CENTRAL ATLANTIC REGIONAL ECOLOGICAL TEST SITE (CARETS): A PROTOTYPE REGIONAL ENVIRONMENTAL INFORMATION SYSTEM

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16 Abstract The USGS CARETS project is testing the applicability of ERTS-1 data as input to a regional land use and environmental information system. The project is intended to be a prototype of a new USGS function, under the direction of the Chief Geographer, developing standards for the classification, mapping, and scientific analysis of land use and land use change. Accomplishments during the 6-month period ending December 31, 1972 include: (1) completion of a land use data base for the entire test region, compiled from NASA high altitude aerial photography; (2) demonstration of the feasibility of extracting several categories of land use information from ERTS MSS data for a portion of the CARETS region, including features of particular importance for monitoring critical change in the shore zone; (3) demonstration of the feasibility of detecting some significant land use changes on ERTS imagery (4) demonstration of several methods of relating remote sensor-derived land use data to environmental impact (geological, hydrological, and climatological) of land use change; (5) operation of an experimental user information center delivery of land use information to a major user agency, and obtaining preliminary user evaluations of the results of this investigation; and (6) demonstration of the feasibility of employing computerized "geographic information systems" procedures in handling remote sensor-derived land use information in a variety of formats to suit user requirements.

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c. Problems impeding progress of the investigation.

Owing to cloud cover over portions of the CARETS area, complete aircraft underflight coverage has thus far not been obtained. Since the CARETS research design calls for systematic comparison of land use data sets derived from the aircraft data with those derived from ERTS-1 data, the lack of complete underflight coverage has been an impedance to the progress of the investigation. We have been in close touch with the U-2 pilots, and have been assured that CARETS coverage will have high priority during the January missions over this area. Therefore we look forward to satisfactory completion of those missions with clear weather so that this phase of the investigation can proceed. We feel that part of this problem may have arisen from different definitions of the area covered by "CARETS". The area defined as the test site for the USGS - CARETS project is precisely that outlined on the maps that have accompanied our proposals and other documents (Figure 1). Once-over cloud-free high altitude aircraft coverage for 1972-1973 is essential for the entire CARETS region. Only those portions of the test site which were not satisfactorily covered with RC-10 color infrared photography on the missions of August, October, and December 1972 are required for cloud-free aircraft coverage in January 1973.

Another major problem has been obtaining satisfactory quality photographic copies of ERTS imagery for land use analysis. Examination of some of the excellent-quality, enhanced, color-combined examples of

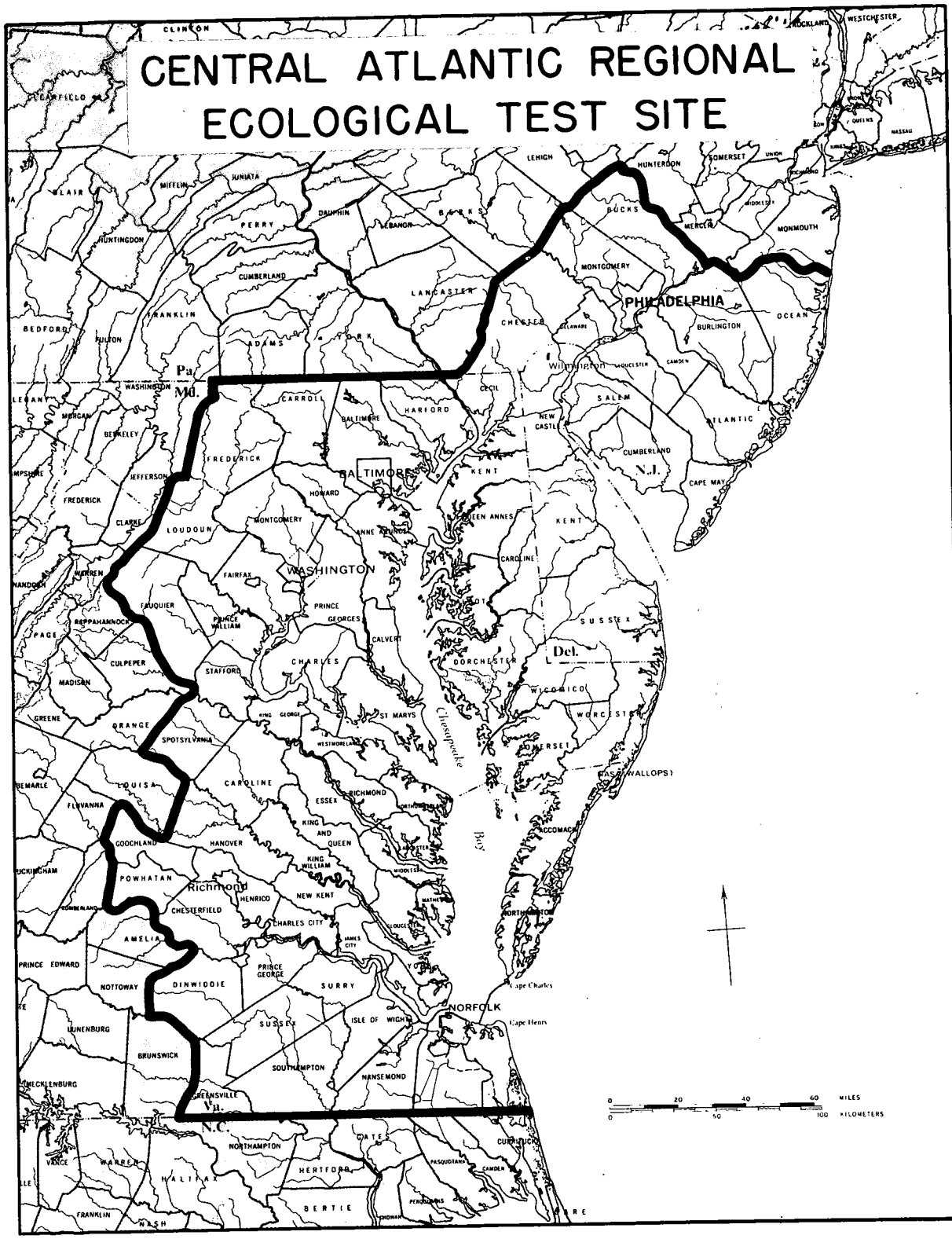

Figure 1. CARETS Location Map

ERTS imagery which NASA has produced for illustrative and public information purposes has convinced us that the ERTS system has exciting capabilities for detailed study of land use, even better than our pre-launch hopes. However, this principal investigator does not receive ERTS data from NASA in a form suitable for land use analysis, and we have spent considerable time and effort investigating ways to prepare photographic copies of the data so that analysis and mapping can be done expeditiously. The USGS-CARETS investigation is perhaps at a further disadvantage in this regard, being a team or program investigation of a sizable region, dealing with a large number of ERTS images, having to develop fairly elaborate working procedures for preparing the data, and requiring extra prints for user evaluation. Thus we cannot afford expensive color custom processing of the type that has produced the most striking renditions of ERTS frames. Not having our own photo lab turns out to be a serious impediment in obtaining satisfactory processing. We do have at our disposal an I^2S color composite viewer, and one possibility for preparing ERTS material for analysis is to make a 35mm color transparency from the viewer screen, then use the transparency in enlarging projectors for detailed analysis. This has the obvious disadvantage of introducing two additional generations into the hard-copy product. We believe that this problem of producing high quality ERTS photo products in quantity for principal investigator use deserves further NASA attention, and we would be happy to cooperate in any way possible.

d. Discussion of the accomplishments during the reporting period and those planned for the next reporting period.

d. 1. Accomplishments during previous 6-month period

d.1.1. Introduction: CARETS Concept and project design

The USGS - CARETS project is testing the applicability of ERTS-1 data as input to a regional land use and environmental information system. It is an experimental demonstration of a particular way of looking at a geographic region based on remote sensing data, that is, based on a sampling of the electromagnetic radiation reflected from the land and water surfaces of that region, and captured by airborne and spaceborne remote sensors passing overhead. The information system being developed is a combination of procedures and devices to package the sensor data, deliver them to users, and receive feedback in the form of evaluation of the experimental products and services. The system produces a quantitative characterization of "land use" in such a way that area-by-area comparisons of data sets derived from ERTS-1 can be made with other data sets derived from high-altitude aerial photos, topographic, geomorphic, hydrologic and census data, of the types that have been traditionally used as inputs to the regional land use planning process. Target user groups are land use planning agencies and others having requirements for land use information as inputs to regional planning, forecasting, or environmental quality models.

