Applications of Remote Sensing to Soils, Land Use, Urban Areas, and Surface Hydrology in Iraq

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APPLICATIONS OF REMOTE SENSING TO SOILS, LAND USE, URBAN AREAS, AND SURFACE HYDROLOGY IN IRAQ

I. INTRODUCTION

My six months visit to the Laboratory for Applications of Remote Sensing (LARS) at Purdue University (February-July 1976) was in accordance with the agreement between the State Organization of Minerals in Iraq and LARS at Purdue University for training six Iraqi scientists in the applications of computer-assisted techniques in analyzing remote sensor data for mapping Iraq's natural resources.

The six Iraqi scientists who participated in this program included three geologists, a soil scientist, a forester, and a computer scientist.

Three objectives were stated in the agreement:

1. To train six Iraqi scientists in the applications of computer-aided analysis of LANDSAT multispectral data.
2. To aid the Iraqi scientists in the analysis of two frames of LANDSAT data over Iraq.
3. To provide technical assistance to Iraq in the implementation of a program of computer-aided analysis of LANDSAT data.

To fulfill the above objectives for soil delineation, land use, urban classification and surface hydrology phases, I did the following:

1. I got acquainted with the LARSYS system through reading references, studying a series of minicourses, and studying the LARSYS educational package which is composed of seven units:

    a. Unit I - orientation to remote sensing technology, principles and pattern recognition.
    b. Unit II - summary of LARSYS data analysis capabilities and limitations.
    c. Unit III - orientation to terminal hardware and terminal procedures.
    d. Unit IV - experiences in punching and transmitting cards, receiving punched and printer output, and running a LARSYS program when given the control card listings.

e. Unit V - practice in using the terminal writing and executing LARSYS program.

f. Unit VI - analysis of a detailed example and a case study in classifying field crops using aircraft data from the state of Indiana.

g. A case study using LARSYS for analysis of LANDSAT data.

2. I did research on soil delineation, land use, urban classification, and surface hydrology on a Baghdad frame and part of the Duhok frame at the Zakho area.

3. I attended the National Soil Erosion Conference which was held at Purdue University from 24-26 May 1976.

4. I attended the Symposium on Machine Processing of Remotely Sensed Data which, also, was held at Purdue University from 29 June-1 July 1976.

5. I visited ERIM once and BENDIX twice in Michigan to be acquainted with their systems of remote sensing technology.

6. I made many field trips with some soil scientists of Indiana for application and correlation of remotely sensed data with field condition data.

7. I attended many seminars and group discussions on the applications of remote sensing.

8. As a result of the above activities, I have been encouraged to submit two papers to the American Society of Agronomy, one to the Agronomic Division entitled: "Land Use Inventory of Baghdad Area by Digital Analysis of Landsat Data" and the second one to the Soil Science Division entitled: "Delineating Soil Boundaries in Iraq by Digital Analysis of Landsat Data."

My stay at LARS was very fruitful. I sincerely thank all LARS staff who made such an accomplishment possible in such a short time.

II. STAGES OF PROGRAM FULFILLMENT

To fulfill the objectives for soil delineation, land use, urban classification and surface hydrology phases, I did the following:

1. I became acquainted with the LARSYS system through reading references and through the LARSYS Educational package.

The LARSYS Educational package is a set of instructional materials developed to train users to analyze remotely sensed multispectral data using LARSYS, a computer software system developed at LARS/Purdue University.

Each unit of the LARSYS Educational package is designed to take a user from an initial point, defined by its objectives. Each unit provides informational materials, an opportunity for the userto practice and study the skills or ideas presented, and a problem or test situation to help him determine whether he has met the objectives of that unit.

The LARSYS Educational package consists of seven Units:

a. Unit I - entitled "An Introduction to Quantitative Remote Sensing." This is an introduction to remote sensing stressing the role of pattern recognition in numerically-oriented remote sensing systems. Its specific purpose is to provide a common background and orientation for the LARSYS computer software system. For new users, this manual introduces concepts and terminology which are needed later on.

b. Unit II - This unit entitled "LARSYS Software System" is an overview which consists of a recorded tape that accompanies a display book and user notes. It takes the viewer through a typical remote sensing data analysis sequence and illustrates the commonly used features of the LARSYS processing function.

c. Unit III - This unit entitled "Demonstration of LARSYS on the 2780 Remote Terminal" provides the user with an introduction to the data processing hardware that he will be using and introduces him to some additional aspects of the LARSYS software system. Instructor's notes have been designed so that persons with only a modest amount of experience with the terminal can satisfactorily run the demonstration.

d. Unit IV - This unit, entitled "The 2780 Remote Terminal: A Hands-on Experience," gives the user an experience in transmitting cards, receiving punched and printer output, and running a LARSYS program when given the control card listings.

e. Unit V - Unit V is composed of many short problems which the user solves by using the computer terminal and LARSYS processing functions. The purpose of these problems is to increase the user's experience in the use of LARSYS for multispectral data analysis and to help him develop an appreciation for the capabilities and limitations of the LARSYS software system.

f. Unit VI - This unit entitled "Guide to Multispectral Data Analysis Using LARSYS" (with accompanying example and case study) is geared toward a supervised analysis approach in analysis of a detailed example and a case study using aircraft data.

g. Unit VII - This unit is entitled "A Case Study Using LARSYS for Analysis of LANDSAT Data." It combines techniques from both supervised and unsupervised approaches and applies these techniques to data collected by the Earth Resources Technology Satellite, now known as LANDSAT. This unit was very helpful during the analysis of two frames over Iraq.

Several units of a minicourse series with the recorded tapes and visual aids were studied. The content of the series is briefly outlined below.

(1) Definition and explanation of remote sensing. The objectives of this minicourse are to define remote sensing, identify the two main components of the remote sensing process, to learn the three kinds of variations in field strength that make remote sensing possible, and cite examples of remote sensing systems based on:

°Electromagnetic field variations
°Force field variations
°Acoustic field variations

also, to learn about the two systems of remote sensing, the active and the passive.

(2) Electromagnetic spectrum, solar radiation, and atmospheric windows. The objectives of this minicourse are:

(a) to identify the wavelength ranges for

°the optical portion of the spectrum
°the visible band
°the near, middle and far infrared bands
°the ultraviolet band
°the reflective portion of the spectrum
°the emissive portion of the spectrum

and also to identify the wavelength ranges of photographic sensors and the optical-mechanical scanners.

(b) to define the term "atmospheric window" and to identify the atmospheric windows that are useful in remote sensing application.

(c) to qualitatively describe how the spectrum would change if the temperature were increased or decreased (given the spectrum of a 300° K black body).

(3) Photographic remote sensing systems. The objectives are:

(a) to be able to, when given the transmission characteristics of an optical filter, identify it as a high pass, low pass, or band pass filter.

(b) to know the two most common types of black and white film used in remote sensing systems and state the spectral band in which they are sensitive.

(c) to describe how films and filters are combined to form a multiband remote sensing data collecting system.

(4) Interpretation of color infrared photos. The objectives are:

(a) to know the advantages and limitations of color infrared film.

(b) to know the characteristics of color infrared film.

(c) to be able to interpret color infrared film.
(d) to know the importance of color infrared film.

(5) Optical-mechanical scanners. The objectives are:

(a) to describe optical-mechanical scanner systems.
(b) to identify scanning system parameters.
(c) to describe typical scanner configurations.
(d) to describe examples of scanner data.

(6) Interrelation of multispectral scanner data. The objectives are:

(a) to describe the process used to generate an image from multispectral scanner numerical data.

(b) to use spectral and spatial information to identify major ground cover type.

(c) to identify a field of bare soil in day and night by thermal imagery.

(7) Radar systems. The objectives are:

(a) to know the advantages of radar sensors.
(b) to know radar parameters.
(c) to produce the radar image.

(8) Satellite systems: ERTS and SKYLAB. The objective is to become acquainted with orbit, sensors, data characteristics, data flow of these satellite systems.

(9) Mission planning—considerations and requirements. The objectives are:

(a) to know why user needs to define his information needs.

(b) to be acquainted with the primary altitudes from which remote sensing data is collected and to be able to describe the characteristics of the data collected from these altitudes.

(c) to learn about the importance of reference data to support analysis tasks.

(d) to know the reasons for variations in spectral response of vegetative and soil situations.

(10) Spectral reflectance characteristics of vegetation. The objectives are:

(a) to define the three energy-matter interactions that may take place when energy in the reflective portion of the spectrum strikes a leaf.

(b) to define the approximate wavelength (in μm) where chlorophyll absorption dominates and where the yellow and red leaf pigments absorb energy.

(c) to identify the approximate spectral location of the five primary absorption bands, found in green vegetation between 0.4 and 2.6μm wavelength, and to describe the cause of absorption at each of these wavelengths.

(d) to be able to state the relationship between moisture content and leaf reflectance in the middle infrared wavelength.

(11) Spectral characteristics of earth surface features. The objectives are:

(a) to know the major factors influencing the amount of reflectance from surface soil.

(b) to know the relationship between reflectance and moisture content in soils.

(c) to be able to sketch the approximate shape of the reflectance curves for clear and turbid water.

(d) to be acquainted with the relative spectral response for vegetation, soil, and water in the visible, near infrared, and middle infrared wavelengths.

(12) Pattern recognition for remote sensing. The objectives are:

(a) to know how a "data vector" is formed from the responses of multispectral scanners.

(b) to draw decision boundaries between distinctly separable sets of training samples.

(c) to classify an unknown data vector when the decision boundaries are given.

(d) to describe the differences between supervised and unsupervised classification procedures.

2. Acquaintance with LARS Computational Facilities Stage.

a. Products and Services Available.

(1) Computer Services
(2) Reformatting Services
(3) LARSYS Products
(4) Operational Procedures

b. Hardware, Software, and Data
c. Documentation
d. How to Use the Computer

(1) Operating Terminal
(2) Punching and Reading Cards
(3) Receiving Output
(4) Running Batch Jobs

e. LARSYS Software System
f. LARSYS Hardware System

3. Introduction to Multispectral Data Analysis Using LARSYS with Analysis of Case Study which include:

a. Examination of Data Quality
b. Coordination of Imagery and Ground Observations
c. Selection of Candidate Training Samples
d. Refinement of Training Fields and Classes
e. Obtaining Statistical Characteristics of the Training Samples
f. Feature Selection
g. Classification

The case study performed was on field crops in Indiana, using aircraft data.

4. Soils delineation, land use, urban classification, and surface water hydrology of the Baghdad frame and part of Duhok frame near Zakho.

a. Objective. The main objective of the study is to demonstrate the feasibility of remote sensing application to these fields of interest.

b. Brief description of areas studied. The Baghdad frame region is located in the middle of Iraq, mostly in the floodplain of the Tigris and Euphrates valley, Tigris and Euphrates Terraces, Alluvial fan, and part of the Western Desert.

Soils of this frame belong to the following Great Soil Groups: Gypsiorthids, Petrogypric Gypsiorthids, Lithic Gypsiorthids, Quartzipsamments, Torrifluvents, orriorthints, Torrerts, and Salorthids. Some parts of the frame are waterlogged and marsh areas.

The Baghdad region is characterized by long, dry, hot summers and rather short, cool winters. The variation in temperature among seasons and between day and night is great. Rainfall occurs in winter, but only small amounts, and agriculture is impossible without irrigation.

Natural vegetation is sparse as a result of extreme dryness of air, high rate of evaporation, low rainfall and high temperature. The already sparsely developed natural cover has been largely reduced, due to over-grazing, cutting and mismanagement.

Mixed orchards and various field crops are grown near the rivers and in irrigated projects.

The Duhok frame is located in the North of Iraq. The studied area (Zakho Area) is part of it.

The area is composed of mountains and intermountain valley.

The climate of this region is characterized by cool, moist winters and mild, dry summers. The diurnal and seasonal temperature variations are less here than in the rest of the country.

Most soils of the Zakho area belong to vertisols, entisols, inceptisols, lithosols, and regosols.

Orchards and summer field crops are possible only with irrigation.

c. Data and Materials. Multispectral scanner data, collected by LANDSAT-1 from two areas in Iraq, were used for this research. One area (185 x 185 km) in the middle of Iraq includes Baghdad, and the other area in the north of Iraq includes Zakho.

The data of the area in the middle of Iraq were collected on December 26, 1972. The data of the area in the North were collected on July 14, 1973.

Both of the above frames were geometrically corrected (Anuta, 1973) before processing.

Other data available were:

(1) Soils and Soil Association map of Iraq at scale 1:1,000,000 (2) Aerial photographs at scale of 1:35,000 for some areas, (3) topographical maps for some areas at scale of 1:20,000 (4) false color image scale of 1:250,000 of the two runs, (5) Baghdad map at scale of 1:30,000 (6) black and white photo-image at scale of 1:1,000,000 and (7) Iraq photographic mosaic of LANDSAT images which was prepared by the Earth Satellite Corporation photographic laboratory (Figures 1, 2, 3 and 4).

III. PROCEDURES

The general procedures for processing the data are:

1. Selection of training areas
2. Clustering
3. Cluster class identification
4. Separability
5. Pool and merge statistics
6. Classification and evaluation

The above general procedures involve:

(a) Definition of a group of spectral classes (training classes);

(b) Specifying these to a statistical algorithm which calculates defined statistical parameters;

(c) Utilizing the calculated statistics to train a pattern recognition algorithm;

(d) Classifying each data point within the data set of interest (such as entire LANDSAT frame) into one of the training classes, and finally,

(e) Displaying the classification results in map or other forms.

However, many refinements to that general procedure have been developed at LARS during the past few years, especially in step (a) where the most common techniques for defining training classes involve the "supervised" and the "non-supervised" (clustering) approaches.

Figure 1. Soils and Soil Association Map of Iraq (After Altaie, 1968). Outlined area corresponds to Baghdad frame studied.

Figure 2. Simulated color infrared composite (bands 4,5, and 7).

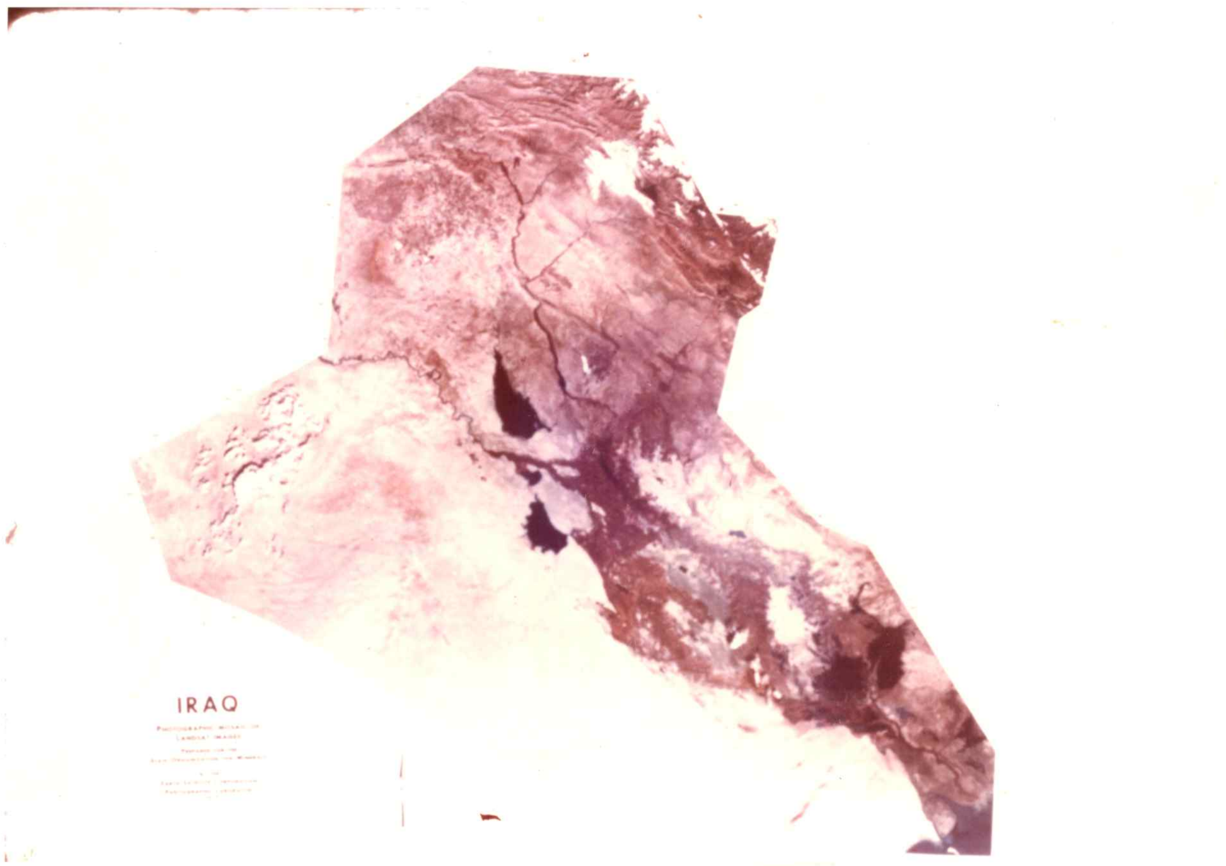


Figure 3. Iraq Photographic Mosaic of LANDSAT Images.

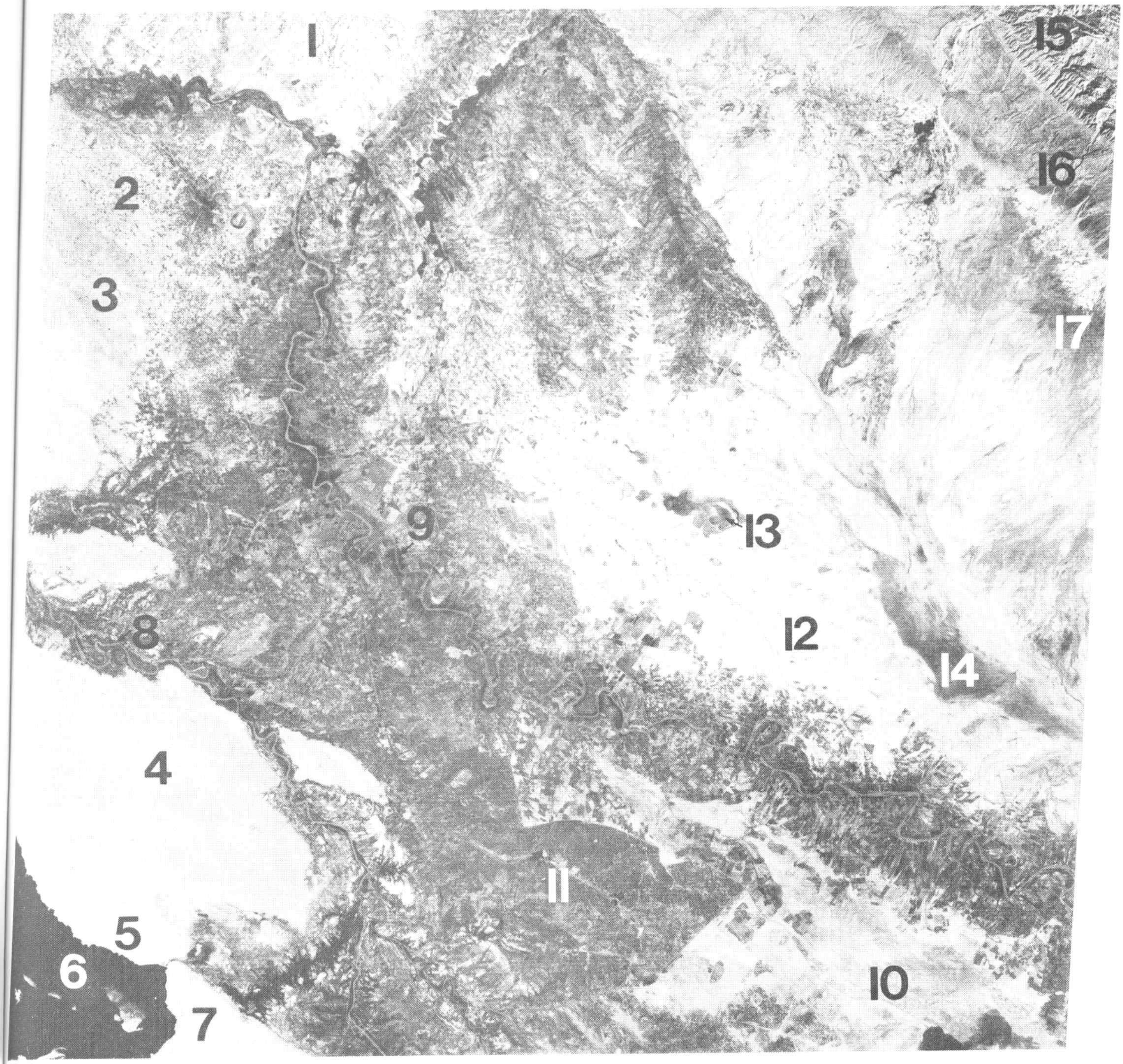


Figure 4 - shows the band 5 (.6-.7 micrometers) image of Baghdad Frame collected 26 December 1972.

1. Lower Tigris Terrace (Salorthids)
2. Middle Tigris Terrace (Tarrifluents)
3. Higher Tigris Terrace (Gypsiorthids)
4. Lithic gypsiorthids
5. Gypsiorthids
6. Razzaza Lake
7. Quartzipsamments
8. Euphrates River
9. Tigris River
10. Fallow land
11. Irrigated land (Torrifluents, Torriorthents, Torrerts)
12. Fallow land (Salorthids)
13. Marsh land
14. Saline & waterlogged soils
15. Lithic calciorthids, severely eroded
16. Lithic calciorthids
17. Fan soils (Torrifluents)

In the "supervised" approach, the analyst selects areas of known cover types (whether crop, soil, water or others) and specifies these to the computer as training fields, using a system of x-y coordinates. The statistics are obtained for each cover type category. The data are then classified, and the results evaluated. Because the analyst has defined specific areas of known cover types for computer training, such classifications are referred to as "supervised." This method is fine if (1) the analyst has good ground truth, and (2) the objects classified are homogeneous for extended areas.

The second method uses a clustering algorithm which divides the entire training area into a number of spectrally distinct classes. The analyst can specify the number of spectral classes into which the data will be divided if he has a good knowledge of the area. The spectral classes defined by the clustering algorithm are then used to classify the data, but at this point the analyst may or may not know what cover type is defined by each of the spectral classes. Normally, after the classification is completed, the analyst will identify the cover type represented by each spectral class by using available support data, such as a land use map, soil map, etc. Because the analyst need not define particular portions of the data for use as training fields, but must only specify the number of spectral classes into which the data are to be divided, a classification using this procedure is call "non-supervised."

Additionally, two variations of these basic methods for defining training classes have been developed. One is to select training areas of known cover type (a supervised approach up to this point), but then utilize the clustering algorithm to refine the data into a number of unimodal spectral classes for each cover type. This method is referred to as a "modified-supervised" approach (Fleming, 1975). The second variation involves designating small blocks of data (30-60 lines by 40-60 columns) to the clustering algorithm and then identifying each spectral class within these small "cluster training areas." The statistics for the desired information classes are then formulated by combining spectral classes from the several cluster training areas. This last method is called the "modified non-supervised" or "modified-clustering" approach. This last method appeared to be the best to use for the following reasons:

(1) Not enough ground observations available for the areas studied.

(2) The variation in a very short distance of the surface features studied.

(3) The Baghdad frame data was obtained at a very unfavorable time, i.e., in mid-December when vegetation cover is just started and when soils are moist in general.

The modified unsupervised (modified clustering) approach which I followed in my analysis is comprised of four basic steps including:

1. Defining training areas dispersed over the entire study site, with three to five cover types present in each training area (Appendix A);
2. Eigenclustering* each training area separately, comparing map with supporting data, and reclustering if necessary (Appendix B);
3. Combining the results of training areas, using the XSEPARABILITY** algorithms, and developing a single set of training statistics (Appendix C);
4. Classifying the training areas as a preliminary test of training statistics, modifying statistics deck if necessary, and classifying the entire study region (Appendix D).

---

*Clustering is a data analysis technique by which one attempts to determine the "natural" or inherent relationships in a set of observations or data points.

Eigencluster has a different method of initializing the iterative clustering algorithm. This method takes into account the direction in which the major "spread" of the data lies.

