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Attachments:

ERTS Program Summary - Task List
Type I reports for each of the ten tasks

ERTS PROGRAM SUMMARY

Under Contract NAS5-21783

TASK	PRINCIPAL INVESTIGATOR	MMC #	UN #	SHORT TITLE
I	Polcyn	063	200	Water Depth Measurement
II	Thomson	077	621	Yellowstone Park Data
III	Thomson	137	636	Atmospheric Effects (Colorado) ✓
IV	Bryan	072	201	Lake Ice Surveillance ✓
V	Sattinger	086	225	Recreational Land Use ✓
VI	Polcyn	114	635	IFYGL (Lake Ontario) ✓
VII	Malila Nalepka	136	612 178	Image Enhancement
VIII	Wezernak	081	625	Water Quality Monitoring ✓
IX	Horvath	079	606	Oil Pollution Detection ✓
X	Vincent	075	422	Mapping Iron Compounds

Eighth Type I Progress Report - 1 January 1974 - 28 February 1974
Task I - Water Depth Measurement - 1388
F. C. Polcyn, UN 200, MMC 063

Data processing for the Bahama Bank and Lake Michigan test sites has been completed, and the final report for this task is in progress.

Eight Type I Progress Report - 1 January 1974 - 28 February 1974
Task II - Yellowstone National Park Data - 1398
F. J. Thomson, UN 621, MMC 077

The final report is in preparation and will be submitted soon.

Integration of materials for the final report is under way, which includes the thirteen category recognition map, sections prepared by Dr. Harry Smedes, U.S.G.S., and the ERIM summary of the project results on recognition and mapping of land use areas for the area of the Yellowstone Park used as a test area.

Eighth Type I Progress Report, 1 January 1974 - 28 February 1974
Task III - Atmospheric Effects in ERTS-1 Data - 1410
F. J. Thomson, UN 636, MMC 137

The general objectives of this task are to determine the effects of the atmosphere on the ability of pattern recognition devices to classify terrain objects and to assess their significance relative to other factors affecting the automatic classification of terrain objects. The project is a cooperative one between ERIM personnel, Dr. Harry Smedes of the U.S.G.S., and Mr. Roland Hulstrom of Martin-Marietta Corporation.

Activity during this reporting period has been concerned with the definition of accurate signatures for the recognition mapping phase of this task. Several iterations of signature extraction from training areas designated on ERTS data of 20 August 1972 have been performed at the request of Mr. K. Jon Ranson at Colorado State University. The objective of this effort is to establish a data base of signatures, for each of the dominant terrain classes in the test site, that will encompass a range of conditions caused by the inherent variability of terrain materials as well as slope and aspect variations.

Once accurate signatures are established, further statistical analyses will attempt to determine their suitability for accurate classification of the test site. Variations among signature means (within channel and between channels) will be related to the physical characteristics of the training sets, slope and aspect variations, and if possible, to varying base elevation.

Eighth Type I Progress Report, 1 January 1974 - 28 February 1974
Task IV - Lake Ice Surveillance - 1406
M. Leonard Bryan, UN 201, MMC 072

During this reporting period two aspects of the task were developed. The one is a reinstitution of the ice flights which were to have been conducted during the 1972-1973 winter season. Because these radar flights are planned for 6 March 1974, which is a day before the ERTS-1 pass and because the cost of the flights will be at essentially no cost to the ERTS-1 project, we have decided to await the results of these flights before making any further significant expenditures on the project. Secondly, funds for completion of the task have been received, thus allowing a continuation of our work.

The visual analysis of ERTS-1 data of April 1973 for the Lake Erie shoreline of southeastern Michigan has been initiated and is partially completed. For the study period, data from several sensors are available, including black and white infrared aerial photography, ERTS-1 imagery and side looking radar. By using the several sensors we can make comparisons of the water/land boundary in relation to flooding and thereby evaluate the effectiveness of each sensor for determining this boundary. Also it is planned to use as an additional comparison the ERTS-1 CCT of this area to produce an automatic recognition map of this land/water boundary.

The proposed program for the next reporting period is the following:

a) Complete the visual analysis of the ERTS-1 frame, with respect to the land/water boundaries for the April 1973 data. This review will use 18 x enlargements of the 9 x 9 precision processed negatives.

b) Complete the visual analysis of the SLAR of the southeastern Michigan flooded areas using the April 1973 data, and make comparisons of this analysis with the black and white IR aerial photography and the ERTS-1 data mentioned above.

c) Prepare a recognition map, using ERTS-1 CCT of the same area for the April 1973 data.

d) Conduct ground truth operations (during the first week in March, 1974) of the ice in Whitefish Bay in conjunction with the proposed radar flights.

Eighth Type I Progress Report - 1 January 1974 - 28 February 1974
Task V, Recreational Land Use - 1387
I. Sattinger, UN 225, MMC 086

Work is continuing on the use of multitemporal processing of multispectral scanner data to increase the effectiveness in discriminating between wetland and forested areas. This work is being done with two frames of ERTS data, acquired on 27 March 1973 and 7 June 1973. The Southeast Michigan areas being studied include the George Reserve, Stinchfield Woods, and the Chelsea-Waterloo and Pinckney Recreation Areas.

Also we are defining and evaluating the most likely applications of ERTS data for analysis of recreational land and open space. In the following sections, some preliminary conclusions are presented on the utilization of ERTS data for these purposes.

Applications of ERTS Data

ERTS data should prove to be useful for a number of functions related to the analysis of recreational land and open space. Specific applications discussed below may either use ERTS data directly in special studies or take advantage of a multi-purpose computer-based data bank which incorporates ERTS data and data from other sources.

The latter approach is likely to be effective and economical, since the functions of recreational land identification and analyses closely parallel in many respects the broader function of land inventory and evaluation needed for the implementation of effective methods of land resource management. Land use and natural resource inventories provide the data base needed for many specific purposes, such as land use regulation, highway or power line corridor selection, wildlife habitat assessment, and forest inventory. The techniques developed in other investigations for applying ERTS data for these purposes can also be used for the recreation application. This statement applies to techniques for combining ERTS data with other sources of data through the use of geographic referencing systems and to the use of computer-based information storage and retrieval systems.

Regional Surveys

During the early phases of regional surveys of recreation potential, major emphasis is placed on obtaining gross data on recreational land supply for comparison with present and projected recreation demand. This requires the identification of those sites which have desirable physical characteristics for development, with special emphasis on soils, topography, vegetation, and water resources. Many of these physical factors can be observed by remote sensing methods. Rather general criteria can be applied to estimate this supply (See Table 1). Some field work should be conducted to confirm or improve the preliminary evaluation made from remote sensing coverage.

TABLE I

SOUTHEAST MICHIGAN RECREATION LAND SURVEY
SITE EVALUATION CRITERIA

	Max. Score
* Land Area	25
* Lake Surface Area	25
* River and Stream Size	15
* Waterfront Length Along Lake	25
* Miles of River or Stream	25
Relief	15
* Vegetative Cover	20
Accessibility	10
* Threat of Adverse Land-use Changes	20
Environmental Intrusions	10
Unique Features	15
Aesthetics	10

* Observable from ERTS data.

ERTS data would have adequate resolution for this purpose and would have the added potential for automatic rating of suitable sites. It has the additional advantage of providing more up-to-date information than is likely to be available from photography, and, thus, ensures better accuracy and facilitates frequent updating of survey results.

Recreational site evaluation requires consideration of a number of factors not directly observable by ERTS. For final site selection, the mapping of potential recreational areas from ERTS data should be combined with information on soils, topography, population distribution and income levels, transportation networks, land ownership, and use of adjacent land. This additional information, provided from sources other than remote sensing, could be prepared in the form of map overlays or, for automatic analysis, could be incorporated into the computer data base on the same geographical grid as the ERTS-derived data.

Delineation of Open Space

A significant application of ERTS data is to delineate open space in a rapidly urbanizing area as an important indicator of environmental quality. Continuous monitoring of ERTS data can be used to determine the rate and direction of urbanization as it affects the availability of open space. This information expressed in quantitative form should serve to stimulate action to preserve areas needed to maintain environmental quality or to provide recreational opportunities.

This application requires methods of defining the rural/urban boundary in a metropolitan area and relating open space to signatures of vegetation and other surface types. Previous experience on which such methods can be based was reported in the Seventh Type I Progress Report. The identification of open space exclusively from ERTS data may be subject to some error, particularly in distinguishing urban areas with substantial vegetative cover from space without residential development. However, once an inventory of potential recreation sites and delineation of open space has been completed, it can be updated frequently through the analysis of ERTS imagery collected sequentially in time.

Site Development

In some cases, ERTS data may be useful in the early stages of recreation site planning. For geographically extensive sites, such as scenic trails, abandoned railroad right-of-way, wild or scenic rivers, long shorelines, and large park areas, preliminary layouts of structures, roads, services, impoundments, etc., might be made. Any detailed planning of such facilities, however, would require the acquisition and study of aerial photography.

Monitoring Environmental Conditions

ERTS data may be used for a number of purposes in continued monitoring of environmental conditions for large recreational sites. Such purposes include the monitoring of water pollution, sedimentation and eutrophication of sizable bodies of water, detection of damage to forests through disease, insects, drought, or fire, and observation of successional changes.

Wildlife Habitat Assessment and Management

ERTS data may lend itself to the identification and assessment of suitable deer habitat by analyzing vegetation cover to identify sources of food, size and type of open areas adjacent to forest cover, and availability of water. Management of deer habitat could be assisted through continuous monitoring of these conditions. Similarly, waterfowl habitat preservation and management requires data on wetland size and distribution, adjacent land use, and availability of surface water.

Specific Applications

For summarizing the above discussion, Table 2 presents a representative list of specific uses of ERTS data for recreation planning and management. The applications listed are oriented toward Michigan's extensive forest and water resources. The feasibility of using ERTS data, either alone or in combination with other sources of data, will depend on the needed resolution and on the ability to discriminate various kinds of land use and land cover or specific land and water conditions. The extent of this capability has been demonstrated by (1) the results obtained in this project, and (2) the results obtained by many other ERTS investigators.

