BIOGRAPHY

James R. Wray

James R. Wray is a senior geographer-cartographer in the U.S. Geological Survey's Geographic Applications Program. He is responsible for urban aspects of the Program, and for design of cartographic aspects of a geographic information system, including such user-oriented end products as the looseleaf Atlas of Urban and Regional Change. Mr. Wray earned degrees in Geography at the University of Chicago. He is author of "Photo Interpretation in Urban Area Analysis" in the Manual of Photographic Interpretation, published by the American Society of Photogrammetry. His earlier work, reported in this Manual, partly inspired the "Census Cities Project." Mr. Wray has taught geography, cartography, or remote sensing at his alma mater and at four other universities. As consulting geographer-cartographer he designed urban data systems which combine use of image interpretation and map tools to serve the specific needs of government, planners, and private industry. Among systems he has helped to develop are applications in public utilities, advertising and marketing, civil defense, and census planning.

CENSUS CITIES PROJECT AND

ATLAS OF URBAN AND REGIONAL CHANGE

by

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INTRODUCTION

A large segment of the USGS Geographic Applications Program is concerned with the urban applications of remote sensing. The Program's current urban research goals can be demonstrated by an experiment on the combined use of sensors and census data, and of aircraft and spacecraft sensor platforms. Early phases of this experiment received some attention as the "Census Cities Project," and one of the user oriented end-products will be a looseleaf "Atlas of Urban and Regional Change," hence the double theme in the title of the paper.

The Census Cities Project has several related purposes:

1. to assess the role of remote sensors on high altitude platforms for the comparative study of urban areas;

2. to detect changes in selected U.S. urban areas between the 1970 census and the time of launching of an Earth-orbiting sensor platform prior to the next census;

3. to test the utility of the satellite sensor platform to monitor urban change (When the 1970 census returns become available for small areas, they will serve as a control for sensor image interpretation.);

4. to design an information system for incorporating graphic sensor data with census-type data gathered by traditional techniques;

5. to identify and design user-oriented end-products or information services; and

6. to plan an effective organizational capability to provide such services on a continuing basis.

THE RESEARCH DESIGN

The design of the "Change Detection Experiment" is illustrated in Figure 1. In this figure each of the rectangles is a symbol representing a page in the Atlas of Urban and Regional Change, a user oriented end-product. The horizontal rows represent steps in the research design. The vertical columns represent imagery and imagery interpretation at different times and from different sensor platforms. The experiment begins with the procurement of high altitude aircraft photography near the dates of the 1970 census for a sample of U.S. cities. From that photography a rectified mosaic is made for each city and is fitted with a grid, or rectangular coordinate system. The next step is to prepare an overlay showing the 1970 census statistical areas and their centroids. This overlay helps to relate the census data to the information generated from the aerial photography. The next step is to complete the land use analysis and measurement of land areas in each category and each census tract. An additional step, not illustrated in Figure 1, calls for listing the land use information for 1970 in computer-retrieval format.

When the Earth Resources Technology Satellite (ERTS) is launched in 1972, we will also receive high altitude aircraft photography over the same test sites, plus television imagery from the satellite itself. From the aircraft photography, we plan to make another land use analysis, but we will not need to repeat the making of a gridded photo mosaic or the overlay showing the census statistical areas. Another overlay will show changes detected between the 1970 land use and the 1972 land use. Besides the locational details recorded on the overlay, the new land use information will also be recorded in computer retrievable format. The 1972 land use analysis will serve as a basis for interpreting the imagery from the satellite. Thus, it will become possible to determine how well the imagery from the satellite can be used to detect the location, kind, and intensity of urban land use change between 1970 and 1972.

ACQUISITION OF REMOTELY SENSED IMAGERY

Twenty-six urban test sites selected for this experiment are shown in Figure 2. A twenty-seventh test site is the Pittsburgh metropolitan area in southwestern Pennsylvania. These sites represent a ten percent rank-size sample of U.S. urban areas. Inland and coastal cities are represented and so also are most regions of the country. There are more cities in the South because we already have Gemini and Apollo photography for the lower latitudes. For twenty of the urban test sites, photo missions were completed during the April-to-July period when the 1970 census was being taken.

One of the test sites for which photography was received is the Washington, D.C. Urbanized Area. Figure 3 shows the flight lines and areas covered by that mission. The Washington coverage was acquired on NASA Mission 128-d, June 28, 1970, with an RB-57B aircraft at 50,000 feet above terrain. There were three north-south flight strips spaced about 18.5 kilometers apart. The diagram in the lower right corner shows the area covered by each of the cameras aboard the aircraft. The legend shows there were nine cameras.

Figure 4 is a diagram of the nine photo-sensors for a central frame over the Washington test site. One the left are sample frames from three metric cameras, and on the right, sample frames from six Hasselblad cameras. The cameras for the planning of the mission are the two RC-8s, which use roll film 24 centimeters wide. Both cameras have a focal length of 152.6 millimeters, and produce an image scale of 1:100,000 at a flight altitude of 15.2 kilometers. One of these cameras has color infrared film with a minus-blue filter. The other camera has black-and-white panchromatic film used with the same filter. A portion of the RC-8 color infrared photo is shown in Figure 5. Each of the full RC-8 photos covers a square 22.8 kilometers on a side, or an area of 520 square kilometers. Photographs are taken with sixty percent overlap in line of flight and about thirty percent sidelap between flight lines. This provides stereoscopic coverage and permits three-dimensional viewing. A backup camera is also provided in the 24-centimeter film width format. This is a Zeiss camera with a 305 millimeter focal length lens. It procures pictures at 1:50,000 and covers a square 11.4 kilometers on a side, or an area of 129 square kilometers. This camera also is loaded with color infrared film but the lens is fitted with a "D" filter. With the Zeiss camera there is edge-to-edge coverage in the line of flight, but there is some gap in coverage between flight lines.

