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INTERDISCIPLINARY APPLICATIONS AND INTERPRETATIONS OF ERTS DATA WITHIN THE SUSQUEHANNA RIVER BASIN

Resource Inventory, Land Use, and Pollution

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16. Abstract

An interdisciplinary group in ORSER-SSEL at Penn State University is analyzing ERTS-1 data. The geographical area of interest is that part of the Susquehanna River Basin in Pennsylvania. The objectives of the work have been to ascertain the usefulness of ERTS data in the areas of natural resources and land use inventory, geology and hydrology, and environmental quality. Specific results include a study of land use in the Harrisburg area, discrimination between types of forest resources and vegetation, detection of previously unknown geologic faults and correlation of these with known mineral deposits and ground water, mapping of mine spoils in the anthracite region of eastern Pennsylvania, and mapping of strip mines and acid mine drainage in central Pennsylvania. Both photointerpretive techniques and automatic computer processing methods have been developed and used, separately and in a combined approach.

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Preface

The purpose of this report is to present a comprehensive review of the efforts of the Office for Remote Sensing of Earth Resources (ORSER) of the Space Science and Engineering Laboratory (SSEL) at The Pennsylvania State University in analyzing ERTS-1 data over the period June 1, 1972 to May 31, 1973. This has been an interdisciplinary effort involving nine faculty members from six departments in three colleges of the University. The geographical area of interest is that part of the Susquehanna River Basin which lies in Pennsylvania. The general objectives of the work were to: (1) ascertain the practical usefulness of the spatial and temporal data provided by ERTS; (2) develop interpretation techniques; (3) apply remote sensing in regional resource management; (4) provide graduate training and undergraduate instruction in remote sensing; and (5) evaluate the effectiveness of interdisciplinary research and university-industry related research. Specific objectives were grouped into four major categories: (1) inventory of natural resources and land use; (2) geology and hydrology; (3) environmental quality; and (4) digital processing and pattern recognition.

Specific results include a study of land use in the Harrisburg area, discrimination between types of forest resources and vegetation, detection of previously unknown geologic faults and correlation of these with known mineral deposits and ground water, mapping of mine spoils in the anthracite region of eastern Pennsylvania, and mapping of strip mines and acid mine drainage in central Pennsylvania. Both photointerpretive techniques and automatic computer processing methods have been developed and used, separately and in a combined approach.

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Acknowledgements

The work reported here was primarily supported by the National Aeronautics and Space Administration, Goddard Space Flight Center, under contract number NAS 5-23133, supplementary support was provided by the Space Science and Engineering Laboratory (SSEL) at The Pennsylvania State University. In addition, the contribution of significant amounts of unfunded computer time by the University is acknowledged. A special note of appreciation is given to Nanna Bolling for the compilation, editing, and production of this report.

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INTRODUCTION

The purpose of this report is to present a comprehensive review of the efforts of the Office for Remote Sensing of Earth Resources (ORSER) of the Space Science and Engineering Laboratory (SSEL) at The Pennsylvania State University in analyzing ERTS-1 data over the period June 1, 1972 to May 31, 1973. This has been an interdisciplinary effort involving nine faculty members from six departments in three colleges of the University. The geographical area of interest is that part of the Susquehanna River Basin which lies in Pennsylvania. The general objectives of the work were to: (1) ascertain the practical usefulness of the spatial and temporal data provided by ERTS; (2) develop interpretation techniques; (3) apply remote sensing in regional resource management; (4) provide graduate training and undergraduate instruction in remote sensing; and (5) evaluate the effectiveness of interdisciplinary research and university-industry related research. Specific objectives were grouped into four major categories: (1) inventory of natural resources and land use; (2) geology and hydrology; (3) environmental quality; and (4) digital processing and pattern recognition.

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ORSER ORGANIZATION AND PROCEDURES

Operating as a division of the Space Science and Engineering Laboratory, ORSER occupies a unique position within The Pennsylvania State University. The following pages describe the establishment and history of ORSER, its objectives and personnel, and the handling and management of data to facilitate their use by ORSER investigators.

THE ESTABLISHMENT AND HISTORY OF ORSER

In 1970, an interdisciplinary group was established at The Pennsylvania State University with the capability of participating in projects involving the use of remotely sensed data of earth resources. This group of investigators is called the Office for Remote Sensing of Earth Resources (ORSER) and is composed of personnel from the following disciplines: agronomy, air pollution, civil engineering, computer science, electrical engineering, forestry, geology, geophysics, hydrology, plant pathology, pattern recognition, and soils. ORSER was formed as a division of, and with financial support from, the Space Science and Engineering Laboratory (SSEL) which is a part of The Pennsylvania State University's Intercollege Research Program (Figure 1).

Administered by the Office of the Vice-President for Research and Graduate Studies for the University, SSEL functions as a subunit of the Institute for Science and Engineering. A major purpose of SSEL is to give focus to research and graduate study in the space sciences and space-related sciences and engineering, to provide support services of a technical and administrative nature to programs operated in existing departments, and to administer funds for the support of new programs developed within departments or on an interdepartmental basis. Major financial support for SSEL has come from the NASA office of University Affairs through the Sustaining University Program. Activities of the Laboratory since 1965 have included 40 separate research projects involving 106 faculty members and 115 graduate students from 31 departments in four colleges of the University.

ORSER was established by SSEL to encourage interdisciplinary research activities involving remote sensing. To insure that this group functions in an interdisciplinary nature, a problems-orientated approach has been taken so that each problem or task is directly represented in the organizational structure. This allows associates from various disciplines to work together toward a common goal rather than have each discipline devoted to a specific project. The present organization of ORSER is shown in Figure 2 . An Associate Professor of Electrical Engineering, Dr. George J. McMurtry, and an Associate Professor of Soils, Dr. Gary W. Petersen, serve as

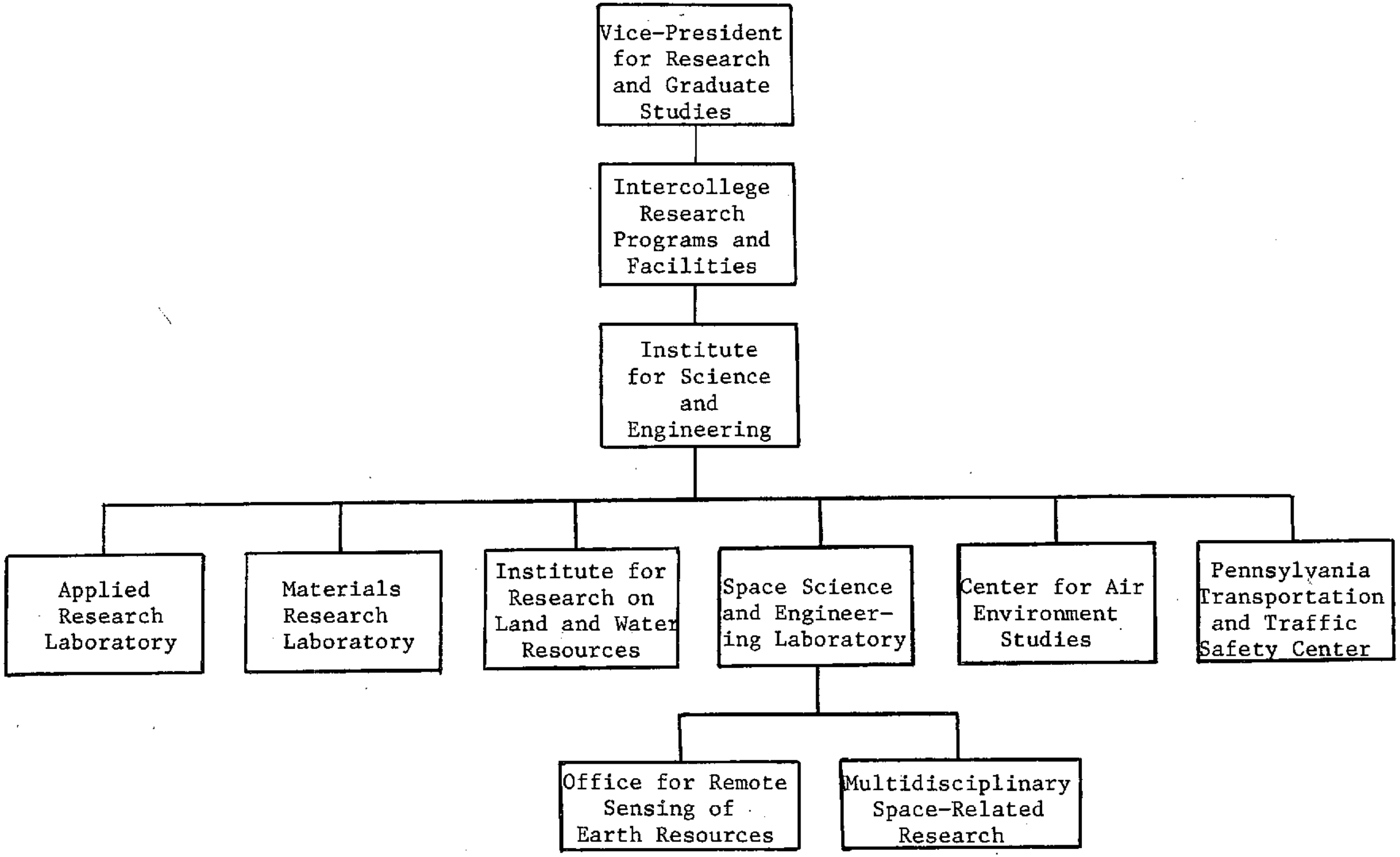

Figure 1 : The position of ORSER in the central research organization of The Pennsylvania State University.

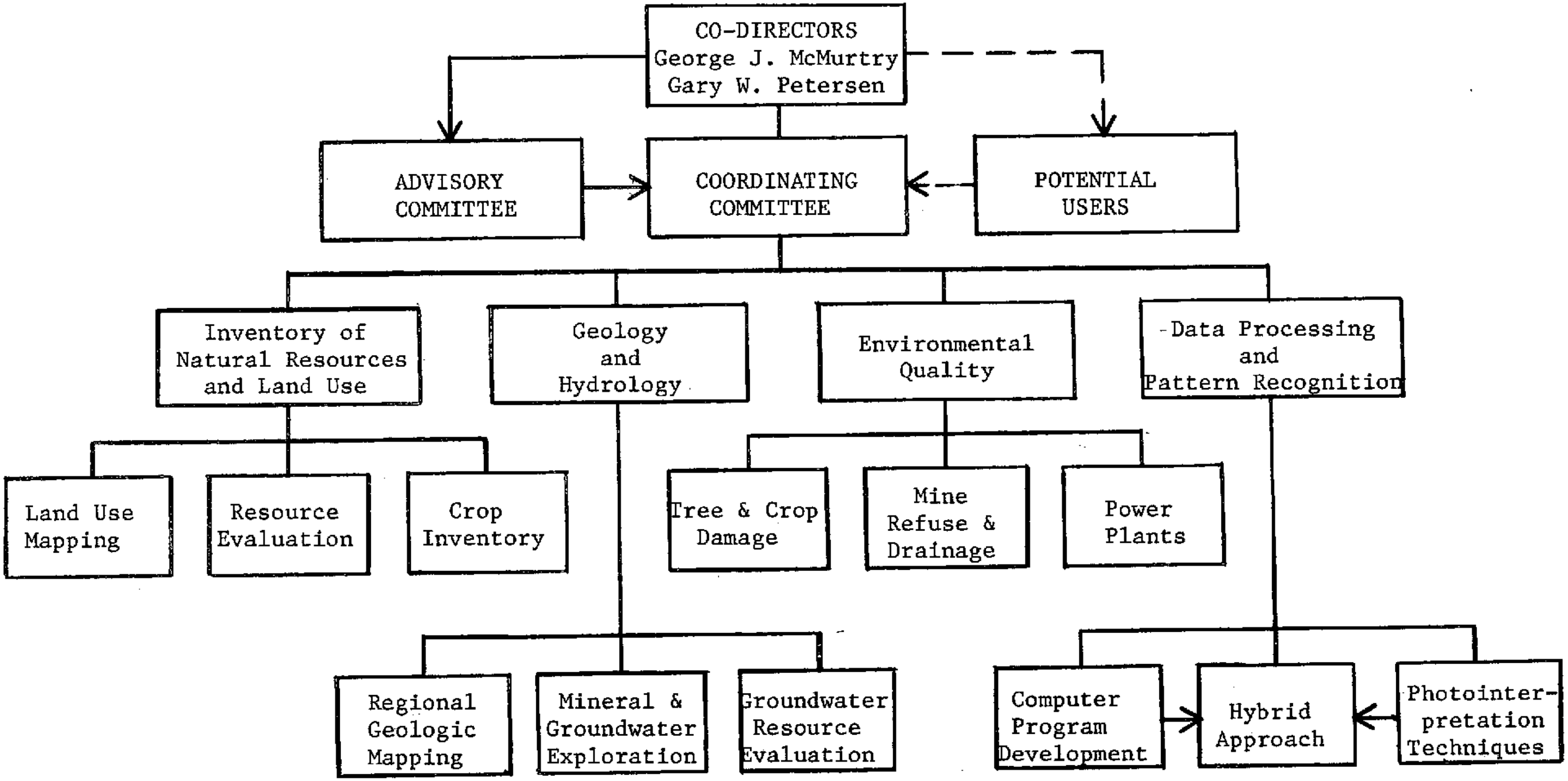

Figure 2 : Chart of ORSER organization, indicating major fields of current investigation.

co-directors. Each task has a principal investigator or co-investigators, jointly making up a coordinating committee along with the co-directors. This coordinating committee oversees the research efforts of ORSER and encourages and develops future research endeavors. The co-directors also meet as required with an advisory committee for consultation, advice, and reports of progress. The advisory committee consists of the director of SSEL, the scientific advisory committee of SSEL, and the deans of interested colleges or their appointed representatives. There is also direct communication between the coordinating committee and potential users of the research results. Examples of these users are:

U. S. Department of the Interior

U. S. Forest Service

U. S. Soil Conservation Service

Northeast Watershed Research Center

Susquehanna River Basin Commission

Other regional planning commissions

Pennsylvania State Planning Board

Pennsylvania Department of Environmental Resources

Pennsylvania Department of Transportation

County planning commissions

Local planning commissions

In an effort to gain increased experience in the utilization of ERTS-1 type remotely sensed data, ORSER contracted the Bendix Corporation in May 1971 to obtain data in central Pennsylvania. The Bendix aircraft recorded eight bands of multispectral scanner data in analog form. This was converted to digital format, using the hybrid computer system. Black and white imagery constructed from the data types, as well as color photography with overlap sufficient for stereoscopic coverage, were also supplied by Bendix. Other remotely sensed data, obtained by aircraft from the University of Michigan, were made available by the U. S. Bureau of Public Roads. Segments of this data were analyzed with both the Penn State data processing system and the LARS (Laboratory for the Applications of Remote Sensing) facilities at Purdue.

On June 1, 1972, ORSER/SSEL received the present contract from NASA for a two-year program in the analysis and interpretation of ERTS-1 data. The principal area of interest has been the Susquehanna River Basin. With these funds from NASA, and additional funds provided from the University through SSEL, ORSER has developed interpretation techniques for ERTS-1 MSS data in both photographic and digital form, has provided graduate and undergraduate training in remote sensing, and has contributed to the education of governmental agencies and the public in the value and potential uses of ERTS data.

During the past year, ORSER has been assisting the MITRE Corporation in analysis of ERTS-1 data, using both photointerpretation and automatic data processing techniques. A contract has been finalized with the U. S. Army Corps of Engineers for a remote sensing floodplain feasibility study on the West Branch of the Susquehanna River. ORSER was recently granted a contract to participate in the analysis of data obtained by the Earth Resources Experiment Package (EREP) contained on the manned satellite, SKYLAB.

On the basis of experience with ERTS-1, EREP, and aircraft remotely sensed data, and using its current efficient operational data processing system as a foundation, it has been proposed that ORSER conduct an interdisciplinary investigation involving the processing of ERTS-B data with a view toward applications to resource and environmental problems in Pennsylvania. This proposal was submitted to NASA in January 1973. A portion of this work would involve providing assistance to the various governmental agencies in Pennsylvania in the emplementation of their own data processing and interpretation procedures, particularly as they apply to the proposed Pennsylvania Resource and Land Information (PENNRALI) system.

PERSONNEL

Twenty-one scientists, most of whom are faculty members of The Pennsylvania State University; nineteen graduate students and assistants; four undergraduate student workers; and one secretary have been involved in the ORSER program. Many of these personnel have not been directly supported on the ERTS contract, but have been involved in the analysis of ERTS-1 data and in related remote sensing activities. The research personnel are as follows:

Co-Principal Investigators

George J. McMurtry, Assoc. Prof. of Electrical Engineering
Gary W. Petersen, Assoc. Prof. of Soil Genesis

Co-Investigators

Shelton S. Alexander, Prof. of Geosciences
F. Yates Borden, Assoc. Prof. of Forestry
David P. Gold, Assoc. Prof. of Geology
Richard R. Parizek, Prof. of Geology
Stanley Pennypacker, Res. Assoc. of Plant Pathology
Brian J. Turner, Asst. Prof. of Forest Management
Harmer A. Weeden, Prof. of Civil Engineering

Associated Personnel

Danielle Applegate, Computer Analyst in Remote Sensing
Gert Aron, Asst. Prof. of Civil Engineering
Nanna B. Bolling, Image Analyst in Remote Sensing
Todd W. Bowersox, Res. Asst. in Forestry
Charles E. Brown, Grad. Asst. in Geology
Milena F. Bucek, Grad. Asst. in Geology
Monty L. Christiansen, Asst. Prof. of Landscape Architecture
Seon Chung, Grad. Asst. in Electrical Engineering
James L. Dein, Grad. Asst. in Geophysics
Robert W. Douglass, Assoc. Prof. of Forestry
Peter W. Fletcher, Prof. of Forestry
Eric L. Fritz, Grad. Asst. in Plant Pathology
John W. Harman, Instructor in Engineering

Associated Personnel (continued)

Joseph R. Hoosty, Grad. Student in Electrical Engineering
(Now serving with the U.S. Coast Guard)

Russell J. Hutnik, Prof. of Forest Ecology

Gerald L. Jubb, Jr., Asst. Prof. of Entomology

M. Dennis Krohn, Grad. Student in Geology

Henry M. Lachowski, Grad. Asst. in Forestry
(Now with TRW Systems Group in Houston, Texas)

Richard F. Masse, Grad. Asst. in Forestry

George A. May, Grad. Asst. in Agronomy

Benjamin F. Merembeck, Grad. Asst. in Forestry

Melvin H. Podwysocki, Grad. Asst. in Geology
(Now with Goddard Space Flight Center)

Carl E. Rambert, Grad. Asst. in Electrical Engineering

Michael T. Roberts, Grad. Asst. in Geology

Michael A. Scanlin, Grad. Asst. in Geophysics

Charles H. Strauss, Instructor in Forest Economics

Donald N. Thompson, Res. Asst. in Forestry

Karen W. Volk, Grad. Asst. in Geology

Darrel L. Williams, Grad. Asst. in Forestry

A. David Wilson, Grad. Asst. in Agronomy

DATA TYPES HANDLED BY ORSER

Table 1 summarizes the principal remotely sensed data types supplied by NASA and handled by ORSER.

ERTS-1 Data

ORSER's standing order for ERTS-1 data was for scenes covering the Susquehanna River Basin, consisting of an area defined by the following coordinates:

Table 1: Summary of Remote Sensing Data Available in ORSER

Satellite or Aircraft	Approx. Altitude	Sensor	Portion of Spectrum Covered (Micrometers)	Approx. Color Range	Designation	Study Format	Approximate Ground Area Covered in One Image	Approximate Scale	Approx. Ground Resolution (RS unit)
ERTS	500 miles	RBV	.475-.575 .580-.680 .698-.830	Blue-grn Grn-yel Red-IR	Channel 1 2 3	7x7 in. color composites	13,200 sq. miles	1"=15 miles or 1:1,000,000	150 ft
		MSS	.500-.600 .600-.700 .700-.800 .800-1.100	Green Or-red Red-IR Near IR	Channel 4 5 6 7	7x7 in. B&W transparancies and computer compatible tape	13,200 sq. miles	1"=15 miles or 1:1,000,000	260 ft
U2	65,000 feet	Cameras	.475-.575 .580-.680 .690-.760 .510-.900	Blue-grn Yel-red Red-IR Grn-IR	Sensors: 1 or 11 2 or 12 3 or 13 4 or 14	70 mm film in B&W and IR color	480 sq. miles	1"=7 miles or 1:445,000	60 ft
		MSS	70 mm scanner imagery available for selected areas in Pennsylvania						
C-130	5,000 to 15,000 feet	Cameras	.450-.705 .475-.585 .500-.900 .590-.710 .700-.930	All vis. Blue-grn Grn-IR Or-red Near IR	See indiv. flight line annotation	9x9 in. color transparancies 70 mm B&W and color transparancies	1.4 to 21 sq. miles 1.8 to 26 sq. miles	1"=700-2700 ft 1:6000-1:22,000 1"=2600-10,000 ft 1:22,000-1:120,000	1-3 ft 3-30 ft
		MSS	.340-13.00	UV thru thermal IR	24 channels (Bendix Recorder)	Computer compatible tapes and	-	-	10 ft
						70 mm film	A strip 1.3 to 5.2 miles wide	-	30 ft
C-54	5,000 to 15,000 feet	Cameras	.500-.900	Grn-IR	See individual flight line annotations	9x9 in. color IR transp.	1.5 to 20 sq. miles	1"=700-2700 ft 1:6000-1:22,000	1-3 ft
			.400-.475 .475-.585 .590-.930	Viol.-bl. Blue-grn Or.-IR		4x4 in. B&W transparancies	1.5 to 20 sq. miles	1"=1400-5400 ft 1:12,000-1:44,000	3-15 ft

Latitude	Longitude
4200N	7800W
4200N	7600W
4000N	7600W
4000N	7900W
4100N	7900W

It was specified that data only be sent for scenes which had 70 percent or less cloud cover. As of May 30, 1973, data had been received for 76 scenes. A summary of the breakdown for these data types is shown on Table 2 . Twenty-six of these scenes appeared to be more than 70 percent cloud covered, and several appeared to be 100 percent cloud covered when viewed with the naked eye on a channel 7 black-and-white transparency. Sets of four computer compatible tapes were received for 55 scenes (in ten cases duplicate sets were received). Of the 21 scenes for which tapes were not sent, three were cloud-free and six more had less than 50 percent cloud cover.

Of the 76 scenes for which some form of data were received, transparancies for all four channels, as requested in the standing order, were received for 55 scenes. Of the remaining 21 scenes, transparancies for channels 5 and 7 were received for 11 scenes, transparancies for only channel 7 were received for 9 scenes, and a transparency for channel 5 alone was received for one scene. Although not on the standing order, the following data formats were also received: 10 color composite transparancies and 9 paper prints, 19 sets of paper prints in 4 channels and paper prints in channel 7 for two additional scenes, sets of four 70 mm negatives for 7 scenes and sets of four 70 mm positives for 13 scenes. Some of these were sent in response to retrospective orders. Three retrospective orders for data were sent: on October 11 and December 27, 1972; and on May 25, 1973. These were requests both for data missing from the standing order shipments and additional data found desirable for the various projects conducted by ORSER personnel.

Data quality has generally been excellent. Some difficulty has been experienced with channel 6 data on a number of scenes. This problem has been particularly noticable in the computer processing, often necessitating the exclusion of channel 6 in the analysis. Borden has devised a method of correction of the banding causing the problem in

Table 2 : Data Types Received for ERTS-1 Scenes

	Imagery Received[a]			
		Channels		
% Cloud Cover	7 only	5 and 7	4 thru 7	Received[b]
0-2	0			0
		0		0
			22	19
3-25	4			0
		2		1
			7	7
26-50	1			0
		1		1
			4	4
51-70	1			0
		2		2
			6	5
71-75	2			0
		4		4
			0	0
76-100	1[c]			1
		2		1
			16	10

[a]Only transparancies are recorded here.

[b]Twenty percent of these were received in duplicate.

[c]One additional scene in channel 5 only, with no tape set, was received.

channel 6 (see "Program Development and Revisions," elsewhere in this report). Application of this correction method has eliminated the banding problem in all data to which it has been applied.

Underflight Data Supplied by NASA

As can be seen from Table 1, various forms of underflight data have been received by ORSER. These constitute a major form of "ground truth" for study of ERTS data.

The most extensive underflight coverage has been by the U2 aircraft, flown at 65,000 ft. The earliest flight received was flown in September 1971, the latest in January 1973. Many of the earlier flights covered large sections of the eastern seaboard outside Pennsylvania. However, to date, approximately 2000 miles of flightline have been flown inside Pennsylvania, covering an estimated 44,000 square miles of area. Of the four spectral bands of photography commonly available for these flights, the color-IR has been found the most useful. This imagery is in constant use by ORSER personnel and by students for correlation with digital maps from ERTS data. For two flights in 1972, MSS imagery -- degraded to ERTS quality -- has been received.

Low altitude data have been gathered by the C130 and C54 aircraft, flying at altitudes ranging from 4000 to 17,000 ft. Approximately 1600 miles of flight line have been flown in Pennsylvania by the C130 and 700 miles by the C54. The C130, flying out of Houston, Texas, is equipped with two types of cameras and an MSS system. The C54, flying out of Wallops Island, Virginia, is equipped with two cameras. Together, these two aircraft have provided excellent data for use by ORSER personnel.

Two of the cameras in the C130 yield 9 x 9 inch color transparancies, one in visible color and one in "false color" IR. Five additional cameras yield 70 mm film in five different portions of the visible and infrared spectrum. The MSS system collects data in 24 channels. Preliminary imagery from one of these channels is sent to ORSER, from which segments for coverage in the form of imagery and computer compatible tapes in several channels are chosen. These are then supplied by NASA on request.

To date, 35 tapes of data have been received -- all from the July 1972 flight. These have been reformatted for use in the ORSER system, and analysis has begun in a few areas. Of the photography, the 9 x 9 inch color format has been found the most useful.

One of the cameras on the C54 is a four-lens I^2S camera, yielding simultaneous imagery from four segments of the electromagnetic spectrum in 70 mm black-and-white format. The other camera takes "false color" IR photographs similar to those from the C130 aircraft, in 9 x 9 inch format. These have definitely been found more useful than I^2S photography.

Data from both aircraft are being increasingly used by ORSER personnel and by students. The seasonal coverage by the C130 is proving especially useful in studies involving soils, agriculture, and tree stands. The proximity to Pennsylvania of the C54 aircraft, at the Wallops Island location, is of particular usefulness in overcoming the difficult weather conditions found in the State. In several instances the C54 has been able to fly on short notice to take advantage of a cloudfree day, yielding some superb photographs. This aircraft has also flown some short, useful flightlines the need for which had not been anticipated before the C130 flight requests were submitted.

Other Underflight Data

Two sets of underflight data other than those supplied by NASA have been used by ORSER. In May of 1971, ORSER contracted the Bendix Corporation to fly several flightlines in central Pennsylvania, to collect data with an eight channel MSS system and take black-and-white and color photography. These data were used to gain experience with remotely sensed data simulating that of ERTS before ERTS-A was launched. A set of 24-channel MSS data, with accompanying photography, was collected by aircraft from the University of Michigan, and supplied to Penn State by Dr. Harold T. Rib. These data covered an area in Lancaster County, Pennsylvania, and were used for several pre-ERTS studies. They are also being used in a present study of the Lancaster area (see Wilson and Petersen, "Agricultural Land Use," elsewhere in this report).

Other Data

An extensive map collection is housed in the ORSER laboratory. An effort has been made to have on hand three copies of all USGS 7 1/2 minute quadrangle maps that cover low-altitude flightlines. Three or more copies of topographic maps on a scale of 1:250,000 covering the entire state of Pennsylvania are on hand, and an order has been placed for one copy each of all 7 1/2 minute quadrangle maps for Pennsylvania which are not already in the ORSER files. Aeronautical charts of Pennsylvania are available, as well as several stream and land resource maps.

Soil survey reports and other county reports are available either in the ORSER office, or in the offices of cooperating departments such as Civil Engineering, Agronomy, Forestry, and Geology. Additional physiographic, soil, vegetation, stream, and geologic maps are also available from these departments. A complete set of reports from the Susquehanna River Basin Study, conducted in 1970 by Susquehanna River Basin Commission[1] is available in the ORSER library, as well as numerous proceedings of symposia on remote sensing and related subjects.

DATA HANDLING

Within ORSER, data handling is a function that is considered separate and distinct from that of data processing. The latter involves the development of programs, specification of formats and procedures, and adaption of these to remotely sensed data. Data handling, on the other hand, is considered to be primarily a problem of management and control of the flow of data in daily operations. Specifically, this involves the cataloguing and storing of incoming data, preliminary processing in accordance with system requirements and formats, consolidations and integration of ground truth and other data with remotely sensed data, and the preparation of data subsets according to their specifications.

[1]Dept. of the Interior, 18th and East St. NW, Washington, D.C. 20240

The Computation Center at Penn State maintains complete facilities and services which are available to ORSER without funding requirements. A Computation Center staff member serves in a continuous liaison role with ORSER. The procedures for handling of ERTS data are flexible in order that they may be adapted to meet varying requirements. As more experience is gained in the use of ERTS and EREP data, and as the requirements of user agencies in the state become more well-known, specific handling procedures can be expected to be modified.

The initial processing of data (referred to hereafter as the "quick-scan selection process") is outlined in Figure 3 . Following receipt of the data package consisting of imagery and digital data, it is examined by various means. These include the visual study of the imagery (e.g., with light tables and stereoscopes) and preliminary digital processing (e.g., intensity and uniformity maps, statistical information, subsets). This initial look at the data is coordinated by the investigator with ground truth and supporting aircraft data.

Figure 4 outlines the procedures which are used for the establishment of selected subsets of data as determined by the various investigators. Upon receipt of the data from NASA, the quick-scan selection process is conducted to help select those parts of the data that specific investigators would like to examine in detail. Supporting aircraft and ground truth data also aid the investigators in this selection process. Once the selection is complete, subsets of ERTS and aircraft data are placed on magnetic tape or other suitable storage format. Appropriate ground truth is also stored with each subset.

Figure 5 illustrates the general data processing procedure from the investigator's viewpoint. The investigator calls for a specific subset of data from storage and has it processed through the various programs used for data processing and pattern recognition. In determining the exact programs to be used, the investigator is aided by supporting aircraft data and ground truth as well as continuous feedback and interaction with specific data processing and pattern recognition programs. After processing is complete, the final product is made available to NASA and published as appropriate.

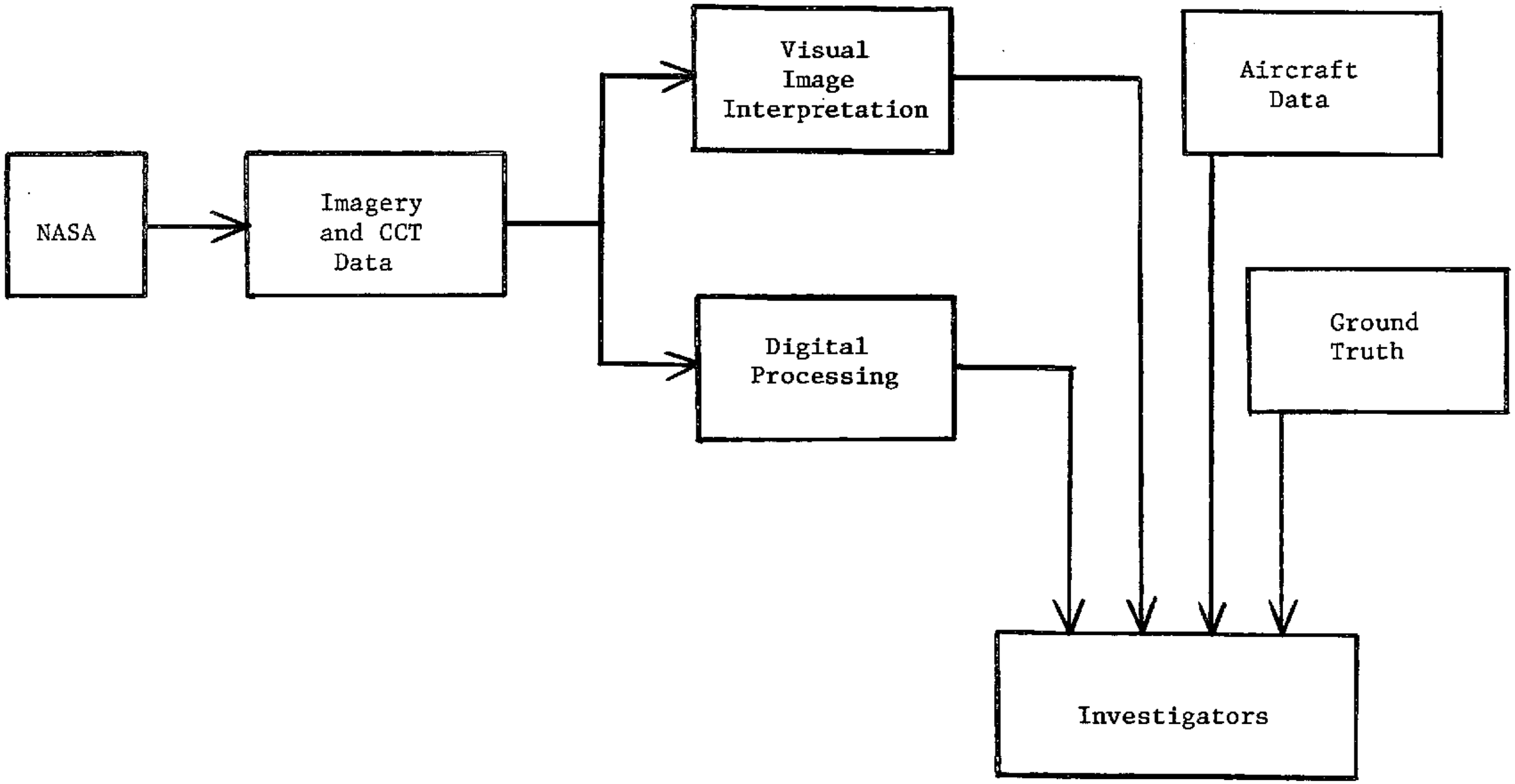

Figure 3 : The "quick-scan" selection process.

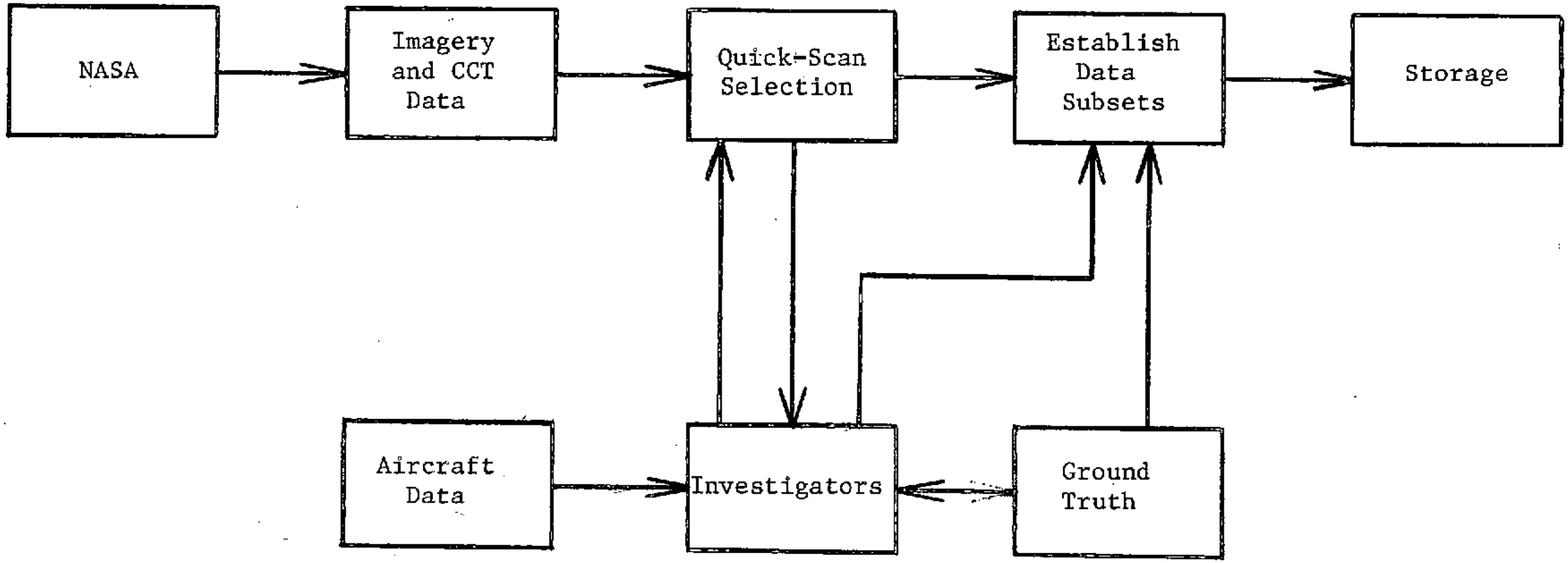

Figure 4 : Procedure for the selection of subsets.

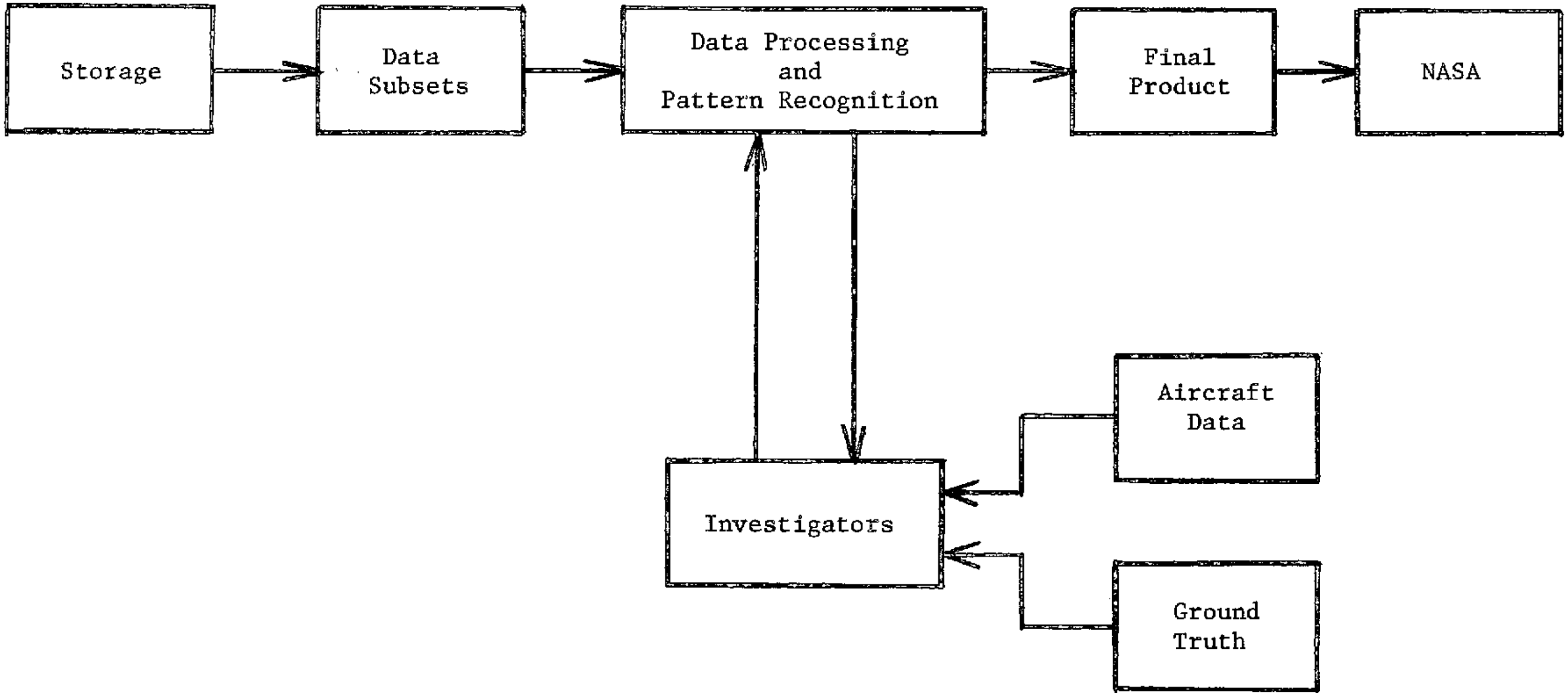

Figure 5 : Data processing procedure from the investigator's viewpoint.

Basic storage and retrieval procedures for imagery and digital data have been developed, and descriptions of these procedures may be found in Appendices A and B, respectively.

DATA PROCESSING

Through experience with ERTS-1 and aircraft data, ORSER has developed an effectively operational system for processing both imagery and computer compatible tapes. This system is described below.

Processing Imagery

Photointerpretive equipment, study facilities and imagery storage closets are located in the ORSER Laboratory, in Room 218 of the Electrical Engineering West building. Three light tables (including one with high intensity lights) are provided for the study of transparencies and films of various sizes, either as rolls or as individual frames. Film roll holders on one of the tables permit simultaneous viewing of two film strips, each up to 9 inches wide.

A Bausch & Lomb Zoom 70 Stereoscope is available for use with 70 mm C130 and U2 film or for detailed study of ERTS-1 images. Single images may be viewed at enlargements from 10 to 120X using the single lens attachment. When this attachment is replaced by the rhomboid assembly, image pairs in the 70 mm format may be viewed stereographically. The zoom feature of this unit permits viewing at any scale from 10 x 30X with no adjustment of stereo fusion necessary during the continuous change in scale. The Zoom Stereoscope may be used on its small light table base, with two 70 mm film reel holders attached, or it may be used on a bracket above the high-intensity light table. In this latter arrangement, the stereoscope can be moved at will across two 70 mm film strips mounted simultaneously on the light table, and along their length for a distance of 24 inches.

An Old Delft Stereoscope and two mirror stereoscopes (one with a binocular attachment) are provided for the study of 9 X 9 inch stereo pairs. Two of these stereoscopes permit viewing at two scales: 1.5X and 4X for the Old Delft, and 1X and 6X for the mirror stereoscope. Projection equipment is also available in the laboratory, including a 35 mm slide projector and a Visucom high intensity overhead projector.

A Bausch & Lomb Zoom Transferscope has recently been ordered. This instrument permits projection of opaque or transparent images onto a plain surface or another image, with the capability of magnification in any direction, or selectively in a single direction, from 1 to 14X. With this instrument a photograph can be projected onto a computer-generated character map, with adjustment for the line and element distortion inherent in the high speed printer output.

In addition to the ORSER equipment listed above, a completely equipped photogrammetric and photointerpretation laboratory in the Department of Civil Engineering is available for use by ORSER personnel. Particular pieces of equipment found to be useful in this laboratory include a Kelsh plotter and an American Optical Delineascope which has been used to project 70 mm U2 imagery. An Itek reader-printer for 35 and 70 mm film and a Saltzman Projector for aerial photography are available in the Department of Geology. Various types of equipment for collecting ground truth and producing other related information exist in the several departments of the co-investigators and are available to ORSER.

For image reproduction, The Pennsylvania State University is fortunate to have a wide variety of photographic and reproduction facilities available. Still Photography Services, of the Division of Instructional Services, is staffed and equipped to provide professional, high quality, products meeting all research and publication requirements. Enlargements, contact prints, and slides in color as well as black and white are readily obtained. Complete DIAZO and OZALID facilities are also available on campus.

Processing Digital Data

The ORSER system for processing MSS digital tapes[1] was developed for use by a wide variety of researchers working in remote sensing at The Pennsylvania State University. These potential users represent many disciplines and have a wide range of experience and skill in computer usage.

Computer Processing Facilities

Automatic data processing equipment utilized by ORSER personnel is primarily located at The Pennsylvania State University Computation Center. The principal computer is the IBM System 370 Model 165, consisting of a main frame and attached devices for input and on-line storage. A Remote Job Entry (RJE) system is available and is the most common method used by ORSER to process remote sensing data. The RJE system permits use of IBM 370/165 from any of several remote terminals. Any compatible terminal may be used to process data via the RJE system, including equipment at non-University Park locations tied in by long-distance telephone connections. An IBM 360/50 is also available as well as an IBM 1401 computer. Display equipment at the Computation Center includes an AGT-30 ADAGE graphics terminal and computer, and a CalComp 564 plotter. Extensive analog and hybrid processing equipment, as well as other digital systems, are also available on campus.

The IBM 370/165 is dedicated to general University research and educational uses as well as to similar non-University uses. Users may have access to the computer in any of three ways: (1) central and remote high speed dispatch points operated by the Computation Center, (2) slow speed RJE terminals using IBM 2741 or similar terminals supported by the user or by the Computation Center, and (3) intermediate speed remote batch terminals, such as the IBM 2780, supported by the user or the Computation Center. The processing system for MSS data

---

[1]This system is described by Borden in: "A Digital Processing and Analysis System for Multispectral Scanner and Similar Data," Remote Sensing of Earth Resources, (F. Sharokhia, ed.), Vol. 1, University of Tennessee Space Institute, Tulahoma, Tennessee.

was developed for use with any of these entry points. ORSER investigators have direct access to the RJE terminals and one has been ordered for the ORSER laboratory. These terminals are used for most developmental work. Bulk output for final runs is directed from an RJE terminal to any of the high speed terminal sites. No program card decks need to be input, as the MSS data processing programs are kept in library files. Files for building control information or for storing output are available to the user. MSS data is input from magnetic tapes which, along with user-owned working tapes, are managed by the Computation Center. Non-University users as well as University users may join the system, either locally or via long distance telephone lines.

A standard digital tape format was designed within which all known MSS sources can conveniently be placed. More than one file per tape is allowed as well as a continuation of a file to another tape. Within the file, four kinds of records exist: (1) identification records, (2) table of contents records, (3) MSS response records, and (4) history records. Each MSS response record consists of a complete scan line. Each scan line is numbered and scan lines are always in ascending order in a file. A working file will usually contain one or more small parts of the whole data set. The table of contents is particularly useful in such cases in avoiding costly searching for data which are not present in the file.

The system is couched in a multivariate framework. Although it is understood that some operations do not require this statistical basis, this approach is, overall, most appropriate. Each observation, identifiable by scan line and element number, consists of a vector with as many components as there are channels. At present, each vector is composed of just MSS response values. It is anticipated, however, that the vectors will be augmented by transformed scanner data; or by additional, nonscanner, data such as topographic information.

The system is not in a conversational mode, where the user and the system dynamically interact during processing. Each program accepts input control specifications, processes the MSS data according to the specifications, and outputs the results. The user prepares the control specifications for each program. Although the system is non-conversational, the preparation of the control specifications by a user operating from an RJE terminal is conversational. For non-RJE operation, control specifications are made and entered into the system by punched cards. All control specifications on the RJE are identical in format to the corresponding punched cards.

The Digital Data Processing System

The programs discussed here are all operational and are documented at the user's level. Although many other programs are used, those discussed here illustrate the general approach to the processing of MSS tapes. Detailed descriptions of ORSER programs currently available may be found in ORSER/SSEL Technical Report 10-73.

The digital tape processing system for MSS data described here is regularly run for production and has been extended to meet the needs of various related projects. The system was designed to be easily augmented, typified by the addition of a number of supervised and unsupervised analysis and classification algorithms. The general procedure to be employed for a previously unstudied area or type of target will be presented and illustrated here. The procedure to be employed for areas or targets which have been previously investigated differs slightly from that shown here and is less complex.

The first step is to select the particular targets and areas of interest, primarily using maps. Consultation of the catalogues of imagery and digital tapes will indicate what data are available and their quality. Tapes corresponding to the selected scenes are chosen and the areas of useful data are specified. Subsets are then produced on separate tapes, using the SUBSET program[1]. These subsets are prepared to gain rapid processing and short turn around time. It is likely that this step has already been done in the process of cataloguing and storing ERTS tapes by ORSER, in which case the appropriate library subset tapes would be selected directly.

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[1]Complete program descriptions may be found in ORSER-SSEL Technical Report 10-73.

A run is then made with the NMAP program to show the overall pattern of the data. This program is written to map element brightness, using all channels or any subset of channels. The norm of each multivariate vector is taken as the measure of brightness. The norm is then converted to a percentage of the maximum possible value. This value is translated to the mapping symbol for the percentage range within which it falls. The process is repeated for every element in every scan line in the data blocks specified by the user. Output from the NMAP program consists, then, of a brightness map.

The UMAP program is run next, to map areas of local spectral uniformity. Each element is compared with its near neighbors using the euclidean distance between spectral signatures as the measure of simularity or dissimularity. If the largest distance is smaller than a value specified by the user, then the symbol for uniformity is assigned to that element. One or more categories of uniformity can be mapped according to distances specified by the user. All elements with distances from their neighbors greater than those specified are mapped as contrasts. The map output shows the pattern of uniformity and contrasts from which the user can designate coordinates for training areas for the targets of interest and determine high contrast boundaries between uniform areas.

Signatures and associated statistics are next obtained by the use of the STATS program, which computes the multivariate statistics for one or more training areas obtained from UMAP or similar output. The user designates a training area by line and element coordinates and the program computes the statistics for all of the data which fall within the boundaries. The mean and standard deviation vectors are found, and the correlation and variance-covariance matrices are computed as well as the eigenvalues and eigenvectors of these matrices. Frequency histograms for selected channels are also computed.

When most of the targets have been identified by training areas, a classification run is made using the classifier or classifiers deemed most appropriate for the mix of targets under consideration. A variety of classification programs are available, including parametric and non-parametric classifiers with either linear or quadratic discriminant functions. Preprocessing before classification is also possible, using programs for normalization, principal components, etc. The output of these programs is in the form of a character (or digital) map, with each category of classification represented by a unique symbol.

Digital maps are useful primarily as working maps for the user in the analysis of MSS data. They are inherently distorted in the length-to-width relationship because of the fixed number of lines and characters per inch of high-speed printer output. The LMAP program, yielding output on the CalComp plotter, is intended for the production of distortion-free, finished copy, line maps. There are three main advantages to line maps when compared to character maps: (1) orthographic maps to a selected scale can be made, (2) photographic overlays can be prepared for these maps (this is quite important in the comparison of classification results with corresponding imagery), and (3) legible maps for publication purposes can be prepared.

An example of the use of the programs described above is given in Figures 6 through 16. The MSS data used for this analysis came from ERTS-1 scene 1028-15295, scanned on August 20, 1973. This is an area northeast of Clearfield, Pennsylvania, on which U.S. Route 80 and the West Branch of the Susquehanna River cross. The location of the test site is shown in Figure 6, which was taken from two 7 1/2 minute USGS quadrangle maps. As these maps were printed in 1959, before Route 80 was constructed, the highway has been drawn in on the figure. Figure 7 and 8 show map output for NMAP and UMAP, respectively. The strip of low brightness in Figure 7 follows the river, as does the blank (non-uniform) area shown in Figure 8 . Basic statistics for the "stripmine" category, obtained by the STATS program are shown in Figure 9 . Statistics from a series of such sample sites are input to a classification program. Figure 10 shows the output from the DCLASS, program which classifies according to a minimum euclidean distance algorithm. Only two categories are represented by symbols; unclassified elements are left blank. LMAP output using data from the DCLASS program is shown in Figure 11.

It frequently happens that a sample target is not of sufficient size or area to lend itself to categorization using the STATS program.

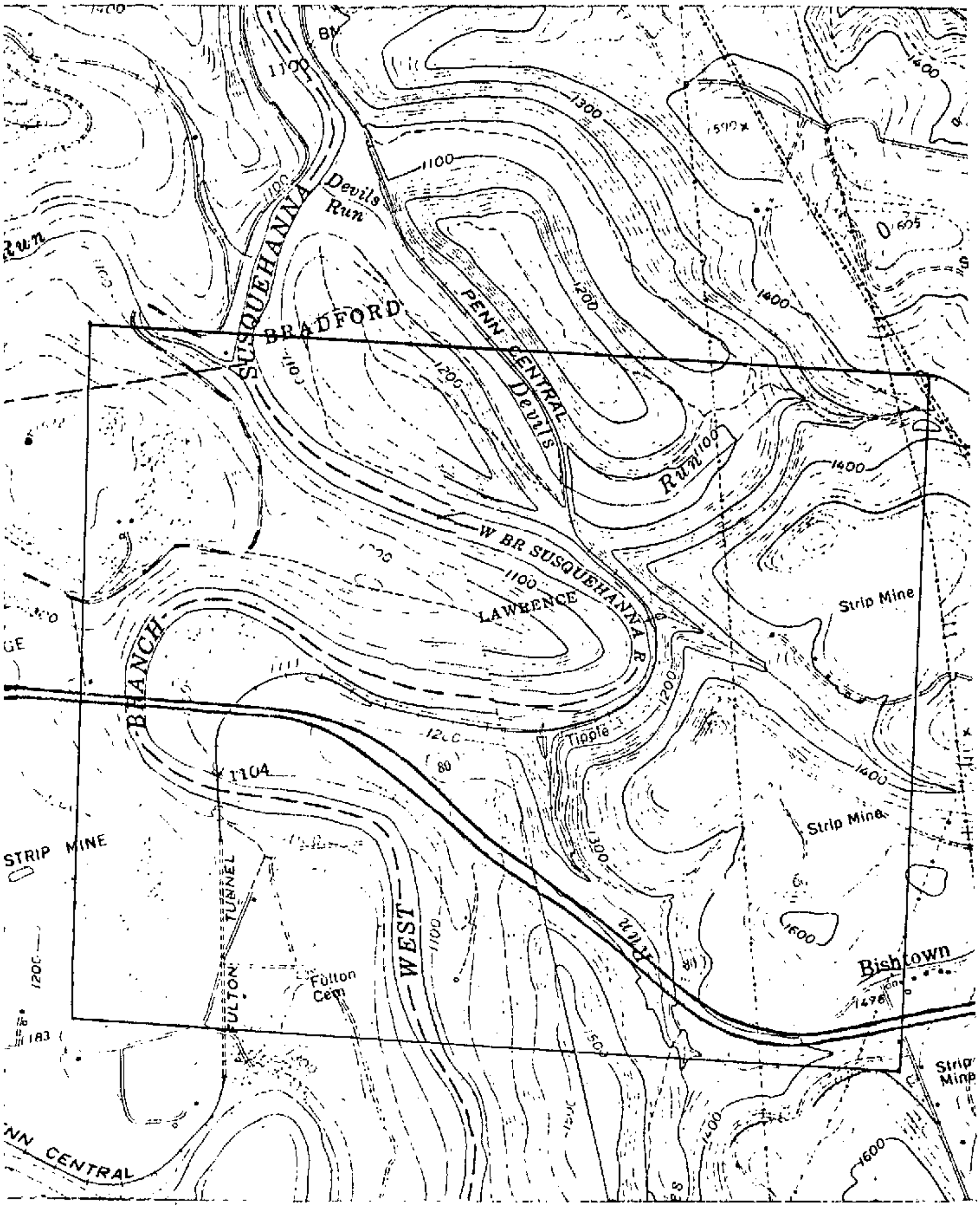


Figure 6 : Test site northeast of Clearfield, Pennsylvania. (Taken from USGS 7 1/2 minute quadrangle maps, "Clearfield" and "Lecontes Mills," both printed in 1959.)

```
        BLOCK SPECIFICATIONS
        --------------------

            BEGINNING LINE 1030
               ENDING LINE 1059
        BEGINNING ELEMENT 2470
            ENDING ELEMENT 2525
            LINE INCREMENT    1
         ELEMENT INCREMENT    1

  2470|2475|2480|2485|2490|2495|2500|2505|2510|2515|2520|2525|
      |    |    |    |    |    |    |    |    |    |    |    |
1030 |XXXXXXXXXXXXX- -XXXX-XXXXXXXXXX--XXXXXXXXXXX----XXXXXXXX|
1031 |XXXXXXX--XXX-X-  XXXXXXXXXXXXXX--XXXXXXXXXX----XXXXXXXXX|
1032 |XXXXXXX--XXXXXX-   -XXXXXXXXXXX---XXXXXXXX-----XXXXXXXXX|
1033 |XXXXXXX----XXXXX---    -XXXXXXXXX  -XXXXXXX-----XXXXXXXX|
1034 |XXXXXXX---XXXXXXX-----   --XXXXXX-  --X----------XX---XX|
1035 |XXXXXXXXXXXXXXX-XXXXX-----    --X----------------X---XXX|
1036 |-X---XXXXXXXXXXXXXXXXXX-------   --------------XX---XXXX|
1037 |X----XXXXXXXXXXXXXXXXXXXXXX-XXX-  ----XXXXXX-XX-X---XX-X|
1038 |X--XXXXX---- --XXXXXXXXXXXXXXX--X-- --XXXXXXXXXX-------X|
1039 |XX---XX--XXXXXX---XXXXXXXXXXXXXXXXX-  ---XXXXXXXXXX----X|
1040 |XXXXXXX-XXXXXX-X-----XXXXXXXXXXXXXXXX- -----XXXXXXX-----|
1041 |XXXXXX--X--XXXXXXX-    ---XXXXXXXXXXX- --XXX---XXXXXXXX-|
1042 |XXXXXX--XXXXXX--XXXX-       ----XXX-   --XXXXXXXXXXXXXX-|
1043 |XXXXXX--XXXXXXXXXXXX-------    -   -------XXXXXXXXXXX-XX|
1044 |XXXXXX- XXX-XXXXXXXXXXX------------------XXXXXXXXXXXXX--|
1045 |XXXXXXX-  -X-XXXXXXXXXXXXXXXXXXX--------XXXXXX-XXXXXXXXX|
1046 |XXXXXXXX-    -XXXXXXXXXXXXXXXXXXX------XXXXXXXX----XXXXX|
1047 |XXXXXXX-XXX--   ------XXXXXXXXXXX--XXXXXXXXXXXXX--------|
1048 |XXXXXX--XXXX--XXXXXX-  -XXXXXXXXX--XXXXXXXXXXXXX----XX--|
1049 |--------XXXXXXXXXXXXXX  XXXXXXXXX-XXXXXXXXXXXXXXXX-XXXXX|
1050 |-------XXXXXXXXXXXXXXX- -XXXXXXXXXXXXXXXXX--------XXXXXX|
1051 |XXXXX----XXXXXXXXXXXXXX- -XXXX-XXXXXXXXXXX----XXXXXXXXXX|
1052 |XXXXX-----XXXXXXXXXXXXX- -X--X--XXXXXXXXX----XXXXXXXXXXX|
1053 |XXX-------XXXXXXXXXXXXX  -XXXX-X-XXXXXX--XXXXXXXXXXXXXXX|
1054 |XXXXX-----XXXXXXXXXXXXX  -XXXXXX-XXXXXXXX-XX-XXXXXXXXXXX|
1055 |XXXXX-----XXX-XXXXXXXXX  -XXXXXX-XXXXXXXX--XXXXXXXXXXXXX|
1056 |XX-XX---XXXXXX-XXXXXXXX- -XXXXXX-XXXXXXXXXXXXXXXXXXXXXXX|
1057 |XXXXXXX-XXXXXXXX-XXXXXXX-  XXX---XXXXXXXX-XXXXXXXXXXXXXX|
1058 |XXXXXXXXXXXXXXXXXXXXXXXXX- -XXX---XXXXXXXX-XXXXXX-----XX|
1059 |XXXXXXXXXXXXXXXXX-XXXXXXXX- -XXXXXXXXXXXXX-XXXXXX-XX-XXX|
      |    |    |    |    |    |    |    |    |    |    |    |
  2470|2475|2480|2485|2490|2495|2500|2505|2510|2515|2520|2525|

  CLASS   : 14.0      CLASS - : 20.0      CLASS X : 100.0
```

Figure 7: Brightness map (NMAP).

```
BLOCK SPECIFICATIONS
--------------------

   BEGINNING LINE 1030
      ENDING LINE 1059
BEGINNING ELEMENT 2470
   ENDING ELEMENT 2525
   LINE INCREMENT    1
ELEMENT INCREMENT    1
```

```
 2470|2475|2480|2485|2490|2495|2500|2505|2510|2515|2520|2525|
     |    |    |    |    |    |    |    |    |    |    |    |
1030 |UUUUUU--UUUUU    UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU|
1031 |UUUUUU-U-UUUUU      -UUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUUU-|
1032 |UUUUU--U---UUUU   --    -UUUUUUUUU- UUUUUUUUUUUUUUUUUU-U|
1033 |UUUUU--UUU-UUUUUUU-   --   -UUUUU U -UUUUUUUUUUU-       |
1034 |UU--------UUUUUUUUUU--   U-    ---- UUUUUUUUUUU--UUUUUU-|
1035 |UUU--UUUUUUUUUUUUUUUUUUUU-- -UU  UUUUUUUUUUU---UUUUUUUU|
1036 |UUUUUUUUUUUUUUUUUUUUUUUUUUUU-- -- UUUUUUUUU--UUUUUUUUUU|
1037 |UUUU--U        -UUUUUUUUUUUUUUU--  U-UUUUUU---------UUUU|
1038 |--UU-U -       -  UUUUUUUUUUUUUUUU-   ---UUUUUU- ----UUUU|
1039 |UUUUUU - UU-- - -  UUUUUUUUUUUUUUUUUU U--UUUUUU-UU-UUUU|
1040 |UUUUU-   -  UUUU-- U-    --UUUUUUUUUUU UUUUUUUUUUUUU-U---|
1041 |  --- UU-UUUUUUUUU   U-    *  - -UU-  UUUUUUUUUUUUUU--UU|
1042 |-  -- UUUUUU------UU-      -UU --   U -UUU-  U-UUUUUU-UU|
1043 |UUUUU U-UUU------UU--UUUUU--    -U--UUUU--UU  -UUUUUUUUU|
1044 |UUUUU     UUUUUUUUU-UUU-U-U------UUUUUU-UUUU-   -UUUUUU-|
1045 |UUUUUUU  -   -UUUUUUUUUUU-UUUUUUUUUU--UUU     ---  -UUUU|
1046 |UUUUU----   U-      --UUUUU-UUUUUUUUUU-UUU   UUUUUU-- --|
1047 |UUU---U-UUU-U        -  UUUUUUUUUUUUUU- --  UUUUUUUUUU-U|
1048 |- ----U UUUUUUUUUU-     -UU-UUUUUUUUUUU-  -UUUUUUUUUUUUU |
1049 |UUUUUU- UUUUUUUUUUUUU U UUU--U--UUUUUUUUUU--    -U-UU---|
1050 |-  UUU-  U-UUUUUUUUUU- --UUUU--- -UUUUUUUUUUU-UUUUU-U  |
1051 |UU-UUUUU -UUUUUUUUUUUU U UUUUU---U--UUUUUUUU-U-    -- - |
1052 |UUUU-UUU- UUUUUUUUUUUU U UUUUUUU---U--UUUUUU-UUUU-UUUU|
1053 |UUUUUUUU- UUUUUUUUUUUU U UUUUUUUUUU--UUUUU-UU--UUU-UU--|
1054 |UUUU-UUUU UUUUUU-UUUUU U UUUUUUUUUUU--UU-UUU-UUU--UUUUU|
1055 |UUUUUUU---UUUUUUUUUUU - -UUUUUUUUUUUUUU---UUUU---UUUU|
1056 | U-  --UUUUUUU--UUUUUU-     UUUUUUUUUUUU---UUUUUUUUU--UU|
1057 |UUUUUU--UUUUUUU--UUUUUUU - UUUUUUUUUUUUUUUUUUUUUU------|
1058 |UUUUUU-UUUUUUU- --UUUUUU-   -UUUUUUUUUUUUUUUUUUUUUUUUUUU|
1059 |UUUU-  UUU--UU-  -UUUUUUU----UUUUUUUUUUUUUUUUUUUUUU--UUU|
     |    |    |    |    |    |    |    |    |    |    |    |
 2470|2475|2480|2485|2490|2495|2500|2505|2510|2515|2520|2525|
```

```
CLASS U : 5.0                    CLASS - : 8.0
CLASS   : 15.0                   CLASS * : 100.0
```

Figure 8: Uniformity map (UMAP).