TABLE 2

SPECIFIC RECREATIONAL APPLICATIONS OF ERTS

Recreational Application	ERTS Function
Monitoring of wilderness or natural areas.	Vegetation mapping. Detect fire damage or other change.
Identification of camping, boating, swimming, picnic and park sites.	Map size and distribution of water and land areas, vegetation category, shoreline, adjacent land use and transportation network.
Scenic road or trail route selection.	Map land use and land cover, identify scenic areas.
Scenic or wild river evaluation. Riverfront park site selection.	Map vegetative cover and development of adjacent land along river flood plain and valley.
Inland lake management.	Detect pollution and eutrophication. Monitor residential development.
Great Lakes shoreland management.	Detect pollution. Map water circulation along shore and at estuaries. Map shoreland use. Map shoreline flooding. Monitor extent and condition of vegetation on sand dunes. Identify sites for harbors, beaches, residential development, etc.
Waterfowl habitat preservation.	Inventory wetland size, classification, and adjacent land use.

TABLE 2 (cont.)

Recreational Application	ERTS Function
Deer habitat preservation.	Analyze vegetation cover to identify sources of food, size and type of adjacent open areas, and availability of water.
Deer habitat assessment.	Monitor condition of vegetation, forest burn or cutting.

Eighth Type I Progress Report - 1 January 1974 to 28 February 1974
Task VI - IFYGL (Lake Ontario) - 1384
F. C. Polcyn, UN 635, MMC 114

Progress during the two month period 1 January - 28 February 1974 concerned three aspects of this International Field Year for the Great Lakes (IFYGL) - ERTS program. Processing of ERTS-MSS data from the Lake Ontario Basin for mid-August 1972 continued. During this reporting period we were concerned with the following tasks:

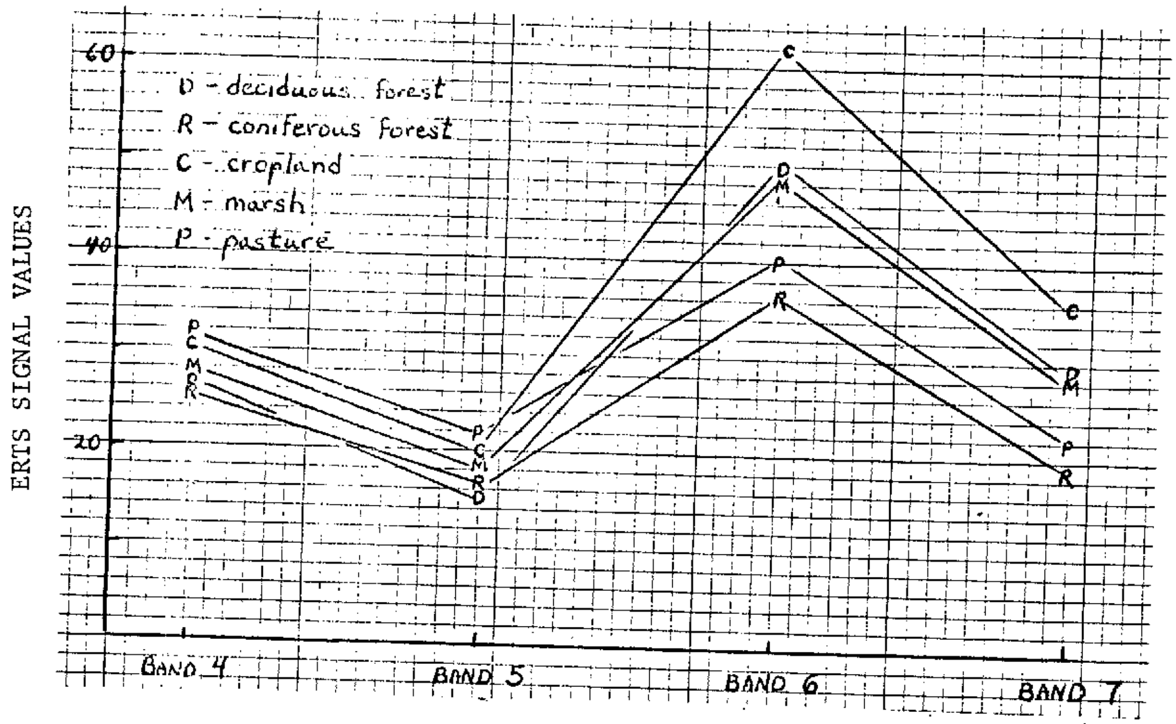
1) Digital computer analysis of signatures of terrain features,
2) Assessment of analog (SPARC) recognition images of ERTS data, and
3) Further definition of an operational ERTS data processing system for large area surveys.

The procedure and results of each of these tasks are summarized below.

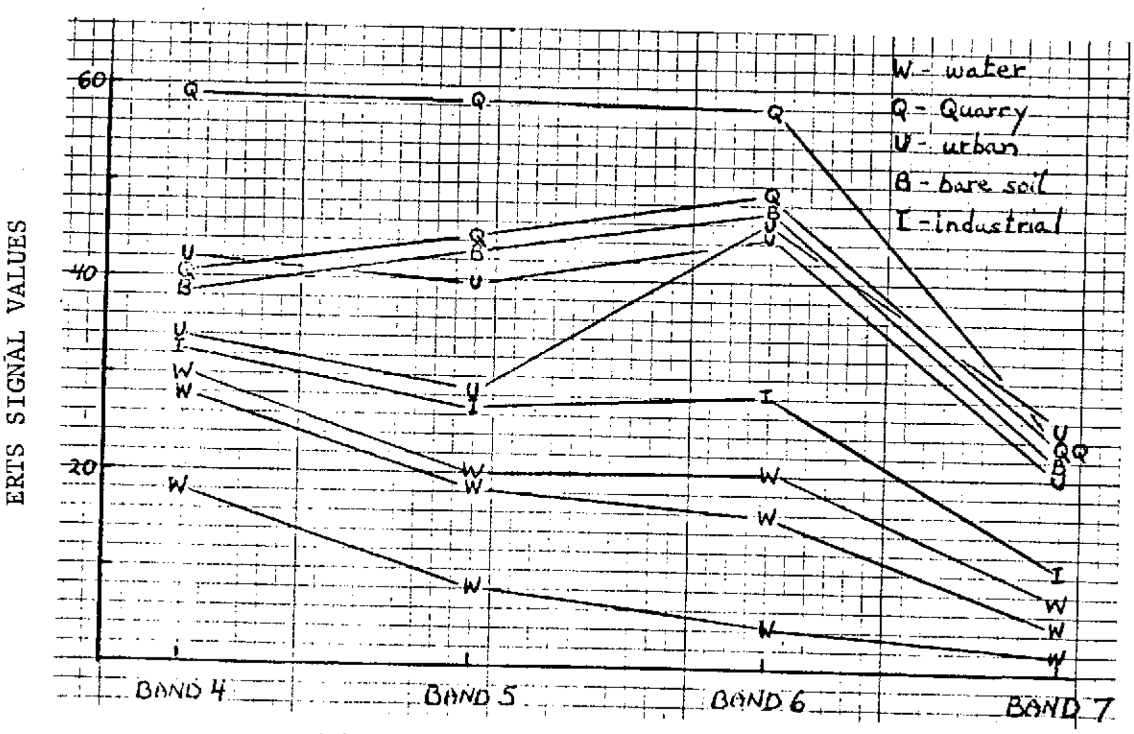
Digital Signature Analysis

During this investigation we have obtained more than 50 signatures of average signal values in the four ERTS spectral bands. Most of these signatures, representing a variety of different terrain classes, were obtained from either the Rochester or the Oakville portions of the Basin. Analysis of these signatures provides information concerning the nature of ERTS data and the extent to which we may selectively discriminate these classes using different processing techniques. Figure 1 shows mean values for different types of spectral signatures on two different, but comparable graphs. Figure 1a shows the mean spectral characteristics of a number of vegetation classes, and Figure 1b shows essentially non-vegetation terrain classes. The most significant characteristic of vegetation signatures is the sharp increase in signal values between ERTS Bands 5 and 6, corresponding to a marked increase in vegetation reflectance between the 0.60 to 0.70 μm (chlorophyll absorption) band and the 0.70 to 0.80 μm (foliar reflectance) band. The non-vegetated terrain classes show no such marked increase and, in fact, for water tend to decrease at the longer wavelengths.

If these signatures for vegetation and non-vegetation were superimposed, their variances would overlap for each ERTS band. As a result we would find that quarries and bare soil are distinguishable (characterized by discretely different ranges of signal values) from water and vegetation in the visible bands (4 and 5),but that they are entirely within the range of vegetation in the near infrared bands (6 and 7). Also surface water may be indistinguishable from heavy vegetation in the visible, but is certainly separable from vegetation in the near infrared. In looking at these signatures, it is clear that no one spectral band provides unambiguous separation of all terrain classes on the basis of ERTS mean signal values. We may be able to separate water from all other terrain classes



(a) Representative Vegetation Signatures



(b) Representative Non-Vegetation Signatures

FIGURE 1. SPECTRAL SIGNATURES FOR TERRAIN FEATURES FROM ERTS-MSS DATA FOR THE LAKE ONTARIO BASIN - 19, 20, 21 August 1972.

using the near infrared bands (6 and 7) and quarries might be distinguishable from other categories on the basis of their high values in the visible bands, but we require information from several of the ERTS bands to make positive identification of the terrain feature. Which ERTS bands should be used and how are they to be handled?

The simplest quantitative processing technique is level ("density") slicing of individual spectral bands. If a discrete range of signal values in any single data channel can be associated uniquely with a terrain class of interest, this range may be electronically gated such that only those signals falling within that range are printed-out or tallied on a counter. For example, surface water areas have ERTS signal values which are lower than all others in the near infrared bands (6 and 7). A level slice excluding all signal values above 20 and 10 for ERTS bands 6 and 7, respectively, allows production of an image showing only surface water areas with these data. Likewise it is possible to designate certain urban or quarry areas by level slicing only the highest signals in ERTS Bands 4 or 5. The objective is to determine which single band, or minimum combination of single bands, may be used in discriminating terrain classes of interest.

