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INVESTIGATION OF LAND USE OF NORTHERN MEGALOPOLIS USING ERTS-1 IMAGERY

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16. Abstract

Primary objective was to produce a color-coded land use map and digital data base for the northern third of Megalopolis, a task accomplished in 5 months (January-May 1973). Secondary objective was to investigate possible applications of ERTS products to land use planning, which task was done in the two remaining months (June-July 1973).

Many of the materials in this report already have received national, dissemination as a result of unexpected interest in land use surveys from ERTS. Of special historical interest is the first comprehensive urban-type land use map from space imagery, which covered the entire state of Rhode Island and was made from a single image taken on 28 July 1972.

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PREFACE

Objective

To map and digitize the land use of the northern third of Megalopolis, and to look into the possible utility of ERTS as a planning tool.

Scope

Area covered: the three states Massachusetts, Connecticut and Rhode Island.

Degree of detail: eleven categories of land use, scale 1:250,000.

Method of interpretation: "manual" (human-visual), using only conventional photo-laboratory products.

Summary of Conclusions

Using ERTS-1 imagery it is completely practical to compile useful 11-category land use maps of states or groups of states. Dollar costs and speed of mapping both favor ERTS over aircraft by more than one order of magnitude.

Initial conferences with the planners of 5 New England states indicate an almost unanimous favorable interest in ERTS and its probable successors. The degree of enthusiasm for ERTS-1 is essentially in inverse proportion to the completeness of data in the present land use files of the state concerned. All states are keenly interested in high-altitude aircraft imagery as a source of supplemental coverage for ERTS (not as a replacement or substitute for improved resource satellites).

Recommendations

That conferences already under way between the Dartmouth College Project in Remote Sensing and the planners of the New England states be continued to determine how and to what extent present and future state and interstate planning requirements can be met by ERTS-1, ERTS-B, Skylab, and EOS.

That NASA and the USGS make every effort to serve the tremendous interest that exists today in the satellite aspects of the land use and management program, by insuring as rapid an increase in image resolution as the state-of-the-art will allow.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

I INTRODUCTION

With the launching on 23 July 1972 of a satellite devoted entirely to the observation of the Earth's natural and cultural resources, the post-aircraft era in thematic mapping began. Among the investigations funded by NASA to utilize the imagery from the first Earth Resources Technology Satellite was one for the investigation of the land use of northern Megalopolis, by the Dartmouth College Project in Remote Sensing.[1]

The objectives of the investigation were (1) to map and digitize the land use of the northern third of Megalopolis, and (2) to evaluate ERTS as a planning tool, including exploration of the practicability of identifying the urban-rural interface and certain special-interest areas, predicting land use trends, and recommending improvements in land use planning.

Although this report is submitted as a final report, it is felt that we have just arrived at the threshold of the analytical phase. The seven months since comprehensive imagery became available have been used largely in the mapping and data-bank aspects of the study, together with various expository activities at the national level.[2] Evaluation of the products is just now becoming possible.

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[1] "Proposal for a Contract to Investigate the Land Use of Northern Megalopolis Using ERTS-A Photography: Submitted to NASA Headquarters Office of University Affairs by the DCPRS in April 1971. Approved as Contract NAS 5-21749, 1 April 1972.

[2] (1) NASA Authorization for Fiscal Year 1974, Hearings before the Committee on Aeronautical and Space Sciences, United States Senate, Ninety-Third Congress, First Session, on S.880, March 12, 14, 15, 21 and 22, 1973 (Washington, D.C.: U.S. Government Printing Office, 1973). Part II, pp. 820-822 and 1062-1080.

(2) Symposium on Significant Results Obtained from the Earth Resources Technology Satellite - 1: Proceedings of a Symposium held by Goddard Space Flight Center at New Carrollton, Maryland on March 5-9, 1973. NASA SP-327. (Washington, D.C.: National Aeronautics and Space Administration, 1973). Vols. I-III.

See especially: Vol. I, Technical Presentations: Section B, Robert B. Simpson and David T. Lindgren, "Land Use of Northern Megalopolis", pp. 973-980.

Vol. II, Summary of Results (X-650-73-127 Preprint, May 1973) David T. Lindgren and Robert B. Simpson, "Land Use and Mapping", pp. 100-105.

Vol. III, Discipline Summary Reports (X-650-73-155 Preprint, May 1973) Wayne D. Mooneyhan, "Land Use and Mapping", pp. 18-29.

(footnotes continue on next page)

Two "Significant Results" have been reported during the progress of this investigation.[1] One was completion of the first comprehensive, urban-type land use map from space imagery, a map of the State of Rhode Island, scale 1:250,000. This now historic map has been widely distributed as an example of an ERTS-derived product. The second "Significant Result" was the completion of the main objective of the investigation, a map of the land use of the three northern Megalopolitan states Massachusetts, Connecticut and Rhode Island.

For aid in orientation, a map showing the Boston-Washington Megalopolis among the urban concentrations of the United States has been included (Fig. 1). The location and boundaries of the test area are shown in Figure 2. An identification map (Fig. 3) was compiled from Bureau of Census maps of the 1970 Standard Metropolitan Statistical Areas (SMSAs) of New England superimposed on a highway map base. It serves the double purpose of identification and of presenting the most detailed pre-ERTS map source for northern Megalopolis.

The principle participants in this investigation have been.

Dr. Robert B. Simpson, Professor of Geography, Dartmouth College, Principal Investigator
Dr. David T. Lindgren, Assistant Professor of Geography, Dartmouth College Associate Investigator (in charge of imagery interpretation aspects)
Mr. David J. Ruml, Assistant in Research) (many contributions, but
Mr. William Goldstein, Assistant in Research) especially computer software development and operations)
Mr. John C. Buschmann, Assistant in Research (imagery interpretation)
Dr. Van H. English, Professor of Geography, Dartmouth College (cartography)

The assistance of Mrs. Milka Chitou Goldstein, Miss Gwendolyn English and Mrs. Eureka Gardner also is acknowledged.

(continuation of footnote 2, page 1)

(3) Earth Resources Technology Satellite-1 Symposium Proceedings, Sept. 29, 1972. X-650-73-10. (Greenbelt, Md.: NASA Goddard Space Flight Center, January 1973). Robert B. Simpson, "Urban-Field Land Use of Southern New England: A First Look", pp. 100-107.

(4) The following unpublished presentations:

EROS Data Center Dedication Technical Sessions, Sioux Falls, S.Dakota, 6 August 1973. Robert B. Simpson, "Applications in Land Use Analysis".

Sixty-Ninth Annual Meeting, Association of American Geographers, Atlanta, Georgia, 17 April 1973. Robert B. Simpson and David T. Lindgren, "Land Use of Northern Megalopolis".

David T. Lindgren, Robert S. Yuill and Robert B. Simpson, "Creation of a Land Use Map and Data Base from High Altitude Areal Photography: The New Haven Area", presented by David J. Ruml.

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[1] See NASA Earth Resources Survey Program, Weekly Abstracts, National Technical Information Service, U.S. Department of Commerce, Nos. 93-73-08 Feb. 19, 1973 (p. 26), and 93-73-30 July 1973 (p. 104).

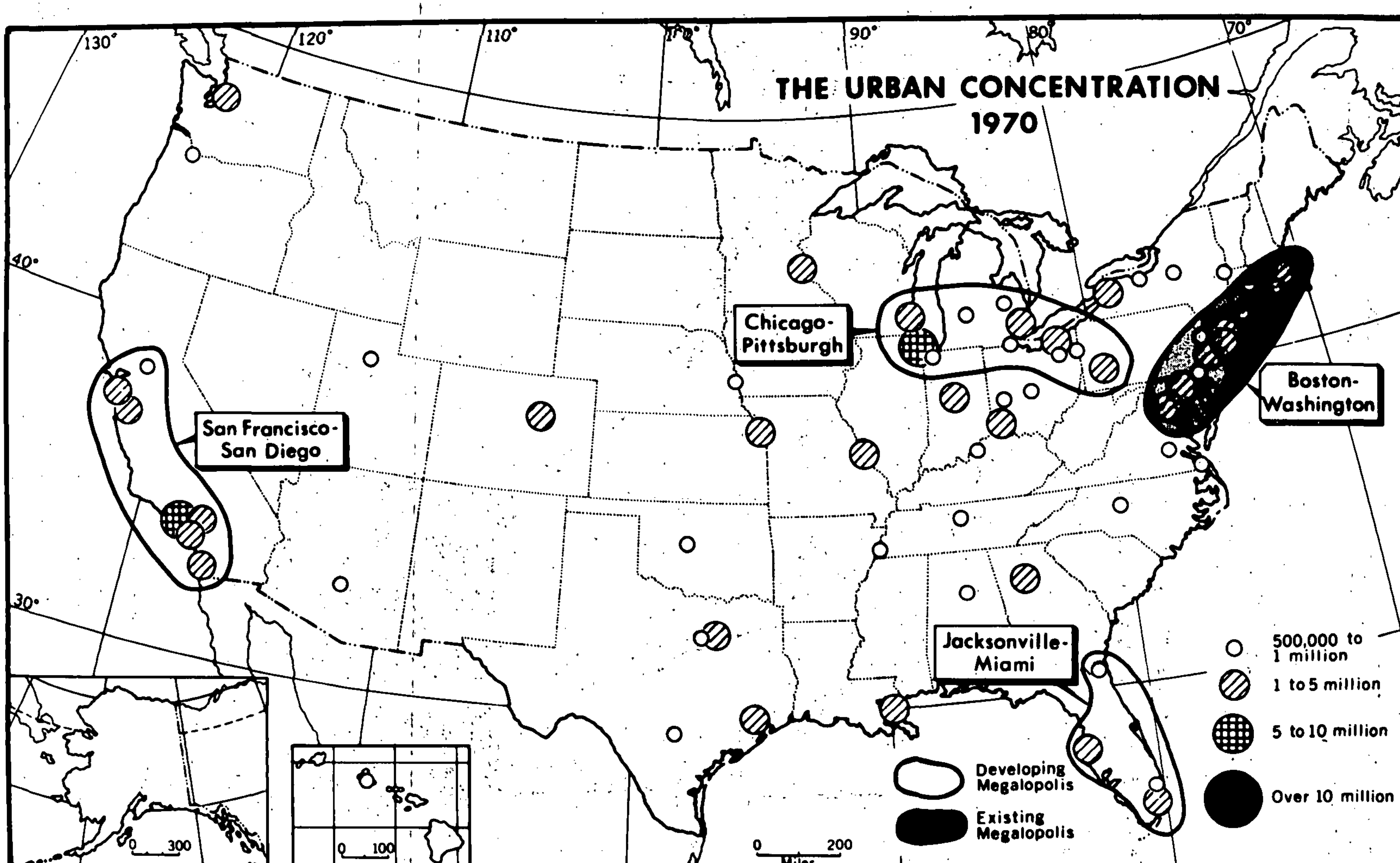

Figure 1. The Boston-Washington Megalopolis.