CHANNELS USED : 1 2 3 4

MEANS AND STANDARD DEVIATIONS FOR GIVEN CHANNELS

29.55	26.86	30.78	13.83
3.29	4.80	5.21	3.79

VARIANCE-COVARIANCE MATRIX

10.82			
14.91	23.09		
0.78	0.23	27.16	
-3.27	-5.68	18.00	14.33

CORRELATION MATRIX FOR GIVEN CHANNELS

1.00			
0.94	1.00		
0.05	0.01	1.00	
-0.26	-0.31	0.91	1.00

EIGENVALUES COMPUTED FROM CORRELATION MATRIX.

EIGENVALUES WITH THEIR ASSOCIATED PERCENTAGES:

2.21	1.70	0.06	0.03
55.4	42.4	1.4	0.8

EIGENVECTORS:

0.5227	-0.4645	-0.7059	-0.1129
0.5416	-0.4368	0.6347	0.3362
-0.3800	-0.6257	0.2327	-0.6402
-0.5376	-0.4493	-0.2115	0.6814

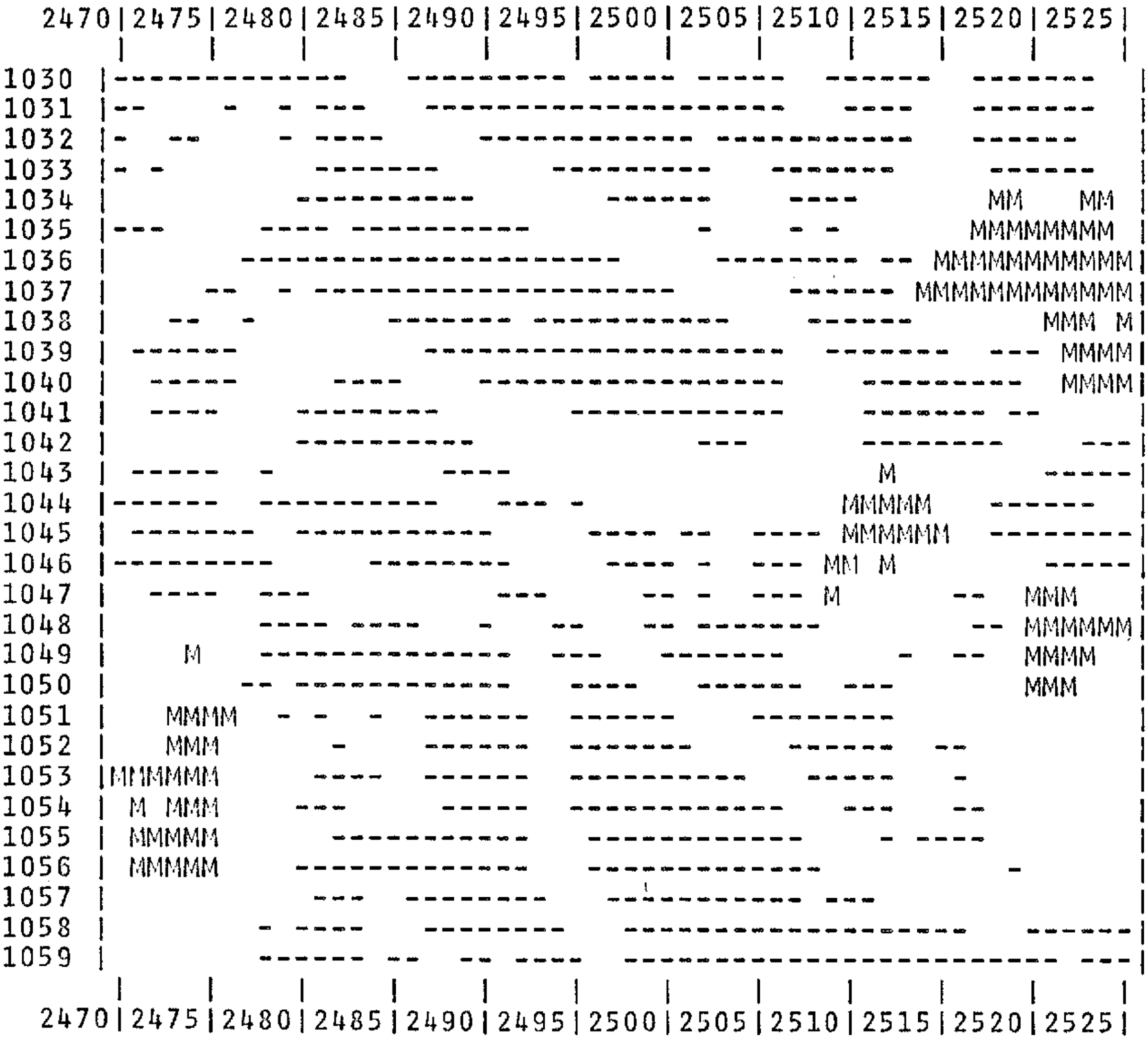
DET.= 0.705D-02

SAMPLE CATEGORY : STRIPMINE

Figure 9 : Statistics of sample areas for a category obtained by STATS.

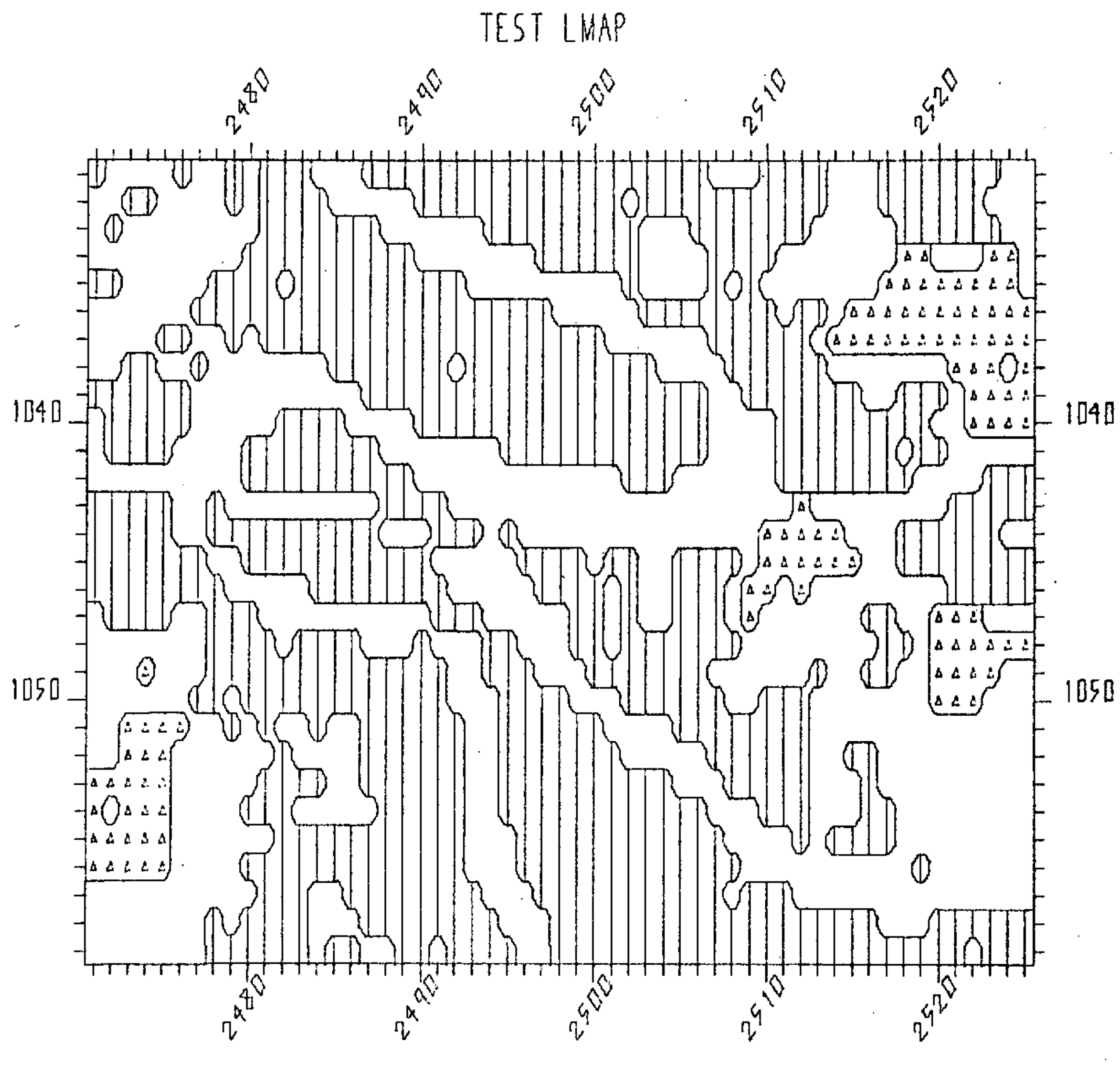
BLOCK SPECIFICATIONS

```
   BEGINNING LINE 1030
      ENDING LINE 1059
BEGINNING ELEMENT 2470
   ENDING ELEMENT 2525
   LINE INCREMENT    1
ELEMENT INCREMENT    1
```



SYMBOL M : STRIPMINE SYMBOL - : VEGETATION

Figure 10: Classification map using signatures obtained by STATS.



Δ: STRIPMINE
|: VEGETATION
BLANK: Other

Figure 11 : Preliminary classification map of the Clearfield area (LMAP).

Such targets may be linear features such as streams, or a series of small scattered features which are not large enough to be represented as uniform areas by UMAP. In such cases, these areas are defined for analysis by an unsupervised classifier which develops its own set of spectral signatures and statistics using a clustering algorithm. The map output of one such program, DCLUS, is shown in Figure 12. The accompanying statistics are shown in Figure 13, and the input data for DCLASS for the categories to be classified are shown in Figure 14. A comparison of Figure 12, with the DCLASS output of Figure 10 reveals that DCLUS was able to map some features which could not be mapped by DCLASS with STATS signatures. Map output from DCLASS, using DCLUS signatures, is shown in Figure 15. Figure 11 shows this same classification in LMAP form.

The approach employed for change detection or where a temporal dimension is involved is similar to the approach for non-temporal analyses in many respects. The major difference is in the establishment of permanent training areas for supervised analysis and classification and permanent analysis areas for unsupervised analysis and classification. These areas must be selected and specified more carefully and with more refinement than when the temporal dimension is not of interest.

```
BLOCK SPECIFICATIONS
--------------------

    BEGINNING LINE 1030
       ENDING LINE 1059
 BEGINNING ELEMENT 2470
    ENDING ELEMENT 2525
    LINE INCREMENT    1
 ELEMENT INCREMENT    1

  2470|2475|2480|2485|2490|2495|2500|2505|2510|2515|2520|2525|
      |    |    |    |    |    |    |    |    |    |    |    |
1030 |---XXXX------.*.---------XXX----.----XXXXXX---..-------+ |
1031 |--X++X-..XXX--.**---------XXXX-------XXXXXX--...-------++|
1032 |XXXXXX+..-XX---.* *.------------.---XXXX----...---XX-X  |
1033 |-XXXXXX....-XX----.*  *.----------**.--------.....------X|
1034 |+XX  X+...-XXX------.** **.------***.----.......===.*==+|
1035 |---+++++----X-----------..*****..-....- -  ...-.=======M |
1036 |.+.  ++---------------------..***---------.--.=========MM|
1037 | ....-XXXXXX-----------X---------.**...------+===========|
1038 |-..--XX-******.------XXXXX---------.**.--------+++...=====|
1039 | X----X.  SSSS+=*-------XXXXXX---------*.--------XX---.====|
1040 |XXX----* S++----.**.----X-XX--X-------.*..-------------=====|
1041 |XX---X*=+.---------.* **..-----X-X----**..-------XX-++++.|
1042 |MM+++++*.+------------.*      *....---***...--X----XXXXX---|
1043 | -----*.-++++++++++----....*** *****......== XXXXXXXX----|
1044 |--XXX-**--------------+++---.-...........  ..===M=+XXXX----.-|
1045 |+-------**-------------+++-+-XX-X--..----.=======+XX------|
1046 |-----X---* **.---------+++++---XX-..---.==MM+X++....-----|
1047 |XX----  .---..******..---++++++-XX-.----+=MM+XXX--.====...|
1048 |+++++++= ----.-----+++=**.--+ +--XX-------+++XXXXX--.======|
1049 |=========-X---------------**---+++-X----XXXXXXXXXXX-++==MMMM|
1050 |*=    ==-XX--XXX----XX-.*.-----+++XX---XXXX--..======= S S|
1051 |=MM=======XXXXXXXXX-----.*------- M++---X----.=.++++ M SXX|
1052 |MMMMM===  .XXXXXXXX----X**---------+ +++-------..--XXXX+++M+|
1053 |MM===== =.XX--XX+-------**--------------+++------ = -XXXX ++ +|
1054 |MMMMM= ===-X-++X++---X-* -------------X+++---+=+-XXX  ++++|
1055 |M===== ==.XX---------XX--*  X--X------X-X+++.------XX++X SXX|
1056 |M=====*.++X----------XX--. .------------XXX++++++++++-+XX+ +|
1057 |++++++==+++---++-----XXX-.**-----------XXXX--+++++++++++++|
1058 |++++++S+-XX---+M+----X---.*.-----------X------------..------|
1059 |+++++SSX-------+---=--XX----**------------XXX--------------.---|
      |    |    |    |    |    |    |    |    |    |    |    |
  2470|2475|2480|2485|2490|2495|2500|2505|2510|2515|2520|2525|

 CHANNELS USED  :  1  2  3  4
 INITIAL CRITICAL DISTANCE  : 8.5
```

Figure 12: Signature map by DCLUS.

UN-NORMALIZED CATEGORY SPECIFICATIONS

CHANNELS-		1	2	3	4
1	-	19.74	12.03	41.97	26.84
2	=	29.33	26.80	28.50	12.22
3	+	26.85	22.80	41.38	22.61
4	X	21.84	14.02	49.40	31.55
5	*	20.37	14.79	21.24	9.87
6	.	20.41	14.24	30.24	17.24
7	M	35.67	37.00	36.67	15.00
8	S	32.50	32.00	49.50	26.50

DISTANCES OF SEPARATION FOR CATEGORIES

		1 -	2 =	3 +	4 X	5 *	6 .	7 M	8 S
1	-	0.0	26.6	13.6	9.3	26.9	15.3	32.3	24.9
2	=	26.6	0.0	17.2	32.1	16.8	16.3	14.8	26.1
3	+	13.6	17.2	0.0	15.7	26.0	16.4	19.0	14.1
4	X	9.3	32.1	15.7	0.0	35.6	24.0	34.0	21.5
5	*	26.9	16.8	26.0	35.6	0.0	11.7	31.5	39.0
6	.	15.3	16.3	16.4	24.0	11.7	0.0	28.2	30.3
7	M	32.3	14.8	19.0	34.0	31.5	28.2	0.0	18.2
8	S	24.9	26.1	14.1	21.5	39.0	30.3	18.2	0.0

CHANNELS USED : 1 2 3 4
INITIAL CRITICAL DISTANCE : 8.5
SAMPLE SIZE : 500

Figure 13: Statistics obtained by DCLUS.

CHANNELS USED: 1 2 3 4

CATEGORY NAME	NUMBER	SYMBOL	LIMIT
STRIPMINE1	1	M	8.5
STRIPMINE2	2	M	8.5
PAVEMENT	3	>	8.5
RIVER	4	R	8.5
VEGETATION1	5	-	8.5
VEGETATION2	6	-	8.5
VEGETATION3	7	-	8.5

UN-NORMALIZED CATEGORY SPECIFICATIONS

CHANNELS-		1	2	3	4
1	M	35.67	37.00	36.67	15.00
2	M	29.33	26.80	28.50	12.22
3	>	26.85	22.80	41.38	22.61
4	R	20.37	14.79	21.24	9.87
5	-	19.74	12.03	41.97	26.84
6	-	21.84	14.02	49.40	31.55
7	-	20.41	14.24	30.24	17.24

DISTANCES OF SEPARATION FOR CATEGORIES

		1 M	2 M	3 >	4 R	5 -	6 -	7 -
1	M	0.0	14.8	19.0	31.5	32.3	34.0	28.2
2	M	14.8	0.0	17.2	16.8	26.6	32.1	16.3
3	>	19.0	17.2	0.0	26.0	13.6	15.7	16.4
4	R	31.5	16.8	26.0	0.0	26.9	35.6	11.6
5	-	32.3	26.6	13.6	26.9	0.0	9.3	15.3
6	-	34.0	32.1	15.7	35.6	9.3	0.0	24.0
7	-	28.2	16.3	16.4	11.6	15.3	24.0	0.0

Figure 14: Category specifications and separations for DCLASS.

```
BLOCK SPECIFICATIONS
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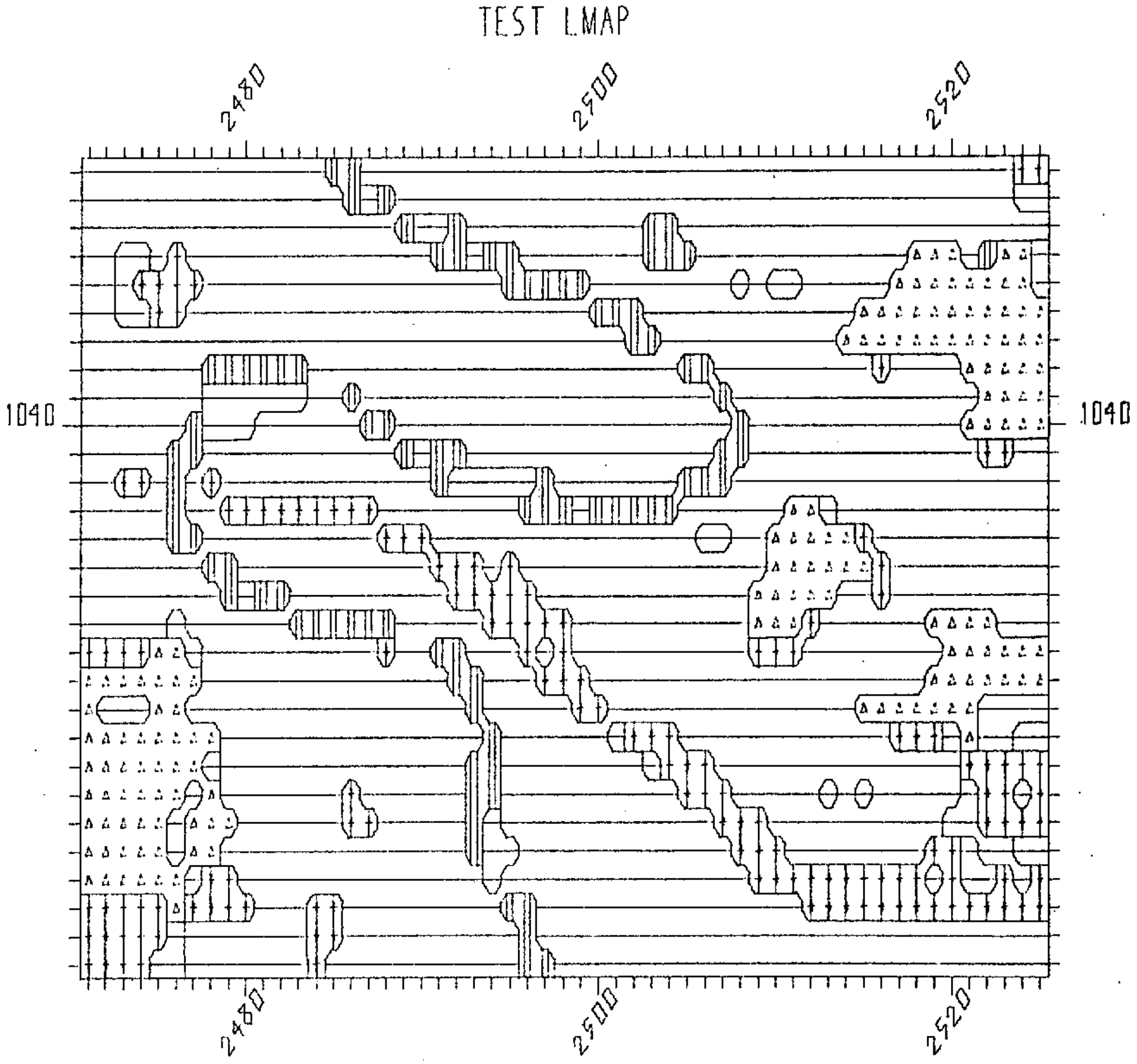
   BEGINNING LINE 1030
      ENDING LINE 1059
BEGINNING ELEMENT 2470
   ENDING ELEMENT 2525
   LINE INCREMENT    1
ELEMENT INCREMENT    1

 2470|2475|2480|2485|2490|2495|2500|2505|2510|2515|2520|2525|
     |    |    |    |    |    |    |    |    |    |    |    |
1030 |--------------R---------------------------------------> |
1031 |---------------RR-------------------------------------->>|
1032 |----------------R R-----------------------------------  |
1033 |-------------------R  R----------RR---------------------|
1034 | --  ->--------------RR RR-------RRR------------MMM-RMM |
1035 |--- >>>>-----------------RRRRR-------- -  -----MMMMMMMM |
1036 |---  >>-----------------------RRR------------MMMMMMMMMMM|
1037 | ------------------------------RR----------MMMMMMMMMMMM|
1038 |--------RRRRRR---------------------RR--------->----MMMMM|
1039 | -------      --R--------------------R--------------MMMM|
1040 |-------R   ------RR--------------------R------------MMMMM|
1041 |------RR-----------R RR--------------RR------------->>--|
1042 |M-->>-R->------------R     R-------RRR------------------|
1043 | -----R-->>>>>>>>>--------RRR RRRRR------MM ------------|
1044 |------RR---------->>>---------------  --MMMMM>----------|
1045 | -------RR----------->>>->--------------MMMMMM>---------|
1046 |---------R RR---------->>>>>------------MMMMM-->---------|
1047 |------ ------RRRRRR----->>>>>-----------MMM>------MMMM---|
1048 |>>>>>MM ----------->--RR---> >----------->>>---------MMMMMM|
1049 |MMMMMMMM--------------RR--->>>--------------------MMMMMMM|
1050 | M    MM-----------------R----->>---------------MMMMMMM  |
1051 |MMMMMMMMM---------------R------ >>>------------->>> M  --|
1052 |MMMMMMMM --------------RR-------- >>>--------------->>>>>|
1053 |MMMMMMM M-------->------RR----------->>>----- - ----- >> >|
1054 |MMMMMM MMM------>>-----R ------------>>>----------  >>>>|
1055 |MMMMMM MM--------------R  ------------>>>-------->>-  --|
1056 |MMMMMMM->>-------------- -------------->>>>>>>>>>->--> >|
1057 |>>>>>>M>>>>--->>---------RR--------------->>>>>>>>>>>>>>|
1058 |>>>>>> ------->>----------R----------------------------|
1059 |>>>>>  ------->-----------RR---------------------------|
     |    |    |    |    |    |    |    |    |    |    |    |
 2470|2475|2480|2485|2490|2495|2500|2505|2510|2515|2520|2525|

SYMBOL M : STRIPMINE                     SYMBOL > : HIGHWAY
SYMBOL R : RIVER                         SYMBOL - : VEGETATION
```

Figure 15: Classification map using signatures obtained by DCLUS.



Δ: STRIPMINE
+: HIGHWAY
||: RIVER
—: VEGETATION

Figure 16 : Classification map of the Clearfield area (LMAP).

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SUMMARY OF RESEARCH AND ACTIVITIES

In addition to the topics discussed in this chapter, it should be noted that several projects are being conducted by ORSER personnel that are not funded by the ERTS contract. These include ongoing investigations in the use of remote sensing to locate potential recreational areas, to determine the intitiation and progression of insect and plant disease epidemics in the grape vineyards of northwestern Pennsylvania, and to map agricultural land use in north-central Montana and southern Texas.

OBJECTIVES

A brief outline of the response by ORSER to the general and specific objectives listed in its ERTS-A proposal to NASA in January 1972, is present below. Detailed discussion of the results of the work performed in the past year is presented in the results section of this report.

General Objectives

1. Ascertain the practical usefulness of the spatial and temporal data provided by ERTS. The use of ERTS data alone has been studied by various investigators and students -- see especially the reports by Merembeck and Borden, and by Thompson and Borden. Most of the projects undertaken under this contract have demonstrated the value of aircraft data used in conjunction with that from ERTS. The value of the temporal nature of ERTS data will be explored more fully in the coming year; Turner and Williams, in their task report, discuss the results of merging ERTS scenes from two different seasons. The computer program MERGE has been written, and is expected to be used frequently during the coming year. The usefulness of ERTS-type missions in locating previously unknown features and relating information previously considered unrelated has been most significantly demonstrated in the task report by Gold, Parizek, and Alexander.

2. Develop interpretation techniques. ORSER has developed an extensive operational capability for processing, interpreting, and analyzing remotely sensed multispectral data. A data processing system has been developed for use on the IBM Systems 370 Model 165 computer with a variety of remote terminals. The source language is FORTRAN IV. The system is implemented at The Pennsylvania State University Computation Center, where the complete facilities and staff are available to ORSER. The data processing system is capable of producing statistical information, performing pattern recognition routines, and generating other types of analyses of remotely sensed data. Computation cost efficiency has been emphasized throughout the development. Character maps

are produced by each component of the system except for the statistics program, which produces the statistical data used by other components and for external statistical analyses. Line maps corresponding to any character map can be produced to a given scale without scanner or character map distortions. Non-University users have access to this data processing system by means of remote terminals connected by telephone lines to the Computation Center.

ORSER has equipped a remote sensing laboratory with a Bausch and Lomb Zoom Stereoscope, a Bausch and Lomb Zoom Transferscope,[1] an Old Delft scanning stereoscope, and a Visucom overhead projector. Three light tables have been equipped with film reel holders which will accommodate up to two 9 in. reels for simultaneous viewing of two formats of underflight photography. Use has also been made of the completely equipped laboratory for photogrammetry and photointerpretation in the Department of Civil Engineering.

3. Apply remote sensing in regional resource management. The application of remote sensing analysis techniques to regional resource management is dependent on the results of studies in which these techniques are developed. These studies have occupied the first year of this program. Contacts have been made with agencies of the Commonwealth of Pennsylvania (e.g., The Pennsylvania Department of Transportation, The Pennsylvania Department of Environmental Resources), and efforts will be made to assist State personnel in solving their resource management problems. The various State agencies will be assisted in the implementation of their own data processing and interpretation procedures, particularly as they apply to the Pennsylvania Resource and Land Information (PENNRALI) system.

4. Provide graduate training and undergraduate instruction in remote sensing. Graduate students have been involved in all aspects of the task investigations. On two task projects, graduate students (Merembeck and Krohn) were the primary investigators. During the past spring term, Borden conducted a combined undergraduate and graduate course in remote sensing data analysis (Forestry 497-597). ORSER co-investigators and several graduate students participated in a seminar on remote sensing held weekly during the winter and spring terms of 1973.

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[1]On order.

This seminar was taken for credit by some graduate and undergraduate students and attended by many other students, as well as by faculty from several departments and colleges. Several co-investigators supervised students in special projects directly or indirectly dealing with remote sensing techniques and data, both from ERTS and underflights. ORSER personnel have been called upon to give lectures and demonstrations on remote sensing and its applications in several courses during the past year.

5. Evaluate the effectiveness of interdisciplinary research and university-industry related research. Personnel from seven departments and three colleges in the University have been successfully working as co-investigators on this project. During the past year, ORSER has performed work as a subcontractor to the MITRE Corporation on their ERTS investigation. A subcontract is being negotiated with the General Electric Company for use of their image enhancement and graphic display system, GEMS (General Electric Multispectral System). A joint research proposal with HRB Singer has been submitted to the Appalachian Regional Commission for evaluation of remotely sensed data in mine subsidence studies.

Specific Objectives

1. Inventory of natural resources and land use. Significant results have been attained in mapping land use, agricultural croplands, and forest resources. A project to identify and characterize soil parameters has been started and will be continued next year. Inventory and data collection systems designed to aid in problems of land use management will also be a focus of attention in the second year.

2. Geology and hydrology. The study of lineaments and fracture patterns has been a focus of concentration this past year. Numerous geologic studies have shown these features to be strongly correlated with mineral and groundwater resources. These relationships are discussed in detail by Gold, Parizek, and Alexander, in their task report. In addition to the work done in structure and terrain analysis by the above

co-investigators, Krohn has reported on his work with the geology of the Lancaster County area, as studied from ERTS-1 data.

3. Environmental quality. Coal refuse in the anthracite mining areas of Pennsylvania has been effectively mapped from ERTS-1 data by Thompson and Borden. Alexander and Dein have mapped strip mines and detected the effects of acid mine drainage waters from ERTS scenes. Damage to vegetation by air pollution and by insects is being studied by Pennypacker and Fritz. The groundwork for a study of the environmental effects of atomic power plants has been laid by Alexander, Parizek, and Gold. It is expected that several of these plants will come into operation in the next year and monitoring of their effects can be begun.

4. Use of remotely sensed data to complement studies of atmospheric effects and climatic mapping. The investigator who was expected to perform this work is no longer with the University. He was the State Climatologist, whose position was abolished by NOAA, and he has been reassigned elsewhere without replacement. There is no one presently available to conduct the work proposed in this objective.

5. Digital processing and pattern recognition. Computer programs to handle digital data, and revisions of these, are constantly being developed. These are discussed by Borden, et al., in the task report on "Program Development and Revisions." The programs are described in detail in ORSER-SSEL Technical Report 10-73. ORSER has developed the "hybrid technique" of processing ERTS-type data. This technique involves the close correlation of ERTS-1 MSS digital output with underflight photography (especially U2 photography) for the positive definition of training areas for classifying programs. It is expected that use of the Bausch and Lomb Zoom Transferscope, recently ordered, will lead to further refinements of the hybrid technique. Analog to digital conversion and processing of MSS data on the hybrid computer has been studied by Rambert and McMurtry, and is reported on in the chapter on tasks. Multistage sampling, temporal models, and techniques of mathematical ecology for spatial patterns will be developed during the second year of this investigation. With the assistance of the General Electric Company's GEMS system, machine-aided imagery analysis and graphic display techniques will be evaluated, commencing in October 1973.

PUBLICATIONS AND PRESENTATIONS

The publications and presentations of ORSER personnel during the period of this report are listed below.

Publications

Alexander, S. S., J. Dein, and D. P. Gold, 1973. The Use of ERTS-1 Data for Mapping Strip Mines and Acid Mine Drainage in Pennsylvania. Symposium on Significant Results Obtained From the Earth Resources Technology Satellite - I. Goddard Space Flight Center. NASA. p. 569-577.

Borden, F. Y., D. N. Thompson, and H. M. Lachowski, 1973. Identification and Mapping of Coal Refuse Banks and Other Targets in the Anthracite Region. Symposium on Significant Results Obtained From the Earth Resources Technology Satellite - I. Goddard Space Flight Center. NASA. p. 1067-1075.

Gold, D. P., 1973. Potential Geological Applications of Remotely Sensed Data from ERTS and SKYLAB. Research in the College of Earth and Mineral Sciences. The Pennsylvania State University, University Park, Pa.

Gold, D. P., R. R. Parizek, and S. S. Alexander, 1973. Analysis and Application of ERTS-1 Data for Regional Geological Mapping. Symposium on Significant Results Obtained From the Earth Resources Technology Satellite - I. Goddard Space Flight Center. NASA. p. 231-247.

Hoosty, J. R., 1972. A Preprocessing and Classification System for Remotely Sensed Multispectral Scanner Data. M.S. Thesis. The Pennsylvania State University, University Park, Pa.

Lachowski, H. M., 1973. Canonical Analysis Applied to the Interpretation of Multispectral Scanner Data. M.S. Thesis. The Pennsylvania State University, University Park, Pa.

Lachowski, H. M., and F. Y. Borden, 1973. Classification of ERTS-1 Data by Canonical Analysis. Symposium on Significant Results Obtained From the Earth Resources Technology Satellite - I. Goddard Space Flight Center. NASA. p. 1243-1253.

Rambert, C. E., 1973. Analog to Digital Conversion System for Multispectral Scanner Data. M.S. Thesis. The Pennsylvania State University, University Park, Pa.

Weeden, H. A., F. Y. Borden, D. N. Applegate, and N. B. Bolling, 1973. Investigations of an Urban Area and Its Locale Using ERTS-1 Supported by U2 Photography. Symposium on Significant Results Obtained From the Earth Resources Technology Satellite - I. Goddard Space Flight Center. NASA. p. 1015-1023.

Wilson, A. D., G. A. May, and G. W. Petersen, 1973. Mapping of Agricultural Land Use from ERTS-1 Digital Data. Symposium on Significant Results Obtained From the Earth Resources Technology Satellite - I. Goddard Space Flight Center. NASA. p. 1055-1059.

Presentations

Gold, D. P., "Remote Sensing: What it is and its Potential Applications to Geology," University of Southern Illinois, Carbondale, Ill., May 1973.

Gold, D. P., "Analysis of Lineaments and Fracture Traces," University of Southern Illinois, Carbondale, Ill., May 1973.

McMurtry, G. J., "Remote Sensing of Earth Resources," Naval Research Reserve Seminar, State College, Pa., Jan. 1972.

McMurtry, G. J., "The Engineer's Role in Ecology," panel discussion, IEEE Student Branch Meeting, The Pennsylvania State University, University Park, Feb. 1972.

McMurtry, G. J., "Interdisciplinary Studies in Remote Sensing," Marine Sciences Consortium, Wallops Station, Va., Aug. 1972.

McMurtry, G. J., "Preliminary ERTS Findings," Naval Research Reserve Seminar, State College, Pa., Oct. 1972.

McMurtry, G. J., "Monitoring of Natural Resources by Aircraft and Satellites," AIAA Seminar, The Pennsylvania State University, May 1, 1973.

Petersen, G. W., "Interdisciplinary Applications and Interpretations of Remotely Sensed Data," HATS Space Congress, Huntsville, Ala., Nov. 1971.

Petersen, G. W., "Remote Sensing - A New Tool," Penn State Turfgrass Conference, University Park, Pa., Feb. 1972

Petersen, G. W., "Potential Agricultural Applications of the Earth Resources Technology Satellite," American Society of Agronomy Meetings, Newark, Del., June 1972.

Petersen, G. W., "Remote Sensing," Path Valley Young Farmers Association, Willow Hill, Pa., Oct. 1972.

Petersen, G. W., "Satellite Sensing - A New Perspective of Pennsylvania," Lime and Fertilizer Conference, The Pennsylvania State University, University Park, Pa., Jan. 1973.

Petersen, G. W., "Agricultural Applications of ERTS Data," Soil Scientists Meeting, The Pennsylvania State University, University Park, Pa., Jan. 1973.

Petersen, G. W., "The Earth Resources Technology Satellite," Staff Seminar, College of Agriculture, The Pennsylvania State University, University Park, Pa., March 1973.

Turner, B. J., "Remote Sensing of Earth Resources," Division of Forestry and Wildlife Resources, Virginia Polytechnic Institute and State University, Blacksburg, Va., May, 1973.

COOPERATION WITH GOVERNMENTAL AGENCIES

The involvement of ORSER personnel in remote sensing activities has resulted in various contacts with personnel representing a number of governmental agencies. At the Commonwealth level, this has involved cooperation with the Department of Environmental Resources and the State Office of the Soil Conservation Service. Discussions with the Department of Environmental Resources have concerned assisting the Commonwealth in development of an environmental resource and land use inventory program to serve as a basis for a state environmental master plan. The Pennsylvania Geological Survey has shown considerable interest in these activities. The Soil Conservation Service, in cooperation with ORSER personnel, is investigating the potential of using ERTS digital data to map land use.

At the national level, contacts have been made with personnel from the Corps of Engineers, the U. S. Geological Survey, the National Park Service and several NASA facilities. This has resulted in the submission of proposals to the Corps of Engineers, National Park Service, and the Department of Interior.

Discussions have also taken place with personnel from the Environmental Protection Agency and the Great Lakes Basin Commission regarding the mapping of land use within the Great Lakes Basin using ERTS data.

NASA Langley personnel, working in cooperation with the Environmental Protection Agency, has also expressed interest in the work presently being conducted on the delineation of areas affected by acid mine drainage and a proposal has been submitted for a subcontract to the HRB Singer Corporation under their proposal to the Appalachian Regional Commission for a study of remote sensing applications to mine subsidence problems.

Personnel from the FAO and UNDP offices of the United Nations have also approached ORSER personnel about offering assistance to the Peruvian government for developing their remote sensing capabilities.

The varied activities of ORSER have resulted in visits by approximately 50 people in the last year to inquire about various aspects of our program. This has included visitors from the Pennsylvania Department of Environmental Resources, Pennsylvania Geological Survey (Director), Corps of Engineers, U. S. Geological Survey, Soil Conservation Service, National Park Service, NASA - Goddard, NASA - Longley, NASA - Houston, the United Nations, and personnel from several corporations and companies as well as many private citizens.

COST-BENEFIT ANALYSIS

Two major components of the cost for analyzing and interpreting ERTS-1 digital data are, computing cost and personnel cost. Computing cost can be partitioned into the cost for spectral signature identification and the cost for processing bulk data after signatures have been identified. The major personnel cost is associated with the development of signatures, since remote sensing analysts and interpreters are required for this phase. In the processing of bulk data, much less personnel time is required, although analysts and interpreters remain closely involved in evaluating the products.

In the Susquehanna River Basin test site in Pennsylvania, two characteristics dominate the analysis and interpretation of ERTS-1 data. These are, the diversity of targets and the areal smallness of target units. Compared with other areas, when these characteristics are less pronounced, signature identification presents a greater challenge and is therefore likely to be more costly. In addition, the cost for signature identification is contingent upon the nature of the particular problem to be solved and therefore it is difficult to categorically specify this cost.

In the computation cost evaluations, the computer run costs are based on the standard rates charged at the Computation Center of The Pennsylvania State University. The ORSER MSS computer analysis methods emphasize the minimization of computation costs by being designed for signature identification based on short computer runs on small subsets of ERTS-1 data.

Data for personnel and computation cost were obtained for a typical ERTS scene analysis. For the identification of 22 signatures judged necessary to meet the analysis objectives, the personnel cost was \$400 and the computation cost was \$600, a total of \$1000. Using the 22 signatures, mapping of a full ERTS-1 scene cost \$560, based on a cost of \$0.043 per square mile. Considering signature identification cost plus full-scene processing cost, the cost per square mile was \$1.60. For subsequent scenes of the same area, signature identification cost would be expected to be substantially less because, in the first time through, a great deal of personnel time and computer cost are spent in familiarization and learning for the specific area and targets. Much of this work does not have to be repeated in subsequent analyses of the same area.

Data have been accumulated for the computation costs of running different programs. For subsetting a complete ERTS-1 digital tape, the cost has averaged \$0.032/square mile. The cost of running mapping and classification programs has been found to be dependent on the number of signatures as well as the area to be mapped. The dollar cost per square mile (C) as a function of the number of signatures (S) has been found to adhere to the following formula:

$$C = S\ (2.56)\ 10^{-3}$$

For 15, 30, and 60 signatures, this cost is \$0.038, \$0.075 and \$0.154, respectively.

The above calculations of analysis and processing costs have not taken into account the cost of developing the digital computer processing system. The system was developed so that it could be easily used for processing ERTS-1 as well as any other satellite or airborne platform MSS digital data. System development costs will not be included in production analyses for some time to come, until reasonable estimates of future production demands can be achieved. The system development has not been financially supported by the ERTS-1 project, although it has received partial NASA support through a sustaining University grant. Extension and modification of the system has been partially supported in the ERTS-1 project; this has been found necessary to meet specific requirements of the ERTS-1 project and the diverse users on the project.

The total development cost of the system, excluding the minor cost directly attributable to the ERTS-1 project mentioned above, was approximately $76,000 of which $55,000 in support came from general University funds and $21,000 came from SSEL/NASA sustaining University grant funds. This cost is summarized below.

	University General Funds	SSEL/NASA Funds	Totals
Computer Cost	$51,100	$ 1,200	$52,300
Personnel Cost	4,000	20,000	24,000
Total Cost	$55,100	$21,200	$76,300

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INVENTORY OF NATURAL RESOURCES AND LAND USE

Significant results have been attained in mapping land use, agricultural croplands, and forest resources. A project to identify and characterize soil parameters has been started and will be continued next year. Inventory and data collection systems designed to aid in problems of land use management will also be a focus of attention in the second year.

LAND USE MAPPING

F. Y. Borden, H. A. Weeden, D. N. Applegate, and N. B. Bolling

This project was designed as a test of the hybrid approach to data processing, developed by ORSER (see section by this name, elsewhere in this report). An area just south and west of Harrisburg, Pennsylvania, was chosen because the same area had been used in the development of the hybrid approach and it was thought desirable to be able to compare the results of the two studies. Three constructive frames of U2 photography (nos. 13, 14, and 15) from sensor 14 of flight 72-124, flown in July 1972, were used. These were mounted between glass plates and projected onto the digital output, using an American Optical Company Delineascope, Model D. One of these photographs is shown in Figure 17 . Digital data from ERTS-1 scene 1080-15185, collected October 11, 1972, were used in the analysis. A portion of the channel 7 image of this scene is shown in Figure 18.

Procedure

After the study area was subset from the NASA tapes onto working tapes, NMAP[1] and UMAP were run for review of definable boundaries and selection of the first set of training areas. The most easily recognized targets from spectrally homogeneous areas with positive widely separated geographic locations were chosen. (The Susquehanna River is an excellent example of such a target.) These targets were positively identified by projecting the U2 photograph onto the NMAP output. Scale distortions of this map, however, prevented proper registration of the photo over the entire area of the map. This required a distribution of positively identified targets throughout the area in order that adjacent portions of the scene could be sequentially brought into proper registration. Areas 10 to 25 cm square (representing approximately 0.2 to 0.4 square miles) could be brought into registration by this method.

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[1]For complete program descriptions, see ORSER-SSEL Technical Report 10-73.

As thematic maps were produced, using the STATS and DCLASS programs, they were refined and new training areas were chosen by comparison with the U2 photograph. These maps were produced in separate categories (such as all vegetation) for ease of checking. Figure 19[1] shows such a map. Note first the easily recognized Susquehanna River on the upper right, with the meandering Conodoguinet Creek entering from the left. In addition to the river and the creek, the map shows the categories of OPEN LAND, FOREST, and GOLF COURSE. Some areas verified by correlation with the U2 photograph are outlined on this map. Lesser areas, now geographically fixed and interpreted from the photograph, were then defined. The number and variety of targets was thus expanded with respect to both the type and the extent of geographic separation. This cyclic operation was repeated until it was considered necessary to use cluster analysis where uniform areas of sufficient size could not be found to define training areas for the STATS program. The DCLUS program, which uses the techniques of cluster analysis to find signatures for areas of small size or spectral nonhomogeneity, was then applied. The majority of training areas processed with this program were selected by the photointerpreters on the U2 photograph and then correlated with the computer map. (The industrial and suburban categories shown in Figure 20 were developed in this way.) The map was verified by correlation with the U2 photography and the targets successfully defined were outlined. This comparison revealed that one of the areas mapped as suburban also included a considerable number of agricultural fields (the category of SUBURB CONFUSION in Figure 20). When one considers the mixed character of a suburban area, consisting of roofs, lawns, shrubs, and streets, it is easy to see how some of those combinations might resemble a mixture of small fields or long and narrow fields resulting from contour plowing. The signature for this category (number 2) and that for FIELD (number 3), shown in Table 3, reveal that these two signatures do not have a wide separation. Thus, confusion between these two categories could be anticipated. In contrast, the separability of category 1 (RIVER) from every other category is quite large, implying

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[1]Figures 19, 20, and 21 were transcribed from the character maps using the program LMAP, which corrects for the distortion of scale inherent in the character map output on the printer.

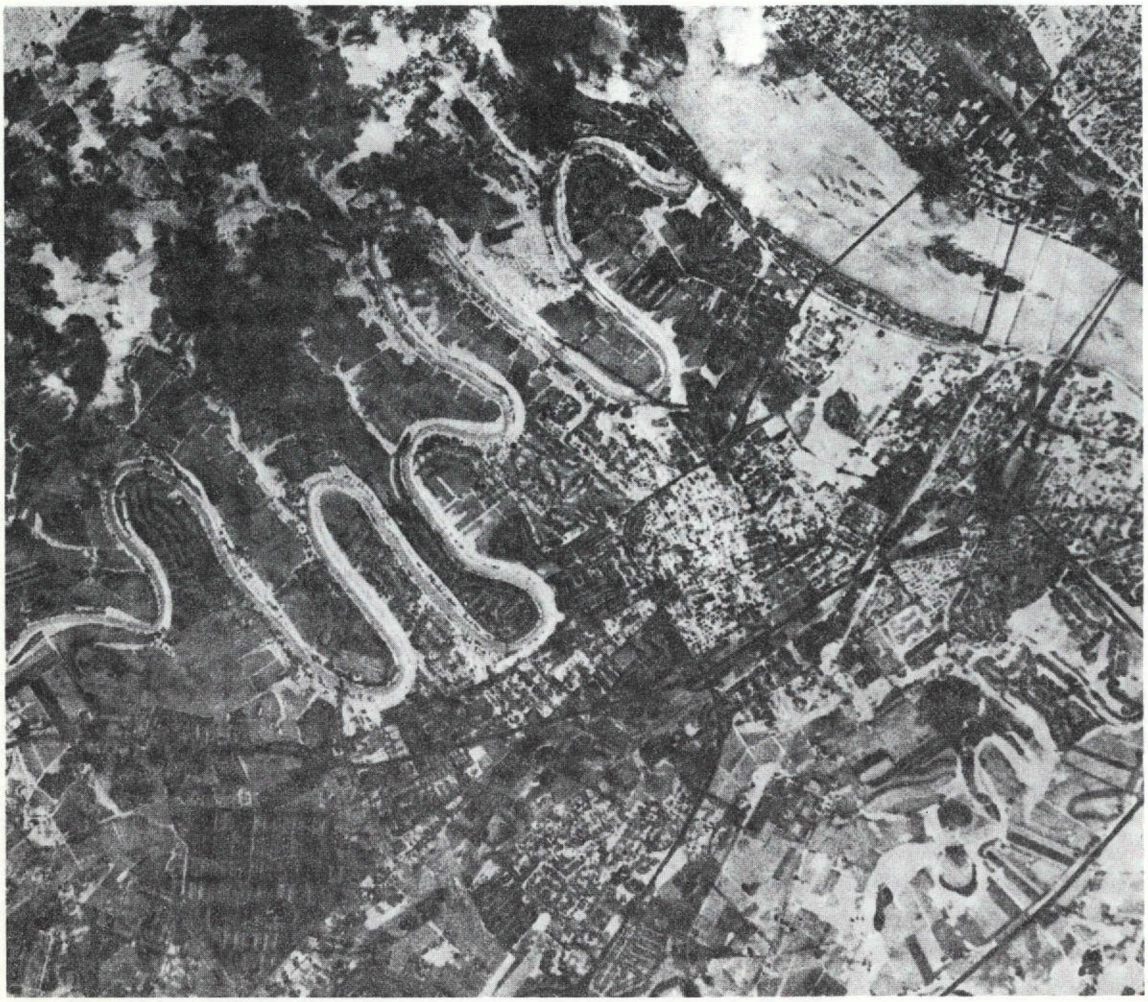

Figure 17: Black and white enlargement of a portion of the U2 photograph of the Harrisburg area. (Flight 72-124, sensor 14, frame 34619).

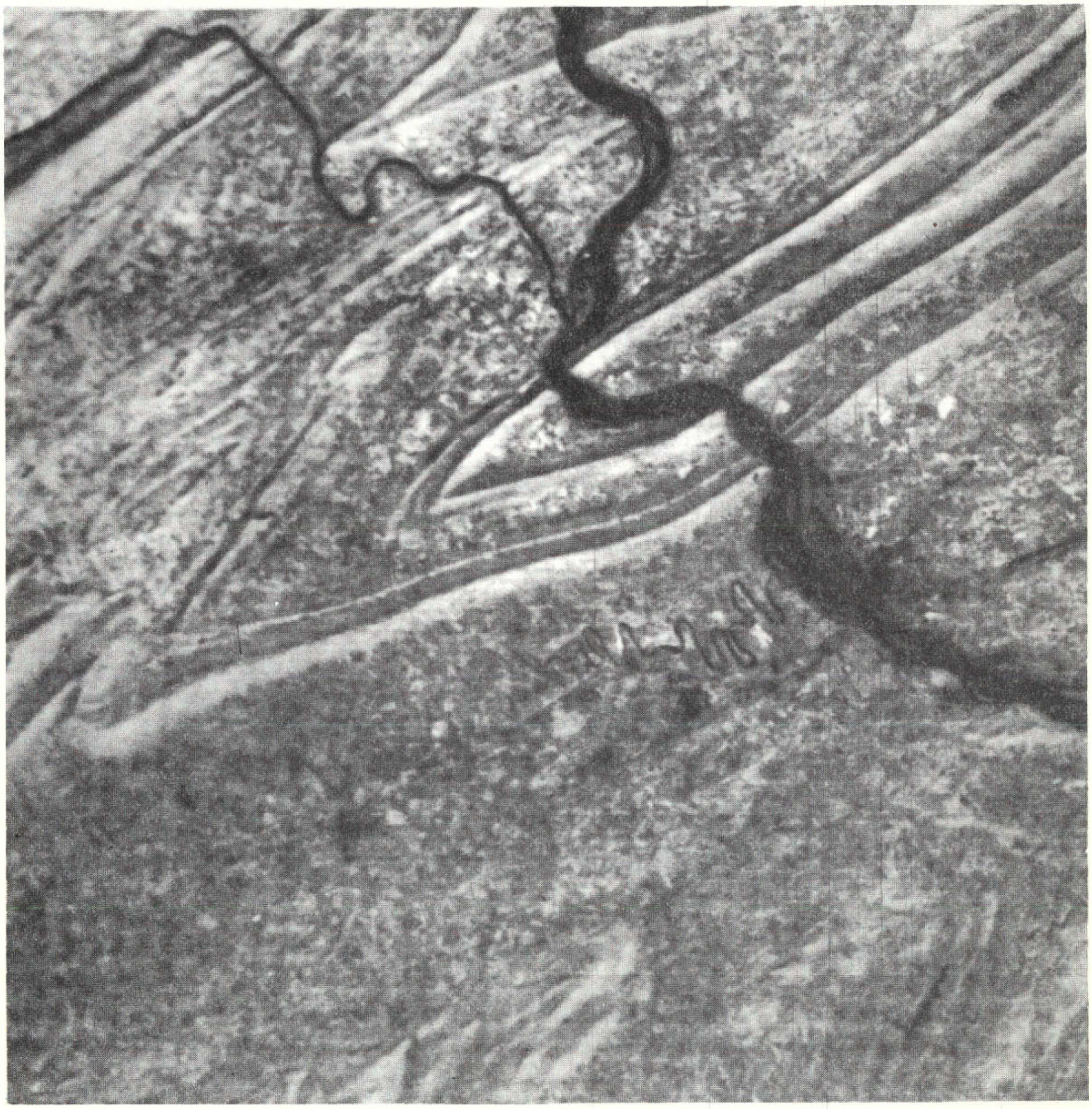

Figure 18: Enlargement of a portion of the channel 7 ERTS-1 image of the Harrisburg area. (Image 1080-15185, October 11, 1972; 1 inch equals approximately 5.7 miles)

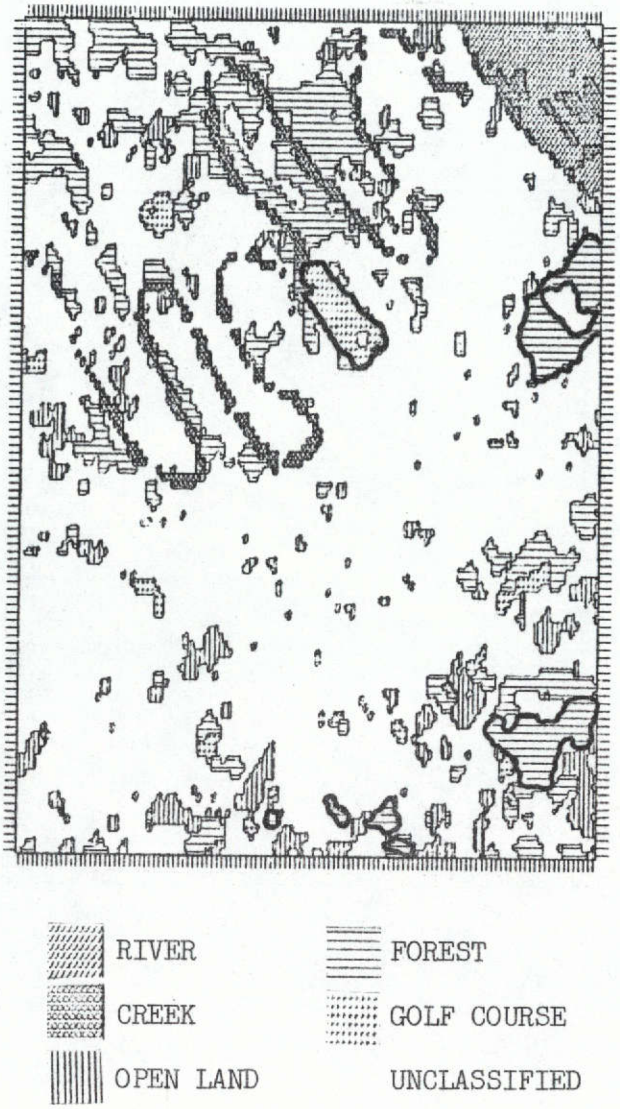

Figure 19: Classification map of vegetation categories. (Plotted on the CALCOMP plotter, using the LMAP program.)

