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FINAL REPORT

VOLUME ONE

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INVESTIGATIONS USING DATA IN ALABAMA FROM ERTS-A

Principal Investigator

DR. HAROLD R. HENRY

Submitted to

Goddard Space Flight Center
National Aeronautics and Space Administration
Greenbelt, Maryland

August, 1974

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Submitted by

Bureau of Engineering Research
The University of Alabama
University, Alabama

August, 1974

ACKNOWLEDGMENTS

In a project incorporating the research of several senior investigators, several professional teams providing secondary support, and several semi-independent studies by investigators working on advanced degrees, it is difficult to segment the fruits of the effort and assign appropriate recognition to all who have made significant contributions. When a research project such as the one reported here has been largely structured around the voluntary cooperation and only partially subsidized efforts of the ultimate users of research results, the task of making appropriate acknowledgments is all the more difficult. It is not possible in space allotted here to recognize a large number of individuals from both public agencies and private firms who aided us by making some attempt to use ERTS data or at least taking their time to discuss with us why they were not able to utilize the data or the analyses provided by various researchers. To this group we acknowledge our general gratitude.

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The Alabama Development Office which closely monitored the research output, provided us with many insights into their actual and political needs and furnished critiques and feedback on the land-use studies.

The Marshall Space Flight Center which provided the Scientific Monitor for the project in addition to computer time and expertise for automatic classification techniques.

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The various regional planning agencies which provided valuable feedback.

To these agencies and industries, I and the other members of the professional staff express our deep gratitude.

I also wish to express my personal appreciation for the work of the senior staff and key assistants who are appropriately recognized individually in the credits given in the various sections of this final report. This group, incidentally, includes the Geological Survey of Alabama and various members of their staff in their role as project researchers, a function overlapping but partially independent of their input as a user agency. Marshall Space Flight Center also falls into the category of both official participant and contribution of major inputs as an independent entity.

The process of pulling the parts together and keeping up with the details always depends upon key personnel in the behind-the-scene staff.

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Harold R. Henry
UN 604

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INTRODUCTION AND SUMMARY

Overview

As suggested by the Acknowledgments, this final report pulls together the more significant findings of a diverse group of professional investigators and incorporates the insights and contributions of an even larger number of participants whose contributions ranged from casual comments to detailed written evaluations. The results of these efforts are presented at several levels of integrated insights in order to provide readers with the appropriate level of detail for their particular purposes. The general format for reporting the results of this study is as follows:

Bimonthly Reports (previously submitted)--provide insights into the day-to-day operations, specific problems, and a number of details on the specifics of interdisciplinary and interagency coordination.

Volume I: Methodology and Findings (this report) presents an overview of project organization and results plus five Sections representing the insights and findings of the all but one of the research teams providing the basic interdisciplinary inputs.

Volume II: Theses and Special Reports is presented in several independent Sections which report the results of specific supplemental studies following a single aspect of the basic thrusts. These works, all byproducts of academic research applied to specific operational problems, reflect independent individual viewpoints as opposed to the staff syntheses reported in Volume I.

Volume III: Report of the Geological Survey of Alabama. This report collectively serves as the sixth general disciplinary thrust, and might well have been organized as part of Volume I. Presentation as a separate Volume, however, gives emphasis to the dual role the agency served as an ultimate user as well as a discipline-oriented research unit. Papers similar to the special reports of Volume II are also incorporated.

The organization of the report only partially reflects the multifarious objectives of the several tasks undertaken in this project. The dimensions of the effort were both interdisciplinary and inter-agency, overlapping into a matrix of technical inquiries applied to specific application of remotely sensed data in applied applications. The areas of technical interest include geography, geology, marine science, environmental management, regional planning, computer technology, and economics. Applied areas of emphasis included the activities of users ranging from agencies such as Geological Survey of Alabama staffed with technically trained professional researchers to smaller field offices of governmental agencies with an interest in potential output but virtually no in-house expertise in remote sensing technology.

Organization for Presentation of Experimental Results

Except for the generalized findings reported in this introductory section, the major results of specific applications are presented in the several other sections of this volume. By and large, these results reflect a synthesis of findings of several related studies conducted either by or under the direction of senior staff investigators. These major divisions report on the experimentation and general conclusion relative to land use and associated resource management, an application in water quality controls and regulation, and an application to the general marine science problems and coastal zone planning. In addition, two general support functions were available to all project participants. Reports on computerized application and economic evaluations are found in Sections Four and Five. The major divisions of primary research efforts reflect the project organization and format of material which has already been reported in the several bi-monthly reports.

The five sections outlined above emphasize the technical applications of ERTS data. A major part of the research effort, however, was to monitor the interaction among the participants and assess the needs for improving the transfer of knowledge and techniques as opposed to the team development of application as emphasized in the several numbered sections. The monitoring role and general conclusions related to user acceptance are reported in this introduction.

Communications and Distribution

The communications plan for both interdisciplinary and interagency interaction is spelled out in greater detail in a paper presented at the Eighth International Symposium on Remote Sensing, Ann Arbor, Michigan, in June, 1972. In this paper, the Principal Investigator teamed with the State Geologist of Alabama and the Director of the Environmental Applications office of MSFC to provide detailed insights into the mechanics of coordinating the diverse activities of project participants to bring the fruits of developmental experimentation to specific applications. This paper is presented as Appendix I of this introduction.

An integral part of data distribution problems was the liaison function. In addition to providing ERTS data to a number of scheduled users of the information, the project staff was to disseminate research findings to potential users, and to facilitate the distribution through limited processing of data for user agencies upon request. In order to fulfill this function, a library of ERTS findings and reports was established. Photographs and publications were catalogued under subject and author headings for quick reference and dissemination. Approximately twenty agencies requested and received data from the library, with several agencies making personal visits for more extensive searches.

The need for the liaison function and a network of researcher-user contacts were established in previous work. Interest of project personnel in remote sensing dates back to 1969, and several staff members began actual work on identifying and working with potential users of remotely sensed data in May 1970. (See Appendix II for a detailed survey of project history.)

The accomplishments and insights provided by these activities are reported after a selective presentation of related technical findings.

Summary of Selected Findings Related to General Conclusions

The several independent investigations in the land use sections first demonstrated the feasibility of developing land use maps for manual classifications and later demonstrated additional economics of effort through automatic classification techniques. The latter method clearly emerged as the superior approach with one major limitation--excessive use of computer time. An incomplete extension of the experimentation to correct this deficiency, reported by the computer section, indicates that this technical difficulty will soon be overcome by using a modified clustering technique.

Potential user agencies, directly observing and making suggestions on the experimental applications, felt that neither mapping technique produced results consistent with the quality desired by state and regional planners or the quality demanded in conventional applications such as county andmunicipal zoning. Their enthusiastic response to accomplishments and projected development of the land use methodology centered around the pressing needs for state and for multi-county planning functions, pending legislation on state land use planning, and related requirements such as coastal zone management.

In regard to the areas of future potential interest, ERTS output offers a partial solution to the problems of a meaningful data base, which in turn offers a new way of assessing the problems. ERTS data also offers a longer range potential for frequent, low cost inventories of land use subject to time series analysis. Over time, these independent potential advantages are expected to develop into an integrated new approach to land management.

Environmental quality management through systematic monitoring and analysis of pollution indicators is clearly demonstrated as a feasible and potentially cost effective approach for regulatory agencies. The indisputable comparability of the quality to ERTS-acquired data with conventional methods of data acquisition gave rise to cost comparisons showing ERTS economics as presented in reports of both environmental and marine science experiments. Moreover, tentative plans are already underway for the further use of methodology developed and the use of large quantities of data collected but not yet utilized.

It is also worth noting that the problem of resolution served as a basic reason or excellent excuse to postpone the use of ERTS data until quality improvements are introduced. Right or wrong, a high percentage of potential users believe that existing military technological needs was available but unused.

In regard to data not utilized, both project experimenters and agencies requesting data experienced some excessive time lags in delivery and in the quality of the data received. This was particularly true in regard to getting delivery of 40 x 40 ERTS prints and duplicates of 9 x 9 prints were of very poor quality. In addition, the cost of enlargements (through GSFC or in many cases, private firms) placed a financial constraint on several experiments. Some of these problems are covered extensively in the report by Geological Survey, but were more extensively criticized in user feedback. After some of the problems were worked out and second throughts were given to the potential missed, some experimenters are now getting data not previously received.

Checks and greater in-depth probes of the cost-savings feature documented in the use of DCP's gave rise to a more precise identification of the long term contribution to be expected from remote sensing technology. In spite of recognizable economics of ERTS methodology over old methods and use of data, the staff judged the greatest future value to be in innovative uses producing knowledge not now available through alternative sources of data or existing methodology. Whittle, for example, reports in Section Two that his most significant conclusion relates to the newly created capability of modeling and verification of river quality in large and remote areas. The DCP, with transport flexibility, is superior to on-shore installations primarily because it can be moved and reused to find optimal points of data collection. The real benefit is not so much the substitutability of ERTS methodology as the new horizons opened up.

The findings summarized above are clearly interrelated to difficulties encountered and conclusions reached in regard to project data requested for the Cost Benefit study conducted by Earth Satellite Corporation for NASA and the Department of the Interior. As reported in the section on Economic Considerations, a conserted effort was made by the project researchers to clearly segment cost-effective comparisons, i.e., uses of ERTS data as an alternative to conventional methodology, and the conceptually more difficult "benefit" which might accrue from the application of ERTS data in generating new knowledge. The results of project efforts overwhelmingly indicates the future role of remote sensing to be in innovative, new, and complimentary uses for existing techniques rather than providing a substitute. Moreover, the economists have serious reservations as to the possibility of developing meaningful estimates of the value of the still undefined "benefits" to be derived from future applications.

Learning Curves

The finding summarized above appears to have particular relevance to the national concern for a Cost-Benefit evaluation in general and the Learning Curve in particular. The Learning Curve, as utilized in the EarthSat framework for evaluation, refers roughly to the anticipated rate of technological innovation as monitored in our assessment of user acceptance of ERTS data. Our secondary but intensive effort to make both data and the results of application as widely available as possible would tend to shorten the curve by accelerating the rate at which the technology would be adopted by user agencies.

Our evaluation of user acceptance, in turn, sought to find out (1) what would be done with remotely sensed data that user agencies already recognize as operational and (2) what else must be done before the methods are accepted for implementation. In general, we were not optimistic that present budgets of potential users would be used to adopt the methodologies either on board or those being developed in the near future. In spite of some enthusiastic individual response, it is clear that most agencies need additional proof and time for decision-makers to absorb the implications of findings to date. This was particularly true in regard to applications which threaten the institutional structures. Land use planners, for example, are not particularly anxious to implement office procedures which may require personnel with specialized training in a new area.

More technical and innovative applications, such as the river (and coastal area) modeling, have received instant acceptance as summarized above and reported in greater detail in other reports. Extension of the projected output to social and economic benefits, however, must first overcome political as well as institutional resistance. In an open seminar presenting the results of this application, for example, much time was devoted to a challenge and detailed proof of the quality of the data output. After establishing validity of data readings, the discussants, who include several industrial representatives, personnel from U.S. Geological Survey, Bureau of Mines, and a number of state agencies, turned to the general validity of measuring the level of pollution from the highly conventional indicators utilized in the experiment.

These factors lead to the general conclusion that the learning curve for most applications will in all probability take two or three times as long to reach a level of general implementation as would normally be estimated if only technological lags were considered. For future ERTS projects, our experience also suggest relative less emphasis on voluntary user participation, more direct and totally funded demonstration projects of actual application, and relative more emphasis on new and complimentary applications as opposed to substitute uses in the production of "conventional" products.

APPENDIX I

Paper presented

at the

Eighth International Symposium

on

Remote Sensing

Ann Arbor, Michigan
June 1972

USE OF DATA FROM SPACE FOR EARTH RESOURCES EXPLORATION AND MANAGEMENT IN ALABAMA

by
George McDonough[(1)] P. E. LaMoreaux[(2)]
and Harold R. Henry[(3)]

Introduction

The University of Alabama, the Geological Survey of Alabama and the George C. Marshall Space Flight Center are involved in an interagency, interdisciplinary effort to use remotely sensed multispectral observations to yield improved and timely assessment of earth resources and environmental quality in Alabama. It is the goal of this effort to interpret these data and provide them in a format which is meaningful to and readily useable by agencies, industries and individuals who are potential users throughout the State.

In order to assess the full range of potential users of these data in Alabama, a study was conducted by the University and the Geological Survey in 1971. During this study the several hundred potential users which were contacted by project personnel were informed of the remote sensing applications which can make use of observations from NASA's Earth Resources Technology Satellite and associated aircraft flights. These contacts were made by telephone calls, letters, personal conferences, and two symposia (one in Tuscaloosa and one in Mobile). The potential users were informed as to the possible applications of remote sensing from space in the area of land use, resource inventory, environmental control and others. Only a few of the people contacted were already familiar with

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(1) Director of Environmental Applications, Marshall Space Flight Center

(2) State Geologist of Alabama

(3) Professor and Head, Civil and Mineral Engineering Department, The University of Alabama

some aspects of remote sensing while the majority had no prior knowledge concerning this tool and its areas of applicability. In spite of this, the responses were enthusiastic and indicated that there would be a large amount of use of remotely sensed data after some degree of interpretation had been accomplished.

To give some idea of the breadth of possible users, categories and uses in Alabama, the following results of this user study are given below.

Professionals who said they could use the data beneficially included urban planners, regional planners, foresters, geologists, ecologists, hydrologists, agronomists, biologists, physicists, astronomers, chemists, agriculturists, civil engineers, chemical engineers, agricultural engineers, mining engineers, geographers, limnologists, entomologists, architects, archaeologists, demographers, lawyers, and university faculty members.

Possible categories of use were estimated to include land use, cartography, hydrology, geology, transportation, ecology, forestry, fisheries, minerology, meteorology, morphology, agriculture, oceanography, archaeology, topographical mapping, demography, planning and wildlife studies.

Detailed uses which were included as potentialities are flood control, soil studies, resource inventory, surface water studies, mineral exploration, ground water studies, water temperature studies, growth trends, surveying and mapping, air quality management, water quality management, disaster detection, damage evaluation, sediment transport, traffic studies, erosion control, irrigation, zoning, crop conditions, recreation, management, urban and regional planning and pesticide studies.

The enthusiastic response from potential users as described above indicated that the planning of varied state-wide applications of remote sensing oriented toward a broad base of grass roots users would be a timely and beneficial effort in Alabama. Therefore The University of Alabama, the Geological Survey of Alabama and the Marshall Space Flight Center joined efforts to utilize this tool in state-wide applications.

Objectives

The objectives of this effort are:

(a) To determine the applicability of remotely sensed data from ERTS for inventory and management of the natural resources and the improvement of the quality of the environment in Alabama.

(b) To apply photographic interpretation techniques and statistical data management techniques to remotely sensed multispectral observations and ground truth measurements of pertinent resource characteristics and environmental parameters to yield improved and timely assessment of the State of Alabama resources and environmental quality in an appropriately condensed format which is meaningful to and readily useable by individuals in the various cooperating user agencies throughout the State of Alabama.

(c) A long-range objective is to develop an effective procedure for processing and interpreting the remotely sensed data so that information in forms most suitable for ultimate users can be extracted and communicated to them. It is anticipated that the ultimate users will be public policy technicians and decision makers as well as private industries.

Discussion of Objectives

On the basis of the evaluation of the Apollo 9 photographs it is anticipated that ERTS imagery could aid in the following areas related to water resources:

1. Determining areas of ground water movement.
2. Determining areas of ground water discharge.
3. Determining areas of ground water recharge.
4. Determining areas of future sinkhole development.
5. Determining areas of anomalies of low flow in streams.
6. Determining areas of possible pollution through malfunction of salt water lines in oil fields.
7. Determining changes in thermal patterns of reservoir and streams.
8. Defining surface drainage and runoff patterns.
9. Determining changes in sediment load in reservoirs.
10. Locating lineaments, fault trends and domal structures and other geological features.

Several additional aspects of the proposed project will be of particular interest to those engaged in traditional environmental engineering activities. For the sake of classification they can be described as falling into one of the following problem-application areas.

1. Potamology
2. Lacustral Systems
3. Estuarine & Marine Systems
4. Predictive & Evaluative Hydrology
5. Atmospheric Pollution

The water quality management studies related particularly to the rivers will be to determine the impact upon practical water resource management which can be effected by diurnal reporting of such parameters as stage, discharge, temperature, dissolved oxygen concentration, specific conductivity, pH, turbidity, and wind velocity by the strategically located DCS platforms.

Significant lacustral studies are made possible by the existence of relatively large navigation and hydroelectric impoundments on the rivers in the study area. The multispectral data for the impoundment areas will be evaluated for use in the preparation of isoplethic maps of depth as well as for areal delineation. The data will also be assessed for their utility in monitoring remotely detectable types of extraneous materials including turbidity and pollutants. It may be possible to detect, identify and continue to observe benthic colonies of interest in the impoundments. The thermal IR data may also furnish leading indications of known and expected thermal lacustral process occurrences important for effective water resource management.

Mobile Bay and adjacent portions of the Gulf of Mexico will be the site of estuarine and marine studies similar to the lacustral studies described above. In addition to their use for the determinations of depth, shoreline and current mapping, the ERTS data will be used to monitor projected oil drilling activity in Mobile Bay for the occurrence of possible oil spills. Their utility for monitoring other pollutional sources already existent there is anticipated. The effect of this repetitive data of greater areal extent than any ever before available upon the effective management of these water resources will be assessed.

In the areas of predictive and evaluative hydrology, it is intended to relate spectral data to parameters obtained from ground based instruments to provide better means of predicting discharge rates of the rivers. Also, similar data will be used to evaluate the accuracy of areal flood extents so predicted.

The improvement of prediction of stream discharge rates will be sought first by extrapolation of sparsely instrumented precipitation surveillance networks by use of the remotely sensed data. MSFC's unsupervised classification algorithms will group all resolution elements that look essentially the same to a photographic or electronic sensor. With such a classification it is anticipated that a few precipitation readings can then be extrapolated throughout a large area by identifying all other resolution elements which look spectroscopically similar to the element sampled by the ground truth reading. A major electric utility having hydroelectric facilities in the study areas has indicated intense interest in the use of such improved predictive and evaluative methods.

Within the duration of the proposed study, existing state and federal laws will begin to take effect for the abatement of significant air pollution problems within the study area. It is planned to use the ERTS data, insofar as it is possible, to indicate the magnitude of improvement which those abatement efforts produce. Birmingham and Mobile are the two major urban areas which will be studied as regards air pollution but there are other significant isolated pollution sources as well.

The conceptual approach to the use of remote sensing data in social and economic planning centers around communications and distribution. This emphasis complements other aspects of this effort which are concerned with collecting, organizing and reporting in useful form hydrologic, geologic, oceanographic and other environmental and earth resources data. Research described above resulted in an accurate identification of potential users and user categories. One major problem, however, will be in the transmission of data from analyst to the end user. There is an immediate need to translate the items of data output into a form usable by state agencies and law makers. The technical literature is virtually meaningless to public policy technicians and decision-makers.

It has been only recently that the need for better management of the state's resources has been recognized. Former policies in regard to resource development have been limited to discovery and advertisement of the assets which provide jobs and wealth; now, greater emphasis is placed upon technical analysis of the problems of economic growth and development and the need for appropriate legislative control over resources, land use and other aspects of an orderly development process. The state's primary planning office, ADO, and its regional counterparts in the state's multicounty development district are just beginning to become operational.

The primary need within these planning units, beyond the considerable accomplishment of recognizing the need for organization in the first place, is for useful and current data relevant in managerial decisions. High on this list of data required is information on land use and water quality and quantity. Analysis of existing data is admittedly amenable to the understanding and forecasting necessary for establishing policy on environmental quality, but data useful in the day to day implementation of policy is still a major operational bottleneck in sound regulation. The possibility that ERTS acquired data could eliminate this bottleneck will be investigated.

Planning agencies have a clear responsibility to document the extent and causes of environmental damages over extensive areas, and place industrial expansion damage in proper prospective. ERTS data could probably be effective in such documentation. Moreover, managerial data generated, analyzed or distributed by planning agencies is not limited in usefulness to the public sector. These agencies could provide a useful outlet for dissemination of information from ERTS and other sources to private industries which would support and enhance their operations. These usages of ERTS data will require the closing of the communication gap between the scientific and the resource manager or public policy maker who will use the information digested from the remotely sensed data.

Since the long range objective of the project is to develop an effective procedure for processing and interpreting the remotely sensed data and disseminating meaningful information to users, Figure 1 emphasizes the fact that information will be distributed to appropriate users from several intermediate stages of processing and interpretation. Feedback from the users (as shown in Figure 1) will be very important in refining the interpretation and processing in order to obtain the most useful form of the output.

Figure 2 is a diagram of data and information flows which emphasizes the disciplines which will be brought to bear in interpretation and evaluation at the University of Alabama and the Geological Survey of Alabama. This diagram shows that explicit evaluation and management of information flows will be performed on all information output to users. The indicated feedback will serve to allow an iterative approach to the preparation of optimum formats for the output information.

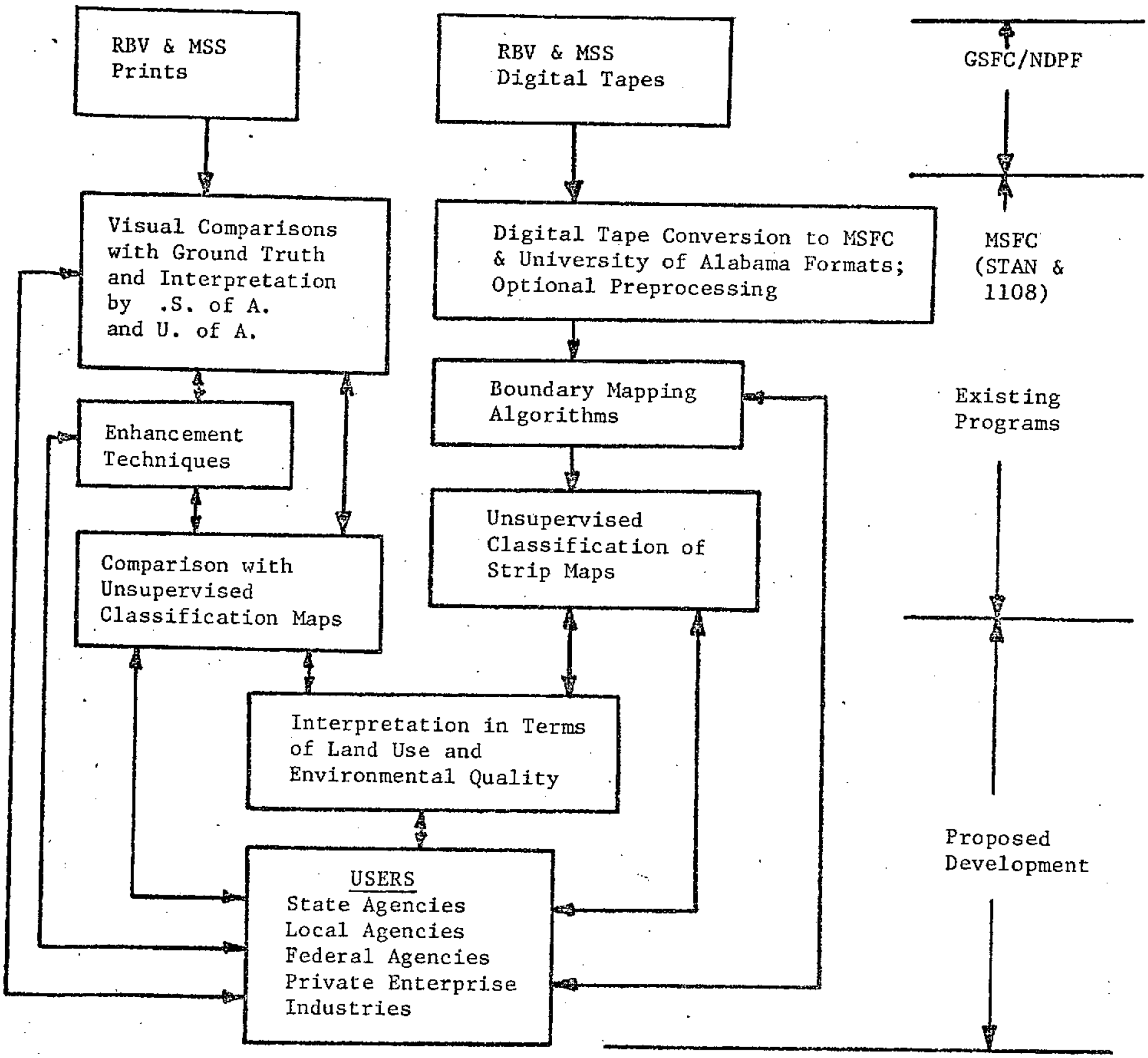

Figure 1. Block Diagram of Data Flow.

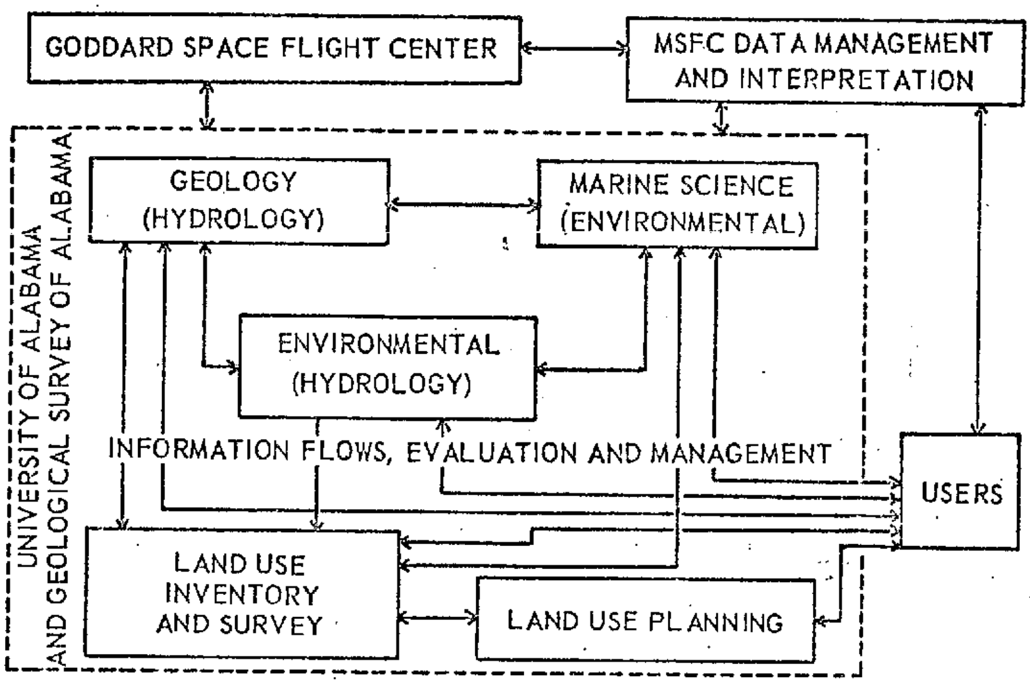

Figure 2. Diagram of Data Flow Emphasizing Disciplines, Information Flow Evaluation, and Feedback from Users.

Description of System for Collecting Ground Truth

The investigation will extend throughout the entire State of Alabama which is encompassed by the latitude and longitude values as shown in Figure 3. Ground truth by conventional means and by DCS platforms will be collected throughout the state during the investigation. Field data in support of these studies will be obtained primarily by direct field investigations and from existing data sources.

Ten DCS platforms, fully instrumented with appropriate sensors, are being planned for this investigation. Their locations are indicated on Figure 3. Three of the platforms will be on buoys in Mobile Bay and, in addition to contributing to this proposed study, will also contribute to the additional comprehensive study of Mobile Bay which is being planned by the Marine Science Institute of The University of Alabama.

It is intended that each of the ten DCS platforms be instrumented with eight sensors chosen to measure appropriate parameters which may be included in but not necessarily limited to the following list: precipitation, air temperature, soil temperature, humidity, soil moisture, river water level and discharge, ground water level, turbidity, salinity, pH dissolved oxygen, turbidity, specific conductivity, wind velocity, current direction and velocity, wave height and tidal depth. Parameters to be measured at each of the ten strategically located platforms will be chosen to give the most meaningful information at the particular location and the parameters for a particular platform may change during the investigation.

Multistage Sampling Techniques

Multistage sampling utilizing satellite data, multispectral photography from aircraft flights and ground truth data with emphasis on the data obtained from the DCS platforms will be performed over specific problem areas within

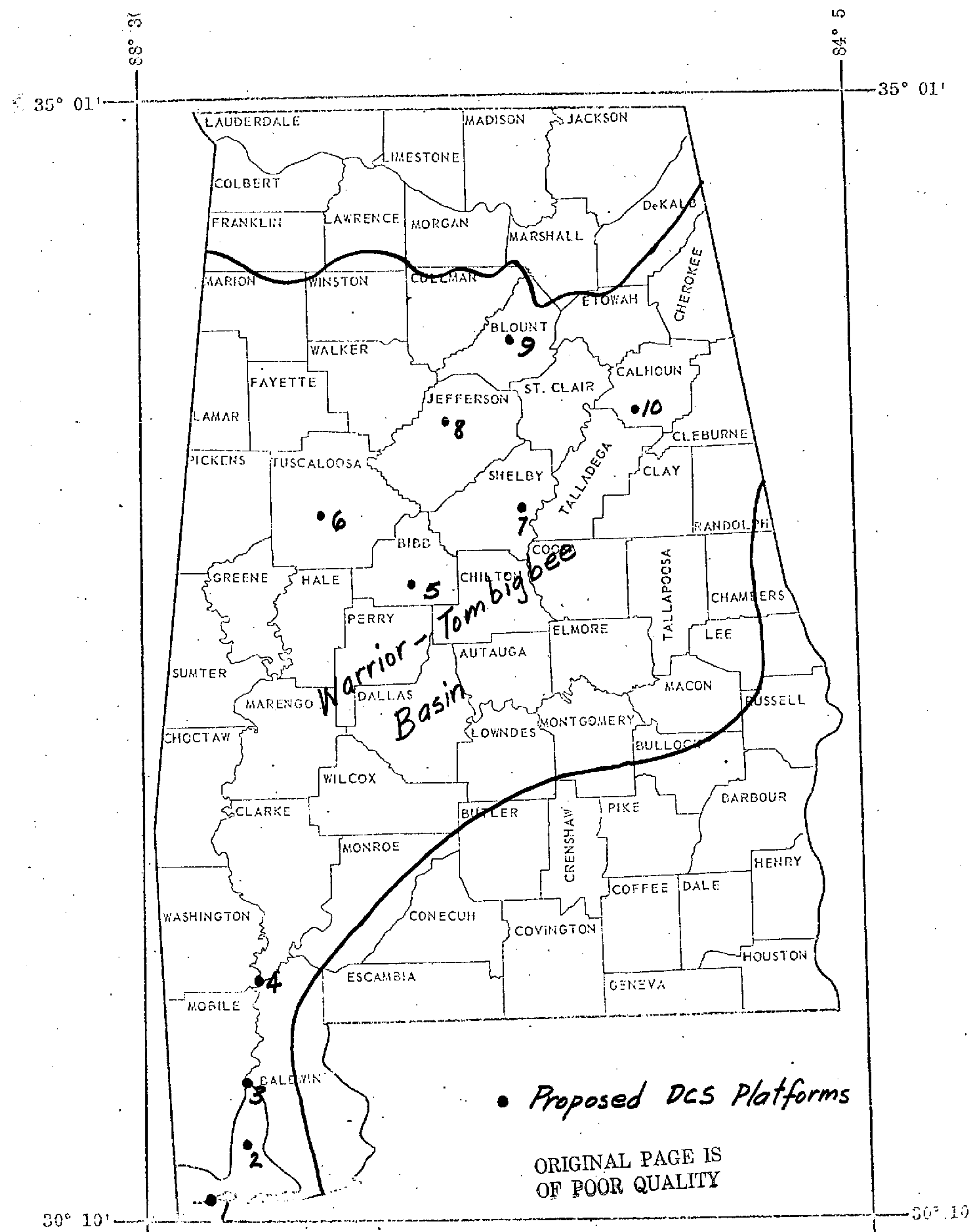

Figure 3. Location of Test Area
(The Entire State of Alabama)

the state. These are (1) a corridor from Tuscaloosa to Birmingham and (2) a corridor from Mobile Bay to the confluence of the Alabama and Tombigbee rivers. Each of these corridors is approximately sixty miles long. The widths of the corridors will be variable depending upon the number of lines of flight that can be scheduled at each sampling time. It is anticipated that a minimum of three and a maximum of six flights over each area will be necessary for application of the multistage sampling techniques. The dates of flights will be scheduled to detect seasonal variations in vegetation and pollution and the number of lines of flight in each corridor will be determined according to the availability of equipment and the sampling requirements. The time of day of the flights will be scheduled so that the aircraft data will provide an optimum supplement to the satellite data.

The choice of the Tuscaloosa-Birmingham area and the Mobile Bay area for the application of multistage sampling techniques stems from two main reasons, namely:

(1) They both are principal growth areas in which environmental problems are increasing rapidly.

(2) The first area is in the central part of the Warrior-Tombigbee drainage basin (outlined in Figure 3) which constitutes a complete hydrologic and geologic unit convenient for study. The second area is at the mouth of this river system and all influents into the system must pass through this area.

It should be noted also that the ultimate use of the data from all levels will be to furnish information to planners, regulatory agencies and private enterprise for the conservation, development and use of the resources of Alabama. The ten DCS platforms will be used to determine whether the automated collection of ground based data from selected sites can be combined with aircraft and satellite data so that timely interventions (which otherwise might be impossible) may be accomplished to conserve resources and improve environmental quality.

Expected Results of Investigation

It is anticipated that the results of this investigation will (a) determine the feasibility of using remotely obtained spectral data in land use planning, in inventorying and managing natural resources in Alabama, and in improving the environmental quality control in the state.

It is also anticipated that the participation and close liaison among The University of Alabama, the Geological Survey of Alabama, the George C. Marshall Space Flight Center, and the Alabama Development Office will be effective in developing a method and procedure for translating the remotely sensed data into information which can be effectively used by governmental agencies and industry by integrating it into the decision-making processes for environmental control, resource management and land use.

APPENDIX II

Paper presented

at the

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DAILY OPERATIONS OF AN INTERDISCIPLINARY RESEARCH PROJECT INVOLVING EXTERNAL GROUPS

by

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1. Introduction

The successful operation of a broadly based interagency, interdisciplinary research project depends greatly on the research philosophy of the people involved and the history of the development of the project. Therefore, this presentation will be started with a discussion of prerequisites which the writer feels should be present in abundance in order for such a venture to be successful.. Also, in order to give some specificity to the discussion the Alabama Earth Resources Technology Satellite (ERTS) Project will be used as an example.

The first prerequisite for success is a strong motivation to participate on the part of each professional involved in the project. It is necessary that he approach the work as an entreprenuer whose reputation and future advancement are at stake. In order for this prerequisite to be present in abundance the following set of conditions usually have to be satisfied:

a) The area in which the participant will work must fall solidly within his area of expertise. He must feel comfortable with the basic subject matter which is used as a foundation on which new contributions are constructed.

b) He must be convinced that by cooperating in this venture he can obtain additional professional recognition within his profession at large and within his own organization. Concomitant to this he must be convinced that his efforts will lead to the publication of professional papers and to promotions and increase in income.

c) It is necessary that participants find opportunities within the project to fit in their personal research interests and to provide research activities for their graduate students.

d) It is usually very helpful in maintaining the motivation of university researchers if each can stay convinced that the total activity on the project will upgrade and enhance the educational function of his department. Assuming that the subject matter is compatible this can be done by involving as research assistants as many students, both undergraduate and graduate, as possible and by introducing new project results into courses. In some cases it may be appropriate to introduce new courses to accomplish this.

e) The motivation of university researchers and those in cooperating state and federal agencies can usually be enhanced by maintaining a strong service aspect within the project. In order to do this, there has to be a close liaison maintained between the researchers and the users of the project output.

The second prerequisite necessary for the success of an interdisciplinary, interagency research project is the enthusiastic endorsement by all levels of management within each group participating. This requires that the researchers do a thorough job of matching the goals of the project with the goals of their own organization. Information required to do this will also strengthen the research proposal which is prepared for submission to the sponsoring agency. Since it can be expected that some aspects of the operation of a project involving external groups will not fit into the mold of established administrative procedures, this continuing enthusiastic endorsement by management is necessary to facilitate the approvals for exceptions and precedents that will be necessary. After the initial endorsement, this must be maintained by some effective liaison activity between investigators and administrators. This activity has to be initiated by the investigators.

The third prerequisite necessary for the success of such a venture is that it should provide a possibility of obtaining an effective and timely solution to a critical problem in which the public is vitally interested. This prerequisite will provide much of the cement necessary to bind the different groups together. It will also provide substantial support for obtaining the endorsement of administrators as discussed above.

The fourth prerequisite necessary for the success of such a project is that each investigator have a healthy respect and appreciation for all the other disciplines and organizations involved. An interdisciplinary interorganizational project, in which the work of one discipline affects that of the others, cannot function without effective communication among the disciplines and organizations involved. This cannot be achieved without mutual respect and appreciation. Even then, investigators have difficulties in learning new terminologies and new concepts associated with other disciplines.

2. Development of the Alabama ERTS Project

As stated in the introduction, the Alabama ERTS Project will be discussed as an example of a project involving external groups. This project, which is sponsored by NASA, is being conducted jointly by The University of Alabama, the Geological Survey of Alabama and the George C. Marshall Space Flight Center. It is an interdisciplinary effort to use remotely sensed multispectral observations to yield improved and timely assessments of earth resources and environmental quality in Alabama. It is the goal of this effort to determine the feasibility of interpreting these data and providing them in a format which is meaningful to and readily useable by interested agencies, industries and individuals throughout the State. Since so much of what occurs in the daily operation of such a project depends upon attitudes and understandings that were developed during the developmental stages of the project, some history of its development will be given here.

During 1969, the writer and some of his colleagues in the Department of Civil and Mineral Engineering at The University of Alabama undertook a study of applications of remote sensing to environmental and earth resources problems in Alabama.

In April 1970 the writer visited the Washington offices of the USGS and NASA to investigate the state of other projects in this area as well as possible funding.

In May 1970 interested researchers at The University of Alabama and the Geological Survey of Alabama held preliminary discussions concerning a joint venture. This was followed by a June 1970 meeting including several researchers, in addition to the State Geologist and a Vice President of The University of Alabama. At this meeting, the enthusiastic endorsement of top management was obtained.

In June 1970 a group from The University of Alabama and the Geological Survey of Alabama attended a preliminary briefing for potential ERTS investigators at Goddard Space Flight Center in Maryland. This group included a civil engineer, a mining engineer, a geologist, a marine scientist, a physicist and an economist.

In late June, 1970, it was decided that the Geological Survey of Alabama and The University of Alabama would jointly submit a proposal to the U. S. Geological Survey under the USGS remote sensing program. This was for a small study to identify and establish information on potential users of remotely sensed data in Alabama. This project was awarded in September 1970 for the duration of one year. This cooperative effort between The University of Alabama and the Geological Survey of Alabama involved a geologist, two hydrologists, an environmental engineer, and an economist. It represented a continuation of a successful history of cooperation between the two organizations in investigations concerning water and other natural resources. During the performance of this work the two organizations made preliminary plans to submit a rather large proposal to NASA to participate in the Earth Resources Technology Satellite Program.

In January, 1971, researchers and administrators from The University of Alabama presented to the top management of the George C. Marshall Space Flight Center, in Huntsville, Alabama, tentative plans for submitting a proposal to NASA headquarters for the purpose of participating in the Earth Resources Technology Satellite Program. This presentation was to obtain the endorsement of the management of the Marshal Center if possible.

In February, 1971, researchers and management personnel of the Marshall Space Flight Center initiated a meeting with The University of Alabama and the Geological Survey of Alabama for the purpose of discussing the participation of Marshall researchers in the Alabama ERTS proposal. It should be noted that NASA headquarters was receiving proposals under the ERTS Program from organizations internal to NASA as well as from organizations external to NASA. As a result of this meeting, it was decided that the three organizations, namely, The University of Alabama, the Geological Survey of Alabama and the Marshall Space Flight Center would submit a joint proposal with The University of Alabama as the proposed prime contractor.

In February, 1971, representatives from the U of A, the GS of A and MSFC attended a briefing for potential ERTS investigators at the Goddard Space Flight Center in Maryland.

In April, 1971, the Alabama ERTS proposal was submitted to NASA Headquarters. The proposal contained contributions from each of the three participating organizations and from investigators representing the disciplines of hydrology, geology, environmental engineering, mineral engineering, computer science, statistics, marine science, economics, and management. University of Alabama professionals were drawn from the Colleges of Engineering, Arts and Sciences and Commerce and Business Administration. The College of Engineering furnished the largest group of investigators including the principal investigator. The interdisciplinary cooperation necessary for the preparation of the proposal was facilitated by the fact that a number of the investigators were already working together on the previously mentioned joint project with the Geological Survey of Alabama. The communications and conferences held during the proposal preparation were valuable in establishing liaison and rapport which were essential in the later operation of the project.

In July, 1971, two state-wide symposia for potential users of remotely sensed environmental and earth resource information were conducted by personnel of The University of Alabama and the Geological Survey of Alabama. These important contacts with users were the beginning of a liaison effort which has been continuous up to the present time. Approximately 2,000 invitations to the symposia were mailed. At the one held in Tuscaloosa, about 80 people were present whereas approximately 65 were present at the Mobile symposium. These meetings were educational and informative with the purpose of presenting practical uses of the remotely sensed data and answering questions. A wide range of private industries and public agencies were represented by the attendees. Also, a wide range of disciplines were present - from ecologists and engineers to economists, urban planners and lawyers.

In September, 1971, the joint project for the identification of users of remotely sensed data was completed. The information which was compiled for this project was available for use on the larger Alabama ERTS project which had been proposed to NASA.

In November, 1971, a paper on the Alabama Remote Sensing application study was presented jointly by researchers from The University of Alabama and the Geological Survey of Alabama to the Congress on Space for Mankind's Benefit at Huntsville, Alabama.

In November, 1971, NASA headquarters personnel called a meeting to recommend revisions to our Alabama ERTS proposal. Attending were researchers from The University of Alabama, the Geological Survey of Alabama, the Marshall Space Flight Center as well as NASA headquarters scientists and managers. One of the prime results of this meeting was the decision that the users of the remotely sensed information should be brought into the project in a more tangible way. It should be emphasized that considerable liaison in this regard had already been performed and a very important aspect of the original version of the proposal was communication with and feedback from users of our interpretive output. However, in line with this decision, further liaison was accomplished and strong letters of endorsement with expressions of intent to use the data for applications were received from the Governor of Alabama, the Chief of the Special Studies Division of the Office of State Planning, the Director of the Alabama Development Office, the Governor's Science Advisor, the State Geologist, the Assistant Commissioner of the Alabama Department of Conservation and Natural Resources, the Director of the Alabama Water Improvement Commission, the Engineer for the State Health Department, the Director of the Marine Resources Division of the Alabama Department of Conservation, the State Community Planner, the Planning Director of the East Alabama Regional Planning and Development Commission, the Executive Director of the Top of Alabama Regional Council of Governments, the Officer-in-Charge of the Gulf Coast Water Hygiene Laboratory of the Environmental Protection Agency, the Deputy District Engineer of the Mobile District of the Corps of Engineers, the Natural Resources Manager of the Alabama-Mississippi Office of the Environmental Protection Agency, and the Microbiologist for the Shellfish Sanitation Branch of the Public Health Service.

In December, 1971, the revised Alabama ERTS proposal was submitted with the user-researcher communication and liaison aspect considerably strengthened.

In January, 1972, the Marshall Space Flight Center awarded an eight month grant to the Civil and Mineral Engineering Department of The University of Alabama for the purpose of collecting some pre-ERTS ground truth data

In March, 1972, the Governor of Alabama appointed an Earth Resources Data Committee consisting of representatives of all the state agencies involved in applications involving Earth Resources and also representatives from The University of Alabama, Auburn University, MSFC, and The University of Alabama in Huntsville. The Alabama Development Office representative serves as chairman and the committee serves as an official user liaison group.

In June, 1972, a paper on the Alabama ERTS project authored jointly by researchers from The University of Alabama, the Geological Survey of Alabama, and the Marshall Space Flight Center was presented at the Eighth International Symposium on Remote Sensing at Ann Arbor, Michigan.

In June, 1972, the Summer Faculty Fellowship Program sponsored jointly by ASEE, NASA and Auburn University convened at the Marshall Flight Center. The topic chosen for group investigation and study was the development of a concept and plan for an Earth Resources Information Storage and Retrieval System. Among the speakers to the group were researchers from the three organizations associated with the Alabama ERTS project. The scope of the plan developed by this summer activity included all types of conventional earth resources information in addition to remotely sensed data.

In July, 1972, the first Earth Resources Technology Satellite known as ERTS-1 was launched at Vandenburg Air Force Base.

In August, 1972, funding of the Alabama ERTS project was begun as a part of the NASA Earth Resources Technology Satellite Program.

3. Organization and Daily Operation of Project

The organization and daily operation of the Alabama ERTS project are built on two basic premises, namely:

(a) That each professional is in charge of his portion of the project and understands how it interfaces with the other researchers, disciplines and agencies. He has responsibility and authority to make whatever changes are needed in the daily opeartions of his group.

(b) That each professional is intimately familiar with the history of the project development and the goals of the project and that he has a personal motivation to work on the project, as described in the introduction.

It is apparent from the foregoing discussion of the history of the development of the project that the management of the three organizations involved enthusiatically endorse the work, that the research itself is very timely and that mutual respect exists among all the disciplines and organizations represented. This does not mean that difficulties and misunderstandings do not arise, but it does mean that there is a solid foundation for developing workable compromises.

The work on the project by the University of Alabama has emerged so that there are five distinct groups each headed by a faculty researcher. These groups encompass activities in the following areas:

(1) Environmental Considerations, Hydrology, Water Resourses.

(2) Land Use, Mineral Exploration, Geology.

(3) Marine Science.

(4) Data Processing and Data Management.

(5) Economic Considerations and User Liaison.

Each faculty researcher has a group of graduate and/or undergraduate students working for him and is responsible for submitting bi-monthly progress reports to the project director.

The project work of the Geological Survey of Alabama is the responsibility of a GS of A co-investigator who has the cooperation as required of the professionals within his own organization. The principal project activities within the GS of A fall within the following areas:

(1) Geology

(2) Hydrology and Water Resources

(3) Geographical Considerations and Change Detection.

The GS of A co-investigator is responsible for submitting a bi-monthly progress report to the project director.

The project work of the Marshall Space Flight Center is the responsibility of two co-investigators there. The work at MSFC falls primarily in the categories of:

(1) Data Processing and Statistical Analysis

(2) Environmental Considerations, Land Use, User Liaison.

Each of the Marshall co-investigators is responsible for submitting a bi-monthly report to the project director.

The foregoing description of the organization of the project contains some apparent duplications of effort. However, actual duplications are avoided by the maintaining of a close liaison among the cognizant researchers.

It also should be mentioned that as a general policy, a graduate student will not be given a research assistantship on the project unless he plans to write his thesis on some aspect of the research. We have had one Master's thesis completed on the Alabama ERTS project and have three more in progress. Also, there are three additional graduate research assistants who are preparing thesis proposals on the project. In addition, four research reports on the project have been prepared and submitted in various courses by other student assistants.

The daily and weekly operation of the project is a matter for each of the professionals to work out for his own area. In addition, each graduate student is given independent responsibility in the specific area of his research and is expected to submit independent bi-monthly progress reports.

The primary means of communication among the various groups within the University are weekly ERTS project meetings which are limited to ninety minutes or less. These meetings are informal information exchanges and usually each of the 10-15 people attending take the opportunity to give some account of his activity and ask questions relating to the interfacing of his work with other aspects of the project. In this way weak areas become apparent and can be eliminated or strengthened. The GS of A and MSFC researchers have open invitations to attend any of these meetings. The GS of A co-investigator and some of his colleagues attend about four out of five of the meetings. It should be noted that the GS of A is located on the University campus. The Marshall investigators attend approximately bi-monthly. Since the Marshall Space Flight Center is located 150 miles from the University campus, personal contact between University researchers and Marshall researchers is usually on a reciprocal travel basis with trips made as needed by cognizant researchers. Of course, much use is made of the telephone.

Approximately once each three or four months a large project meeting is held of all project personnel including professors, graduate students, co-investigators and support personnel from the MSFC and the GS of A. These meetings are attended by 30 or more people and will usually last about four hours. Representatives from the Alabama Development Office and other user groups are also invited. These meetings are for the purpose of a general project review and oral reports of progress will be presented by selected team members. As a result of comparing progress made with project goals, it will be determined that some areas of research should be accelerated while others should be de-emphasized.

In the conduct of the Alabama ERTS project we have found that an effective and pleasant way to keep management informed is to have an occasional luncheon to which are invited some of the researchers, the department head, the dean, and the vice president or assistant vice president of the University, the State Geologist, and appropriate officials from the Marshall Space Flight Center. Often this can be arranged to coincide with one of our large project meetings or with some other function so that it is not necessary that special trips be made just for the luncheon. The informal atmosphere of such a gathering is productive of good relationships among the people involved. Of course, departmental reports, memoranda, and oral reports are all used to keep management informed. It is gratifying to report that the administrations of The University of Alabama, the Geological Survey of Alabama, and the Marshall Space Flight Center are all continuing to give enthusiastic support to this project.

4. Conclusion

In conclusion, it is the opinion of the writer that if the prerequisites, as listed in the introduction, are present, an interdisciplinary interagency research project can be a success with a minimum of organizational constraints. This opinion is based upon personal experience with the Alabama ERTS project. These prerequisites are:

1. Each researcher should have a strong personal motivation to work on the research project.

2. There should be a strong endorsement from all levels of cognizant management in each organization involved.

3. The research should present the possibility of a timely solution to a pressing problem.

4. There should be a mutual respect and appreciation among the researchers of the various disciplines and organizations represented.

LAND USE, MINERAL EXPLORATION, GEOLOGY STUDIES

Reynold Q. Shotts

and

Joseph A. Robinson

SECTION ONE

of

VOLUME ONE

INVESTIGATIONS USING DATA IN

ALABAMA FROM ERTS-A

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LAND USE, MINERAL EXPLORATION, GEOLOGY STUDIES

INTRODUCTION

One important environmental activity in the future is monitoring man's use of the land. The amount of land is finite while demands on the land are increasing. Each year the earth must support more people. Since any condition approaching zero population growth cannot be expected for many years, if ever, the demand on the land cannot be expected to stabilize. In the United States there is also a trend toward smaller families, increasing the demand for land area to accomodate more households per unit of population. In addition, families have higher average incomes enabling them to travel more and to consume more.

These developments result in the often unsightly spread of housing developments, factories, and the accompanying service facilities required. Precious open space, productive agricultural land, dense forest, scenic coastlines, and valuable mineral deposits have been exploited, in many cases not for their best use. Too often this condition has resulted from poor planning. A more organized approach is required involving systematic land-use planning, whereby some government exercises its right of eminent domain to direct and control land utilization.

Until recently the problem of land-use planning has been largely unaddressed. The need to clean up dirty water, polluted air, and our accumulated solid waste seemed more pressing. Several recent developments however, point up the growing awareness of the need for land-use planning.

The National Land Use Bolicy and Assistance Act is being considered in Congress. This legislatio- proposes that each state inventory its land and develop a state-wide land-use and regulatory plan. A typical plan would earmark specific land for large-scale development, environmental preservation, and public facilities. States that did not comply would face having their share of federal funds reduced. The bills in the two houses of the congress are now in a state of "suspended animation."

In a separate development, a task force appointed by President Nixon submitted a report recommending a wide assortment of measures for more rational land use. The report appears to have been written to placate the conservationists.[1] In one of its major conclusions it states, "It is important that state and local legislative bodies continue to adopt planning and regulatory legislation aimed at carrying out land-use objectives and that legislative bodies make clear that police powers are regarded as valid authority to achieve more orderly development and to protect natural, cultural, and aesthetic values."[2]

In view of the current interest in land-use planning, the availability of timely land-use data is especially important. Consequently, the development of techniques to gather and interpret the needed land-use data takes on added significance.

To make competent land use decisions, Alabama state planners and policy-makers must have accurate, timely information on the many interrelated aspects of their activities. Land use is just one of these aspects, but one which in recent years, has become progressively more important in seeking solutions to the problems of urban sprawl, forest depletion, strip mining, and other problems in the total environment.

Land use sometimes reflects man's impact on the environment in a readily discernible and vivid way.

The Alabama legislature met and adjourned its regular 1973 biennial session without considering a general land use law. Since none of the proposals before the Congress, most of which appear to involve the idea of "guidelines" for the enactment of State laws, have yet been passed, any state not presently having a land use law and the experience gained from its operation may find it more practical to wait for federal legislation.

Information provided by the Alabama ERTS project should be of value when the legislature does consider a land use law after federal legislation has been enacted. Among the most useful items should be the following:

1. The historical survey as to immediate past patterns of land use in broad categories and for use in comparison with present and future patterns, with indicated changes or trends.

2. The principal land use prevailing in each county or physiographic province in the State.

3. Comparisons as to time - and cost - effectiveness of various methods of obtaining land use information from ground surveys and mapping, including low-altitude aerial, high-altitude aerial, and satellite surveys.

4. Provision of cost-effectiveness data for various systems of monitoring air and water pollution and, possible, mineral land restoration work, forestry and agricultural health.

5. Provide specific land use studies and comparisons for limited areas as models. These have come largely through graduate theses.

6. Provide a small pool of trained personnel to think in terms of remotely sensed data, land uses and environmental problems that may be used to provide data and know-how for implementing land use control or regulatory systems.

One important facet of land use that merits much attention but often receives little, is the use of land as a source of minerals. The mineral resource and geology phase of the Alabama ERTS investigation, together with ground truth found on geologic maps, in reports and in the files of the Geological Survey of Alabama, other state agencies and of many private companies, should prove invaluable in the drawing up and the implementation of any future state land use regulations to consider minerals sources.

The average citizen thinks of land use laws in terms of their direct effect upon him and his land, seldom recognizing that indirect effects may be as important, or even more important, than direct ones. If he is opposed to land use regulations it is often because he fears he will not be allowed to do with his land what he wants to do, whether it is to build a subdivision, mine a valuable limestone deposit, or use it in some other profitable way. If he is for land use laws, it is often because he thinks of them as protecting him, or his land, from the subdivision developer, the miner, the dam builder, etc. In the case of minerals and other land-derived materials, land use laws that do not recognize and provide for extraction of these materials in a period of temporary land use, will do more to choke our economy and lower our standard of living than to close a control of credit or of prices or of almost any other economic factor. The final report of the President's Commission on Materials Policy recommends that "...Congress adopt a national land use policy and supporting statutes which will:[3]

- promote comprehensive planning for public and private lands;

- provide a means for evaluating land uses and institutions or practices and establishing criteria which take account of economic and national security needs and environmental, aesthetic and social values;

- recognize the responsibility of the states and local units of government to develop programs for non-Federal lands and assist states in the formulation, coordination and implementation of land use planning policies;

- assist the states to improve regional and local planning processes; and

- require coordination within the Federal Government and with the States, of federal and federally assisted programs which significantly affect land uses."

The report discusses the urban land use conflicts whereby many needed mineral deposits may be lost to urban development and recommends that "States use a quarrying and mining zoning classification to reserve essential mineral lands until deposits have been worked out." The conflicts are sharpest over sand, gravel, stone, shale and other widely used building material ingredients but they do exist for coal and other minerals.

In the discussion of surface mining, the Committee concludes that "surface mining is important to the nation" and that "the objective of federal and state laws and regulations should be the control of surface mining to minimize environmental degradation and provide for prompt reclamation of the land so it can be used for other purposes, rather than prohibition of surface mining." Multiple, successive use planning for surface mined land is stressed.

An amazing statement made in the report is that "about 50 percent of the coal and <u>90 percent of all other minerals</u> produced in the United States except petroleum and natural gas, are extracted by surface mining methods."

In the planning for local zoning of active mineral source areas there usually is enough ground truth available but in long range planning of provisions for possible mineral occurrences, the lineaments, circular features and other structures revealed in remotely sensed data should assist greatly in planning on a regional basis.

Any data developed on the ERTS project with regard to monitoring acid mine drainage or mined land disturbance could be advantageous in formulating land use regulations.

Thus, the ERTS project and any future remote sensing activity should provide a large store of information for use in land use planning for the benefit, not only of the future environment and quality of life but also for the good of the state's three greatest basic land-derived industries; agriculture, forest products and minerals-energy.

I. HISTORICAL LAND USE INVENTORY

Extraction of land use data from two different time frames with subsequent comparison of the data sets should greatly facilitate the detection of land-use change, especially on a regional basis. The purpose of compiling a historic inventory of land-use information for the entire State of Alabama for the time period 1961 to 1971 was actually twofold: (1) it provided the state with its first state-wide accurate, consistent, and timely land-use maps, and (2) it provided a heretofore nonexistent "historic" land use data base for subsequent comparison with land-use data later extracted from ERTS-I and other remotely sensed imagery.

A. Source Material

The historical land use data were compiled from standard black-and-white U.S. Department of Agriculture air photo mosaics. Mosaics for all 67 counties in the state were dated from 1964 to January, 1969, and were at a scale of 1:63,360 (one inch to one mile).

In order to assist with interpretation of features seen on the mosaics, some of the original photos from which the mosaics were made were consulted and data from many other sources were collected.

Data, supplementary to photographs, is known as ground truth and as much of it was collected as was practical. Supplementary information was obtained form Alabama county highways maps, USGS topographic maps, geologic maps, and land-use maps of the area under study, and from ground truth obtained by visits to the area. All of these helped to determine percentages of various land uses contained in each square kilometer.

Telephone calls as well as trips were made for information on features difficult to recognize on maps or photos. Strip mine works and certain natural features were plotted on the county highway maps so they could be looked for on the photo mosaics by the land classification coder.

B. Scale and Coordinates

A primary objective of the Alabama ERTS project was to summarize quantitatively the land-use information from the air photo mosaics and ERTS-I images in as clear and useful a form as possible. It was obvious at the start that the first step had to be the definition of an area or a series of areas (cells) and to describe them in terms of land-use information. Various grids were available for use: arbitrary grids such as those based on a certain number of acres or square miles; specific portions of topographic maps; the Alabama state plane coordinate system, or the Universal Transverse Mercator (UTM) grid were all considered.

For the purposes of this investigation, the selection of the UTM grid system was a fairly easy one. The Alabama state plane coordinate system was considered unduly awkward for two reasons: (1) the state was divided into two separate zones, and (2) the grid was measured in feet. In contrast, the UTM grid fits Alabama entirely into one zone (Zone 16, see Figure 1). The UTM grid within each zone is referenced to a central meridian which, for Zone 16 is 87 degrees west longitude designated as the 500,000 meter meridian. Values of meridians west of this line within Zone 16 decrease, while values of those east of the 500,000 meter base line increase. Figure 2 illustrates the UTM, Zone 16 grid system superimposed on a map of Alabama. Within this system, almost any size of grid

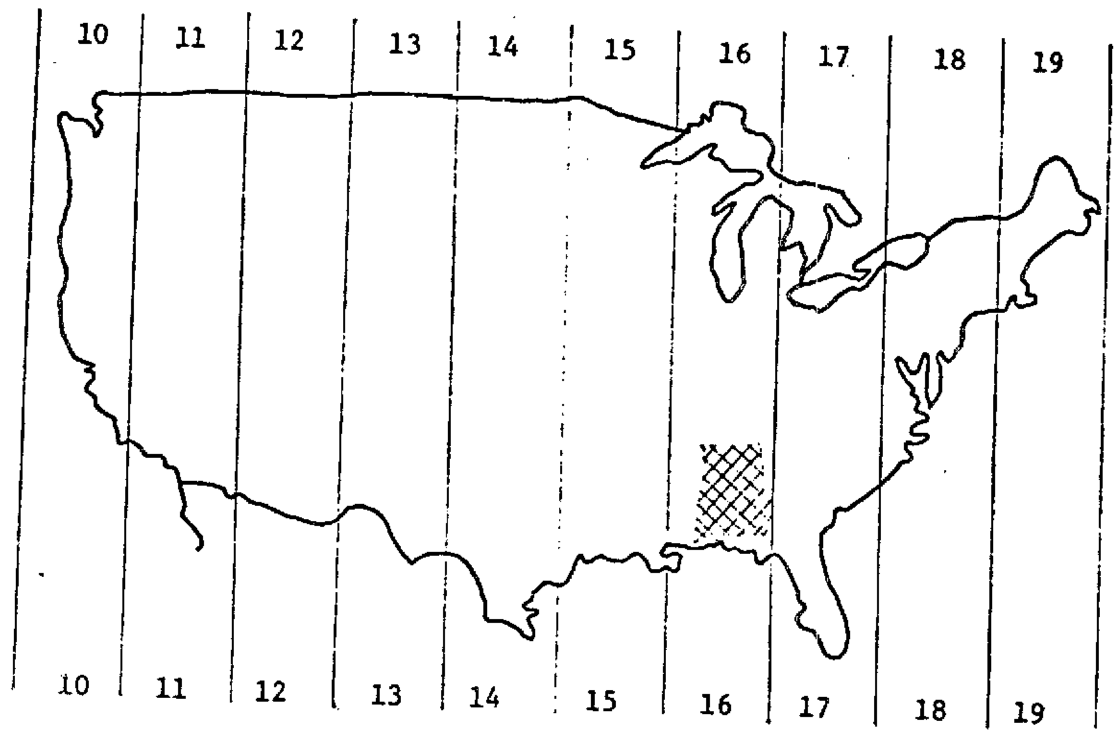

Figure 1. UTM Zones of the United States.

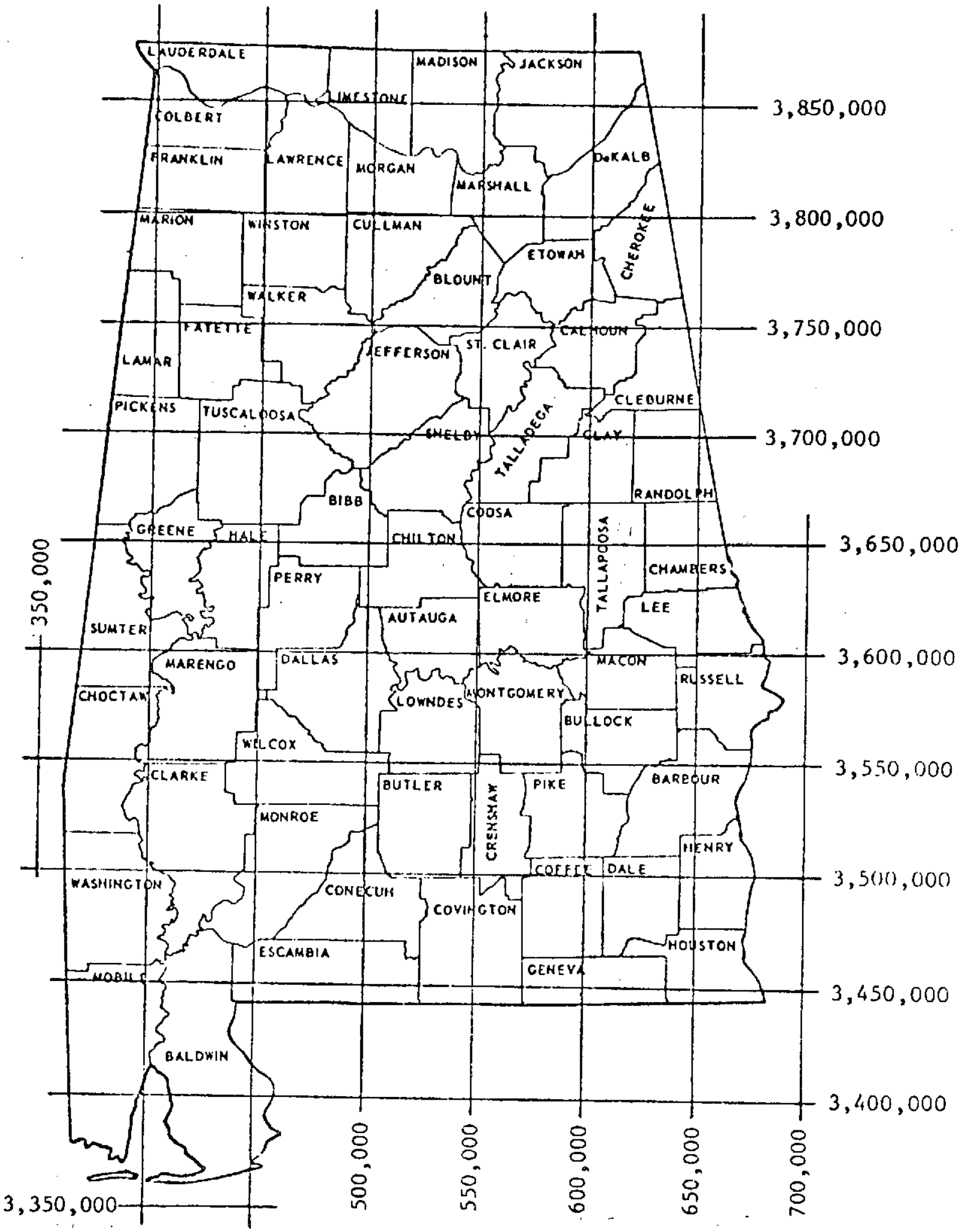

Figure 2. Universal Tranverse Mercator Grid.
UTM Zone 16
50,000 Meter Squares

cell can be selected.[4] Another attraction of the UTM system is its world-wide application, an important feature, should the metric system be adopted in this country. Furthermore, each UTM grid unit is square and of constant size which facilitates computer analysis and display. The fact that remotely sensed data from ERTS-I was to be referenced according to the UTM system was also a prime consideration in its selection.

After selecting the grid system to be used, the exact cell size was determined. The main considerations in determining optimum cell size were the amount of information required, minimum resolution of SCS and ERTS-I imagery, and the amount of time required. For the purpose of coding land-use information from air photo mosaics at a scale of 1:63, 360, a one square kilometer cell size was selected (15.8 millimeters square at that scale). This size of cell allowed technicians to pencil in twelve digits comfortably and at the same time not compromise the amount of information coded by enlarging the cell size. The one square kilometer cell size was again employed in gathering land-use data from ERTS-I imagery. The scale of the imagery and its minimum resolution of about 300 feet restricted the size of a workable cell to not less than one square kilometer. Therefore, to facilitate comparison with the historic data and to maintain consistency, a cell size representing one square kilometer (one square millimeter on the 9.5 inch image) was used. At one square kilometer, the entire State of Alabama contains 135,289 cells.

Land-use information was recorded by pencil onto transparent grid overlays prepared at the Marshall Space Flight Center. The grid cells each represented one square kilometer on the ground and measured 15.8 millimeters square thus corresponding to the scale of the air photo mosaics.

Several preparatory steps had to be taken prior to actual land use coding. First of all, it was necessary to transfer the UTM grid system from United States Geological Survey topographic maps at a scale of 1:250,000 to the one inch to a mile county highway maps. This was accomplished by measuring the distance between parallels and meridians of the Alabama state plane coordinate system and UTM system on the USGS maps and then measuring off these same distances from the Alabama state plan coordinate system on the county highway maps employing a scale conversion factor of 1:3.94.

The next step involved positioning the transparent grid overlay on the county highway maps so as to be aligned with the UTM parallels and meridians previously plotted on the map. The grid was then labeled accordingly. When properly aligned, prominent road junctions, river meanders, and other features, along with county borders, were outlined on the grid. The grid was then transferred from the county highway map to the air photo mosaic. The outlines on the grid overlay of features extracted from the county highway map were aligned with those same features contained in the air photo mosaic. In this manner, the UTM system and grid were correctly positioned on the mosaic.

A total of twelve numerical digits were penciled into each 15.8 millimeter square cell. Referring to Figure 3, the first digit in each cell was placed in the upper left-hand corner and indicated an outstanding feature of particular interest. If there were none, a zero was recorded in that position. For example, every cell containing any part of a particular town may have been given the number "1", and any cell containing any part of a navigable stream in the same county as the town may have been given the number "2", etc. A cell containing both the city

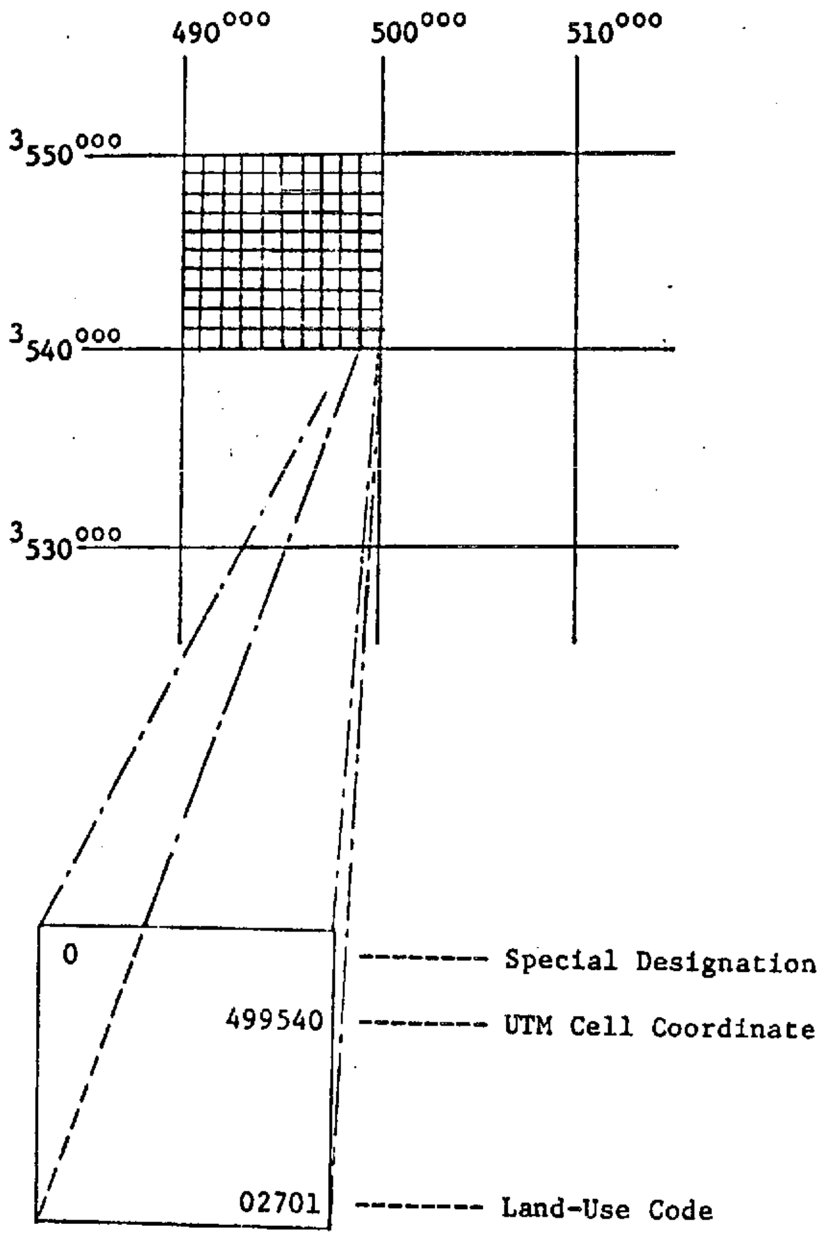

Figure 3. Scheme of Coding Historic Land Use.

and the river would have been given the number corresponding to the city. This code was different for each county depending on the number of towns over 2500 population according to the 1970 U. S. Census and the number of large lakes and navigable streams.

The next six digits recorded referred to the location of the lower left-hand corner of the cell according to the UTM grid system. The first three digits refer to the meridian and the last three to the parallel comprising the left-hand and bottom sides of the cell, respectively. The reader should note that in recording the UTM cell coordinate, an abbreviated form was used. For example, the vertical line (meridian or easting) listed in Figure 3 as 500,000 is abbreviated in the cell to 500. Likewise, the horizontal line (parallel or northing), listed as 3,540,000, indicated that the parallel was 3,540,000 meters north of the equator. It appeared in the cell as 540, since the first digit "3" is constant through the entire length of the State.

The last five digits at the bottom of the cell indicate the percentages of each land use contained within the cell. The numbers were given in the same order of land-use categories as follows: urban, agricultural, forestland, water, and barren land, A sixth digit representing nonforested wetland was recorded when necessary. Each digit represented tens of percent of one square kilometer occupied by each land use. Hence, the five digits given in Figure 2 indicates that the cell contained zero percent urban land, 20 percent agricultural land, 70 percent forestland, zero percent surfact water, and 10 percent barren land. 100 percent of any land use per cell was disignated by a "+"; therefore, a cell containing nothing but forestland was given the following land-use code: 0 0 + 0 0.

Although it took almost seven months to analyze and record the 1.6 million bits of information for the State of Alabama's 135,389 square kilometers, the methodology utilized makes it the most sophisticated inventory of this magnitude ever attempted in the state. The care with which land-use data extracted along with the many checks imposed for accuracy and consistency is believed to make it one of the most accurate and useful in existence.

The historical land-use mapping was done in considerable detail, relative to the extent to which land uses were evident on the air photo mosaics. The result of this compilation was an accurate but complex data base which served both as a product in itself and as a historical reference with which to compare ERTS-I and other remotely sensed data.

The computer mapping programs for pictorial display of the digital data, MIADS and SYMAP, were investigated in detail and ultimately found to be too restrictive in either cell size and scale limitation or lack of combinatorial capability and required computer time, respectively.[4] Therefore, a program was developed by Dr. E. T. Miller of the Department of Civil and Mineral Engineering, The University of Alabama, for analyzing and displaying the land-use inventory data.[5,6] Through this program, termed ERTSMAP, computer maps were generated which depicted the percent of a certain land use per cell according to an eleven step density scale. Figures 4 through 9 illustrate, in reduced form, the type of maps generated for each of the five categories of land use. Similarly, the program was able to generate maps of dominant land use per cell. A map of dominant land use per cell is given in Figure 9.

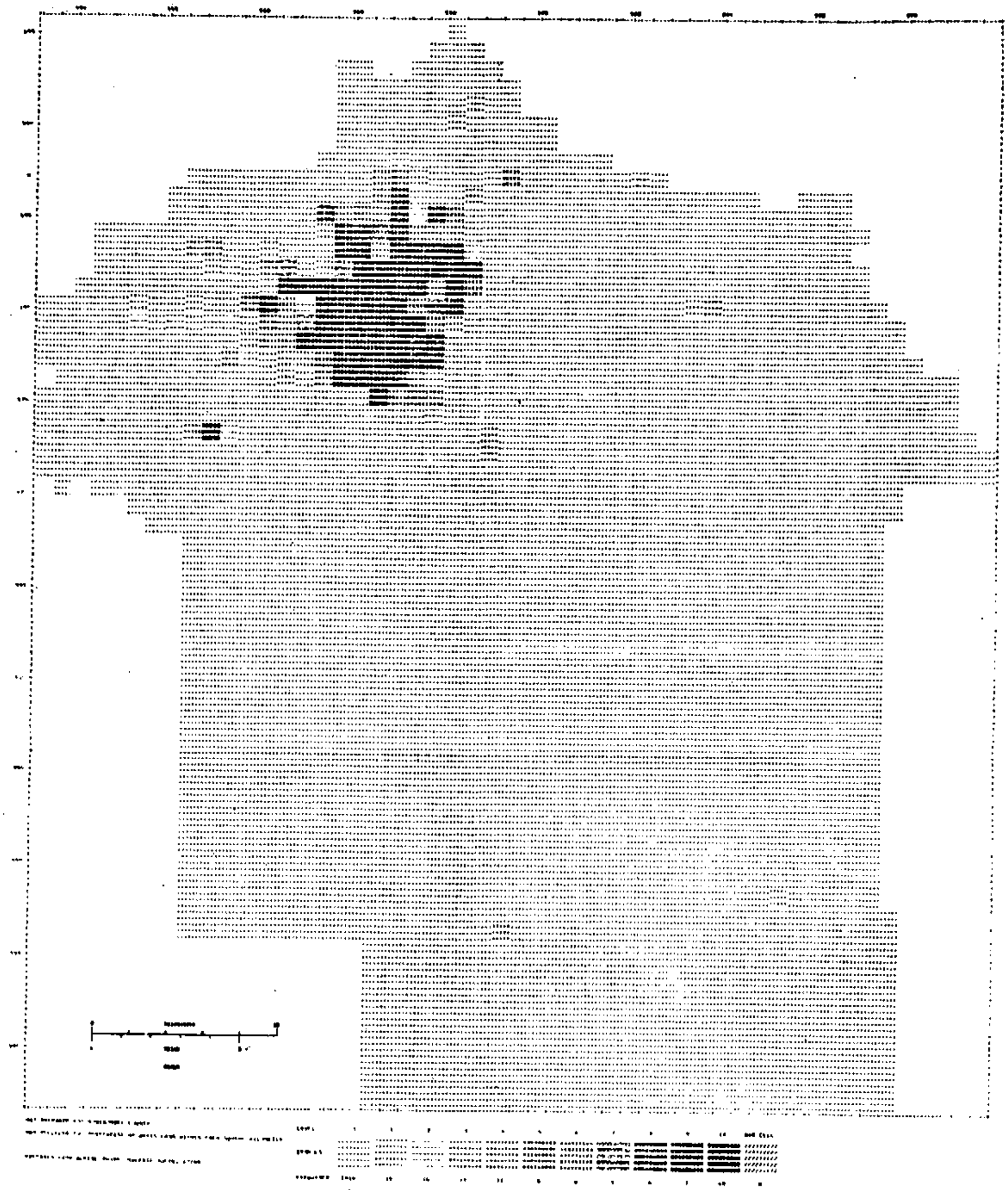

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Figure 4. Map Depicting the Percent of Urban Land Per Square Kilometer in Montgomery County.

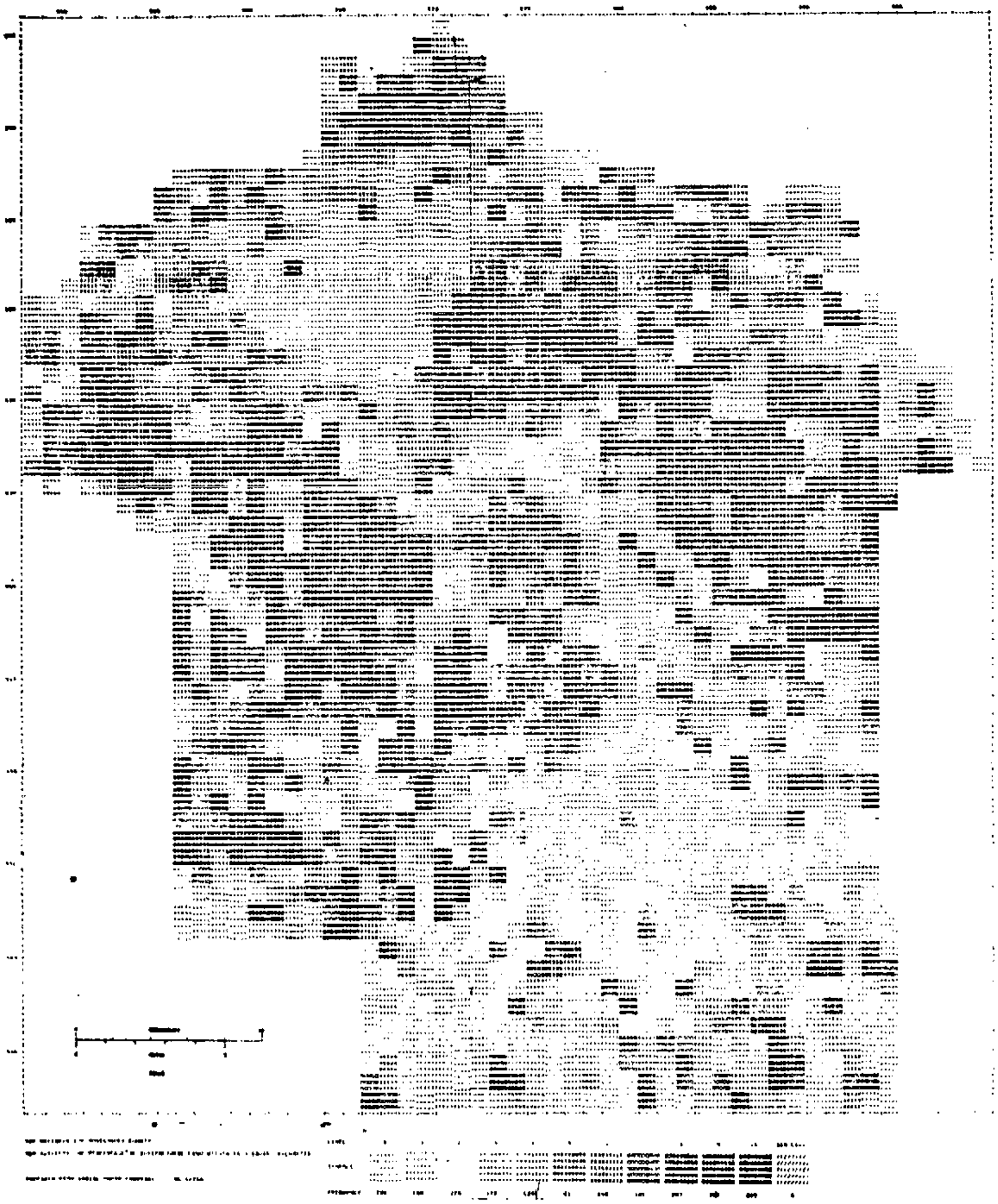

Figure 5 Map Depicting the Percent of Agricultural Land Per Square Kilometer in Montgomery County.

