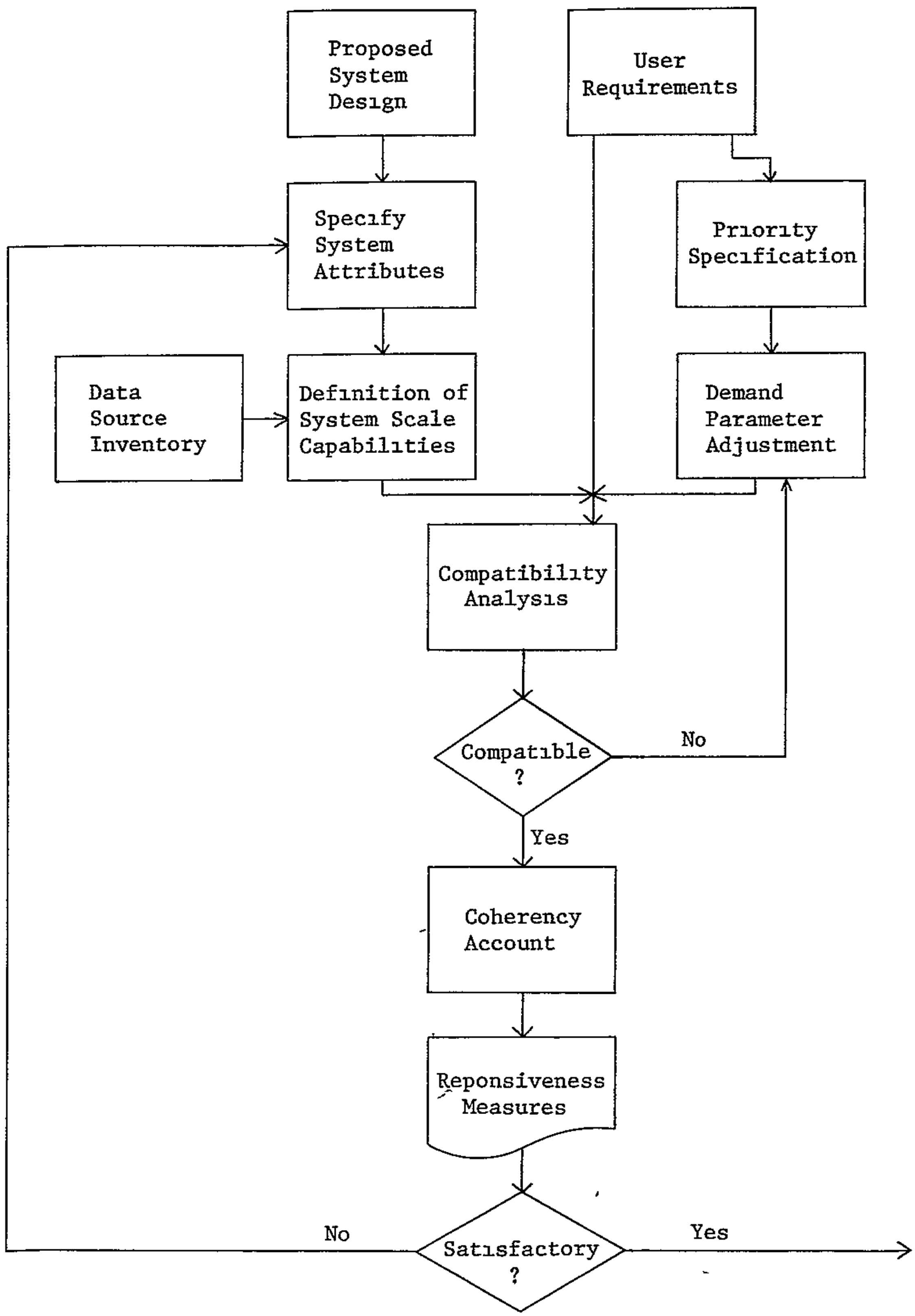


Figure 8

Source: Tomlinson, 1972, p. 1260

the extent of contributions that can be made to the impact statements by products of the system.