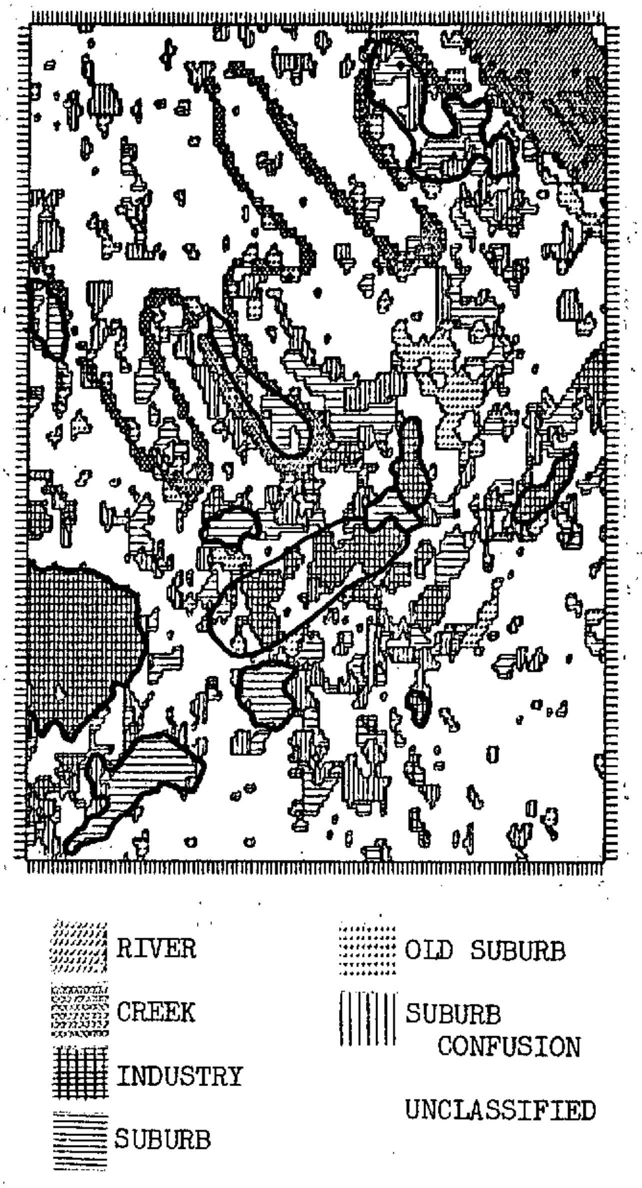

Figure 20 : Classification map of industrial and suburban categories. (Plotted on the CALCOMP plotter, using the LMAP program.)

Table 3 : Distances of Separation for Some Categories Used in Mapping the Harrisburg Area

Name	Number	1	2	3	4	5
RIVER	1	0.0	31.8	31.5	14.2	31.4
SUBURB CONFUSION	2	31.8	0.0	1.1	18.3	14.2
FIELD	3	31.5	1.1	0.0	18.0	13.8
INDUSTRY 1	4	14.2	18.3	18.0	0.0	17.7
INDUSTRY 2	5	31.4	14.2	13.8	17.7	0.0

no problem in classifying this category correctly. A mixture of two categories (4 and 5) was found to consistently appear in industrial areas on the initial output. Although these two signatures were relatively widely separated, and thus retained as separate entitites, they were assigned to the same symbol (+), thus yielding a uniformly mapped area on the output. More work is required with the category of HIGHWAYS. It comes up well in areas of high subject-to-background contrast, but is weak in urban and suburban areas. Perhaps the mapper will have to produce highway networks by the judicious connection of scattered symbols. This is not a satisfactory procedure. Other spectrally nonhomogeneous targets definable by cluster analysis that are different but worthy of further study are quarries and small streams.

In the third and final level of mapping, the thematic map was reviewed for clarity. At this stage the resulting map output was too refined and confusing to the reader. Some categories were combined, as explained above for the industrial areas. Stray symbols were suppressed using the CLEAN option. A careful review of map objectives at this stage served as a guide to the final number of categories to be mapped. The final output also includes a table expressing the percentage of the area mapped for each category. Figure 21 is the completed map. It represents a combination of the maps shown in Figures 19 and 20. However, in order to make the map readable, forest areas were combined with unclassified areas. The hope of diminishing the unclassified area may rest in the merging of data from scenes for different seasons of the year.

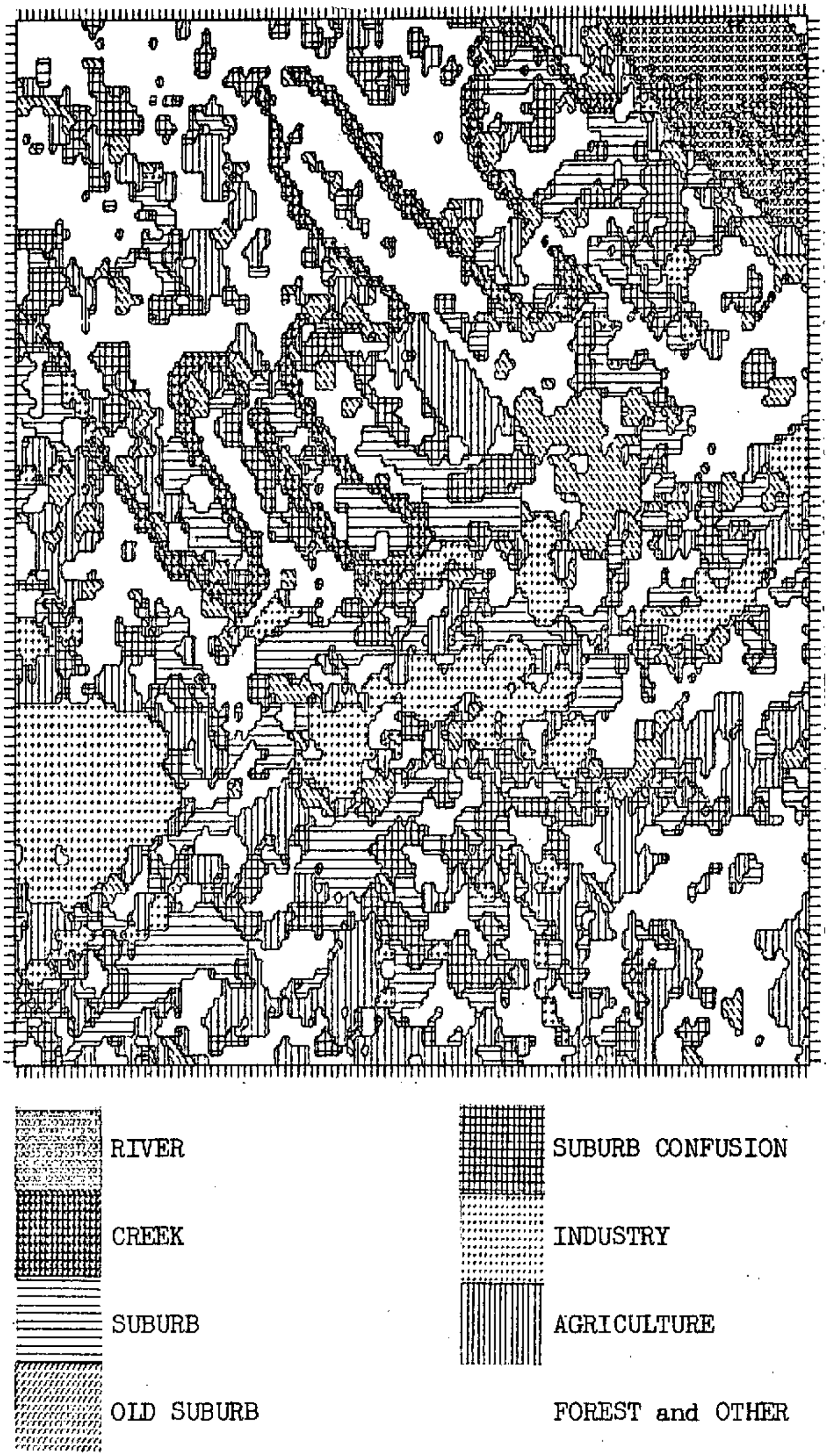

Figure 21: Classification map of all categories. (Plotted on the CALCOMP plotter, using the LMAP program.)

Results and Conclusions

The following results and conclusions were drawn from this study:

1. The categories of water, forests, high density suburbs, old suburbs, industrial areas, and parking lots and concrete were reasonably well defined.
2. The categories of agricultural fields, highways, and low density suburbs need more study.
3. Some items highly desirable in land use mapping may not be obtained because of small size or low subject-to-background contrast.
4. The temporal aspect of the data has not yet been sufficiently exploited.
5. The combined efforts of interpretation of ERTS images, aircraft underflight photographs, and computer-generated character maps has the potential to generate land-use maps of high quality.

It should be added that subsequent efforts to further refine the techniques described here were hampered by the inability to pinpoint small geographic areas on the thematic maps because of the line-and-element distortion inherent in the character maps generated by the printer. ORSER recently ordered a Zoom Transferscope from Bausch and Lomb. The use of this device with color transparencies of underflight photography should offer great improvement over the method of simple projection, because of the differential scale adjustments possible with this instrument.

Aircraft underflight data are vitally important to the ultimate refinement of thematic maps from ERTS digital data. In order to make maximum use of the photointerpreter in the establishment of signatures, it is necessary to provide images at a larger scale than that of ERTS-1 MSS prints, in order that microfeatures may be read. As these features are properly identified with underflight data, they can be used to establish computer processed signatures for subsequent mapping of large areas.

AGRICULTURAL LAND USE MAPPING

A. D. Wilson and G. W. Petersen

Three diverse agricultural sites were chosen with the intent of developing an approach to agricultural land use mapping from ERTS-1 data. Spectral, spatial, and temporal factors are being used to map land use and to delineate soil associations. The relative usefulness of photointerpretation, image enhancement, and computer analysis in this effort are being explored. Ground truth, in the form of underflight photography and multispectral scanner (MSS) data; results from ground-based projects conducted by Federal, State, and University personnel; and actual visits to the test sites; are being used in conjunction with ERTS-1 data analysis.

Site Selection

The three sites selected for analysis include one each in Pennsylvania, Texas, and Montana. Difficulties encountered in an initial study of the Lancaster County area, in Pennsylvania, led to study of the sites in Montana and Texas, where agricultural features are larger and more uniform than those found in Pennsylvania. The extensive ground truth data available for these two sites, including on-site familiarity with the areas on the part of one of the investigators (Wilson), was an added factor in their selection. The three sites, taken together, represent a broad range of soils, soil parent materials, climate, modes of agricultural operation, crops, and field sizes.

Ground Truth Sources

USGS 7 1/2 minute quadrangle maps (1:24,000) are being used to locate and identify cultural features, drainage areas, and other geographic landmarks for all three sites. Geologic maps are consulted for information concerning possible subsurface features and bedrock bodies which may have surface expression or influence overlying soils. County soil survey maps, prepared on a base of aerial photography, provide ground truth for soil classifications. Ground truth sources specific for each site are discussed in the section dealing with that site.

Methodology

The method of procedure for each of the three areas under study has been as follows:

1. Locate the specific area on ERTS-1 images and computer tapes; subset the area onto a working tape. Locate the area on available underflight photography; investigate other ground truth sources.
2. Use the NMAP and UMAP programs[1] to further specify the area and locate immediately identifiable features. Compare the computer output to the ERTS image and to high-altitude aircraft photography, when available.
3. Use statistical and classifying programs to further identify and classify vegetation types, crop species, soil associations, and cultural features on the computer-generated thematic maps. Relate these to the available ground truth information, including high and low altitude aerial photography.
4. Continue analysis until a satisfactory map has been obtained.

The data analysis methods evolved in the study of the three sites will be compared with those developed by the General Electric Corporation, using their data analyzer, "Image 100." This machine presents ERTS-1 data on a color cathode ray tube. Training areas can be selected and manipulated visually in the discrimination of land use classes. A hard copy of the results displayed on the cathode ray tube can be obtained at any point in the process.

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[1]Detailed program descriptions may be found in ORSER-SSEL Technical Report 10-73.

Lancaster County, Pennsylvania

An area approximately 300,000 acres in size was selected for analysis within Lancaster County, in southeastern Pennsylvania. This county, noted for its quality agricultural production, is the center of the Pennsylvania Dutch country. Field size is generally small (4 to 10 acres) with major crops of corn, hay, small grains, and tobacco. The economy of the area revolves around livestock, with much of the crop production being used for feed. The soils are residual, derived largely from limestone, shales, and sandstones. The climate is humid; rainfall in excess of 40 inches per year is evenly distributed throughout the growing season. The landscape is bisected by many small streams. The topography is characterized by broad valleys separated by ridges of sandstone and shale. Native vegetation is of mixed oak, or oak and hickory.

The test site is covered by low altitude photography (5 to 15 thousand feet) on a seasonal basis, and by high altitude photography (65,000 ft) on a periodic basis. In addition to the study of data from these flights (predominantly by C130 and U2 aircraft), maps and county reports have been consulted for topographic, geologic, and soil information and field data are collected on visits to the area in conjunction with ERTS-1 overpasses.

Procedure

This site was the first of the three sites selected for a study of agricultural land use. The first clear ERTS-1 scene available of the area, therefore, was selected for study, even though optimum conditions for the study of agricultural land use do not exist in the fall, with most of the crops harvested and crop residues littering many of the fields. The scene was that of October 11, 1973 (1080-15185). Approximately one inch of rain was recorded three days prior to this ERTS-1 pass, and the first frost of fall occurred the night before.

A channel 7 positive transparency were overlaid on a map at the scale of 1:1,000,000 to locate the towns of Lancaster, Denver, Blue Ball, and Lititz. Highway networks, urban areas, and vegetative patterns were delineated on overlays on these transparancies. Possible target areas were selected for computer analysis. A subset of the test area was made from the NASA tape onto an ORSER working tape. Computer-generated brightness maps, using the NMAP program, were visually related to the transparencies by pattern association. This was done for individual channels, as well as for all four channels combined. Remote sensing units seen on the brightness map were related to geographic features shown on topographic maps at the 1:24,000 scale. A 35 mm slide of the geology of the area[1] was projected onto the digital brightness maps to identify features which might have geologic significance. Sandstone ridges, limestone valleys, drainage patterns, and some cultural features were determined from the brightness map. Bright areas were associated with bare fields and quarries, and a dull area was identified as a swamp.

A uniformity map, using the UMAP program, was output, and compared to the brightness map. From these two maps, training areas were selected for analysis by the STATS program. This program develops a variety of basic statistical values and determines signatures from selected training areas. These statistics are used in supervised classifiers such as the DCLASS program. Results of using these signatures with the DCLASS program, however, were inconclusive for the Lancaster area because the map patterns could not be recognized.

The problems encountered with the supervised classification, led to the use of the unsupervised classifier, DCLUS. This classifier randomly selects up to 900 points and forms up to 10 separable categories with a minimum critical euclidean distance between categories chosen by the user. A minimum distance of 2.0 was chosen in this case. Output is in the form of a map of the area, a table of spectral signatures of the categories, and a table of the euclidean distances between the categories. Five widely separated categories were delineated by this method. The first two were related to forested sandstone ridges. These areas agreed very closely with vegetated areas indicated on the USGS topographic maps. The third category corresponded closely to bodies of water, such as

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[1]This slide was made from the 1960 edition of the Geologic Map of Pennsylvania, put out by the Pennsylvania Topographic and Geologic Survey.

swamps, farm ponds, and streams. The last two categories occurred in cultivated areas. One of these categories had a high response in channels 5 and 6, and was tenatively identified as mapping areas of bare soil. Areas which did not fall into any of these categories were not mapped.

The DCLUS program was then used in small areas to subclassify some of these five categories, and to establish signatures for some areas which had not yet been mapped. The resulting map is shown in Figure 22. (The category specifications and symbols for this map are shown on Table 4.) By this method, the water signature was further subdivided into four categories: CLEAN WATER, two categories of DIRTY WATER, and VEGETATED WATER. Many additional categories were established within the forested and cultivated areas, but they presented a pattern too complex for clear identification from the ground truth available at the time of this analysis. Using the town of Denver, which did not register on the output, (and does not lie within the area shown on the figure), an attempt was made to develop a signature for small communities. This was only partially successful, probably due to the fact that a large percentage of Denver is vegetated. Individual fields could not be mapped. This was partially because of their small size (usually less than five acres) and partially because of the wide variety of agricultural practices, including contour plowing. Aircraft data were an invaluable aid in the analysis of the DCLUS output. It was from these photographs that the true complexity of the land use patterns of Lancaster County became evident and the problems of mapping these from ERTS-1 data were clarified.

Results and Conclusions

The use of ERTS-1 digital data for the automatic mapping of land use categories appears feasible. Forest land, cultivated land, and water were classified within 25,000 acres in an area of very complex land use patterns. Additional classifications made within these categories are being identified from ground truth as it becomes available. Four water classifications have been identified and verified.

Because of the complexity of the land use patterns in the Lancaster County area, it was deemed wise to turn attention to the two western

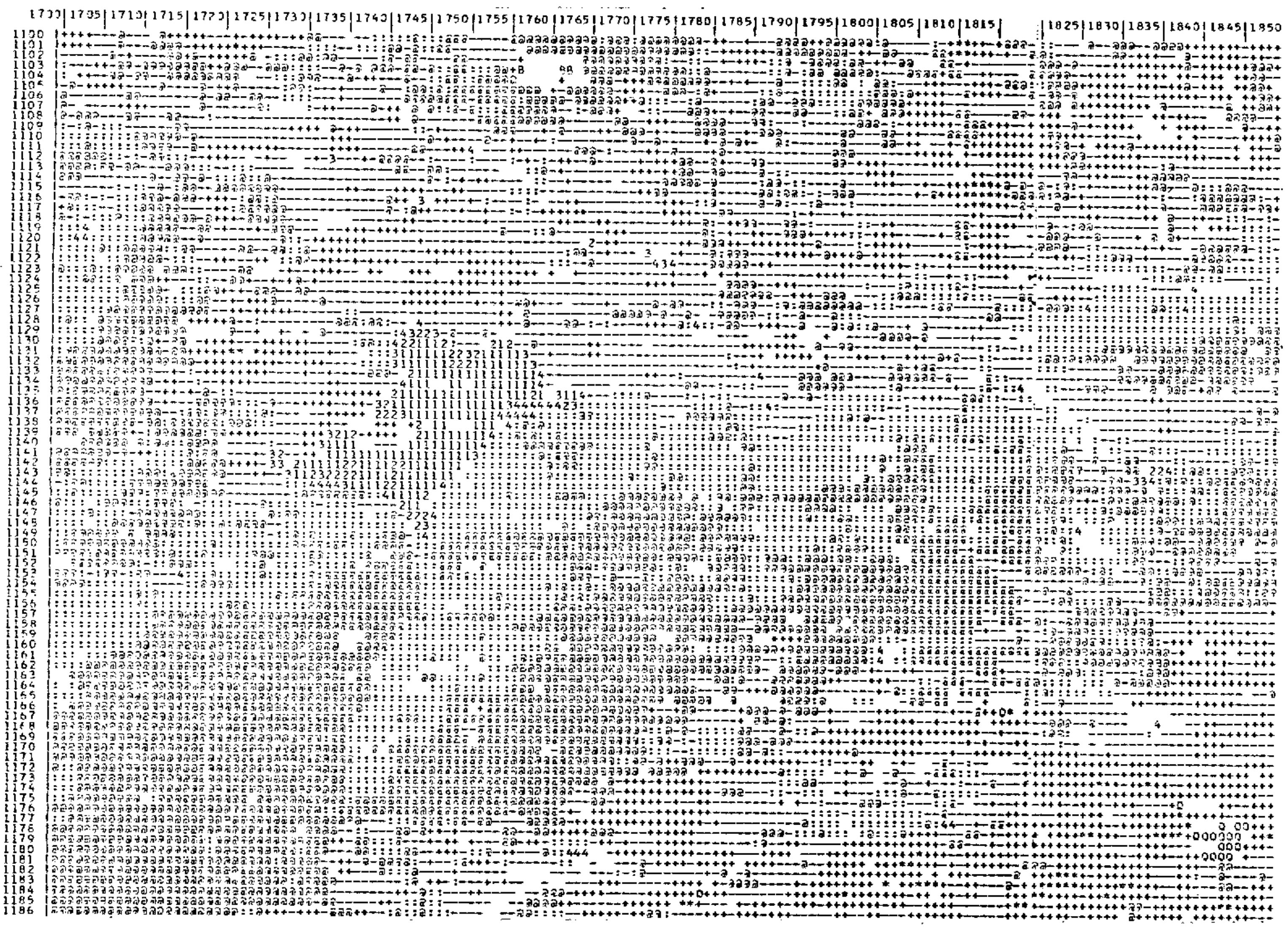

Figure 22: Classification map for the Lancaster County area. (Symbols are defined on Table 4.)

Table 4 : Category Specifications and Symbols for the Lancaster Area Map

Category Name	Number	Symbol	Specifications Channels: 1	2	3	4
QUARRY	1	Q	40.75	36.25	30.25	11.50
FOREST	2	:	20.80	13.30	26.85	15.40
FOREST	3	:	18.36	10.43	23.00	13.36
QUARRY	4	Q	47.86	49.29	45.29	18.57
UNKNOWN	5	/	45.25	41.25	49.19	25.25
CULTIVATED FIELDS	6	+	34.14	35.57	40.24	19.95
CULTIVATED FIELDS	7	+	32.78	30.00	38.63	20.00
SUNNY FOREST	8	@	23.40	16.07	38.33	23.53
CLEAN WATER	9	1	20.15	12.86	9.37	2.33
DIRTY WATER	10	2	21.00	14.67	10.00	3.33
DIRTY WATER	11	3	21.60	16.20	15.80	7.20
VEGETATED WATER	12	4	21.00	14.25	17.75	7.50
QUARRY	13	Q	41.13	38.67	33.27	13.43
QUARRY	14	Q	39.00	33.83	28.00	11.00
QUARRY	15	Q	42.58	40.33	36.48	15.08
ROCK OUTCROP	16	B	43.88	38.46	52.50	27.60
PASTURE	17	-	25.50	21.08	31.53	17.57
PASTURE	18	-	25.22	21.77	27.02	14.11
CULTIVATED FIELDS	19	+	27.60	25.77	30.72	15.76
PASTURE	20	-	22.82	17.25	27.49	15.54
SUNNY FOREST	21	@	20.13	12.40	32.98	21.17
CULTIVATED FIELDS	22	+	32.20	33.16	36.19	17.46
CULTIVATED FIELDS	23	+	28.62	25.68	35.83	18.92
CULTIVATED FIELDS	24	+	29.73	29.34	32.46	16.31
SUNNY FOREST	25	@	22.73	15.11	32.61	19.50
SUNNY FOREST	26	@	20.61	13.11	36.52	23.42
BARE SOIL	27	*	37.00	42.42	43.33	20.25
BARE SOIL	28	*	39.71	46.86	45.43	21.43
CULTIVATED FIELDS	29	+	27.50	24.17	37.33	20.17

agricultural areas before continuing with the Lancaster study. Experience gained from study of these areas of larger fields and farms would most likely be of considerable assistance in later study of Lancaster County, after data from the summer of 1973 becomes available.

Hill County, Montana

The Hill County, Montana, site is located in the Hard Winter Wheat Belt of the Northern Great Plains. The climate is semi-desert to arid, with up to 15 inches of rainfall occurring mostly in the winter and spring. Soils are developed in glacial till; the topography is flat to gently rolling; an occasional stream bed traverses the terrain. In areas of lesser rainfall, large sections have been left in native short grass vegetation, used as rangeland for cattle. The temperature has a large daily fluctuation as well as a large seasonal variation.

The region is entirely agricultural, with major crops of winter wheat, spring wheat, and barley, in two-year rotation with summer fallow. Farm size varies from 1500 to 5000 acres, with individual fields ranging from 40 to 100 acres in size. Fields are usually either 1/2 to 1 mile long, with widths from less than 2178 feet (80.5m) to one-quarter mile (402.3m). The land is surveyed on the township and range system. Most fields are rectangular in shape and oriented north-south, to control wind erosion. However, the government programs on acreage production allotments confuse the pattern, forcing farmers to plant less than full fields to satisfy their acreage requirements.

Two test sites were selected. The location of these is shown in Figure 23. The principal site is the Kenneth E. Wilson farm near Kremlin, Montana. The primary investigator is personally acquainted with this site and the surrounding fields. A secondary test site is located approximately 20 miles northeast of the primary site. The Agricultural Stabilization and Conservation Service (ASCS) has collected ground truth for this area for each pass of ERTS-1 since launch. These data are in the form of records of crop, stage of growth, and condition, for each field. Species identification and acreage measurements have been supplied by the U. S.

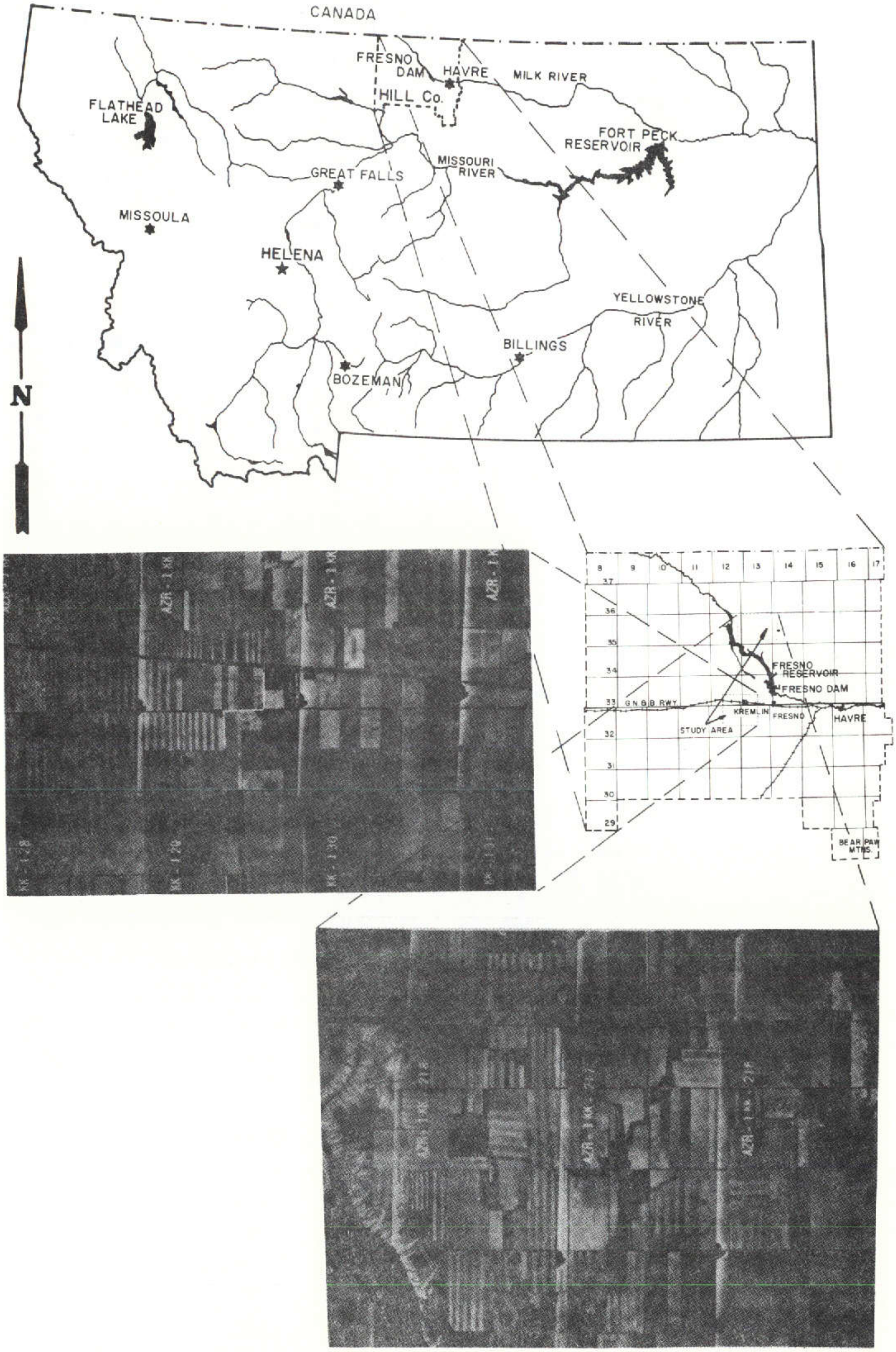

Figure 23: Location of the two test sites in Hill County, Montana.

Department of Agriculture (USDA) Crop Reporting Service. The U. S. Geological Survey (USGS) has recently flown this area of Montana as part of their program to up-date the topographic maps of the United States. These photographs are available at various scales and have been used in conjunction with field ground truth. USGS topographic maps at a scale of 1:250,000 were used to locate specific field boundaries. A U. S. Bureau of Soils 1920 Reconnaissance Soil Survey Map, and a USGS 1955 Geological Map of Montana, both at a scale of 1:500,000 were also available for use. For the primary test site, the ASCS Crop Planting Plan was used, and a photomosaic of the area, put out by the USDA in 1969 at a scale of 1:63,360, was extremely useful. Weather data for the first two weeks in September 1972 are presented in Table 5 .

Procedure

The objective of this study was to produce a thematic map of the area depecting the following categories: stubble, fallow, native grassland, planted pasture, farmsteads, roads, railroads and water bodies.

Table 5 : Weather Data for Hill County, Montana, the First Two Weeks in September, 1972

Date	Temperature		Precipitation
	Maximum	Minimum	
9/1/72	88	41	None
9/2/72	96	47	None
9/3/72	82	47	Trace
9/4/72	72	46	None
9/5/72	70	49	None
9/6/72	75	41	None
9/7/72	83	35	None
9/8/72	90	41	None
9/9/72	91	54	None
9/10/72	87	50	None
9/11/72	92	48	None
9/12/72	91	52	None
9/13/72	89	62	None

ERTS-1 scene 1052-17452, from September 13, 1972, was selected. The primary test site lies approximately between lines 1300 and 1400 and elements 1850 and 2200; the secondary test site is located within lines 1098 and 1160 and elements 2035 and 2222. (These test sites are shown on photomosaics in Figures 24 and 25.) A slight banding of data in channels 4, 5, and 6 appears as a lowering of response values by approximately 2 percent. This banding is not consistent through the scene.

A previously prepared template was used as a guide to select lines and elements of an area to subset. The SUBSET program[1] was used to convert data from the NASA to the ORSER format and to subset the data onto a working tape. A small block of the area was run with the NMAP program to set the class intervals for a complete run of the tape by NMAP. The large (8 by 8 ft) brightness map was used to locate the specific block that included the desired test sites. Several runs were made with different groupings of brightness percentage classes until a map was produced that appeared to best represent the expected field pattern.

Uniformity maps were produced using the UMAP program and several class intervals. This program compares nearest neighbors. If the percentage difference between the adjacent RSU's (remote sensing units) is less than a user-chosen class group, the program assigns the appropriate mapping symbol to that RSU. For this data, the class including all RSU's with less than 5 percent brightness difference between adjacent RSU's tended to produce large areas of uniformity. These patterns were larger than the expected field pattern. When the class was reduced to 4 percent the areas of uniformity were less than full fields. It was decided to use the 4 percent uniformity groups for selection of spectral signature training sites. These areas of uniform brightness were input to the STATS program. It was necessary to select some areas outside the specific test sites as neither site contained large enough areas of uniform brightness for statistically valid sampling. The initial training areas for signature determination were based on brightness, rather than a mapping

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[1]For complete program descriptions see ORSER-SSEL Technical Report 10-73.

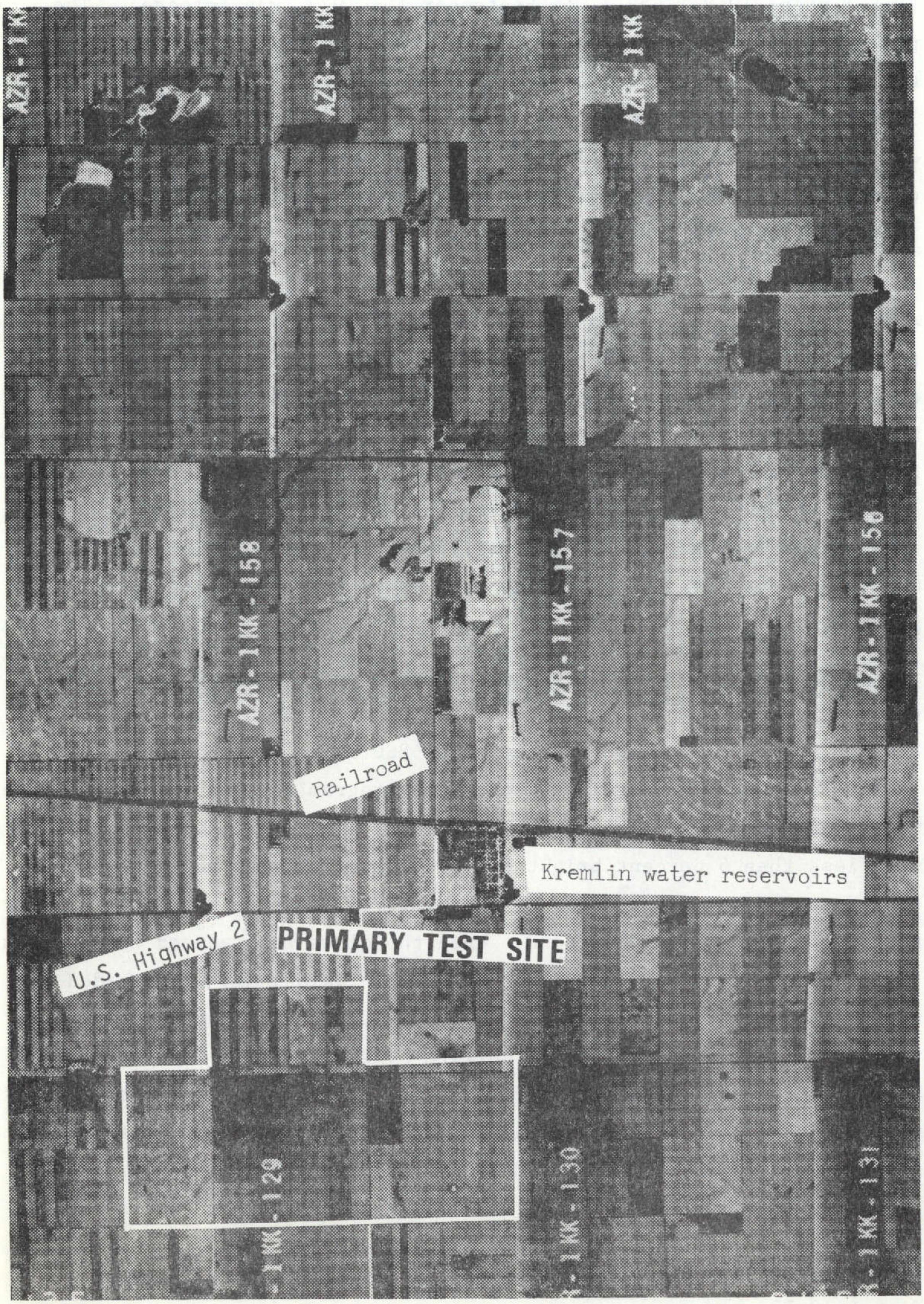

Figure 24: Primary test site shown on the 1969 USDA photomosaic, at a scale of 1:63,360.

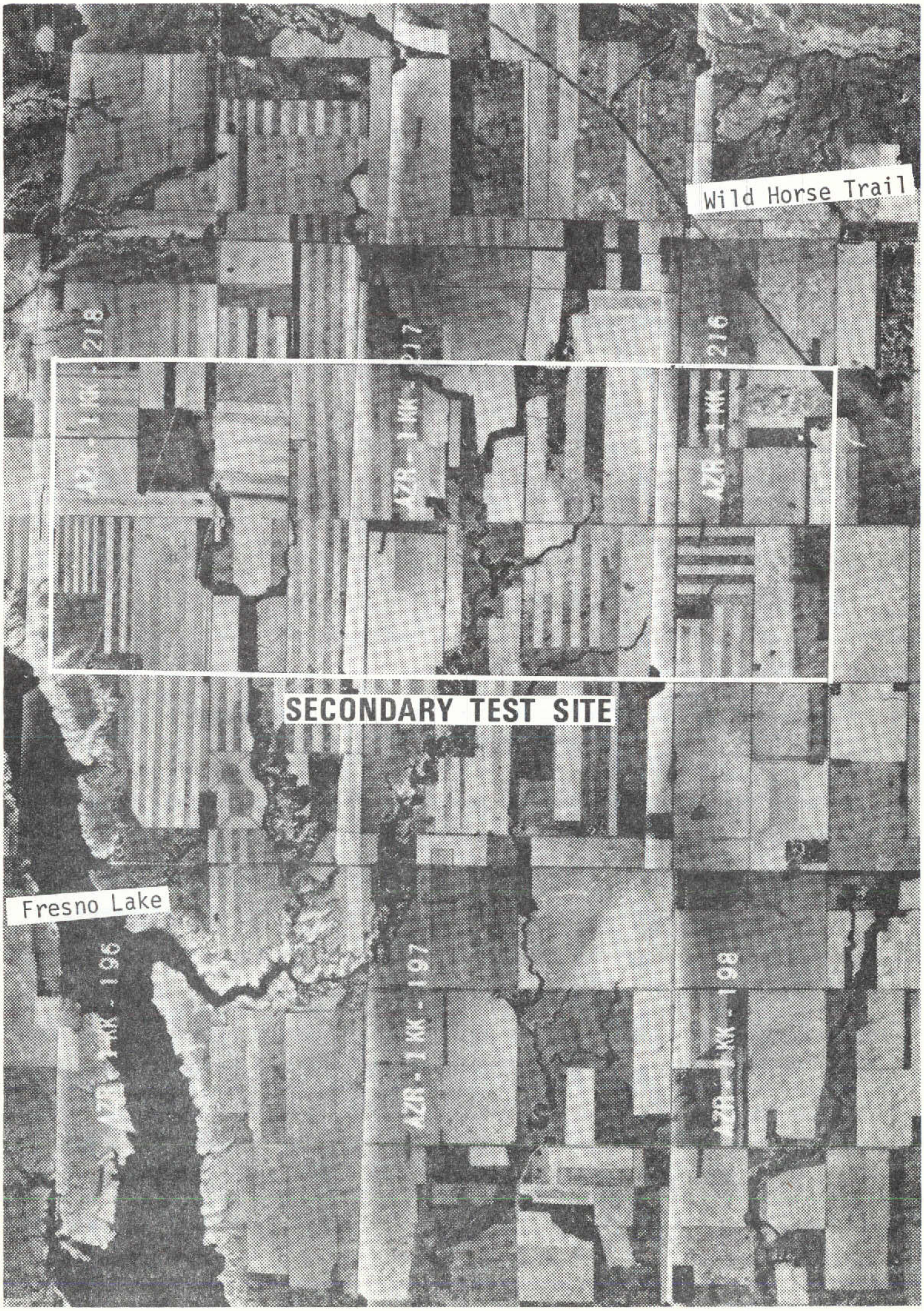

Figure 25: Secondary test site shown on the 1969 USDA photomosaic, at a scale of 1:63,360.

category, such as stubble or summer fallow. This was necessary because it is very difficult at this stage to precisely identify a character in the computer output with respect into its corresponding ground location. A preliminary signature classification is frequently of considerable aid in relating computer output to surface features.

The signatures obtained from STATS were then input to the DCLUS program. At this stage there were two locators. Near the primary test site, a linear trace was either the main track of the Great Northern and Burlington Railroad or U.S. Highway 2, which parallels the railroad. Fresno Dam, near the secondary test site, was readily apparent. The location of the community of Kremlin, with its water storage ponds, was not clear. In order to more precisely locate this town, a grid was constructed which could be placed over the computer output to measure distances from a known locator, such as Fresno Dam. This grid was laid out north-south, hence not parallel to the ERTS-1 orbit, by adjusting the pixel size by the cosine of the azmuth. The pixel size, 57.55 meters across the elements and 79.3 meters down the lines, was then scaled to the computer output. When this grid was laid over the DCLASS map, it was found that the blank area thought to be Kremlin was actually a deserted homestead, 1.5 miles east of Kremlin.

An area just large enough to encompass the community of Kremlin, now precisely located, was then selected for analysis with the unsupervised classifier, DCLUS. A critical distance of 3.0 between the classes was chosen in an attempt to develop the maximum number of signatures. In addition to locating the water storage ponds at Kremlin, it was hoped that a railroad signature and a housing-farmstead signature could be developed. The water reserviors were successfully mapped by three characters, but when the other nine signatures were mapped by DCLASS it was found that several were similar to previously classified areas and the remainder could not be related to any known object. Once the water ponds at Kremlin had been located, attention was directed to the Kenneth E. Wilson farm in the primary test site, for which accurate ground truth was available. DCLUS was run on a small area to determine a signature for farmsteads. The only useful signature in this output was one that appeared to map the trees around the house. When this signature was put into DCLASS it did, in fact, map the trees at two farmsteads as well as grass field boundaries.

The categories and signatures obtained at this stage are presented in Table 6 and discussed below. Portions of the maps of these categories is shown as Figures 26 and 27.

SUMMER FALLOW. A signature was developed that is capable of mapping the majority of fields known to be in summer fallow. Four additional signatures were developed, each of which is capable of mapping portions of known summer fallow fields. At the present time it can only be speculated that observable ground differences such as soil type or moisture can be correlated to the various bare soil signatures. These additional bare soil categories show linear traces attributable to poor scan lines. After completing the mapping of the two test sites, an area was found that had not been classified by any of the other signatures. The pattern in the output was the size of adjacent 40-acre strips. The STATS program was used to determine a signature for these areas. This signature had the highest reflectance of any signatures previously developed. It was similar to a signature called LOW SPOT as it had been found in a low spot in the primary site. It was postulated that this signature (FIELD WEST OF LAKE) was, in fact, a smooth, bare crusted field such as occurs after a rain shower on rod-weeded summer fallow. The previous signature was then renamed CRUSTED, ROUGH as the field in the primary test had a furrowed, clod-like surface. The area mapped by these two signatures had not been worked since the last rain shower. SUMMER FALLOW is shown as -'s on Figures 26 and 27. FIELD WEST OF LAKE is shown as |'s.

STUBBLE. This category required four signatures. It was not possible to find any one signature capable of completely mapping known stubble fields by themselves, although there was often a predominant signature in a field. Whether this signature is indicative of a particular crop type is unknown at this time. Another possible correlation is between signatures and yield, as measured by thickness of stand and weed growth, but this would be very difficult to prove at this time.

Table 6: Categories and Associated Spectral Signatures Used to Map Hill County, Montana

CATEGORY NAME	NUMBER	SYMBOL	LIMIT	SPECTRAL RESPONSE FOR CHANNEL 4	5	6	7
SUMMER FALLOW	1	-	5.0	31.77	32.59	31.52	14.49
SUMMER FALLOW	2	-	6.0	30.33	31.33	31.67	15.33
SUMMER FALLOW	3	-	6.0	30.71	31.82	30.98	14.35
SUMMER FALLOW	4	-	6.0	30.73	31.29	30.59	13.61
SUMMER FALLOW	5	-	6.0	33.50	34.50	32.00	16.00
STUBBLE	6	*	6.0	33.66	34.34	37.61	18.20
STUBBLE	7	*	6.0	37.68	41.79	41.22	19.14
STUBBLE	8	*	6.0	27.06	25.03	33.94	17.47
STUBBLE	9	*	6.0	34.31	36.38	42.81	19.13
VEGETATION	10	V	6.0	29.69	27.20	28.54	13.46
RANGE	11	R	6.0	23.50	22.50	33.00	17.00
PRAIRIE	12	P	6.0	26.67	25.00	25.67	13.00
MUD FLATS	13	1	6.0	39.66	37.69	21.12	3.50
MUDDY SHALLOW WATER	14	2	6.0	38.32	33.07	15.09	1.77
MUDDY WATER	15	3	6.0	34.51	24.50	9.98	1.23
CLEAR WATER	16	4	6.0	27.96	16.52	7.23	0.98
KREMLIN WATER	17	5	6.0	26.50	22.00	18.00	8.00
LAKE SHORE	18	6	6.0	30.87	23.12	17.00	5.50
CUT BANK	19	B	6.0	45.50	46.75	40.50	18.00
CRUSTED, ROUGH	20	C	6.0	40.94	46.00	43.50	19.94
FIELD WEST OF LAKE	21	1	6.0	43.71	48.62	49.57	23.14
CREEK	22	7	6.0	23.55	17.76	38.73	22.79

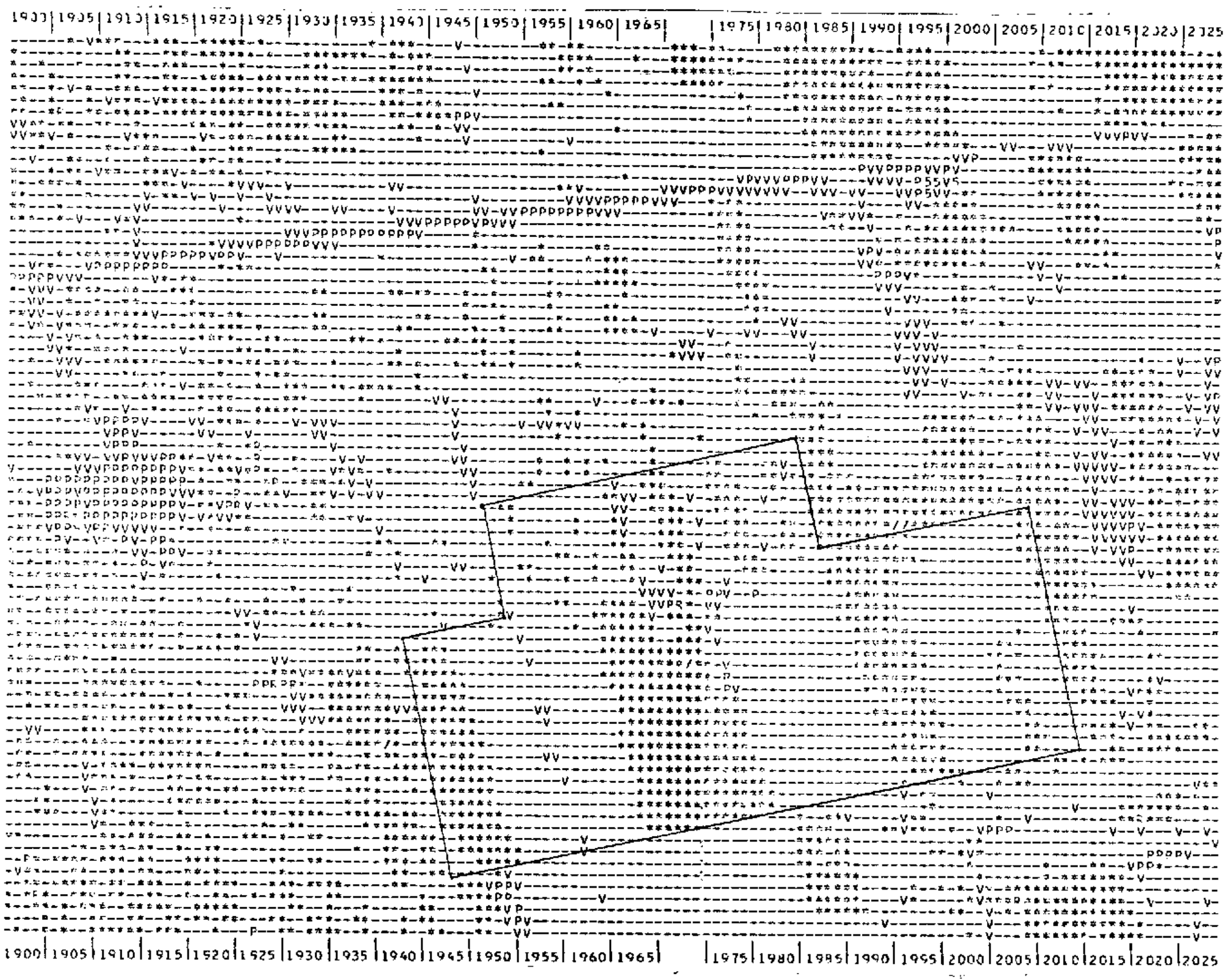

Figure 26: Classification map of the primary test site. (Symbols are defined on Table 6.)

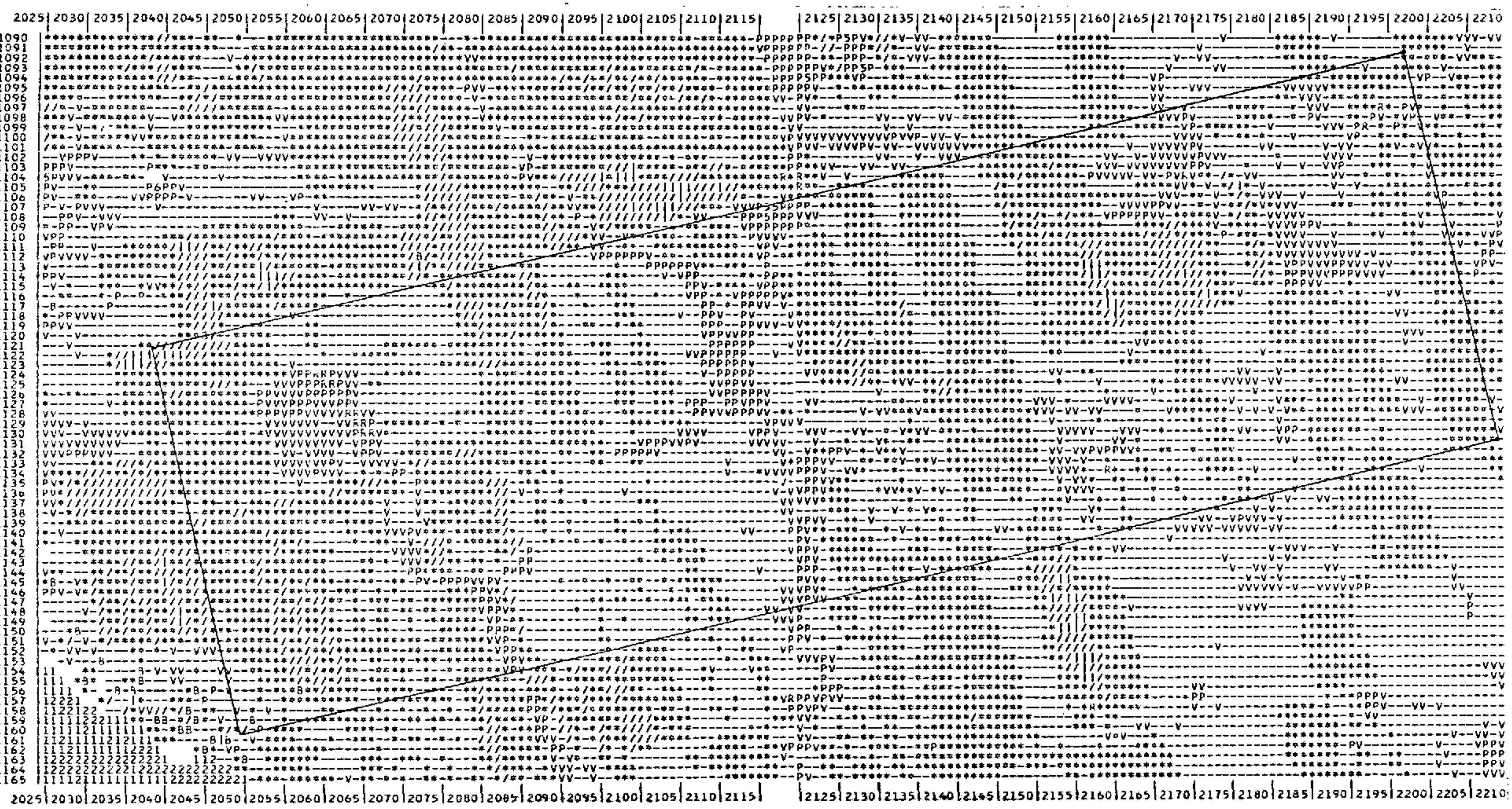

Figure 27: Classification map of the secondary test site. (Symbols are defined on Table 6 .)

In the primary test site, there is some improper classification of stubble as summer fallow. When lines are compared on single channel NMAP output for channels 4, 5, or 6, banding of data is evident. These bands are also seen on DCLASS output. STUBBLE is shown as *'s on the figures.

WATER. There are five signatures in the water category. Four of these map out the storage reservoir of Fresno Dam. The difference between these signatures can be attributed to increased sediment and shallower water encountered away from the dam area. The fifth signature, KREMLIN WATER, locates the water storage reservoirs at the community of Kremlin. These reservoirs cover an area 660 feet by 1320 feet, and contain water with a high percentage of suspended clay. The signatures are probably also influenced somewhat by the surrounding vegetation.

In a 72 square mile area lying predominantly east and south of the primary test site, there were a total of approximately 1500 acres classified as KREMLIN WATER. Parts of this area were checked against available ground truth and it was found that this was a valid calssification. With no reason to expect confusion with other categories, it should be safe to assume that there is sufficient water stored in farm ponds and surface depressions in this area to yield the water signature. This signature is mapped with 5's on both figures. The other water signatures are mapped with numerals 1 through 4 (although 3 and 4 do not appear on the restricted area of the figures shown here).

VEGETATION. A signature from a DCLUS run was found to map the grassy strips between summer fallow fields. The vegetated strip is less than 20 ft wide where this signature was developed. Areas of vegetation are also frequently found associated with these signatures. It appears also that a considerable amount of grazed, short grass, vegetation is being improperly classified as STUBBLE or SUMMER FALLOW around Fresno Dam on the DCLUS output. VEGETATION is mapped with V's in the figures.

RANGE and PRAIRIE. Areas of dense or ungrazed grassland are mapped with either the RANGE or the PRAIRIE signature. The PRAIRIE signature is predominant, and the RANGE signature is required to "fill in the blanks." PRAIRIE is mapped with P's on the figures; RANGE is mapped with R's.

CUT BANK. The level of Fresno Dam is approximately 150 ft below the surrounding land. Gullies carrying runoff water to the lake are often located with the CUT BANK signature, which maps eroded areas. Areas around these eroded spots are often mapped with the VEGETATION signature or the PRAIRIE signature, indicating moisture available for grass growth. The CUT BANK signature is mapped with B's.

CREEK. A CREEK signature, which was specific for the willow and brush areas along Big Sandy Creek and the Milk River, was also added. This signature is not shown on the figures, as the water courses are outside the portions of the maps displayed.

Results and Conclusions

A land use map of a three mile area in Hill County, Montana was successfully prepared. An additional 12 square mile area was also mapped with only one improper classification: an area of grazed, native short grass vegetation was mapped as STUBBLE and SUMMER FALLOW. The location of the Great Northern and Burlington Railroad could be seen as a linear trace of VEGETATION and PRAIRIE categories. U. S. Highway 2 could not be mapped. The location of farmsteads could often be inferred by small groupings of VEGETATION, PRAIRIE, and CUT BANK signatures. Loose, bare soil (SUMMER FALLOW) was differentiated from crusted bare soil. It was not possible to make valid separations within SUMMER FALLOW categories, possibly because of bad scan lines within the data. Six categories of Water were defined with their differences related to sediment content and depth.

To determine the validity of these categories over a larger area, 150 square miles were mapped. No obvious, improper classification resulted. The field patterns remained regular, alternating between SUMMER FALLOW and STUBBLE. The Milk River, flowing out of Fresno Dam was discernable, as was a creek flowing into the Milk River.

Analysis Cost Estimates

It is estimated that between 15 and 30 minutes of computer time was involved in this project. Total signature costs were approximately

$1000 ($600 for the computer, $400 for personnel). Utilizing these 22 signatures, it is estimated that $560 would be required to map an entire ERTS-1 frame (8,535,478 acres). At current computer rates charged at Penn State, this mapping would cost $0.000065 per acre. Spreading the $1000 signature development costs over the 6 to 8 ERTS frames that could be mapped in this area at this time of year, would result in a negligible increase in cost per acre.

Hidalgo County, Texas

The Texas test site lies north of the Rio Grande River in Hidalgo County. Most of the area is under canal irrigation, with well irrigation in the northern portion. Major crops include citrus fruits, vegetables, sugar cane, cotton, and sorghum. Large areas of unirrigated rough land have been left in native vegetation for pasture. Fields range from 20 to over 40 acres in size. The climate is semi-humid with over 30 inches of rain per year, most of which occurs in the winter and spring months. Irrigation is generally required for summer and fall crops. Most soils are developed from aeolian deposits of sand and silt. In the flood plain valley, the soils are composed of alluvial silts and clays. The topography is generally flat with an occasional gully cutting toward the river.