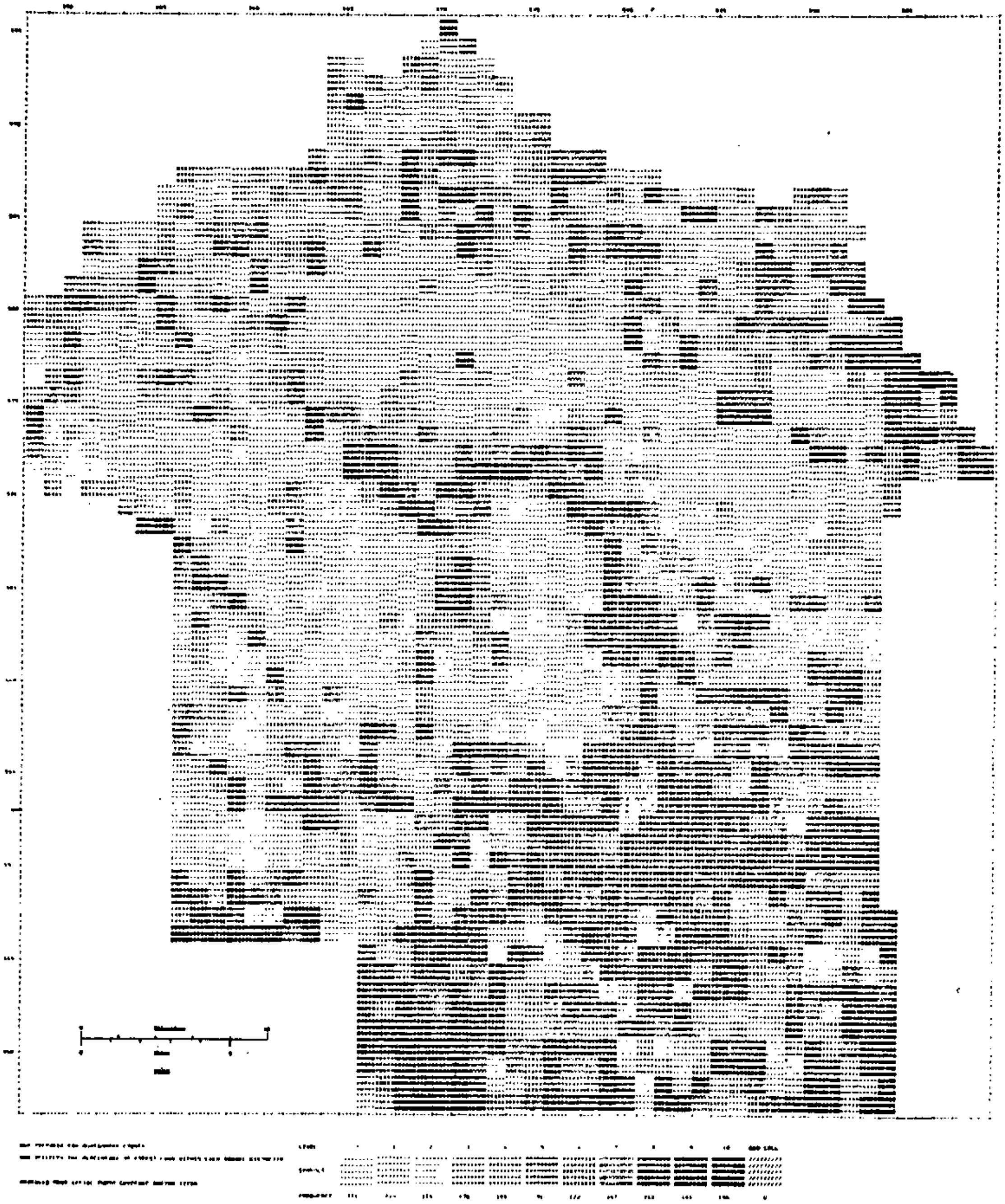

Figure 6 Map Depicting the Percent of Forest Land Per Square Kilometer in Montgomery County.

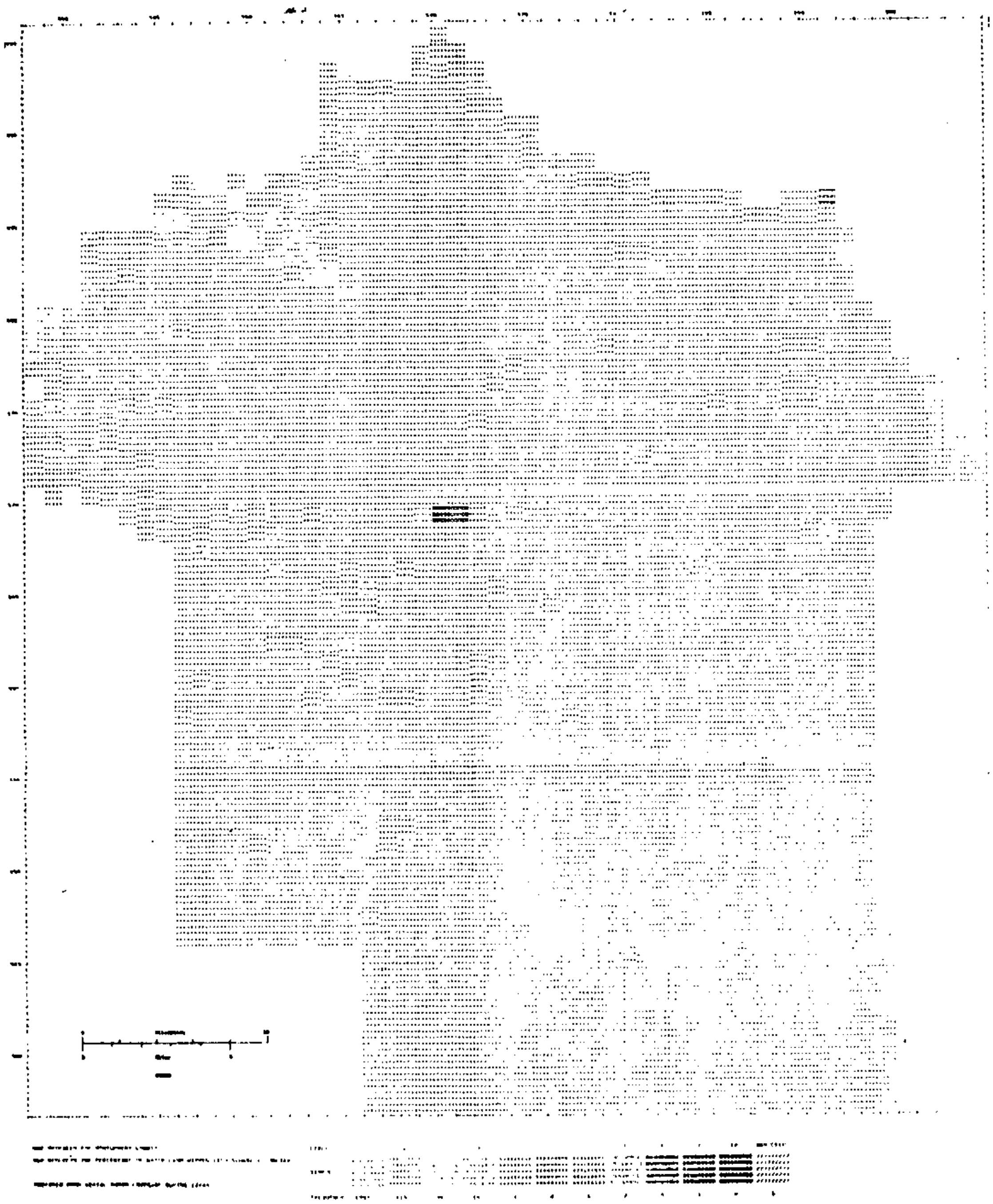

Figure 7 Map Depicting the Percent of Water Per Square Kilometer in Montgomery County.

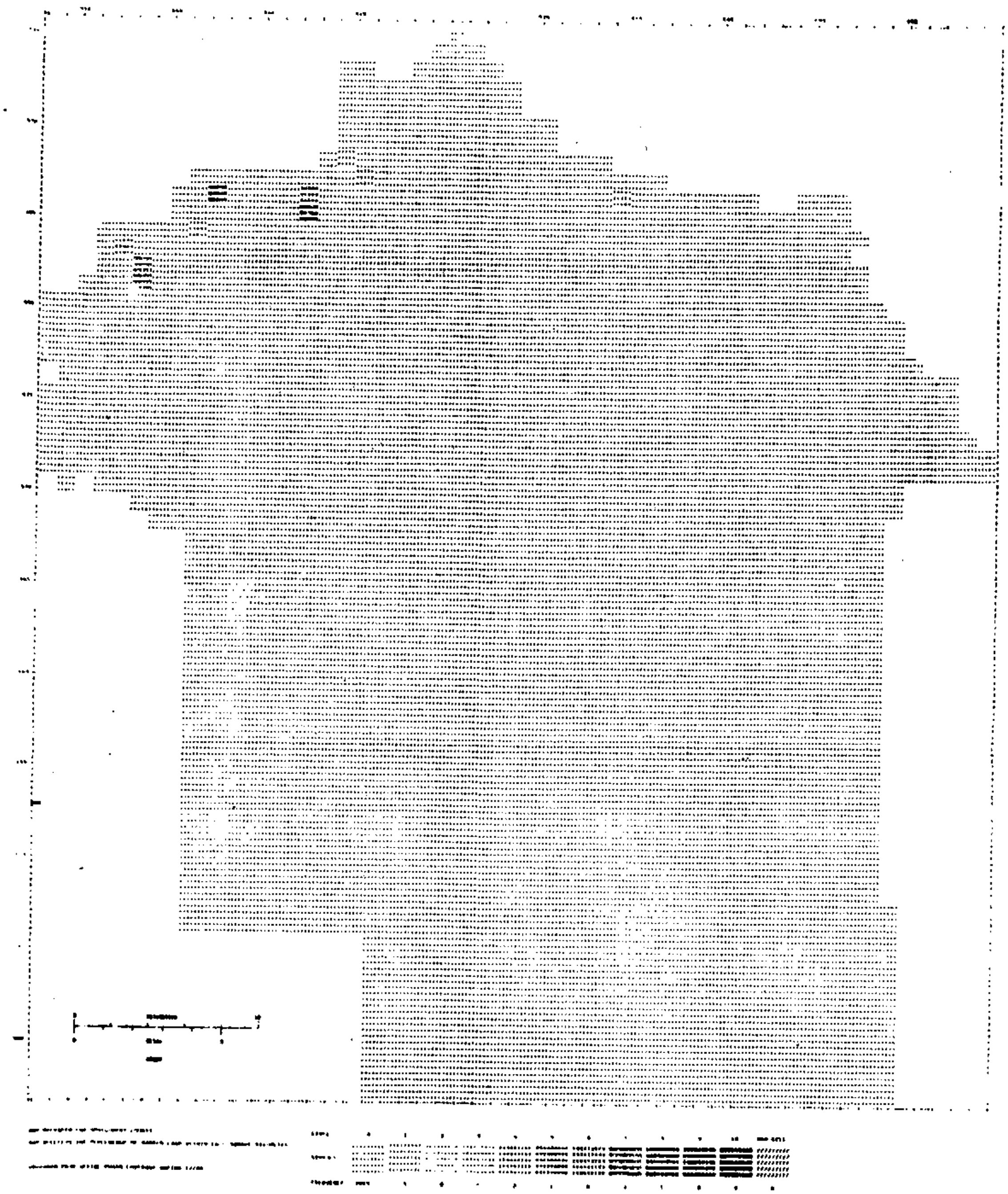

Figure 8 Map Depicting the Percent of Barren Land Per Square Kilometer in Montgomery County.

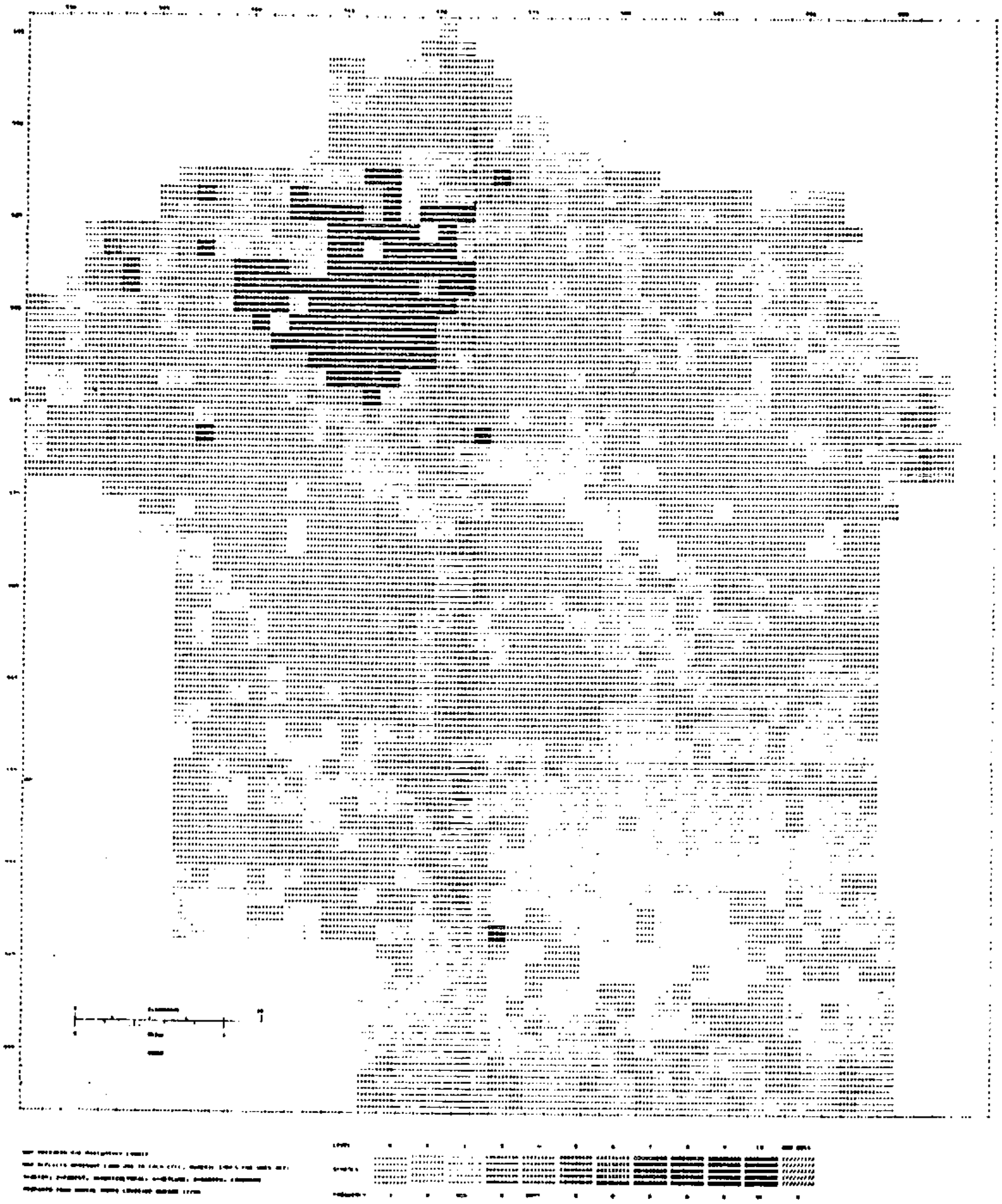

Figure 9 Map Depicting Dominant Land Use Per Square Kilometer in Montgomery County.

1. Feature Recognition

At the first level of land-use categories used for compilation of the data, little if any magnification was necessary except in troublesome, extremely complex areas. Accuracy of interpretation was for the most part dependent on the technicians understanding of the classification and, to a lesser degree, a function of the technician's skill and experience in air photo interpretation. Swanson makes a distinction between "interpretation" and "recognition."[7] Recognition is actually an instantaneous reaction, while interpretation involves more "thought and consideration of the local environment and/or related structures." Not only did technicians have to interpret what was on the ground, but also how much of what was recognized occurred in each cell. It was estimated that between 20 to 30 seconds were required for interpretation, estimation, and recording of the data per cell. Interpretation, of course, was more time consuming when consulting between technicians was necessary.

Tone and texture were the primary considerations in land-use interpretation. Geometric configuration was of lesser importance, but was helpful in distinguishing between nonforested agricultural land and land undergoing extraction. Impoundments of water also aided in the location of sand pits and quarries. Since most counties were photographed in late autumn or early spring, the majority of agricultural fields were devoid of growth and therefore were readily distinguishable from forestland.

C. Classes of Land and Methods of Classification

No ideal classification of land use has yet been developed and probably never will be. Each land-use classification in existence today was designed with a specific purpose in mind. A classification system must meet most of the needs of users or face rejection.

In developing a land-use classification scheme for use with remotely sensed data, Anderson, et al., made the distinction between "land use" and "land cover."[8] Land use refers to man's activities on land directly relating to the land while land cover denotes the natural vegetation and cultural construction on the surface. Obviously, some of man's activities directly influence the type of land cover, e.g., agriculture, urban growth, strip mining, and water management. Other activities, however, such as hunting and fishing, cannot be determined by remote sensing: and an area utilized by hunters and fishermen would better be classified as forests and lakes. Land cover, therefore, is the basic criterion in the first and second levels of the land-use classification described by Anderson and used in this investigation.

All primary levels in Anderson's classification would seem to be distinct and separate entities in themselves, but even such a supposedly obvious feature as a water-land interface can become impossible to map in areas of periodic flooding or in marshes. Equally difficult to delineate is the urban-rural interface in winter when the barren agricultural fields give much the same spectral response as paved parking lots and streets. Problems of this type are inherent in any classification scheme and must be considered in the final analysis.

Anderson's land-use classification system was adopted for use in this study because (1) it provided continuity with the majority of other researchers in the United States, (2) the classification was considered compatible with the resolution capabilities of the sensors aboard ERTS-I, and (3) the scheme simplified identification, reduced interpretation errors, and provided a format which could easily be modified in order to make it compatible with other land-use classification systems. The land-use classification produced by Anderson, et. al., for the Inter-Agency Steering Committee on Land Use Information and Classification is represented in Figure 10.

All land use in Alabama, both past and present, was classified according to six of the first level categories in Figure 7, namely: urban, agricultural, forest, water, barren land, and nonforested wetland. Restricting the classification to these six categories facilitate accuracy, consistency, and speed.

The aforementioned six Level I land-use categories are further defined below in order to provide the reader with a better understanding of what was considered as being in each of these six land-use categories. As previously mentioned, the same six categories representing a somewhat generalized level of classification and interpretation were utilized in coding land-use information from both air photo mosaics at a scale of 1:63,360 and ERTS-I imagery at a scale of 1:1,000,000. For the former, the classification undoubtedly could have been much more refined, including sub-categories in Level II and even Level III; and for the latter, great effort was often involved in discriminating between even the Level I land-use categories.

Each of the following definitions necessarily was conceived early in the land-use coding phase of the project. The process did not stop there however; the land-use categories were scrutinized and redefined on a daily basis as problem areas were encountered. Likewise, the initial analysis of ERTS-I imagery imposed new stresses on the classifications land cover and in some cases reduced the number of Level I categories detectable to four while at the same time rendering information about second and even third level land use. The number of land-use categories

First Level	Second Level
Urban and Built-up	Residential Commercial and Services Industrial Extraction Major Transport Routes and Areas Institutional Strip and Clustered Settlement Mixed Open and Other
Agricultural	Cropland and Pastures Orchards, Groves, Bush Fruits, Vineyards and Horticultural Areas Feeding Operations Other
Rangeland	Grass Savannas (Palmetto Prairies) Chaparral Desert Shrub
Forestland	Deciduous Evergreen (Coniferous and Other) Mixed
Water	Streams and Waterways Lakes Reservoirs Bays and Estuaries Other
Nonforested Wetland	Vegetated Bare
Barren Land	Salt Flats Sand (other than beaches) Bare Exposed Rock Beaches Other
Tundra	Tundra
Permanent Show and Ice Fields	Permanent Snow and Ice Fields

Figure 10. Anderson's Land-Use Classification Scheme.

used or imposed was due to the geographic area under study, the atmospheric conditions at time of acquisition by the sensor, the level of land-use complexity per cell, the amount of distortion and "noise" due to data transmission and photographic aberations, and the purpose for which the analysis was being made.

The urban and built-up land-use category includes all areas of intense structural development such as cities, towns, villages, ribbon developments along roads and waterways, power plants, and small clustered developments around major highway interchanges. Areas lying within an urban area, which otherwise would have been classified according to another of the Level I categories, i.e., forest land, were coded as urban and considered to be parks or low density residential areas. Highways were not included in any of the land-use categories and were not coded. The patterns of other land uses, however, which were to some extent dependent on highway development, did indicate the highway's presence.

Agricultural land was a category given to almost all nonforested land not occupied by cities, water, or extractive industries. In some instances, a distinction could be made between croplands and other nonforested land on the basis of their geometric shapes.

Forest lands were perhaps the least difficult of all the land uses, with the exception of water, to recognize; although delineation of the forest-nonforest interface was often very difficult. Also included in this category were areas devoid of trees but located in the midst of expansive forests. This is particularly true in Alabama where large blocks of forest land are cut and replanted every twenty to thirty years. No distinction was made as to whether the trees were deciduous or evergreens, although this distinction was sometimes feasible.

All areas coded as water include areas that are persistently inundated. Streams not actually visible but only inferred were not coded as such but were included within the land use in which they were found. No distinction was made between fresh and saline water or between natural lakes and man-made reservoirs, nor was the intended use of the water body or stream indicated.

Nonforested wetland referred to those areas where little or no forest crown was visible and where standing water was evident or strongly inferred. This category was usually deleted in the actual coding process since it was contained in only a few of the southern-most counties.

The Barren Land category was restricted to beaches and sand bars, bare rock exposures, strip-mined areas, borrow pits, and rock quarries. Land that was barren due to agricultural tillage and urban expansion was not included in this category.

The small scale of ERTS photography required modification of this land use classification system. Many Level II and even Level III categories were detectable on ERTS-I images on a scale of 1:1,000,000, but were classified according to their respective Level I categories to facilitate land-use mapping and change detection on a regional scale. While the classification used was very broad and helpful, it did not take into consideration some of the characteristics peculiar to ERTS-I imagery. Therefore, the classification scheme contained in Figure 11 was developed for use with ERTS imagery at least on local levels.

This classification was formulated directly out of this investigation of ERTS-I imagery and considers only those land-use features which are readily recognizable. It also provides a means of discriminating between

I. URBAN

   A. Urban Core

   B. Noncore (residential)

II. RESOURCE PRODUCTION

   A. Agricultural

   B. Forest

      1. Continuous

      2. Discontinuous

   C. Extraction

III. TRANSPORTATION

   A. Motoring

      1. Primary

      2. Secondary

   B. Railroads (?)

   C. Airports

IV. WATER RESOURCES

   A. Rivers and Lakes

      1. Fresh

      2. Saline

      3. Turbid

      4. Transitional

   B. Marshland

Figure 11. A Feasibile Land-Use Classification Scheme for Use with ERTS Imagery.

turbid water (either fresh or saline) and nonturbid water, a condition which is very apparent on MSS 4 (spectral green) and MSS 5 (spectral red).

Classifying airports as a third level land-use category, was considered misleading considering their size and importance, and hence, they were classified under the general heading of transportation in Figure 11. A question mark was placed after railroads under "transportation", because to date, no railroad lines have definitely been identified. They are included here, however, in the event that they are detected later using more sophisticated equipment.

D. Results and Summaries

The results of the historical land use inventory, using Soil Conservation Service photo mosaics, are included in some form in the two regional studies discussed in the following chapters. The coded data for all 67 counties in the state has been placed on computer cards and is available for use with any type of computer program for comparison with coded ERTS or other data, dominant land use mapping, etc.

II. SPECIAL AREA INVESTIGATIONS

Although general descriptions were prepared of almost every scene photographed by ERTS-I, over Alabama, only two detailed studies of selected areas were made. In these areas, not only ERTS data, but results of the historical land use studies, including all available ground truth, were accumulated and applied to certain problems peculiar to these areas. One by-product of the studies was some comparison and correlation of data from different sources.

The principal special studies were one for the Southeast Alabama area (Montgomery - Phoenix City - Dothan), made by Richard P. Wilms and one for the Tuscaloosa area, by Lee S. Miller. Both were in the form of Masters' thesis. Both theses also included some special sub-studies that will be described in this chapter.

A. Southeast Alabama Area (Wilms)

The objectives of this investigation were designed specifically to be in conjunction with the over-all goals of the University of Alabama ERTS Project. Objectives were chosen which would not only demonstrate the feasibility of gathering land-use information from ERTS-I data, but which would also demonstrate its practicality and even preferability over other forms and sources of data. These objectives were not spontaneously generated but were composed, edited, written, and rewritten many times over a period of almost seven months. From their conception in late 1972, the the objectives were developed, defined, and redefined as the project gained momentum. Only after detailed analysis of the first ERTS-I images had been completed were the objectives of this effort clearly envisioned.

The first of this project's objectives was to produce an accurate and timely land-use inventory of a predetermined target study area using photographic interpretation techniques in assessing multispectral scanner data from ERTS-I. This objective was intended to test the feasibility of gathering accurate, timely land-use data from ERTS-I imagery for comparison with, and update of, the historical data gathered in the prelaunch phase of the project.

Since change in any area could have far-reaching effects, it is imperative that we be able to understand, monitor, and thus predict patterns of change. Realizing that general land use is an excellent indicator of the nature and degree of regional change,[10] the second objective of this investigation was to produce maps of change for any land-use category or combination of categories by comparing historical land use data with that obtained from ERTS-I. Achievement of this objective would hopefully reveal specific patterns of development, on the basis of which, certain trends and recommended courses of action could be determined.

The third objective, that of obtaining spectral signatures of both physical and cultural features through the correlation of ERTS-I data with existing ground-truth information, is actually a by-product of and part of the basic structure of the entire study. At the heart of any analysis of remotely sensed data is a clear understanding of the sensor's resolution capability, the general types of ground cover imaged, and the ultimate purpose of the analysis. Determining spectral signatures of objects on the ground is not merely the process of assigning a certain level of gray to a feature to be invariably associated with that feature. Topography,

Figure 12. Nineteen County Target Study Area.

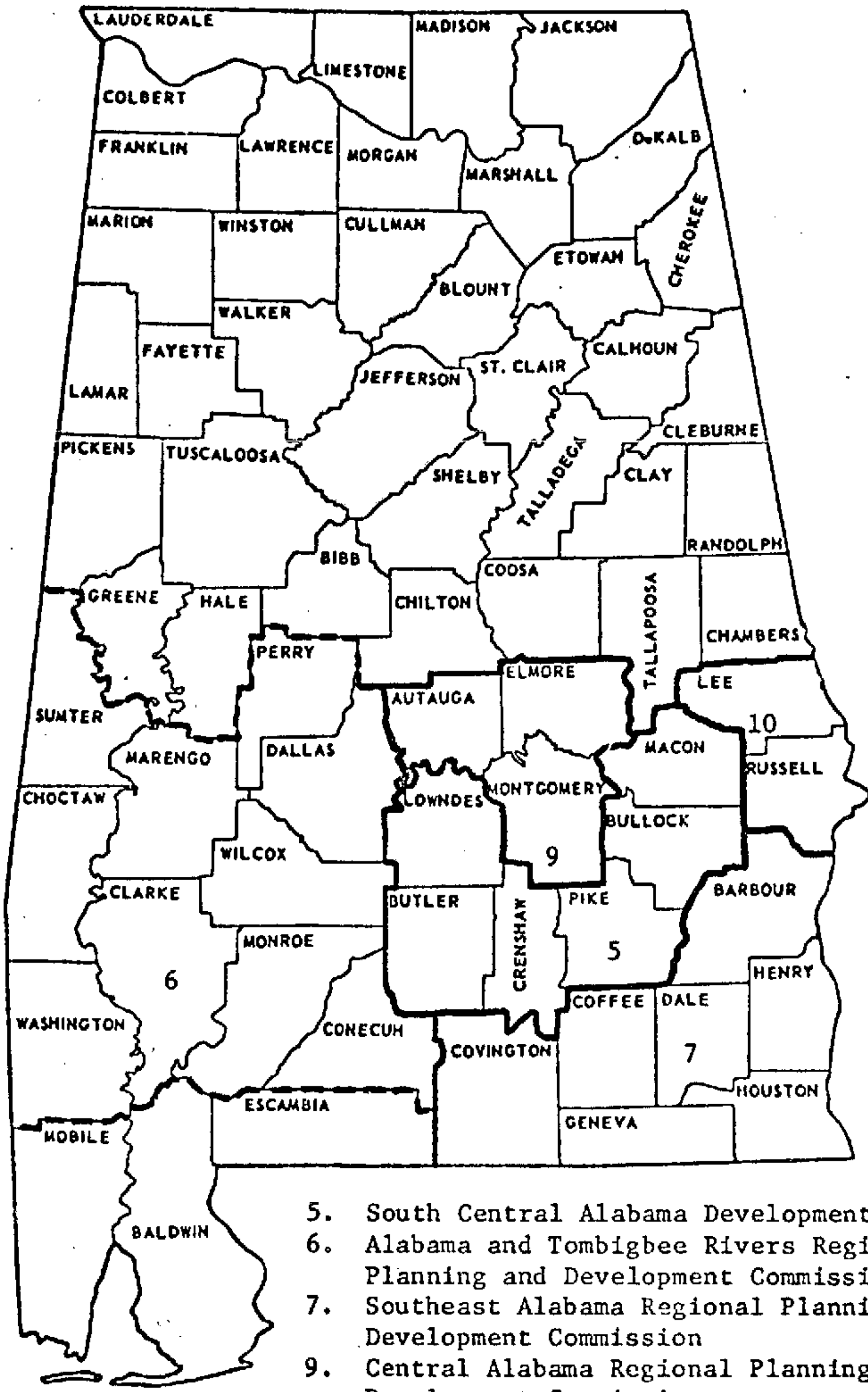

Figure 13. Alabama Development Office State Planning Districts Corresponding to the Target Study Area.

Figure 14. State Planning and Industrial Development Board Area No. 2. (Fantus, 1966)

climatic conditions, sun angle, and image processing all play a significant role in determining what a feature's spectral response will be: hence, the same features even just a few kilometers apart may possess very different spectral signatures. It is, rather, the response of features relative to that of the surrounding ground cover which is so important.

The fourth and final objective of this investigation depends upon the successful completion of the first three objectives and yet, is considered the most important of the four. The objective was to demonstrate the practicality of the ERTS-I program, but would also be of significant benefit to public planning agencies, private industries, and policy makers in their planning and regulatory functions.

The target study area for this investigation consisted of nineteen counties in the southeastern corner of Alabama (See Figure 12). These are: Autauga, Elmore, Macon, Lee, Lowndes, Montgomery, Bullock, Russell, Butler, Crenshaw, Pike, Barbour, Conecuh, Covington, Coffee, Dale, Geneva, Henry, and Houston counties. The total area of all nineteen counties comprises over 25 percent of Alabama's entire land area of 135,289 square kilometers.

Four State Planning and Development Districts (5, 7, 9, and 10) of the Alabama Development Office (ADO) are represented in whole, as well as one county from District 6, Conecuh County. Figure 13 illustrates the configuration of the four districts within the target study area. Conecuh County was included so that the target study area would encompass all of the Alabama State Planning and Industrial Development Board Area Number 2 as given in Figure 14. An obvious effort was made to include as many state planning districts as possible in the target study area for the purpose of establishing a working relationship with those districts and to demonstrate to them the applicability of ERTS-I data in their own areas.

In addition, three USDA Soil Conservation Services Areas are represented. All counties of Area 5 are included as are seven counties of Area 4, and one county of Area 6 (See Figure 15).

Most of the nineteen-county area is covered by ERTS-I scene K-3 (See Figure 16). Three additional scenes were required for complete coverage, however: K-2, L-3, and J-3.

The area under investigation lies almost entirely within the coastal plain of Alabama, characterized primarily by a moderate topography (10 to 25 percent slope) (See Figure 17). Subsurface geology includes Mesozoic shales, clays, and sandstones in the northern portion and Cenozoic limestones, sandstones, and loose agglomerates in the southern portion. Paleozoic metamorphic and igneous rocks are confined to the northern halves of Elmore and Lee counties.

In areas underlain by relatively easily-eroded shales, clays, and chalks, cleared agricultural land prevails with forests lining the rivers and streams. Conversely, in areas overlying the more resistant sandstones, uninterrupted forest crown cover occupying the ridges stands out vividly in contrast to the cleared agricultural land occupying the surrounding valleys.

The Alabama, Conecuh, Tallapoosa, Choctawhatchee, Coosa, and Chatahoochee rivers dominate the area's drainage system. In addition, many smaller rivers were inferred from dendritic drainage patterns. Many multipurpose lakes have been formed along these rivers including Lake Mitchell on the Coosa River in Autauga County; Lake Martin reservoir on the Tallapoosa River in Elmore County; Lake Harding and W. F. George reservoir on the Chatahoochee River in Lee and Henry counties respectively; and smaller lakes such as Point "A" Lake and Gantt Reservoir on the

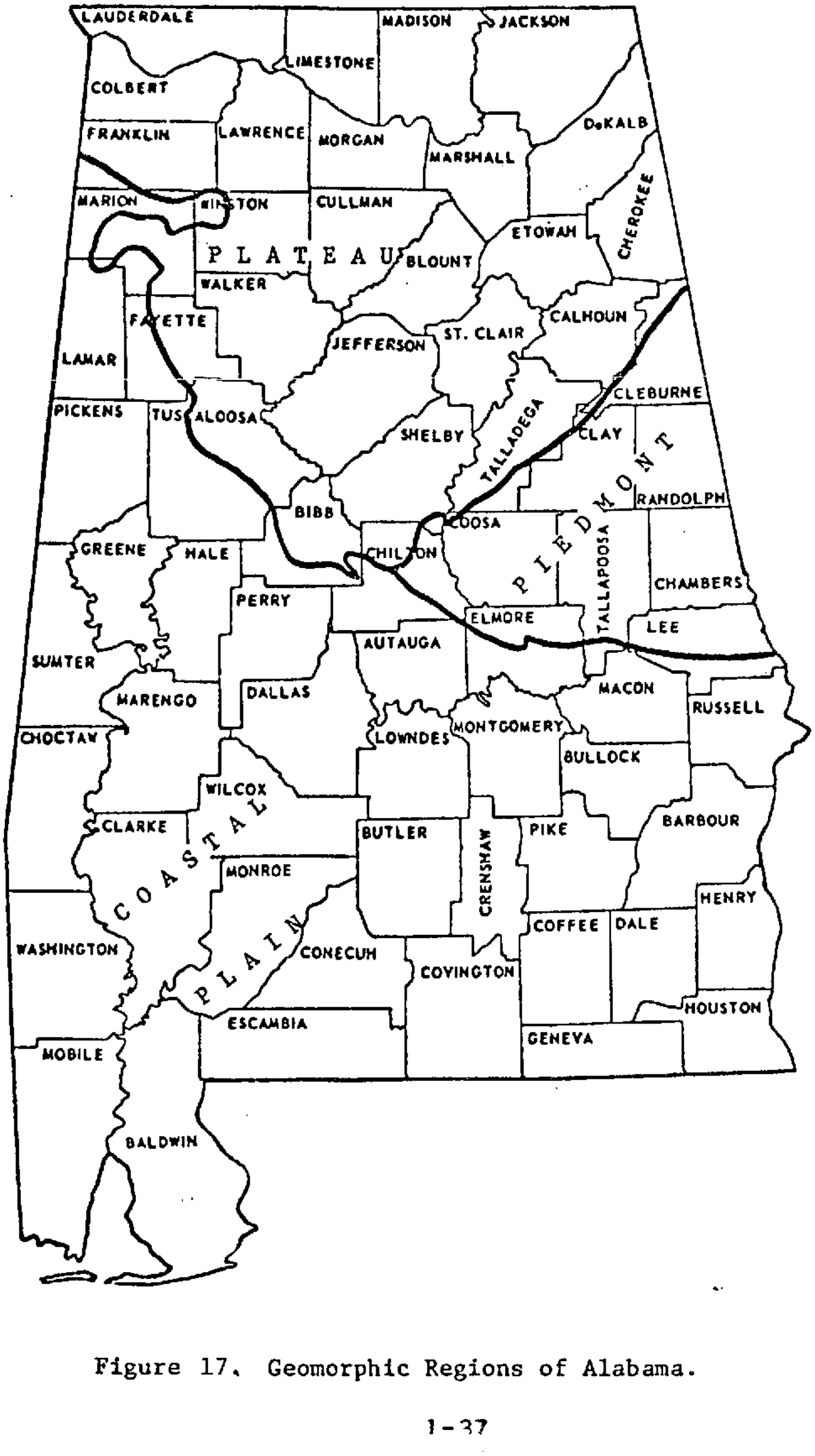

Figure 17. Geomorphic Regions of Alabama.

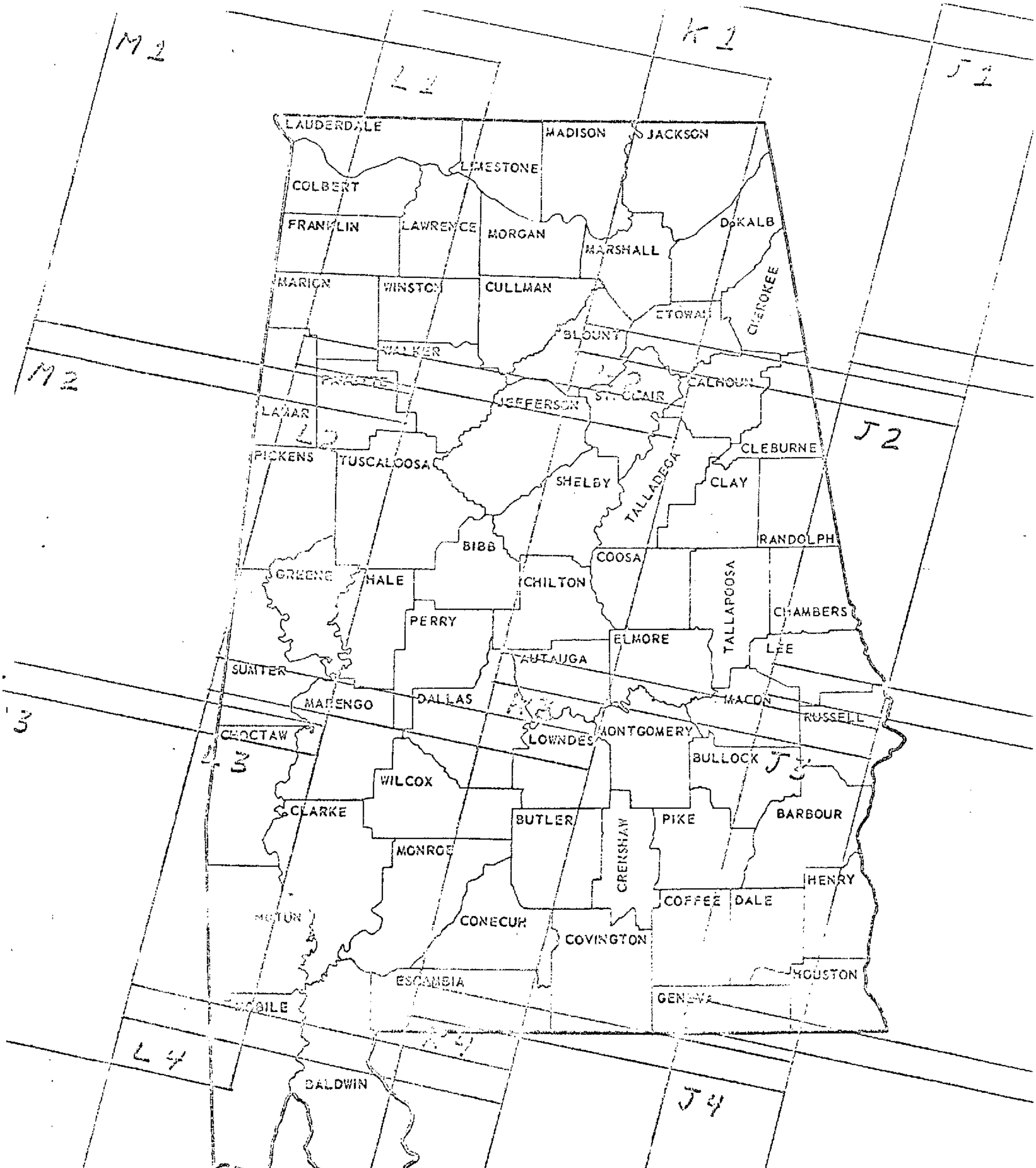
M 2
L 2
K 1
J 1
LAUDERDALE
MADISON
JACKSON
LIMESTONE
COLBERT
FRANKLIN
LAWRENCE
MORGAN
DEKALB
MARSHALL
MARION
WINSTON
CULLMAN
CHEROKEE
ETOWAH
BLOUNT
WALKER
M 2
CALHOUN
ST. CLAIR
JEFFERSON
LAMAR
J 2
CLEBURNE
PICKENS
TUSCALOOSA
SHELBY
TALLADEGA
CLAY
BIBB
RANDOLPH
COOSA
GREENE
HALE
CHILTON
TALLAPOOSA
CHAMBERS
PERRY
ELMORE
LEE
AUTAUGA
SUMTER
MACON
MARENGO
DALLAS
RUSSELL
CHOCTAW
LOWNDES
MONTGOMERY
BULLOCK
WILCOX
CLARKE
BUTLER
PIKE
BARBOUR
MONROE
CRENSHAW
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Figure 16

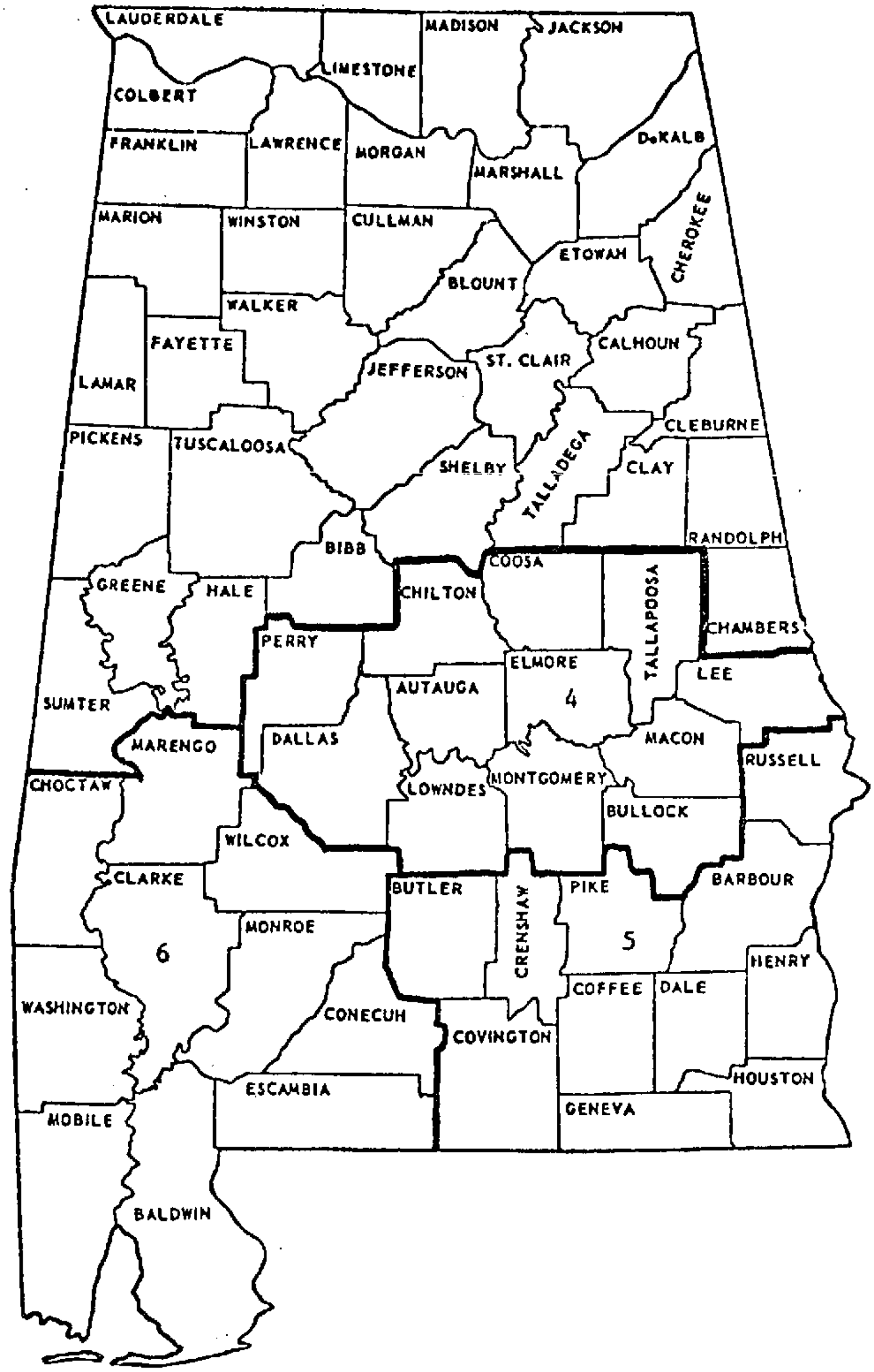

Figure 15. USDA Soil Conservation Service Areas Corresponding to the Target Study Area.

Conecuh River in Covington County and Lake Tholocco on a tributary of the Choctawhatchee River in Dale County.

A preliminary evaluation of the ERTS-I scenes, covering most of the target study area, revealed the major urban areas of Montgomery, Dothan, Auburn-Opelika, as well as the smaller towns of Andalusia, and Tuskegee.[11,12] Concerning routes between many of these cities evident on ERTS imagery included I-65, I-85, US-231, US-80, and US-29. Other cities outside these scenes which were easily detected were Phenix City and Eufaula on the Chatahoochee River.

The great diversity of land-use types was a prime consideration in the selection of southeastern Alabama as the target study area. All land uses detectable by ERTS-I are represented. In addition, industrial growth in the area over the past ten years, a critical factor in urban growth, was very substantial.[13] This was also significant in the choice of target study areas, in that rapid urban growth as well as the increasing cultivation of previously forested areas facilitate change detection on a regional scale. Another important factor in its selection was previous personal experience in the area.[11]

1. Techniques

Timely land-use data were compiled from ERTS-I images using MSS bands four, five, and seven. Data compilation was achieved in much the same manner as in the compilation of historic data. Instead of percentages of each land use being coded for each cell, only dominant land use per cell was recorded due to the small scale and resolution of the ERTS-I images. The images were at a scale of 1:1,000,000 so that a one millemeter square grid cell represented one square kilometer on the ground.

Again, there was some preparation required before actual land-use information could be extracted from the imagery. "Quick-look" scene analyses depicting cultural and physical features within an entire ERTS-I scene, although highly generalized, provided the preliminary evaluation necessary for more detailed investigation later. Specific problem areas and interesting phenomena were often uncovered and resolved before embarking on a more systematic evaluation. Besides merely indicating possible problem areas, the scene analyses may in themselves provide needed information and insight to planning agencies and policy makers.

Following the preliminary analysis, a more detailed, cell-by-cell land-use inventory was initiated. First of all, an outline map of all 19 counties was prepared on semi-transparent millimeter graph paper using the boundaries established for the historic data base. These county outlines were at the same scale as the ERTS-I imagery facilitating overlay. In this case, however, the grid was placed underneath the ERTS-I positive transparency. The semi-transparent grid served to diffuse light from the light table more evenly and was less grainy than the glass of the light table. In addition, the grid indicated which areas of the image corresponded to the cells in each county.

The next procedure involved positioning the image correctly on the millimeter grid containing the county outlines and labeled according to the UTM system. At least three natural or cultural features were selected from each scene utilized. They were selected on the basis of temporal stability, detectability on ERTS-I imagery, and location relative to each other. Since the UTM coordinates of the cells containing the features were taken from four to seven year old air photo mosaics, features which may have changed location during that time, such as river meanders and strip pits, were unacceptable. The features selected as locational references necessarily had to be clearly defined on the scene to be registered. Finally, the features were chosen so as to form as large a polygon as possible within the scene. Overlapping scenes always had at least one common reference point, thus providing continuity and accuracy. Reference points selected included the intersection of two runways at an airport, the confluence of two rivers, small lakes, and dams. Features which could have been used include the intersection of major highways, geologic and geomorphic features, and persistent, stationary, industrial sources of smoke plumes.

After deciding what the locational features would be, their UTM designation was taken form the air photo mosaics. This cell was then outlined on the millimeter grid. It was then a simple matter to align the features in the image with their corresponding cells on the grid. When properly aligned, the center of each registration mark at the four corners of the image was indicated on the grid to facilitate rapid and accurate registration of different spectral bands of the same image without having to repeat the process of feature alignment.

With the county grid and image correctly aligned, a transparent acetate "working" grid, at the same scale as the first grid and the image, was placed over the image and aligned with the grid underneath. This point-grid possessed only a dot in each corner of every millimeter square grid and therefore did not obliterate any of the detail in the scene itself. Pens especially adapted to writing on acetate were used to indicate significant features and coding progress on the grid overlay.

MSS band seven (0.8 to 1.1 microns) was used to code the cells in each county which were dominated by surface water. This initial step was necessary in order to forego the possibility of erroneously classifying a lake or reservoir as some other form of land use when viewing MSS band four and five (visible bands). After color-coding these water-dominated cells, the acetate "working grid" was applied to the same scene in band four (spectral green) and band five (spectral red).

Beginning at the top-most left-hand corner of the county, each row of cells was coded from left to right for dominant land use per cell. Using a hand-held 5X magnifier, the dominant land use was determined and communicated to a technician who then recorded that information in the corresponding space on a blank computer printout of that particular county. In this manner, the land-use information for an entire county was recorded in approximately one and one-half hours and in a form ideally suited for subsequent computerization.

After land-use compilation was completed for each county, the data was put into computer format and stored for future comparison with and update of the historic data base. Dominant land-use maps, similar to Figure 9, were generated from this information.

2. Feature Recognition

Water features were best delineated on the two infrared bands, MSS six and MSS seven, because of the water's total absorption of electromagnetic energy in that portion of the spectrum (700 to 1100 nanometers). Due to the small scale of the imagery, small rivers were barely visible and could only be infrared from land-use patterns. Small ponds, often less than 100 meters wide, were visible on band seven, however.

MSS five (spectral red) was of great value in the recognition and delineation of certain cultural features because of its high contrast ratio. Urban areas, visible as pale gray tones, were evident, although care had to be taken not to confuse the urban fringe with agricultural land. Where the city was surrounded by darker-toned forest land, the urban-rural interface was readily apparent. Interstate highways as well as some secondary roads were clearly distinguishable. By following these transportation routes, it was possible to locate other urban areas not immediately evident.

Although most of the land-use information was extracted from MSS five, no single MSS band was sufficient in itself. Therefore, supplemental information in the form of 1:250,000 USGS topographic maps and 1:63,360 county highway maps was employed. This information was used only to verify the location of a town already coded and was not used to locate urban developments prior to the coding process. Furthermore, whenever ground truth negated the existence of a town in a cell which had been coded as urban, the urban classification was retained. By not "doctoring" the land-use data from ERTS-I in such a manner, a more realistic evaluation of ERT's potential was obtained.

3. Historic Data Base

The historic land-use information was compiled according to the procedure previously given above. To facilitate comparison of this data to land-use data acquired from ERTS-I, it was necessary to modify the mapping algorithm to produce maps portraying dominant land use per square kilometer. For example, a cell originally containing 10 percent urban, 40 percent agricultural, and fifty percent forestland would be represented on the dominant land-use map simply as forestland.

As can be seen from Table 1, most of the cells in each county contained no more than two land use categories. In a few of the cells containing two or more categories, the dominance was shared by two categories, e.g. a cell

TABLE 1

The Number of Cells (in Percent) Containing a Certain Number of Land-Use Categories

County	Number of Land-Use Categories Per Cell					
	1	2	3	4	5	6
Conecuh	30.88	68.27	0.85	0.00	0.00	0.00
Covington	34.74	65.53	1.64	0.07	0.00	0.00
Crenshaw	28.36	70.82	0.82	0.00	0.00	0.00
Dale	15.04	81.97	2.99	0.00	0.00	0.00
Elmore	25.90	66.21	7.42	0.48	0.00	0.00
Autauga	19.71	74.35	5.81	0.12	0.00	0.00
Barbour	22.02	74.16	3.22	0.59	0.00	0.00
Bullock	15.79	83.35	0.86	0.00	0.00	0.00
Butler	26.95	71.32	1.74	0.00	0.00	0.00
Geneva	8.82	86.76	4.28	0.13	0.00	0.00
Henry	19.19	77.73	3.01	0.06	0.00	0.00
Houston	14.01	81.71	4.28	0.00	0.00	0.00
Lee	26.87	69.70	3.30	0.12	0.00	0.00
Lowndes	21.10	76.10	2.83	0.05	0.00	0.00
Macon	22.70	74.33	2.90	0.06	0.00	0.00
Montgomery	24.90	66.81	8.09	0.19	0.00	0.00
Pike	10.47	87.13	2.40	0.00	0.00	0.00
Russell	23.57	71.86	4.20	0.36	0.00	0.00
Coffee	18.30	79.75	1.95	0.00	0.00	0.00

containing 50 percent urban and 50 percent agricultural land. When this occurred, a "tie-breaker" was included in the mapping program to assign priorities to the six classes of land use. The order of preference was offered by officials of the Alabama Development Office to correspond to the cell's potential for urbanization. The order of preference is as follows: urban, barren land, wetland, agricultural, forest, and water. In other words, a cell in which barren land and forest land share the dominance, the cell would appear simply as barren land on the map of dominant land use.

Although the dominant land-use maps facilitate comparison with ERTS-I data, care must be exercised in their interpretation. For example, a small community may occupy a portion of four cells but dominate none and, therefore, not be displayed on a dominant land-use map. Likewise, a cell may contain three different land-use types where none of the three constitute even fifty percent of the cell (e.g. 30 percent urban, 30 percent agricultural, 40 percent forestland), but because forestland is the dominant land use in the cell, although not even half the area, the cell appears as totally forest on the dominant land-use map.

From Table 2 it can be seen that most of the counties are predominately forestland in a forest to agriculture ratio of roughly two to one. Geneva and Houston counties reverse this relationship and are mostly agricultural by a ratio of two to one over forestland. Montgomery County contains only slightly more agricultural land than forestland. Urban areas constitute just slightly more than one percent of the area according to the historic data. Of course, this reflects only those communities which dominate one square kilometer or more on the grid; hence, many smaller communities were not represented.

TABLE 2

The Distribution (in Percent) of Land Use Types in Each County According to the Historic Data Base and Using Dominant Land Use in Each Cell

County	Urban	Agri.	Forest	Water	Barren	Wetland	Bad
Autauga	0.63	24.19	74.86	0.32	0.00	0.00	0.00
Barbour	0.64	30.20	67.55	1.36	0.21	0.00	0.04
Bullock	0.24	43.15	56.61	0.00	0.00	0.00	0.00
Butler	0.50	17.86	81.19	0.15	0.00	0.25	0.05
Coffee	1.15	39.35	59.50	0.00	0.00	0.00	0.00
Conecuh	0.24	13.09	86.67	0.00	0.00	0.00	0.00
Covington	0.70	27.94	71.07	0.29	0.00	0.00	0.00
Crenshaw	0.19	23.02	76.79	0.00	0.00	0.00	0.00
Dale	0.79	29.94	58.07	0.00	0.00	0.00	11.20
Elmore	0.90	29.96	65.07	4.07	0.00	0.00	0.00
Geneva	0.71	66.78	32.38	0.00	0.00	0.13	0.00
Henry	0.46	41.13	56.97	1.44	0.00	0.00	0.00
Houston	3.18	65.50	30.35	0.32	0.00	0.00	0.65
Lee	2.25	23.50	73.13	1.06	0.00	0.00	0.06
Lowndes	0.16	43.06	55.60	0.00	0.00	0.00	1.18
Macon	0.86	38.47	60.67	0.00	0.00	0.00	0.00
Montgomery	4.43	53.10	42.04	0.14	0.29	0.00	0.00
Pike	0.94	39.65	59.36	0.00	0.00	0.00	0.05
Russell	2.01	28.46	66.29	1.59	0.06	0.00	1.59

Notice that in Table 2, the seventh column applies to "bad cells." This is somewhat of a misnomer in that, in most cases, "bad cells" were intentionally coded as such to provide a means of identifying military installations and reserves. Indeed, the occurrence of only a few randomly spaced "bad cells" indicate what the name implies, that is, the presence of an anomaly in either coding or key-punching. The presence of an agglomeration of "bad cells" in any one area, however, always indicates the presence of a military installation. Examples of this are in Russell County (27 "bad cells" corresponding to Fort Benning Military Reservation) and in Dale County (156 "bad cells" corresponding to Fort Rucker). A more appropriate title for these cells, rather than "bad cells", would be the term "other," denoting a cell dominated by a land use other than the standard six classifications.

4. ERTS-I Data Base

The compilation of land-use information from ERTS-I imagery was previously described. This dominant land use per square kilometer was computerized and entered into the data file to allow internal correlation and comparison of data acquired by ERTS-I with the historic data discussed in the previous section.

Table 1 contains the results of the land-use survey from ERTS-I imagery. As in Table 2, this survey indicates that forestland is still the dominant land use in most of the counties. Unlike Table 2, however, no barren or wetland was recorded in Table 3.

"Bad cells" in Table 3 indicate card-punch or computer printout errors and not military reserves as in the historic data base. Military bases appeared as urban or forest areas on ERTS-I imagery and were coded as such

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TABLE 3

The Distribution (in Percent) of Land Use Types in Each County According to ERTS-I Data

County	Urban	Agri.	Forest	Water	Barren	Wetland	Bad
Autauga	1.70	37.40	59.13	1.77	0.00	0.00	0.00
Barbour	3.22	36.51	59.13	1.69	0.00	0.00	2.16
Bullock	1.65	35.01	62.42	0.00	0.00	0.00	0.92
Butler	1.69	25.21	70.97	0.00	0.00	0.00	2.13
Coffee	1.78	40.39	57.83	0.00	0.00	0.00	0.00
Conecuh	1.27	23.59	75.14	0.00	0.00	0.00	0.00
Covington	1.13	29.63	68.84	0.40	0.00	0.00	0.00
Crenshaw	2.58	40.25	57.17	0.00	0.00	0.00	0.00
Dale	3.73	32.95	63.03	0.29	0.00	0.00	0.00
Elmore	4.13	39.59	50.96	5.32	0.00	0.00	0.00
Geneva	2.79	54.25	42.96	0.00	0.00	0.00	0.00
Henry	1.89	51.74	44.73	1.64	0.00	0.00	0.00
Houston	7.98	68.68	23.34	0.00	0.00	0.00	0.00
Lee	5.92	23.07	69.01	2.00	0.00	0.00	0.00
Lowndes	1.44	43.48	54.97	0.00	0.00	0.00	0.11
Macon	3.59	40.26	56.15	0.00	0.00	0.00	0.00
Montgomery	9.00	58.30	32.70	0.00	0.00	0.00	0.00
Pike	2.98	54.15	42.69	0.00	0.00	0.00	0.18
Russell	4.96	43.56	51.13	0.35	0.00	0.00	0.00

which accounts for the relatively low percentage of "bad cells" in Table 3. Accordingly, the coding of forestland inside the bounds of a military reserve previously coded as "bad cells" would account for an apparent increase in forestland in a county when in actuality, the total number of acres in forests may have decreased. Dale County is an excellent example. While most counties increased in agricultural land at the expense of forestland, Dale County increased in both categories as well as in urban. According to ERTS-I imagery, Fort Rucker was not coded as "bad cells" but was coded as urban and forested.

5. Regional Change

Table 4 illustrates the change in each land-use category as a percent of the total county area. As would be expected, urban land use increased in all nineteen counties. Also to be expected was the spread of agricultural areas at the expense of previously forested land. This was true for sixteen of the nineteen counties in the target study area. Likewise, in most of the counties experiencing agricultural growth, there was a corresponding decrease in forestland. Surface water increased or decreased very little in any of the nineteen counties; and where changes in this category were noted in Table 4, they were probably due to a slight misalignment of the grid during the coding process or failure to detect the water body on the ERTS-I imagery.

One broad goal of this study was to evaluate the utility of ERTS-I data to problems of land-use management. There is no greater need for management and planning in field of urban development. Urban areas are usually the most dynamic of the six primary land use categories and are excellent indicators of the economic and social climate of the region.

TABLE 4

The Change of Each Land-Use Type as a Percent of Total County Area

County	Urban	Agri.	Forest	Water	Barren	Wetland	Bad
Autauga	1.07	13.21	-15.73	1.45	0.00	0.00	0.00
Barbour	2.58	6.31	-11.13	0.33	-0.21	0.00	2.12
Bullock	1.41	- 8.14	5.81	0.00	0.00	0.00	0.92
Butler	1.19	7.35	-10.22	-0.15	0.00	-0.25	2.08
Coffee	0.63	1.04	- 1.67	0.00	0.00	0.00	0.00
Conecuh	1.03	10.50	-11.53	0.00	0.00	0.00	0.00
Covington	0.43	1.69	- 2.23	0.11	0.00	0.00	0.00
Crenshaw	2.39	17.23	-19.62	0.00	0.00	0.00	0.00
Dale	2.94	3.01	4.96	0.29	0.00	0.00	-11.20
Elmore	3.23	9.63	-14.11	1.25	0.00	0.00	0.00
Geneva	2.08	-12.53	10.58	0.00	0.00	-0.13	0.00
Henry	1.43	10.61	-12.24	0.20	0.00	0.00	0.00
Houston	4.80	3.19	- 7.01	-0.32	0.00	0.00	-0.65
Lee	3.67	- 0.43	- 4.12	0.94	0.00	0.00	-0.06
Lowndes	1.28	0.42	- 0.63	0.00	0.00	0.00	1.07
Macon	2.73	1.79	- 4.52	0.00	0.00	0.00	0.00
Montgomery	4.57	5.20	- 9.34	-0.14	-0.29	0.00	0.00
Pike	2.04	14.50	-16.67	0.00	0.00	0.00	0.13
Russell	2.95	15.10	-15.16	-1.24	-0.06	0.00	-1.59

It is obvious, therefore, that the continuous monitoring of these urban areas and periodic mapping of their growth would vacilitate the resolution of many regional planning problems. Despite the necessity of information concerning the location and extent of cities and towns, however, previous sources of such information represent the results of a variety of ad hoc procedures that have developed over the years. In contrast, ERTS-I provides regional planners with timely and synoptic information concerning the urban expansion within their areas.

Figure 18 is an example of the type of urban change maps that can be generated by comparing ERTS-I data to an accurate historic base map. By putting the urban change maps for all nineteen counties together to form a mosaic such as Figure 18, regional urban growth trends are more likely to become apparent.

Figure 18 indicates that many towns not displayed on the historic dominant land-use maps were evident for the first time according to ERTS-I imagery showing substantial growth of smaller as well as larger urban areas. The causes of this urban growth and its resulting growth trends will be discussed further.

The data in Table 4 indicates that the dominant transition to rural land use in the target study area was from forest to agriculture. Bullock, Geneva, and Lee counties, however, experienced a decline in agricultural land with all but Lee County exhibiting a corresponding increase in forest-land. In Lee County, the loss of agricultural land was not substantial (less than one percent) and can be attributed to either an error in coding or the transgression of previously farmed and forested lands by the expanding Auburn-Opelika urban area. The decrease of agricultural activity in Geneva County is partly due to the expanding practice of growing trees for pulp-wood and to errors inherent in the production of dominant land-use maps. For example, in Geneva County, farm fields tend to aggregate between wooded dendritic stream patterns. The areas surrounding even smaller tributaries are often swampy and unsuitable for agricultural activity and are thus wooded. Therefore, most fields are contiguous with forested areas surrounding fingerling streams or larger rivers. These forested areas did not constitute the dominant form of land use in most of the cells in the historic data base, however, and the cells were coded as predominantly agricultural. When using ERTS-I data (dated September, 1972), however, many of the fields still contained vegetation, which, along with the fact that the dark forested areas tended to overshadow and blur the lighter-toned agricultural fields, accounts for the apparent decrease in cultivated land and an apparent increase in forested land. The situation in Bullock County was somewhat more intriguing and proved to be a valuable lesson in the compilation of land use from low-resolution imagery as well as a commendation of the seasonal coverage afforded by ERTS-I. The apparent decrease in agricultural land and increase in forestland was not so much the result of an error in interpretation, per se, as it was the failure of the MSS sensors aboard ERTS-I to discriminate between growing vegetation in farm fields and natural forest crown cover surrounding them. Inspection of January ERTS-I imagery of the same area indicated that many of the fields, then devoid of vegetation, had been erroneously coded as forestland using September imagery. This dramatically demonstrated to the writer the great benefits of the seasonal coverage rendered by ERTS-I.

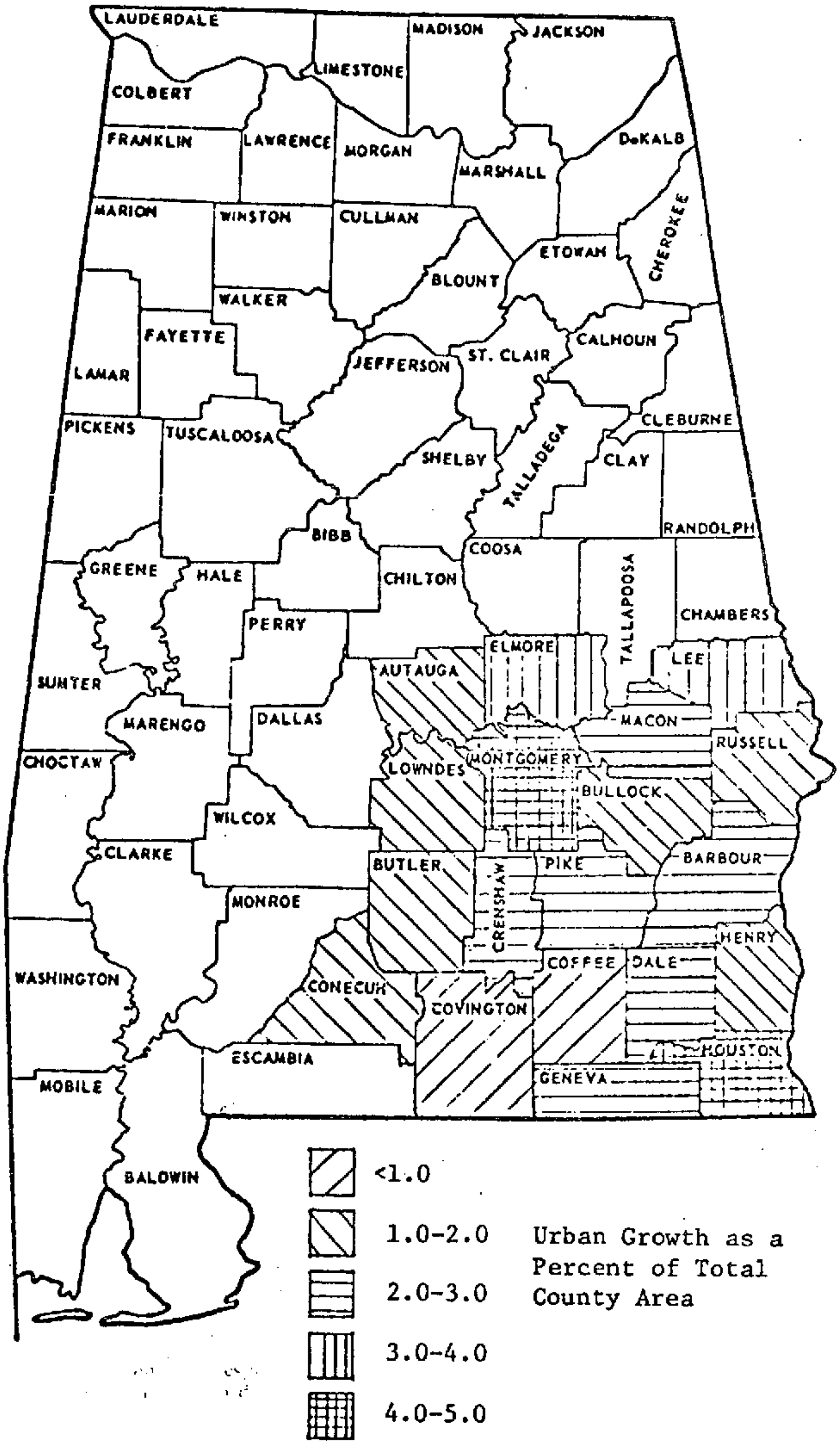


Figure 19. Pattern of Urban Growth in the Target Study Area.

6. Trend Detection and Analysis

Figure 19, a representation of the urban information contained in Table 4, illustrates, on a county-by-county basis, the major centers of urban growth in southeastern Alabama. According to Figure 19, Montgomery and Houston counties have exhibited the greatest amount of urban growth over the past nine and five years, respectively, followed closely by Elmore and Lee counties. Macon, Crenshaw, Pike, Barbour, Dale, and Geneva counties were next in line with an urban expansion of between two and three percent of the total county areas.

Some definite regional trends in urban development are evident from Figures 18 and 19. It can be seen that the city of Montgomery (Montgomery County) apparently is the hub of at least three and possibly four emerging growth corridors. For example, Dale and Pike counties constitute an apparent growth corridor between the cities of Montgomery and Dothan (Houston County). This corridor, as in most cases, seems to follow the major transportation artery linking the two cities. Urban devleopment along the route (US-231) and has been heavy. Completion of construction making the route a four-land divided highway will certainly tend to accelerate the construction of ribbon developments and will probably help to attract light industry to towns with direct access to the highway. In addition, the town of Ozark in Dale County has expanded southward along Alabama highway 85 toward the small town of Pleasant Hill which in turn is developing toward Fort Rucker. The commercial and industrial market at Fort Rucker as well as the aesthetic appeal of nearby Lake Tholocco no doubt played a major role in this expansion.

Macon County, which increased over two and one-half percent in urban area since 1964, is a definite expansion corridor for the cities of

Montgomery and Auburn-Opelika (Lee County). This corridor follows I-85 running eastward from Montgomery County up through the Auburn-Opelika area and further along US-432 toward Phenix City. Auburn and Opelika have grown together along this route and together are extending along I-85 in the direction of Montgomery. Growth of the city of Tuskegee as well as of other towns in Macon County are also believed to have benefited from this highway. Increased trade and travel between the commercial, industrial, and governmental center of Montgomery, the educational center at Auburn, and the markets of Atlanta, Georgia, should stimulate further growth in the area.

A substantial urban growth in Elmore County may indicate the development of an urban thrust from the city of Montgomery toward the commercial and industrial center in Jefferson County to the North. The development of urban areas along I-65 would seem to reinforce this observation, but further detailed analysis involving more of the northern counties would be required to determine its actual existence.

A fourth growth corridor is indicated by urban development in Lowndes, Butler, and Conecuh counties. Again, a major transportation artery is the center line of this corridor which follows I-65 from Montgomery to Mobile. The establishment of a "superport" off the coast of Alabama should give this corridor one of the highest growth potentials in the state.

A possible expansion corridor seems to be developing between Dothan and the Phenix City (Russell County) area along the Chatahoochee River as indicated by a substantial urban increase in Barbour County, primarily at Eufaula on the W.F. George Reservoir. Unlike the previously discussed expansion corridors which followed major transportation routes linking population centers, the Dothan-Eufaula-Phenix City corridor would seem to owe its urban growth more to the multi-use potential of the W. F. George Reservoir and the Chatahoochee River; US-432 would also play a significant role.

Several secondary urban expansion corridors are indicated by Figure 18. For example, US-82 between Montgomery and Midway in Bullock County and Comer Batesville, and Spring Hill in Barbour County. The growth of these towns may indicate a possible secondary growth corridor. An interesting pattern of urban growth has developed parallel to the corridor just described. It lies for the most part in Macon County along Alabama highway 26 and the Seaboard Air Line Railroad running eastward out of Montgomery. In Russell County, this ribbon of urban developments continues to follow highway 26 which is now paralleled by the Central of Georgia Railroad line heading up to Phenix City and Columbus, Georgia.

Finally, urban expansion along Alabama highway 52 from Dothan to Geneva (Geneva County) warrants attention as a possible growth corridor between Dothan and the military and resort center of Pensacola, Florida. All of these primary and secondary corridors as detected from ERTS-I data are represented in Figure 20.

Figure 18 is a graphic demonstration of ERTS-I's ability to monitor and detect land-use change accurately and at a cost much less than by conventional methods. Urban and regional planners, armed with this timely and comprehensive information, will be better able to make vital decisions quickly and efficiently.

7. Conclusions and Recommendation

ERTS-I was launched as an experimental model to test its sensing and telemetry systems and to determine its usefulness as a tool in solving environmental problems. The results of this investigation indicate that using

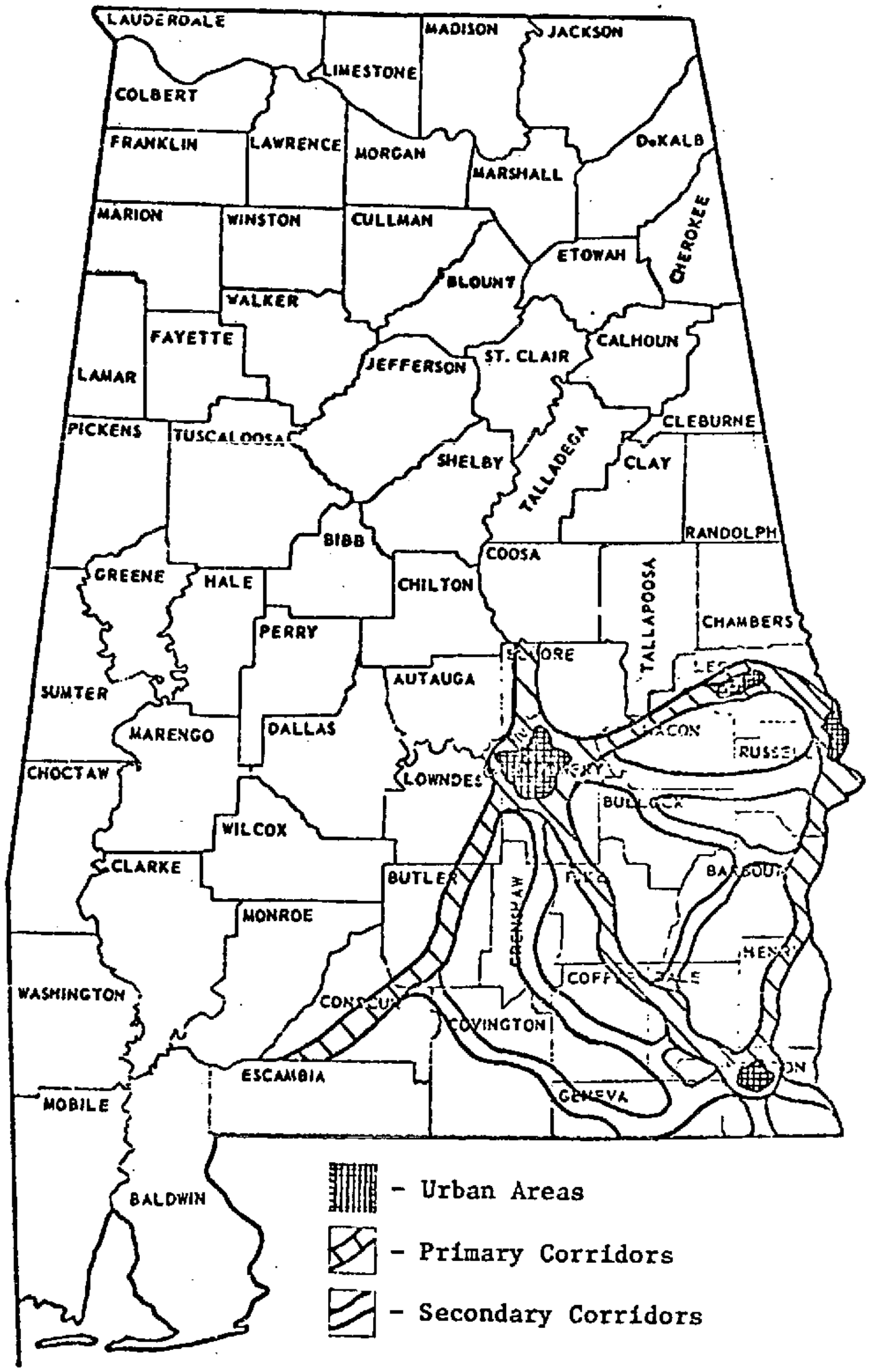


Figure 20. Urban Expansion Corridors Detected from ERTS-I Imagery.

ERTS-I imagery for land-use inventory and planning on the regional level is not only feasible, it is preferable over more conventional sources of information. Detailed local urban planning would, of course, require large scale low altitude imagery and substantial ground truth. On the other hand, data compilation for an entire state or region using large scale imagery would prove prohibitive in both time and money. For example, land-use information was extracted from ERTS-I imagery for an entire county in about one and one-half hours. This compares to a period of fifteen hours required for the land-use inventory of the same area using air photo mosaics. It is evident, therefore, that a complete and timely land-use inventory could be accomplished for all 67 counties in Alabama after each four day pass of the satellite and before the next sequence of passes eighteen days later. This constitutes a significant achievement over the seven months required using conventional air photo mosaics which were, at best, two years old.

Although the emphasis of this study was on regional land-use inventory and planning, results of other investigations also demonstrate the utility and versatility of ERTS-I data. It is probable, however, that ERTS-I has its greatest potential in the field of regional planning.

This investigation has demonstrated the feasibility of efficiently collecting timely land-use data over large regions of the state. Furthermore, it is evident that change detection using ERTS-I imagery, at least on the regional level, is possible, and that growth trends based upon these changes will be of significant benefit to regional planners and policy makers

Cities and towns can be mapped from ERTS-I imagery and then compared to historic data to detect the amount of areal change that has occurred. A study comparing population growth to this areal growth would benefit city planners in predicting future urban sprawl based on population growth statistics. Conversely, such a study might result in a method of predicting a town's population and population increase by its geographic extent as detected by ERTS-I.

It is important to remember that ERTS-I is not a solution in itself, but only a tool to be used in solving problems of the environment. Therefore, a study should be initiated to investigate the "applied" resolution capabilities of the satellite's sensors; i.e., at what scale and for what purposes are ERTS-I images preferable over other sources of data and when they are not. This study might also reveal the accuracy with which land-use can be extracted from ERTS-I imagery. Although trends in land-use development can be predicted accurately on the regional level from land-use change maps, it is important that the type of change and the accuracy of ERTS-I in detecting it on the local level be known.

The synoptic coverage afforded by ERTS-I should be utilized to investigate local changes in ground cover among the four seasons of the year. It was previously stated that agricultural land was more easily delineated on January imagery when the fields were barren than on September imagery when the fields were still supporting a vegetative cover. This type of study may furnish a procedure whereby certain types of land use are mapped using imagery from the best suited season of the year.

After the land-use inventory using ERTS-I imagery is complete for the entire state, the data file should be expanded to include transportation arteries and selected socio-economic factors. This would enable optimum site location analyses to be run for any region in the state. Likewise, the urban trend analysis described previously should be expanded to the rest of Alabama.

Finally, an industrial air pollution survey should be attempted. This would involve detecting smoke plumes on ERTS-I imagery, pinpointing their sources and mapping their extent, thereby providing a means of determining the areas most affected by air pollution and perhaps modeling the dissemination patterns.

B. The Tuscaloosa Area (Lee Miller)

1. Objective

Gathering land-use data from remotely situated vehicles (remote sensing) is a particularly promising approach to compiling up-to-date land-use inventories. A variety of sensors have been developed to gather data and a number of techniques devised to interpret it.

One interpretation technique that is available for data is the composite sequential clustering (CSC) technique. It is an unsupervised classification technique which automatically groups the land into a number of categories according to the digital data collected by ERTS for each section of land. The technique's final product is a digital map of an area with the locations of each category delineated. If the CSC technique is to be useful in the inventory of land use from ERTS data of Alabama, several things must be investigated. Specifically, the exact relationship between the automatically derived categories and visually interpreted land-use categories must be understood. This understanding can only be gained by applying the technique to areas in a variety of regions throughout the State, during different seasons, and under varying conditions. Only then can the technique's utility as a tool for deriving timely land-use data be ascertained.

At this point, the CSC technique has been applied to only one area in Alabama. An area including the Huntsville Alabama Jetport was studied by Mr. Robert Cummings of the Marshall Space Flight Center. Additional study areas need to be analyzed in other regions.

This study was designed to satisfy part of this need by analyzing areas selected from the region around Tuscaloosa, Alabama. The ERTS data used for analysis was gathered during early spring (March 28, 1973). The Tuscaloosa area was chosen for several reasons. One of the reasons for selecting it was the great diversity of land use existing within a small area. Consequently, the study plots were relatively small. Ample ground-truth data was available in the form of multispectral photographs taken during U-2 underflights on February 22, 1973, and RB-57 underflights on April 29, 1973. Low-altitude coverage (12,600 feet) of the Tuscaloosa area was flown May 18, 1973. Another advantage of selecting study areas near Tuscaloosa was the close proximity to the University of Alabama. This facilitated the gathering and checking of ground-truth. Spring coverage was chosen because the high altitude underflights used for ground-truth were available only for this season.