The Hasselblad cameras all use roll film, 70 millimeters wide. Three are loaded with black-and-white film, three with color film. Two of the cameras have a black-and-white panchromatic film, one filtered with a green filter and one with a red filter. The third contains black-and-white infrared film. These three cameras simulate the three television cameras which are expected to be aboard the ERTS-A platform. In the ERTS data handling systems these three different television images can be combined to form one false color image. The composite image is represented by the fourth camera, which contains color infrared film and the same minus-blue filter used on the RC-8 cameras with color infrared film. The fifth camera contains panchromatic color film with a stronger blue filter for additional haze penetration. The sixth camera also has panchromatic film; it is filtered with a number three filter to render the scene about as you and I would see it looking through the camera sight at the time the picture was taken. Each of the Hasselblad cameras has a 40 mm focal length lens which covers about 438 square kilometers (slightly less than the RC-8 camera), producing an image scale of 1:382,000 from a flight altitude of 15.2 kilometers above terrain.

This same multispectral, census-contemporaneous imagery has been received for most of the urban test sites. This data base represents a truly unique opportunity for comparative urban study!

UTILIZATION OF THE IMAGERY

As called for by the research design, the first step in the analysis is the preparation of a rectified photo mosaic, fitted with a rectangular coordinate grid. Figure 6 shows a portion of the mosaic for Washington, D.C. This portion is a simulated page in the Atlas of Urban and Regional Change. The grid interval is one kilometer. The publication format will have a mosaic square 20 kilometers by 20 kilometers at 1:100,000. This square is placed to the left of the center on a page measuring 28 centimeters from north to south and about 38 centimeters east to west. This is the same size as one standard page used for computer printout. The right hand panel provides legend space for overprints or overlays, or for extension of the map area. Pages may be bound at top or at left, or used singly, and folded into reports using the page size of conventional office stationery.

As in other experiments proposed for the Department of the Interior's Earth Resources Observation Systems (EROS) Program, the Universal Transverse Mercator projection and rectangular coordinate system is in use, and all distances and areas are expressed in metric units. Geographic coordinates and bar scales in non-metric units will also be shown, however, and the various State coordinate systems can be indexed for users who require them.

The next step in the urban analysis is the preparation of an overlay showing the census statistical areas. A simulation of the census overlay is shown in Figure 7. The fine solid lines in the figure represent the census tract boundaries at the same scale as in Figures 6 and 8. The numbers represent the census tract identification. Some of the tract lines are state boundaries, county boundaries, or boundaries of incorporated cities. These delimit political areas and other "user" areas for planning and decision-making. A supplementary overlay would show additional point and line features appearing on the mosaic, or essential to its interpretation.

The next step is the analysis of area features, especially land use. This is illustrated in Figure 8, a simulated overlay or overprint for the same area in Washington, D.C. The land use interpretation is done directly on an overlay to the color infrared photography at 1:100,000. The smallest mapping unit is a square 0.2 kilometer on each side, or four hectares, or about 11 acres. This is not much larger than the area covered by the blunt end of the color pencil used in the image interpretation. The minimum sized mapping unit is larger than the anticipated resolution cells. The legend shows the nested land use classification system presently being tested in the prototype analysis of the Washington test site. There are eight urban classes and five non-urban classes. Three of the classes are repeated, so there are really only ten different categories. The Urban and Non-Urban land use categories can be expanded or contracted according to the scale and minimum-size area for mapping purposes. Land ownership information garnered from "ground truth" may be shown on the supplementary overlay.

After mapping land use to the limits of the mosaic, a single boundary line is drawn around the central mass of "Urban" land uses. This is taken as the boundary of the urban area at the time of the photography. It becomes the "real estate" definition that will form the basis for comparison with other urban areas similarly delimited, or for analyzing changes in one urban area at different times.

The next step in the analysis is to measure the area of land in each land use category and to report the totals by census tract. The information for a particular time period is then stored in computer retrievable format. The land use overlays and area measurements for two different time periods will form the basis for change detection, and for the analysis of location, kind, and intensity of change.

STATUS OF THE WORK

The graph in Figure 9 provides a frame of reference for reporting what the Census Cities Project has accomplished so far and what remains to be done. This figure is a graph, on which are plotted 213 U.S. Urbanized Areas having more than 50,000 population in 1960. Population is scaledon the X-axis. The Y-axis shows land area in square kilometers. The "Urbanized Area" is an official census delimitation of the built-up area around central cities of 50,000 or more population. Adjoining cities, whether entirely built-up or not, are either wholly included, or wholly excluded. The minimum density is about four hundred persons per square kilometer. This definition is more inclusive than the corporate city; but it is less inclusive than the Standard Metropolitan Statistical Area, since the latter is comprised of whole counties. The Urbanized Area, then, is more nearly comparable to the mass of urban land use that is likely to be detected and delimited by interpretation of air photos and other sensors. Even so, a delimitation based on actual urban land use, as derived by image interpretation, can effect more meaningful area comparison than a delimitation that may include large tracts of open unimproved land which happens to have corporate status. On the graph, the small dot in the upper left corner represents the New York Urbanized Area, with 14,000,000 persons on 4,650 square kilometers. The small dot in the lower right corner represents Mayaguez, Puerto Rico, with 53,000 persons on 10 square kilometers. Ranging between these extremes are all other urban areas. Some regional central tendencies can be discerned although they are not annotated on the graph as it is reproduced here. The Census Cities test sites are represented by triangles and are identified in the diagonal legend. This reads from left to right in population rank order and comprises roughly a ten percent sample. A similar model, refined by land use delimitation and regional interpretation, will be one result of our experiment. It can be used to estimate inter-censal population and to project the cost of analyzing land use in all U.S. urban areas.