The user study is considered to be of first priority in the development of this or any other system on a national scale. As has been stated recently, "It is a matter of considerable concern that many... collectors of data are starting data banks without first defining why and how they wish to use them. Such systems are probably destined to fail..." (Tomlinson and others, 1972, p. 1156).

A second special aspect of interest in a user study should concern the training of personnel in techniques for using the proposed system and contributing to State and local inputs to the federally maintained system Personnel now employed in at least some of the States are not familiar with the operational capacities of such a system and its potentialities.

FURTHER TECHNICAL DEVELOPMENT

In spite of the striking progress made in the improvement of both the hardware and software needed for functioning geographic information systems, (Tomlinson and others, 1972), the ideal system for national use is not yet in sight. Important priority tasks should be the development of Level III of the classification system, further experimentation with automatic spectral and spatial pattern recognition, and provision for optional graphic or statistical printout.

User contacts indicate that a system without a Level III classification will have only limited utility. Once in hand, however, the data at Level III detail may be easily used for the production of Level II or

Level I classifications, where economy of generalization on a large scale is the most important consideration. The development of an operationally acceptable classification for Level III, therefore, should be undertaken as soon as possible. Inasmuch as Level III is of particular interest in the land use distinctions to be made in the rapidly changing fringes of metropolitan areas, the classification as developed should be first tested in one of the metropolitan regions.

Until data of relatively high resolution are available from satellite observation, the hardware part of the system should be kept in as fluid a condition as is compatible with construction of an operational system. Any other course invites excessive, indeed, wasteful expenditure on the program. Nonetheless, several tasks of development will be critical to the evolution of a responsive, high-capacity, universally applicable land and related resource use information system. One critical point is in the development of automated pattern recognition.

The only readily available products of the current system are aerial photographs, which require expensive interpretation for most of their land use data applications. The maps prepared of districts in the Norfolk and Washington metropolitan areas required a large amount of hand coversion before a map could be produced or any digital recording made possible. For recording on a continental scale something more efficient must be found, especially since the important Level III classification will require even greater discrimination among classes than the Level II interpretations in the experimental areas thus far.