The composite sequential clustering technique employs the data from the satellite to ascertain the number of land uses than can be discerned and to print out the location of the various classes of land use. The primary question to be answered when applying the technique to an area is how many different types of land-use classes can be discerned while still maintaining an acceptable degree of accuracy. The main thrust of this investigation is then to determine what types of land use are easily identified by the unsupervised interpretation of ERTS data (indicated by high classification accuracy) and what types of land use cannot be easily identified (indicated by low classification accuracy).

The land within each study area is assigned to a land-use class by its ground cover. Hence, in a sense, the term "land-use class" is misleading. The area is not necessarily classified as to its use but rather as to its ground cover. It is the characteristics of the area's cover that is sensed by ERTS and used to classify the land. Anderson, et. al., concludes that land cover is the basis of categorization of land use at the primary level.[8] Therefore, for our purposes, the area's land cover is the only criterion for land use. Despite its inaccurate connotation, the term "land use" will be used interchangably with the terms "land cover" and "ground cover".

Each data point from ERTS represents a "composite" of land-use information for an area 70 meters (230 feet) square. An area this large can easily contain more than a single type of land cover. For example, a data point might contain a building, a wooded area, and a section of road. The combination of reflectance may make such a point unclassifiable. In any case, such situations are analyzed.

The land-use classification system used in this study is arbitrarily contrived to meet the needs of the areas studied. Typically the user and the situation dictate the classification system that is used.[8] Although the classification system specifically for remotely sensed data has been devised, no attempt is intentionally made to relate land use in the Tuscaloosa area to it. Whether the resulting land-use classes conform to any classification is secondary. The primary criterion is rather than they can be effectively identified from ERTS data by the unsupervised classification technique.

The unsupervised clustering technique used in this investigation is one of many such techniques. Although some of the various techniques are

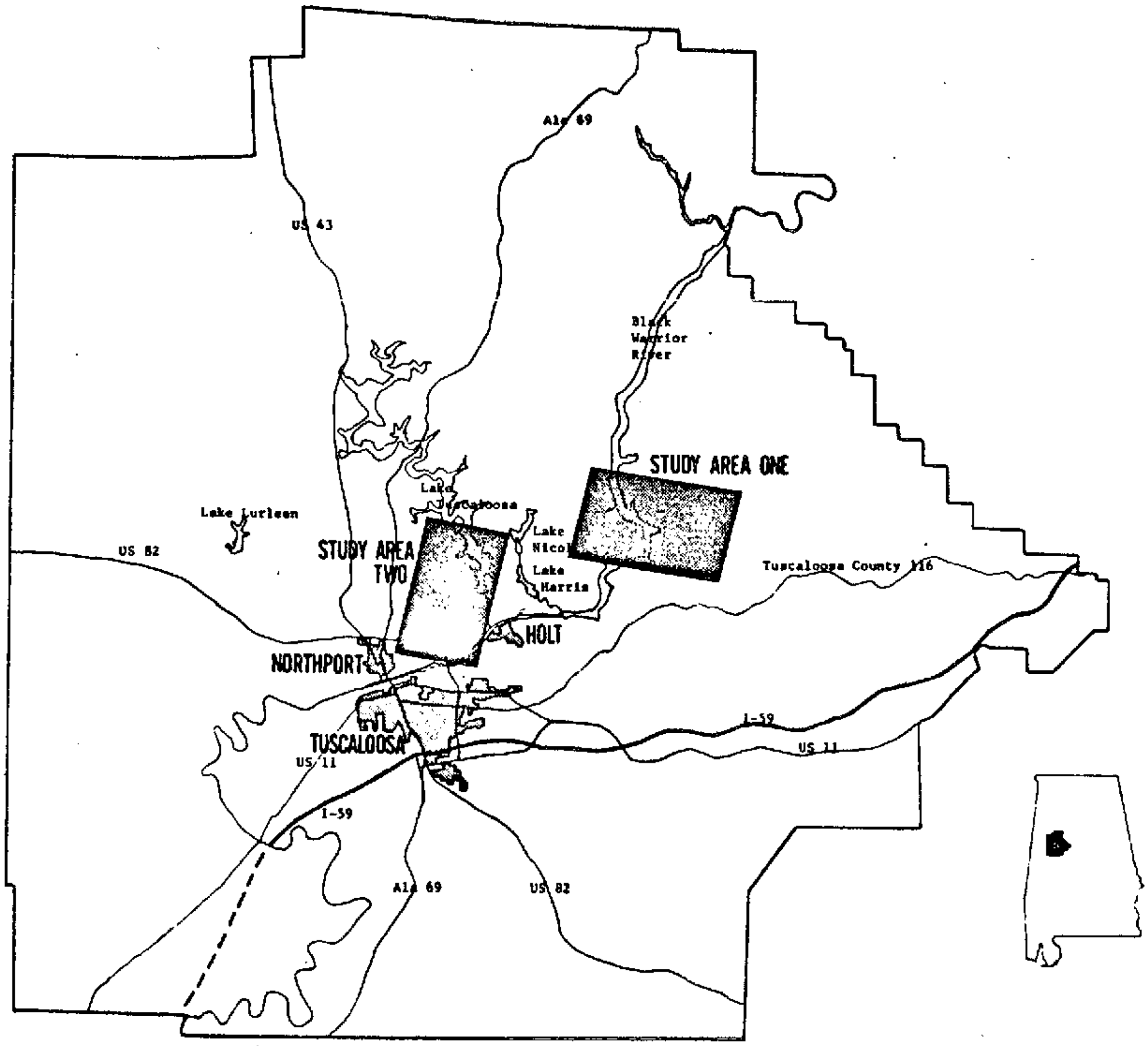


Figure 21. Location of Study Areas in Tuscaloosa County, Alabama

discussed, no attempt is made to evaluate the merits of the CSC technique relative to other methods on the basis of their performance in the study areas, whether it be in terms of the speed of accuracy of classification.

As outlined in the previous section, the study areas used for analysis should contain the types of land use that are characteristic of the region. This implies that some region be defined in West Alabama, and study areas selected such that every type of land cover is represented. A comprehensive study of this sort is not within the scope of this study. A quick examination of the air photo coverage of the Tuscaloosa areas, however, revealed the major types of ground cover that were present and should be included in the study areas.

The initial task was to eatablish criteria for the selection of the study areas. These criteria were selected in such a way that many factors affecting the quality of the ERTS data and the effectiveness of the clustering technique could be determined.

With these criteria in mind, study areas were chosen by examining high altitude photography of the Tuscaloosa area (February 22, 1973 coverage). Several plots meeting the criteria were delimited on a transparent acetate overlay. These plots were then reduced in area as much as possible while still maintaining their usefulness. After the exact location of the areas had been determined, they were located on maps according to the Universal Transverse Mercator (UTM) coordinate system. Finally those study plots of less importance were discarded. The two sub-areas selected are shown in Figure 21.

ERTS data of the area from early 1973 was examined to find the most suitable data for analysis. Its suitability was judged from the amount of cloud cover, the quality of the data, and the date it was collected.

The March 28, 1973, coverage was chosen (ERTS frame E-1248-15562). Although some clouds were over portions of Tuscaloosa County, the areas of interest were largely cloud free. The quality of the data was excellent and was gathered within five weeks of the February air photo coverage.

2. Analysis of the Unsupervised Classification

After the results of the clustering technique were received, the first task was to locate the digital data on the ground-truth map. This was done by overlaying the ground-cover map with a sheet of mylar and referencing various features that were recognizable on both the ground-cover map and the computer classification with their location in the digital data. These reference points throughout the study area were then used to size and fit a grid of data point locations over the entire area.

This grid was used two ways. In one application it was used to digitize the ground-truth map. In other words, the dominant category of ground cover for each data point or each cell in the grid was coded onto computer cards for subsequent automatic comparison with the computer classification. This automatic comparison simply noted how the unsupervised classification of each data point compared with the classification on the ground-truth map, noting each combination of interpreted ground cover category versus automatically-derived category, and displaying the results in a matrix where the number of data points with each type of combination was shown. For example, a typical number in the matrix indicated how many data points interpreted as pine forest were classified by the clustering technique into one automatically derived category.

The grid was also very useful in visually comparing the two classifications. This was done by using the grid to produce a color coded digital map of the automatically classified categories. By simply overlaying both the digital map and the ground truth map, visual comparisons were possible. The digital map was also very helpful in detecting patterns in the classification.

The actual processing of the digital data was done by personnel at the George C. Marshall Space Flight Center. To initiate this action, a data processing request form was completed for each study area. To complete this form, each study area was first located within the ERTS data. To complete the necessary information, the number of land-use classes desired from the classification in each study area and the number of spectral bands used to image the area were listed.

Prior to completion of the automatic classification, information was gathered concerning the ground cover of the study areas. This information, commonly called ground-truth, came from several sources.

The primary souce was high altitude photographs. An air photo of each study area was selected and this served as the base for the ground-cover or ground-truth map. The air photo was first projected to a workable scale. From this projected image the area's ground cover boundaries were drawn on translucent mylar. This boundary map was then used for notations concerning various characteristics of the region's land cover and as the base for the area's ground-cover map.

The primary task in the production of a ground-cover map was identifying the region's ground cover in such a way that all land in the region could be classified into one of a finite number of categories. To do this, the information contained in air photos of each study area was supplemented by field checking, examination of low altitude imagery, and interviews with those familiar with the agriculture, forestry and mining of the area. This supplemental information aided in the interpretation of the air photo so that the area's land cover could be grouped into classes and a ground-cover map produced.

Analysis of each study area involved evaluating the classification technique's effectiveness as a tool to inventory land use. There were several statistical and visual tools instrumental in making this evaluation. A discussion of some of these tools follows.

3. Manual Interpretation of Land Use

To adequately evalute the unsupervised classification, a method for quantifying the comparison of the automatically-derived classes to the existing land use was required. The ERTS-derived categories were simply numbers assigned to acre-sized parcels of land arranged in a grid-like array over the land. Before any quantitative comparison was made, the ground-truth information had to be expressed in the same form.

This expression involved classifying the land into a finite number of land-use categories and producing a ground-truth map. This was done after the classification map was received and examined for the number of classes generated and the patterns formed.

Several factors were considered in the selection of those categories suitable for comparison. Some categories were included because they seemed to have an effect on the classification. Other categories were included in order to show they were undetectable by the the technique. All categories selected had to be easily identified on the air photo coverage.

A grid of ERTS data point locations was fitted to the ground-truth map so comparison would be possible. Each interpreted land-use category was then assigned a number and the data on the ground-truth map was transferred onto computer cards in the form of the dominant land-use category per data point on the grid. The result was a number assigned to each data point, the same form as the ERTS-derived categories.

4. Interpreted Land-Use in Study Area One

The ground-cover in this area was classified into six categories (Figure 22). These six categories were interpreted from an air photo taken April 29, 1973, with a VC-8 camera using Aerochrome color infrared 2443 film which has a spectral response in the range of 0.5 to 0.9 microns. The photograph was at a scale of approximately 1:122,000.

The first category was deciduous and mixed forest. During the spring the deciduous trees were foliated and appeared bright pink on the photograph. Where the deciduous trees were mixed with pine, the pink was somewhat duller but did not present enough contrast for consistent identification. Consequently, deciduous and mixed forest were classed together.

The second category was pine forest. These areas appeared dark on the spring coverage. Although some deciduous trees were present in these areas, the proportion was very low.

The cloud shadows were category three. The cloud shadows (and clouds discussed later) were located by projecting the ERTS image of MSS band six onto the map.

Water in study area one was category number four.

The stripped areas and barren land were grouped together to form category five. These areas appeared white on the photograph.

Clouds were designated as blanks on the computer cards. This was done to correspond with the fact that the unsupervised classification did not create a separate class for clouds but simply considered them unclassifiable.

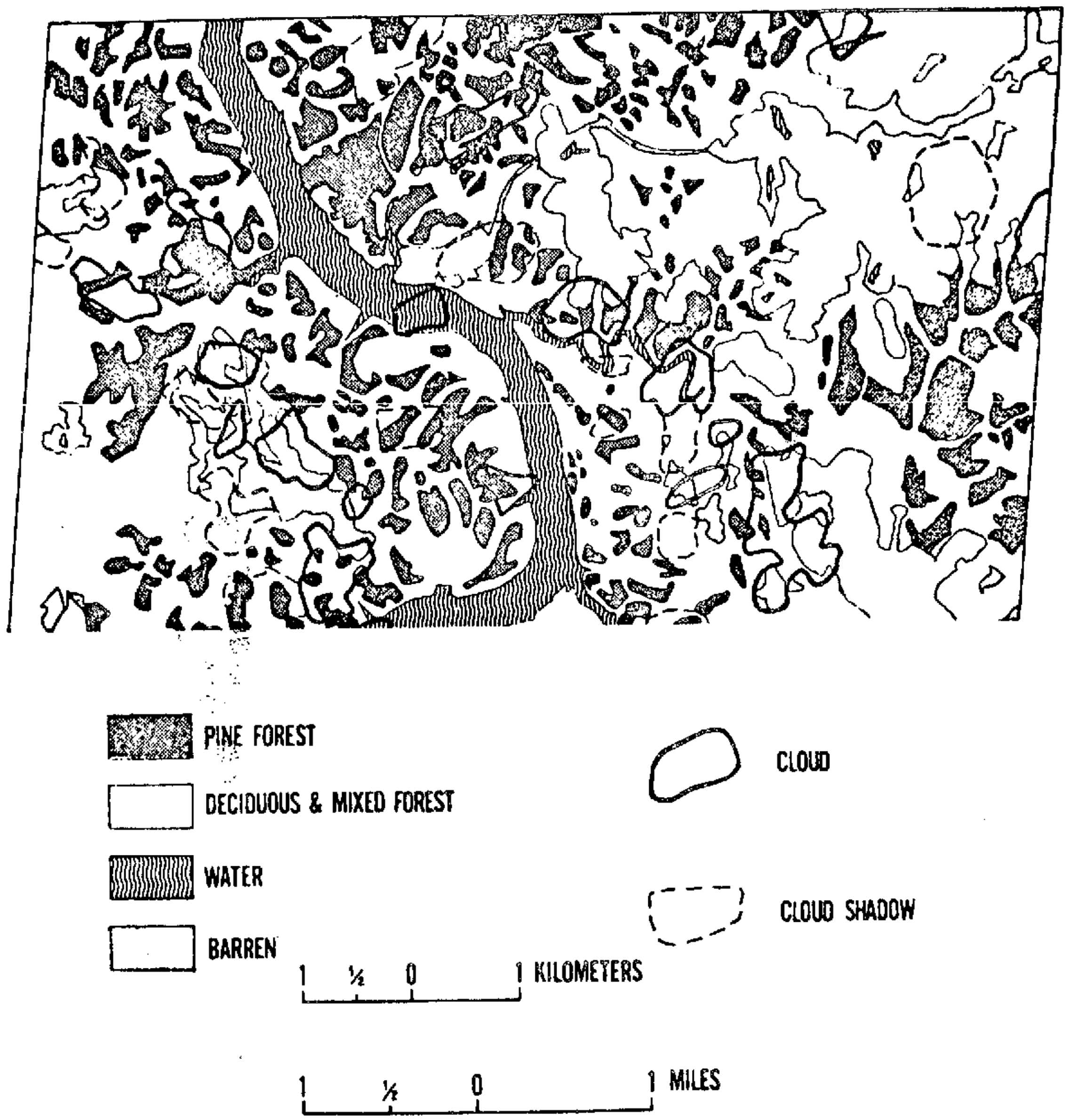


Figure 22. Map of Interpreted Categories for Study Area One

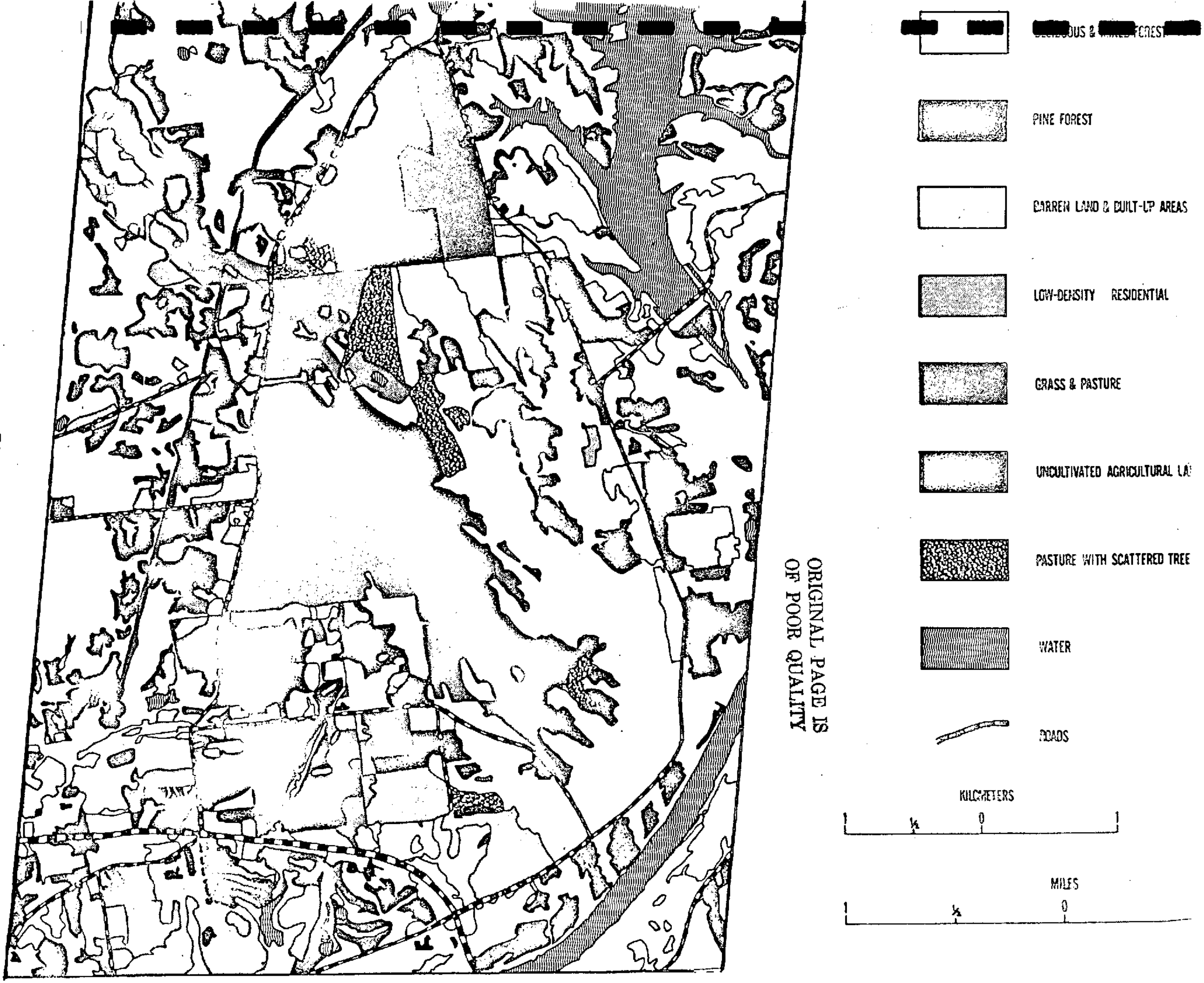

[redacted]OUS & [redacted]FOREST[redacted]
PINE FOREST
BARREN LAND & BUILT-UP AREAS
LOW-DENSITY RESIDENTIAL
GRASS & PASTURE
UNCULTIVATED AGRICULTURAL LA
PASTURE WITH SCATTERED TREE
WATER
ROADS
KILOMETERS
1 ½ 0 1
MILES
1 ½ 0

Figure 23

5. Interpreted Land Use in Study Area Two

Eight different categories were selected in study area two (Figure 23). These were interpreted from imagery identical to that described in the previous section.

Categories one and two, the two forests categories, were identical to those described for study area one.

The third category was pasture with scattered trees. The grass in these areas was short and largely exposed between the widely spaced trees.

Water was class four as in study area one.

The fifth category was low-density residential. Both small farms and residential subdivisions were classed in this category. Both areas contained many types of ground cover in a small area. Subdivisions were composed of roof tops, cement, asphalt, grass, and trees. Land in small farms consisted of roof tops, grass, trees, barren land, and gardens. Since both were characterized by similar ground-cover combinations and extreme areal complexity, they were classed together.

Categories six and seven represented open non-forested areas. Class six was grass and pasture land. This was land that supported growth of living grass and appeared a dull pink to a light burgundy color. Generally, these were areas where the grass was short. Class seven was uncultivated agricultural land. This land was covered with the residue from the harvest of the previous autumn. Subsequent investigation (after the naming of the category) revealed that this category also included unused fields grown up with tall grass and shrubbery which appeared as a gray color on the photography.

Barren land and built-up areas were considered to be category number eight. Barren land included tilled agricultural fields as well as land left bare because of construction. A built-up area was defined as high-density urban land which was completely devoid of vegetation. This included such features as shopping and business areas, roads, a federal housing project, warehouses, and a school. Barren land and built-up areas were classed together since both types of land were unvegetated and appeared to have a high reflectance.

6. Automatically-Derived Classes

Several visual and statistical tools facilitated analysis. The classification map itself was one tool when it was produced at the correct scale for comparison. This was done by assigning each class a color and producing a color-coded digital map at the scale of the grid.

The spectral signatures of the classes could be easily compared when the statistical characteristics of the classes were transcribed into a graphic form (Figures 24 and 25). The units of reflectance on the abscissa range from zero (total absorption) to sixty-four (total reflection). The range of the data within one standard deviation of the mean reflectance in each band is indicated by bars above and below each point.

The automatic comparison of the interpreted categories to the ERTS-derived classes was used in two ways. The characteristics of each ERTS-derived class could be easily studied by noting the percentage of the class that corresponded with each interpreted category (Tables V and VI). Similarly, the characteristics of each interpreted category could be evaluated by noting the percentage of the category that corresponded with each ERTS-derived class (Tables VII and VIII).

To aid in understanding the interrelationship of the clusters in multi-dimensional space, the Euclidian distance between each pair of cluster centers was calculated (Table IX and X). Those cluster centers separated

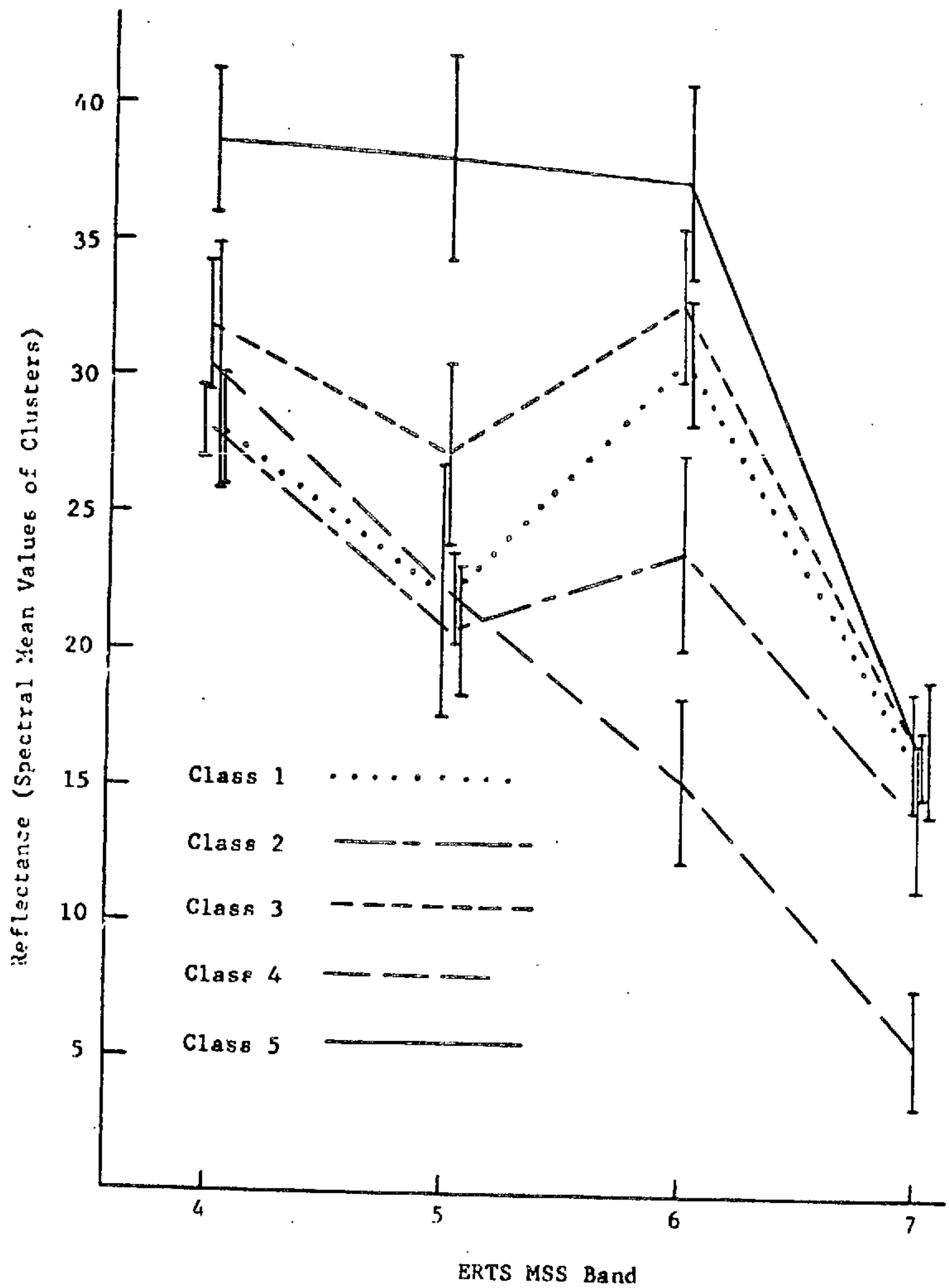


Figure 24. Spectral Signatures of Automatically-Derived Classes in Study Area One

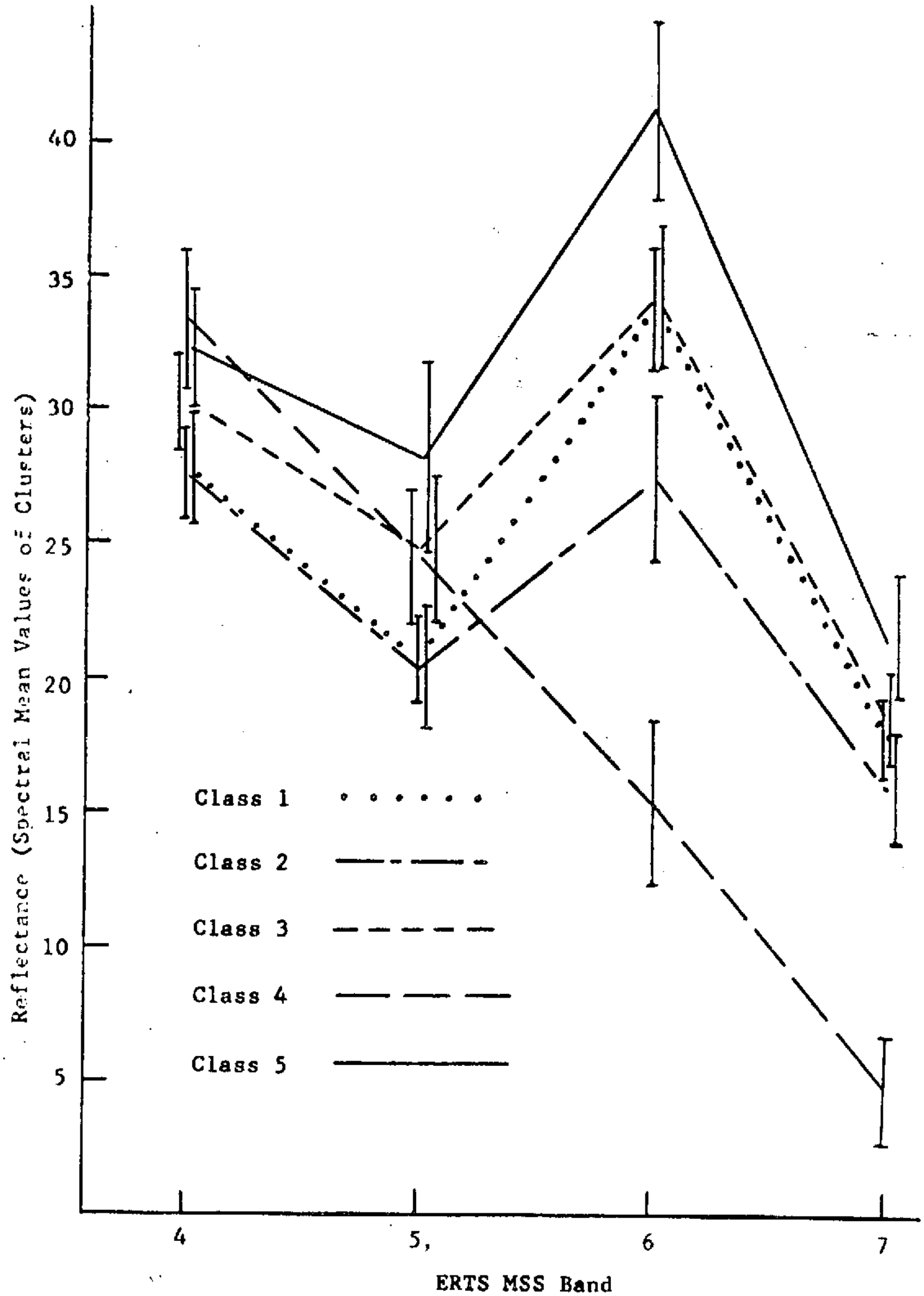


Figure 25. Spectral Signatures of Automatically-Derived Classes in Study Area Two

TABLE V

COMPARISON OF INTERPRETED CATEGORIES AND AUTOMATICALLY-DERIVED CLASSES IN TERMS OF THE PERCENTAGE OF EACH AUTOMATICALLY-DERIVED CLASS FOR STUDY AREA ONE

	Class 1	Class 2	Class 3	Class 4	Class 5	Unclassified
Deciduous & Mixed Forest	67.2 (2072)	46.9 (694)	57.6 (1009)	13.8 (109)	17.4 (156)	15.4 (255)
Pine Forest	27.5 (850)	30.4 (449)	12.8 (224)	1.4 (11)	3.9 (35)	4.7 (77)
Cloud Shadow	0.6 (20)	8.7 (129)	1.1 (21)	34.9 (276)	1.0 (9)	9.3 (154)
Water	0.9 (28)	7.2 (106)	0.4 (7)	44.4 (349)	1.1 (10)	6.6 (109)
Stripped Areas & Barren Land	2.8 (88)	5.4 (80)	23.3 (408)	4.6 (36)	66.9 (600)	26.6 (441)
Clouds	1.0 (30)	1.4 (21)	4.8 (84)	0.9 (7)	9.7 (87)	37.4 (619)
Total	100.0 (3088)	100.0 (1479)	100.0 (1753)	100.0 (788)	100.0 (897)	100.0 (1653)

TABLE VI

COMPARISON OF INTERPRETED CATEGORIES AND AUTOMATICALLY-DERIVED CLASSES IN TERMS OF THE PERCENTAGE OF EACH AUTOMATICALLY-DERIVED CLASS FOR STUDY AREA TWO

	Class 1	Class 2	Class 3	Class 4	Class 5	Unclassified
Deciduous & Mixed Forest	66.6 (1117)	63.7 (503)	43.3 (539)	13.1 (35)	11.7 (224)	7.1 (66)
Pine Forest	17.6 (296)	25.6 (202)	7.6 (95)	2.6 (7)	1.5 (28)	2.7 (25)
Pasture with Scattered Trees	1.9 (32)	0.6 (5)	2.4 (30)	0.0 (0)	2.1 (41)	0.5 (5)
Water	0.5 (8)	6.4 (51)	4.3 (54)	83.2 (223)	0.3 (6)	7.0 (65)
Low-Density Residential	1.2 (20)	0.3 (2)	6.0 (75)	0.0 (0)	8.1 (158)	3.9 (36)
Grass & Pasture	5.0 (84)	1.4 (11)	9.6 (120)	0.0 (0)	25.8 (494)	21.5 (199)
Uncultivated Agriculture	3.9 (65)	0.6 (5)	14.4 (178)	0.0 (0)	32.8 (629)	23.9 (221)
Barren Land & Built-Up Areas	3.3 (56)	1.4 (11)	12.4 (153)	1.1 (3)	17.7 (339)	33.4 (309)
Total	100.0 (1678)	100.0 (790)	100.0 (1244)	100.0 (268)	100.0 (1917)	100.0 (926)

TABLE VII

COMPARISON OF INTERPRETED CATEGORIES AND AUTOMATICALLY-DERIVED CLASSES IN TERMS OF THE PERCENTAGE OF EACH INTERPRETED CATEGORY FOR STUDY AREA ONE

	Class 1	Class 2	Class 3	Class 4	Class 5	Unclas-sified	Total
Deciduous & Mixed Forest	48.3 (2072)	16.2 (694)	23.5 (1009)	2.5 (109)	3.6 (156)	5.9 (255)	100.0 (4295)
Pine Forest	51.6 (850)	27.3 (449)	13.6 (224)	0.7 (11)	2.1 (35)	4.7 (77)	100.0 (1646)
Cloud Shadow	3.3 (20)	21.2 (129)	3.4 (21)	45.3 (276)	1.5 (9)	25.3 (154)	100.0 (609)
Water	4.6 (28)	17.4 (106)	1.1 (7)	57.4 (349)	1.6 (10)	17.9 (109)	100.0 (609)
Stripped Areas & Barren Land	5.3 (88)	4.8 (80)	24.7 (408)	2.2 (36)	36.3 (600)	26.7 (411)	100.0 (1653)
Clouds	3.5 (30)	2.5 (21)	9.9 (84)	0.8 (7)	10.3 (87)	73.0 (619)	100.0 (848)

TABLE VIII

COMPARISON OF INTERPRETED CATEGORIES AND AUTOMATICALLY-DERIVED CLASSES IN TERMS OF THE PERCENTAGE OF EACH INTERPRETED CATEGORY FOR STUDY AREA TWO

	Class 1	Class 2	Class 3	Class 4	Class 5	Unclas-sified	Total
Deciduous & Mixed Forest	45.1 (1117)	20.2 (503)	21.7 (539)	1.4 (35)	9.0 (224)	2.6 (66)	100.0 (2484)
Pine Forest	45.3 (296)	30.9 (202)	14.5 (95)	1.0 (7)	4.3 (28)	3.8 (25)	100.0 (653)
Pasture with Scattered Trees	28.4 (32)	4.4 (5)	26.5 (30)	0.0 (0)	36.3 (41)	4.4 (5)	100.0 (113)
Water	2.0 (8)	12.5 (51)	13.3 (54)	54.3 (223)	1.4 (4)	16.0 (65)	100.0 (407)
Low-Density Residential	6.8 (20)	0.7 (2)	26.0 (75)	0.0 (0)	54.0 (156)	12.5 (36)	100.0 (289)
Grass & Pasture	9.3 (84)	1.2 (11)	13.2 (120)	0.0 (0)	54.4 (494)	21.9 (199)	100.0 (908)
Uncultivated Agriculture	5.9 (65)	0.5 (5)	16.2 (178)	0.0 (0)	57.3 (629)	20.1 (221)	100.0 (1098)
Barren Land & Built-Up Areas	6.4 (56)	1.3 (11)	17.6 (153)	0.3 (3)	38.9 (339)	35.5 (309)	100.0 (871)

TABLE IX

EUCLIDIAN DISTANCES BETWEEN AUTOMATICALLY-DERIVED CLUSTER CENTERS FOR STUDY AREA ONE

	Class 1 (green)	Class 2 (yellow)	Class 3 (orange)	Class 4 (blue)	Class 5 (purple)
Class 1 (green)	-	7.336	6.752	18.768	20.412
Class 2 (yellow)	7.336	-	12.036	12.288	24.719
Class 3 (orange)	6.752	12.036	-	21.236	13.669
Class 4 (blue)	18.768	12.288	21.236	-	30.470
Class 5 (purple)	20.412	24.719	13.669	30.470	-

TABLE X

EUCLIDIAN DISTANCES BETWEEN AUTOMATICALLY-DERIVED CLUSTER CENTERS FOR STUDY AREA TWO

	Class 1 (green)	Class 2 (orange)	Class 3 (yellow)	Class 4 (blue)	Class 5 (purple)
Class 1 (green)	-	6.618	4.793	23.593	12.070
Class 2 (orange)	6.618	-	8.640	17.911	17.403
Class 3 (yellow)	4.793	8.640	-	23.410	8.817
Class 4 (blue)	23.593	17.911	23.410	-	31.168
Class 5 (purple)	12.070	17.403	8.817	31.168	-

by small distances are more similar than those separated by large distances. This matrix of distances helped in understanding misclassified data points.

The CSC technique generated five classes in each study area. The characteristics of each class in each study area are discussed in the subsequent sections.

7. Automatically-Derived Classes in Study Area One

A classification map of this study area, was made in false color for the thesis but is not reproduced here. Classes one and two (green and yellow) are primarily forest in this classification since almost ninety percent of all areas in these two classes correspond with areas interpreted as either pine or deciduous forest. About seventy percent of class three (orange) also corresponds to areas interpreted as forest (Table V). It is apparent that the forested areas in study area one are represented by three different classes.

The class into which a section of forest is classified depends on three factors - the slope of the land, the density of the forest, and the type of trees in the forest. An excellent example of the effect alope has on the classification is shown along the banks of the Black Warrior River where the slopes are quite severe. The ERTS pass was made about 9:30 A.M. local time, the same time of day the air photo of the area was taken. It was reproduced in color, but is not shown. Examination shows the effect the morning sun angle had on the light striking each bank of the river. The slope on the west bank received the direct rays of the sun while the slope on the east bank faced away from the sun. The classification reflected this difference in illumination. Whereas the characteristics of the forest are the same on both banks of the river (Figure 22), the west bank was classified as three (the higher reflectance) and the east bank was classified as two (the lower reflectance). Reasonably, class one indicated similar forest on moderate slopes since its reflectance is between class two and class three (Table XI and Figure 24).

The density of the trees and the lushness of the foliage also has a definite effect on the reflectance of the forest. Logging areas, for example, have low tree density and were classed as three. One such area is in the western section of the study area just west of the large strip mine. The sparse cover within the area is quite evident in the false color photo of the area. Examination of the same area on the unsupervised classification false color map, shows the entire area classed as three.

Although the effect of forest type is less evident than the first two factors, examination of Table VII does reveal the slight effect forest type exert on the classification. The data indicates that areas classified as pine forest tended to have lower reflectance than areas classified as deciduous and mixed forest. Class three, the high reflectance class, contains almost twenty-four percent of the deciduous trees and only about fourteen percent of the pine trees while class two, the low reflectance class, contains only sixteen percent of the deciduous trees and over twenty-seven percent of the pines (Table VII). Evidence seems to indicate that the classification of any resolution element of forest in this study area depended on its slope, the density of the trees, and the type of trees in the forest.

Class three also represents a considerable portion of the stripped areas (25 percent). Examination of air photos showed stripped areas classified as three consisted of spoil banks and strip pits filled with water. The area within a resolution element classed as three was probably some combination of exposed rock, shadow, and water.

About sixty-seven percent of the land classified as five (purple) corresponds with stripped areas and barren land. Stripped areas classed as five tend to be more even than those areas classed as three. Since there were fewer shadows and areas of standing water combined with the rock, the reflectance was higher (Figure 24). The resulting signature is probably that of exposed shale and sandstone.

About ten percent of class five corresponds with clouds. Examination of the false color photo shows that these class five data points tend to cluster around the edge of clouds which are indicated by large parcels of unclassified points. The location of these points may be where the clouds were especially thin. The light reflected by the land beneath the clouds is obscured from the satellite by the cloud cover. Near the edges, however, the clouds are thin enough to permit passage of the longer wavelengths of light. This light is detected by MSS band seven. Data collected under these conditions records the high reflectance of the clouds in MSS bands four, five, and six, but records the much lower reflectance of the land beneath in MSS band seven. Examination of the second false color photo shows that this approximates the spectral signature of class five. Consequently, it is not surprising that class five data points occur at the edges of the clouds.

Finally, class five cells also indicate the location of the tilled agricultural field in the area. The small cluster of purple in the extreme southwest corner of the false color photo is the location of this field.

Class four cells (blue) indicate the location of water and cloud shadows in about eighty percent of the cases. Since class four has a very unique spectral signature (Figure 24) and the cluster representing class four is quite distant from the other clusters (Table IX), it would seem that more than eighty percent of the class would be identified with water or cloud shadows. The reason for this is twofold. There was some difficulty in aligning the grid with respect to the Black Warrior River. Consequently, a significant percentage of the class four points corresponded with the forested areas bordering the river. Secondly, many of the resolution elements along the border of the river dominated by water in the manual interpretation are actually composite data points (combinations of water and forest) and were classified into other classes.

Unclassified data points (blank) denote the location of clouds in about thirty-seven percent of the cases. The unclassified points corresponding to clouds are different from toher unclassified areas in that they are in contiguous parcels, whereas other unclassified data points are broken up into small areas.

A significant percentage of unclassified points are also found in stripped areas (26.6 percent). The nature of these unclassified points will be discussed below.

8. Automatically-Derived Classes in Study Area Two

As in study area one, the CSC technique generated five classes. The classification map of the area is shown in a second false color may not be shown here. Classes one (green), two (orange), and three (yellow) appear to have approximately the same spectral characteristics as the first three classes in study area one (Figures 24 and 25, and Tables XI and XII). Again the forested areas are identified by either of these classes. Examination of Table VI shows that classes one and two identify forested areas in about eighty-six percent of the cases and a significant portion of the points classed as three also represent forest (51 percent).

TABLE XI

SPECTRAL CHARACTERISTICS OF AUTOMATICALLY-DERIVED CLASSES FOR STUDY AREA ONE

	Spectral Mean Values				Spectral Standard Deviations			
	MSS Band				MSS Band			
	4	5	6	7	4	5	6	7
Class 1 (green)	28.282	21.929	30.607	16.095	1.266	1.695	2.268	1.436
Class 2 (yellow)	27.640	20.867	23.721	13.892	1.802	2.577	3.684	2.637
Class 3 (orange)	31.810	27.309	32.626	16.485	2.387	3.441	2.768	2.488
Class 4 (blue)	30.320	22.187	15.244	5.513	4.495	4.556	3.015	2.280
Class 5 (purple)	38.319	38.107	37.221	16.455	2.869	3.854	3.629	2.351

TABLE XII

SPECTRAL CHARACTERISTICS OF AUTOMATICALLY-DERIVED CLASSES FOR STUDY AREA TWO

	Spectral Mean Values				Spectral Standard Deviations			
	MSS Band				MSS Band			
	4	5	6	7	4	5	6	7
Class 1 (green)	27.787	20.822	33.769	17.820	1.121	1.481	2.411	1.420
Class 2 (orange)	27.634	20.625	27.419	15.972	1.720	2.199	3.008	2.083
Class 3 (yellow)	30.282	24.855	34.014	13.473	1.676	2.650	2.842	1.846
Class 4 (blue)	33.339	24.544	15.313	4.73[illegible]	2.676	2.413	3.261	2.114
Class 5 (purple)	32.420	28.162	41.263	21.589	2.083	3.734	3.363	2.265

The classification of forest in study area two was determined by two primary factors - the density and height of the forest, and the type of trees. The slope of the land did not seem to influence the classification.

There is considerable evidence that the density and height of the forest was the overriding factor in its classification. Large areas classified as two (low reflectance) were found to have significantly higher density and/or significantly taller tree height than surrounding areas classified as one or three. Large forested areas classified as three (high reflectance) were also checked and these areas tended to be sparsely wooded with shorter trees. For example, there is an orchard in the area where the trees are widely spaced at regular intervals. This entire area was classed as three. The interpreted category of "pasture with scattered trees" is another excellent example of a sparsely wooded area. Examination of this class in Table VIII shows that class three (high reflectance) has a much higher percentage of this category than class two, the low reflectance class (26.4 percent compared to 4.4 percent). Apparently, areas where the tree density is low tended to be classified as three

The type of forest seemed to be a secondary factor. In this study area as in study area one, pine forest seemed to have a lower reflectance than deciduous and mixed forest. Class three (high reflectance forest) contains almost twenty-two percent of the deciduous trees and only about fifteen percent of the pines while class two (low reflectance forest) contains only twenty percent of the deciduous trees and over thirty percent of the pines.

The type of forest obviously affects the classification to some degree. By examining the condition of the forest during the ERTS pass, some explanation for the difference in reflectance is possible. According to the Alabama Forestry Commission the first leaves appeared on the deciduous trees in early April, after the ERTS pass. However, the leaves on the shrubs and bushes which comprise the underbrush typically appear before there is any foliage on the trees. Consequently, the condition of the forest during the ERTS pass was nonfoliated deciduous trees, foliated pine trees, and foliated underbrush.

The broad leaves on the underbrush reflect light well. When deciduous forest were imaged, the underbrush exposed by the barren deciduous trees produced high reflectance readings, but when pine forest were imaged, the pine needles obscured the high reflectance of the underbrush by diffusing the light. Consequently, the pine forest tended to have a lower reflectance than the deciduous and mixed forest.

As in study area one, class three also represented some non-forested categories. A large part of the residential land was classed as three (26 percent). These residential areas are situated in moderately dense forest. Large sections of open fields were also classified as three. High grass and shrubbery were found growing in these areas. Perhaps the most unique characteristic of this class is that data points classed as three are a significant part of every category (Table VII). The location of class three offers one explanation for this. They are found in significant numbers on the borders of forested and non-forested categories. Consequently, one is led to believe that class three often represents a composite of forest and other types of land cover. Class four data points (blue) correspond to surface water locations about eighty-three percent of the time. As discussed in the previous section and from examination of Table X, the spectral signature of water should make it an easily identified class, yet the results of the automatic classification seems to indicate poor performance in the identification of surface water. There are several reasons for this. The alignment of the Balck Warrior River was very poor. An explanation of this could not be found since other features in the area lined up well. In any case, this caused areas interpreted as forest along one bank of the river to align with data points in class four. Along the other side of the river the surface water spectral signature aligned with that of those classes indicating forest. This resulted in an unusually high percentage of resolution elements interpreted as forest to correspond with class four (13.1 percent) and an unusually high percentage of points interpreted as water to correspond with classes one, two, or three (27.8 percent). A second reason for the poor identification of water was the presence of composite data points (combinations of water and forest) which tended to decrease the apparent area of surface water since they were not classed as four.

Class five (purple) was the class with the highest reflectance in this study area. Generally this class was representative of nonforested categories - grass and pasture, uncultivated agricultural land, and barren and built-up areas.

When areas categorized as grass and pasture, or uncultivated agricultural land was classified as five, the area was covered with short grass or the residues from the harvest of the previous autumn. Class five was also the principle indicator of the category denoting barren land and built-up areas.

A significant percentage of the pasture with scattered category and the low-density residential category was classed as five. When pasture with scattered trees was classed as five, it was in an area where the trees were unusually sparse. When low-density residential areas were classed as five, the subdivision was in an area of very few trees.

An unusually large percentage of class five corresponds with forested areas (13 percent). The reason for this is obvious when one considers that class five is the largest single automatically-derived class and the two forest categories comprise almost half of the study area. Since each covers so much area, any slight misalignment of the grid of data point locations would cause many forested areas and areas classified as five to correspond.

Unclassified data points were not indicative of any particular category. In fact, unclassified data points comprise a significant portion of every non-forested category. The reason for this is discussed in the subsequent section.

9. Unclassified Data

The unclassified data in each study area appears to be the major problem in the application of the CSC technique to ERTS data. The initial assessment concerning the nature of unclassified data prior to analysis of the results was that composite data points would produce "freak" spectral signatures and be left unclassified. One category indicative of extreme diversity within limited areas and consequently containing a high percentage of composite data points is the low-density residential category. Yet, this category's percentage of unclassified points was about average (Table VI).

Unclassified data points seem to be most common in water, which is represented by class four, and in high reflectance areas, which tend to be represented by class five and somtimes class three. One reason for this can be seen by examining the spectral signatures of class four and five in each study area, and then noticing the distance of these two classes from the other clusters in Tables IX and X. Both are quite a distance from each other and from clusters one, two, and three. Since all data points beyond three standard deviations from any cluster center are left unclassified, points in the region of clusters one, two, and three would be more likely to fall within the required distance of some cluster center compared to points with high reflectance or points in the region of cluster number four.

Another explanation for the unclassified data is the presence of "bad" data caused by "banding" in the data. This data is used along with the "good" data in the establishing of classes and in the improvement of the cluster center locations. Since the accuracy of this data is extremely doubtful, it alters locations of the cluster centers and the values of the standard deviation vectors. This slight alteration in the location of the cluster centers and the decision hyperplanes has the effect of leaving otherwise "good" data unclassified and changing the classification of other data.

Perhaps the best explanation for the unclassified data is that the first step of the CSC technique does not establish enough initial cluster centers. This explanation is quite feasible when one notes that most of the unclassified data corresponds with water and high reflectance categories. Since very few cluster centers were established in the portions of multidimensional space used to classify these categories, it is not surprising that many data points in these areas are not within three standard deviations of a cluster center and are left unclassified.

Whatever the reasons for the existance of unclassified data and the limited number of classes generated by the technique, these remain as the primary problems to be addressed in the application of the CSC technique to ERTS data. The following chapter summarizes the performance of the CSC technique, proposes several modifications to the technique and projects its practical applications.

10. Conclusions

The application of the CSC technique to ERTS data of portions of Tuscaloosa County showed that the delineation of several types of ground cover was possible. Areas whose interpretation depends primarily on texture and shape such as urban areas could not be identified while areas whose interpretation depends on the density of the foliation were delineated even better than is possible from conventional air photo interpretation.

The spectral classes generated by the CSC technique do not conform to interpreted land-use categories well enough to permit the inventorying of land use in an area. Too few classes were formed and many of the classes that were formed corresponded to several land-use categories. Similarly, many of the interpreted land-use categories were well divided between the ERTS-derived categories. This situation can be improved by the generation of more spectral classes and redefining new interpreted land-use categories to correspond more closely with the area's spectral response.

Additional research is needed in several areas. ERTS data gathered during other seasons of the year must be processed and evaluated to change changes in classification can be noted. Perhaps the different reflectance caused by changes in foliation will result in better recognition of various types of ground cover.

The problem of "banding" must be addressed. The best solution appears to be elimination of the "bad" data from the classification. Although this has been proposed, at this writing no program has been created to detect the "bad" data and eliminate it.

Research is also needed concerning the effectiveness of the new method of establishing initial cluster centers proposed by Dalton.[15] Although it will be a part of the CSC technique eventually, at this writing it has not been implemented into the computer program. When it is implemented, its performance must be tested and compared.

Comprehensive research of the same nature as this study is absolutely necessary to an adequate understanding of the nature of unsupervised techniques as they apply to ERTS multispectral data. As research is completed in the areas outlined in the previous paragraphs, the CSC technique can become an effective tool in the manipulation of ERTS data for deriving meaningful and timely land-use information.

C. Other Scene Analysis

1. Brewton-Pensacola-Panama City Scene[16]

This analysis utilized cloud-free ERTS imagery acquired on December 27, 1972, on the satellite's eighth pass over the area. The frame studied in this report, designated E-1157-15505,)Scene K-4) covers an area from northwestern Escambia County in the northwest and eastern Baldwin County in the west-central portion of the scene to West

Panama City Beach in the east-central portion of the scene. Approximately 50 percent of the scene, the southern portion, extends out into the Gulf of Mexico (Figure 26).

The area under investigation in this report lies entirely within the coastal plain. Underlying strata are Cenozoic in age and consists mainly of unconsolidated sands, gravels, sandstones, clays, and soft limestones. The latter account for a great number of sinkholes, drained and ponded, in the northeastern portion of the frame. Very recent fluvial deposits occupy the flood plains of major streams and rivers.

Topographically, the area is relatively flat. From an elevation of approximately 250 feet in the north, the land gently slopes toward the south and the Gulf of Mexico. This drop of 250 feet over a linear distance of 80 kilometers is a slope of less than one degree.

The edge of the land mass is characterized by many bays and inlets both large and small; for example, Perdido Bay, Pensacola Bay, and Choctawhatchee Bay. In addition, a continuous offshore barrier island, Santa Rosa Island, runs nearly half the length of the ocean front forming Santa Rosa Sound and protecting a portion of the intercoastal waterway.

The entire land area in frame E-1157-15505 for the most part is drained by the Perdido, Escambia, Blackwater, Yellow, and Choctawhatchee Rivers (Figure 26). All flow directly into tidal bays.

The analysis of this frame began by delineating water bodies using an MSS-7 (near-infrared) positive transparency mounted on a standard light table. Numerous rivers, lakes, and ponds as well as tidal inlets and bays and of course the ocean are all clearly evident. The number, proximity, and nearly-circular shape of potholes in the northeastern

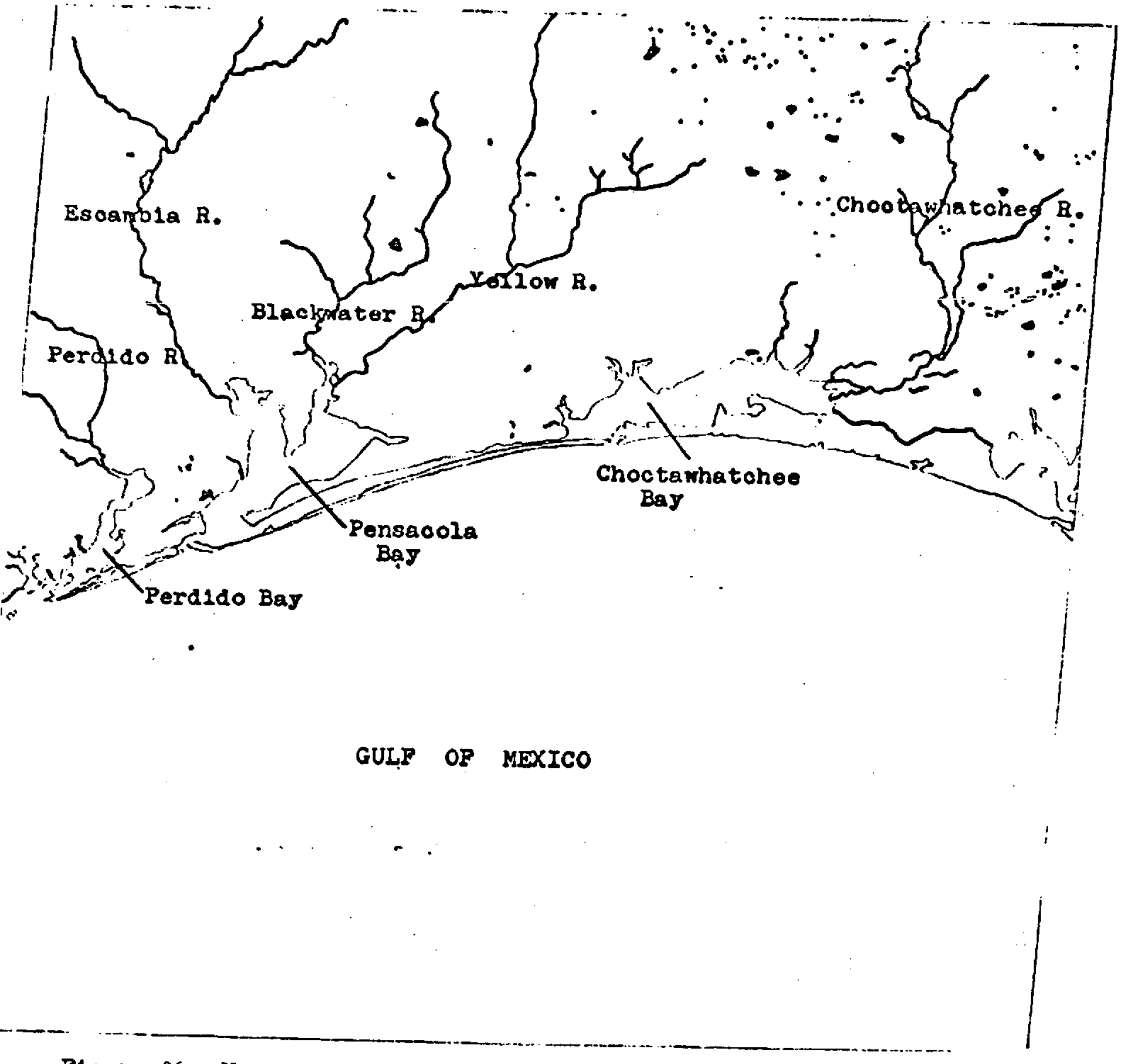


Figure 26. Map showing rivers and lakes as interpreted from ERTS frame E-1157-15505

portion of the frame was indicative of the karst topography in that area. Water impounded in some of the depressions facilitated their location. As indicated in previous reports, ponds smaller than 100 meters in diameter were often clearly visible. In addition to natural rivers and streams, man-made watercourses, such as the intercoastal waterway canals, were very obvious not only due to the total absorption of electromagnetic energy by the water on MSS-7 and the linear configuration of the canal itself, but also because of the high reflectance of energy by the rip-rap along the side of the canal as indicated on MSS-5 (spectral red).

MSS-5 was specifically suited for sensing other cultural features such as urban centers, agricultural lands, and transportation routes. Figure 27 illustrates the roads and cities which were visually apparent on ERTS imagery. Both major highways and secondary roads were detectable as were many secondary roads inside the city of Pensacola. In addition, the US-98 highway bridge between Pensacola and Pensacola Shores and the Al-399 highway bridge between Gulf Breeze and Pensacola Beach are both readily visible. Numerous other bridges such as the US-10 and US-90 bridges over Escambia Bay and the US-331 bridge over Choctawhatchee Bay were delineated and mapped. The ability of ERTS-I to image these bridges is a remarkable demonstration of the satellite's resolution potential in imaging linear features which are narrower than the stated minimum resolution of about 250 feet.

Land use in this scene is dominated by Eglin Air Force Base in the center of Figure 28 (ruled area). In keeping with a previously established policy of not mapping land use within the bounds of a military reservation, only the extent of the base was plotted on Figure 28.

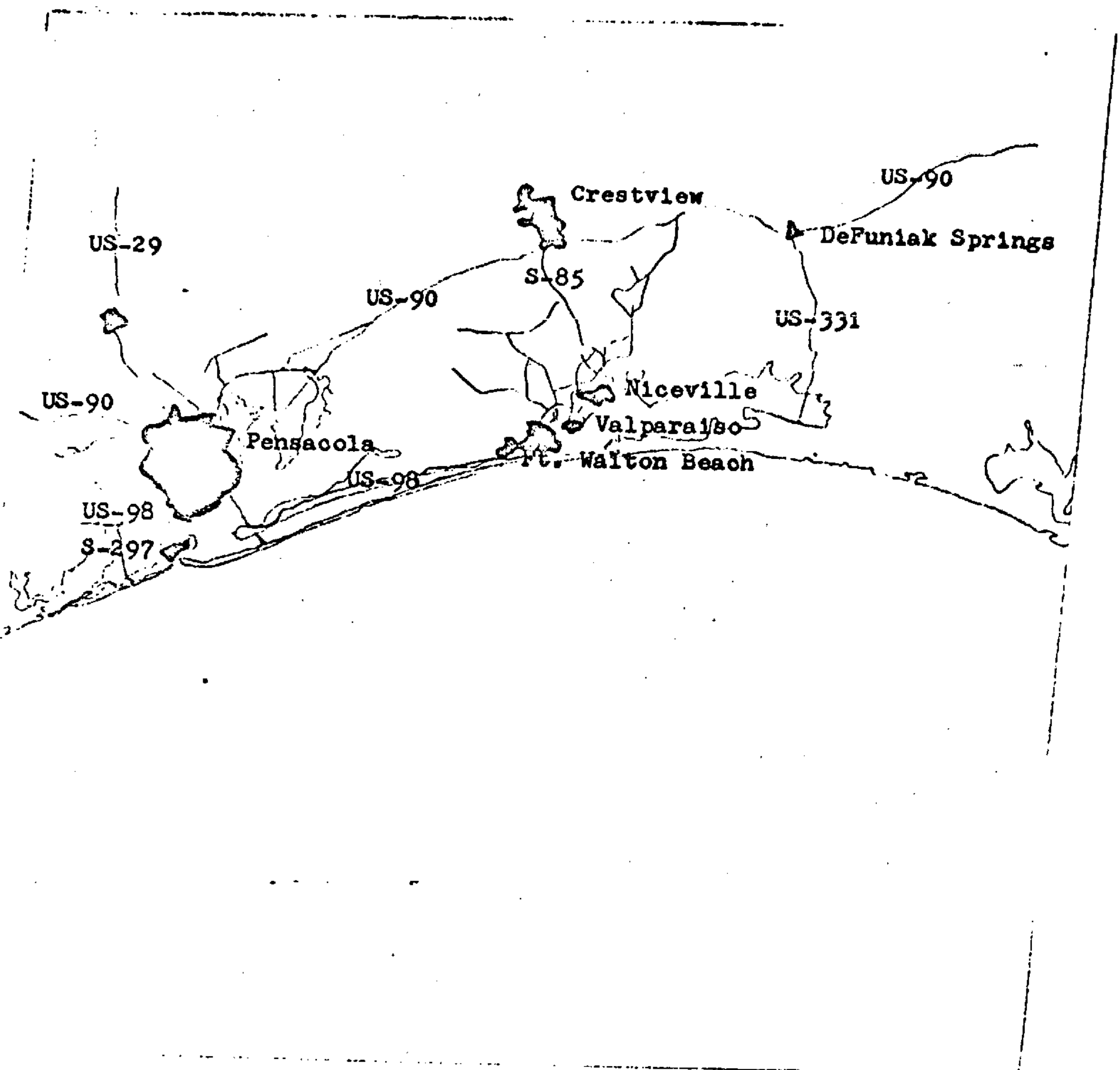


Figure 27. Map of transportation arteries and urban centers as interpreted from ERTS frame E-1157-15505

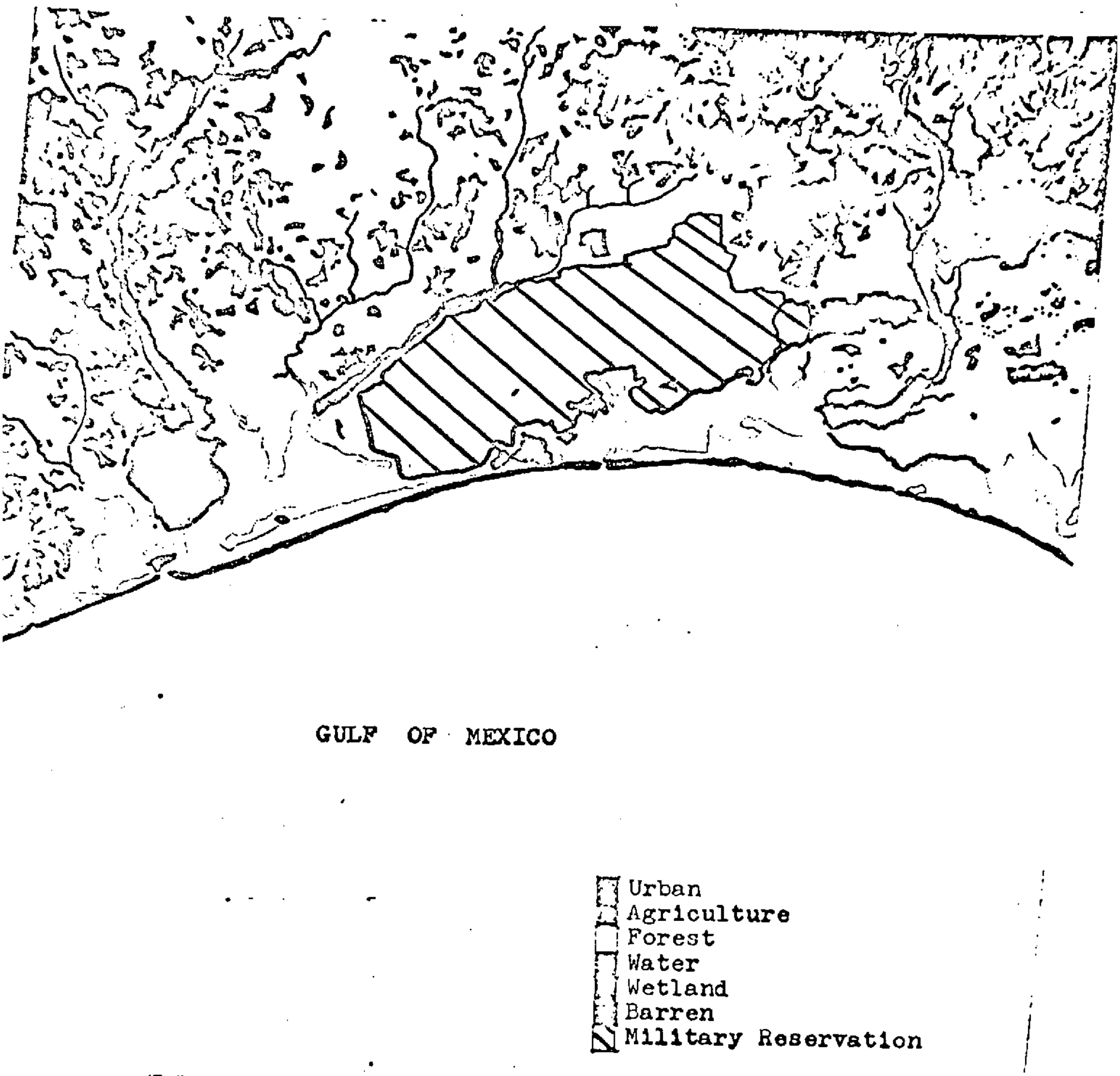


Figure 28. Land use as interpreted from ERTS frame E-1157-15505

Notice, however, that an intriguing triangular feature in the southeastern portion of the base was mapped. This was later determined to be a high-altitude bombing target measured from the ERTS imagery to be approximately three km. (1.85 miles) on a side.

Another intriguing feature immediately to the east of Eglin A.F.B. and designated on Figure 28 by the letter "a" was a large group of circular irrigation patterns. The very high reflectance and circular shape of these fields first led to the belief that they were bombing targets. The circles, most of which appeared white on MSS-5, had a measured diameter ranging from about 800 meters to almost 1200 meters and areas of approximately 160 acreas each. Through a telephone conversation with officials of the Agricultural Stabilization and Conservation Service in DeFuniak Springs, Florida, it was learned that these irrigation patterns were owned by the American Farm Corporation and were planted in soybeans and wheat. It was also learned that much of the area around these corporate owned farms had been planted in conifers ten to twenty years previously. This area had been very difficult to classify because of the very slight variations in tone over the area and had previously been coded as land covered by scrub grass and short bushes and trees.

Beaches, solid black on Figure 28, were readily apparent on MSS-5 and facilitated comparison with existing maps of the area made years before. No serious discrepencies were immediately apparent. However, shoreline configuration will be studied in detail at a later date.

Some of the rivers in the scene, particularly the Escambia, Yellow, and Choctawhatchee rivers were bordered by what appeared to be wetlands, some of which appear to be four km in width. These corridors appeared dark gray on MSS-7, thus indicating an abundance of water. It is not known at this time whether this signature is indicative of standing water, soil moisture, or plant vigor due to an excess of water or a combination of the three. The geographic extent of this zone would seem to rule out the possibility of standing water, but all options are being considered at this time.

This area, although lying mostly outside the State of Alabama, contains some of the most interesting and intriguing features yet encountered. The "wetland" along the courses of rivers should be investigated further on spring-time imagery of Alabama. The mapping of these areas, along with recently flooded areas from ERTS imagery, could form the basis of a broad regional planning and zoning regulation which would prohibit new construction in these areas and would eventually transform these flood-prone areas into parks and recreational areas which would not seriously be affected by spring floods.

Land use patterns were difficult to delineate. This was due in part to the fine mixing of agricultural and forests in the area, and also due perhaps to atmospheric haze off the Gulf of Mexico. In any event, more sophisticated analytical equipment is required in complex areas such as this.

2. Evergreen-Montgomery-Troy Area[17]

Cloud-free ERTS imagery covering the Montgomery scene was acquired on September 28 and again on October 16, 1972, on the satellite's fourth and fifth passes over the area, respectively. The frame studied in this report, designated E-1085-15501 (Scene K-3), covered an area from southwestern Escambia County, Alabama, in the southwest to east-central Russell County, Alabama, in the northeast; encompassing all or part of 22 counties in Alabama and a small portion of the Florida panhandle (Figure 16).

The area under investigation lies almost completely within the coastal plain of Alabama. Subsurface geology includes Mesozoic shales, clays, and sandstones in the northern portion and Cenozoic limestone, sandstones, and loose agglomerates in the southern portion of the scene.

Morphologically, the area covered by the image is dominated a great degree by the nature of the underlying rocks. In areas underlain by relatively easily eroded shales, clays, and chalks, cleared agricultural land dominates most of the area with forests lining the rivers and streams. Conversely, in areas underlain by the more resistant sandstones, uncut forest cover occupying the ridges stands out vividly in contrast to the cleared agricultural land in the surrounding valleys. The southeastern portion of the frame exhibits considerable dendritic drainage suggesting considerable relief, although it does not display the ridge formation found in more northern scenes (Figure 29).

The forested land appears dark gray to black on the black-and-white print of the multi-spectral scanner (MSS) 4 (spectral green) and MSS-5 (spectral red) images in contrast to the cleared land. The forest covered ridges therefore stand out vividly against the light gray tones of the agricultural valleys, thereby enhancing the impression of greater relief. Another advantage of the tone of the forest pattern is that the forested areas on the satellite imagery can easily be compared to the forest overprint on 1:250,000 scale topographic maps.

The analysis of this frame began by first delineating surface water features using the two infrared bands, MSS-6 and MSS-7 (Figure 30).

The Conecuh, Alabama, and Choctawhatchee rivers can clearly be seen on the ERTS imagery. Because of the almost total absorption of electromagnetic radiation in the near infrared band (700-1100 nanometers)

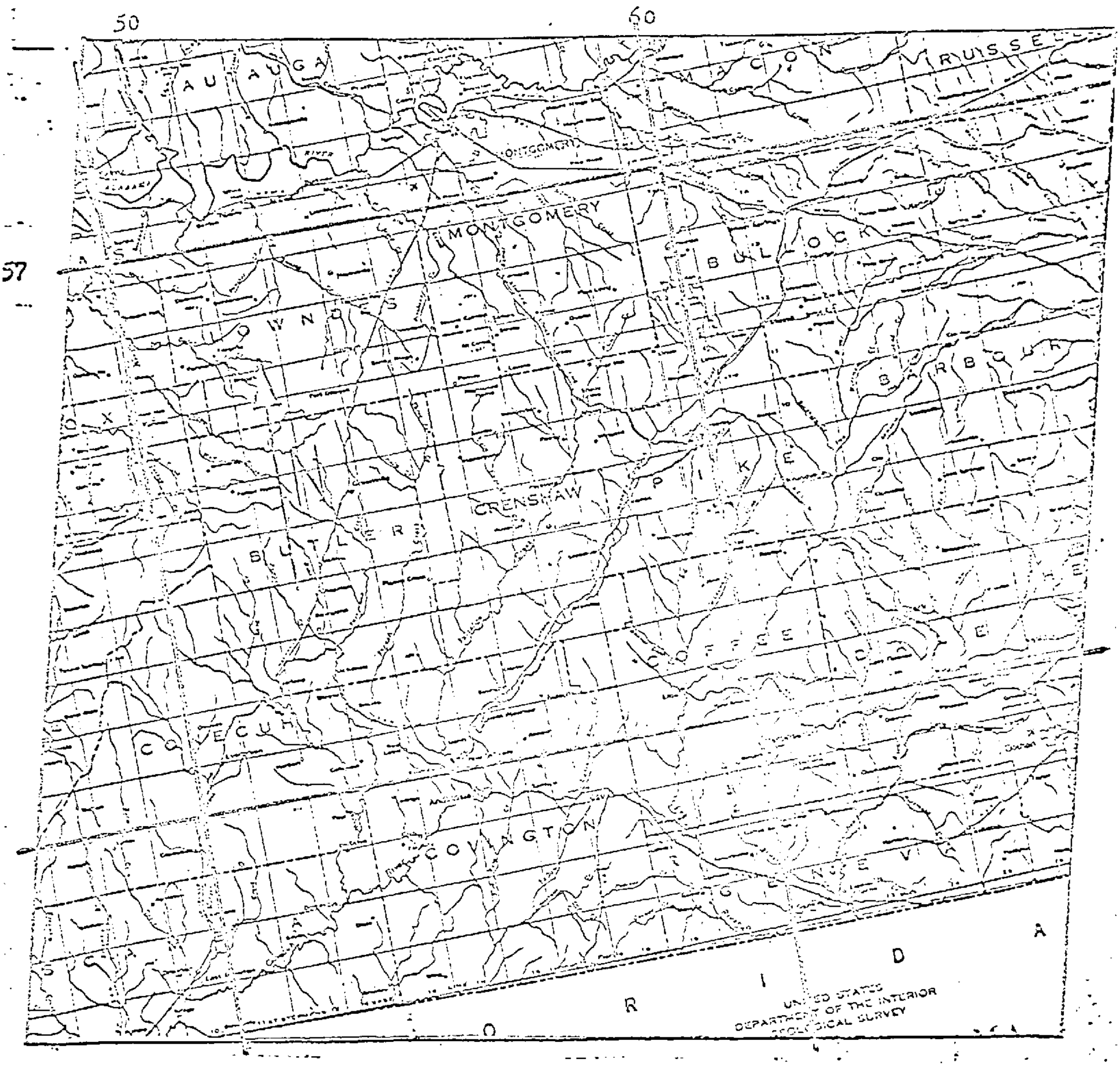


Figure 29. Map showing political divisions and UTM meridians and parallels corresponding to ERTS frame E-1085-15501

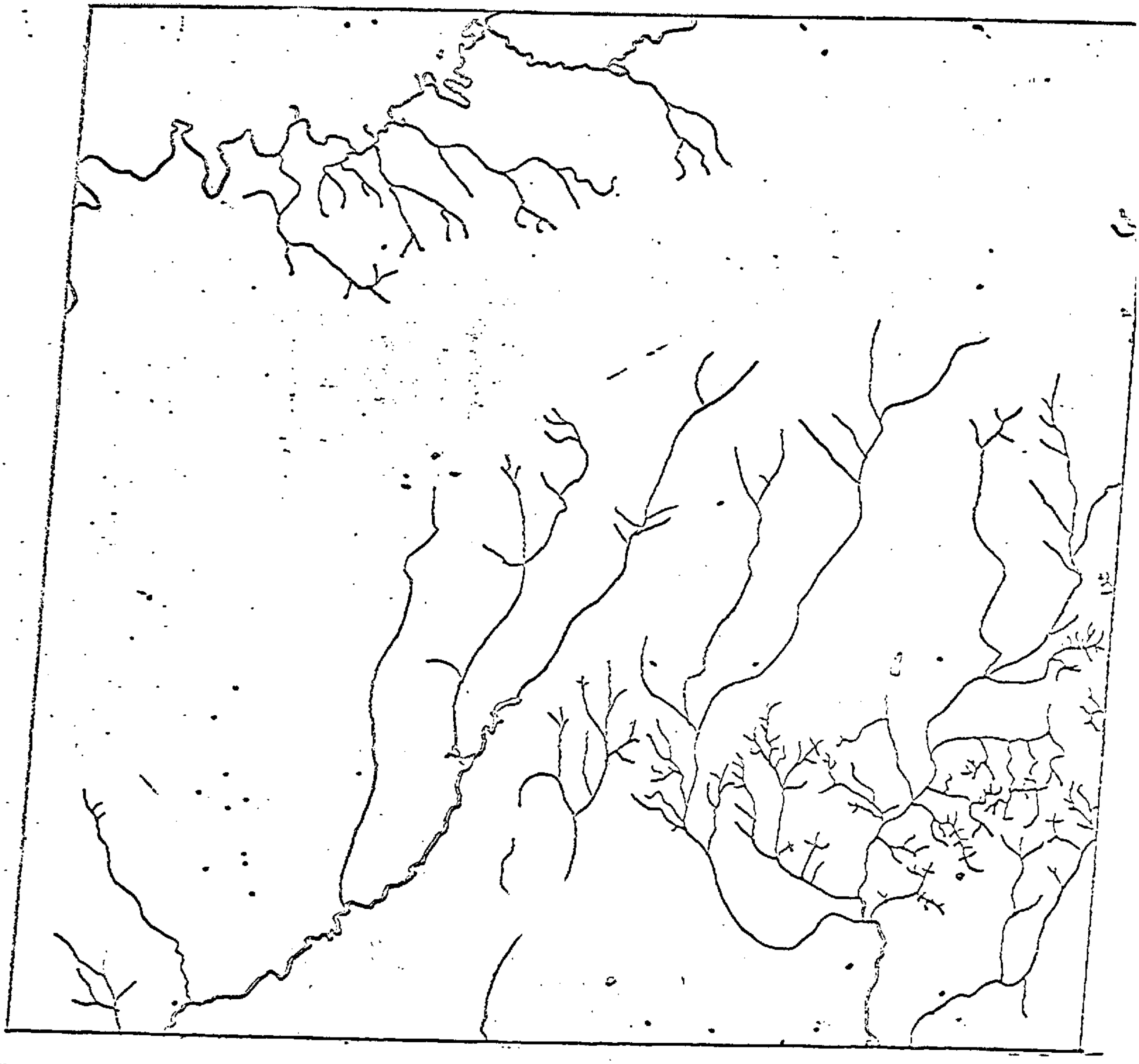
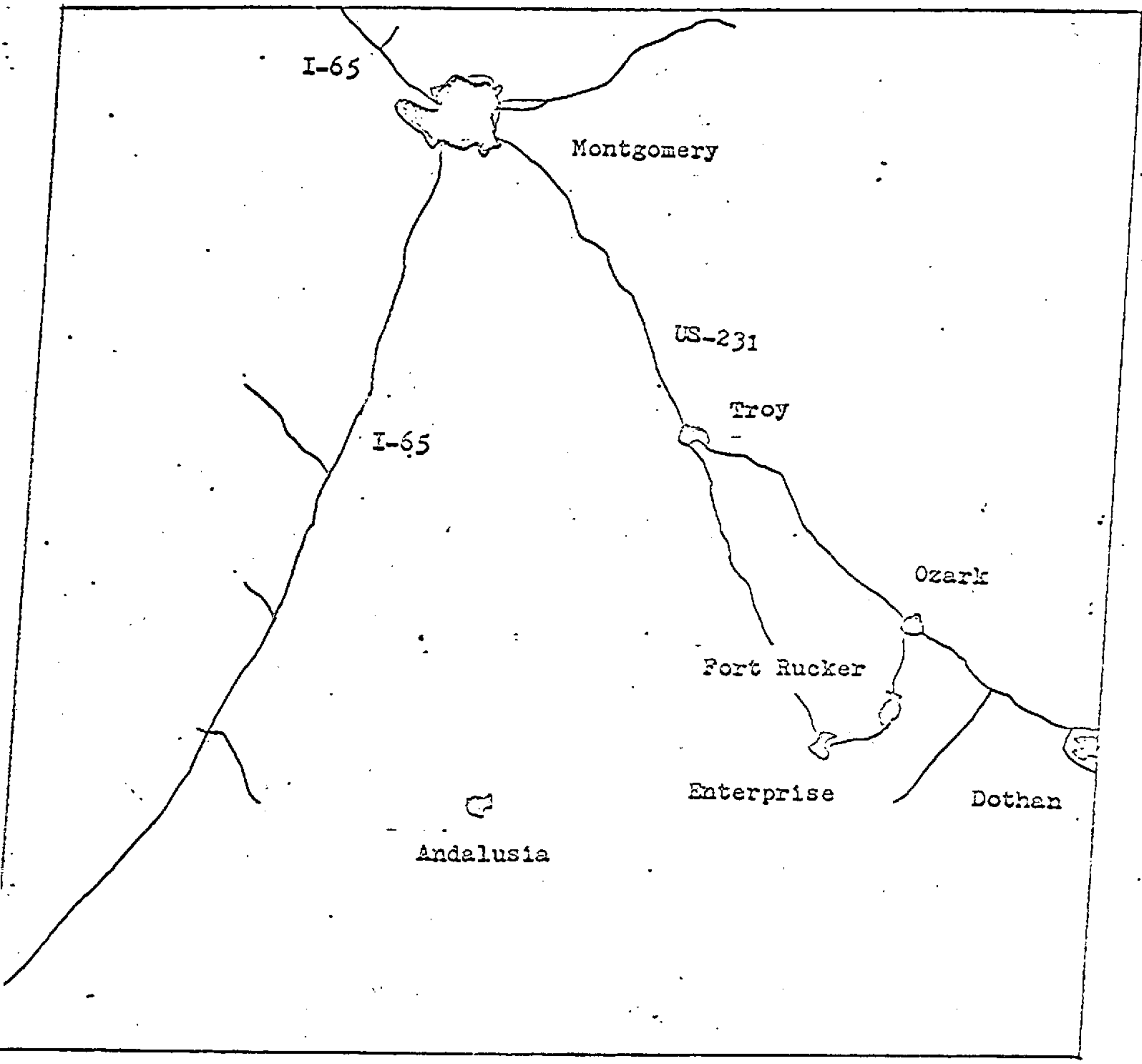


Figure 30. Map showing drainage patterns as interpreted from ERTS frame E-1085-15501

of MSS-6 and 7, the black tone of the water dominates the image. However, due to the small scale of the imagery (1:1,000,000), smaller rivers were barely visible and could only be inferred from land use patterns. MSS-7 (800-1100 nm), the sharpest of the IR bands, was used for delineating water bodies. Even though streams were often not distinguishable, small ponds often were. For example, in Montgomery County, Edward's Ponds, near Sprague on U. S. Highway 331, some of which were less than 100 meters wide, could readily be identified on band 7.