The covariance matrix for all the data to be clustered is calculated; and its largest eigenvalue and the corresponding eigenvector are found. The initial cluster centers are then placed along the line defined by the mean of all the samples and the principal eigenvector. The largest eigenvalue is used as a measure of the variance of the data along this line and determines the distance between the initial cluster centers.

The method has been developed to handle some cases where the regular LARSYS clustering algorithm had some difficulty; in particular when the data is negatively correlated in two or more features.

**The SEPARABILITY processing function calculated statistical distances between pairs of classes. These distances are used to determine how to combine cluster classes from different cluster areas to form training samples for information classes.

The XSEPARABILITY (modified SEPARABILITY) has an additional output which is not available in the regular LARSYS SEPARABILITY processor. This is a "class grouping table" which is produced from a systematic grouping algorithm (Davis and Swain, 1974) which seeks to minimize the number of groups while ensuring that no dissimilar classes are placed in the same group.

Because of the limitation of computer time I had to classify a large area of Baghdad frame every fourth line and fourth column. However, in test areas I classified every second line and second column and every line and column to see if the 1:100,000 scale map loses detail compared to 1:50,000 and 1:25,000 scale maps.

The detailed procedure followed in this study is:

1. Selection of training areas.

The basic goal for selecting training areas is to obtain representative samples of all spectral classes present in the study area. To do this, a representative sample of each cover type, soil type, water type, and urban units must be included in at least one but preferably two training areas.

The training areas selected were between 5-10% of the total area studied depending on the complexity of the areas studied.

After candidate training areas were selected, their coordinates were specified in terms of lines and columns as follows:

Training Area #1.	Lines (975, 1050)	Columns (400, 500)
Training Area #2.	Lines (975, 1050)	Columns (820, 920)
Training Area #3.	Lines (975, 1050)	Columns (1100, 1200)
Training Area #4.	Lines (1134, 1200)	Columns (475, 575)
Training Area #5.	Lines (1090, 1165)	Columns (915, 1015)
Training Area #6.	Lines (1153, 1228)	Columns (1540, 1640)
Training Area #7.	Lines (1425, 1500)	Columns (552, 622)
Training Area #8.	Lines (1443, 1518)	Columns (1012, 1112)

(See Appendix A)

2. Eigenclustering of training areas.

The MSS data for each training area were Eigenclustered into a number of spectral classes, independent of all other areas. In this manner, a greater number of spectral classes were obtained and the amount of computer time reduced (as compared to clustering all training areas together). There was some duplication of spectral classes when clustering was done independently. However, with merging statistics and XSEPARABILITY in the subsequent stages, these duplicated cluster classes were combined. Each training area was clustered into 6-10 classes, depending on the complexity of the area. Each spectral class resulting from eigenclustering was interpreted utilizing general knowledge of the area, aerial photographs when available, general soils and soil association map of Iraq, and a map of Baghdad city, but initially, I depended on the modes of graphs of mean spectral response vs. wavelength for each cluster class (Figures 5, 6, 7, 8, 9 and Appendix E) and also the ratio of visible wavelength and the near infrared wavelengths (Table 1).

The control cards to obtain the ratios were:

```
*RATIO
FROM CARDS
PRINT
OPTION VIS(1,2), IR(3,4)
DATA
  (Statistic deck of each spectral class)
END
```

3. Combining the cluster classes resulting from eigenclustering the training areas.

Merging the statistics decks and running the XSEPARABILITY algorithm can be done in one job if the number of classes does not exceed 60.

The control cards used for this step were:

```
BATCH  ID  IRAQ  FLAYEH
BATCH  OUTPUT  FLEXLAB1  FLEXLAB1
I  LARSYSXP
*MERGE
CLASSES ENTIRE (1,2,3,4,5)
PUNCH
DATA
  (The 5 statistics decks)
END
- COMMENT SEPARABILITY OF CLASSES IN ALL TRAINING AREAS OF
  BAGHDAD CITY.
*XSEP
COMBINATION 4
SYMBOLS A, B, C, D, E, F, G, H, I, J, K, L, M, N, O, P
SYMBOLS Q, R, W, T, U, V, W, X, Y, Z, $, =, +, /, -
SYMBOLS A, B, C, D, E, F, G, H, I, J, K, L, M, N, O
SYMBOLS P. Q. R. S. T. U, V, W, X, Y, Z
PRINT  DIV(1500)
END
```

XSEPARABILITY is calculated for all spectral classes to provide information on which ones are similar enough to be combined. The combined spectral classes are then identified and named, and consequently called spectral information classes.

4. Classification

As a final check before classifying the entire study area, the training areas were classified. The classification results were then compared with the support data to make sure no errors

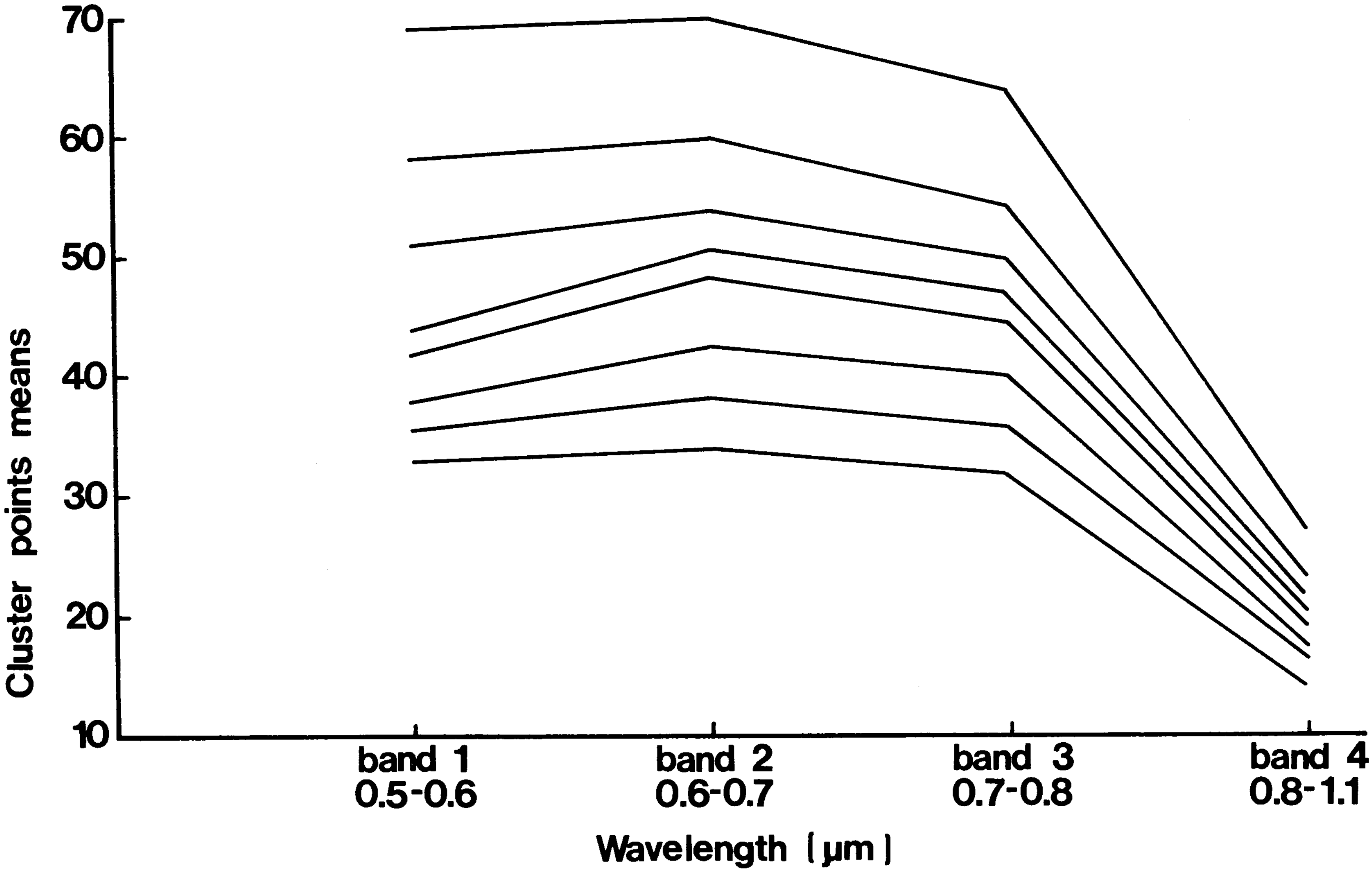


Figure 5 - Graphs of cluster classes of various soil types.

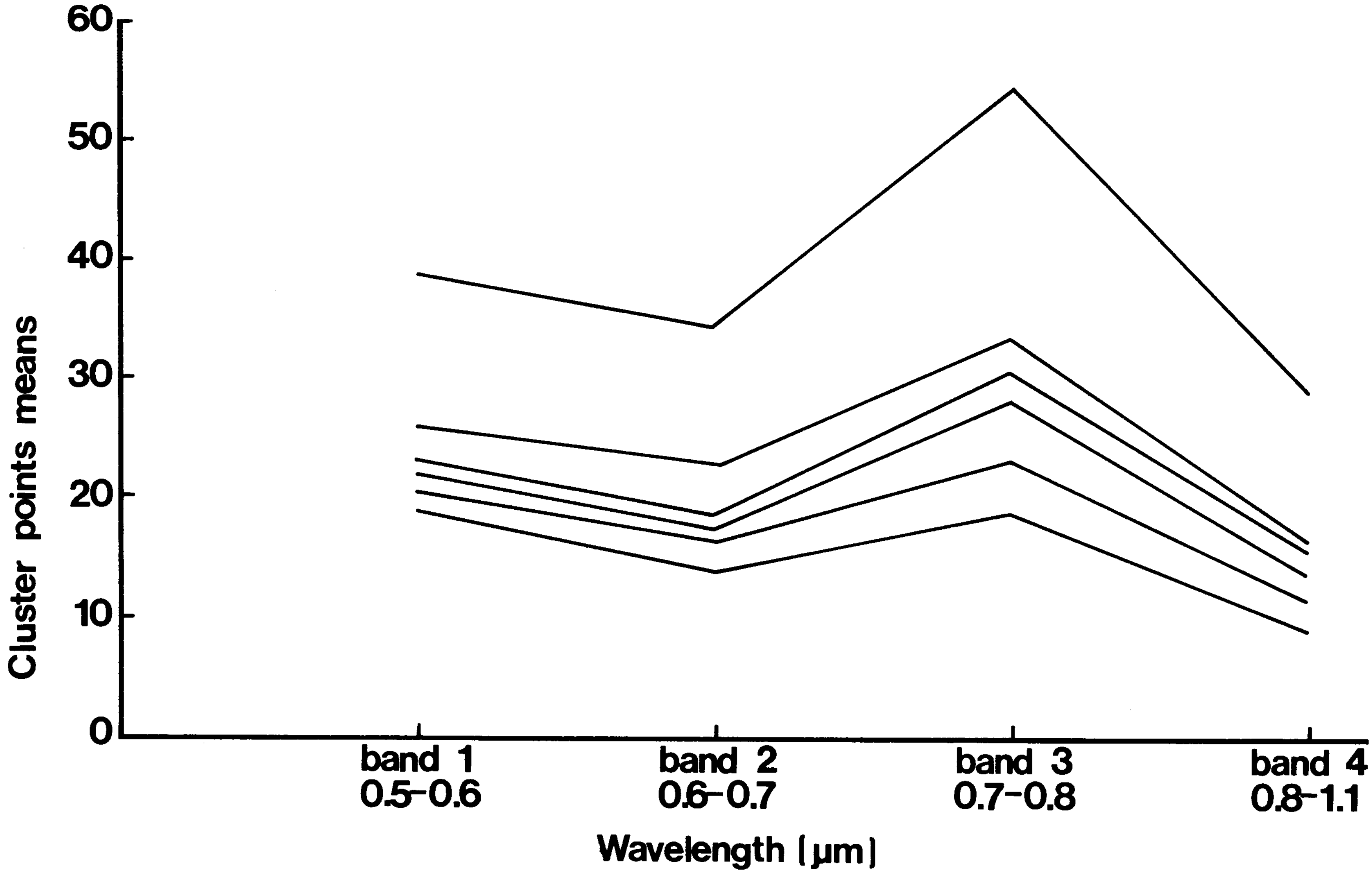


Figure 6 - Graphs of cluster classes of various vegetative types.

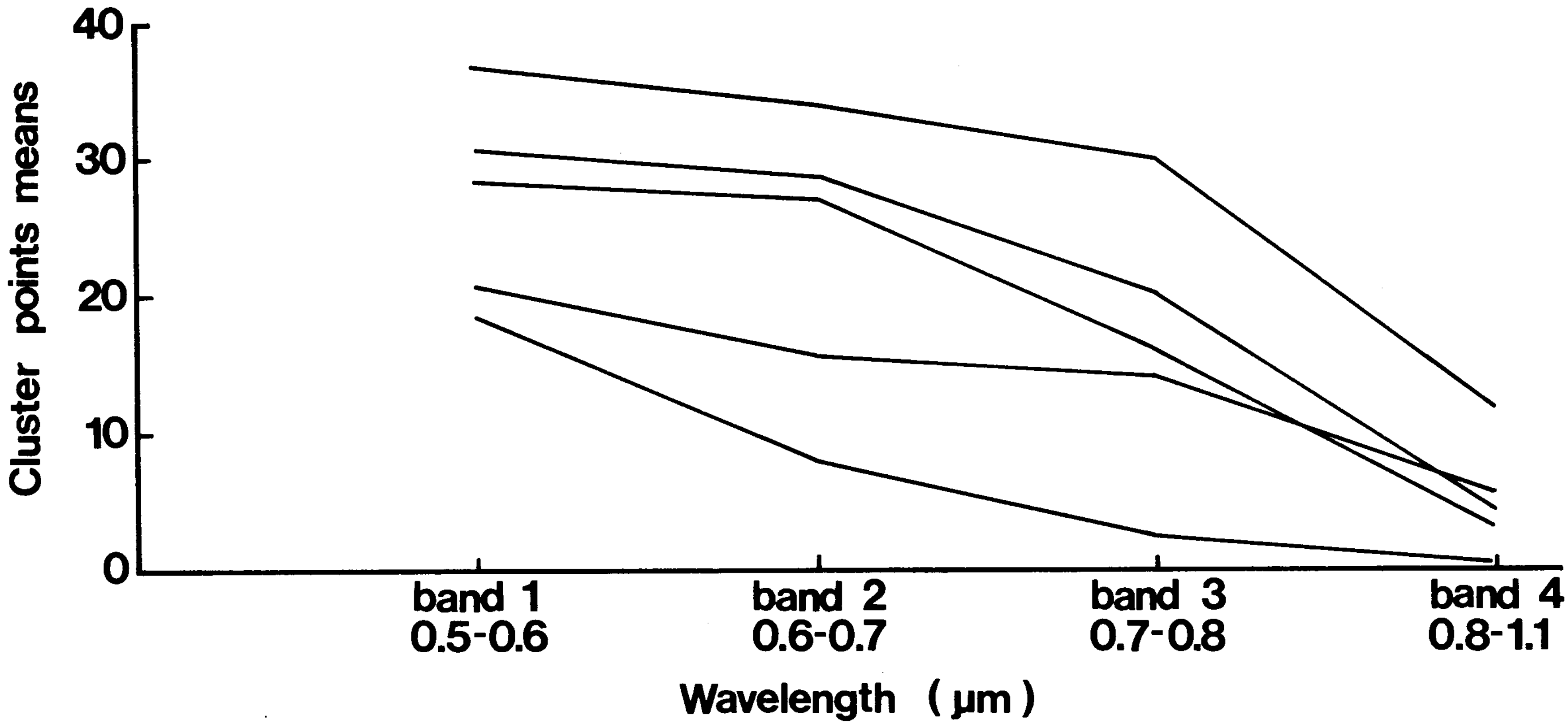


Figure 7 - Graphs of cluster classes of various water types.

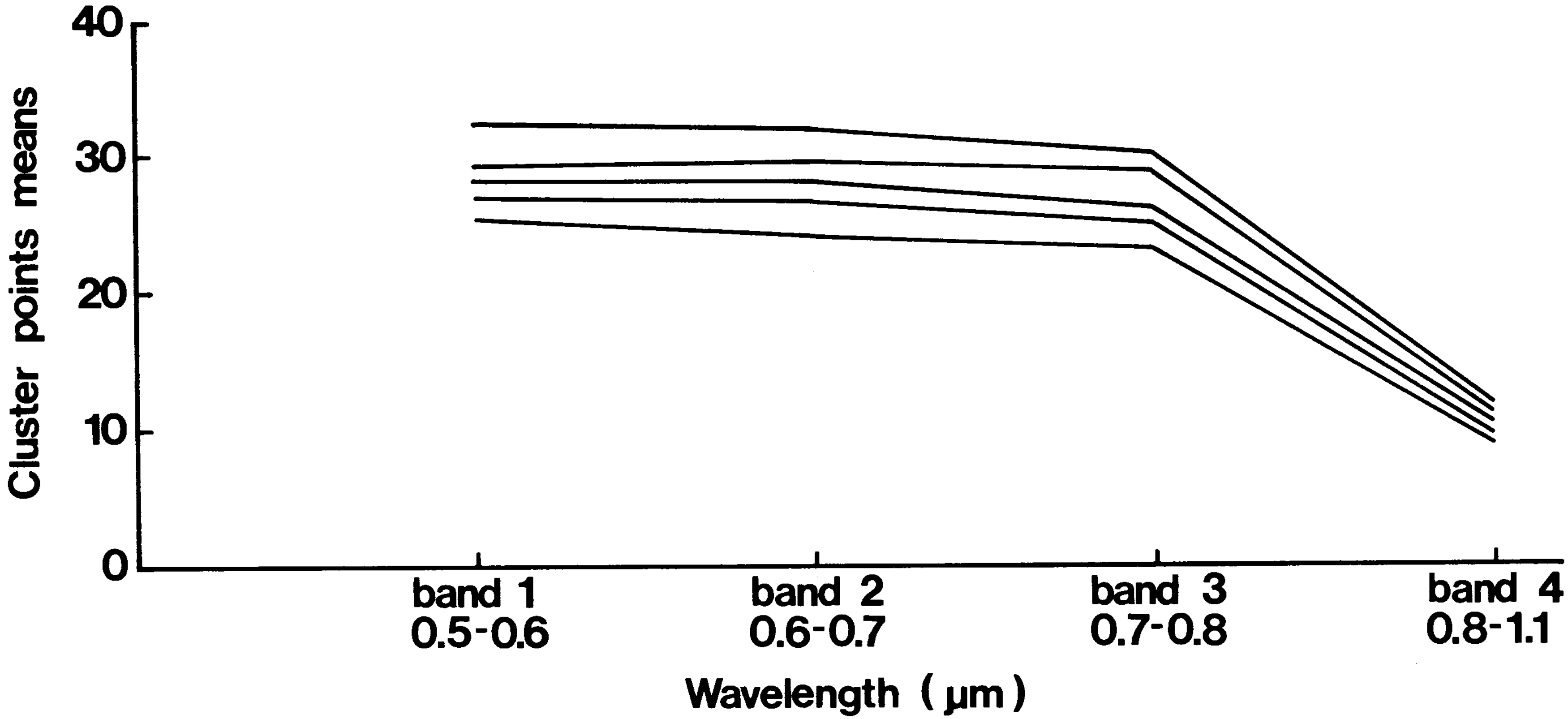


Figure 8 - Graphs of cluster classes of various urban types.

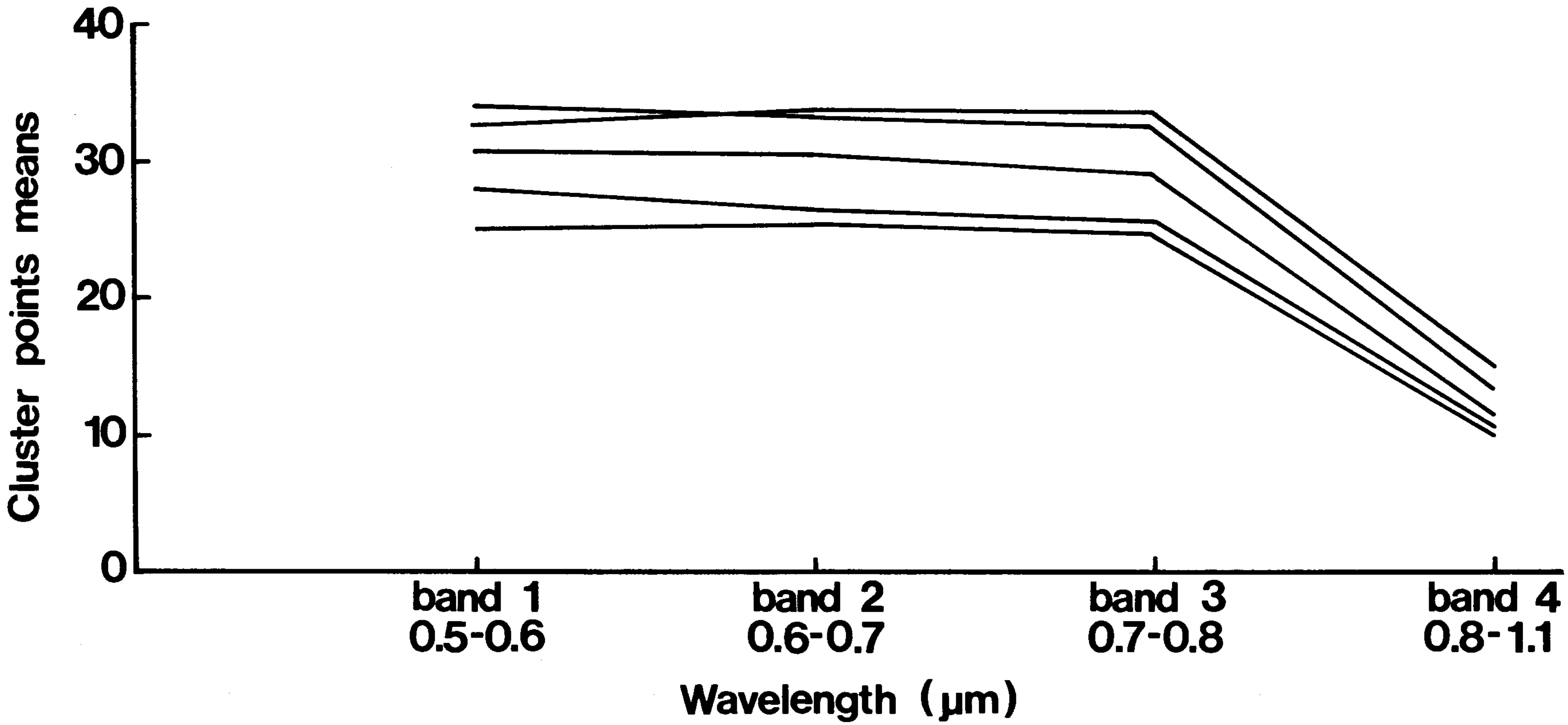


Figure 9 - Graphs of cluster classes of various wetlands.

Table 1. Ratios of Various Cover Types

Cover Type	Magnitude	Vis/IR	Pct.Vis.	Pct. IR
Soils	141.67	1.3582	57.59	42.41
	114.78	1.3984	58.31	41.69
	180.25	1.3825	58.03	41.97
	154.51	1.3527	57.50	42.50
	108.07	1.3996	58.33	41.67
	146.67	1.3619	57.66	42.34
	132.73	1.3673	57.76	42.24
	187.12	1.3861	58.09	41.91
	119.43	1.4540	59.25	40.75
	198.17	1.3938	58.22	41.78
	229.38	1.5267	60.42	39.58
	181.67	1.6456	62.20	37.80
Vegetation	65.29	1.0199	50.49	49.51
	81.64	1.0266	50.66	49.34
	70.39	0.9869	49.67	50.33
	93.00	0.8170	44.96	55.04
	82.00	1.0883	52.11	47.89
	72.20	1.1419	53.31	46.69
	87.60	1.0768	51.85	48.15
	91.09	0.9032	47.46	52.54
	88.31	0.9979	49.95	50.05
	63.18	1.1802	54.13	45.87
	73.52	1.0923	52.21	47.70
Water	76.43	3.0021	75.01	24.99
	78.75	3.1322	75.80	24.20
	81.61	3.1216	75.74	24.26
	84.64	2.3679	70.31	29.69
	80.79	2.7254	73.16	26.84
Urban	83.46	1.5087	60.14	39.86
	74.58	1.5070	60.11	39.89
Shadow	48.94	2.0259	66.95	33.05
	54.96	1.8670	65.12	34.88

were made in labeling classes or that any desirable classes were not deleted. Since no errors were detected, the entire study area was classified.