Land use analysis is underway on the three largest urban test sites: San Francisco, Boston, and Washington. Work in seven smaller areas is also underway. In all on-going work, special attention is being given to the identification of urban environmental problems which can be studied by spatial analysis--including the use of remote sensors, and computer mapping techniques. We are also giving attention to the identification and direct involvement of prospective users in the applications of remote sensing techniques to the solution of environmental problems.

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GLOSSARY OF TERMS

Census statistical area. A clearly defined area of any size used for reporting the results of a census. Boundaries are either those established by law or which are clearly visible roads or streams which are not likely to change. In this way, the census reports data for political areas, and changes from one census to the next. In urban areas, the census statistical area for which the greatest variety of socio-economic data are reported is the census tract. It varies in area size and population size, but on the average it will have between 4,000 and 5,000 persons.

Centroid. An arbitrarily selected coordinate point within a small area delimited on a map or photograph. The point may be described in any coordinate system. It is used as an "address" to describe the location of all data counted within the area outlined.

Gridded photo mosaic. A composite of several aerial photographs, corrected (or rectified) for distortions due to camera tilt (but not necessarily those due to relief), and fitted with a grid of squares. The grid is preferably a rectuangular coordinate system with a clearly defined relationship to the geographic coordinate system and to an appropriate map projection.

Land use analysis. A systematic classification of areas with respect to their use by man. Point and line features in an aerial photograph are usually interpreted first. Land use analysis is essentially the interpretation of area features or areal associations of point and line features (depending on scale or resolution). Land use analysis is often the first step in the many specialized applications, any one of which imposes limits on the classes chosen. For urban mapping land use by image interpretation it is appropriate to use classes that are based on apparent use; details can be added by applying information not necessarily derived from the photos.

Simulated overlay. Figures 6, 7, and 8 are "simulations" of pages in the Atlas of Urban and Regional Change. They are not actual pages or overlays, but are simplified for presentation as illustrations. The actual pages or overlays will be larger, more detailed, and executed with finer line work.

Standard Metropolitan Statistical Area (SMSA). Another census statistical area. It is comprised of whole counties and some central cities which are not parts of counties. (The county is the principal political subdivision of a state.) The SMSA includes much more land than the "Urbanized Area."

Urbanized Area. One kind of census statistical area. It most closely resembles the mass of built-up urban area one would recognize as "urban" and delimit on a small scale air photo. However, whole corporate cities are included, so extensive areas of non-urban land use may also be included.

User-oriented end product. This is a looseleaf, statistical Atlas of Urban and Regional Change, a flexible photographic, cartographic, and statistical tool that will provide a basic synthesis of land use and related data. Yet, it also leaves to the user the opportunity to re-interpret the data, and to make additional thematic studies.