MSS-5 (red) proved to be of great value in the recognition and delineation of certain cultural features (Figure 31). For example, the cities of Montgomery, Troy, Andalusia, Ozark, Enterprise, Dothan, and Fort Rucker were all visible as pale-gray tones. Many of the connecting highways such as I-65, U.S. 231, and I-85, as well as secondary roads were clearly distinguishable. By following transportation routes such as these, it was possible to locate other urban areas not immediately evident. Other man-made features that stood out were some quarries near the city of Montgomery as well as Dannelly Field, Maxwell A.F.B. and Gunter A.F.B., the three latter of which are all third level land use categories. The air field in Ozark, Alabama, was also evident.

The Level I interpretation was performed by simply overlying a grid on a 9.5 x 9.5 inch positive print of the Montgomery scene mounted on a standard light table (Figure 32). MSS-5 was selected for the interpretation because it has the highest contrast ratio of the four bands. No single MSS band was sufficient in itself however, and 1:250,000 USGS topographic maps and 1:63,360 state highway maps were of considerable supplemental assistance in interpretation.



igure 31. Map of transportation arteries and urban areas as interpreted from ERTS frame E-1085-15501

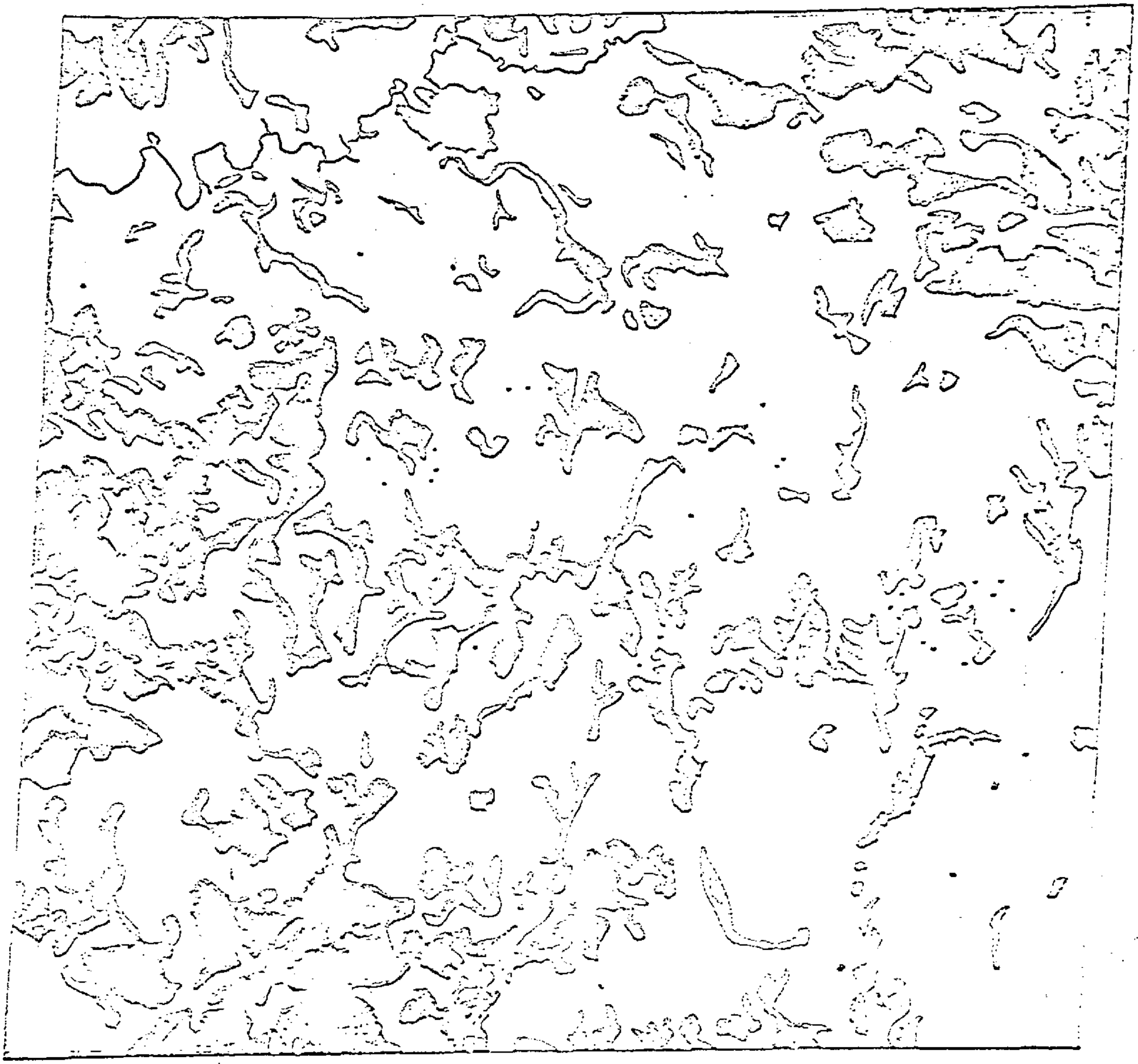


Figure 32. Land use as interpreted from ERTS frame E-1085-15501

Urban
Agricultural
Forest
Water

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The actual interpretation took approximately 2.5 man days. Areas of more homogeneous land use would require less time, while areas of greater land use density would require more time.

Level I land use categories as well as some categories in levels II and III could be delineated. In addition, rivers and streams that could not be seen could often be drawn in by inference from land use and physiographic patterns. Agricultural and forest cover patterns indicate both topography and subsurface geology in the scene.

3. Anniston-Clanton-Opelika Area[16]

This study utilized cloud-free imagery acquired on December 27, 1972, on the satellite's eighth pass over the area. The frame studied in this report, designated E-1157-15500, covered an area from north-central Blount County in the northwest to southeastern Russell County in the southeast; encompassing all or part of 22 counties in Alabama as well as a part of west-central Georgia as far east as Newman, Georgia (Figure 16).

Morphologically, the area is dominated by the Piedmont Upland (Figure 33). The Piedmont is a maturely dissected surface overlying Precambrian to carboniferous igneous and metamorphic rock. The upper portion of the Piedmont is characterized by ridges and is the mountainous portion of the area. According to Johnston,[19] the ridges are due to the presence of very resistant harder rock, their trends indicating structure. These ridges were especially prominent on the ERTS frame (MSS-7) and therefore easily mapped.

The southern portion of the Piedmont is also underlain by Precambrian to Paleozoic igneous and metamorphic rocks, but according to the ERTS imagery, it contained no striking topographic features such

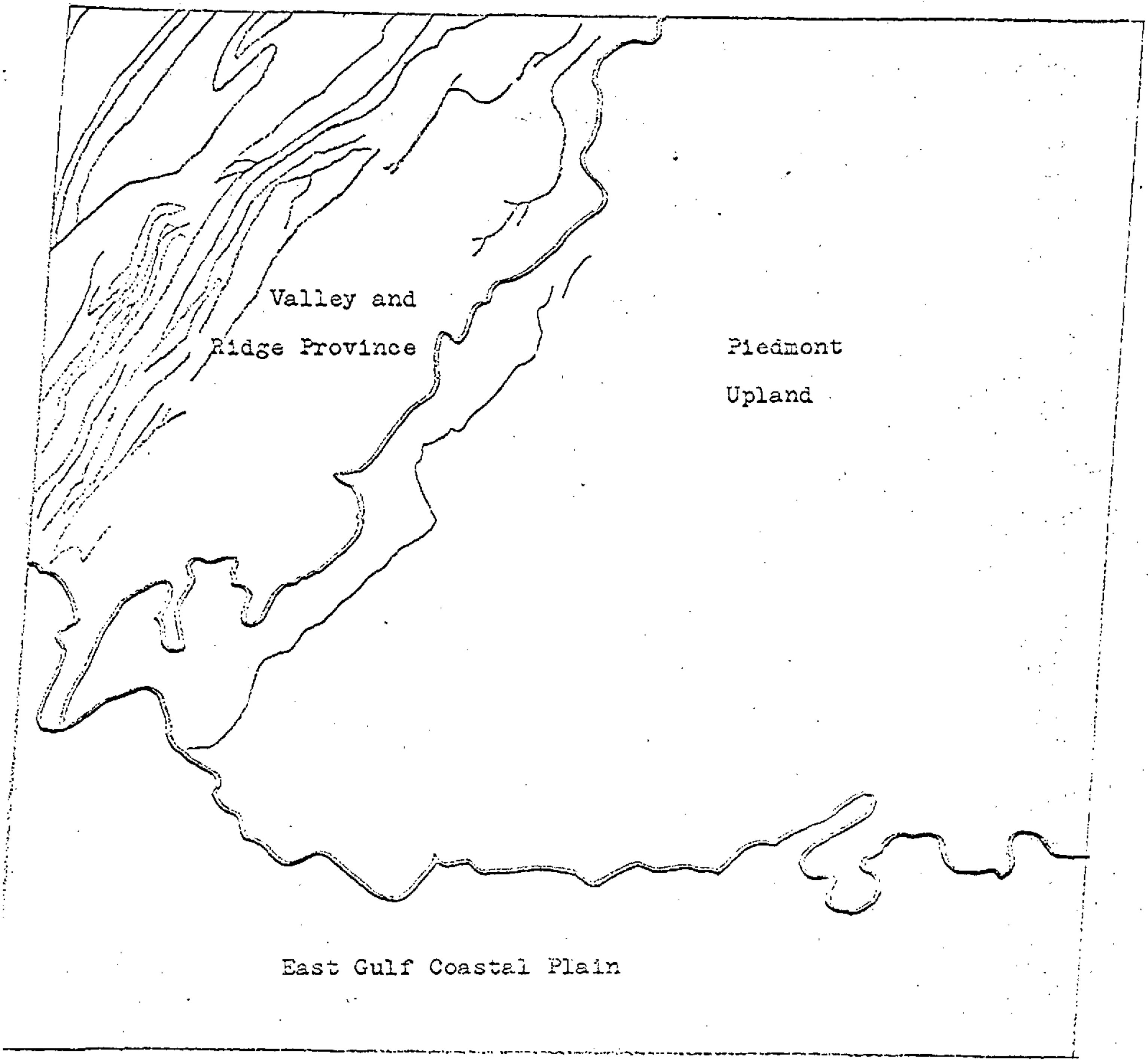


Figure 33. Map showing physiographic regions as interpreted from ERTS frame E-1157-15500

as the ridges of the northern portion. Hence, this portion of the Piedmont is generally more cultivated.

The northwestern corner of frame E-1157-15500 is characterized by northeastward trending valleys and ridges consisting of Paleozoic sandstones, shales, limestones, and dolomites. The maturely eroded unconsolidated Tuscaloosa formation (Cretaceous) portion of the East Gulf coastal plain makes up the southern portion of the frame.

The entire area covered in frame E-1157-15500 is drained by the Coosa, Tallapoosa, and Chatachoochee rivers (Figure 34). All three rivers are dammed to some extent, forming multi-purpose reservoirs. The confluence of the Coosa and Tallapoosa rivers in the southern portion of the scene forms the Alabama River which then flows past the city of Montgomery on its way to Mobile Bay.

The analysis of this frame began by first delineating rivers and lakes using MSS bands 6 and 7 (near infrared). Figure 34 indicates all such water features that were readily recognized on ERTS imagery. Smaller ponds (some less than 100 meters in diameter) were detectable on band 7 even though not indicated on Figure 34.

MSS-5 (spectral red) was optimum in the recognition and delineation of cultural features (Figure 35). Urban areas, appearing as pale gray tones, were evident, although care had to be taken so as not to confuse the urban fringe with agricultural land. Where the city was surrounded by darker toned forested land, the urban-rural interface was readily apparent.

Land use (Figure 36) was mapped off ERTS imagery using primarily MSS-5. Considerable supplemental "ground truth" data, in the form of USGS topographic maps and state highways maps, aided in interpretation.

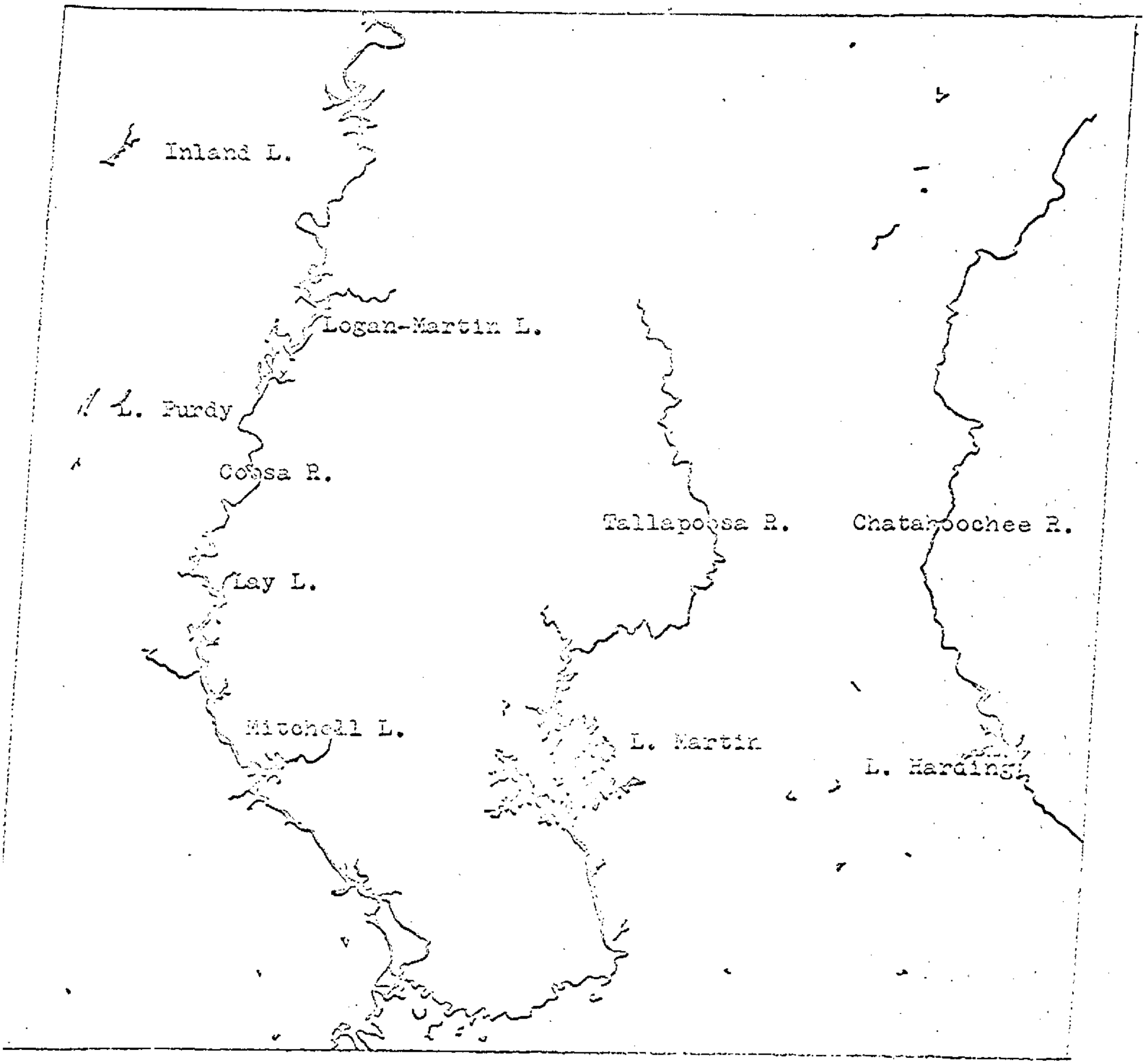
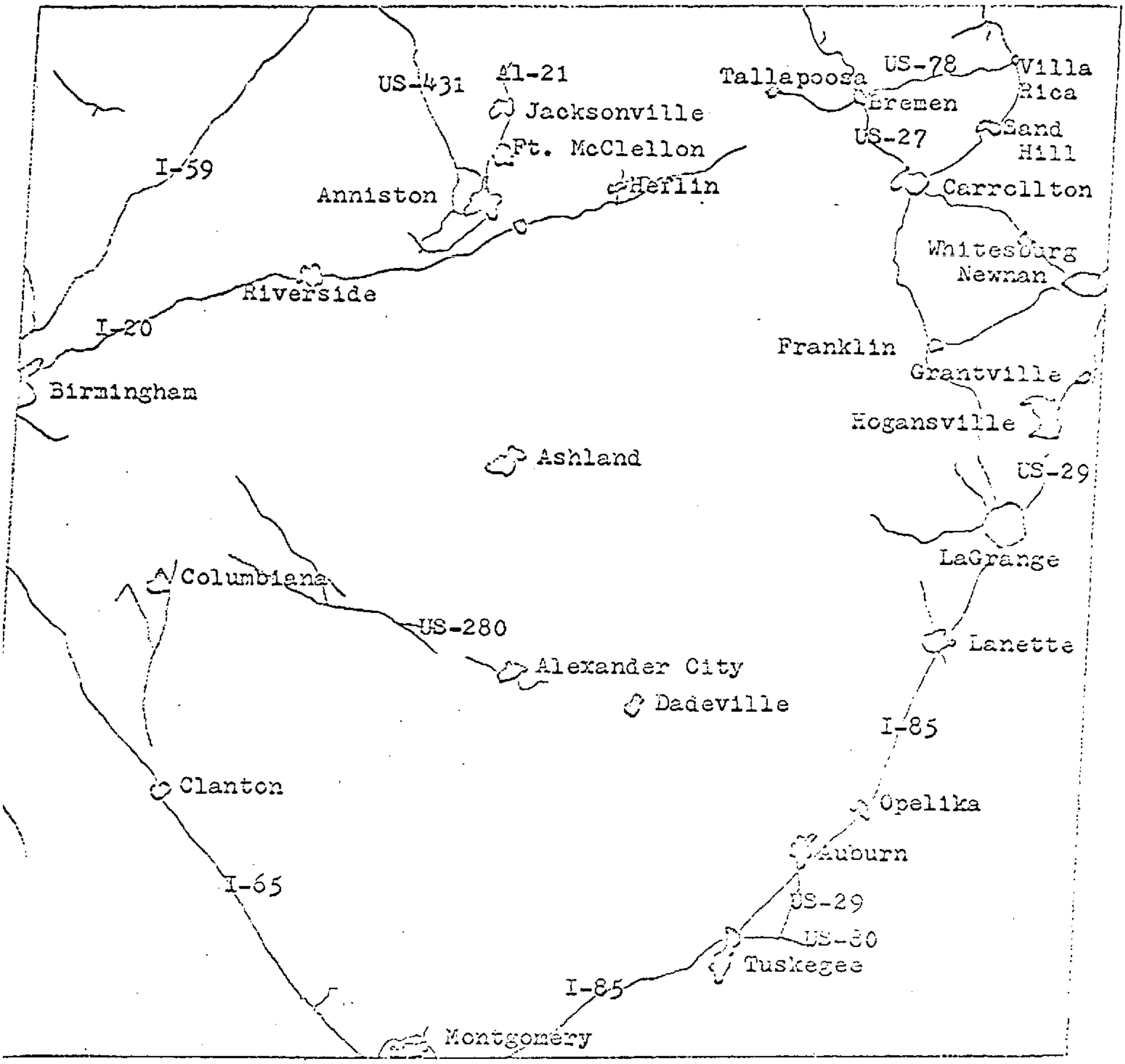
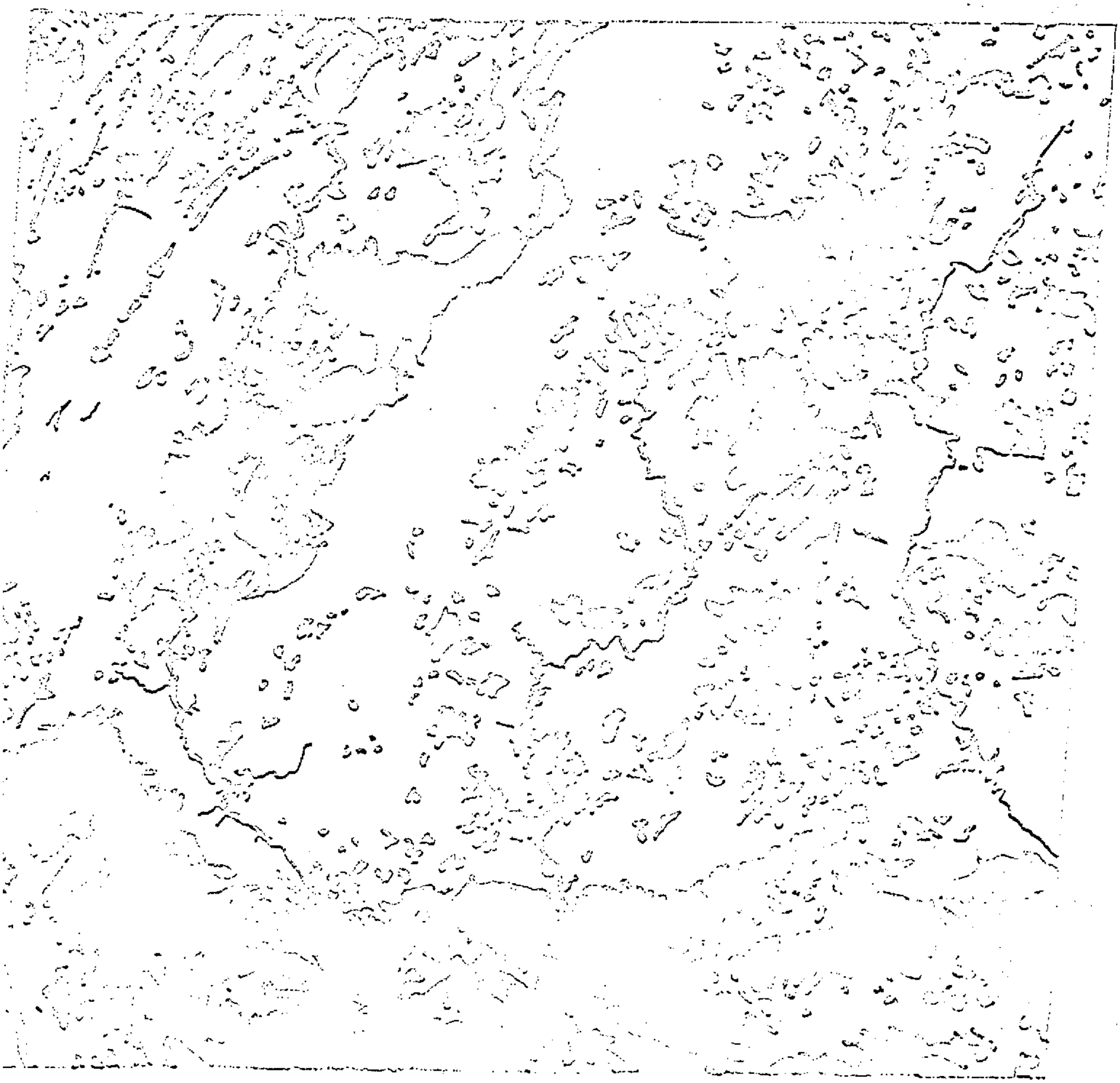


Figure 34. Map showing rivers and lakes as interpreted from ERTS frame E-1157-15500



igure 35. Map of transportation arteries and urban areas as interpreted from ERTS frame E-1157-15500



ure 36. Land use as interpreted from ERTS frame E-1157-15500

Urban
Agricultural
Forest
Water

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Land use down to Level III could be delineated in some instances in this scene. The agricultural and forest patterns helped to indicate both topography and subsurface geology. Shadows of prominent ridges in the Piedmont and Valley and Ridge Province caused minor problems in delineating land use patterns in shadowed areas, but the effects of shadows from both clouds and physiographic features should be considered in any analysis of ERTS imagery.

4. Gadsden-Rome-Scottsboro Area[20]

Frame E-1157-15494 (Scene K-1) occupies all or part of eight northeast Alabama counties, northwest Georgia, and southeast Tennessee (See Figure 16). This area is quite obviously very diverse in physical appearance, land use patterns, and cultural characteristics. Thus a certain amount of difficulty can be expected from a land use analysis of this area resulting from this variability of landscape and subsequent abrupt changes in land use patterns.

As has been the usual case, very good results in delineating natural features has been realized from the use of band 7. The only problems to be anticipated are those associated with the features most visible on the lower end of the spectral band.

Scene K-1 encompasses a greater variety of physiography than any other in the Alabama area. Four such provinces can be readily identified including: 1) the Cumberland Plateau (southwest part of the Appalachain Plateau), 2) the Ridge and Valley, 3) the Piedmont, and, 4) the Blue Ridge Mountains (See Figure 37). Therefore, no vast continuous stretches of homogenous land use or landscape can be expected from the investigation of this scene. In such terrain, agriculture is restricted to the valleys, forests predominate on the upland interfleuves, urban build-ups are primarily limited to stream valleys of the more accessible regions, and transportation routes rarely cut across the numerous topographic barriers (See Figures 37, 38, 39).

As might be expected the underlying geologic formations of this area, are just as complex and inconsistent as the surface land use patterns, which lends quite favorably to a probably cause - effect circumstance. The plateau area is composed primarily of nearly horizontal sandstones and shale beds which have been vertically cut by the still-degrading youthful streams forming a maze of dendritic drainage patterns. Dips are steep only near the edges of the plateaus. The ridge and valley system is made up of limestones in its valley but are alternated with ridges of older and much more resistant cherty limestones. The Piedmont and Blue Ridge regions are composed solely of old crystalline metamorphic rocks forming a series of very irregular folded and faulted uplands which allow for only minimal human habitat and usage.

Drainage patterns of this region are quite varied according to subsurface structural control including the typical dendritic pattern of the plateau, parallel drainage in the ridge and valley province, and the trellis and derranged drainage of the very irregular Piedmont formations. In this area fewer stream valleys were noticeable while larger streams predominate reflecting a coarse drainage pattern (See Figure 40). As viewed on band 7 the following streams were identifiable: 1) the Tennessee River, 2) the Elk River, 3) the Locust Fork of the Warrior River, 4) the Coosa River with Weiss Lake, 5) the

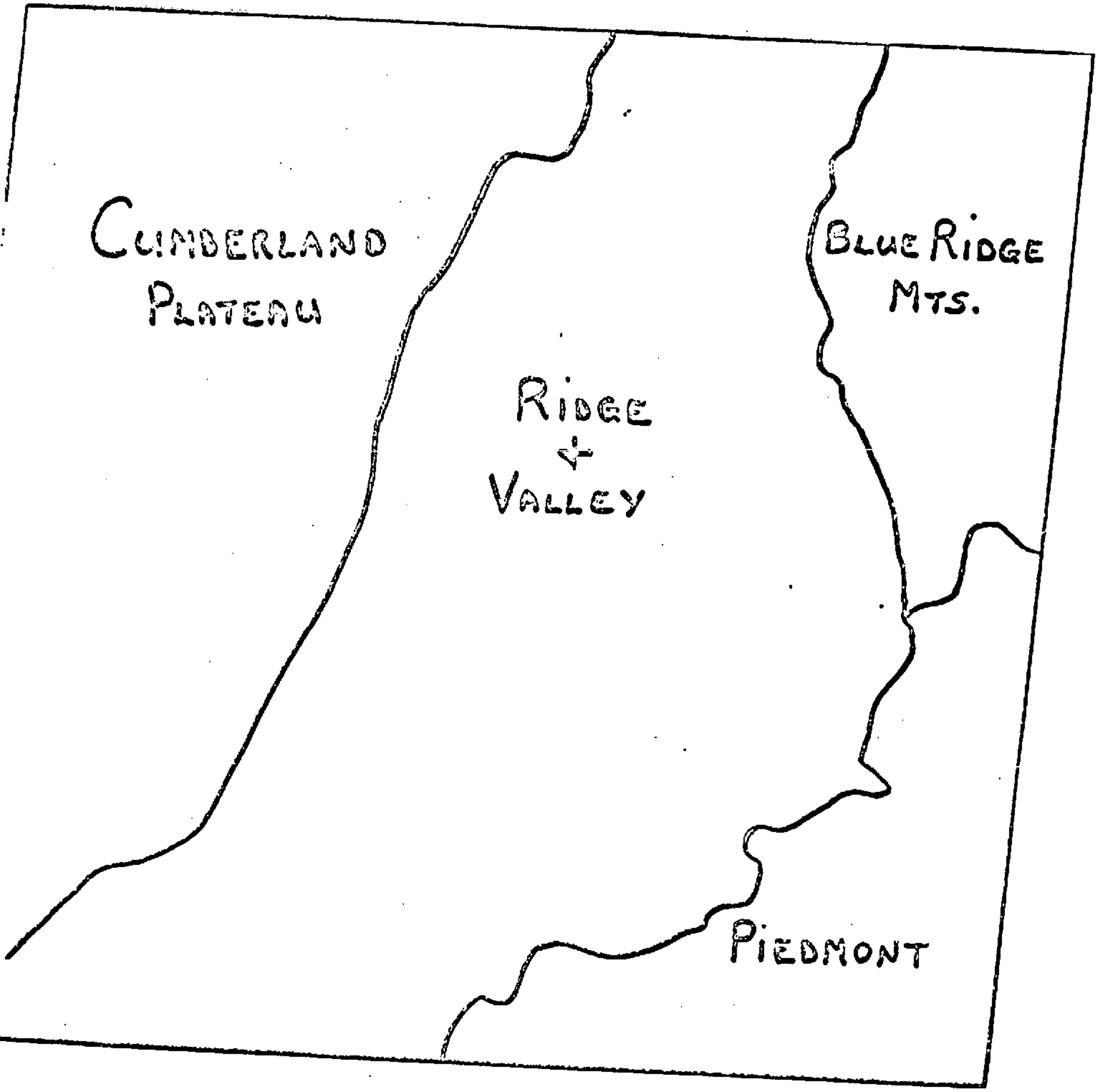

Figure 37 - Physiographic Provinces
MSS Band 7, December 27, 1972, Scene K-1

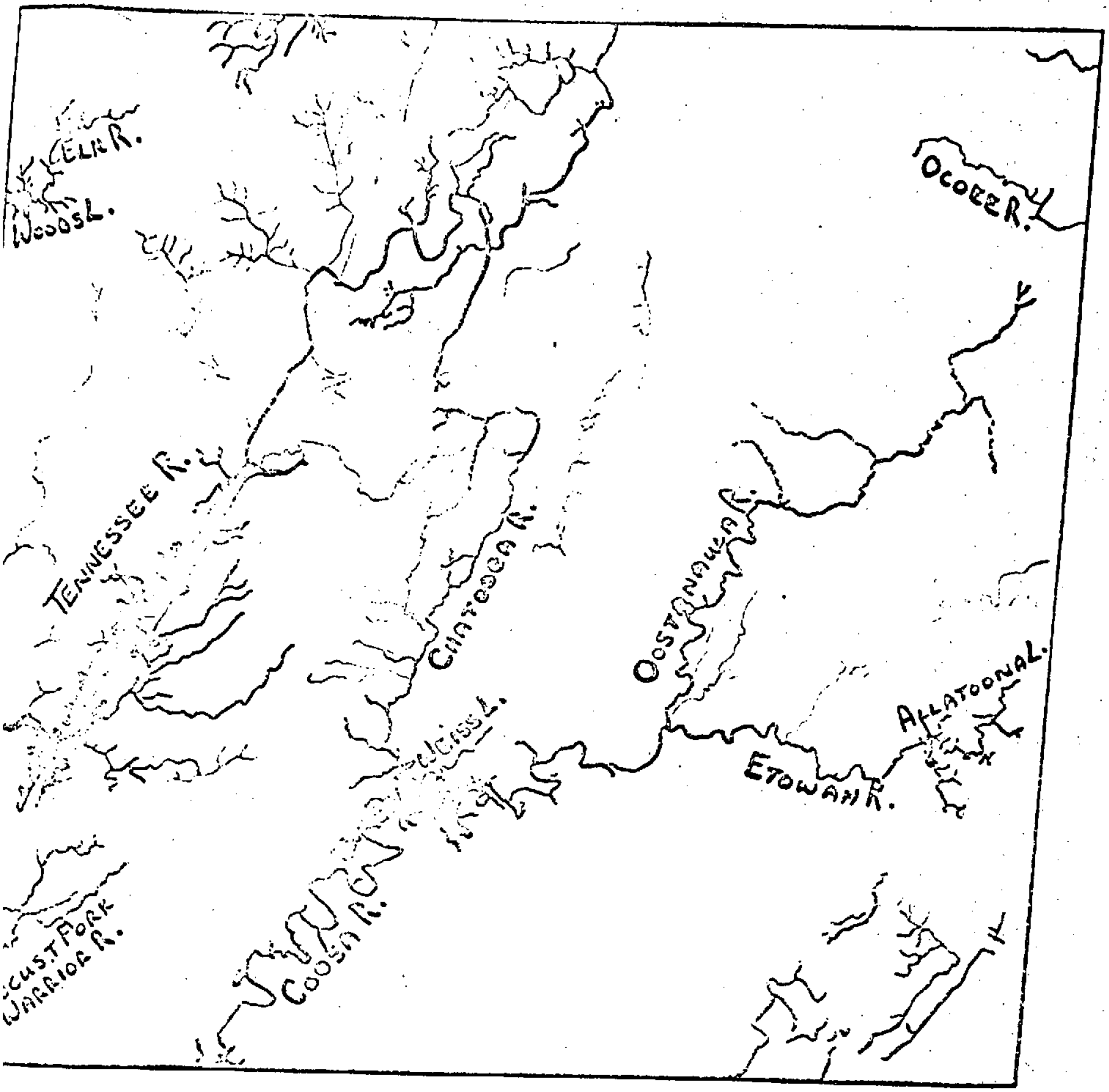

Figure 38, Drainage Patterns
MSS Band 7, December 27, 1972, Scene K-1

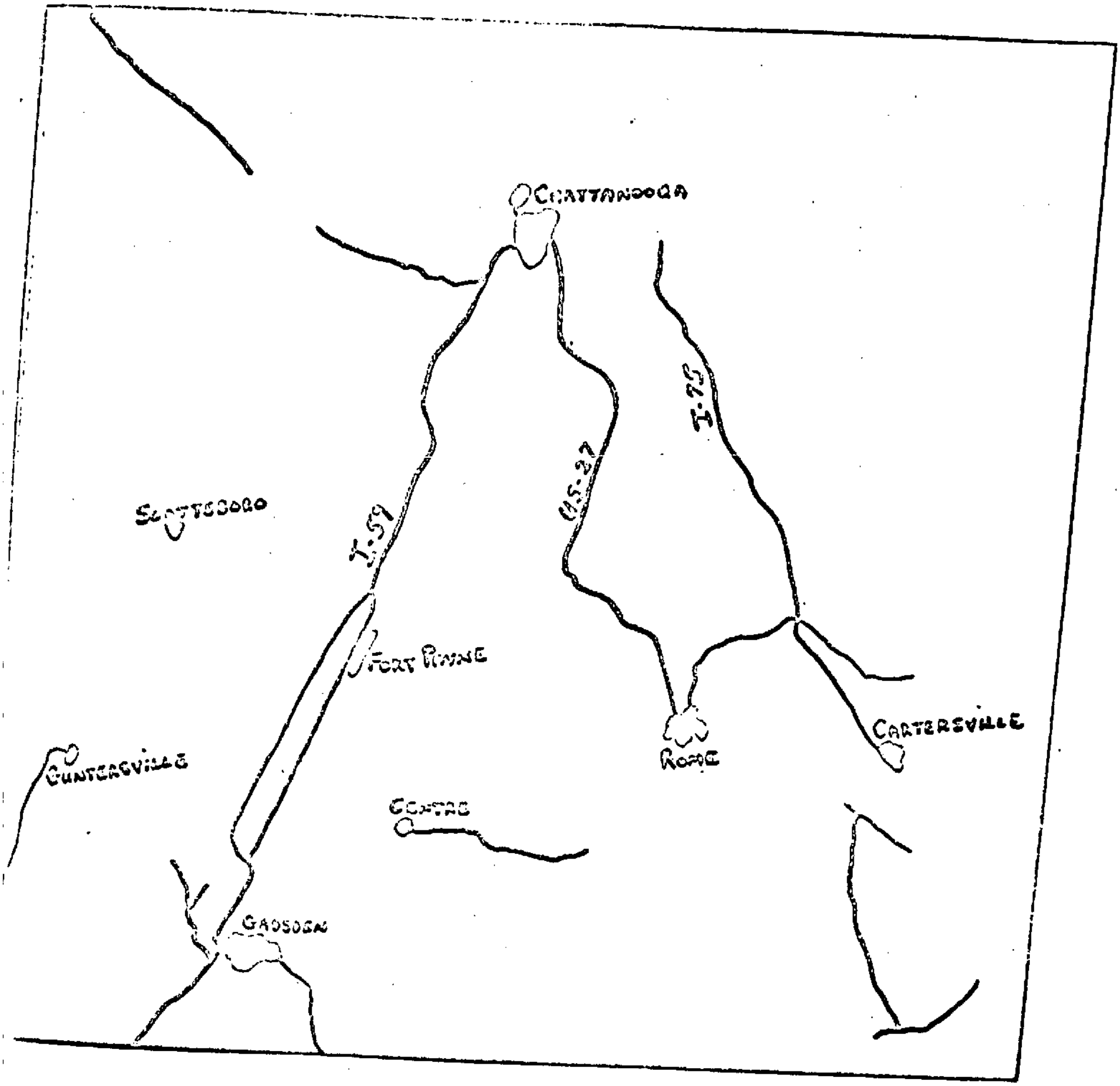

Figure 39 - Urban Areas and Transportation Arteries
MSS Band 5, December 27, 1972, Scene K-1

Figure 40- Land Use
MSS Band 5 & 7, December 27, 1973, Scene K-1

Urban
Agriculture
Forest
Water

Chatooga River, 6) the Ocoee River, 7) the Etowah River with the Alltoona Lake, and 8) the Oostanaula River.

From band 5 major highways were fairly easily identified (See Figure 39; however, some sections of road were definitely obscured by either topographical irregularities or by the evergreen stands of pine trees in the Piedmont area.

Quite naturally, agricultural plots in this region are very small and widely distributed because of the dense local relief (See Figure 40). Therefore, no over-all general pattern of land use seemed to emerge while viewing bands 4 and 5 of scene K-1 with the exception of farm land forming a linear pattern following the trends of the limestone valleys in the western part of the scene.

In such an area where cultural features are so small and do not follow any set pattern, images of a much larger scale combined with false color additive would be most desirable for accurate feature recognition. However, band 7 remains a very workable tool for the identifying and classifying of natural surface features.

5. Phenix City-Columbus-Dothan Area[21]

ERTS scene J-3 is located along the southern border between Alabama and Georgia. It contains Russell, Barbour, Hale, Houston, and Henry counties, and portions of eight other Alabama counties (Figure 16). The Alabama-Georgia border runs through the center of the scene, and a very small portion of northwest Florida is also included. Frame E-1264-15452 of April 13, 1973 was chosen for study because of its complete freedom from cloud cover.

Walter F. George Reservoir and the Chattachoochee and Flint rivers are easily identifiable. Numerous small lakes and ponds in the southern half of the scene stand out clearly.

There are not many urban areas in this scene, those which are present are less easily detected than on other scenes. The Auburn-Opelika and Columbus-Phenix City areas stand out fairly well, but other major cities such as Dothan and Albany were extremely difficult to locate. Many highways were detected and identified, although most of these could only be followed for a short distance. One puzzling feature was an unidentified road in northeast Bullock County, about five miles southwest of Hurtsboro. This apparent road corresponds to no major highway or railroad and could not be a bridge or an air field because none exist in this area. Yet it is better defined, more distinct, and more highly reflectant than any other road in the scene. Other analyst have observed that rural roads sometimes appear quite distinct on ERTS imagery. This Bullock County road is probably an outstanding example of this phenomenon.

The entire scene is dominated by agricultural land. Only urban areas and waterways provide a break in this dominance. There is some forested land, almost all of which is restricted to the immediate vicinity of rivers and streams. Indeed, the forested land can be used for inference of streams which are not actually observable on imagery.

An interesting feature was observed in southwestern Russell County. This feature appears most prominently on band 5 and can also be seen on bands 4 and 6. It is circular in shape and about 0.8 miles in diameter. All efforts to classify it were unsuccessful. (See Figures 41-44).

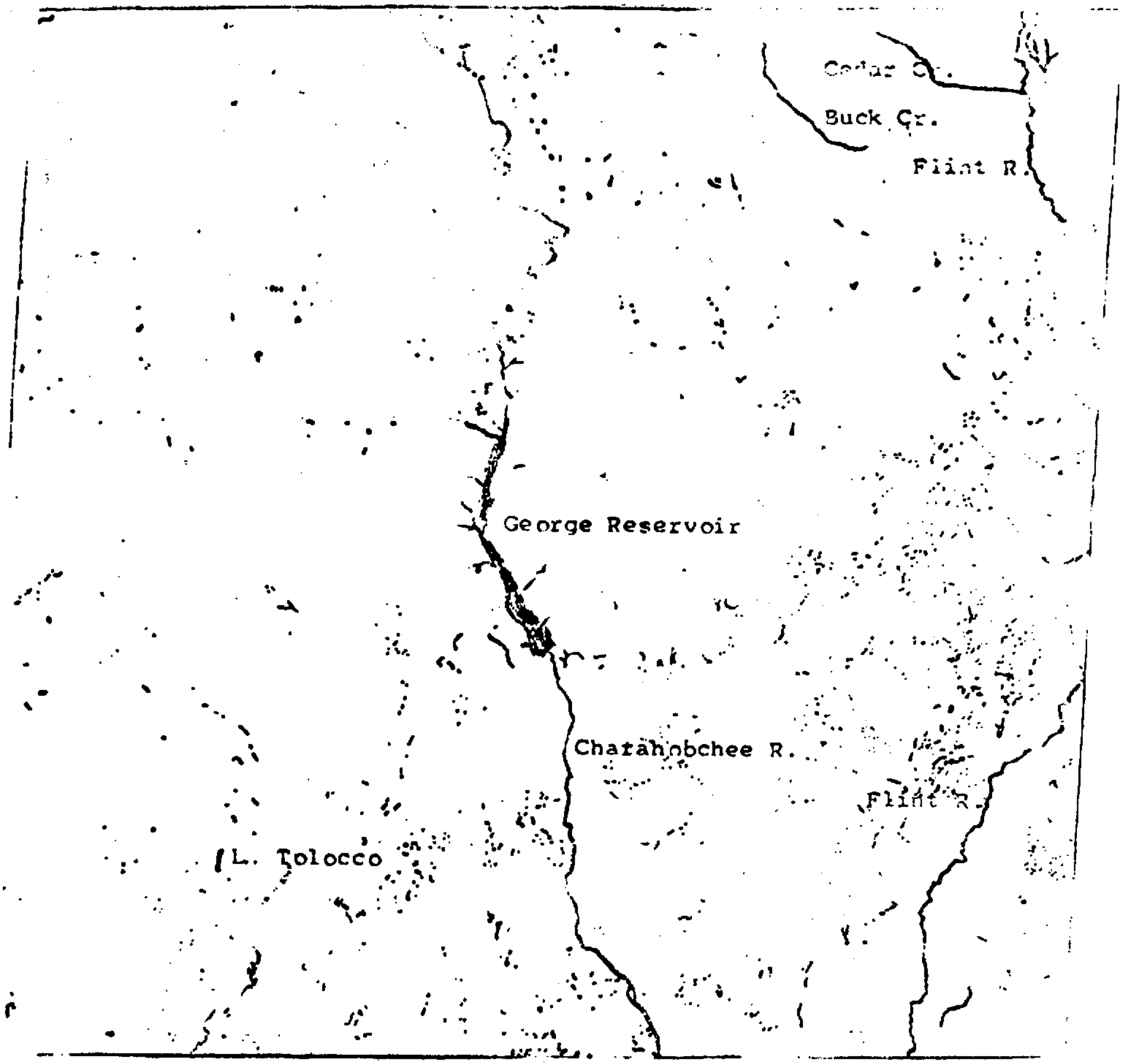

Figure 41. Bodies of water as interpreted from ERTS frame E-1264-15452.

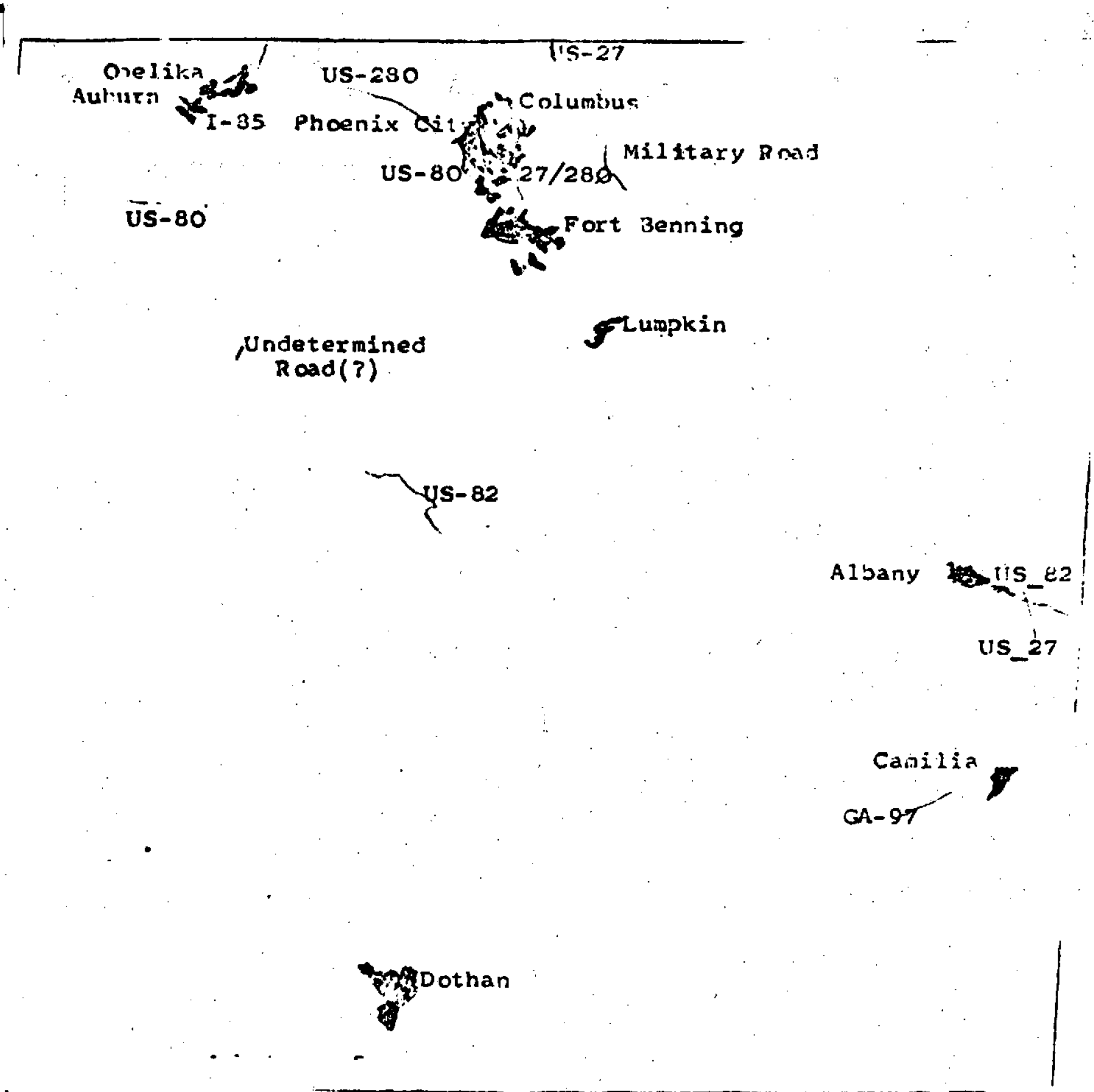

Figure 42. Urban areas and highways as intrepreted from frame E-1264-15452.

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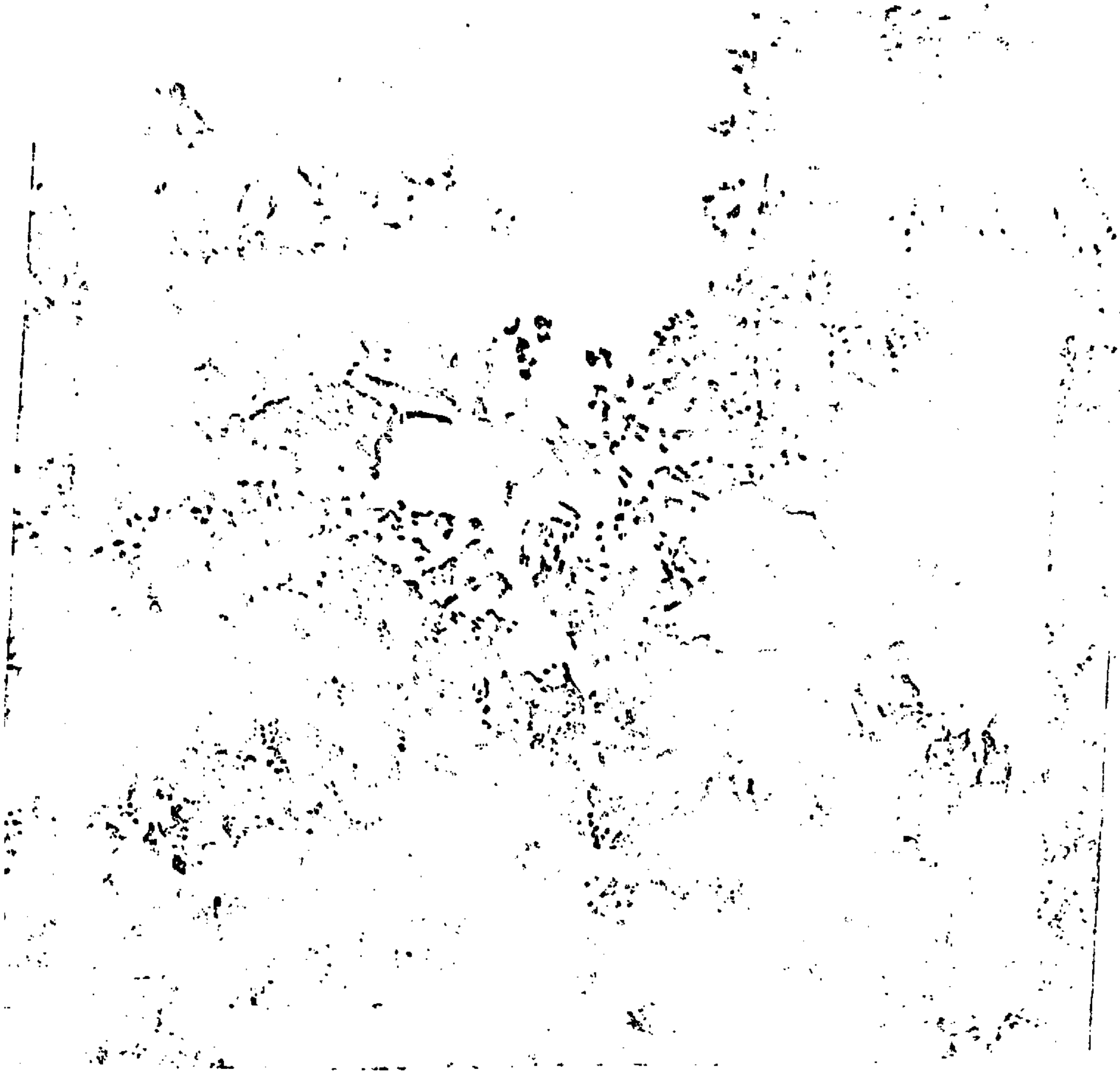

Figure 43. Agricultural land interpreted from ERTS frame E-1264-15452.

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Figure 44. Forrested land as interpreted from ERTS frame E-1264-15452.

6. Cullman-Decatur-Huntsville Area[22]

The study of scene E-1158-15552, located in north Alabama and southeastern Tennessee, resulted in varying degrees of success. The December 28 scene was chosen for evaluation for three reasons: 1) total freedom from cloud, 2) lack of obscuring foilage, and 3) a position shift in the frames occurred during the late fall with earlier scenes positioned significantly southerly in comparison to subsequent imagery. Thus, good results were realized from efforts to delineate natural features such as drainage patterns and topographical features, while difficulty in detecting cultural boundaries was incurred.

The coverage area included all or parts of 17 counties lying primarily within the Tennessee River Valley. This territory is extremely heterogeneous in physical appearance, as well as in resulting land use patterns.

The study area (henceforth referred to as Scene L-1) lies primarily within two physiographic provinces: 1) the Appalachain Plateau (including the Cumberland Plateau and Eastern Highland Rim) and 2) the Valley and Ridge (See Figure 16).

Subsurface geology reflects the topographic character quite well from the sandstones and shales of the highly dissected plateau territory to the more resistant sandstones, cherty limestones and hard shales capping the ridges alternating with valley limestones of the Valley and Ridge Province. Rock types include Mississippian limestones along the Tennessee River, unconsolodated material of the Tuscaloosa group in the extreme west, Fort Payne chert in the extreme north and Pottsville sandstones in the south portion.

This underlying material greatly influences the patterns of surface features, both natural and cultural. Rich river alluvium,results in fairly widespread cultivation of the Tennessee River bottom lands, especially from Decatur to the Tri-Cities area. The upland regions of the plateau appears more heavily forested due to inaccessibility resulting from the dendritic erosional patterns (See Figure 45), quite typical of a plateau in a humid region. As can be inferred from Figure 46, continuous transportation arteries are limited because of difficulty in crossing the numerous interfleuves at right angles. In addition, local routes are restricted by structural control to following erosional valleys without the usual and convenient connector roads. Similarly, transportation routes in the Ridge and Valley are usually limited to the more elongated valleys, along with subsequent land use build up. Land usages (first order) diminish in magnitude as one moves away from the broad expanse of the lower Tennessee River Valley and into the more dissected uplands.

As previously mentioned, stream patterns and topographic irregularities are quite readily identifiable on band 7. Easily recognized streams and water empoundments include: 1) Tennessee River and TVA lakes, 2) Elk River, 3) Shoal Creek, 4) Cypress Creek, 5) Piney Creek, 6) Indian Creek, 7) South Sauty Creek, 8) Big Spring Creek, 9) Coosa River, 10) Locust Fork of the Warrior River, 11) Inland Lake, 12) Mulberry Fork of Warrior River, 13) Lewis Smith Lake, and 14) Bear Creek. The drainage, (Figure 45), takes on a dendritic pattern in the Plateau area whereas trellis and parallel drainage dominate the Ridge and Valley area. It is estimated that no smaller than fourth order streams can be detected.

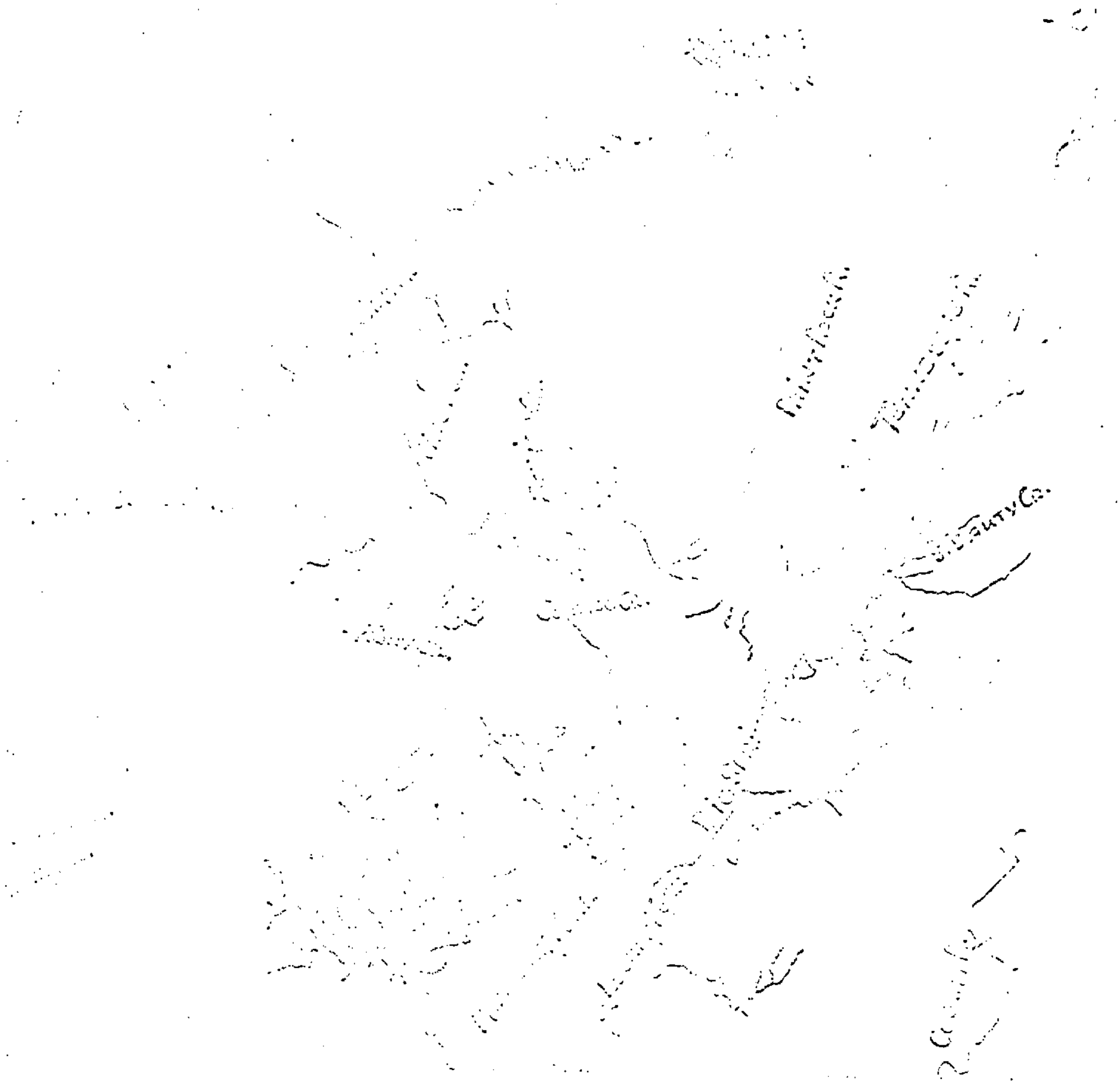

Figure 45. Drainage Patterns, Band 7, L-I
December 28, 1972

Figure 46 Transportation Arteries and Cities, Band 5, L-I December 28, 1972

As in the case of surface water, forested ridges have a very dark signature in comparison to the much lighter surrounding land as seen on band 7. Therein lies the only incurred problem in differentiating features on band 7; both water and ridges appear very similar in their shade of gray. Linear trends must be relied upon to contrast the two surface features.

The detection of highways from a band 5 scene was limited to major routes and even then not always through their entire length. On occasion some sections of road seemed to be obscured by topographical features.

Analysis of land use in such an area of diversity as north Alabama and at such a small scale is difficult at best. The contrast is not nearly good enough to depict vivid boundaries, especially in an area with such small agricultural plots as in north Alabama. Therefore, large tracts of land on scene L-1 will be termed indistinguishable because an exact differentiation between forest and agricultural, especially in winter cannot be done with the naked eye. With much intense study of a large area, certain definite patterns do begin to emerge. These patterns seem to be somewhat structurally controlled by the fairly rugged terrain encountered here.

Again, it can be said that definite individual physical features which contrast the surrounding land can be readily identified on band 7 of ERTS imagery. However, accurate isolation and definition of land use in a complex area cannot be realized without some type of enhancement equipment such as false color additive or extreme magnification.

7. Florence-Russellville-Moulton Area[23]

The study of scene E-1177-16005 (Scene M-1) located primarily in northwest Alabama, northeast Mississippi and southern Tennessee (See

Figure 16) resulted in a somewhat greater measure of success than those scenes previously submitted. It is suspected that two factors are responsible for this unexpected improvement: 1) extremely dry, clear weather in the area, and 2) a lack of diversity in the physical make-up of the area. Thus, the difficulty usually incurred in differentiating agricultural plots from hardwood forests (defoliated at the time) was somewhat lessened by the existence of larger farms. Again, natural physical features were quite easily discernible, mainly due to the season chosen for study with associated lack of obscuring live vegetation.

The scene area included all or part of only seven counties in Alabama. Therefore, one basic inherent problem of a lack of corraborating cultural maps adversely affected the identification of and location of such features as major highways and cities.

The study area (referred to as M-1 encompasses primarily two physigraphic provinces: 1) the Appalachain Plateaus (including the western Highland Rim on the extreme north) and 2) the East Gulf coastal plain (See Figure 48).

The subsurface geology of the Plateau area remains quite characteristic of a dissected plateau in a subtropical humid climate with soluable Bangor limestones (which are quite easily cut by stream action) in the southern portion to the more resistant but still erodable cherts and shales of the western Highland Rim. As a result drainage patterns take on the characteristic dendritic erosional forms of degrading streams in soft subsurface material (See Figure 47). As a result of this fairly rugged terrain, urban build-up and connecting transportation arteries are somewhat limited by the parallel streams, thus restricting transport routes to eroded valleys with towns located along streams (See Figure 49).

These topographical restrictions of the plateau are absent from the coastal plain west of the Tennessee River. Here agriculture is more widespread due to the flatness of the area as well as the presence of recent river alluvium. In this section, towns appear to be more numerous but smaller due to the agriculturally oriented land use of the area.

Natural physical features which possess the greatest amount of reflection contrast were by far the easiest recognized of all features in scene M-1. As can be seen on Figure 47, many streams were identified with those large enough for actual sighting of water. Large identifiable streams include: 1) Tennessee River, 2) Tombigbee River, 3) Cumberland River, 4) Elk River, 5) Tuscumbia River, 6) Bear Creek, 7) Shoal Creek, 8) Cypress Creek, and 9) Town Creek (See Figure 47).

The detection of cultural features such as highways and cities was restricted by lack of contrast to those of very large magnitude. At best, only sections of road could be accurately discerned from surrounding landscape (See Figure 49) and then only in the southern portion where more evergreen trees exist to add to the reflectance difference.

Actual land use patterns seem to be more easily detected in this area than others of north Alabama. This phenomenon is probably caused by the larger tracts of agricultural land resulting from a more homogenous terrain and better alluvial type soil (See Figure 50).

As was the case in other scene analyses, the winter season is most desirable for detecting natural features but not those of man-made origin whereas unfoliated hardwood forests possess very similar spectral signatures to those of fields.

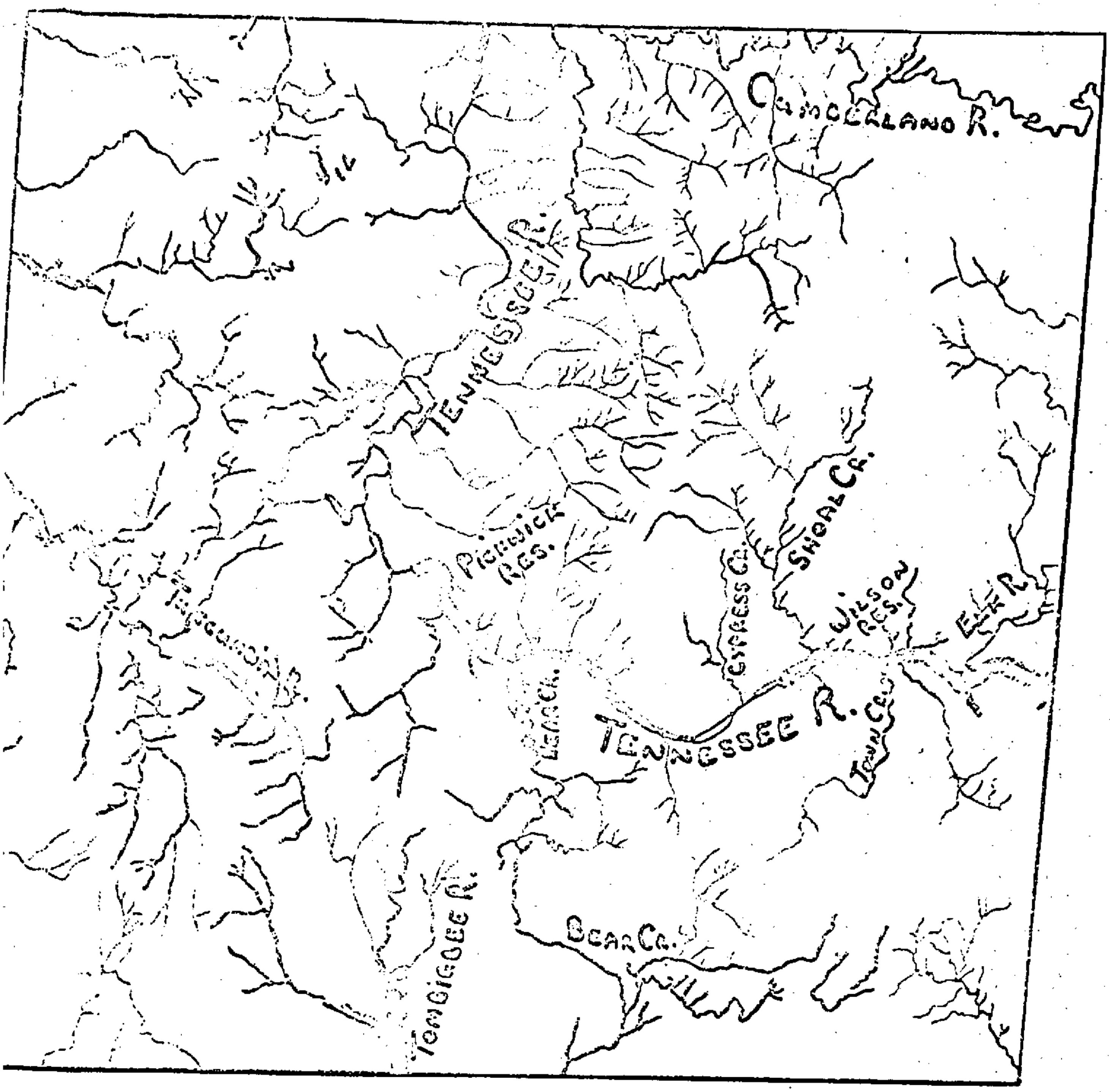

Figure 47
Stream Patterns
MSS Band 7
January 16, 1973
Scene M-1

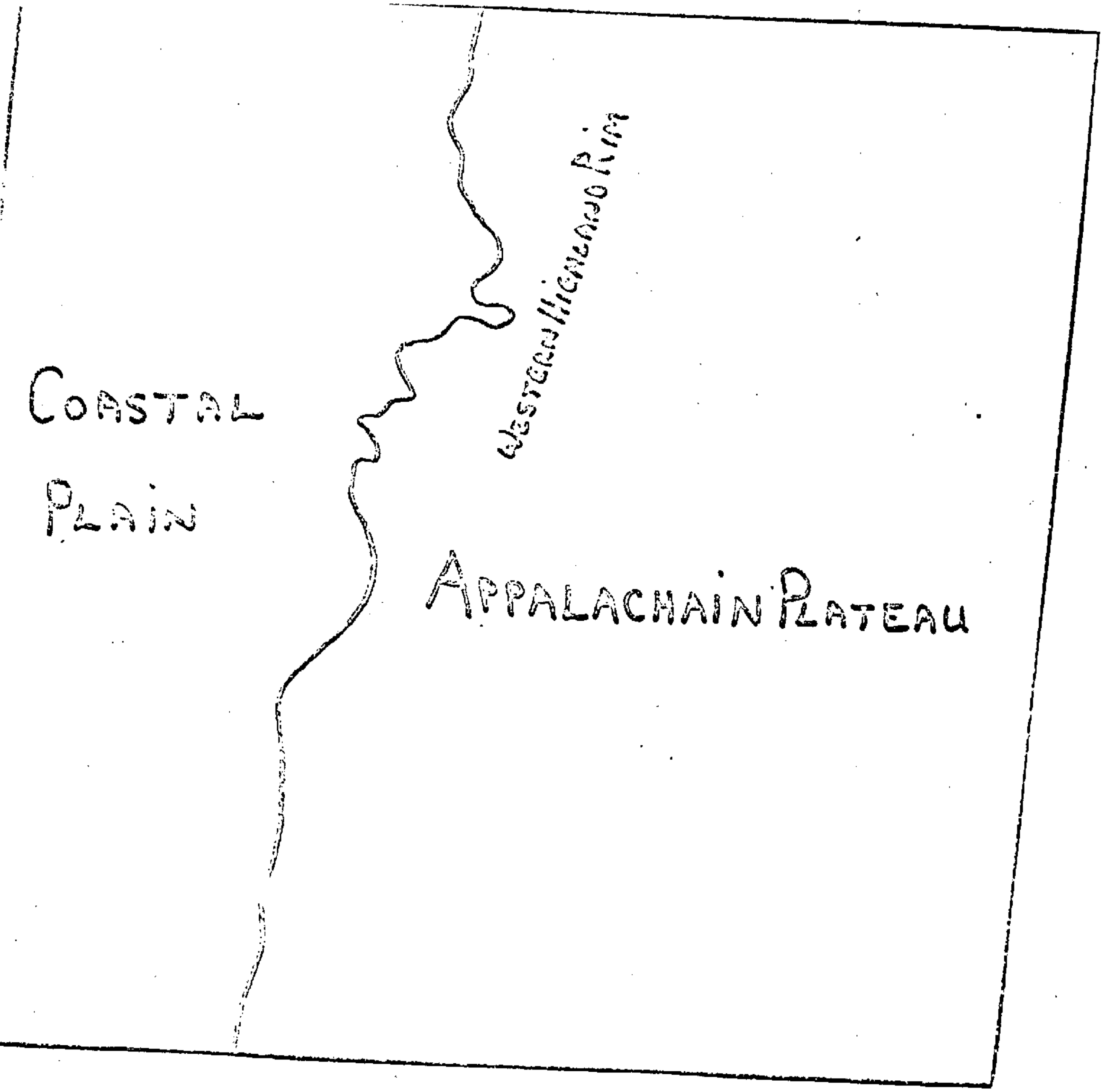

Figure 48
Physiographic Provinces
MSS Band 7
January 16, 1973
Scene M-1

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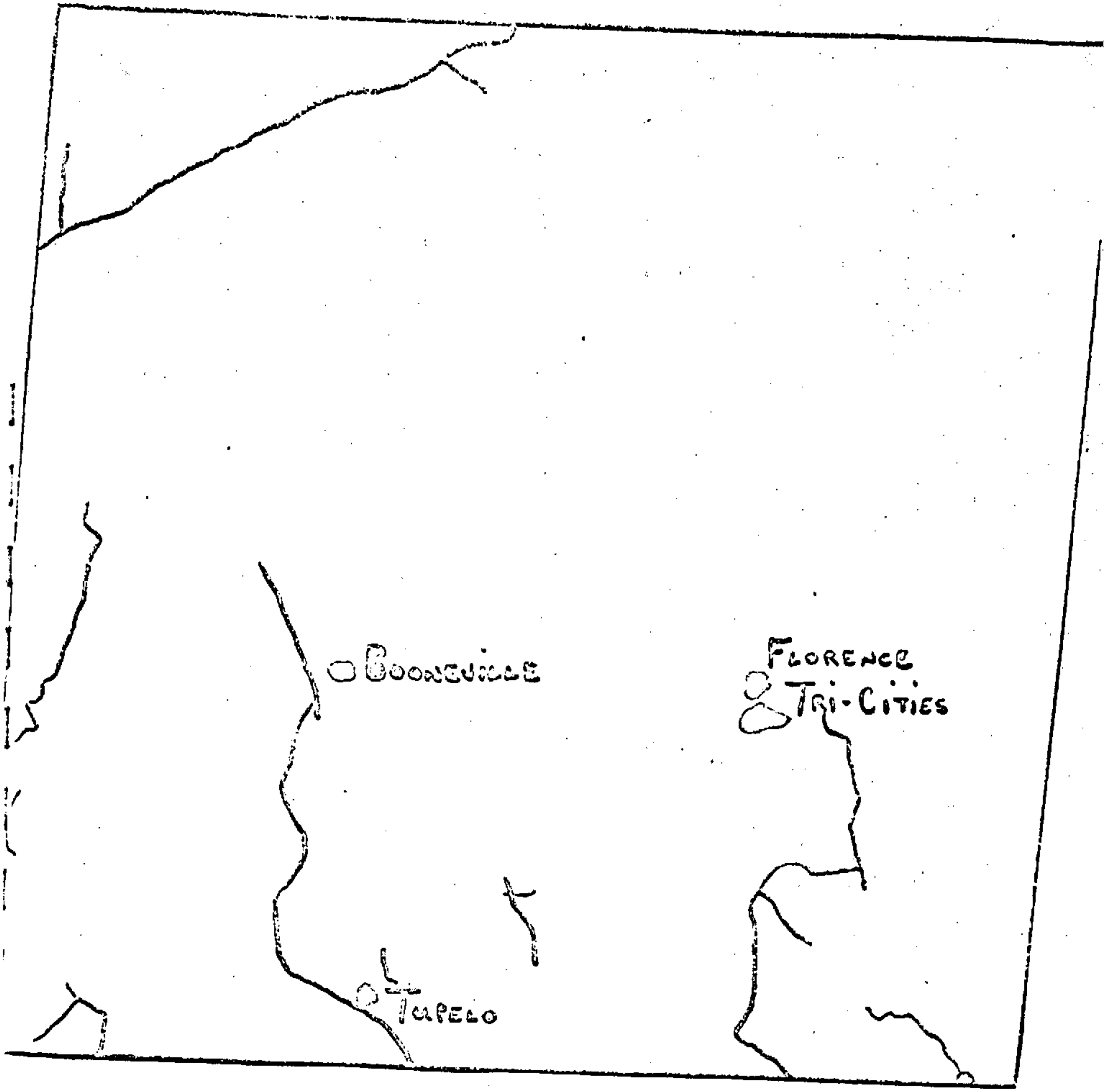

Figure 49
Urban Areas and Transportation Arteries
MSS Band 4
January 16, 1973
Scene M-1

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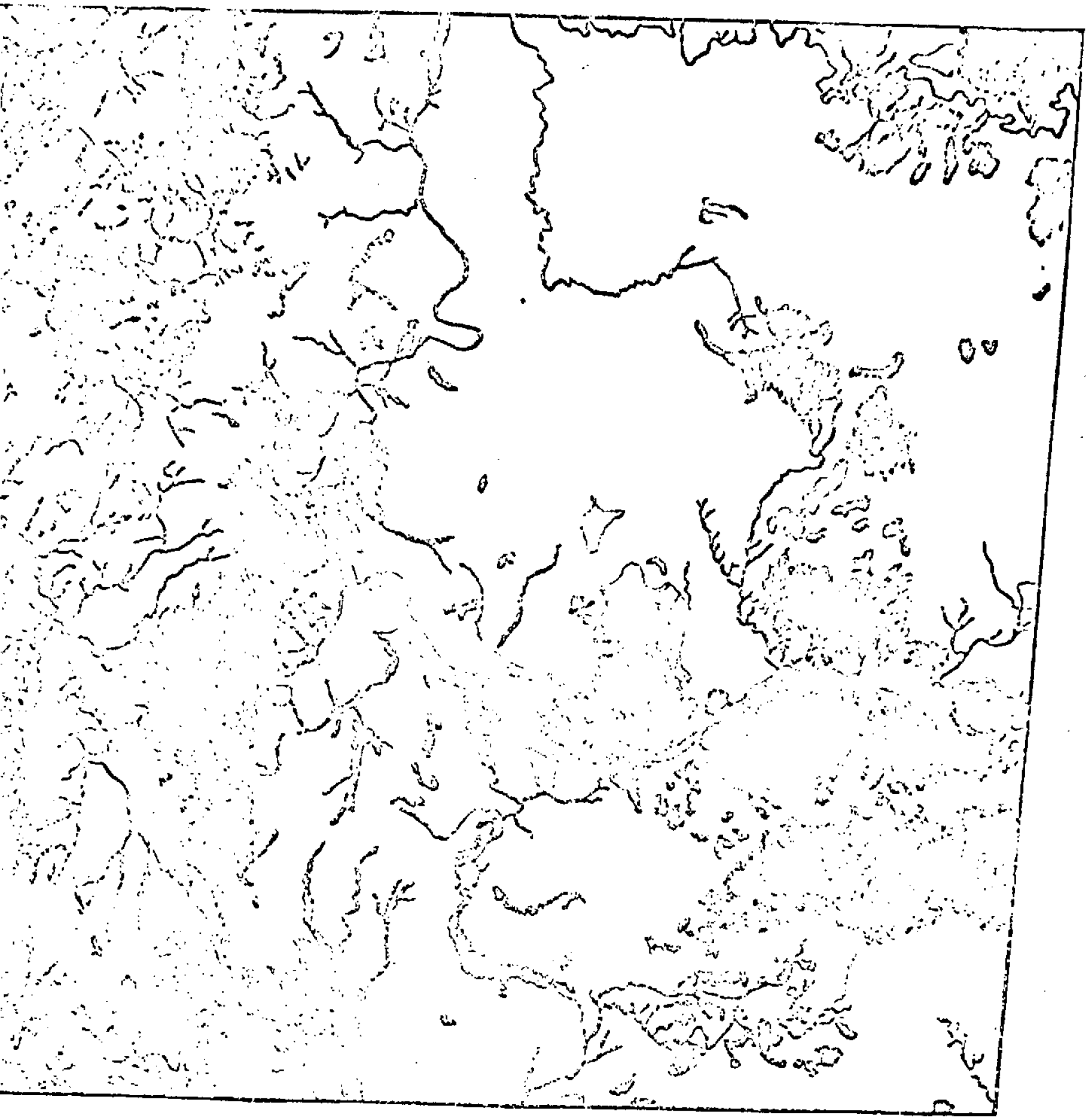

Figure 50
Land Use Patterns
MSS Bands 5 and 7
January 16, 1973
Scene M-1

URBAN
WATER
AGRICULTURE
FOREST

III. OTHER SPECIAL STUDIES

A. Detecting the Spread of the Gypsy Moth[24]

The gypsy moth (Porthetria dispar) is a forest insect native to eastern Europe and Asia where it causes moderate and infrequent damage. However, when taken from its native environment, the insect displays a capacity for changing into a costly and destructive menace to forests. In 1869 such a transition was begun when a French biologist introduced gypsy moth eggs into Medford, Massachusetts. He hoped to produce a sturdy strain of silk-producing insects by crossing the gypsy moth with the silkworm moth and raising it in a very conducive environment. As could be expected, these larvae escaped from the Medford experiment, thus creating the current gypsy moth infestation problem in the northeastern United States.

During these subsequent years of habitation in this favorable environment, the gypsy moth has spread over 200 thousand square miles while defoliating forest and ornamental trees in the process. The moth has now become established in all or portions of nine states from Maine to Maryland. Past records of outbreaks within this area have shown preferred hosts to consist mainly of hardwoods but with older larvae successfully feeding on pine, cedar or spruce. These conifers are usually killed by one season of complete defoliation while hardwood species may be killed by two successive years of defoliation. In areas having 50 percent or more hardwood trees (preferred hosts) there is generally a three to five year phase following initial introduction in which the insect becomes generally distributed at low densities throughout the region. Phase two may bring a population explosion throughout the entire area for several years in succession. Eventually, a population collapse occurs followed by local abundance on the more susceptible upland oak sites.

The potential threat of the gypsy moth to southern forest resources has been analyzed by several persons over the past forty years, and their findings reveal some interesting speculations. On the basis of suitable hosts being present, the insect is expected to eventually occupy the entire region in which oaks are a component of the forest stands. Evidence is accumulating to indicate that southern hardwood forests might be highly susceptible to defoliation, and therefore, may experience greater mortality than that occurring in the Northeast. This factor, combined with a milder climate and a virtual predator-free habitat in the Southeast, offers some very bleak possibilities.

In a thesis written by Glenn Ray Pritchett at The University of Alabama, the possibility of using ERTS data to locate and predict gypsy moth infestation in forests was examined. In his thesis, Mr. Pritchett (1) determined the net effect of natural restrictions on the potential population spread, (2) analyzed the net effect of artificial suppression measures on population growth and subsequent dispersion, (3) utilized nonlinear regression techniques to predict pregressive population diffusion, and (4) used ERTS-I imagery to illustrate an unbroken chain of favorable environs and preferred host forests along the Valley and Ridge Province of the Appalachian Mountains from Pennsylvania to north Alabama.

Mr. Pritchett used a mosaic of 70 millimeter ERTS-I images (covering approx 10,000 square miles) which depicted the series of linear ridges (a component of the Valley and Ridge Province) spanning the intermediate zone between the current New England infestation and Alabama. MSS (multi-spectral scanner) band five was chosen for display purposes because the reflected green (dark areas on the images) received by the scanner in the satellite is the best band for depicting forest vegetation.