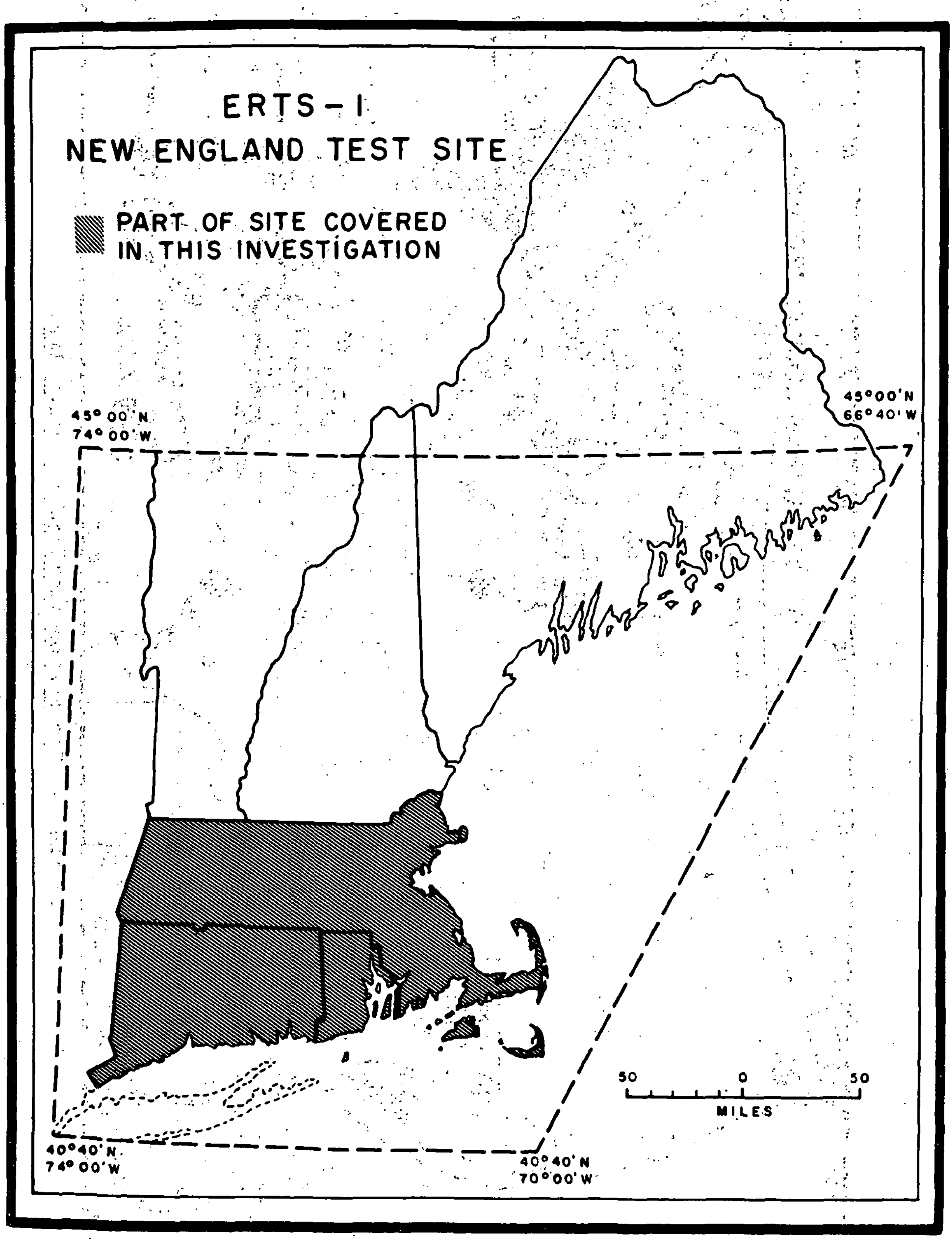

Figure 2. <u>The Test Area.</u>

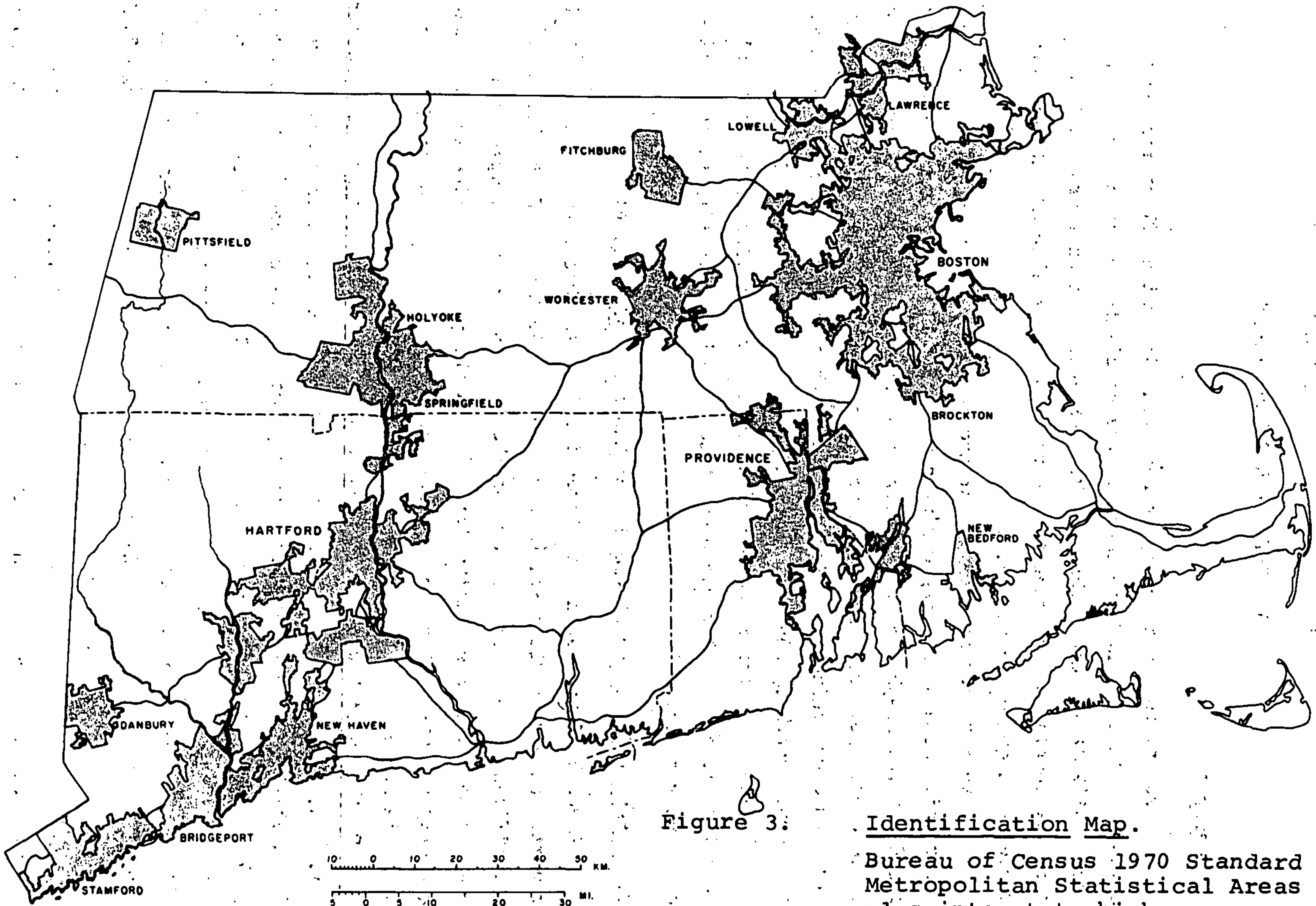

Figure 3. <u>Identification Map</u>.

Bureau of Census 1970 Standard Metropolitan Statistical Areas plus interstate highways.

II MAKING THE LAND USE MAP

A. THE COLOR-CODED VERSION

1. General

It was planned originally to map from ERTS using RBV photography, but by the time the RBV equipment in the satellite was inactivated in August 1972 it was clear that the Multi-Spectral Scanner product had superior resolution and that the systems-corrected ("bulk") MSS imagery would be adequate locationally.

In order to get maximum scalar and locational accuracy over a 15,000 square mile area a base map was traced on a sheet of mylar from the pertinent 1:250,000 topographic sheets, along with the state boundaries and a network of reference points. The actual interpretation was done onto draft "chips" of acetate averaging three inches square, then transferred onto the final base map. Match-up never required adjustments of more than 1/8-inch.

Preliminary activities included limited exploration of the I^2S color additive viewer, a color microdensitometer and of a density slicer, all with negative results.

2. First Product: Prototype Map of Rhode Island (Fig. 4)

A month after launch this investigation was chosen as one of ten to be reported at a NASA "first-look" conference at GSFC on 29 September 1972. A "Significant Result" in the form of the first urban-type comprehensive land use map made from a satellite (Fig. 4) was the product. (The somewhat skewed geometry of this initial map results from an early error in formatting at GSFC, later corrected).

On the initial Rhode Island map eight categories of land use were differentiated, thus comparing favorably with the basic eleven-category legend used for high-altitude aircraft land use maps of the Boston and New Haven areas a year earlier. Although many things about the ERTS Rhode Island map made it an item of interest, it drew special attention because it proved conclusively, although presumptively, that the world had entered a new era in thematic mapping: a thousand-square miles - an entire state-had been mapped in 40 man-hours of interpretation time.

There were several scattered clouds over Rhode Island at the time the imagery for this first map was recorded (28 July 1972, Image No. 1005-15005). A question at the time was "How long will it be before cloud-free coverage of

Figure 4. First Urban-Type Land Use Map from Space

The state of Rhode Island on 28 July 1972.
Complete in 40 man-hours of interpreter time.

(see next page for legend)

New England is recorded?" The answer proved to be about ten weeks (six orbits), for in mid-October a polar air mass over New England permitted essentially cloud-free coverage of most of the test site (along with most of eastern United States). During the eight months which have elapsed since October 1972 however, there have been only a few other cloud-free days, confirming the over-riding requirement for prolonged repetitive coverage for satellite mapping.

3. Mapping the States of Massachusetts, Connecticut and Rhode Island (Fig. 5).

Good weather over New England in mid-October 1972 provided the first fully useful imagery. Nine-by-nine transparencies of the four principal scenes in the four required bands (MSS 4,5,6 and 7) became available from the NDPFC on 18 December 1972, and the General Electric Photo Laboratory in Beltsville, Maryland, provided the essential 1:250,000 CIR transparencies of those scenes on 3 January 1973. Working from the CIR transparencies a single photointerprete completed the three-state land use map (Fig. 5) in draft form within three months (1 April 1973). However, it took another two months (1 June 1973) to complete the final color-coded map. Thus, the hand-coloring of the final map took almost as much time to complete as the initial photointerpretation.

[1] ID Nos.

1096-15065	(27 Oct.)	(centered on	Keene, N.H.)
1077-15005	(08 Oct.)	("	Portsmouth, N.H.)
1096-15072	(27 Oct.)	("	New Haven, Conn.)
1077-15011	(08 Oct.)	("	Providence, R.I.)

The fifth and final scene used to produce the 3-state map (ID No. 1040-15552 dated Sept. 1972 and centered on Provincetown, Mass.) became available for mapping on 24 March 1973.

Figure 4. First Urban-Type Land Use Map from Space.

LEGEND

SINGLE-FAMILY RESIDENTIAL	yellow
MIXED SINGLE- & MULTI-FAMILY RESIDENTIAL	orange
COMMERCIAL & MANUFACTURING	red
TRANSPORTATION & UTILITIES	black
RURAL RESIDENTIAL & OPEN SPACE	light green
WOODLAND	dark green
AGRICULTURAL (ROW CROPS)	brown
WATER	blue
OBSCURED BY CLOUDS	white

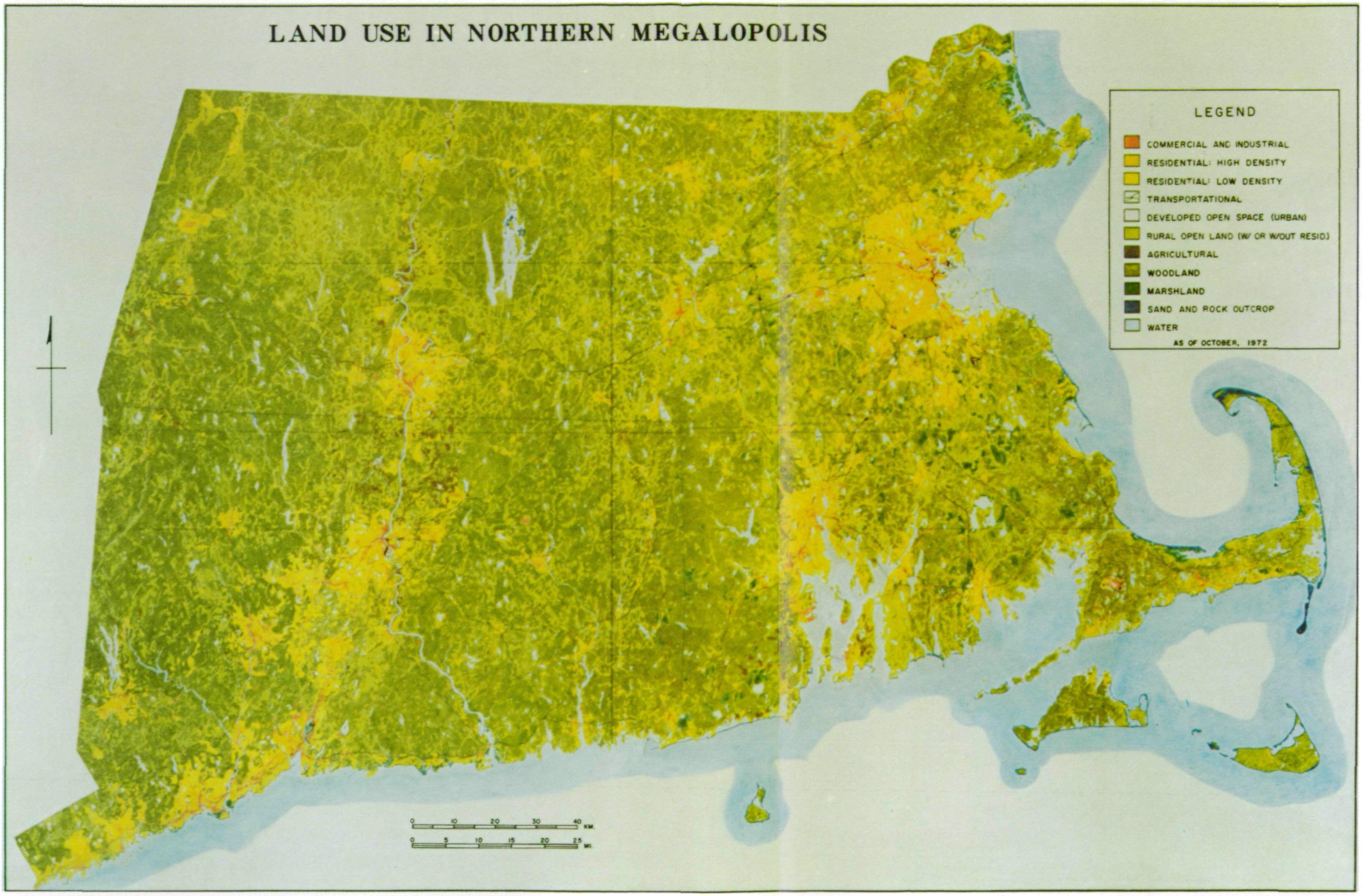

Figure 5. Photo-Reduced Version of Manuscript Map of Land Use in Northern Megalopolis.

Includes entire states of Massachusetts, Connecticut and Rhode Island. Compiled from 5 frames of ERTS-1 imagery. The original of this map is 33 x 51 inches in size.
scale 1:250,000
(see Figure 6 for computer version)

The legend for the three-state map consists of 11 categories, three more than appeared on the initial Rhode Island map of September 1972. The additional categories include Marshland, Sand and Rock Outcrop, and a third called Developed Open Space (Urban). Two further changes were also made in the legend. The Single-Family Residential category was changed to Residential: Low Density, and the Multifamily and Mixed Residential to Residential: High Density. While it is arguable that the differences may be only one of semantics the new terms better reflect what is actually being observed on the ERTS imagery.

As a means of evaluating the capacity of ERTS imagery to provide land use data the following chart (Table 1) has been produced. It illustrates the range of land use identifications from the simplest to the most complex. At the simplest level ERTS is extremely effective for delineating water from land. The CIR composite, as well as MSS bands 6 and 7, reveal the presence of lakes and ponds as small as 300 feet in diameter and streams, because of their linearity, as narrow as 50 feet. Only particularly marshy areas present any difficulty; because they appear dark on CIR transparencies they can occasionally be confused with water bodies.

Of the land categories Woodland can be delineated with the greatest ease. Only where the outer edge of suburban development merges with woodland is it difficult to classify land use. However, it would be just as difficult to classify this situation in the field. With seasonal coverage available future land use maps should at a minimum differentiate between deciduous and coniferous vegetation; scrubland could perhaps be a third category.

In the non-wooded areas the builtup categories can be relatively well differentiated from the non-builtup categories. In fact, if one were interested only in builtup areas as a whole, and many state planners would consider that sufficient, ERTS would be an effective medium for displaying them. At this point the ease and accuracy of land use interpretation is very great. However, as the builtup category is subdivided into more detailed categories, both the degree of error and the degree of difficulty in interpretation begin to increase

Within buildup areas the residential categories are unquestionably the most difficult to interpret. There are basically two densities of residential development that can be inferred from tonal differences on the CIR imagery-

Table 1.