Two hypotheses have guided the formulation and development of the USGS/CARETS project: (1) the "land use" visible to the remote sensors is an indicator or resultant of a number of interacting environmental and socio-economic processes, and (2) knowledge of those processes and the changing land use patterns they produce is important to environmentally-conscious regional planning and management. Furthermore, there is an implication that the CARETS method of regional analysis might provide a "shortcut" to an urgently-needed understanding of the environmental impact of land use changes that are now taking place. For those who are intimately aware of the great detail and complexities of the "environmental impact" situation now being faced at all levels of government, this claim may seem to be an overly-ambitious one. If remote sensing systems can provide timely data on land use change, however, and if some general principles can be established on the relationships of certain kinds of land use change to environmental impact, then the ERTS-based system can be a powerful sampling strategy for environmental monitoring. More detailed tools of regional analysis can be focused on precisely those localities where the need for such analyses and information to guide planning is most acute, namely where the critical changes are taking place. Land use and related information resulting from the combined satellite and aircraft observations in the CARETS region will be made available to those responsible for determining what changes in land use are to be allowed in the future. Incorporated in the demonstration will be some assessment of what the probable environmental impact of such changes might be.

CARETS is further being conducted within the U.S. Geological Survey as a prototype of a new operational program, under the direction of the USGS Chief Geographer, charged with developing standards for the classification, description, mapping, and scientific analysis of land use and land use change. Achieving compatibility of federal, state, and regional descriptions of land use, and interchangeability of land use data, are goals of that program. The CARETS ERTS-1 investigation is closely attuned to those program goals, and in fact is a principal example of the new program developments in geography and land use analysis which have resulted from close cooperation between NASA and USGS. The CARETS project thus predates the period of this six-month report, evolving as a result of a sequence of cooperative program actions between the two agencies stemming from the NASA 1970 census-contemporaneous high-altitude aircraft flights and the development of the concept of the ecological test sites. Listed among the primary accomplishments of this reporting period is the final pre-ERTS sharpening of the CARETS research design, a proposed method of regional environmental analysis. Based upon a sampling strategy involving three levels of land use data derived from satellite and airborne remote sensors, the CARETS research design calls for a sequence of three interrelated program steps or subtasks, namely, (1) land use analysis, (2) environmental impact assessment, and (3) user evaluation. During the six-month period of this report most of the effort was devoted to the land use analysis portion of the project, although some progress was also made in the environmental impact and user evaluation phases. Complete demonstration of the operation of the information system,

incorporating spacecraft and aircraft data analysis for the entire region, must await the second year of the project.

d.1.2 Land Use Analysis

d.1.2: 1. Classification and mapping rationale.

"Land use" is the central concept of both the CARETS research design and the USGS Geography Program of which it is a part. Quotes are used to indicate that the term is one of very broad currency in both the scientific literature and governmental agencies, and therefore, has been given a rather wide variety of meanings, depending on the context of a particular study or the mission of a particular government agency. It is also figuring very prominently in current legislative activities at federal and state levels (having been traditionally thought of as something of primary concern to local governments), and is rightly being recognized as one of the key elements of concern involving the environmental impact of man's activities. The CARETS model requires that "land use" be mappable with the aid of sensing devices carried in satellites and aircraft and then be made a central component of an experimental environmental information system; therefore it is essential for these purposes that the term be quantifiable and operationally defined. This could be done by proclamation at the outset, except that the "information systems" context requires that the real requirements of users be the determinants and ultimate rationale for the entire information system. Therefore the operational definition of "land use" in CARETS will be

arrived at through a series of trials and refinements, incorporating user feedback at each stage. Whether the quotation marks can be removed will depend on the degree of success that can be achieved in reconciling detailed user requirements with rigorous requirements of logic, environmental analysis, replicability, and interchange of data among diverse users.

The starting point for the CARETS definition of land use is a classification scheme that grew out of the activities of the Interagency Committee on Land Use Information and Classification and a Washington conference of selected user representatives held in June 1971 (U.S. Geological Survey, 1972). This scheme was somewhat revised and subsequently published in USGS Circular 671 (Anderson, Hardy, and Roach, 1972). Slight departures from that scheme in CARETS are the result of refinements that pertain to the specific scale and type of remote sensing data utilized. These differences are documented and will appear in a technical report to be released during the next reporting period. Such detailed documentation, which could not be included in Circular 671, must be a part of any land use data set which is proposed for widespread use and data exchange as part of a land use information system.

As pointed out in Circular 671, a number of concepts have been traditionally combined in defining or describing the phenomenon known as land use. To permit widest use with remote sensing data, the proposed standardized classification system uses primarily "cover" (or more properly, "surface expression") and "activity". "Activity"

denotes man's use; it can often be inferred by means of the photo-interpretation process. Other "non-visible" land descriptors such as ownership can be added as overlays to the information system base. In practice where different activities overlap and different "covers" overlap or grade into one another in transitional situations, somewhat arbitrary mapping rules have to be set up which enable analysts to make decisions in assigning each land (or water) element to one of the classification categories. Knowledge of those rules and decisions is essential to the user of the resulting map or information system. Dimensions of the land surface description, other than cover and activity, also complicate the mapping task, for example, the ownership of land parcels, the time of the observation, as in seasonal variations, and the size of the fundamental mapping or observational unit. All of these may be significant with respect to users' requirements. Any particular land use map or information system is necessarily a compromise between desired level of detail and limitations of program resources which dictate the degree of consolidation or aggregation which will be contained in the product that can be delivered to the users. The CARETS investigation intends to exploit the flexibility of multistage satellite and aircraft remote sensing data collecting systems, requiring that selections of data to be included in the information system be governed by balancing cost factors against priorities determined by the urgency of the problems to be solved. The adjustment of the developing information system to the region's problems and priorities is to be looked

upon as an adaptive process, arriving at as nearly an optimal solution as possible. The resulting land use classification scheme itself is but one of a number of sampling strategies to be employed in investigating the impact of the ERTS data-collecting system upon the quality of the environment in the test region.

Accomplishments under the land use analysis subtask are in three general categories: preparation of the high-altitude aircraft data base, preliminary land use interpretation of the MSS data from ERTS-1, and preliminary tests of procedures for digitization and computer analysis of the land use data base.

d.1.2.2 High-altitude aircraft data

This reporting period saw the completion of the 1970 high-altitude aircraft data base for the entire CARETS region with the exception of a few square kilometers in the peripheral portions of the test region that were missed by the original aircraft coverage. This data base is to be the primary operational data set for the CARETS experiment; it will be used to derive the land use/population ratios when compared with the high-altitude aircraft data from the ERTS underflight missions, and as the basis for evaluating the accuracy of land use data sets derived from ERTS-1 and their suitability for assessing the environmental impact of land use changes.

The 1970 data base exists at this writing in three components: the "raw" aerial photography from NASA/MSC Missions 144 and 145 (scale 1:120,000 and 1:450,000), the rectified photomosaic compiled by the USGS from the RC-8 color infrared photography from those missions, and the land use maps made as overlays to the photo-mosaics.