For vegetated areas there is no single band which uniquely distinguishes vegetation from non-vegetation. Two or more spectral bands are required to make this separation. To determine the most useful bands for distinguishing vegetation and non-vegetation classes, mean signature values from 12 terrain classes were supplied to an IBM 360 computer. Mean signal values for the four ERTS bands were listed as variables 1 through 4 and correlation coefficients were computed for each of the pairwise ERTS band combinations. Signatures included surface water, bare soil, crop, marsh, pasture, hardwood, conifer, and mixed-forest. Table 1 shows these correlations.

TABLE 1.
CORRELATION COEFFICIENTS FOR FOUR ERTS BANDS USING
TWELVE SPECTRAL SIGNATURES FROM THE OAKVILLE REPRESENTATIVE BASIN

	BAND 4	BAND 5	BAND 6	BAND 7
BAND 4	1.0000			
BAND 5	0.9589	1.0000		
BAND 6	0.2384	0.1806	1.0000	
BAND 7	0.0653	-0.0000	0.9792	1.0000

Several interesting facts emerge from Table 1. ERTS Bands 4 and 5 (visible) and ERTS Bands 6 and 7 (near IR) are very highly correlated - coefficients of 0.9589 and 0.9792, respectively. Also, ERTS Bands 4 and 5 are only slightly correlated with ERTS Bands 6 and 7. Indeed, Band 5 is virtually uncorrelated with Band 7. These facts suggest that for these 12 terrain signatures significant spectral differences occur primarily between the visible and the near IR bands. A ratio of an ERTS near IR band to an

ERTS visible band may provide better discrimination of the above terrain classes than any single band alone.

The logic of ratio processing of two spectral bands is illustrated in Fig. 2. If all terrain classes are represented by two possible character states (light and dark) in two spectral bands (Band 1 and Band 2), four different spectral classes are possible -- dark in both bands (A), light in Band 1 and dark in Band 2 (B), light in both bands (C), and dark in Band 1 and light in Band 2 (D). A level slice of either one band or the other will discriminate only two groups of two classes each. If Band 1 is used, A will be confused with D, and B with C. If Band 2 is used, A will be confused with B, and C with D. However, level slices of a ratio of Band 1 and Band 2 discriminate (approximately) three groups of the four possible classes -- B, D, and A with C. Ratio level slices are represented by straight lines through the origin of the graph. Note that discrimination of all four classes may be accomplished by sequentially slicing first one, then the other spectral band; but our objective is to find, if we can, the simplest and fastest method for processing these ERTS data. If a linear decision rule performed on a single data channel (a spectral band or combined bands) can provide the desired spatial information, it makes little sense to use a more elaborate statistical procedure.

Table 1 suggests that a ratio of ERTS Band 5 (0.6 to 0.7 μm) with ERTS Band 7 (0.8 to 1.1 μm) may be useful, although several other ratios were also tested. Table 2 shows the correlation coefficients for ERTS single bands and three different ratios of ERTS bands.

TABLE 2.
CORRELATION COEFFICIENTS FOR FOUR ERTS BANDS AND THREE RATIOS OF ERTS BANDS FOR TWELVE SPECTRAL SIGNATURES FROM THE OAKVILLE REPRESENTATIVE BASIN

	Ratio 6/5	Ratio 7/5	Ratio 7/6
BAND 4	-0.3864	-0.3616	-0.2072
BAND 5	-0.4379	-0.4129	-0.2289
BAND 6	0.7867	0.7997	0.8397
BAND 7	0.8761	0.8923	0.9109
RATIO 6/5	1.0000	0.9963	0.8993
RATIO 7/5		1.0000	0.9175
RATIO 7/6			1.0000

From Table 2 ratios involving ERTS Bands 6 and 7 are slightly negatively correlated with the ERTS visible bands (4 and 5) and positively correlated with the ERTS near IR bands (6 and 7). Also, there is very little difference between ratios 7/5 and 6/5 when comparing these twelve signatures.

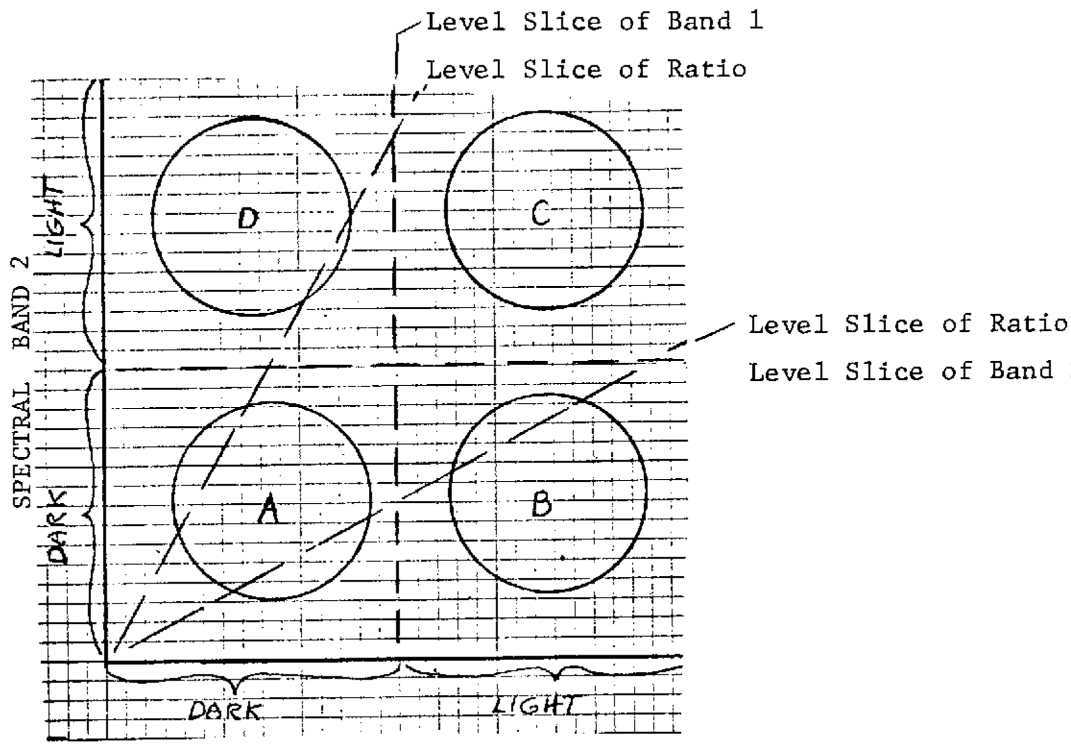


FIGURE 2. ILLUSTRATION OF SPECTRAL DISCRIMINATION USING LEVEL SLICING OF SINGLE SPECTRAL BANDS AND A RATIO OF TWO BANDS

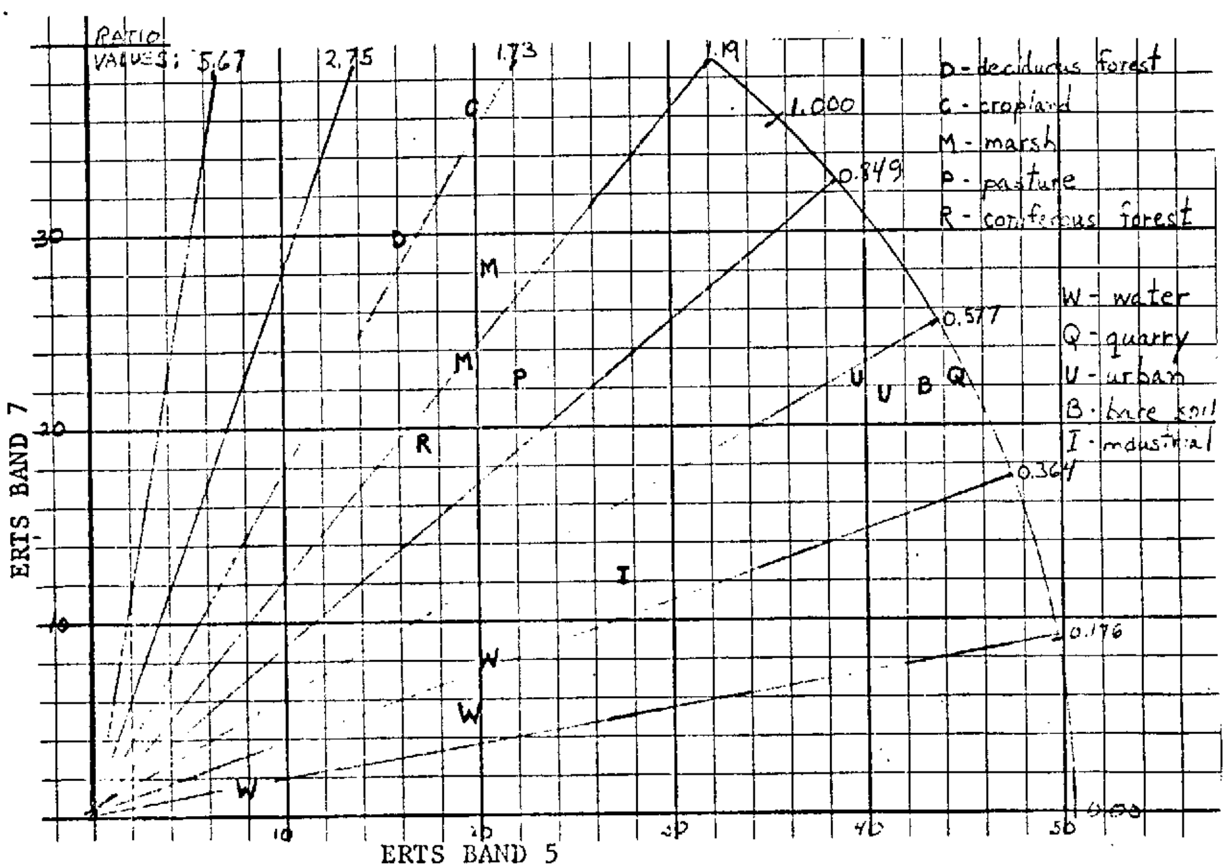


FIGURE 3. TWO DIMENSIONAL PLOT OF SPECTRAL SIGNATURES FOR TERRAIN FEATURES

Figure 3 shows a graph of the mean signal values in two ERTS bands for the signatures shown in Fig. 1. This graph is similar to Fig. 2 except that actual signal values have been plotted. Ratio values may be represented by the slope of the straight line connecting the signal values to the origin of the graph. These values are listed along the arc of the graph. From the dispersion of points in this graph we can assess the feasibility of level slicing to discriminate terrain classes of interest.