ERTS Land Use Identification Scheme

Water	XXX	XXX	XXX	XXX
Land	Woodland	XXX	XXX	XXX
	Non-Wooded	Builtup	Residential	Residential: Low Density
				Residential: High Density
			Non-Residential	Commercial and Industrial
				Transportational
				Developed Open Space (Urban)
		Non-Builtup	Developed	Agricultural
				Rural Open Land (with or without Residences)
			Undeveloped	Marshland
				Sand and Rock Outcrop

high density and low density. The Residential: High Density category refers to those areas where residential development is so intense that few lawns or trees are found; such an area appears dark blue on the CIR imagery. The Residential: Low Density category, on the other hand, refers to that area, broadly termed the suburbs, where dwellings are spaced further apart, and where subsequently lawns, trees, and shrubbery are plentiful; these areas appear pinkish. Although the two densities are interpretable, an exact definition is impossible.

A third, partially residential category, Rural Open Land (with or without Residences) was derived specifically for the ERTS imagery. This category reflects a common feature of the generally wooded New England landscape - rural roads bordered by open pastureland with houses and occasional small farms strung out along them. On the ERTS imagery neither the housing nor the roads are visible but the linear pattern of open fields is quite distinguishable. The main difficulty in using this category is in the determination of where the Residential: Low Density category ceases to be applicable and where the Rural Open Land becomes applicable.

As a means of determining the approximate range of population densities for each of the three residential categories, a digital computer was used to solve a series of simultaneous equations. The areal unit used as a base was the county. For each county, the square kilometers occupied by each residential land use multiplied by an unknown density variable (persons per square kilometer) was assumed to equal the total population. Thus, the equation

$$A\ (X) + B\ (Y) + C\ (Z) = P,$$

where

A = square kilometers of Rural Open Land
X = persons per square kilometer
B = square kilometers of Residential: Low Density
Y = persons per square kilometer
C = square kilometers of Residential: High Density
Z = persons per square kilometer
P = total population,

was run for each county against the other twenty-six counties (three at a time because of three unknowns) to determine density ranges.

On the further assumption that the three classes of residential land shown on the land use map accounted for the total known population of each county, the following ranges of population density were determined for each class:

Rural Open Land	0-350 persons/sq. km.
Residential: Low Density	250-2,000 persons/sq. km.
Residential: High Density	1,800-10,000 persons/sq. km.

Non-residential land uses within builtup areas can be interpreted with only slighly less difficulty than the residential. For example, the commercial-industrial-institutional land uses which ordinarily appear blue-black on the CIR imagery can be delimited fairly well, although along waterfronts, as in Boston, they merge with Water, while in other areas they may merge with the Residential: High Density. As for the category Transportational, major highways and airports can be consistently identified but railroads and secondary highways cannot. Powerlines are visible where they pass through wooded areas but they have not been annotated unless visible for 15 miles or more.

Developed Open Space (Urban) is a category devised exclusively for ERTS imagery. If refers to such land uses as golf courses and cemeteries, which appear pink within the bluish-black of heavily urbanized areas. In rural areas this category cannot be applied meaningfully because such land uses merge with the pink of fields and woodlands.

Most non-builtup categories can be effectively applied. Agricultural land use refers exclusively to row crops or cultivated fallow land. In summer row cropland appears similar to Rural Open Land on the ERTS imagery, but when recently plowed as in the fall, it takes on a distinctive blue tone. Unfortunately in the latter instance row crops can be confused with Commercial and Industrial areas. Thus, both summer and autumn imagery should be utilized in mapping this land use category.

The non-builtup categories were relatively easy to identify. Major areas of marsh show well since CIR is a particularly useful medium for this purpose. Sand and Rock Outcrop is a minor category although important along the coast, where beaches are a popular recreation feature.

Two final notes should be made concerning the photointerpretation procedure for the color-coded map, the first of which relates to differences in the dates of imagery used, while the second relates to the different types of imagery used. In the first instance, the western part of the project area was mapped from 27 October imagery, the eastern part from 8 October imagery. The differenalthough only one of nineteen days, nevertheless caused some interpretation problems because of changes during that period in the sun's angle and in the defoliation of the tree cover. For example, on the 27 October imagery shadows on the north and northwestern slopes of ridges often appeared as water bodies; only through the use of additional imagery could an accurate identification be made. The Rural Open Land category was also more difficult to apply on the 27 October imagery because the tonal differences between open fields and woodland had faded. Thus, it would seem for purposes of land use analysis the earlier autumn imagery is preferable to the later autumn imagery.

In the second instance, it became necessary to map Cape Cod and the Islands from black-and-white positive transparencies of MSS Bands 5 and 7 because of the unavailability of a color-infrared composite of this area. Band 7 was used almost exclusively for the delineation of land-water interfaces, while Band 5 was best for land use patterns. However, there were many problems in depending exclusively upon Band 5 for land use identifications. Roads and powerlines, for example, showed up very well, but many urban categories were indistinguishable. As a result considerable reliance had to be placed upon RB-57 coverage in order to produce a relatively accurate land use map of that area. Thus, for a land use map of at least 11 or so categories, the color-infrared composites are preferable. The black-and-white imagery is best reserved for specialized purposes.

As recapitulation, five months after the basic land use map has been completed, it seems desireable to point out that the following constraints were imposed at the time of its compilation, for various reasons: we did not use multiseasonal coverage, we relied exclusively on MSS bulk-processed products and we seldom made use of individual bands of imagery.

B. THE COMPUTER VERSION (Fig. 6)

This ERTS investigation has relied entirely on the Dartmouth College computer facilities for support in both the visual and statistical analysis of land use information. The DCPRS involvement with computer graphics began in 1970 with a program capable of three-shade printing written for use on the Boston and New Haven high altitude aircraft studies. That program and its successors have differed from generally available programs in their orientation towards generalization rather than extrapolation, and thus their larger data capacity. Despite our manual interpretation of the ERTS imagery (the computer has not been used for reading the digital tapes) we have a very high data density, approximating one cell per ten picture elements.

In the course of the present investigation DCPRS has developed an improved system which not only produces graphics comparable to the earlier ones but also efficiently can manipulate the significantly larger data files (more then 600,000 cells). The new system delivers more versatile maps and drastically reduces tabulation and statistical analysis time.

A cell-by-cell land use input was the first phase of the operation. An innovation here was the design of a new type grid cell overlay for the color-coded land use map. The cells were 1/4 square kilometer (62 acres) in area, but they were designed as elongated rectangles rather than the traditional squares. The ratio between the two sides of the rectangle was set at 6 to 10, which corresponds to the shape of the character spaces on the high speed line printer. As a result the maps produced are orthogonal, rather than elongated either horizontally or vertically as they are when produced from a square-celled grid. The rectangular grid format has not impaired the utility of the graphic or numerical products for measurement, sampling, or statistical analysis.

The majority use for each rectangular cell was read left to right down each of the nine panels. The 37.5 kilometer panel width provided for 100 cells, in accordance with the subsequent printing format. The numeric symbols were typed in free format into disc-storage files. These files were then proofread for technical cell omission or duplication and some typographic (but not decision) errors, and reformatted in reduced bit under program control. A similar procedure, modified by a grouping option, was followed in loading a political sub-division overlay matrix.

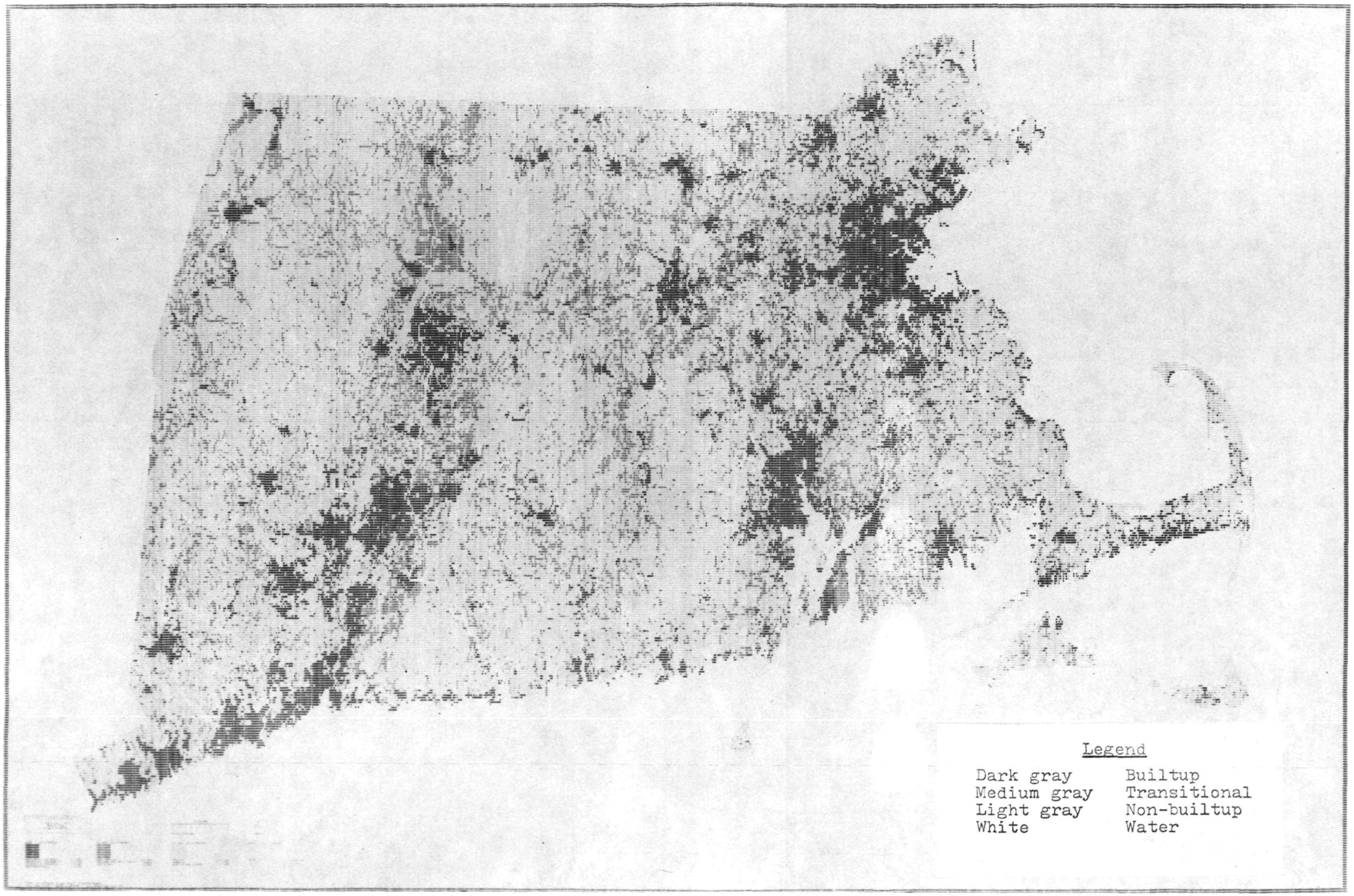

Figure 6. Photo-Reduced Version of Computer Printout Map of Land Use in Northern Megalopolis.

The original of this map is 62 x 92 inches in size, scale 1:151,000. It was derived from the color-coded manuscript map reproduced as Figure 5. Each data cell represents 1/4 square kilometer.

The mapping and tabulation program has been divided into two sections. The first section is executed in time-sharing foreground where, by conversation, users may specify the desired output. One can order a map for the entire test site, a state, a county, or, by providing X, Y coordinates, any rectangular sample site. The user also creates any four-way partition of the eleven land use categories, and selects a grey tone for each of his four groups. From this point the program runs for thirty seconds[1] executing the instructions and writing a binary version of the map to a new file. As it searches the data files it maintains counters on each of the uses which are within the chosen site and upon its conclusion prints the total in terms of either area or percentage. The elapsed time for this program varies from five to ten minutes. The second section of the program is executed in background where our time limit is higher and more importantly, where the run-time to real-time ratio is substantially higher than in time-sharing. This is important, as over eight minutes are used in the conversion of the binary test site file to one of nine bit ASCII characters that can be executed by the high speed line printer. Due to the overprinting, the printer advances only 250 lines per minute and thus more than twelve minutes are spent in typing.

In summary, this investigation has produced a system that enables even the non-programmer to order and within the half hour receive: a map of the entire test site which visually highlights any single use or combination of uses in a form less visually complex than the multi-colored maps, and also a file of the summary tabulations formatted for direct use with the Dartmouth System's correllation, regression, and clustering routines. Perhaps the greatest, but as yet untapped, asset of this system is its application to change detection studies. The ERTS data has delivered a ten-fold reduction in the lag between data acquisition and analysis. Manual cartography at present consumes the majority of the remaining time differential. In the future, with the application of the computer, changes need only be interpreted, then appended to the base file.

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[1] These time figures represent mapping the entire test site.

III COMPARABILITY, COST- AND TIME-EFFECTIVENESS

A. COMPARABILITY

The state of Connecticut is unquestionably one of the national leaders in the quality and completeness of its land use data. Just this year after three years of preparation a new land use map was published at a cost of more than a million dollars. This map was compiled from low-altitude photos of a scale 1:12,000, that is, almost 90 times larger than ERTS. The resultant map was of a scale 1:24,000 and contained 55 categories of land use which had been field checked mostly by the various sub-state planning agencies.

At the same time a small-scale version of this map was published (1:250,000) on which the 55 categories of land use had been aggregated into eleven, thus corresponding closely to the ERTS map. While it is unrealistic to expect the two products to provide highly similar results, it does provide an exceptional opportunity to examine the validity of the ERTS map both visually as well as statistically.

Figure 7 is an illustration of the two maps, which in spite of the color differences appear very much alike. Actually, the most noticeable difference, the greater builtup area on the ERTS map, is more apparent than real. The lowest residential category on the official Connecticut map simply does not show up well. However, in the Westchester County area near New York City the low density category does show up and there in fact the total builtup area exceeds that of the ERTS map.