The area was flown in July of 1971 to obtain a 1:60,000 scale photomosaic. This mosaic is being used in conjunction with available maps and field-derived ground truth collected by the Weslaco Station of the Agricultural Research Service (ARS) (U. S. Department of Agriculture). This data is collected on an agricultural field basis, and consists of crop, stage of growth, and field condition.

Procedure

Initial contact was made with Dr. C. L. Wiegand of the ARS/USDA office in Weslaco in the fall of 1972. Approximately two weeks were spent in the area in December of that year, encompassing the time of the December 16 ERTS-1 overpass (scene 1146-16323). Arrangements were made at this time to receive copies of a portion of the ERTS support underflight data from C130 Flight 207, flown July 17, 1972. A 24-channel Bendix scanner was operated on this flight. A preprint of this scanner imagery has been received, along with computer compatible tape of data from eleven channels (see Table 7). The following ground truth data was collected by ARS personnel at the time of this underflight:

1. Field identification
2. Crop species
3. Percent crop cover
4. Percent weed cover
5. Crop maturity
6. Crop height
7. Crop condition
8. Soil condition

The Soil Conservation Service (SCS) has provided photocopies of soil mapping along the flight line. The ARS office is providing ground truth data for selected fields in the study area, collected on December 16, 1972, the date of the ERTS-1 overpass. They are also providing black-and-white and color copies of the 1:96,000 special aerial mosaic of

Table 7 : Spectral Ranges for Eleven Channels of Data Collected on C130 Flight 207 Over Hidalgo County, Texas

Channel	Wavelength Range (in microns)
3	0.46 - 0.52
4	0.54 - 0.58
6	0.65 - 0.69
9	0.83 - 0.88
10	0.98 - 1.04
11	1.20 - 1.30
12	1.53 - 1.63
13	2.10 - 2.38
18	9.00 - 9.50
19	9.50 - 10.20
20	10.20 - 11.00

Hidalgo County -- photography flown in 1971, by Ames Research Center, for a ground truth base map for ERTS-1 studies. ERTS bulk digital tapes and imagery for the December scene (1146-16323) were ordered in January 1972. The tapes were received in mid-April, but the imagery has not yet arrived.

Preliminary Results and Conclusions

Analysis of data from this site has just begun. Brightness maps, generated by the NMAP program[1], clearly show the Rio Grande River. Several large fields, presumably of growing crops, can be seen on the Mexican side of the river. Vegetable cultivation on the U. S. side is shown by high reflectance in a regular field pattern. Citrus fruit cultivation is not evident from these first brightness maps. However, the change from irrigated to dry land is apparent, as is the difference between bare soils and native vegetation seen at this time of year (December).

Summary and Conclusions

Agricultural areas were selected for analysis in southeastern Pennsylvania, north central Montana and southern Texas. These three sites represent a broad range of soils, soil parent materials, climate, modes of agricultural operation, crops and field sizes. In each of these three sites, ERTS-1 digital data were processed to determine the feasibility of automatically mapping agricultural land use. In Pennsylvania, forest land, cultivated land, and water were separable within a 25,000 acre area. Four classes of water were also classified and identified, using ground truth.

A less complex land use pattern was then analyzed in Hill County, Montana. A land use map was prepared showing alternating patterns of summer fallow and stubble fields. The location of farmsteads could be

[1]For complete program descriptions, see ORSER-SSEL Technical Report 10-73.

inferred, along with that of a railroad line. A river and a creek flowing into the river were discernable. Six categories of water, related to sediment content and depth, were defined in the reservoir held by the Fresno dam. These classifications were completed on a 150 square mile area.

Analysis of the data from Texas is in its formative stages. A test site has been selected and a brightness map has been produced.

Continuing Investigation

During the 1973 growing season, thematic maps of the cropping pattern for each of the three test sites will be produced as data from good quality ERTS scenes become available. Soil and moisture conditions, vegetative cover and crop conditions will be determined. It is hoped that such information will assist the farm manager to plan for optimum use of his land.

The level of land use mapping will be refined beyond that attained to data. It is hoped that crop types, soil types, various assemblages of native vegetation, and several water categories will be delineated. An attempt will be made to map towns and individual farmsteads, as well as roads. With towns, farmsteads, and roads mapped, orientation within a scene will no longer present the major problem experienced early in this investigation.

The individual agricultural land use maps prepared for each of the test sites will be evaluated and compared as follows:

1. For each test site, land use maps prepared for different seasons will be compared, and seasonal data will be merged in those cases where a significant gain in map accuracy will result. The most desirable season, or seasons, for agricultural land use mapping in each area will be determined.

2. The optimum mapping methods determined for each site will be compared, to answer the question: Is there a single method which can be applied to all three sites, or must modifications of a single method or entirely different methods be applied to different types of agricultural areas?

3. The utilitarian value of ERTS-1 data will be evaluated with respect to its usefulness as a major input into land management plans.

4. The performance of the ERTS-1 data collection systems will be evaluated with a view toward suggesting modifications for future data collection platforms.

SOIL RESOURCES EVALUATION

H. A. Weeden and J. W. Harman

The Civil Engineering contribution to an evaluation of soil resources should be in terms of the identification and classification of soil units with significantly different physical properties. These physical properties contribute to an understanding of the strength and internal drainage characteristics of soil and/or bedrock. If the investigator can establish the particle size distribution and the moisture content of a soil, he can then hypothosize the internal friction and cohension of the soil particles. The normal processes of photointerpretation which have stood the test of time -- namely the recognition of landform, drainage, erosion, vegetation, color or gray tone variations, and culture (sometimes requiring recognition of micro-features)-- have been applied to ERTS-1 images. For maximum information of the type desired, the investigation requires photographs or other remotely sensed data related to bare field conditions, which normally exist in Pennsylvania in the late spring when the farmers have completed plowing. In the absence of such data, as the project got underway in September, attention was initially devoted to the evaluation of photointerpretation techniques alone on ERTS-1 imagery as a means of producing separable categories of land use. This work is described elsewhere in this report under the title, "Land Use Mapping."

Work is now in progress which will fully exploit soil and rock information on both ERTS and aircraft underflight data. Flights have been made over central Pennsylvania by U2, C130 and C54 aircraft, at high and low altitudes. Both color and infrared (false color) photographs have been taken. A multispectral scanner was operated on the C130 flights. Photographs and multispectral scanner (MSS) data for summer, fall, winter, and spring are under analysis.

Objectives

The primary objective of the present investigation is to evaluate the application of satellite and airborne multispectral scanning information to bare soil and rock identification. The results will be in the form of soil maps related to engineering applications. The secondary objective is to attempt an extension of computer mapping of soils to areas covered by vegetation.

Mapping of Bare Soil and Rock

Test areas to compare soil and rock ground truth with computer maps have been selected in the vicinity of Harrisburg. These areas include unique and positively identifiable plots for spectral signature training, such as freshly cultivated fields, quarries, borrow pits and waste areas. Ground truth will be obtained from soil maps issued by the U.S. Department of Agriculture, with their accompanying engineering test data; boring and test data obtained from recent projects of the Pennsylvania Department of Transportation (PENNDOT); and field reconnaissance.

For satellite MSS data, both the Bausch & Lomb Zoom Transferscope and a Kelsh-type plotter with a high-intensity quartz halogen lighting system will be used for studying the imagery from each channel, and for mapping from the imagery. The computer software developed by ORSER will be used with training areas to make progressively better thematic reconnaissance maps. For airborne MSS data, current photo analysis techniques will be used for mapping from aerial photography, while the thematic mapping from MSS data will be of intermediate form with greater detail. In each case, maps from scanner imagery or photography will be combined with the computer-generated thematic map to make an improved map. It is expected that the usefulness of these maps will be largely governed by their resolution. Because signatures from the airborne MSS data will be of higher resolution, these signatures will be used again with the ERTS-1 MSS data to further improve the reconnaissance mapping. The coordinated maps will finally be compared with known ground truth to evaluate their usefulness.

Mapping of Vegetated Areas

Vegetation remains a major problem in the application of MSS data to soil and rock mapping. To date, it has been virtually impossible to map any type of soil boundary in heavily vegetated areas. Three methods will be attempted in this study:

1. Sequential data sets obtained throughout the year will be analyzed. Some of the problem of crop and grass cover of farmland may be eliminated by the exposure of a greater portion of the fields as they are freshly plowed. Deciduous and annual vegetation will be less of a problem in winter scenes.

2. The zoning of vegetation type and its relationship to soil and rock types will be studied. The differentiation of vegetation by computer software may be used to delineate soils.

3. An attempt will be made to directly map inferred soil types by spectral differences, disregarding the amount of vegetative cover. These spectral differences may be a function of differences in the vegetation itself, as controlled by soil type, or they may be a function of soil reflectance as seen through the vegetation. Most likely they will be an effect of both factors.

Scope

Anticipated mapping objectives and the corresponding parameter identifications to meet these objectives are presented in Table 8. The investigation will be carried out within the same area (in the vicinity of Harrisburg) used for the land use mapping study. However, the work will be concentrated in Cumberland County, west of the Susquehanna River. Within this area, at least four 500-acre test sites will be located over sandstone, shale, limestone, and igneous intrusive bedrock, respectively. Reconnaissance mapping from the satellite MSS data will be of a general nature and will include the entire study area. The maps will be at

Table 8: Mapping Criteria Versus Identifying Parameters for Soil Resources Evaluation

Mapping Criteria	Identifying Parameters
Soil texture	Landform, pattern, vegetation, culture
Depth to bedrock	Topographic position, vegetation
Parent material	Landform, vegetation, tone
Geologic structure	Landform, lineaments, slopes, horizontal offsets
Groundwater depth	Landform, topographic position, vegetation
Groundwater fluctuation	Vegetation, tonal patterns

approximately the scale of the standard USGS 7 1/2 minute quadrangle map (1:24,000). The intermediate mapping from the airborne data will be semi-detailed in nature. It is anticipated that a scale factor of 1:12,000 or smaller will be used. All of the test sites will be mapped in this manner.

SURVEY AND INVENTORY OF FOREST RESOURCES

B. J. Turner and D. L. Williams

Before it is possible to determine the role of ERTS-1 data in a forest resources inventory, it is necessary to explore the limits of these data for discriminating vegetative differences. When these limits are known, progress toward the development of multi-stage sampling designs, detection of insect defoliation, etc., can be rapidly made. Results to date are encouraging. Computer processing of MSS tapes is yielding far more information than appeared possible from visual examination of ERTS imagery. However, there are some difficulties to be overcome before this preliminary phase of study can be considered satisfactorily completed.

Purpose and Scope

The initial goal of this project was to determine the extent to which it is possible to discriminate between coniferous and non-coniferous forest vegetation using ERTS-1 data, under typical Pennsylvania conditions of intimate mixtures of these two vegetative types. It was anticipated that this would lead to further exploration and problem definition.

The test area chosen, shown on the U2 photograph in Figure 28, is a part of The Pennsylvania State University Experimental Forest in Stone Valley, Huntingdon County. This area includes the 70 acre University dam and the surrounding forest land, comprising approximately 4500 acres. This particular area was chosen for the following major reasons:

1. the vast amount of ground truth information available from previous vegetation studies on this area, carried out by various University groups;

2. the availability of adequate coniferous vegetation, both natural and planted;

3. the presence of a large area of uniform reflectance (the University dam) as a geographical reference point; and

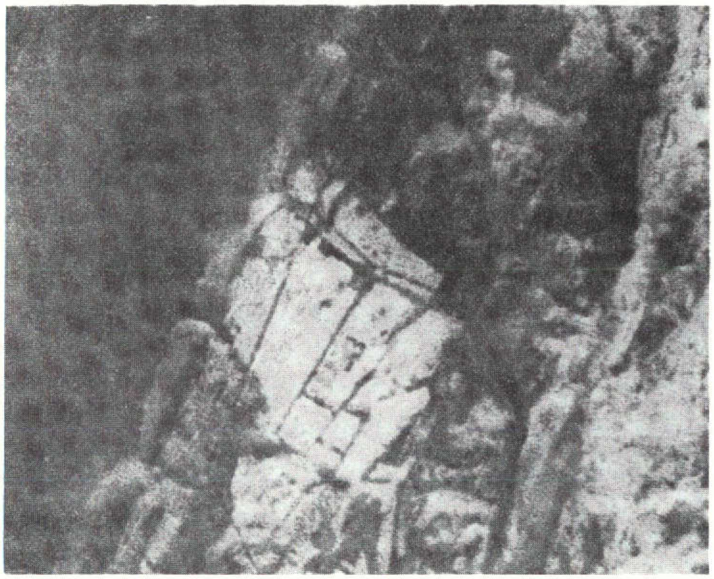

Figure 28: Enlargement of U2 photograph of the Stone Valley area. (Flight 73-009, sensor 12, frame 126; approximate scale: 1 inch = 0.9 miles)

4. the proximity of the area (about 12 miles) to the campus, facilitating ground checking.

Data Sources

Data from two ERTS-1 overpasses were used to give representative summer and winter conditions. These were:

1. Date: September 6, 1972
   Scene number: 1045-15243
   Tape number: #2 of 4
   Quality: Relatively cloud-free over test area
   Channels: Initially all 4, but channel 6 gave bad data in every sixth scan line and was not used in most of the analysis

2. Date: January 10, 1973
   Scene number: 1171-15245
   Tape number: #2 of 4
   Quality: Cloud-free, overall low reflectance
   Channels: All 4

Principal underflight support photography came from two U2 70 mm films. These were:

1. Date: June 7, 1972
   Flight number: 72-094
   Flight line: U-V
   Frame numbers: 172-173
   Sensors: 11 through 15
   Quality: Very good over test area

2. Date: January 25, 1973
   Flight number: 73-009
   Flight line: M-N
   Frame numbers: 126-127
   Sensors: 11 through 13
   Quality: Very good over test area

Photography from two small aircraft flights, privately flown for the Recreation and Parks Department of The Pennsylvania State University, were also used. These were flown on April 21 and May 10, 1972, and provided stereo coverage at a scale of 1:3000 and 1:12,000, respectively. Two maps were used: the USGS 7 1/2 minute quadrangle map of Pine Grove Mills, derived from 1962 photography; and a map of vegetative cover types of The Pennsylvania State University Experimental Forest, produced in 1965 (from 1962 photography) by the Pennsylvania Cooperative Wildlife Research Unit of the U.S. Department of the Interior.

Analytical Procedure

Separate work tapes were prepared, using the SUBSET program[1], from data from the September and January ERTS scenes for an area encompassing the test site. The first stage of analysis was concerned with locating geographical reference points, using the program NMAP. It became immediately apparent from the NMAP printouts that a channel of bad data was causing misrepresentation. Every sixth scan line of the printout consisted of sporadic data. This problem was "corrected" by eliminating all data from channel 6, and working only with channels 4, 5, and 7. This permitted use of data from the September scene, one of the few clear passes over the test area, but created at least two problems. First of all, the channel eliminated was the one containing the most information on vegetative cover. And secondly, because vegetation is such a dominating feature in summer imagery, elimination of the bad channel caused considerable changes in the overall reflectance values. As a result, the reflectance class limits for NMAP had to be recalculated to get satisfactory map output.

After these adjustments were made, NMAP printouts of the September and January scenes were compared. The low reflectance of the University dam in the summer scene permitted easy identification of this body of water, simplifying orientation within the test area. The dam was partially frozen over and snow covered in the January scene, and resembled the surrounding snow-covered land surface. This was confirmed from

[1] See ORSER-SSEL Technical Report 10-73 for complete program descriptions.

examination of the U2 imagery. For this scene, therefore, ridge shadow patterns were used, and compared with those of the September scene, for locational purposes.

The second stage of analysis was concerned with obtaining spectral signatures for gross vegetation cover types. The class limit adjustments made on the NMAP program for the September scene had resulted in such excellent definition of features that the intermediate steps of STATS and ACLASS were unnecessary, and the DCLUS program was run directly. This program maps a given area, assigns specific symbols to areas having the same spectral signatures, and calculates the spectral signatures for each symbol. The quality of the output can be enhanced by varying the critical angles or distances, and the sample size. These techniques were used until satisfactory results were obtained. The vegetation map of the Experimental Forest was used to identify the gross patterns of specific symbols on the map. A close resemblance of gross features was easily noticed, especially for pine plantations and the dam. For the January scene, a map obtained by DCLUS was used to define training areas for the STATS program, to check on the uniformity of these areas, and to compare STATS signatures and DCLUS signatures. These signatures were then combined as inputs to ACLASS and DCLASS runs, producing maps that discriminated the following targets: conifers, hardwoods, and shaded hardwoods. This map is shown in Figure 29; the categories, symbols used, and other information relevant to this map are shown in Table 9. The RATIO program was used with both scenes, to discriminate between conifers and non-conifers, using a ratio of channel 4 to channel 7 and using