From Fig. 3, ratio values greater than 1.0 are vegetation classes; ratio values between 0.46 and 1.0 are urban, bare soils, and quarries; and values less than 0.38 are water areas. In other words, using a ratio of ERTS band 7 to ERTS band 5 we can discriminate vegetation from both surface water and other non-vegetated surfaces (urban, industrial, quarries, and bare soils). Within each group of terrain classes it is not clear the extent to which individual classes are separable from other classes. For example, the urban areas appear very similar to the bare agricultural field. Likewise, a deciduous forest may look similar to dense green agricultural crops on the basis of ratio values -- although there is empirical evidence that the ratio of ERTS band 7 to ERTS band 5 adequately distinguishes forest from agricultural areas for these data.

Ratios of spectral bands have the additional interesting property of being less effected by changes in terrain illumination than the original bands which make up the ratio. Changes in illumination of the terrain generally increase or decrease the radiance in each band proportionally; thus the ratio value changes little. This fact means that in addition to providing better spectral separation of significant terrain categories, the ratio values may be a more reliable indicator of certain classes, under changing atmospheric conditions and from one area to another, than discrimination based on mean signal values of ERTS bands alone.

Recognition Processing

ERTS-MSS data of the Lake Ontario Basin, comprising portions of eight ERTS frames, were processed for recognition of selected terrain classes. These data were dark-level corrected prior to processing as described in previous reports. The recognition processing was accomplished using a Recognition Computer (SPARC). The SPARC is a prototype special purpose high-speed computing system. It is capable of performing likelihood ratio decision processing with up to 12 spectral bands of data at the rate of greater than decision processing with up to 12 spectral bands of data at the rate of 10,000 decisions per second. With this speed of computation and after initial selection of appropriate decision criteria, the SPARC required about one hour to produce a single recognition image for the Basin. Much of this time was for manual tape editing and recording of digital counts for area determination. Ten recognition images, representing a variety of terrain features, were produced.

The first step of the decision process was to level slice the near IR ERTS-Band 7 for recognition of surface water. With water areas designated by this level slice all subsequent processing was performed on the remaining "non-water" data. Input data to the second step were ratios of ERTS Bands 5 and 6 and Bands 5 and 7. Subsequent digital analysis of these two ratios indicated coefficients of correlation between these two ERTS ratios of 0.996 (see previous section). Consequently the likelihood ratio decision rule which was applied to these two ERTS ratios probably accomplished little more than level-slicing of the IR/red ratio.

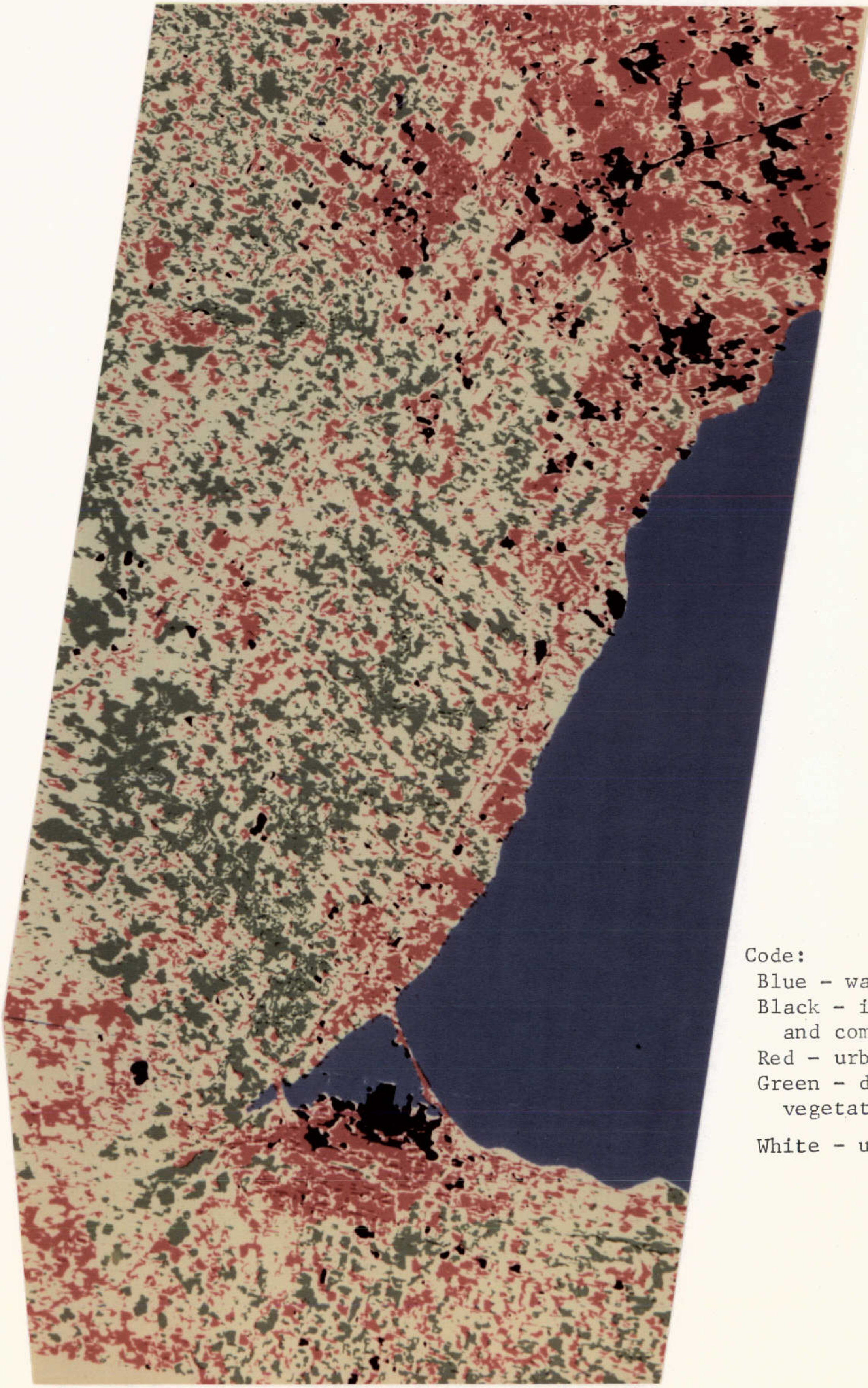
Preliminary analysis of the recognition results has concerned the western-most portion of the Basin, for which extensive ground observations and supporting aircraft imagery are available. Two color-coded composite recognition images for a 35 km by 65 km area between the Ontario cities of Hamilton and Toronto were prepared at a scale of approximately 1:300,000. This area includes the cities of Burlington, Oakville, Port Credit, and Brampton and the 21,000 hectare East and Middle Oakville Representative Basin. This latter area is the site of an IFYGL hydrological study by the Ontario Ministry of the Environment during the Field Year.

Figure 4 is a copy of a portion of a 1:250,000 scale map showing the Hamilton-Toronto portion of the Basin. This map may be compared with the composite color-coded recognition images shown in Figs. 5 and 6. Only six of the ten recognition classes are included. All recognition criteria were obtained from portions of the Basin more than 100 miles distant from this area.

Figure 5 shows the distribution of surface water, industrial and commercial areas, other urban areas, and dense green (mostly forested) areas. With the exception of the water, each of these classes is characterized by a different range of near IR/red ratio values. The highest ratio values are for the green vegetation and the lowest, for industrial and commercial ("impervious") urban areas. Included with the latter are limestone quarries and 8-12 lane highways which occur in Toronto. The non-industrial urban and unrecognized less-green vegetation (agricultural) areas represent intermediate ratio values. Not shown in this image are recognition misclassifications associated with the presences of clouds and cloud shadows in other portions of the Basin. Clouds have ratio values similar to industrial and commercial areas, although they can easily be delineated by level slices of ERTS Band 5. Cloud shadows have low values in both the visible and IR bands and there appears to be no way to distinguish these from "clean" water.