The mosaics and maps are at a scale of 1:100,000, in square sheets 50 cm on a side, each sheet representing an area 50 km by 50 km on the earth's surface. Thus the map sheets, if pieced together to form a single map of the entire CARETS test site would occupy a space about 4½ meters in the north-south direction by 3½ meters in the east-west direction. Slightly over 7 square meters of this map are utilized in depicting the 72,000 sq. km (28,000 sq. miles) of land area in the test region, with Level II land use categories mapped for all recognizable areas larger than 2 mm (200 meters ground distance) in one direction. Sheets are keyed to the UTM (Universal Transverse Mercator) grid system, Zone 18, so that each element of each photo-mosaic and land use map is relatable to an earth grid location system. If desired, photo and land use data elements can be converted to location with respect to latitude and longitude, either by computer transformation of the map projection, or by scaling from latitude-longitude ticks on the UTM grid overlay margins. It takes 50 of these map/mosaic sheets, or portions thereof, to cover the entire CARETS area. Location and numbers of each sheet are shown on the index map (Figure 2).

The land use categories that were observed and mapped in the CARETS data base, along with the notation used on the maps in their present form, are listed in Table 1.

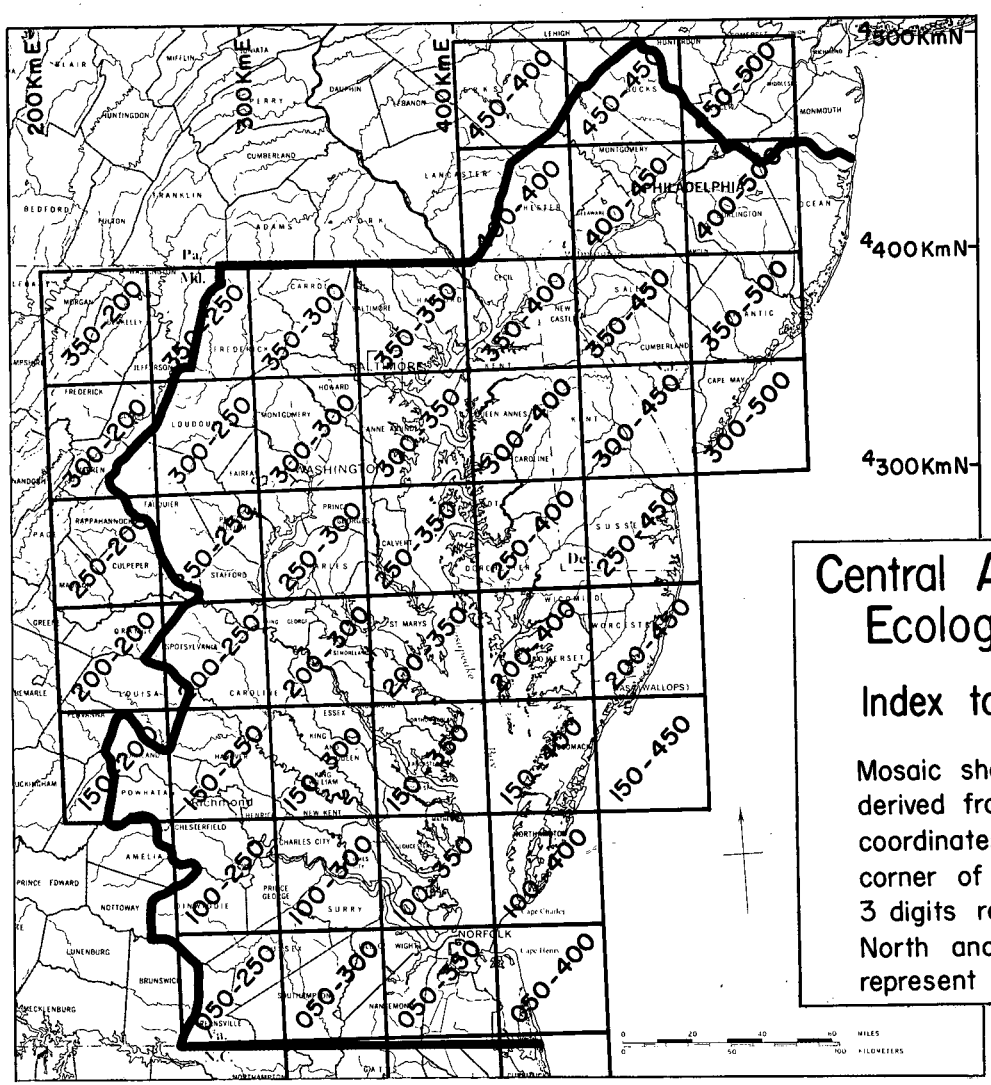

Figure 2. CARETS Index to Mosaic and Land Use Map Sheets

Table I. Land use categories in CARETS data base.

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

The Level II CARETS land use maps in their present form are only an intermediate product in the overall CARETS experiment; they will next be digitized and prepared for a number of computer measurements and manipulations, among which are area measurements, overlaying with other data sets such as census, drainage basin, and geological material maps, and aggregating into Level I units for comparison with the Level I interpretations of ERTS-1 data. However, since there are a number of experimenters and cooperating user agencies, who have expressed interest in obtaining preliminary copies, arrangements are now being made to place the entire set of 50 photomosaics and land use maps on "Open File" in the USGS. Inquiries may be addressed to the CARETS principal investigator, Robert H. Alexander, U.S. Geological Survey, Geographic Applications Program, Washington, D.C. 20244, phone 202-343-5985. In order to speed up final release and publication of the maps, we are requesting that users of these preliminary products provide us with corrections and suggestions for improvement where errors are found to exist, or where interpretations are in question.

In addition to the major effort devoted to the completion of the Level II mapping, a small amount of effort was put into an examination of possible Level III category definitions. It was found necessary to devote some attention to Level III so that a firmer basis would be available for relating the relatively small-scale Level I and Level II categories to users' requirements which are more detailed, including requirements for environmental impact of land use change. The rationale of the Interagency Steering Committee and Circular 671 is that Level I would be used primarily with satellite data, Level II

would be used primarily with high-altitude aircraft data, and the land use system compiled at the Federal level would be largely confined to Levels I and II of the proposed standardized classification. However, in order to demonstrate the feasibility of tying Levels I and II to more detailed land units, and further to facilitate interchange and aggregation of land use data among various users and at several levels, the CARETS research has suggested some Level III categories, a few of which have already proven to be obtainable from ERTS-1 data, and most of which are surely mappable from enlargements of the excellent quality high-altitude aircraft photography. Examples of some proposed Level III categories which have been experimentally identified and mapped in a portion of CARETS are shown in Table II.

Table II. Examples of some Level III land use categories.

Level II Category	Examples of Proposed Level III Categories
11-Residential	High density residential Low density residential (or single-family) Mobile homes
15-Transportation, etc.	Airports Superhighways Port facilities Railroads Railroad yards and shops etc.
21-Cropland and Pasture	Row crops Cover crops Pasture

Even Level IV or greater detail might also be obtained through careful use of a multi-stage sampling procedure embracing ERTS and aircraft data. The CARETS investigation, during the next reporting period, will propose a complete Level III scheme for the test region, which will be compatible with both traditional cartographic and computer methods of mapping land use, and which will enable the data sets derived from remote sensing to be related to "ownership" parcels by means of an overlay process -- again, which can be performed either manually or within a computerized information system.

d.1.2.3. Preliminary analysis of ERTS-1 data

At the end of this first six-month reporting period, the CARETS investigation team in the USGS is still becoming familiar with the mechanical problems of receiving, plotting, viewing, and preparing hard-copy prints or transparencies for detailed analysis. The major analytical tasks, preparing land use maps of the entire region, entering those maps into a digital land use file, and making machine measurements and comparisons with other data sets, are still to be done, and will be reported on in later reporting periods. However, in the course of preparing for those larger analytical tasks, we have made a general first-look assessment of the data we have received to date, and a more detailed analysis of three frames.