Table 9: Category Statistics for the ACLASS Map Shown in Figure 29

Category Name	Number	Symbol	Limit	Count	Percent
CONIFERS	1	(P)	10.0	842.	20.
SHADE	2	(S)	10.0	1266.	31.
HARDWOODS	3	(H)	10.0	828.	20.
SNOW	4	(X)	10.0	1.	0.
OTHER	5	( )	0.0	1204.	29.
		TOTAL COUNT		4141.	

```
 1080|1085|1090|1095|1100|1105|1110|1115|1120|1125|1130|1135|1140|1145|1150|1155|1160|1165|1170|1175|1180|
     |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
505 |HHHHHHHHHHHHHHHHH   SSSSSSSSSSP  HHHHHHHHHHHHHHHHHHH   SSS PPP  PPPHHHHH H H SSSSSP    PPP SPPPSSSSHHHHSS|
506 |HHHHHHHHHHHHHHHHH   SSSSSSSSSSS   HHHHHHHHHHHHHHHHHHH   SS    P    SP H  HH  H SSSS  H PPPPS SSPSSSS HH SSS|
507 |HHHHHHHHHHHHHHHH   SSSSSSSSSSS  HHHHHHHHHHHHHHHHHH     SP HH  HH   HHHH SSS  S H   H PP    SSPSSSPHHSSSSS|
508 |HHHHHHHHHHHH      SSSSSSSSSSS  HHHHHHHHHHHHHHHHH  SSS     HHHH  S HHHH   H     SS   PP HHHSSSSPS    PSSSSSS|
509 |HHHHHHHHHHH     SSSSSSSSSSSS HHHHHHHHHHHHHHH  HH SSSP H  HHH     H  HHHHH P   SS  PP HH  SSPPSPPSSSSSSSSS|
510 |HHHHHHHHH     SSSSSSSSSSSSS HHHHHHHHHHHHHHH  HH SSS    H      S HHH   . HH   PP SPPPPPPP SSPSSSSSSSSSSSSSS|
511 |HHHHHHHHH     PSSSSSSSSSSS   HHHHHHHHHHHHHH HH   SS     HH      H HHHH   HH     P  SPP      SSSSSS    SP   S |
512 |HHHHHHH   SPSSSSSSSSSSSSS  HHHHHHHHHHHHH H    SS    HH  HH HHHHHHHHHS HHH     P    SP P   SSSSSS H SSSS   SSS |
513 |HHHHHHHH    SSSSSSSSSSSS   HHHHHHHHHHHHH    H H SS HHHH  HHHHH  HHHHH P HHHSPPS HHPP   SSSSSSSSSSS    SSS H|
514 |HHHHH   SSSSSSSSSSSSSSS HHHHHHHHHHHHH     HH SSS H      HHHHH       P PP HH         SSP  SSSSSS H       SSSS  S|
515 |HHHHH  SSSSSSSSSSSSSS    HHHHHHHHHHHHH     HH PS              HH      PPP  HH      H  P  SSSSS HH SS  SSSSS     |
516 |    SSSSSSSSSSSSSSSS HHHHHHHHHHHHHH           PSPPP           SS        SPSSPP  H SS     SSSPPPPSSSSS SSSSSS HH |
517 |PPSPPSSSSSSSSSSSSSS  HHHHHHHHHHHHHH          SPPPPPPPSP          H P  SSSSPP PSSSSSSS  SPPSSSSSS H SSSSSS HH |
518 |SSSSSSSSSSSSSSSSS    HHHHHHH    HH      SSSPPP  PSP              SSSSP     H SSSSSSSSPPSPPPPPPSSSSS HHH P|
519 |SPSSSSSSSSSSSSSSS   HHHHHHHH      H  SSSSS PPPP PPPPP SPHH    HH  SSP      HHH SSSSSPPSSSSPSSSSSSSSS HHHH S|
520 |SSSSSSSSSSSSSS      HHHHHHHHHHHHHHH SSSS    PPPP SPPPSP     H     H SSS   HHHHH      SCSPPSPPSSSSSSSSSSSS    PP SS|
521 |SSSSSSSSSSSS      HHHHHHH  HHHHHHSSSP PPPPPSPP PPPPP     HH HH SP   P  HHHHH  SSPSSSSSSPPPPPPPPSPPP PPPSS|
522 |SSSSSSSSSSS      HHHHHHHHHHHHHHHHHH SSPPPPPPSSPPPPPPPPPP        HHS   S HH   HH SSSSSSSSP PPPPPPSSSPPP   SSSS|
523 |SSSSSSSSSS     HHHHHHHHHHHHHHHHHH      S PPPPPPPPPPP   PPPP              SS HHHH SS   SSSSSSP PSSPSSSSS    PPPPSSS|
524 |SSSSSSSSS     HHHHHHHHHHHHHHHHH      SSS   PPPPPPPPPPPP   PPPPP          SS     HHH      SSSSS   SPSP SSSS      PPPSS H|
525 |SSSSSSSS HHHHHHHHHHHHHHHHHH      SS H   SPPPPPPPPSSPPSSPPPPPP        SSSSSSPPSS   SSSSS HH       SSSSS     PPPSSSHH|
526 |SSSSSSS    HHHHHHHHHHHHHHHHH    SSS H PPSPPPPPPPPPPPPPPPPPSSP         SS                SSSS HHSS SSSSSSSP   .PSSS HH|
527 |SSSSS     HHHHHHHHHHHHHHH      SSSHH PP PPPPPPPPPPPPPPPP PSP       SS         SP      SSSS HHSPP SSSSSSSPPPPPSS H P|
528 |SSSSS HHHHHHHHHHHHHHH        SSSH     PP PPPPPPPPPPPPPPPPPPPP        SS           SSSSSPHH PPPSSSSSSSSSPPPPPSP   PP|
529 |SSSS      HHHHHHHHHHHHHH      SS H    P        PSPPPPPPPPSSPSPPPPPP   H   SSS     P   PPSSSSS PPP PSSSSSSS       PPPSPPPS|
530 |SS      HHHHHHHHHHHHHHH        SSHH PP      SSPPP PPPPPPPPPPP     HH SSS        SSPSSSS      PPSSSSSSSSPP HH SSPPSSSS|
531 |S  HHHHHHHHHHHHHHHHH         PP PP        SSSSPPP PPPPPPPPPP         H SS  PPSSSPSSSS         PSSSSSSSSSP   SSSSS      P|
532 |     HHHH   HHHHHH H     SSSSPPPPPPPP    SSSSPPPPPPPPPPSSPPSPSS HHHH   S PPPSSPSSSS         PPSSPSSSSS HH SSSSS      SSS|
533 |    HHHHHHHH.HHHH       SSSS      PP          SSP PPPPPPPPPSPPPPPPSHHHH         S PPP   SSP   PPSSSSSSSSSS HH SSSP PPPPPPP|
534 | HHH HHHHHHHH          SSS HH PPPP        SSSSPPSPPPPPPSSPPP PS HH SS   SSPSSS    PPPPPSSPPPPSSSS            SPSP   PPPSSSP|
535 |  HHHHHHHHHHHH         SS   HH      PPP      SSPPPPSSSPPPSPPP   PP    SSSSPP SSSSSP PPPPPPSSSSSPSSS      PSPSP HPPPPPPSP|
536 |HHHHHHHHHHHHH        SSSS HH PPSPP        SSPPSPPSPP PPPPP SS     SSSP      SSSS H PPPPPSSPPSSSSSS    PSSSPP    PPSP SP |
537 |HHHHHHHH     H    SSS    H PPPSP          SSPPSSSSPPPPSSPPPPP PPP PP     SSSS H PPPPPPPPPPSSSSSSS  SSSPSP      PSP SPP |
538 |HHHHHHHH           SSSS       PPPSP       SSSSSSPSS   SSSS PPP P SPPPPP   SSSSS HPSSSSPPSSSPSSSS       SSSSP PPPSP SSP  |
539 |HHHHHHH        PSSSP      PPPSPP     SSSPPSSPPPP SPSS   P   PSSSP P   SSSSS H PPSPPSSPPPPSSS       SSSS   PP SP SSP   |
540 | HH             PSSS          PPP     SSSSSSSSSPPPPP SS   HPPS PPPPPP   SSSSSS H PPSPPSSPPPSSSSSSSSSSS     PPP SPSSS      |
541 | HHH           SSSP  PP            SSSP SSS   PPP H SP     PP     PPPPPPPSSSSS HH PPPPPPPPPSPPP          SSS      PPPP SSS   SS|
542 |H     SPPSSSSP       PP          SSSS SSP  SPPPPPSPPP PP     PPPPPP SSSSS          PPPPPSSPSSSS      SSSS HHH    PPSSS       S |
543 | H    PPPPSSS              S     H  SP    PSSSPPPPPPPPP   P       PPPPPSSSS   PP   PPPSSSPSSSPSSSSSSSSHH   H    SSS    SS     |
544 |      PPPPSS                     SSS      SSSSPPPPPPPPPPPSSSPP SPPPPPSSSS    PP      SSSSSSSSSSSSSSSSSHH H        SS    SS      |
545 |     SSSSPPP             H   HH SS HH PSSPPP   PPPPPPPPSSSP    P      PSSSS      PP   SSPSPPPSPSSPSSSSPH  P  H  X    SP    P       S|
     |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |    |
 1080|1085|1090|1095|1100|1105|1110|1115|1120|1125|1130|1135|1140|1145|1150|1155|1160|1165|1170|1175|1180|
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Figure 29 : ACLASS map of the January scene. This map is a product of STATS signatures developed from training areas defined on DCLUS output. (The symbols are defined in Table 9.)

information derived from the DCLUS program to set the discriminating ratio. The results from the RATIO program for the September scene are shown in Figure 30.

The third stage of analysis was concerned with using the combined data from both scenes, yielding seven channels of information, to refine the vegetational mapping. Before this could be done, however, it was necessary to locate precisely a geographic area common to both scenes. This was done by assigning a single category symbol, for pine plantations, to the January ACLASS and the September RATIO maps. These two maps were then superimposed on a light-table and the symbol areas matched as closely as possible. It was determined that the September 6 scene differed from that of January 10 by +68 scan lines and +81 elements. Data from the two scenes were then subset together onto a working tape, using the program MERGE. The UMAP program was used on this seven-channel data to locate training areas for the STATS program, which produced signatures which were then input to the ACLASS program. After some experimentation with critical angles, a satisfactory map, shown in Figure 31, was produced with ACLASS. The following vegetation types were defined: hardwoods, shaded hardwoods, hemlock hardwoods, conifers, fields, and water. Symbols and statistics for these categories are shown in Table 10.

Table 10: Category Statistics for the ACLASS Map of Merged Data Shown in Figure 31

Category Name	Number	Symbol	Limit	Count	Percent
HARDWOODS	1	(*)	8.0	362.	9.
SHADED HARDWOODS	2	(S)	8.0	331.	8.
HARDWOODS	3	(*)	8.0	377.	9.
HARDWOODS	4	(*)	8.0	473.	11.
HARDWOODS	5	(*)	8.0	826.	20.
HEMLOCK-HARDWOODS	6	(=)	7.0	469.	11.
CONIFERS	7	(P)	7.0	538.	13.
WATER	8	(+)	13.0	58.	1.
FIELDS	9	(|)	8.0	556.	13.
OTHER	10	( )	0.0	151.	4.
			TOTAL COUNT	4141.	

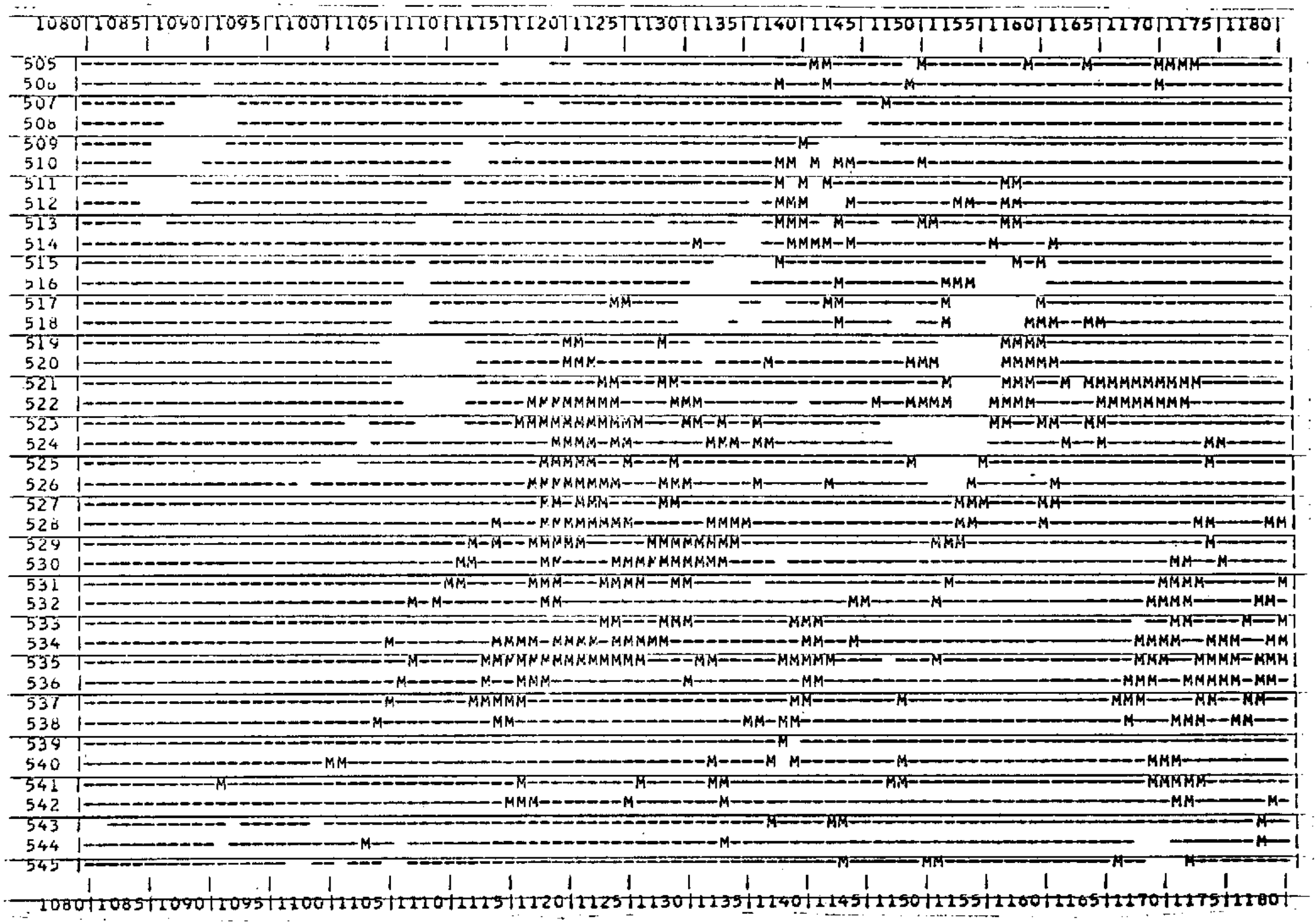

Figure 30: RATIO map of the September scene. A ratio of channel 4 to channel 7 was used, with information derived from the DCLUS program used to set the discriminating ratio. Conifers are mapped with M's, all other classified vegetation with -'s; unclassified elements are blank.

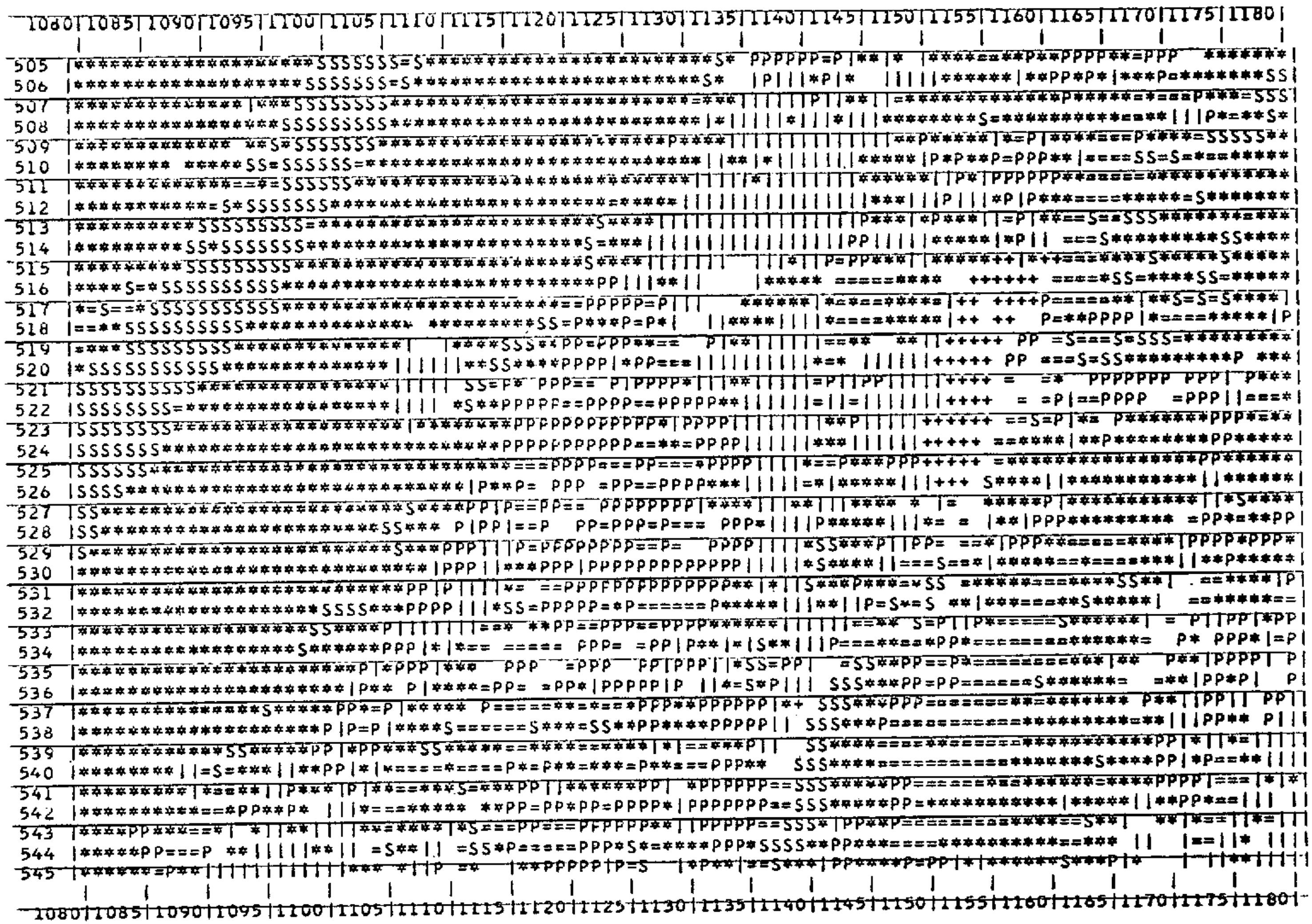

Figure 31 : ACLASS map resulting from merging the September and January scenes. (The symbols are defined in Table 10 .)

Ground truth, in the form of maps, underflight photography, and a visit to the field area, was used to check the final map produced by the ACLASS program from the merged data. The USGS 7 1/2 minute topographic map was practically the same scale as the digital printout, facilitating the transfer of stream systems and roads to an overlay on the computer map. This map was then compared to the U2 and large-scale underflight photography, and to the vegetation map of the experimental forest. A half-day field inspection of the test area further refined the comparison with ground truth.

Results

Comparison of the vegetation map (Figure 32) with an LMAP printout of the ACLASS map from the merged data (Figure 33) indicates the accuracy that has been achieved in mapping vegetation classes in the test area by this method. The following results from this study have been realized:

1. Three ORSER programs (RATIO, ACLASS, and DCLUS) were able to isolate and map coniferous forest vegetation provided the conifers occurred in blocks of approximately five acres or more and comprised the bulk of the vegetation in those blocks. This was verified by ground truth, and was achieved on both summer and winter scenes.

2. The merging of winter and summer scene data made it possible to differentiate hardwoods with coniferous understory from hardwoods on the one hand and conifers on the other. This possibly was suggested when it was observed that conifers occurred in some areas in the winter scene maps which had been classified as hardwoods in the summer scenes. This area of apparent confusion was verified, by field-checking, as being hardwoods with an understory of hemlocks.

3. Discrimination between coniferous species on the basis of spectral characteristics alone does not appear very promising. However, where a particular species is associated with another vegetation type, discrimination is possible. Thus, hemlocks with hardwoods can be differentiated from coniferous plantations, and it seems likely that Virginia pine and table mountain pine on old fields can be also defined as a

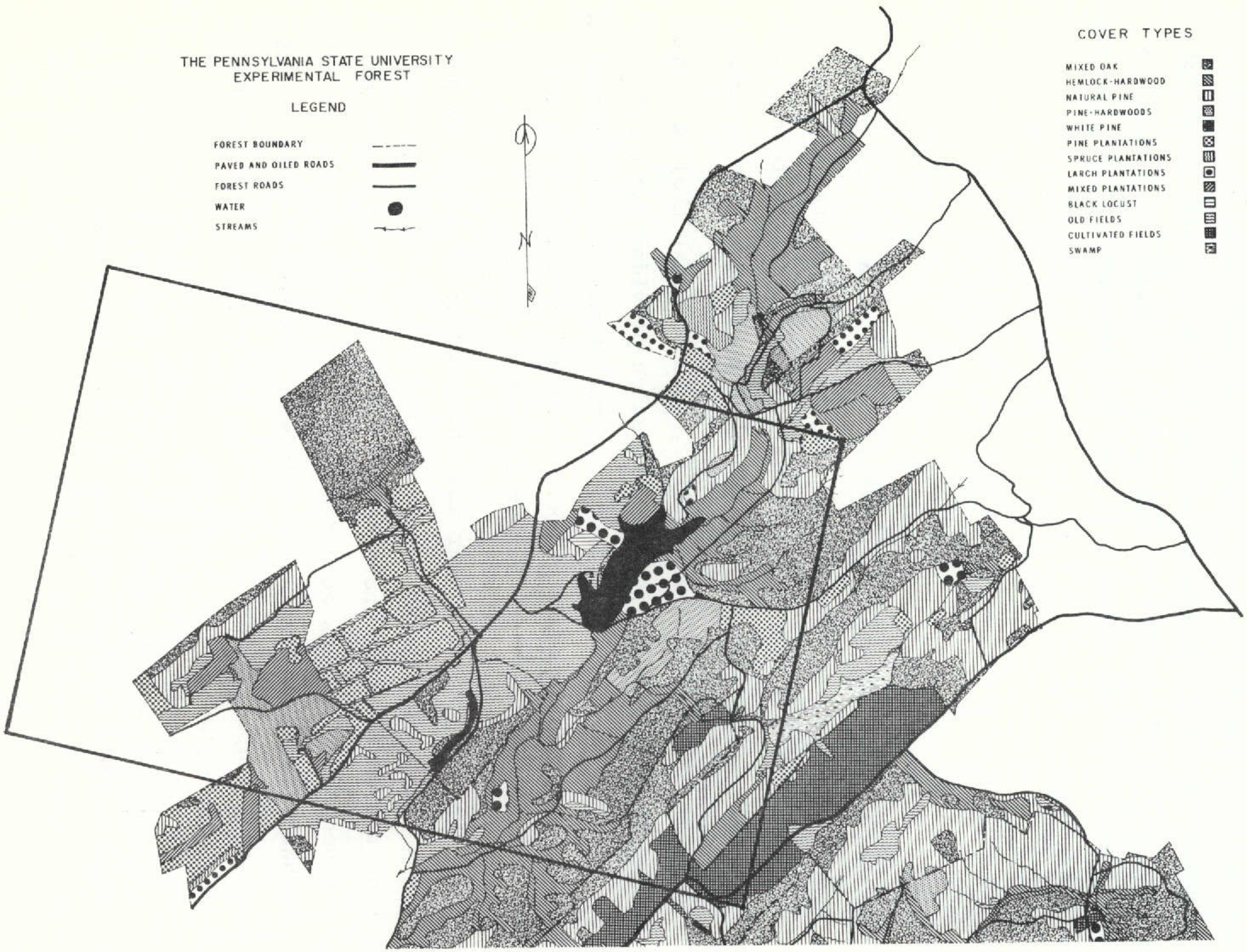

Figure 32: A portion of the vegetation map, indicating the Stone Valley test area. (Map printed in 1965 from 1962 photography by the Pennsylvania Wildlife Research Unit.)

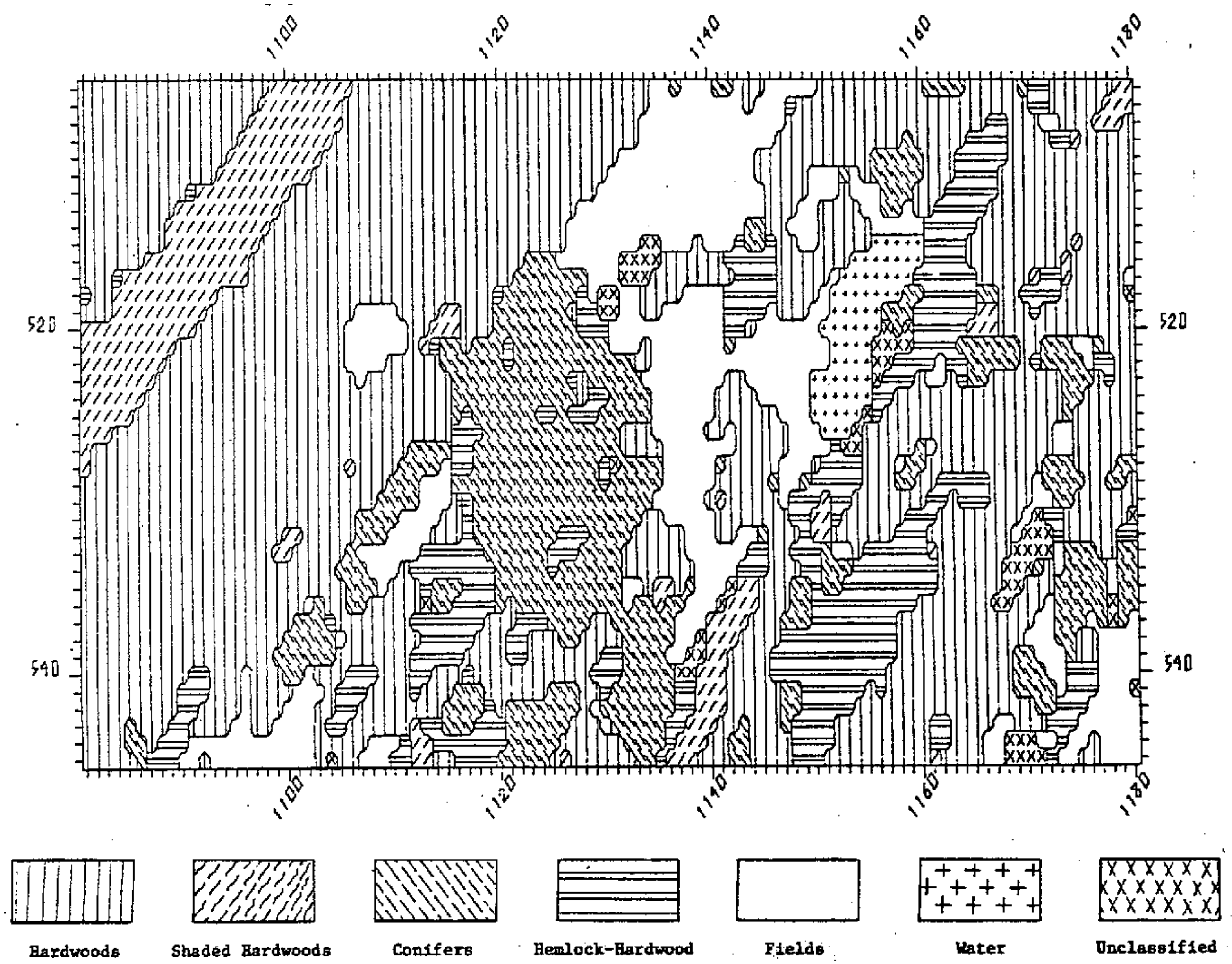

Figure 33: LMAP printout of the ACLASS map shown in Figure 31.

separate category. However, the separation of spruce plantations from red pine plantations does not appear promising.

4. Discrimination between hardwood types in this scene does not appear very promising when using only winter and summer data, except where these types are characterized by association with evergreen species. The addition of spring and fall data may help. However, variation in hardwood type within the test area is not great.

5. Although major ridges do not occur within the experimental forest, their presence in the mapped scenes indicates potential problems in matching vegetation signatures in the shaded areas with signatures of the same vegetation type under open light. This is to be further investigated.

6. Clear-cut areas of more than 20 acres in size were easily detected by computer processing.

Conclusions

By computer processing of ERTS-1 tapes it is possible to identify and map major forest types. The precision of classification appears to be such that it could serve as a useful first stage of a multi-stage sampling scheme for forest inventory. Refinement of vegetation type identification is made possible by using merged data from different seasonal overpasses. Before this preliminary phase can be considered completed, however, further work is needed to explore additional refinements of classifications, to statistically analyze classification accuracy, and to develop procedures for classifying shaded vegetation.

INVESTIGATION OF VEGETATIVE COVER CONDITIONS

B. F. Merembeck and F. Y. Borden

Vegetative cover conditions of two areas of northwestern Pennsylvania are under investigation. The first is in the vicinity of the southern branch of the Allegheny Reservoir (the "Kinzua" area) in the Allegheny National Forest in Warren County; specifically, it is the area immediately adjacent to the western side of the reservoir. The second is in the vicinity of the reservoir on the East Branch of the Clarion River (the "East Branch" area) in Elk County, particularly to the south and east of the reservoir. Both areas are heavily forested with open patches of vegetation throughout. The Kinzua test site is situated completely within the Allegheny National Forest while the East Branch test site presents an interesting combination of private land, state forest, and state game lands meeting near the base of the dam, permitting close comparison of land use patterns. Location of both sites on ERTS-1 images is facilitated by the presence of reservoirs and streams. The initial goals were to distinguish between forest and open vegetative areas; and within the open areas, to distinguish between herbaceous vegetation, scrub, and small saplings. It was anticipated that these distinctions would lead to mapping of various game cover types and estimations of carrying capacities for different game species in a given area. They would also be useful in evaluating land use changes over a period of time by comparison of current maps with succeeding imagery at intervals of perhaps a year or so. In the forest and open areas we hoped to determine individual species groupings.

Data Sources

ERTS-1 scene 1028-15295, taken August 20, 1972, was used to study both sites. There was a significant amount of cloud cover in this scene, which was to cause considerable trouble in the investigation. An image of a better scene, 1046-15295 from September 7, 1972, was available; however, computer compatible tapes were not received during the time of the investigation. Verification of the ERTS-derived maps was obtained from U2 flight 72-094, flown on June 7, 1972. Both test areas are on this flight line, and the photography over the areas is excellent and relatively cloud-free. Photography from sensor 14, false color infrared, was the most useful, providing the maximum amount of information on vegetation. Frame numbers 155-158 covered the Kinzua area, and frames 161-163 covered the East Branch area. Stereographic viewing was provided by the Bausch & Lomb Zoom 70 stereoscope in the ORSER laboratory.

Methodology and Analysis

Supervised, unsupervised and partially supervised approaches to the investigation were attempted. The partially supervised approach proved to be by far the most fruitful, and is recommended for study of scenes in which there are many shadows and numerous targets with varied characteristics.

Supervised Mapping

The initial approach was to use the NMAP-UMAP-training areas-STATS-DCLASS sequence of computer programs in the ORSER library[1]. The Kinzua area was chosen first, as it had larger patches of open vegetation than the East Branch area. It was hoped that these targets would yield a larger number of data points per training area, and hence result in a more statistically valid analysis. The first run of NMAP revealed an immediate problem with clouds. In spite of numerous adjustments of parameters, only the reservoir, the holding pond, and cloud shadows, could be registered. Comparison with the U2 photography revealed that not a single open vegetative area had been mapped. The terrain is hilly, and the 9:30 AM sun angle creates a very complicated light and shadow pattern. Superposition of the further complicating pattern of numerous clouds and cloud shadows made interpretation of the NMAP output virtually impossible. The UMAP program was next run on the area. Sufficient patterns could be identified on this map to reveal that an area of converging road and vegetation patterns (seen on the U2 photographs), which

[1] See ORSER Technical Report 10-73 for program descriptions.

could give a number of excellent training targets, was under clouds in the ERTS scene. At this point the East Branch area was considered for study.

Initial work with the Kinzua area had given some indication of the parameters to use for an NMAP run of the East Branch area. However, even with further "fine tuning" of the parameters, only gross features were registered. A very few open areas did seem to be mapped. A run of UMAP revealed that two scan lines were out of register (scan lines 263 and 264). (As the corresponding lines on the adjoining tape are in registry, this is probably an error in processing.) Again, very few uniform areas (with the exception of water) were mapped in this hilly terrain. In spite of these poor results, it was decided to make an attempt to establish training areas for the STATS program. The output maps from UMAP and NMAP were superimposed on a light table, and sites which had the greatest probability of being open vegetative areas were outlined. These sites were not very large, averaging 10 to 20 acres.

The output from the STATS program and the first DCLASS map revealed two interesting things. First of all, none of the areas mapped corresponded with an open area shown on the U2 photograph. Secondly, eight signatures had reasonably good histograms, indicating that each was a valid signature for a yet-to-be-determined feature. (It was later revealed that these signatures were related to large targets, such as forested areas, the reservoir, and creek vegetation). The first DCLASS map, using all 16 signatures from the first STATS run, each with a separate symbol, proved impossible to read. Reduction of the number of symbols and changing the critical distances did not significantly improve the output. Finally, using water, cloud, creek, and cloud shadow symbols (categories 4, 5, 9, 6, and 18, respectively, on Table 11) as reference, each of the other symbols was mapped individually on a series of DCLASS outputs. Spatial orientation was then possible and new training areas were defined for STATS. The second run of STATS with the newly defined signatures again revealed a good set of histograms for the areas previously yielding good signatures. However, there were no new useable signatures. A run of DCLASS revealed that no additional discernible pattern or group could be mapped, and known open areas were mapped by several symbols.

Table 11: Signatures Developed During Supervised and Unsupervised Mapping of the East Branch Area

Category Number	Category Name	Symbol	Signatures			
			Channel 4	Channel 5	Channel 6	Channel 7
1	NW CREEK	-	18.60	11.40	42.87	29.20
2	NW 1	-	19.00	12.72	45.94	30.56
3	NW 2	-	19.04	10.92	44.75	29.58
4	WATER	+	24.20	12.43	7.13	1.20
5	CLOUD	C	52.08	48.33	68.58	37.00
6	SHADOW 1	S	14.82	6.64	12.41	5.79
7	NW TOP	-	18.65	11.08	46.13	31.01
8	SE 1	=	19.32	11.63	51.11	34.38
9	CREEK	*	19.65	11.90	40.29	25.35
10	OPEN A	O	22.44	14.11	41.11	24.56
11	SE 2	=	20.38	12.42	57.96	38.69
12	THIN 1	T	22.40	14.80	48.60	27.80
13	THIN 2	T	23.40	14.90	58.65	36.30
14	HEMLOCK 2	#	17.87	10.25	29.37	16.87
15	THIN 3	T	25.50	19.00	54.00	33.00
16	HEMLOCK 1	#	19.00	11.50	30.00	16.50
17	CLOUD 1	C	31.00	24.00	58.50	35.50
18	SHADOW 2	S	15.60	6.93	17.13	9.00
19	CLOUD 2	C	35.60	30.40	60.80	38.20
20	CLOUD 3	C	39.67	34.67	63.00	39.33
21	CLOUD 4	C	45.00	40.00	66.00	38.50
22	CLOUD 5	C	32.29	24.71	57.14	35.71
23	CLOUD 6	C	27.67	21.67	54.67	35.67
24	CLOUD 7	C	30.00	22.64	57.82	36.36
25	OPEN B	@	25.04	16.08	69.32	43.00

All suspected forest signatures (categories 1, 2, 3, 7, 8, and 11) were then mapped individually and the maps superimposed on a light table. The areas were found to lie parallel and right next to one another. Inspection of the signatures in channel 6 revealed that their values were in ascending order, left to right on the map, and then repeated themselves. It was apparent that the signatures went from the creek, up the northwest aspect of a hill, over the hill, and down the southeast aspect to another creek or valley. This traverse encompassed a total of six signatures shown by two symbols. The names and symbols of these signatures were then changed, using one symbol for the northwest aspect, and another for the southeast aspect, to give a spatial comparison with the U2 photography. A rerun of the map with these categories is shown in Figure 34, on which an example of the mapped aspects has been delineated. (The area mapped in Figure 34 is the northeast corner of the portion of the study area shown on the U2 photograph in Figure 35). If an open area on the U2 photograph is on the northwest aspect of a hill, the symbol for that aspect would be expected to be mixed with the symbol for the open area. It is unknown, at this stage of the investigation, how much of the difference in reflectance with aspect is a function of shadow and how much is due to vegetation differences with hill aspect. The U2 photographs show a similar pattern but they are also affected by sun shadow. Creek vegetation is, however, definitely different from that found on the hills. Low altitude photography or a visit to the area will eventually be needed.

The successful mapping of hills and creeks at this stage, made it possible to precisely locate areas within the test site. However, not a single open vegetative area had yet been mapped. It was apparent that the supervised mapping procedure was not suitable for a study area of this type. The technique is useful for relatively large uniform areas, where large number of data points of the same spectral characteristics are grouped together. However, it is of very limited usefulness for small areas consisting of very few data points, where most of these points lie near the interface between the training area and contrasting areas around it. This confusion is compounded by the native inhomogeneity of training targets, such as open areas containing varied vegetation patterns.

Figure 34: DCLASS map of hill aspects in a portion of the East Branch area. Symbols for CREEK, SHADOW, and CLOUD were mapped for reference.

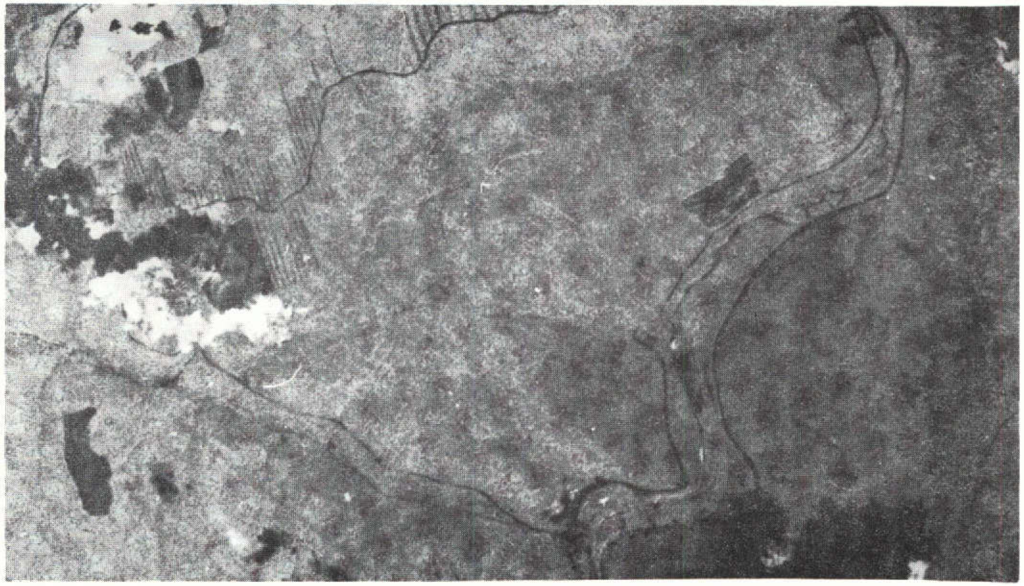

Figure 35: Black and white enlargement of U2 photograph of a portion of the East Branch area. (Flight 72-094, sensor 14, frame 720009; approximate scale: 1 inch = 1.4 miles)

Unsupervised and Partially Supervised Mapping

The unsatisfactory results from the investigation described above led to the use of the DCLUS program, which develops its own set of spectral signatures, using a clustering algorithm, and outputs a map on the basis of these. The initial run, of a relatively large area, yielded the three forest signatures originally obtained from STATS. However, there was still considerable confusion registered in small areas. It was then decided to "partially supervise" the DCLUS program, by working with very small areas known to be the open areas of vegetation sought. The first such open site was on the northwest aspect of a hill. The area was not homogenous; it had some patches of almost bare ground surrounding a row of what appeared on the U2 photograph to be coniferous trees. The OPEN A signature (category 10) came from this run, but a signature for the trees was not obtained. That signature (HEMLOCK 1, category 16) came from running DCLUS on an area of trees tentatively identified as hemlocks. These two signatures and their critical distances derived from DCLUS, were added to the signatures judged to be good from the earlier STATS run. Using the default critical distance of 10, this set of signatures (categories 1 through 11, 16, and 18 on Table 11) was input to the DCLASS program. The resulting map, shown on Figure 36 , shows the OPEN A training area, labelled "A." It can be seen that the row of trees is effectively mapped with #'s derived from area B. Also within area A are -'s, indicating the site is located on the northwest aspect of the hill. Note also that category 10 (OPEN A) did an excellent job of mapping a road on the opposite side of the creek (compare to the photograph in Figure 35).

A distinct advantage to using the DCLUS program is that, in addition to obtaining a signature, the optimum critical distance can be determined by watching the change in symbol clustering with changes in critical distance. This feature has proven invaluable in mapping small areas. If the critical distance becomes too small, the whole target, except for one or two points, may suddenly disappear. This is probably due to "edge" effects on the signatures, causing the elements near the interface with adjacent areas to disappear when the critical distance is too small. If the critical distance is too large, the symbols scatter all over the map on both large and small targets.

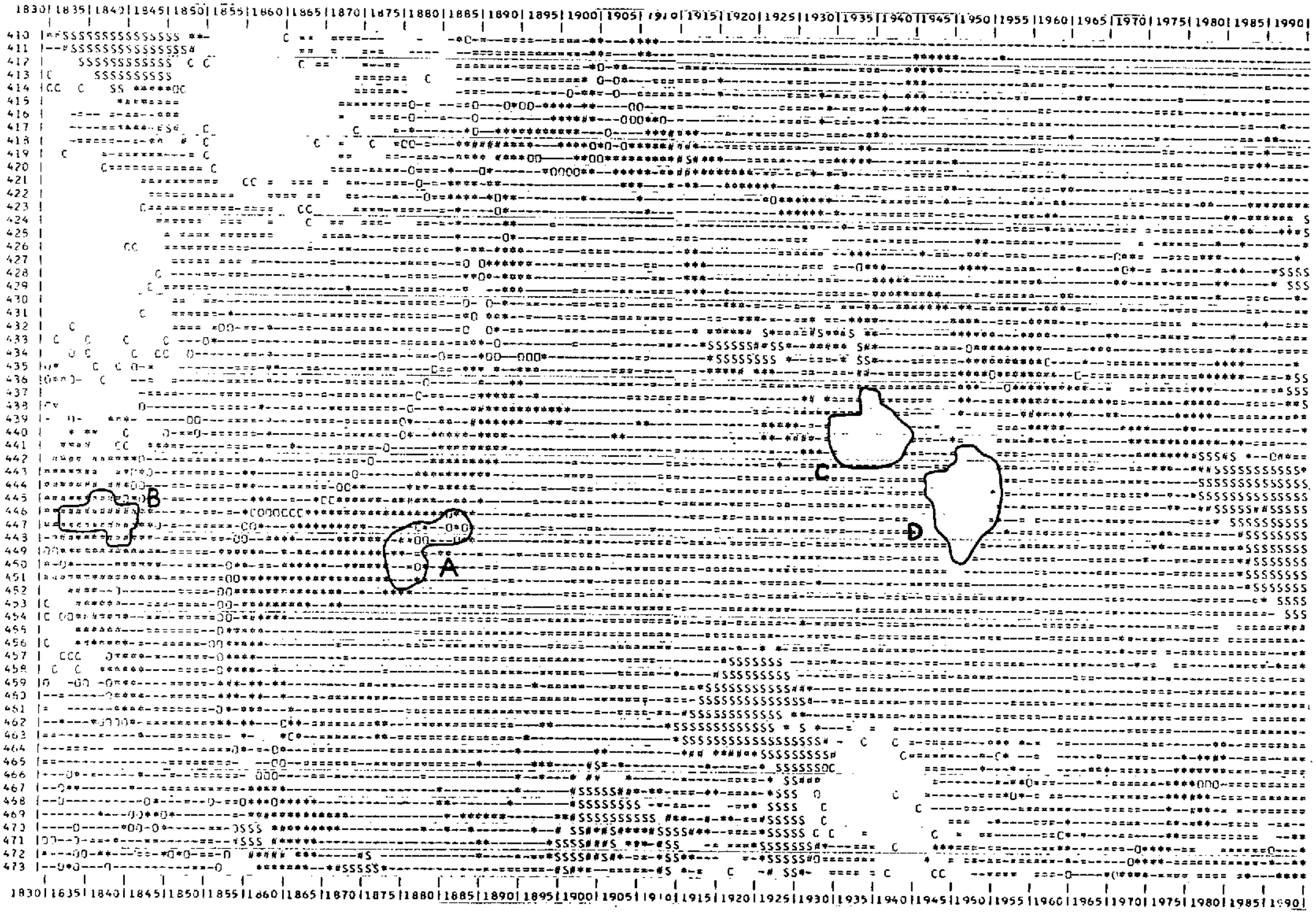

Figure 36: DCLASS map of the East Branch area, combining eleven STATS and two DCLUS signatures. Outlined areas are discussed in the text.

Frequently, in using DCLUS for small targets, a signature on a fairly small block may not classify, regardless of the critical distance used. In this case, there are three procedural options:

1. Increase the number of sample points and leave the size of the block the same. In this case, the number of mapping symbols and categories must also be increased.

2. Decrease the size of the block and keep the number of categories and symbols as they were. This seems to be a better alternative than the one above. Of course, the location on the map must be known precisely to use very small blocks. Often the choice of a relatively large preliminary block (four to five times the size of the intended target area) will serve to locate the target block. An additional advantage to decreasing the size of the target block is the reduction in computer time used in multiple runs, to determine the proper critical distance.

3. Decrease the size of the block and increase the number of mapping symbols and categories. This option has not yet been found necessary.

Having determined a working methodology for obtaining signatures from DCLUS on the study area, additional signatures were defined. A rerun of DCLUS on two blank areas, thought to be clouds, proved interesting. One of these (area C on Figure 36) gave seven distinct signatures (categories 17, and 19 through 24), which were added to the cloud signatures determined earlier. These were easy to differentiate from vegetation, as they had much higher reflectance values in channel 5 and 6 than did vegetation. The second blank target (area D) was, however, definitely not a cloud. It had previously not been classified due to a very high reflectance value in channel 6. Comparison with the U2 image (see Figure 35) showed this to be an area which looked as if it had been clear cut and is now regenerating. This signature was assigned the name of OPEN B (category 25). THIN 1 and THIN 2 (categories 12 and 13 on Table 11) were obtained from a patch of thin vegetation that runs up and over a hill. The large distance of separation between these two signatures is most likely a function of shadows caused by the sun angle. THIN 4 (category 15) came from the same area, using a different critical distance. These three signatures, used as a group, seemed to map areas of thin vegetation with considerable accuracy. A map using all the current signatures was then run (Figure 37). The training area for the THIN signatures came from area E shown on this map.

Preliminary Results and Conclusions With Plans for Further Investigation

Figure 37, the DCLASS map obtained at the time of this report, reveals several interesting features. Areas D and F, for instance, have clearly different characteristics, both on the ERTS scene and on the U2 photograph. More vegetation is present in D than in F, in fact, D seems to have a signature unique for this study area. By comparison, a considerable amount of what looks like bare soil seems to be evident in area F. This map also demonstrates that there still is some confusion between the THIN signatures and some clearly OPEN targets. Area F was not on the map from which the THIN signatures were developed, and the next task is to use DCLUS to develop one or more signatures and critical distances for this relatively large open area.

Another open area, G, just below D, further indicates the need to refine the THIN signatures to distinguish between THIN and OPEN areas. Area G is spatially well defined on the U2 photograph to be two separate areas, the lefthand portion being on a ridge and the righthand partially in a small valley, with a small forested southeast-aspect hillside between them. Spectrally, both areas are quite mottled. The map bears this out, assigning some forest symbols between the portion on the ridge to the left and the portion in the valley to the right. It is interesting to note the rather small distances of separation that these open areas, currently mapping as THIN, will have among themselves; and between themselves and the new signatures, once they have been classified by DCLUS. The greatest distance of separation between any two of the present THIN signatures is 13.2 (see Table 11), and most of this difference is quite likely due to shadow. It is anticipated that very small critical distances will have to be used to properly separate and classify these signatures. An area north of those shown in Figure 37 was largely left

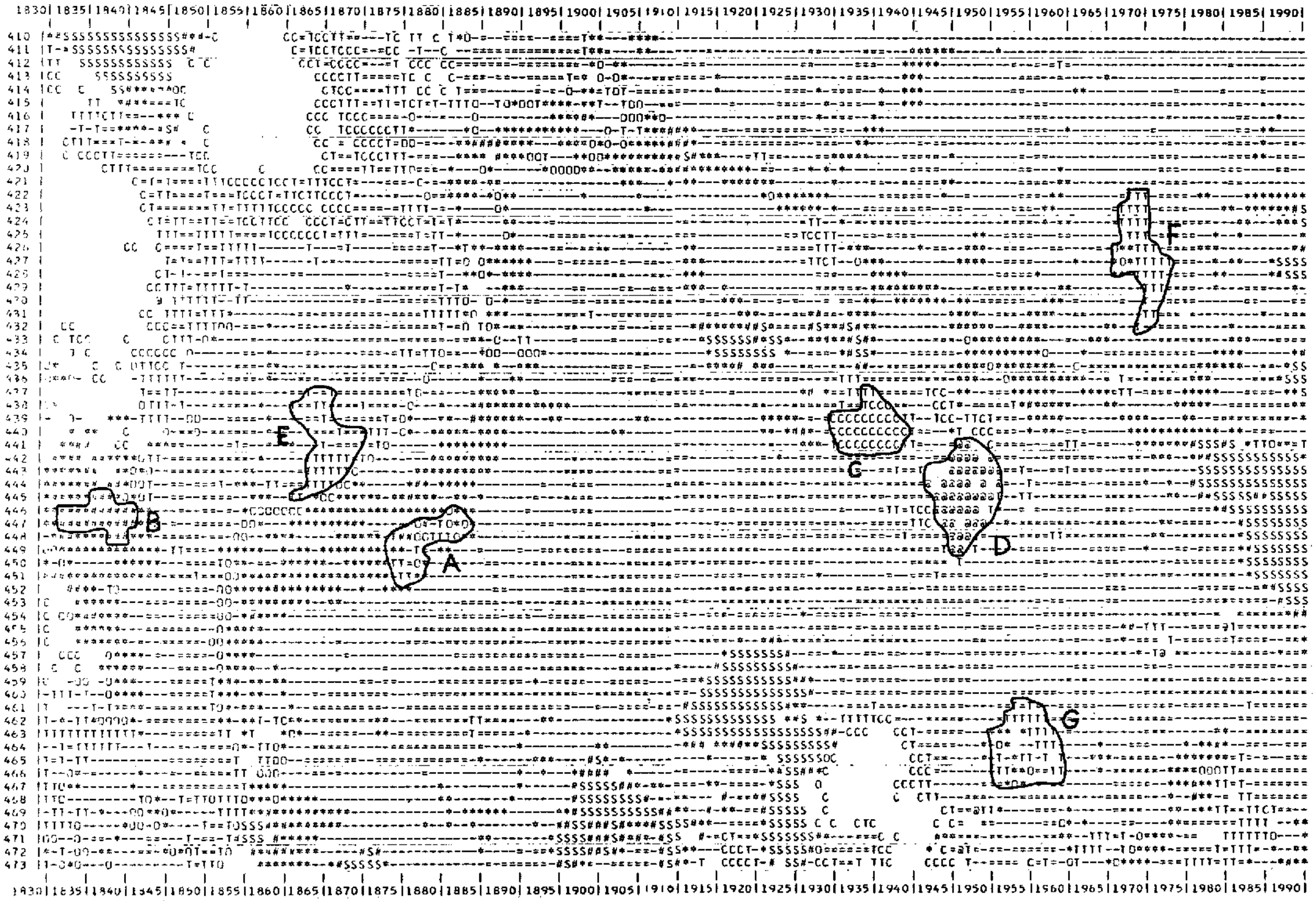

Figure 37 : DCLASS map of all signatures shown in Table 11 . Outlined areas are discussed in the text.

blank on the map, indicating that it could not be classified with the signatures used. This is a cutover area on a plateau, entirely surrounded by a combination of OPEN, FOREST, and THIN signatures on the map. DCLUS will be used to get signatures and critical distances for the unclassified parts of this area.

The following steps are planned in continuing this research:

1. A very complex little valley to the south and west of the East Branch site has been chosen. It is planned to use the current signatures to map this area to see how well they classify closely bunched targets.

2. An attempt will be made to distinguish between various type of open cover. It has proven possible to distinguish between conifers and deciduous trees when one is predominant in an area, but it may be possible, with further refinement of signatures, to determine two different height classes and to identify them from their spectral differences. It is possible that merging summer and late fall scenes will facilitate differentiation between deciduous and conifer vegetation, due to the difference in spectral response of deciduous growth in two seasons.

3. Signatures developed and refined on the East Branch site will be used in an attempt to map the Kinzua area. This area is very similar in vegetation and terrain to that of the East Branch and the refinement of signatures obtained on cloud and supposed-cloud areas in the East Branch site should considerably clarify the mapping of the Kinzua area.

4. It is planned to use the more sophisticated classifiers, such as the RATIO and CANAL programs. The CANAL classifier requires more statistical information than the channel means provided by the DCLUS program. Therefore, DCLASS maps using DCLUS signatures will be used, instead of maps generated by UMAP, in an attempt to specify training areas for the STATS program. If this technique is successful, we will be able to use a DCLUS-DCLASS-STATS sequence of programs to generate comprehensive statistics for small training areas.

5. It is becoming quite evident that further refinement of the signatures for these areas will rapidly lead to a need for underflight photography of a larger scale than that provided by the U2

aircraft. Subtle differences, such as those we hope to determine in areas currently mapped as THIN are not discernable on U2 photographs, and these photographs suffer from some of the same shadow difficulties as the ERTS scenes. It will be highly desirable to obtain low-altitude underflight photography at an early date.

GEOLOGY AND HYDROLOGY

The study of lineaments and fracture patterns has been a focus of concentration this past year. Numerous geologic studies have shown these features to be strongly correlated with mineral and groundwater resources. These relationships are discussed in detail by Gold, Parizek, and Alexander, in their task report. In addition to the work done in structure and terrain analysis by the above co-investigators, Krohn has reported on his work with the geology of the Lancaster County area, as studied from ERTS-1 data.

ANALYSIS AND APPLICATION OF ERTS-1 DATA FOR REGIONAL GEOLOGICAL MAPPING

D. P. Gold, R. R. Parizek, and S. S. Alexander

Painstaking symthesis over many years has provided regional, state, national, and global geologic maps. However, the synthesis of features on one scale does not guarantee that a larger feature will necessarily be apparent on the smaller scale map generated. Artifacts in mosaicing, poorly known scaling laws, and inconsistent conditions (variable sun angle, albedo, seasons, etc.) of data collection are more likely to obscure than enhance subtle features. The advent of ERTS however, presents an unparalleled opportunity for the analysis of a large body of data on a small scale, gathered under consistent conditions. This is the ideal situation for the discovery and study of large scale features and their geologic significance.

Objectives

The initial objectives of this study are two fold:

1. Regional geologic mapping: a few well known areas have been studied in detail, with a view toward application of the results to larger areas.

2. Linear and transgressive features apparent on ERTS and all scales of aircraft imagery are being studied. Again, for smaller scale linear features, initial study has been concentrated on a few well known areas.

Because we have a considerable body of ground truth data for establishing correlations, and because there is a theoretical basis for possibly linking linear features through scale, we feel that objective number two will have the best and quickest economic pay-off in terms of hydrogeology, engineering and environmental geology, and ore-deposits.

Methodology

The methodology is continually developing as we gain experience in interpreting the imagery and learn to recognize the real and significant signals. The criteria used in mapping like areas (visual similarity in tone, spatial patterns, or texture) are classified according to whether they represent a direct or indirect manifestation of the bedrock condition. In forested areas such as Pennsylvania, a knowledge of the indirect indicators is important for geologic interpretations even though their relationship to the bedrock conditions may not be understood. The main mapping criteria used are:

1. Boundaries or interfaces that separate areas of different tone, texture, or pattern. Whereas irregular boundaries generally result from differences in land use (arable land versus forests), smooth and regular boundaries commonly reflect geologic control, especially where layered rocks are involved. Combinations of these two relationships (e.g., forest cover over untillable rocky areas) enhance contrast and interpretability, if the correlation can be made and the cause identified from ground truth data. For example, the diabase sills in eastern Pennsylvania show up best on channel 5 because their overlying forest cover stands in contrast to the surrounding cultivated fields.

2. Linear transgressive features (lineaments) that show as narrow bands of contrasting tone and topography, or that displace areas of like tone or pattern. These are generally long features (five to several hundred km long). Some morphologically represent the alignment of wind and water gaps, and others represent the surface expression of features such as dikes, faults, and zones of fracture concentration without any apparent displacement.

Three criteria were used to select geographic areas for detailed evaluation: 1) the availability of good ground truth data, 2) the presence of underlying rocks with good lithologic contrast, and 3) the presence of abundant faults. The areas chosen are:

1. the Traissic Basin of eastern Pennsylvania and associated diabase sills

2. the Anthracite Basin around Scranton

3. the Precambrian inliers of the Reading Prong

4. the Martic Line north of Philadelphia

5. transgressive long lineaments through Mount Union and Tyrone

6. transgressive lineaments in the South Mountain area

7. short and intermediate lineaments, for orientation and density comparisons, in different parts of the State.

The choice of a contained problem in a restricted area is important at this stage, not only to keep down digital processing costs but also to keep the computer-generated maps to a manageable size (each character represents approximately 1.1 acre).

The evaluation is being conducted in three stages:

1. Primary correlations are sought by projecting the available ground truth geologic boundaries onto enlargements (1:250,000) of ERTS imagery in all available channels. Anomalies are checked out first on other maps (agricultural, soils, highways, topographic, etc.), and followed with a field check where necessary.

2. Selected areas are mapped by computer, using cluster analysis and the digitized data, with the parameters controlled (supervised) from training areas.

3. This is followed by unsupervised computer mapping (i.e., free from known geologic biases) to bring out any latent features that might have geologic significance.

Geologic Structures

A mosaic of ERTS-1 images of Pennsylvania was prepared using the first available cloud-free scenes. No attempt was made to obtain uniform tone or alter individual frames. Rather, the frames were simply spliced together to permit an early study. Physiographic and structural provinces are displayed spactacularly on this mosaic, and the resolution achieved in some images enables one to trace formation contacts for hundreds of kilometers. Bedrock structures show up well, especially on channel 7 in midwinter scenes, even where not accentuated by topography or vegetation. On channel 5 imagery at a scale of 1:250,000, the contacts of some lithologic boundaries in eastern Pennsylvania (see Figure 38) can be placed with the accuracy of 400 meters (1/4 mile) with respect to the 1960 Geologic Map of Pennsylvania. Much of this error may be a result of transferring the boundaries from ERTS imagery to the base map. The mapping of superimposed structural features such as faults, particularly along the northern end of the Traissic Basin, was disappointing. While the margin of the Reading Prong could be traced from the tonal and land use variations, the geologically mapped faults were not everywhere apparent. Vegetation enhancement over the Triassic diabase sills and dikes rendered mapping both simple and accurate. Fracture and drainage patterns, and tonal variations, serve to distinguish certain rock types but generally little bedrock is sufficiently well exposed to exhibit a direct spectral response. Most contacts are reflected indirectly, in the condition and type of overlying soil, vegetation, and land use.

Linear Features

Perhaps the most encouraging and unexpected characteristic of ERTS imagery is the number, distribution, and patterns of unspecified linear features which can be seen. Geologists have long recognized the presence of straight to slightly curved linear features on the earth's surface. These vary in size from a few to tens of meters, for systematic and nonsystematic joints, to "lineations" tens of kilometers long that have no obvious field expression and are visible only on airphoto mosaics. To distinguish among features recognizable on aerial photographs, Lattman[1] defined a "fracture trace" as a "natural linear feature consisting of topographic (including straight stream segments), vegetation, or soil

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[1]Lattman, L. H. (1958) "Technique of Mapping Geologic Fracture Traces and Lineaments on Aerial Photography," Photogram. Engineering, Vol. 24, p. 568-576.

Figure 38: ERTS image of an area east of Harrisburg, Pennsylvania, with geologic features outlined. 1) Precambrian rocks of the Reading Prong, 2) the Triassic Basin (dashed lines) and diabase sills, 3) the Conestoga formation, and 4) the Martic Line in the Piedmont province. (Enlargement of ERTS image 1080-15185, channel 5, October 11, 1972.)

tonal alignments, visible primarily on aerial photographs and expressed continuously for less than one mile." Those greater than one mile (1.6 km) he termed "lineaments." A considerable amount of work has been done with joint traces, and joint orientation studies in the field, and more recently (since 1957) with fracture traces. Using ground based and aircraft data as well as that from ERTS, we now recognize at least six scales of linear features. While there must be a mechanism linking those between the joint and fracture trace scales, theory suggests that the same mechanism may link all scales.

Many lineaments that transgress regional structural grain and also physiographic province boundaries have been discovered from visual examination of ERTS-1 MSS bulk-processed images. ORSER geologists, who have mapped some lineaments and portions of others from high quality aerial photo-mosaics and from low-flying aircraft, and who have studied aerial photographs and conducted field work for years in central Pennsylvania, did not recognize the trend of many of the major lineaments of the State until ERTS images became available. Linear features are detectable on ERTS images and mosaics, as well as on underflight photography, as lines or bands defined by an alignment of valleys, of wind and water gaps, and by straight stream segments or a linear change in image tone. Many are subtle features, especially in areas of low relief, and the tonal contrast may vary a long their length. They may be enhanced in mountainous areas by a low sun angle. Shorter linear features (several meters to several kilometers in length) are best seen on aerial photography or ERTS enlargements. When features 15 or more kilometers long are being mapped, enlargement may render the longer lineaments (over 100 kilometers) less obvious. Lineament mapping from ERTS digital tape data is cumbersome because of the variation of lineament expression along strike (e.g., between ridges and valleys, or even from one valley to another) and because of the difficulty of distinguishing lineaments from man-made effects (such as roads) and artifacts of data collection (such as scan lines). Our work to date has been concentrated on visual approaches, because the human eye is more sensitive for mapping these features than any machine processing tried so far.

A first attempt at a "megalineament" map of Pennsylvania on a 1:1,000,000 mosaic of channel 7 images has been completed (see Figure 39). A rose diagram of lineament orientation frequency for this map has been constructed (Figure 40), as well as a length frequency histogram (Figure 41). The necessary computer programs to analyze the orientation and length of linear features and to compare these in different cells have been developed[1]. Similar analyses on intermediate and short lineaments in a test area east of Harrisburg are being performed to try and establish whether or not lineament lengths are part of a continuum or have a stepped distribution. Orientation comparisons will be made with areas of known folds and faults in an attempt to determine if a single or divergent pattern exists in various parts of Pennsylvania. This will be tested around the major flexure in the Appalachian folded mountain chain. Because lineaments are sensed as a trace on the surface and are perceptible as subtle changes in tone or contrast that may vary along their length, lineament mapping in this test area is being duplicated, using the same images and two operators (Parizek and Gold), to determine the reproducibility of the technique. Both orientation and density data are being recorded.

Three scales of lineaments have been recognized: 1 to 5 miles (1.6 to 8 kms), 5 to 50 miles (8 to 80 kms), and 50 miles (80 kms) to a few hundred miles (kms) long. Lineaments on a subcontinental scale are anticipated. Little is known about their length, frequency, and relationship to fracture traces and joints, but there appears to be an inverse relationship of length to abundance and density. Lineaments mapped to date appear to have a consistent relationship to fold and fault axes, are generally straight features, appear to cut across physiographic provinces, and are not influenced by faults. Their linear nature regardless of topography suggests they are the surface expression of near-vertical fractures or fracture zones. They transgress rocks of all ages in Pennsylvania and blankets of Pleistocene glacial drift do not obscure them. These deep-seated features must imprint themselves

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[1]See Podwysocki, M. H., "Computer Applications of Fracture Trace Analyses," and "Computer Algorithms for Use in Fracture Trace and Lineament Analysis," NASA X Documents 644-73- (in press).

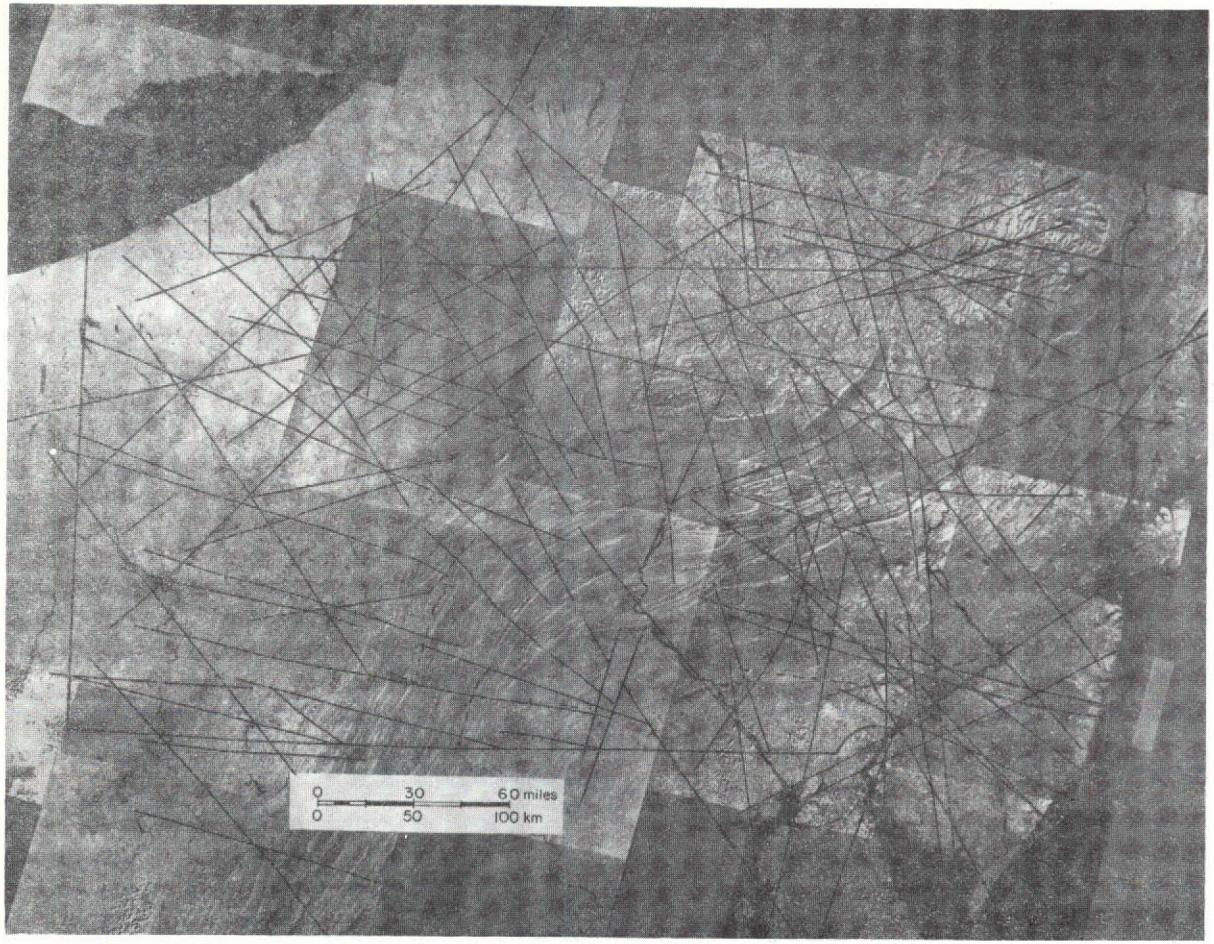

Figure 39: Megalineament map of Pennsylvania, plotted on a mosaic base of 1972 channel 7 ERTS images.

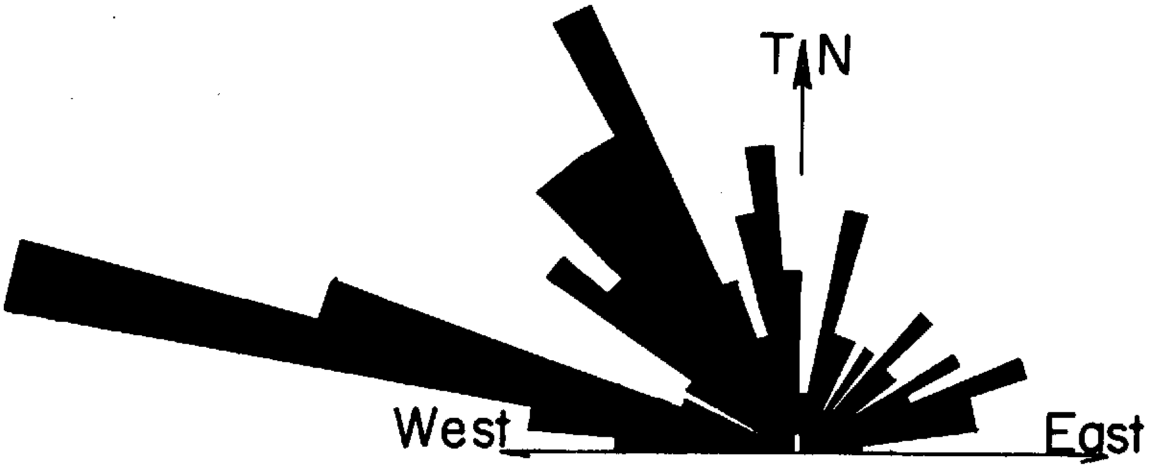

Figure 40: Rose diagram of long lineaments plotted on the megalineament map of Pennsylvania.

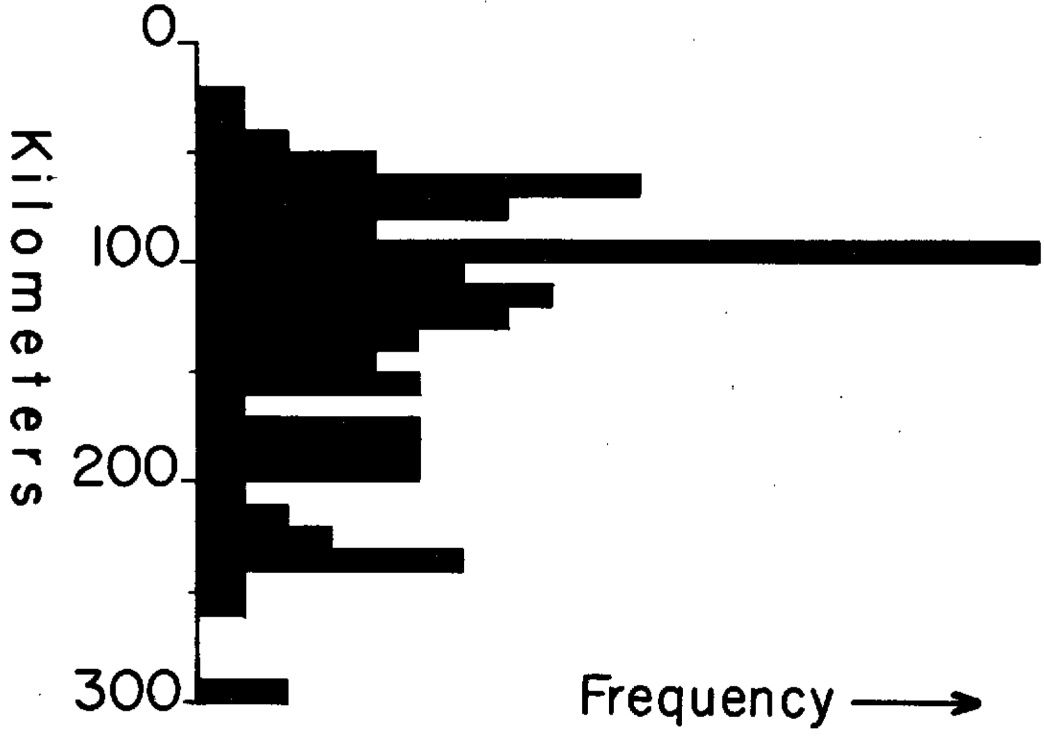

Figure 41: Histogram of long lineaments plotted on the megalineament map of Pennsylvania.

on younger deposits in a systematic manner and are themselves inherently old. Major lineaments, for example, can be traced from Precambrian metamorphic and igneous rocks through overlying Paleozoic sedimentary rocks and into the down-faulted sediments and diabase sills of the Triassic Basin. They must represent either rejuvenated fractures, a "tectonic inherence" from the underlying crustal rocks; or a recently imposed fracture system, as might be expected from stresses associated with a drifting lithospheric plate.

Some "lineaments" are actually fault traces, in that lateral offsets in individual rock layers can be established. Many major faults previously mapped in Pennsylvania that are transverse to regional stratigraphic or structural strike appear on ERTS images. Many previously unmapped faults also should become obvious with further study. Recently, the probable motion deduced from first arrival directions of both the P and S waves for an earthquake near Philadelphia, was combined with lineament directions mapped from ERTS-1 imagery to locate the most probable fault plane. The seismic data were compiled by Dr. Shammus of the Geophysical Section of the College of Earth and Mineral Sciences, at Penn State, in co-operation with seismologists from the Lamont Geophysical Observatory of Columbia University, New York.

The unexpected density of short and intermediate length lineaments mapped on 1:250,000 scale of ERTS-1 channel 7 images in the test area east of Harrisburg (Figure 42) suggests a scaled-up version of fracture traces. If the lineaments overlie fracture zones (as is suspected) and prevail to depths corresponding roughly to the same order as their length (as implied by theory), then these implications are important to: 1) stream and river control and the evolution of landscape; 2) groundwater movement; 3) oil and gas migration and leakage; 4) underground gas storage; and 4) engineering foundation exploration, analysis, and design. Part of our research thrust is in the three-dimensional characterization of these lineaments. Unfortunately, obtaining pertinent information at depth on a feature of this scale is difficult and may take years of careful synthesis of data on sinkhole development; drilling and pumping records; and poor ground conditions in mines, quarries, and highway construction projects.

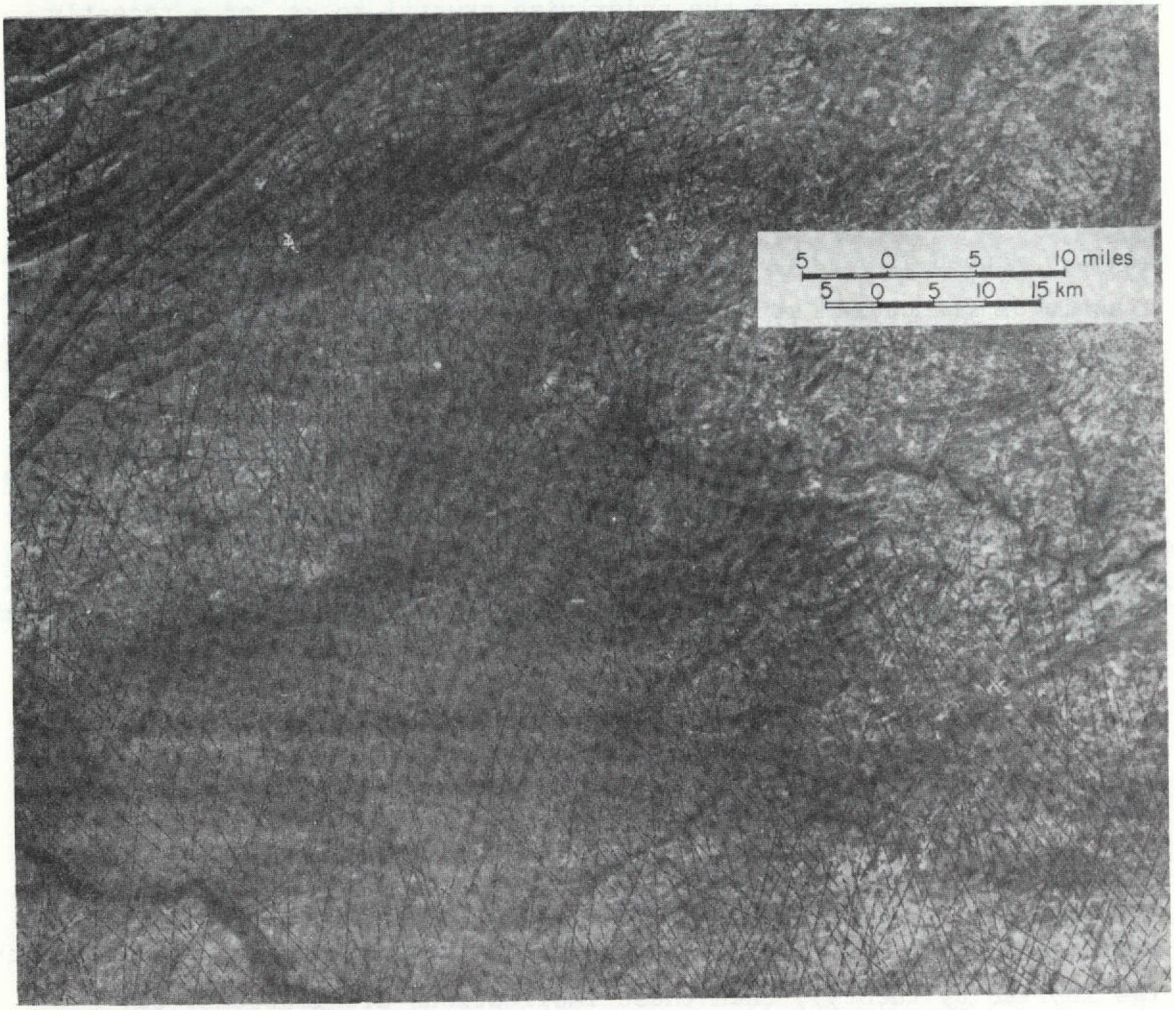

Figure 42: Short to intermediate lineaments crossing the Valley and Ridge, Great Valley, Triassic Basin, and Piedmont structural provinces east of Harrisburg, Pennsylvania. The Susquehanna River appears at the lower left and the Schuylkill River in the northeastern half of the figure. Reading is located on the Schuylkill near the center. (Enlargement of ERTS image 1116-15192, channel 7, November 16, 1972.)

Conclusions

Geologic Structures

The scale relationships of geologic information available on data sensed at different altitudes has not been investigated, as originally proposed, because of the lack of underflight data in areas where good ERTS imagery first became available. However, we have looked at the problem of scale as it affects lineaments and fractures in other areas. We suggest there is a link in mechanism between joints; fracture traces; and short, intermediate, and long lineaments; and that their identification is related to scale. A study of this link is a major objective of one aspect of our ongoing research. We plan also to systematically map lineaments and fold axes of Pennsylvania on a scale of 1:250,000. A tectonic map of the State will then be developed, with the aid of existing structural data provided by the Pennsylvania Topographic and Geologic Survey.

Ore Deposits

A most important spin-off of the lineament map is its potential application to the location of ore deposits. Using ERTS imagery, close correlation has been observed between metallic ore deposits and the Mount Union-Tyrone lineament in Pennsylvania (Figure 43). Five metallic sulfide deposits are known to be located along this lineament. The bedrock conditions are currently being investigated, and underflight photography along this feature has been requested. In the Ebensburg area, an investigation is being conducted to determine the quality of coal and mining conditions relative to short lineaments observed on the ERTS imagery. The groundwork has been laid to procure quality control data from the Bethlehem Steel Corporation underground mines near Ebensburg. We have started a program to investigate mining problems and the possible relationships between lineaments and coal distribution and quality on the Allegheny plateau, near Clearfield. A similar study is planned near the major lineaments cutting the anthracite field in the Wyoming basin, near Scranton and Wilkesbarre.

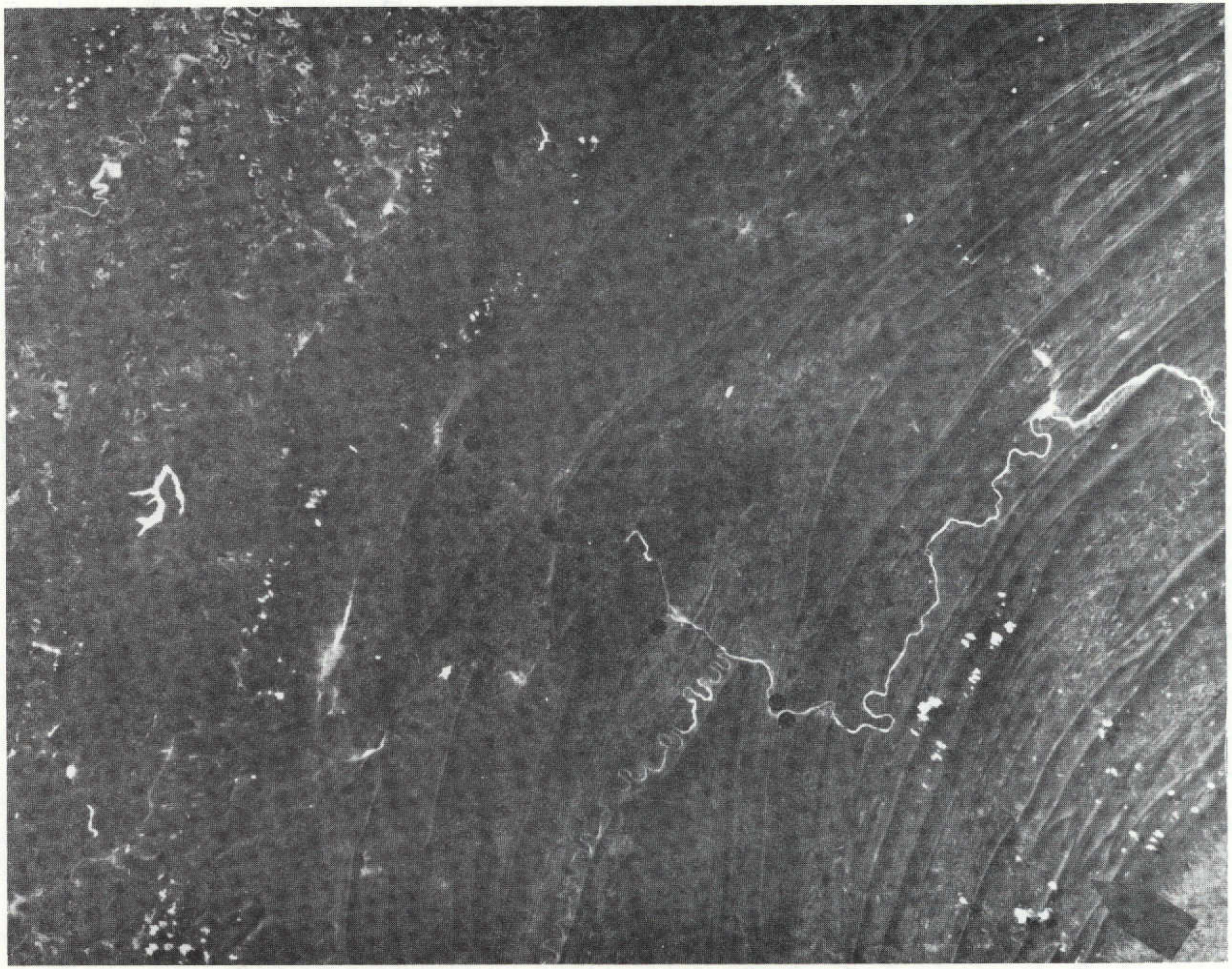

Figure 43: Major lineament between Mount Union and Tyrone, Pennsylvania, which correlates closely with known metallic ore deposits. Lead and zinc deposits are shown as dots. Note that this lineament also localizes the Juniata River along this stretch. (Negative enlargement of ERTS-1 MSS image 1045-15243, channel 7, September 6, 1972.)

Ground-water

Locations of known ground-water sources are being correlated with fracture traces and lineaments observed on ERTS imagery. Investigations at Penn State since 1961 have established the significance of the use of fracture trace mapping techniques to locate highly productive water wells drilled in carbonate rocks. Many of these areas were otherwise very poor water producers. Investigations in areas of siltstone, shale, coal, and sandstone sequences are showing a similar relationship of fracture traces to well yields[1]. In preliminary studies, Parizek has found an association of well yields and water gap locations, and it has been frequently observed that large scale lineaments tend to pass through water gaps. For each of the four watergaps under study, well yields have been found to be nearly double those of wells located in the same formations adjacent to the water gap. Various geologic and hydrologic factors other than lineaments could account for the yield differences observed, and these must be isolated and studied. However, success to date indicates that ERTS data will be a highly productive source of information for linear mapping on a regional scale that should aid in ground-water exploration.

Aeromagnetic Intensity

A preliminary examination of the relationship of lineaments observed on the ERTS mosaic to such aeromagnetic intensity maps as are available for Pennsylvania, revealed a distinct difference between the correlation in the western and the eastern portions of the State. In western Pennsylvania, where the lineaments appear to connect magnetic lows, the magnetic anomalies are thought to be basement controlled. In the eastern portion of the State the anomalies are highly concentrated and tightly intertwined, with no visible relationship between lineaments and the magnetic patterns.

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[1]Brown, R. L. and R. R. Parizek (1971) "Shallow Ground-water Flow Systems Beneath Strip and Deep Coal Mines at Two Sites, Clearfield County, Pennsylvania," Special Research Report, SR-84, Coal Research Section, The Pennsylvania State University, University Park, Pa.

Continuing Research

ERTS imagery provides a timely base for mapping lineaments, a new class of structural element, and the ground follow-up (geological and geophysical probing for the three-dimensional aspect) should aim to characterize these features, not only to facilitate the development of a genetic classification but also to assess their economic potential and utility. The ERTS program has already spurred the development of a theory to account for the size and frequency of "linear" features on all scales[1], and these should be refined so that dynamic analyses of stress distribution are possible. We foresee in the study of linear features from ERTS data a resurgence in studies of regmatic shears and global fracture patterns and a possible tie into plate tectonics. More important is the potential use of lineament mapping in mineral and groundwater exploration. The ERTS programs provides a new research tool which improves on the resolution of features that were previously rather obscure. Hardware from the ERTS program provides us with such a new tool.

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[1]This theory was offered by Moody and Hill in 1956 ("Wrench Fault Tectonics," Bull. Geol. Soc. America, Vol. 67, p. 1207-1246) and is being developed by Gold, Parizek, and Alexander.

GEOLOGIC INVESTIGATIONS OF THE GREAT VALLEY IN PENNSYLVANIA

D. Krohn and D. P. Gold