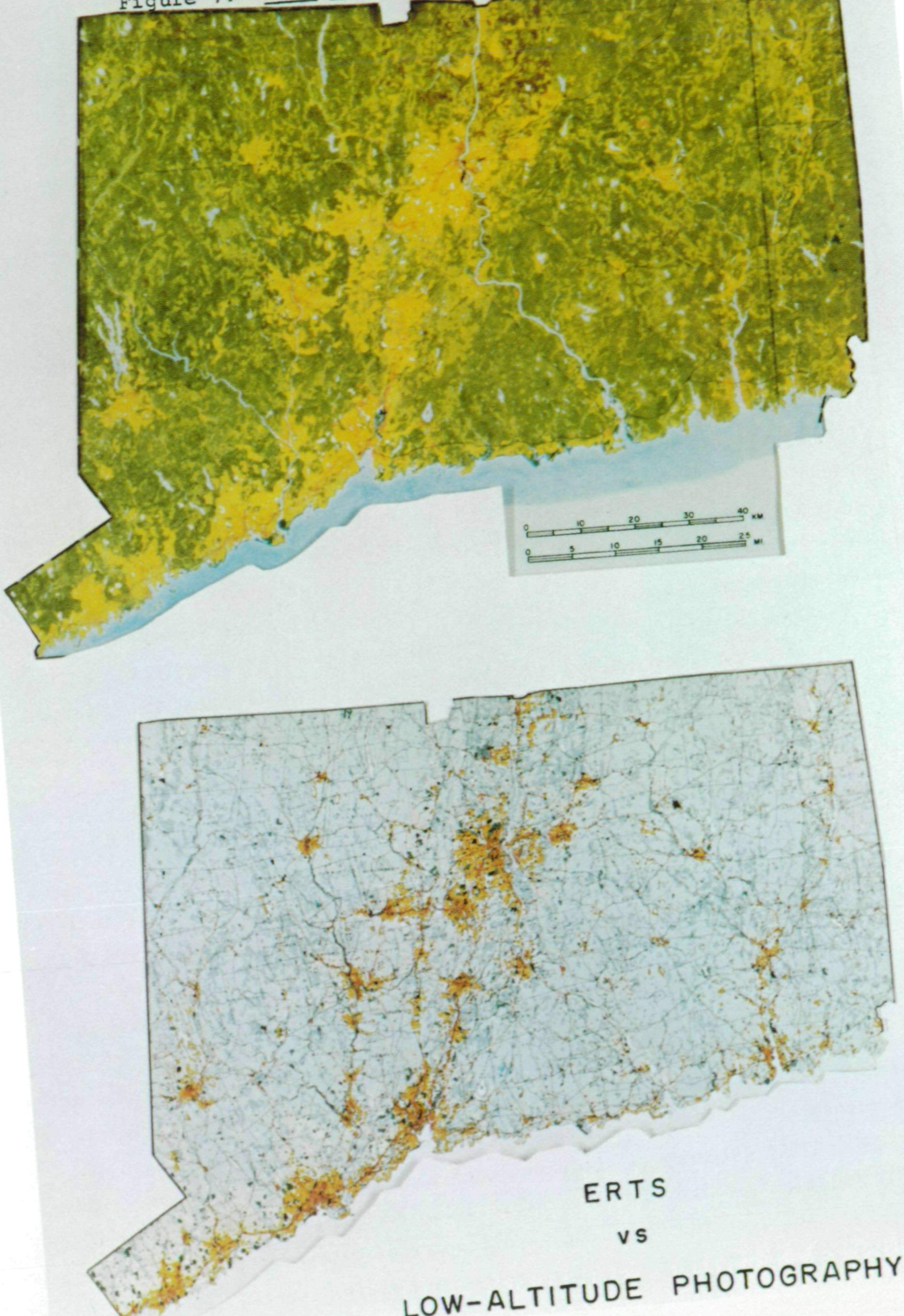
In the undeveloped categories there appears to be more detail on the ERTS map. However, for their map the Connecticut planners had aggregated Woodland, Openland, Wetland, and Excavation into a single category. Again the differences are more apparent than real.

Finally, there is one major area of disagreement along the Thames River and particularly around Norwich. The builtup area is definitely underestimated on the ERTS map.

With these several exceptions, however, the ERTS-derived map compares very favorably with the official Connecticut map.

In addition to the visual comparison a statistical comparison is also being undertaken utilizing data provided by the Connecticut Office of State Planning and by ERTS. To carry out the comparison the 55 categories of land use data provide by the Office of State Planning had to be aggregated into the

Figure 7. Land Use, State of Connecticut.



eleven ERTS categories (Appendix A). Unfortunately in the aggregation process numerous problems of definition arose of which several have not yet been satisfactorally resolved. Furthermore there are some inherent problems in the ERTS data. Basically these data are derived by a sampling procedure, that is by determining the majority land use of each quarter-kilometer cell. Certain types of land uses, particularly linear ones, are consistently underenumerated.

Although the statistical analysis of the two sets of data is only in a preliminary stage certain trends are becoming clear. For example, three categories stand out because of a considerable difference between data sets. The three are Sand and Rock Outcrop, Marshland, and Agricultural.

In the Sand and Rock Outcrop category the ERTS total is higher than the official Connecticut figure. However, the only comparable category to Sand and Rock Outcrop in the Connecticut data is Swimming Areas which is obviously a more restrictive term. In the case of Marshland, which ERTS apparently under-estimated, it is a matter of scale; only large areas of marsh can be detected on ERTS imagery, the numerous smaller areas going undetected. As for the Agricultural category, the underestimation by ERTS reflects the fact than on the available imagery and here in humid northeastern United States, only those areas which were bare in the fall could be identified. This is a very narrow definition compared to that of Connecticut.

For several other categories there appears to be a moderate difference between the ERTS data and the official Connecticut data. Developed Open Space (Urban) is a category applicable exclusively to ERTS. Since Connecticut did not differentiate between urban and rural it is not surprising there is little correspondence between data. ERTS also underenumerates Transportational land areas. For one thing, only airports and interstate highways could be detected on ERTS, and for another, most linear features are ignored in the sampling process.

The remaining categories display relatively small differences. The two residential categories, High Density and Low Density, apparently correlate well although the ERTS data appears to include a slight overestimation of the Low Density category at the expense of the High Density category. If confirmed this is primarily an interpretation problem. As for an apparent underenumeration of the Commercial and Industrial category, this is probably accounted for by the fact only large sites are visible on ERTS imagery. Hundreds of small Commercial and Industrial facilities go undetected. Woodland and Water both tended to be overenumerated. In the case of Woodland this probably reflects the use of October imagery, with the still-heavy foliage masking much low-density housing on the outer fringes of suburbia. Early spring imagery might cause a reduction in the Woodland category, with a comparable increase in Residential: Low Density. The overestimation of Water probably reflects the inclusion in the ERTS data of some portions of Long Island Sound. The data for the final category, Rural Open Land (with or without Residences), corresponded quite well.

In spite of the problems of definition and comparability, the statistical analysis of the data should be extremely useful when completed. In the meantime this present qualitative comparison is believed useful in illustrating the strengths and weaknesses of ERTS in providing land use data. It is serving to highlight some of the present difficulties, while simultaneously showing where further research is necessary. The end result will undoubtedly be a better understanding of ERTS's capabilities.

B. COST- AND TIME-EFFECTIVENESS

1. General

We have assumed that if a meaningful land use map could be made from ERTS-1 imagery it would be at a saving in time and money over other means of production. The completion of the three-state ERTS map makes it possible to test this assumption. In the evaluation which follows, the cost of land-use mapping from ERTS is compared to that from high-altitude aircraft (RB-57 and U-2, scale 1:100,000) and from medium-altitude aircraft (scale 1:20,000).

The cost of compiling a land use map varies tremendously with the size and location of the area to be covered, the scale used, the number of categories to be mapped, and the degree of complexity inherent in the landscape. Cost also depends on administrative considerations such as overhead and profit, type of manpower utilized, whether or not the cost of obtaining the imagery is included, and whether the coverage will be stereoscopic or monoscopic. Finally, cost estimates depend on the "experience factor". A large body of knowledge is available on costs for operational mapping at medium scales, but very little (and none of it "operational") on costs for mapping from high altitude aircraft or space platforms.

However, since the only way to arrive at good cost figures is by a series of approximations, a second approximation has been attempted by the Dartmouth College Project in Remote Sensing and is offered herewith.

The ERTS-1 figures which follow result from the present investigation, which has involved mapping approximately 15,000 square miles of southern New England at a scale of 1:250,000 from a single set of CIR transparencies (October 1972), prepared by photo laboratory processes only. This basic mapping imagery was augmented by reference to ERTS-1 Band 5 (red band) black/white transparencies of the same images, and to available NASA high-altitude aircraft photography and topographic maps, for parts of the area and from time to time.

The high-altitude figures too are derived from the experience of the DCPRS in the investigative mapping of land use of the Boston and New Haven areas (approximately 1,500 sq. mi.) using NASA RB-57 photography under USGS/GAP contract in 1970-71.

The lower (medium-altitude) aircraft figures represent the numerical averages of estimates provided by three commercial air-photo mapping organizations with extensive experience in northeastern United States. These companies range from small to large, and were asked to base their estimates on a theoretical contract to map the variegated urban-rural landscape of the entire state of Connecticut (5,000 square miles).

In each case purely human-visual ("manual") image interpretation is assumed, using conventional photo laboratory products. Field checking would be limited, but readily available published ground truth would be used extensively.

A tremendous saving in the time and money needed to process, position, and interpret ERTS images as compared to aircraft photography is implicit in Table 2. This is true even if one reduces by 50% the number of high- and medium- altitude prints required, by eliminating the requirement for stereoscopic coverage.

2. Comparison of Dollar Costs (Table 3)

Column (a) of Table 3 shows that the image interpretation phase of land use mapping can be done from ERTS for about $1/sq. mi. in comparison with approximately $10/sq.mi. from high altitude aircraft and $15/sq.mi. from medium-altitude planes. The latter estimate may be more conservative than the other two since it is based on competitive commercial operational experience rather than on investigative research programs.

The basis for the figures is shown in extensive footnotes to the table.

3. Comparison of Time Required (Table 3)

Table 3 reveals a greater spread in time-in-work estimates than in dollar-cost estimates, depending on the platform used for data collection. According to column (b) of Table 4, as much area will be mapped in one day of ERTS land use interpretation as in 7 days of U-2 or RB-57 interpretation or in 31 days of conventional photo mapping.

4. Validating the Estimates

It appears that the foregoing informed approximations may be accurate overall to within ± 30%, with the spread in cost figures being somewhat smaller than that in time figures. The greatest extremes are found in the time-spread for medium-altitude aircraft imagery interpretation, where the highest and the lowest of the three commercial time estimates vary from the mean by 66% and 80% respectively. In compensation reassurance can be derived from the fact that the median time (and cost) figures for the medium-altitude products were furnished by a contractor who actually has done the hypothetical job called for by

Table 2

Estimates of Comparative Image Coverage

	Sq. Stat. Mi./Image	No. Fresh Sq. Stat. Mi./Image	Scale	Image Dimensions
ERTS-1	13,225[1]	7,247[2]	1:1,000,000	7 x 7
High-altitude aircraft	202	36[3]	1:100,000	9 x 9
Medium-altitude aircraft	8.1	1.7[4]	1:20,000	9 x 9

[1] Assuming 100 n. mi. on a side

[2] Assuming approximately 34% sidelap and 10% overlap (latitude 44°N)

[3] Assuming approximately 58% sidelap and 58% overlap (stereoscopic coverage,

[4] Assuming approximately 40% sidelap and 66% overlap (stereoscopic coverage)

Table 3

Estimates of Comparative

Cost- and Time-Efficiency in Land Use

Mapping

	(a) Cost ($/sq.mi.)	(ratio)	(b) Time (interp.hrs/ 1000 sq.mi.)	(ratio)	(c) Scale of Imagery	(d) Status (ratio)
ERTS-1	$ 1.06[1]	1:	45[5]	1:	1:1,000,000	1: Experimental
High-altitude aircraft	10.46[2]	10:	328[6]	7:	1:100,000	10: Experimental
Medium-altitude aircraft	15.50[3] (23.80)[4]	15: (22:)	1,380[7]	31:	1:20,000	50: Operational

Assumptions:

* Product is a numerically coded b/w, or rough color-coded, map with 11 categories of land use
* Costs and time shown are for imagery interpretation phase only (no charge for imagery)
* Bases for individual derivations are shown in the footnotes which follow

Footnotes:

[1] Basis: This figure represents an approximation of DCPRS experience in experimentally mapping three southern states of New England (14,371 sq. mi.) under NASA contract in 1973 as follows:

Photo interpreter, 4 months, including direct, fringe and indirect costs; commercial photo lab special film processing and enlarging; field check and ground truth; and management including direct, fringe and indirect)

Total	$ 15,300

Average cost of $ 1.06/sq. mi.

(footnotes continued on next page)

(footnotes continued)

[2] Basis: based on DCPRS experience in experimentally mapping the Boston area (1,100 sq. mi.) under USGS contract in 1970.

Photo interpreter time reduced from 12 to 9 weeks due to reduction of categories mapped from 24 to 11, and elimination of extensive hand coloring.

Total $ 11,506

Average cost of $10.46 sq. mi.

[3] Basis: cost estimates received from three commercial mapping agencies, for mapping an area similar to state of Connecticut (5,000 sq. mi.)

Average of the 3 was $15.50 per sq. mi. (for interpretation and map making only)

[4] Basis: this figure represents $15.50 plus $8.30/sq. mi. for photography the average of prices submitted be the 3 companies.

[5] Basis: same as for footnote (1)

14,371 sq. mi. in 4 months (640 hrs.) of interpretation time

Average of 45 hrs. interpretation per 1,000 sq. mi.

[6] Basis: same as for footnote (2)

1,100 sq. mi. in 9 weeks (360 hrs.) of interpretation time

Average of 328 hours interpretation per 1,000 sq. mi.

[7] Basis: Average of the time estimates received from the three contractor referred to in footnote (3) above

1,000 sq. mi. in 1,380 hrs. interpretation time

Average of 1,380 hrs. interpretation per 1,000 sq. mi.

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the estimates. His estimates were only 17% away from the average speed of mapping, and 13% from the average dollar costs.

In summary, the figures in Table 3 have been compiled from experience probably as extensive as is yet available in the ERTS program, but it is regional experience and the figures should be revised as national experience accures.

In an effort to get a rough idea of how the foregoing figures might effect time and cost for a "typical" ERTS-type mission, they have been applied to the problem of mapping eleven categories of land use for a medium-sized state (Appendix B).