One of the most striking initial conclusions to be drawn from examination of the ERTS data is one that goes beyond the specific purposes of the CARETS investigation: ERTS provides a remarkable

regional-scale view of the earth's surface. This regional-scale view can be obtained, for example, by making prints of ERTS frames at a scale of about 1:100,000, piecing together a mosaic representing a single swath (four such frames traverse the entire length of the CARETS region) and examining the images at arm's length rather than with a magnifying glass. This method displays, almost at a glance, the major structural and drainage features of a region, the relationships of the major cities to those larger features, and perhaps most importantly from the point of view of a geographer, patterns of spatial association of features that may be clues to regional developmental processes. The major geological and hydrological controls to land usage, (for example, the Appalachian Mountains, the Atlantic Ocean, the Chesapeake and Delaware Bays and their tributary rivers and estuaries) are easily identifiable by inspection. Closer examination reveals more subtle geological and hydrological controls to the land patterns, such as regional outcrop trends, folds and faults, and the major stream patterns, which stand out prominently because of vegetation differences.

Superimposed on these patterns controlled by the major geological and hydrological features is another mosaic of distinctive landscape patterns, visible at the regional scale as distinctive tones and textures, which represent the integration of myriads of separate forested tracts, farms, towns and roads. Clearly there are distinct mappable units, in this overall landscape pattern, each unit containing a homogeneity of tone and texture. Thus the farmland patterns of the

Shenandoah Valley, at the western margin of the CARETS region, are distinctly different from those of the Piedmont area which in turn are distinct from the more forested, more sparsely settled area on both sides of the lower Potomac estuary. The major metropolitan areas of Washington and Baltimore (Frame no. E-1080-15192, 11 Oct. 72) have in turn a distinct light pattern in the red (MSS 5) band, or a blue appearance in the color-combined view analogous to color infrared film.

It is hypothesized that these landscape units will provide a valuable stratification for areal sampling to determine where more detailed aircraft or ground measurements might be taken, following the "photomorphic region" concept used by MacPhail, Peplies, and others (Peplies and Wilson, 1970; MacPhail and Lee, 1972). The preparation of data sets derived from ERTS data, formatted in the same geographic information system as the high-altitude data base mentioned above, will provide a means of making quantitative comparisons, to test the notion that these ERTS-derived regional units (or photomorphic regions) may be indicators for environmental or socio-economic variables such as population numbers, major economic activity, closeness of linkages with other areas, etc.

Frame E-1045-15243, 6 Sept. 1972 is the first ERTS image received by the CARETS project. It covers a portion of the central Appalachians, showing clearly the dominant pattern of the forested ridges of the Valley and Ridge Province, and the much lighter-shaded lowlands in

between. The image area covers only the northwestern portion of the CARETS test region. The analysis reported here concerns only the "land use" aspects of the scene.

A detailed check of land use types observable was made in that portion of the image covering portions of Frederick, Carroll, and Montgomery counties in Maryland. Data analysis took place with the aid of an I^2S multispectral color additive viewer and a film projector viewer. In hopes that there would be replicable standards of film density in the 70mm transparencies supplied to us, documentation of filter and brightness settings on the I^2S was kept, and is reported fully in the report by Fitzpatrick and Lins (See section f., below).

After becoming familiar with handling of the ERTS 70mm transparencies, and developing suitable feature identification procedures, Fitzpatrick and Lins produced an experimental Level I land use map at a scale of 1:330,000 (10x enlargement of the original 70mm transparencies). Since the color additive viewer used did not have sufficient enlargement power for the scale of map chosen, the researchers encountered some problems in tracing interpreted features and bringing them into register with the map base. Verification of interpreted Level I land use categories was made by referring to aircraft photography and topographic maps. Examples if I^2S filters and settings found advantageous are shown in Table III.

Table III. I^2S filters and settings for land use determination.

Land Use Type	MSS Band	Filter	Illumination Setting
Urban & Built Up	4	Blue	7
	5	Green	7
	6	Red	6
	7	Red	5
Transportation Routes	4	Blue	5.5
	5	None	4.5
Water Bodies	4	Blue	7
	6	None	5
	7	Green	5.5
Forest	4	Blue	7.5
	5	Green	6.5
	6	Red	6
	7	Red	4.5
Agricultural Land	4	Blue	7
	5	Green	7
	6	Red	6
	7	Red	6

The resulting land use map was not checked for accuracy -- this will be done when 1972 high-altitude aircraft underflight data are obtained. In the absence of such underflight data, however, a quick field check was made in a portion of Frederick County, Maryland, to identify some of the small bright spots on the ERTS image, in an area known to be undergoing some land development. It was hypothesized that such bright spots might be indicative of areas of development, since cleared land and urban surfaces have higher albedos than almost any other land surfaces in this region. In terms of the objective of locating areas of change, however, the test was somewhat disappointing. Of 19 "bright spots" that were field checked, 12 turned out to be fields that had

been just harvested or plowed at the time of acquisition of the ERTS data, two were quarries, three were large buildings which had been there longer than two years, and two were actually clearings or construction sites, i.e., changes that had taken place since the acquisition of the 1970 high-altitude aircraft data base. One was a new highway construction site; the other was a shopping center and adjacent apartment complex under construction.

The results of the preliminary examination of Frame E-1045-15243 were encouraging as to the possibility of mapping land use Level I and in some cases Level II categories; more research needs to be done, however, on the problem of identifying land development changes of types that are of interest to land use planning and environmental monitoring, and separating such changes from other highly-reflective features in the scene.

Frames E-1079-15131 and E-1079-15133, 10 October 1972 were examined for applicability to the monitoring of shoreline changes affecting land use along the barrier islands. The two frames encompass a stretch of the middle Atlantic coast from Long Island, New York, to Assateague Island, Maryland. The narrow barrier islands have an importance exceeding their relatively small area in the test region; being under tremendous recreational and developmental pressures, they are also arenas for counter-pressures from various citizen groups and public agencies aiming at preservation more nearly in the natural state. In a study

under way at this writing, Dolan and Vincent have found that several features important for monitoring changes in the barrier island environment are visible on the ERTS imagery. These include: (1) ocean shoreline, including sand waves and indications of storm-caused erosion, (2) interface between sand flats and marshes, (3) interface between marsh and lagoon, (4) turbidity patterns in ocean and estuaries, and (5) vegetation distributions. Following is an assessment of the utility of each of the ERTS MSS bands for monitoring the barrier island environment:

MSS 4: Sand Surfaces are evident, as are sand to vegetation transitions. The band is not good for the differentiation of vegetation types, or of the beach from the surf zone.

MSS 5: The sand to marsh transition is best indicated on this band. Turbidity distributions are easily observable. Marsh to water, and shore to water transitions are not sharp.

MSS 6: The interface between water and land, and vegetation transitions are evident on this band; however, it is poor for sand to marsh transitions.

MSS 7: This band is the best for the water-land interface and in particular, for discerning the shoreline. Dune ridges and vegetation patterns also shown very well. It is not good for mapping sand-vegetation transitions.

Dolan and Vincent are convinced that ERTS can be a significant augmentation of aircraft imagery and field observation for the study and monitoring of coastal environments. A multilevel remote sensing program will permit the selection of the observation tool which is most appropriate to the scale of the process being observed. ERTS is particularly appropriate for observing the effects of regional-scale processes acting along barrier-island coasts.

d.1.2.4. Automatic Data Handling Techniques

During the reporting period an extensive investigation was conducted into various computer-based methods of storing, retrieving, and manipulating land use data derived from the aircraft and satellite imagery for the CARETS area. Computer assistance was determined to be necessary to speed area measurements and other calculations required on detailed land use data covering so large an area, and to provide flexibility in retrieval format as specified by users who are cooperating with the CARETS investigation.