The area of study for this project is the Great Valley, the easternmost extension of the Appalachian Valley and Ridge province. In southeastern Pennsylvania the Great Valley traverses a wide arc from north to east. The particular area of concern was from South Mountain (Carlisle) to the Reading Prong (Reading). In this region the Valley is about 10-15 miles wide. The Great Valley was selected for an area of study for the following reasons:

1. Well-defined boundaries. The forested quartzite ridge of Blue Mountain to the north and the forested diabase ridge of the Triassic basin enclose and stand in sharp contrast to the cultivated land in the valley.

2. Geographic Reference Points. Two major rivers, the Susquehanna and the Schuylkill, act as geographic benchmarks for locating specific areas within the valley. This is especially important in working with computer compatible tapes.

3. Variety of Rock Units and Structural Elements. Including the two boundary areas, there are five major lithologies to be differentiated in the Great Valley area. From north to south these are as follows:

Area	Lithology
The Valley & Ridge Province	(1) Tuscarora Formation (orthoquartzites)
The Great Valley	(2) Autocthonous Martinsburg Formation (graywackes)
	(3) Allocthonous Martinsburg Formation (shales)
	(4) Cambro-Ordovician Carbonates (limestones & dolomites)
The Triassic Basin	(5) Newark Formation (red beds & diabase)

Also within the Valley are a variety of structural features, such as thrust faults, normal faults, and overturned folds.

4. Well-documented ground-based Geology. This area has been studied in detail by the Pennsylvania Topographic and Geologic Survey.

5. Availability of ERTS-1 Data. Several scenes of this area are relatively cloud free; also both the ERTS-1 images and the corresponding ERTS-1 tapes of that scene are available in the ORSER library.

6. Availability of Underflight Data. U2 flights (flown at 65,000 ft) as well as C130 flights (flown between 5000-15,000 ft) have been flown over areas of the Great Valley recently. Patterns and features mapped or noted in ERTS images can thus be checked with higher resolution photography.

7. Personal Knowledge. The authors have a good working knowledge of the topographic and cultural features of the area.

Methodology

ERTS-1 image 1080-15185 from 11 October 1972, was selected as the scene for analysis of the Great Valley because, as of the end of December 1973, it had not been exceeded in quality. Photographic enlargements were made from 4 by 5 inch negatives of approximately one quarter of the area of the 9 by 9 inch transparencies in each of the four channels. These enlargements, made on 16 by 20 inch paper, were on a scale of approximately 1:250,000, which represents an upper practical scale limit for terrain and geologic analysis.

One set of enlarged images centered around the city of Reading and covered a portion of the Great Valley from Allentown in the east to Harrisburg in the west. They included a large portion of the Reading Prong as well as much of the Triassic Basin. The second set of enlarged images centered around the city of Carlisle, and covered the portion of the Great Valley from Lebanon to the east to Hagerstown (Maryland) to the southwest. South Mountain was included in this set of enlargements. There was approximately 25 percent overlap between these two sets.

The first step in the photointerpretive procedure was to prepare an overlay of the topographic, hydrologic and cultural features in the area by projecting a USGS 1:100,000 topographic map on the enlarged ERTS image with a Salzman Projector. Major rivers were found to be the best identifying feature; highways were too indefinite and mountain boundaries were too vague. The final overlay included the major drainage systems, cities, forest areas and highways. The drainage pattern, in particular, was useful in later analysis. This overlay was used as a guide to orientation in the geologic interpretation of the scene.

The digital data processing system described in the second chapter of this report was used in conducting a preliminary digital analysis of a portion of the Great Valley, using the digital data tapes from the same scene interpreted visually.

Results

The features discerned on the October 11 ERTS scene of the Great Valley are summarized on Table 12 and discussed below.

Lithologic Separations

The contrasting boundary lithologies of the Great Valley, the quartzite ridge of Blue Mountain to the north, and the diabase ridge to the south, were easily recognized. Because they are heavily forested, they appear dark on channels 4 & 5, and their appearance on channels 6 & 7 was due probably to a low sun angle. Blue Mountain and the other fold mountains appeared as a single continuous bright line. The diabase ridge to the south had a much broader and dimpled appearance compared to the fold ridges. On channel 7 this area has a swirled appearance which may represent flow swirls from an intrusive center.

Lineaments

Joints, fracture traces and lineaments are three expressions of linear features at different scales. A joint is a fracture usually perpendicular to bedding which does not show any displacement. Joints commonly appear as patterns of intersecting sets on a scale of inches up to a thousand feet. Fracture traces are the linear surface expression

Table 12: Geologic Features Interpreted from Enlargements of the October 11 ERTS Image

Feature	Channels
Contrasting topographic areas that are emphasized by differences in tone and vegetation and define physiographic boundaries.	4, 5, 6, & 7
Broad areal patterns of consistent texture that seem to represent areas of similar lithologies. These areas are most readily discriminated by the change in texture at their boundaries. Vegetation tends to enhance the patterns.	4 & 5 (mainly)
Linear features (lineaments) trending north-northwest that transect through the Great Valley and other physiographic provinces.	4, 5, 6, & 7
Linear features that parallel the strike direction in the Great Valley. These appear as lines on the images in contrast to merely an alignment of features. These features appear to correspond to lithologic boundaries or fault traces.	6 & 7
Anamalous areas of high reflectance. These areas may indicate water-saturated soils, but have no apparent geologic affinity.	6 & 7

of joints, or zones of joint concentration, as seen on the ground surface or from low-level aerial photography; they are on a scale of a thousand feet to a mile. Lineaments are linear features from one to several hundred miles in length that are discernible from aerial photography or small scale maps. They are recognized by the linear alignment of a series of discontinuous features. These features seem to be related to the regional tectonic pattern; their intensity and points of intersection have a significant effect on ground-water movement.

Examination of ERTS-1 images reveals many lineaments at all scales that transgress not only physiographic provinces but also rocks as old as the Precambrian and as young as the Triassic. Sixty lineaments were plotted directly on the photographic enlargements.

In channels 6 & 7 three sets of characteristic directions for the lineaments were observed. In the eastern section of the Great Valley around Lebanon, the dominant direction was N 10°E. From the Susquehanna River westward, two intersecting sets of lineament patterns appeared, one heading approximately N 15°W, the other N 70°W. In channels 4 & 5, besides the N 10°E, N 15°W, and N 70°W, a N 45°W direction was also apparent.

Other Linear Features

A dark band striking west approximately bisects the Great Valley. It extends westward from east of Lebanon, southwest to Harrisburg, crosses the Susquehanna River and terminates in a "Y" just south of the Conodoquinet Creek, a total distance of about 35 miles. This feature differs from the lineaments because it is not an alignment of unrelated objects, but actually appears as a dark continuous line, particularly on channel 7. This line corresponds geometrically to the carbonate-shale boundary in the middle of the Lebanon Valley sequence, an interpretation which is supported by the differences in texture and tone on either side of this linear feature. Closer analysis from ground truth and U2 data complicates this apparently simple explanation. A major east-west artery, Route 422, with a string of houses and small villages and towns coincides with this line. A railroad also parallels this highway. West of Annville, a series of elongated limestone quarries falls in this linear zone. On the U2 infrared imagery these quarries are shown as distinct black lines, and a stereoscopic examination reveals an escarpment, just north of the linear feature. This difference in relief can be explained by the relative erosional resistance of the shales compared to the carbonates. Because the escarpment lies to the north, a continuous shadow of the escarpment is not recorded on the images.

The system of faults is complex. In the vicinity of Annville, fault contacts appear as straight lines, indicating steeply dipping fault planes. To the west, where allocthonous carbonates and the autocthonous carbonates units overlap, the fault trace is highly curved and complex, indicating inclined fault planes. Thus there are two areas of carbonate lithology and two areas of shale lithology that should be detected on the image. A dark linear feature is visible in the U2 infrared imagery which corresponds on a topographic map to a low ridge known as Chambers Hill. The reasons for this dark response along the fault trace vary. In places the linear pattern is only an expression of cultural features on the ground surface, e.g., the quarries or the highway. Bedrock control is expressed in its westward extension through Chambers Hill and across the Susquehanna River.

One of the major thrust faults recognized on geologic maps of this area is the Yellow Beeches. This fault is exposed along the edge of Chambers Hill and extends northward into the Martinsburg formation. On the ground the fault trace in the Martinsburg formation appears as a "distinct textural break and a possible lithologic change running approximately through the middle of the Martinsburg belt with more disordered structures to the south."[1] Such a change in texture is visible on the channel 7 ERTS-1 image, near Harpers, where the tonal pattern changes across a straight boundary. A change in texture is also visible on the infrared images of the U2 underflight.

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[1]MacLachlan, D. B. and Root, S. I. (1966) Comparative Tectonics and Stratigraphy of the Cumberland and Lebanon Valleys: Guidebook for the 31st Annual Field Conference of Pa. Geologists, Pa. Topo. & Geol. Survey, p. 78-79.

High Reflectance Areas

Several anomalous areas of high reflectance were noted on channel 7 imagery near the town of Hershey. A few miles to the south, the diabase ridge separates into two arms and their pattern on channel 7 appears swirled. Whether these anomalous areas are related to the diabase or are merely artifacts of the image is unknown at this time.

Conclusions

Several conclusions can be drawn from the examination of enlargements of ERTS-1 images of the Great Valley:

1. Geologic features that are apparent as gross changes on topography and vegetation are easily recognized. Such features readily define physiographic provinces.

2. Geologic features that are expressed as escarpments or differences in relief are identifiable subject to interpretation.

3. Primary geologic structures are not visible unless they are separated by a distinct topography or tonal pattern.

4. A series of linear features -- tenatively defined as lineaments -- are readily visible at all scales.

ENVIRONMENTAL QUALITY

Coal refuse in the anthracite mining areas of Pennsylvania has been effectively mapped from ERTS-1 data by Thompson and Borden. Alexander and Dein have mapped strip mines and detected the effects of acid mine drainage waters from ERTS scenes. Damage to vegetation by air pollution and by insects is being studied by Pennypacker and Fritz. The groundwork for a study of the environmental effects of atomic power plants has been laid by Alexander and Scanlin. It is expected that several of these plants will come into operation in the next year and monitoring of their effects can be begun.

MAPPING OF ANTHRACITE REFUSE

D. N. Thompson and F. Y. Borden

One of the most serious land reclamation problems facing Pennsylvania and other coal-producing areas is the accumulation of wastes from coal mining and processing. After separation of the marketable coal from the slate, shale, and low-grade coal, these coarse-textured wastes have most often been simply piled in the nearest accessible place, creating virtual mountains of barren black refuse. Finer-textured material is transported in hydraulic suspension and accumulated in large settling basins. Conspicuous in both size and ugliness, such refuse piles contribute both silt and acid pollution to streams. Some have caught fire, producing sulfur dioxide air pollution; blowing silt from settling basins is also a locally severe problem. These difficulties are compounded by the fact that most of the waste accumulations are either within or very close to towns or cities.

Although the coal waste is a potentially valuable resource and much of it may eventually be used, the problems it creates demand more immediate solution. Effective reclamation programs are likely to involve reshaping of the piles, treatment to ameliorate adverse chemical and physical conditions, and establishment of vegetative cover. Planning and implementation of such programs will require the development and periodic updating of inventories of the number, extent, and location of areas in need of reclamation. Because such inventories would be needed on a regional scale and because of the need for periodic updating, it was felt that ERTS-1 multispectral scanner (MSS) data would be an ideal source of the needed information. A study of the feasibility of such an applied use of ERTS-1 data is now in progress.

Site Selection

An area including the southern and middle fields of the Anthracite Coal Region of eastern Pennsylvania (Figure 44) was chosen as representative of those areas most seriously affected by mining. The anthracite

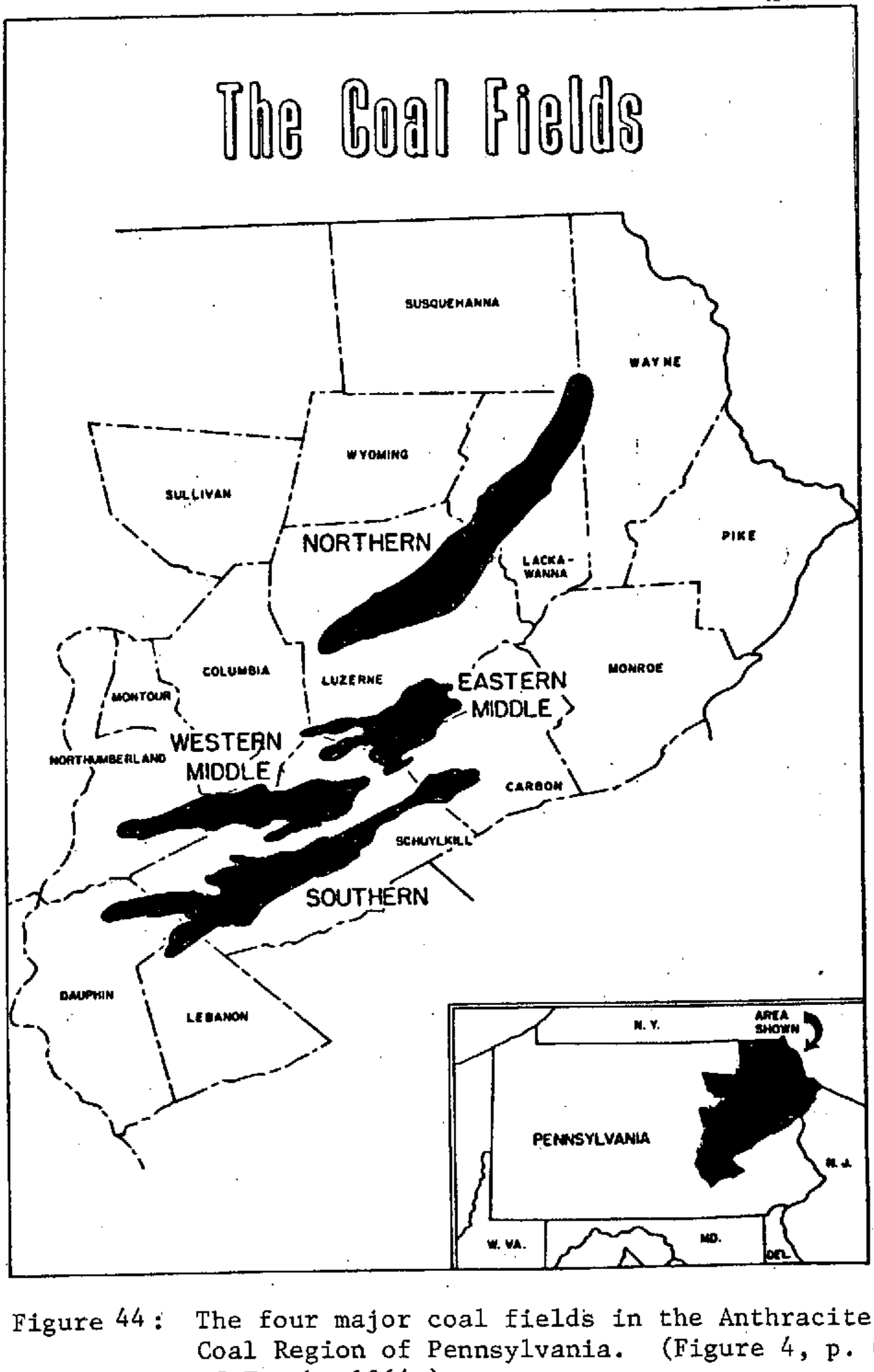

Figure 44: The four major coal fields in the Anthracite Coal Region of Pennsylvania. (Figure 4, p. 6, of Frank, 1964.)

coal fields are relatively compact areas with well-defined boundaries; they have been the subject of several studies that were expected to be helpful in the verification of our results. All data analysis has been by computer processing of digital MSS data using the active program package developed by ORSER. Thus far, data from only a single scene have been utilized, that of October 11, 1972 (scene number 1080-15185).

Preliminary Investigation

For the initial phase of the investigation, the eastern tip of the Southern Anthracite Field was selected for intensive study. This relatively small area, shown as Area 1 in Figure 45 , is bounded by mountain ridges and includes the coal-mining towns of Nesquehoning, Summit Hill, Lansford, Coaldale, and Tamaqua. All of these towns have locally extensive refuse accumulations and substantial segments of the surrounding land have been strip-mined.

Procedure

The first step in analysis was production of an intensity map using the NMAP program[1], which maps the total reflectance recorded in the four channels on the data tape. After adjustment of the program parameters, this map clearly delineated the mountain ridges and the Lehigh River valley, permitting accurate orientation with respect to features seen on the USGS 7 1/2 minute topographic maps. Additional digital maps were then produced using the UMAP program, which identifies areas of comparative local uniformity of spectral response. By inspection of these uniformity maps in conjunction with both the intensity maps and the topographic maps, initial training areas for determination of spectral signatures were selected. These areas were thought to represent reservoirs, coal refuse accumulations, silt basins, towns, strip-mines, and several vegetation types. Since no underflight data were available, few targets could be identified unequivocally and some guesswork was involved.

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[1]Program descriptions may be found in ORSER-SSEL Technical Report 10-73.

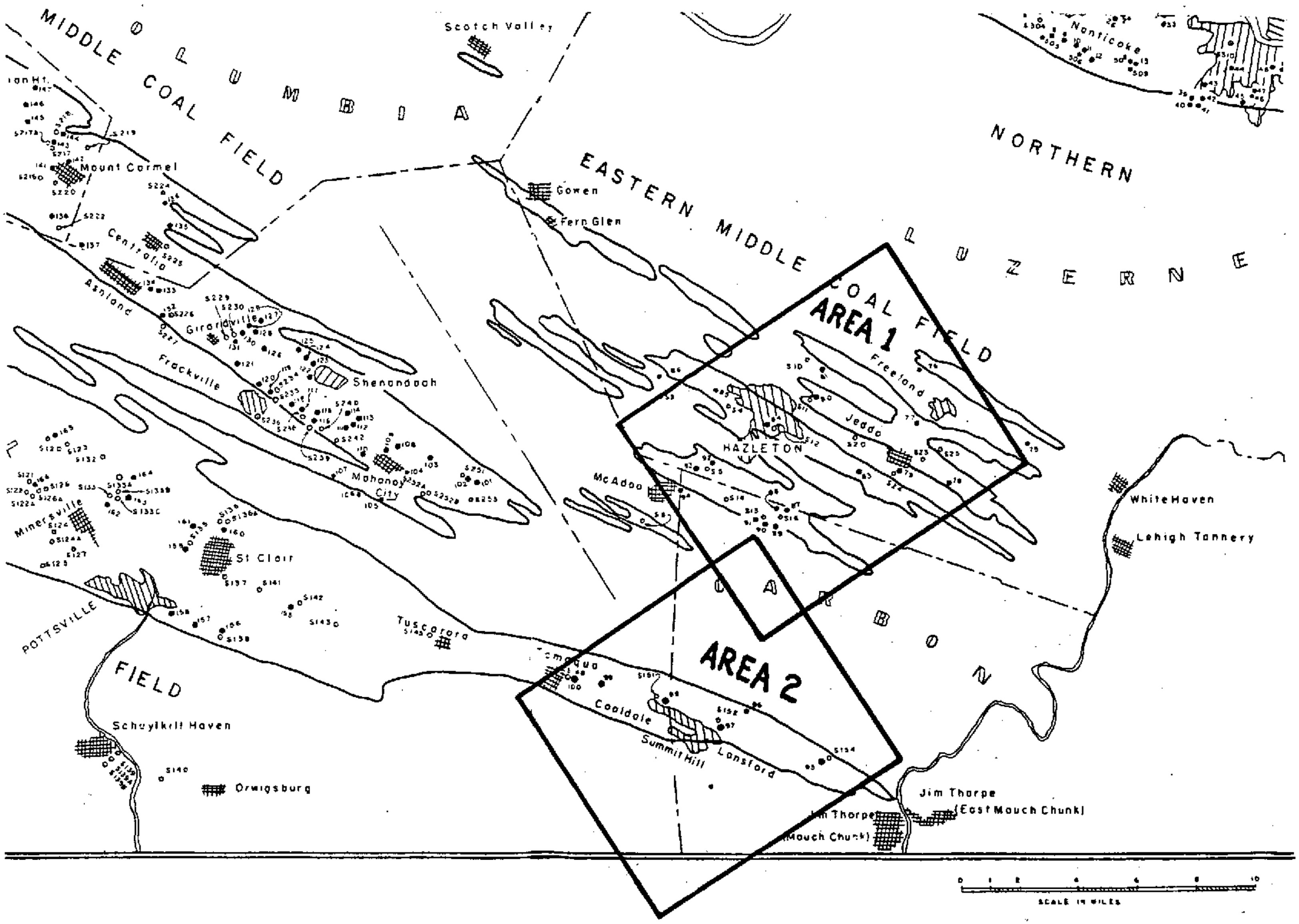

Figure 45: The two areas of preliminary investigation. (Shown on a base map from Peters, Spicer, and Lovell, 1968, p. 38.)

Using these signatures, the first trial classification maps were produced. The euclidean distance classifier called DCLASS treats each data point or category-defining spectral signature as a point in four-dimensional space. Each data point is assigned to that category for which the euclidean distance between the points is minimum, providing the distance is less than some specified critical value. A different critical value was specified for each category based on its minimum distance from any other category with a different mapping symbol. Without underflight coverage, known target areas could not be defined by photointerpretation. Most additional category-defining signatures were therefore developed using a cluster analysis algorithm (the DCLUS program) for small areas of interest. The categories thus defined were identified by inference from the pattern of their spectral response and by reference to the topographic maps. A profusion of signatures was developed in this manner and then reduced to manageable proportions by grouping those with very small calculated distances of separation. Signatures so determined were added to the original classification categories and additional digital maps were produced. The foregoing procedure was reiterated several times until a reasonably satisfactory map of the area was obtained. Particular importance was placed on the correct mapping of the coal refuse and silt.

The study was then extended to the second area shown in Figure 45, which includes the communities of Hazleton, McAdoo, and Freeland, as well as vast deposits of coal refuse. Using the same set of categories, with signatures based on targets in Area 1, digital maps of Area 2 were obtained.

Results

The classification map of Area 1 is shown in Figure 46. (It should be noted that although the working map was in digital form, the map displayed in this figure, and those following, has been plotted from the digital map using the LMAP program. This program corrects for the line and element distortion inherent in the digital output.) All known coal refuse piles and silt basins, as determined from topographic maps and from previous studies (Peters, Spicer, and Lovell, 1968; Frank, 1964),

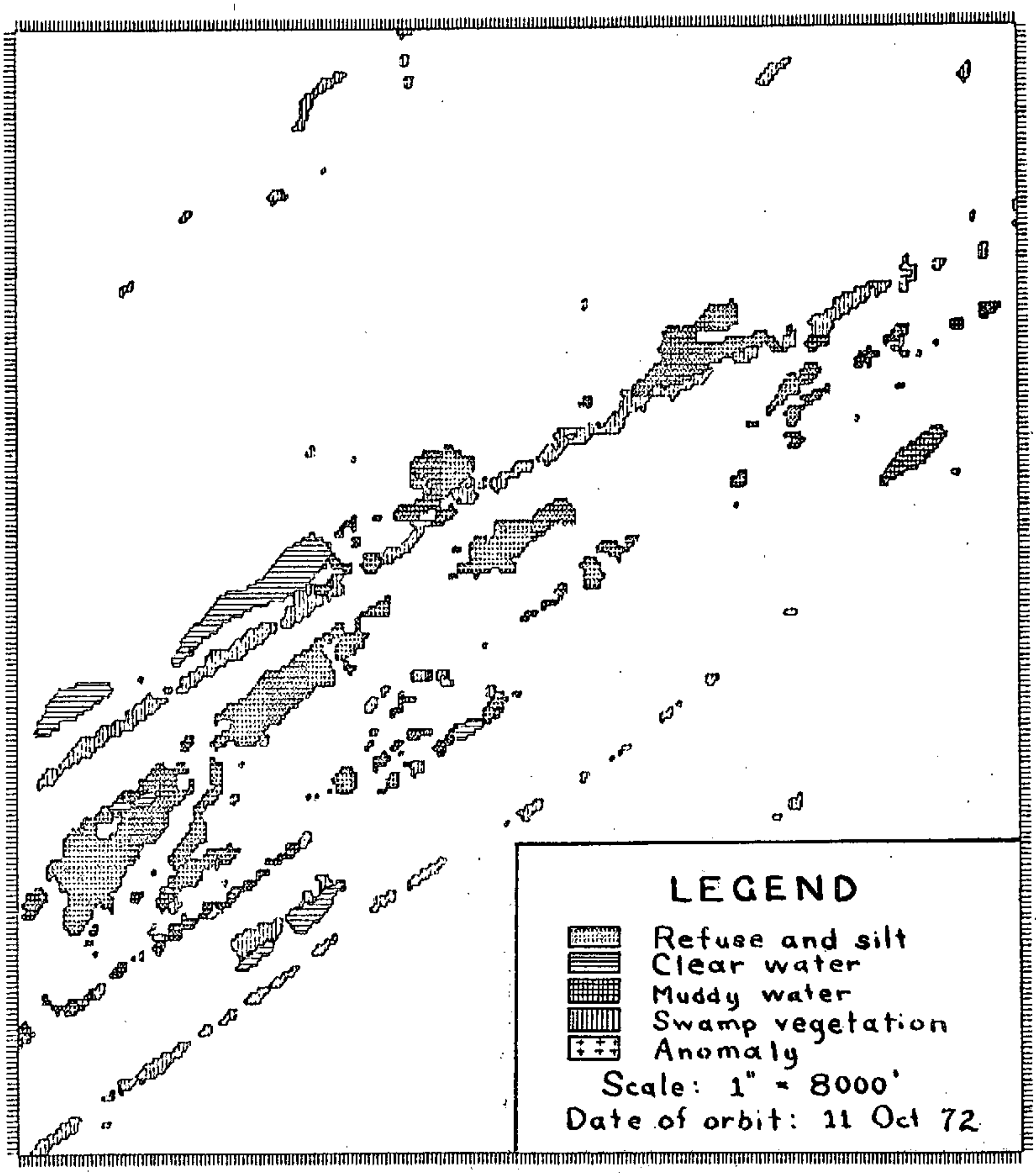

Figure 46 : Computer map generated from ERTS-1 data, showing coal refuse accumulations in the east end of the Southern Anthracite Field.

were mapped as either refuse or silt. There was some confusion between these two materials since they are similar in composition and color, differing primarily in texture. Confusion also occurred where the nearly black carboniferous rocks associated with the coal measures have been exposed by strip-mining. Such strip-mine spoil, being the same geologic material as most of the coal refuse, has roughly the same pattern of reflectance. Consequently, some areas of unreclaimed black strip-mine spoil were mapped incorrectly as coal refuse. Although unfortunate, this consequence may not be serious, since the same kinds of environmental and reclamation problems are involved in either case. One lake, near the east-central edge of Figure 46, was first identified as coal refuse, but seemed anomalous because of its location on the opposite side of a ridge from any other evidence of mining. Because its spectral signature, as determined by cluster analysis, was intermediate between those of coal refuse and water, it was tentatively called muddy water. Although no impoundment showed on the topographic map, subsequent on-the-ground inspection confirmed the existence of a newly constructed dam and lake. Other small water bodies that showed on the digital maps, but not on the topographic maps, were determined to be water-filled abandoned strip-mine pits.

A computer-generated map of Area 2 is shown in Figure 47. The results were similar to those from Area 1, with all known refuse piles and silt basins again mapped successfully. Water bodies were easily identified, including several more not shown on the topographic maps. All towns and cities in both areas were also mapped correctly and four-land highways could be discerned where they traverse forested areas. The problem of some strip-mine spoils being mapped as coal refuse persisted, although its true severity cannot be evaluated until underflight photographic coverage of the area is available. The only other major shortcoming in this phase of the analysis was a three-way confusion among some strip-mines, towns, and agricultural areas. As previously stated, the towns themselves were mapped almost entirely correctly. However, some strip-mines and much farmland were also mapped as towns. The inverse of this incorrect classification is not a problem, as strip-mine and vegetation symbols rarely occurred in anomalous places.

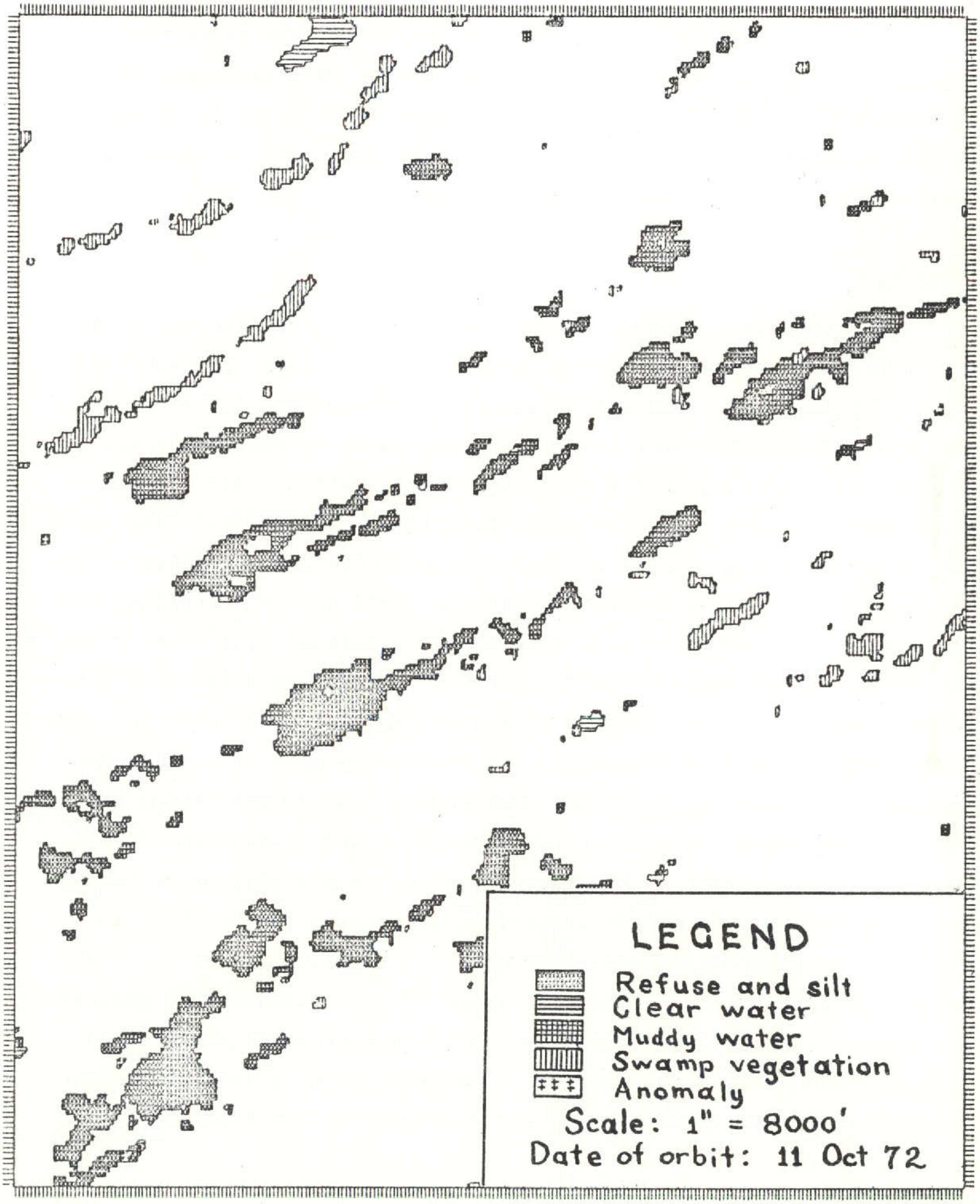

Figure 47 : Computer map generated from ERTS-1 data, showing coal refuse accumulations in the eastern end of the Eastern Middle Anthracite Field.

Application

The basic intent of the application phase of this study was to produce working maps of the location and extent of coal refuse and silt accumulations in the Middle and Southern Anthracite Fields. Such maps should be useful to mine inspectors, land reclamation and water pollution control personnel, and the mining industry.

Procedure

The study area, as shown on the map of the Anthracite Region in Figure 48 , was subdivided into 27 mapping blocks; each approximately 7 by 8.5 miles. The size was chosen for convenience: it kept the computer printout for each block small enough to handle easily and to reduce to a convenient scale for publication. Digital maps of each block were produced using the same classifier and, at first, the same set of categories as in the preliminary investigation. Because of the large area involved, substantial portions could not be classified and there were many seemingly anomalous classifications. The cluster analysis procedure was employed in these cases to identify additional categories, which were then used in subsequent mapping. In addition, several signatures obtained in a study of the Harrisburg area (see "Land Use Mapping" by Borden, et al., elsewhere in this report) were added to the list of categories. This area overlaps the southwestern tip of the coal region study area. The current list of categories, presented in Table 13, includes 59 distinct spectral signatures representing 13 different mapping categories. Representative spectral patterns for several categories are plotted in Figure 49. As the set of signatures was expanded and refined, additional maps were produced and features such as towns, lakes and reservoirs, mountain ridges, and coal refuse accumulations were identified by correlation with the topographic maps.

Results

The principal result, to date, of the application phase of this study was a set of 27 character maps, one for each of the 27 mapping blocks shown in Figure 48. A line map (generated from the digital map

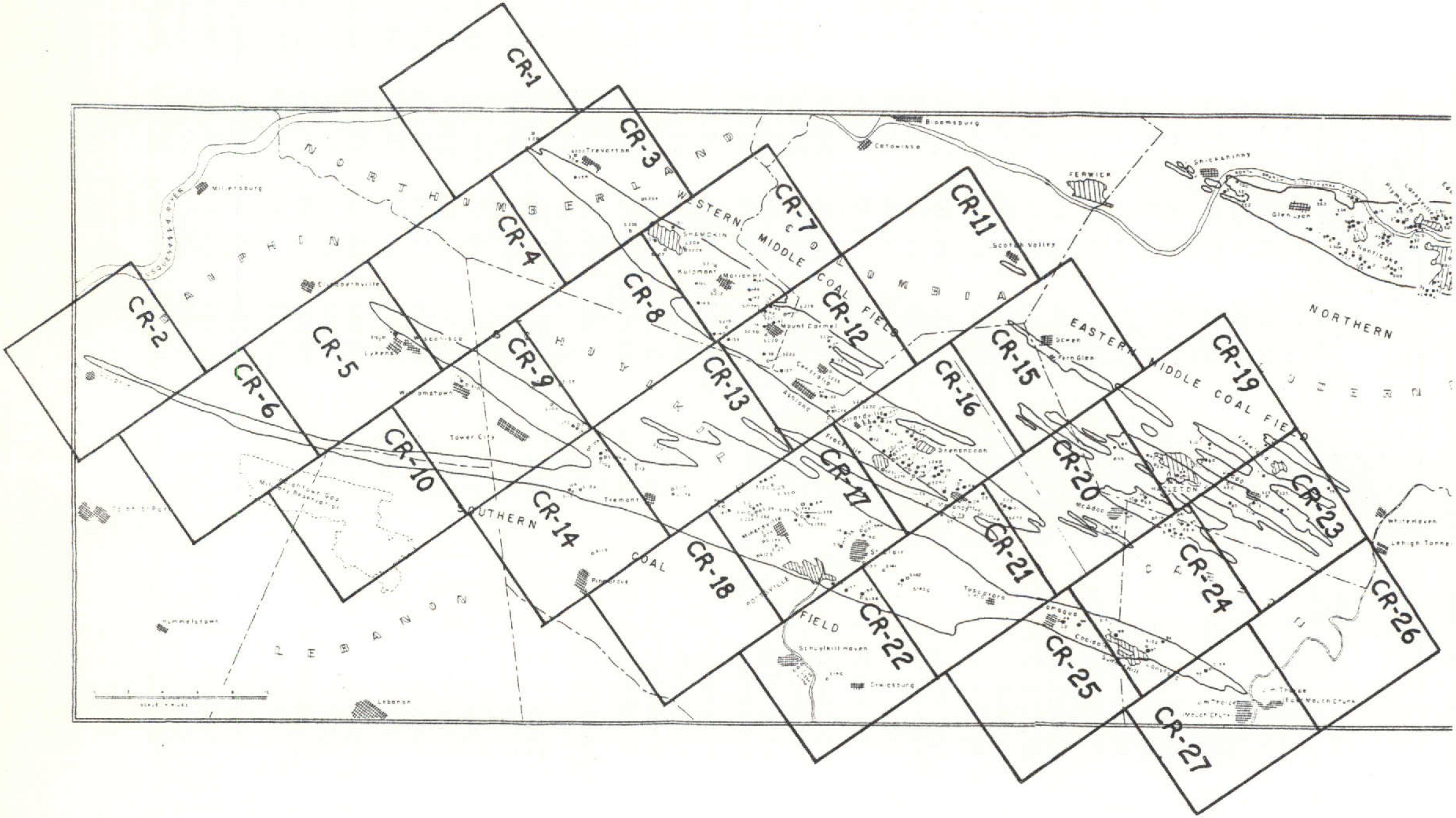

Figure 48: Mapping blocks used in the application phase of the study.(Shown on a base map from Peters, Spicer, and Lovell, 1968, p. 38.)

Table 13: Categories and Spectral Signatures for the Anthracite Area

Category Number	Category Name	Classifying Limit	SPECTRAL SIGNATURE Channels 1	2	3	4
1	CLEAR WATER	6.7	16.79	7.57	4.79	0.69
2	TURBID WATER	5.5	16.40	8.16	5.87	1.42
3	RIVER WATER 1	2.8	16.36	8.63	8.96	3.43
4	MUDDY WATER 1	3.3	20.12	15.67	10.10	1.98
5	RIVER WATER	4.5	18.31	9.90	6.03	0.89
6	MUDDY WATER 2	1.6	18.76	10.38	8.33	2.86
7	MUDDY WATER 3	1.3	19.08	11.92	11.08	3.92
8	MUDDY WATER 4	5.7	23.85	14.23	7.88	1.54
9	REFUSE 1	3.4	20.88	14.43	12.34	4.42
10	REFUSE 2	3.2	20.23	13.39	13.32	5.26
11	REFUSE 3	4.7	21.77	15.59	14.73	5.84
12	REFUSE 4	1.3	19.73	12.99	11.04	3.66
13	REFUSE 5	2.1	24.37	19.50	17.11	6.49
14	SILT 1	1.6	18.49	10.79	9.79	3.26
15	SILT 2	2.8	16.50	9.58	11.33	4.58
16	STRIPMINE 1	2.1	24.44	19.50	18.80	7.69
17	STRIPMINE 2	3.1	29.20	26.66	24.92	9.92
18	STRIPMINE 3	3.2	26.10	22.82	24.55	10.79
19	STRIPMINE 4	3.6	32.62	31.46	31.70	14.77
20	STRIPMINE 5	3.7	30.58	29.42	28.33	11.65
21	STRIPMINE 6	3.5	21.02	15.47	18.47	8.54
22	INDUSTRY 1	3.1	28.75	24.50	22.92	9.00
23	INDUSTRY 2	3.2	26.97	21.87	20.70	8.74
24	INDUSTRY 3	12.0	42.00	38.00	30.33	11.33
25	BARE SOIL	15.2	36.00	41.33	42.50	17.00
26	TOWN 1	3.6	33.21	28.67	30.12	13.32
27	TOWN 2	3.2	25.23	19.48	21.46	9.70
28	TOWN 3	3.2	27.57	22.38	26.62	12.69
29	TOWN 4	3.7	24.56	20.51	27.33	14.08
30	TOWN 5	4.0	24.50	19.26	23.74	11.42
31	TOWN 6	3.9	24.05	18.97	26.45	13.61
32	TOWN 7	1.8	21.26	13.78	26.08	14.70
33	TOWN 8	3.3	24.81	18.08	27.73	15.00
34	TOWN 9	3.2	30.14	27.14	37.14	19.00
35	TOWN 10	3.5	26.40	21.80	28.20	13.90
36	ROAD 1	5.3	28.82	25.45	30.73	15.32
37	ROAD 2	3.5	26.50	23.18	30.64	16.02
38	ROAD 3	4.7	27.42	23.47	31.68	16.84
39	BRUSH 1	3.3	25.08	19.77	30.19	16.27
40	BRUSH 2	5.0	24.41	19.62	32.64	18.50

(Continued)

Table 13 (Continued)

Category Number	Category Name	Classifying Limit	SPECTRAL SIGNATURE Channels 1	2	3	4
41	BRUSH 3	4.8	22.44	20.11	30.56	17.33
42	BRUSH 4	3.6	23.14	18.97	30.06	16.97
43	VEGETATION 1	2.5	20.42	15.12	31.80	18.99
44	VEGETATION 2	4.8	19.61	15.12	29.62	17.86
45	VEGETATION 3	1.8	19.65	14.01	25.43	14.25
46	VEGETATION 4	3.5	21.46	16.85	27.62	15.31
47	VEGETATION 5	3.8	18.14	12.81	23.86	13.81
48	VEGETATION 6	2.4	19.34	12.46	26.48	15.33
49	VEGETATION 7	2.2	20.52	12.96	27.31	16.11
50	VEGETATION 8	3.9	19.18	17.00	25.27	14.27
51	VEGETATION 9	2.5	20.96	16.48	33.41	20.20
52	VEGETATION 10	5.7	20.93	15.99	36.47	22.17
53	VEGETATION 11	9.5	22.12	17.97	39.72	24.19
54	VEGETATION 12	9.0	19.92	13.44	38.87	24.29
55	VEGETATION 13	3.2	27.81	25.14	36.09	19.12
56	VEGETATION 14	3.5	20.15	14.43	20.83	10.69
57	VEGETATION 15	4.5	18.27	12.05	18.64	9.52
58	SWAMP 1	3.8	18.39	12.72	20.56	11.94
59	SWAMP 2	3.6	18.44	10.50	13.59	6.53

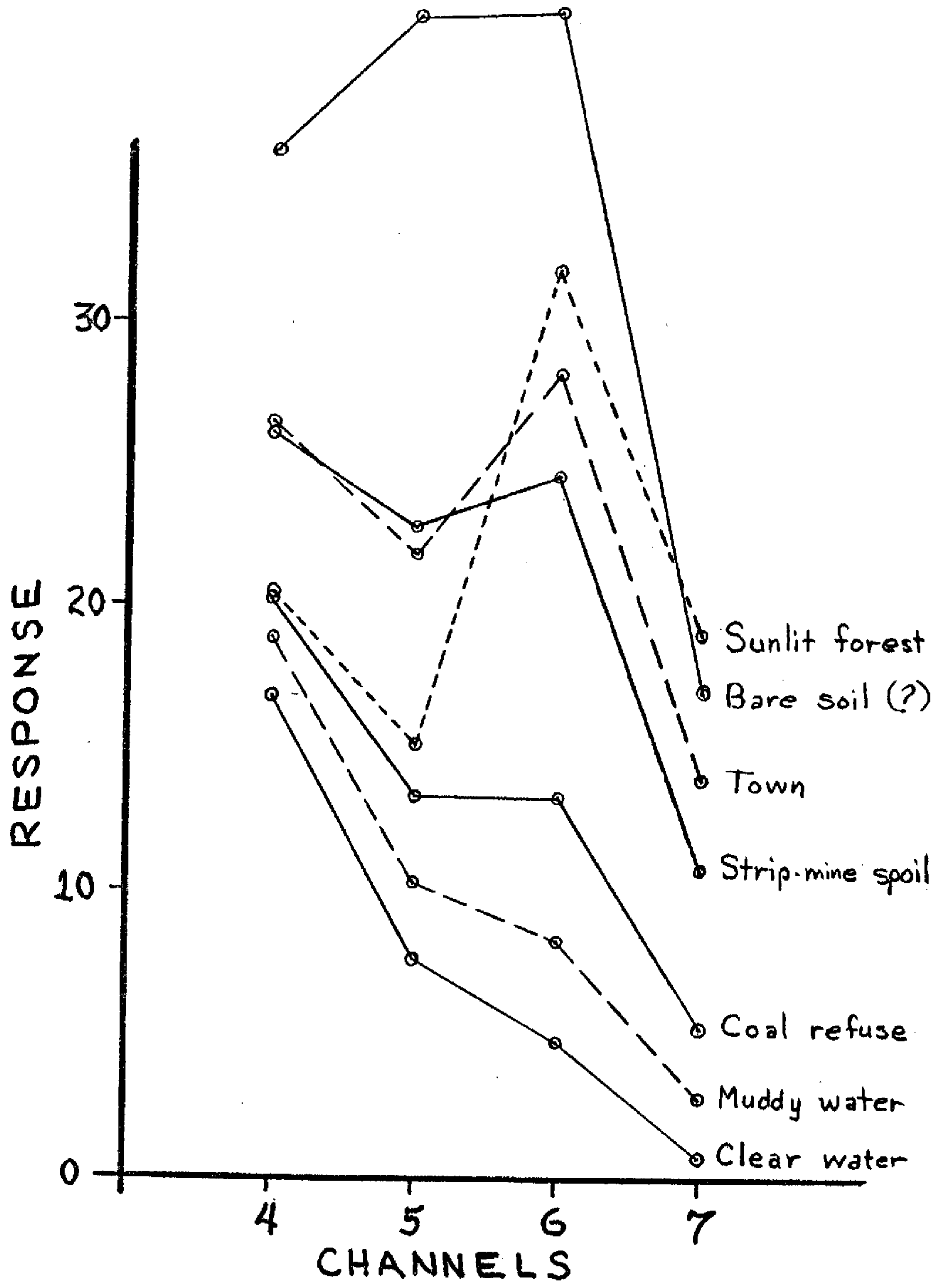

Figure 49: Representative spectral patterns for several major categories.

by the LMAP program) of block 16 is shown in Figure 50. For the sake of clarity, only the targets of major interest are shown, with vegetation included to outline the mountain ridges, for orientation. All other categories, although included in the classification, were left blank. It was found necessary to determine signatures for all targets of significant areal extent, even those of no great intrinsic importance; otherwise such targets might be incorrectly classified into one of the categories of particular interest.

Results throughout the 27 blocks are similar to those in the preliminary phase, although the additional signatures identified have produced significant improvements. All major towns and cities and major mountain ridges have been identified throughout the area, by comparison with 7 1/2-minute topographic maps. These have been noted on working copies of the digital maps, for orientation purposes, along with named lakes and reservoirs, and major four-lane highways. Together, these features make it possible to establish the location, with respect to known geographic points, of almost any area of interest on the digital maps. The study by Peters, Spicer, and Lovell (1968) includes a numbered listing of many of the refuse banks and silt basins in the Anthracite Region, but with apparent emphasis on those large enough to have potential commercial value. Point locations for these deposits are shown by number on the map on which Figure 48 is based. Many of these deposits do not show on the topographic maps, but all can be located on the digital maps we have produced. Additional deposits, not on the Peters, Spicer, and Lovell map, are shown on the digital maps. Some can be verified by reference to the topographic maps or to the study by Frank (1964); others cannot, and verification will depend on either on-site inspection or underflight photography. Difficulties have been encountered in attempts at on-site inspection due to lack of usable access roads and the problems of on-the-ground orientation in country so thoroughly devastated by mining activity. Although the locations of the coal refuse banks and silt basins are accurately established by the digital maps, it appears that in some instances their extent is exaggerated. This is probably the result of the previously discussed misclassification of some strip-mine spoils as refuse.

Figure 50 : Line map of block 16, showing targets of major interest. (Scale: 1 inch = 6000 ft)

With the widened area under investigation, it was found necessary to add additional signatures representing coal refuse and water in order to correct some misclassifications. The resultant greater range of spectral patterns in each of these categories, however, seems to have created a new problem. Many refuse and silt deposits now map partly as water, as is evident in Figure 50. In some cases, the presence of water in these locations can be verified from the topographic maps. Other instances, however, seem highly unlikely and it is probable that some refuse is being misclassified as water. It is felt that this problem can be resolved by further refinement of the set of characteristic signatures being used.

The three-way confusion among some strip-mines, towns, and agricultural areas encountered in the preliminary phase of this study, apparently has carried over into this second phase of the investigation. The problem has, however, been made less serious by selective elimination of those signatures that caused most confusion. Additional signatures representing urban and industrial areas were added and virtually all towns and cities now map solidly. A glance at the northwest portion of Figure 50, however, shows that the problem of some farmland mapping as towns persists, as does the mapping of some strip-mined land as towns. We feel that this primarily occurs on partially reforested strip-mines. The overall problem seems to be a consequence of the fact that all three categories are mosaics of vegetation and some dissimilar material: roofs and pavement in the case of towns, bare soil on farmland, and bare spoil on the strip-mines. It can be seen from the patterns shown in Figure 49 that taking the mean of the signatures for strip-mine spoil and sunlit forest would give a pattern very close to the town signature shown. This makes it unlikely that the problem can be completely resolved merely by further juggling of the characteristic signatures, although some improvement should be possible. It is likely that more refined techniques, such as merging data from several scenes of the same area, thereby making use of the temporal dimension, will lead to the solution of this problem.

Plans for Further Study

The most important effort in the continuation of this investigation will be verification of the results by comparison with underflight photography. Such data are not yet in hand, but flights have been requested. Further refinement of characteristic signatures is also planned. Major emphasis will be placed on exploitation of temporal changes, by merging data from several passes, in order to clarify the areas of confusion which have persisted through the study. Extension of this investigation to the Northern Anthracite Field, which includes the major cities of Scranton and Wilkes Barre, is also contemplated.

References

Frank, R. W. (1964) "A Guide for Screen and Cover Planting on Anthracite Mine-Spoil Areas," Research Paper NE-22, North East Forest Experiment Station, Forest Service, U.S. Department of Agriculture.

Peters, J. W., T. S. Spicer, and H. L. Lovell (1968) "A Survey of the Location, Magnitude, Characteristics, and Potential Uses of Pennsylvania Refuse," Special Research Report SR-67, Coal Research Office, The Pennsylvania State University.

ACID MINE DRAINAGE AND STRIP MINES

S. S. Alexander and J. L. Dein

The objective of this study is to assess the usefulness of ERTS-1 data, particularly multispectral scanner (MSS) data, for (1) monitoring the areal extent of stripping for coal, (2) detecting areas adversely affected by acid mine drainage, and (3) determining the effectiveness of reclamation and abatement procedures of stripped areas.

Procedure

An area along the West Branch of the Susquehanna River was chosen for the initial tests of the present study because it contains old stripped areas, new stripped areas, and numerous examples of acid mine drainage and related effects associated with the mining of bituminous coal in Pennsylvania. In addition, detailed ground-based geological and geophysical observations are available for a portion of the area near Kylertown. Aircraft underflight data from U2 and C130 flights are available for portions of the test area as well. These additional data provide important ground truth for evaluating the results obtained from digital processing of ERTS-1 multispectral scanner (MSS) tapes.

The MSS digital data tape for the September 6, 1972 pass over Pennsylvania (scene 1045-15240) was used for computer analysis of the area. Even though data from channel 6 were too poor to be usable, remarkably good results were obtained by using data from channels 4, 5, and 7 simultaneously to identify the characteristic features of stripmined areas and acid mine drainage effects.

The data processing consisted first of subsetting the original data tape to obtain a working digital tape covering a test area approximately 20 x 20 miles square located in Clearfield County, on the West Branch of the Susquehanna River, and extending south from Karthus to Philipsburg. Using a series of computer programs developed by Borden and other members of the ORSER staff (see ORSER-SSEL Technical Report 10-73), the test area tape was analyzed. First we located areas of both uniformity and high spatial contrast. These data alone defined the approximate boundaries of some stripped areas and showed distinctive features such as the river and Interstate 80. Unambiguous correlations with conventional map features could then be made. We found that application of the cluster analysis program developed by Turner (DCLUS) provided the best definition of stripped areas as well as other features in the test area. Basically, this program groups the data points into clusters each of which has a characteristic spectral response. No prior knowledge about the spectral response is required in this mode of operation, although predetermined training areas can be used as a program option. Not only was it possible to identify stripped areas unambiguously, but additional subclassifications were found to represent real differences in conditions, such as trenched areas, recent workings, and partly vegetated peripheral zones.

Several portions of the Susquehanna River itself were classified in the same category as strip mines. While surprising at first, this finding is now believed to represent refuse from nearby stripping that was dumped along the banks, in which case the classification was proper. Other areas along the river were placed in the same category as areas of dying or dead vegetation caused by acid mine drainage elsewhere in the test area. The inference that the Susquehanna River in this area is highly polluted by acid mine drainage is correct[1].

Especially detailed analysis was carried out for a small area around Kylertown. Subdivisions of the stripped areas that were distinctly classified in this test area were: trenched areas, backfills, and new stripping or areas cleared for future stripping operations. These subdivisions are shown in Figure 51. Areas of dying or dead vegetation caused by acid drainage from these mines were distinctly classified by cluster analysis and were spatially located correctly, including a very small one that has been studied extensively with ground-based methods.

A U2 photograph of the area covered by Figure 51 is shown in Figure 52, and Table 14 summarizes the cluster analysis results for the

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[1]Appalachian Regional Commission (1969) "Acid Mine Drainage in Appalachia," Appalachian Regional Commission, 1666 Connecticut Avenue, Washington, D. C. 20235.

Table 14 : Spectral Responses from Cluster Analysis of the Kylertown Area

Categories	Number	Symbol	Channels 4	5	7	Percent Area
Forests	1	-	23.43	14.29	24.42	68
Open fields	2	X	27.20	21.37	21.27	17
Trenches (strip mine)	3	+	30.50	25.72	11.00	4
Backfills (strip mine)	4	*	32.89	30.67	14.56	5
Affected by acid mine drainage	5	0	24.67	15.67	14.33	1
New stripping	6	=	38.00	41.00	19.00	1
Cleared for future stripping	7	Z	46.00	52.33	23.67	1

Table 15 : Distances of Separation for Categories from the Kylertown Area

Category number and symbol		1 (-)	2 (X)	3 (+)	4 (*)	5 (0)	6 (=)	7 (Z)
1	(-)	0.0	8.62	19.00	21.33	10.25	30.91	44.24
2	(X)	8.62	0.0	11.63	12.80	9.33	22.52	36.30
3	(+)	19.00	11.63	0.0	6.54	12.09	18.81	33.30
4	(*)	21.33	12.80	6.54	0.0	17.11	12.36	26.91
5	(0)	10.25	9.33	12.09	17.11	0.0	29.01	43.44
6	(=)	30.91	22.52	18.81	12.36	29.01	0.0	14.64
7	(Z)	44.24	36.30	33.30	26.91	43.44	14.64	0.0

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BLOCK SPECIFICATIONS
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    BEGINNING LINE 2137
       ENDING LINE 2170
 BEGINNING ELEMENT  635
    ENDING ELEMENT  690
    LINE INCREMENT    1
 ELEMENT INCREMENT    1
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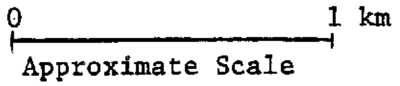

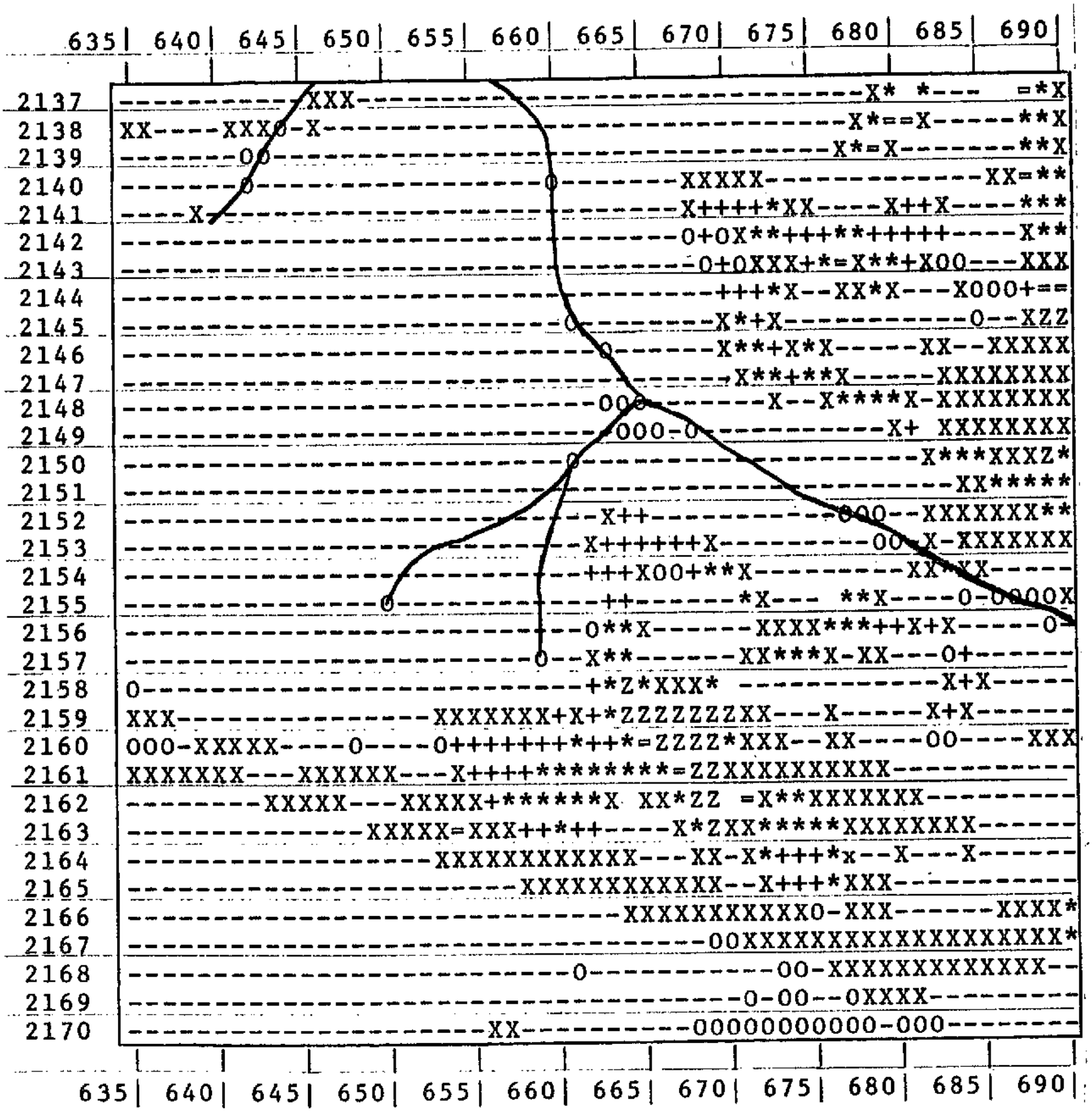

Figure 51: Classification map for the Kylertown area. Symbols are defined in Table 14.

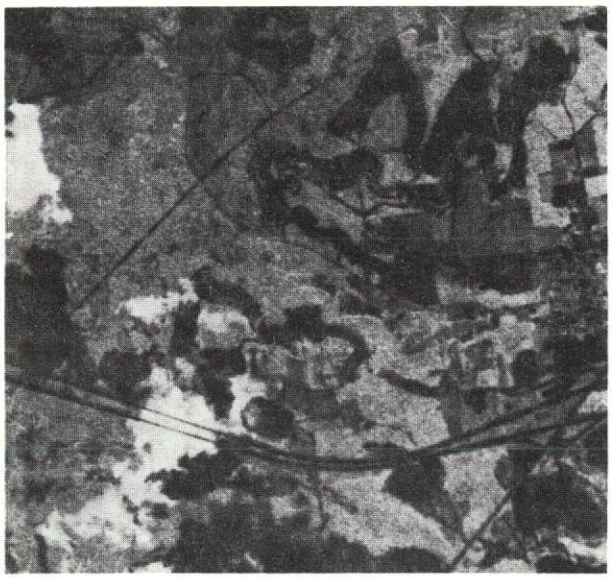

Figure 52: U2 photograph of the Kylertown test area. (Flight 72-094, sensor 14, frame 72511) Route 80 can be seen crossing the lower portion of the scene.

area. From examining U2 and C130 underflight photography we were able to identify the categories of features found by the cluster analysis. These are listed in the first column of Table 14. The degree to which these categories are separated is indicated in Table 15, where the distances of separation among the clusters are given. The smaller the distance between two categories the more similar they are. For example the subclassifications 3 and 4 that differentiate trenched portions of stripped areas from backfills have a relatively small distance of separation and are generally similar in spectral response, as can be seen from the values on Table 15.

The digital processing used here has the further advantage that not only are features correctly classified but the total area affected by stripping can be routinely calculated from the estimates of the total area represented by each category output by the cluster analysis program. For example, we found that strip mines cover approximately 20 percent of the test area around the Susquehanna River and about 11 percent of the area around Kylertown. The last column of Table 14 gives the percentage area represented by each category for Kylertown.

The spectral response was found to be quite similar for all stripped areas within the test area. Presently we are using the characteristic spectral response of this area to classify adjacent areas with the objective of eventually mapping and classifying accurately the stripped areas of Pennsylvania and the areas affected by acid mine drainage. We also anticipate repeating the analysis of this area for different seasons to ascertain the optimum conditions for mapping acid mine drainage effects.

While visual examination of the ERTS-1 imagery reveals the location of the larger strip mines, it is not possible to distinguish visually the subclassifications and details found by the digital analysis described above. Areas affected by acid mine drainage cannot be discerned or identified by visual analysis of the ERTS imagery. Therefore, digital processing is required to extract adequate information on the details of strip mining and acid mine drainage.

In order to check the validity of the digital processing results for the Kylertown area, photographs from the C130 flights of July 1972 were analyzed; in particular the 9" x 9" visible color and color infrared frames (numbers 139 and 140 of Roll 39, and 150 and 151 of Roll 40, respectively) were studied. The features classified in Table 14 were distinct in these photographs. From analysis of the underflight images there is evidence of stress on vegetation associated with the areas designated in Table 14 as affected by acid mine drainage. This correlation of underflight evidence and digital classification is of particular importance because stress caused by acid mine drainage cannot be identified by visual analysis of ERTS-1 imagery. This vegetative stress was further confirmed by field checks in the Kylertown area. Both C130 and U2 underflight data were used to verify the spatial extent of the areas classified presently as stripped. There is considerable difference between the areas of stripping indicated on the USGS 7 1/2 minute quadrangle maps of 1959 and those from ERTS-1 digital analysis. Our results agree closely with the 1971 topographic maps of this area on which areas of recent stripping are included.

Conclusions

1. ERTS-1 MSS data can be used with appropriate digital processing programs to map the extent and type of stripping that exists at the present time, including subclassifications of each stripped area.

2. Based on the preliminary findings of this report, it appears feasible to use ERTS-1 data to monitor the extent and location of current strip mining activity for large regions and to evaluate the effectiveness of reclamation and pollution abatement procedures.

3. Surface areas affected by acid drainage from strip mines can be located and mapped effectively through careful digital processing of the ERTS-1 MSS data. They cannot be located from visual analysis of ERTS-1 imagery.

4. Temporal coverage of stripped areas spanning different seasons supplied by repeated ERTS-1 passes promises to provide even more powerful classification criteria because of the profound effects that strip mines and acid mine drainage have on vegetation.

MONITORING POWER PLANTS

S. S. Alexander and M. A. Scanlin

The objective of this task is to monitor the effects of power plants on the local environment and in particular to follow the temporal changes induced by the installation and activation of the nuclear power plant on Three-Mile Island in the Susquehanna River near Harrisburg, Pennsylvania.

Because of a delay in the activation of the Three-Mile Island nuclear facility only a limited amount of work was devoted to this task during the past year. However, we examined the ERTS-1 coverage and C130 underflight imagery at two altitudes (5000 and 15000 ft) for this area and found the installation to be easily identifiable at each altitude. These data provide information on the pre-activation initial conditions at different scales for Three-Mile Island and vicinity. Apart from the bare areas resulting from the construction of the plant and associated buildings, there are no discernible effects of the plant on the surrounding areas in this preactivation stage, as expected.

Because of the availability of repeated ERTS coverage during each season in this pre-activation period, it will be possible to monitor induced local and regional effects on the environment both spatially and temporally when the plant is put into production. Among the expected direct perturbations are increased cloud cover and fog, reduced flow in the Susquehanna River and higher temperatures locally and downstream from the plant. There will be induced effects on soil moisture content, vegetation, and possibly land use patterns in surrounding areas. Also, the ecology of stream life may be altered significantly around and downstream from the plant. We believe these effects can be detected and mapped both spatially and as a function of time from ERTS data. Analysis of the MSS digital data in particular will provide detailed (quantitative) changes in the spectral signatures of the area, including the river itself. Ultimately, the objective is to compare the environmental effects induced by conventional and nuclear power plants and the areal extent of these effects as a function of average power produced. These results will be useful in planning for future power production to achieve maximum output with minimal undesirable side effects.

AIR POLLUTION AND INSECT DAMAGE TO VEGETATION

S. P. Pennypacker and E. L. Fritz

The objective of this study is to utilize ERTS-1 data and photo-interpretive techniques to detect and monitor the occurrence and progression of air pollution damage and insect defoliation in vegetative areas. A model for detection and evaluation of damage to vegetation from air pollution and insects is being constructed, incorporating the use of ERTS-1 imagery, underflight photography, and field data. In the multi-stage design, damage detection would come from ERTS imagery, evaluation from underflight photography, and verification from field data.

At the time of this writing, cloud-free ERTS-1 coverage of eastern Pennsylvania was available from September 1972 through the beginning of April 1973. Although these scenes, covering the dormant season of late fall through early spring, have not provided data directly beneficial to the tasks of this investigation, preliminary study of them has revealed that black-and-white transparencies of channel 7 imagery and color composites from channels 4, 5 and 7, lend themselves to this investigation. Excellent delineation of relatively small surface features, both natural and man-made (ridge tops, streams, lakes, major highways, etc.) has been obtained through enlargement and projection of color composite transparencies. These enlargements (of scenes 1079-15131, 1080-15183, and 1080-15185) have revealed that feature delineation is superior to that obtained from corresponding enlarged black-and-white prints.

Air Pollution Damage

The initial test site for the pollution investigation is the area surrounding a zinc smelter at Palmerton, Pennsylvania. This site provides essentially a point source of pollution. Sulfur dioxide, emitted to the air from the smelter and from an adjacent paint factory, causes severe and consistent damage to vegetation in the vicinity. Local stable weather conditions are known to cause monthly fumigation of 0.2 to 0.5 ppm sulfur dioxide, levels which are sufficient to visibly affect vegetation. The severity of this damage will be classified by species during the 1973 growing season. Large scale underflight data will be used to determine the feasibility of using ERTS data to evaluate the extent of the effect of air pollution on vegetation. Both sets of imagery will be correlated with ground truth.

Annual damage is known to occur to a 15 acre white pine stand and to deciduous trees on a five mile stretch of ridge north of the source. If a model can be formulated to detect these areas, this model will later be tested in other areas within the State where conditions favorable for large scale fumigations are known to have occurred.

Insect Damage

The relatively small acreages severely affected by air pollutants, and the resultant difficulty of studying all but the largest of these on ERTS-1 imagery, has led to the expansion of the investigation to include areas affected by insect damage. Of major interest are areas which have been subject to gypsy moth, oak leaf roller, and oak leaf tier defoliation. The occurrence of epidemics caused by these insects is readily apparent from the geometric increase in affected acreage within the state of Pennsylvania. For example, damage by the gypsy moth over the last 27 years is shown below[1]:

Year	1945	1957	1968	1969	1970	1971	1972
No. of acres Affected	11	60	60	830	10,500	92,000	404,060

On Figure 53, the areas of gypsy moth infestation in 1972 have been divided into two classes of defoliation severity: moderate (30-60%) and heavy (60-100%). These areas have also been delineated on USGS 7 1/2 minute quadrangle maps. Oak leaf roller and oak leaf tier damage has been monitored in a manner similar to that of the gypsy moth (Figure54).

[1]Data from Report of James O. Nichols, Forest Pest Management Staff, Department of Environmental Resources, Harrisburg, Pennsylvania, 1973.

In Pennsylvania counties, areas of heavy infestation by these three agents range from an estimated 200 to 100,000 acres. It is highly probable that the change in vegetative surface characteristics of areas of this magnitude will be detectable on ERTS-1 imagery.

Enlargements of color composites of the study site during the 1973 growing season will be made as they become available. These will be compared to insect damage expected to occur during this season. Periodic plotting of affected areas, as predicted from ERTS data, onto maps which delineate between hardwood and softwood species composition, will facilitate observation of the location and progression of damage to foliage.

Studies reveal that two consecutive years of heavy defoliation (over 60% of foliage removed) will kill approximately 30 percent of an oak stand, and mortality will be approximately 60 percent after three years of heavy defoliation. However, after only two years of defoliation, food reserves in a tree may become critical and result in total mortality even though further defoliation may not occur. In contrast to hardwoods, a single year of complete defoliation of evergreens can, under certain conditions, result in mortality.

Monthly tabulation, by species composition, of area affected, severity class, and number of times each area or portion thereof was defoliated, provides the manager with an up-to-date summary of timber stand conditions. The delineation of the progression of epidemics with time will serve as documentation for incorporation into both state and private management practices of both agronomic and forest land. Such information will assist in the timing of chemical and biological control measures and can lead toward the possible alteration of present management plans to salvage affected areas of standing timber.

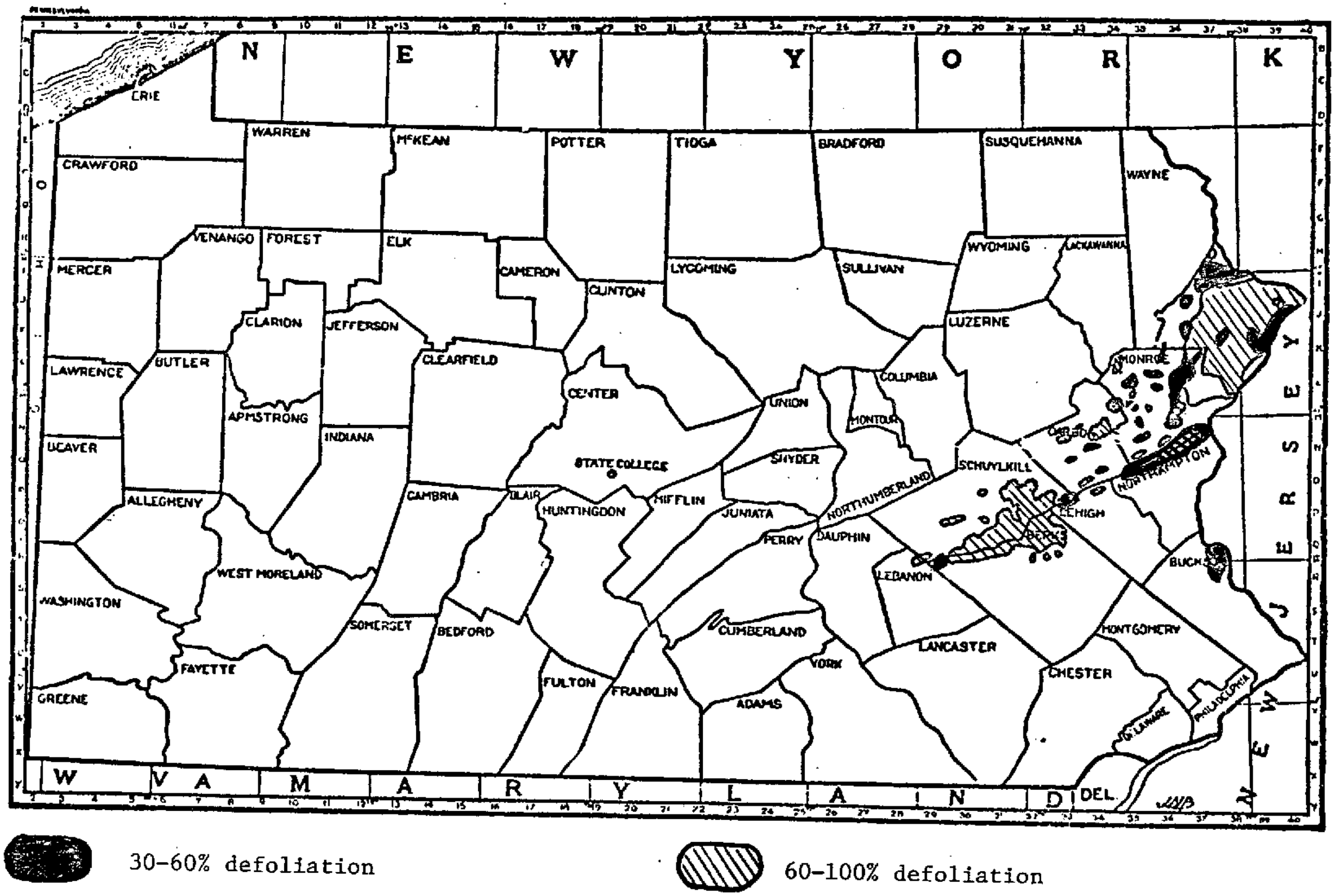

Figure 53: Gypsy Moth damage in Pennsylvania in 1972. (Aerial Survey by the Pennsylvania Department of Environmental Resources, Harrisburg.)

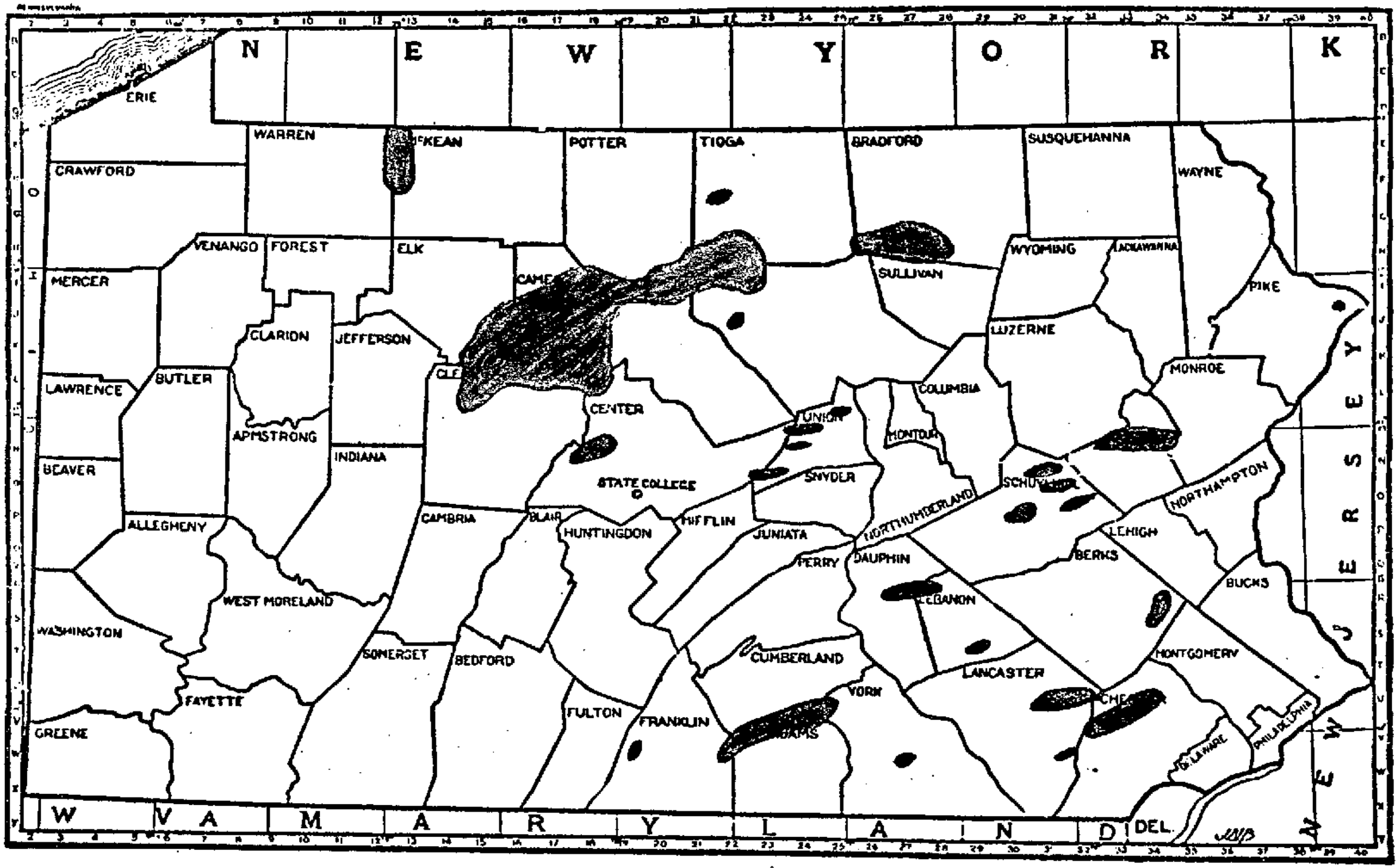

Figure 54: Oak Leaf Roller and Oak Leaf Tier damage in Pennsylvania in 1972. (Aerial survey by the Pennsylvania Department of Environmental Resources, Harrisburg.)

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DATA PROCESSING AND PATTERN RECOGNITION

Computer programs to handle digital data, and revisions of these, are constantly being developed. These are discussed by Borden, et al., in the task report on "Program Development and Revisions." The programs are described in detail in ORSER-SSEL Technical Report 10-73. ORSER has developed the "hybrid technique" of processing ERTS-type data. This technique involves the close correlation of ERTS-1 MSS digital output with underflight photography (especially U2 photography) for the positive definition of training areas for classifying programs. It is expected that use of the Bausch and Lomb Zoom Transferscope, recently ordered, will lead to further refinements of the hybrid technique. Analog to digital conversion and processing of MSS data on the hybrid computer has been studied by Rambert and McMurtry. Multistage sampling, temporal models, and techniques of mathematical ecology for spatial patterns will be developed during the second year of this investigation. With the assistance of the General Electric Company's GEMS system, machine-aided imagery analysis and graphic display techniques will be evaluated, commencing in October 1973.

DEVELOPMENT OF THE HYBRID APPROACH TO DATA PROCESSING

H. A. Weeden, F. Y. Borden, D. N. Applegate, and N. B. Bolling

In response to a request by MITRE Corporation[1], ORSER evaluated two approaches to ERTS-1 MSS data analysis: photointerpretation of imagery, and computer processing of digital tapes. Subsequently, ORSER combined these two methods, developing the hybrid approach to ERTS data processing. This method has been successfully applied in many of the research projects conducted by ORSER personnel in the past year. The development of the hybrid approach to data processing is discussed here.

A site consisting of 144 square miles surrounding Harrisburg, Pennsylvania, was chosen for study of land use categories. Initially, two separate research teams studied the two forms of ERTS-1 data, imagery and digital computer tapes. Weeden and Bolling concentrated their efforts on using photointerpretive techniques on ERTS imagery, while Borden and Applegate analyzed the digital data using only USGS 7 1/2 minute quadrangle maps as a reference. As the objective at this preliminary stage was to determine the extent to which these two different approaches might succeed individually in mapping land use, there was no interaction between the two teams during the first few weeks of the study.

Photointerpretation of ERTS-1 Imagery

The imagery used in the photointerpretation study was that of September 6, 1972, covering the Harrisburg area, namely image number 1045-15243 in the four channels of the multispectral scanner (MSS). This ERTS scene was chosen as the best representation of the study area available at the time. The photointerpretation was carried out independent of outside aid. There was no ground truth study of the test

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[1]ORSER performed this work under Mitre Purchase Order N35490, as directed by Edward A. Ward. For the sake of convenience, ORSER used the same test area to work out the combined techniques, although this phase of the project was not under the sponsorship of the Mitre Corporation.

area, no coordination with other researchers using computer programs, and no previous study of maps or aerial photos at larger scales. The intent was to determine what could be read directly from ERTS imagery alone. Although both interpreters had a traveler's acquaintance with the Harrisburg area, care was taken not to identify items by their geographic location. Graytone variations were recorded, but interpreted only where their shape provided interpretive clues.