For the purpose of predicting a future trend it was necessary to separate the moth's history in the U.S. into two divisions, a pre-DDT usage era and a post-DDT usage era. This decision was made on the basis of the obvious depressive effect on population growth during the 1930's and 1940's and on the basis of an expected continuous ban on the insecticide. Therefore, only the data beginning 1960 (the earliest data available after the 1958 ban of DDT general use) was used in the evaluation. Using historic spread data and regression analysis, a geographic diffusion graph was produced. An analysis of the projected geographic diffusion indicates a computed arrival date of the gypsy moth in northeast Alabama within the next 38 years.

B. Comparison of ERTS and U-2 Photographs

In an attempt to determine the accuracy obtained by coding land from ERTS photographs, land use figures obtained from U-2 and ERTS photographs of the same land mass were compared. U-2 land use figures were interpreted as "ground truth".[25] The difference between U-2 land use figures and those figures registered by ERTS was interpreted as the number of cells which were coded differently by ERTS.

NUMBER OF CHANGES FOR ______ COUNTY

ERTS DATA POSITION 2 * ERTS DATA POSITION 7 * CODE

TYPES	NOT PRESENT (..)	PRESENT (0)	IN FIRST ONLY (-)	IN SECOND ONLY (+)	TOTAL IN FIRST POS	TOTAL IN SECOND POS
URBAN	309	17	0	47	17	64
AGRICULTURE	294	24	32	23	56	47
FOREST	60	241	56	16	297	257
WATER	369	3	0	1	3	4
BARREN	372	0	0	1	0	1
WETLAND	373	0	0	0	0	0

POSITION TWO

POSITION ONE	URBAN	AGRICULTURE	FOREST	WATER	BARREN	WETLAND	CLOUD
URBAN	17	0	0	0	0	0	0
AGRICULTURE	16	24	16	0	0	0	0
FOREST	31	23	241	0	0	0	0
WATER	0	0	0	1	1	0	0
BARREN	0	0	0	3	0	0	0
WETLAND	0	0	0	0	0	0	0
CLOUD	0	0	0	0	0	0	0

Reading The Matrix

Position 2 corresponds to the land use digit obtained from U-2 airphotos.

Position 1 corresponds to the land use digits obtained from ERTS.

Reading down the Urban column, the interpreter of the U-2 photographs classified 17 cells as urban and the ERTS interpreter classified 17 cells as urban. However the U-2 interpreter also classified 16 cells as urban that were classified as agriculture by the ERTS interpreter. Finally the U-2 interpreter classified 31 more cells as urban that looked like forest to the ERTS interpreter. The cells that the ERTS interpreter classified as agriculture or forest when they were really urban, probably occurred in residential areas.

The accuracy obtained is the sum of the diagonal numbers divided by the total number of cells or $\frac{285}{373}$ = 76.4%.

FIGURE 51

Fig. 52

NUMBER OF CHANGES FOR COUNTY

ERTS DATA POSITION 2 * ERTSDATA POSITION 7 * CODE

TYPES	NOT PRESENT (.)	PRESENT (0)	IN FIRST ONLY (-)	IN SECOND ONLY (+)	TOTAL IN FIRST POS	TOTAL IN SECOND PO
URBAN	385	2	2	5	4	7
AGRICULTURE	282	56	32	24	88	80
FOREST	64	278	23	29	301	307
WATER	394	0	0	0	0	0
BARREN	394	0	0	0	0	0
WETLAND	394	0	0	0	0	0

POSITION TWO

POSITION ONE	URBAN	AGRICULTURE	FOREST	WATER	BARREN	WETLAND	CLOUD
URBAN	2	2	0	0	0	0	0
AGRICULTURE	4	56	28	0	0	0	0
FOREST	1	22	278	0	0	0	0
WATER	0	0	0	0	0	0	0
BARREN	0	0	0	0	0	0	0
WETLAND	0	0	0	0	0	0	0
CLOUD	0	0	1	0	0	0	0

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$$\text{Accuracy} = \frac{336}{393} = 85.5\%$$

Fig. 53

NUMBER OF CHANGES FOR COUNTY

ERTS DATA POSITION 3 * ERTSDATA POSITION 7 * CODE

TYPES	NOT PRESENT (.)	PRESENT (0)	IN FIRST ONLY (-)	IN SECOND ONLY (+)	TOTAL IN FIRST POS	TOTAL IN SECOND P
URBAN	698	3	9	7	12	10
AGRICULTURE	275	250	79	113	329	363
FOREST	266	264	111	76	375	340
WATER	712	0	1	4	1	4
BARREN	717	0	0	0	0	0
WETLAND	717	0	0	0	0	0

POSITION TWO

POSITION ONE	URBAN	AGRICULTURE	FOREST	WATER	BARREN	WETLAND	CLOUD
URBAN	3	5	3	0	0	0	0
AGRICULTURE	3	250	72	4	0	0	0
FOREST	4	107	264	0	0	0	0
WATER	0	0	1	0	0	0	0
BARREN	0	0	0	0	0	0	0
WETLAND	0	0	0	0	0	0	0
CLOUD	0	0	0	0	0	0	0

$$\text{Accuracy} = \frac{517}{717} = 72.1\%$$

The scale on the ERTS photographs was 1:1,000,000 and the scale on the U-2 photographs was approximately 1:136,000. By use of a computer program called CHGMAP the following results were obtained. (Figs. 51-53)

C. Application of ERTS-I Imagery for Detecting Coal Spoil Embankment Fires[26]

Satellite imagery is a sophisticated system for repetitive coverage of the earth's surface. The full potential of this technique has not been realized, but investigations are continuing to exploit its uses. Each of the four bands of electromagnetic radiation wavelengths have different characteristics, and each is suited for optimum use in particular situations.

Bands four and five sense radiation wavelengths in the 500-600 NM and the 600-700 NM ranges, respectively. This visible actinic radiation may be photographed by ordinary means. These images are particularly useful in color changes in fields, tree vegetation, and urban areas. Even though most ERTS products are not in color, most practitioners feel that color enhancement is a needed dimension for the ERTS data user.

The most useful technique of enhancement the writer was able to use was the reversed image, which was named a "posoprint" for use in this study. The posoprint is made from a positive instead of a negative, which results in an image with reversed colors. These posoprints, along with the normal images in bands four and five, were surveyed for detection of the coal spoil embankment fires with mostly negative results.

The reflected actinic light integrated with the reflected light of the surroundings to yield mostly indecipherable boundaries. This problem was enhanced by the fact that the sensing mechanism was many miles away (the scale on a 9.5 inch print is 1:1,000,000). Naturally the image displayed no signs of the fires or the clay cover.

Bands six and seven, which receive radiation wavelengths from 700-800 NM and 800-1100 NM, respectively, were useful in the detection of the coal spoil embankments.

On the normal imagery, coal spoil embankments would appear dark in relation to their surroundings, but due to grey scale effects, the contrast is better on the reversed image. These embankments appear to be indistinguishable from other similar spots on the image to the unskilled ERTS user. The unskilled user must know what he seeks and its approximate location. Otherwise the image may be meaningless. The printed images did not show any distinguishable characteristics to indicate the presence of fires or hot spots on any of the spoil embankments. It was apparent that during the assimulation and transfer of data bits the ERTS imaging system lost the necessary information for this particular application. However, computer analysis of such data may indicate much more than the eye can detect. Practical application of the computer for this use is still in the future.

The ERTS-I remote sensing system currently is unstable and inefficient. Data quality is variable due to problems in transfer and mechanics. The frequency of data is an advantage providing no clouds cover the target area. The writer found cloud cover to be a major problem in the repetitive data gathering process. The applications of ERTS-I imagery is limited in this field because of the small scale of the products.

Banding, grey scale stabilization, distortion, and development technique stabilization also present problems of definition and clarity for the ERTS-I data user.

D. Optimal Site Studies[9,27]

The first attempt at locating optimal plant sites employed a procedure of weighting certain parameters.[9] The parameters were chosen in such a way as would best demonstrate ERTS-I's value in locating optimal sites. Another attempt at locating optimal industrial sights employed the use of a linear programming computer program.[27]

Following is a discussion of both procedures.

1. Weighting Procedure[9]

In demonstrating the usefulness of ERTS-I imagery through an optimum site location program, it was first necessary to define a suitable cell size, the type of "test" industry, and the locational criteria. The procedure was applied to a 20,800 square kilometer area lying entirely within the Southeastern part of Alabama.

A ten by ten kilometer square cell size was selected. On a regional level, a smaller cell size would have been inappropriate, requiring a more exacting local or "micro" analysis of the environment far beyond ERTS-I's capabilities. Conversely, a larger cell size would have generalized the information to such an extent that it would have been self-defeating.

For demonstration purposes, an industry type was selected which would utilize as many ERTS-I detectable parameters as possible. Since the target study area had primarily an agricultural economy, the obvious choice was that of an "agro-industrial" development which would utilize many types of farm products. This development would be an agglomeration of industries, some of which would use farm produce as their chief raw material while others would produce goods for use on the farm.

The locational criteria were chosen which would best demonstrate ERTS-I's value in this type of procedure. For the most part, these physical parameters are applicable to almost every industrial development, thus suggesting ERTS-I's versatility. The weights given to each of these parameters would change from industry to industry and from region to region.

The following parameters were chosen:

1. Market and Labor Availability
2. Agricultural Rating
3. Plant Site Availability
4. Availability of Surface Water
5. Growth Potential
6. Accessibility by Roads
7. Accessibility by Railroads.

Market and labor availability is important to any industry and agricultural industry is no exception. Urban centers must be of sufficient size to supply the required facilities to the company as well as a trained labor force. This involves a broad tax base and community acceptance and also well equipped vocational and high schools. These socio-economic factors would, of course, only be applied on the local level. Therefore, the number of urban cells per macro cell (100 square kilometers) was taken to represent an available market and labor potential.

The agricultural rating of each macro cell was important to the agro-industrial development used in this demonstration. It referred to the number of dominant agricultural cells in the macro cell. It was important that this type of development be close to the agricultural activity because of the perishable nature of the raw materials and because services offered by the development would be needed as quickly as possible, especially during critical seasons of the year.

The availability of plant sites is another important consideration. In an agricultural region, farm land is at a premium; therefore, industries using farm products should strive to be close to the farms and yet not displace the agricultural activity. Since urban and agricultural land are already in production and water and wetland are unsuitable for the location of an industry, forest dominated cells in each macro cell were considered to represent suitable construction sites.

Since this region has an abundant water supply underground as well as on the surface, the availability of surface water was not a critical factor. Nevertheless, water is readily detectable on ERTS-I imagery and could be important to an industry requiring supplemental amounts of water for its processes. Aesthetic appeal of a nearby lake or reservoir and the economic benefits of a navigable stream would, in some cases, be important. Therefore, the number of water dominated cells per macro cell was included.

Transportation, whether by truck or train, greatly influences the location of an industry by affecting a compromise between locating near the market and near the source of raw materials. In this case, interstate highways were weighted heavier than railroad lines.

then summed and divided by "20", the sum of the weights, to obtain a numerical value representing that macro cell's suitability for the location of an agro-industrial development. The weights imposed on each of the seven criteria are given below:

1.	Market and Labor Availability	4
2.	Agricultural Rating	3
3.	Plant Site Availability	4
4.	Availability of Surface Water	1
5.	Growth Potential	4
6.	Accessibility by Roads	3
7.	Accessibility by Railroads	1
		20

Although the procedure outlined above was accomplished manually for this investigation, it was designed specifically for future computer application. The same land-use data used in the change detection analysis of the preceding chapter and already in the computer data file could be utilized in a location search technique based upon weighted computerized map combinations. Information concerning access routes as well as socio-economic factors will also have to be entered into the data file to facilitate subsequent micro cell evaluations. With such data in computer format and with ERTS-I providing synoptic updating of the land-use data file, it will be a simple matter to supply industries, public services, and state planning agencies with optimum location maps based upon their sets of weighted criteria. In addition, elimination of manual compilation and comparisor of data will facilitate inspection of regional or state-wide are is using even smaller macro cells than used in this demonstration at less time and cost.

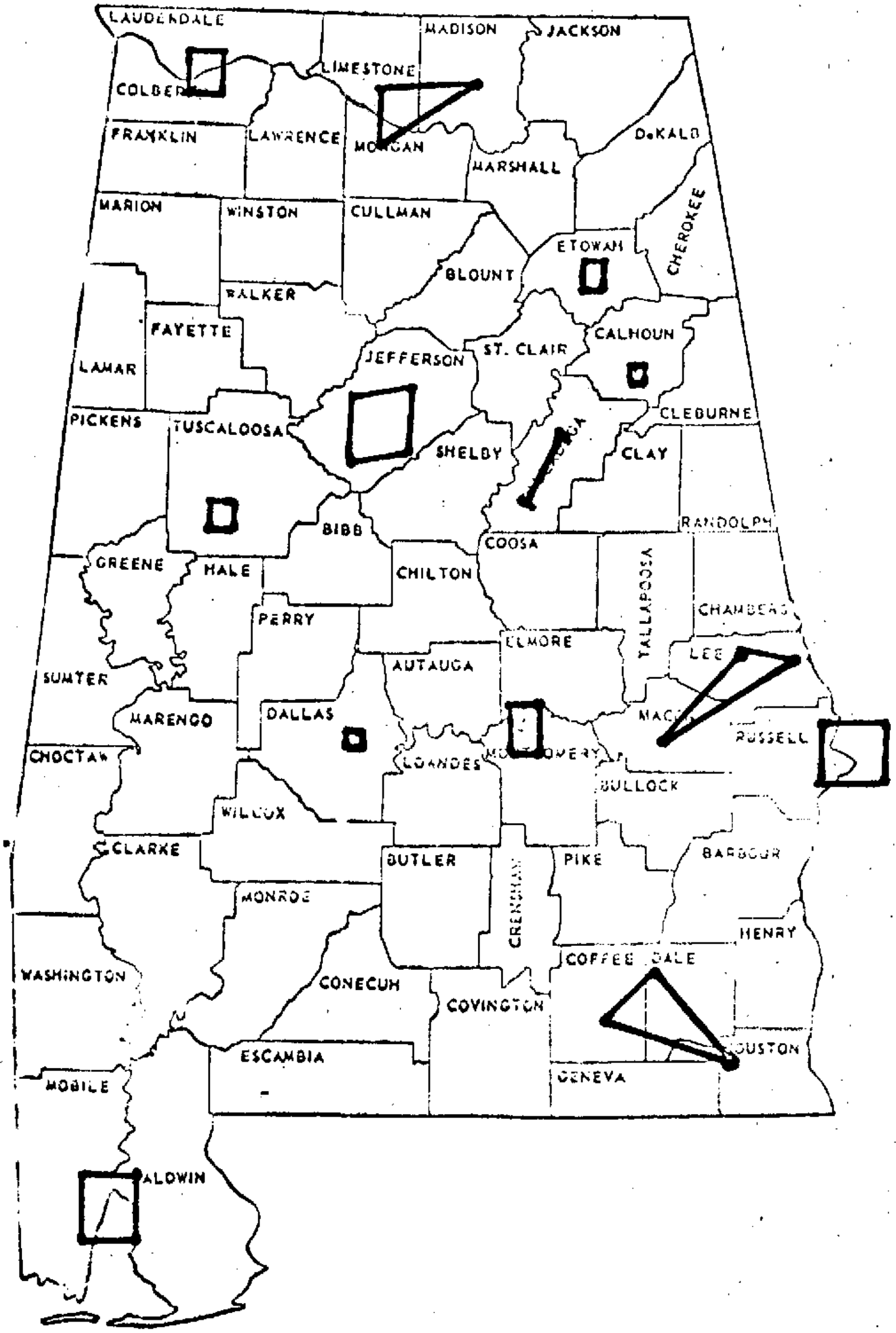
3. Optimization of Plant Sites[27]

In a thesis presented to Dr. Harold R. Henry by Richard P. Wilms, the author used ERTS land use data to locate optimal sites in Southeast Alabama.[9] In the thesis, Wilms used seven weighted parameters to determine the suitability for the location of an agro-industrial development. By means of the weighted numbers, an optimal site was chosen. This procedure, while workable for small areas, would prove burdensome for a large area.

In an attempt to improve the location of plant sites in Alabama, a linear programming computer program was used. The state was divided into consumer and agricultural regions (Figures 54 and 55). The consumer regions consisted of cities with populations of 10,000 inhabitants or greater. If cities of 10,000+ inhabitants fell within close proximity of each other the cities were grouped together to form regions. The state was divided into twelve consumer regions with over one-third the population of Alabama in these regions.

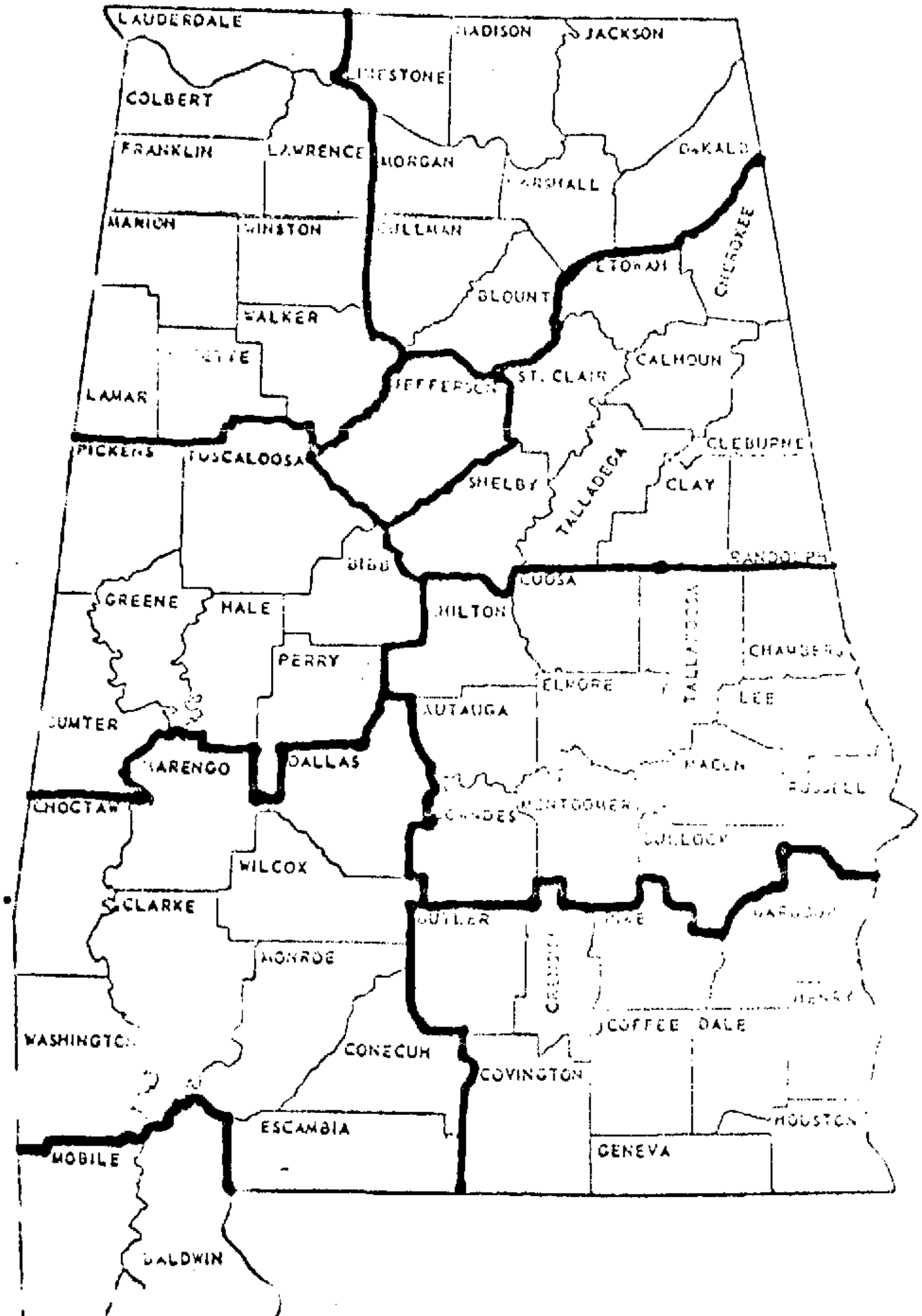
When the state was divided into agricultural regions, the division between regions was made on county lines in such a way as to equalize (as near as possible) the number of square miles in each region. Nine agricultural regions resulted.

The procedure used to optimize plant locations was a pseudo-optimal procedure. Several locations for a plant would be chosen and then the (ton/miles)/day between all the regions was minimized for each plant site. The linear optimization program used the Simplex method to solve the matrix.



Consumer Region

Fig. 54



Agricultural Region

Fig. 55

Fig. 56

Optimizing the Location for One Plant

Agricultural Region	Plant	Consumer Region
1		1
2		2
3		3
4	A	4
5		5
6		6
7		7
8		8
9*		9
		10
		11
		12
		13*

* Products entering or leaving the state.

The following equations are considered the basic equations. More constraints can easily be added to make the results more reliable and/or realistic.

Let x_{ij} be the weight/day between i and j.

M_{ij} = mileage between i and j.

$Prod_i$ = Amount produced at i.

Con_j = Amount needed by consumer region j.

R = Reduction factor due to waste at plant.

Fig. 56

Objective function : Minimize (weight - miles)/day.

$$\begin{aligned}\text{Min. } z = {} & M_{1A}x_{1A} + M_{2A}x_{2A} + M_{3A}x_{3A} + M_{4A}x_{4A} + M_{5A}x_{5A} + M_{6A}x_{6A} + \\ & M_{7A}x_{7A} + M_{8A}x_{8A} + M_{9A}x_{9A} + M_{A1}x_{A1} + M_{A2}x_{A2} + M_{A3}x_{A3} + \\ & M_{A4}x_{A4} + M_{A5}x_{A5} + M_{A6}x_{A6} + M_{A7}x_{A7} + M_{A8}x_{A8} + M_{A9}x_{A9} + \\ & M_{A10}x_{A10} + M_{A11}x_{A11} + M_{A12}x_{A12} + M_{A13}x_{A13}\end{aligned}$$

Subject to: $x_{1A} \leq \text{Prod}_1$

$x_{2A} \leq \text{Prod}_2$

$x_{3A} \leq \text{Prod}_3$

$x_{4A} \leq \text{Prod}_4$

$x_{5A} \leq \text{Prod}_5$

$x_{6A} \leq \text{Prod}_6$

$x_{7A} \leq \text{Prod}_7$

$x_{8A} \leq \text{Prod}_8$

$x_{9A} \leq \text{Prod}_9$

$x_{A1} \geq \text{Con}_1$

$x_{A2} \geq \text{Con}_2$

$x_{A3} \geq \text{Con}_3$

Fig. 56

$x_{A4} \geq Con_4$

$x_{A5} \geq Con_5$

$x_{A6} \geq Con_6$

$x_{A7} \geq Con_7$

$x_{A8} \geq Con_8$

$x_{A9} \geq Con_9$

$x_{A10} \geq Con_{10}$

$x_{A11} \geq Con_{11}$

$x_{A12} \geq Con_{12}$

$x_{A13} \geq Con_{13}$

$$a(x_{1A} + x_{2A} + x_{3A} + x_{4A} + x_{5A} + x_{6A} + x_{7A} + x_{8A} + x_{9A})$$
$$- x_{A1} - x_{A2} - x_{A3} - x_{A4} - x_{A5} - x_{A6} - x_{A7} - x_{A8} - x_{A9}$$
$$- x_{A10} - x_{A11} - x_{A12} - x_{A13} \geq 0$$

Figure 56 presents the general equations for the simple case of locating only one plant and shipping directly from agricultural to plant to consumer region. The addition of two or more plant sites being optimized at the same time would greatly increase the number of equations. Due to the large number of equations, a problem could arise since the Simplex method becomes burdensome with large problems. However, methods do exist which will allow a large linear problem to be broken up into smaller problems.

Admittedly, the procedure followed when one plant site was optimized was a very simple case. In this case it was assumed that no interchange of products between consumer regions was possible. However, in reality, a product may be shipped from one city to another city with the carrier making stops in other cities in close proximity. The equations deemed necessary to simulate the above condition are presented below. Again only one plant site at a time was optimized.

TABLE 13

Producer Region	Plant	Consumer Region
1		6
2	5	7
3		8
4		9
		10

The possible combinations of travel used are listed below. The combinations are one-way combinations.

TABLE 14

From	To
5	6
5	7
5	8
5	9
5	10
6	7
6	8
6	9
6	10
7	8
7	9
7	10
8	9
8	10
9	10

Equations:

Let M_{ij} = mileage between i and j

x_{ij} = tons/day between i and j

R = a ratio which proportions the product to the cities under consideration. Example $x_{57} = R\ x_{76}$ where R is the ratio of the amount needed of x_{57} to the total of x_{57} and x_{76}

T = total demand

V = smallest amount to be produced at plant

W = capacity of plant

$$\text{Min } Z = M_{15}\ x_{15} + M_{25}\ x_{25} + M_{35}\ x_{35} + M_{45}\ x_{45} + M_{57}\ x_{57} + M_{76}\ x_{76} + M_{65}\ x_{65} + M_{59}\ x_{59} + M_{98}\ x_{98} + M_{87}\ x_{87} + M_{75}\ x_{75} + M_{59}\ x_{59} + M_{910}\ x_{910} + M_{107}\ x_{107} + M_{75}\ x_{75} + M_{56}\ x_{56} + M_{58}\ x_{58} + M_{510}\ x_{510}$$

Subject to:

$$x_{57} + x_{76} = T$$

$$x_{59} + x_{98} + x_{87} = T$$

$$x_{59} + x_{910} + x_{107} = T$$

$$x_{57} = R\ x_{76}$$

$$x_{59} = R\ x_{98}$$

$$x_{98} = R\ x_{87}$$

$$x_{59} = R\ x_{910}$$

$$x_{910} = R\ x_{107}$$

$$x_{56} = T$$

$$x_{58} = T$$

$$x_{510} = T$$

$$x_{15} + x_{25} + x_{35} + x_{45} - x_{56} - x_{57} - x_{58} - x_{59} - x_{510} = 0$$

$$V < x_{15} < W$$

$$V < x_{25} < W$$

$$V < x_{35} < W$$

$$V < x_{45} < W$$

As in the first case these are the very basic equations. More constraints should be added to adapt the linear problem to the area.

At the beginning of this research, the author hoped to relate ERTS data to the optimal site location program. Data collected from

ERTS photographs was used to locate agricultural and consumer regions. ERTS data was more useful when agricultural or forested areas were inventoried. However, the kinds of crops or trees in these areas could not be distinguished. Further classification of land into various crops or trees was a major if not insurmountable problem.

Because of the region to region interface, large areas need to be coded for land use using ERTS data. In this case the whole State of Alabama plus regions of adjoining states needed to be classified for lang use. The completion of this job proved to be too time consuming and was halted when about 30 percent of the area was coded.

During the final weeks of the ERTS project at the University of Alabama research will be directed toward locating new highways using ERTS data. If land use is coded using dominant land use cells, the location of a new highway could be determined that would minimize the cost of acquiring the land.

E. The Economics of Land Use Data Collection

1. Land Use Data Cost Approximations[28]

A fundamental land use classification study using ERTS, in part, simply provides an alternate method to the classification using SCS photography to reach the same objective. Use of high altitude airplane photography is a third alternative and composite sequential clustering methods for ERTS data constitute a fourth alternative. Coding of land use data by ERTS is essentially a repetition of the coding that has already been accomplished by other methods. Indeed, land use studies of large and small areas have been made for a long time, often on the ground, and all superterra studies are merely alternate approaches. Some benefits that did not come with older methods of land use study may be discovered and thus be subjected to cost-benefit analysis but these appear to be more likely in the geology, minerals and ground water phases of the present study, than in routine land use inventories.

Illustrated by the discovery of hitherto unknown lineaments, circular structures and any other structural features, and their implications for mineralization and water supply, we have both new discoveries and a possible new method of doing things that have been done by other methods before. It seems unlikely that any minerals will be discovered by ERTS methods but they may provide us with some new, more probable places in which to look. Minerals and water have been searched for in many ways in the past but they have generally been "gnats eye" views and now remote sensing provides a "birds eye" view.

So far as being an alternative method to ground exploration, ERTS is susceptible to cost-effectiveness analysis and as a new method, to cost-benefit analysis. Until actual discoveries are made, however, there appears to be no way to calculate cost-benefits. Only experience that gives measurable success from measurable efforts can serve as a basis for quantitative cost analysis.

Traditional land use studies involving maps, ground truth, etc., can be analyzed for cost-effectiveness. ERTS methods, even though they may not show exactly the same information or even as much of it, should be susceptible also. Only, however, if ERTS reveals facts important in land use that are <u>not</u> revealed at all, or as well, by the other methods, would comparative cost-benefit analyses be used.

In the mineral-water part of the study, one can begin to list possible benefits that may accrue from ERTS photography, but there appears to be no way to make a quantitative cost benefit analysis until some benefits have actually arrived.

The study of the geology and mineral resources of the State of Alabama has been carried on for more than a century and a half by many people using many methods. In 1845, Sir Charles Lyell, the most famous of the early English geologists, visited The University of Alabama and the State and wrote much about his observations. In 1847, the State began geological investigations when Michael Toumey, Professor of Geology at The University of Alabama, was instructed to spend four months studying the geology of the State. The next year he was appointed the first State Geologist and began the first geological survey of the State. Until recent years, all geological study was conducted at or from the surface by foot, buggy or automobile reconnaissance, mapping, sample collecting, and study of underground mine works. Only in recent years were indirect methods of geophysical or geochemical traverses and aerial and satellite photographic studies introduced.

At least four direct methods of study are now available for obtaining surface information on the geology and mineral (including groundwater) resources of the State. Allowing for some possible overlap or arbitrary distinctions, they are:

1. Surface reconnaissance. To this method is easily added some drilling, sampling, inspection of accessible mine workings and geophysical or geochemical traverses.
2. Low level photography. The altitude from which photographs are made usually are in the range 12,000-12,500 feet (3658

to 3810 meters). Photographs resulting from these flights are usually on a 1,000 to 2,000 feet per inch (305 to 610 km per inch) scale.

3. High altitude (U-2) photography is usually done from altitudes of 60,000-65,000 feet (18,900-19,800 meters). Some of these photographs are on a scale of 1:60,000 or 5,000 feet (1524 meters) to the inch.

4. Earth Resources Technology Satellite (ERTS) photographs from 560 miles out in space are repeated in any given area every 18 days. Photographs in four separate electromagnetic spectral ranges are made simultaneously. The 9" x 9" transparencies and photographs commonly furnished for study are on a scale of about 1:1,000,000 or about 15.73 miles (9.9 km) per inch.

It will be noted that these four methods of obtaining information, as listed, are progressively remote from the surface and therefore features shown on them are on a progressively smaller scale.

Each method also has its advantages and disadvantages. Method 1, for example, is readily and almost simultaneously augmented by useful auxiliary methods such as sampling for laboratory study, drilling and sampling of unexposed material and various geophysical and geochemical surveys. This is not possible with the three photographic methods. Because of its great surface resolution, observations such as the distribution of types of vegetation indicative of certain underlying conditions (i.e., cedar trees on limestone befrock) or the exact dip angle of rock strata, are more difficult or impossible to get from photographs. A disadvantage is, however, that so much detail is seen that gross integrating features such as long, cross-country lineaments, may be missed entirely.

Another great disadvantage of surface work is a long time frame and great expense per unit of time or of area covered.

Photographic methods have the advantage of a birds-eye view rather than a gnats eye view or, in a more classical analogy, on the ground we see only the trees but above it we can see the woods. By using special ranges in the electromagnetic spectrum, photography can pick up things often more difficult to detect on the ground such as hot spots on coal refuse banks, otherwise undiscovered warm water flows, or even the "spectral signatures" of certain types or growth stages of vegetation for estimating probable productivity of field crops. Certain rock outcrops, lava flows, or aquifers may even prove to have "spectral signatures".

Gross geological features that are observed on the surface may show up well in superterra photographs. Low level photography of Alabama be the Soil Conservation Service, for example, shows by means of stream valley alignment, probable NW-SE fault in T6S R10, NE, Dekalb and Cherokee counties, Alabama. Much longer and more diffuse lineaments appear in an Apollo 9 photograph of an area south of Jackson, Dekalb and Cherokee counties and are quite evident on ERTS photographs. One of the lineaments seems to extend more than 100 miles into Tennessee. Structural features such as lava flows, eroded astroblemes and domes may also be seen from remote distances.

When it comes to third dimensional features such as heights of hills, bluffs and stripmine highwalls, photographic methods are poor unless there is stereoscopic coverage.

Comparing the four methods and their costs is obviously somewhat like comparing the merits of apples, oranges and peaches as a fruit. Table XV shows comparable cost figures obtained for certain projects of different magnitudes and with somewhat different objectives and cost factors. As they stand they are hardly comparable but will serve as a starting point.

The high and low altitude photography costs given are only for the flights and delivery of the photographs. To be useful in mineral evaluation work, someone must carefully study all photographs, along with other existing geological data and make interpretations. This cost will be mostly in salaries of personnel and will depend on the type and grade of personnel used. Such study certainly adds to the costs shown in Table XV.

The ERTS costs shown are for a land use study of a 13-county area, including Montgomery, and was limited to manpower costs. For a mineral resource study, more time may be required and possibly at higher salaries for personnel. A tripling of the cost shown in Table XV would bring the cost per square kilometer to only one cent.

The most striking feature of the table is the very evident reduction of unit cost per area covered with increase in distance from earth. The ratio of the distances, with the surface as unity, run about 1:12,500: 65,000:3,000,000 while the ratio of costs are only about 33,550:2,030:120:1.

There are some large flaws in the figures of Table XV. It is seldom that a reconnaissance geological map must be made "from scratch". There

TABLE 15

Method	Gross Cost, $	Unit Cost, $		Adjusted Unit Cost
		mi^2	km^2	km^2
1. Making a reconnaissance geological map of an Ala. Co., including some drilling sampling and analysis(1)	25,000 per county	33.03	12.75	12.75
1A. Same for a larger or more geographically complex county(2)	40,000 per county	40.00	15.44	-
2. Low altitude photographs of a 75 mi^2 urban area(3)	1,500	20.00	7.72	11.04
3. Quotation for high altitude photograph for Alabama(4)	60,000	1.18	0.457	4.03
4. ERTS photography of Montgomery, Ala., area for land inventory(5)	130	0.00984	0.0038	0.38

Table Footnotes

(1) This is for an "average" Alabama county of 757 square miles (1960 km^2) area and an approximate median cost in a $15,000 to $40,000 range.

(2) A large county (1,000 mi^2) at maximum cost.

(3) City of Tuscaloosa photographed by a commercial aerial photographic company.

(4) Communication, Dr. George Whittle, ERTS Contract NAS5-21876.

(5) Mr. R. Paul Wilms, Fifth Bi-Monthly Project Report, June 7 - August 6, 1973, Contract NAS5-21876, page 9.

is always a large body of available geological knowledge to study in any county or district and usually some regional or district maps are available. The assessment of the mineral potential or any county or region may require more study and correlation of old data than of new.

In the last column of the table are some adjusted costs to include reproduction and personnel. Assuming that the 25,000 low altitude photographs of an average Alabama county (757 mi^2 or 1960 km^2) would require the equivalent of one \$18,000 per year geologist, working six months, \$9,000 would be added to the cost. Making this \$10,000 seems reasonable and would add \$5.10/km^2 to the unit cost.

High altitude photography would require study, in the same area, of only about 1,000 photographs. The time would not be reduced quite proportionally because each photograph, covering a larger area, would require more time. Four months would be \$6,000 for salary. Using \$6,500, the cost per km^2 would be 3.32.

One county may be split between two ERTS photographs but as about 10 photographs cover the entire state, there are an average of 6.7 counties per photograph. Assuming about one-half month equivalent time, would give \$750 or \$0.38/km^2. The ratios of the adjusted costs in Table XV are 33.6:29.1:10.6:1.

If all four methods of Table XV yielded exactly the same quantity and quality of data, then the indicated adjusted costs should be comparable. As has been indicated, this is not true. All the remote sensing methods must have added to their interpretations some subsurface and surface work before they can be verified in terms of actual mineral deposits. This is true, to a lesser extent, even of reconnaissance geological mapping.

The problem becomes one of assigning to each method the proper probabilities for indicating the presence of mineral deposits. In the absence of any scheme of evaluation parameters, all methods probably will continue to be used with emphasis on what each apparently does best in the hope that a minimum cost combination will eventually be found.

About all that can be done now, toward cost-benefit analysis, is to list possible benefits. With regard to ERTS photography some of these may be:

1. Because of its ability to pick up large geological features, some originating from large-scale tectonics or ancient extra-terrestrial events, ERTS photography may indicate new metal-logenic provinces or probable extensions of known ones. Discovery of these possible provinces would require much time and enormous expense by traditional methods.
2. ERTS and other remotely sensed data that serve the search for mineral concentrations also serve many other human activities, thus, if new metallogenic provinces are found by traditional methods, virtually all the cost is chargeable to the minerals industry. Remotely sensed data are used for weather prediction, field crop evaluation, land use study, national security sur-veillance and many other activities that share the cost.
3. Remote sensing methods may detect structural features that indicate possible traps for water or petroleum fluids.
4. Although not yet well developed, "spectral signatures" may be worked out for detecting certain rock outcrops, including

moist strata; mine refuse and spoil banks, permafrost areas, etc. ERTS resolution does not appear to be sufficiently great for monitoring surface mining activity, as yet.

Less general cost estimates on mineral resource investigations may be shown in another part of this report.

2. Costs of Monitoring Strip Mine Reclamation[29]

A study was conducted to determine the feasibility of using ERTS-I imagery to survey and monitor stripmine reclamation by (a) visual and graphical techniques and (b) by the use of computer mapping. This report will be concerned only with the use of visual and graphical techniques to identify the various parameters sought in this investigation.

The study areas selected were three stripmines, two of which are inactive, each displaying a varying amount and time in the reclamation process. The study areas were first visually assessed by the author and recorded on photographs. Secondly, the same areas were carefully examined on U-2 infrared photography, using the same parameters, and lastly, ERTS-I imagery was examined for identification of the same parameters.

The summary of results has been tabulated in Table 16. Each parameter was evaluated as good, fair, or poor as monitored through a particular system. A rating system was developed for system evaluation. This system rates "good" as three points, "fair" as two points and "poor" as one point. By knowing the number of parameters, a system may be rated by the following formula:

TABLE 16

Summary of Results

Number of Parameters	Visual Parameter Surveyed	Monitored by 65000' Infrared Photography				Monitored by ERTS-I Imagery			
		G	F	P	U	G	F	P	U
1.	Area Topography	✓					✓		
2.	General Mine Topography	✓						✓	
3.	Highwall Condition		✓						✓
4.	Spoil Pile Dimensions		✓						✓
5.	General Vegetation		✓					✓	
6.	Tree Types		✓					✓	
7.	Grasses			✓				✓	
8.	Aga of Tree Growth		✓					✓	
9.	Soil Condition			✓					✓
10.	Water Quality		✓						✓
11.	Drainage Alterations	✓							✓
12.	Total Mined Area	✓						✓	
13.	Advancing Faces	✓						✓	
	QUALITATIVE POINTS PER COLUMN	3	2	1	0	3	2	1	0
	TOTAL EVALUATION POINTS PER COLUMN	15	6	2	0	0	2	7	0

G - Good

F - Fair

P - Poor

U - Undetermined (Generally insufficient definition in image to identify parameter).

$$\theta = \left[\frac{3G + 2F + P}{3N}\right] 100\% + \sigma$$

where, θ = System efficiency

G = Number of parameters rated "good"

F = Number of parameters rated "fair"

P = Number of parameters rated "poor"

N = Total number of parameters

σ = Enhancement factor

For the 65,000' U-2 infrared system,

$$\theta = \left[\frac{3G + 2F + P}{3N}\right] 100\% + \sigma$$

$$\theta = \left[\frac{3(5) + 2(6) + 2}{39}\right] 100\% + 15\%$$

$$\theta = 89.5\%$$

For the ERTS-I system,

$$\theta = \left[\frac{3G + 2F + P}{3N}\right] 100\% + \sigma$$

$$\theta = \left[\frac{3(0) + 2(1) + 7}{39}\right] 100\% + 15\% = 38\%$$

A cost effeetive analysis was made for ground observation, U-2 high altitude data, and ERTS-I data. The three systems are explained in the following paragraphs.

The first system that was analyzed is the one that is currently used, although not all of the stripmined land is surveyed each year. Costs on foot were as follows: transportation, gas, vehicle costs, and personnel costs including inspection time, office and driving time. In addition, visual aid costs were estimated for general use.

The result was a cost of \$0.575 per acre to visually look at each acre of stripmined land.

A high-altitude system was evaluated for a "per acre" cost. The general costs included: airplane rental, film development and processing, film costs, office equipment, engineer costs, office costs and miscellaneous. The total cost was \$0.43 per acre. However, when we divide the cost per acre by the system efficiency we get,

\$0.43 /0.895 = \$0.48 per acre for the cost for system equivalent.

Lastly, an attempt was made to evaluate the cost to use ERTS-I imagery for monitoring stripmine reclamation. An estimation for engineering office time, support information, film cost with processing, visual aids and miscellaneous costs. The result was a cost of \$0.91 per acre. Then, \$0.91 divided by the system efficiency yields:

\$0.91 /0.38 = \$2.40 per acre for system equivalent.

In summary, the ERTS-I system is not as efficient as the high altitude photography as applied to surveying stripmine reclamation. In addition, the ERTS-I system is five times more expensive to operate for the same equivalent system performance as high altitude photography. It should be noted that all the calculations are based on a per acre of stripmined area in that year.

3. Land-Use Compilation Comparison of Air Photo Mosaics and ERTS[30]

Nineteen counties were coded for one dominant land use study using ERTS-I imagery. These counties total 33,911 km^2 or about 25.06 percent of the total area of Alabama. This information was compared to the historic data base to detect change and land-use trends and will ultimately be used to update the historic data file.

A preliminary cost evaluation of gathering land-use data from ERTS-I imagery was obtained by comparing the process to that used in collecting historic land use from conventional air photo mosaics. The results are shown below:

	Historic	ERTS
Grid Registration (hrs)	19.00	4.00
Coding Process (hrs)	282.59	28.50
Total (hrs)	301.59	32.50
Labor Rate ($/hr)	4.00	4.00
Total Cost ($)	1,206.36	130.00
Cost Per Cell (cents)	3.6	0.38
Cost Ratio	9.5	1.0

This analysis does not, of course, take into consideration the cost and depreciation of equipment or the relative detail afforded by the two methods. It is obvious that the historic data base renders a much more detailed survey of the area, but the timeliness of ERTS data, along with its relatively small cost, may prove it to be of greater value than the historic data.

With both the historic and the ERTS-derived data bases in computer format, it is a relatively simple procedure to compare the two internally for the purpose of generating a land-use change map for any of the six primary land-use categories. Figure 58 illustrates an urban change map for Montgomery County, Alabama. Each character in the printout represents one square kilometer. The following symbols were used to denote land use change:

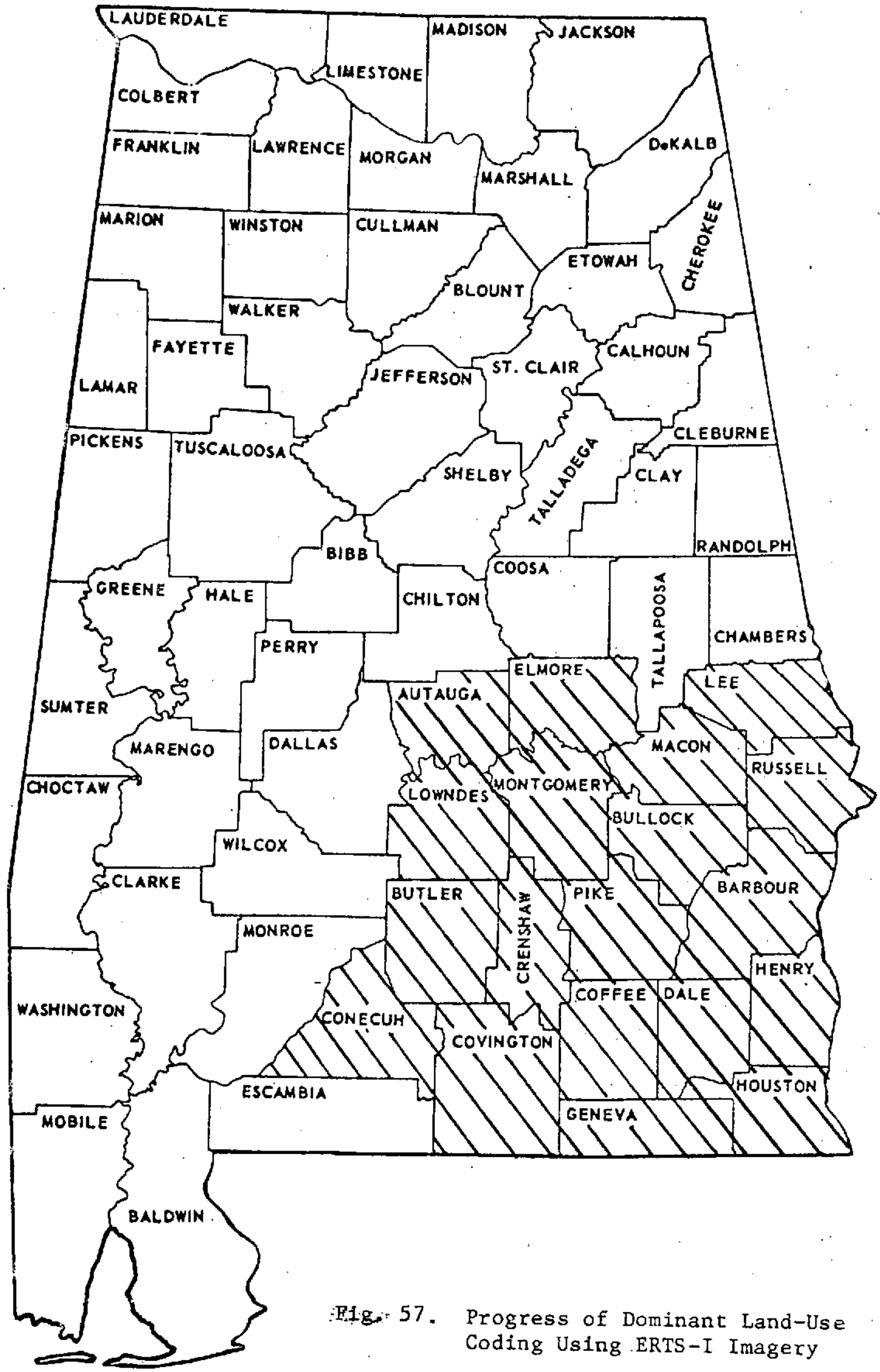


Fig. 57. Progress of Dominant Land-Use Coding Using ERTS-I Imagery

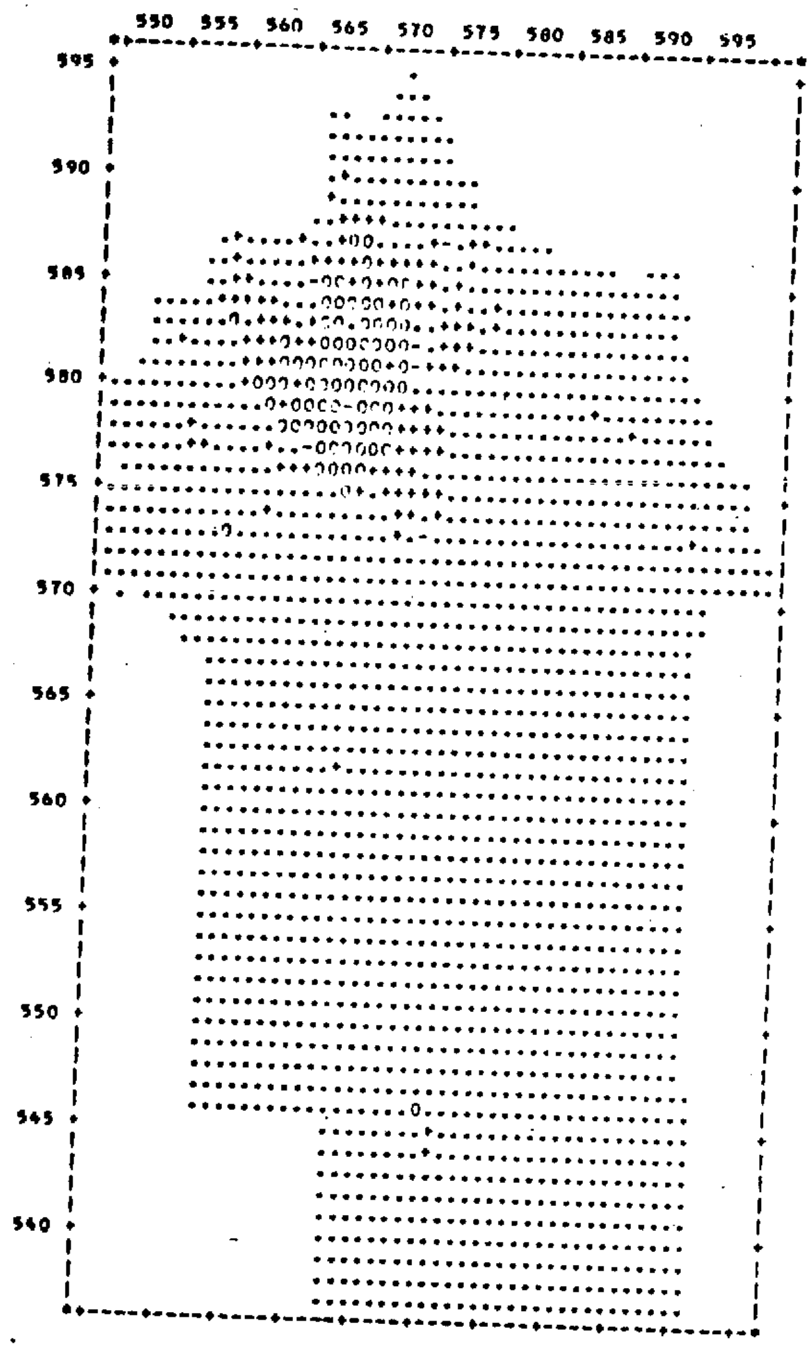


Fig. 58. Urban Change Map of Montgomery County, Alabama.

Symbol	Urban in Historic Data	Urban in ERTS Data
•	no	no
0	yes	yes
+	no	yes
–	yes	no

Since urban land use is, in most cases, the most dynamic of the seven and growth in urban areas is indicative of a sound economy, regional planners and policy makers must be cognizant of what changes are taking place and of apparent trends in land use development. The urban change maps of the 19 county target study area were combined in mosaic form and analyzed for the purpose of detecting trends in urban development.

IV. USER SERVICES

A. Inventory of Possible User

The potential users of ERTS data are many and work in various professional areas. An alphabetical listing of potential users in Alabama can be found in reference 31.

B. Conference Activities[32]

Between March 13 and April 24, 1973, four public seminars were held on remote sensing applications with special emphasis on ERTS applications. Invitations were mailed to about 200 University of Alabama faculty, geologists, regional development office directors, Alabama Development Office personnel, Judges of Probate in the state and other potentially interested citizens. All papers programmed were delivered except for one in the last seminar which was omitted for lack of time.

Attendance varied from a dozen to more than 30.

Following are the announcements of the four seminars and the program of the first one. Appended also are the programs of the last three seminars. The March 20 and April 17 dates were omitted so that the series covered a six weeks period.

Announcing

REMOTE SENSING

With Emphasis on the Earth Resources Technology Satellite

Room 337 H. M. Comer Hall (Min. Ind. Bldg.)
University of Alabama
March 13, 1973
2:00-4:00 p.m.

For all workers with, potential users of, and citizens interested in remotely sensed data from satellites and aircraft.

PROGRAM

"Types of Imagery and Applications to Earth Resources" - Mr. C. T. N. Paludan, Environmental Applications Office, Marshall Space Flight Center.

"Land Use Inventory, Regional Planning and Resource Management" - Mr. Ed. Hudspeth, Alabama Development Office, Montgomery, Alabama.

"Interests of the Corps of Engineers" - Lt. Col. Terrance Connell, Deputy District Engineer, Mobile District, Corps of Engineers, U. S. Army.

There will be an informal time of discussion and refreshments after the formal talks. During this time there will be an opportunity to view ERTS photographic products for Alabama and to ask individual questions.

The preceeding seminar program is one of four planned for this Spring. Tentative subjects for the other three seminars are:

March 27: METHODS FOR OBJECTIVE ANALYSIS OF ERTS DATA AND SOME ECONOMIC AND SOCIAL PROBLEM APPLICATIONS

"Computer Techniques and Capabilities" -

"Some Special Studies in Land Use Inventory, Regional Planning and Resource Management" -

April 10: GEOLOGICAL APPLICATIONS OF ERTS DATA

"Possible Re-interpretation of Some Geological Features Based Upon Earth Imagery" -

"Utilization of Remote Sensing Imagery as a Tool for Interpretation of Geological Structure and Mineralization in Alabama" -

April 24: APPLICATIONS OF ERTS AND OTHER REMOTE SENSING DATA TO ENVIRONMENTAL PROBLEMS OF POLLUTION DETECTION, WATER QUALITY AND LAND DISTURBANCE.

"Pollution Detection and Water Quality" -

"Land Disturbance" -

PROGRAM

April 24, 1974

APPLICATIONS OF ERTS AND OTHER REMOTE SENSING DATA TO ENVIRONMENTAL PROBLEMS OF POLLUTION DETECTION, WATER QUALITY AND LAND DISTURBANCE.

1. "Pollution Detection and Water Quality" - Dr. George P. Whittle, Department of Civil and Mineral Engineering, University of Alabama, and C. Lamar Larrimore, Graduate Student in the Department.

2. "Possibilities for Monitoring Strip Mining and Other Land Disturbances" - Professor Reynold Q. Shotts, Department of Civil and Mineral Engineering, University of Alabama.

3. "Digital Processing of ERTS Data" - Robert Cummings, Environmental Applications Office, Marshall Space Flight Center.

There will be an informal time of discussion and refreshments after the formal talks. During this time there will be an opportunity to view ERTS photographic products for Alabama and to ask individual questions.

This seminar program is one of four planned for this Spring. Other subjects covered by the seminars were land-use planning, computer techniques, resource planning, interpretation of geologic structure and mineralization, and resource management.

PROGRAM

March 27: METHODS FOR OBJECTIVE ANALYSIS OF ERTS DATA AND SOME ECONOMIC AND SOCIAL PROBLEM APPLICATIONS

"Computer Techniques and Capabilities in Land-Use Mapping."- Dr. E. T. Miller, Professor of Civil Engineering, The University of Alabama.

"Some Special Studies in Land Use Inventory, Regional Planning and Resource Management." - Mr. Dean Matthews, Director, Top of Alabama, Regional Council of Governments (TARCOG), Huntsville, Alabama, and Mr. Paul Wilms, Graduate Student, The University of Alabama.

There will be an informal time of discussion and refreshments after the formal talks. During this time there will be an opportunity to view ERTS photographic products for Alabama and to ask individual questions.

The preceeding seminar program is one of four planned for this Spring. Tentative subjects for the other seminars are:

PROGRAM

April 10: GEOLOGICAL APPLICATIONS OF ERTS DATA

"Change Detection in Mobile Bay" - Charles D. Weilchowsky and Jacque Emplaincourt.

"The Structural Significance of Multispectral Apollo 9 Photographs to Appalachian Tectonics" - James A. Drahovzal.

There will be an informal time of discussion and refreshments after the formal talks. During this time there will be an opportunity to view ERTS photographic products for Alabama and to ask individual question.

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ENVIRONMENTAL, HYDROLOGY, WATER RESOURCES

George P. Whittle

SECTION TWO

of

VOLUME ONE

INVESTIGATIONS USING DATA IN

ALABAMA FROM ERTS-A

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ENVIRONMENTAL, HYDROLOGY, WATER RESOURCES STUDIES

Introduction

The Alabama ERTS project had at its disposal a number of data collection platforms (DCPs) designed and constructed at the Marshall Space Flight Center to monitor certain critical water quality parameters. A total of seven DCPs were made available to the entire ERTS project. Two of the supplied DCPs were utilized in an estuary study conducted in Mobile Bay, Alabama, while the remaining five DCPs were utilized in a study of a fresh-water river system. This report is concerned with the fresh-water river system involving a segment of the Black Warrior River located in west-central Alabama. The Mobile Bay study is reported in a following section of this volume.

The DCPs employed in the river system were designed to contain a total of eight sensors. Four water sensors were installed: (1) dissolved oxygen, (2) pH, (3) conductivity, and (4) temperature. Two additional sensors were installed to monitor the percent charge on the two rechargeable batteries and two spaces were left blank with no sensors. The DCPs employed in Mobile Bay were different in design and capability from those employed in the river system study. A description of these platforms will be found in the Marine Science report.

Purpose of Environmental Study

The primary purposes of this study are:

1. To study and possibly demonstrate the feasibility of applying remotely sensed, space-acquired water quality data to the management of water resources in Alabama.
2. To identify and educate users with regard to the potential benefits to be derived from space-acquired data.
3. To interpret and disseminate on a timely basis beneficial information to ultimate users, especially policy makers and regulatory agencies.
4. To determine if use of the DCP remotely sensed data concept results in a significant improvement on a quality, quantity, or economic basis of the user's decision making ability and actions related to management of environmental quality.

Description of the DCP System

The instrumentation used in the DCPs for monitoring water quality, while in some respects similar to conventional instrumentation, embodies some innovative features in its design and construction. Figure 1 shows a schematic diagram of a DCP employed in this study. Its primary components consist of the radio transmitter, rechargeable batteries and calibration instrumentation inside the upper housing, the antenna located on top of the housing, and the sensors which are included in the lower extremity of the DCP. The DCPs were installed in the river by attachment either to a metal pole which had been driven securely into

PRIMARY COMPONENTS:

1 - Metal Pole (support)

2 - Sliding Fastener

3 - Housing for Analyzer Unit, Battery, and Electronic Unit

4 - Antenna

5 - Connector from Sensor to Analyzer Unit in Housing

6 - Quick Release Pin

7 - Sensor

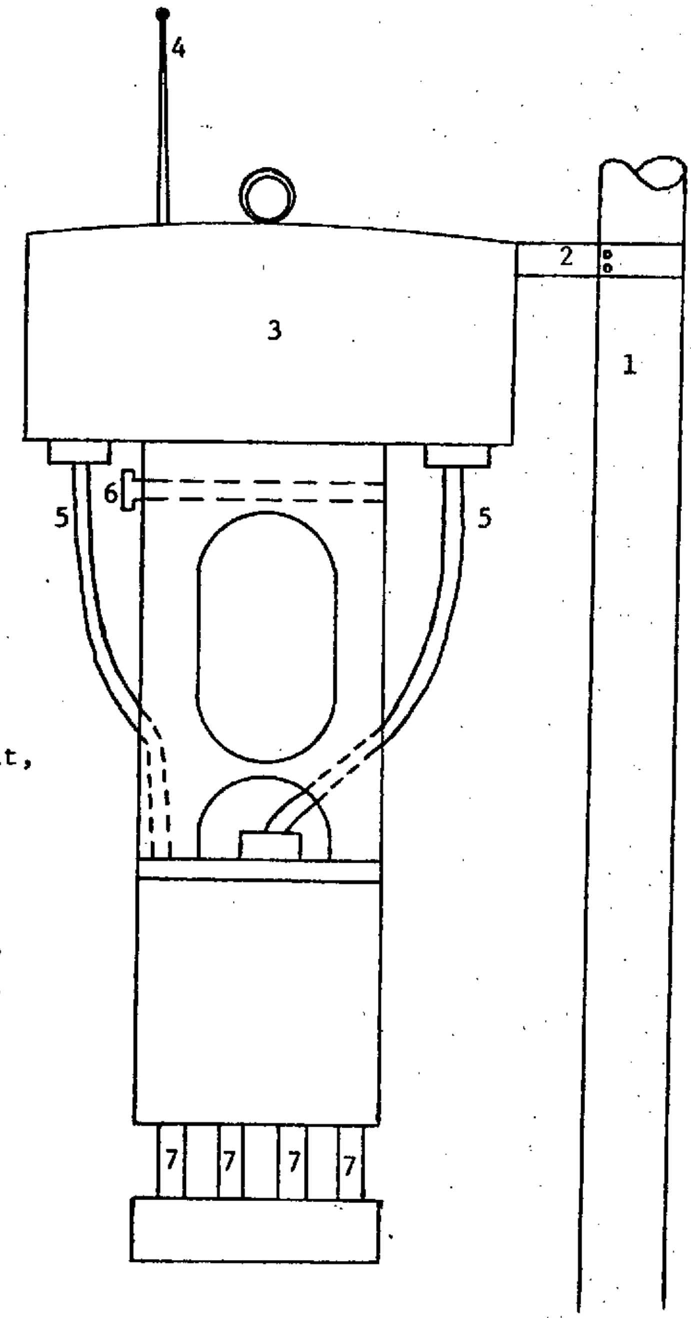

Fig. 1. ERTS Data Collection Platform

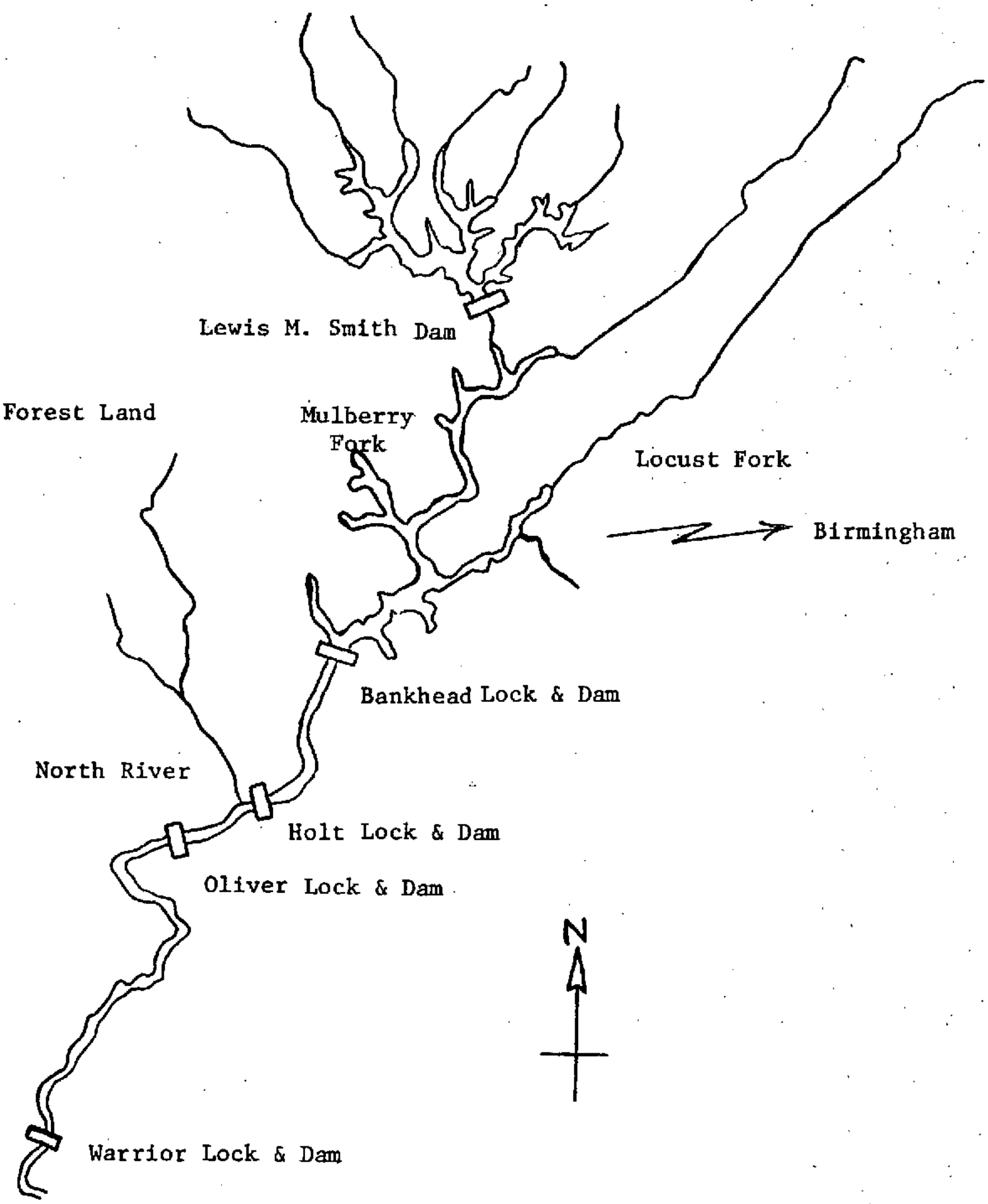

Fig. 2. The Black Warrior River Basin

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polluted water conditions in the highly industrialized area between Holt and Oliver dams as shown in Figure 3. In addition, both Bankhead and Holt dams have hydroelectric power generating units as well as locks for barge traffic which represent diversified demands upon the available water resources.

In order to monitor a water basin in an effective manner, it was necessary that the locations of the DCPs be selected such that measurements of water quality would yield the most useful data for management of water resources. To aid in selecting locations, Mr. Charles Lamar Larrimore, a graduate student and trainee on an Environmental Protection Agency grant, undertook as part of his thesis[1] the selection of the most useful locations for data collection platforms. Selection of these locations was based primarily on the parameter of dissolved oxygen since this is one of the most important parameters employed to characterize water quality. In the selection process, several locations were found where critically low concentrations of dissolved oxygen usually occurred. To test the utility of these locations in water basin management, a mathematical model was proposed in which the data input from these locations could be used to predict water quality over the entire reach of the river studied. Application of the model utilizing historic data yielded, in most cases, agreement within 10 percent of predicted values with the observed values. Data collected by DCPs at these locations would serve not only to monitor areas of critical dissolved oxygen concentrations but would also be employed in the prediction of water quality within the basin system. Using DCP data as input, the mathematical model would serve to predict allowable waste discharges

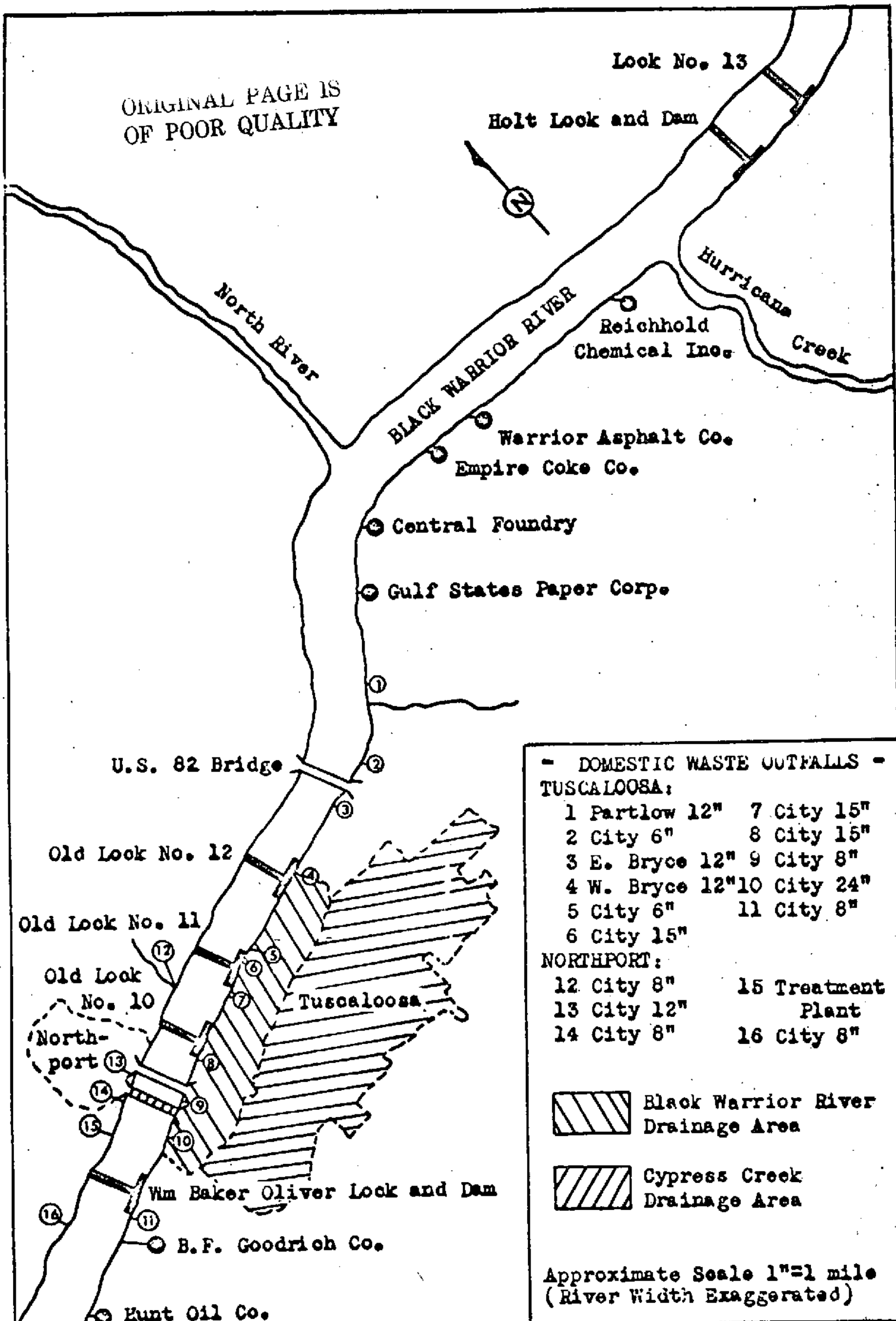

Fig. 3. Industrialized Area of Warrior River Between Holt and Oliver Lock and Dam.

such that water quality standards set by the Alabama Water Improvement Commission would be maintained.

The locations selected and dates of installation for the DCPs, as well as the locations of conventional boat sampling stations, are presented and discussed under the next subheading.

Cooperative Study-Conventional Boat Sampling and DCP Program

During the period in which the DCPs were being installed and remote-sensing initiated, several local industries vitally concerned with water quality formed a consortium and contracted with The University of Alabama to conduct a conventional boat survey of a segment of the Warrior River. These industries were shown on the previously presented Figure 3 and their approximate river mile locations are given in Table 1 below.

TABLE 1

CONSORTIUM OF LOCAL INDUSTRIES

Industry	Warrior River Mile Location
Reichhold Chemicals, Inc.	345.7
Warrior Asphalt Corp.	344.4
Empire Coke Co.	344.2
Central Foundry Co.	343.5
Gulf States Paper Corp.	342.7

A portion of the funds provided by the industrial consortium was used to purchase a suitable sampling boat. The boat purchased was a twin-pontoon, platform boat approximately 24 feet long by eight feet wide equipped with a 70 hp outboard motor. The DCP program was presented to the industrial consortium and, as a result, a cooperative venture evolved in which the sampling boat was employed for both conventional sampling and installation and serving operations for the DCPs. Correspondingly, the boat was outfitted to allow the performance of these dual functions.

A total of eight stations were selected for conventional sampling on the basis of two to three times per week. Four of the conventionally determined quality parameters were identical to those monitored by the DCPs, namely: dissolved oxygen, pH, conductivity, and temperature. In addition, a biochemical oxygen demand (BOD) sample was obtained and analyzed on a weekly basis for each of the conventional sampling locations.

Table 2 shows the river mile locations of the conventional stations and, for comparison, the river mile locations and dates of installation of the DCPs are also given. These locations are also noted on a map of the river basin shown in Figure 4.

The conventional boat survey was conducted during the period July 23 to November 1, 1973. The dual survey program together with the close proximity of several conventional sampling and DCP locations afforded an excellent opportunity for a comparison of the two monitoring techniques.

Data Collection

The transmission of water quality data was accomplished almost immediately after the installation date for each DCP listed in Table 2. The data punched on computer cards were received from the ground receiving station at Goddard, Maryland from four to eight days after data transmission from the DCP. The data was stored in the University

TABLE 2

LOCATIONS OF DATA COLLECTION PLATFORMS AND CONVENTIONAL

SAMPLING STATIONS IN WARRIOR RIVER

NASA DCP or Conventional Station Designation	Location R.M.	Installation or Initial Sampling Date	Location Description	Parameters Measured at All Stations
6224	385.0	5/13/73	Confluence of Locust and Mulberry Forks	Dissolved Oxygen, Temperature, Conductivity, pH. Measured at 5 ft. depth by DCPs and at 5 ft. and multiples of 10 ft. to bottom by conventional sampling. Conventional BOD at 5 ft. depth.
F	364.5	7/23/73	Lower End of Rock Quarry	
6060	364.0	6/27/73	Below Bankhead Lock & Dam	
B	354.1	7/23/73	Above Bluff Creek	
1	347.1	7/23/73	Old Lock 13	
6357	346.5	8/7/73	Below Holt Lock and Dam	
3	346.3	7/23/73	Above Hurricane Creek	
4	344.6	7/23/73	Warrior Asphalt Dock	
5	342.9	7/23/73	E-Z Kraft Dock at Gulf State Paper Corp.	
6	341.4	7/23/73	Below Finnell Bridge	
SD	338.5	7/23/73	State Docks	
6061	338.2	8/30/73	Above Oliver Lock and Dam	
6323	335.0	10/12/73	Below Oliver Lock and Dam	

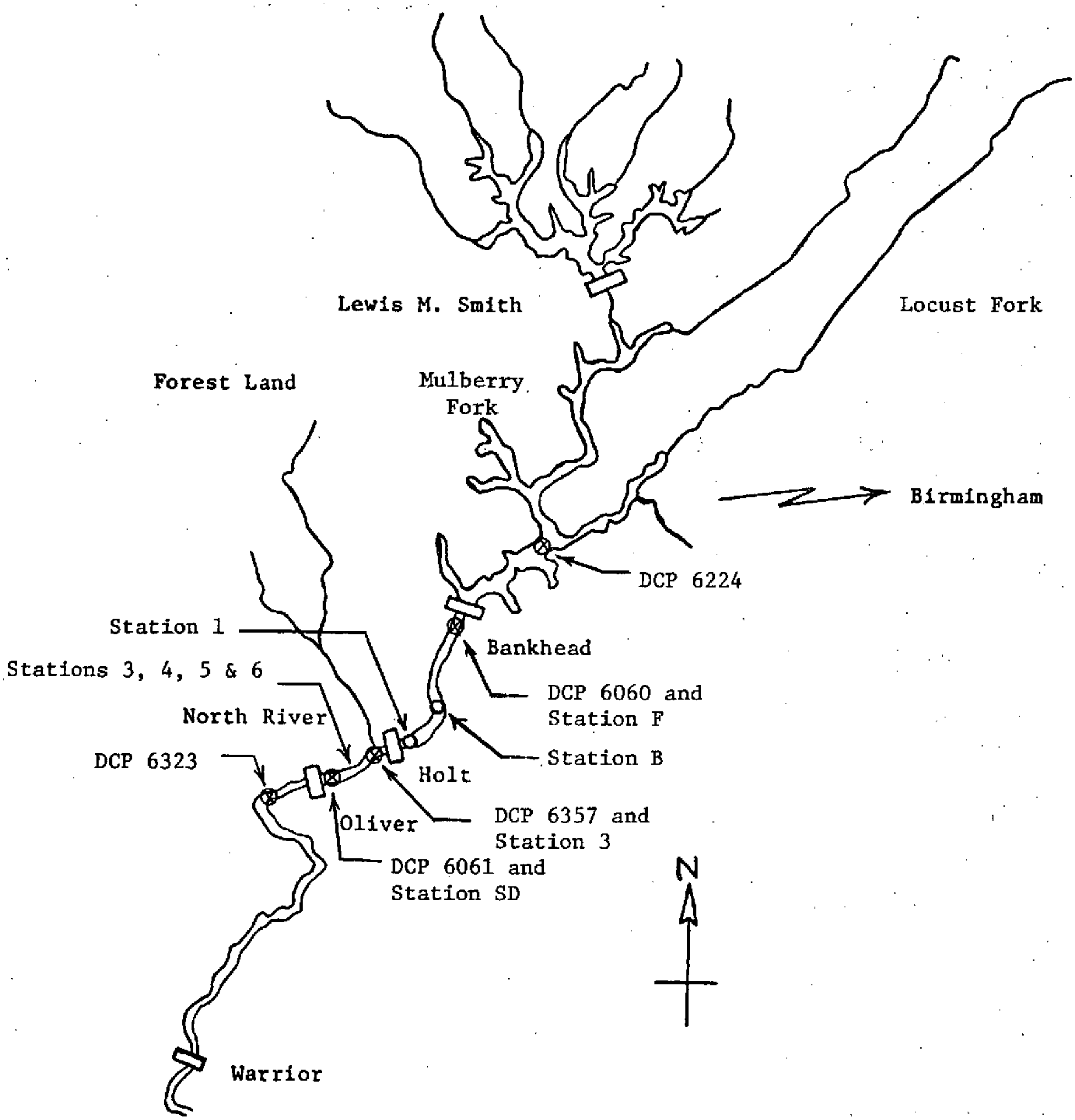

Fig. 4. The Black Warrior River Basin Showing Locations of DCPs and Conventional Sampling Stations.

computer in a format specially designed for storage of water quality data. Computer programs were prepared for recall and display of the water quality data in tabular or graphical form. Examples of the tabulated and graphed data in computer formats are shown in Table 3 and Figure 5, respectively.

Data were transmitted and collected for the period May 25, 1973 to December 26, 1973. During this period, approximately 18,896 transmissions of water quality data excluding the battery percent-charge data, were obtained from all of the five DCPs. For a specific DCP, two to four transmissions approximately three minutes apart from each of the sensors constituted a data point. Since one water quality data point is represented by an average of three transmissions within a 6 to 12 minute time period, the 18,896 total transmissions represent approximately 6,298 separate water quality measurements.

Employing the ERTS orbital data for this section of Alabama, a timer on board the DCP was set to activate the sensors approximately twenty minutes before an orbital overpass. The sensors were activated for a three-hour period and deactivated for a nine-hour period. Normally, two data points were transmitted during the three-hour period approximately 104 minutes apart due to the satellite completing two orbits during this time period. The cycle for the sensors of three hours on and nine hours off was maintained until, on a subsequent servicing run, the timer was adjusted to compensate for satellite orbital changes. Since service runs were not made at the same times on all DCPs, the transmission times varied for all DCPs.