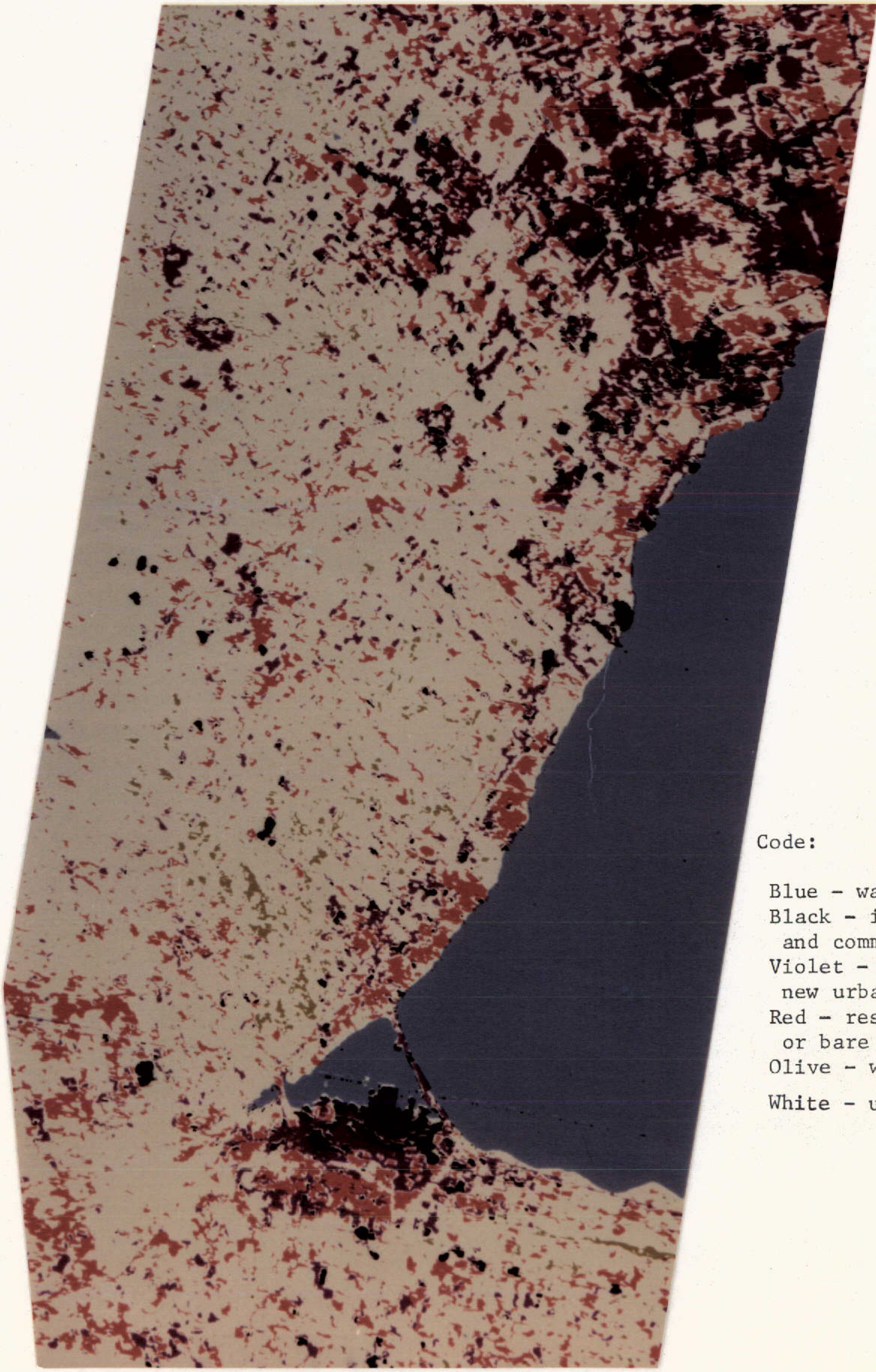
Figure 6 shows three classes of urban recognition based on the IR to red ratio. Both the water and industrial-commercial recognition are the same as the previous figure. The remaining urban areas are further discriminated on the basis of their IR/red ratio values - with the older residential areas having greater values than new residential and "dense" city-center commercial and residential areas. These latter two recognition categories are characterized by differences in vegetation density - the new residential and city-center areas having less green vegetation than the older residential areas. Indeed several older residential areas along the Lake Ontario shoreline are not recognized as urban due to the occurrence of many shade trees.

FIGURE 4. PORTION OF 1:250,000 SCALE MAP SHOWING AREA OF TERRAIN CLASS RECOGNITION IN FIGURES 6 AND 7.



Code:
Blue - water
Black - industrial and commercial
Red - urban and bare
Green - dense, green vegetation
White - unrecognized

FIGURE 5. TERRAIN CLASS RECOGNITION FOR THE HAMILTON-TORONTO AREA OF THE LAKE ONTARIO BASIN 21 AUGUST 1972.



Code:

Blue - water
Black - industrial and commercial
Violet - dense or new urban
Red - residential or bare
Olive - wetlands
White - unrecognized

FIGURE 6. IMPERVIOUS MATERIALS RECOGNITION FOR THE HAMILTON-TORONTO AREA OF THE LAKE ONTARIO BASIN 21 AUGUST 1972.

Figures 5 and 6 are intended to indicate the nature and degree of detail associated with high-speed computer processing. Although individual large building areas and highways are identifiable,considerable spatial detail has been lost due to limitations of the analog processing and playback system. Advances in special purpose computer development and data playback systems are likely to mitigate these limitations in the near future.

Large Area Surveys

In the arena of remote sensor applications, the Earth Resources Technology Satellite (ERTS-1) represents a "broad brush" approach to remote detection and mapping of earth resources. Its usefulness results not from a high degree of image detail nor from a spectral resolution which allows accurate identification of a great variety of terrain features. Other orbital and airborne sensor systems provide far greater spatial and spectral resolutions than ERTS. The main strength of ERTS is its ability to record and transmit terrain information from vast and remote areas - whole geographical regions and political states - in a short and repetitive period of time. A 10,000 sq. mile area (6.4 million acres) is imaged in 24 seconds by ERTS and the same area may be rescanned every 18 days. At the time of this report ERTS is in its 54th cycle of the earth, and after a year and a half is still obtaining data. Clearly a wealth of earth resources information is contained in remote sensor data of such frequent coverage of a large portion of the earth's surface. This abundance of ERTS data represents the principle challenge to ERTS data handling and processing systems. How may useful quantitative terrain information be extracted from large volumes of ERTS data in a timely and economical manner?

Traditionally, two methods are available for processing remote sensor data. One is to treat an ERTS image as essentially an aerial photograph and to rely on the patience and skill of an interpreter in identifying features or conditions of interest. This method sometimes employs the use of color to enhance the visual interpretability of the image. Color-additive viewers are often used for this purpose. The other method of ERTS data processing is to use sophisticated computer spectrum-matching techniques to automatically classify terrain elements. This method was developed for use with aircraft multispectral scanner data and provides objective and detailed information concerning the scene.

For several reasons neither of these two methods of data processing are necessarily optimum for use with ERTS data. The human interpreter, with or without color enhanced imagery, cannot begin to identify features on the basis of all of the spatial and spectral information contained in an ERTS frame. Large area trends can be noted and delineated by the interpreter but quantitative analysis is not practical. In contrast, automated spectrum-matching techniques do offer quantitative identification and tabulation of scene features on a pixel by pixel (1.1 acre) basis. The major problem with the computer-implemented analysis is that it is far too costly to be performed on a routine basis for all ERTS data of interest. The method was developed for experimental use with small quantities of high spatial and spectral resolution aircraft data. The common use of relatively slow general-purpose digital computers is not geared for handling large amounts of low resolution ERTS data.

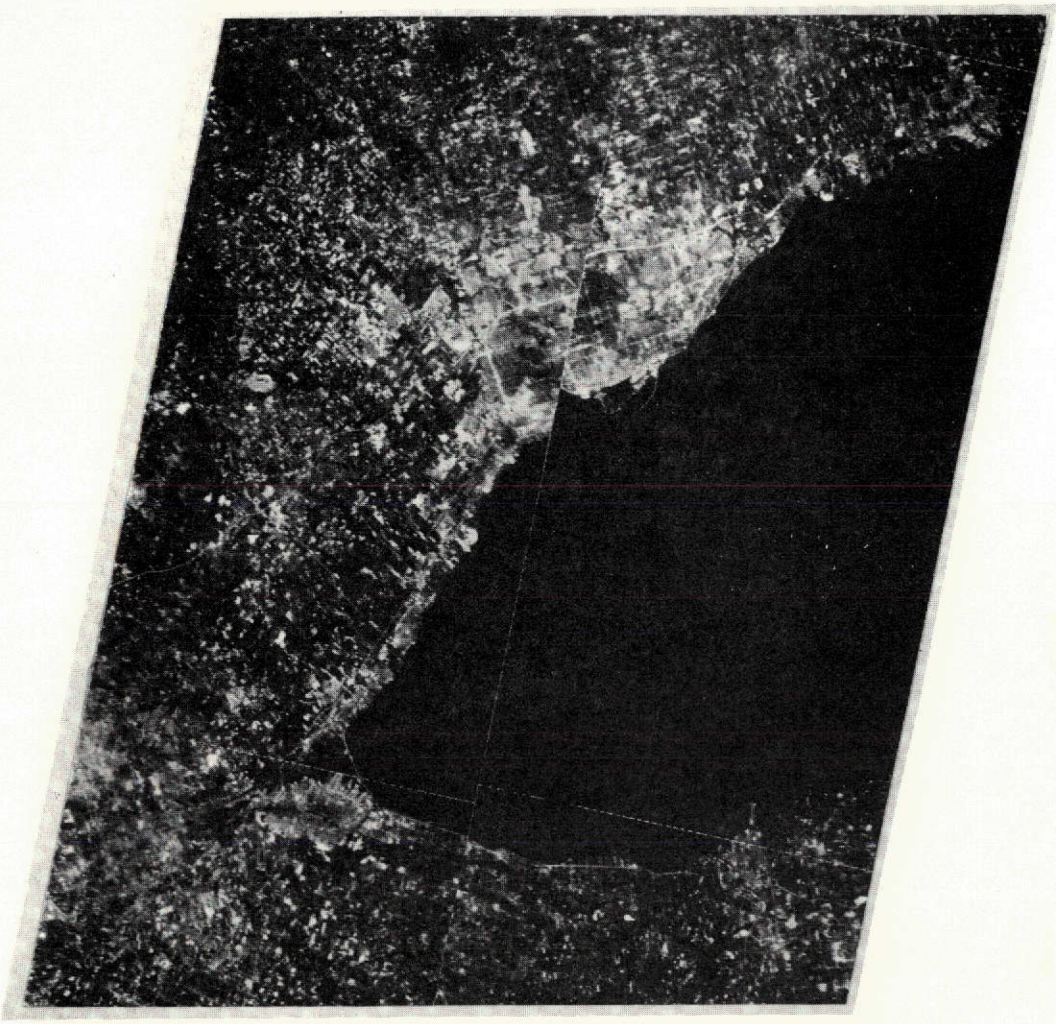
The middle path, intermediate in processing sophistication, offers an optimal approach for obtaining earth resources information from ERTS data. This method utilizes the image interpreter's knowledge of spatial and spectral properties of various terrain features and the machine's ability to detail and quantify information from an ERTS scene. It combines and uses two electronic techniques: level ("density") slicing or thresholding and (ratio) image enhancement. The middle path of ERTS data processing may be used to handle large volumes of data in a quantitative, but less sophisticated manner than through the use of spectrum matching techniques. It is economical owing to the fact that cumbersome and expensive general purpose digital computers are not required. The principle requirement is for analog or high-density digital tapes of ERTS-MSS data and a minimum of video data playback electronics. Included in the electronics should be capabilities for emphasizing subsets of the dynamic signal range of the data ("contrast stretching"); adding and dividing signals in two bands; and level slicing (or "thresholding") the output signals just prior to imaging on a cathode ray tube (CRT). Associated with the level slicing capability should be a digital counter to maintain a tally of the number of elements recorded.