The imagery was studied under the following conditions:

1. Direct inspection of the image on a light table under magnifications of 4.5X and 7X, using a direct viewing lens or one lens of an Old Delft stereoscope.

2. Projection of the image by means of a Visucom overhead projector, from 10 ft, onto a flat screen at a magnification of 4X.

3. Projection of the image onto a table by means of a single Kelsh Plotter projector, at a magnification of 4.5X.

4. Projection of a glossy positive 4X enlargement using a Saltzman projector, resulting in a further enlarged scale of 7.5X (or 2 miles to the inch).

The above systems were, as far as we know, the only ones available at The Pennsylvania State University at the time. Working at contact scale proved useless for documentation, although considerable detail could be observed with the hand lens. The overhead projector also could not be used, as the projected image could be viewed clearly only from a position of several feet from the screen. The Kelsh Plotter was second only to the Saltzman in usefulness. It permitted direct projection of the image onto a table, where features could be mapped as observed. However, only a very small portion of the image could be viewed at one time, making it difficult to determine significant graytone signatures and to maintain consistency in delineating them. Mapping by this method was, in addition, a very slow process. The Saltzman projector appeared to give the best overall image definition combined with rapid tracing of observed features. It's chief drawback was the necessity of using photographic prints rather than the images themselves, resulting in some loss of graytone resolution.

Positive glossy prints of the portion of the ERTS scene covering the test area were made for use in the Saltzman projector. Only a small portion of the site (approximately 36 square miles) was chosen for study, as this portion was considered to be sufficient to illustrate the problems involved and the results obtainable by photointerpretive techniques. The time involved in producing land use maps from these prints, using the Saltzman, varied from 1 to 2 1/2 hours, depending on the channel. Channel 5 took the longest, and channels 6 and 7 the shortest, time to map. The results were of such quality that it was not considered worthwhile to attempt to planimeter the areas for quantification of the land use categories. Table 16 summarizes these results. It can be seen that in only a few cases could a feature be uniquely determined by this technique, and in virtually no case could it be completely delineated. On no channel was it possible to unambiguously determine areas of suburban development and agriculture. A comparison of results from the four channels reveals widely differing assignments of areas to these two categories, as well as to the category of "forest." In several areas, on all channels, it was not possible to determine accurately the shoreline of the Susquehanna River. Only two orders of streams could be seen: the Susquehanna River and major streams entering it. A few lesser streams were seen on the original imagery by inspection with the hand lens. Subsequent discussion with other researchers indicated that better images are obtainable and somewhat greater detail can be mapped on these.

This study clearly revealed that photointerpretive techniques, when applied to ERTS imagery, are unsatisfactory as a single means of determining land use categories, for the following reasons:

1. It is not possible, by the means attempted here, to unambiguously delineate areas of land use categories or water quality.

2. Establishment of indices for land use categories requires planimetry of areas. Where areas cannot be clearly outlined their size cannot be accurately determined.

3. Up to 2 1/2 hours were spent in mapping a small portion of the study area in a single channel. Clearly, mapping an entire ERTS scene in all four channels would take a large amount of time with very limited useful results.

4. A brief inspection of U2 imagery (flown at 60,000 ft) of the same area indicates that some improvement of photointerpretive

Table 16 : Results of Photointerpretation of ERTS Imagery Using the Saltzman Projector

Land Use Category	Channel 4	Channel 5	Channel 6	Channel 7	Preferred Channel
Drainage	Incomplete. Islands obscured. Shorelines grade into forest.	Incomplete. Shorelines grade into forest.	Confused with urban.	Some confusion with urban.	Seven
Roads	Very incomplete.	Clearly defined where white. Unrealiable when parallel to scan lines. Many dark lines could be roads or drainage.	Rarely seen and poorly defined.	Rarely seen.	Five
Urban	Grades into suburban.	Confused with probable bare fields. Otherwise fairly distinct.	Minor confusion with suburban	Confused with drainage.	Five and six
Suburban	Not differentiable from urban. Confused with agriculture.	Not differentiable from agriculture.	Confused with agriculture.	Fair to poor distinction from both agriculture and urban.	All poor, due to confusion with agriculture.
Forest	Not differentiable from drainage and often confused with agriculture.	Some confusion with drainage.	Confused with agriculture.	Confused with agriculture.	Five

(Continued)

Table 16 (Continued)

Land Use Category	Channel 4	Channel 5	Channel 6	Channel 7	Preferred Channel
Agriculture	Confused with forest and often with suburban.	Not differentiable from suburban.	Confused with both forest and suburban.	Confused with forest and with portions of suburban.	All poor, due to confusion with forest and suburban.
Construction	Confused with established concrete areas (e.g., airport) and areas of erosion.	Confused with established areas of concrete and with urban.	Indistinct.	Not visible.	Four.
Erosion and siltation	Confused with construction.	Not visible.	Not visible.	Not visible.	Four.

techniques could be realized by using U2 photography to train the photo-interpreter to recognize ERTS signatures. This would, however, considerably increase the time requirements for a given area of investigation.

5. Better images are now available for the use with the Saltzman technique. These images are produced by photographic enhancement at the expense of radiometric fidelity. However, enhanced images are recommended when photointerpretive techniques are required for a "first look."

Digital Analysis of ERTS-1 Data

The data used in the digital analysis of the study area was from August 1, 1972, scene number 1009-15244. Cloud cover was inconsequential over the area of interest. All four MSS channels were used in data processing; however, channel 7 was of poor quality. Using an Ozalid print of the channel 7 image as a guide, two subsets of the full scene were put on two separate subset tapes, using the SUBSET program[1]. This program, in addition to selecting the subsets, reformats the data to be compatible with all of the analysis and mapping programs of the ORSER data processing system. The first subset was defined as scan lines 937 through 1150 and elements 2790 through 3010. The second subset consisted of lines 1051 through 1200 and elements 3010 through 3228. Both of the subsets came from the third tape of the four for the scene.

The first step in the analysis was the production of a brightness map of the area, using the NMAP program, for the purpose of locating patterns and targets in the area of interest. This initial output (and all subsequent computer map output) was compared with USGS 7 1/2 minute quadrangle maps of the area, printed in 1963 and 1969. A uniformity map was then produced, and five signature training areas were defined on this UMAP output. These areas were: river water, forest, railway yard, central urban, and an unknown target which was found to be similar to the forest target. The training areas were defined for the STATS program and the mean vectors (spectral signatures) and covariance matrices were computed.

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[1]For complete program descriptions, see ORSER-SSEL Technical Report 10-73.

Uniform areas could not be found for many targets. For example, clusters of uniform elements were either nonexistent or too small for reliable signatures for creek water. The cluster analysis program (DCLUS) was modified and used to estimate signatures for creek water, roofs (e.g., tops of large building complexes), and highways. The central urban and railroad signatures obtained with training areas were verified by cluster analysis. The two methods produced results in perfect agreement. The highway signature obtained by cluster analysis was found to be a great deal more general than for highways alone. By using the signature for classification and mapping large areas, it was found that suburban areas were very well mapped with the highway signature and it was therefore renamed.

After an initial set of signatures was obtained, trial maps of blocks of data in the subsets were made. A second stage of target and signature determination was begun on the basis of these maps. The areas which were unclassified were investigated and, by the use of the methods applied before, additional signatures and targets were identified. At this stage, training areas were allowed to include a lower level of uniformity. The number of observations and the number of subareas within the training area for each target were, therefore, substantially increased to overcome the effect of decreased uniformity. The 7 1/2 minute quadrangle maps were used in target identification to make sure that all subareas included in a training area were of the same target.

Having obtained these additional signatures, the whole area from both subsets was mapped. Only 10 to 15 percent of the area remained unclassified. The patterns of unclassified elements appeared to be related to non-urban land use, possibly agriculture. One of these areas by chance fell within the boundaries of the cluster analysis used for the determination of the creek signature. The cluster analysis had classified the area homogeneously and the pattern matched the pattern of the unclassified area on the large map. The signature for OPEN LAND, was taken from that run. Three Mile Island, on the Susquehanna River, is mapped on the 1963 Middletown 7 1/2 minute quadrangle sheet as open land. However, initial processing indicated that the area is now something other than open land, and a check of the underflight photography of the island revealed the construction of an atomic power plant. A cluster analysis was run on the island and surrounding water area, resulting in the signature BUILDING. This signature, in addition to yielding a classification for Three Mile Island, filled in substantial areas in the Harrisburg metropolitan district which had been previously unclassified. From the quadrangle maps these areas appeared to consist of heavy industry and warehouses. The final map was based on a set of thirteen signatures and only three percent of the total area remained unclassified. The full set of category information, with signatures, is given in Table 17.

The euclidean distances of separation of categories are given in Table 18. A critical distance of 10.0 was used for every class except RIVER WATER, which had a value of 15.0 assigned to it. In the classification scheme, an element was assigned to the class for which the euclidean distance from it to the class signature was smallest if the distance was smaller than the critical distance for the class. If the distance was greater than the critical distance, the classification would be attempted for the next nearest class, and so on. If the element could not be assigned to any class under these rules, it was unclassified. Consider RIVER WATER, for example. The distance of separation from each of the other categories is, in every case, greater than 15.0. Therefore, there is no chance of confusion between RIVER WATER and any other category according to the rules of classification. There are a few other categories for which the same is true, based on the critical value of 10.0. For most of the classes, however, there exist a few distances which indicate potential confusion. Consider classes 2 (RAIL) and 5 (URBAN) of Table 18. The distance of separation between these two classes is only 2.3. There is, therefore, a potential for confusion between the two classes.

Three other pairs of classes have small distances of separation which should be mentioned. In addition to the aforementioned problem with the RAIL signature, this signature also has a relatively small distance of separation from the CREEK signature. Whether confusion actually exists or not in classifying rail and creek targets can only be resolved by ground truth. It is possible that there might be enough

Table 17: Category Information for the Full Set of Signatures

Number	Name	Symbol	Limit	Ch 4	Ch 5	Ch 6	Ch 7	Count	Percent
1	FOREST 1		10.0	29.28	18.76	46.68	27.60	3655	8
2	RAIL		10.0	37.00	29.45	29.09	10.91	887	2
3	RIVER	W	15.0	33.18	22.48	17.76	4.78	2956	6
4	VEGETATION		10.0	31.78	21.61	41.06	22.00	1249	3
5	URBAN	*	10.0	36.13	28.25	29.71	12.58	1622	3
6	GRASS	–	10.0	32.83	22.83	43.79	22.50	6844	14
7	FOREST 2		10.0	28.25	18.21	49.54	29.82	5329	11
8	ROOF	V	10.0	52.50	55.00	56.00	22.00	130	0
9	SUBURB	#	10.0	38.74	31.88	48.01	23.88	11796	25
10	PAVEMENT	@	10.0	40.59	36.50	51.95	25.59	2738	6
11	CREEK		10.0	33.30	23.52	31.04	13.48	1119	2
12	OPEN LAND		10.0	33.40	22.74	61.00	35.23	5303	11
13	INDUSTRY	+	10.0	42.42	37.58	39.20	15.90	2241	5
	UNCLASSIFIED							1425	3

Table 18 : Distances of Separation for Mapping Categories

Categories	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0.0	27.6	37.2	8.8	25.5	8.0	3.8	44.4	16.7	21.8	22.0	17.2	26.8
2	27.6	0.0	15.1	18.8	2.3	20.3	31.3	41.7	23.1	28.3	7.7	40.8	14.9
3	37.2	15.1	0.0	29.0	15.7	31.5	41.0	56.5	37.4	43.1	15.9	52.9	29.9
4	8.8	18.8	29.0	0.0	16.7	3.2	12.5	42.0	14.3	20.8	13.4	24.0	20.2
5	25.5	2.3	15.7	16.7	0.0	18.4	29.2	42.0	22.0	27.4	5.7	39.1	15.1
6	8.0	20.3	31.5	3.2	18.4	0.0	11.4	39.6	11.7	18.0	15.6	21.4	19.3
7	3.8	31.3	41.0	12.5	29.2	11.4	0.0	45.2	18.3	22.6	25.7	14.4	29.6
8	44.4	41.7	56.5	42.0	42.0	39.6	45.2	0.0	28.1	22.7	45.3	40.1	26.9
9	16.7	23.1	37.4	14.3	22.0	11.7	18.3	28.1	0.0	6.6	22.3	20.2	13.7
10	21.8	28.3	43.1	20.8	27.4	18.0	22.6	22.7	6.6	0.0	28.4	20.4	16.2
11	22.0	7.7	15.9	13.4	5.7	15.6	25.7	45.3	22.3	28.4	0.0	37.0	18.8
12	17.2	40.8	52.9	24.0	39.1	21.4	14.4	40.1	20.2	20.4	37.0	0.0	33.9
13	26.8	14.9	29.9	20.2	15.1	19.3	29.6	26.9	13.7	16.2	18.8	33.9	0.0

sediment, low vegetation, and water in the yards to give a true response for the creek classification. The two other pairs of categories with small separation distances are CREEK with URBAN, and HIGHWAY with SUBURB. The reason for the similarity of CREEK and URBAN signatures is not known at this time. The similarity of the HIGHWAY and SUBURB signatures was not unexpected, because the initial highway signature was renamed SUBURB when it gave very good mapping results for suburban areas. The new highway signature was obtained later on and may indeed have also been based on targets very similar to those of the suburban signature. It seems, however, that the new highway signature is more related to parking lots and similar paved and unpaved areas than it is to the suburban signature. Actual highways are mapped by both symbols.

Some serious problems exist in naming the categories. Some of them are easily named correctly, such as RIVER WATER and FOREST. Little emphasis was put on the names of other categories because they were named only inferentially, with no direct means of being sure of the targets. It is not at all an easy matter to pick out vegetation signatures in ERTS data simply by looking at the signatures. It is even more difficult to identify other signatures. The quadrangle maps are of limited utility since they do not generally give the kind of information needed to identify a category except on an inferential basis. Ground truth or aerial photographs, such as used in identifying the construction on Three Mile Island, would have been very helpful in specifically identifying and naming the targets.

A small part of the DCLASS map is shown in Figure 55. The river and islands in the river are readily apparent. The central metropolitan area of Harrisburg, mapped with *'s, can be seen in the upper right portion of the figure. Heavy industrial and warehouse areas, mapped with +'s, can be seen adjoining the downtown area of Harrisburg. Across the river, the Camp Hill suburban area can be seen mapped with #'s. The @'s in Camp Hill possibly indicate parking lots or bare ground, and the -'s indicate parks, cemeteries, and similar green areas. A summary of the mapping results is included in Table 17. The percentage in each category is the relative acreage in the category. The count for each category is the actual number of elements classified in the category.

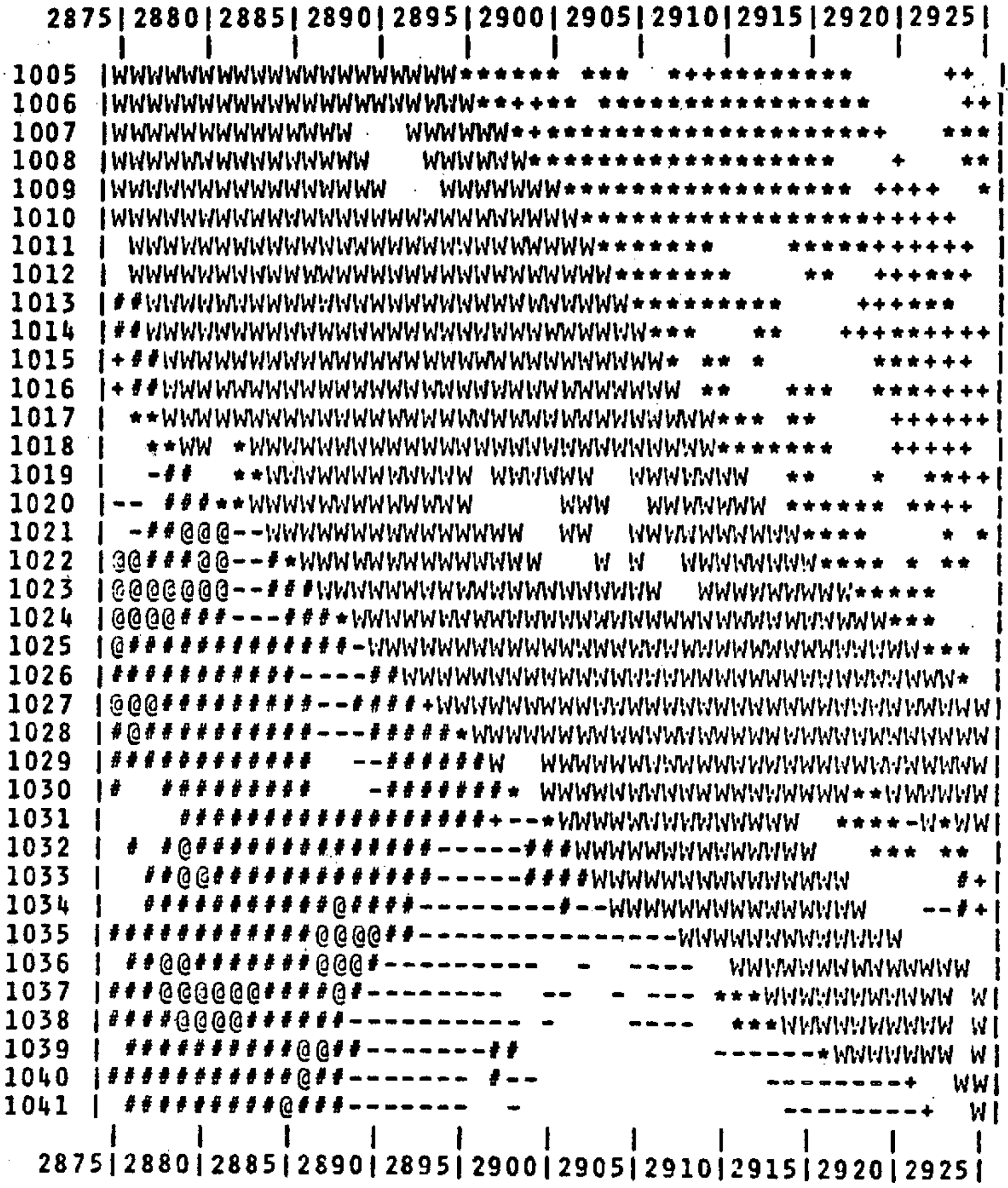

Figure 55: Portion of DCLASS map of the Harrisburg area, with six categories. Symbols are defined in Table 17 and described in the text.

The conversion factor to acreage is approximately 1.12 acres/element, based on the distance of separation between elements in a line and between lines.

The results of this study amply demonstrate that ERTS-1 data can be translated to maps using only USGS 7 1/2 minute quadrangle maps for reference. The computer generated maps agree quite well with the quadrangle maps except that the fine detail of the latter maps cannot be achieved with ERTS-1 data. The ERTS data based maps indicate that more significant land use categories can be mapped than has been done on the quadrangle maps. In addition, the obvious and serious deficiency of the quadrangle maps is very strongly demonstrated: they are obsolete in many areas, even over the short period of time since the 1969 publication dates. The maps made in 1963 are of exceedingly limited utility in areas where rapid transitions in land use are in evidence. Because of their obsolescence and the absence of sufficient land use classification categories, the use of USGS quadrangle maps alone to support ERTS data based mapping is definitely inadvisable. Underflight photography or imagery, and photointerpretation of these, are, without question, a needed basis of support for digital mapping of ERTS data. Some timely ground truth is also necessary to resolve anomalies. It was found that very little else could be done without such additional support. Signatures could be refined and the number of signatures could be increased, but there was no justification for such additional work since the end result would be the same, in that the interpretation would still lack sufficient support.

Combined Techniques

After separate analysis of ERTS-1 data by photointerpretation alone and by computer processing of MSS digital data without the assistance of photointerpretation, it became apparent that each method had shortcomings which might be overcome if the methods were combined. Computer differentiation of areas from scanner data is far superior to that done by the human eye. Computation of areas from the digital data makes delineation of these areas unnecessary and is far more accurate than planemetric methods at the scale of ERTS MSS imagery. Since the end result of processing ERTS-1 data is a map, the automated processes of thematic mapping by computer is the efficient way to go. However, "ground truth" is the key to correct signatures for this mapping. Underflight data and photointerpretation of underflight photography, as well as of ERTS imagery, are vital links leading to valid signatures for the thematic map. A marriage of these two disciplines, photointerpretation and computer processing, is essential for maximum utilization of ERTS-1 data. The two analysis teams, therefore, combined forces and evolved a method of ERTS MSS data analysis referred to as the "hybrid approach" and shown in Figure 56. This method involves intimate interaction of the computer analyst and the photointerpreter, using high-altitude photography (U2) for comparison with the computer output. The hybrid approach was first successfully applied in a land use study of the Harrisburg area originally examined by the two separate methods. This study is discussed in, "Land Use Mapping," by Borden, et al., elsewhere in this report.

Conclusions

ORSER feels strongly that a hybrid approach is essential to ERTS data analysis. Computer differentiation of areas from scanner data is far superior to that done by the human eye; but the photointerpreter, working with underflight photography, is an essential and integral part of data processing for providing identification of features exhibited on computer output.

The results of this investigation has shown that ERTS digital data can be translated into map form using only USGS maps for reference. However, such maps are frequently insufficient to provide enough information for classification, particularly in areas where rapid transitions in land use are evident and maps become obsolete very quickly. It has also been shown that photointerpretation techniques can be applied to ERTS imagery. However, in only a few cases could a feature be uniquely determined by this method alone. The use of U2 and C130 imagery has been found to improve these interpretation results, but photointerpretive techniques have not been completely satisfactory as a single means of analysis.

Explanation of the steps shown in Figure 56.

PRELIMINARY PROCEDURES

A.[1] Determine scan line and element limits.
B. This becomes the working tape.
C. Identify clouds.
D. Review scene for definable boundaries.

FIRST LEVEL MAPPING

A. Collaboration of the photointerpreter and computer mapper. Select easiest targets first. Choose spectrally homogeneous items with positive geographic locations. Select replications in widely separated areas.
B. Identify some targets (training areas) on NMAP or UMAP.
C. Check for uniformity on UMAP. Attempt to find a large number of like elements. Loop A, B, and C until a sufficient number of training areas are identified.
D. Review statistical characteristics of defined targets.
E. Make first run on classification map.
F. This is a verification step. Project U2 image onto computer map. Identify satisfactory classifications. If some areas lack definition, redefine training areas.

SECOND LEVEL MAPPING

A. Attempt to identify items outside training areas.
B. Define items not subject to definition by training areas. These might be linear features or stream channels. Add these to the list of signatures and continue.
C. This a recycle, with smaller training areas and more weight placed on cluster analysis.

THIRD LEVEL MAPPING

A. Review the classification categories originally defined as desirable. If present map output is unnecessarily refined, combine some groups.
B. Some categories will require broadened spectral parameters. A series of successive approximations will be required to define these units. The resulting training areas will be less spectrally homogeneous.
C. Requires collaboration of the photointerpreter and the computer mapper.
D. Establish limiting goal.

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[1]The letters correspond directly to those shown in the diagram.

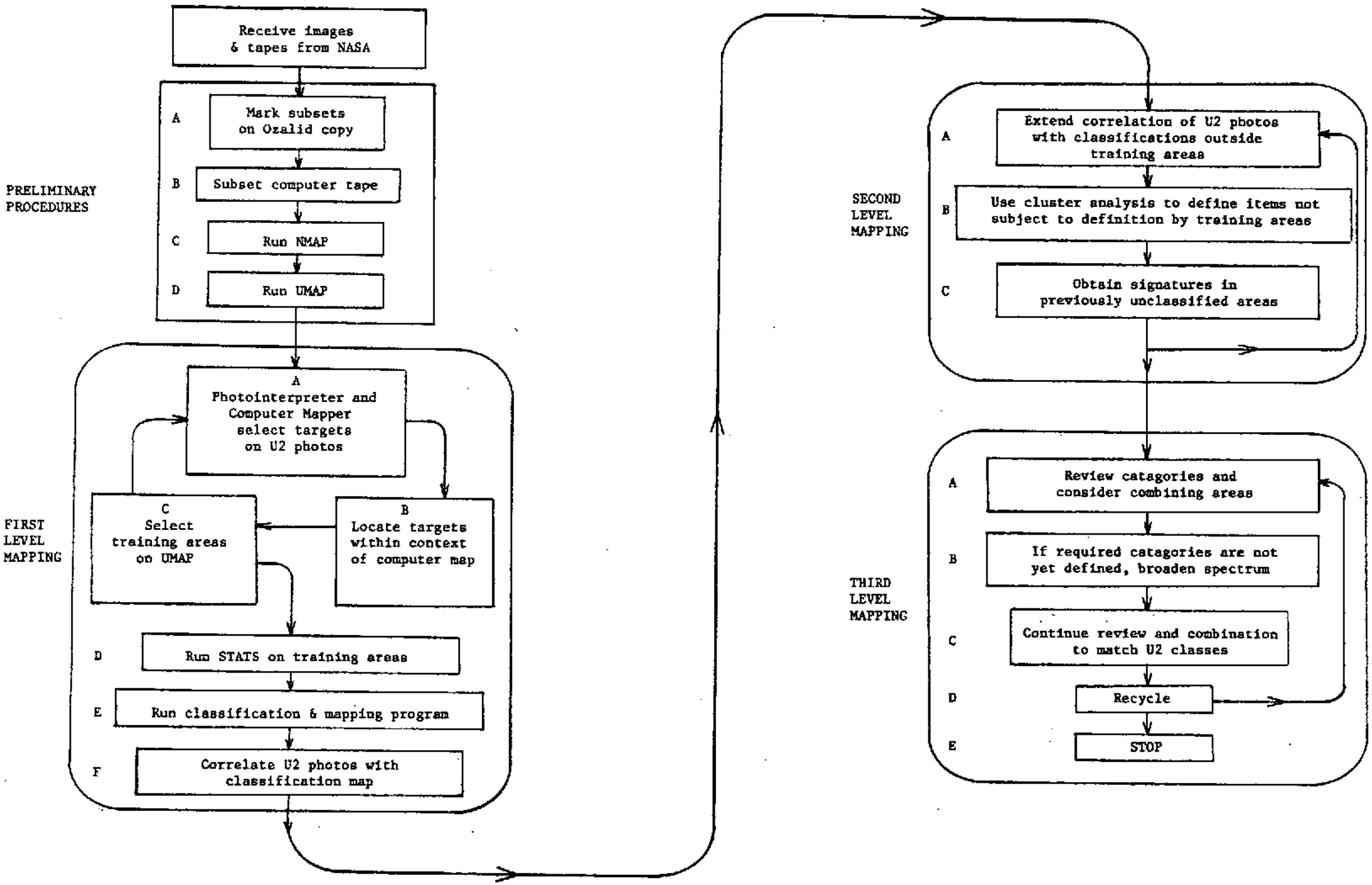

Figure 56: Flow diagram for the hybrid approach to ERTS data processing.

PROGRAM DEVELOPMENT AND REVISIONS

F. Y. Borden, D. J. Turner, H. M. Lachowski, and D. N. Applegate

The digital data processing system upon which the work discussed below was based was described by Borden in March of 1972[1]. Many programs in use at that time have been revised or incorporated into new programs which have been developed. These developments and revisions are described in separate sections. Most of the complete program descriptions are found in ORSER-SSEL Technical Report 10-73. A few programs are still undergoing revision, and their descriptions have not yet been written.

All program descriptions to date have been entered into Remote Job Entry (RJE) Batch And Terminal (BAT) files and kept on disk storage. The documents are stored so that they can be processed by the FORMAT program. This program, designed by The Pennsylvania State University Computation Center personnel for System/360 and System/370, permits rapid editing and printing of papers and reports directly onto a system printer, using upper and lower case and special characters. This is particularly useful for program descriptions because it permits the addition of new control card descriptions and new computational method descriptions as they are incorporated into the programs. It also is a method of recording program revisions, since the original description is edited by use of control cards rather than by revising the original file.

A system for cataloguing and storing all remote sensor digital tapes has been devised. The tapes are stored in the inactive library in the ORSER office and in the active library located at the Computation Center. All NASA-ERTS and Houston C130 source tapes are in the inactive library (if they are not in the active library being subset). Most permanent subsets of these tapes, and ORSER users data tapes, are stored in the active library. Tape catalogues have been made for each of the four classes of tapes: NASA-ERTS tapes, permanent subset tapes of NASA-ERTS tapes, ORSER users data tapes, and other data tapes used by ORSER. Detailed descriptions of these tape catalogues are given in Appendix B.

[1] Borden, F. Y. (1972) "A Digital Processing and Analysis System for Multispectral Scanner and Similar Data," Journal Paper No. 4148, The Pennsylvania State University, University Park, Pa.

A user's guide to the ORSER MSS digital data processing system will soon be completed. The manual describes the preprocessing activities that should be completed before computer processing begins. It instructs the user how to select the tape containing the area of interest (i.e., source, permanent subsets, ORSER users tapes), and how to enter a tape into the active library if it is not already there. Instructions are given for using the programs from an RJE system or from punched cards, and descriptions of the more commonly used RJE commands are included. Sample RJE sessions showing how program control cards and tape names are changed are included. A description of commonly used control cards is included in the manual, since many control cards are common to a number of programs. These cards are listed by name only under the appropriate program description and entered by name and description in the manual. If a control card in the program has the name of a commonly used card but differs in any way from the description in the manual, it is described in the description of the program to which it applies.

Program Development

The RATIO program has been developed to classify and map multispectral scanner remote sensor data based on the ratio of two selected channels. This program has been especially useful in mapping and analyzing vegetation classes. For example, consider the two vegetation classes, coniferous and non-coniferous vegetation. Since coniferous vegetation, in general, has less reflectance in the reflected infrared region than does non-coniferous vegetation, one can choose the ratio denominator channel from the chlorophyll region and the numerator channel from the reflected infrared region. These two classes can then be separated on the basis of ratio, since the ratio values for coniferous targets will be lower than those for non-coniferous targets.

The MERGE program has been developed to merge ERTS-1 MSS data for up to six passes over the same area. These merged tapes may then be used in any of the other programs in the system. Merged data tapes are useful in studying the effects of temporal change and may possibly improve the classification of certain targets.

The map comparison (MAPCOMP) program has been developed to compare two digital classification maps of the same ground area. Each map is classified according to the computational methods used in the ACLASS program. Each element in each map is assigned a category number or a category symbol, depending on an option specified by the user, and then compared. A comparison map and summary table are then output. The program was developed particularly to compare maps generated from merged ERTS-1 MSS data for one area viewed on different dates.

The remote sensing unit identification program (RSU) has been developed for correlating ground truth samples with particular MSS remote sensor units. Scale data is input to the program to determine the height and width of the remote sensor unit along the flightline nadir, and scanner data is input to determine the variation in widths of each remote sensor unit as its distance increases from the nadir. A base line is chosen on the ground with end points which can be identified by scan line and element numbers. These points, along with the length of the base line, are input to the program. The position of every ground truth sample can then be defined in terms of the angle and distance from the base line, and the element and scan line numbers associated with that sample point can be calculated. This method has already been used successfully to determine RSU locations of soil samples in Lancaster County, using MSS aircraft data. A description of the RSU program will be written if sufficient interest develops for its use.

Program Revisions

All programs have been revised to output a special tape information heading if the input tape contains ERTS data. New OPEN subroutines have been added to every program, to read in the special continuation identification records generated for Houston C130 and LARS[1] data. Previously, a user could not specify two or more block cards with overlapping lines.

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[1] Laboratory for Applications of Remote Sensing, Purdue University.

Subroutine GETLIN has been changed in every program (except SUBSET) to alleviate this problem. All programs have been revised so that they can be executed from a punched card deck as well as from an RJE terminal. The organization of the identification record on all ORSER format tapes has been generalized. A platform description word (ERTS-1 satellite, C130 aircraft, etc.) and a word indicating the source tape of the data have been added. All original source tape identifications are stored on each subset tape generated from that source tape.

Almost every program in the system has been revised or updated by the addition of new control cards or by the insertion of new codes to improve speed and to decrease storage needs. All program descriptions have been updated to include new control cards. Revision in each program will be given below; for a more detailed description of new control cards, the individual program description, available on request from ORSER, should be consulted.

An ERTS card and a C130 card have been added to the TPINFO program so that information from ERTS and C130 source tapes can be printed out. A FILE card has been added to allow the user to obtain information from succeeding files of a C130 tape. Output from the TPINFO program has been adjusted to fit on one page so that printouts can be inserted into a tape information catalogue.

A LEVEL card has been added to the NMAP and UMAP programs to allow the user to specify the maximum number of gray scale levels for each channel. Previously, it had been set to 256 for aircraft data and 128 for ERTS-1 data, but it was found for some channels in ERTS data that the maximum was 64. A NOMAP card has been added that suppresses map output, allowing printing of the summary page alone. It is useful only for reducing the number of output records; there is no saving in run time. Additional summary output is now generated by the NMAP program. Average, maximum, and minimum response values in the block for each channel are given. In addition, the mean responses and standard deviations are given for all six modulo line numbers for each channel, as explained below in the description of the RECAL card used in the SUBSET program.

A feature that has been added to NMAP, as well as the ACLASS program, is the CLEAN option. The CLEAN card initiates a "cleaning" operation after the map classification has been performed. (The computational methods involved in the "cleaning" operation will be discussed in a later publication by F. Y. Borden.) All stray symbols corresponding to the symbol specified on the CLEAN card are eliminated from the map. A CLEAN ALL card, which has the above effect on all symbols on the map, can also be specified. These options are useful to clarify final map output before publication or presentation.

The SUBSET program has been revised to handle conversion from the ERTS-1 and C130 source tape formats to the ORSER tape format. Special GETLIN and OPEN subroutines were written for each case. Previously, all channels were automatically subset from the source tape. Now, a CHANNELS card has been added to allow a user to specify the channels he wishes to have subset. This allows the user to specify any combination of elements and channels, as long as the resulting record does not exceed the maximum record size. This option is especially useful when subsetting C130 tapes, which contain up to 24 channels and 700 elements. A FILE card has been added to allow the user to subset from the second file of a C130 tape. A FLIGHT card has been added to allow the user to specify a flightline description or a user's identification for the subset tape identification record.

One particularly important addition to the SUBSET program is the RECAL (recalibration) card. It has been observed that bad data values occur on some ERTS-1 MSS data tapes every sixth line for one or more channels. The RECAL card is used to correct for such severe banding. Data used on this card is generated by the NMAP program. The generation of this data is described in the following section, "Correction of Banding in MSS Digital Data."

Several control cards have been added to the ACLASS program. An ORDER card has been implemented that specifies the order of the channel response values on the SIGNATURE card. Previously, it had been assumed that response values for every channel on the tape would be wanted on the SIGNATURE card, but it became apparent that this would not always be the case (e.g., poor data on channel 6 frequently made it desirable to eliminate response values for that channel). The CLEAN and CLEAN ALL cards have also been implemented in ACLASS.

Two revisions have been made in ACLASS. One is that the program can now handle a maximum of sixty different categories instead of thirty. The second is an extension to the scheme used to improve computational efficiency. This scheme goes briefly as follows: Let b be the smallest distance of separation among all categories. Then, if the distance of separation, d, between any given element and any category does not violate the constraint for that category and $d \leq b/2$, that element can be classified in that category without any further computation. The extension is this: Let b_i be the smallest distance of separation between category i and any of the other categories. Then an element can be classified in category i without any further computation if the distance of separation, d_i, between that element and category i does not violate the constraint for category i and if $d_i \leq b_i/2$. As a result of this scheme, fewer categories need to be examined before correct classification occurs.

A new version of ACLASS, the DCLASS program, has been developed. This program functions exactly like ACLASS with the exception that it uses distances instead of angles in the computation of separations between any two response vectors. ACLASS normalizes all response vectors so that the length of each becomes unity, thereby making the angles and distances equivalent. DCLASS does not normalize response vectors; therefore, the vector lengths are not unity and the angles and distances are not equivalent. DCLASS has been developed especially to take full advantage of the brightness factor in ERTS-1 data, since the scanner angle is negligible at that height and therefore causes no variability in the overall scene brightness.

A NORM card has been added to DCLASS and is used to eliminate overall brightness differences from one ERTS scene to another. The average norm lengths from each scene are specified on the card, and brightness factors are computed for each scene and then applied to all category signatures and to all data on the tape before classification begins. The card has been designed to be used with merged satellite data.

DCLASS and ACLASS have since been combined (hereafter called "ACLASS/DCLASS"), and each is specified by using a DCLASS or ACLASS control card. A combined program description is planned. A version of the ACLASS/DCLASS program has been developed to allow the user to specify areas of any polygonal shape to be classified and mapped, as well as blocks of a rectangular shape. These areas are specified in the input deck by AREA cards exactly as in the STATS program. This option is useful for tabulating acreage of various targets within irregularly shaped boundaries.

The ACLUS program has undergone several revisions. A CRITICAL card has been added to specify a critical angle for map output. If the card is not present, limiting distances are computed for each cluster, as was previously done automatically. A BAT card has been added, so that all final cluster signatures can be output into an RJE BAT file. Computational efficiency in the map classification portion of the program has been improved in the same way as described above for the ACLASS/DCLASS program. A version of the ACLUS program, DCLUS, has been developed which uses unnormalized data and computes distances of separation betweel clusters instead of angles, similar to the DCLASS program. ACLUS and DCLUS have been combined (hereafter called "ACLUS/DCLUS") and can be run by specifying an ACLUS or DCLUS control card. A combined program description is planned.

The LMAP program, which is used to reproduce computer maps to any scale on a CalComp plotter, has been revised in several ways. A PHOTO card, specifying the photo nadir scan line, the photo nadir element, and the height of the aircraft, has been added so that photographic distortion can be introduced into the plotter map. Four new plotter symbols have been incorporated into the program. A method has been devised to speed up the plotter whereby continuous horizontal and vertical lines are stored until completed, and then sent to the plotting routine to be output. A description of this program has not yet been written.

The CANAL program has been developed. This program computes the canonical analysis for categories of multispectral scanner data, and then uses these computations in classification and mapping. The canonical analysis portion of this program is based on the mean vectors and covariance matrices for the categories, and produces the minimum number of linear transformations yielding the maximum separability among these categories. The classification portion of the program transforms each observation using the initial transformations, and classifies it according to its euclidean distance of separation from the transformed mean vector of each of the categories. A classification map is output. ORSER-SSEL Technical Report 10-73 should be consulted for a more detailed description of the computational methods used by this program.

Correction of Banding in MSS Digital Data

In the ERTS-1 instrument configuration, six banks of the four channel sensors record data for six scan lines simultaneously. MSS digital data have been received in which data for some sensors have been nonconformable with data from the rest of the sensors. The effect was first recognized by banding with a modulo of six in computer output maps. To investigate the problem, the NMAP program was extended to compute the mean and variance for each channel for each line modulo six. It was apparent that the problem had to do with calibration or processing of the data by NASA. It was also apparent that the data could be recalibrated, at least in an approximate way, by use of the MSS data alone.

Output from the NMAP program indicates which sensors in which of the six banks of sensors are involved. The SUBSET program has been extended to allow input of recalibration parameters for the offending sensor data. The following correction is then applied:

$$\hat{X}_{ijk} = [(X_{ijk} - \overline{X}_{k\ell})/s_{k\ell}] * s'_{k\ell} + \overline{X}'_{k\ell}$$

where

$\hat{X}_{ijk}$ is the recalibrated value for scan line i, element j, and channel k;

X_{ijk} is the corresponding original value;

$\overline{X}_{k\ell}$ is the computed mean for channel k and for line ℓ = modulo (j, 6) + 1 taken from NMAP output;

$s_{k\ell}$ is the corresponding standard deviation;

$s'_{k\ell}$ is the recalibration standard deviation computed as the average of unaffected standard deviations for channel k based on NMAP output; and

$\overline{X}'_{k\ell}$ is the corresponding recalibration mean.

This correction has eliminated the banding problem in all data to which it has been applied.

ANALOG TO DIGITAL CONVERSION AND PROCESSING OF MSS DATA USING A HYBRID COMPUTER

C. E. Rambert and G. J. McMurtry

The objective of this investigation was to design and implement a process for the conversion of multispectral scanner data from FM magnetic tape recordings to digital magnetic tape recordings of a previously defined format. Specifically, the problem was to design a system which will directly accept analog data from FM magnetic tape recordings produced by the Bendix eight-channel multispectral scanner, sample the analog data, convert those samples to digital numbers, arrange those digital values into standard ORSER format, and output the data onto digital magnetic tape in standard IBM System 360 nine track tape mode of 32 bit words written in 800 bits-per-inch density. The design was further restricted to implementation on existing systems available to ORSER. It also was required that the multispectral scanner and the conversion system maintain a high degree of accuracy in the measurement and sampling of the spectral response of the subject. Thus, simultaneous sampling is considered advantageous over simple multiplexing in which each channel is sampled as it is input to the analog-to-digital converter, no two channels ever being sampled at the same instant.

The system used for implementation was the hybrid computer operated by the Hybrid Computer Laboratory of The Pennsylvania State University. The hybrid computer consists of a Digital Equipment Corporation PDP-10 digital computer and an EAI 680 analog computer mated by a special interface unit to translate data and control signals from one computer to the other. The sampling and conversion of the multispectral scanner data is controlled by a digital program. The maximum sampling speed is limited by hardware speed, including not only the maximum speed (31,700 samples per second) of the converter, but also the instruction execution speed of the controlling digital computer. Prior to this project, the maximum sampling speed available was limited by existing subroutines to approximately 11,000 samples per second. For the Bendix data, a theoretical minimum rate of 10,000 samples per second was required.

Normally, up to five times the minimum sampling rate is used for convenient interpretation. Thus, up to 50,000 samples per second could be used. The 11,000 samples per second is therefore an undesirably limited maximum sampling rate when the hardware is theoretically capable of a maximum of 31,700 samples per second.

A new subroutine was developed so that data rates approaching the hardware maximum might be achieved. The sampling periods and rates obtained with the special subroutine depend upon the number of channels sampled and that part of core in which the program is located. However, the sampling rates for eight channels of data were increased to 19,544 samples per second (2443 samples per second per channel) in fast core and 17,496 (2187) in slow core. This is an obvious improvement over the previous maximum of approximately 11,000 samples per second.

Besides the higher speed, there are other features in the new subroutine designed for the specific application of multispectral scanner data conversion. One such feature affects simultaneous sampling of all channels. Also, the time between samples may be fixed (constant) for all samples, or an adaptive sampling rate, such as that required to geometrically correct multispectral scanner distortions, may be utilized. Once the multispectral data is converted into raw, digital numbers, it must undergo another conversion into the specified ORSER format before it is ready for storage on magnetic tape. There are three operations in this conversion. The first operation involves both a scale change and an axis translation. The second operation, of rearranging, not only fits the data to the required format but also reverses the order of the samples, so that maps made from the output have the standard point of view (that of looking down from above as if in an aircraft) instead of the mirror image (as if looking up at the earth's surface from below), as would happen if no change were made. The third operation reduces the data storage requirement by a factor of four, by packing four consecutive 8-bit words into one 32-bit word. Another subroutine improved the speed of writing onto magnetic tape by at least a factor of four over the existing magnetic tape subroutine. In addition, both of the new subroutines offer the programmer more flexibility than their predecessors as a result of their simplicity.

The advantages of the conversion system developed in this investigation over a simple bulk digitizing system are five-fold. First, more precise control of the sampling of the analog signals by the hybrid system fits the data into the coordinate system more accurately than does simple digitizing. Second, the final product of the hybrid system can be written in the format required by any user system instead of a single format particular to the digitizing system. Third, the conversion system requires no specialized equipment for implementation; it is strictly a software system which could be easily altered to new specifications without equipment changes. Fourth, the hybrid implementation allows geometric corrections to be performed on the MSS data as it is being sampled. Fifth, the analog computer provides preprocessing of the data before conversion.

Upon completion of the conversion system implementation, the system was used to convert the analog data from 13 flightlines flown on 5 May 1971 by Bendix Corporation. The data was originally recorded on one-inch-wide magnetic tape at 60 ips with an Ampex FR 1600, 14-track wide-band FM tape recorder that has a cutoff frequency of 200 kHz at that speed. Due to the unavailability of a comparable tape playback unit for use in the Hybrid Computer Laboratory, the data was rerecorded onto half-inch-wide magnetic tape with an Ampex FR 1300, seven-track FM tape recorder at the Bendix ground station in Ann Arbor, Michigan. At the same speed, 60 ips, the FR 1300 has an upper cutoff frequency of 20 kHz.

The Bendix scanner senses eight spectral bands. The eight analog signals plus a synchronization signal fit easily on the 14-track recorder, but there are two signals too many for the available seven-track unit. To resolve this problem, two seven-track tapes were made from the original 14-track recording, each containing only six data channels and the synchronization channel. The four data channels estimated to contain the most information appear on both tapes. These analog tapes were converted to digital data and then merged on the IBM 360 at The Pennsylvania State University Computation Center. For verification purposes, a comparison for each flightline was made between the imagery produced on a film recorder from the original flight tape and the computer-generated reflectance map of the same flightline and channel, produced from the digitized rerecorded data.

The limit of computational efficiency was observed during the digitizing runs. It was determined that the new digitizing system results in an average of 2.75 percent of the computer time spent waiting for the next scan line, i.e., the system resulted in 97.25 percent efficient use of the computer while the program is in the digitizing phase.

There are a number of extensions of this investigation that could prove useful. The preprocessing of analog data prior to sampling and conversion could be treated as a feature extraction problem. The concept of non-linear sampling to compensate for scanner geometry could be carried further by using actual terrain contour information instead of assuming the terrain to be flat.

As discussed above, the immediate objective of this work was to digitize the Bendix data. This data was collected over central Pennsylvania and will serve as a source of ground truth for high altitude aircraft and satellite studies, as well as a direct source of information in itself. The conversion system which was developed is suitable for digitizing other aircraft data. Discussions have been held with Johnson Spacecraft Center personnel regarding the possibility of digitizing some data collected on the supporting C130 aircraft program.

COMPARISON OF PREPROCESSING AND CLASSIFICATION TECHNIQUES AS APPLIED TO MULTISPECTRAL SCANNER DATA

J. R. Hoosty and G. J. McMurtry

The objective of this research was to develop and compare various preprocessing and classification techniques for pattern recognition applications to multispectral scanner (MSS) data[1]. This work was performed during the pre-launch phase of the ERTS-1 study and, since no ERTS data was available, the data used was taken from a set of MSS data collected in 1969 by the University of Michigan aircraft over southeastern Pennsylvania. This body of data had been collected for the Federal Highway Administration and was made available to Penn State by Harold T. Rib.

Trainable classifiers implementing different discriminant functions were studied, and linear and quadratic discriminant functions were selected for implementation. Training was achieved by adjustment of parameters within the discriminant functions, based upon known sets of MSS observations (training sets). Eight different pattern classes (concrete, asphalt, Elk soil, Berks soil, grass, trees, crops, and Penn soil) were chosen for classification, with 50 to 60 patterns per class in the training set. Classifiers were categorized with respect to the type of training employed as well as discriminant function form. Two general types of training were conducted: parametric and nonparametric. Parametric classifiers train on the statistical parameters of the training set. The nonparametric classifiers assume a discriminant function with unknown coefficients. These coefficients are adjusted by a correction rule contingent upon the classification of the patterns in the training set. The four classifiers implemented were (see ORSER-SSEL Technical Report 10-73 for program descriptions):

1. Parametric classifier with linear discriminant function (MINDIS).

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[1] Hoosty, J. R. (1973) "A Preprocessing and Classification System for Remotely Sensed Multispectral Scanner Data," M.S. thesis, The Pennsylvania State University, University Park, Pa.

2. Parametric classifier with quadratic discriminant function (PARAM).

3. Nonparametric classifier with linear discriminant function (NPARMAP).

4. Nonparametric classifier with quadratic discriminant function (QUADMAP).

Principal components analysis and data normalization were chosen as the preprocessing methods to be implemented as options to the classification programs. The implemented classifiers were run using the following options: unpreprocessed data; principal components analysis using 13, 6, and 2 components; and normalized data. Comparisons were made between preprocessing and classifier results in the areas of separability of the training set, accuracy on the test set, computation speed, and overall appearance of the output site map.

All classifiers reached an acceptable level of separation as evidenced by training set classification, and accuracy as evidenced by test set classification. The technique of initially running classifiers using crude classes and then inspecting the site map in collaboration with aerial photographs and soil maps proved to be excellent for refining pattern classes. This procedure was a forerunner of the more formalized hybrid approach developed later. Considering computation time, the classifiers with the more complex discriminant functions (quadratic) were slower than those with less complex discriminant functions (linear). Nonparametric classifiers generally took longer during the training phase than did parametric classifiers. Assumptions of initial weight values near the pattern class means allowed the nonparametric classifier with linear discriminant function to train faster than the same classifier with the initial weight values assumed at a greater distance from the class means.

Principal components analysis provided a means of dimension reduction while maintaining an acceptable level of classification accuracy. Using the number of principal components (6) corresponding to 99 percent of the total variance, yielded class separation and classification accuracy comparable to using all the dimensions or principal components (13). However, in general, there was an obvious deterioration in class separation and classifier accuracy which accompanied dimension reduction below the value corresponding to 99 percent of the variance.

The results of data normalization as a preprocessing technique were not conclusive. However, in general the results indicated that classification with normalized data is comparable to, and in some instances better than, classification performed with unpreprocessed data. Some indication also exists that data normalization may remove unwanted noise.