TABLE 3

TYPICAL COMPUTER PRINTOUT OF DCP DATA

PLATFORM	DATE	TIME	SENSOR(1)	SENSOR(2)	SENSOR(3)	SENSOR(4)	SENSOR(5)	SENSOR(6)	SENSOR(7)	SENSOR(8)
			DO	CONDUCTIVITY	PH	TEMP	PCT.CHG.	PCT.CHG.		
G 6060	SEP 15,'73	23:12:46 CDT	4.666	180.39	6.705	27.156	80.39	61.17	0	0
G 6060	SEP 15,'73	23:15:54 CDT	4.588	180.39	6.705	27.352	80.39	61.17	0	0
N 6060	SEP 16,'73	10:06:14 CDT	4.235	180.39	6.627	26.764	80.39	61.17	0	0
N 6060	SEP 16,'73	10:09:23 CDT	4.784	180.39	6.627	26.764	80.39	61.17	0	0
G 6060	SEP 16,'73	11:46:52 CDT	4.470	180.39	6.627	26.960	80.39	61.17	0	0
N 6060	SEP 16,'73	11:46:52 CDT	4.470	180.39	6.627	26.960	80.39	61.17	0	0
G 6060	SEP 16,'73	11:50:01 CDT	4.352	180.39	6.666	26.960	80.39	61.17	0	0
N 6060	SEP 16,'73	11:50:01 CDT	4.352	180.39	6.666	26.960	80.39	61.17	0	0
N 6060	SEP 16,'73	21:35:18 CDT	4.823	207.84	7.098	26.960	80.39	61.17	0	0
N 6060	SEP 16,'73	21:41:26 CDT	4.901	207.84	7.098	27.156	80.39	61.17	0	0
N 6060	SEP 16,'73	21:44:34 CDT	5.725	207.84	7.176	27.156	80.39	61.17	0	0
G 6060	SEP 16,'73	23:18:41 CDT	4.941	207.84	7.176	26.960	80.39	61.17	0	0
G 6060	SEP 16,'73	23:21:49 CDT	4.745	203.92	7.137	26.960	80.39	61.17	0	0
N 6060	SEP 17,'73	10:12:41 CDT	4.980	203.92	7.137	26.960	80.39	61.17	0	0
N 6060	SEP 17,'73	10:15:50 CDT	4.941	203.92	7.098	26.960	80.39	61.17	0	0
N 6060	SEP 17,'73	21:43:55 CDT	4.470	196.07	7.098	26.764	80.39	61.17	0	0
N 6060	SEP 17,'73	21:47:04 CDT	4.235	196.07	7.098	26.960	80.39	61.17	0	0
N 6060	SEP 17,'73	21:50:13 CDT	4.039	196.07	7.098	26.764	80.39	61.17	0	0
G 6060	SEP 17,'73	23:24:37 CDT	4.745	196.07	7.137	26.764	80.39	61.17	0	0
N 6060	SEP 18,'73	10:18:40 CDT	4.705	152.94	6.862	26.176	85.09	63.92	0	0
N 6060	SEP 18,'73	10:21:55 CDT	4.352	141.17	6.823	26.176	85.09	63.92	0	0
N 6060	SEP 18,'73	21:49:08 CDT	3.999	121.56	6.941	26.176	84.70	63.52	0	0
N 6060	SEP 18,'73	21:52:17 CDT	3.999	125.49	6.941	26.176	84.70	63.52	0	0
N 6060	SEP 18,'73	21:55:27 CDT	4.039	125.49	6.941	26.176	84.70	63.52	0	0
N 6060	SEP 19,'73	10:22:17 CDT	3.843	172.54	6.941	25.588	84.70	63.52	0	0
N 6060	SEP 19,'73	10:25:27 CDT	3.882	172.54	6.941	25.588	84.70	63.52	0	0
N 6060	SEP 19,'73	21:53:58 CDT	4.039	180.39	6.980	26.176	84.31	63.13	0	0
N 6060	SEP 19,'73	21:57:08 CDT	4.039	176.47	6.980	26.176	84.31	63.13	0	0
N 6060	SEP 19,'73	22:00:17 CDT	3.882	176.47	6.980	26.176	84.31	63.13	0	0
N 6060	SEP 20,'73	10:27:14 CDT	3.803	176.47	6.980	25.784	84.31	63.13	0	0
N 6060	SEP 20,'73	10:30:24 CDT	4.313	172.54	6.980	25.980	84.31	63.13	0	0
N 6060	SEP 20,'73	10:33:34 CDT	4.156	172.54	6.980	25.980	84.31	63.13	0	0
N 6060	SEP 20,'73	21:58:18 CDT	4.039	180.39	6.980	26.176	83.92	63.13	0	0
N 6060	SEP 20,'73	22:04:36 CDT	3.647	180.39	6.980	26.176	83.92	63.13	0	0
N 6060	SEP 21,'73	10:34:22 CDT	2.941	156.86	6.509	26.176	83.92	63.13	0	0
N 6060	SEP 21,'73	10:37:32 CDT	3.098	156.86	6.509	25.980	83.92	63.13	0	0
N 6060	SEP 21,'73	22:05:17 CDT	3.843	180.39	6.980	26.176	83.92	62.74	0	0
N 6060	SEP 21,'73	22:08:26 CDT	3.686	180.39	6.980	26.176	83.92	62.74	0	0
N 6060	SEP 21,'73	22:11:36 CDT	3.686	180.39	6.980	26.176	83.92	63.13	0	0
N 6060	SEP 22,'73	08:56:25 CDT	3.686	223.52	6.941	25.980	83.92	63.13	0	0
N 6060	SEP 22,'73	10:37:37 CDT	3.607	180.39	6.980	26.176	83.52	62.74	0	0
N 6060	SEP 22,'73	10:40:46 CDT	3.529	180.39	6.980	26.176	83.52	62.74	0	0
N 6060	SEP 22,'73	10:43:56 CDT	3.529	172.54	6.862	26.176	83.52	63.13	0	0
N 6060	SEP 22,'73	22:10:19 CDT	4.235	184.31	6.980	26.372	83.52	62.74	0	0
N 6060	SEP 22,'73	22:13:28 CDT	4.156	184.31	7.019	26.372	83.52	62.74	0	0
N 6060	SEP 22,'73	22:16:37 CDT	4.078	184.31	6.980	26.372	83.52	62.74	0	0
N 6060	SEP 23,'73	10:44:52 CDT	3.960	180.39	6.941	26.372	83.52	62.74	0	0
N 6060	SEP 23,'73	10:48:02 CDT	3.882	180.39	6.980	26.372	83.52	62.74	0	0
N 6060	SEP 23,'73	10:51:11 CDT	4.039	180.39	6.980	26.372	83.52	62.74	0	0
N 6060	SEP 23,'73	22:16:54 CDT	4.509	180.39	7.058	27.352	83.13	62.74	0	0
N 6060	SEP 23,'73	22:19:08 CDT	4.392	180.39	7.058	27.549	83.13	62.74	0	0
N 6060	SEP 23,'73	22:22:16 CDT	4.549	180.39	7.058	27.352	83.13	62.74	0	0
N 6060	SEP 24,'73	09:10:07 CDT	4.392	192.15	6.980	26.764	83.13	62.74	0	0
N 6060	SEP 24,'73	10:54:04 CDT	4.156	180.39	7.058	26.960	83.13	62.74	0	0
N 6060	SEP 24,'73	22:22:17 CDT	4.313	180.39	6.980	26.568	83.13	62.35	0	0
N 6060	SEP 24,'73	22:25:26 CDT	4.239	180.39	6.980	26.568	83.13	62.39	0	0
N 6060	SEP 24,'73	22:28:36 CDT	4.196	180.39	6.980	26.568	83.13	62.35	0	0
N 6060	SEP 25,'73	10:57:24 CDT	4.196	211.76	6.901	26.372	83.13	62.35	0	0

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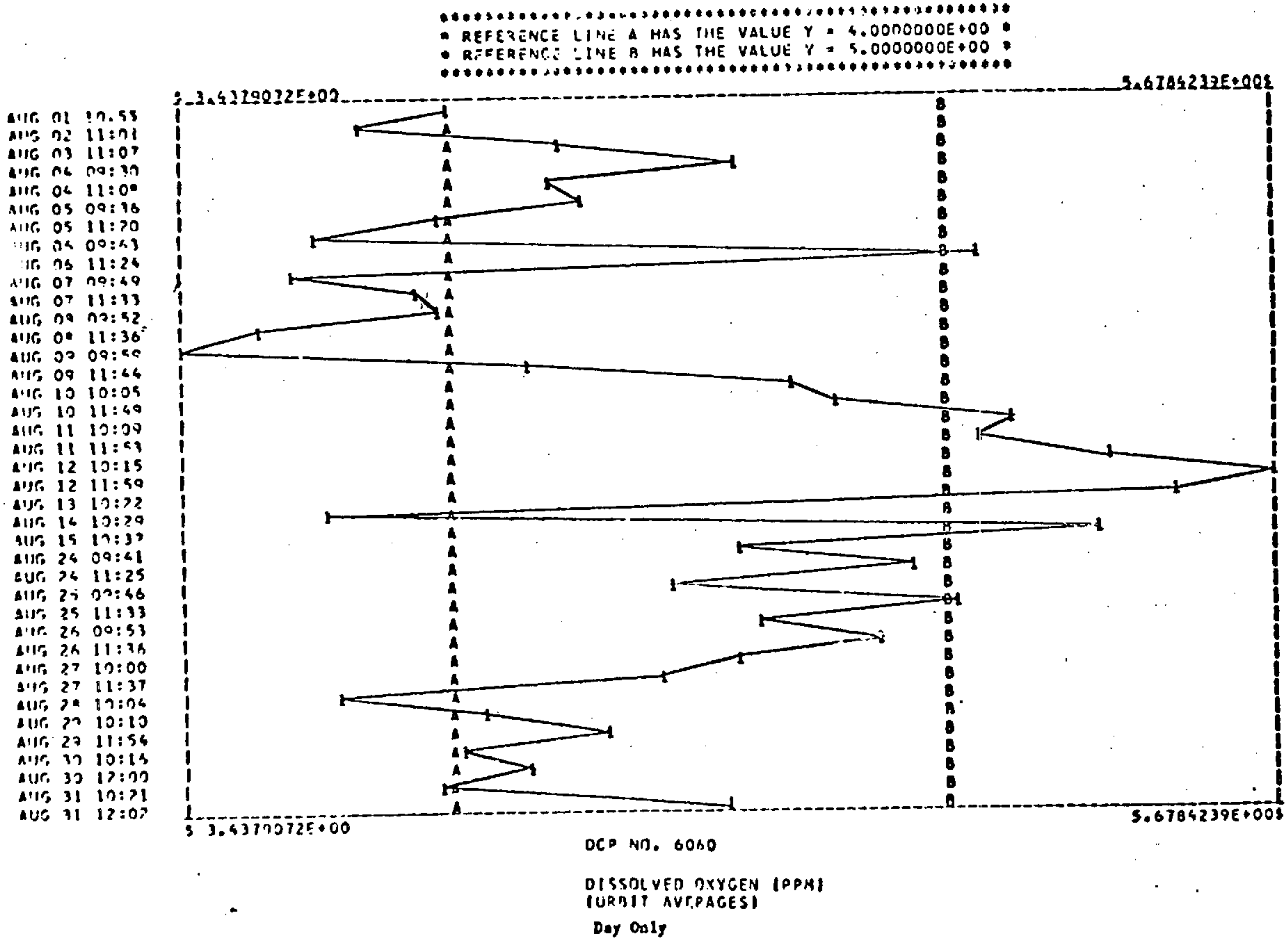

Fig. 5. Averaged Orbital Dissolved Oxygen Values for Daylight Hours Collected by DCP No. 6060 for the Month of August, 1973.

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During the period July 23 to November 1, 1973, the results from the conventional boat survey were collected and tabulated for comparisons with the remotely-sensed DCP data.

On December 25, 1973, heavy rainfall in the river basin produced an unusually high flooding condition with attendant high floor velocities in the Warrior River. As a consequence, two of the DCPs, Nos. 6357 and 6061, were torn from their moorings and washed downstream. These two DCPs were originally located in reaches of the monitored river segment where the river channel narrows and flow velocities are highest during flooding conditions. These DCPs were attached to floats which were anchored by means of cables to a 30 ft. section of 2 inch cast iron pipe fitted with a spear-point on one end. It is believed that the DCPs were floated from the sampling locations due to insufficient slack in the cable and/or insufficient weight of the anchor when the elevated water levels were reached during the flood condition.

All remaining DCPs were removed from the river during the first two weeks of January, 1974 and the monitoring part of the program was terminated. Efforts to locate the two missing DCPs have been unsuccessful due, in part, to frequent precipitation and high water levels during the entire late winter and early spring seasons. Search efforts are continuing and it is hoped that the DCPs will be located and retrieved during the periods of low water levels encountered during the summer and early fall seasons.

Uses of Data

All of the data transmitted by the DCPs and initially stored in the computer were carefully screened to eliminate those data considered to be unreliable because of lack of proper sensor calibration, sensor malfunction, and other known factors. A discussion of the reliability of the collected data is presented in the following part, Evaluation of DCPs and Sensors.

The data considered to be reliable were restored in the computer allowing a data recall in a suitable format for presentation to ultimate users. A copy of the data was furnished to the State pollution control agency, the Alabama Water Improvement Commission. Subsequently, the Commission requested the data to be furnished on a computer tape suitable for input to their data bank as well as for input to the Environmental Protection Agency's national STORET water quality data bank. This was accomplished such that the DCP locations have been established as official sampling points in both the state and national data banks. The DCP data were utilized to verify some abnormally low dissolved oxygen values measured in the Warrior River by the Commission using conventional analytical techniques. The two sets of data compared very well and the low dissolved oxygen values were verified.

The DCP data were graphically plotted in two ways: (1) the averaged daily (daylight) dissolved oxygen (DO) values transmitted by the DCPs were plotted against the time of transmission for the period July 22, 1973 to October 27, 1973; (2) the averaged weekly DCP dissolved oxygen values were plotted against the river mile locations of the DCPs. The dissolved oxygen values measured on the conventional boat survey sponsored by members of the consortium of local industries were plotted on the appropriate graphs for a direct comparison with DCP results. In addition, regression analysis for correlation and precision were performed in a comparison of DCP and conventional results.

On May 2, 1974, a report on the conventional and DCP results, including a computer printout of DCP data, was delivered to members of the consortium of local industries. A copy of this report is presented in Appendix A and a discussion of this report is presented later on the evaluation of the DCP system.

On May 28, 1973, a presentation of the ERTS-DCP system and the results of the studies was made to a number of representatives of potential user organizations. In addition to members of the consortium of local industries, representatives of the Alabama Power Company, the Alabama Water Improvement Commission, the U.S. and Alabama Geological Surveys, and other organizations were in attendance. There was a significant exchange of information and ideas among the participants and, in general, the ERTS-DCP concept received a very favorable reception.

The DCP data are also being utilized to verify a proposed mathematical model for dissolved oxygen in the Warrior River. This work is presently in progress as a result of a contract received from the Alabama Water Improvement Commission to model the Warrior River and other selected stream segments. This model will be employed in allocating industrial and municipal discharges to the streams in order to maintain established water quality standards. In this study, the DCP data is being applied in a most practical manner to meet the needs of a user organization.

In summary, the presentation of the DCP concept and data to potential users has created much interest among the industrial and governmental organizations toward use of the ERTS-DCP system for the management of water resources. This is particularly true with regard to the Alabama Water Improvement Commission's future plans to monitor water resources in conjunction with developed mathematical models.

Evaluation of DCPs and Sensors

A. Operation and Maintenance of DCPs

This part describes the problems encountered with operation of the DCP system as well as other particulars related to servicing operations for the platforms.

During the period of operation of the DCP system it was found that the dissolved oxygen and temperature sensors maintained calibration well and provided better data in terms of quantity and accuracy than did the conductivity and pH sensors, which seemed to be much more delicate and likely to present malfunction problems.

Service and calibration work on the DCPs was performed on a weekly basis, primarily due to loss in accuracy of dissolved oxygen readings when the servicing interval was longer than one week. It appeared that the membrane on the DO sensor gradually became coated with silt, retarding passage of oxygen through the membrane. Growth of this silt deposit was retarded by disconnecting the circulation motor which appeared to be driving the water and silt directly into the membrane. It was reasoned that the natural flow of the river would provide sufficient purging of the oxygen-depleted water around the membrane and insure accurate readings. The other sensors could have been serviced less frequently; however, for reasons of convenience they were also calibrated weekly along with the DO sensor.

It was later found that DO readings could be improved by merely wiping the membrane each week with a soft tissue, rather than replacing the membrane at each servicing.

The four nickel-cadmium batteries which powered the data collection platform were rotated each week and replaced with freshly charged batteries once a month. The reason for rotating the pair of batteries for the sensors and the pair of batteries for the transmitter was to minimize the heavier drain placed on the batteries by the sensors, such that all four batteries could be replaced at the same time. After operating approximately one month, the batteries were down to 70 percent of full charge, at which point the loss of charge began to affect the values of water quality parameters measured by the sensors. Therefore, at this time interval the batteries were replaced.

In the absence of any unusual problems, the servicing and calibrating procedure for a single DCP required approximately 45 minutes. During servicing, the DCP was entirely removed from the water and placed on an upright stand on the deck of the boat. The stand was elevated sufficiently to permit servicing of the DCP without disconnecting the sonde, the section containing the sensors.

The dissolved oxygen sensor was calibrated against the DO value of a sample of water from a five-foot depth measured by the Winkler titration method. Conductivity and temperature sensors were calibrated against meter voltages corresponding to known values of the particular parameters. Calibration of the pH sensor involved standardization against two buffer solutions of known pH values. Additional measurements by conventional analytical techniques for the above apramaters were taken on samples of water also drawn from a five-foot depth.

Only a few problems were encountered with the buoy itself. The antenna cable leading from the transmitter to the antenna was found to be detached forcibly on a few occasions. This problem was corrected by allowing more slack in the antenna cable than that allowed in the cable holding the DCP to the float. Another problem encountered was seepage of river water into the buoy. This was caused by worn "O" rings on the lip of the buoy and was solved by replacing the worn rings.

The loss of two DCPs during periods of high flow emphasized the need for adequate moorings and anchorage. Only one location in the river was found suitable for driving a fixed support on which the DCP could move vertically with the raising and lowering of the water level. This type of installation withstood the flooding very well. The remaining DCPs were attached by a short cable to a float which was anchored to the pipe section anchor by a longer cable. For two DCPs the anchor cable was not of sufficient length and the anchor was not of sufficient weight to prevent floating of the entire installation during periods of high water level and high flow velocities. It is believed this problem can be averted in future operations by providing proper cable length and anchor weight.

B. Reliability of Sensors

As mentioned previously, some sensors were found to be more reliable than others with regard to trouble-free operation. Of the 18,896 total data transmissions from four water quality sensors for all five DCPs, 12,725 transmissions were considered to be reliable. As discussed previously, these numbers of transmissions represent approximately 6,298 total and 4,241 reliable separate water quality data points, respectively. For convenience, the totals of the data transmissions will be employed in the statistical analyses that follows.

Based on the total and reliable transmissions, the percent reliability for all transmissions has calculated to be 67.3 percent. Of particular interest is the reliability experienced with each of the water quality sensors. For all five installed DCPs, the total of 18,896 transmissions divided by four sensors yields 4,724 transmissions for each type of sensor. Dividing the number of reliable transmissions for each sensor type by the total figure of 4,724, a percent reliability for each sensor type was obtained as shown in Table 4 below.

TABLE 4

PERCENT RELIABILITY FOR EACH TYPE OF WATER QUALITY SENSOR

Sensor	Total Transmissions	Reliable Transmissions	Percent Reliability
Dissolve Oxygen	4,724	4,611	97.60
Conductivity	4,724	2,519	53.32
pH	4,724	1,050	22.22
Temperature	4,724	4,545	96.21

The calculations presented in Table 4 clearly show that both the dissolved oxygen and temperature sensors performed in a very satisfactory manner. The pH and conductivity sensors performed much less satisfactorily. It should be pointed out that the term "reliability" as used in this report includes factors not entirely related to the performance of a sensor. For example, on occasion the conductivity range switch on the sensor was inadvertently set on the incorrect scale and these readings were counted as unreliable.

The greatest problems occurred with the pH probe. Calibration was extremely difficult to maintain and most of the readings taken between calibration and servicing runs were considered to be unreliable. These sensors are commercial units and it is anticipated that improved sensor design may eliminate many of these problems in any future operations.

An analysis of the transmissions received from each DCP was performed to determine if any of the DCPs were more reliable than others. The results of this analysis are shown in Tables 5 and 6. The results shown in Table 6 support the previous finding in that the DO and temperature sensors performed exceptionally well on all five DCPs. For pH measurements, the sensor on only one DCP, No. 6060, may be considered to be reliable. The high reliability of this pH sensor (99 percent) indicates that pH probes may be obtained that yield much better reliability than indicated from the overall results of this study.

C. Reliability of Data

Three of the DCP installations were located within one-half mile or less of the locations of three of the stations sampled on the conventional boat survey sponsored by the local industries. This allowed a direct comparison of the DCP results obtained by conventional means. Figures 6, 7 and 8 graphically compare these two sets of data on dissolved oxygen values employing the averaged daily (daylight) DO values

TABLE 5

NUMBER OF DATA TRANSMISSIONS FOR EACH SENSOR AND DCP

DCP No.	Date Installed	Reliable Transmissions Per Sensor: Dissolved Oxygen	Conductivity	pH	Temp.	Total Transmission Per Sensor	Total Transmission Per DCP
6224	5/13/73	1925	1722	0	1822	1969	7876
6060	6/27/73	845	511	891	890	900	3600
6357	8/07/73	925	0	0	926	932	3728
6061	8/30/73	861	286	159	852	868	3472
6323	10/12/73	55	0	0	55	55	220

TABLE 6

PERCENT RELIABILITY FOR EACH DCP

AND TYPE OF MEASUREMENT

DCP No.	Dissolved Oxygen	Conductivity	pH	Temp.	Total
6224	97.8	87.5	0.0	92.5	69.4
6060	93.9	56.8	99.0	98.9	87.1
6357	99.3	0.0	0.0	99.4	49.65
6061	99.2	33.0	18.3	98.2	62.2
6323	100.0	0.0	0.0	100.0	50.0

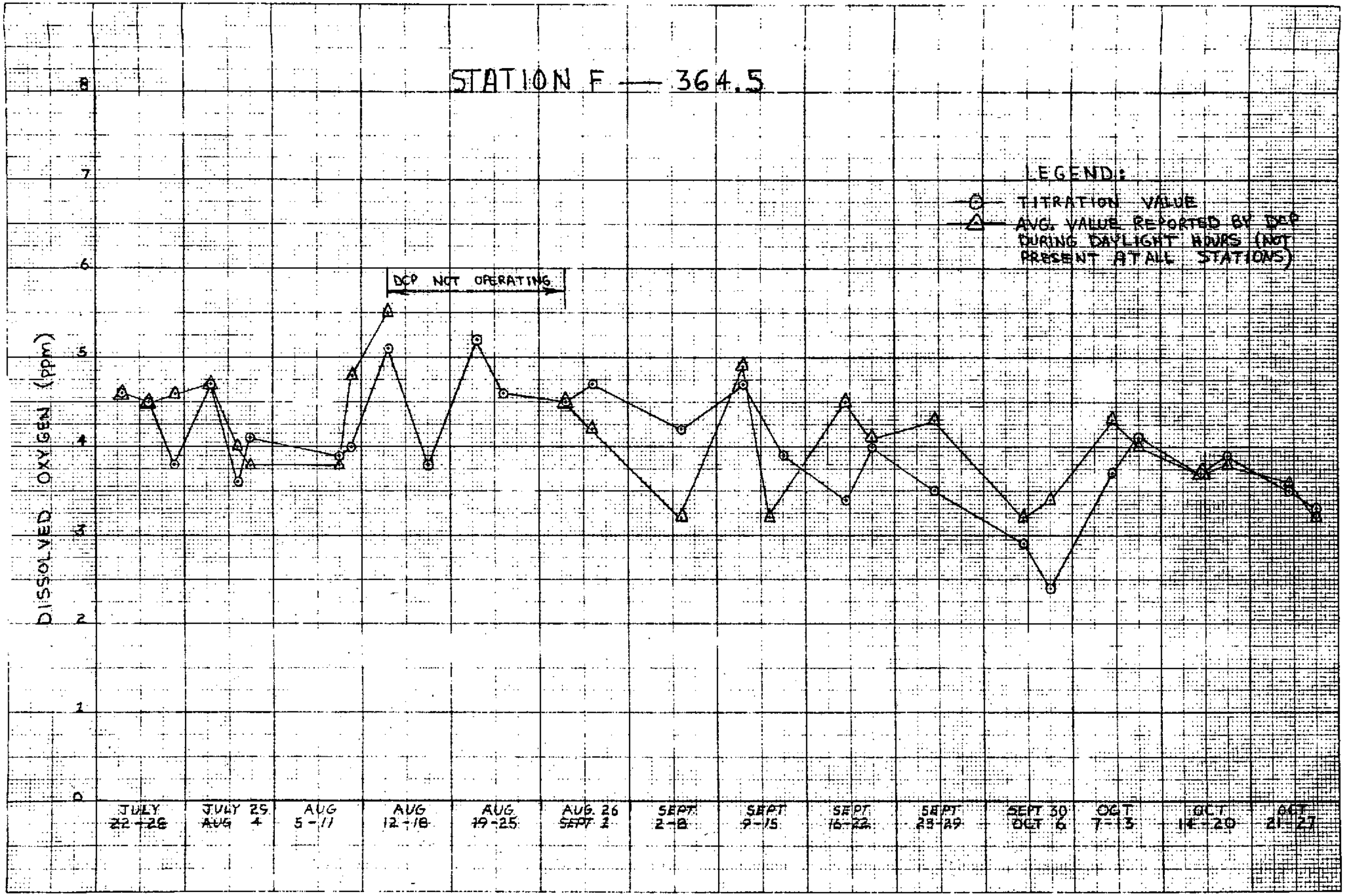

Fig. 6. Comparison of Dissolved Oxygen Values Obtained by Boat Sampling (Titration) with the Averaged Daily (daylight) Dissolved Oxygen Values Reported by ERTS Data Collection Platform (DCP) No. 6060 Located at R. M. 364.0 for Period July 22 - October 27, 1973. Station F Located at Lower End of Rock Quarry.

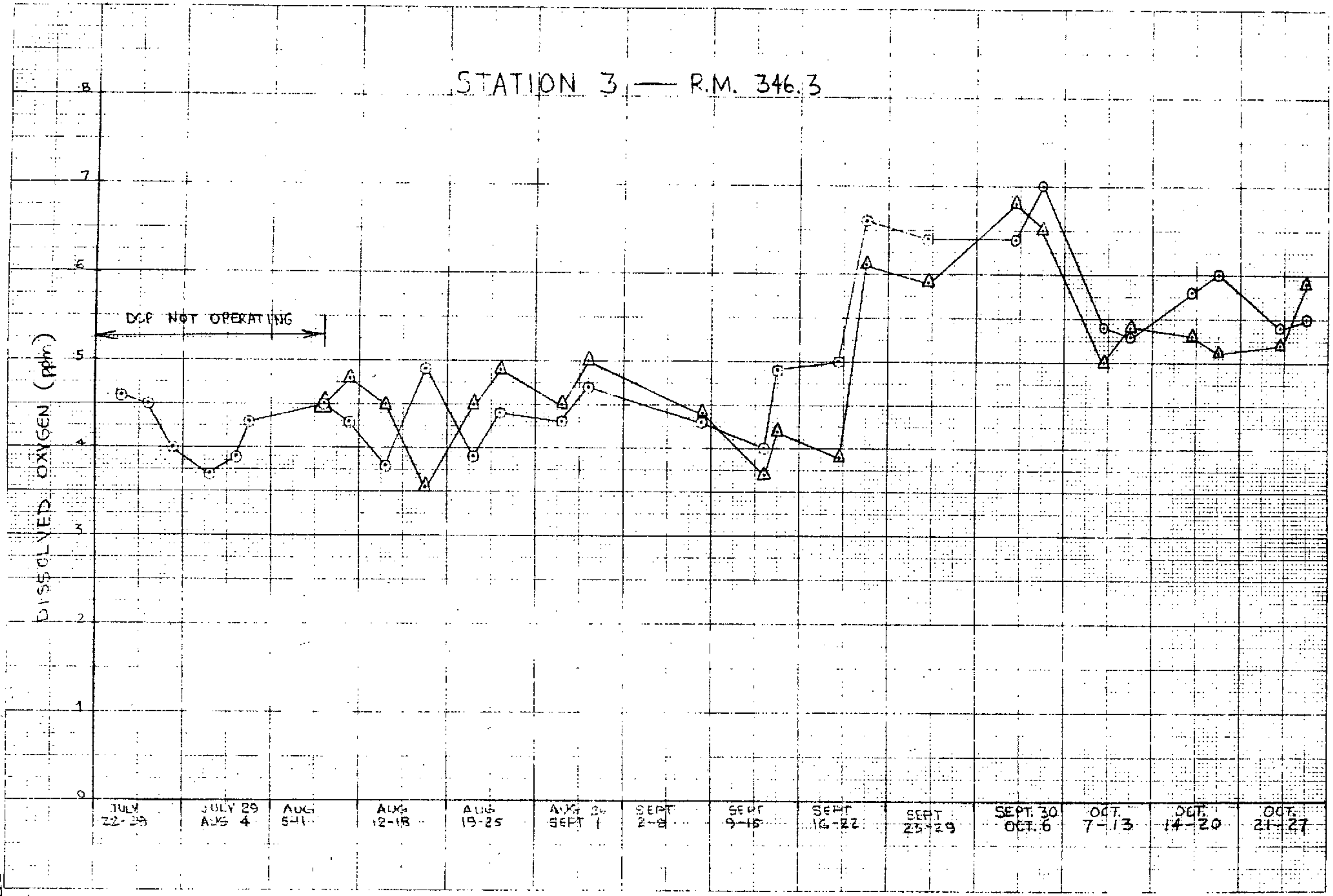

Fig. 7. Comparison of Dissolved Oxygen Values Obtained by Boat Sampling (Titration) With the Averaged Daily (daylight) Dissolved Oxygen Values Reported by DCP No. 6357 Located at R. M. 346.5. Station 3 Located Above Hurricane Creek.

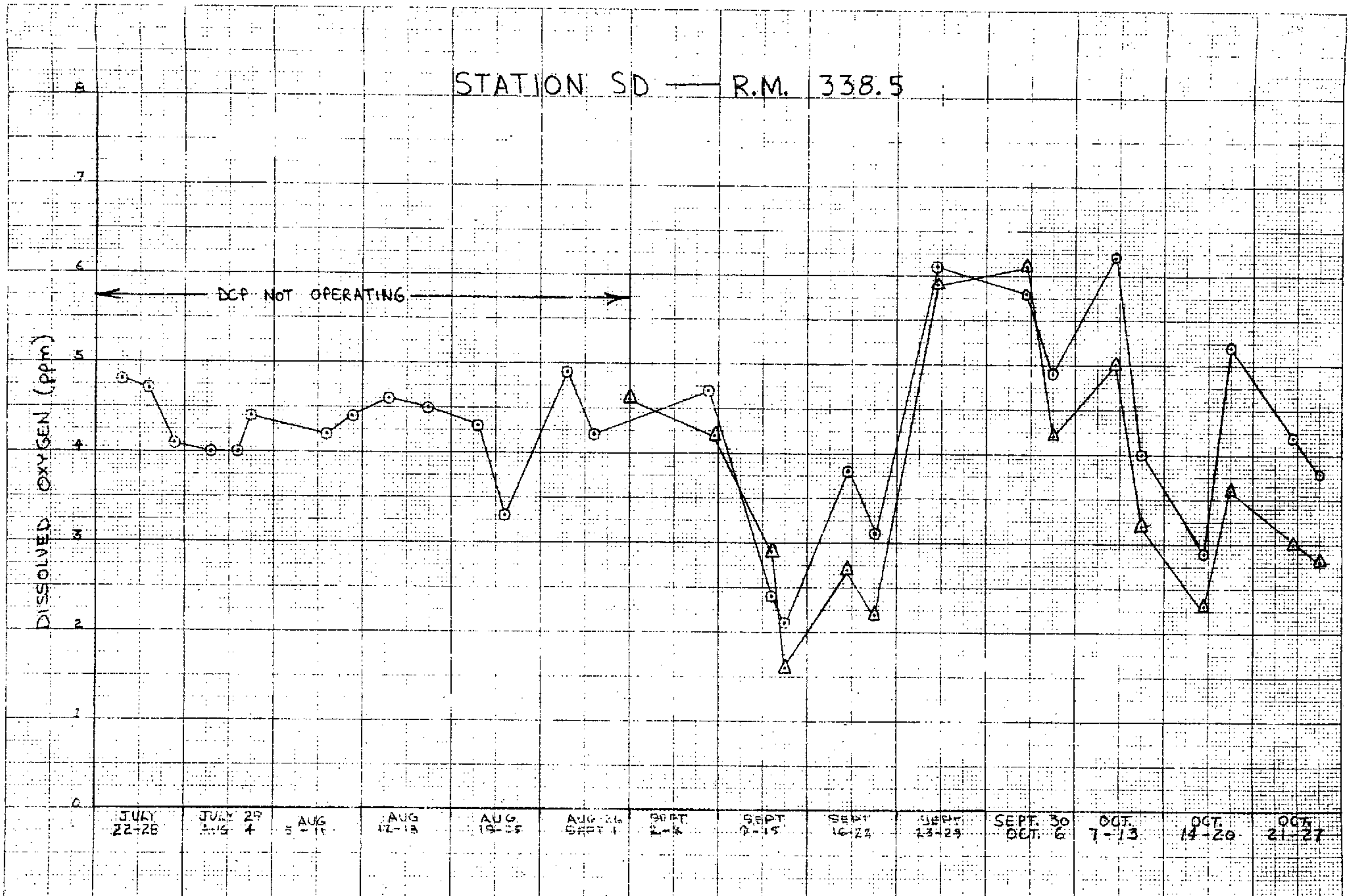

Fig. 8. Comparison of Dissolved Oxygen Values Obtained by Boat Sampling (Titration) With the Averaged Daily (daylight) Dissolved Oxygen Values Reported by DCP No. 6061 Located at R.M. 338.3. Station SD Located at State Docks.

transmitted by the DCPs. These graphical comparisons show that the results obtained by the DCPs agree reasonable well with the results obtained by conventional boat surveys. The greatest difference between the two sets of results is approximately 1.0 mg/1 dissolved oxygen. The trends of DO measurements correspond exceptionally well for the two data sets over the time period, especially when it is considered that the two sets of measurements were not taken at precisely the same locations and averaged daily results for the DCPs were compared with point measurements made on the boat surveys.

The DCP and conventional boat sampling results were compared statistically in two ways utilizing matched-pair sets of data. The first matched-pair data were obtained from calibration studies in which a DCP was removed from the water after an operation period of about two weeks and, without any adjustment, the sensor probes were placed in approximately standardized solutions. The value given by the probe was then compared or matched with the known value of the standardized solution. During the study period, a total of twenty matched-pair data sets were obtained for all DCPs in operation. An equation for the regression line by the least sum square method was calculated for each of the matched-pair values of dissolved oxygen, temperature, pH, and conductivity. The regression lines, together with the correlation coefficient, the standard error of estimate, and the 95 percent confidence interval, are presented in Figures 9, 10, 11, and 12 for DO, temperature, pH and conductivity, respectively.

A second set of matched-pair data was obtained from field studies by selecting those boat sampling results measured near a DCP location

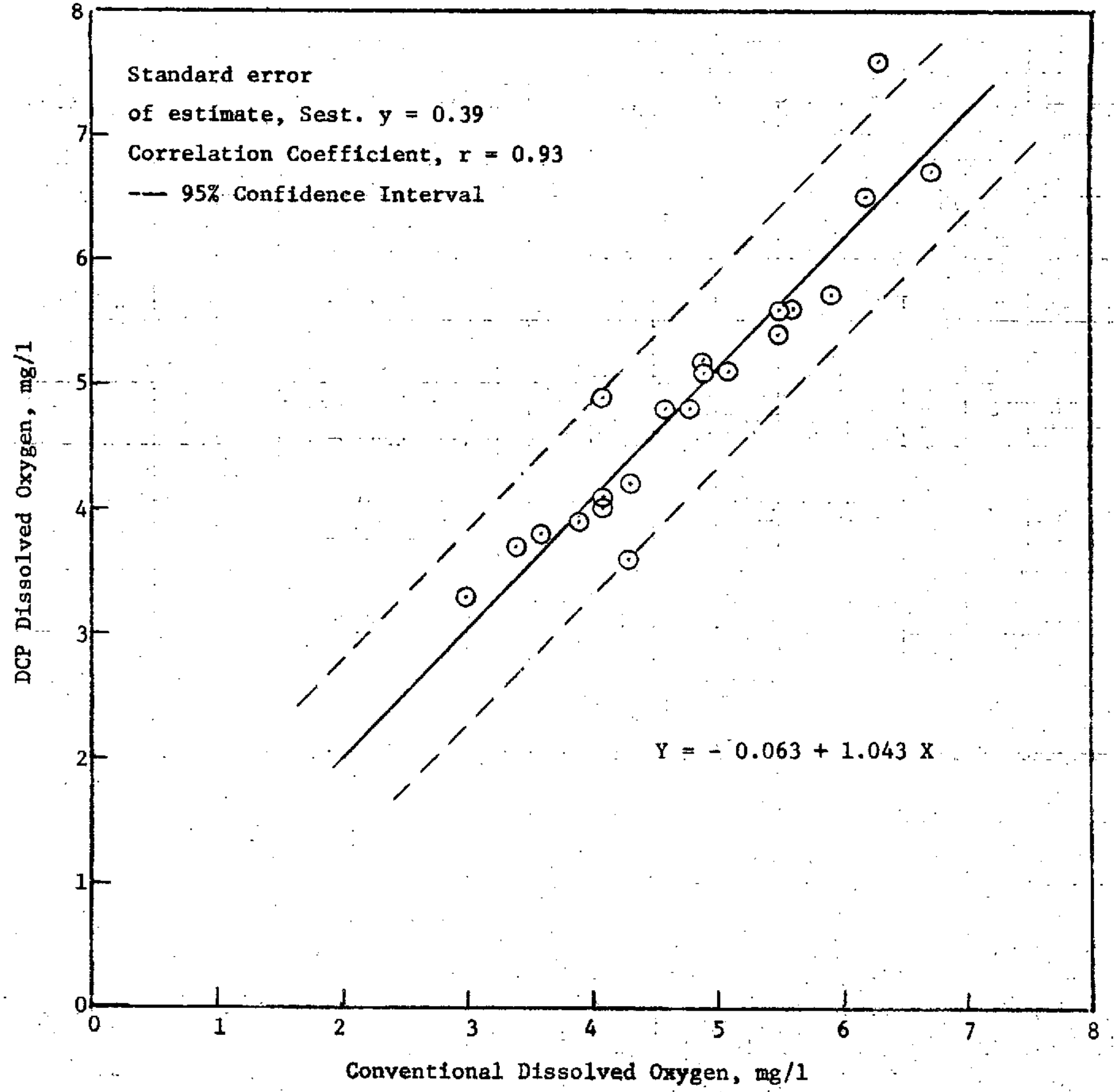

Fig. 9. Dissolved Oxygen Regression Line for Calibration Studies Calculated by Least Squares Method.

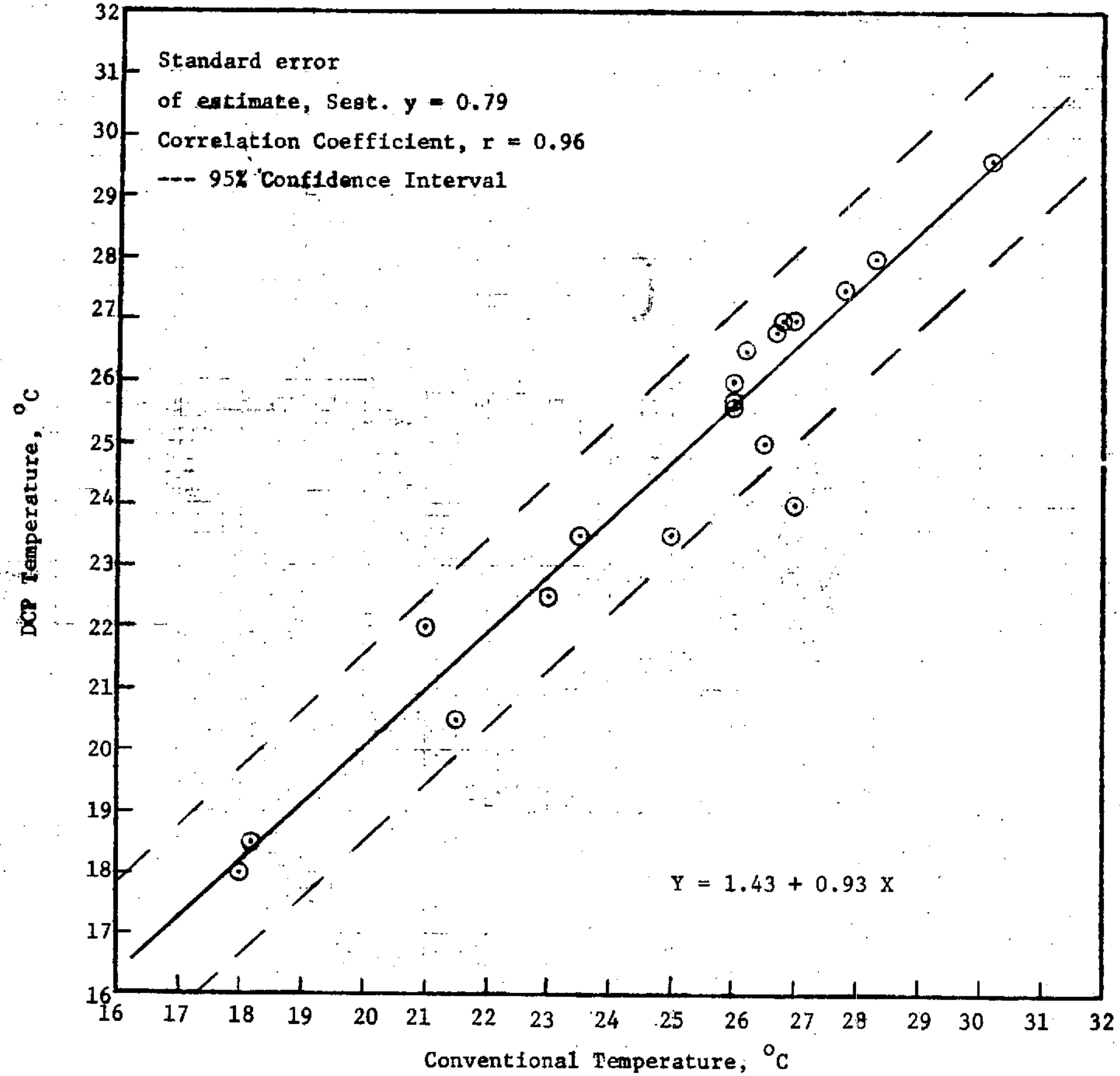

Fig. 10. Temperature Regression Line for Calibration Studies Calculated by Least Squares Method.

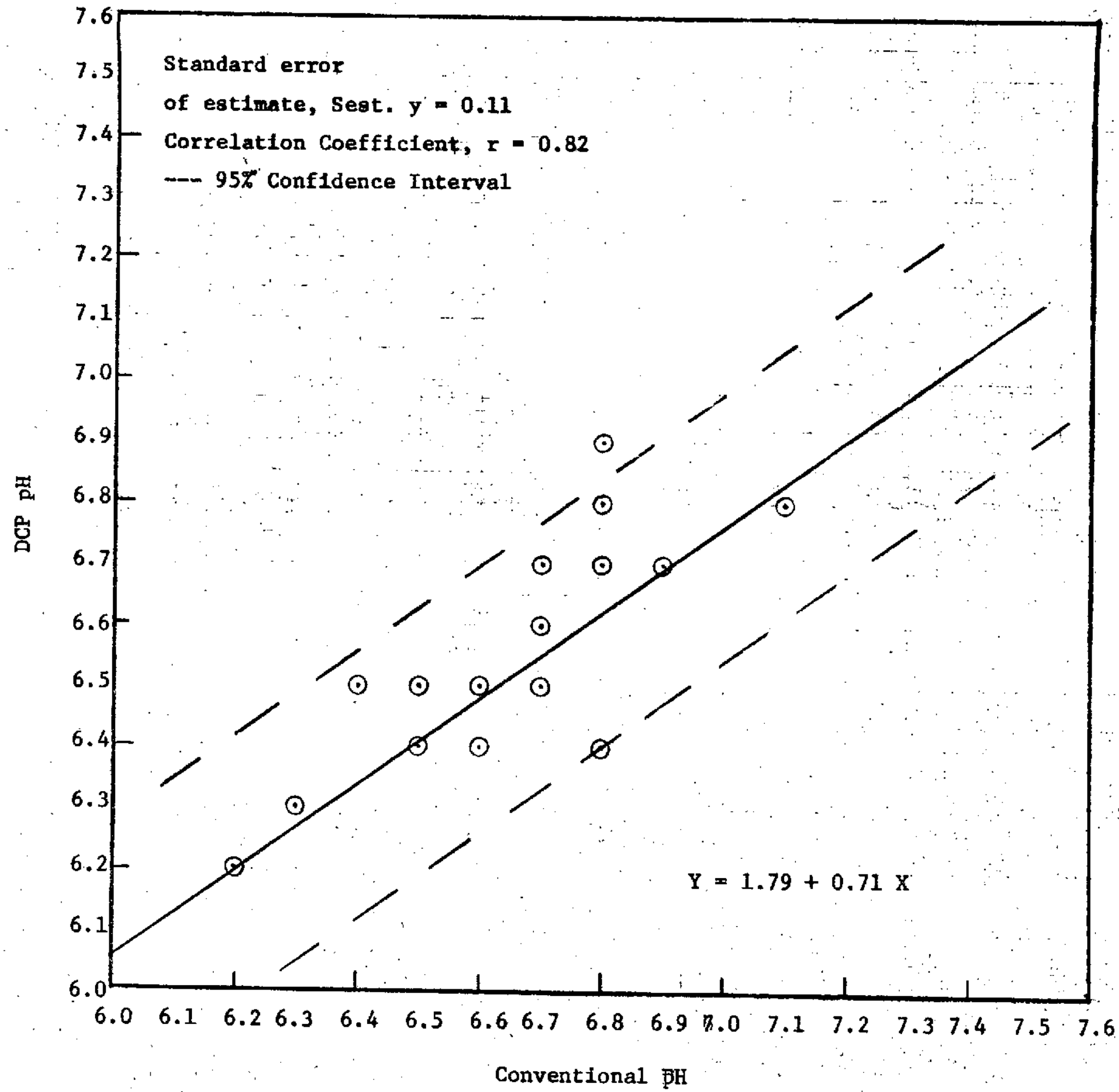

Fig. 11. pH Regression Line for Calibration Studies
Calculated by Least Squares Method

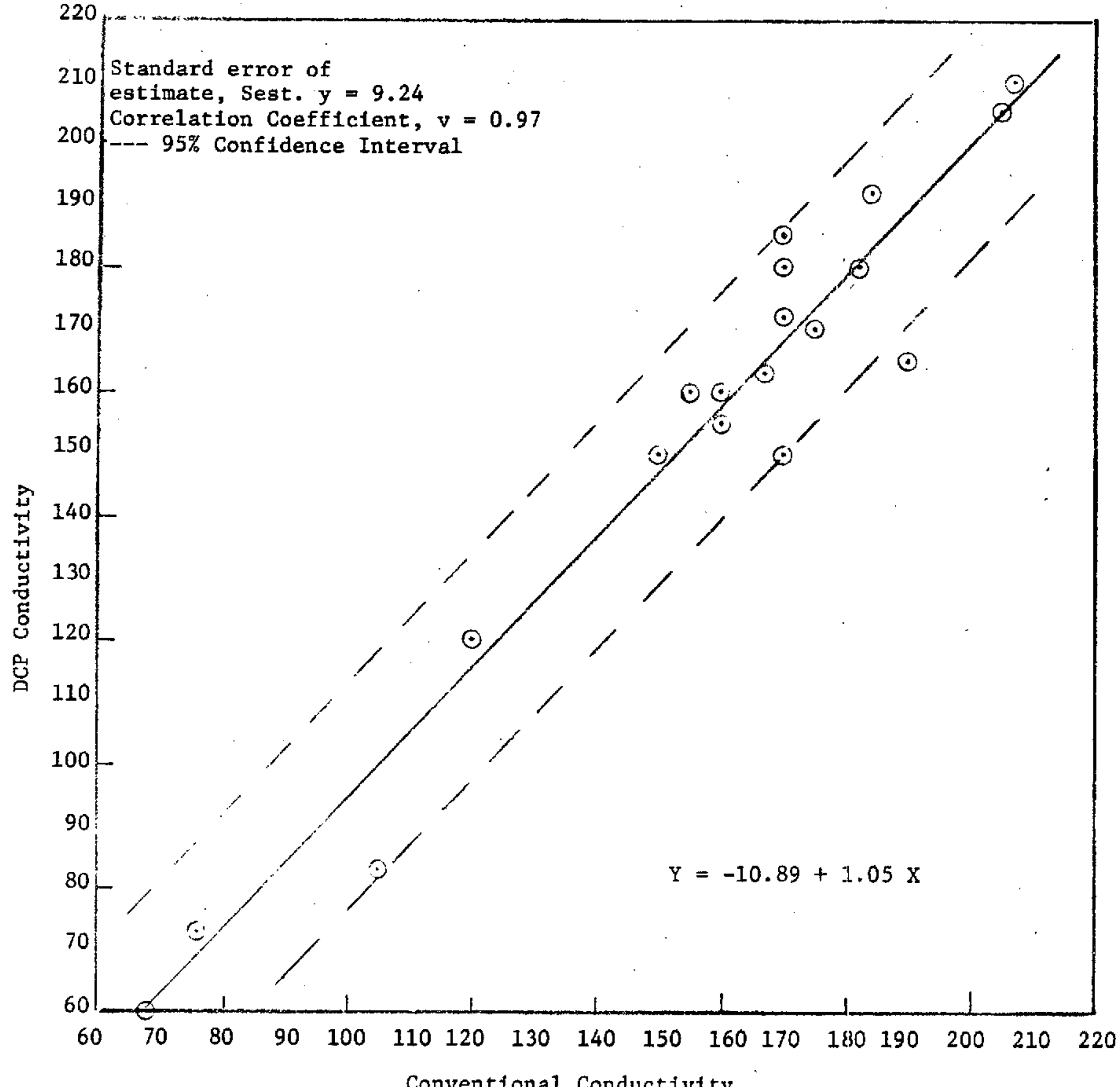

Fig. 12. Conductivity Regression Line for Calibration Studies Calculated by Least Squares Method.

where both boat and DCP results were measured on the same day at approximately the same time. A maximum difference in actual sampling times of two hours was set as a limit for a comparison of these results. This two-hour time limit was selected on the premise that, under most conditions, the water quality would not change appreciably. The results of statistical analyses similar to those performed on the first data set are graphically presented in Figures 13, 14, 15, 16 and 17.

Assuming that the boat sampling results (conventional) are the "true" values, the precision which with the same parameter may be measured on a DCP may be obtained by employing two times the standard error of estimate, $S_{est.\ y}$. A convenient way to express the precision of the DCP results is by use of the percent relative standard error of estimate calculated by:

$$\text{Rel. Std. Error of Estimate} = \frac{2\ S_{est.\ y}}{\overline{X}} \times 100$$

where $\overline{X}$ = mean of values.

Since a homoscedastic distribution is assumed, the median value of the measured parameter, rather than the mean value, is employed to express precision. The results of this statistical approach are presented in Table 7.

As might be expected, the field study results were less precise than the calibration studies due to the differences in sampling times and to the fact that the sampling locations were not identical. The calibration studies indicated good precision was obtained with

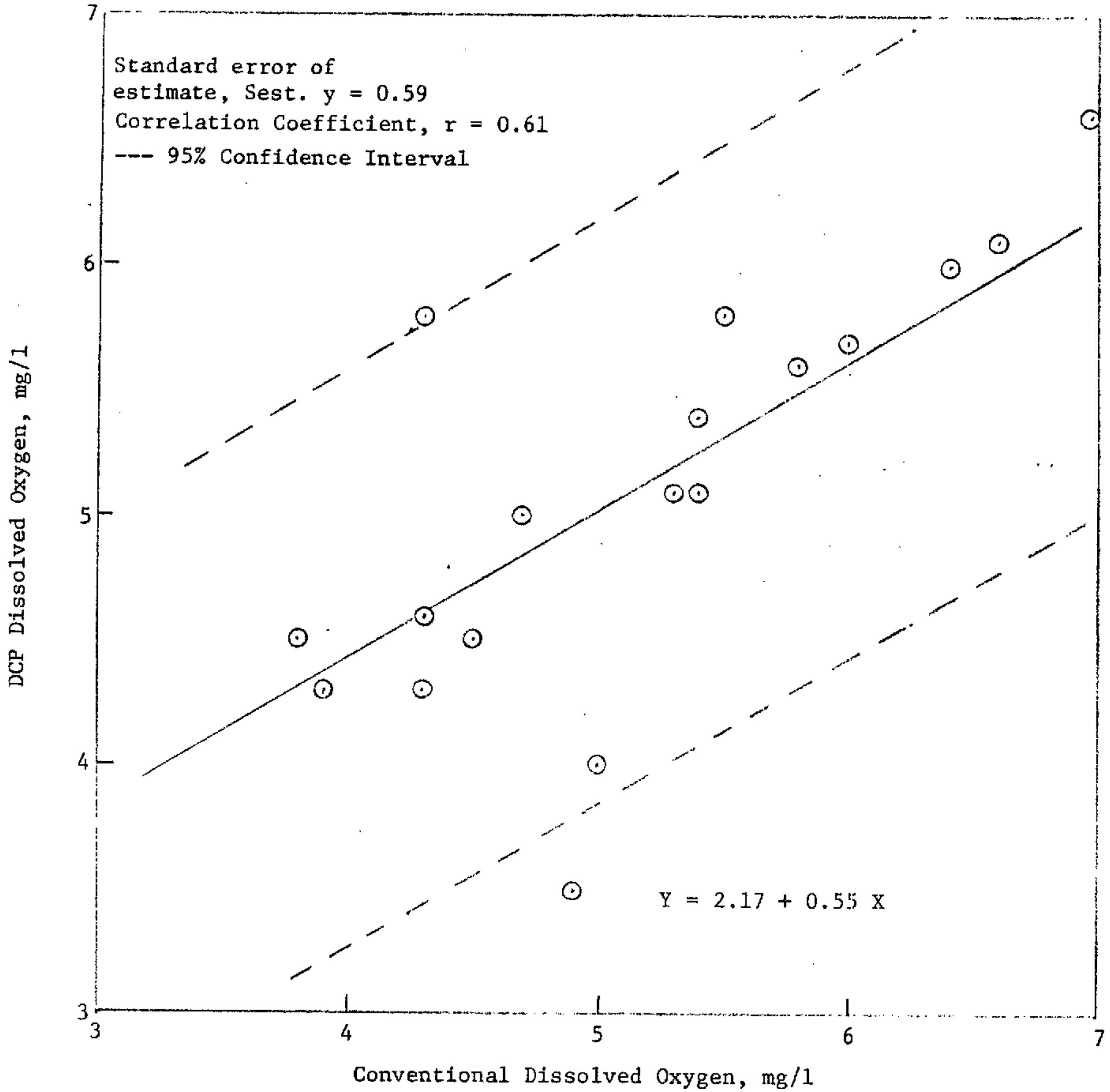

Fig. 13. Dissolved Oxygen Regression Line for Field Studies at Station 3 and DCP No. 6357 calculated by Least Squares Method.

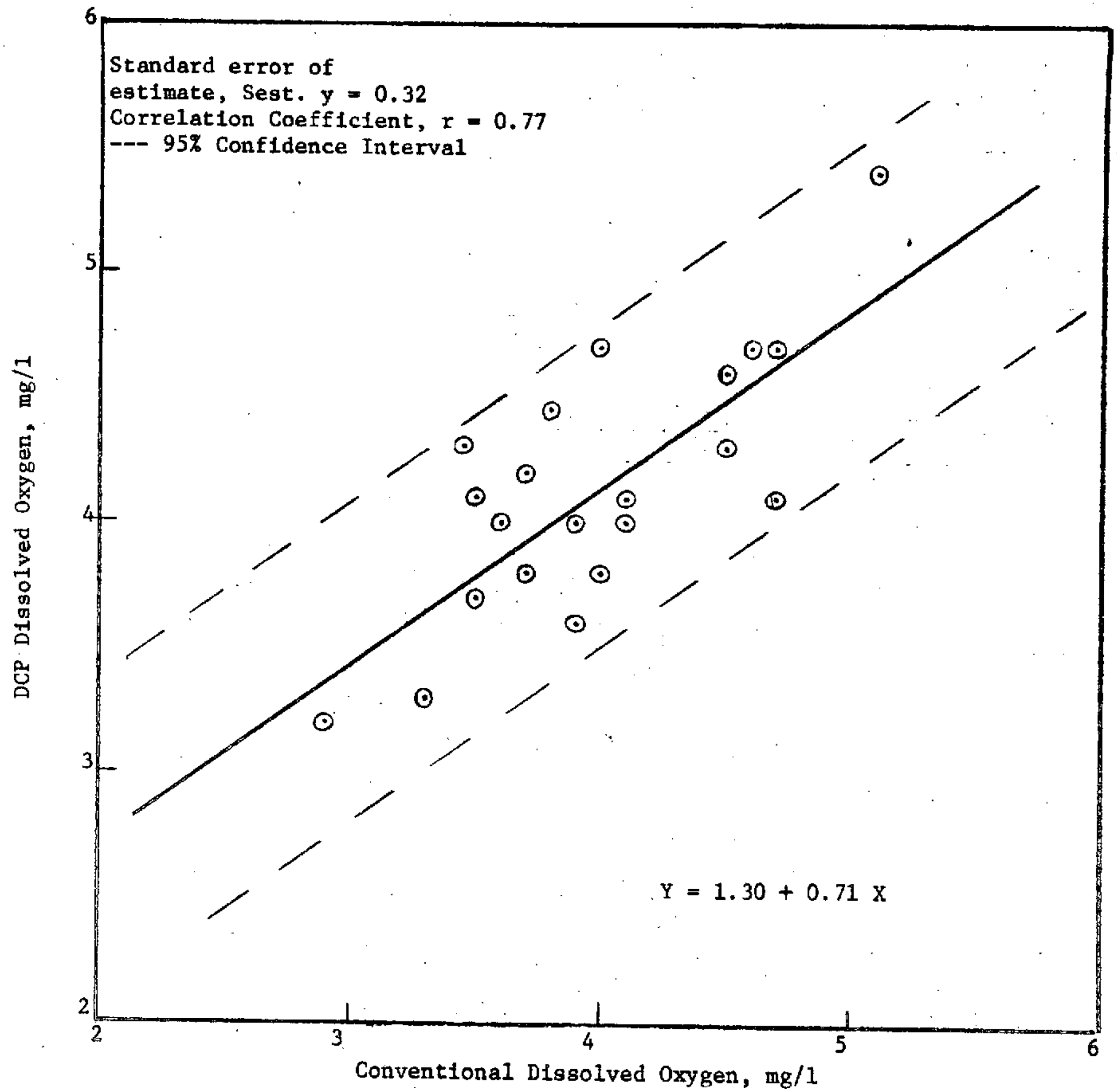

Fig. 14. Dissolved Oxygen Regression Line for Field Studies at Station F and DCP No. 6060 Calculated by Least Squares Method.

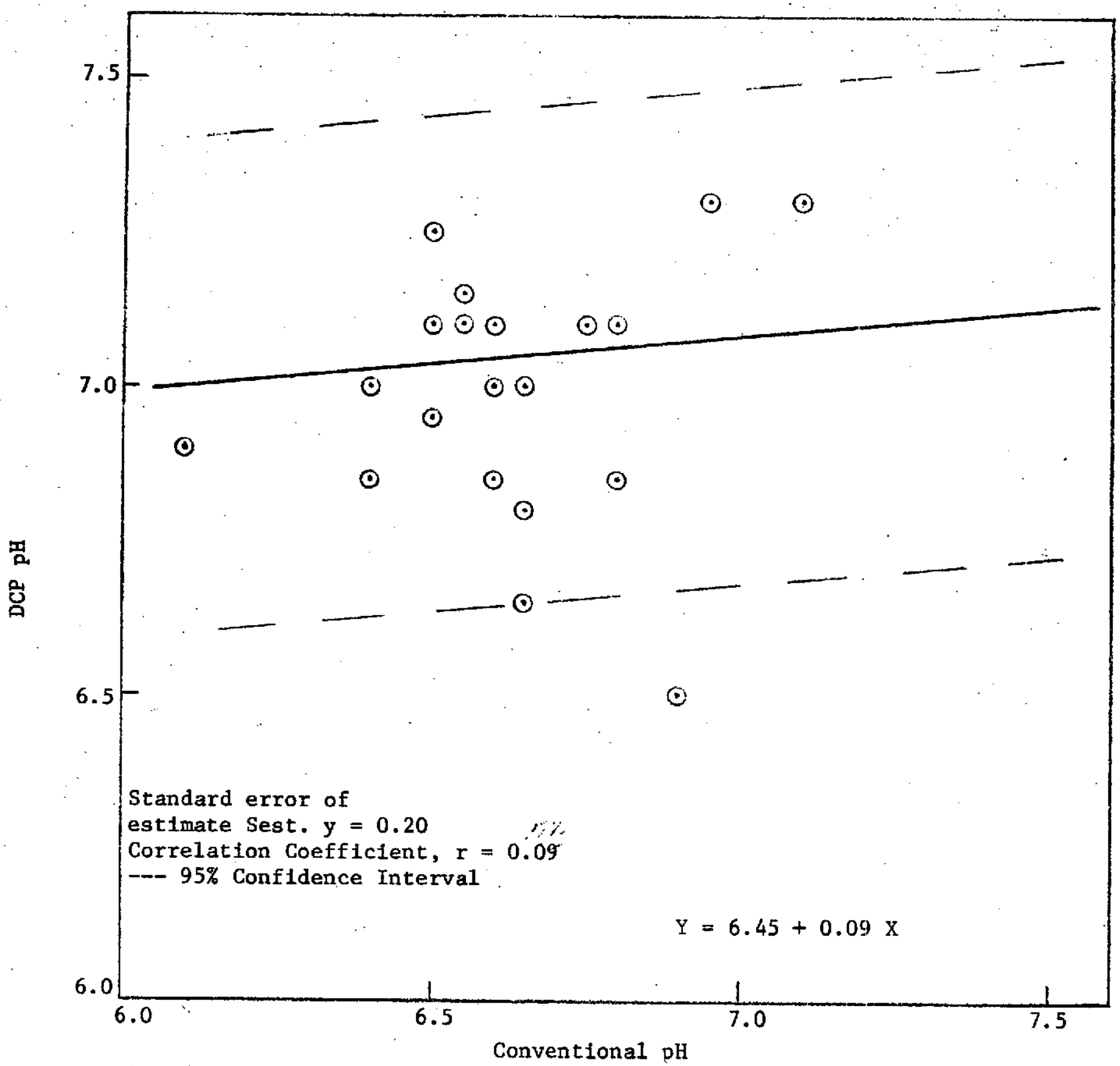

Fig. 15. pH Regression Line for Field Studies at Station F and DCP No. 6060 Calculated by Least Squares Method.

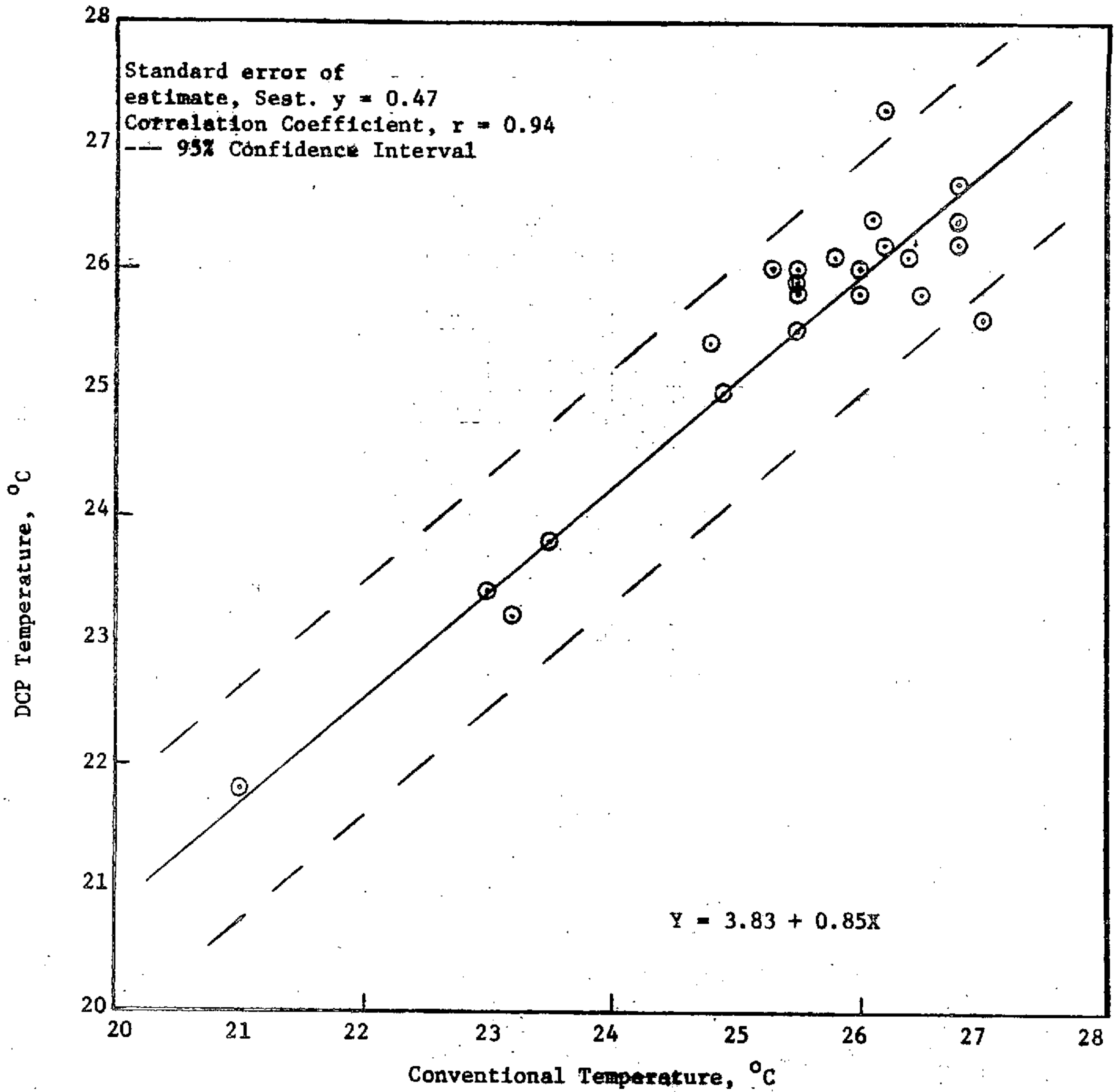

Fig. 16. Temperature Regression Line for Field Studies at Station F and DCP No. 6060 Calculated by Least Squares Method.

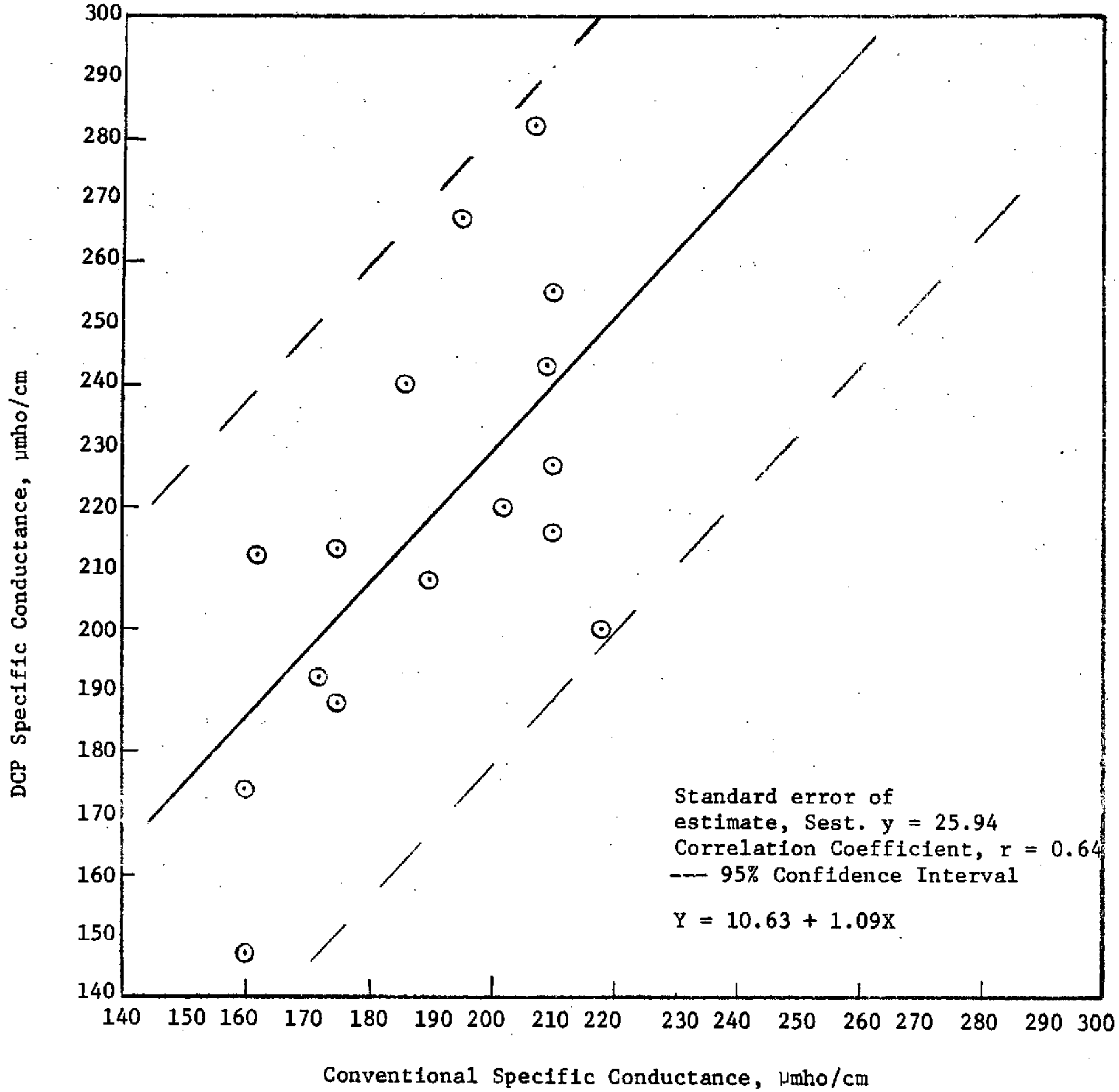

Fig. 17. Conductivity Regression Line for Field Studies at Station F and DCP No. 6060 Calculated by Least Squares Method.

temperature, pH, and conductivity. The dissolved oxygen study indicated that the "true" value of DO may be measured by a DCP within $\pm$ 0.8 mg/1.

D. Cost Analysis

The concept of cost/effectiveness may be applied to the DCP monitoring system since it is possible to remotely-sense water quality data by conventional monitoring stations. Also, as will be discussed, a cost-benefit approach may also be applied.

In applying both concepts, two comparisons may be made: (1) the DCP system vs conventional sampling from a boat; (2) the DCP system vs on-shore conventional monitoring stations capable of transmitting the data to a central receiving station. These two comparisons are based on the same data output from both the ERTS and conventional systems as the same water quality sensors may be employed in both systems.

As discussed previously, a conventional boat sampling survey was conducted concurrently with the DCP program in a cooperative effort involving the University and five major industries on the river. The river was sampled at eight sampling stations on one to three days per week. The cost of this survey, not including the purchase of the sampling boat, was approximately $4,200 for a four-month period. This cost, however, is not realistic since student salaries were utilized in calculating the funds required. A better comparison may be made based on man-hours expended on the conventional and DCP programs during a four-month period as related to the number (data bits) of water quality results collected on each program. A summary of this analysis is shown in Table 8 below.

TABLE 7

ANALYSIS OF PRECISION OF DCP RESULTS

Parameter Measured	Median Value	Percent Relative Standard Error of Estimate, 95 Percent Confidence Interval	
		Calibration Studies	Field Studies
Dissolved Oxygen, mg/l	5.0	± 15.6	± 23.6 (1)
	4.0		± 16.0 (2)
Temperature, °C	25.0	± 6.3	± 3.8 (2)
pH	6.7	± 3.3	± 6.0 (2)
Conductivity, μmho/cm	170	± 10.8	
	190		± 27.0 (2)

(1) Conventional Station 3 and DCP No. 6357.

(2) Conventional Station F and DCP No. 6060.

TABLE 8

MAN-HOUR/DATA COLLECTED ANALYSIS

Program	Man-Hours Per Week	Data Bits Collected/Week	Man-Hours Per Data Bit
Conventional	40	80	0.50
DCP	40	448	0.09

Although this analysis shows a labor cost ratio of approximately 5.5 to one in favor of the DCP system based on data bits collected, it should be noted that the conventional survey covered eight stations compared to five stations sampled on the DCP program. On an equal number of sampling stations basis, it is estimated that the DCP man-hours required would be doubled; however, the number of data bits collected would be increased by the factor eight over five so that the man-hours per data bit would increase to only 0.11. The labor cost analysis would still favor the DCP system by a factor of 4.5 to one. The advantages and disadvantages of the two systems with regard to the number of stations and data bits collected is discussed in a following part on cost/benefit analysis.

A comparison of capital and non-labor operating costs is difficult to evaluate. The cost of constructing a DCP for this study may be estimated to be approximately $20,000 each. This figure includes research and development costs and it is estimated that on a production basis the DCP cost would be about $10,000 per unit. The cost of the satellite, launching, ground receiving stations, and support personnel cannot be utilized in the present system since these costs would be prorated over the entire future users of the DCP concept.

In this study it was determined that the cost of the sampling/ calibration boat and ancillary analytical equipment and supplies would be the same for both systems, approximately $3500. The DCP system would require in addition a number of rechargeable batteries and a battery charger on which firm commercial costs are not known. It is clear that capital costs for the ERTS system would be much higher than that required for conventional boat surveys and the higher capital costs must be balanced by any additional benefits obtained with the ERTS system.

For a conventional on-shore sampling station, the capital cost per unit is in the range of $10,000 to $23,000 for four to five water quality parameter measurements. These costs include sensors, recorders, housing structures, piping, electrical power lines and one-way transportation expenses for the initial installation. It is estimated that one-man year is required to calibrate, service, and collect data on a two-week interval for five to eight stations located on a 50 to 100 mile river reach. The capital costs of on-shore stations and remotely-sensed DCPs may be considered comparable, as well as labor costs for calibration and servicing.

To summarize a cost/effectiveness approach, the DCP capital cost (excluding satellite), including sampling boats, special batteries and chargers, would probably cost three to four times conventional boat sampling capital costs based on operations as opposed to experimentation. In a comparison with on-shore installations, the capital costs of on-shore and DCP stations would probably be comparable for the determination of identical water quality parameters. Maintenance costs would be approximately the same for all three systems. The quantity of data generated by the DCPs will cover established conventional needs much more frequently in a comparison with boat surveys, but will be about the same as that generated by on-shore installations.

A cost/benefit approach is also applicable to the DCP system as certain benefits are obtained which normally are absent from conventional systems. These include: (1) the ability to monitor continuously day and night, summer and winter, under adverse environmental conditions in a comparison with boat surveys; (2) portability and quick transport features of DCPs compared to the lack of these features in on-shore facilities; (3) elimination of need for conventional power sources, air-conditioning, and submerged piping structures required for on-shore installation; (4) ease of access for servicing and calibration deemed better than for conventional methods. The benefits of these features are not easily priced but should be considered in comparative study.

Discussion of Results

A DCP-satellite system was installed in a major waterway in Alabama and employed to monitor important water quality for use in the management of water resources. Although difficulties were encountered with the operation of some pH sensors, the accuracy and precision of DCP data are quite acceptable in a comparison with conventionally acquired data.

From an operational and economic standpoint, the capital cost of a DCP system is three to four times that required for a conventional boat survey; however, the operating cost for a conventional survey is at least 4.5 greater than that for a DCP system to acquire a unit of information.

The capital cost of a DCP is comparable to, or perhaps somewhat less than, the capital cost of a conventional on-shore monitoring station. The total operating costs for these two systems are comparable, but on-shore installations would be favored in a comparison of operating costs per unit of information when it is considered that the on-shore data may be continuously recorded.

Assuming that the satellite was in orbit, the DCP system would offer distinct advantages over conventional boat surveys and on-shore installations for certain types of waterways to accomplish specific tasks. For example, for large streams flowing through remote-areas, the DCP features of portability, the lack of need for conventional power sources, and the ease of access by boat for servicing would make their use extremely attractive in a comparison with conventional systems. The portability of the DCPs would greatly facilitate initial model development as it is often necessary to monitor many locations on a trial and error basis in efforts to locate critical areas. The larger quantity of data supplied by DCPs in a given time period when compared with boat surveys would also be of maximum benefit in model development. After a model has been verified, the data from a reduced number of DCP strategically placed in the waterway would serve as input to the model for prediction and management of water quality. Since locations of critical points vary with flow, temperature, and other water characteristics, the quick transport feature of the DCPs would again prove useful for the monitoring of a variety of sampling points.

For monitoring of specific areas such as impoundments, and certain segments of easily accessible streams where long-term records of stream flow and water quality are required for the prediction of low flows and flooding conditions, the on-shore installations appear to be the one of choice when compared with DCPs.

Conventional boat surveys appear to be most useful and desirable in short-term monitoring of large streams during periods of critical conditions where low initial costs are a prime consideration.

Conclusions

The following conclusions are offered as a result of this investigation.

1. The DCP-concept has been demonstrated to be a feasible and productive system for the acquisition of water quality data for use in the management of water resources.
2. The water quality data collected by DCPs, after elimination of known erroneous results, are adjusted to exhibit acceptable accuracy and precision in a comparison with conventionally acquired data.
3. The DCP system offers distinct operational and economic advantages in the monitoring of waterways where model development and verification are the primary objectives.
4. A purpose of this investigation has been fulfilled with regard to identification and education of potential users of the remotely sensed, space-acquired data.
5. The results of this investigation has been interpreted and disseminated on a timely basis to ultimate users

including policy makers and regulatory agencies by means of seminars, informal meetings and discussions, and correspondence.

Recommendations

Based on the results of this study, it is recommended that a DCP system be employed on an operational basis in conjunction with Federal and State regulatory agencies for waterway model development and verification and, subsequently, for the monitoring of the waterway to insure that established water quality standards are maintained.

APPENDIX I

APPENDIX I

2 May 1974

TO: Members of Consortium of Local Industries:
Gulf States Paper Corporation,
Reichhold Chemicals, Inc.,
Empire Coke Company
Central Foundry Company,
Warrior Asphalt Company of America, Inc.

FROM: George P. Whittle, Project Director

SUBJECT: Summary of Results of Warrior River Water Quality Survey for Period July 22 to October 27, 1973.

The purpose of this memorandum is to present a brief description of the results obtained on the water quality survey of a segment of the Warrior River conducted during the summer of 1973.

Water quality data were collected by two methods: (1) conventional boat sampling; and (2) remote sensing utilizing NASA data collection platforms (DCP) and the Earth Resources Technology Satellite (ERTS). All of the DCP results were carefully screened to eliminate those known or suspected to be in error because of sensor inoperation or malfunction, incorrect calibration, and other factors noted during the period of DCP operation. A computer print-out of the results judged to be reliable, together with a list of sensor locations, is attached to this memorandum.

Part A of this memorandum contains Figure 1 through 8 which graphically present the dissolved oxygen results obtained at the boat sampling stations and the results obtained at those DCP locations which correspond closely to the boat sampling locations. Figures 9 through 22 in Part A show the dissolved oxygen profiles on a weekly basis for the segment of the river surveyed. The appropriate DCP results are also shown in these figures for comparison.

The results obtained by the boat sampling and the DCP techniques were subjected to a statistical regression analysis and the results are presented graphically in Figures 1B through 9B in Part B of this report. Two sets of matched pairs of data points were analyzed. The first matched-pair set was obtained from calibration studies. In this study a DCP was removed from the water after an operation period of about two weeks and, without any adjustment, the probes were placed in an appropriate standardized solution. The value given by probe was then compared with the known value of the standardized solution. During the study period, this procedure was performed for a total of approximately twenty times for all the DCPs in operation. A line of best fit by the least squares method was calculated for each of the values of dissolved oxygen, pH, conductivity and temperature. Figures 1B through 4B show the results of this analysis together with the 95% confidence interval given by twice the calculated standard error of estimate.

The second set of matched-pair data was obtained by selecting those boat sampling results measured near a DCP location where both boat and DCP results were measured on the same day at approximately the same time. A maximum difference in actual sampling times of two hours was set as a limit for a comparison of these results. This two-hour time limit was selected on the premise that, under most conditions, the water quality would not change appreciably. The results of this study are presented graphically in Figures 5B through 9B.

A tabulation of the averaged daily flows for the survey period, measured at the U.S.G.S. gaging station above Oliver Lock and Dam, is also included with this report for your information.

George P. Whittle

George P. Whittle

PART A

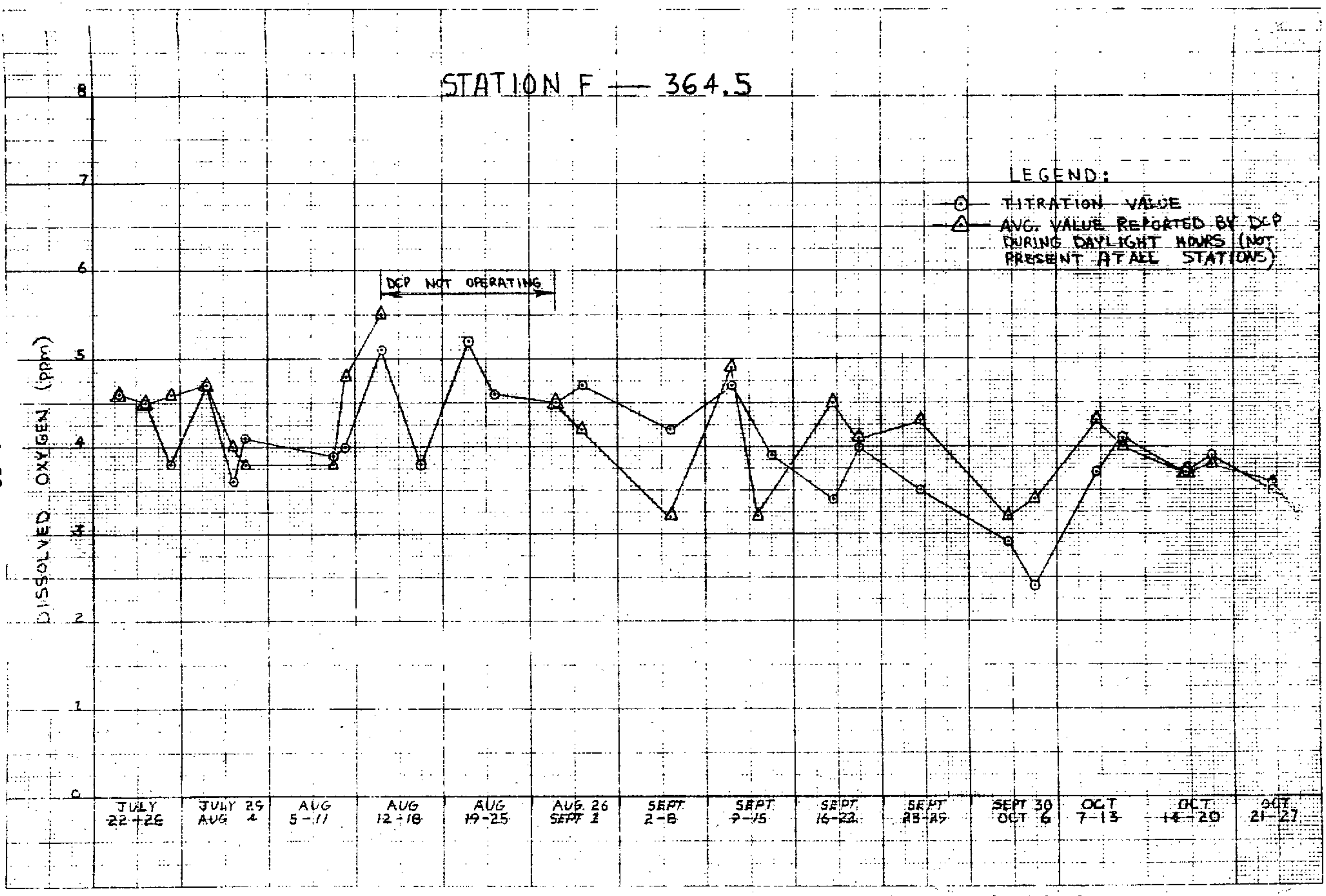

Fig. 1. Comparison of Dissolved Oxygen Values Obtained by Boat Sampling (Titration) with the Averaged Daily (daylight) Dissolved Oxygen Values Reported by ERTS Data Collection Platform (DCP) No. 6060 Located at R. M. 364.0 for Period July 22 - October 27, 1973. Station F Located at Lower End of Rock Quarry.