The classification for some areas were accomplished in various scales (1:25,000; 1:50,000; and 1:100,000) to see how much detail, if any, was lost.

The control cards for classification are shown below:

```
ID BATCH
BATCH  MACHINE  BATMED
BATCH  ID  IRAQ  FLAYEH
BATCH  OUTPUT  FLEXLAB1  FLEXLAB1
-RUNTABLE
DATA
RUN (72075401), TAPE (3255), FILE (1)
END
*CLAS
RESULT  TAPE (701), FILE (2)
```

5. Photo. Color-Coded Photos of Classification Results.

Classification classes can be represented by 16 gray levels (in black-and-white) or by colors selected by number from a preprogrammed set of 32 colors. Individual classes or groups of classes may be assigned any of these gray levels or colors in the same manner as symbols are assigned in the line printer display of classification results.

IV. RESULTS AND DISCUSSION

1. Soils Delineation

Conventional soils mapping techniques in Iraq will be briefly discussed. Black and white aerial photos and photomosaics are used as map bases. Ten percent of the area was selected as a sample area in such a way that all soils and soil conditions of the studied area will be represented. That 10% was subjected to detailed investigation. Using the results above and photointerpretation of the whole studied area, a base photointerpretation map was prepared. Then soil boundaries were verified in the field to modify soil boundaries, if necessary, by describing an auger hole for every 10 hectares and describing one soil profile for every 10 hectares.

Soil samples from auger holes and profiles were sent to laboratories for soil analysis. Using all data and materials above, final soil maps and reports were prepared.

This process is very costly and time consuming.

Within the past decade, advances in airborne and space-borne sensor systems have made it possible to obtain vast quantities of spectral reflectance data over large geographic areas in a very short time. Such data-acquisition systems, when coupled with computer-aided analysis, offer the soil scientist a very helpful tool for surveying soil characteristics.

With this in mind, Baghdad frame (185 x 185 km) and part of Duhok frame were analyzed.

Although data of the Baghdad frame consisted of a single date collected on December 26, 1972 where the land had neither good crop cover nor clear bare soils, the results of classification were good.

We should realize that this method cannot be a substitute for the conventional method but can be a useful tool to facilitate soil survey. Also, we have to keep in mind that the usefulness of reflectance data for soil mapping is limited by the fact that conventional soil series are differentiated by both surface and subsurface properties; hence, a technique dependent on surface distinctions would not discriminate between soils which themselves are differentiated by subsurface features only. However, (1) if detailed soil survey were done for sample areas and correlations were established between surface characteristics and subsurface characteristics; (2) and if variations in spectral response within a soil rype are smaller than the variations between soil types, then great success in soil mapping could be achieved.

Maps delineating other soil characteristics such as organic matter content (Baumgardner, 1970) and internal drainage patterns, salinity and waterlogging can also be produced using computer-aided analysis of multispectral reflectance data. The production of soil-characteristic maps by this method depends primarily on the degree of correlation between the spectral properties of the soils and the significant physical and chemical soil properties. Soil color has a major influence on the reflectance, but variations in soil moisture and in the surface condition (roughness, texture, crusting, or cultural practices) also modify the reflectance; crusted soils have a higher reflectance value than routh, dry higher than wet, and sandy higher than clayey.

For the soil scientist, the promist of computer-aided analysis of reflectance data lies not so much in achieving a one-to-one relationship with the categories of the traditional soil surveys as in determining broad soil characteristics and soil patterns over wide areas in a short time. There is adequate evidence that reflectance data gathered at satellite altitudes can also be an effective tool for use in soil mapping programs particularly when future LANDSAT will have better spectral and spatial resolutions.

The Baghdad frame was studied every 4th line and 4th column due to limitation in computer time. However, some important areas were studied every line and every column. The frame was divided into two parts, the western part and the eastern part.

(1) The western part of the Baghdad frame was studied excluding Baghdad city, because the urban classes mixed with irrigated land classes when analyzed together.

The results of separability grouping (Threshold = 1500) of information classes of all training areas of the Baghdad frame west were:

GROUPS	IDENTIFICATIONS	SYMBOLS
1	Soil 1	1
2	Orchards	T
3	Wet land	I
4	Water 1	W
5	Vegetation	V
6	Soil 2	L
7	Soil 3	J
8	Soil 4	C
9	Water 2	b̸
10	Water 3	.
11	Water 4	-
12	Water 5	/
13	Water 6	=
14	Water 7	+
15	Soil 5	'
16	Soil 6	K
17	Soil 7	F
18	Soil 8	B
19	Null	M

Reduced image of PRINTRESULTS of various parts of the Baghdad frame west is shown in Figures 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, and 21 with various symbols and combinations of symbols (see Appendix D for complete maps).

The results of separability grouping (Threshold = 1500) of some important areas around Baghdad (studied every line and every column) were:

a. North of Baghdad area.

GROUPS	IDENTIFICATIONS	SYMBOLS
1	Soils 1	1
2	Soils 2	-
3	Vegetation	V
4	Irrigated Crops 1	.
5	Soils 3	/
6	Irrigated Crops 2	+
7	Water	b̸
8	Orchards	T

Figure 10 is a PRINTRESULTS of part of North of Baghdad area with 8 classes (reduced scale). Figure 11 is a color-coded photo of North of Baghdad showing the Tigris River (blue), orchard (dark green), vegetation (light green), irrigated land (brown), and various types of soils (grey, pale brown, yellow, and white).

b. West of Baghdad area.

GROUPS	IDENTIFICATIONS	SYMBOLS
1	Soils 1	1
2	Soils 2	-
3	Wet land 1	·
4	Soils 3	ƀ
5	Water	W
6	Orchard	T
7	Wet land 2	J

Figure 12 is a PRINTRESULTS of part of West of Baghdad area with 7 classes (reduced scale).

c. Northwest of Baghdad area.

GROUPS	IDENTIFICATIONS	SYMBOLS
1	Soils 1	ƀ
2	Soils 2	+
3	Soils 3	-
4	Soils 4	/
5	Wet land 1	·
6	Wet land 2	I
7	Wet land 3	J
8	Vegetation	T

d. Baghdad City

GROUPS	IDENTIFICATIONS	SYMBOLS
1	Soil 1	·
2	Urban/Residential	+
3	Water	ƀ
4	Orchards	T
5	Soil 2	-
6	Soil 3	/
7	Soil 4	1
8	Urban/Commercial	O
9	Vegetation	V

Figures 13, 14, and 15 are PRINTRESULTS of various parts of Baghdad City showing urban/residential (+), urban/commercial (O), orchards (T), vegetation (V), and soils (·).

Figure 16 is a color-coded photo of Baghdad City, showing river water (blue), vegetation (green), commercial (gray), residential (light brown), and bare soils (yellow).

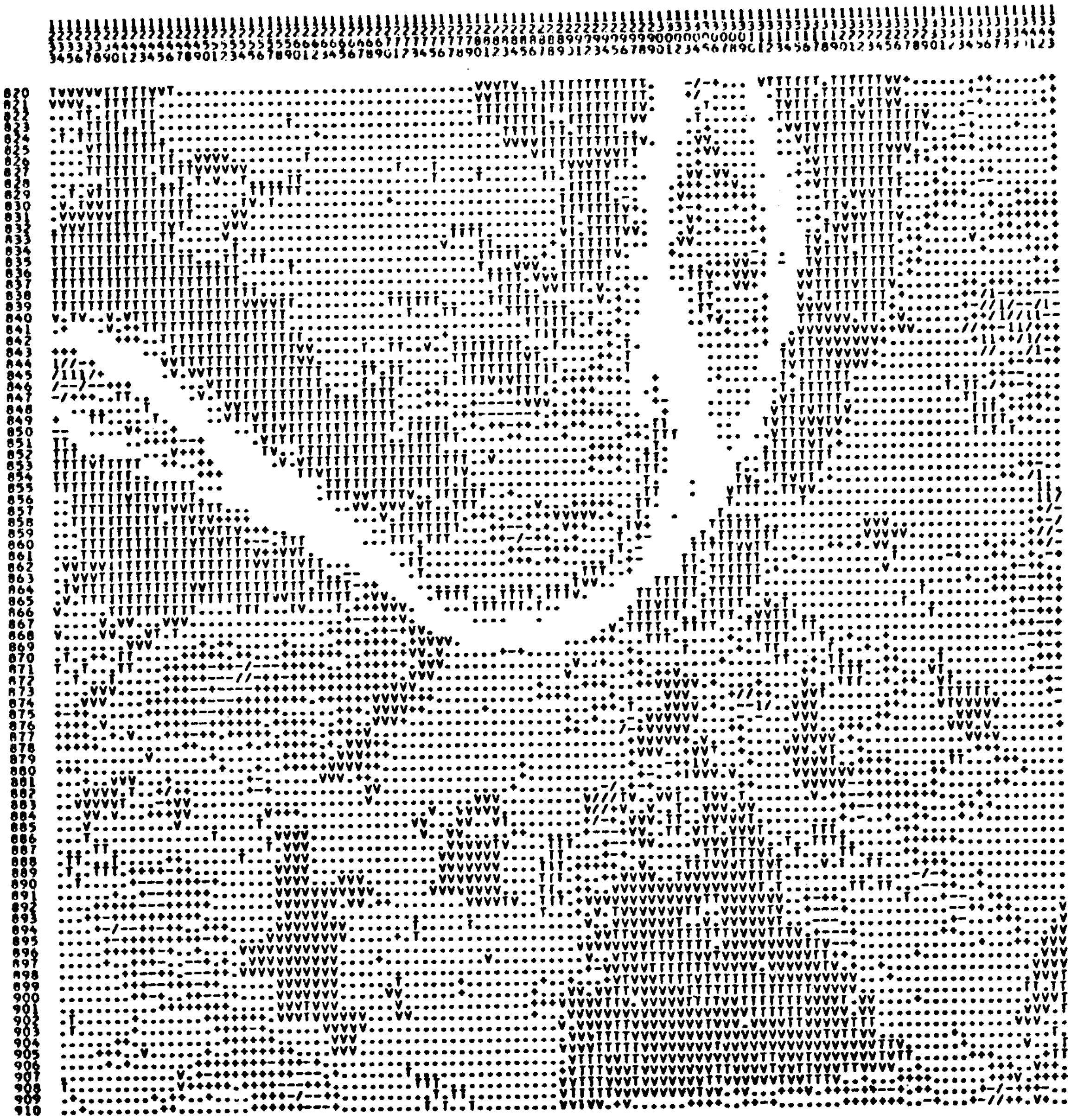
CLASSIFICATION TAPE/FILE NUMBER ... 721/ 1

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
I	C1	/	C5
-	C2	+	C6
V	C3		C7
.	C4	T	C8



NUMBER OF POINTS DISPLAYED IS 10101

10103 CPU TIME USED WAS 8.150 SECONDS. (LARSPN)

Figure 10. PRINTRESULTS of Part of North of Baghdad.

Figure 11. Color-Coded Photo of North of Baghdad.

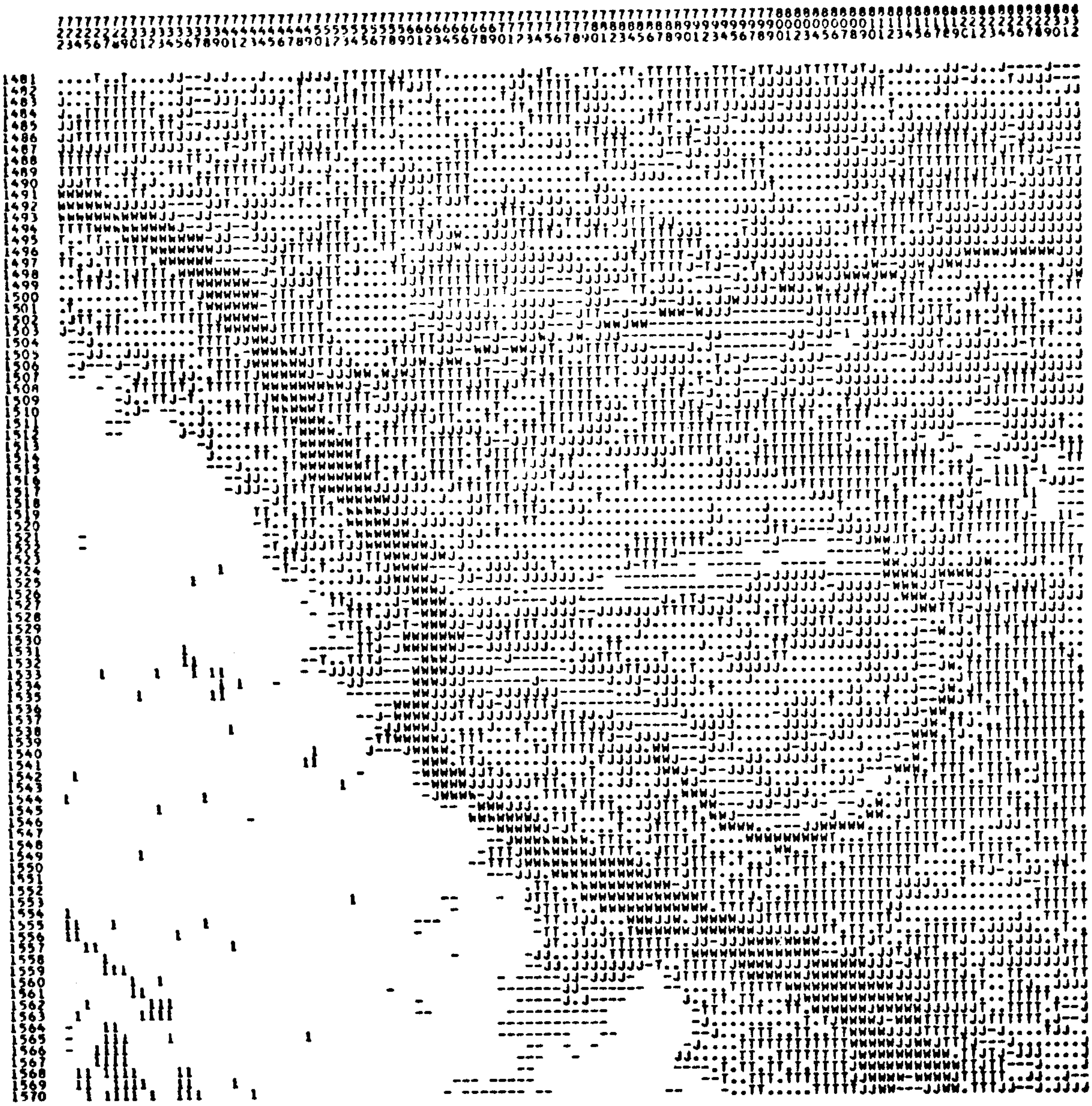
CLASSIFICATION TAPE/FILE NUMBER ... 701/ 7

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.50 TO	0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND	0.60 TO	0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND	0.70 TO	0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND	0.80 TO	1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
I	C1	W	C5
-	C2	T	C6
.	C3	J	C7
	C4		



NUMBER OF POINTS DISPLAYED IS 9990

I0103 CPU TIME USED WAS 9.243 SECONDS. (LARSPN)

Figure 12. PRINTRESULTS of Part of Baghdad Frame (West).

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.50	TO	0.60	MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND	0.60	TO	0.70	MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND	0.70	TO	0.80	MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND	0.80	TO	1.10	MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS
.	C1
+	C2
	C3
T	C4
.	C5

SYMBOL	CLASS
.	C6
.	C7
O	C8
V	C9

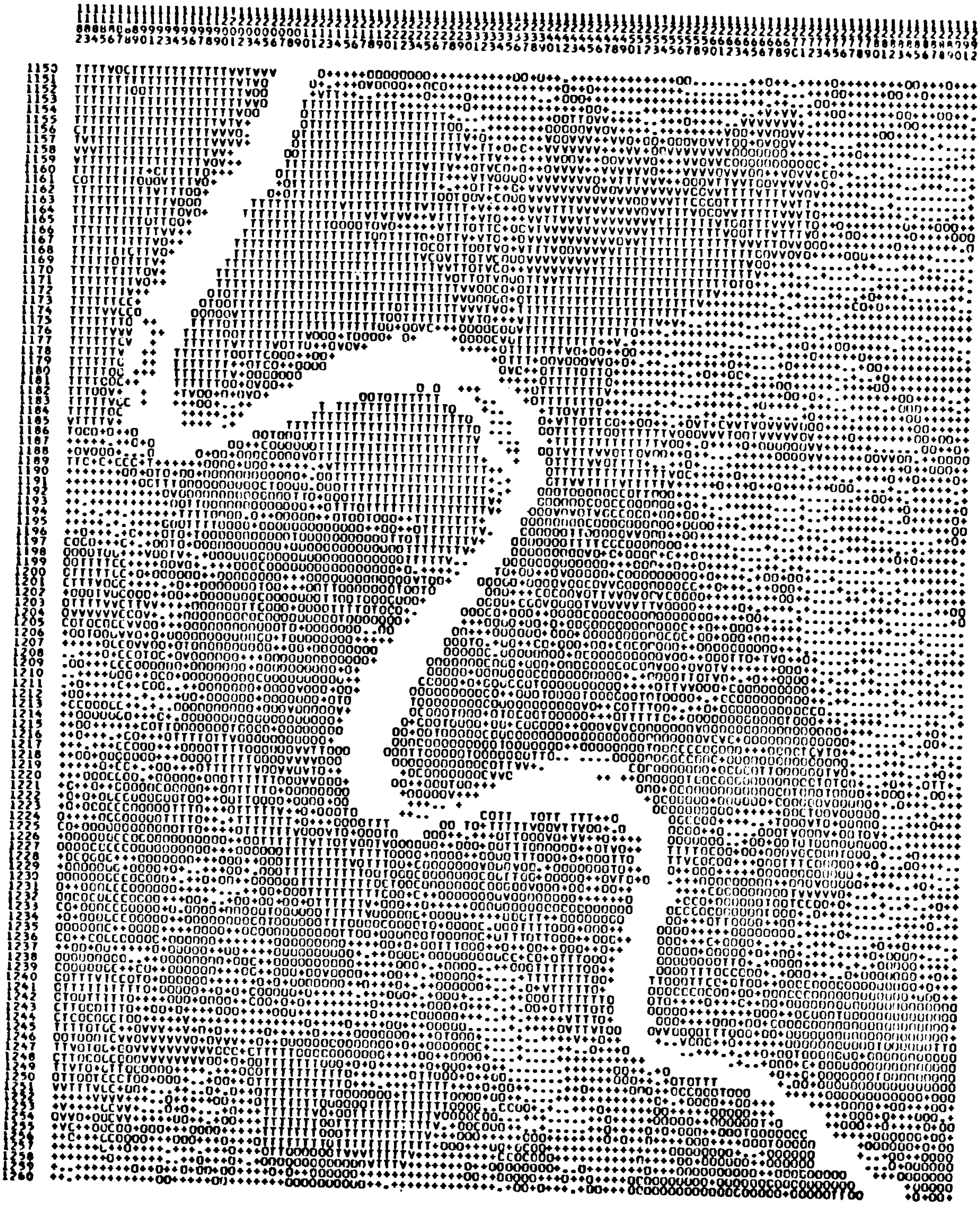


Figure 13. PRINTRESULTS of Part of North Baghdad.

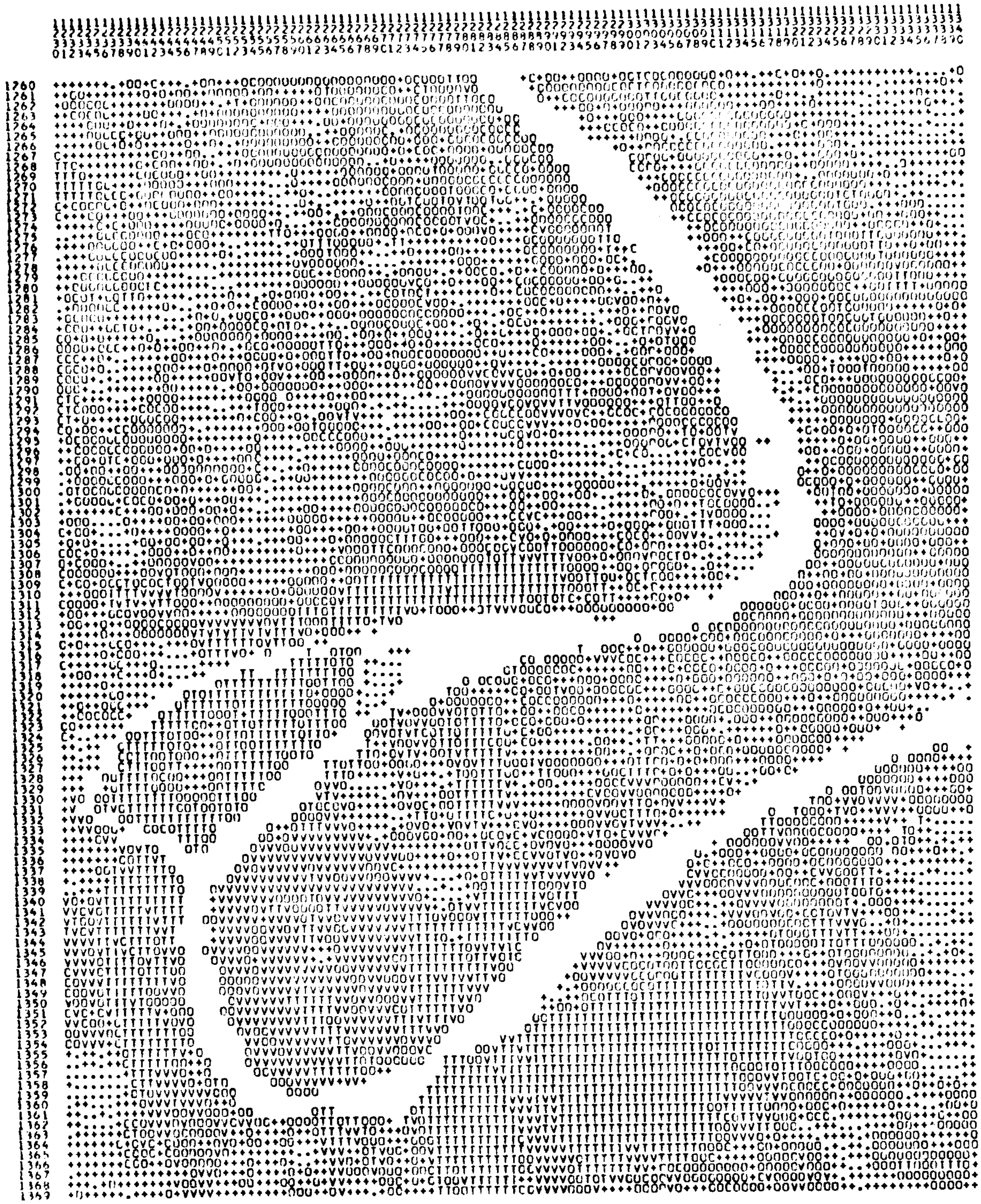
CLASSIFICATION TAPE/FILE NUMBER ... 705/ 7

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
.	C1	-	C6
+	C2	.	C7
	C3	O	C8
T	C4	V	C9
.	C5		



NUMBER OF POINTS DISPLAYED IS 12210

Figure 14. PRINTRESULTS of Part of South Baghdad.