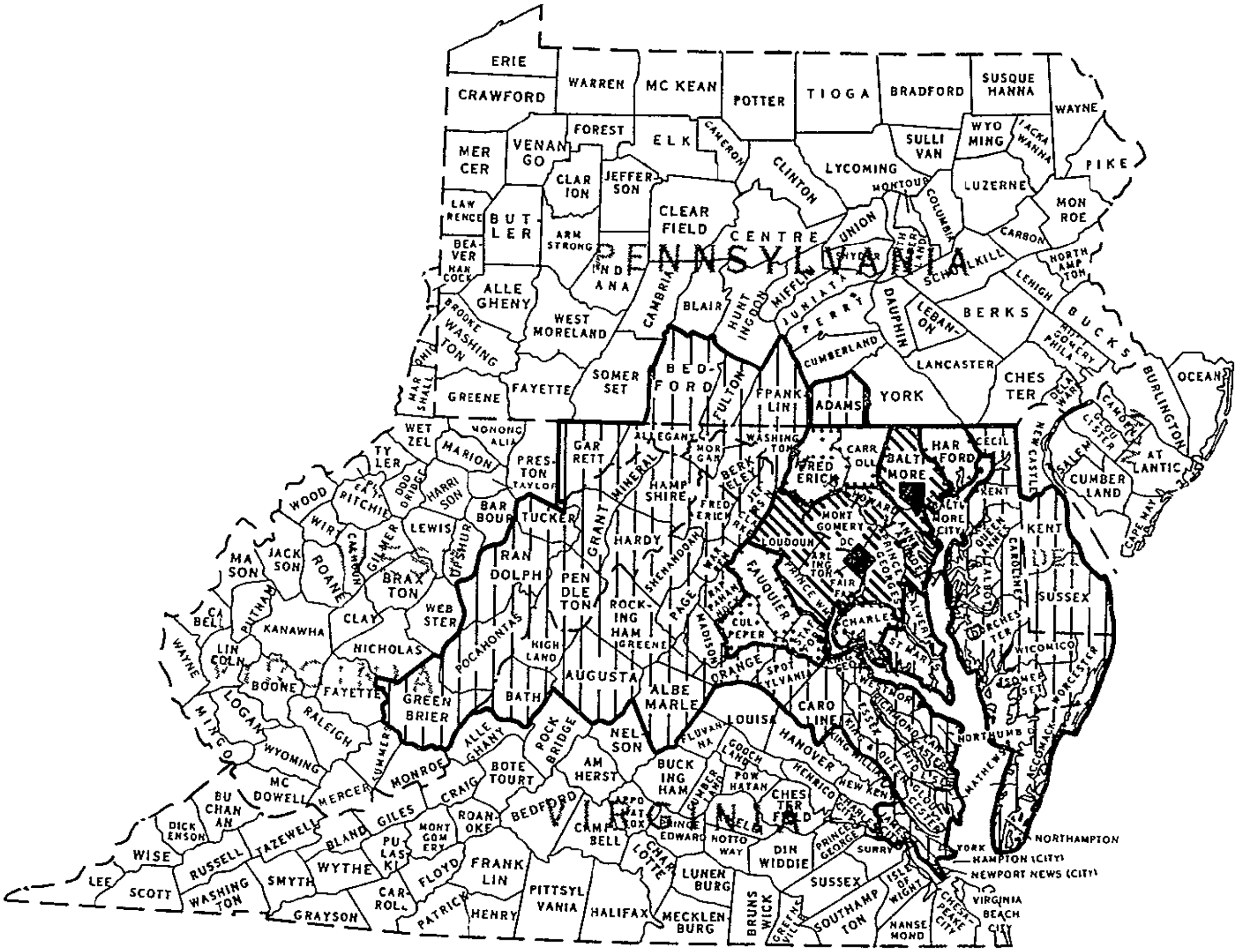
A great deal of technical effort in recent years has been applied to the problem of automatic cartography. Almost 50 different types of systems were listed in a recent review of technical aids available for these purposes in 1972 (Tomlinson and others, 1972, p. 922-1123). The major achievement of these systems is in machine storage and automated output, input for the most part still depends heavily on a man-machine relation. The step to a more automated pattern recognition of input for machine storage and machine products is the most difficult, as delay in this achievement has shown. It must be achieved, however, if a monumentally expensive processing system on a national scale is to be avoided. Automated pattern recognition would also seem to be critical in achieving a desirable level of costs for uses requiring frequent replication.

Another priority step should be somewhat more readily achieved. Most user contacts thus far have indicated that information in statistical form is required as well as information in graphic form. If a choice had to be made between the two, many users would take the statistical information. A combination of the two, however, was much more desirable for most uses than either one alone. The achievement of an automated graphic-statistical interconvertibility, therefore, should be a target for early achievement.

APPLICATION OF THE SYSTEM TO A METROPOLITAN REGION

User contacts thus far have shown that arbitrarily defined areas like CARETS will have limited value in the next stages of cooperation between the operators of a land and related resource use information system and its users. This report has already addressed the desirability of using State boundaries as the limits for regional data collection that will be of greatest interest and most use to State government agencies. Another unit must be recognized very soon in operations such as this, for which the ultimate capacities of the system will be admirably suited. the extended metropolitan region, or metropolitan field (Ackerman and others, 1972).

Extension of the CARETS coverage to the Washington-Baltimore extended metropolitan region would be a valuable next step. This 30,000 square mile area, including a large block of the total CARETS region, is one of the most dynamic of all the metropolitan regions in the United States. As has been noted, the mapping of the inner zones of the Washington region already has been completed at a Level II detail. (Zones of the extended metropolitan region are shown in figure 9.) Analysis of the metropolitan area as a whole can serve as a prototype for those regions of the country where probably 80 percent of the total population lives. They are, furthermore, the regions within which probably 90 percent of the land use changes of the country are taking place, where many of the most serious ecological problems are found, and where overlapping uses are most serious. The immediate goal, in this case, will be the development of the model system for monitoring the land use of a multistate metropolitan region.