Annotated examples of each of these capabilities are shown in Figs. 7 through 11 for a 100 km by 75 km portion of the western Lake Ontario Basin. Figure 7 shows a video image of ERTS Band 5 for this area. The most distinctive feature concerning this image is the light image tone associated with the non-water and non-vegetated portions of the Basin. Major highways, quarries, bare soil, and urban areas are all distinctively light in tone.

Figure 8 indicates some of the water quality information and detail available from ERTS data in the visible wavelengths. Scattering of green light (ERTS Band 4) by suspended solids within the lake is indicated by light patterns for the lake area. Current patterns as well as input sources of pollution are identifable in this image. For example the relatively great load of suspended solids contributed by the outfalls of the Welland Canal and barrier effect of the Niagara Plume are clearly indicated. In obtaining this image almost all land information has been lost.

Figure 9 shows a video image of ERTS Band 7 for this area. In this image water areas are uniformly dark and vegetation is variously indicated by light image tones. Urban areas and highways are intermediate in tone. A level slice of only the dark areas of this image is shown in Figure 10. All signal values below a preselected level have been printed out as white (black on the film negative). A digital tally of these water areas indicates that 24.8% of the scene (1670 sq miles) is surface water. This same procedure may be repeated for other image features which have unique signal ("image tone") ranges.

Figure 11 shows a ratio image of ERTS Bands 5 and 7. (Compare Figure 11 with Figures 7 and 9.) This ratio image shows heavy vegetation areas (forests and dense green crops) as light in tone. Both water and urban areas are quite dark. This image provides a better indication of vegetational density differences which occur over this area than any of the previous images. Indeed, the green forest areas are separable on the basis of tone and pattern from most of the agricultural areas.



WESTERN LAKE ONTARIO BASIN

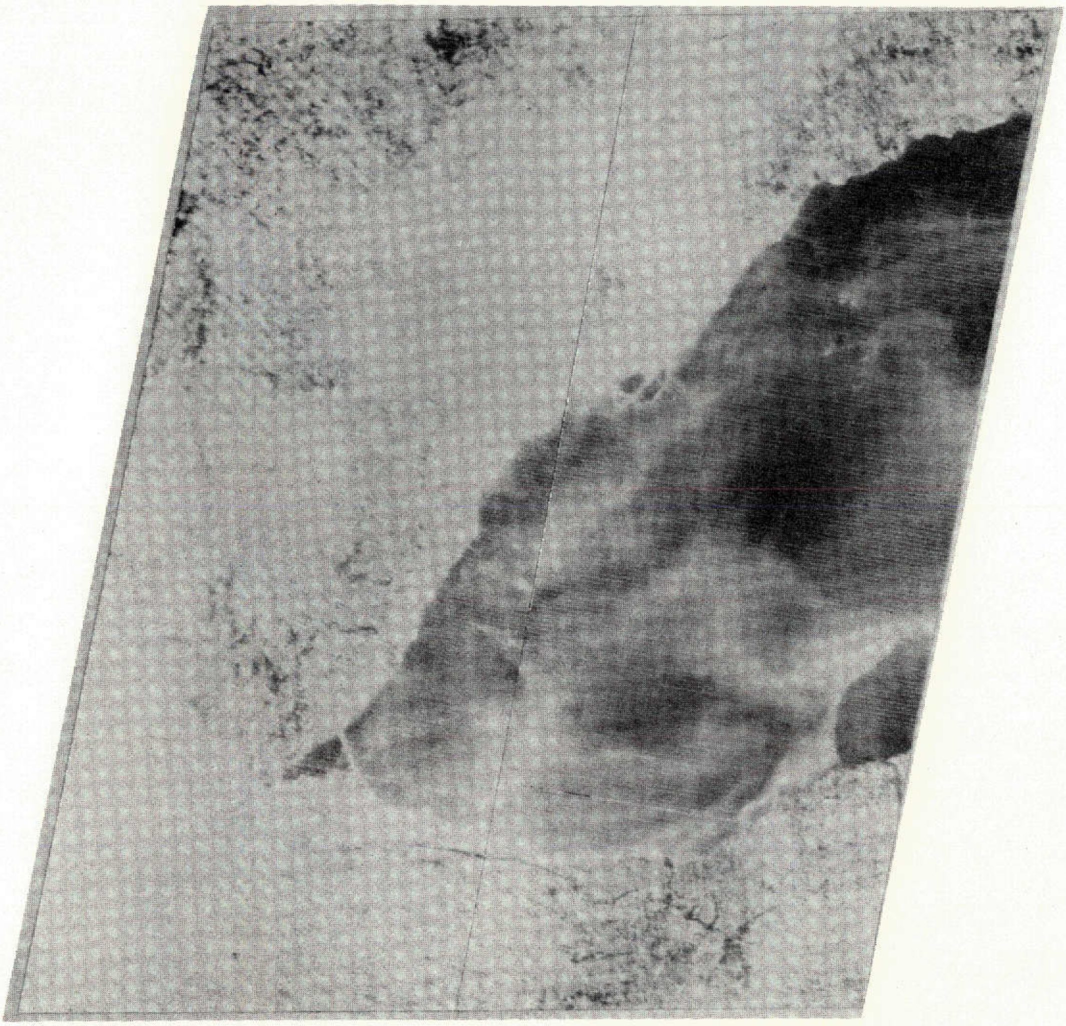
ERTS-1 0.6 - 0.7 μm

21 August 1972 - Frame 1029-15345

ERIM

IFYGL

FIGURE 7.



WESTERN LAKE ONTARIO BASIN

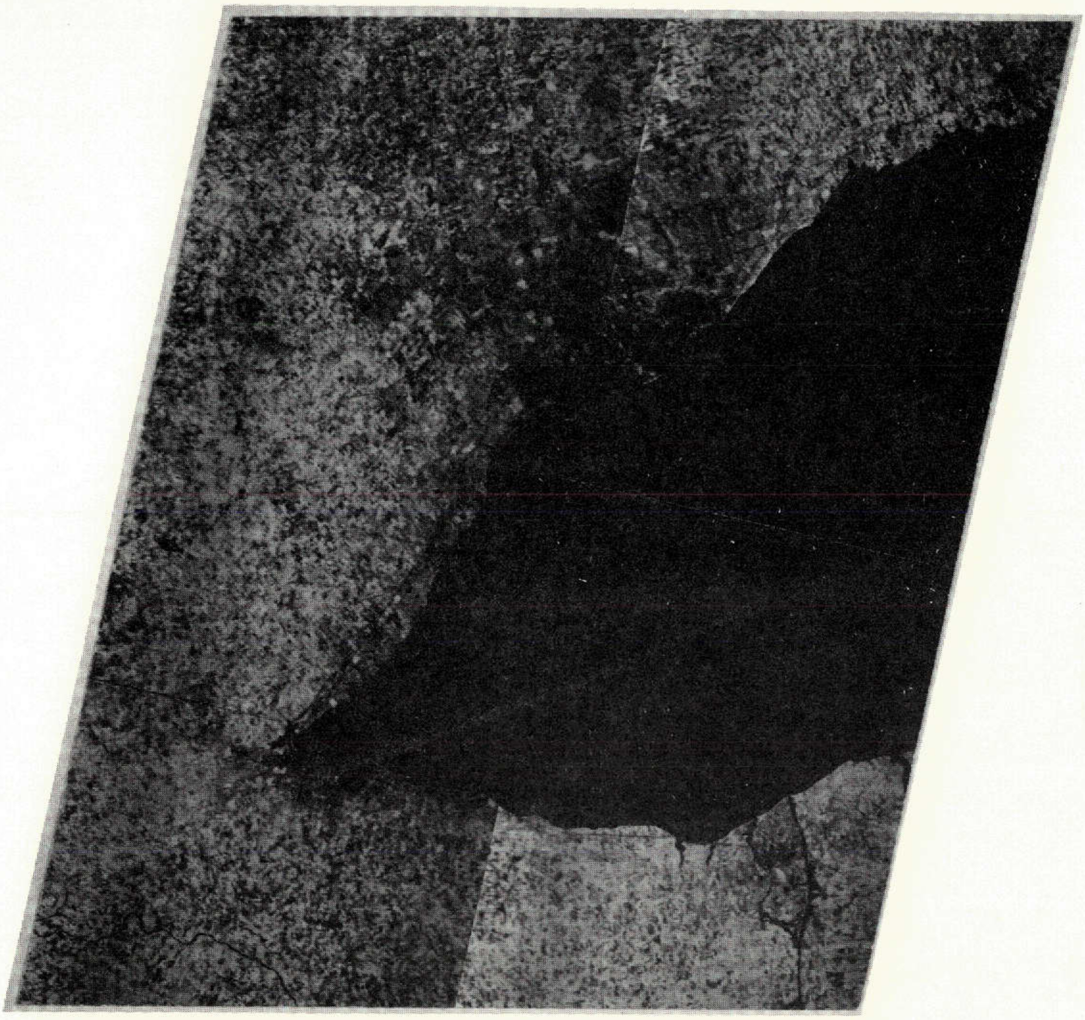
ERTS-1 0.5 - 0.6 μm

21 August 1972 - Frame 1029-15345

ERIM

IFYGL

FIGURE 8.