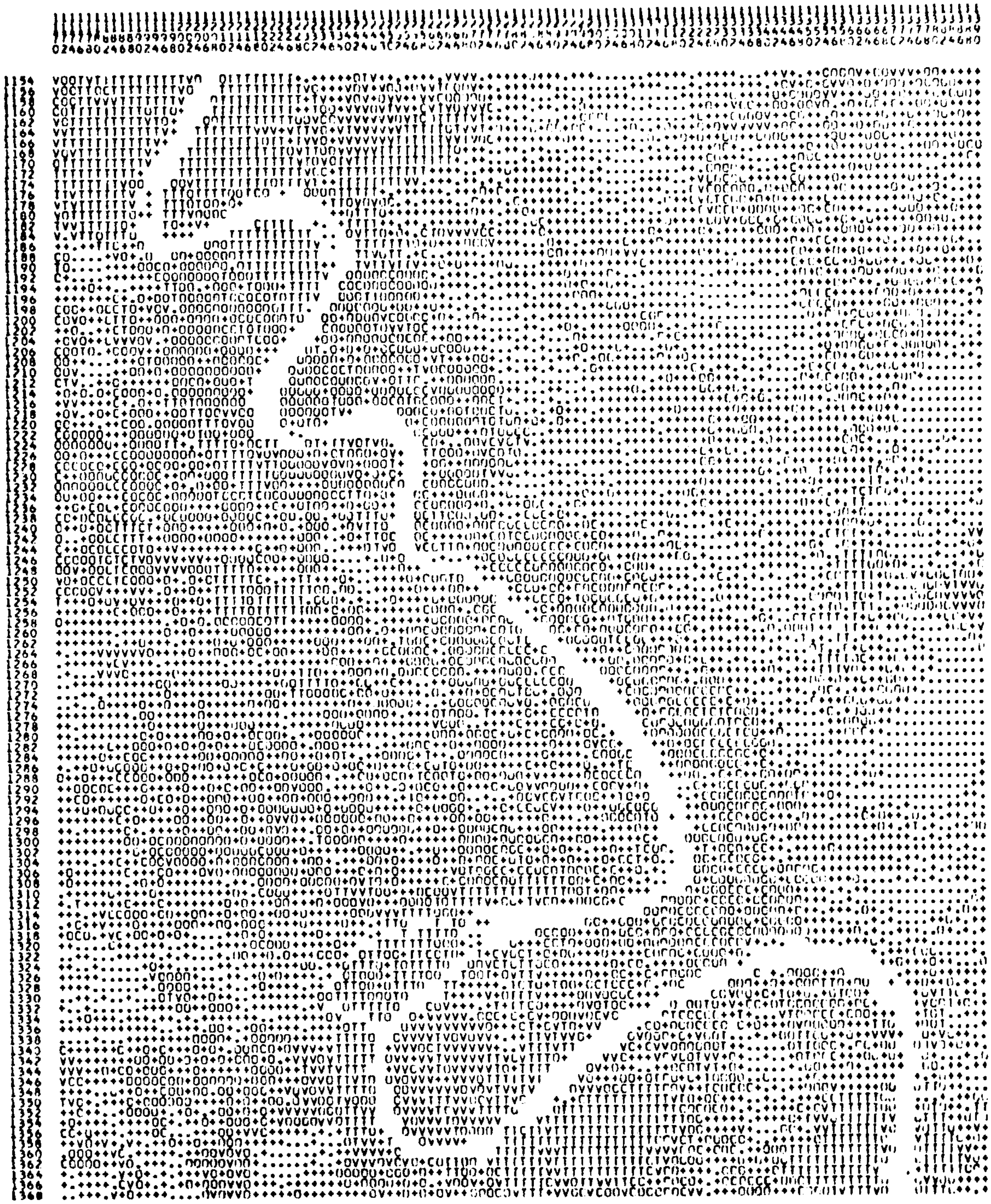
CLASSIFICATION TAPE/FILE NUMBER ... 7057 7

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
.	C1	.	C6
+	C2	.	C7
	C3	C	C8
T	C4	V	C9
.	C5		



NUMBER OF POINTS DISPLAYED IS 11988

Figure 15. PRINTRESULTS of Baghdad City Every 4th Line and Every 4th Column.

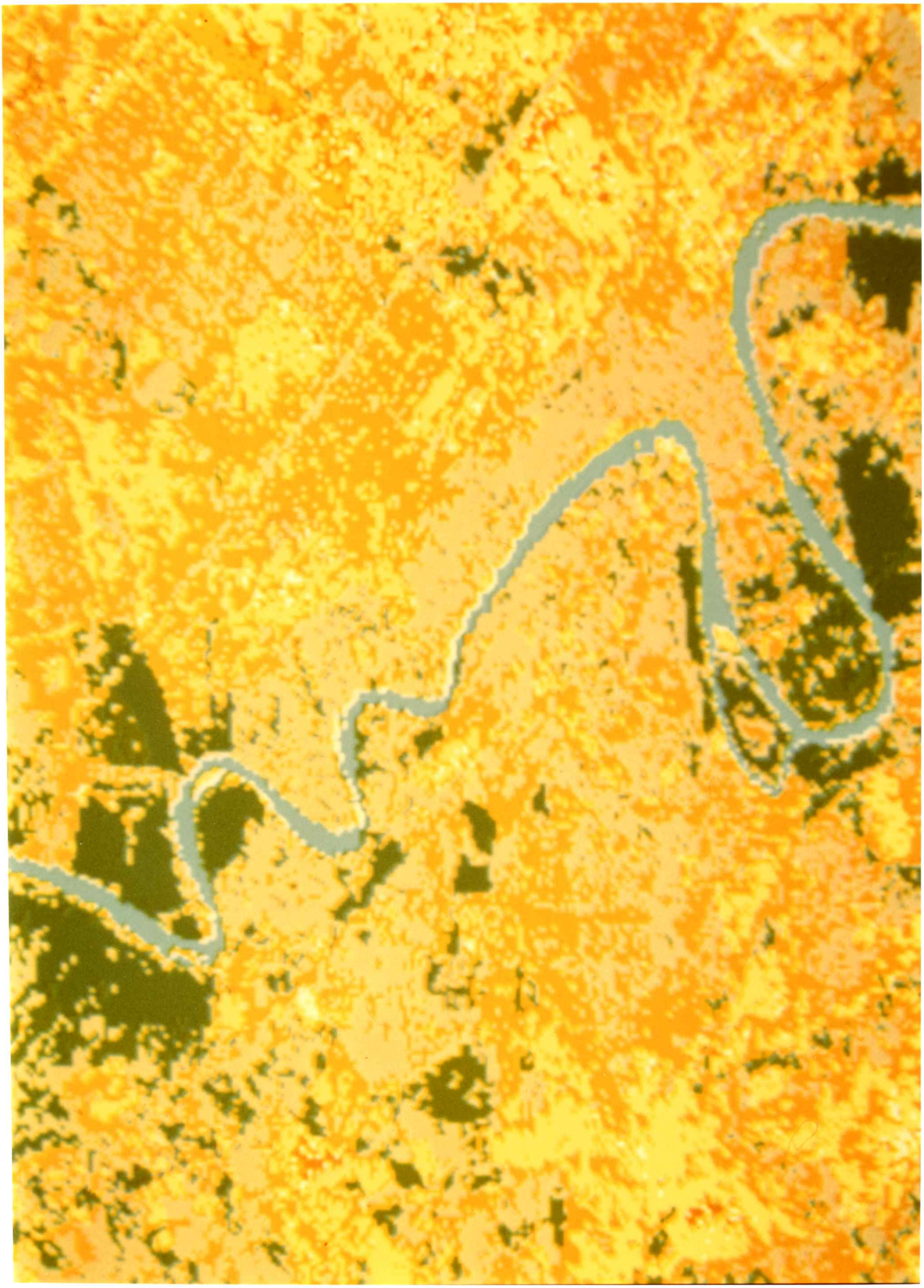


Figure 16. Color-Coded Photo of Baghdad City.

The results of separability grouping (Threshold = 1500) of Baghdad Frame West with different symbols were:

GROUPS	IDENTIFICATIONS	SYMBOLS
1	Soil 1	.
2	Orchard	T
3	Wetland	I
4	Water 1	W
5	Vegetation	V
6	Soil 2	L
7	Soil 3	-
8	Soil 4	+
9	Water 2	U
10	Water 3	U
11	Water 4	U
12	Water 5	U
13	Water 6	U
14	Water 7	U
15	Soil 5	.
16	Soil 6	J
17	Soil 7	=
18	Soil 8	/
19	Null (No data available)	M

Figures 17, 18, 19, 20, 21 and 22 are PRINTRESULTS of various parts of Baghdad Frame West with various symbols and groupings.

Figures 23, 24, and 25 are color-coded photos of various parts of Baghdad Frame West.

(2) The Eastern Baghdad Frame. The results of separability grouping (Threshold = 1500) of information classes of all training areas of the Baghdad Frame East were:

GROUPS	IDENTIFICATIONS	SYMBOLS
1	Soil 1	'
2	Vegetation 1	T
3	Water	W
4	Soil 2	I
5	Soil 3	B̸
6	Soil 4	.
7	Soil 5	/
8	Vegetation 2	T
9	Soil 6	+
10	Soil 7	1
11	Soil 8	=
12	Soil 9	J
13	Soil 10	-
14	Shadow	B
15	Null (No data available)	M

CLASSIFICATION TAPE/FILE NUMBER ... 701/ 8

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
.	SOIL1	U	WATER4
I	ORCHARD	U	WATER5
I	WETLAND	U	WATER6
W	WATER1	U	WATER7
V	VEG	'	SOIL5
L	SOIL2	J	SOIL6
-	SOIL3	=	SOIL7
+	SOIL4	/	SOIL8
U	WATER2	M	NULL
U	WATER3		

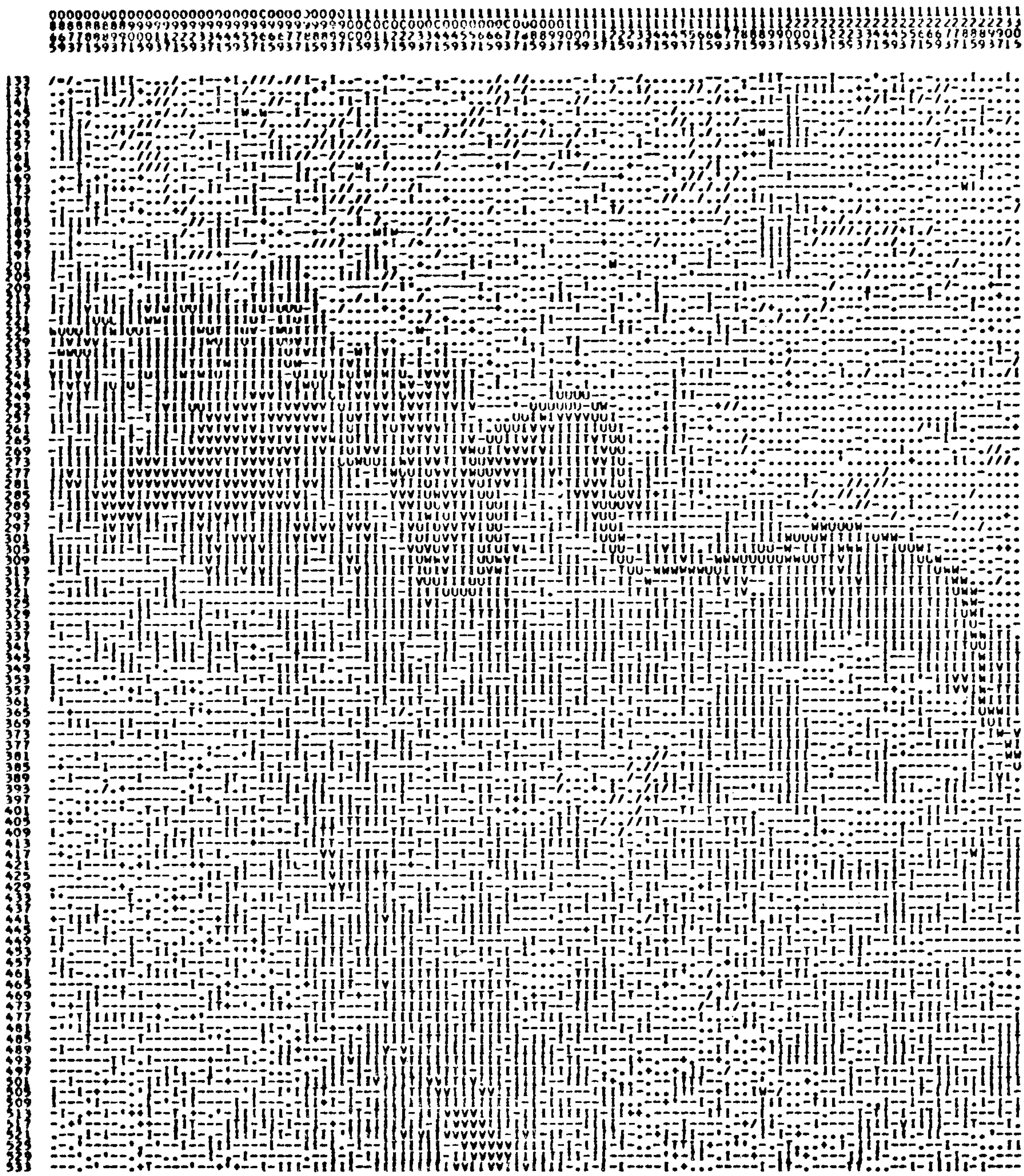


Figure 17. PRINTRESULTS of Baghdad Frame (West) Northwestern Part.

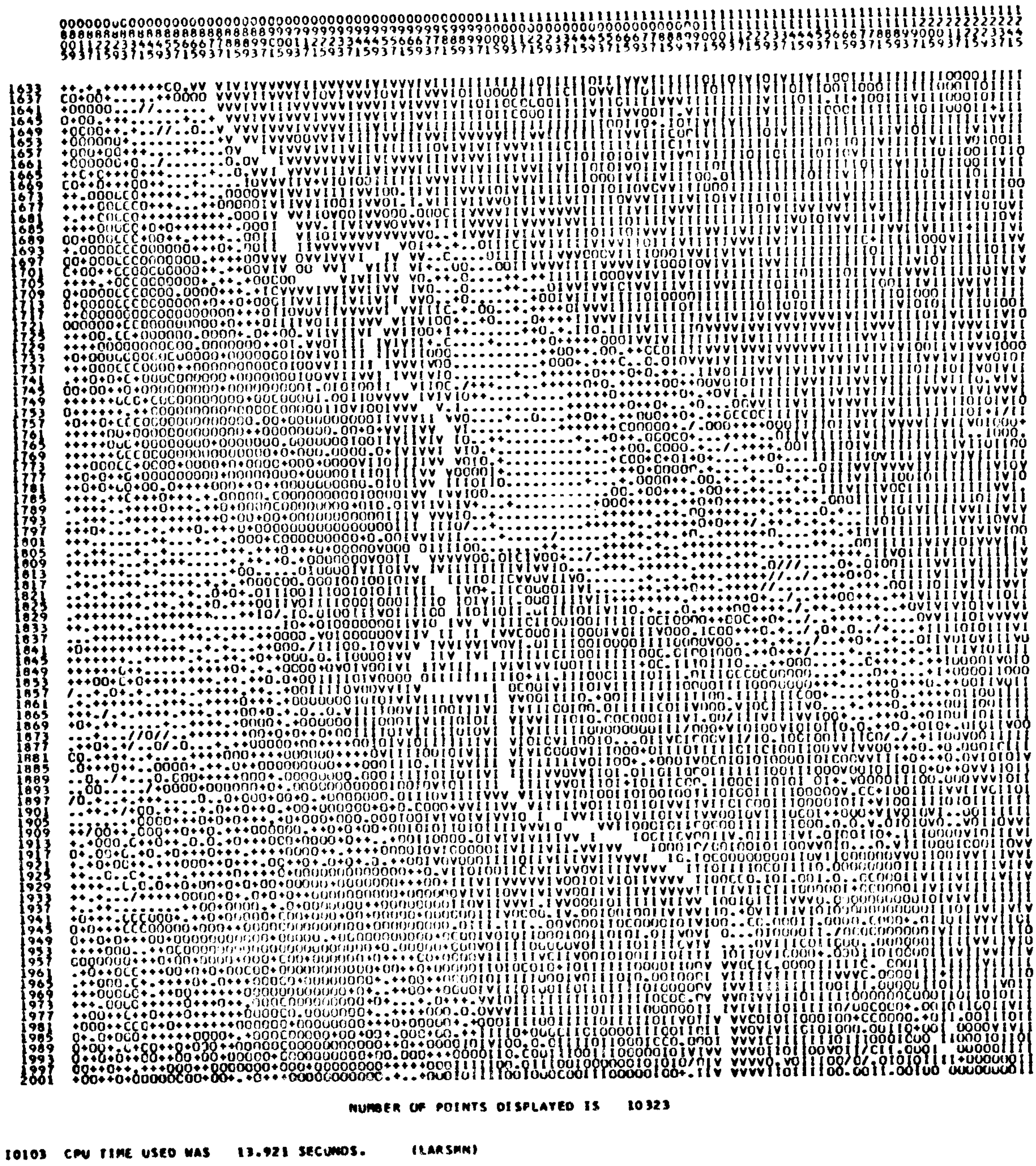
CLASSIFICATION TAPE/FILE NUMBER ... 7017 8

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.50 TO	0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND	0.60 TO	0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND	0.70 TO	0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND	0.80 TO	1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
.	SOIL1		WATER4
V	ORCHARD		WATER5
I	WETLAND		WATER6
	WATER1		WATER7
V	VEG	O	SOIL5
O	SOIL2	O	SOIL6
O	SOIL3	O	SOIL7
+	SOIL4	/	SOIL8
	WATER2	M	NULL
	WATER3		



NUMBER OF POINTS DISPLAYED IS 10323

I0103 CPU TIME USED WAS 13.921 SECONDS. (LARSMN)

Figure 18. PRINTRESULTS of Baghdad Frame (West) Southwestern Part.

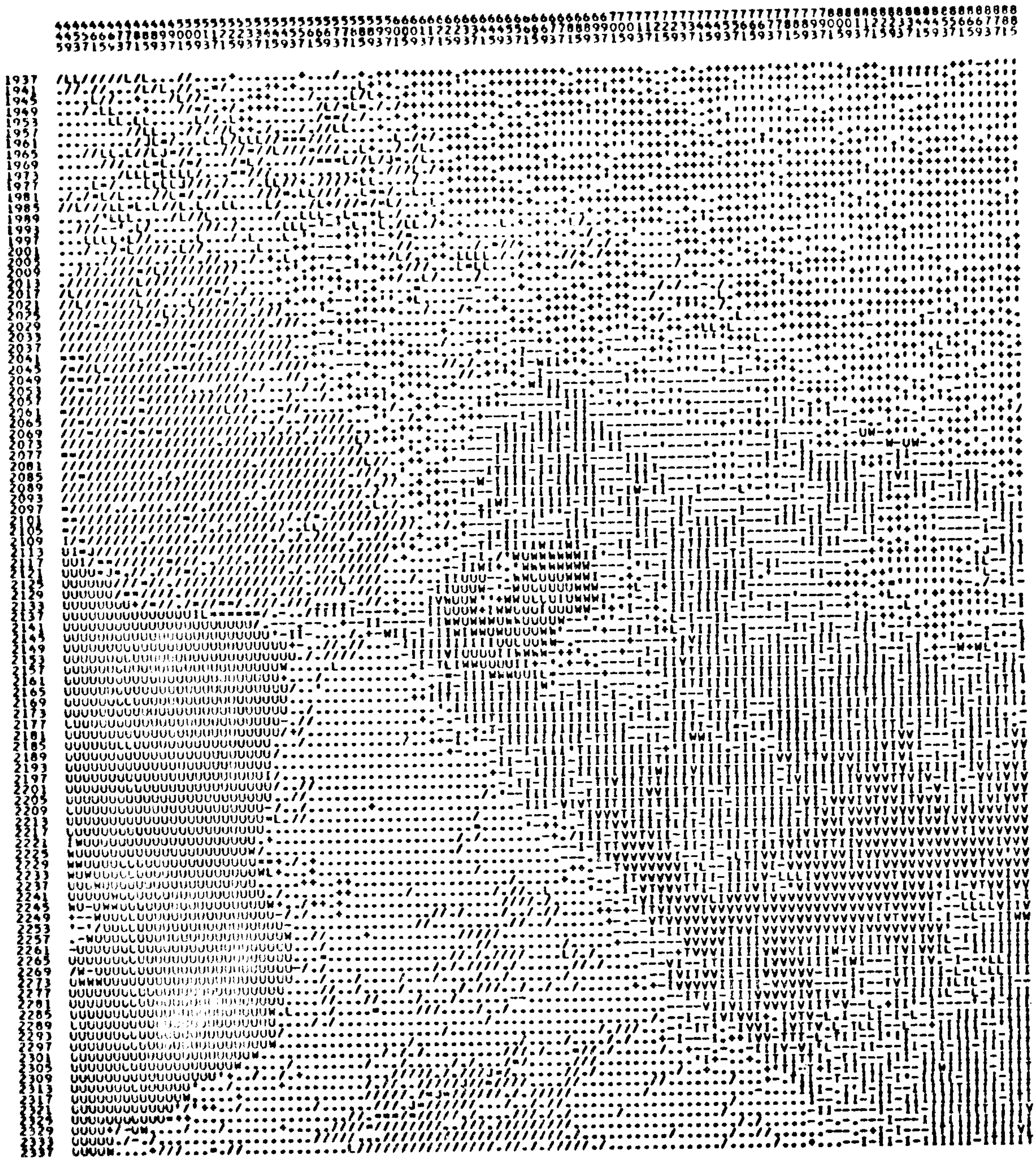
CLASSIFICATION TAPE/FILE NUMBER ... 701/ 8

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
.	SOIL1	U	WATER4
T	ORCHARD	U	WATER5
I	WETLAND	U	WATER6
W	WATER1	U	WATER7
V	VEG	'	SOIL5
L	SOIL2	J	SOIL6
-	SOIL3	=	SOIL7
+	SOIL4	/	SOIL8
U	WATER2	M	NULL
U	WATER3		



NUMBER OF POINTS DISPLAYED IS 11211

Figure 19. PRINTRESULTS of Baghdad Frame (West) Razzaza Area.