The CARETS experimental information system encompasses data flow from sensor to cooperating users through a number of processing steps. Automation or partial automation might be employed advantageously at several of these steps, among which are the following: initial image data compaction or pre-processing; extraction of multispectral signature data from the images; assignment of multispectral data sets to land use categories; verifying the land use categories thus identified; mapping the land use onto a gridded base map or mosaic; computing area measurements; summing area measurements by land use categories for counties or other planning regions; and retrieving and displaying land use data in a variety of scales and category aggregations. Major research and development efforts will still be required if ERTS-derived land use information is to flow automatically through the various steps described above and fulfill the operational needs of users at reasonable costs. However, to prove ERTS feasibility for supplying land use data to users, it is just as necessary to demonstrate the feasibility of

incorporating ERTS data on land use into a user-directed information system, as it is to demonstrate that any particular kind of land use can be detected on the ERTS image. After an examination of the information flow from remote sensor to user, it was determined that the first emphasis for automatic data-handling in the CARETS project would be toward the user end of this information flow system, rather than toward the input end involving sensor technology, telemetry, or direct image processing techniques. It is recognized that eventually the input end of this information flow system will have to be largely automated if large-area land use analysis is to become an operational reality; therefore, methods of improving automation at the input end are also under close scrutiny in the CARETS project, with the requirement that the result is a user-deliverable project.

CARETS users (principally land use planning agencies at state or metropolitan level) have been found to require land use information primarily in the form of maps and quantitative area summaries of the information contained in the maps. CARETS relies on photo-interpreters to accomplish the preliminary data reduction tasks, that is, classifying the image scene into land use units on the basis of pattern, tone, texture, knowledge of the region, and associative clues. This process results in the production of land use maps with the individual units separated from one another by means of lines drawn with reasonably fine drafting pencils. The task for automatic data handling, then, is to reduce this line map with the enclosed land use units or "polygons" into digital form for further quantitative analysis and entry into the experimental information system. The user requirement which governs construction of the basic information file is that the land use information be retrievable in a variety of combinations, aggregations,

and disaggregations, and that land use information for a particular location on the earth's surface be associated with a variety of other data sets, for example, water resource data, geological data, slope, vegetation, and population characteristics.

The CARETS investigation relied to a large extent on the work of the International Geographical Union (IGU) Commission on Geographical Data Sensing and Processing in its two symposia on geographical information systems (Tomlinson, 1972). Plans for later participation by the IGU group in USGS land use programs were completed during this reporting period.

Toward the end of this reporting period the CARETS team conducted some successful experiments with digitizing, storing, retrieving, making area measurements, and plotting land use data automatically in polygon form, using high-altitude aircraft data as samples. Yet to be selected is a software system which will allow overlay, intersection, and update calculations to be performed in the machine. The CARETS project decision on selection of components of the information system will take place during the next reporting period, so that land use data sets derived from ERTS imagery can be processed and displayed in a variety of formats for user evaluation.

d.1.3. Environmental Impact Assessment

The environmental impact portion of the CARETS investigation deals with two facets of the land use/environment relationships that are now facing the region's planners. The first concerns the physical limitations or constraints that are placed upon various land use types by factors of the physical environment; the second facet concerns effects that land use change have in turn on environmental quality. A very difficult equation must be balanced by planners who have to decide what types of growth and land use change will be permitted, knowing that they may still be around to see the consequences of their decisions. The issue of environmental quality is at the heart of the federal-level concern over land use policy that has been expressed by legislators and conservationists. The possible cost savings through use of common remote sensing data sources is a federal-level issue that has been known primarily to experts, and has not yet been widely regarded by the public as a principal reason for activities of the federal government in the field of land use.

The physical constraints on development were investigated with respect to the geological features affecting land use in the Norfolk-Portsmouth SMSA, a test site within the CARETS region that has been selected for detailed experimentation with procedures that might later be applied in the whole region. This effort was supported by the EROS Program, and resulted in the completion of a "Map of Earth Materials" (for example, sand, clay, peat, etc.) and their distribution at and near the surface, at a scale of 1:100,000. Sources other than remote sensing

were used to compile this map. Each map unit is further described in terms of its topographic expression, and present vegetation types, as well as features affecting agricultural and engineering work, as follows: drainage characteristics, soil types and agricultural adaptability, adaptability to earth work in wet periods, feasibility for use as top soil, feasibility as source of construction materials, and feasibility for foundation material. The map is to be used as an overlay to the maps of land use change developed from the ERTS and aircraft data, and will be a guide to the regional planners in selecting most suitable sites for new development.

With respect to the impact of land use change on environmental quality, three areas of investigation were pursued during the period of this report: land use-environmental impact modeling, hydrological impact of land use, and climatological impact of land use. As outlined under section d.1.1. above, these investigations seek to develop a sampling strategy to enable quick assessments of the probable environmental effects of land use patterns and changes observed by the remote sensing observation systems.

The modeling effort, conducted through a contract with the Department of Environmental Sciences at the University of Virginia, resulted in a major study that was completed during the period of this report. (Goodell et al., 1972). This study was supported by NASA Supporting Research and Technology (SR & T) funding prior to the initiation of the

ERTS-A CARETS investigation. The University of Virginia study confirmed other evaluations made by the CARETS team, namely that a major requirement for meaningful assessment of the environmental impact of land use change is the capability of bringing together in a common analytical framework several overlapping physical and social data sets. Because of the complexity of the linkages between a cultural process and environmental response, the Goodell study proposes a modular approach to the modeling effort, with the initial approach considering air and water quality as functions of land use within the framework of the hydrologic cycle (Goodell et al., p. 11-12).

A primary requirement of such an effort is the identification and quantification of the environmental impacts of the various activities associated with land use: food production and processing, transportation and communication, raw materials production and processing, manufacturing and commerce, and habitation and recreation. Identified environmental effects of these activities are principally from the following; 1) fossil fuel consumption in power production, transportation, and heating; 2) fertilizer and pesticide application; 3) animal and human wastes; 4) accelerated erosion from construction, land use change, and drainage basin alteration; 5) industrial and manufacturing effluents; 6) solid waste generation and disposal; and 7) altered patterns of surface runoff and diminished ground water reserves.

Understanding the relationships among all of these factors and land use requires the handling of prodigious amounts of data, and dictates the requirement that all of the data sets be prepared in a compatible framework for computerized analysis. Furthermore, Goodell's work pointed out the necessity of developing more detailed land use descriptors than contained in the two-level land use classification recommended by the Interagency Steering Committee. The work presently under way formulating a Level III set of land use categories (see section d.1.2.2 above) is a direct response to that need.

Goodell's study collects several data sets for a portion of southern Virginia, and demonstrates the difficulties encountered in obtaining suitable and timely data on variables other than land use in the formats compatible with analytical requirements. These results lend encouragement to the CARETS model which attempts to establish broad relationships between land use and environmental impact, while providing detailed ERTS-related data sets on current and changing land use, appropriately keyed to the earth grid.

The hydrological impact of land use was investigated in a preliminary way during the reporting period, and will be continued during the next reporting period under funds anticipated from the EROS Program. The approach was to seek empirical relationships between infiltration, runoff, sediment yield, and water quality on the one hand, and land use patterns and change on the other. The study by Goodell et al. (op. cit.) presented some formulas and data sets indicating, for example, the wide variety of sediment yields in the coastal plain from

major Level I and II land use types. USDA estimates of soil loss from erosion in tons per acre per year are as follows: cropland, 3.83; cropland treated for soil conservation, 1.92; pasture, Q.85; forest, 0.28; urban, 5.78. Goodell's estimate of the annual sediment loss from the southern one-quarter of the CARETS region is 8×10^6 tons, 37.1% of which is generated from urban areas (p. 43). The land use data upon which that estimate was based, however, are more than five years old. ERTS-derived data will be used to update such estimates, and when aggregated by watershed areas, will help to quantify the sediment and water quality problems in such areas as the Chesapeake Bay and its tributary estuaries. Similar procedures can be used to evaluate the effects of various land uses on water quality, runoff, and infiltration, once a basic yield or "calibration" estimate is obtained for each of the land use classification categories.