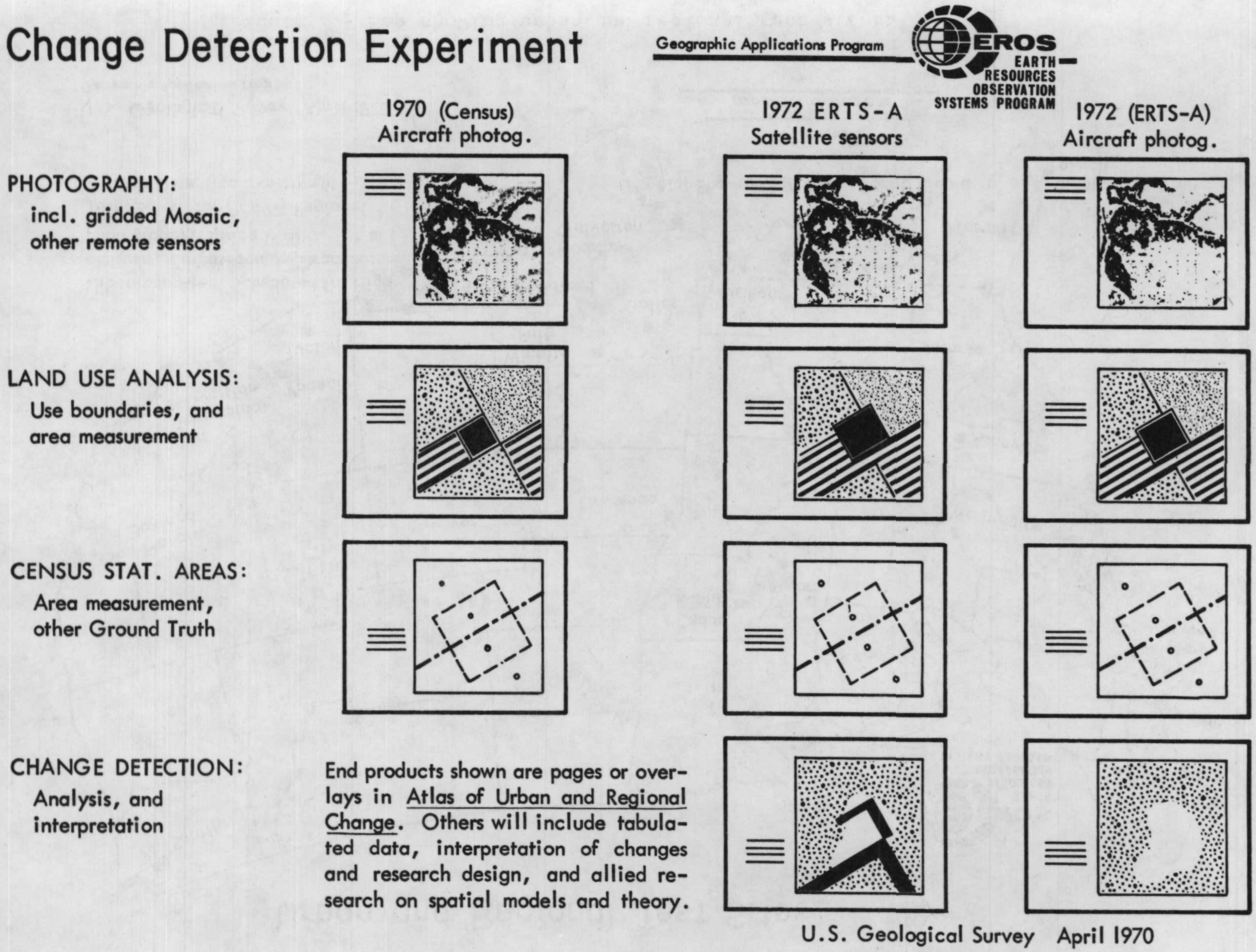

Figure 1.- Steps and sensor components in urban change detection experiment.

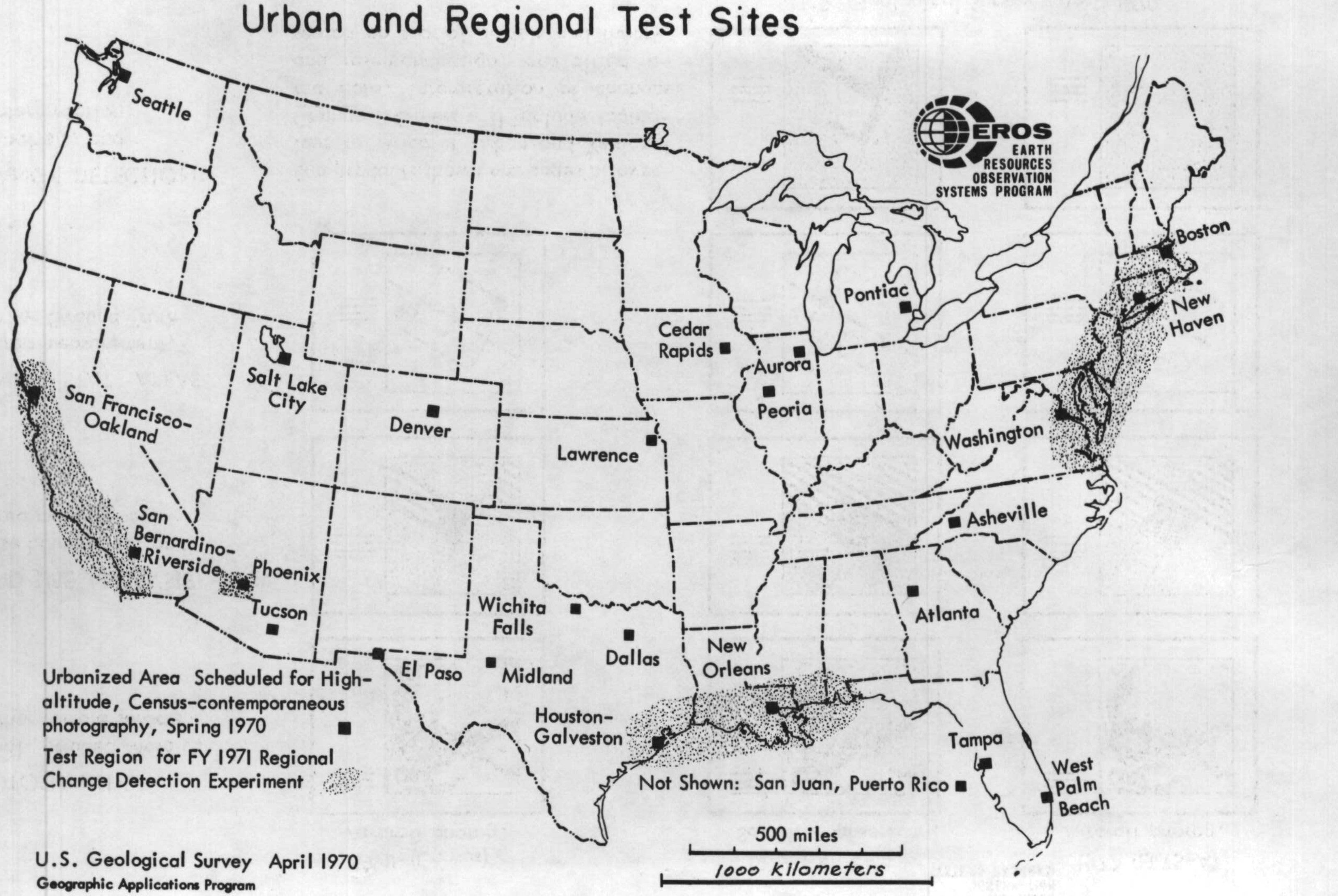

Figure 2.- Map showing urban and regional test sites.