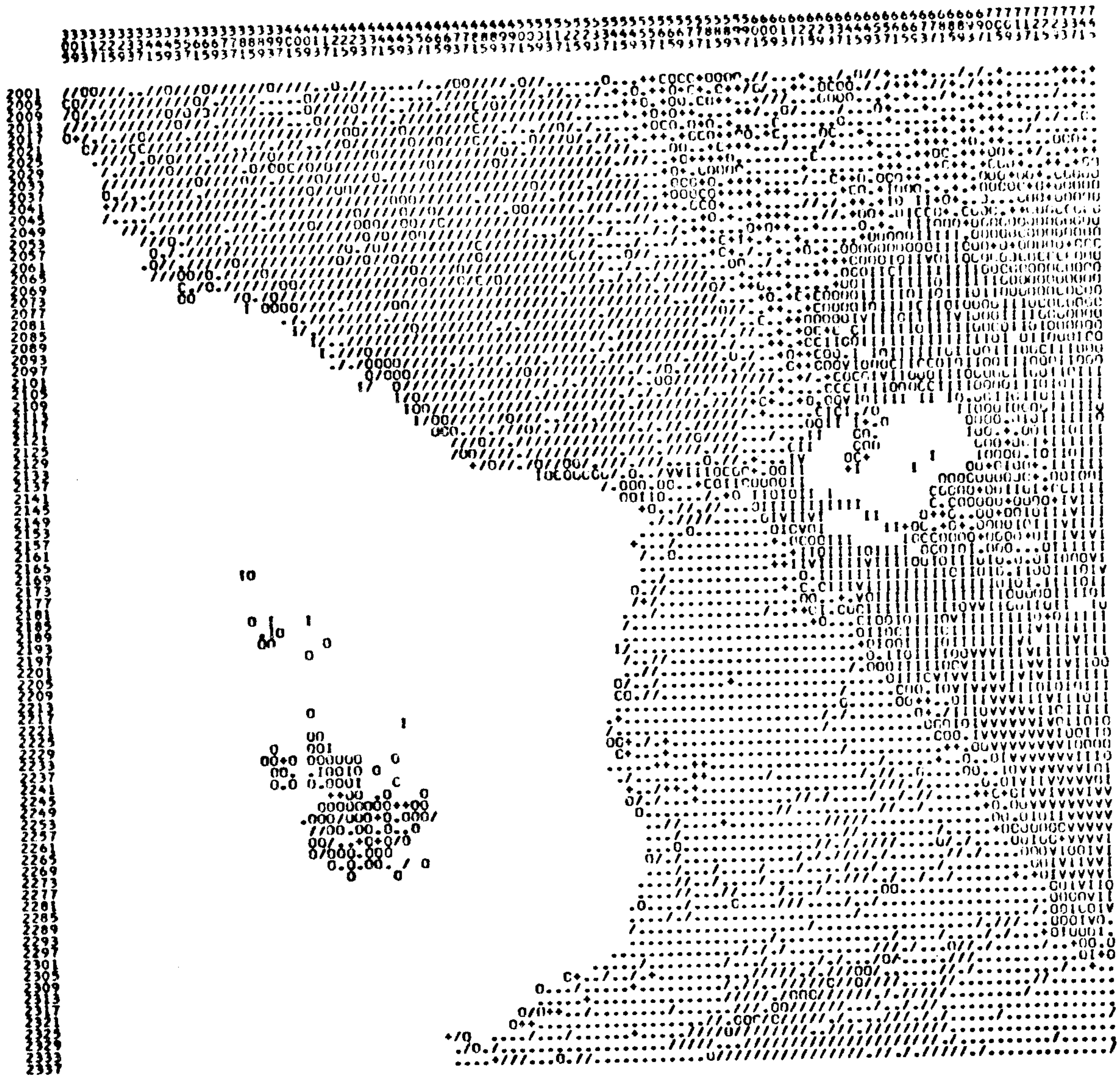
CLASSIFICATION TAPE/FILE NUMBER ... 701/ 8

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0
CHANNEL 2	SPECTRAL BAND	0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0
CHANNEL 3	SPECTRAL BAND	0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	C0 = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
.	SOIL1		WATER4
V	ORCHARD		WATER5
I	WETLAND		WATER6
	WATER1		WATER7
V	VEG	0	SOIL5
0	SOIL2	0	SOIL6
0	SOIL3	0	SOIL7
+	SOIL4	/	SOIL8
	WATER2	M	NULL
	WATER3		



NUMBER OF POINTS DISPLAYED IS 9435

10103 CPU TIME USED WAS 14.092 SECONDS. (LARSPH)

Figure 20. PRINTRESULTS of Baghdad Frame (West) Razzaza Area, Showing Grouped Classes.

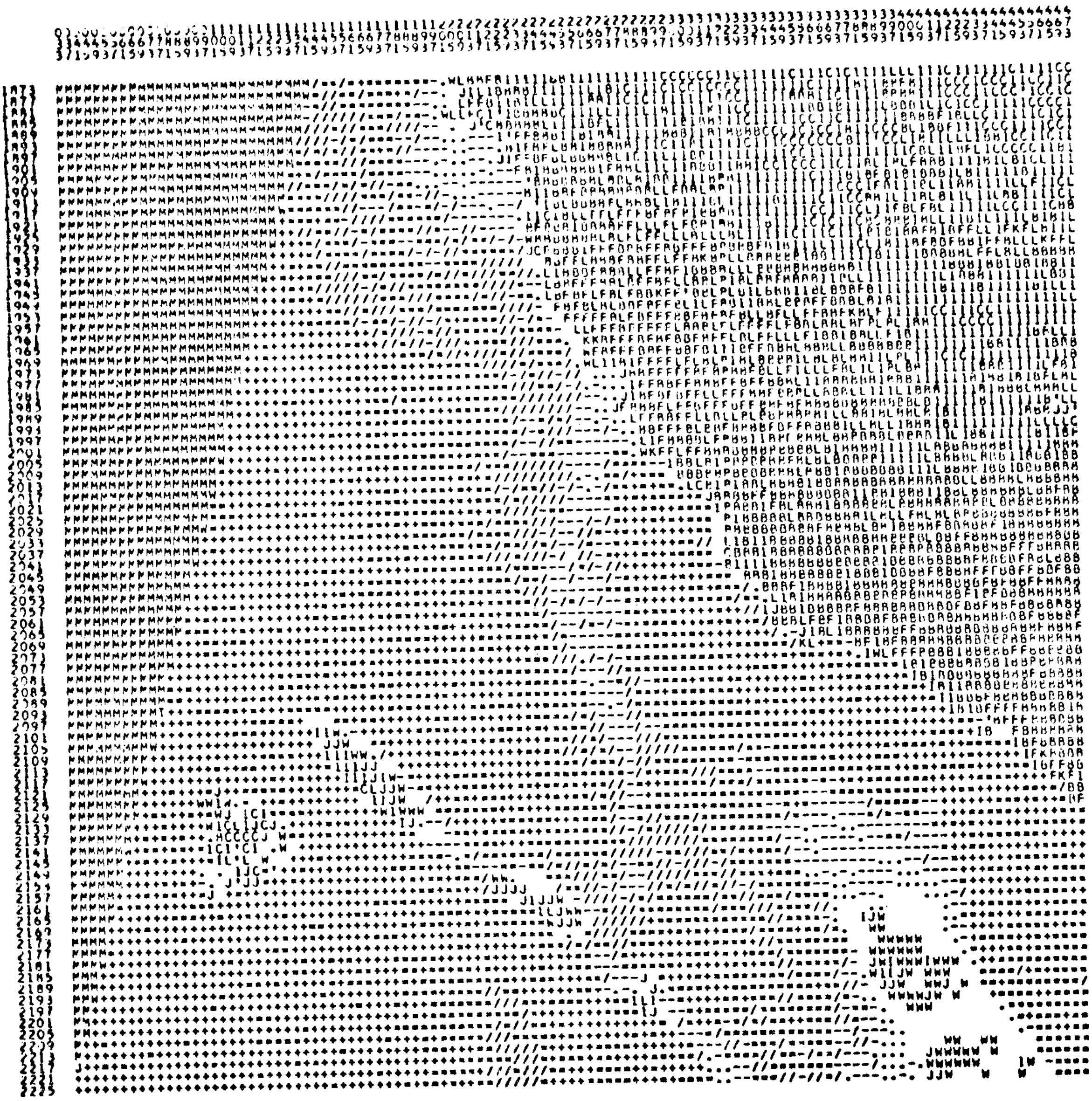
CLASSIFICATION TAPE/FILE NUMBER ... 701/ M

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
I	SOIL1	-	WATER4
F	ORCHARD	/	WATER5
I	WETLAND	=	WATER6
W	WATER1	+	WATER7
V	VEG	'	SOIL5
L	SOIL2	K	SOIL6
J	SOIL3	F	SOIL7
C	SOIL4	B	SOIL8
	WATER2	M	NULL
.	WATER3		



NUMBER OF POINTS DISPLAYED IS 9879

1.103 CPU TIME USED WAS 13.652 SECONDS. (LARSMN)

Figure 21. Razzaza Area, Showing Various Types of Water of the Lake and Other Vegetation and Soil Classes.

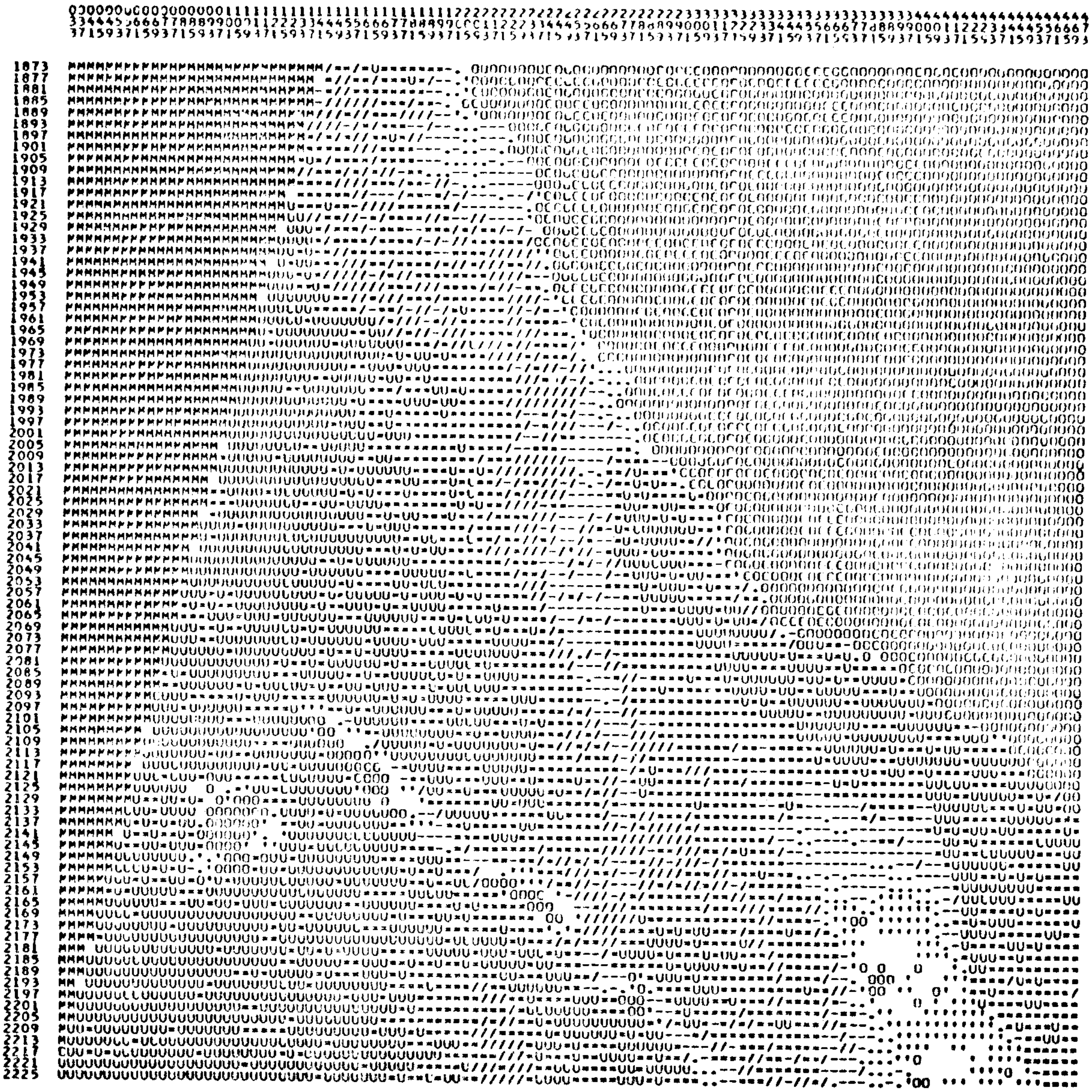
CLASSIFICATION TAPE/FILE NUMBER ... 701/ 8

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND	0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND	0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
C	SOIL1	-	WATER4
O	ORCHARD	/	WATER5
O	WETLAND	=	WATER6
	WATER1	U	WATER7
O	VEG	O	SOIL5
O	SOIL2	O	SOIL6
O	SOIL3	O	SOIL7
O	SOIL4	O	SOIL8
'	WATER2	M	NULL
.	WATER3		



NUMBER OF POINTS DISPLAYED IS 9879

Figure 22. Razzaza Area, Showing Various Types of the Lake Water.

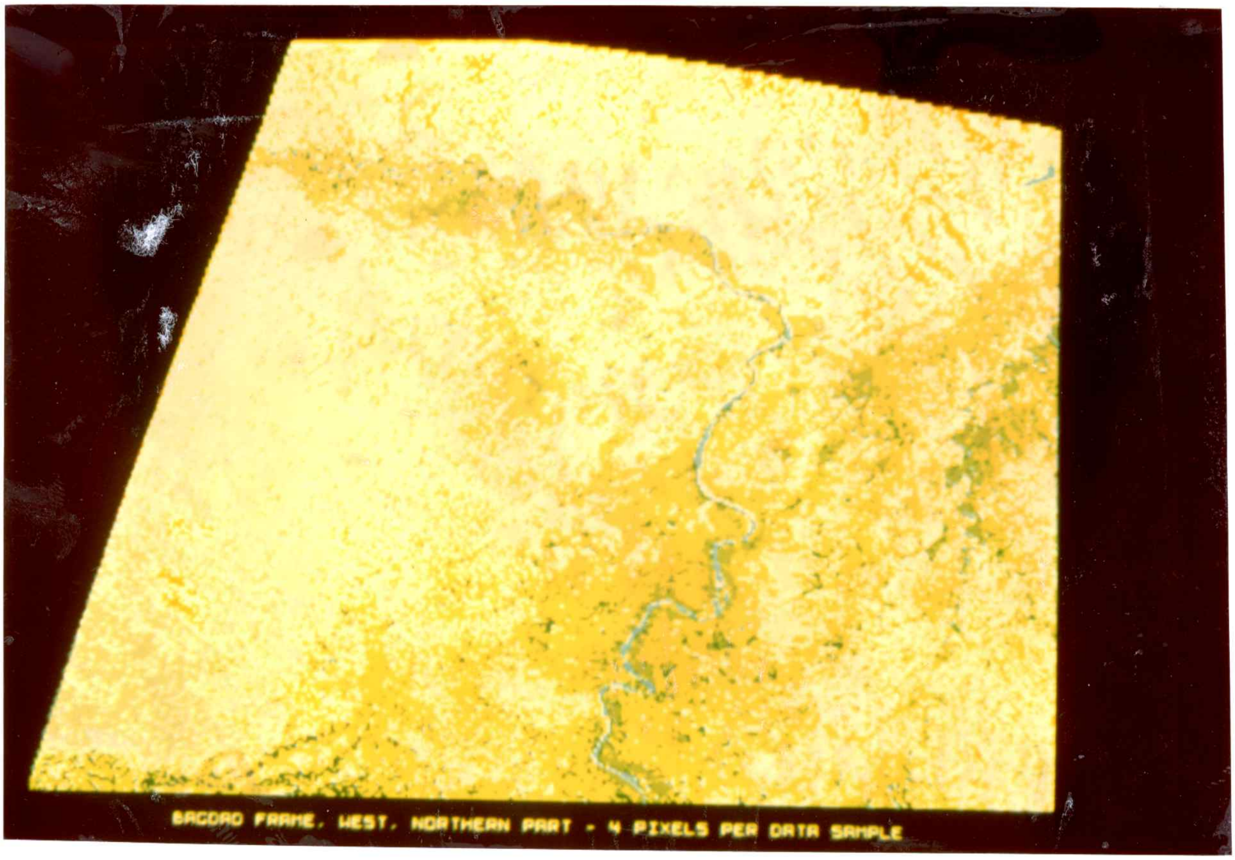


Figure 23. Color-Coded Photo of Baghdad Frame (West) Northwestern Part Showing Tigris River (Blue), Vegetation (Green), Irrigated Land (Light Brown), Various Soil Types (White, Pale Brown, Orange, Gray).

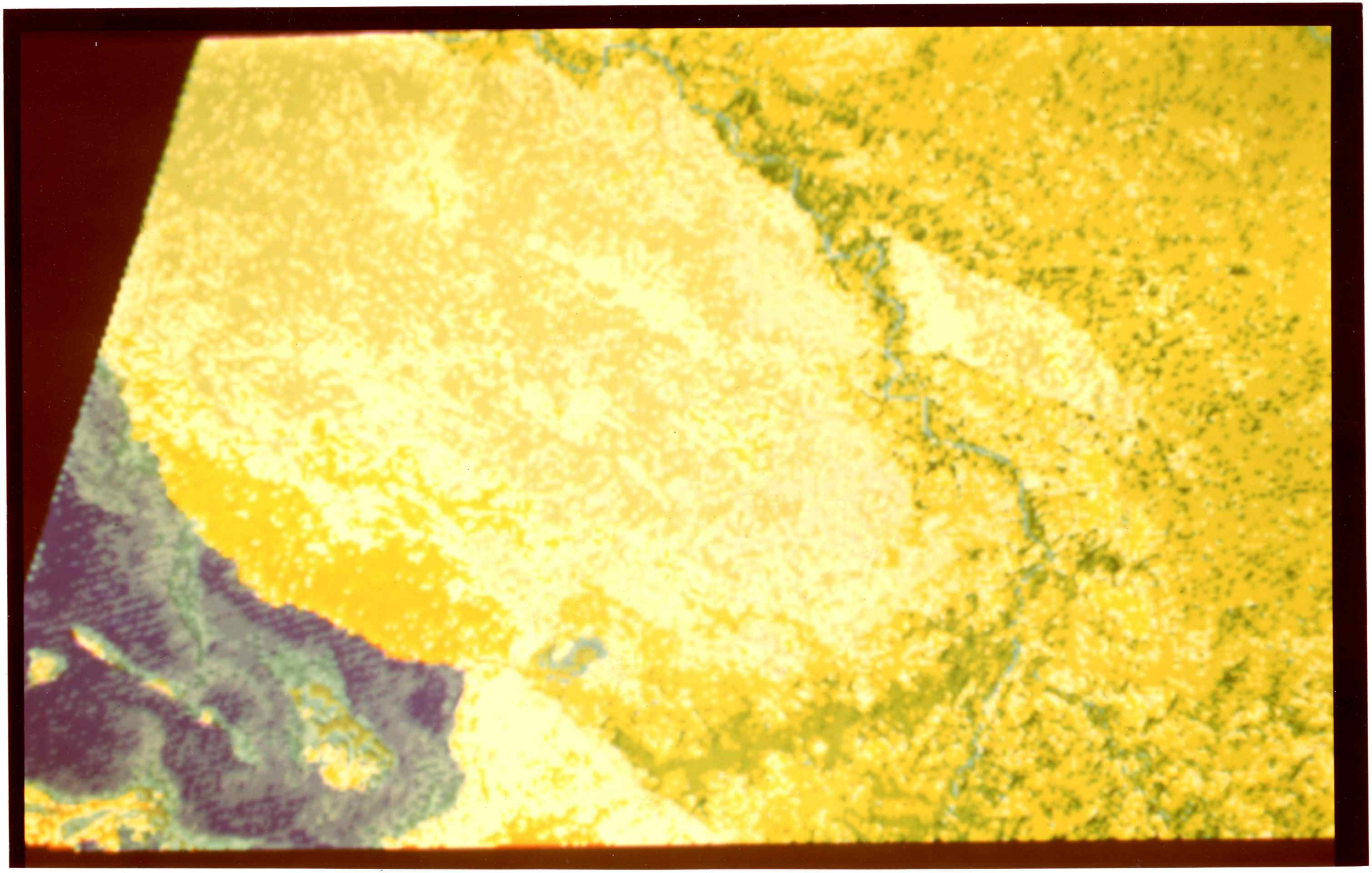


Figure 24. Color-Coded Photo of Baghdad Frame (West) Southern Part.

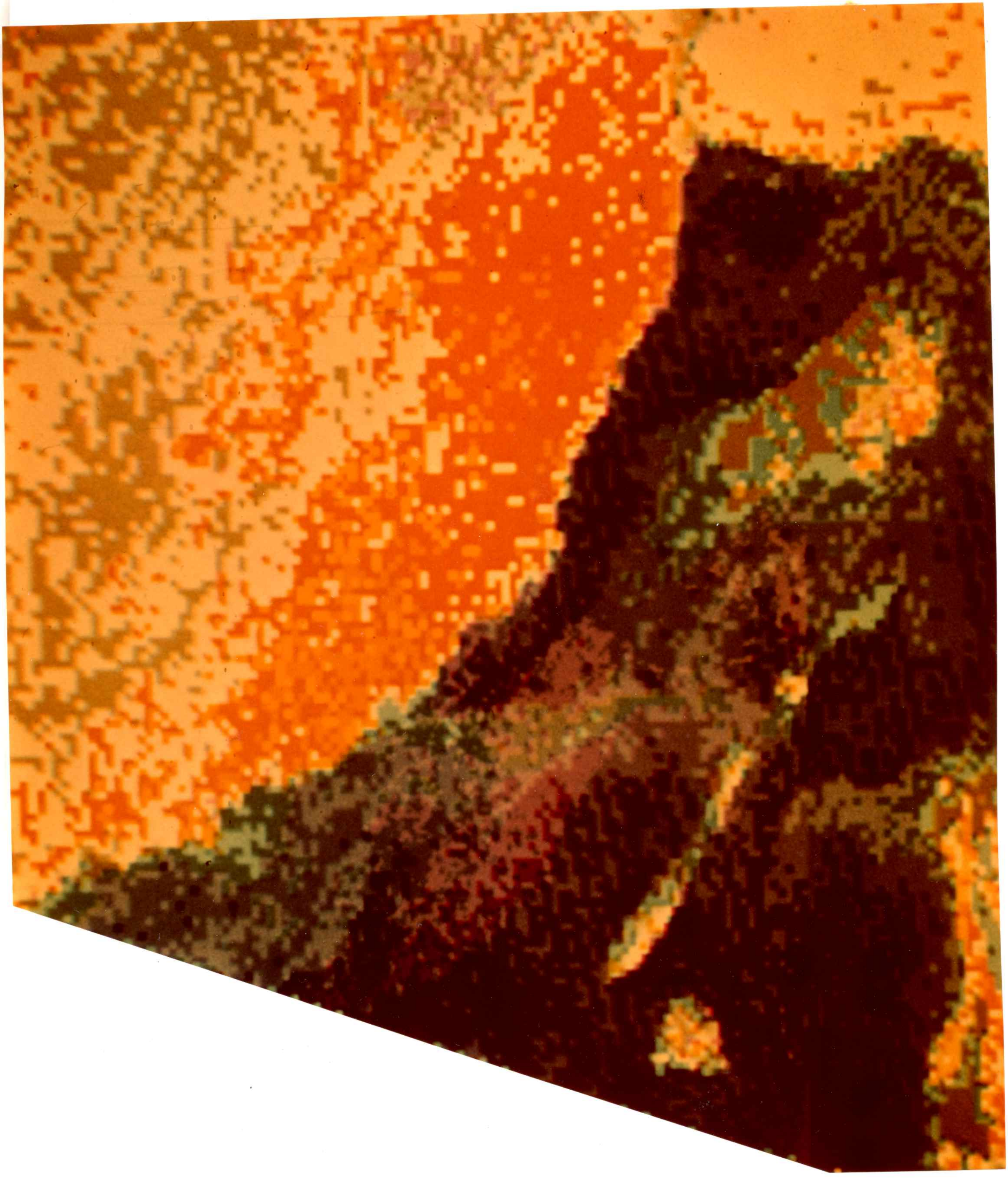


Figure 25. Color-Coded Photo of Razzaza Area, Showing Various Water, Vegetation and Soil Types.

Figures 26, 27, 28, 29, and 30 are PRINTRESULTS of various parts of Baghdad frame east with various symbols and grouping (reduced scale).

Figures 31, 32, and 33 are color-coded photos of various parts of Baghdad frame east.

(3) Zakho Area. The results of separability grouping (Threshold - 1500) of information classes of all training areas of the Zakho area were:

GROUPS	IDENTIFICATION	SYMBOLS
1	Soil 1	₿
2	Soil 2	.
3	Soil 3	-
4	Soil 4	/
5	Soil 5	1
6	Soil 6	+
7	Vegetation & shadow	T
8	Water	W

Figure 34 represents the PRINTRESULTS of part of the Zakho area (reduced scale).

Figures 35 and 36 are color-coded photos of parts of the Zakho area.

2. Land Use.

Digital analysis of the LANDSAT-1 data provided maps delineating the following land use categories for the Baghdad frame and part of the Duhok frame: Soils of various types, orchards, cultivated crops, surface water of various types, waterlogged lands, urban/commercial, and urban/residential.

This land use inventory is a significant contribution for regional planning and may be used as a base map with which to compare future changes in land use in the Tigris-Euphrates floodplain and other regions in the country.

3. Urban Classification.

Many attempts were made to classify the urban areas of Baghdad within the region of the floodplain, but the results were not satisfactory. The problem is that the urban classes (commercial and residential) mixed with irrigated land classes of the region. Looking to the spectral responses of these two groups revealed that both groups have about the same response patterns (Figures 8 and 9).