Investigations of the climatological effects of land use patterns were carried out in Norfolk and Baltimore test sites within CARETS, and will be reported on during the next reporting period. The Norfolk investigation demonstrates the application of the CARETS land use information system to air quality planning, by showing the relationships of land use units to emission, diffusion, and fallout patterns of sulfur dioxide and suspended particulates. The Baltimore study involves the calibration of multispectral scanner (aircraft) data to yield albedo and thermal emission calculations, which are in turn to be used to test a newly-developed simulation model for the study of the urban heat island effect. The climatological factors (albedo, thermal emission, surface roughness, and transpiring area) of the test site will be

related to land use categories of the CARETS classification system, so that estimates of the microclimatological effects of proposed land use changes can be made known to planners.

d.1.4. User Evaluation

d.1.4.1. CARETS Information Center

The CARETS Information Center, located in Room 853, 1717 H Street, N.W., Washington, D.C., has been maintained during the period of this report as a center where representatives of the principal user agencies of the region could visit and have access to remote sensing data and other related materials pertaining to the demonstration project operation. As of the close of this reporting period, preparations are under way to modify the Information Center to better handle ERTS data and the computer products that are expected to become available during the next reporting period.

Available for user inspection in the Information Center are all 9-inch and 70mm film from NASA aircraft missions over the test region, all ERTS imagery that has been received thus far, the 1:100,000 scale photomosaics that were compiled from the high-altitude aircraft data from NASA Missions 144 and 145, the Level II land use maps that were prepared by the CARETS team, ERTS microfilm (browse file), index maps, mission reports, and selected reference material, including topographic and geologic maps, to aid in interpretation of the imagery of the CARETS region.

Equipment available to aid the Information Center visitors includes light tables, a 30-inch screen viewer-projector with magnification up to 20 times, an I^2S color additive viewer for viewing ERTS and other multispectral imagery, and microfilm readers.

d.1.4.2. Preliminary Interchange with User Agencies

In addition to user visits to the Information Center, interaction with users was carried on by means of direct visits to their offices, and by meetings of staff personnel of both the CARETS team and planning agencies. All the region's users of land use data are of interest for evaluation of the utility of the ERTS data and the products that can be produced from a system that incorporates both ERTS and high-altitude aircraft data. However, to achieve earliest impact in accordance with CARETS priorities, user interaction during the period of this report was concentrated principally upon those groups representing the major planning agencies in the largest portions of the CARETS region that were mapped first. Those groups are the Maryland State Planning Department, the Virginia Division of State Planning and Community Development, and the Southeastern Virginia Planning District (the District which includes the Norfolk-Portsmouth SMSA where the most detailed CARETS system tests took place). In the case of Maryland, the State land use inventory was under way during this period, and arrangements were made to incorporate the CARETS high-altitude data base directly into that inventory, with some editing and field checking of the data to be provided to CARETS in return. Using the same land use classification system as that adopted for CARETS, Maryland extended, using

their own funds, the land use map to the portion of the state not covered by CARETS.

The user applications that the CARETS project considers of highest priority for evaluation of the ERTS-based information system are those that get closest to a user's decision on a proposed land use change. To provide support for those decisions, the CARETS effort has concentrated on land use inventory (a map of present land use and quantification of that map in terms of areas occupied by each land use type) and land use inputs to forecasting models. Input to forecasting models includes not only the inventory information, but also information on rates and locations of land use change, plus correlative information on land capability and environmental impact of land use.

Other user agencies with these concerns that were involved in close coordination during the period of this report are the Metropolitan Washington Council of Governments, the Baltimore Regional Planning Council, the Northern Virginia Planning District, New Jersey Department of Environmental Protection, and the City of Norfolk. Other users or potential users who either came into the Information Center or were otherwise contacted by CARETS staff included the RALI program of the Department of the Interior, the Department of the Interior Office of Regional Planning, the Bureau of Indian Affairs, the Bureau of Sport Fisheries and Wildlife, the Geologic Division of the Geological Survey, the U.S. Bureau of the Census, the Virginia Divsion of Mineral Resources, and representatives of several universities in the region. In addition, contacts with groups from outside the region who have similar interests included the National

Science Foundation, the Environmental Protection Agency, the Oak Ridge National Laboratory, the Tennessee Valley Authority, state agency representatives from Alabama, Wyoming, Montana, Iowa, Illinois, California, Michigan, New York, Washington, and Arizona, the World Bank, and representatives from England, Germany, Australia, Ireland, and Canada.

d.2. Accomplishments planned for next reporting period

By the time of the next six-month reporting period, it is planned to have completed a Level I land use map of the entire CARETS region prepared from ERTS-1 imagery and compiled at a scale of 1:250,000. Also, the high-altitude aircraft data base will be updated for those areas where change has occurred since 1970. Enlargements of ERTS imagery will be systematically screened for indications of land use change from one classification category to another. Change indications will be sought from both the time of the high altitude aircraft data base in 1970 and from the times of early ERTS images to those from ERTS passes toward the end of the reporting period. Overlay maps for selective retrieval of land use data by census areas, counties, drainage basins, and selected geologic regions will be prepared. Some digitization of land use maps and other map overlays will be started, so that during the following reporting period computer displays and calculations can be performed, relating the ERTS land use data sets to those derived from the aerial photography.

Geological, hydrological, and climatological impact of land use changes will be investigated in the Norfolk and Washington-Baltimore test sites, resulting in reports and map products during the next reporting period. Preliminary assessment of CARETS images, maps, area measurements, and other products from the ERTS investigation will be extended to users representing all of the state-level planning offices, including those of Delaware, Pennsylvania, and New Jersey, which were not previously asked to review products developed by the CARETS project. To summarize the products and services that will be available to the users, a data catalog for the CARETS project will be prepared and distributed among users and prospective users of the region.

e. Discussion of significant scientific results and their relationship to practical applications or operational problems including estimates of the cost benefits of any significant results.

The significant results of this investigation thus far are summarized as follows: (1) completion of the research design for the USGS/CARETS demonstration project, consisting of a proposed method of integrated regional environmental analysis linking land use, environmental impact, and user evaluation; (2) preparation of photomosaics and land use maps at a scale of 1:100,000 from NASA high-altitude aircraft data for the entire region; (3) demonstration of the feasibility of extracting several categories of land use information from ERTS-1 MSS data for a portion of the CARETS region; (4) demonstration of the feasibility of detecting some significant land use changes on ERTS imagery; (5) demonstration of the feasibility of attaching environmental impact significance to the remote sensor-derived land use data; (6) delivery of land use information derived from high-altitude aircraft data to a state planning agency representing one of the region's major users (Maryland) for direct incorporation into its statewide land use inventory; (7) demonstration of high interest by other user groups in the test region in the products and services provided by this investigation; and (8) determination of the viability of setting up a computerized geographic information system as part of the CARETS investigation, to facilitate the handling of sensor-derived land use data in a variety of formats to suit user requirements.

The proven ability to obtain verifiable land use information from a combination of satellite and aircraft sensors is in itself a significant scientific result of the CARETS investigation. Such information is useful per se, even in its preliminary and incomplete form at the present stage of the project. That usefulness is attested to by the requests that have already been received from state agencies in Maryland, Virginia, and New Jersey, for copies of the maps and data summaries that apply to their respective areas.