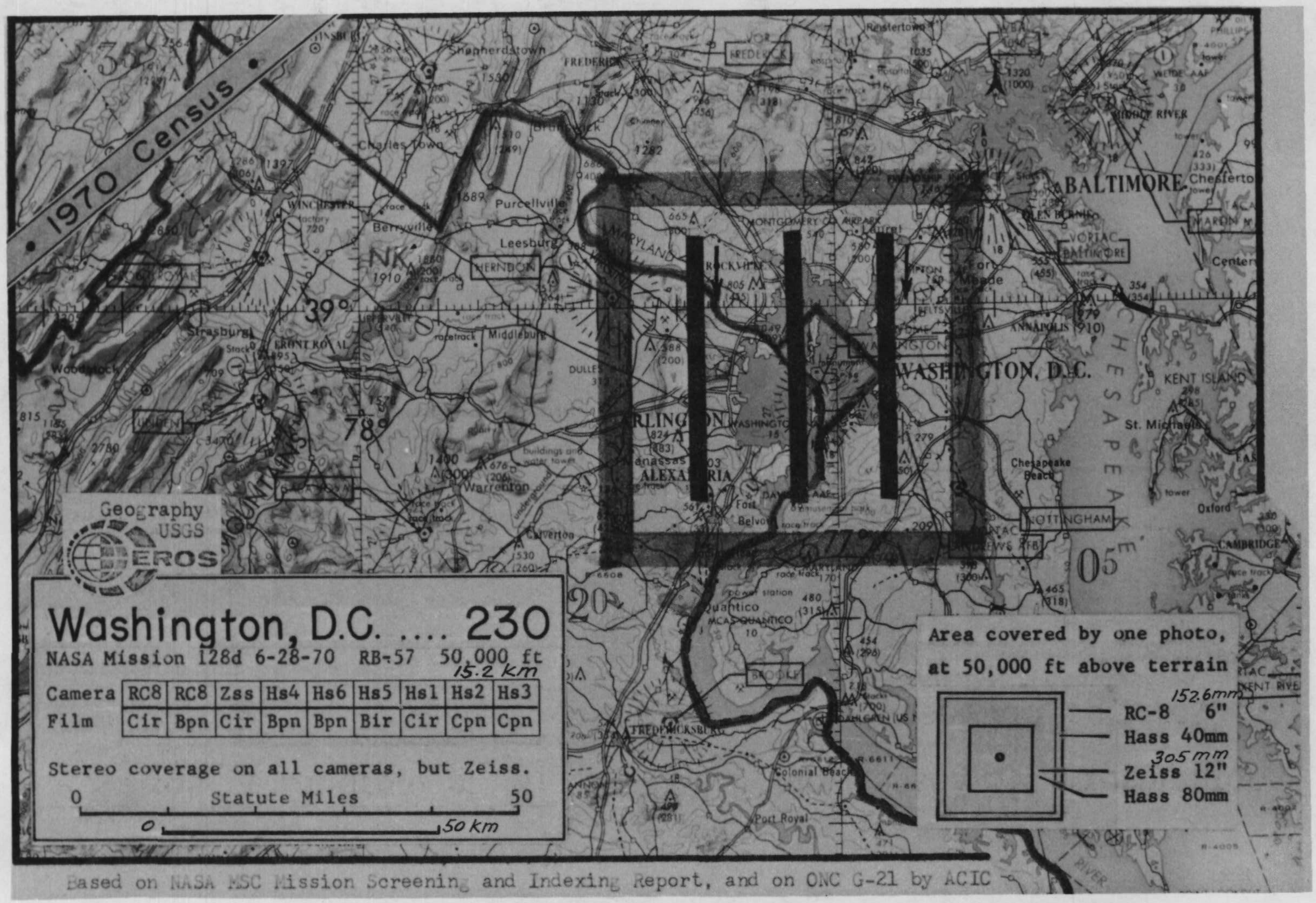

Figure 3.- Map showing flight lines and sensor coverage area, Mission 128, Washington, D.C.