WESTERN LAKE ONTARIO BASIN

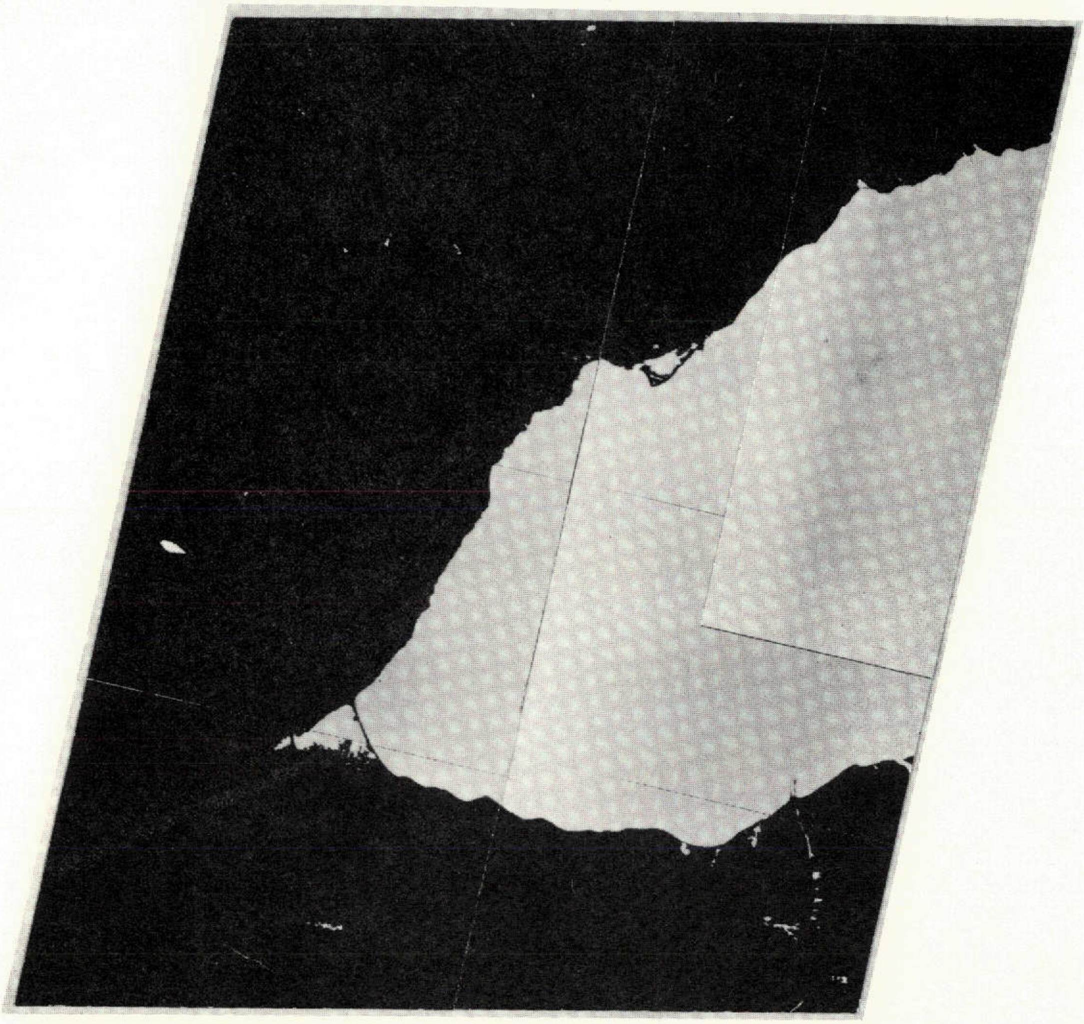
ERTS-1 0.8 - 1.1μm

21 August 1972 - Frame 1029-15345

ERIM

IFYGL

FIGURE 9.



WESTERN LAKE ONTARIO BASIN

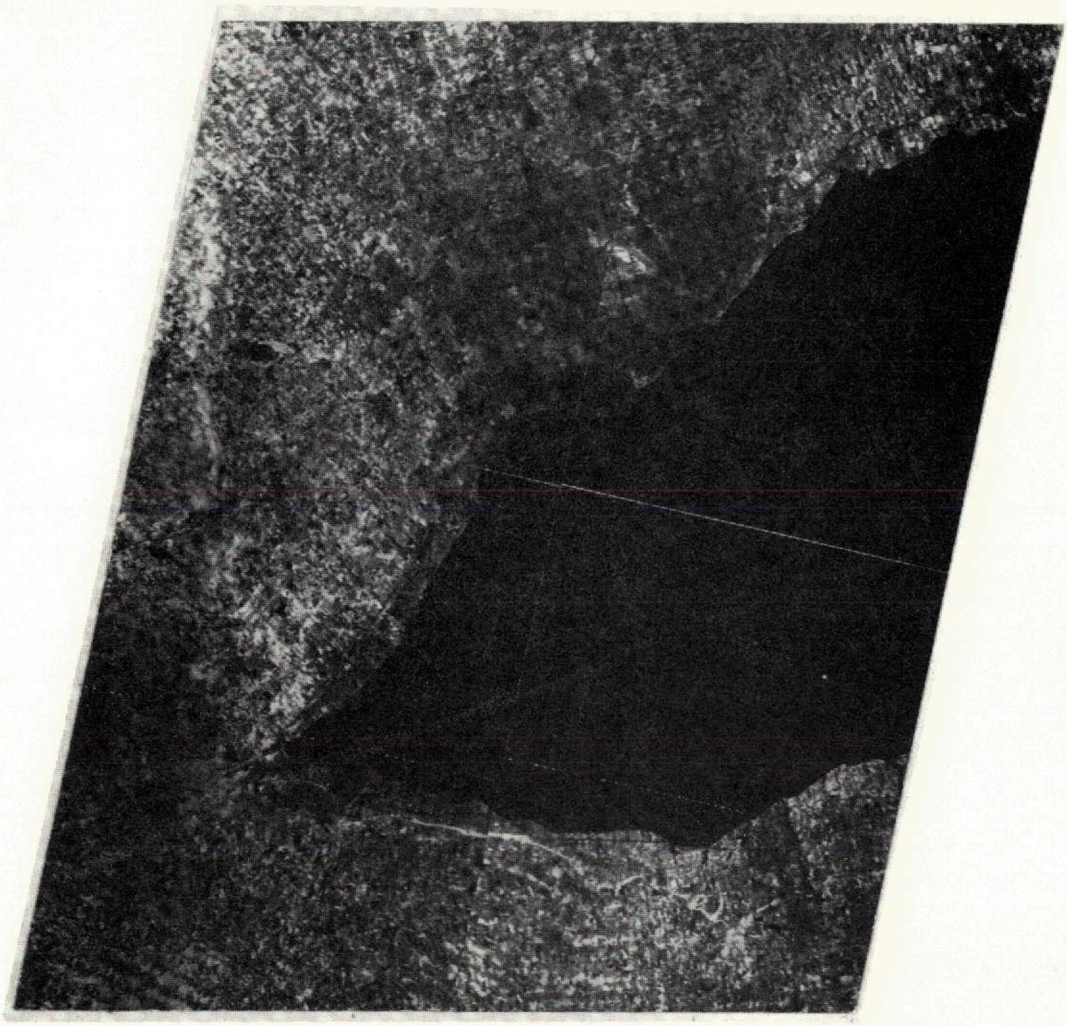
ERTS-1 Level Slice 0.8 - 1.1μm

21 August 1972 - Frame 1029-15345

ERIM

IFYGL

FIGURE 10.



WESTERN LAKE ONTARIO BASIN

ERTS-1 Ratio $\frac{0.8 - 1.1\,\mu m}{0.6 - 0.7\,\mu m}$

21 August 1972 - Frame 1029-15345

FIGURE 11.

ERTS data can provide generalized quantitative terrain information for large areas (10,000 square miles +) through a combination of simple (non-computer) electronic enhancement techniques and human image interpretation. Figure 12 is a schematic diagram, similar to Fig. 3, of the use of level-slicing with single and ratioed ERTS bands to obtain that information. The threshold levels and accuracy of the resulting imagery and statistics will vary with the spatial, spectral, and temporal quality of the ERTS data. This diagram shows generalized spectral relationships of these Lake Ontario data using vertical, horizontal, and radial lines to represent level slices of the visible, near IR, and IR/visible ratio bands, respectively. Needless to say, the environment is a spectral continuum and lines indicating the terrain features are somewhat arbitrary--depending upon the nature of the data and definitions of the categories. The significant point is that large amounts of ERTS data may be handled quickly, quantitatively, and inexpensively in this way. Other linear decision rules, such as the addition or subtraction of signals from two or more bands may also prove useful.

Significant Results

The significant results of this reporting period concern the nature of ERTS recognition for the Lake Ontario Basin. Using mean signature values of 12 terrain classes it was found that coefficients of correlation between ERTS Bands 4 and 5 and ERTS Bands 6 and 7 are 0.9589 and 0.9792, respectively. This fact suggests, but does not prove, that the most significant spectral differences occur between the visible and near IR bands. Ratio images of these bands tend to confirm this suggestion.

Recognition images of the Toronto-Hamilton portion of the basin were primarily based on ERTS Bands 7/5 ratio values. Three urban classes and dense green (mostly forest) vegetation were discriminated for the Basin.

From the above results it is concluded that relatively simple level ("density") slicing techniques may be effectively used for processing large amounts of ERTS data. The principle value of ERTS data is its large area and repetitive coverage; not its spatial or spectral resolution.

Major Problems

None

Publications

None

Recommendations

Availability of high-density digital or analog tapes may be essential for the operational use of ERTS data in large area surveys.