Overall site map appearance was best for the classifiers employing linear discriminant functions; however, class boundaries were best defined by quadratic discriminant functions. Asphalt was the most misclassified class of the eight classes selected.

All classification training procedures used in this research were supervised methods; that is the user selected the different pattern classes himself before classifying the data. An unsupervised class selection technique could also be used as preprocessing for the basic classifiers described here. The dimension reduction and corresponding classification accuracy of principal components analysis should also be compared with other feature selection methods, such as divergence and Bhattacharya distance. Sequential pattern classification and feature selection may also be investigated for applications to remotely sensed data.

Judging on the basis of the factors of separability, accuracy, speed, site map appearance, and ease of implementation, the classifiers employing the linear discriminant function are comparable to -- and at times superior to -- classifiers using the quadratic discriminant function. There are certain instances where the quadratic discriminant function has a definite advantage, e.g., in defining class boundaries. A study of the statistical and physical nature of the data proved to be an excellent aid in the selection and implementation of classifiers and preprocessing techniques, and in the interpretation and analysis of corresponding results. It must be concluded that no one preprocessor/classifier combination is universally optimal. A knowledge of the physical aspects of the classification problem (ground truth) along with careful statistical analysis is essential for proper pattern recognition.

CANONICAL ANALYSIS APPLIED TO THE INTERPRETATION OF MULTISPECTRAL SCANNER DATA

H. M. Lachowski and F. Y. Borden

A number of classification methods are known and have been applied to remote sensing data. One method which has the potential of being used as a satisfactory classifier is based on the multivariate statistical technique called canonical analysis, or multiple discriminant analysis. The most useful aspect of canonical analysis for remote sensing studies is its ability to maximize the separability among the categories defined for it. However, because of the great volume of remotely sensed data to be analyzed, and the particular nature of these data, it is necessary to substantially change the existing method. An algorithm for processing remotely sensed data based on the canonical analysis method would enable rapid processing and interpretation of multispectral scanner (MSS) data with digital computers.

Application of canonical analysis to the interpretation and analysis of MSS data was investigated[1]. The existing canonical analysis method was changed substantially to accommodate the great volume of data obtained in the process of remote sensing. The objective of canonical analysis in this application was to obtain the maximum separability among a number of categories. Each MSS observation, identifiable by scan line and element number, consisted of a vector of as many vector elements as there were channels. For each category, the spectral signature (the mean vector) and the covariance matrix were computed on the basis of a number of observations which belonged, by training area definition, to the category. The objective was to derive an orthogonal transformation which would maximize category separability on as few axes as possible. As the result of the transformation, the first canonical axis represented the greatest separability achievable on one axis among all categories, the second axis represented the next greatest separability achievable for remaining axes, and so on. Each unknown

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[1]Lachowski, H. M. (1973) "Canonical Analysis Applied to the Interpretation of Multispectral Scanner Data," M.S. thesis, The Pennsylvania State University, University Park, Pa.

observation was then classified into one of the categories on the basis of the euclidean distance between the transformed unknown vector and each of the transformed category mean vectors. Classification was made into the category for which the euclidean distance was smallest or into the "other" category if the distance was not less than the specified critical distance.

A canonical analysis program was developed[1] for use as a part of the MSS digital processing and analysis system used in ORSER. The system is capable of processing multispectral scanner data collected by an airborne or spacecraft scanner. Input to the canonical analysis program was obtained in either of two ways: (1) through a supervised method, using a program which computes the basic multivariate statistics for any polygonal training area or (2) through an unsupervised method, using a cluster analysis algorithm. Output from the canonical analysis program consisted of maps and statistical analysis information. The digital maps were converted into line maps to a desired scale and with scanner distortion removed.

Two types of MSS data were used to demonstrate the utility of the method: (1) high resolution aricraft data, and (2) low resolution spacecraft data. The MSS data collected by an aircraft (at an altitude of 3000 ft) were used in conjunction with aerial photographs taken at the same altitude. These photographs, together with a detailed soil map, were the sources of ground truth. Most targets were fairly easy to identify on the aerial photographs and, therefore, the interpretation of the computer generated maps was also simplified. The computer generated maps were of sufficient accuracy to be used to determine the location and extent of major cover types, such as forest stands, pastures, agricultural crops, and various soil types. The only source of ground truth for the MSS data collected from the spacecraft (ERTS-1) was a series of photographs taken from a U2 aircraft flying at 65,000 ft. Target identification was considerably more difficult because of the lower resolution of the MSS data. However, successful delineation of strip-mine spoils and of vegetation associated with them, using a river as reference, was obtained. It is feasible, therefore, to apply canonical analysis in conjunction with other computer algorithms to the interpretation of the MSS data.

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[1] See ORSER-SSEL Technical Report 10-73 for a description of this program.

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EDUCATIONAL ACTIVITIES

Considerable emphasis has been placed on the education of University personnel in the area of remote sensing. This began with a series of seminars offered in the Department of Agronomy (Table 19). These seminars were preparatory to the ERTS contract and were useful to introduce remote sensing concepts. During the ERTS contract period, a seminar series was conducted in the Winter term (Table 20) and Spring term (Table 21). These seminars primarily involved ORSER personnel, but the University community were invited. The seminars were well received and well attended.

During the Spring term, a senior and graduate student level problem-orientated course was offered in remote sensing. Emphasis was placed on computer processing ERTS-1 MSS data. Each student conducted a project based on the use of the remote sensor data processing programs developed by ORSER/SSEL. The class consisted of seven undergraduates, eight graduate students, and two auditing students. The undergraduates used the programs in the usual way for general University undergraduates; i.e., by submitting card decks at dispatch stations. The card decks contained program control cards and, at most, about ten system control

Table 19: Agronomy Department Seminars

Date	Topic
January 6, 1972	The Electromagnetic Spectrum and Spectral Signatures
January 13, 1972	Photographic Imaging Devices
January 20, 1972	Nonphotographic Imaging Devices
January 27, 1972	Analog Processing of Electronically Sensed Data
February 3, 1972	Digital Processing of Remotely Sensed Data
February 10, 1972	Interpretations and Applications of Aerial Photography
February 17, 1972	Interpretations and Applications of Multispectral Data
February 24, 1972	Interpretations and Applications of Thermal and Radar Imagery
March 2, 1972	Space Photography
March 9, 1972	Earth Resources Technology Satellite and Earth Resources Experimental Package

Table 20 : Remote Sensing Seminar, Winter 1973

Date	Topic
January 12	The ERTS-1 Sensing Systems
January 19	The Storage and Viewing of ERTS Imagery and Underflight Photos and Scan Data
January 26	A detail look at Multi-Spectral Scan Images and Factors Affecting Their Quality
February 2	The Need for and Use of Underflight Data (Photo and Tape)
February 9	Automatic Data Processing Techniques
February 16	Progress Report on Combined Techniques - Interpretive and Computer
February 23	How to Talk to the Computer (and get an answer)
March 2	ERTS Applications in Agriculture
March 9	ERTS Applications in Geology
March 16	ERTS Applications in Engineering

Table 21 : Remote Sensing Seminar, Spring 1973

Date	Topic
April 10	Remote Sensing of Earth Resources at Penn State
April 13	An Illustrated Summary of the ERTS-1 Symposium
April 24	Remote Sensing Applications to Forest Disease Detection and Recreation Planning
May 1	Remote Sensing Applications to Forest Resource Management
May 8	Remote Sensing and Lineaments in Pennsylvania
May 15	Reconnaissance of Strip Mine Effects by Digital Analysis of ERTS Data
May 22	Mapping Anthracite Coal Refuse with ERTS Data
May 29	The Use of Remote Sensing Techniques in Recreation Planning and Development

cards, which summoned the programs from the program library. No source or object decks were required in their input. The graduate students used the remote job entry system with remote terminals for their work, in conformance with general research use of the University computing facilities. They addressed programs from the same library as that available for card users. By the third week of a ten-week term, all students were using the processing system. All projects were completed with substantive reports by the end of the term. Some of these have been incorporated in the research results of this project report where the work meshed well with the ongoing research program.

Remote sensing techniques have also been incorporated into many courses that are presently being taught at The Pennsylvania State University. This new technology has added a very significant new dimension to the course content.

ORSER personnel participated in local radio and TV (educational and commercial) programs in which the ERTS system was discussed. Newspaper articles were also written about ERTS and ORSER's participation. Although these programs and articles dealt with ERTS in only the most general terms, considerable public and professional interest was aroused. ORSER entertained many visitors and answered many inquiries of general nature, and was forced to decline some requests for specific results which had not yet been released, in compliance with the provisions of Article IX of the contract.

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INTERDISCIPLINARY APPROACH

Interdisciplinary research may be defined as integrated research performed by experts with different disciplinary backgrounds all working together, while multidisciplinary research is defined as research performed by experts with different disciplinary backgrounds working separately to solve different aspects of one problem. ORSER has operated primarily as an interdisciplinary group on the ERTS project, although it must be recognized that a significant amount of multidisciplinary research is also conducted. Some specific examples of interdisciplinary activity include the land use task in which forestry and civil engineering personnel cooperated, the strip mine and acid mine drainage study involving geology and forestry investigators, and soil studies with personnel having civil engineering and agronomy backgrounds. Data processing is perhaps the greatest interdisciplinary activity. This is manifested not only by photointerpretation and computer processing experts working with each other and with other investigators, but also by the development and use of various processing and classification programs by all personnel.

In addition to data processing, various other methods are used in ORSER to encourage and facilitate interdisciplinary research. A principal factor is coordination of the group within the faculty performing the research. An Associate Professor of Electrical Engineering and an Associate Professor of Soils serve as co-directors, performing essential administrative functions; but direction and planning of a long term nature is primarily performed by the investigators as a group during staff meetings. Seminars are scheduled, as discussed elsewhere in this report, and these contribute a means for individual investigators to present their own work and interpretations to the rest of the group. Interaction in these seminars results in increased discussion among the investigators, prevents unproductive duplication of effort, and generally improves the interdisciplinary research.

Although there is a tendency on the part of faculty members to pursue multidisciplinary research, it is interesting to note that some of the greatest interdisciplinary activity involves graduate students assisting the various faculty investigators. The educational results from this standpoint have been extremely gratifying, and it can be reasonably assumed that through such projects the activity of these students after their graduation will be more broad-based and interdisciplinary than that of their predecessors.

It should be noted that the success of any interdisciplinary activity, particularly within a university, will be heavily dependent upon the cooperation and interest of the administration of the institution. The financial and administrative support tendered by the administration at The Pennsylvania State University has been a significant contribution to the success of ORSER. Although it is often difficult to categorize the individual sources of such support, it seems appropriate here to mention three levels of the administrative organization at Penn State. Department heads have been very cooperative in releasing time for faculty members to participate in this work, often without the department receiving financial return proportional to the faculty time involved. At the Dean's level, and involving intercollege cooperation, both financial and administrative assistance has been generously provided by the Space Science and Engineering Laboratory. Also with cooperation at the Dean's level, adequate space and facilities have been made available to ORSER. Finally, support from the office of the Vice-President for Research and Graduate Studies has been most obviously demonstrated by the granting of a very large amount of unfunded time on the University's main computer system. The purpose of mentioning the support of the Administration here is not just to give proper acknowledgement, but to emphasize the important need of such support for successful operation of interdisciplinary groups such as ORSER.

The advantages of the interdisciplinary research performed on this ERTS project by ORSER are many and varied, but most are obvious. It would be perhaps more important to mention some of the disadvantages in this report. It is somewhat difficult to give proper recognition of individual contributions in interdisciplinary projects. This is perhaps most serious in a university where department heads are not always aware of the types of activity of their faculty in such projects. In addition, the results of such research are frequently published in less traditional manners and generally as a jointly authored report, thus subordinating the individual contribution to that of the group. There is also some difficulty in defining suitable doctoral thesis topics in such projects due to the diverse nature of the problems. On the other hand, there are many topics suitable for M.S. theses. Within ORSER, the lack of a staff specifically employed for management and administrative purposes causes some administrative inconvenience and inefficiency. This disadvantage is currently more than offset by the advantage of faculty control of direction and planning. In general, however, the advantages have been found to be significantly greater than the disadvantages in interdisciplinary research as conducted on the ERTS project by ORSER.

OUTLOOK

During the next year, ORSER will continue its present investigation using ERTS data, initiate work using SKYLAB/EREP data, continue to develop the interest and support of other users in State and Federal Agencies, and develop further and refine facilities and procedures for processing and interpreting multispectral remotely sensed data.

CONTINUATION OF ERTS-1 ANALYSIS

All of the work discussed previously will be continued as indicated in most task descriptions. In some cases the work will be expanded to include other technical aspects and geographical areas (within the test site). Some investigations will develop more in-depth analyses, and in some cases both an expanded and deeper investigation will be conducted. Certain other tasks which have had only a minimal amount of work to date will be initiated and developed, e.g., monitoring air pollution and insect damage to vegetation, evaluation of soil resources, and monitoring of power plants.

During the coming year, emphasis will be placed on analysis of the temporal and seasonal aspects of ERTS-1 data. Preliminary procedures have been developed for this analysis. In addition, ORSER will evaluate the feasibility of transferring spectral characteristics from one ERTS scene to another for purposes of classification. Interdisciplinary efforts on all analyses will be continually encouraged and evaluated. Increased usage of aircraft underflight data for ground truth purposes will be emphasized. The ERTS analysis will be conducted simultaneously with initial SKYLAB/EREP work and appropriate comparisons will be made regarding utility of data, scale differences, etc.

FACILITIES AND PROCEDURES

ORSER has recently ordered a Bausch & Lomb Zoom Transferscope, and expects soon to have a Tektronix 4010 display terminal. The Transferscope permits projection of opaque or transparent images onto a plain surface or another image with a magnification of one to fourteen. A differential scale adjustment permits distortion of the projected image in any chosen direction. Thus, for example, an aircraft underflight photograph can be projected onto a computer-generated map, and adjustment can be made for line and element distortion which would be present in high speed printer output. This instrument is expected to enhance significantly the use of the hybrid approach. The Tektronix terminal will be located in the ORSER laboratory or office and connected to the Computation Center by means of a telephone line, thus becoming a part of the RJE (Remote Job Entry) system. In addition to the display of processing results on a scope, the terminal will have a graphics capability and a hard copier will be available. Both of these equipment items are being purchased by The Pennsylvania State University.

The ORSER programs and procedures will continue to be developed and refined, and, as indicated in its ERTS-A proposal, ORSER expects to involve the General Electric Company in the data processing part of the ERTS project by means of their multispectral analyzer, GEMS. It was decided not to initiate this task until the second year of the contract in order that: (1) ORSER personnel would have a better understanding of the use of ERTS data and the potential use of the GE equipment; and (2) the equipment would have been updated and GE personnel would be better able to suggest efficient and effective ways of using the equipment.

APPLICATIONS TO STATE PROBLEMS

ORSER will continue to seek and develop applications of ERTS data to natural resource and environmental problems in Pennsylvania. The Department of Environmental Resources (DER) of the Commonwealth of Pennsylvania is coordinating the development of a model operational system for a statewide environmental and land use information program to be called PENNRALI. This program will serve as the basis for the implementation of the Commonwealth's environmental master plan. An important input to this program will be derived from remote sensing investigations. The integration and management of PENNRALI is to be conducted by the Director of the Bureau of Planning and Research in DER. This Bureau is responsible for managing and coordinating the functions of environmental master planning, impact statement analysis, and the application of advanced environmental technology.

The development of an integrated system for the processing of remotely sensed data on a statewide basis involves the coordinated efforts of personnel in various interpretive disciplines as well as data processing, pattern recognition, and photointerpretative experts. ORSER consists of personnel with such backgrounds and has written an ERTS-B proposal which was incorporated as a major part of the ERTS-B proposal submitted by the Commonwealth. One of ORSER's objectives in the proposal work was to acquaint and assist State agencies with the use of remote sensing data in applications involving statutory and regulatory requirements. Longer term objectives are to assist various State agencies in Pennsylvania in the implementation of their own data processing and interpretation procedures for remotely sensed data, and to assist the Commonwealth in the development of PENNRALI.

OTHER PROJECTS AND PROPOSALS

In addition to the proposed work with the Pennsylvania Department of Environmental Resources, ORSER will continue to develop other applications. An unfunded effort is currently being pursued in the School of Forestry at Penn State regarding forest land use changes as related to recreational uses. This study involves use of ERTS and aircraft underflight data. ORSER continues to provide computational support and assistance to the MITRE Corporation on their ERTS investigation. A contract with the U. S. Army Corps of Engineers for a remote sensing floodplain feasibility study on the West Branch of the Susquehanna River is presently being finalized, and related work is being conducted by ORSER personnel for the National Park Service. Other proposals and potential cooperation with various governmental agencies have been discussed under SUMMARY OF RESEARCH AND ACTIVITIES.

APPENDIX A

STORAGE AND RETRIEVAL OF ERTS AND UNDERFLIGHT IMAGERY

N. B. Bolling

All ERTS and underflight images are stored in the ORSER laboratory, Room 219 Electrical Engineering West. The laboratory contains two closets, one for internal publications (e.g., technical reports, descriptions of computer programs) and one for the storage of film rolls. There is a file cabinet in which are kept packing slips from imagery shipments, miscellaneous information about images and flights (e.g., flight logs), 35 mm slides used in lectures and classes in remote sensing, and hand-out materials which have been used in seminars or for general information to the public. Two map cabinets contain USGS quadrangle map coverage for all tracks of low altitude underflights. Aeronautical charts and maps at a scale of 1:250,000 cover the entire state of Pennsylvania and parts of the surrounding states and Canada. There are drawers for outsized ERTS images (e.g., "blow-ups") and images mounted for display purposes. Current flight line maps are posted on the bulletin boards, along with imagery and photomosaics in current use.

Storage

ERTS images for Pennsylvania are stored in plastic page protectors in large three-ring binders. They are filed in order of date, exposure time, and channel number. Black and white transparancies are filed first, then color composites, then contact paper prints. The first page in the binder is a copy of page 3-8 from the ERTS Data Users Handbook, explaining the alphanumeric annotation of bulk processed MSS images. A few images for scenes outside Pennsylvania are stored in their original envelopes in a file drawer. Images larger than 8 1/2 x 11 in. format (e.g., "blow-ups", framed color composites) are filed by date in a map drawer. Negatives in the 70 mm format are kept in 3 x 5 in. card file boxes, again filed by date, exposure time, and channel number.

Underflight film rolls are kept on shelves and arranged by flight date, flight line, and portion of the spectrum covered. Some 70 mm rolls which originally contained several flight lines have been separated into single flight lines and put on small reels, facilitating simultaneous usage by persons interested in different areas. Rolls of film in the 9 x 9 in. format have not been so divided, due to their bulk and a limitation on storage space.

Retrieval

Information concerning ERTS and underflight data received by ORSER is kept in several large three-ring binders, blue for ERTS and red for underflights.

ERTS Imagery

The first page of the ERTS Key is a photocopy of page 3-80 of the ERTS Data Users Handbook, explaining the alphanumeric annotation of bulk processed MSS images. The second page is a table of statistics of ERTS and underflight imagery and MSS data, shown here as Table 1. Following the alphanumeric key and the table of data statistics, the ERTS Key is divided by dates into sections, one for each group of ERTS passes over Pennsylvania. For example, there is a section for September 4 through 8. The first page in this section is a base map of Pennsylvania (Figure 1) on which is plotted an outline of each scene for which ORSER has received imagery, with date and exposure time indicated. The second page in this section is an OZALID paper print[1] made from the channel 7 transparency of the earliest scene available in the September 4 through 8 series. Key geographic elements can be determined from this print, and the extent of cloud cover can be observed directly. With this print is a cover sheet indicating the formats in which this scene is available for study (e.g., transparencies in various channels, color composites, "blow-ups", 70 mm negatives, computer compatible tapes). There is an OZALID print and cover sheet of information for each scene within the September 4 through 8 sequence. The subsequent sections have the format described above. Each encompasses a series of passes comprising one complete coverage of Pennsylvania in five days. A separate section in the notebook includes an OZALID paper print and cover sheet for the few scenes outside of Pennsylvania that have been received. The final section in the ERTS Key is a guide to the use of the ERTS Standard Catalogues and accompanying microfilm.

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[1]Such a print of an ERTS image is included as the last page of this appendix.

Table 1: Remote Sensing Data Statistics

Satellite or Aircraft	Approx. Altitude	Sensor	Portion of Spectrum Covered (Micrometers)	Approx. Color Range	Designation	Study Format	Approximate Ground Area Covered in One Image	Approximate Scale	Approx. Ground Resolution (RS unit)
ERTS	500 miles	RBV	.475-.575	Blue-grn	Channel 1	7x7 in. color	13,200	1"=15 miles	150 ft
			.580-.680	Grn-yel	2	composites	sq. miles	or	
			.698-.830	Red-IR	3			1:1,000,000	
		MSS	.500-.600	Green	Channel 4	7x7 in. B&W	13,200	1"=15 miles	260 ft
			.600-.700	Or-red	5	transparancies	sq. miles	or	
			.700-.800	Red-IR	6	and computer		1:1,000,000	
			.800-1.100	Near IR	7	compatible			
						tape			
					Sensors:				
U2	65,000 feet	Cameras	.475-.575	Blue-grn	1 or 11	70 mm film	480		60 ft
			.580-.680	Yel-red	2 or 12	in B&W and	sq. miles	1"=7 miles	
			.690-.760	Red-IR	3 or 13	IR color		or	
			.510-.900	Grn-IR	4 or 14			1:445,000	
		MSS	70 mm scanner imagery available for selected areas in Pennsylvania						
C-130	5,000 to 15,000 feet	Cameras	.450-.705	All vis.	See indiv.	9x9 in. color	1.4 to 21	1"=700-2700 ft	1-3 ft
			.475-.585	Blue-grn	flight	transparancies	sq. miles	1:6000-1:22,000	
			.500-.900	Grn-IR	line	70 mm B&W	1.8 to 26	1"=2600-10,000 ft	3-30 ft
			.590-.710	Or-red	annotation	and color	sq. miles	1:22,000-1:120,000	
			.700-.930	Near IR		transparancies			
		MSS	.340-13.00	UV thru thermal IR	24 channels (Bendix Recorder)	Computer compatible tapes and	-	-	10 ft
						70 mm film	A strip 1.3 to 5.2 miles wide	-	30 ft
C-54	5,000 to 15,000 feet	Cameras	.500-.900	Grn-IR	See individual	9x9 in. color	1.5 to 20	1"=700-2700 ft	1-3 ft
						IR transp.	sq. miles	1:6000-1:22,000	
			.400-.475	Viol.-bl.	flight line	4x4 in. B&W	1.5 to 20	1"=1400-5400 ft	3-15 ft
			.475-.585	Blue-grn	annotations	transparancies	sq. miles	1:12,000-1:44,000	
			.590-.930	Or.-IR					

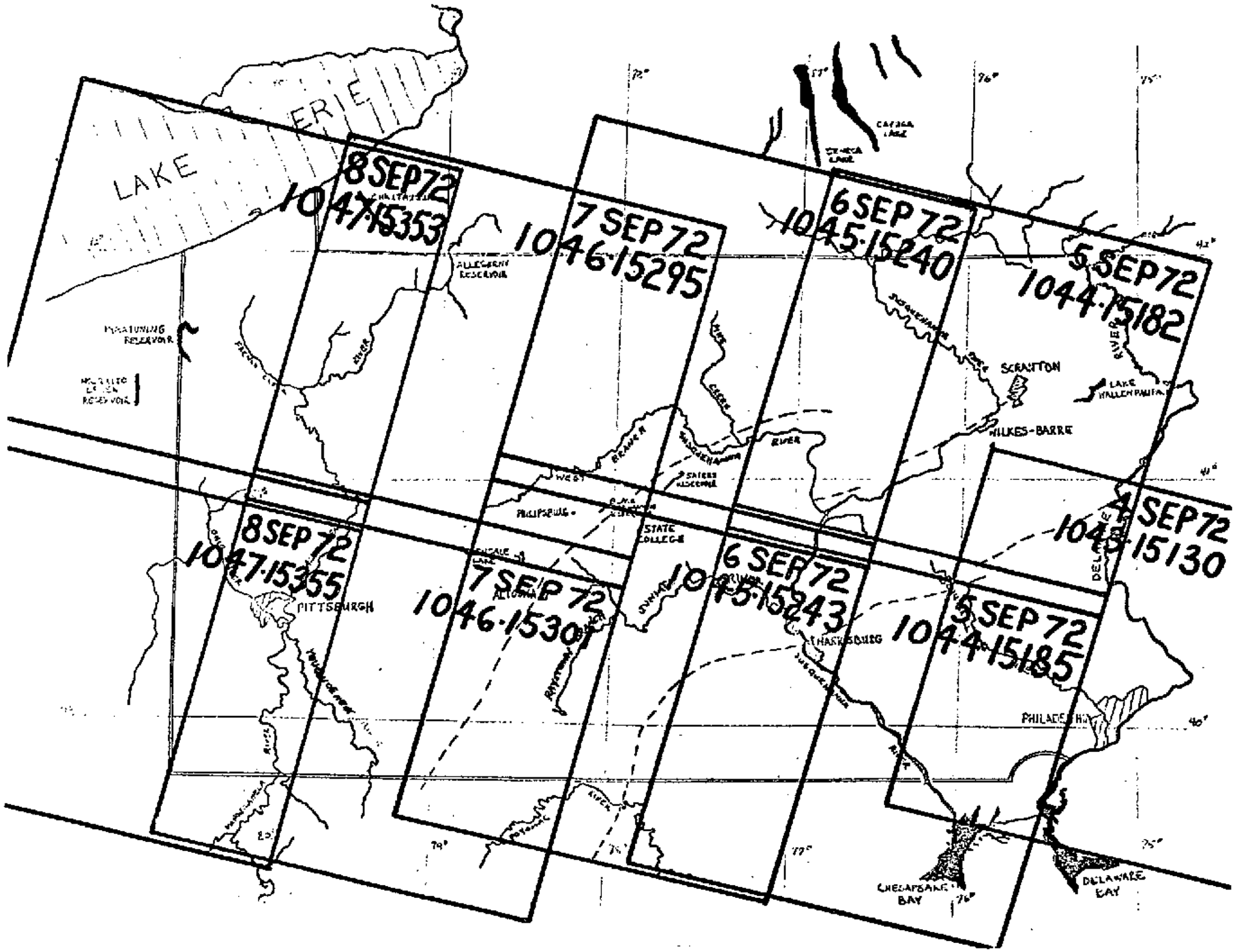


Figure 1: Typical track map for one sequence of ERTS-1 passes over Pennsylvania.

Underflight Data

The first page of the Underflight Key is a note informing potential users that additional information on underflights may be found in the file cabinet, filed under the specific flight type. The second page is a copy of the table of imagery statistics described in the ERTS Key discussion. The third page is an outline map of Pennsylvania on which are drawn flight lines for all underflight coverage of the state, to date, received by ORSER. After this preliminary section of the Underflight Key, the divisions of the notebook are according to flight type (primarily U2 and C130) and the seasons of flight.

The U2 information consists primarily of a data book for each flight, supplied by the Ames Research Center. The track maps provided at the back of each data book have been color-coded to indicate the presence or absence of clouds and haze; and frame numbers, at convenient intervals, have been added. Where flights cover areas in Pennsylvania, a separate annotation sheet has been prepared, indicating geographic locations in the state covered by the flight and the frame numbers on the film, from the various sensors, on which that location may be seen. All U2 flights within Pennsylvania are plotted on an outline map of the state, which is the first page encountered in the U2 section of the Underflight Key.

The C130 information in the Underflight Key consists of a series of information summary sheets, followed by a separate annotation sheet for each flight line. The following summary information is provided: 1) an outline map (see Figure 2) on which is plotted all the flight lines for the season covered by the C130 section following it; 2) a table of photographic information, indicating the portions of the spectrum covered by each camera, the film-filter combination used, the focal length, and similar information; 3) a chart listing the MSS channels and the portion of the spectral band covered by each channel; and 4) a table of MSS imagery and tapes which have been ordered and received. Individual annotation sheets for each flight line follow these summary pages. Each sheet lists key geographic locations on the flight line, with frame numbers for each roll of film on which the location appears (see Figure 3). The format of the photography, its altitude, and the portion of the spectrum covered, are also indicated on each of these sheets for each roll on which the

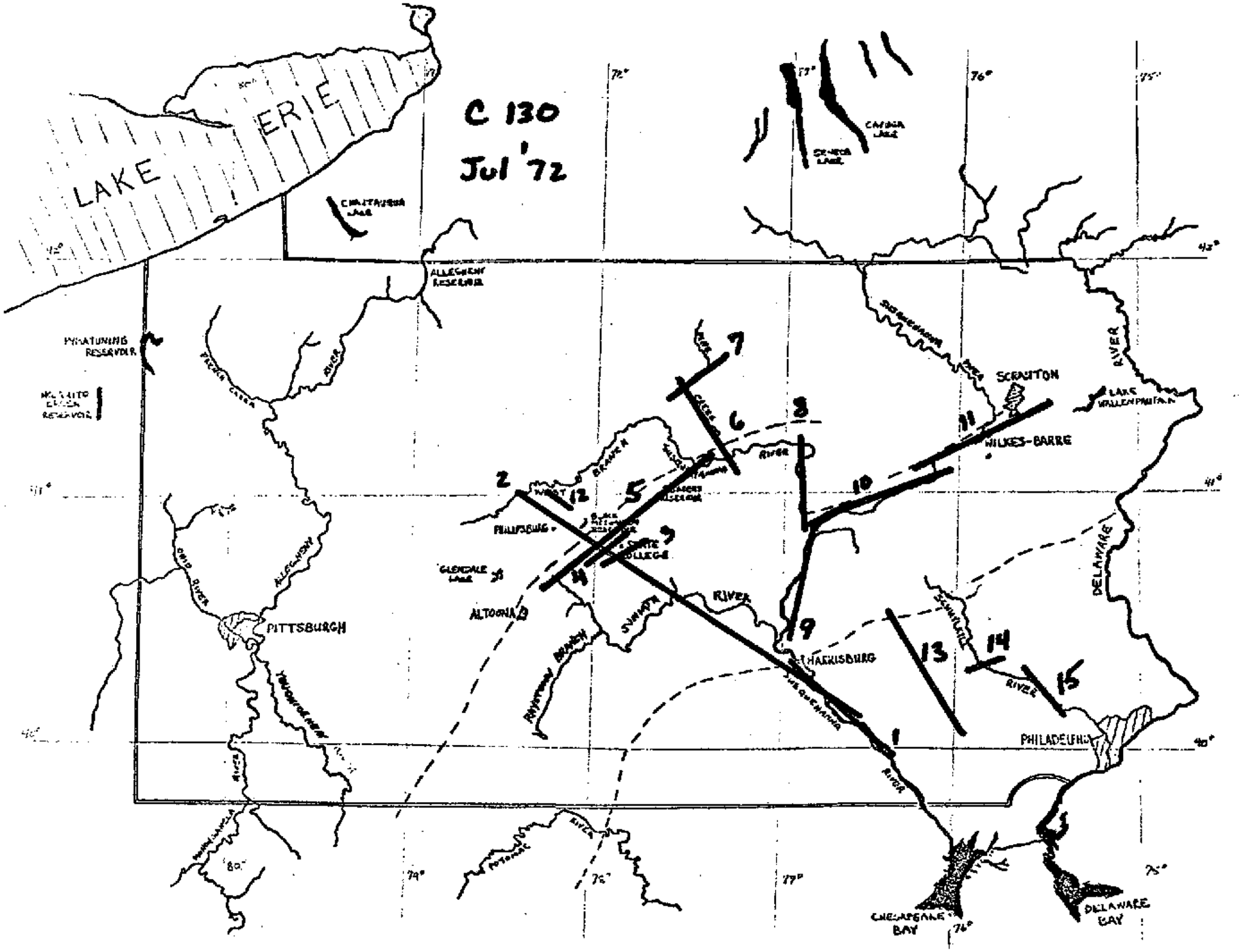


Figure 2: Typical flight line map for C130 flights.

IMAGERY COMPARISON IMAGERY C130 July '72 COVERAGE FLIGHT LINE #3 SKIMONT TO PA. FURNACE

R #	32	33	34	35	36	37	38	General Remarks:
Format	9X9	9X9	70mm	→	→	→	→	GENERALLY GOOD QUALITY
Band	450-705	500-900	500-900	475-585	590-710	700-930	400-700	SOME UNDEREXPOSURE ON ROLL #38
Col/B&W	COLOR	COLOR	COLOR	B+W	B+W	B+W	COLOR	MODERATELY HEAVY HAZE ON ROLL 35
Altitude	4500ft.	→	→	→	→	→	→	VERY SLIGHT HAZE ON ROLLS 34 + 36

FRAME NUMBERS							Location	Remarks
155	155	145	145	145	193	174	START AND SKIMONT	
158	158	148	148	148	197	177	BOALSBURG	
161	161	152	152	152	201	181	SHINGLETOWN	
167	167	157	157	157	212	186	PINE GROVE MILLS	
171	171	162	162	162	219	191	FAIRBROOK	
176	176	168	168	168	229	197	PA. FURNACE	
177	177	169	169	169	231	198	END	

Figure 3: Typical annotation sheet for a C130 flight line.

flight line appears. Data from C54 underflights are recorded in a manner similar to that for the C130 flights.

Borrowing Data Formats from ORSER

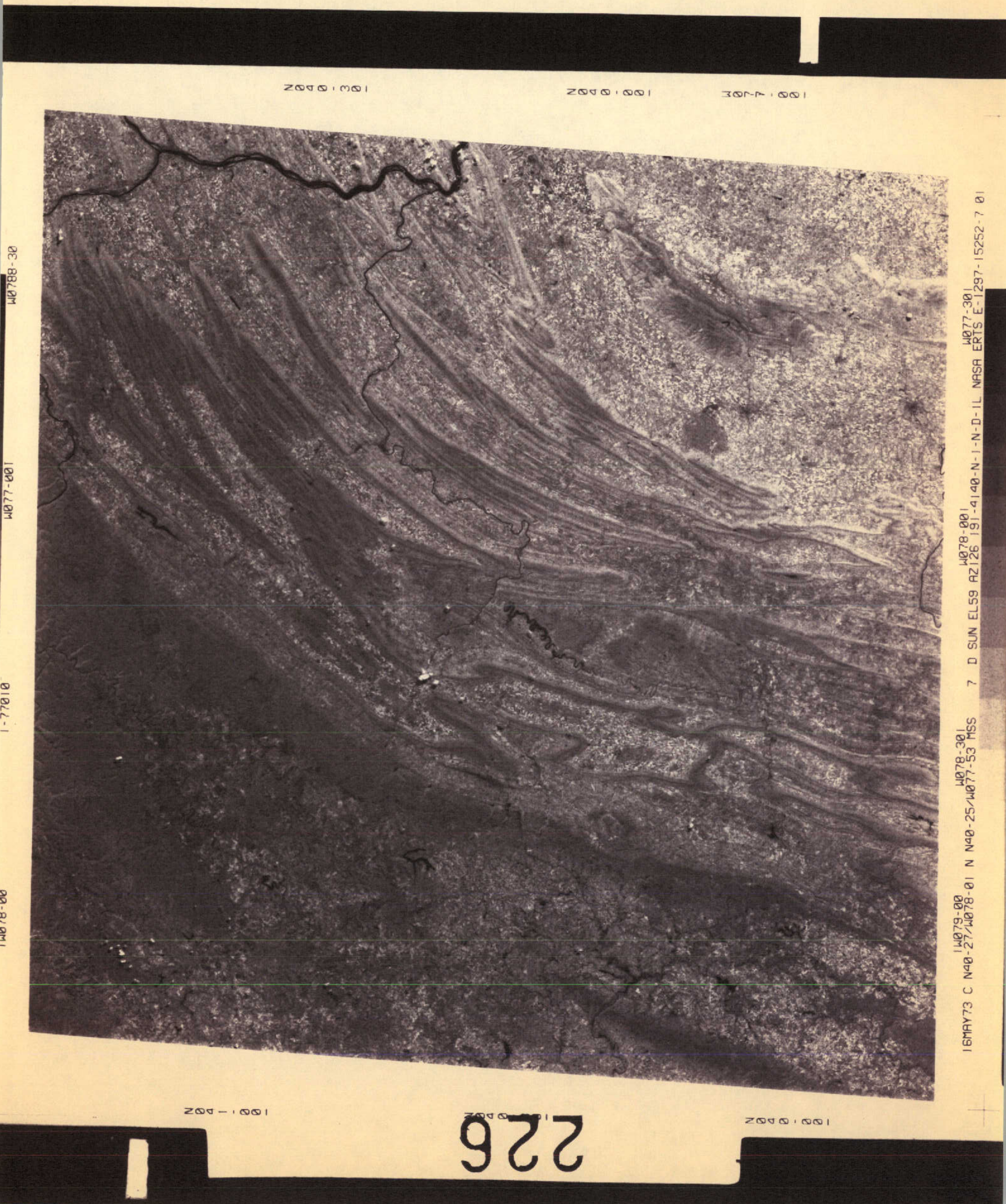
A 4 x 5 in. index card has been prepared for each image, roll of film, or single photographic frame from a film roll (if removed from the film strip). In the case of ERTS formats, the cards are color coded, with a different color for each format (e.g., blue for transparencies, yellow for 70 mm negatives). Each card contains a short description of the item, beneath which is a section with columns for "Date out", "Date in", and the name of the borrower.

When ERTS imagery or tapes are signed out, the borrower is provided with a form on which he is encouraged to indicate the categories of features of the scene which he has found of interest in the course of his research. Initially, he is also provided with a copy of page 4-15 and 4-16 of the ERTS Data Users Handbook listing the Earth Resources Vocabulary suggested for use in filling out ERTS Descriptors forms. The Descriptors forms are later filled out from the information provided by the users and sent to NASA.

Notification of Data Receipt

When new data is received, such as ERTS imagery, underflight film rolls, or computer tapes, the co-investigators on the project are notified within a few days. In the case of ERTS imagery, this notification takes the form of a base map of Pennsylvania on which an outline of the image scene or scenes is traced. The outline is then shaded to indicate cloud cover, if present. The date and exposure number of each image is provided, the available formats are described, and if there is a computer tape set available this is also indicated.

OZALID Print of an ERTS-1 Transparency



APPENDIX B

CATALOGUES FOR REMOTE SENSING DIGITAL DATA TAPES

F. Y. Borden, H. M. Lachowski, and D. N. Applegate

All remote sensing digital data tapes available to ORSER are catalogued and entered into a library. The cataloguing and submission to the library takes place as soon as possible after the receipt of tapes. The library has two sections, active and inactive. The active library section resides in the Computation Center at The Pennsylvania State University and the tapes in that section are managed by the Computation Center in accordance with their policies and procedures. The inactive library section resides in the ORSER facilities at 220 Electrical Engineering West Building. The inactive section is managed by ORSER personnel.

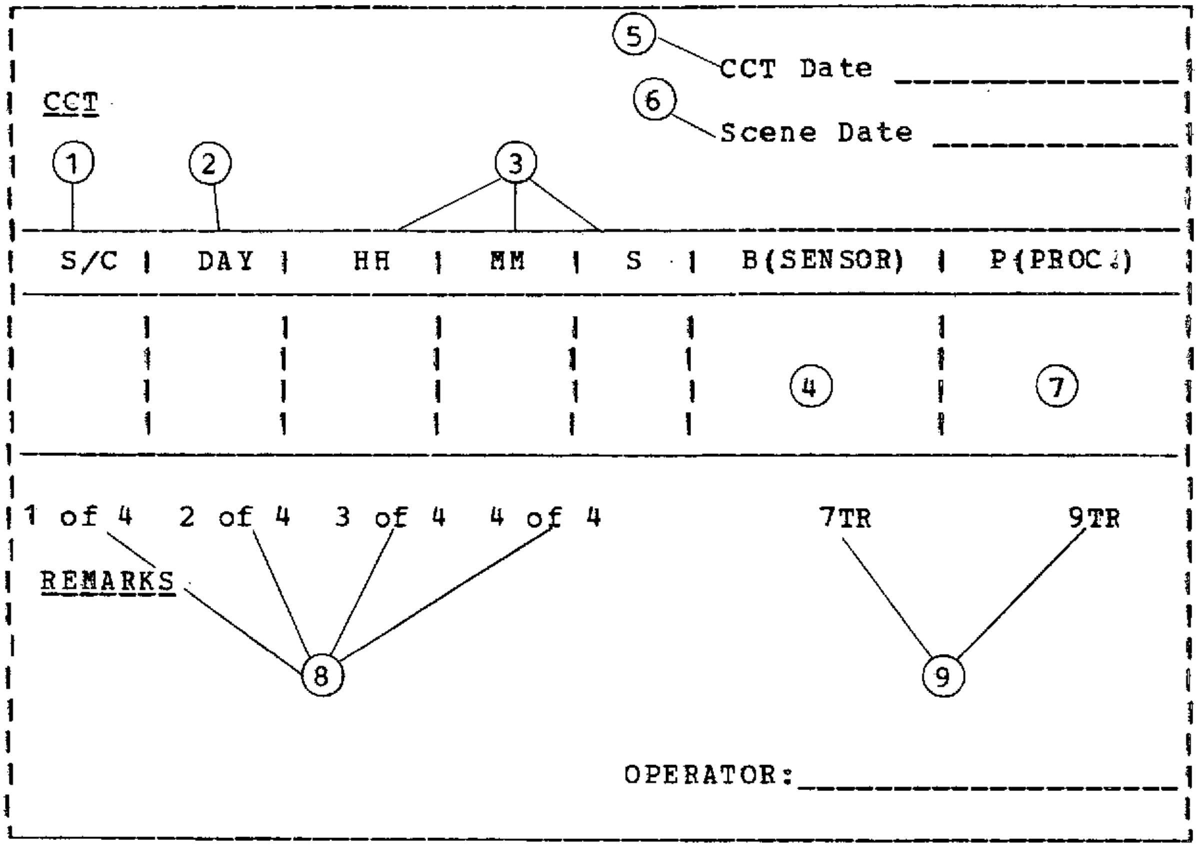
Tape Labels

To meet with the Computation Center requirements, every tape in the active library has been assigned an external label, which appears on the tape cartridge and reel. This is the "ORSER external label." This label must be used in computer processing in accordance with the Computation Center and ORSER program procedures. For convenience in use, each internally labeled tape has identical internal and external ORSER labels. A tape in the inactive library will have been assigned an ORSER external label if, at any time, the tape was in the active library.

The ORSER library is dominated by tapes containing satellite multispectral scanner data from the NASA-ERTS program. Tapes delivered to ORSER from the NASA-ERTS processing facility are referred to as NASA-ERTS tapes. Each NASA-ERTS tape is first entered into the inactive library. Depending on the quality of the data, the tape may remain in the inactive library or be transferred to the active library. For a NASA-ERTS tape entered into the active library, a comprehensive subset tape will be made as soon as possible, after which the NASA-ERTS tape may be returned to the inactive library. The comprehensive subset tape will remain in the active library.

NASA-ERTS tapes that have never been in the active library are catalogued according to the NASA external label. For these tapes, the NASA external label appears on the edge of the tape container as well as on the reel.

All NASA-ERTS tapes have the NASA external label affixed to the tape reel. The NASA external label for satellite data is described in Figure 1. All of the NASA-ERTS tapes and images for satellite data are in bulk processed form. No precision processed satellite data have been ordered. However, the tape management procedures for these would be the same as for bulk processed tapes. The annotation on the bulk and precision processed imagery is organized differently. In Figure 1, the cross-reference of NASA-ERTS tapes to the corresponding imagery is based on bulk processed data and imagery. The scene date, field number 6 in Figure 1, corresponds to the scene date field on the lower left corner of the imagery. The scene identification numbers in fields 1, 2, and 3 of Figure 1 correspond to the scene identification given on the lower right corner of the imagery. The NASA external label scene identification cannot be used as the ORSER external label because the number of digits is too large to meet the Computation Center's external label requirements. The catalogue of NASA-ERTS tapes incorporates the



1 Satellite number. ERTS-1 = 1.

2 The day (since launch) on which the observation was made.

3 Hour of day (HH), minute (MM), and tens of seconds (S).

4 Sensor code: R = RBV, M = MSS.

5 "CCT Date" = Date the computer compatible tape (CCT) was generated.

6 "Scene Date" = Date of observation.

7 Processing code: P = Precision, B = Bulk.

8 Appropriate reel number will be circled by the operator.

9 Number of tracks will always be 9 for ORSER use.

Figure 1. Details of the NASA external label.

cross-reference feature described above. Detailed descriptions of these catalogues are presented later.

File Protection of Tapes

File protection information for each tape is given in the catalogues. Three types of file protection exist for remote sensing data tapes: unprotected, partially protected, and positively protected. File protection governed by the presence or absence of a file protection ring is not reliable because of the conventions and procedures of the Computation Center. File protection is governed by the presence or absence of internal system labels on tapes and the retention date for internally labeled tapes. Tapes that have essentially no protection have internal system labels without any retention date. Each one of these is protected only insofar as it can be accessed by reference to the correct internal label. Working tapes must be of this type in order to be able to accept output. Data that are valuable, in that they would be very difficult or expensive to restore, should not be kept on an unprotected tape.

Positive protection (date protection) can be gained by copying or outputting the data on a tape for which a JCL retention date has been specified. ORSER users should not use the date protection feature. For tapes that should be date protected, ORSER personnel will do it upon request.

An intermediate level of protection exists, called here "partial protection," and occurs only for tapes provided to ORSER from extra-University sources, such as the NASA-ERTS tapes. Partial protection exists for internally labeled tapes in that access to such tapes can be gained only by using Job Control Language (JCL) to specify an unlabeled (not internally labeled) tape. This occurs rarely in routine processing through the Computation Center. In addition, the external label would have to be given (by mistake) or the wrong tape mounted for the tape even to be made physically available to the computer.

Classification of Remote Sensing Data Tapes

Remote sensing data tapes are classified into five categories as follows:

1. NASA-ERTS data tapes,
2. permanent subset data tapes from NASA-ERTS tapes,
3. ORSER users data tapes,

4. other data tapes used by ORSER, and

5. private data tapes.

Catalogues exist and are maintained for each of the first four categories. Tapes in these categories contain data that are available for use by ORSER personnel. Remote sensing data tapes in category five are not considered to be available for use by ORSER personnel and, as such, are not entered into the ORSER tape library. Management of tapes in category five is the responsibility of the individuals to whom the tapes belong.

NASA-ERTS Data Tapes

NASA-ERTS data tapes in the active library are identified by an ORSER external label of the form NAXXXX, where NA identifies the tape as a NASA-ERTS tape and XXXX is the field that identifies the specific tape. These tapes are 9-track, unlabeled, 800 b.p.i. tapes and are partially file protected. They may not be used for output.

NASA-ERTS tapes in the active library contain substantial amounts of potentially useful data. Such tapes may be transferred to the inactive library after comprehensive subset tapes have been made from them. NASA-ERTS tapes that have no useful data (for example, because of 100 percent cloud cover) are not entered into the active library as a general practice and subsets from them are not routinely made.

NASA-ERTS tapes are in the format specified by NASA in "Format and Content Specification for Computer Compatible Tapes," May 1, 1972, published by the Goddard Space Flight Center, Greenbelt, Maryland. They can only be read by the SUBSET program.

Permanent Subset Data Tapes from NASA-ERTS Tapes

It is expected that a permanent subset tape will be made for every NASA-ERTS tape that contains potentially useful data. The NASA-ERTS tapes are not intended to be used as the active data bases for routine use, but rather as archives of data from which active data bases are prepared by subsetting. Therefore, before a user decides to use a NASA-ERTS tape, he should make certain that no suitable subset data tape is in the library. If none exists, then it will be necessary to generate such a subset tape from the NASA-ERTS tape; but, in doing so, the user should define the subset to be broad enough so that another subset from the NASA-ERTS tape does not have to be made.

Permanent subset data tapes from NASA-ERTS tapes will, in general, always be in the active library and are identified by an external label of the form SUXXXX. SU identifies this category and the XXXX field identifies the specific tape. These are 9-track, labeled, 1600 b.p.i. tapes and are date protected so they cannot be used for any other purpose than to contain these subsets. They are in the ORSER format and may be used directly with any programs in the system, including SUBSET. The contents of any of these tapes can be found by referring to the catalogue.

These subset tapes are intended to be used instead of the NASA tape. The advantages of a permanent subset tape over the corresponding NASA-ERTS tape are: (1) the subset tape is in the ORSER format and can be used directly by any program in the system ; (2) the 1600 b.p.i. density doubles the tape processing speed; and (3) where only scattered blocks of data are potentially useful on the NASA-ERTS tape, these have been consolidated on the subset tape thereby eliminating tape processing time devoted to bypassing useless data. If a permanent subset tape has been made, the corresponding NASA-ERTS tape is not likely to be in the active library.

ORSER Users Data Tapes

ORSER users data tapes are identified by RSXXXX, where RS identifies this category and the XXXX field identifies the specific tape. These tapes are catalogued according to the data sets on them if such data sets are essentially permanent and of general utility to ORSER users. Others of these tapes are assigned to ORSER users as work tapes for the purpose of constructing and holding data subsets for their particular uses. Data sets on any of these tapes are considered to be available for use by anyone in ORSER. They may not be reserved for strictly private data sets.

Other tapes in this category may come about as the result of subsetting aerial flight tapes, such as LARS data tapes. In such cases, the subsetting is done to acquire a working copy of an original, to put the data in the ORSER format, to gain data protection, and to take advantage of 1600 b.p.i. density.

After a user has developed a subset of data on one of his assigned tapes, which would be of general interest to other users and which would not be subject to major changes, he should have the tape catalogued according to its contents. ORSER users tapes may or may not be file protected at the discretion of the user in consultation with ORSER personnel.

Other Data Tapes Used by ORSER

Other remote sensing data tapes that are available for use by ORSER personnel are in either the active or inactive library and each may contain remote sensing data from one of a variety of sources. Examples of such tapes are the Bendix flight tapes and LARS data tapes. These are catalogued according to their contents, but there is no particular uniformity in the external labels, except that they are not labeled as belonging to any of the above categories. The tapes may or may not be in the ORSER format; but, in general, they can be read by the SUBSET program using the appropriate control cards. Data on these tapes are available to all ORSER users, but frequently permanent subset tapes have been made from them and these should be preferred for use, for reasons stated earlier. When permanent subsets exist, they are indicated in the catalogue. The catalogue for these tapes indicates whether imagery or aerial photography exist corresponding to data on the tape and, if so, where these can be located.

Private Data Tapes

Users' other private data tapes are the users' own concern, but, to avoid confusion, they should not be labeled as belonging to any of the above categories. They are not catalogued unless the user requests it, under which conditions the data must adhere to one of the acceptable formats and must be available to any other ORSER users.

The NASA-ERTS Tape Catalogue

The NASA-ERTS tapes are catalogued roughly in the order of the overpass of the satellite. The first field in the catalogue line for a tape (see Figure 2) specifies the ORSER external label of the tape. The label appears on the cartridge and on the reel. If an ORSER label has not been assigned, the field will be blank and the NASA external label will apply. The NASA identification field gives the NASA external label in the form and content expressed in Figure 1. This identification corresponds to the image identification. Four reels of tape are required for each scene. Each reel corresponds to a 25 n. mi. wide by 100 n. mi. long strip in a north to south orientation. The reels are numbered from west to east. The date of the overpass is then given. The status field indicates whether the tape is in the active or inactive library. The active library is at the Computation Center. Any tape in the active library can be accessed directly by the user's

ORSER Label	NASA ID	Reel	Imagery Date	Status[1]	Alternate Tape Reference	Imagery Available	File Protected[2]	Date Catalogued	Date Received
NA0012	1045-15240	1	9-6-72	A	SU0001	7	P	12-17-72	11-29-72
NA0013	" "	2	"	A		7	P	"	"
NA0014	" "	3	"	A		7	P	"	"
NA0011	" "	4	"	A		7	P	"	"

[1]A - in active library; I - in inactive library.

[2]File protection: N or blank - not protected; P - partially file protected; Y or date - protected indefinitely or until the specified date.

Figure 2: Sample page from the NASA-ERTS Tape Catalogue.

programs by specification of the tape label in his control information. The inactive library resides at 220 Electrical Engineering West Building. Tapes in the inactive library cannot be accessed directly by programs, but must first be entered in the active library. ORSER will do this for users on request.

The alternate tape reference field indicates whether a subset has been made of all the potentially useful data from the NASA-ERTS tape. If such a subset has been made, the tape label for that subset tape will be specified in the field, otherwise, the field will be blank. Permanent subset tapes will generally be made and are recommended as alternatives to the NASA-ERTS tapes that contain any data worthy of investigation. Subsets will not exist for NASA tapes for which cloud cover is essentially total.

The imagery-available field specifies the channels of imagery for the scene that have been received by ORSER. If imagery has been received, an Ozalid copy of the imagery from one channel will be inserted behind the data sheet for the scene for cross-reference purposes. The quality of the image is not important in this use. The images are marked to show the four 25 n. mi. by 100 n. mi. strips. When permanent subsets have been made, the areas in each subset are marked and the external label of the subset tape is given.

NASA-ERTS tapes are only partially file protected as indicated by the next field. The two date fields are self-explanatory.

The Permanent Subset Tape Catalogue

The catalogue of permanent subset tapes from NASA-ERTS tapes is organized, in general, in the same way as for the NASA-ERTS tapes. Only the differences will be discussed here. The tape label (see Figure 3) always has SU as the first two characters. The subset source field is for reference to the NASA-ERTS tape or the subset tape from which the subset was made. The retention date field specifies the date to which the tape remains positively file protected. If the field is blank, the tape is unprotected. The rest of the information follows the same specifications as apply to NASA-ERTS tapes. The imagery in the "NASA-ERTS Tape Catalogue" shows the general areas included in the subset for each of these subset tapes.

ORSER Label	NASA ID	Reel	Imagery Date	Status[1]	Subset Source[2]	Date Generated	Retention Date[3]
SU0005	1080-15192	1	10-11-72	A	NA0031	3-10-73	
SU0006	" "	2	"	A	NA0032	"	
SU0007	" "	3	"	A	NA0033	"	
SU0008	" "	4	"	A	NA0034	"	

[1]A - in active library; I - in inactive library.

[2]Refers to the actual tape used in generation of the subset.

[3]Tape is positively file protected until the given date, otherwise it is not file protected.

Figure 3: Sample page from the Permanent Subset Tape Catalogue.

The ORSER Users' Data Tape Catalogue

The first field in the "ORSER Users' Data Tape Catalogue" specifies the ORSER label for the tape (see Figure 4). All tapes in this catalogue have RS as the first two letters of the ORSER label. The next field states the name of the user to whom the tape was assigned. If the name "ORSER" is given, the tape is a permanent subset tape of general interest to ORSER users. Tapes that were initially assigned to a specific user and contain subsets of general interest are reassigned to ORSER at the user's request or when the user becomes inactive in ORSER.

The subset source field designates the identification of the tape from which the present tape was generated. An ORSER label is given if such exists and, if not, another appropriate label is given as used in one of the catalogues. The collection date field refers to the day, month, and year the data were collected. The status field indicates whether the tape is in the active or inactive library. The NASA-ID field specifies the NASA internal label if the subset source is a NASA-ERTS tape. The remaining two fields are the same as described for the "Permanent Subset Tape Catalogue."

ORSER Label	User Name	Subset Source[1]	Collection Date	Status[2]	NASA ID (if applicable)	Date Generated	Retention Date[3]
RS0001	ORSER	LARS 4	5-69	A		1-9-73	
RS0002	D. WILSON	NA0015	8-19-72	A	1027-15240	12-1-73	
RS0003	ORSER	SU0001	10-11-72	A	1080-15185	1-10-73	

[1]Refers to the actual tape used in generation of the subset.

[2]A - in active library; I - in inactive library.

[3]Tape is positively file protected until the given date, otherwise it is not file protected.

Figure 4: Sample page from the ORSER User's Data Tape Catalogue.

The Other Remote Sensing Data Tape Catalogue

The "Other Remote Sensing Data Tape Catalogue" is organized to have one tape description per page. The upper part of each page follows the field descriptions of the previous section. The lower part of each page contains a more comprehensive description, according to the headings, than is possible by filling in blanks and is self-explanatory (see Figure 5). For users who submit data tapes to the library in this category, it is extremely important that these sections be filled in with as much detail as possible. Whenever other documents or publications can be referred to for more detail, they should be indicated, but not substituted for the description requested on the form.

Tape Detail Catalogue

Detailed information sheets, obtained by use of the TPINFO program, for data tapes of general interest form the "Tape Detail Catalogue." For subset tapes, the item of major importance in this catalogue is the table of contents giving the line and element specifications for each block subset onto the tape. Information for original tapes is included

Orser label HU0001

Other identification MISSION #207, AREA(S) T, V

Reel number 1

Collection Date JULY 20-21, 1972

Status[1] A

Alternate tape reference ______

Date catalogued 3-15-73

File protection[2] P

Imagery reference:
T- ROLL 89, FRAMES 1-3
V- ROLL 89, FRAMES 7-9

Geographical area description:
FLIGHT #2, HARRISBURG TO PHILLIPSBURG

Purposes for which is intended or has been used:
GROUND-TRUTH DATA FOR ERTS MSS DATA

Description of data collection system, flight, etc.
C130 AIRCRAFT, BENDIX 24-CHANNEL SCANNER (4, 8, 9, 10, 14, 21)
ERROR PRINTOUTS AVAILABLE (REF. SECTION 2.2-107 IN *)

Format description:
UNIVERSAL FORMAT, DISCOURAGED ARRANGEMENT. REFER TO
*EARTH RESOURCES DATA FORMAT CONTROL BOOK, SEPT., 1972.
SECTION 4.2.

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[1]A - in active library; I - in inactive library.

[2]N or blank - not protected; P - partially file protected; Y or date - protected indefinitely or to the specified date.

Figure 5: Sample page from the Other Remote Sensing Data Tape Catalogue.

only if a corresponding complete permanent subset tape has not been made. Working tape information is included only for such tapes that are of general utility for ORSER users. The TPINFO program may be used at any time to obtain information on any tape in the event the TPINFO output for that tape is not found in the "Tape Detail Catalogue."