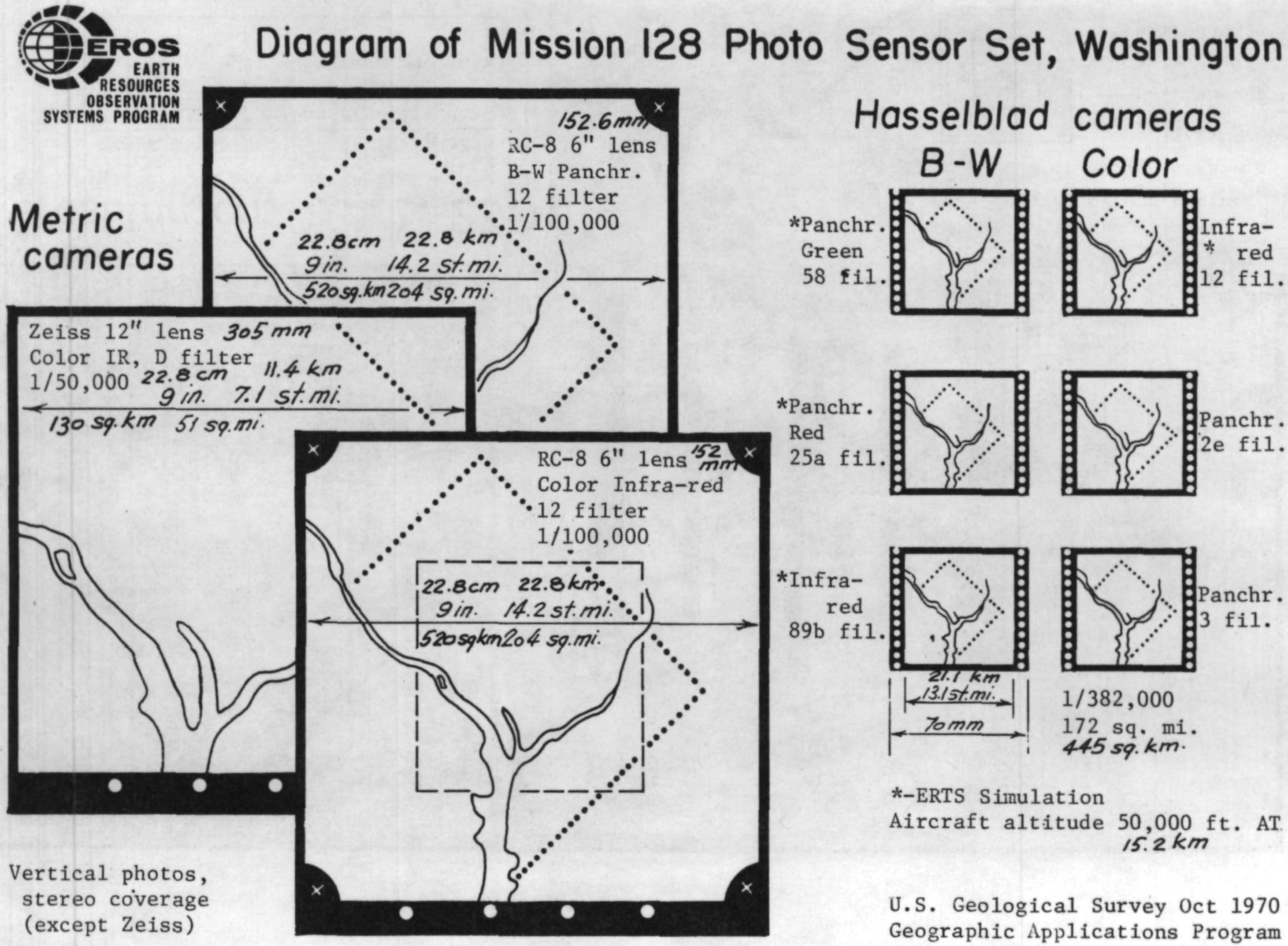

Figure 4.- Diagram of photo sensor set, one frame per camera, Mission 128, Washington, D.C.

Figure 5.- Portion of RC-8 color infrared photo, Mission 128, Washington, D.C.

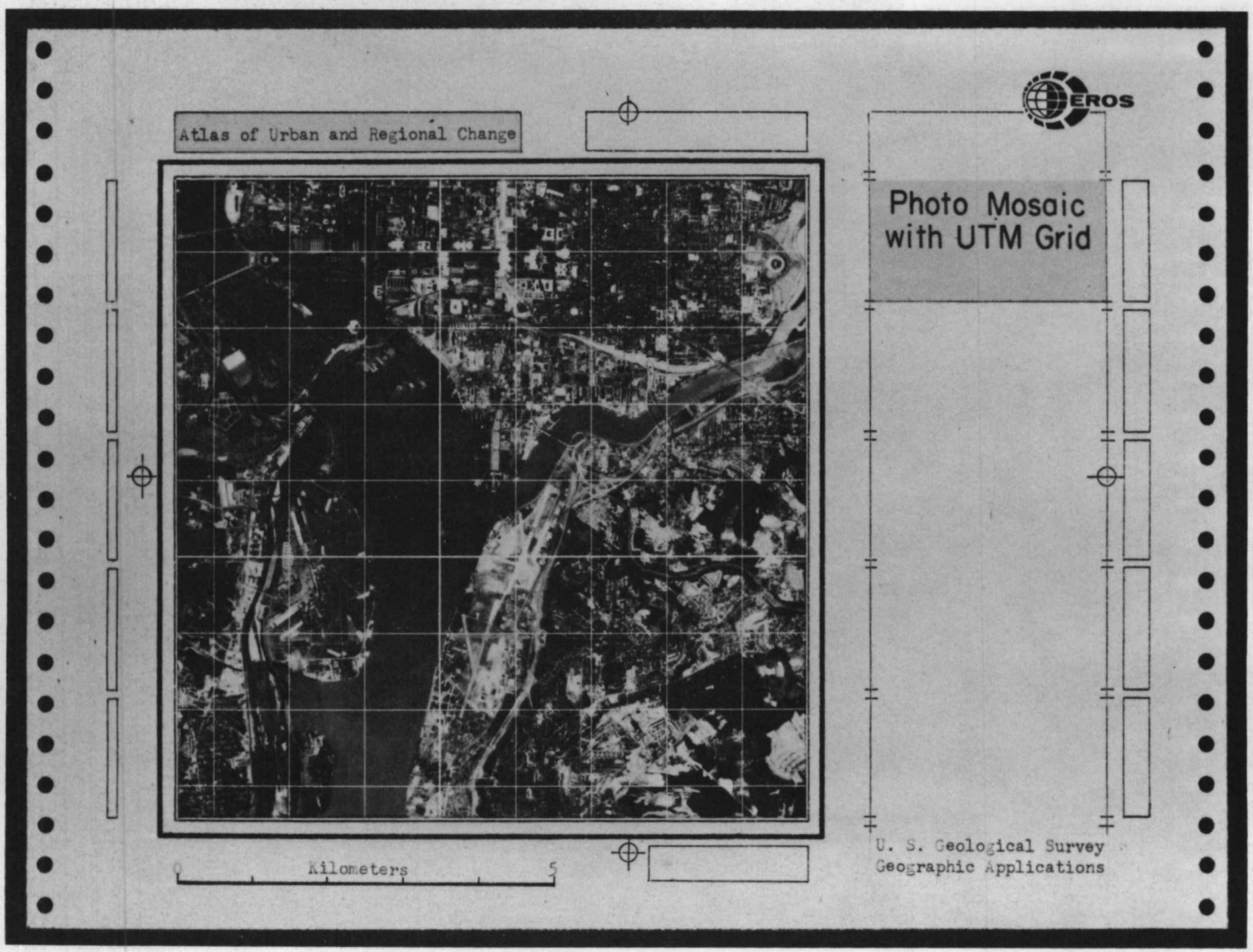

Figure 6.- Atlas of Urban and Regional Change, simulated page with gridded photo mosaic.