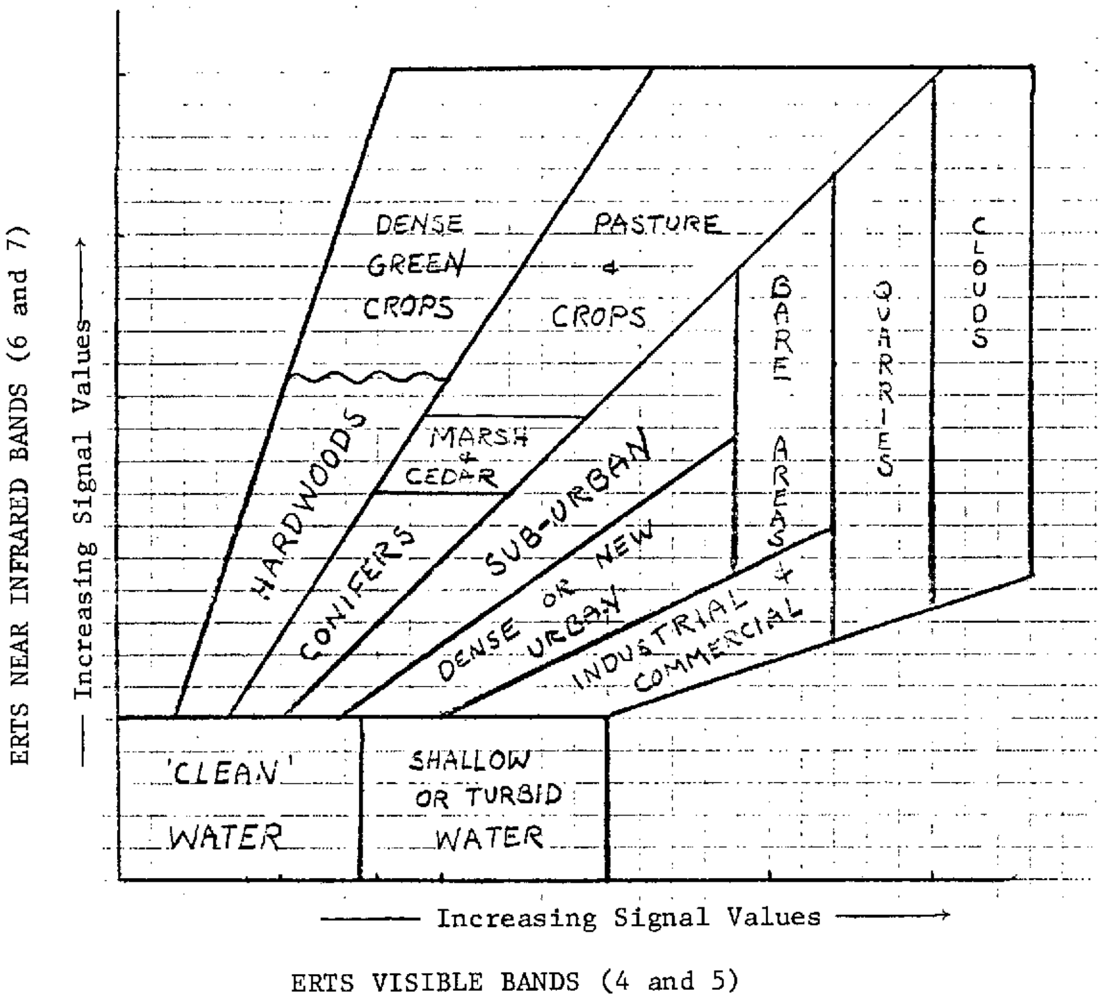


FIGURE 12. SCHEMATIC DIAGRAM SHOWING SPECTRAL RELATIONSHIPS BETWEEN TERRAIN CLASSES FOR THE LAKE ONTARIO BASIN IN AUGUST 1972. VERTICAL, HORIZONTAL, AND RADIAL LINES INDICATE LEVEL SLICES (THRESHOLDS) OF VISIBLE, NEAR IR, AND NEAR IR/VISIBLE RATIOS, RESPECTIVELY.

Eighth Type I Progress Report - 1 January 1974 to 28 February 1974
Task VII, Image Enhancement and Advanced Information Extraction Techniques - 1385
W. A. Malila - UN 612; R. F. Nalepka - UN 178, MMC 136

Introduction

Experience has been gained at ERIM over the past decade in computer processing and extraction of information from airborne multispectral scanner (MSS) data and in modeling atmospheric effects in received radiance signals. The general objective of Task VII is to adapt techniques existing at ERIM for their application to ERTS-1 data, to assess the applicability of these techniques by applying them to selected ERTS-1 data, and to identify any additional problems that might be associated with such processing of satellite multispectral scanner data. Three areas are to be studied: (1) compensation for atmospheric effects in ERTS-1 data, (2) preprocessing for improved recognition performance through signature extension, and (3) estimation of proportions of unresolved objects in individual resolution elements.

The intensive test site for this investigation is an agricultural area South-West of Lansing, Michigan, and the extensive test area also covers several other counties in South Central Michigan. A variety of agricultural crops and woodlots are in the intensive area. The primary crops are corn and wheat, with field beans, soybeans, and alfalfa also represented.

ERTS data were collected on 25 August 1972. Simultaneous multi-altitude underflight coverage was obtained by the Michigan C-47 multispectral scanner aircraft, and ground-based measurements were made of spectral irradiance and sky radiance. RB-57 camera coverage of the region was obtained during June and mid-September. Partial coverage was obtained in June 1973 on a second multispectral scanner mission; the site for the remaining lines was moved to the Willow Run Airport and simultaneous coverage was obtained in September 1973.

Progress and Plans

Preparations were begun for processing data with our proportion estimation algorithm to estimate the fractional composition of individual pixels. For most efficient application of the current version of the computer program on the available data sets, it will be desirable to rotate and deskew the ERTS data so rectangles can be used to define the test sections. In rotating and deskewing ERTS data, we compute a corrected grid and use a nearest-neighbor rule to place pixels on the new grid intersections. A scaling option also is available. The effect of these transformations is to cause shifts of up to half a pixel in locations. Shifts of such magnitudes are of no major consequence in field centers, but can be a problem along boundaries. We have prepared a data set which will allow us to assess the severity of the problem and display results graphically. A set of hypothetical fields of various sizes, used to illustrate pixel assignment procedures in earlier reports (Type II Progress Reports for Jan. - June 1973 and July - Dec. 1973) on this contract, is being rotated and deskewed, and scaled to several different scales (as displayed on a line printer map). Once the analysis of these data is completed, we will select a set of parameters and rotate the ERTS data and proceed with proportion-estimation processing.

Eighth Type I Progress Report - 1 January 1974 - 28 February 1974
Task VIII - Water Quality Monitoring - 1400
C. T. Wezernak, UN 625, MMC 081

Technical work in this program is largely complete except for the task of normalizing ERTS results (W. Lake Erie) for five scene dates in order to relate suspended solids concentration to CCT integer level on a common basis.

A portion of ERTS frame E-1048-15405 was processed to display a phytoplankton bloom in a section of Lake Erie. The digital processing and analytical work performed included "smoothing" of the data using procedures developed at ERIM, analysis of ratios MSS 5/ MSS 6 at selected areas, and preparation of a digital ratio map which delineates areas that contain high surface phytoplankton populations.

A final report outline is now being prepared. Work during the balance of the program will consist of report preparation.

Eighth Type I Progress Report, 1 January 1974 - 28 February 1974
Task IX - Oil Pollution Detection - 1389
R. Horvath - UN 606, MMC 079

During the reporting period, an extensive review of U. S. Coast Guard and EPA oil pollution report files was undertaken. The purpose of this review was to determine whether previously unknown coincidences of significant pollution events and ERTS data takes existed. It was found that clear-weather ERTS coverage appears to exist for a collision-induced oil slick off the California coast on 29 December 1973. Photographic and digital data products of the appropriate frame (1525-18151) have been ordered from NDPF.

It is anticipated that at least the photographic data products for the above frame will be received during the next bimonthly period. Analysis will commence upon arrival.

Eighth Type I Progress Report - 1 January 1974 to 28 February 1974
Task X - An ERTS Experiment for Mapping Iron Compounds - 1383
R. K. Vincent, UN 422, MMC 075

The past months have been spent analysing the results of our processing and evaluating our procedure. We hope to gain a great deal by comparing alternate methods of using the data in order to improve automatic recognition procedures. Consideration of the quality of our normalization value has been of prime importance, as good normalization assumptions are the keystone of recognition. A procedure different from that used in generation of the recognition map has been shown to improve the correlation between laboratory spectra and ratio values measured as voltages on the analog computer. Contrary to our assumption that the normalization area was devoid of vegetation as it appeared on aerial photos, ground truth information indicated that it was approximately 50% dried grass. This factor introduced a probable degree of error for our normalization procedure. Laboratory spectra of dead grass were mixed in equal parts with the spectra of limestone to calculate new ratio values for normalization. Voltage levels would, of course, be constant, but would represent a new type of target area having a different ratio. The resultant improvement (due to the new, more physically accurate, normalization) in correlation of the absolute values of ratioes from ERTS and laboratory spectra for iron-rich Triassic sediments was substantial.

Initial success with these studies led to one more iteration of ERTS -- laboratory comparison. Ground truth information indicated that there was little grass cover over the granite on which we trained. An estimate of 10% grass cover was given in the field notes. Therefore, 10% laboratory spectra of dead grass was mixed with 90% laboratory spectra of granite, the ratioes then compared to those calculated from analog computer values.

It must be noted that in processing, some small voltage values were added to the denominator channel due to the characteristics of the computer. These values add errors to our results for which there are no recoverable values for calculating experimental error. The voltages differ from ratio to ratio. Although it is not clear when these additive factors are significant to your data, when one ratio is consistently different for all materials its absolute values are suspect. Unfortunately, the ratio in which this effect seems to be the largest is MSS Channel 7/Channel 4. It is here that the denominator is sometimes so small in relation to the numerator that the analog computer could not handle it. With improvement in selection of voltage cut-off values, this error can be avoided in future studies.

Ratio image MSS Channel 5/Channel 4 showed unique enhancement of considerable interest and therefore, an independent study of this ratio was performed. Voltage level slices were taken in the highest voltage regions to recognize only those materials with high ratioes. Triassic redbeds were recognized as unique in the scene and their outline corresponds very well with those outcrops mapped on the geologic map. Some slices showed recognition of other areas in the scene which have relatively high ratioes and may correspond to a smaller, but significant, percentage of iron-oxide present. These areas are often associated with oil-bearing locations, due to the exposure of Triassic:

or other redbed formations in structural domes. Other areas of recognition are of regular shape and may be of interest for further oil and mineral exploration. Although spatial resolution may be restrictive, it is thought that the level of iron-oxide content being detected with this single ratio may be on the order of those levels present in alteration products associated with uranium and other mineral deposits. Resources for determining this precisely are not available to us under this study.

In summary, the final report is in preparation. However, features of particular interest are being scrutinized so that their full benefit can be realized, both in terms of geologic results and processing improvement.