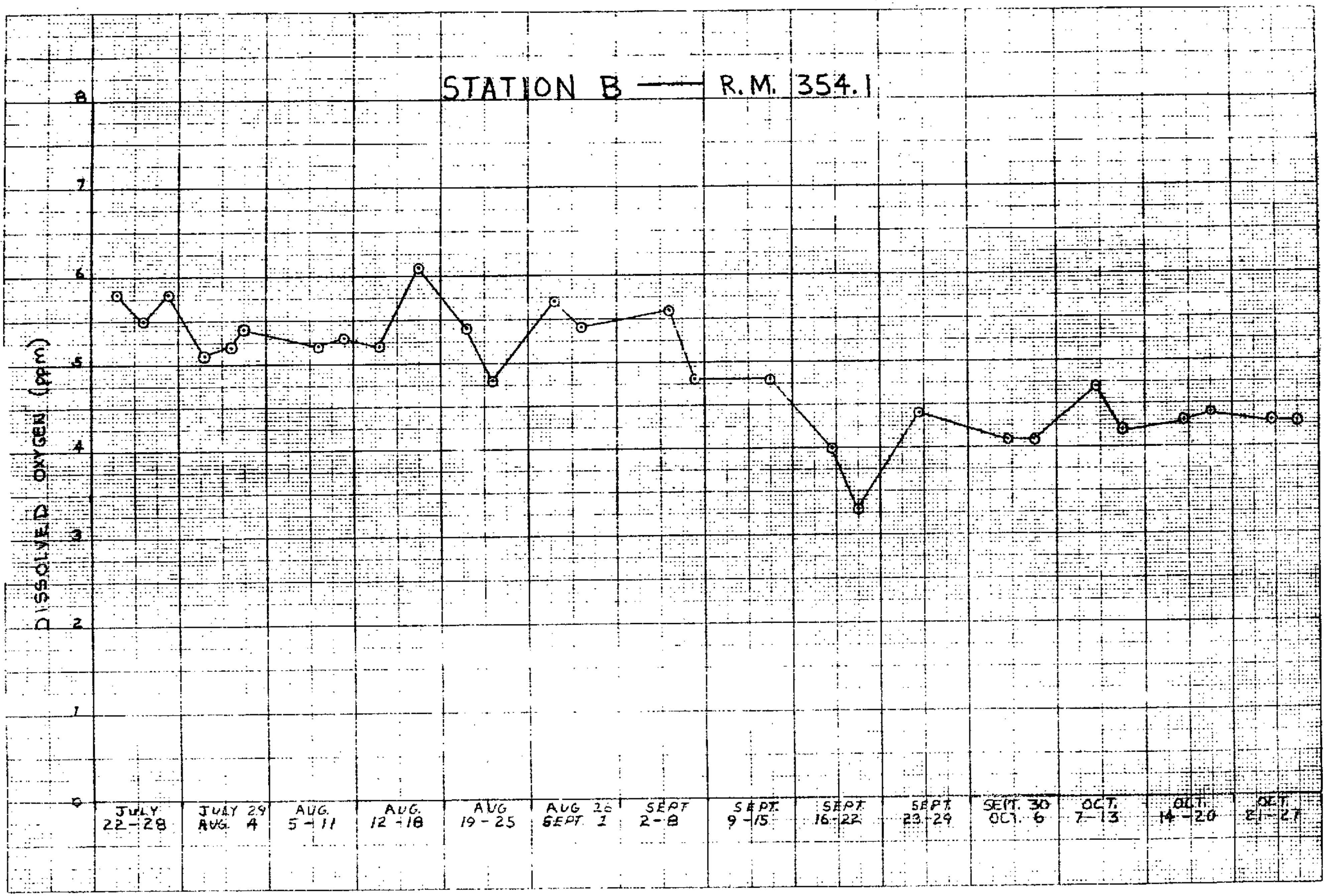

Fig. 2. Dissolved Oxygen Values Obtained by Boat Sampling (Titration) for Period July 22 - October 27, 1973. Station B Located Above Bluff Creek

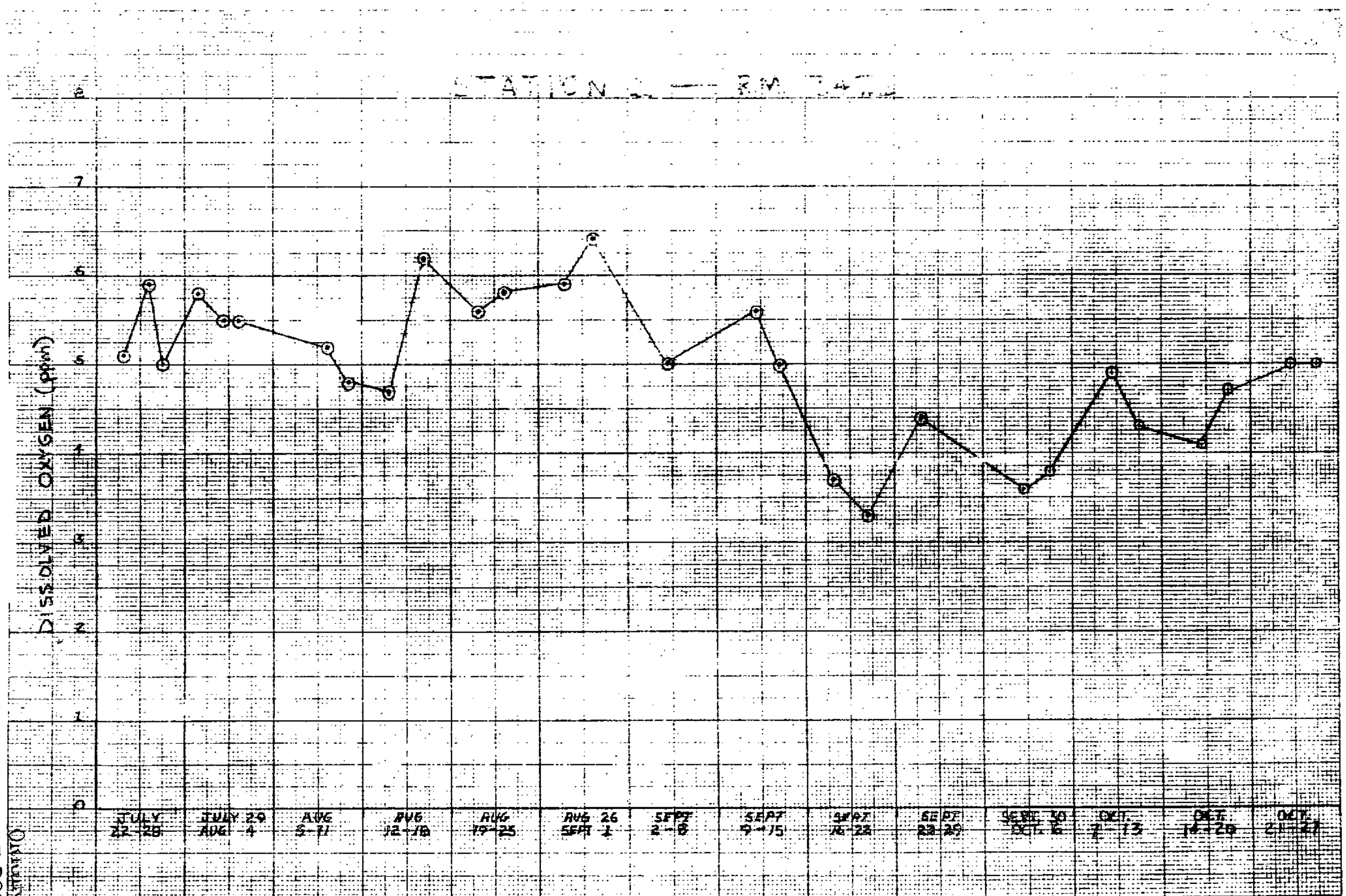

Fig. 3. Dissolved Oxygen Values Obtained by Boat Sampling (Titration). Station 1 Located at Old Lock No. 13.

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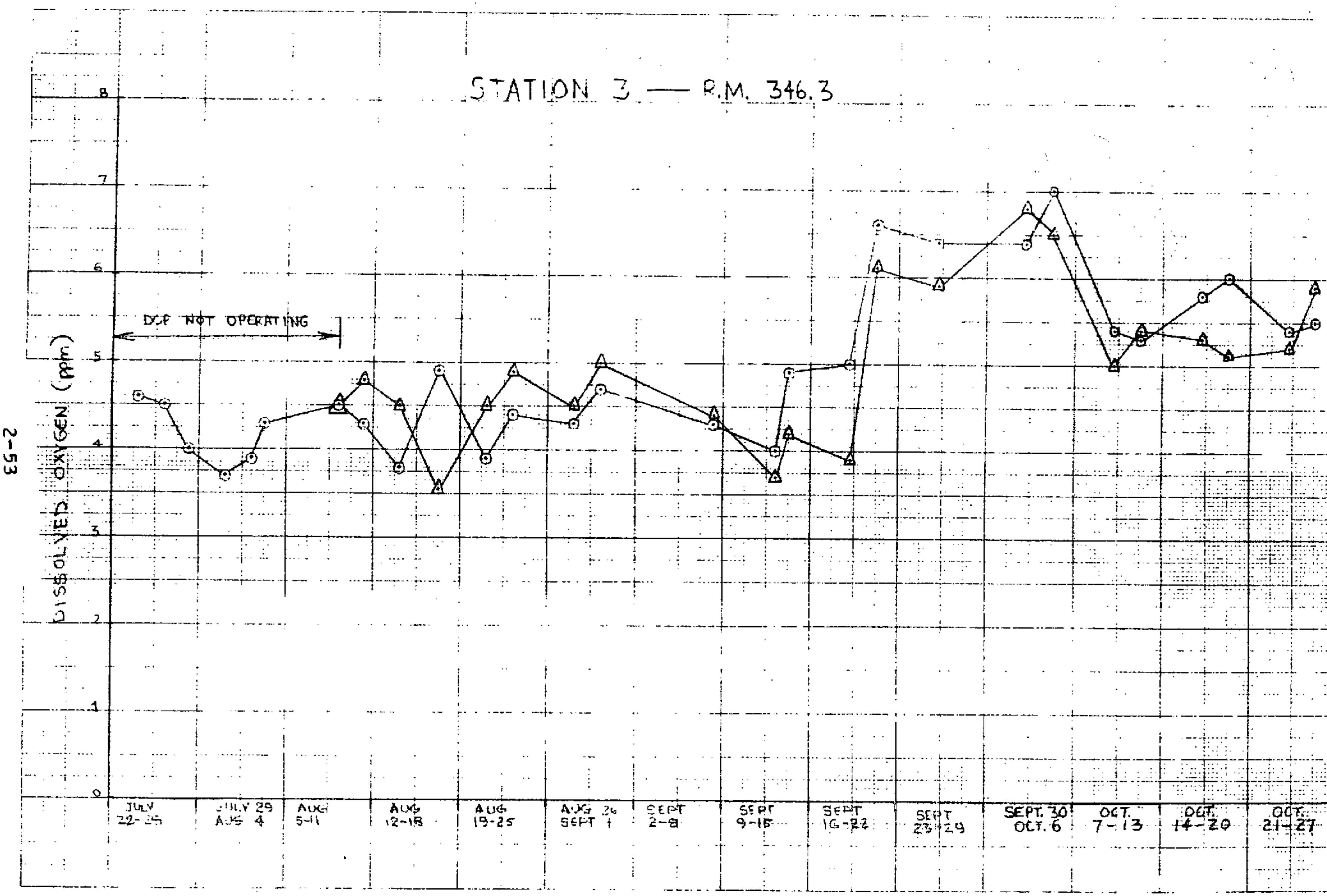

Fig. 4. Comparison of Dissolved Oxygen Values Obtained by Boat Sampling (Titration) With the Averaged Daily (daylight) Dissolved Oxygen Values Reported by DCP No. 6357 Located at R. M. 346.5. Station 3 Located Above Hurricane Creek.

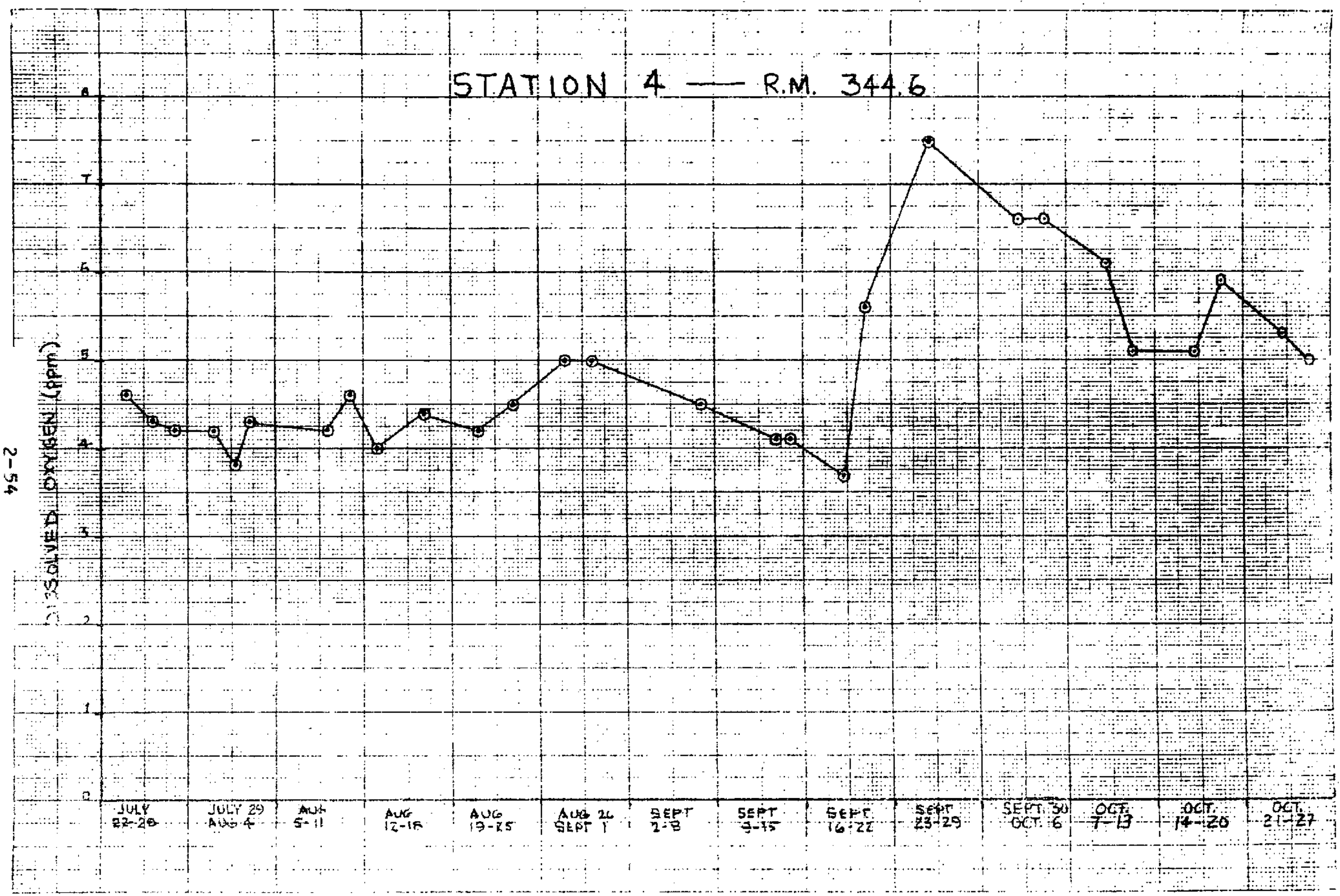

Fig. 5. Dissolved Oxygen Values Obtained by Boat Sampling (Titration). Station 4 Located at Warrior Asphalt Dock.

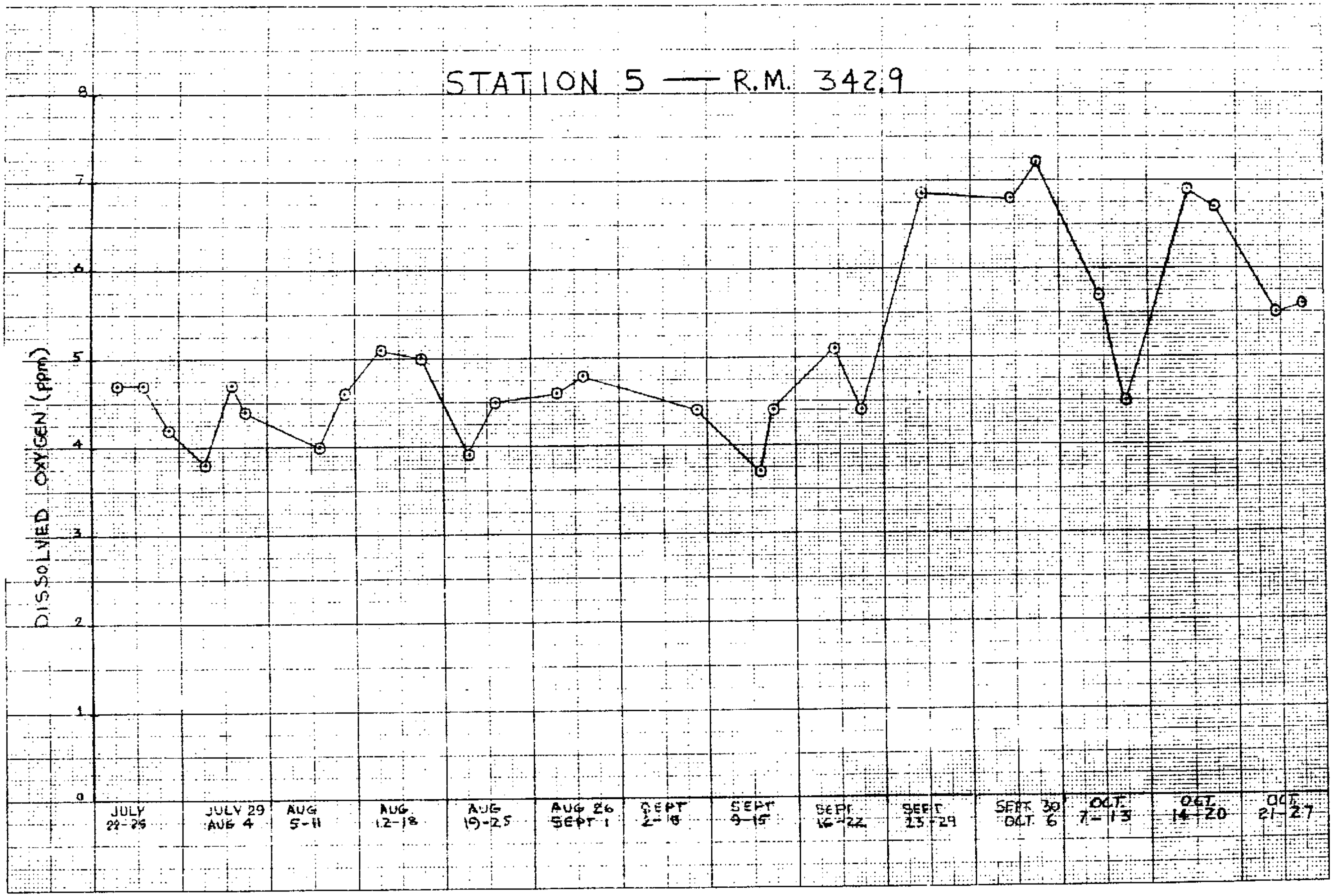

Fig. 6. Dissolved Oxygen Values Obtained by Boat Sampling (Titration). Station 5 Located at E-2 Kraft Dock at Gulf States Paper Corporation.

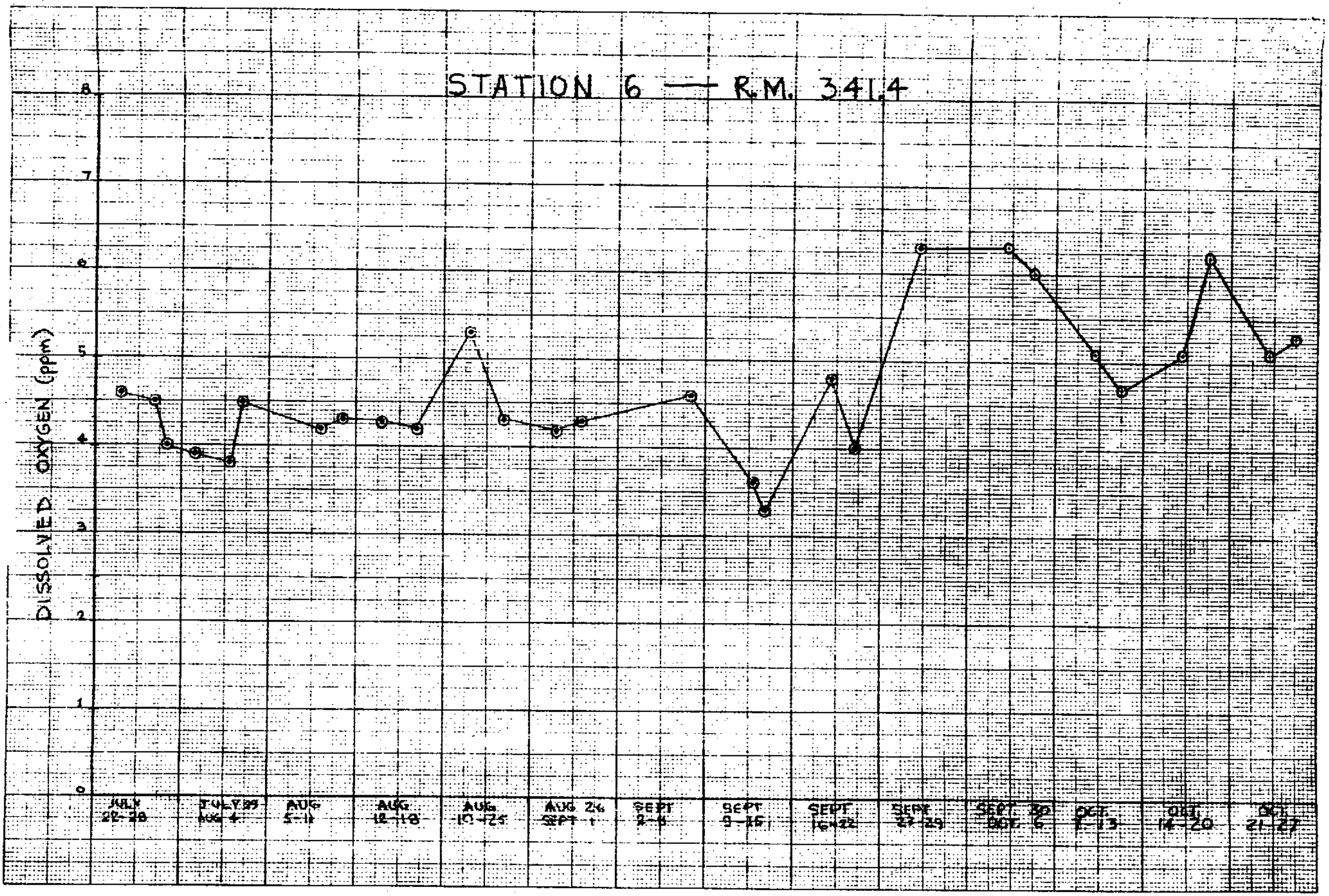

Fig. 7. Dissolved Oxygen Values Obtained by Boat Sampling (Titration). Station 6 Located Below Finnell Bridge.

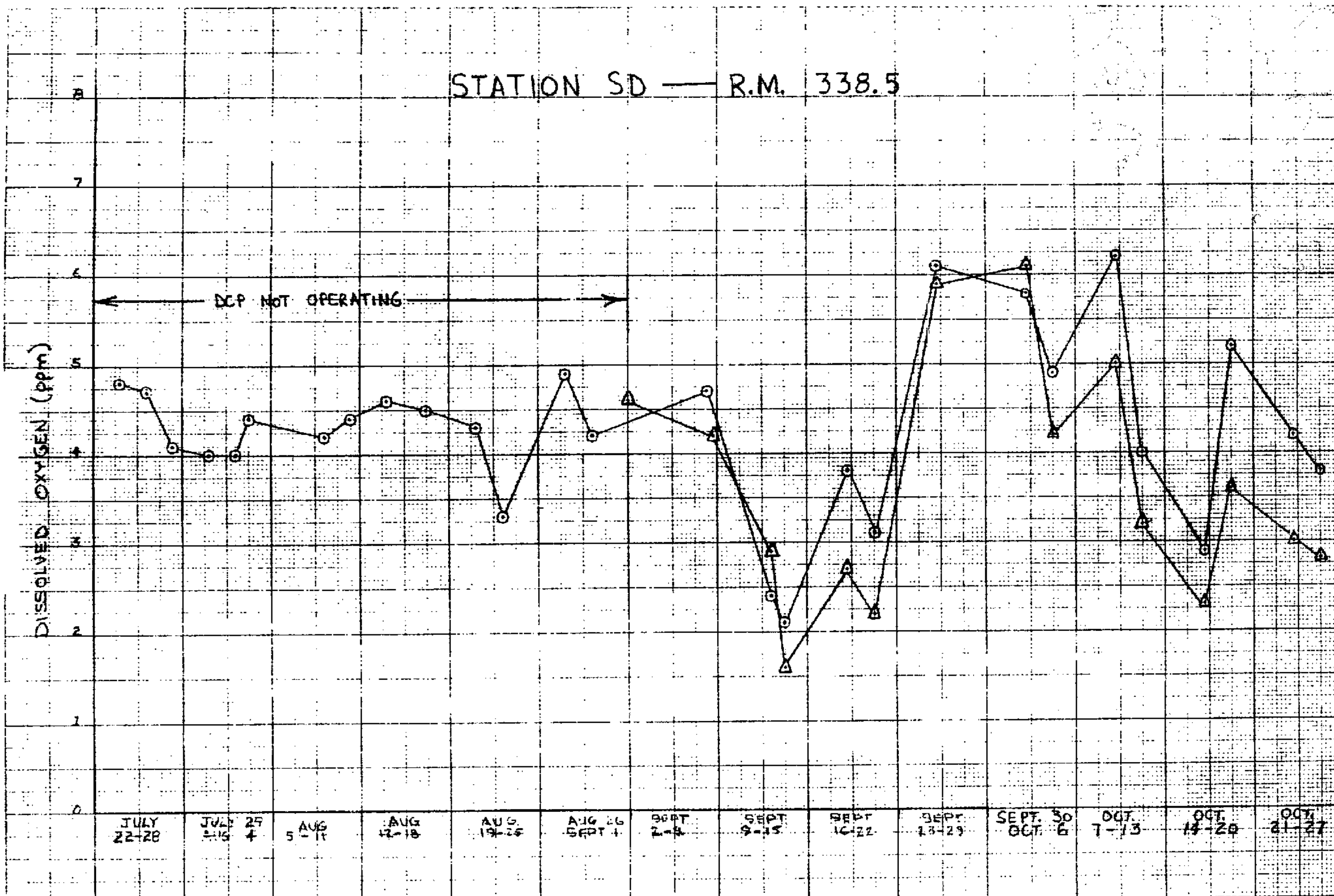

Fig. 8. Comparison of Dissolved Oxygen Values Obtained by Boat Sampling (Titration) With the Averaged Daily (daylight) Dissolved Oxygen Values Reported by DCP No. 6061 Located at R.M. 338.3. Station SD Located at State Docks.

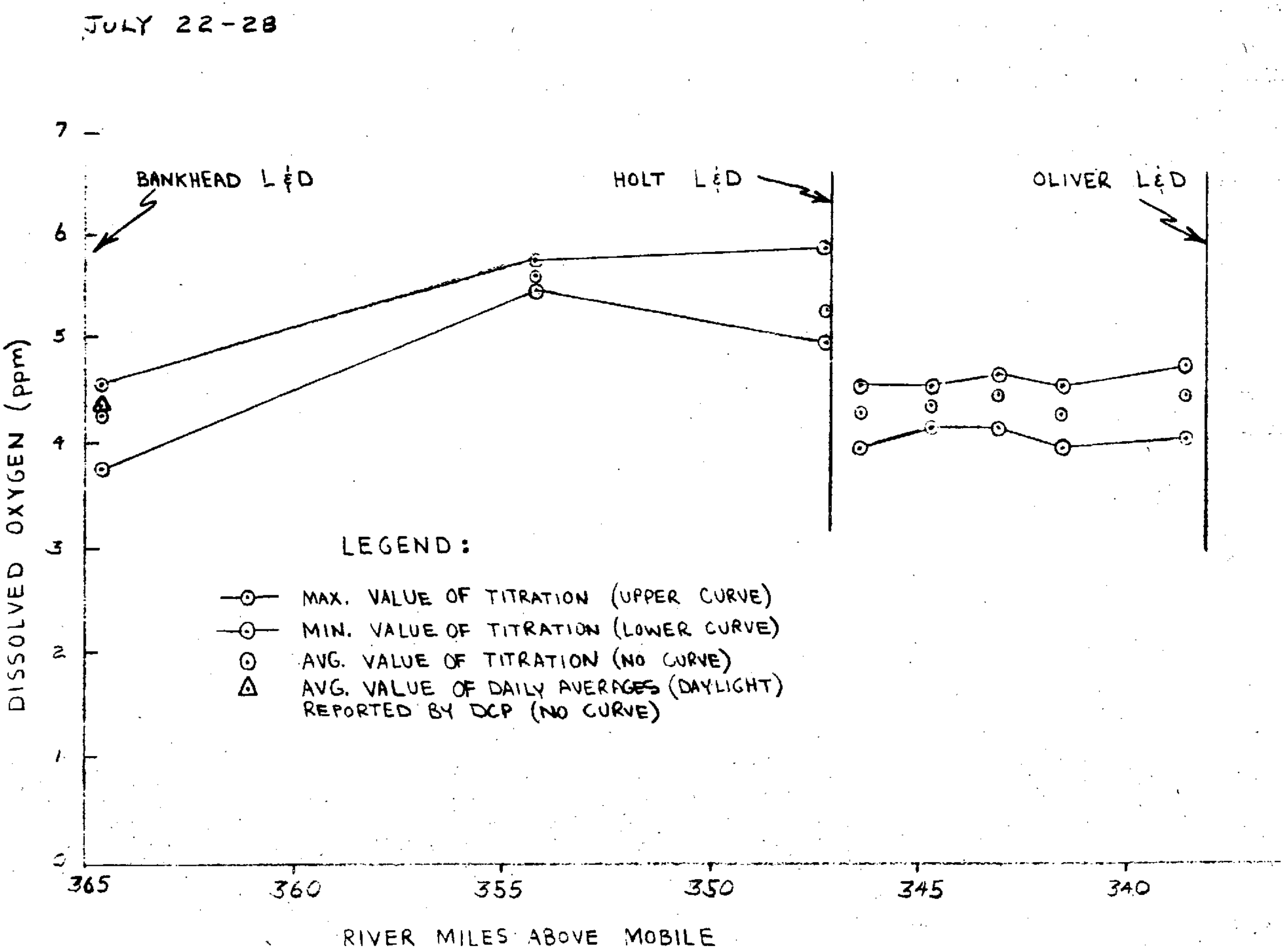

Fig. 9. Dissolved Oxygen Values Obtained for Week of July 22-28, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

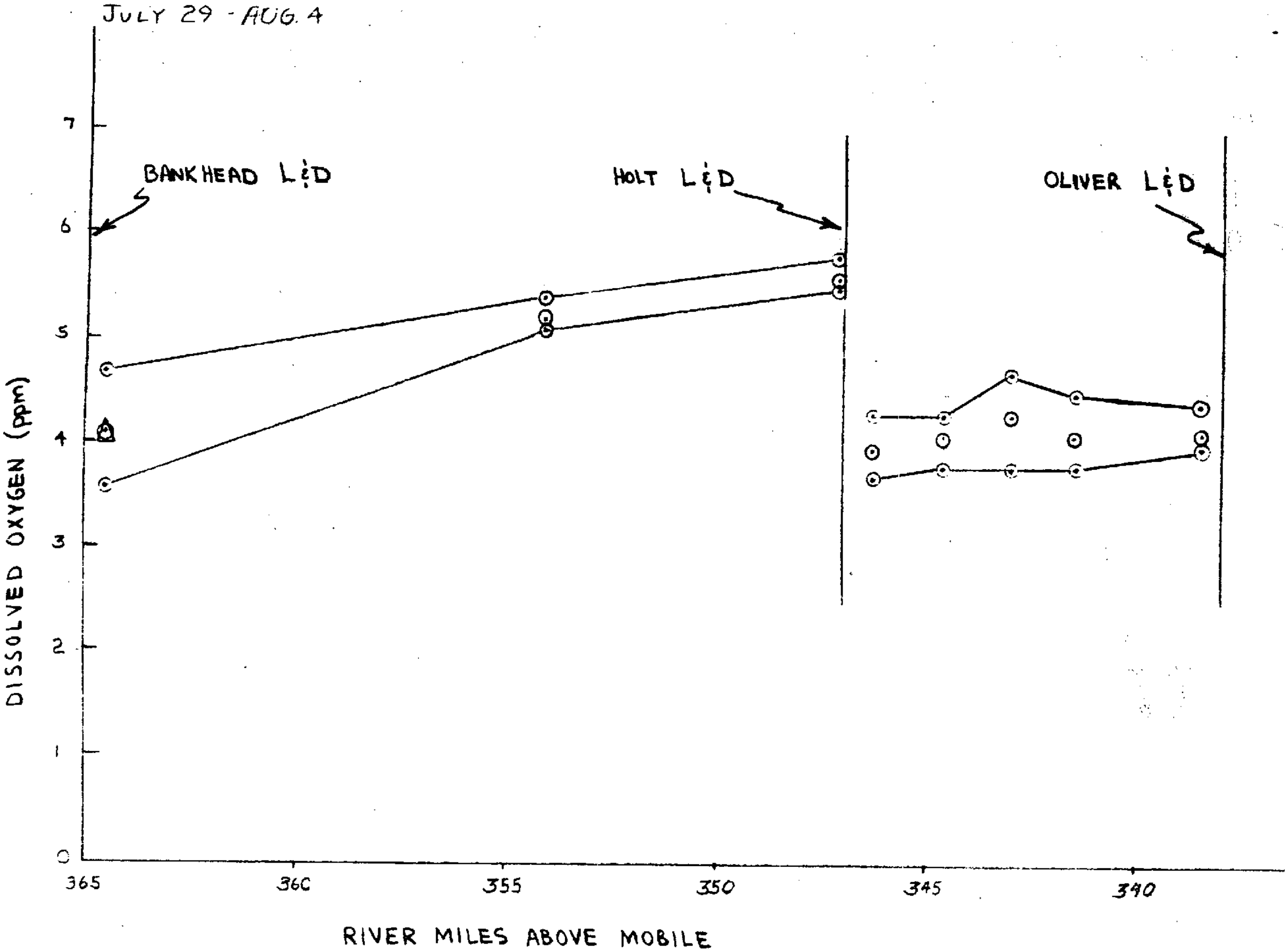

Fig. 10. Dissolved Oxygen Values Obtained for Week of July 29 - August 4, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

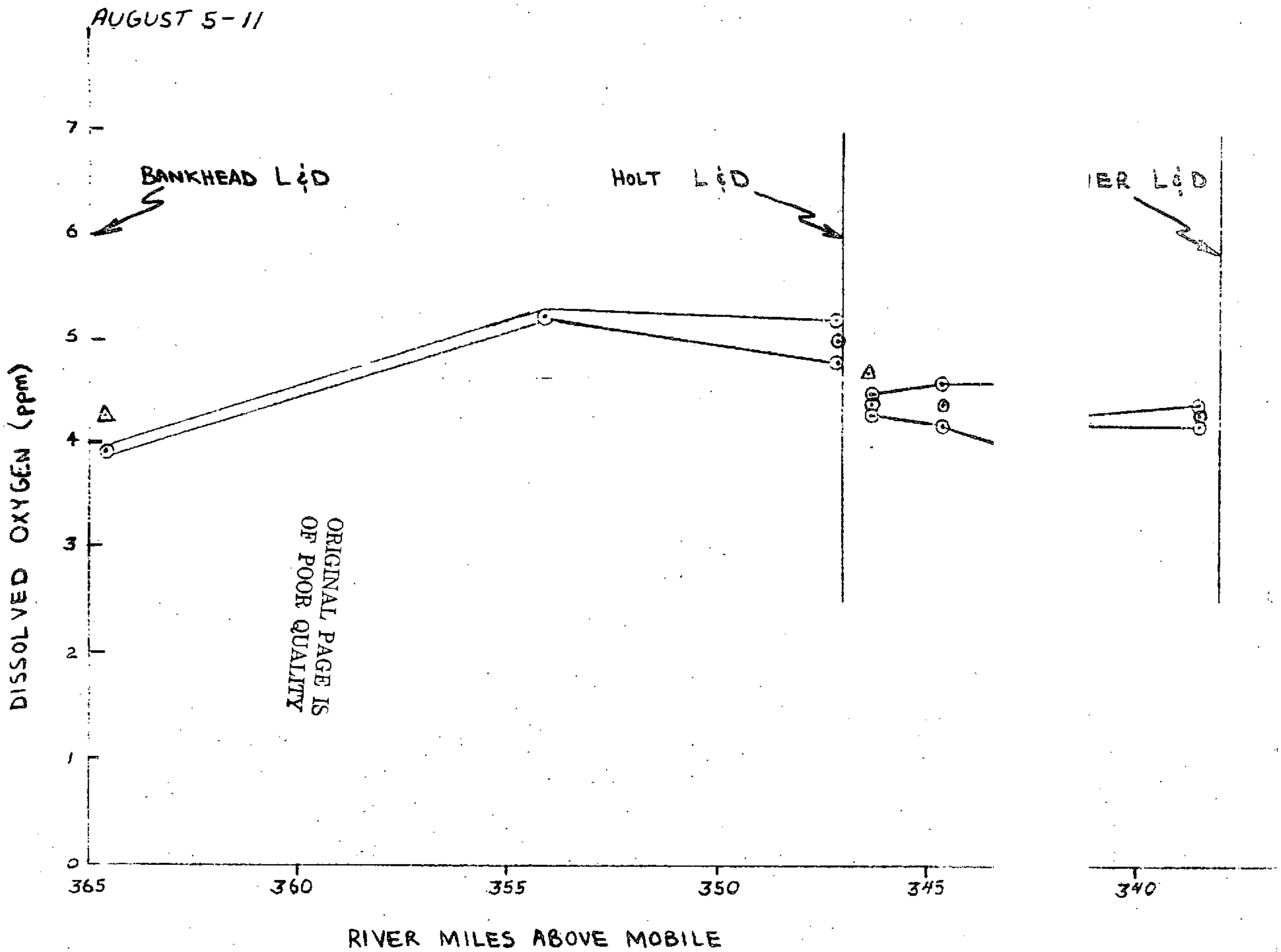

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Fig. 11. Dissolved Oxygen Values Obtained for Week of August 5-11, 1973. The Ope
Circles are Boat Sampling Results. The Open Triangles are DCP Results.

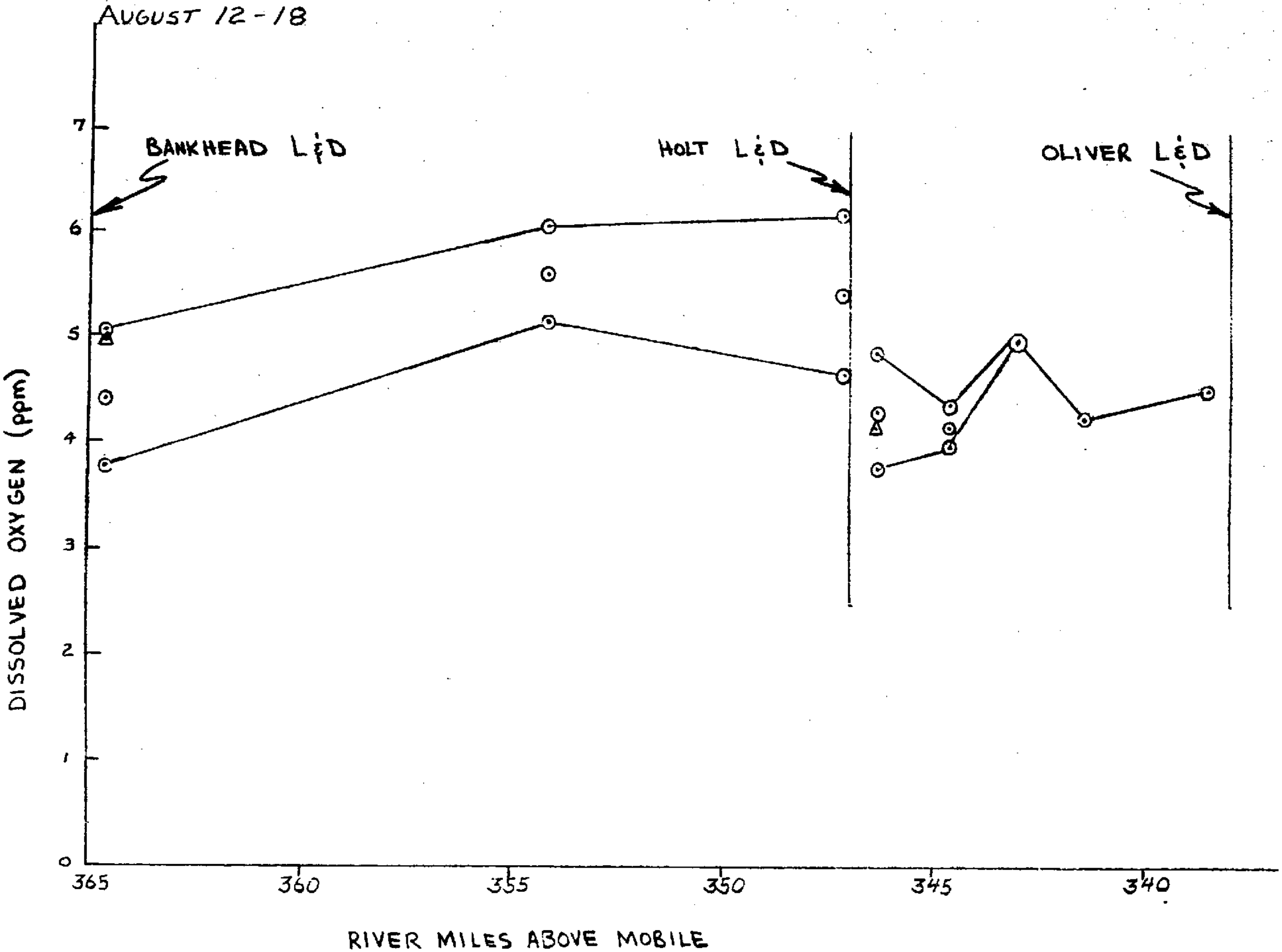

Fig. 12. Dissolved Oxygen Values Obtained for Week of August 12-18, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

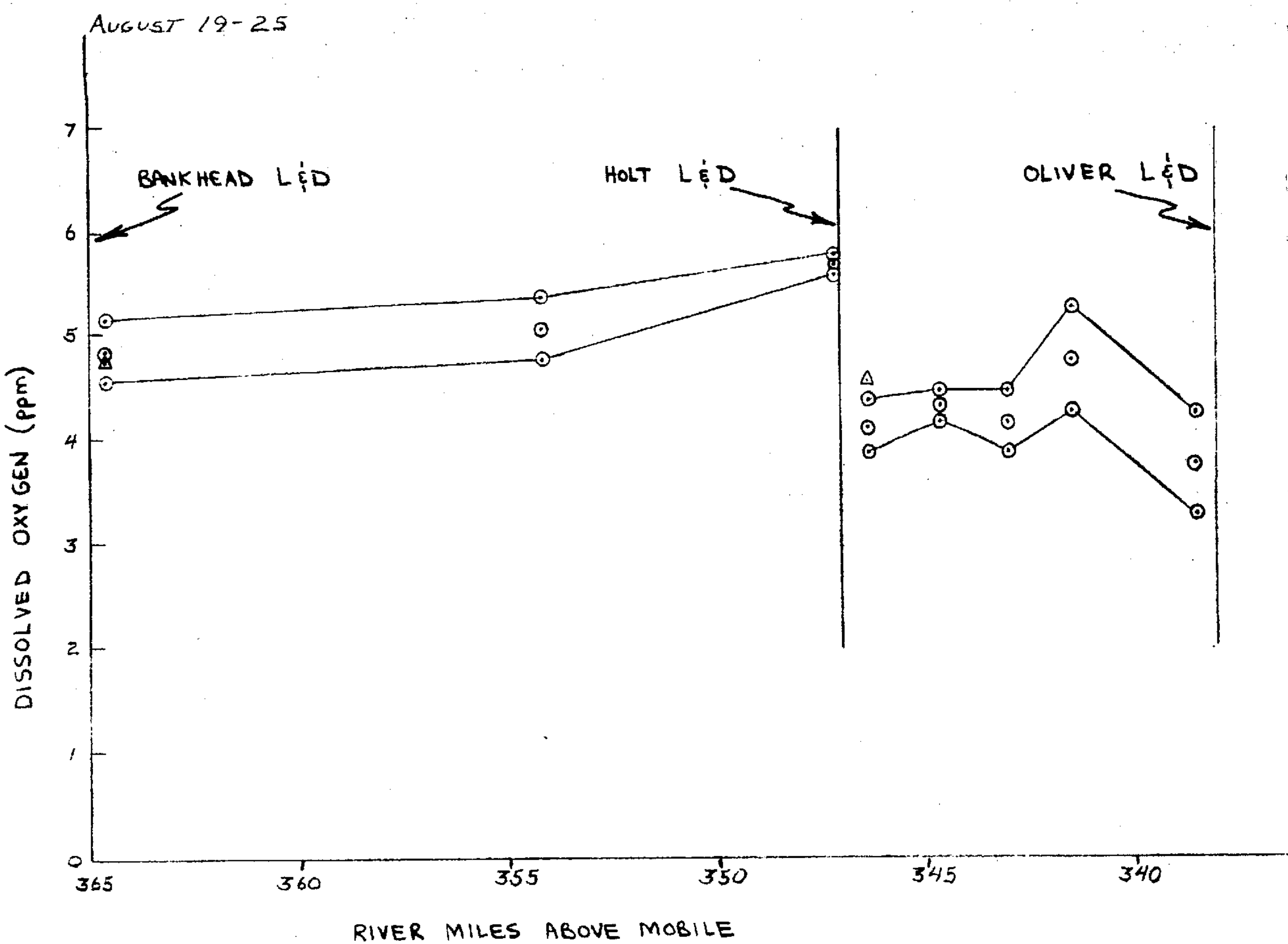

Fig. 13. Dissolved Oxygen Values Obtained for Week of August 19-25, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

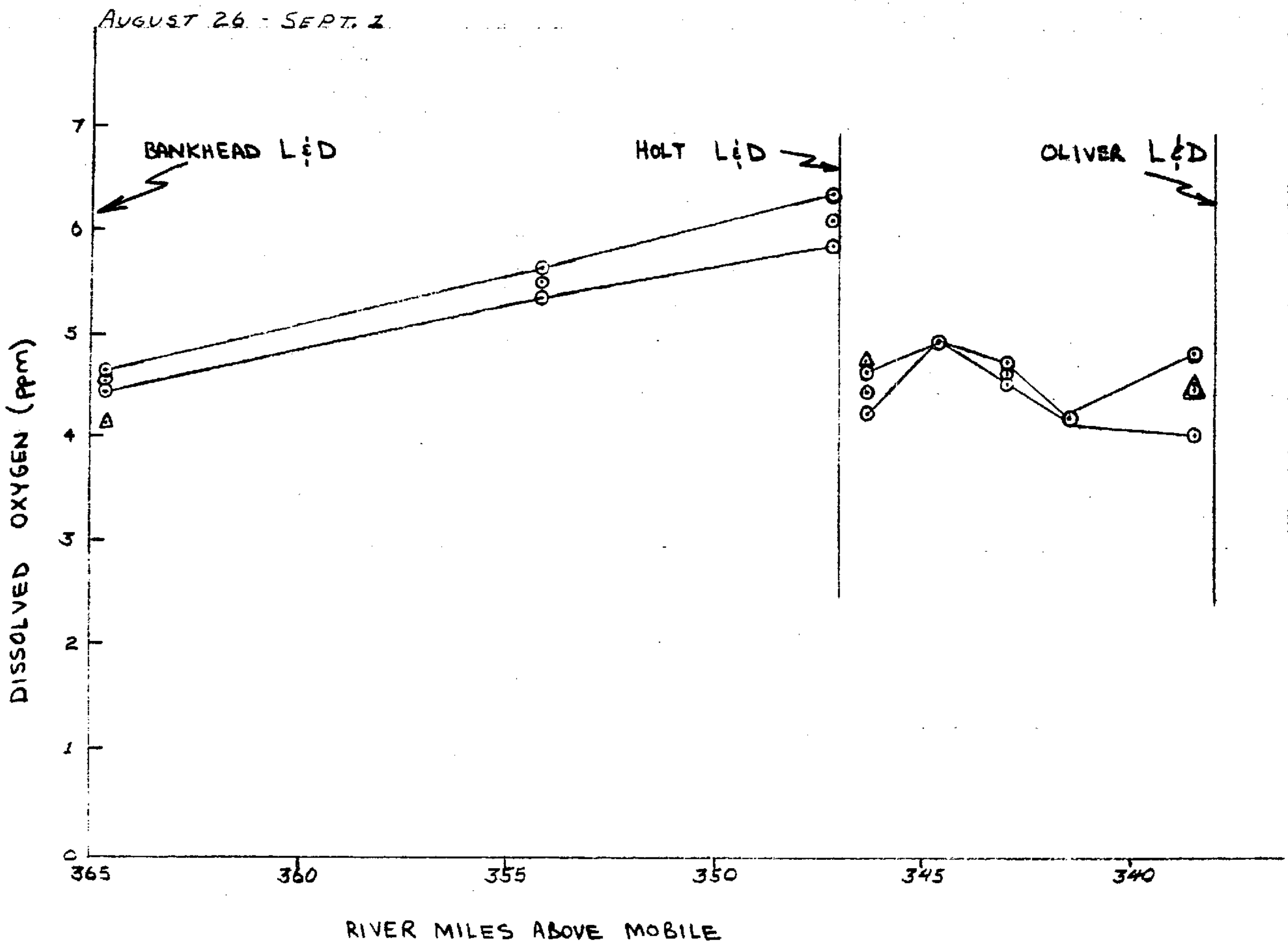

Fig. 14. Dissolved Oxygen Values Obtained for Week of August 26 - Sept. 1, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

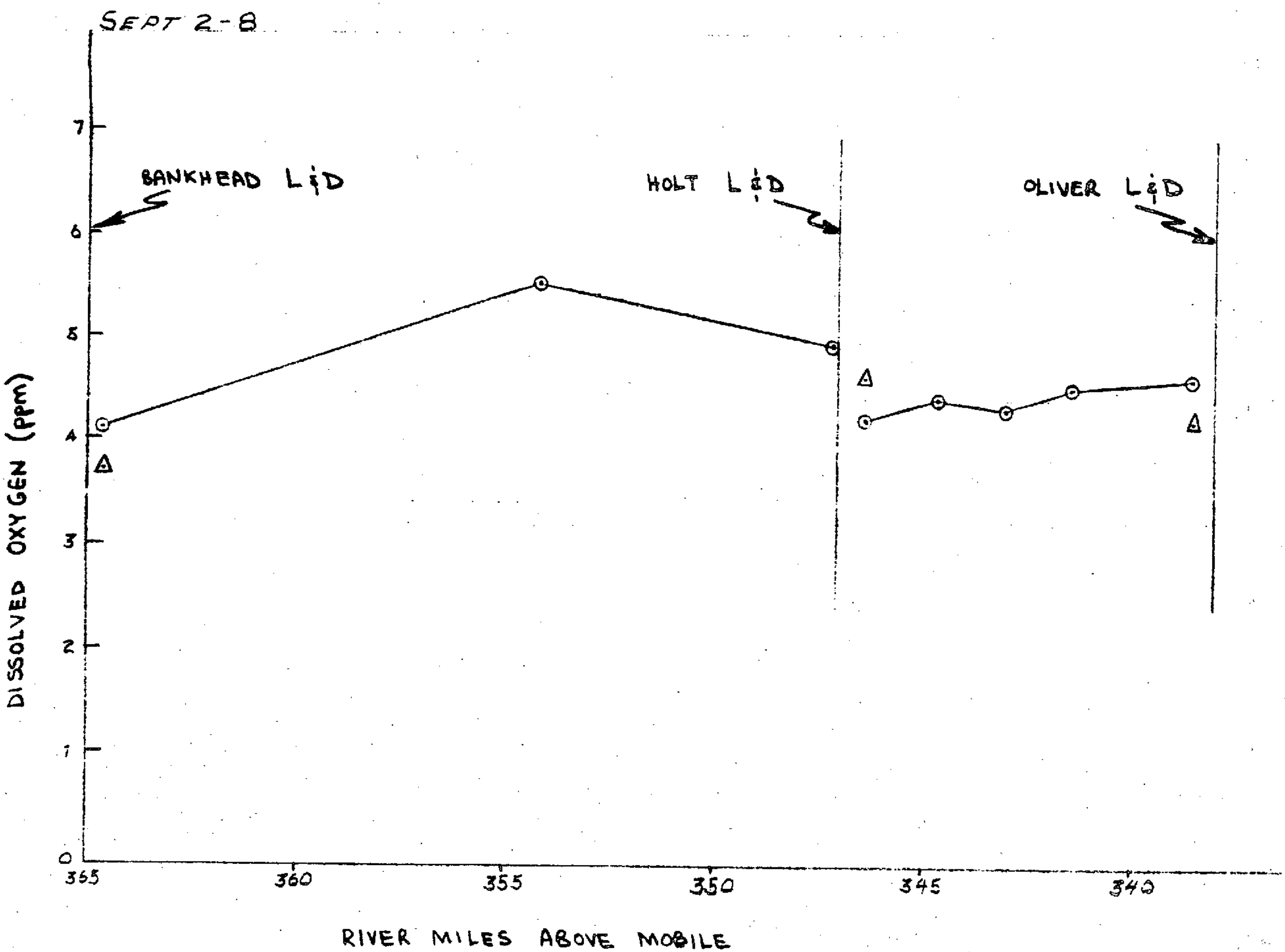

Fig. 15. Dissolved Oxygen Values Obtained for Week of Sept. 2-8, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

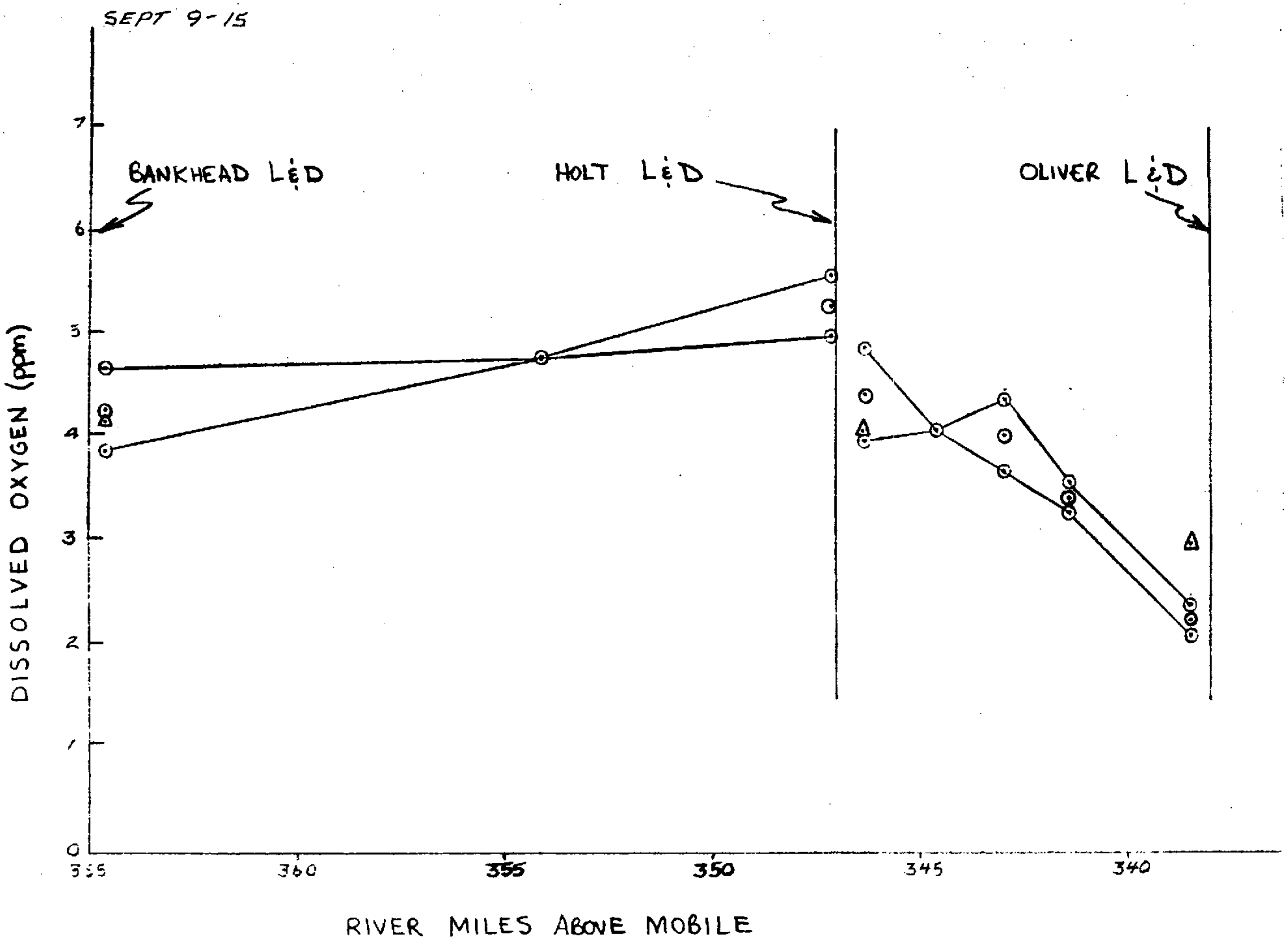

Fig. 16. Dissolved Oxygen Values Obtained for Week of Sept. 9-15, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

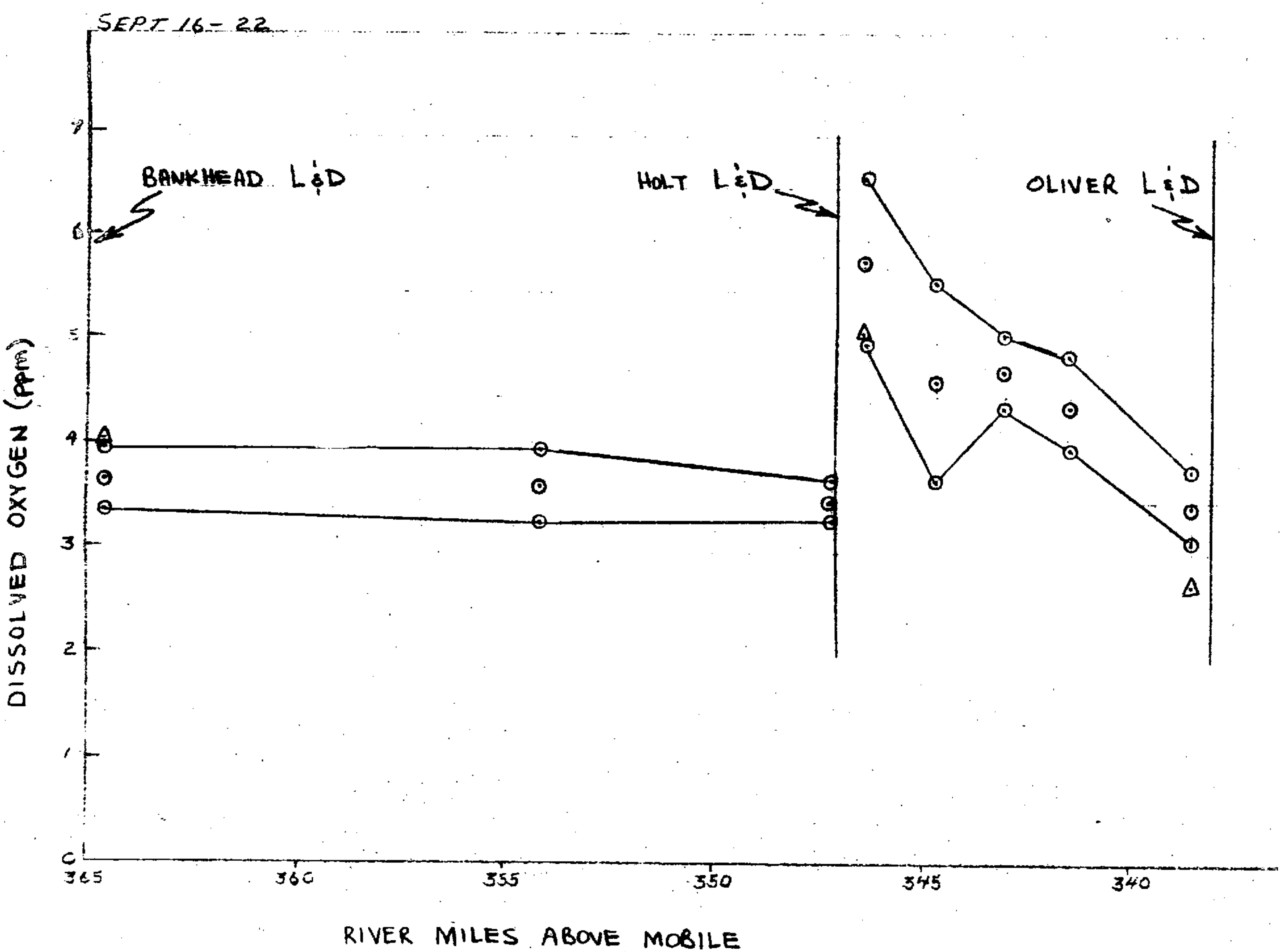

Fig. 17. Dissolved Oxygen Values Obtained for Week of Sept. 16-22, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

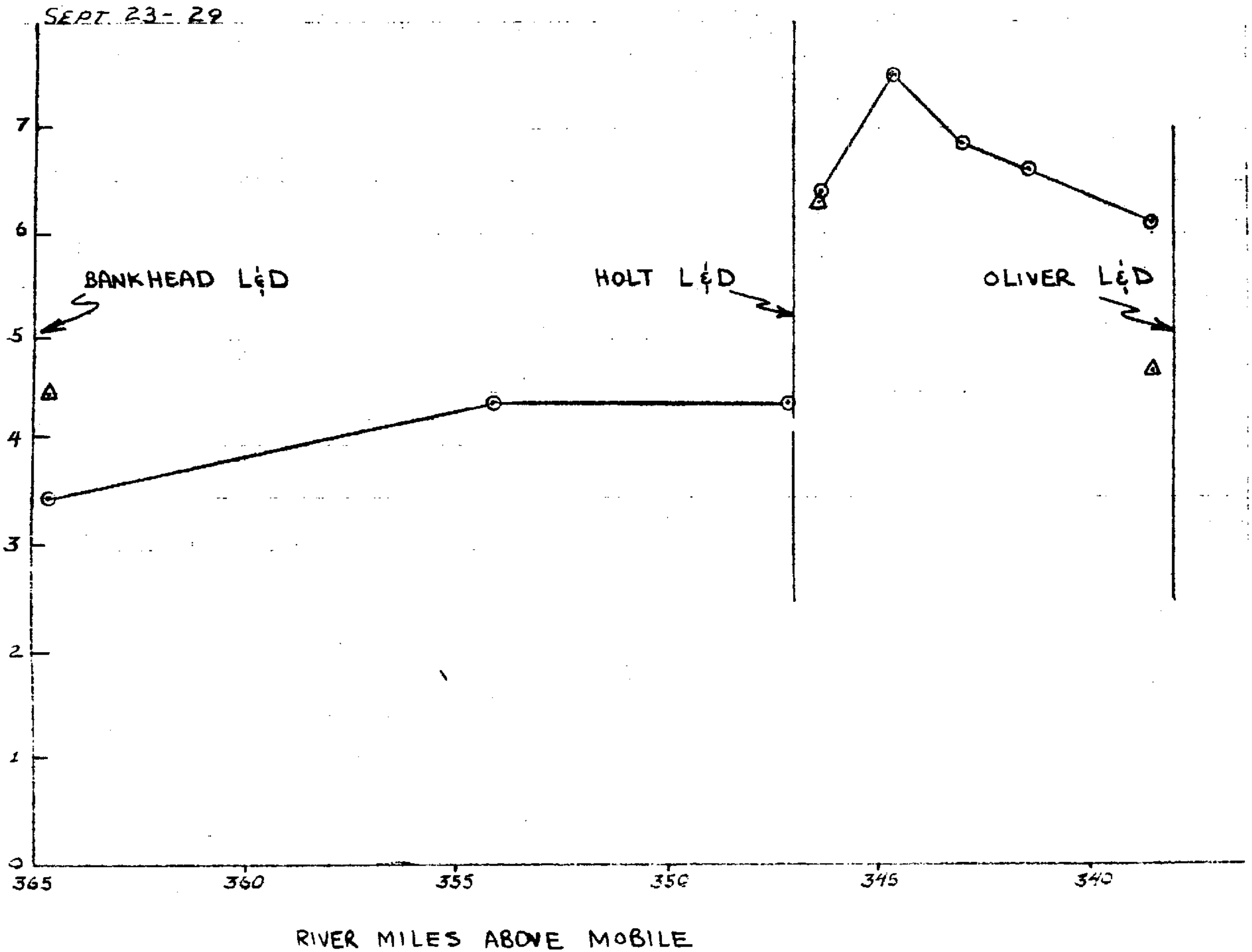

Fig. 18. Dissolved Oxygen Values Obtained for Week of Sept. 23-29, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

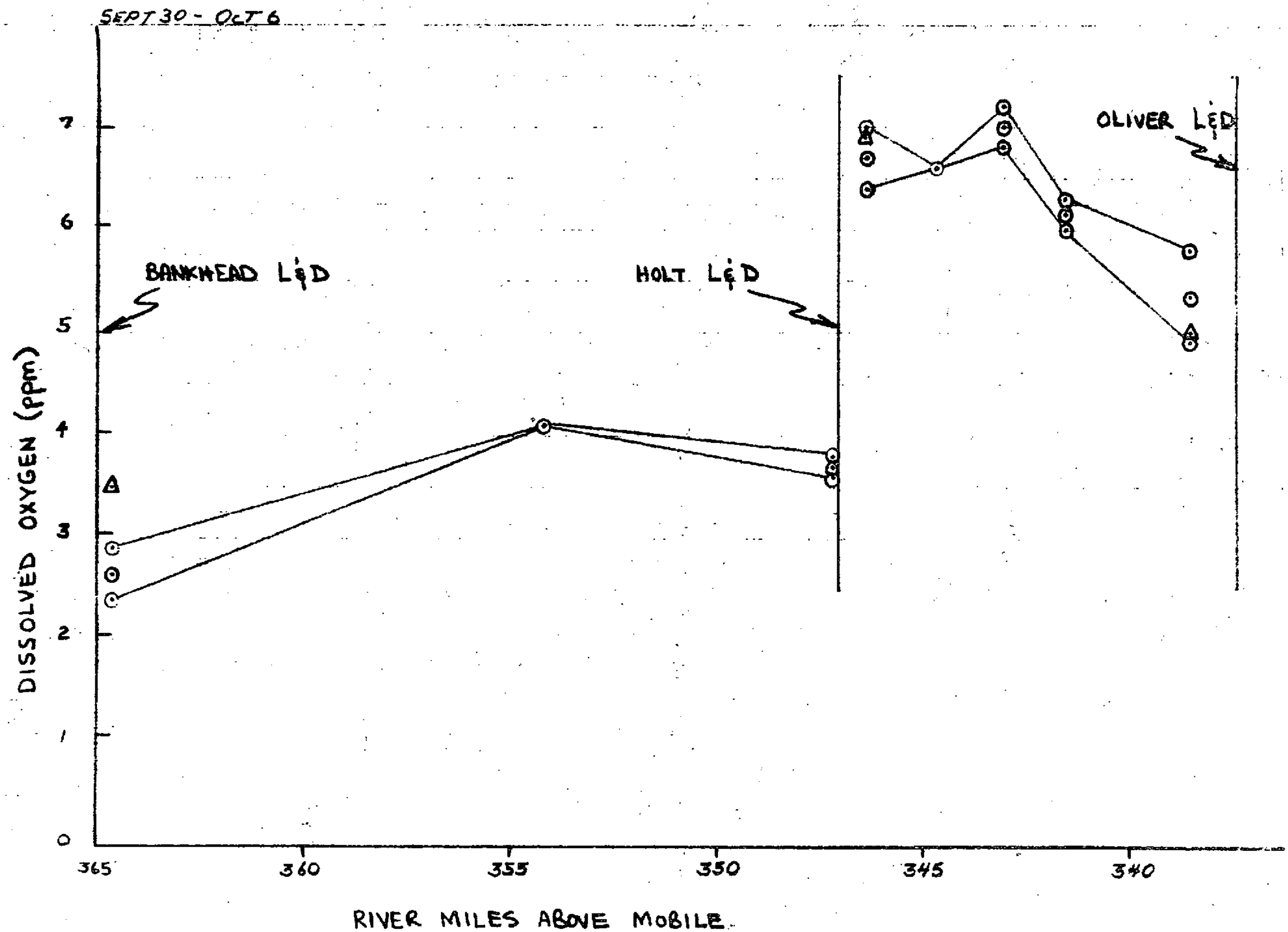

Fig. 19. Dissolved Oxygen Values Obtained for Week of Sept. 30 - Oct. 6, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

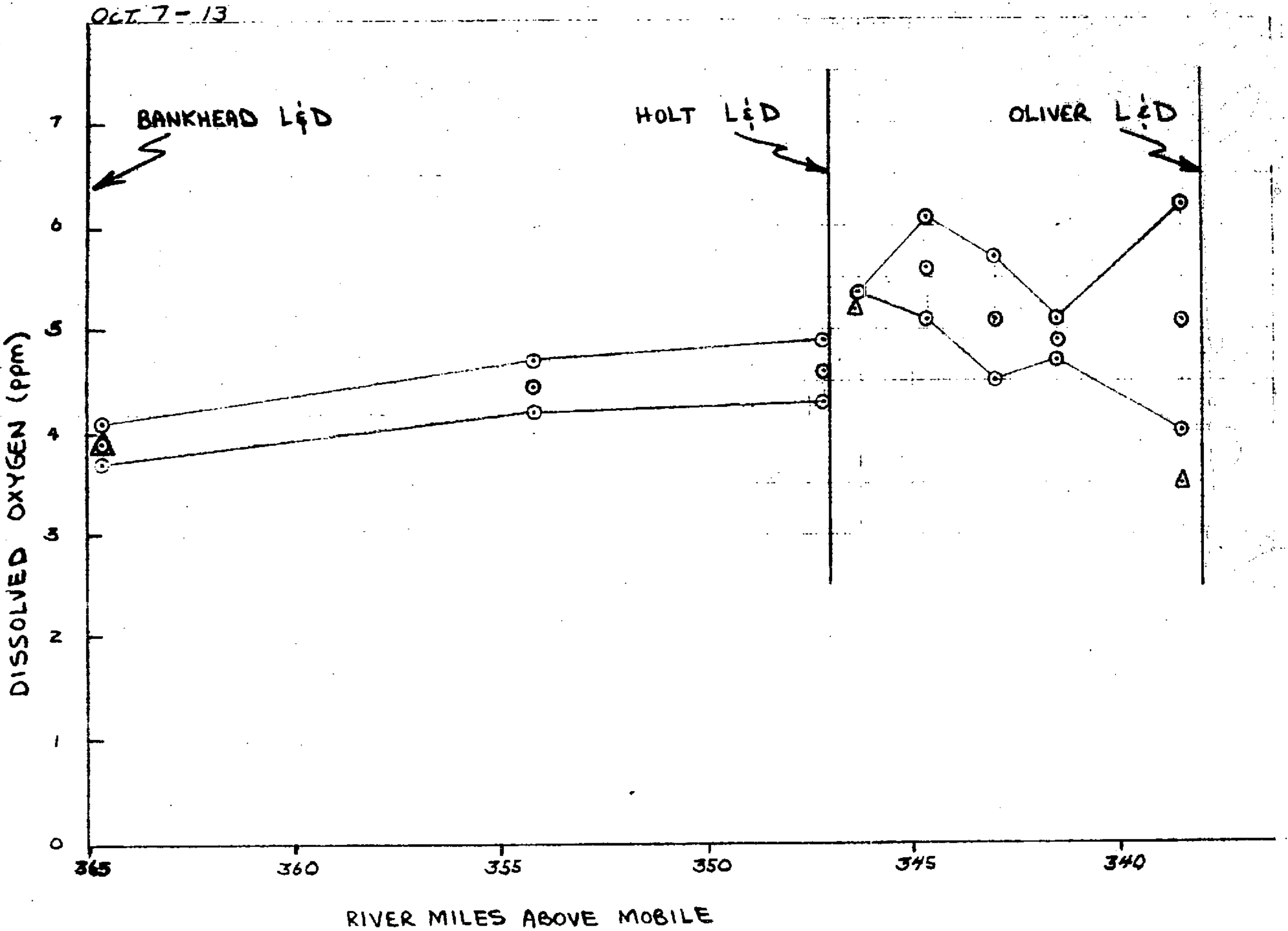

Fig. 20. Dissolved Oxvgen Values Obtained for Week of Oct. 7-13, 1973.

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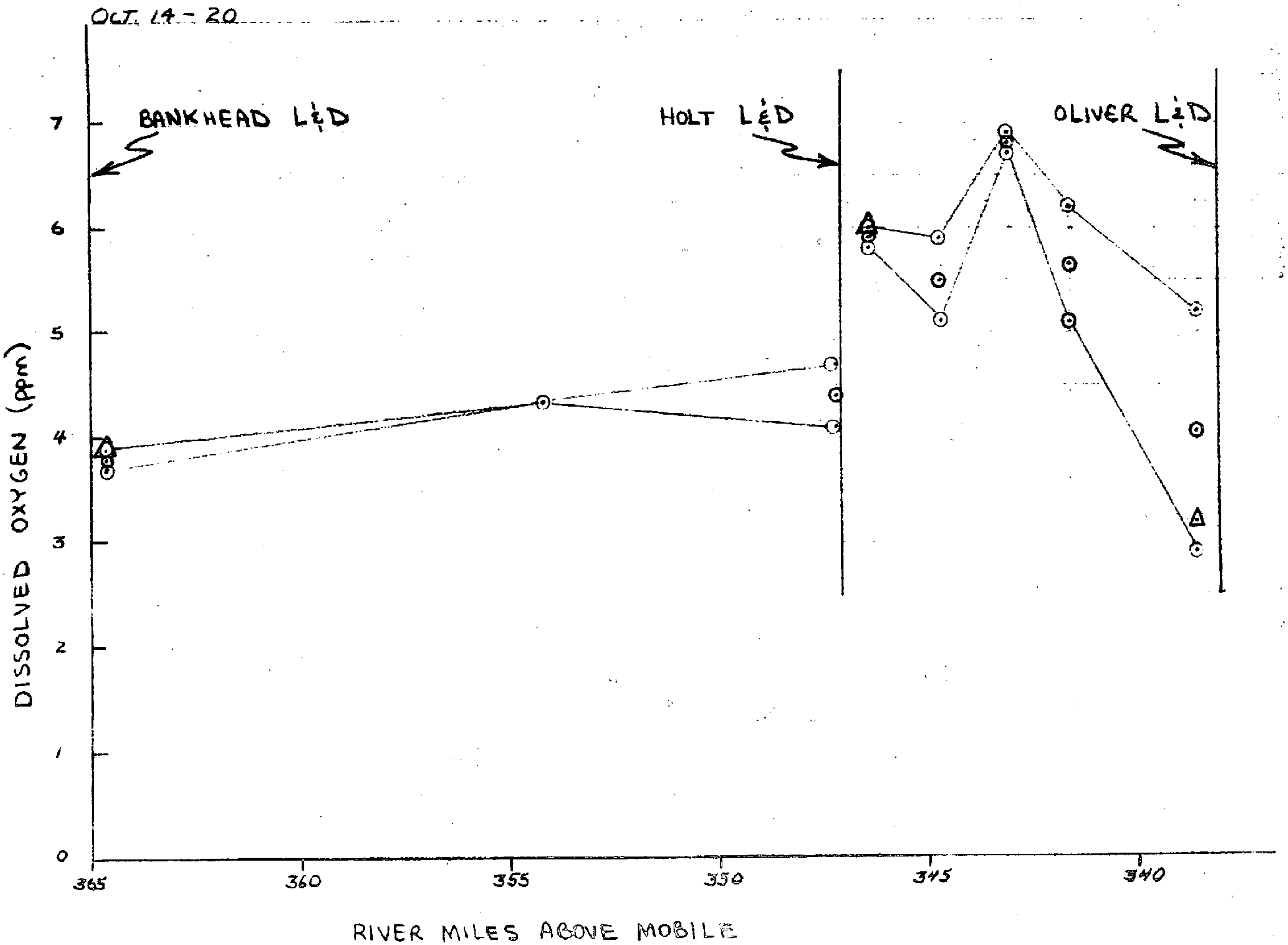

Fig. 21. Dissolved Oxygen Values Obtained for Week of Oct. 14-20, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

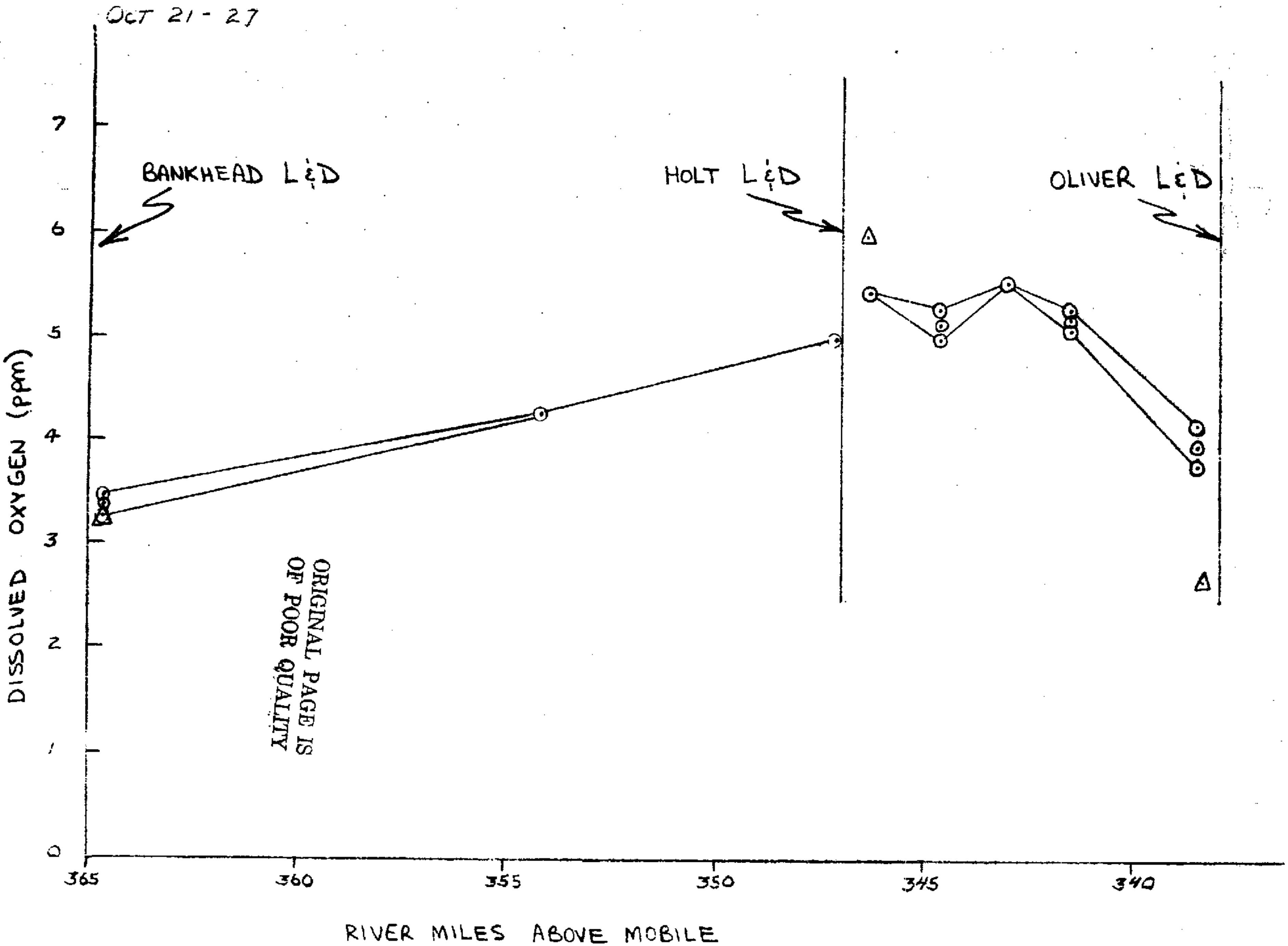

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Fig. 22. Dissolved Oxygen Values Obtained for Week of Oct. 21-27, 1973. The Open Circles are Boat Sampling Results. The Open Triangles are DCP Results.