The scientific results and practical applications that grow from this investigation are going to develop in stages beginning with the already-proven ability to obtain land use information, as described in earlier sections of this report. The exact sequence of these results and applications cannot be predicted or programmed. Furthermore, it is not yet possible to quantify either costs or benefits at this stage of the investigation, and it probably would not be useful to attempt to do so until NASA defines what it requires in these categories, releases cost figures on the aircraft and satellite data, and develops a consistent set of criteria for assigning costs and benefits to the various stages leading to utilization of the satellite data.

In the absence of specific guidelines as to how to report satisfactorily on "scientific results and their relationship to practical applications or operational problems" as requested by NASA in this section, a suggested set of criteria or accomplishment milestones is presented, by which results of ERTS investigations might be compared at various stages leading toward successful utilization. The CARETS

project results are then discussed briefly in light of those accomplishment milestones.

e.1. Suggested accomplishment milestones

Following is a list of suggested accomplishment milestones, leading from the research design for utilization of remote sensor data to a hoped-for improvement in the environment resulting from data provided by satellite systems. The list is suggested as a means of classifying and comparing the results of ERTS investigations. The items are roughly, but not necessarily, in chronological order; the actual sequence of accomplishments will consist of overlaps of several activities and results. It is presumed that NASA would like to demonstrate not only how funded projects result in accomplishments at each step, but also how connections are established through the whole process, so that overall objectives and goals are achieved.

1. Research design for utilization of remote sensor data in earth science or resource applications discipline area.

2. Sensor development, and testing on aircraft and spacecraft.

3. Successful sensor operation in aircraft and spacecraft.

4. Sensor data verification in terms of environmental phenomena (ground truth) from both aircraft and spacecraft.

5. Demonstration of the feasibility of deriving, from a combination of aircraft and spacecraft observations, the type of environmental data required by the research design.

6. Demonstration of feasibility of detecting and verifying change by repeated satellite observations, combined with appropriate aircraft data correlations.

7. Discovery of knowledge that was not known before about some earth resource feature or phenomena.

8. Demonstration of feasibility of incorporating remote-sensor derived data into a resource-agency user's ongoing operation.

9. Developing suitable institutional changes to assure that the remote sensing data can be made continually a part of the user's operational requirements, including provisions for training and development of satisfactory data processing and information systems for handling remote sensor-derived data routinely and in the quantities required.

10. Operating the user agency program, in pursuit of its legally-determined program goals, in conjunction with the necessary new institutional units, on the basis of regularly-received satellite and aircraft data.

11. Setting up benchmarks for measuring environmental change.

12. Developing new knowledge of environmental processes and change through assessment of the results of remote sensing monitoring on a continuing basis.

13. Achieving a measurable improvement in environmental quality that has resulted from the remote sensor-derived data from aircraft and satellites.

e.2. CARETS results in terms of accomplishment milestones

The CARETS project attempts to cut across all the accomplishment milestones listed above. As a multidisciplinary, integrative effort, its intention is to demonstrate how satellite-derived data might be put together and applied to one of the region's environmental problems--the allocation of increasingly scarce land resources to new use demands while at the same time maintaining acceptable standards of environmental quality.

CARETS thus intends to demonstrate how remote sensing data can be traced through a succession of stages to an improved decision on land use, a long and tortuous process at best. Whether it succeeds or not

will necessarily be determined by a thorough evaluation at the end of the project, and criteria for that evaluation will be sought before project completion. In order to assist NASA in making the preliminary evaluation that is called for at this stage, considerable pains have been taken in the present report to explain the direction of the research, as well as the results obtained thus far.

Following the same suggested milestones listed in the previous section, CARETS results and expected results are outlined in the concluding portion of this report:

Milestone	Results and expected results as applied to CARETS
1	CARETS research design, combining land use analysis, environmental impact, and user evaluation, completed and tested.
2 & 3	Already successfully accomplished by NASA.
4	Land use types have been verified from aircraft data in 22 Level II categories and 6 Level I categories in CARETS; and from spacecraft data in 6 Level I categories.
5	Feasibility of assembling a land use data base from high-altitude aircraft data, in standardized format so that update and user exchange of data can take place has been demonstrated. Matching and combining the aircraft with satellite observations awaits the next phase of the project.

Milestone	Results and expected results as applied to CARETS
6	Feasibility of detecting land use change using aircraft data has been demonstrated. Feasibility of detecting Level I land use change between aircraft and satellite observation has been demonstrated. Change detection and verification from repeated satellite observations has not yet been demonstrated, owing to the short time span of satellite coverage thus far. Systematic detection and mapping of land use change, while simple conceptually, has been found to be still a difficult task operationally, primarily because of mechanical difficulties in bringing new data into register with old, for comparison.
7	No new environmental knowledge has been discovered yet in this investigation, although valuable new perspectives on the region were obtained from the regional-scale "integrated" view provided by ERTS; land use change was noted, that was not known to the project team, but it was certainly known to the people involved.
8	Feasibility of incorporating remote sensor-derived land use data into the Maryland statewide land use inventory was demonstrated. Other user response to CARETS products and services has been highly favorable, but falls short of demonstrating incorporation of the new data into an operational activity. This aspect will be pursued with other state agency users in subsequent reporting periods.

Milestone	Results and expected results as applied to CARETS
9	The institutional changes required to realize full benefits of the satellite-derived data have begun, although this requirement lags far behind technological developments throughout the earth observation programs. During the period of this report, the USGS Geographic Applications Program, of which the CARETS demonstration project is a part, received a new mandate from the Director of the USGS to develop appropriate land use information activities, including working toward standards of land use classification enabling the satellite and aircraft data to be utilized on a uniform basis. A new Chief Geographer, Dr. James R. Anderson, was appointed, and a modest staff expansion took place. Similar institutional changes are needed in state agencies where major new land use inventory and planning functions are arising. Much CARETS team effort actually goes into an educational and training function, although this needs to by systematized, as for example in the EROS Program Workshops. CARETS is beginning rudimentary experiments with information systems design and development, which will need to be institutionalized somewhere in the government to achieve full benefit of the potential of applying satellite data to land use inventory and change analysis. Our studies indicate that the data processing and information systems requirements for land use have been vastly neglected in the overall program structure.

Milestone	Results and expected results as applied to CARETS
10	No agency operation has been set up yet under this milestone; the CARETS team plans to define and discuss with potential users how regularly-received land use data derived from satellite observation might be utilized.
11	The 1970 high-altitude aircraft data base, designed as a basis for the CARETS land use change and satellite verification experiments, can also serve as a benchmark for measuring and monitoring environmental change in this region, once the appropriate institutional arrangements for such monitoring become a reality.
12	New knowledge of environmental process and change resulting from the satellite programs must await the scientific assessment of operation of satellite monitoring systems over a period of time. CARETS anticipates such monitoring in its overall design.
13	To determine whether environmental quality is improved as a result of all of the preceding activities, it will be necessary to see if better data on land use and environmental change results in better decisions on future land uses. This will mean not only that the new data improves knowledge, as in milestone 12 above, but also that decision-makers will make use of the new knowledge in land use planning and management. Even though this result may be some time in the

Milestone	Results and expected results as applied to CARETS
13	future, most certainly after the completion of the CARETS investigation, the study is to include proposed criteria for making such a determination through a sample inventory of land use decisions in the region, and through confrontation of the decision-makers with results derived from the earth observation programs.

f. Listing of published articles, and/or papers, preprints, in-house reports, abstracts of talks, that were released during the reporting period:

Fitzpatrick, Katherine A., and Lins, Harry F. (Jr.), 1972, A Preliminary Evaluation of Land Use Mapping and Change Detection Capabilities Using An ERTS Image Covering a Portion Of The CARETS Region, a progress report prepared in support of NASA/ERTS Experiment No. 125, Task 32 (434-641-14-07-60)

Goodell, H.G., Woolheater, C.M., and Echternacht, K.L., 1972, Environmental Application of Remote Sensing Methods to Coastal Zone Land Use and Marine Resource Management: Final Report: Interagency Report USGS-243; NASA Contract No. W-13165, Task No. 160-75-01-32-10; USGS Contract No. 14-08-001-12540, with the University of Virginia.

g. Recommendation concerning practical changes in operations, additional investigative effort, correlation of effort and/or results as related to a maximum utilization of the ERTS system:

(1) Improvements are needed in the delivery of quality color composite copies of ERTS imagery, in a form suitable for land use analysis. It is suggested that NASA investigate economical means of providing photo copy of ERTS imagery to investigators at scales of 1:250,000 and 1:100,000, as well as the scales now provided. The high quality of ERTS imagery justifies interpretation at scales of 1:100,000 or larger for certain land use analysis applications.