IV ERTS AS A PLANNING TOOL

1. General

ERTS can be evaluated as a tool for planning in either of two ways: (1) theroetically and long-term, or (2) pragmatically and short-term. Both are essential. Now that the three-state map and data base have been completed we have a basis for short-term, practical discussions of ERTS with planners. In fact, as this report is being completed such discussions have begun, with visits to the planning offices of five New England capitols: Boston, Providence, Hartford, Concord and Montpelier. State planners reactions have been realistic but favorable. These conferences are the beginning of a continuing study in which, instead of telling the planners what we can do for them with ERTS, they will tell us what they need from ERTS to make it worthwhile.

In the interim it appears that a brief theoretical evaluation of ERTS may be useful. It provides a framework within which the short-range utility of ERTS-1 can be judged.

2. What Planners Do

> "Planning is concerned with decisions,.........primarily those with some effect on spatial arrangements"[1]

One way to dramatize what planners do is to list a few of the paired alternatives between which they are called upon to choose:

Some Planning Dichotomies

City form:	compact	or	dispersed
Growth policy:	limited	or	unlimited
Transportation:	mass highway	or	mass rail
Open space:	more (esthetics)	or	less (economics)
Pollution:	free	or	damped
Housing:	single	or	multiple
Minorities:	concentrated	or	dispersed
Low income:	concentrated	or	dispersed
Disaster:	reconstruction	or	prevention
Health:	hospital	or	well-clinic

Based on Melville C. Branch, City Planning and Aerial Information, (Cambridge, Mass., Harvard University Press, 1971) pp. 13-14.

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[1] Edward Ullman, "Substance and Scope of Regional Planning", in Maynard H. Hufschmidt, Regional Planning: Challenge and Prospects, 1960, p. 22.

As a minimum the task of planners is to present guidelines and alternatives to decision makers. Planners habitually confront the costs of overcoming distance, which in terms of the academic disciplines, says Friedman,[2] leads them to emphasize geography and the economics of location. Planners deal with settlement patterns, which consist of nodes and links and density fields and can be mapped or treated mathematically.

The basic tool of the planner is a "study", which is quantified and usually map-supported. Traditionally it involves economic projections, and more and more frequently requires projections from the social sciences as well.

The advent of the computer has profoundly affected planning, since it makes possible an advanced form of quantified study, the mathematical model. It is quite possible that the next great advance in planning will be in remote sensing. Only this medium seems capable of providing the massive inputs required by the computers, but its utility is not limited to massive data production. Remote sensing has a high potential for selective, low-cost, high-content, easily up-dated, qualitative as well as quantitative information, at a great variety of scales and levels. It is as yet a very under-utilized medium.

3. Levels at which Planners Work

Traditionally planning is done at the grassroots level: in the town or township or individual city. At this level both the planners and the public know personally and intimately the area being planned for. The interests of local individuals, corporations and institutions often have considerable influence.

At the other end of the planning heirarchy is the national level. It is concerned more with broad policy issues and guidelines than with spatial detail. And between these two extremes is a cluster of planning levels often referred to as "regional". At the regional level specific spatial realtionships still are important but individual influence and the power structure are muted, making this in many ways an optimum level for planning.

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[2] John Friedman, "Regional Planning as a Field of Study", in John Friedman and Wm. Alonso, (Eds), Regional Development and Planning: A Reader, Cambridge, Mass., MIT Press, 1964, p. 62.

Near the center of the regional planning cluster is state-level planning, now receiving strong emphasis from the national capitol. For most states effective state-wide planning is just about to begin.

The present workhorse of the regional level, however, is the sub-state grouping, where aggregates of counties, or individual metropolitan areas, have established planning agencies. Many of these sub-state agencies have been in existence for decades.

Although to most people including professional planners "regional" plans mean sub-state plans, regional planning increasingly is coming to mean interstate planning, frequently with physical geography providing the common interest as in river basin planning.

The interstate and state levels appear to have the greatest growth potential for the next decade.

4. <u>A Theoretical Approach</u>

The planning process can be thought of as consisting of four stages or steps:

description
analysis
prediction
modification

The first step is a descriptive one, the taking of an inventory, the making of a map, to show present distributions and intensities.

The next step is analytical: why? Statistically, this step may involve multiple regressions with several independent variables.

With a good descriptive and analytical background, prediction of future trends becomes possible. At this point a time-lapse series of past patterns becomes invaluable.

Finally, with a comprehension of present, past, and probable future trends, the planner probably will be ready to recommend, and effectively support, some modificative changes. With a well-documented plan the chances for a convincing educational program, effective enabling legislation and adequate finance are greatly improved.

5. The Utility of ERTS

In an effort to determine the relative utility of ERTS to the various planning functions and planning levels discussed in the preceding paragraphs, an intuitive 4 x 4 weighted matrix has been designed (Table 4).

This table suggests that ERTS will be most effective in assisting regional planning at the interstate level, a situation fully to be expected in the light of its 78-meter resolution. On the other hand, without going through the logical processes required to make a matrix of this type few individuals would credit ERTS with more value to the predictive function than to the descriptive one. The difference (a score of 15 to 12) results from the fact that the best predictive tool is one which provides a series of time-fixes on the past, a capability implicit in repeditive satellite imagery but very costly in other forms of information gathering.

As would be expected, ERTS lowest utility is at the individual town level. Even here ERTS makes a contribution: the capability of comparing the problems of town A with those of other towns having similar problems wherever they may be, in the same format and at the same scale.

Table 4

Value of ERTS as Planning Tool

[Scale of 5 - 0]

Level	Description	Analysis	Prediction	Modification*	(Total)
			Function		
Town	1	1	1	1	4
Sub-state region	2	2	4	2	10
State	4	3	5	2	14
Interstate region	5	4	5	3	17
(Total)	12	10	15	8	45

RECAPITULATION

[In descending order of value]

Highly Useful Tool (scores of 11 thru 20)

(1) Interstate regional planning in general (17)

(2) Prediction of future land use (15)

(3) State planning in general (14)

(4) Description of present land use (12)

Useful Tool (scores of 6 thru 10)

(5) Analysis of present land use (10)

(6) Sub-state regions (10)

(7) Modification of trends in land use (8) (see footnote below)

Supportive Utility Only (scores of 1 thru 5)

(8) Town planning in general (4)

No Recognizable Value (0)

(None)

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* ERTS as a Tool for the Modification of Land Use Trends

Modification is essentially a "decision" operation, determined either by fiat or by vote. ERTS, however, can contribute much of the information on which the decision is based. It also can be useful later as an agent of enforcement.

V SOME PRELIMINARY DERIVATIVES

1. General

Time has permitted the initial exploration, for illustrative purposes, of three kinds of applications of the data base. These are:

(1) highlighting a single land use against a backdrop of selected other land uses, for analytical or display purposes

(2) zooming in by computer on a small sample of the larger Megalopolitan map, to compare spatial relationships here with those of a classic land use model

(3) overlaying a map of currently builtup areas onto an earlier one to determine the magnitude and direction of change with time.

2. Changes in Land Use with Time

Suggestive of these possibilities is the map showing areal expansion of Boston and satellite cities between 1948 and 1972 (Fig. 8). The 1948 version is from the USGS 1:500,000 Base Map series. The 1972 pattern is traced from the ERTS computer map (Fig. 6). Comparison of the two distributions would have been greatly strengthened had both been ERTS products with comparable map base and format.

3. Changes in Land Use with Distance

The first modern urban land use model, by Von Thunen in the early 19th Century, described and analyzed a concentric zonal arrangement of land use around the center of a city, with intensity of land use varying inversely with distance from the center. Modern geographers profess varying degrees of acceptance of the zonal concept. The map (Fig. 9) collapses 11 categories of land use into four: the two described in the legend, plus a third one consisting of all other land (the non-builtup categories: Woodland, Sand and Rock Outcrop, and Marshland), and a fourth category, Water.

Note that in Figure 9 the computer, by counting cells, indicates that approximately 40% of the Boston area is builtup and 10% is transitional, leaving approximately 50% for non-builtup categories. This 50% ERTS-derived figure corresponds closely to that developed from RB-57 photography in 1970.

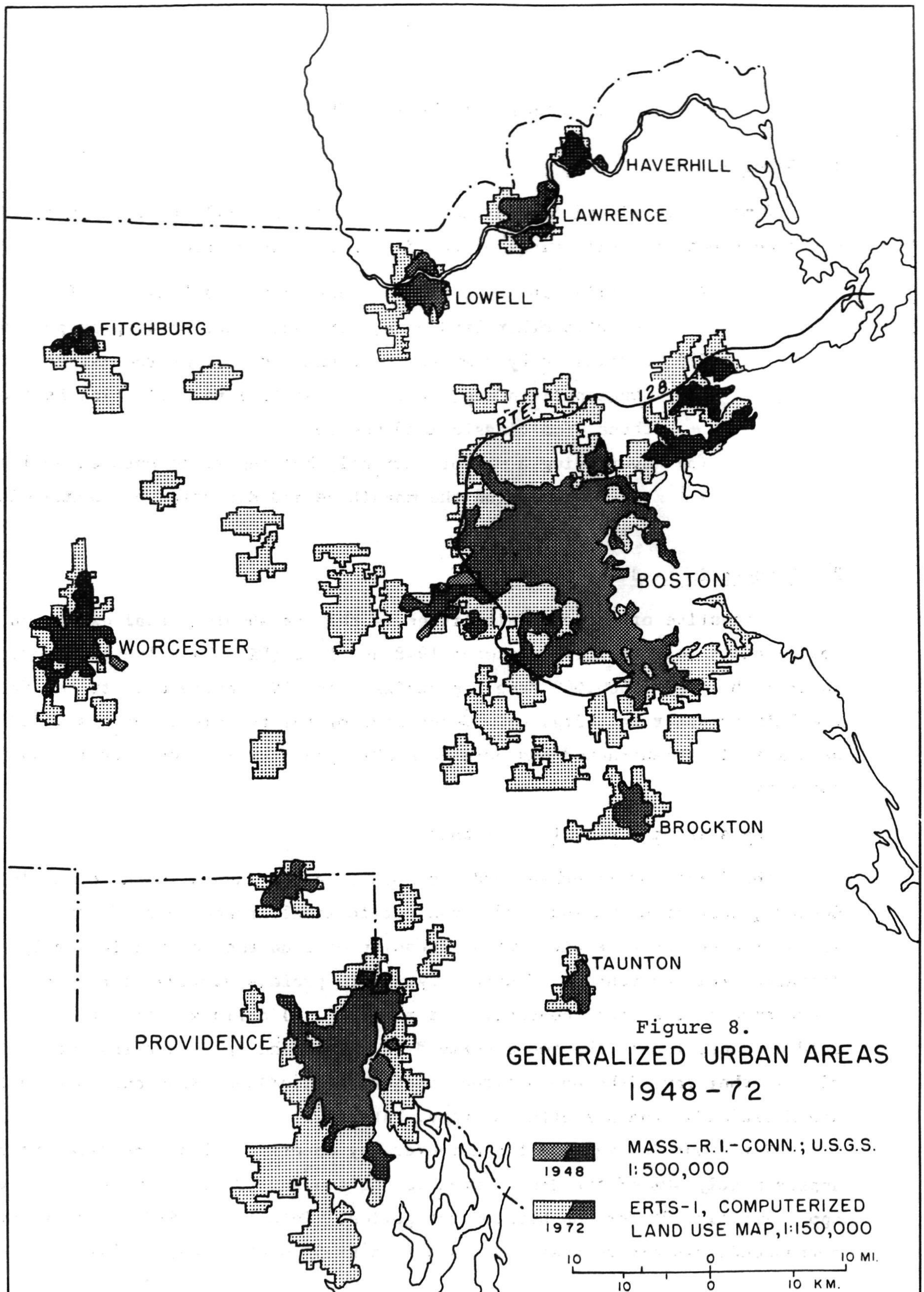

Figure 8.
GENERALIZED URBAN AREAS
1948-72

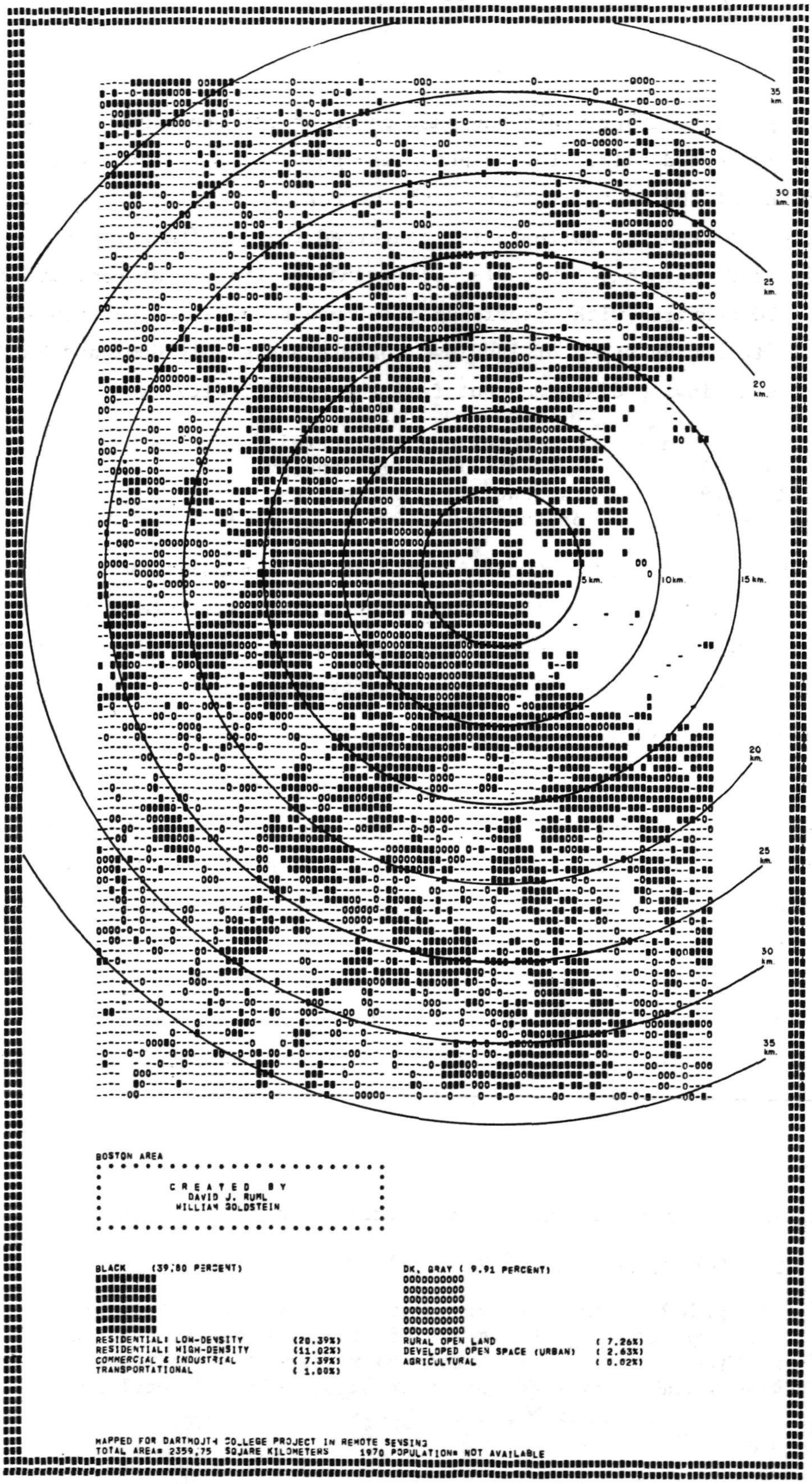

Figure 9. <u>Changes in Land Use with Distance: I</u>

The graph (Fig. 10) reveals the same concentric pattern around Boston, but does it in more detail. The computer assigned each cell to the proper band, each one kilometer wide out from the center of the city, noted which of 11 land use categories dominate it, converted the resulting figures to percentages, and could have (but did not) print out its own histogramic chart.