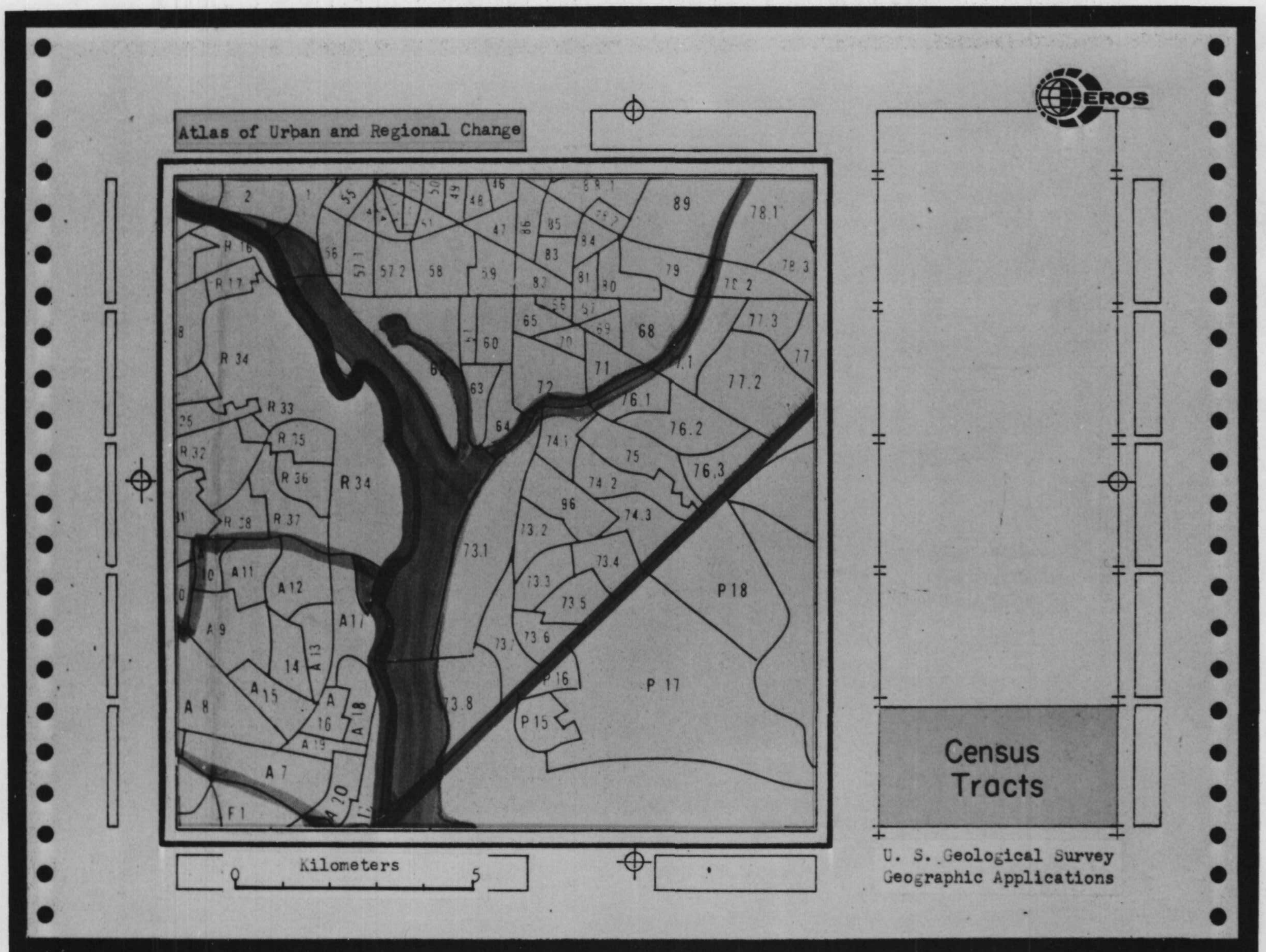

Figure 7.- Atlas of Urban and Regional Change, simulated page with Census Tract boundaries.