(2) The problem of systematic detection and mapping of land use change could benefit from additional NASA effort, possibly resulting in a determination of best methods discovered by ERTS investigators, and further facilitating communication among investigators on this topic.

(3) Coordination among ERTS investigators who are dealing with the identification and mapping of land use is strongly suggested, so that comparability of results can be achieved. The USGS is attempting to develop standards of land use description based on satellite and aircraft data, according to a proposed classification scheme set forth in USGS Circular 671 (Anderson, Hardy, and Roach, 1972). The USGS would appreciate receiving results of ERTS land use investigations in different parts of the county, and information on degree of success in using the proposed classification scheme, or suggested modifications thereof. This applies to land use information extracted from ERTS data by either manual or automatic means. Communications may be sent to Dr. James R. Anderson, Chief Geographer, USGS, or to any of the USGS Geographic Applications Program ERTS-1 investigators: Robert H. Alexander, John L. Place, and James R. Wray, U.S. Geological Survey, Washington, D.C. 20244.

(4) Relating to the previous suggestions, a modification of the ERTS Image Descriptor list to apply specifically to land use categories observable on ERTS images might further facilitate the interchange of land use information, provided that a separate explanation is directed to ERTS investigators and users of the Image Descriptor file. If such a modification is adopted, it should reflect Levels I, II, and III (or higher levels if appropriate) categories of the classification Scheme proposed in USGS Circular 671.

h. Listing by date of any changes in Standing Order Forms:

NONE.

i. ERTS Image Descriptor Forms:

(See pages 48 through 53 following.)

Note: Only descriptors having application to land use terms were selected; in general, terms having primary applicability to geology, hydrology, or meteorology were not cited.

j. Listing by date of any changed Data Request forms submitted to Goddard Space Flight Center/NDPF during the reporting period:

NONE.

ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

NDPF USE ONLY
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DATE 1 January 1973

PRINCIPAL INVESTIGATOR Robert H. Alexander

GSFC

ORGANIZATION U. S. Geological Survey

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
E-1079-15131-5 Bulk Process				Airfield, barrier beach, barrier island, bay, bridge, coast, coastal marsh, coastal plain, coastline, continental, shelf, cropland, inlet, estuary, floodplain, forest, harbor, highway, island, lagoon, lake, marsh, metropolitan area, meander, peninsula, plain ridge, rural area, sea, suburban area, tributary, urban area, vegetation
E-1080-15192-7 Bulk Process				Airfield, bay, bridge, coast, coastline, clearing, cropland, estuary, forest, floodplain, gap, harbor, highway, island, lake, meander, metropolitan area, marsh, mountain, peninsula, plain, ridge, rural area, tributary, urban area, vegetation

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

MAIL TO ERTS USER SERVICES
CODE 563
BLDG 23 ROOM E413
NASA GSFC
GREENBELT, MD. 20771
301-982-5406

GSFC 37-2 (7/72)

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PRINCIPAL INVESTIGATOR Robert H. Alexander

GSFC

ORGANIZATION U. S. Geological Survey

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
E-1045-15252-5 Bulk Process				Airfield, cropland, floodplain, forest, highway, island, meander, piedmont, rural area, vegetation
E-1045-15243-5 Bulk Process				Bridge, cropland, floodplain, forest, gap, highway, ridge meander, mountain, piedmont, urban area, rural area, tributary, urban area, vegetation
E-1080-15194-5 Bulk Process				Airfield, bay, bridge, coastal plain, cropland, estuary, flood plain, forest, highway, island, lake, meander, plain, metropolitan area, peninsula, suburban area, tributary, urban area, vegetation
E-1079-15133-5 Bulk Process				Airfield, back bay, bay, barrier beach, barrier island, bridge canal, cape, coast, coastal marsh, coastal plain, coast line, continental shelf, cropland, estuary, floodplain, forest, highway inlet, island, lake, marsh, meander, peninsula,

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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DATE 1 January 1973

PRINCIPAL INVESTIGATOR Robert H. Alexander

GSFC _____

ORGANIZATION U. S. Geological Survey

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
E-1079-15133-5 continue Bulk Process				plain, salt marsh, sea, tributary, urban area, vegetation
E-1080-15185-5 Bulk Process				Bay, bridge, canal, coastal plain, cropland, dam, estuary, floodplain, forest, highway, peninsula, plain, ridge, rural area, tributary, vegetation

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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ERTS IMAGE DESCRIPTOR FORM

(See Instructions on Back)

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DATE 1 January 1973

PRINCIPAL INVESTIGATOR Robert H. Alexander

GSFC

ORGANIZATION U. S. Geological Survey

PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
110CT72/F/1114/E-1080-15185				Bay, bridge, canal, coastal plain, cropland, dam, estuary, floodplain, forest highway, peninsula, plain, ridge, river, rural area, stream, tributary, valley, vegetation
E-1079-15133-5-01/10-OCT/72				Airfield, back bay, barrier beach, barrier island, bridge, canal, cape, coast, coastal marsh, coastal plain, coast line, continental shelf, cropland, estuary, floodplain, forest, highway, inlet, island, lake, marsh, meander, peninsula, plain, river, salt marsh, sea, stream, tributary, urban area, valley, vegetation
E-1080-15192-7/11-OCT-72				Airfield, bay, bridge, coast, coastline, clearing, cropland, estuary, floodplain, forest, gap, harbor, highway, island, lake, meander, metropolitan area, marsh, mountain, peninsula, plain, ridge, rural area,

*FOR DESCRIPTORS WHICH WILL OCCUR FREQUENTLY, WRITE THE DESCRIPTOR TERMS IN THESE COLUMN HEADING SPACES NOW AND USE A CHECK (✓) MARK IN THE APPROPRIATE PRODUCT ID LINES. (FOR OTHER DESCRIPTORS, WRITE THE TERM UNDER THE DESCRIPTORS COLUMN).

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
E-1080-15192-7/11-OCT-72 continue				tributary, urban area, valley, vegetation
OGSEP72/G/0626/E-1045-15243				Bridge, cropland, floodplain, forest, gap, highway, meander, mountain, piedmont, ridge, river, rural area, tributary, urban area, valley, vegetation,
10OCT72/E/1100/E1079-15131				Air Field, barrier beach, barrier island, bay, bridge, coast, coastal marsh, coastal plain, coastline, continental shelf, cropland, estuary, floodplain, forest, marbor, highway, inlet, island, lagoon, lake, marsh, meander, metropolitan area, peninsula, plain, ridge, river, rural area, sea, stream, suburban area, tributary, urban area, valley, vegetation

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PRODUCT ID (INCLUDE BAND AND PRODUCT)	FREQUENTLY USED DESCRIPTORS*			DESCRIPTORS
110CT72/F/1114/E-1080-15194				Airfield, bay, bridge, coastal plain, cropland, estuary, floodplain, forest, highway, island, lake, meander, metropolitan area, peninsula, plain, river, stream, suburban area, tributary, urban area, valley, vegetation

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