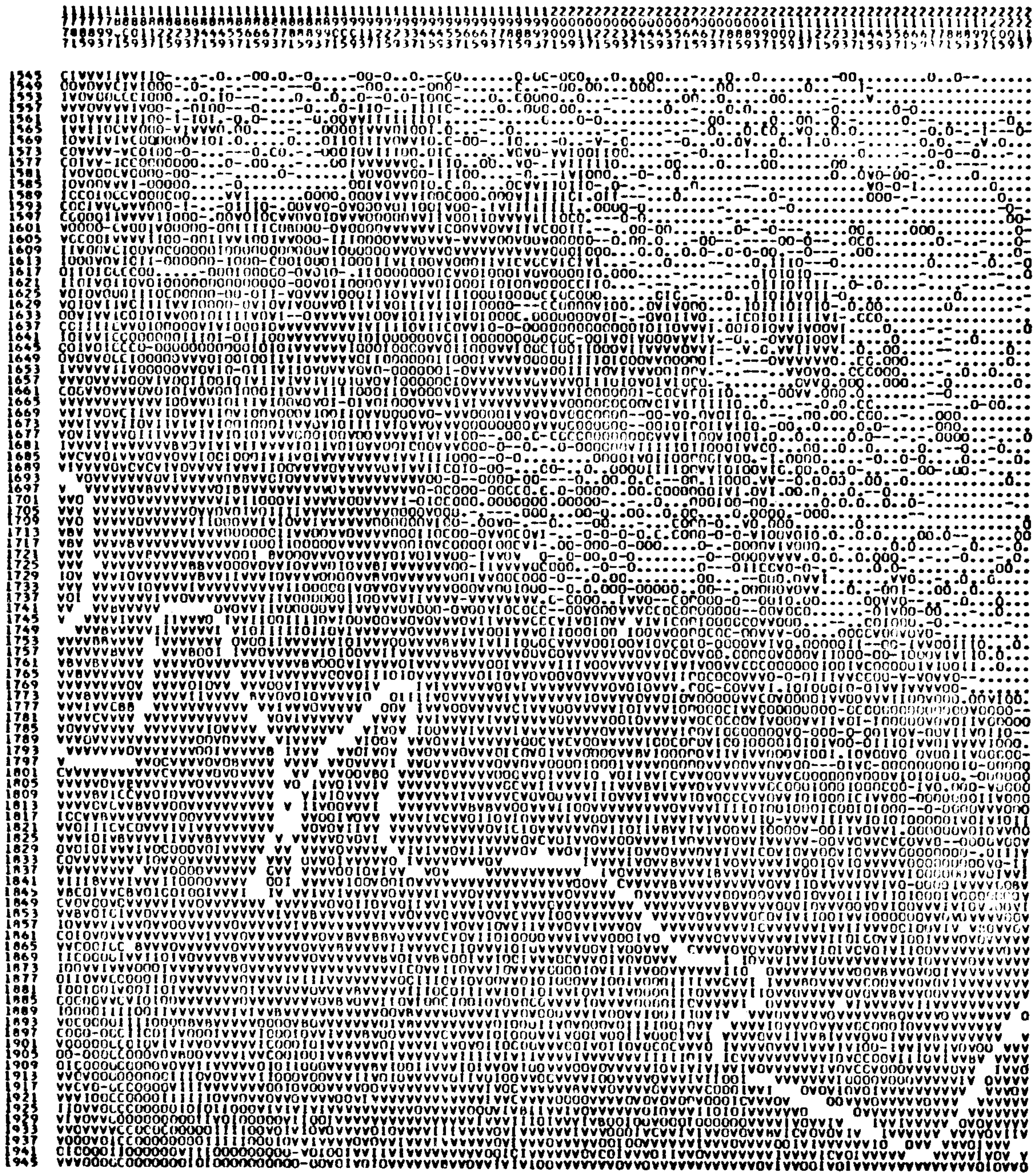
CLASSIFICATION TAPE/FILE NUMBER ... 701/ 6

CHANNELS USED

CHANNEL	1	SPECTRAL BAND	0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL	2	SPECTRAL BAND	0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL	3	SPECTRAL BAND	0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL	4	SPECTRAL BAND	0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
O	SOIL1	O	SOIL6
V	VEG1	O	SOIL7
	WATER	O	SOIL8
I	SOIL2	O	SOIL9
.	SOIL3	O	SOIL10
-	SOIL4	B	SHADOW
O	SOIL5	M	NULL
V	VEG2		



NUMBER OF POINTS DISPLAYED IS 11211

Figure 26. PRINTRESULTS of Baghdad Frame (East), Southern Part.

CLASSIFICATION TAPE/FILE NUMBER ... 701/ 6

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND	0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND	0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
*	SOIL1	+	SOIL6
T	VEG1	1	SOIL7
W	WATER	=	SOIL8
I	SOIL2	J	SOIL9
	SOIL3	-	SOIL10
.	SOIL4	B	SHADOW
/	SOIL5	M	NULL
T	VEG2		

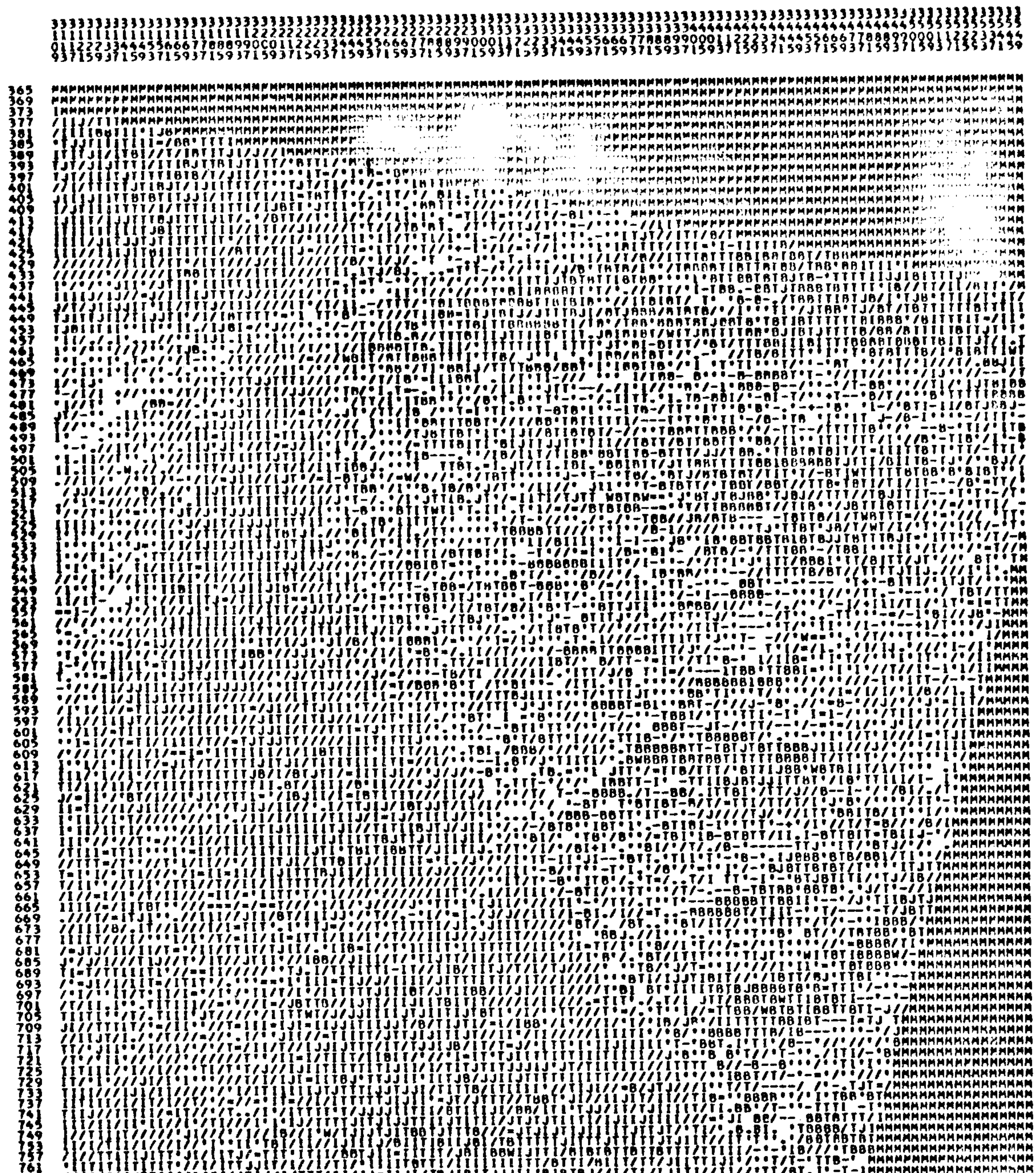


Figure 27. PRINTRESULTS of Baghdad Frame (East), Northeastern Part.

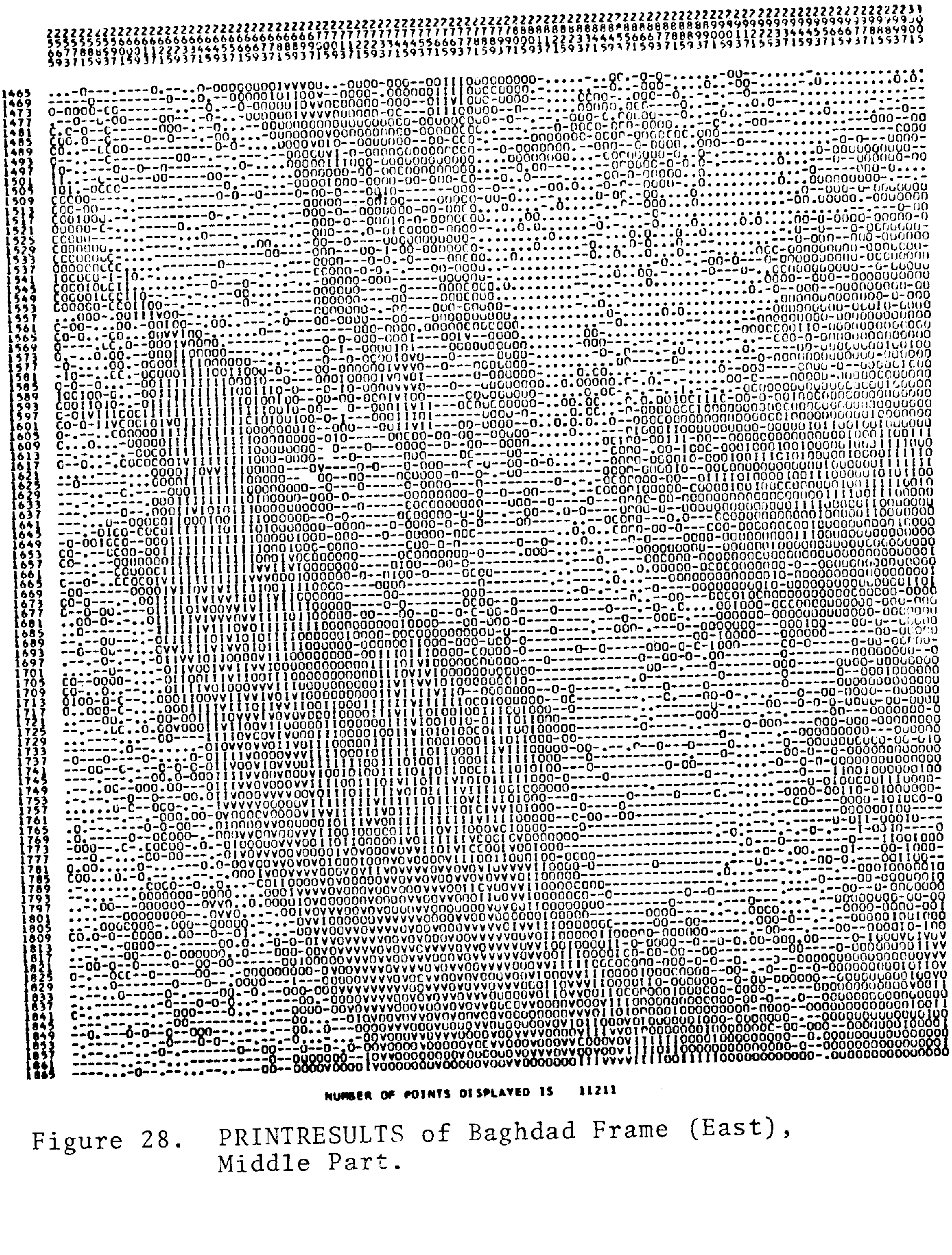
CLASSIFICATION TAPE/FILE NUMBER ... 701/ 6

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
O	SOIL1	O	SOIL6
V	VEG1	O	SOIL7
	WATER	O	SOIL8
I	SOIL2	O	SOIL9
.	SOIL3	O	SOIL10
-	SOIL4	B	SHADOW
O	SOIL5	M	NULL
V	VEG2		



NUMBER OF POINTS DISPLAYED IS 11211

Figure 28. PRINTRESULTS of Baghdad Frame (East), Middle Part.

CLASSIFICATION TAPE/FILE NUMBER ... 701/ 6

CHANNELS USED

CHANNEL 1	SPECTRAL BAND	0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND	0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND	0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND	0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
0	SOIL1	0	SOIL6
V	VEG1	0	SOIL7
	WATER	0	SOIL8
I	SOIL2	0	SOIL9
.	SOIL3	0	SOIL10
-	SOIL4	8	SHADOW
0	SOIL5	N	NULL
V	VEG2		

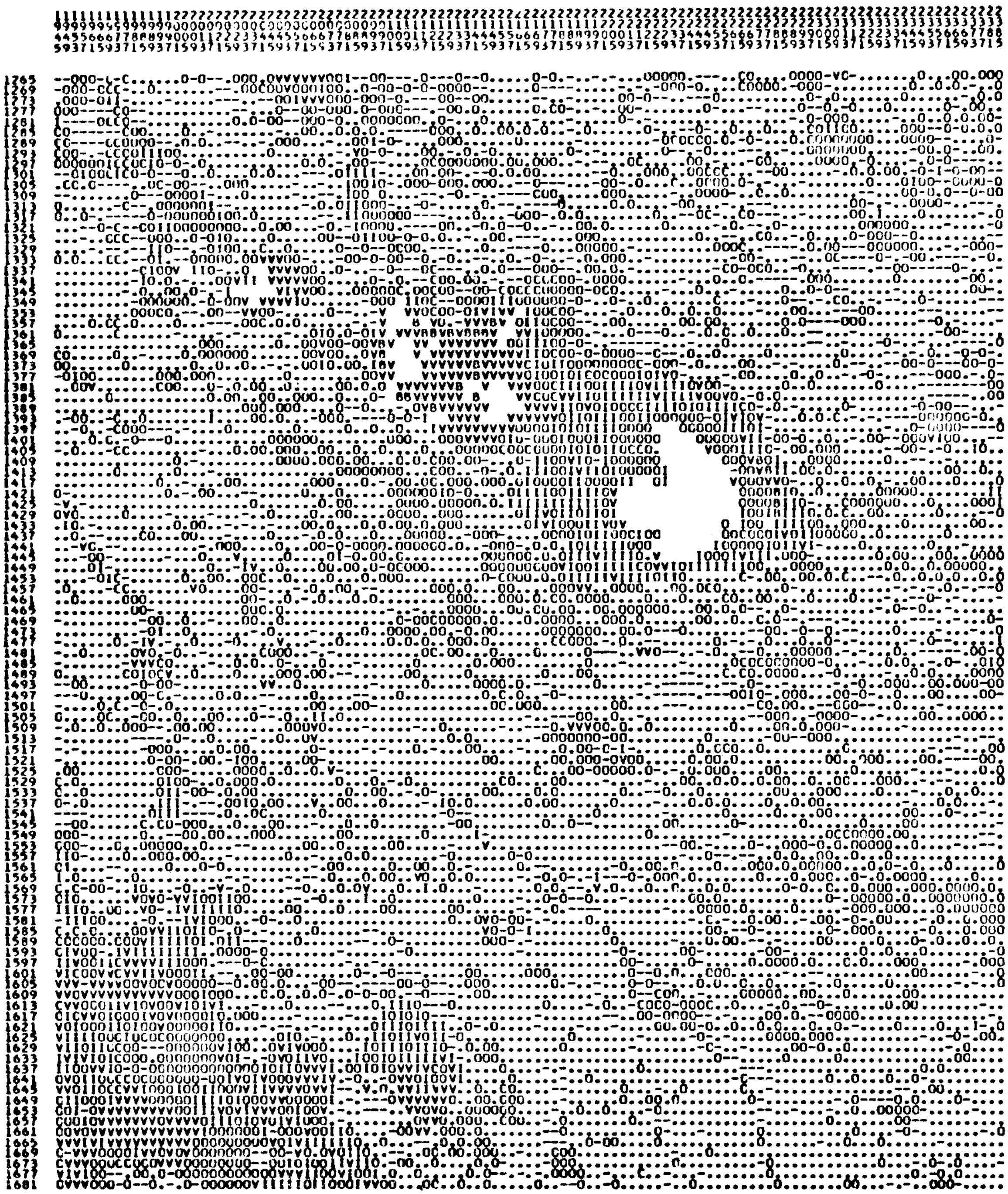


Figure 29. PRINTRESULTS of Baghdad Frame (East), Middle Part.

CLASSIFICATION TAPE/FILE NUMBER ... 7017 6

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
•	SOIL1	+	SOIL6
T	VEG1	I	SOIL7
W	WATER	*	SOIL8
I	SOIL2	J	SOIL9
	SOIL3	-	SOIL10
.	SOIL4	B	SHADOW
/	SOIL5	M	NULL
T	VEG2		

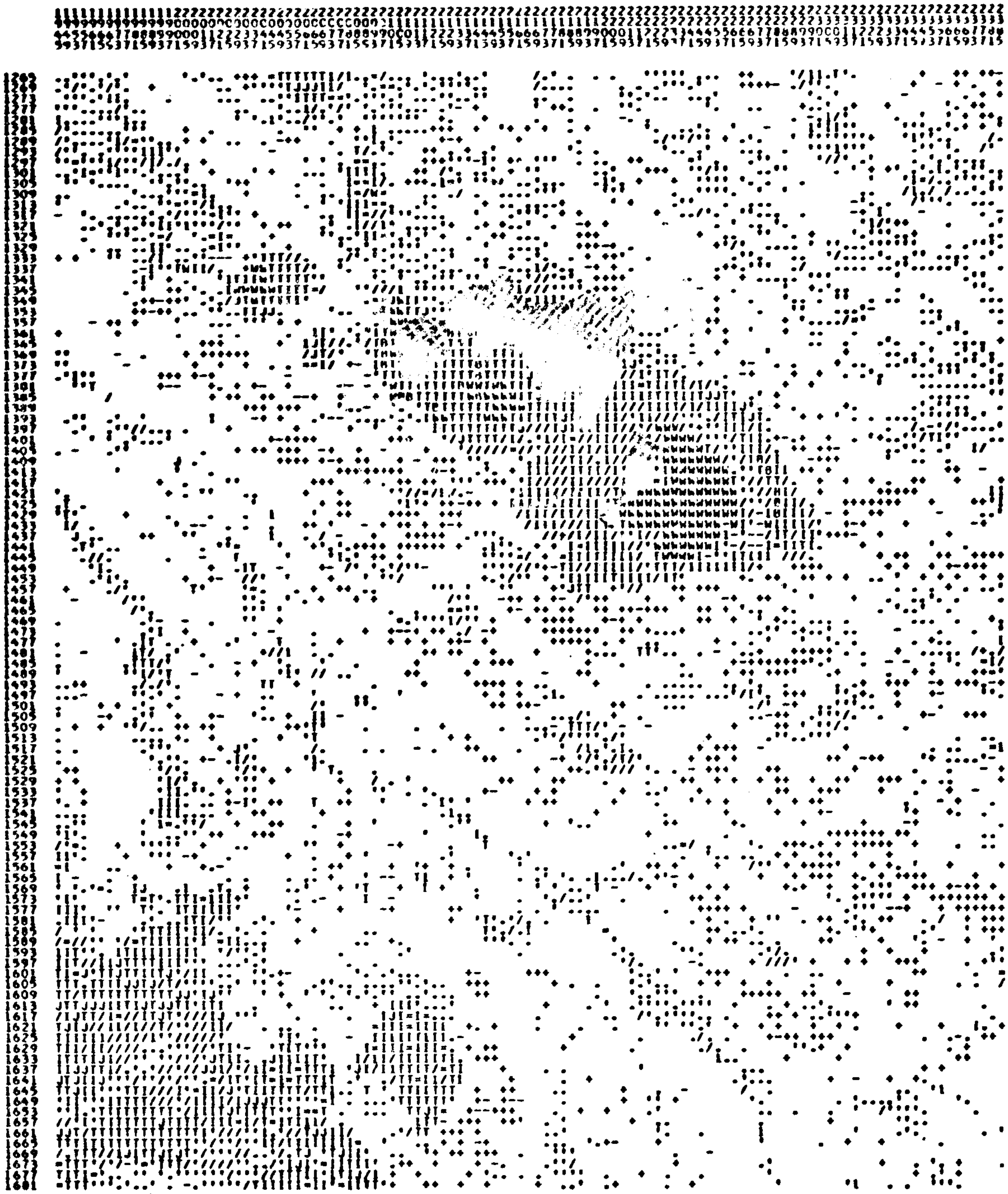


Figure 30. PRINTRESULTS of Baghdad Frame (East), Middle Part.

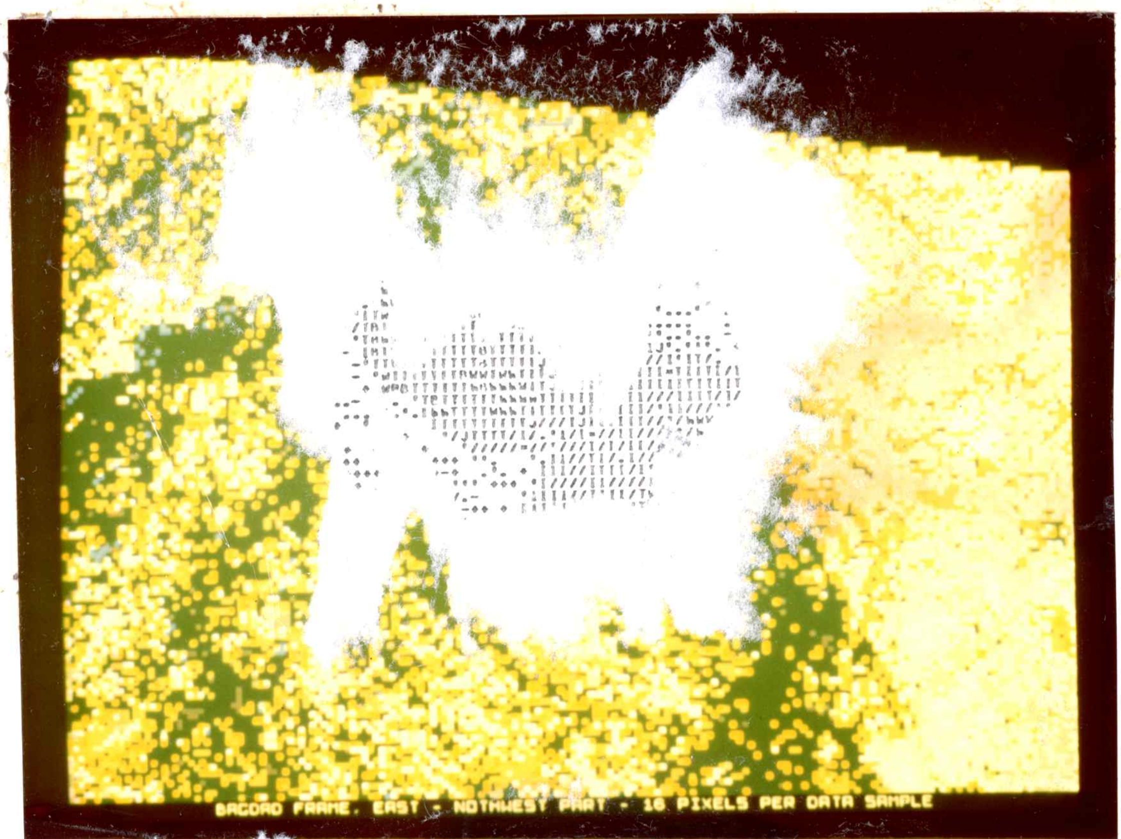


Figure 31. Color-Coded Photo of the Diyala Area, Showing Water (Blue), Vegetation (Dark Green), Normal Soils (Yellow), and Saline Soils (White).