ZONE 1 — WASHINGTON AND BALTIMORE INNER CITIES

ZONE 2 — DENSELY SETTLED INNER SUBURBAN ZONE WITH STRICTLY ADMINISTERED LAND USE CONTROLS

ZONE 3 — COUNTIES IN PROCESS OF URBAN DEVELOPMENT, BUT WITHOUT STRICT PUBLIC CONTROLS

ZONE 4 — OUTER ZONE OF RECREATIONAL DEVELOPMENT, LAND SPECULATION AND INCREASING TIES TO THE OTHER THREE ZONES

Figure 9--Zones of the Washington-Baltimore region

Source: Ackerman and others, 1973, p. 101.

COST-BENEFIT ANALYSIS

It is recommended that a cost-benefit analysis of the proposed land use information system be conducted. Particularly needed at this time are estimates of the costs of acquiring information using traditional data-gathering practices, especially where environmental impact information can be supplied through the proposed system. In view of the interim stage in which the development of hardware, software, and user communications now is, a final cost-benefit analysis should be postponed for a later time. However, an interim report on present costs and information foregone because of those costs is desirable, possibly using the mid-Atlantic area as a source of information.

FURTHER FIELD STUDIES

The field studies already undertaken in the CARETS region show that some lands already have been set to uses for which they are not well suited. Some urban land uses have been shown to conflict not only with other resource use but with the Earth itself. The completion of such studies for all of the urban areas of the United States would be a time consuming task. They are nonetheless an essential background to interpretation of remote sensor survey results and to proper land use planning. Rather than recommend a massive Federal level effort to identify the specific land use problems and determine the relationships between the needed land use information and its role in assessing environmental impact, we propose a cooperative effort involving Federal assistance, where appropriate, to State and local governments. One obvious Federal role would be to issue guidelines and standards for data collection and field investigations to assure economy and comparability of results.

PROPOSED COLLABORATION WITH OTHER AGENCIES

The proposed land and related resource use information system potentially is of interest to a major part of the Federal establishment, to State agencies, and to regional and local governmental or quasi-governmental bodies. Those Federal agencies with whom coordination has already been established include the Army Corps of Engineers, which coordinates all Chesapeake Bay projects, the National Science Foundation, which supports Chesapeake Bay research, the various NASA centers, the Environmental Protection Agency, and the Bureau of Sport Fisheries and Wildlife.

Exchange of information has been conducted with the National Park Service, the Department of Housing and Urban Development, the Office of Naval Research, the Navy's facilities planning activity, the Bureau of the Census, and the Department of Agriculture.

Still other agencies have future interests. Almost every agency with commitments to land management or custodianship, including all services in the Department of Defense and the Bureau of Land Management of the Department of the Interior have a substantial interest in good land use information.

Another large group of interested agencies are those having responsibilities for the administration of environmental or environmentally related programs. Besides the Environmental Protection Agency, such agencies include the Department of Health, Education, and Welfare, the Department of Housing and Urban Development, the Bureau of Outdoor Recreation, the Bureau of Reclamation and agencies having primary responsibilities for programs stimulating State cooperation, like the Office of Water Research and Technology in the Department of the Interior, and the Extension Service of the Department of Agriculture. If a good, relatively inexpensive, frequently replicated set of land and related resource use information data sheets and graphics were available throughout the country, many hundreds of uses could be forecast. Some specialized uses might be seen even for an agency like the Department of Justice. Members and committees of the Congress would surely make use of land use information in support of various legislative activities.

In addition to the Federal agencies, many agencies of State government have requirements for land use information in support of their functions. The State planning office, often having cabinet rank or located in the office of the governor, is a prime example. Other examples are agencies with responsibilities in environmental protection, transportation, commerce, recreation, health, geological or mineral surveys, and agriculture.