Figure 10 confirms with surprising clarity a broad zonal pattern for Boston. The following types of land use sharply and singly dominate bands extending the following distances out from the central city:

0 - ..4 km	Commercial and Industrial
4 - 14	Residential: High Density
14 - 19	Residential: Low Density
19 - 42	Woodland

Note that each of the designated zonal areas is completely dominated by the land use named. There is no mixing of dominants. Note also that the two circumferential highways Route 128 (13 miles out) and I-495 (25 miles out) create resurgences of Residential: Low Density usage.

4. Highlighing Individual Land Uses (Figs. 11-19)

The standard grid-cell-derived computer map product is a single map using a separate symbol for each category of the legend. In the present case this would require only 11 symbols, but with a field of more than 300,000 cells reduced photographically to an 8 1/2 x 11 inch page the patterns would have little meaning.

Successful experimentation was carried out by the DCPRS in its high-altitude aircraft studies with devoting an entire map to each land use category in turn. The resulting map series had high clarity and great utility for analytical studies, checking of accuracy, and display.

Figure 9. Changes in Land Use with Distance: I.

Although this is an enlargement of a segment of the three-state computer map (Fig. 6) it was printed directly from the data bank in this format by a separate sub-routine designed to permit close visual and statistical examination of selected local areas.

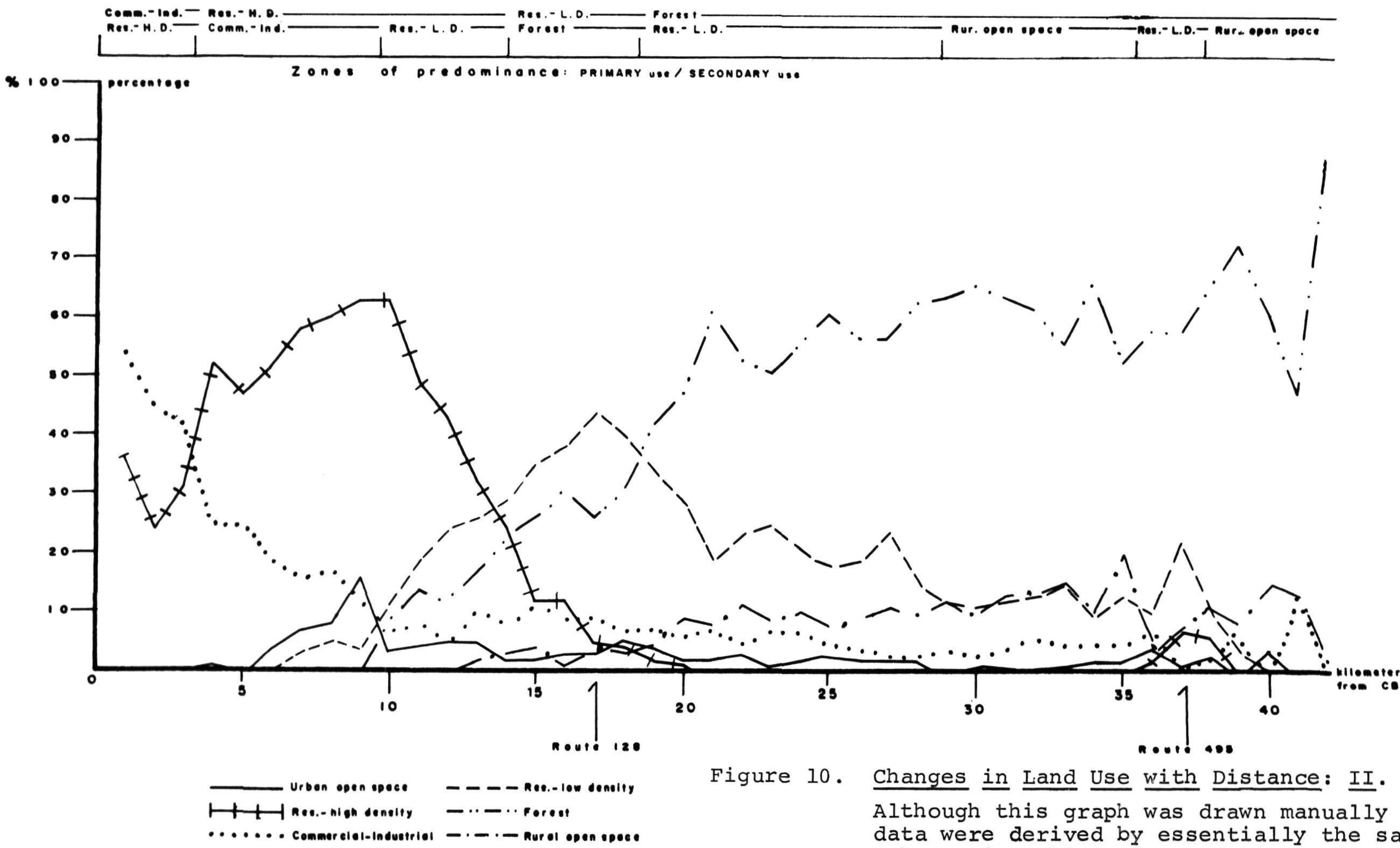

Figure 10. Changes in Land Use with Distance: II.

Although this graph was drawn manually the data were derived by essentially the same sub-routine which produced Figure 9.

In the present case we have experimented with a third, hybrid system, in which each map shows a single land use, but against a muted background of the other categories with which it is closely associated. For example, Commercial and Industrial use is printed in dark gray, against a medium-gray background of the other builtup categories. Selected samples of ERTS using this technique follow.

a. The Builtup Land Use Categories

Among the 11 land use categories mapped, those of Commercial and Industrial, Residential: High Density, Residential: Low Density, and Transportational all are considered to be builtup, or urban, in nature. Figures 11 through 13 show the first three of these builtup categories in turn, in dark gray, against a subdued (medium gray) background of the other three builtup categories. The Transportational category has not been reproduced here.

Figure 11. Commercial and Industrial Use. The image of Megalopolis as an area dominated by factories, warehouses, wholesale and retail establishments, and densely packed housing is shown here to be greatly exaggerated in the areal sense. Traditional water's-edge factory centers such as Boston, Providence, Fall River, and Worcester have been joined by new centers such as Danbury, Bridgeport and Pittsfield, but still that part of the three-state area dominated by Commercial and Industrial activity is less than 3%.

Figure 12. Residential Use: High Density. Immediately surrounding the industrial-commercial core of the cities is an extensive area devoted to high-density residences. Such areas provide areal "substance" to the urban category of land use. In the case of Boston the outer boundaries of the multiple-family housing area correspond closely to a geologic boundary, the contact between the sedimentary rock formations of the Boston Basin and the metamorphic rocks of the surrounding New England upland.

Figure 13. Residential Use: Low Density. "Low Density" in this study refers to concentrations of dwellings high enough to include many of the pre-World War II suburban developments on the fringes of the major cities (for example the extension westward from southwest Boston through Wellesley and Framingham towards Worcester).

Figure 11. <u>Builtup Areas</u>, <u>Commercial and Industrial Use Highlighted</u>.

The image of Megalopolis as areally dominated by factories, warehouses and wholesale and retail establishments is shown here to be greatly exaggerated.

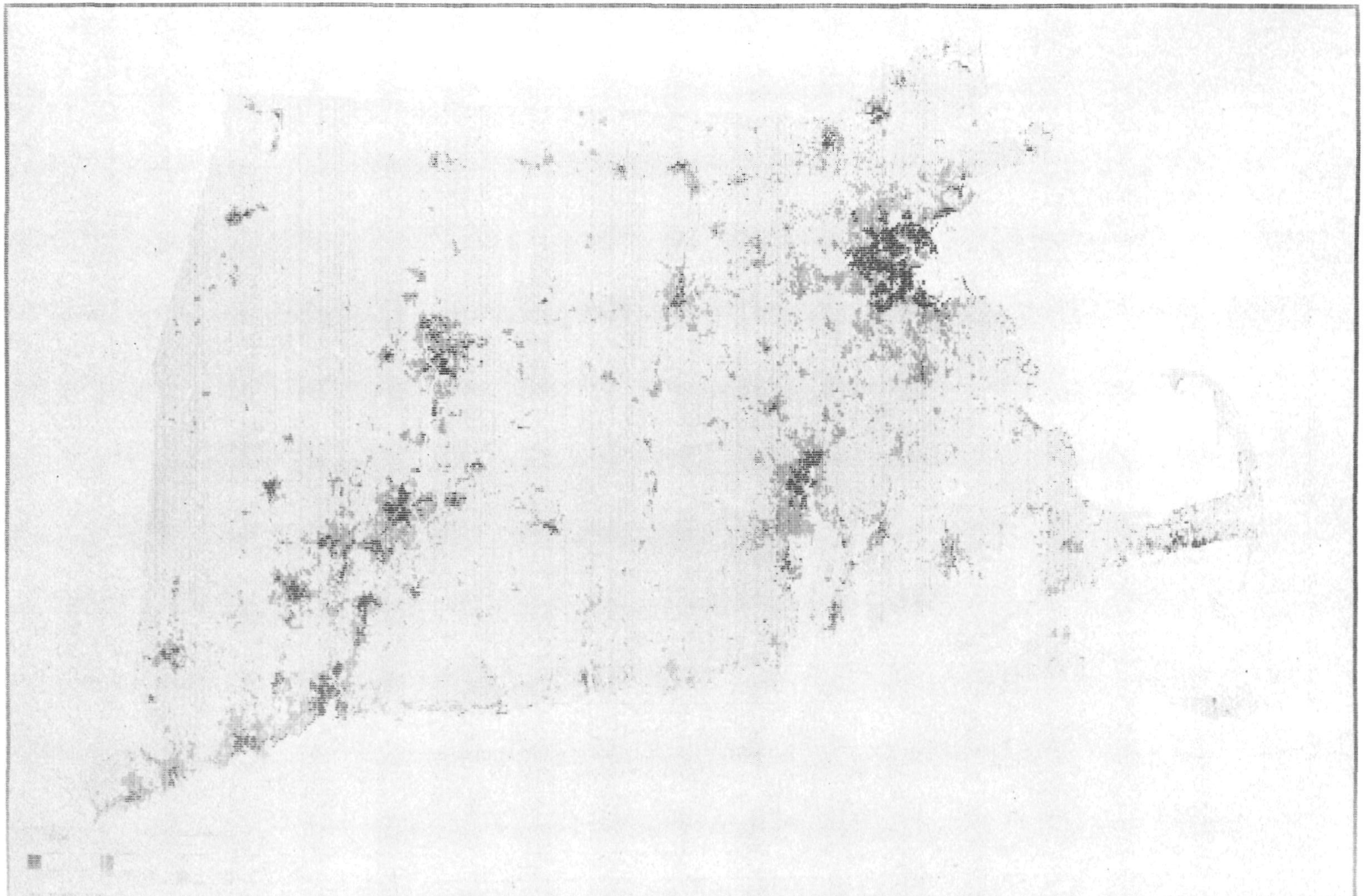

Figure 12. Builtup Areas, Residential: High Density Use Highlighted.

The high-density residential, rather than industrial-commercial category, provides the real substance to urban land use.