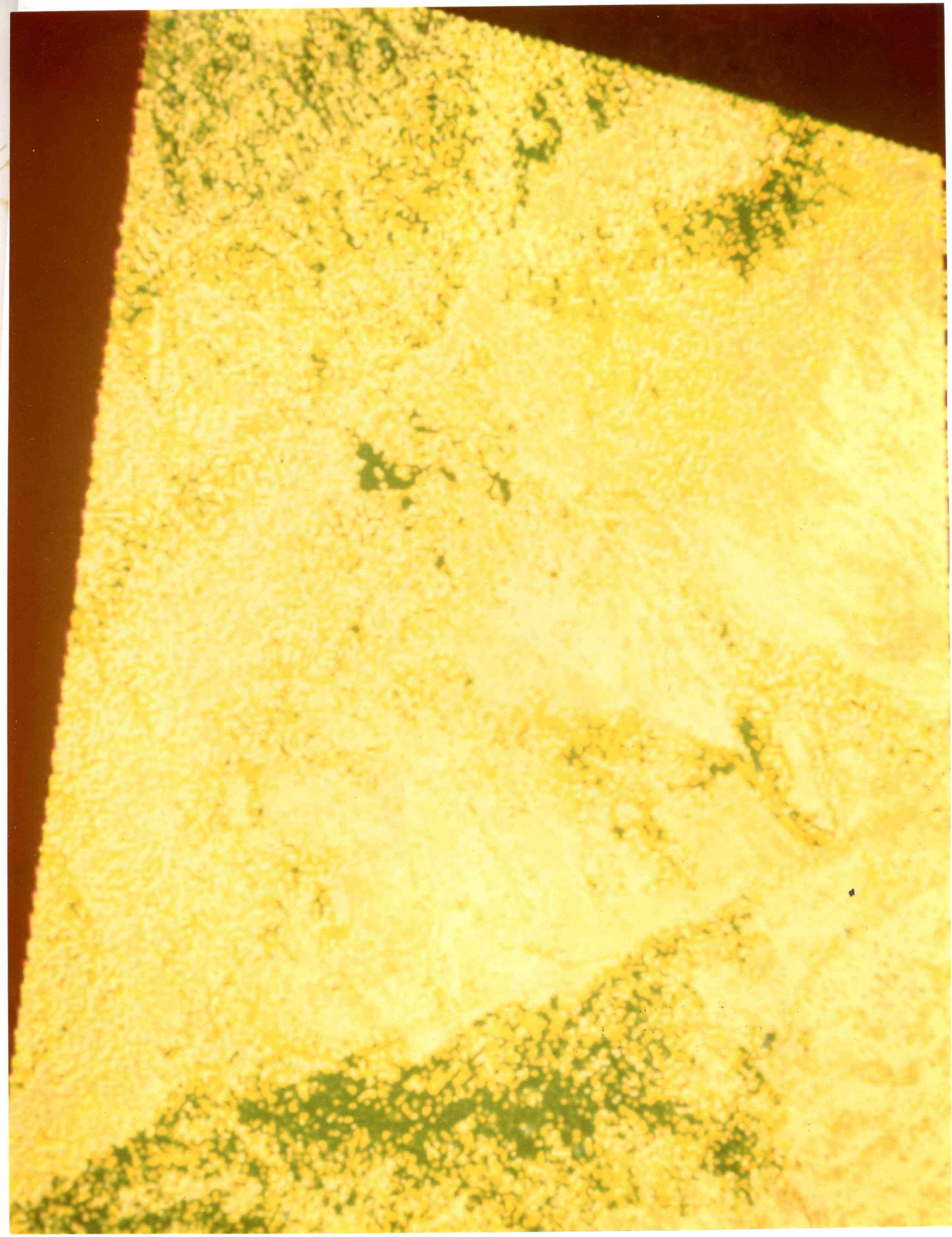


Figure 32. Color-Coded Photo of Baghdad Frame (East) Northern Part Showing Vegetation (Green), Saline Soils (Light Brown), Other Soils (Various Colors).

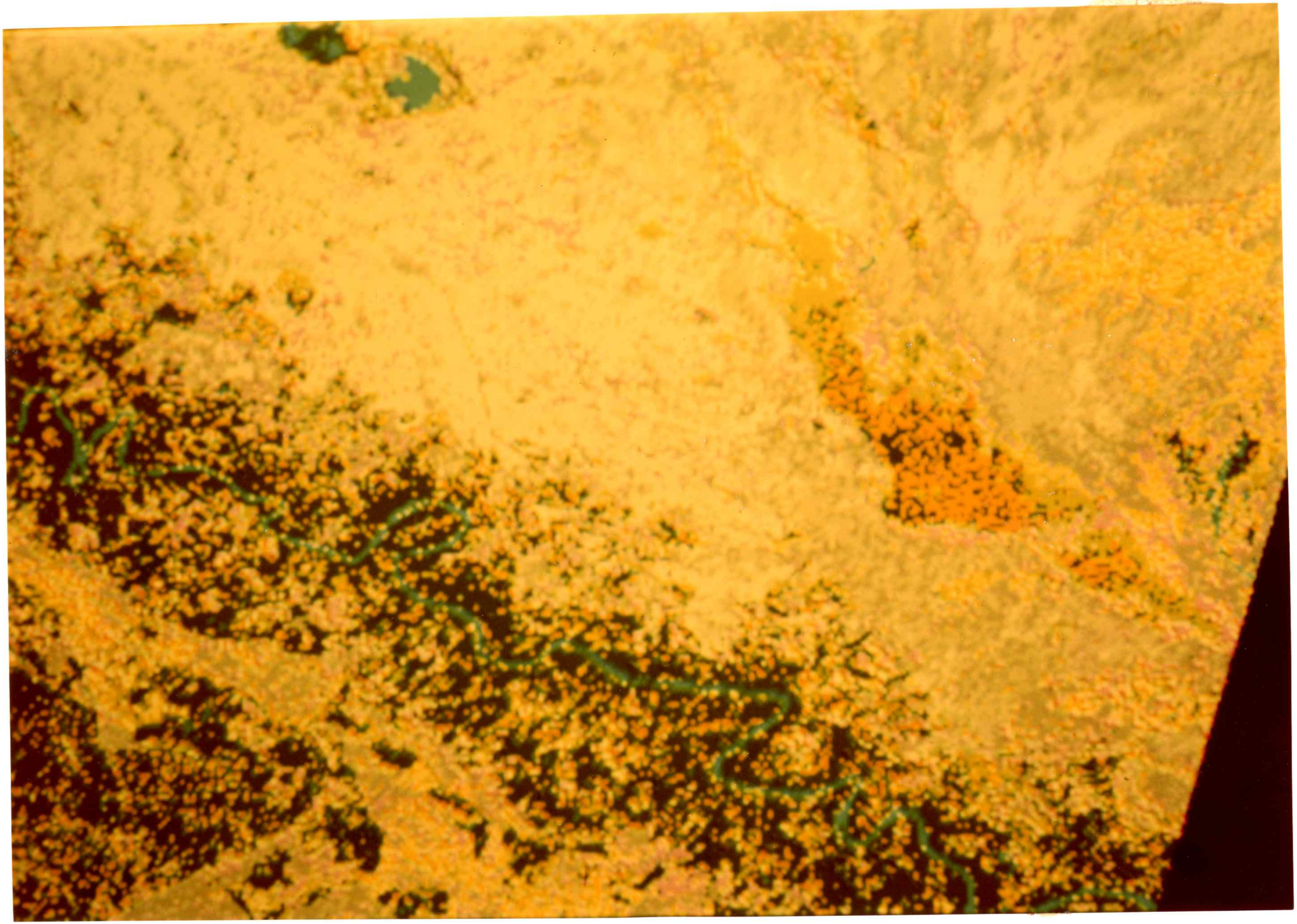


Figure 33. Color-Coded Photo of Baghdad Frame (East) Southern Part Showing Water (Blue), Vegetation (Dark Green), Saline Soils (Light Yellowish Brown), Waterlogged Land (Brown), Other Soils (Various Colors).

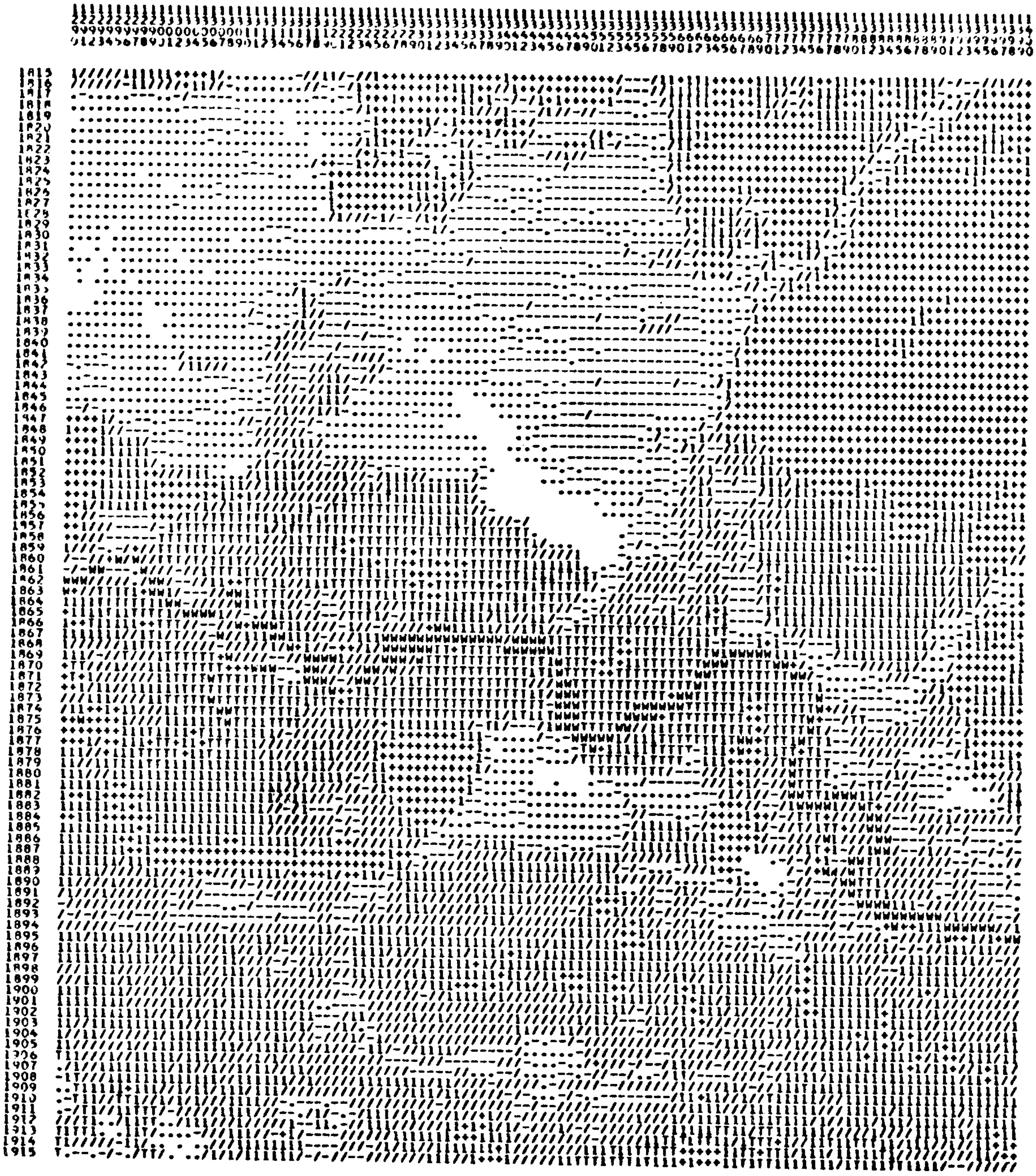
CLASSIFICATION TAPE/FILE NUMBER ... 701/ 4

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
	C1	I	C5
.	C2	+	C6
-	C3	T	C7
/	C4	W	C8



NUMBER OF POINTS DISPLAYED IS 11211

13103 CPU TIME USED WAS 6.587 SECONDS. (LAKSMN)

Figure 34. PRINTRESULTS of Part of Zakho Area.

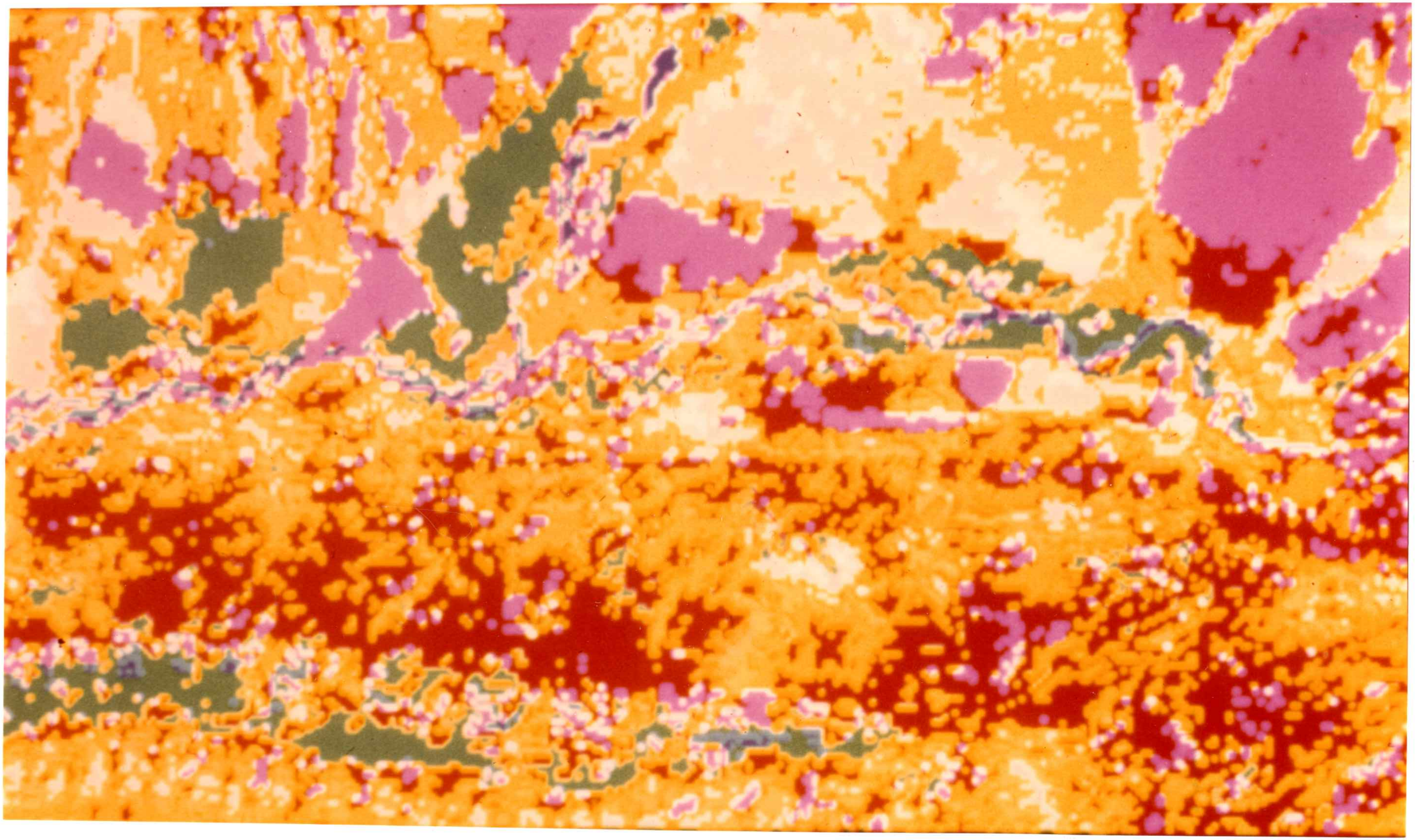


Figure 35. Color-Coded Photo of Zakho Area, Showing Water and Shadow (Blue), Vegetation and Shadow (Green), Various Soil Types (Various Colors).

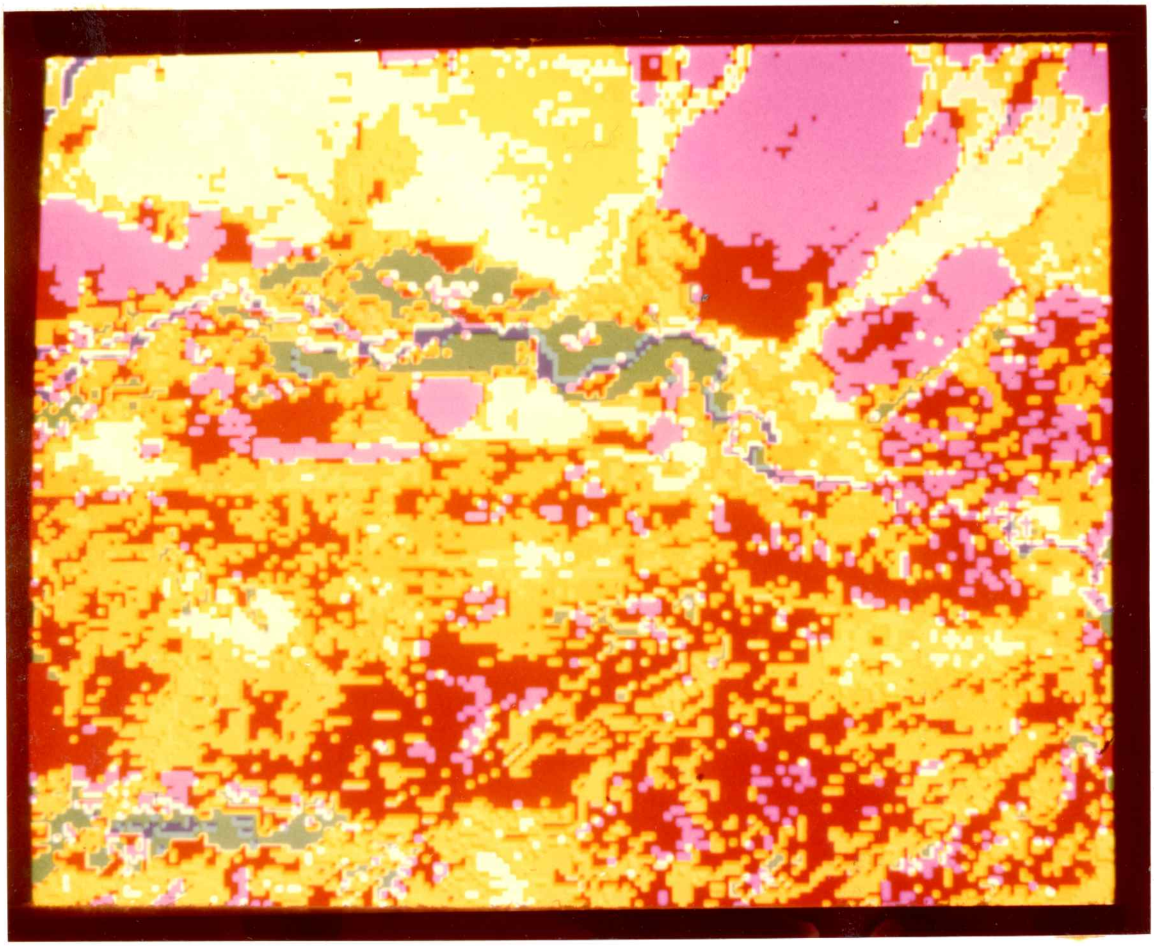


Figure 36. Color-Coded Photo of Part of Zakho Area, Showing Water and Shadow (Blue), Vegetation and Shadow (Green), Various Types of Soils (Various Colors).

Then, Baghdad City was classified separately. With this method a very good map of Baghdad City was generated (Figures 13, 14, 15 and 16).

4. Surface Hydrology.

Water resources data that are useful to the environmental scientists and planners frequently are missing, incomplete, or obtained in fragments in Iraq. A new source of surface hydrological information can be obtained as often as every 18 days through machine processing of Earth Resources Technology Satellite multispectral scanner data.

This study focused on the surface water resources of parts of the Baghdad frame and particularly on Razzaza Lake and the Tigris River at the southern end of Baghdad.

The results of the study indicated that all surface water bodies over 0.5 hectare were identified accurately from LANDSAT multispectral analysis. In some cases, water canals 5 meters in width showed clearly on the resulting maps (Figure 12).

Two distinct classes of water were obtained in the Tigris River at the southern end of Baghdad. One appeared before it got polluted at Dora and the other downstream from that point (Figures 37 and 38).

Three distinct classes of water were delineated in the Razzaza Lake. Their differences may due to variations in (a) silt content, (b) depth and/or (c) presence of macro- and microbiotic forms.

This study indicated that machine processing of LANDSAT multispectral data used alone or in conjunction with conventional sources of hydrological information can lead to the monitoring of the:

(1) area of surface water bodies,
(2) inferences of volume of selected surface water bodies, and
(3) differences in degree of silt and clay suspended in water.

This valuable information obtained from LANDSAT data can be of great help to solve or better understand water resources, water pollution, water erosion, and planning problems in source regions and other regions of the country.

The results of the Baghdad frame classification showed that more than 28 different classes of various types of soils, land use, urban areas, and surface water were obtained. Some

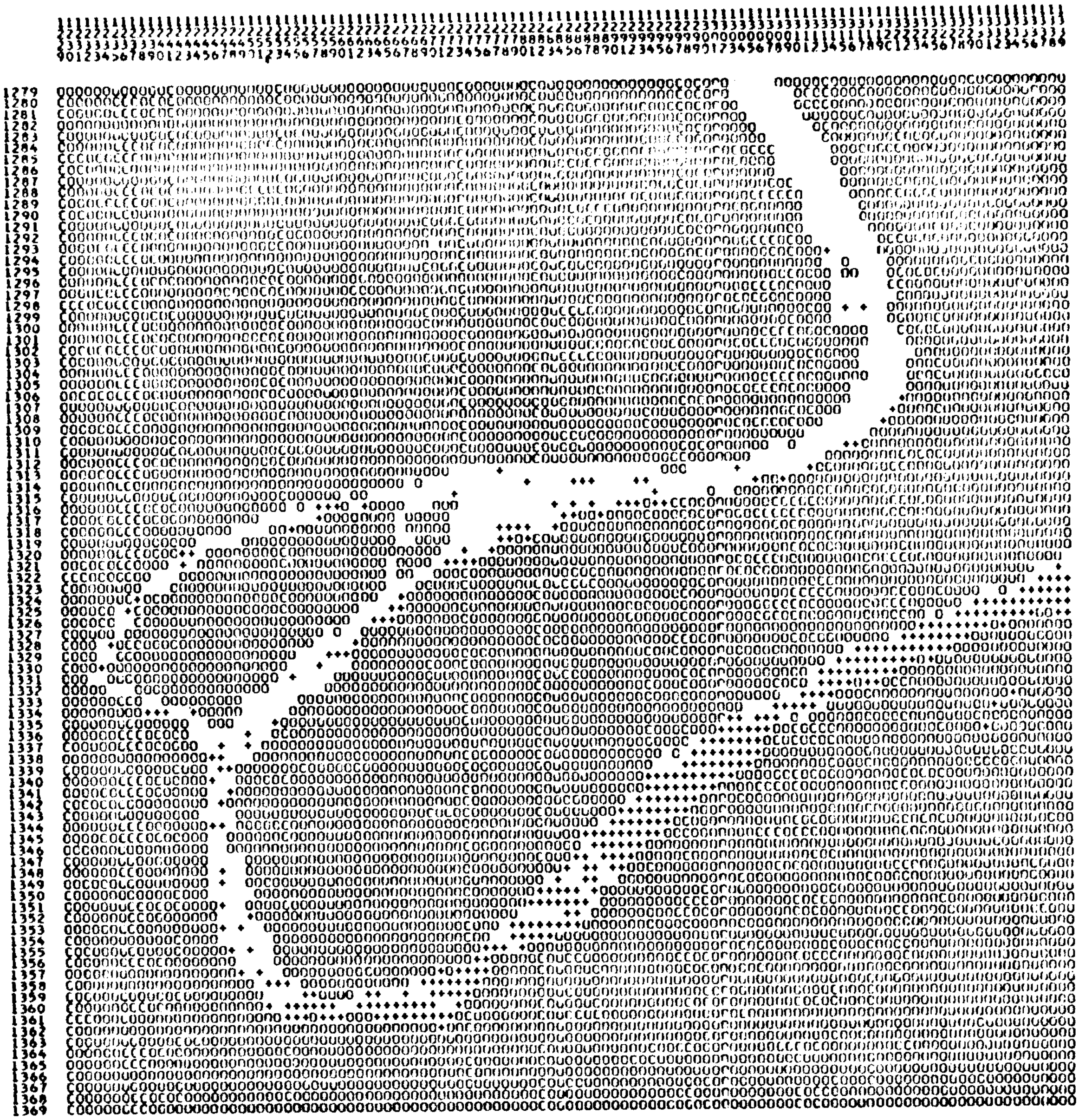
CLASSIFICATION TAPE/FILE NUMBER ... 7017 7

CHANNELS USED

CHANNEL 1	SPECTRAL BAND 0.50 TO 0.60 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0	
CHANNEL 2	SPECTRAL BAND 0.60 TO 0.70 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0	
CHANNEL 3	SPECTRAL BAND 0.70 TO 0.80 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0	
CHANNEL 4	SPECTRAL BAND 0.80 TO 1.10 MICROMETERS	CALIBRATION CODE = 1	CO = 0.0	

CLASSES

SYMBOL	CLASS	SYMBOL	CLASS
0	C1	0	C7
	C2	0	C8
0	C3	0	C9
0	C4	0	C10
0	C5	+	C11
0	C6		



NUMBER OF POINTS DISPLAYED IS 10101

10103 CPU TIME USED WAS 7.788 SECONDS. (LARSMN)

Figure 37. PRINTRESULTS of Part of Baghdad, Showing Clear Water (Blank), Polluted Water (+++) Others (OOO).