Local county and city governments and regional or river basin planning agencies and councils of governments, need land use information and presently are obtaining it from whatever source possible, generally with little concern for compatibility with the systems of adjoining areas. Such groups could become beneficiaries of a national land use information system, providing that their specific needs are carefully coordinated and provided for. Even if a large centralized system proves to be uneconomical or unworkable for other reasons, users at all levels of the governmental hierarchy would benefit from technical communications and assistance on such matters as land descriptions, classification systems, and scale and standards of mapping.

The test site and demonstration project experiments conducted to date have illustrated the pervasive interest in land use information at Federal, State, regional and local levels of government. It has also been apparent that present communication and coordination of land use information programs leaves much to be desired. The proposed national land use information system would be a new institutional entity with a vested interest in stimulating two-way flow of information with all participating agencies, and its effectiveness would be directly proportional to its success in establishing and maintaining that communication.

REFERENCES

Ackerman, E. A., Dyck, R. G., and Shidler, A. E., 1973, Land use institutions in the Washington-Baltimore region--a mirror for metropolitan America, in McAllister, D. M., ed., Environment: a new focus for land-use planning: Washington, D.C., NSF.

Alexander, R. H., 1970, Geography Program, design, structure, and operational strategy: Third Ann. Earth Resources Program Rev., Houston, Dec 1-3, 1970, v. 1, p. 9-1 and 9-9, NASA Manned Spacecraft Center.

__________1972, Central Atlantic Regional Ecological Test Site: Fourth Ann. Earth Resources Program Rev., Houston, Jan. 17-21, 1972, v. III, p. 72-1 - 72-9, NASA Manned Spacecraft Center.

__________1974, CARETS: an experimental regional information system using ERTS data: NASA Goddard Space Flight Center, Third Earth Resources Technology Satellite-1 Symposium, v. I, sec. A., p. 505-522.

American Society of Photogrammetry, 1975, Manual of remote sensing, 2 vols., Robert G. Reeves, ed.-in-chief: Falls Church, Va., American Soc. Photogrammetry.

Anderson, J. R., Hardy, E. E., and Roach, J. T., 1972, A land-use classification system for use with remote sensor data: Geol. Survey Circ. 671, 16 p.

Estes, J. E., and Senger, L. W., eds., 1974, Remote sensing: techniques for environmental analysis, Santa Barbara: Hamilton Pub Co., 340 p.

Gerlach, A. C., 1972, The geography and human-cultural resources working group of the EROS Program: Fourth Ann. Earth Resources Program Rev., Houston, NASA Manned Spacecraft Center.

Gerlach, A. C., Kiefer, W. E., and Geographic Applications Program Staff, 1971, Annual scientific report to the National Aeronautics and Space Administration FY 1971: Washington, U.S. Dept. of Interior EROS Program, Geography and Human-Cultural Resources Working Group, 55 p., 17 figs.

Goodell, H. G., 1970, Environmental application of remote sensing method to coastal zone land use and marine resources management: Third Ann. Earth Resources Program Rev., Houston, Dec. 1-3, 1970, NASA Manned Spacecraft Center.

Gottmann, Jean, 1961, Megalopolis: the urbanized northeastern seaboard of the United States: New York, Twentieth Century Fund, 810 p.

Guy, H. P., 1970, Sediment problems in urban areas: U.S. Geol. Survey Circ. 601-E, 8 p.

Holz, R. K. (ed.), 1973, The surveillant science, remote sensing of environment. Boston, Houghton-Mifflin.

Horton, F. E., 1972, The application of remote sensing techniques to inter- and intra-urban analysis. Iowa City, Inst. Urban and Regional Research, prepared under USGS contract no. 14-08-0001-12505, 243 p.

Kiefer, W. E. and others, 1972, Annual scientific report to the National Aeronautics and Space Administration FY 1972: Washington, U.S. Dept. of Interior,EROS Program, Geography and Human-Cultural Resources Working Group, 65 p.

Leopold, L. B., 1968, Hydrology of urban land planning: a guidebook on the hydrologic effects of urban land use: U.S. Geol. Survey Circ. 554, 18 p.