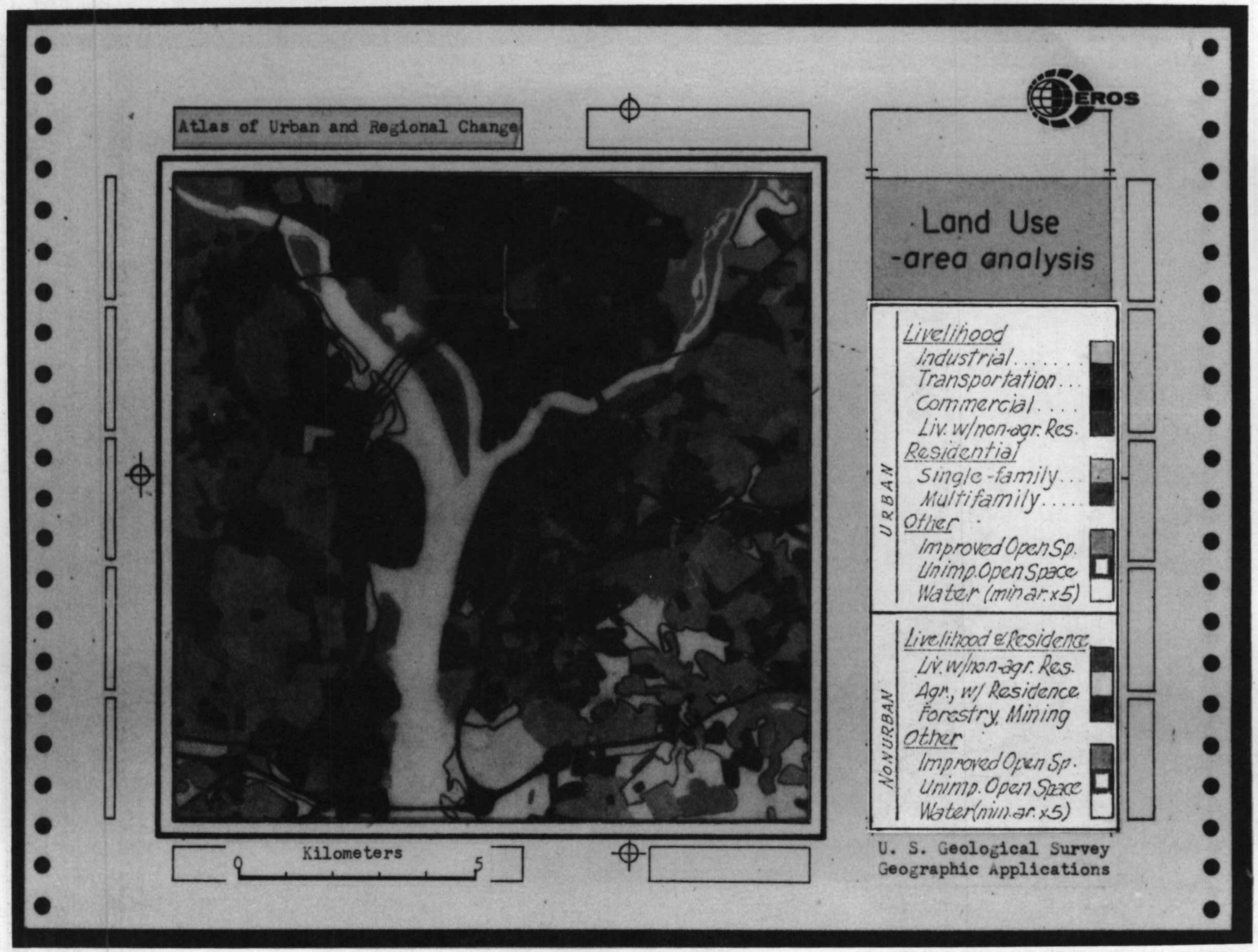

Figure 8.- Atlas of Urban and Regional Change, simulated page with land use interpretation compiled directly over the color infrared photo.

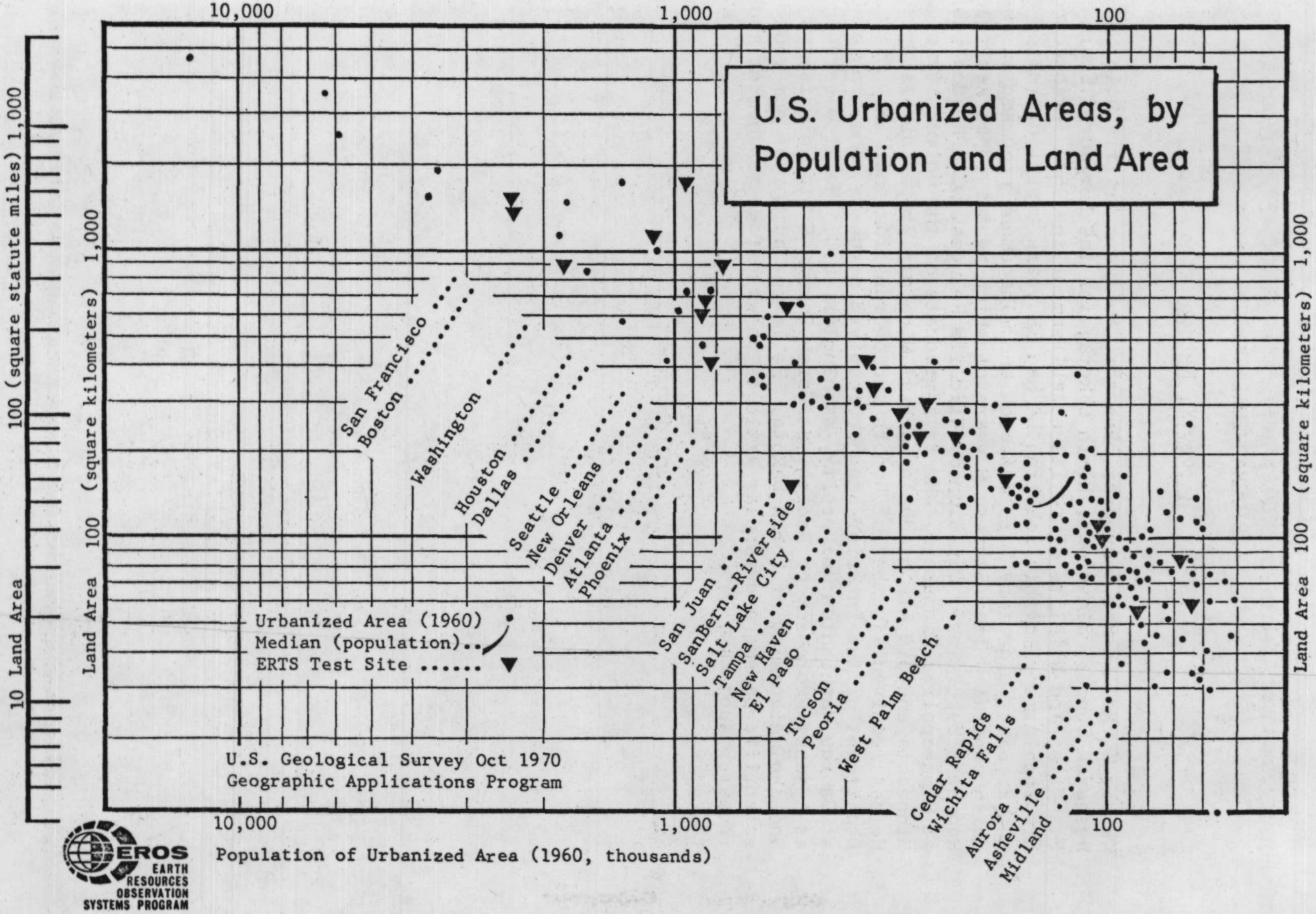

Figure 9.- U.S. Urbanized Areas, 1960, by Population and Land Area. Note ERTS test sites.