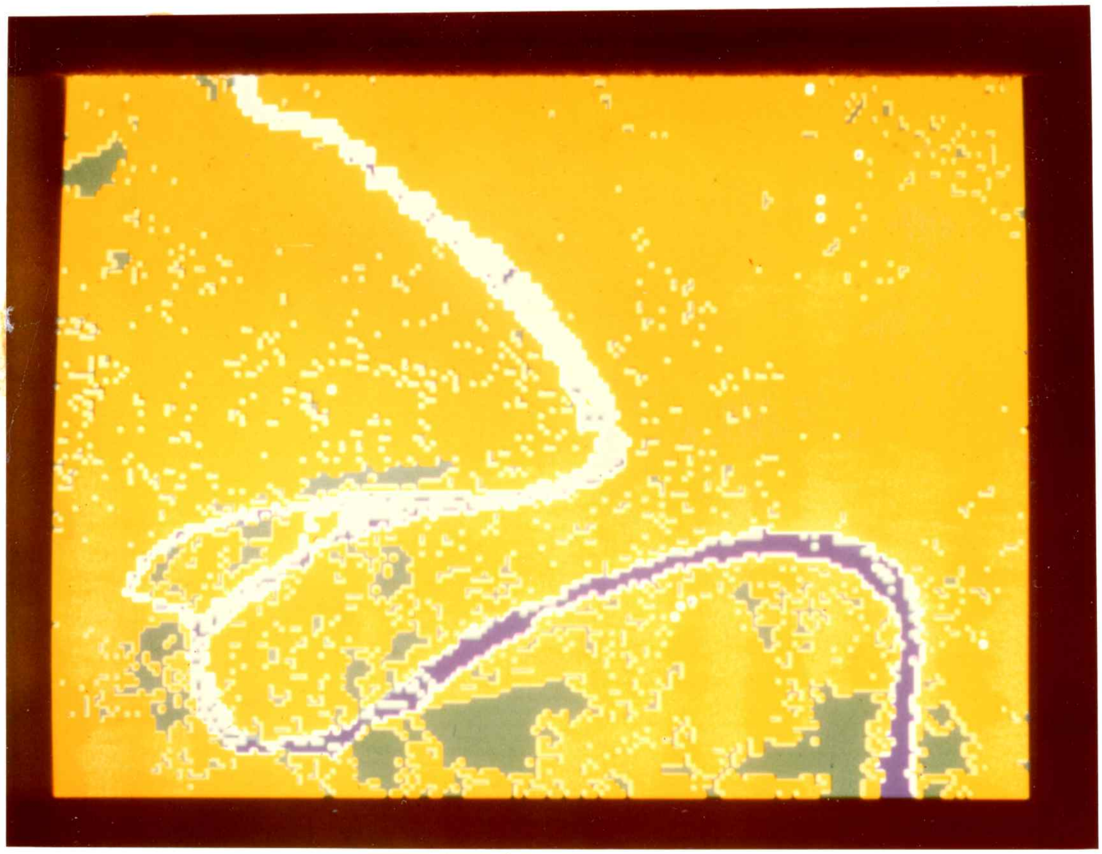


Figure 38. Color-Coded Photo of Southern Part of Baghdad, Showing Clear Water (Light Blue) and Polluted Water (Dark Blue).

of these were interpreted easily with minimal surface information. These were orchards, fully mature field crops, wet land, urban/residential, urban/commercial, clear river water, polluted river water, various types of lake water, many Great Soil Groups (such as Quartzipsamments, Gypsiorthids, Petrogypric Gypsiorthids, Lithic Gypsiorthids and Salorthids), and saline and waterlogged soils.

Other classes have to be checked in the field or compared with accurate maps for final identification.

V. SUMMARY

My work at LARS comprised three stages:

Stage 1 - General introduction to numerous facets of remote sensing

Stage 2 - Detailed education in the pattern recognition approach to multispectral data analysis and

Stage 3 - Research on soils delineation, land use inventory, urban classification, and surface hydrology of the Baghdad frame in the middle of Iraq and part of the Duhok frame in the North of Iraq.

Multispectral scanner data, collected by LANDSAT-1 were used for Stage 3. The Baghdad frame is 185 x 185 km. The data were collected on December 26, 1972. The data of the Duhok frame were collected on July 14, 1973.

Soils of the Baghdad frame comprise the following Great Soil Groups: Gypsiorthids, Petrogypsic Gypsiorthids, Lithic Gypsiorthids, Quartzipsamments, Torrifluvents, Torrents and Salorthids. Some parts of the frame are waterlogged and marshy areas.

This region is characterized by long, dry, hot summers and short rather cool winters. Rainfall is low (6 inches, average) and occurs in winter. Therefore, agriculture is impossible without irrigation.

Natural vegetation is sparse as a result of extreme dryness of the air, high rate of evaporation, low rainfall and high temperature.

Mixed orchards and various field crops are grown near rivers and in irrigated projects.

The Duhok frame is located in the North part of Iraq where the study area (Zakho area) is situated.

The soils of this area are Vertisols, Entisols, Inceptisols, Lithosols, and Regosols.

The climate of this region is characterized by cool, moist winters and mild dry summers. The diurnal and seasonal temperature fluctuation is less than the rest of the country.

Orchards and summer crops are possible with irrigation in this region.

The modified unsupervised (modified clustering) approach was followed in the analysis of the multispectral LANDSAT-1 data of the two regions. This method comprised four basic steps.

1. Defining training areas scattered over the entire study region, with three to five cover types present in each training area (Appendix A);
2. Eigenclustering each training area separately, comparing map with supporting data, and reclustering if necessary (Appendix B);
3. Combining the results of training areas, using the XSEPARABILITY algorithms and developing a single set of training statistics (Appendix C);
4. Classifying the training areas as a preliminary test of training statistics, modifying statistics deck if necessary, and classifying the entire study region.

Because of limitations of computer time, large parts of Baghdad frame were classified to a scale of 1:100,000. However, the classification results were good. Important parts of the frame were classified on a scale of 1:25,000. The results of the latter were very good.

The study indicated that some areas with high complexity lose some details with the 1:100,000 scale classification.

The results of classification of urban site, soil delineation, land use, and surface hydrology were discussed in the text. Evaluation indicated that results were very good.

VI. CONCLUSIONS AND RECOMMENDATIONS

1. The study indicated that application of remote sensing technology to urban classification, soil delineation, land use, and surface hydrology is feasible, quick, timely, and in many cases very accurate.

2. The system, however, is far from being perfect at present, but in the near future will certainly give better results when sensors with greater spectral and spatial resolution are developed.

3. In my study case, excellent results were obtained in identifying water, orchards, and fully grown field crops. However, in rare cases vegetation mixes with shadow.

Good results were obtained in identifying commercial and residential sections of Baghdad City when classified alone. However, when it was classified within a larger region, some difficulty arose due to similarity of reflectance between urban and irrigated land. This could probably have been overcome with a multiple data set.

Good results were also obtained in delineating soil types, but better results were obtained when a small portion of a frame was classified rather than a large portion of the frame which includes many physiographic units.

4. My analysis experience and review of the literature have led me to conclude that remote sensing technology is a very useful tool for many fields such as agriculture, geology, geography, engineering, surveying, forestry, agronomy, soils, land use, urban classification, and surface hydrology. It is especially useful for surface hydrology, land use, and soils.

5. I recommend that this technology be established in Iraq as soon as possible, because it will even be more useful in the near future when better spectral and spatial resolution is developed.

6. I suggest that a multidisciplinary organization be established to develop this technique for the interest of all fields concerned. The stature of LARS is an example of the success of an interdisciplinary approach. If, however, access to this technology can only be through one unidiscipline organization, then I suggest that some arrangement be made to give all fields of interest opportunity to develop on an equal basis.

VII. SELECTED BIBLIOGRAPHY

Anderson, J. R., Hardy, E. E. and Roach, J. T. (1972). A Land-use Classification System for Use with Remote Sensor Data. Geological Survey Circular 671.

Anuta, P. and Bauer, M. (1973). Analysis of Temporal Data for Crop Species Classification and Urban Change Detection. LARS Information Note 110873.

Anuta, P. E. (1975). Computer-Aided Analysis Techniques for Remote Sensing Data Interpretation. LARS Information Note 100675.

Anuta, P. E. (1974)., Spline Function Approximation Techniques for Image Geometric Distortion Representation. LARS Information Note 103174.

Aunta, P. E. (1973). Geometric Correction of ERTS-1 Digital Multispectral Scanner Data. LARS Information Note 103073.

Biehl, L. L. and Silva, L. F. (1974). A Multilevel Multispectral Data Set Analysis in the Visible and Infrared Wavelength Regions. LARS Information Note 082174.

Baker, J. R. and Mikhail, M. E. (1975). Geometric Analysis and Restitution of Digital Multispectral Scanner Data Arrays. LARS Information Note 052875.

Berkebile, J., Russell, J. and Lube, B. (1976). A Forestry Application Simulation of Man-Machine Techniques for Analyzing Remotely Sensed Data. LARS Information Note 012376.

Bartolucci, L. A., Robinson, B. F. and Silva, L. F. (1975). Field Measurements of the Spectral Response of Natural Waters. LARS Information Note 111275.

Bauer, M. E. and Cipra, J. E. (1973). Identification of Agricultural Crops. LARS Information Note 030173.

Bauer, M. E., Cary, T. K., Davis, B. J. and Swain, P. H. (1975). Crop Identification Technology Assessment for Remote Sensing (CITARS). LARS Information Note 072175.

Bauer, M. E. (1975). The Role of Remote Sensing in Determining the Distribution and Yield of Crops. Advances in Agronomy. Vol. 27.

Baumgardner, M. F., Kristof, S. J., Johannsen, C. J. and Zachary, A. L. (1970). Effects of Organic Matter Properties of Soils. LARS Information Note 030570.

Baumgardner, M. F., Kristof, S. J. and Melhorn, W. N. (1972). Journal Paper No. 4937, Purdue University Agricultural Experiment Station. LARS Information Note 110872.

Baumgardner, M. F. Henderson, J. A., Jr. and the LARS Staff. (1973). Mapping Soils, Crops, and Rangelands by Machine Analysis of Multi-temporal ERTS-1 Data. LARS Information Note 121173.

Baumgardner, M. F. and Walker, C. F. (1973). Space Science Aids Agriculture.

Bizzell, R., Hall, F., Feiveson, A., Bauer, M., Davis, B., Malila, W. and Rice, D. (1976). Results from the Crop Identification Technoloby Assessments for Remote Sensing (CITARS) Project. LARS Information Note 012176.

Cary, T. K. and Lindenlaub, J. C. (1975). A Case Study Using LARSYS for Analysis of LANDSAT Data. LARS Information Note 050575.

Cipra, J. E., Swain, P. H., Gill, J. H., Baumgardner, M. F. and Kristof, S. J. (1972). Definition of Spectrally Separable Classes for Soil Survey Research. LARS Print 100372.

Cipra, J. E. (1973). Mapping Soil Associations Using ERTS MSS Data. LARS Information Note 101773.

Coggeshall, M. E. and Hoffer, R. M. (1973). Basic Forest Cover Mapping Using Digitized Remote Sensor Data and ADP Techniques. LARS Information Note 030573.

Ellefsen, R., Swain, P. H. and Wray, J. R. (1973). Urban Land Use Mapping by Machine Processing of eRTS-1 Multispectral Data: A San Francisco Bay Area Example. LARS Information Note 101573.

Emmert, R. A., McGillem, C. D. (1973). Multispectral Geometric Distortion Correction Utilizing the Affine Transformation. LARS Information Note 101473.

Fleming, M. D., Berkebile, J. S. and Hoffer, R. M. (1975). Computer-Aided Analysis of LANDSAT-1 MSS Data: A Comparison of Three Approaches Including a "Modified Clustering Approach. LARS Information Note 172475.

Follestad, B. A. (1974). Computer Analysis of ERTS-1 Imagery and Mapping of Surficial Deposits in a Test Area within the Monticello North Quadrangle, Indiana. LARS Information Note 111774.

Gates, D. M. (1965). A. Head, Radiant and Sensible, Chapter 1, Radiant Energy, Its Receipt and Disposal. National Bureau of Standards, Boulder, CO.

Gupta, J. N., Kettig, R. L., Landgrebe, D. A. and Wintz, P. A. (1973). Machine Boundary Finding and Sample Classification of Remotely Sensed Agricultural Data. LARS Information Note 102073.

Hauska, H. and Swain, P. (1975). The Decision Tree Classifier: Design and Potential. Purdue University, West Lafayette, Indiana.

Henderson, J. A., Baumgardner, M. F. and Walker, C. F. (1974). Preparing Resources Inventories in the Southern Great Plains by Machine Processing of eRTS-1 Multispectral Data. LARS Information Note 022274.

Henderson, J. A., Gardner, J. J., Cipra, J. E. (1973). An Interpretation of a Geologic Map of Fannin County, Texas, Prepared by ADP Techniques from ERTS MSS Data. LARS Information Note 031673.

Hoffer, R. M., Anuta, P. E. and Phillips, T. L. (1971). Application of ADP Techniques to Multiband and Multiemulsion Digitized Photography. LARS Information Note 091071.

Hoffer, R. M. and the LARS Staff. (1973). Techniques for Computer-Aided Analysis of eRTS-1 Data Useful in Geologic, Forest and Water Resource Surveys. LARS Information Note 121073.

Hoffer, R. M. and Staff. (1972). Land Utilization and Water Resources Inventory over Extended Test Sites. LARS Information Note 012772.

Hoffer, R. M. (1971). The Importance of "Ground Truth" Data in Remote Sensing. LARS print 120371.

Hoffer, R. M. (1972). ADP of Multispectral Scanner Data for Land Use Mapping. LARS Information Note 080372.

Hoffer, R. M. and Staff. (1975). Computer-Aided Analysis of SKYLAB Multispectral Scanner Data in Mountainous Terrain for Land Use, Forestry, Water Resources, and Geologic Applications. LARS Information Note 121275.

Jurica, G. M. and Murray, W. L. (1972). Influence of Haze Layers on Remotely Sensed Surface Properties. LARS Information Note 161272.

Kettig, R. and Landgrebe, D. A. (1975). Computer Classification of Remotely Sensed Multispectral Image Data by Extraction and Classification of Homogeneous Objects. LARS Information Note 050975.

Kettig, R. L. and Landgrebe, D. A. (1973). Automatic Boundary and Sample Classification of Remotely Sensed Multispectral Data. LARS Information Note 041773.

Kettig, R. L., Landgrebe, D. A. (1975). Classification of Multispectral Image Data by Extraction and Classification of Homogeneous Objects. LARS Information Note 062375.

Kettig, R. L. and Landgrebe, D. A. (1976). Classification of Multispectral Image Data by Extraction and Classification of Homogeneous Objects. IEEE Transactions on Geoscience Electronics, Vol. GE-14, No. 1, January 1976. LARS Information Note 062375.

Kristof, S. J. and Zachary, A. L. (1971). Mapping Soil Types from Multispectral Scanner Data. LARS Information Note 061471.

Kristof, S. J. (1971). Preliminary Studies of Soils. Reprint from the Journal of Soils and Water Conservation. Vol. 26, No. 1.

Kristof, S. J. and Zachary, A. L. (1974). Mapping Soil Features from Multispectral Scanner Data. Purdue University, West Lafayette, Indiana. LARS Information Note 042674.

Kristof, S. J. and Baumgardner, M. F. (1975). Changes of Multispectral Soils Patterns with Increasing Crop Canopy.

Landgrebe, D. A. (1973). Machine Processing for Remotely Acquired Data. LARS Information Note 031573.

Landgrebe, D. A., Hoffer, R. M., Goodrick, F. E. and Staff. (1972). An Early Analysis of ERTS-1 Data. LARS Information Note 092972.

Landgrebe, D. A., Billingsley, F. C. and Nichols, J. D. (1973). Machine Processing Methods for Earth Observational Data. LARS Information Note 100773.

Landgrebe, D. A. and Staff. (1973). Analysis Research for Earth Resource Information System: Where Do We Stand? LARS Information Note 062273.

Landgrebe, D. (1972). Automatic Classification with ERTS-1 Data. LARS Print 101472.

Lindenlaub, J. and Russell, J. (1974). An Introduction to Quantitative Remote Sensing. LARS Information Note 110474.

Lindenlaub, J. C. (1974). Guide to Multispectral Data Analysis Using LARSYS. LARS Information Note 062874.

Lindenlaub, J. C., Davis, S. M., and Morrison, D. B. (1975). Bringing Remote Sensing Technology to the User Community. LARS Information Note 051975.

McGillem, C. D. (1975). Interpolation of ERTS-1 Multispectral Scanner Data. LARS Information Note 022175.

McGillem, C. D. and Svedlow, M. (1974). Image Registration Error Variance as a Measure of Overlay Quality. LARS Information Note 090274.

Mikhail, E. M. and Baker, J. R. (1973). Geometric Aspects in Digital Analysis of Multispectral Scanner (MSS) Data. LARS Information Note 042473.

Melhorn, W. N. and Sinnock, S. (1973). Recognition of Surface Lithologic and Topographic Patterns in Southwest Colorado with ADP Techniques. LARS Information Note 030273.

Matthews, H. L., Cunningham, R. L., Cipra, J. E. and West, T. R. (1973). Application of Multispectral Remote Sensing to Soil Survey Research in Southeastern Pennsylvania. SSSP, Volume 37, No. 1.

Mausel, P. W., Todd, W. J. and Baumgardner, M. F. (1976). An Analysis of Metropolitan Land Use by Machine Processing of Earth Resources Technology Satellite Data.

Mausel, P. W., Todd, W. J., Baumgardner, M. F., Mitchell, R. A. and Cook, J. P. (1973). Evaluation of Surface Water Resources from Machine Processing of ERTS Multispectral Data. LARS Information Note 030576.

Montgomery, O. L. and Baumgardner, M. F. (1974). The Effects of the Physical and Chemical Properties of Soils on the Spectral Reflectance of Soils. LARS Information Note 112674.

Murray, W. L. and Jurica, J. G. (1973). The Atmospheric Effect in Remote Sensing of Earth Surface Reflectivities. LARS Information Note 110273.

Parsons, C. L. and Jurica, G. M. (1975). Correction of Earth Resources Technology Satellite Multispectral Scanner Data for the Effect of the Atmosphere. LARS Information Note 061875.

Peterson, J. B. (1975). Quantitative Inventorying of Soils and Land Use Differences by Remote Sensing. LARS Information Note 063075.

Ravindra, K. and Silva, L. F. (1973). Emission and Reflectance from Healthy and Stressed Natural Targets with Computer Analysis of Spectroradiometric and Multispectral Scanner Data. LARS Information Note 072473.

Ready, P. J., Wintz, P. A., Landgrebe, D. A. (1971). A Linear Transformation for Data Compression and Feature Selection in Multispectral Imagery. LARS Information Note 072071.

Research Bulletin 919. (1975). Hoffer, R. M. and Staff. Natural Resource Mapping in Mountainous Terrain by Computer Analysis of ERTS-1 Satellite Data. LARS Information Note 061575.

Riemer, T. E. and McGillem, C. D. (1974). Optimum Constrained Image Restoration Filters. LARS Information Note 019174.

Silva, L. F., Schultz, F. V. and Zalusky, J. T. (1974). Electrical Methods of Determining Soil Moisture Content. LARS Information Note 112174.

Stockton, J. G., Bauer, M. E., Blair, B. O. and Baumgardner, M. F. (1975). The Use of ERTS-1 Multispectral Imagery for Crop Identification in a Semi-Arid Climate. LARS Information Note 040775.

Stoner, E. R. and Baumgardner, M. F. (1972). Multispectral Determination of Vegetative Cover in Corn Crop Canopy. LARS Information Note 111072.

Svedlow, M., McGillem, C. D. and Anuta, P. E. (1975). Experimental Examination of Similarity Measures and Preprocessing Methods Used for Image Registration. LARS Information Note 052175.

Swain, P. H., Wu, C. L., Landgrebe, D. A., and Hauska, H. (1975). Layered Classification Techniques for Remote Sensing Applications. LARS Information Note 061275.

Swain, P. H. (1972). Pattern Recognition: A Basis for Remote Sensing Data Analysis. LARS Information Note 111572.

Swain, P. H., King, R. C. (1973). Two Effective Feature Selection Criteria for Multispectral Remote Sensing. LARS Information Note 042673.

Swain, P. H. (1973). Data Processing 1: Advancements in Machine Analysis of Multispectral Data. LARS Information Note 012472.

Tarnocai, C. and Kristof, S. J. (1975). Computer-Aided Classification of Land and Water Bodies Using ERTS-1, MacKenzie Delta Area, N.W.T. LARS Information Note 031875.

Thie, J., Tarnocai, C., Miles, G. E. and Kristof, S. J. (1975). A Rapid Resources Inventory for Canada's North by Means of Satellite and Airborne Remote Sensing. LARS Information Note 031775.

Todd, W. J., Mausel, P. W. and Baumgardner, M. F. (1973). Urban Land Use Monitoring from Computer-Implemented Processing of Airborne Multispectral Sensor Data. LARS Information Note 061873.

Todd, W. J., Mausel, P. W. and Baumgardner, M. F. (1976). Urban Land Use Monitoring of Airborne Multispectral Data. LARS Information Note 032576.

Todd, W. J. and Baumgardner, M. F. (1973). Land Use Classification of Marion County, Indiana, by Spectral Analysis of Digitized Satellite Data. LARS Information Note 101673.

Wacker, A. G. and Landgrebe, D. A. (1972). Minimum Distance Classification in Remote Sensing. LARS Information Note 030772.

West, T. R. (1972). Engineering Soils Mapping from Multispectral Imagery Using Automatic Classification Techniques. LARS Information Note 010772.

Westin, F. C. and Franzee, C. J. LANDSAT Data, Its Use in a Soil Survey Program.

Wu, C. L., Landgrebe, D. A. and Swain, P. H. (1974). The Decision Tree Approach to Classification. LARS Information Note 090174.

Zachary, A. L., Cipra, J. E., Diderickson, R. I., Kristof, S. J. and Baumgardner, M. F. (1972). Application of Multispectral Remote Sensing to Soil Survey Research in Indiana. LARS Print 110972.

VIII. APPENDICES

Appendix A: Gray Scale Prints and Training Areas

Appendix B: Clustering Results of Training Areas

Appendix C: Results of XSEPARABILITY

Appendix D: Classification Maps

Appendix E: Graphs of Mean Spectral Response vs. Wavelength