Madden, C. H., 1974, Land as a national resource, in Harriss, C. L., ed., The good earth of America: planning our land use: Englewood Cliffs, Prentice Hall.

Marble, D. F., and others, 1971, Remote sensors as data sources for urban research and planning: Evanston, Northwestern Univ., Dept. of Geography, prepared as Interagency Rept. USGS-212, U.S. Geol. Survey contract no. R-09-020-024, W-12570 and W-12782, 825 p., 23 figs., 53 tables.

Marble D. F., and Thomas, E. N., 1966, Some observations on the utility of multispectral photography for urban research: Ann Arbor, Fourth Symposium on Remote Sensing of the Environment, April 12-14, 1966, Proc., p. 135-144.

Marschner, F. J., 1959, Land use and its patterns in the United States: Agriculture Handbook no. 153, U.S. Dept. Agriculture.

Meier, M. F., Alexander, R. H., and Campbell, W. J., 1966, Multispectral sensing test at South Cascade Glacier: Ann Arbor, Fourth Symposium on Remote Sensing of the Environment, April 12-14, 1966, Proc., p. 145-159.

National Academy of Sciences-National Research Council, 1966, Spacecraft in geographic research. NAS-NRC Pub. 1353, 107 p.

__________1970, Remote sensing, with special reference to agriculture and forestry, NAS, 424 p.

National Academy of Sciences-National Research Council, 1974, Remote sensing for resource and environmental surveys: a progress review - 1974: NAS-NRC, 101 p.

Pease, R. W., 1970, Climatology of urban-regional systems: Third Ann. Earth Resources Program Rev., Houston, Dec. 1-3, 1970, v. I, p. 4-1 - 4-11, NASA Manned Spacecraft Center.

Peplies, R. W., 1970, The feasibility of using remote sensors for geographic research: Johnson City, East Tennessee State Univ. Remote Sensing Inst., prepared for Office of Naval Research Geography Br. contract no. N00014-67-A-0102-0001, 67 p., 6 figs.

Place, J. L., 1972, An automated map and model of land use in the Phoenix Quadrangle: Fourth Ann. Earth Resources Program Rev., Houston, Jan. 17-21, 1972, v. III, p. 71-1 - 71-19, NASA Manned Spacecraft Center.

Reeves, R. G., ed., 1975, Manual of remote sensing: Falls Church, Va., American Society of Photogrammetry.

Rudd, R. D., 1971, Macro land-use mapping with simulated space photos: Photogramm. Eng., v. 37, p. 365-372.

Simonett, D. S., 1969, The utility of radar and other remote sensors in thematic land use mapping from spacecraft: Univ. of Kansas, Ann. Rept. to U.S. Geol. Survey, contract no. 14-08-0001-10848.

Thrower, N. J., and others, 1970, Satellite photography as a geographic tool for land use mapping of the southwestern United States. Tech. Rept. 69-3, Assoc. Am. Geographers, contract no. 14-08-0001-12009, U.S. Geol. Survey.

Tomlinson, R. F., ed., 1972, Geographical data handling. UNESCO/IGU Second Symposium on Geographic Information Systems, Ottawa, Aug. 1-8, 1972, Internat. Geographical Union, Comm. Geographical Data Sensing and Processing, v. I and II, 1327 p.

U.S. Geological Survey, 1972, USGS-EROS Annual Report to NASA for Fiscal Year 1972.

Wray, James, 1960, Photointerpretation in urban area analysis in American Society of Photogrammetry's Manual of photographic interpretation (ch. 12). Washington.

__________1970, Census Cities Project and atlas of urban and regional change· Third Ann. Earth Resources Program Rev., Houston, Dec. 1-3, 1970, v. I, p. 2-1 - 2-16, NASA Manned Spacecraft Center.

__________1972, The Census Cities Project: a status report for 1971: Fourth Ann. Earth Resources Program Rev., Houston, Jan. 17-21, 1972, v. III, p. 73-1 - 73-21, NASA Manned Spacecraft Center.