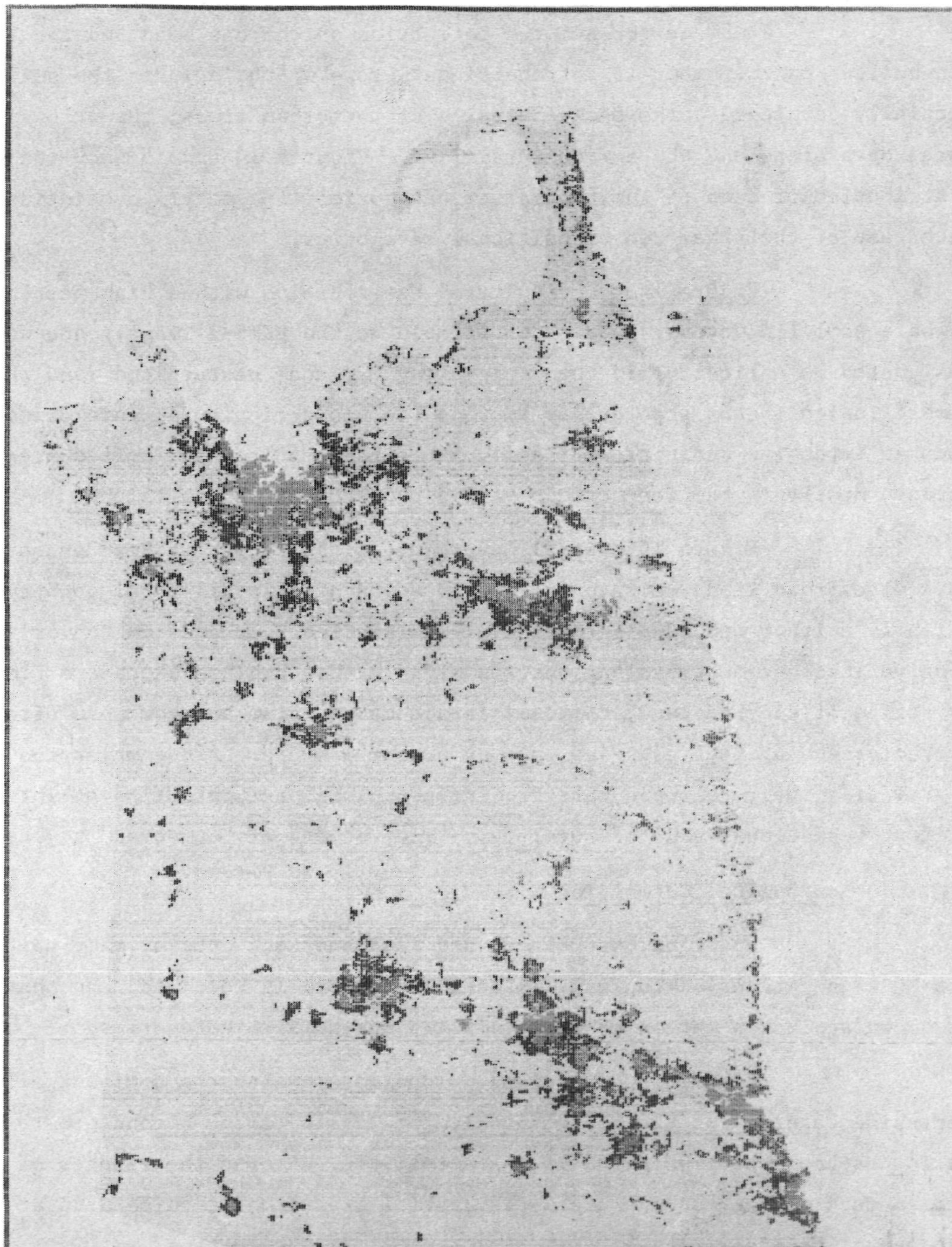

Figure 13. Builtup Areas, Residential: Low Density Use Highlighted. Here, with the expansion of suburban housing after World War II, began the phenomenon of urban sprawl.

B. The Transitional Land Use Categories.

Between the builtup categories on the one hand and the non-builtup on the other is a transitional group which includes the small, partially developed parks and cemeteries of the urban areas, the extensive rural open areas and the agricultural land. Figures 14 and 15 show the distribution of each of the two latter categories in a matrix consisting in each case of the other two transitional categories.

Figure 14. Agricultural Use. Fields with a high percentage of bare soil (in October) were identifiable on the ERTS-1 imagery and were designated as Agricultural, thus relegating hayland, pastureland (and the almost insignificant area of cover crops) to non-agricultural categories. Such an intensive definition of agriculture has resulted in limited areal extent, mostly in the Connecticut Valley and southern Rhode Island.

Figure 15. Rural Open Land, with or without Residences. This widespread land use category includes essentially all rural countryside which is neither wooded nor intensively cultivated. It adds up to very extensive acreages mostly along the roadsides of New England which are flanked by strips of cleared land, commonly farmed at one time but now more often characterized by hayfields and open or brushy pasture. Along major roads and near cities the rural open category includes long pasture strips of intermittent residences, some of rural farm type, others of "commuter" style.

c. Non-Builtup Categories

Woodland, Marshland, and Sand and Rock Outcrop make up the non-builtup category. The only extensive category is Woodland, and that one is shown against a matrix of the other two non-builtup categories.

Figure 16. Woodland. Woodland remains the dominant all-pervasive category of the northern third of Megalopolis. Second-growth mixed deciduous-coniferous woodland is characteristic. Around the fringes of the cities much of the current urban residential expansion is being made at the expense of woodland with or without extensive "clear-cutting".

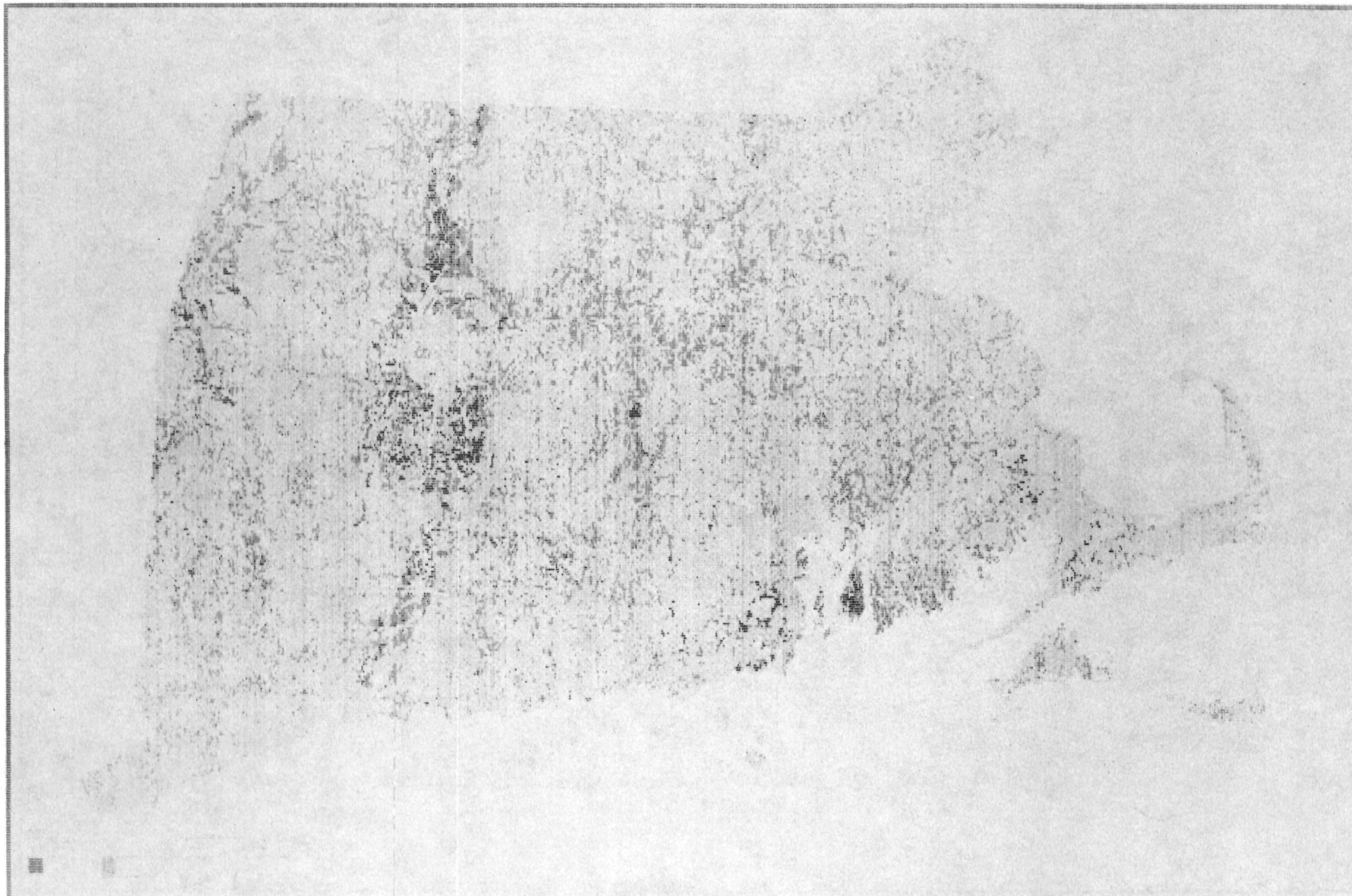

Figure 14. Transitional Areas, Agricultural Use Highlighted.

The agricultural category here is limited to fields bare in October. Much of the surrounding medium gray area (rural open land use) consists of hayland and pasture.

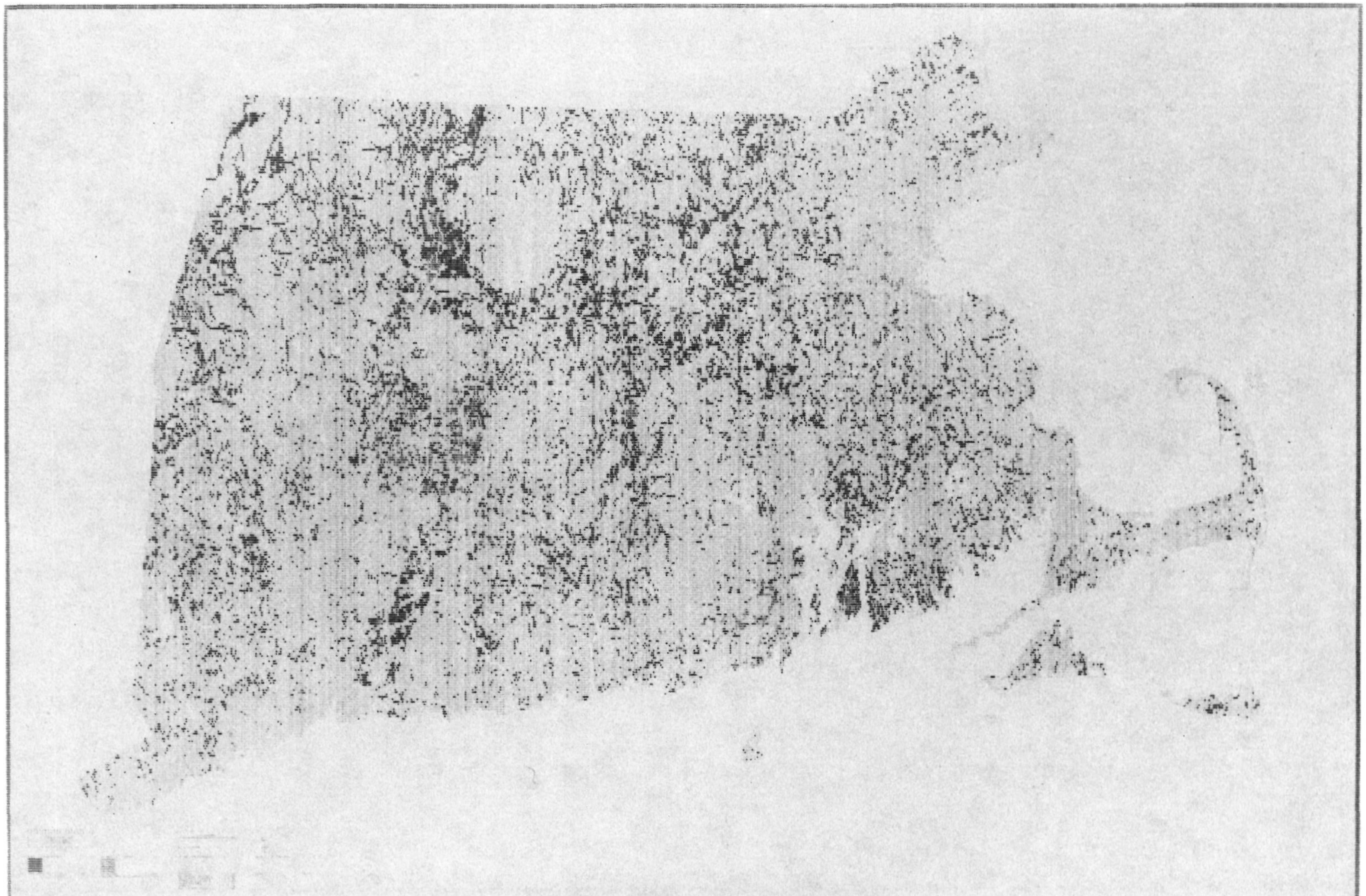

Figure 15. Transitional Areas, Rural Open Land Use Highlighted.

This category goes beyond agricultural use to include abandoned and other vacant rural land, as well as rural residential sites.

Figure 16. Non-Builtup Areas, Woodland Highlighted.

Although the ERTS-based definition of woodland is broader than most, under any definition it is the dominant land use of New England.

d. Maps of Land Use of Individual Political Units

Programs were written to produce separate computer maps of each of the three states and all 27 counties in the area. Only the individual state maps are reproduced here, as Figures 17, 18 and 19.

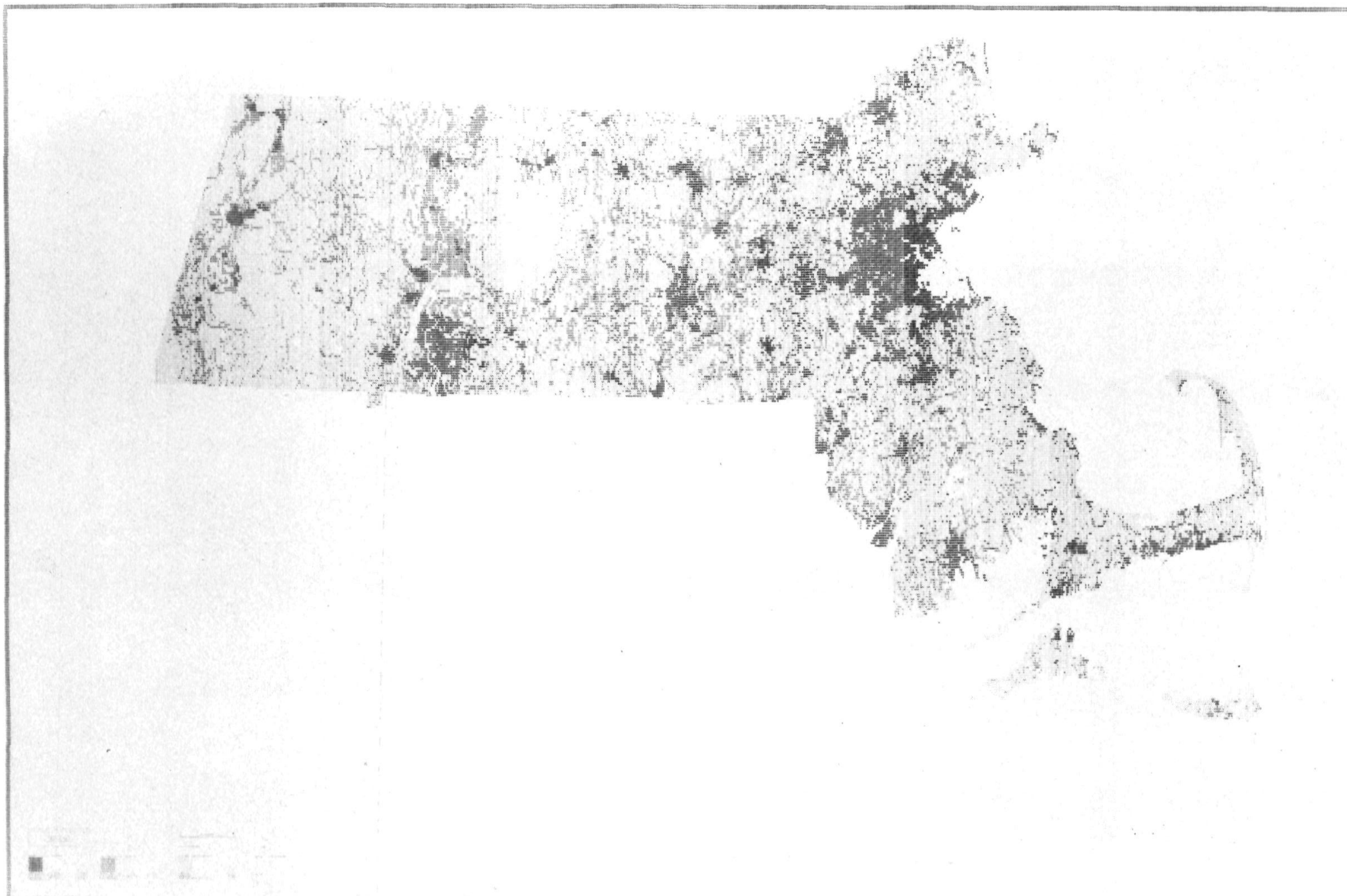

Figure 17. Land Use, State of Massachusets.

Produced from the basic data bank by a separate sub-routine. Note the urbanization that already has occured on Cape Cod.

(For a more legible legend see Figure 6)

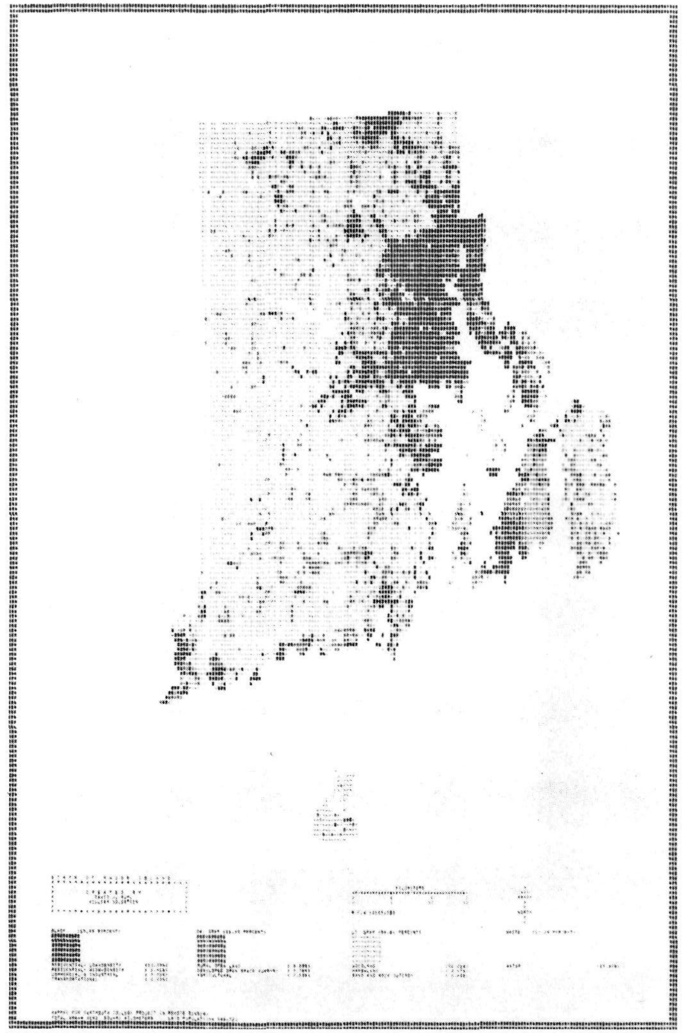

Figure 18. Land Use, State of Rhode Island.
(For a more legible legend see Figure 6)

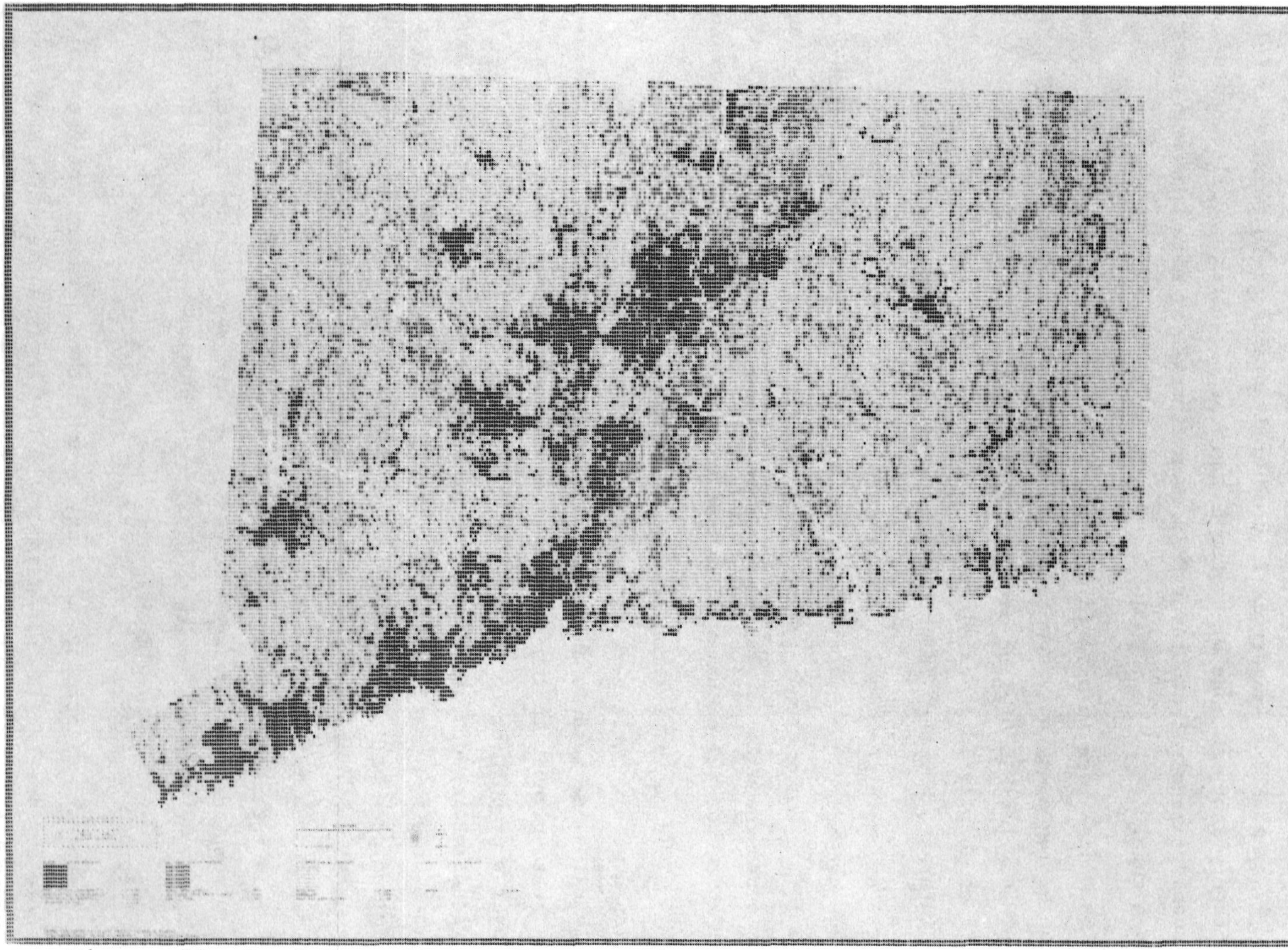

Figure 19. Land Use, State of Connecticut.
This map of Connecticut makes a third variant with the two shown in Figure 7, and in many ways is the most useful even though the usage categories have been collapsed to 4.

(For a more legible legend see Figure 6)

VI CONCLUSIONS AND RECOMMENDATIONS

It is concluded that:

* Using ERTS-1 imagery it is completely practical to compile useful 11-category land use maps of states and groups of states. Dollar costs and speed of mapping both favor ERTS over aircraft by more than one order of magnitude.

* Manual read-in by grid cell provides a rapid and inexpensive method of converting a manually compiled land use map to a much more broadly useful and flexible digital data base, although it involves minor loss of detail especially in linear land use phenomena. There still is important user interest, however, in traditional color-coded maps.

* A theoretical evaluation of ERTS' utility to planners suggest almost open-ended capabilities for the future, especially at interstate and state levels and in the very important time-lapse operations. Realization of this promise will in general be dependent on (1) the image resolution attainable, and (2) mutual willingness to adjust user and maker requirements.

* Based on initial conferences which are not yet fully documented or developed with the planners of five New England states, it can be said that purely ERTS-1 derived land use data are recognized as useful by essentially every state planner in the region. The degree of enthusiasm is more or less in inverse proportion to the quality and detail of the present files of the individual states concerned. States having very detailed, up-to-date and accurate maps and statistics are genuinely interested in ERTS, but as a tool of limited present, and great potential future value. States whose existing maps and files are more fragmental consider ERTS as having real promise as the basis for a first integrative state-wide effort. Both types of states are keenly interested in high-altitude aircraft imagery, but as a source of interim supplemental coverage for ERTS, not as a replacement for it or as a substitute for improved resource satellites.

It is recommended that:

* Conferences already under way between the Dartmouth College Project in Remote Sensing and the planners of the New England states be continued, to determine how and to what extent present and future state and interstate

requirements can be met by ERTS-1, ERTS-B, Skylab, and EOS, with high altitude aircraft support where necessary.

* NASA, the USGS, and other appropriate government agencies make every effort to serve the tremendous interest in the satellite aspects of the land use and management program by insuring continuing coverage, and as rapid an increase in resolution as the state-of-the art will allow..

Appendices

APPENDIX A

PRELIMINARY ASSIGNMENT OF OFFICIAL STATE OF CONNECTICUT LANDUSE CATEGORIES TO THE ERTS CLASSIFICATION

Water

Water (natural and impounded)

Woodland

Commercial forestry production

Forest lands (non-commercial)

Residential: Low Density

Suburban high 1 to 2 families/acre (general housing and mobile home park)

Suburban low 1/2 to 1 familes/acre (general housing and mobile home park)

Residential: High Density

Urban high over 8 families/acre (general housing and mobile home park)

Urban low 2 to 8 families/acre (general housing and mobile home park)

Commercial and Industrial

General light manufacturing

General heavy manufacturing and processing

General trades and services

Motels and tourist courts

Hospitals

Prisons and prison farms

Military bases and reservations

Primary and secondary education

Higher education

Churches and monasteries

General cultural and entertainment

Drive-in theatres, open air concerts

Marinas

Open-pit mines and quarries

Inactive sand and gravel pits

Other resource extraction

Commercial fishing production

Under construction

Transportational

- Railroad
- Highway maintenance
- Airports
- Marine terminals
- Other transportation
- Electric power plants
- Water treatment plants
- Sewage treatment plants
- Solid waste disposal

Developed Open Space (Urban)

- Golf courses
- Fairgrounds and amusement parks
- Parks - leisure and ornamental
- Sports assembly (stadiums, etc.)
- Athletic fields
- Ski areas
- Other outdoor sports and recreation
- Cemeteries

Agricultural

- Active agricultural production

Rural Open Land (with or without Residences)

- Estate under 1/2 families/acre
- Other residential (farm labor camps)
- Highway right-of-way over 100' wide
- Campgrounds
- Open lands (inactive agricultural, scrub, etc.)

Marshland

- Wetlands (bogs, marshes, swamps)

Sand and Rock Outcrop

- Swimming areas

APPENDIX B

MAPPING A MEDIUM-SIZED STATE

In order to project the ratios of time and cost shown in Table 3 of the main text up to a typical "state-sized" ERTS project, it has been postulated that Missouri - a medium-sized state, with approximately 70,000 square miles - is to be mapped in 11 categories. The results are shown in the table on the next page.

The seventy-five thousand dollar task if performed by ERTS is estimated as a million-dollar effort if imaged at medium altitudes (column (a), a price differential large enough to make the difference between having such a map and not having one in many states. Add to this the fact that only 1 1/2 man-years are needed to complete the job using ERTS, compared to 11 to 44 man-years using aerial photography, and it is dramatically apparent that a whole new class of capability has been born with ERTS, assuming only that a satisfactory degree of detail and accuracy is attainable.

The number of images required, as shown in column (c) of the table on the following page reveals such large differentials that they give a feeling of conservatism to the cost and time ratios shown in the remainder of the table. The difference between the effort involved in manipulating 14 images and in manipulating hundreds or thousands of them is considerable.

It should be re-emphasized here that these figures, like those in the main text, cover only the interpretation phase of the mapping effort.

ESTIMATE OF COMPARATIVE COSTS IN TIME AND MONEY

TO MAP A MEDIUM-SIZED STATE

(Extrapolation of figures contained in Tables 2 and 3 of the main text to cover the state of Missouri, area 69,686 sq. mi.

	(a) Cost (000s of $	(ratio)	(b) Interpreter Time (man years)	(ratio)	(c) Images Required (no.frames)	(ratio
ERTS-1	$ 75	1:	1 1/2	1:	14[2]	1:
High-altitude aircraft	730	10:	11	7:	1,936[3]	139:
Medium-altitude aircraft	1,100 (1,700)[1]	15:	44	29:	41,000[4]	2,928:

[1] Including $600,000 for photography at $8.30 sq. mi. (average of 3 contractor estimates).

[2] Assuming 34% sidelap and 10% overlap.

[3] Assuming 58% sidelap and 58% overlap (stereoscopic coverage)

[4] Assuming 39% sidelap and 66% overlap (stereoscopic coverage)

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

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