PART B

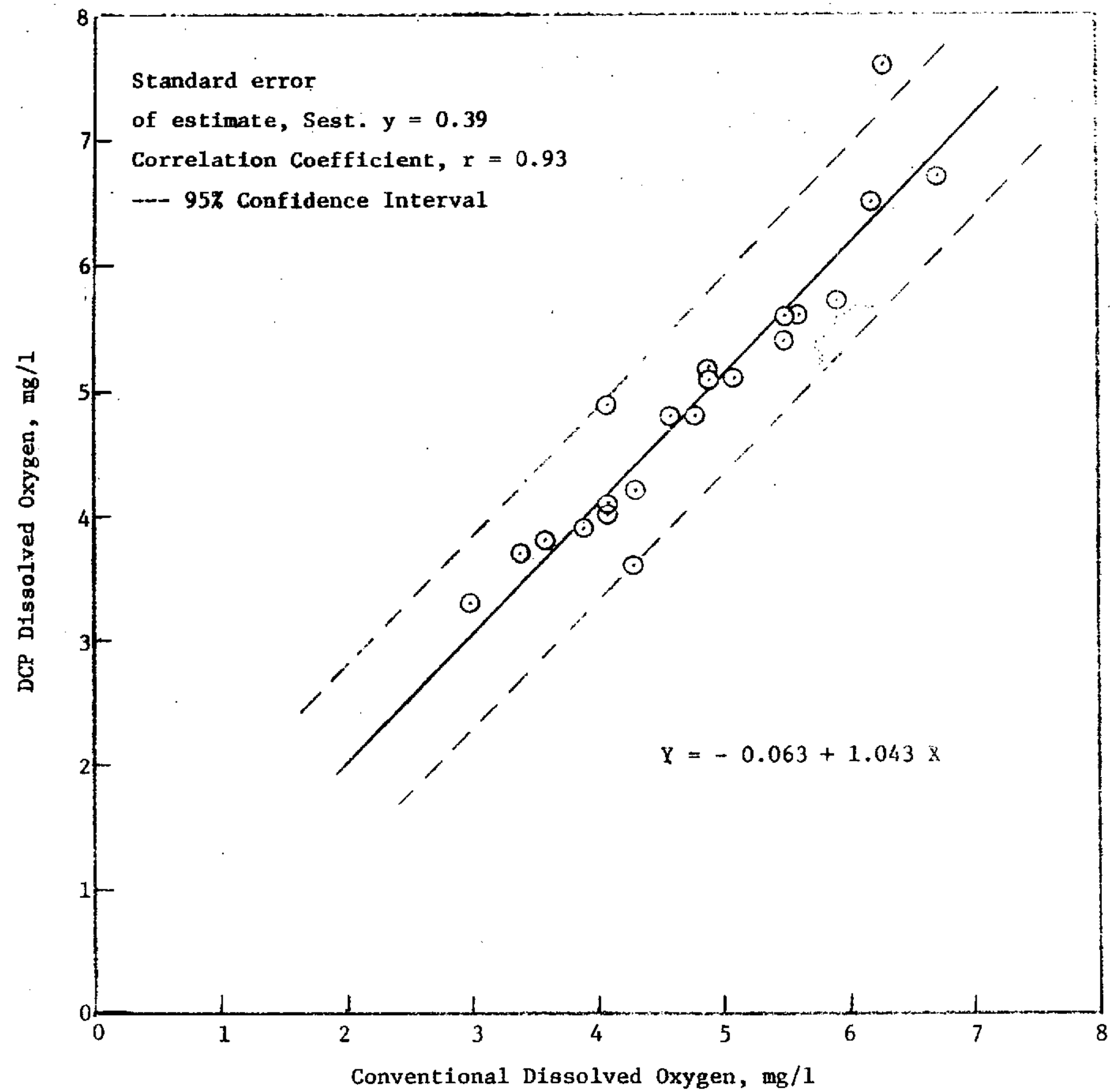

Fig. 1B. Dissolved Oxygen Regression Line for Calibration Studies Calculated by Least Squares Method.

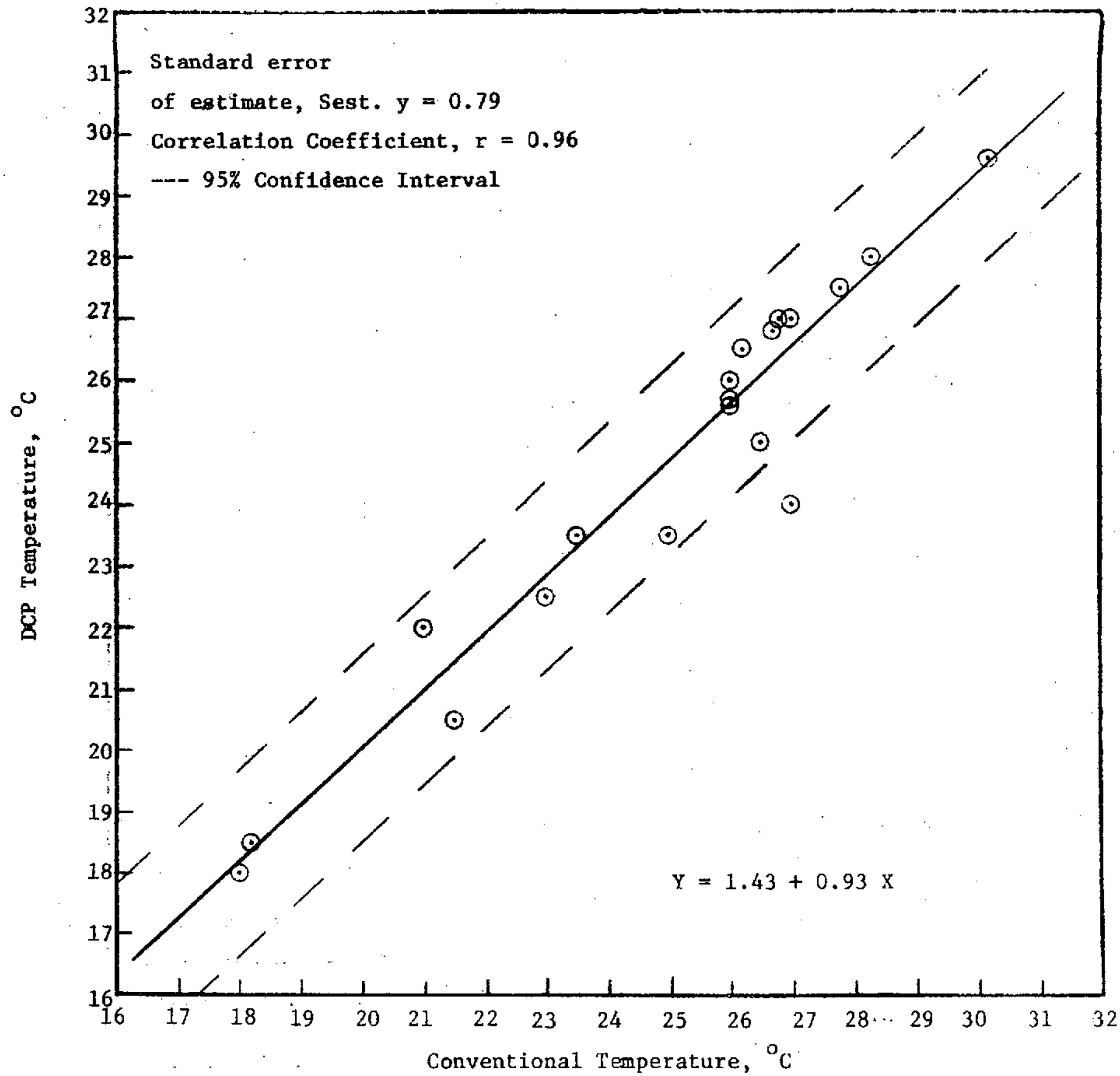

Fig. 2B. Temperature Regression Line for Calibration Studies Calculated by Least Squares Method.

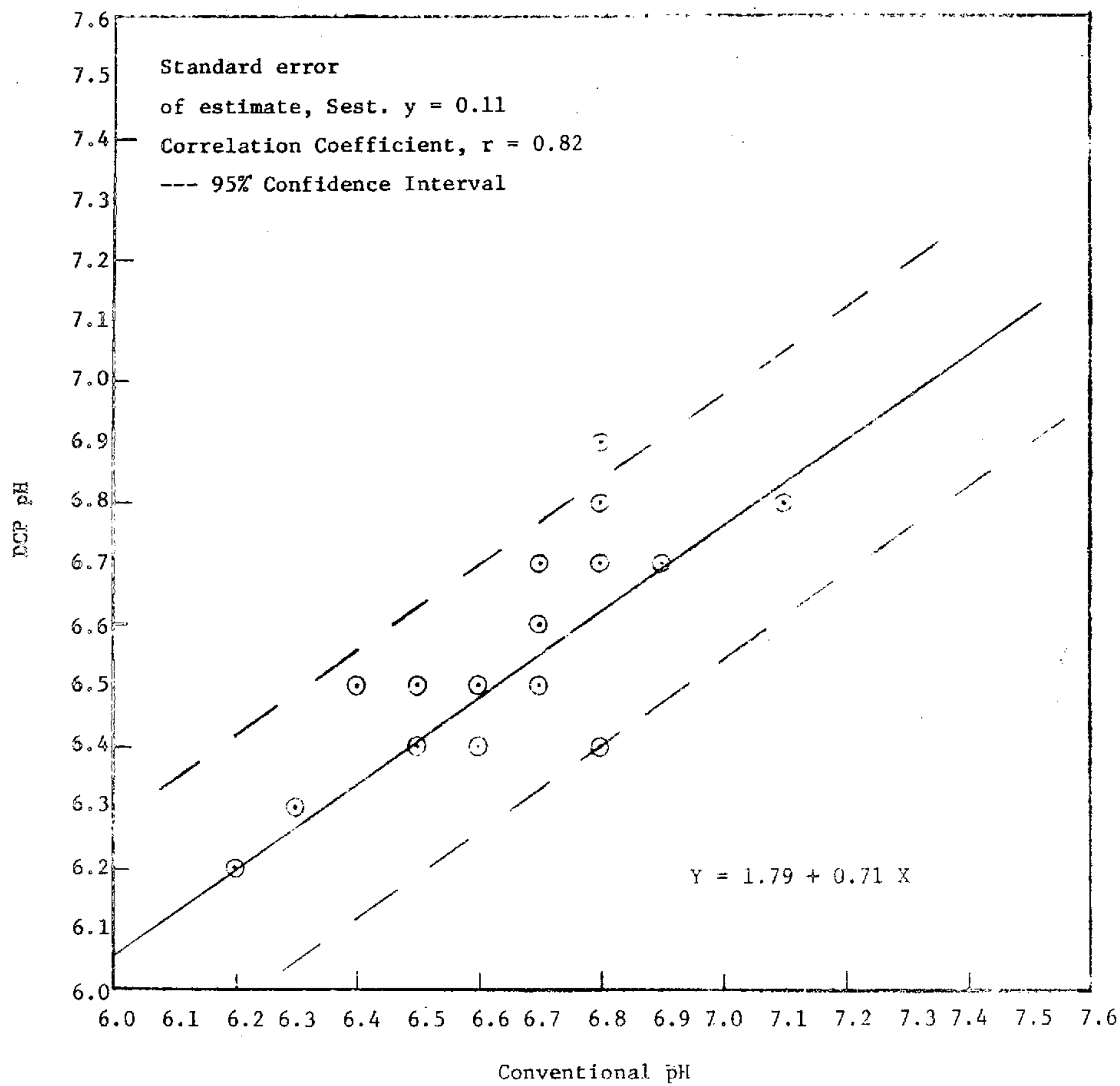

Fig. 3B. pH Regression Line for Calibration Studies Calculated by Least Squares Method.

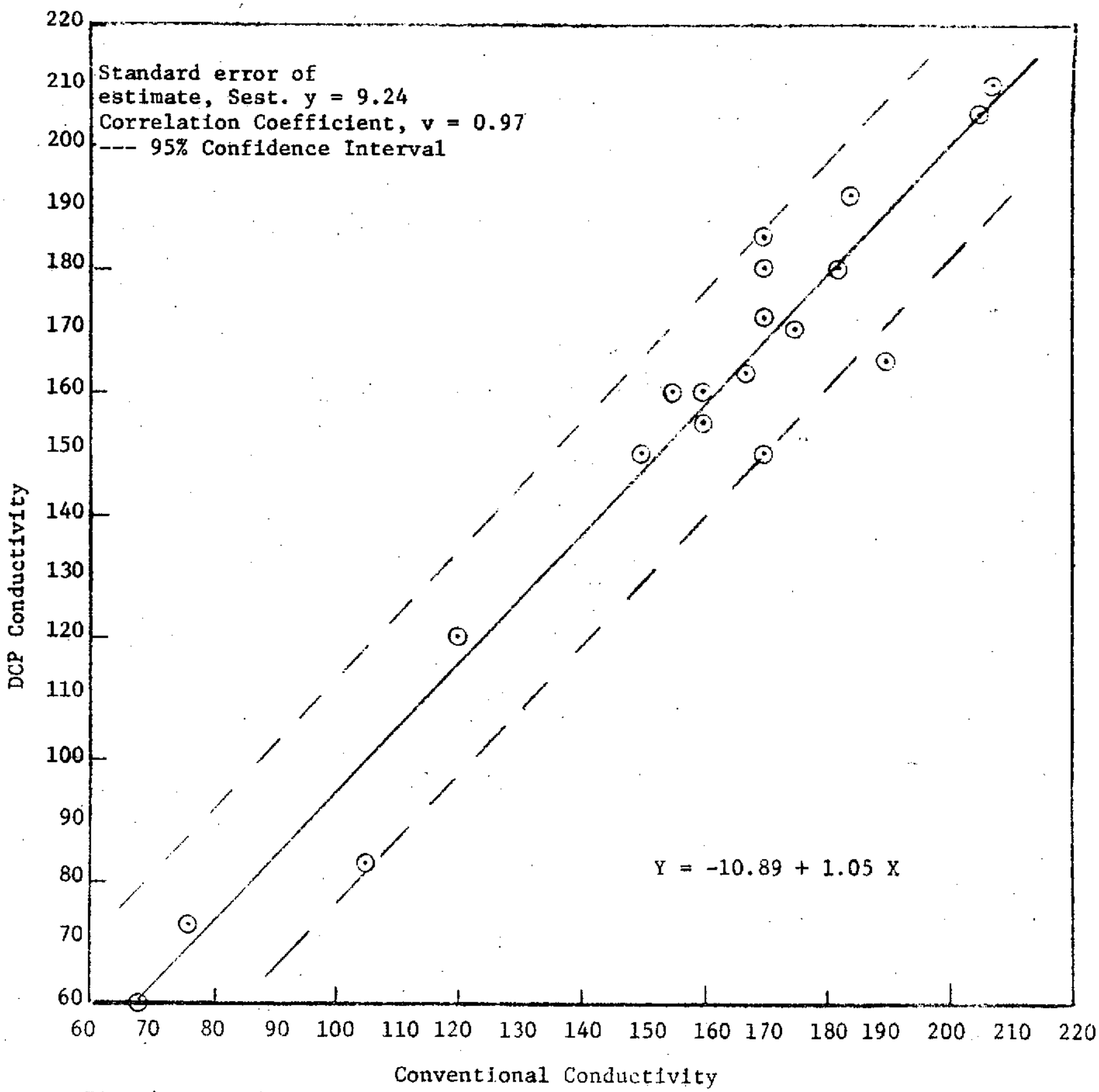

Fig. 4B. Conductivity Regression Line for Calibration Studies Calculated by Least Squares Method.

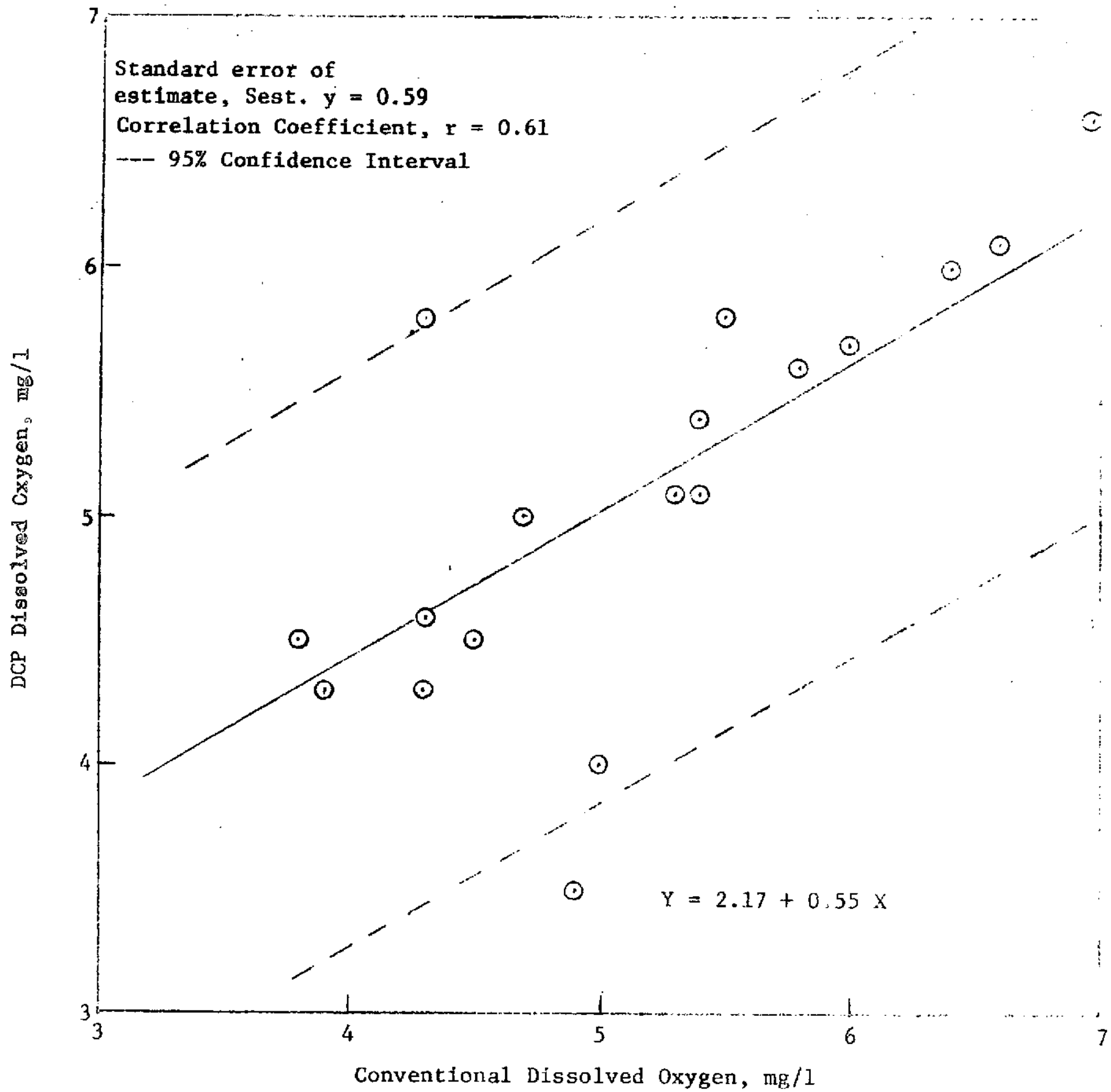

Fig. 5B. Dissolved Oxygen Regression Line for Field Studies at Station 3 and DCP No. 6357 calculated by Least Squares Method

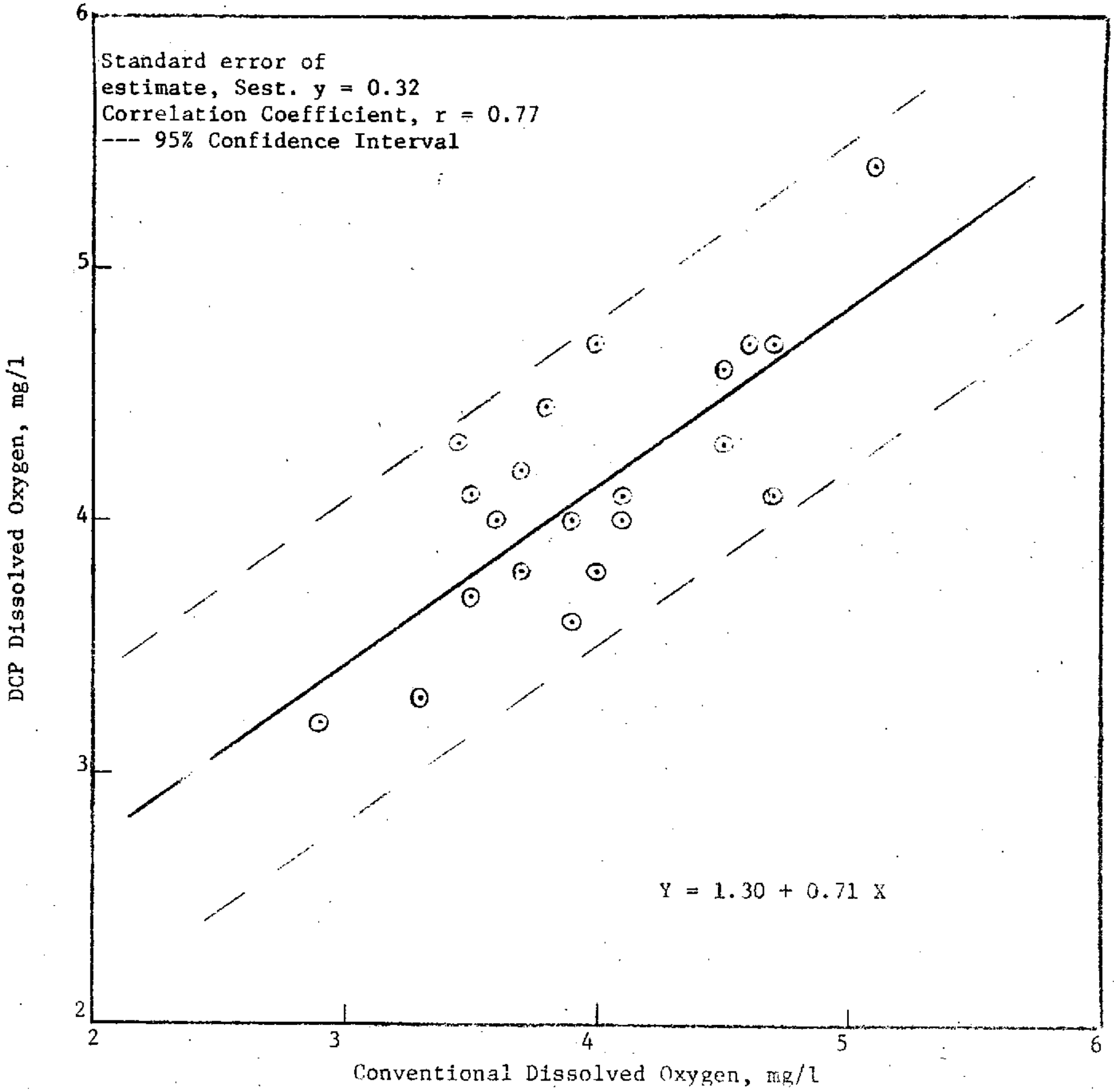

Fig. 6B. Dissolved Oxygen Regression Line for Field Studies at Station F and DCP No. 6060 Calculated by Least Squares Method.

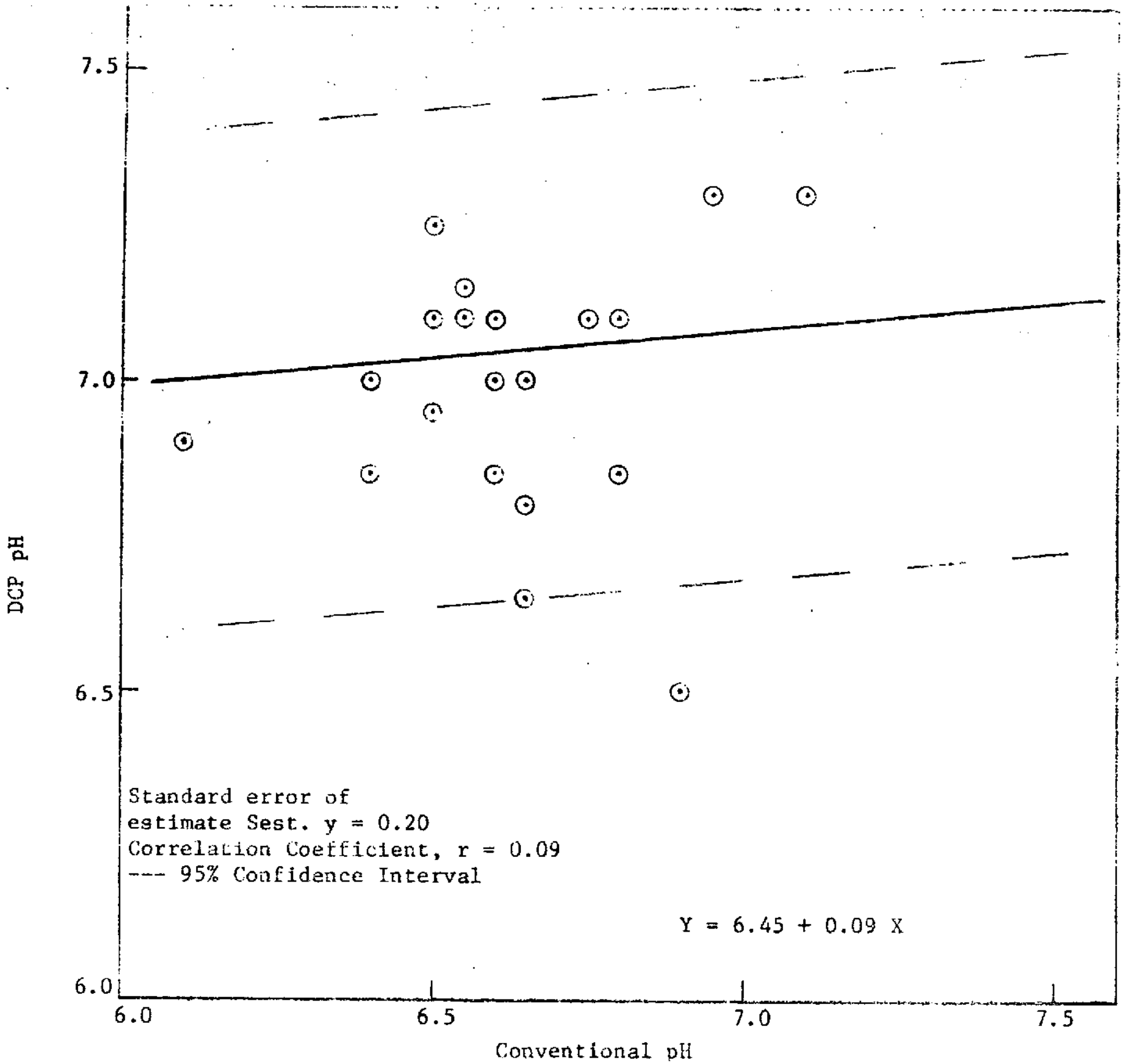

Fig. 7B. pH Regression Line for Field Studies at Station F and DCP No. 6060 Calculated by Least Squares Method.

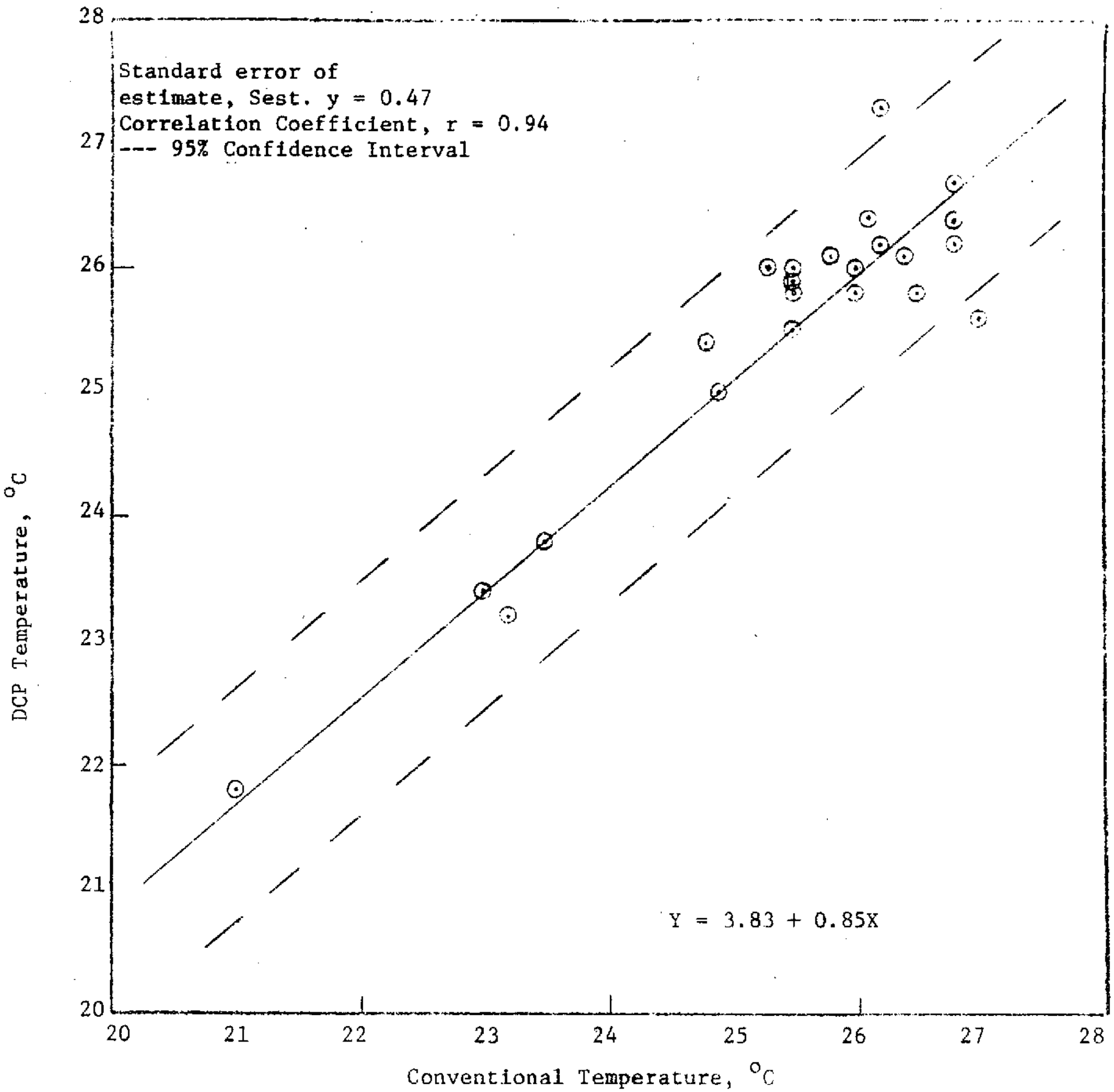

Fig. 8B. Temperature Regression Line for Field Studies at Station F and DCP No. 6060 Calculated by Least Squares Method.

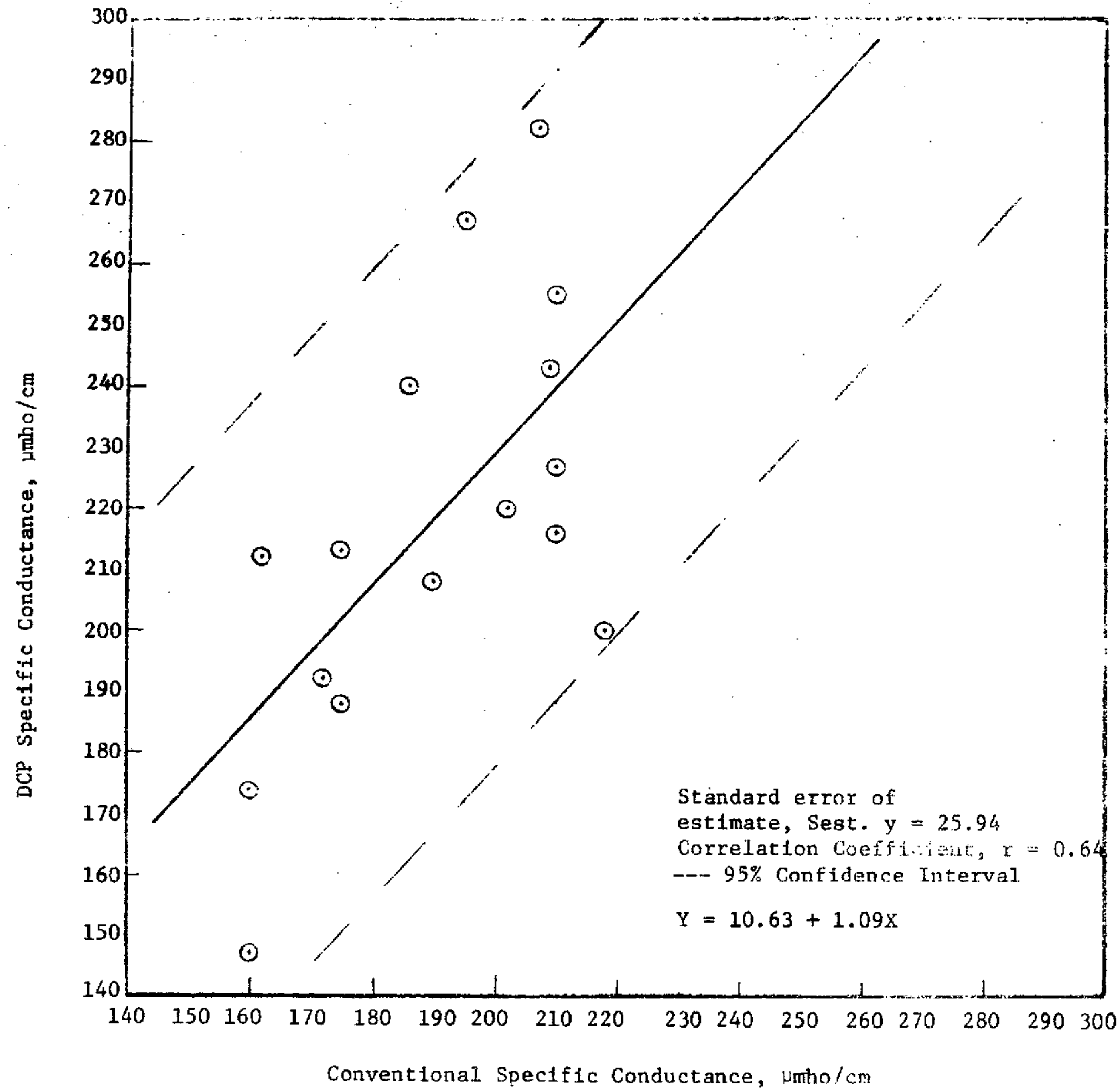

Fig. 9B. Conductivity Regression Line for Field Studies at Station F and DCP No. 6060 Calculated by Least Squares Method

02465000 BLACK WARRIOR RIVER AT TUSCALOOSA, ALA.

USE RT 06 TEST DIFF = 1.0

S DATE	TMAX	MAX	MIN	MEAN	EQ-GH	DATUM SHIFT	MEAN Q	HR	0200	0400	
10-25	1700	41.14	40.03	40.35	40.38		1450	11			
10-26	1630	40.60	39.52	39.97	40.00		554		4007	4006	
10-27	1200	40.59	39.75	39.95	39.98		508		3984	3979	3
10-28	1130	40.58	39.84	40.06	40.09		726		3996	3996	4
10-29	1930	40.99	39.78	40.07	40.11		781		3982	4008	3
10-30	1500	41.77	39.68	40.24	40.32		1300		3998	3990	3
10-31	1130	40.47	39.62	40.06	40.07		701		3989	4003	4
11 -1	2100	40.40	39.48	39.85	39.88		337		3989	3986	3
11-02	1430	40.76	39.74	39.98	40.01		581		3981	3979	3
11-03	0400	40.34	39.78	39.96	39.97		499		3986	4034	3
11-04	1600	40.46	39.63	39.90	39.93		429		3984	3982	3
11-05	1000	41.03	39.79	40.10	40.13		832		4030	3985	4
11-06	1000	40.78	39.67	40.05	40.09		742		3983	3975	3
11-07	0930	40.40	39.53	39.91	39.93		432		4032	4001	3
11-08	1430	42.03	39.69	40.34	40.48		1740		3983	3982	4
11-09	1100	42.38	40.11	40.73	40.83		2860		4019	4023	4
11-10	1530	40.73	39.87	40.23	40.24		1100		4035	4020	4
11-11	0230	40.54	39.77	40.05	40.06		671		4008	4008	4
11-12	1430	41.47	39.79	40.26	40.32		1290		4008	3998	3
11-13	1430	40.53	39.72	40.03	40.05		650		4012	3997	3
11-14	1830	40.41	39.77	39.98	39.99		543		3990	3989	3
11-15	1030	40.87	39.77	40.04	40.07		691		3999	3983	3
11-16	1300	41.14	39.79	40.19	40.23		1070		3986	3981	3
11-17	1730	40.51	39.69	39.93	39.95		457		3992	3989	3
11-18	0200	40.34	39.68	39.92	39.94		447		4034	4026	4
11-19	2030	41.04	39.72	40.13	40.19		963		3979	3980	3
11-20	1830	40.86	39.69	40.05	40.08		706		4008	4027	3
11-21	1400	42.38	39.90	41.03	41.17		4170		4008	4013	4
11-22	1930	41.58	39.91	40.42	40.45		1640		4051	4034	4
11-23	0700	42.02	40.01	40.59	40.66		2300		4024	4018	4
11-24A	1500	41.93	40.08	40.64	40.70		2440		4056	4013	4
11-25	0930	42.24	39.99	40.56	40.65		2270		4034	4018	4
11-26	1130	42.41	40.00	40.92	41.04		3640		4020	4002	4
11-27	2100	42.68	39.89	40.78	40.99		3460		4030	4016	4
11-28	1430	44.18	40.00	43.19	43.23		16300		4269	4264	4
11-29A	0030	43.00	41.27	42.39	42.42		10700		4274	4260	4
11-30A	1400	42.60	40.04	41.46	41.61		6110		4122	4082	4

UNITED STATES DEPARTMENT OF INTERIOR - GEOLOGICAL SU
PRIMARY COMPUTATION OF GAGE HEIGHT

02465000 BLACK WARRIOR RIVER AT TUSCALOOSA, ALA.

USE RT 06

TEST DIFF = 1.0

S	DATE	TMAX	MAX	MIN	MEAN	EQ-GH	DATUM	SHIFT	MEAN Q	HR	0200	0400
	10-01	0030	43.98	40.76	42.23	42.31			10000		4264	4143
	10-02	0030	40.71	40.15	40.35	40.35			1380		4036	4024
	10-03	1730	42.70	40.16	40.78	40.91			3170		4031	4027
A	10-04	1730	41.79	39.79	40.37	40.45			1660		4040	4008
	10-05	1700	41.83	39.93	40.40	40.49			1760		4008	4007
A	10-06	2230	42.19	39.52	40.48	40.63			2210		4004	3993
	10-07	0030	40.82	39.83	40.08	40.11			771		4040	4028
	10-08	2030	41.96	39.68	40.35	40.44			1630		3984	3992
	10-09	2030	42.23	39.84	40.56	40.73			2550		4009	4003
A	10-10	1930	41.15	39.82	40.27	40.31			1260		4024	3998
	10-11	2100	42.06	39.75	40.42	40.55			1970		4000	4023
	10-12	2330	40.60	39.64	40.01	40.04			628		4017	4012
	10-13	0900	40.35	39.49	39.93	39.95			464		3992	[illegible]
	10-14	1830	40.74	39.54	40.02	40.06			674		4007	[illegible]
	10-15	2130	41.91	39.66	40.18	40.31			1270		3975	4012
	10-16	1530	40.58	39.85	40.10	40.12			802		4055	4012
	10-17	2200	41.98	39.77	40.35	40.46			1690		3995	3997
	10-18	0100	40.76	39.79	40.06	40.08			716		4031	4008
	10-19	2130	42.07	39.[illegible]	40.54	40.67			2330		3986	4013
	10-20	2030	41.06	39.71	40.07	40.13			817		4030	4008
	10-21	0100	40.55	39.67	39.95	39.98			516		4024	3985
	10-22	2000	41.68	39.67	40.19	40.30			1250		3979	3980
	10-23	2000	41.13	39.80	40.19	40.23			1060		4006	3985
	10-24	1930	41.59	39.80	40.18	40.27			1160		3993	3990
	10-25	1400	40.78	39.70	39.98	40.01			576	14	4004	3990
PERIOD			43.98	39.49								

02465000 Black Warrior River at Tuscaloosa, Ala.

LOCATION.--Lat 33°12'50", long 87°34'25", in SW¼ sec. 5, T. 21 S., R. 10 W., Tuscaloosa County, near right bank on downstream side of pier of bridge on U.S. Highway 82, in Tuscaloosa, 0.1 mile (0.2 km) downstream from small tributary, 0.2 mile (0.3 km) upstream from Gulf, Mobile & Ohio Railroad bridge, 0.8 mile (1.3 km) upstream from Oliver lock and dam, 4.8 miles (7.7 km) downstream from North River, and at mile 127.0 (204.3 km).

DRAINAGE AREA.--4,828 mi^2 (12,504 km^2).

PERIOD OF RECORD.--January 1889 to September 1894 (gage heights only), October 1894 to December 1902, January 1903 to December 1905 (gage heights and discharge measurements only), August 1928 to current year. Monthly discharge only for period October to December 1894, published in WSP 1304.

GAGE.--Water-stage recorder. Datum of gage is 83.35 ft (25.405 m) above mean sea level. Prior to December 1905, nonrecording gage 0.3 mile (0.5 km) downstream and 300 ft (91 m) downstream from present Gulf, Mobile & Ohio Railroad bridge at datum 2.5 ft (0.762 m) higher. Aug. 1, 1928, to Aug. 28, 1939, nonrecording gage just above former Lock 10, 0.5 mile (0.8 km) upstream at present datum. Aug. 29, 1939, to Mar. 19, 1951, water-stage recorder at site 0.25 mile (0.4 km) downstream and 55 ft (17 m) downstream from Gulf, Mobile & Ohio Railroad bridge, at present datum. Subsequent to Apr. 19, 1944, auxiliary water-stage recorder, and Aug. 29, 1939, to Apr. 18, 1944, auxiliary nonrecording gage, 500 ft (152 m) downstream from Oliver lock and dam at datum 1.08 ft (0.329 m) lower.

AVERAGE DISCHARGE.--53 years (1894-1902, 1928-73), 7,724 ft^3/s (218.7 m^3/s), 21.73 in/yr (552 mm/yr).

EXTREMES.--Current year: Maximum discharge, 97,900 ft^3/s (2,770 m^3/s) Mar. 31 (gage height, 52.71 ft or 16.066 m); minimum daily discharge, 479 ft^3/s (13.6 m^3/s) Sept. 16.
Period of record: Maximum discharge, 224,000 ft^3/s (6,340 m^3/s) Feb. 21, 1961; maximum gage height, 67.7 ft (20.63 m) Apr. 18, 1900; minimum daily discharge, 37 ft^3/s (1.05 m^3/s) Oct. 23, 1953.

REMARKS.--Records good above 6,000 ft^3/s (170 m^3/s) and poor below. Some regulation by Lewis Smith Reservoir on Sipsey Fork (see p. 67,68) by Bankhead lock and dam on Black Warrior River (usable capacity, 112,000 acre-ft or 138 hm^3), Holt lock and dam on Black Warrior River (usable capacity, 115,000 acre-ft or 142 hm^3), and occasionally during periods of low flow by Oliver lock and dam downstream from gage. Diversion through lock valves included in figures of discharge.

REVISIONS (WATER YEARS).--WSP 1002: 1940-43. WSP 1384: Drainage area. WSP 1624: 1900.

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	2,920	1,340	3,790	27,000	17,700	7,150	73,400	15,800	14,400	1,640	5,750	1,950
2	1,270	2,110	2,160	19,100	33,800	5,720	47,900	16,200	11,700	3,410	5,620	1,210
3	1,720	1,150	1,500	11,100	28,600	10,600	30,500	13,500	4,240	6,640	6,500	1,070
4	3,640	1,320	2,880	18,200	19,100	10,300	24,900	12,800	6,950	1,820	4,740	6,550
5	3,370	945	3,130	22,000	14,700	13,500	21,700	11,400	4,830	8,140	2,710	5,260
6	1,690	1,130	5,150	51,900	14,500	18,000	20,100	11,000	5,800	7,400	5,470	4,110
7	1,060	1,150	6,460	48,700	12,400	13,800	31,000	12,500	9,640	10,400	6,600	2,150
8	554	2,010	6,680	67,200	12,800	12,800	31,800	36,200	18,900	3,190	5,840	995
9	735	2,930	4,420	51,400	17,000	10,700	28,600	27,200	14,800	6,820	5,020	793
10	1,390	2,120	5,120	34,300	16,500	11,000	23,100	21,200	7,090	7,040	3,670	1,370
11	1,250	1,360	12,200	21,400	14,000	16,000	21,000	17,900	7,780	8,110	3,940	3,140
12	2,400	655	12,100	17,500	11,500	24,300	16,700	12,200	9,960	6,700	987	3,460
13	1,510	4,050	10,200	16,200	11,300	24,300	13,000	11,900	21,500	6,780	5,800	2,260
14	1,180	2,560	8,050	12,500	35,500	17,000	12,700	9,790	13,000	15,400	10,100	2,220
15	904	2,270	36,900	11,500	38,700	15,500	10,600	6,620	10,900	16,100	5,600	511
16	1,380	3,350	34,500	11,200	27,900	62,900	12,100	6,120	10,700	13,900	4,880	479
17	1,700	1,990	21,700	11,400	23,000	70,800	11,000	1,980	4,470	19,200	3,290	2,990
18	2,130	1,240	14,600	12,000	19,700	59,300	11,400	3,620	6,040	19,300	1,800	1,350
19	1,530	1,470	11,900	20,900	15,600	35,700	12,700	4,320	10,300	16,200	1,670	1,910
20	1,230	6,090	7,900	16,700	15,100	32,100	10,900	7,350	15,800	12,300	4,180	4,020
21	1,190	2,810	14,400	19,000	13,300	27,400	8,370	16,500	9,200	11,600	3,260	3,580
22	1,030	3,540	16,500	50,800	12,300	22,400	2,570	11,600	14,000	6,560	3,990	1,950
23	1,180	2,860	14,100	40,000	11,300	20,100	6,490	7,940	12,400	8,500	3,910	723
24	1,290	2,040	12,800	25,400	11,800	16,800	11,500	6,230	7,970	7,140	3,560	1,740
25	2,540	6,690	8,540	19,300	7,860	43,700	50,000	7,170	5,110	7,650	2,250	753
26	1,800	2,770	7,670	17,700	8,650	36,500	50,800	3,100	7,640	6,660	900	3,240
27	1,410	3,890	7,950	22,100	7,700	27,800	49,600	4,160	7,560	6,580	4,840	1,320
28	1,240	3,440	7,380	20,000	7,580	22,400	40,000	33,700	9,600	5,480	4,920	751
29	1,780	3,320	7,830	15,000	------	21,200	29,700	35,200	5,250	2,790	5,660	902
30	2,700	3,040	7,660	15,500	------	21,400	20,700	23,400	1,740	5,710	5,260	8,830
31	1,380	------	31,100	12,100	------	81,900	------	16,200	------	5,640	5,990	------
TOTAL	51,093	75,640	347,270	759,100	479,890	793,070	734,430	419,920	289,170	266,150	138,401	73,547
MEAN	1,648	2,521	11,200	24,490	17,140	25,580	24,480	13,550	9,639	8,585	4,465	2,452
MAX	3,640	6,690	36,900	67,200	38,700	81,900	73,400	36,200	21,500	19,300	10,100	8,830
MIN	554	655	1,500	11,100	7,580	5,720	2,570	1,980	1,740	1,640	900	479
CFSM	.34	.52	2.32	5.07	3.55	5.30	5.07	2.81	2.00	1.78	.92	.51
IN.	.39	.58	2.68	5.85	3.70	6.11	5.66	3.24	2.23	2.05	1.07	.57

CAL YR 1972 TOTAL 2,371,329 MEAN 6,479 MAX 72,300 MIN 554 CFSM 1.34 IN 18.27
WTR YR 1973 TOTAL 4,427,681 MEAN 12,130 MAX 81,900 MIN 479 CFSM 2.51 IN 34.12

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MOBILE BAY ERTS-A WATER QUALITY DATA BUOY PROJECT

FINAL REPORT

Prepared by
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Prinicipal Investigator

May 1974

MARINE SCIENCE STUDIES

C. Everett Brett

SECTION THREE

of

VOLUME ONE

INVESTIGATIONS USING DATA IN

ALABAMA FROM ERTS-A

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INTRODUCTION

During the period from September 1973 until April 1974 the surface hydrographic and water circulation patterns of Mobile Bay, Alabama and adjacent waters were studied. The results of these studies were to be utilized as "ground truth data" in conjunction with an interpretation study of photographic imagery obtained from the National Aeronautics and Space Administration (NASA) Earth Resources Technology Satellite-A (ERTS-A).

Two modes of collecting "ground truth data" were used: (1) conventional rapid survey with a fast boat producing a quasi-synoptic data base over a six to 24 hour period; and (2) two instrumented buoys anchored in the two openings or passes of the bay.

Unfortunately a mishap in arranging for the imagery to be sent to the Dauphin Island Sea Lab resulted in only a partial delivery of the requested material. Therefore, the imagery interpretation phase of this study was first greatly curtailed and then eliminated for lack of adequate data. The inability to complete this major objective of the study seriously hampers producing a meaningful final report.

However, the knowledge and experience gained in the designing, testing, and implementing the instrumented buoy system into the ERTS-A Data Collection Platform (DCP) network provided invaluable insight for future studies. Therefore the following report will primarily deal with the development of the instrumented buoys and the results obtained from them.

BACKGROUND

Documentation of the hydrographic and water circulation patterns in the Bay-Sound-Estuarine systems of the Gulf Coast of Alabama is conspicuously lacking. The available data is quantitatively small and qualitatively questionable. Yet it is unquestionably recognized that the need to accurately, rapidly and synoptically characterize this environment is paramount when one considers: (1) the natural resources of the area; (2) the level of maritime activities; (3) the rapid expansion of waterfront land use and the growth of recreational utilization; (4) the complex interaction which results when the developmental activities within the adjacent fresh water river systems are ultimately linked with this system; and (5) the accelerated demand for proper coastal zone management. The task of providing such data is, to say the least, challenging.

It was determined that one research platform that could be used to help collect data for this type of project was the Earth Resources Technology Satellite-A of NASA. The end result of much planning, many discussions and a few agreements (with productive end results of course) was the creation of the Mobile Bay ERTS Water Quality Data Buoy Project.

OBJECTIVES

The primary objectives of this project were:

1) design and build data collection platforms, for incorporation into the ERTS-A Program, to monitor selected water quality parameters in the Bay-Sound-Estuarine system along the Gulf Coast of the State of Alabama.

2) field test the DCP's and if time permits, place the units in a routine operational mode.

3) ascertain the feasibility of the DCP's in:

(a) providing ground truth data for ERTS-A imagery investigations; and

(b) characterizing the surface waters of the study locations.

4) carry out a cost/benefit study contrasting the ERTS-A DCP's with other data gathering modes.

PROJECT TIME SCHEDULE

The project time schedule is shown on Table 1. The planned time frames for the various phases are indicated by the solid lines while the actual time frames are indicated by the dashed lines. Note that the duration of a phase was altered from the planned time frame by three to five months.

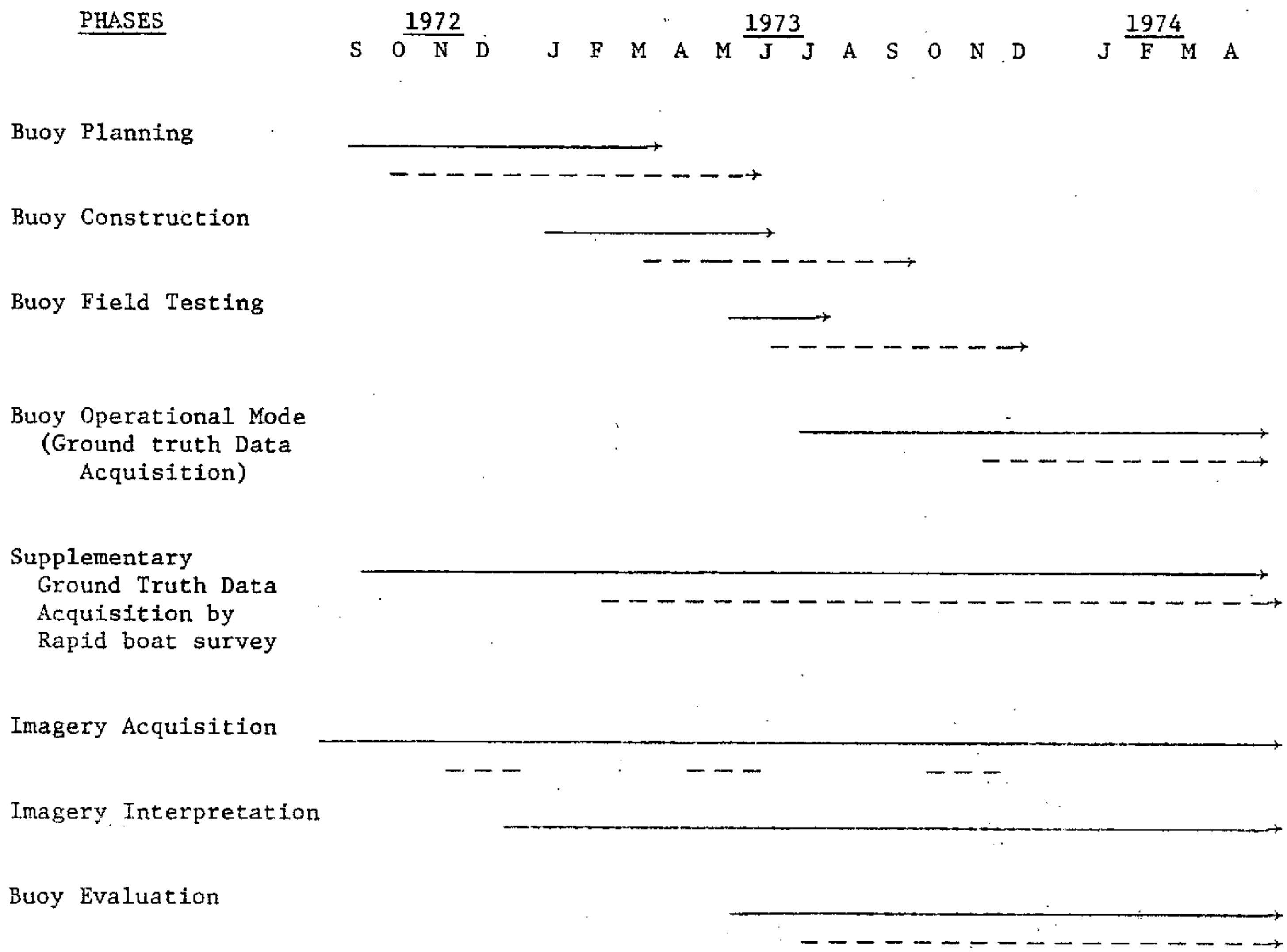

Table 1. Mobile Bay ERTS-A Project Time Schedule

BUOY AND ANCHOR SYSTEMS DESCRIPTION*

The buoy consists of a tripod antenna support mounted on a central instrument pod, which is suspended in a floatation ring. The antenna consists of a disk three feet, nine and a half inches in diameter with a hemispherical dome 26 inches in diameter. A slow flashing light is mounted one foot, eight inches under the antenna.

The floatation ring has an outside diameter of ten feet, and an inside diameter of four feet, five inches. The ring is constructed of stainless steel sheet metal and is filled with foam. The instrument pod is two feet, five inches in diameter. Two boxes mounted on opposite sides of the floatation ring hold 12-volt lead-acid batteries. These batteries provide power for the flashing light and the instrumentation electronics units in the instrument pod.

The instrumentation on the buoy includes a Hydro-Lab Water Quality Surveyor, which measures water temperature and conductivity, and an Inner Ocean current meter, which measures current speed and direction. The probes for the Hydro-Lab unit are contained in a unit called a sonde. The sonde is mounted on the side of the instrument pod. The bottom of the sonde extends six inches below the floatation ring. The sensor for the current meter is supported inside an aluminum tubing frame, which extends two feet below the floatation ring.

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*See attached photo of buoy deployed in the field.

The buoy floats with approximately four inches of the floatation ring submerged. The buoy transmits a data signal every three minutes.

The basic anchor system consists of: (1) an automobile tire which acts as a shock absorber to diminish the effect of wave action; (2) a smaller secondary can; and (3) the anchor hold-fast system. Three-eighths inch chains and shackles are used to connect the various components. The anchor hold-fast system consists of three Danforth anchors linked to a 500-pound circular steel plate at 120° angles with 20 ft. chains. A 25 ft. chain attached to the center of the steel plate is in turn connected to the secondary can. The tire is in turn attached to the secondary can and the buoy is attached to the tire.

SHORE STATION DESCRIPTION

The signal transmissions from the buoys are received by a shore station antenna at the Dauphin Island Sea Lab shore station. The signal passes through a series of amplifiers and then to the convolutional decoder, where it is split. It is recorded in digital form on a Sony cassette tape recorder. It is also decoded and converted to an analog DC voltage for each parameter. The analog form provides input to the Strip Chart Recorder.

Each buoy transmits once every three minutes. Originally every transmission was recorded on magnetic tape for later computer analysis. The strip chart record was used as a rough indication that the buoys were functioning properly. However, the high cost of computer time proved prohibitive, and the system was modified. A timer switch supplies power to the Strip Chart Recorder and the tape recorder for only three out of every fifteen minutes. At the same time, recording capabilities of the strip chart recorder were increased from 22 line utilization to a full 50 lines. This greatly increased the resolution of the records.

The strip chart record is now used as the primary data source. When an area of this record is needed in finer detail, the tape for that time period can be processed for computer analysis.

BUOY LOCATIONS

Table 2 outlines the locations and periods of operation for each buoy. Figure 1 illustrates the two locations of the buoys.

BUOY FIELD TESTING AND MAINTENANCE

Field testing of the various systems and materials began immediately upon delivery of the buoys. Calibration of the instruments was checked while the buoys were on dry land, in a boat slip immediately after launching, and again when they were actually in position.

It was found that several changes were necessary to adapt the buoys to the salt water environment. For example, galvanized steel chains replaced stainless steel cables soon after deployment because of problems in attaching thimbles to the cable. Stainless steel materials were used, however, wherever possible. Also, a standard automobile tire was inserted between the floatation ring and the secondary "can" to prevent chafing from the constant wave action.

	1973				1974			
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.
Buoy Location 1 Eastern end of Dauphin Island (Fort Gaines) Lat. 30° 14.60'N Long. 88° 03.60'W	Buoy 6105			Buoy 6346				
Buoy Location 2 Dauphin Island Bridge (Grant's Pass) Lat. 30° 17.95'N Long. 88° 07.60'W	Buoy 6346			NO COVERAGE				

Table 2. Locations and Periods of Operation for ERTS-A Buoys

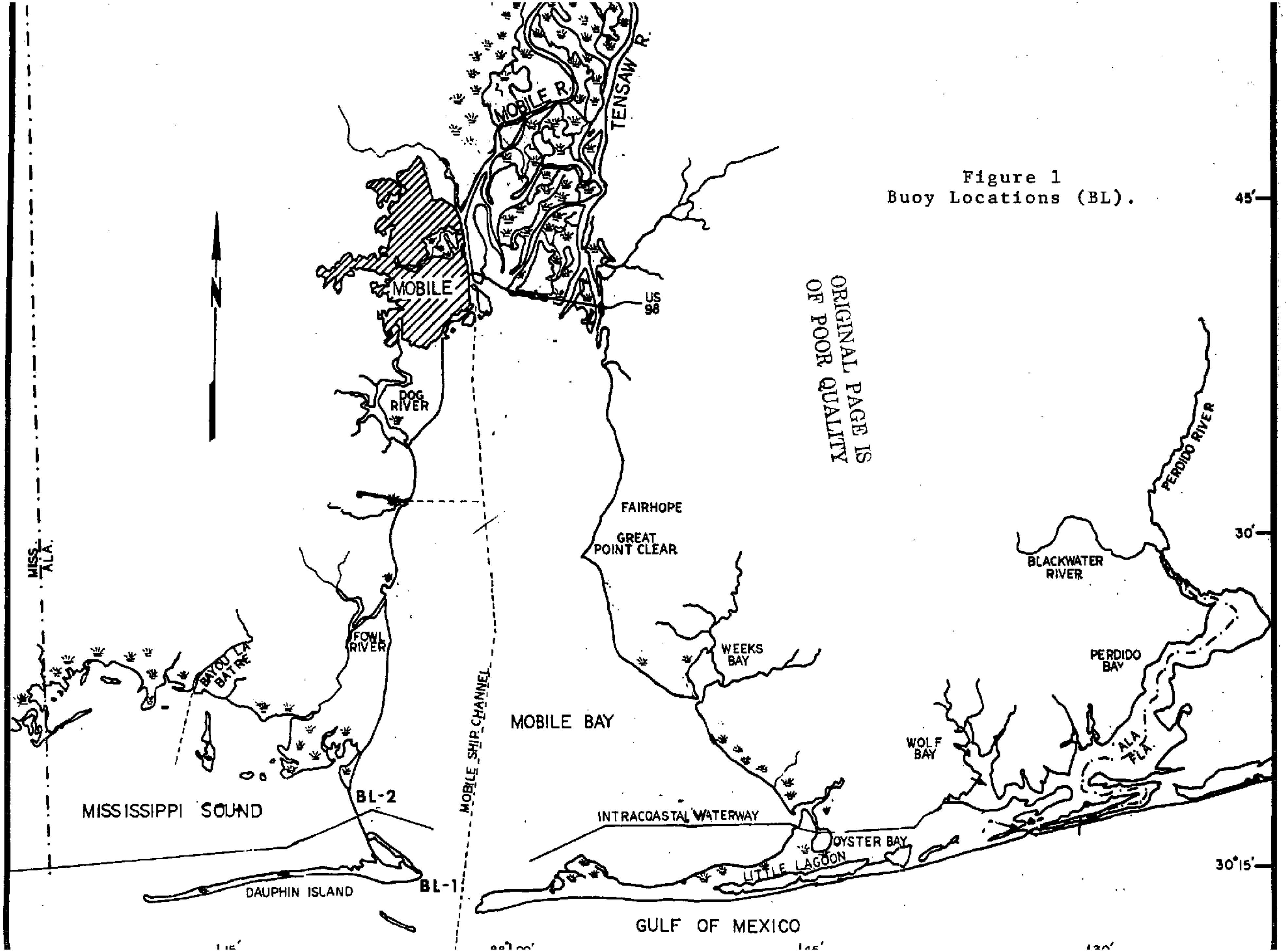

Figure 1
Buoy Locations (BL).

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Sacrifice zinc anodes were also used to reduce corrosion.

Anti-fouling paint and periodic inspection and maintenance were necessary to overcome the problem of bio-fouling.

During the project the buoy from the Dauphin Island Bridge site was lost and recovered one time and the buoy off the east end of the island was lost and recovered twice because of as yet unidentified anchor system problems.

Maintenance for the buoy system consists of the following.

Every two to three weeks the lead acid batteries mounted on the deck of the floatation ring are changed. The used batteries are returned to the Sea Lab for recharging. At the same time, the anchor system is checked for security and wear by a team of divers.

Every four to six weeks, a detailed check is made for the amount and location of fouling on the buoy. All fouling is removed as well as possible.

At six month intervals the buoy is returned to the base for recalibration of the instruments and changing the gel-cell batteries which provide power for the transmitter.

In addition, the buoy is checked daily from shore for position and general condition.

MOBILE BAY ERTS-A IMAGERY INVENTORY

Table 3 lists the Mobile Bay imagery (orbit L, frame 4) that is on inventory at Dauphin Island Sea Lab. A notation is made by each of the satellite overpass dates indicating when rapid boat survey

Date	Band# 4	5	6	7	Comments
8/6/72					
8/24/72					
9/11/72	X	X	X	X	Cloud Cover
9/29/72	X		X	X	Scattered Cloud Cover
10/17/72	X	X	X	X	Clear
11/5/72					
11/22/72					
12/10/72					
12/28/72		X	X	X	Clear; Margin burned
1/15/73		X	X	X	Partly cloudy; margin burned
2/2/73	Present				3 photos present but margin burned so don't know which bands
2/20/73					
*3/10/73					
3/28/73					
*4/15/73					
*5/3/73	X	X	X	X	Very Cloudy
5/21/73	X	X	X		Good, Clear
*6/8/73					
6/26/73					
7/14/73					
*8/1/73					
9/24/73	X		X		Clear
*10/30/73	X		X	X	Clear
1/10/74	X	X	X	X	Clear
1/28/74	X		X	X	Cloudy
*2/15/74					
3/5/74					
*3/23/74					
*4/10/74					
*4/28/74					

* Dates when rapid survey ground truth data were collected

Table 3. Orbit L Frame 4(Mobile Bay) ERTS-A Imagery on Inventory at Dauphin Island Sea Lab as of 18 May 1974.

ground truth data was collected simultaneously with the satellite overpass.

DISCUSSION OF THE RESULTS

Buoy developmental phase: All developmental objectives for this phase were successfully completed. The buoys were fully incorporated into the ERTS-A Data Collecting Platform System. The Dauphin Island Sea Lab shore station became fully operational in mid-program and data recording systems functioned exactly as designed.

Feasibility of the buoys providing ground truth data for ERTS-A imagery investigations: No results are presented for this objective because copies of the needed imagery (Orbit L, Frame 4) of Mobile Bay were unavailable to the Dauphin Island Sea Lab project office.

Feasibility of the buoys being used to characterize the surface waters of the study locations: The data provided by the buoys has proven to be both quantitatively and qualitatively the best available to date for characterizing the surface water of Mobile Bay. Of the three data recording modes, the analog strip chart record was shown to be the most practical when considering both data quality and cost. The data provided by Goddard Space Flight Center from the satellite (computer printout of environmental conditions taken every 12 hours during satellite overpass) had too large a sampling interval to provide adequate data in this location because of the water dynamics. The magnetic tape records were not fully utilized due to insufficient computer programming and machine time funding. However, all of the tapes have been archived and are available for future analysis.

COST BENEFIT ANALYSIS

A. Total Bits of Data Generated by Buoy System

2 buoys x 4 parameters/buoy x 480 sample periods/day x 150 days = 72,000 bits

(1 parameter generates 1 bit of data per sample period)

B. Cost of Buoy System

(1)	Buoys-design and manufacture $30,000 ea. x 2 stations	$60,000
(2)	Shore station	35,000
(3)	Manpower and supplies	20,000
	Total	$115,000

C. Cost if Equivalent Data Were Collected by Conventional Ship Methods

(1)	Ship time $350/day/station x 2 stations x 150 days	$105,000
(2)	Instrumentation $7,000/station x 2 stations	14,000
(3)	Manpower and supplies	846,000
	Total	$965,000

D. Cost per bit of buoy data

$115,000/72,000 bits = $1.60/bit

E. Cost per bit of shipboard data

$965,000/72,000 bits = $13.40/bit

ACKNOWLEDGEMENT

This project received time, expertise, energy and resources from numerous individuals and organizations. But there are two members of the project team that stand far and above the rest and without whom the project would have fallen far short of its present achievements. they are Rex Morton, Chief of Project Operations, from MSFC and George Oakes, On-Site Project Engineer, from Dauphin Island Sea Lab.

DATA PROCESSING AND DATA MANAGEMENT

Edmond T. Miller

SECTION FOUR

of

VOLUME ONE

INVESTIGATIONS USING DATA IN

ALABAMA FROM ERTS-A

Data Management and Data Processing

From the beginning of the project it was anticipated that processing of large amounts of numeric and character data would be required in the pursuit of the goals of the project. Since many of the investigators on the project had little skill in the handling of large amounts of data, it was decided to establish a section, under the direction of Dr. E. T. Miller, whose function would be to provide data processing support for all other activities in the project. This section has been involved in several aspects of the project, including the analysis of land use data, secured from the historical record and from the ERTS satellite, and with the analysis of data transmitted through the satellite data, and it became obvious early that a means for comparison of satellite transmitted data with a historical base record would be needed to test the validity of new land use classification techniques. Two methods of land use classification from the data transmitted from the ERTS satellite were to be employed; manual land use classification performed by observation of the photographic imagery reproduced from digital data from the satellite, and automatic land use classification from the processing of the digital data itself. Since the kinds of information being sought through these techniques is best represented in visual form, it was apparent that both techniques would require some sort of graphic display or map to provide for presentation of the data.

The first chore of the data processing section was to prepare computer programs for the analysis and mapping of land use data, whether secured from historical record or from the ERTS satellite. An investigation of existing mapping programs was conducted to try to determine the best techniques for the display of the data using the hardware available to the project. No capability for line drawings existed on The University of Alabama computer system so the decision was made to use a graphic display technique which could be supported on a standard line printer. The search for a mapping technique led to the consideration of two standard mapping programs, CMAP produced by the Soil Conservation Service and SYMAP produced by Harvard University.

Each of these mapping techniques represents an area on the ground through the characters printed in a group of print positions on the output drawings. One of the major factors in the selection of the mapping technique, therefore, was the relationship between the shape of the area covered on the line printer used as a graphic display device and the shape of the basic unit of land use measurement or cell selected for use in the other portions of the project.

An early decision was made to select a basic land use cell one kilometer square. This size and shape of cell provided a unit which could be easily referenced to the basic Universal Transverse Mercator (UTM) grid system being used to reference locations used in all phases of the project, and permitted the application of the same rules for east-west and north-south positioning of points within the grid. The cell size also provided a good compromise between the size of an ERTS satellite resolution element and the size of areas which could be conveniently classified by visual techniques from both aerial photographs taken at low altitudes and ERTS satellite imagery.

The computer program named CMAP represents each cell of the map by two adjacent print positions in a printed line. Since the spacing of characters on a standard line printer is six lines per inch vertically and ten columns per inch horizontally, the cell was thus represented by a map area 0.2" x 0.17". Because of the desire to maintain scalar integrity in the drawings produced by the computer, the CMAP program was eliminated from further consideration on this point.

The SYMAP program is a general purpose mapping program which allows the user to select his own scale parameters in both the horizontal and vertical directions. Therefore, the difficulties of scalar integrity could be largely overcome by using the SYMAP program. However, in reality, only a few scale options were available since one unit of ground distance must represent a multiple of .10" and .17". The smallest scale which could be used to preserve scalar integrity in both directions was 1/2 inch = 1 kilometer. This scale permitted the 1 square kilometer cell to be represented by a map square containing three print positions in the north-south direction and five print positions in the east-west direction. Apparent shading of the areas was produced by the use of an overprinting technique to produce eleven levels of increasing visual density in the contents of a print position.

In reducing the historical data from low altitude aerial photographs, it was determined that the portion of a cell devoted to a particular land use could be estimated to the nearest 10 percent with a reasonable degree of reliability. Therefore, by using a special character code to represent 100 percent, it was possible to represent the portion of a cell dedicated to a particular land use by a single digit code ranging from zero through nine plus the special character.

This land use information could then be stored in one column of a punched card or one character of random access data on a disc file. These eleven states could also be represented directly through the shading produced by the SYMAP mapping algorithm.

The SYMAP program produced excellent maps of very high quality in all the tests which were performed using the program. However, the fact that SYMAP is a general purpose computer program with many capabilities, causes it to execute relatively slowly because of the need to test continually for the selection of its many options. Furthermore, it was necessary to do a large amount of data manipulation to transform the data being produced by the project staff into a form compatible with the input requirements for the SYMAP program. Initial estimates of the cost of the operation of the SYMAP program proved to be prohibitive.

Therefore, a decision was made to produce a program locally which would duplicate the form of the SYMAP output while by reducing the options available in the mapping program, also reduced the execution time required for the production of a map. The mapping program developed for the project was capable of producing a map identical to that produced by SYMAP in approximately one-tenth the time, thus making it economically feasible to produce maps by computer. A sample of the maps produced by this program showing distribution of forest land in Fayette County is included as Figure 1.

While the programs were under development for the mapping of ERTS land use data, another group within the project was engaged in the classification of land use from low altitude photographs. This information concerning land use was presented in the form of the digital code

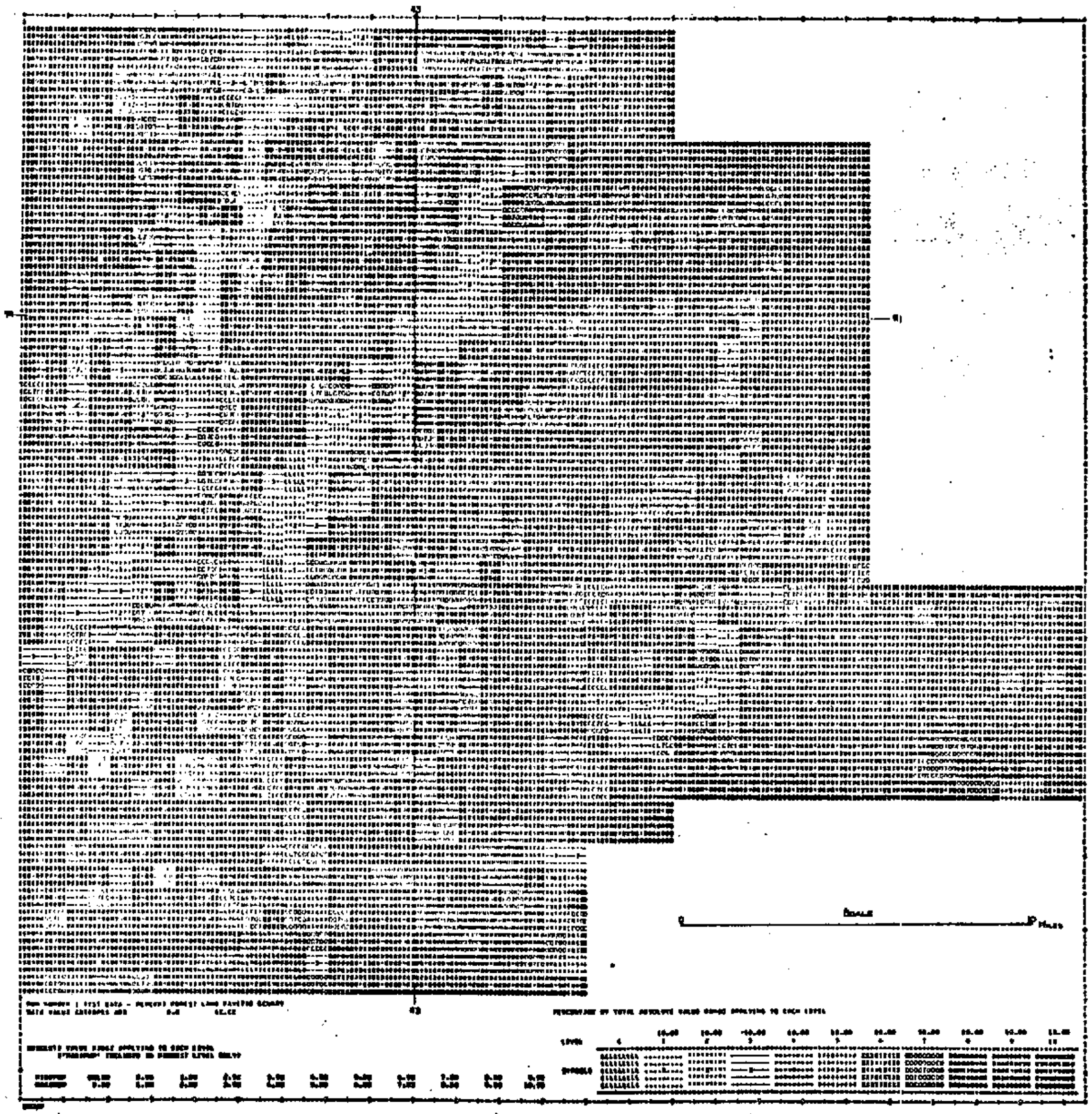


Fig. 1. Map of Forest Land in Fayette County, Alabama.

described above for each of six primary land uses. The land use categories were urban, agricultural, forest, water, barren and nonforested wet land. The personnel engaged in the classification activity entered the land use classifications for each cell on a mylar grid which was overlaid on aerial photographs. The data was then transfered by the data processing staff to punched cards and subsequently from that medium to a permanent indexed sequential disc file. The data record used in this file was 25 characters long. The first two characters in each record were used for the digital representation of the county number within which the cell resided. The third digit in the record was used to represent special land use categories. Characters four through nine in the record were used for the six digit UTM coordinates of the southwest corner of the cell. The next six character positions in the record were used to store the digital codes for percentage of land use in each of the six major land use categories described earlier. The remaining positions in the record were reserved for land use codes and other information which might be required in later investigations utilizing the land use data for each cell.

At the suggestion of potential users of the land use mapping program, the mapping capability was expanded to permit maps to be produced showing the dominant land use in each cell. For this purpose the dominant land use was defined as that particular land use category which occupied the largest proportion of the cell's area. Where two or more land uses shared the largest portion of the cell, the ties were broken by a priority system, ranking uses in the order of urban, agricultural, forest, water, barren, and nonforested wet land in sequence from highest to lowest priority for that classification. It was also discovered that the classification of land use from ERTS photographs, because of the scale of the images themselves, would be restricted to the identification of a dominant land use. No information could be provided concerning the percentage breakdown of land use within a one-kilometer square cell (represented by a square approximately 1 mm by 1 mm) from the ERTS photographs. In order to facilitate the production of dominant land use maps from the historical data and to also facilitate the comparison of ERTS classification and historical classification of land use within a cell, one of the unused positions in the data record was used as a storage location for a code representing the dominant land use within the cell.

Also, at the suggestion of potential users of ERTS data, a summary program was developed to provide a report of total area within a county devoted to each of the six land uses. The output includes the number of cells recorded within the county having each land use by percentage of the cell covered; the acreage represented in these land use categories; and the percentage of the county represented in each of these land use categories. Examples of the summary data provided by this program are included as figures 2 through 5.

Upon completion of the storage of the base year land use data from aerial photographs, attention was turned to the development of programs to facilitate the analysis of changes noted between successive passes of the ERTS satellite or between any two sets of land use obtained for the project. This analysis is also supported by a special purpose mapping program which represents one cell by one print position. These maps are therefore considered to be "work maps" since the scalar integrity of the data is lost. Each square kilometer is represented on the map by a print character 1/6" x 1/10". These maps take

SUMMARY OF DISTRIBUTION OF LANDUSE FOR FAYETTE COUNTY

PERCENTAGE	URBAN	AGRICULTURAL	FOREST	WATER	BARREN	WETLAND	TOTAL
0	1616	692	6	1602	1594	1627	7137
10	1	312	15	17	19	0	364
20	1	230	25	7	8	0	271
30	3	144	41	1	3	0	192
40	1	74	56	0	2	0	133
50	1	45	45	0	0	0	91
60	1	53	81	0	0	0	135
70	1	39	146	0	1	0	187
80	0	23	234	0	0	0	257
90	0	12	312	0	0	0	324
100	2	3	666	0	0	0	671
ERROR	0	0	0	0	0	0	0
TOTAL	1627	1627	1627	1627	1627	1627	9762

NO. OF LANDUSE CODES PER CELL	0	1	2	3	4	5	6	TOTAL
FREQUENCY OF OCCURRENCE	0	671	917	36	3	0	0	1627

Fig. 2. Summary Data (1).

SUMMARY FOR FAYETTE CONTINUED

DISTRIBUTION OF LANDUSE IN TERMS OF ACREAGE

PERCENTAGE	URBAN	AGRICULTURAL	FOREST	WATER	BARREN	WETLAND
0	0	0	0	0	0	0
10	25	7710	371	420	469	0
20	49	11367	1236	346	395	0
30	222	10675	3039	74	222	0
40	99	7314	5535	0	198	0
50	124	5560	5560	0	0	0
60	149	7958	12009	0	0	0
70	173	6745	25254	0	173	0
80	0	4547	46258	0	0	0
90	0	2669	69387	0	0	0
100	494	741	164572	0	0	0
TOTAL	1334	65186	333221	840	1458	0

NO. OF LANDUSE CODES PER CELL	0	1	2	3	4	5	6
IN TERMS OF ACRES	0	165807	226595	8896	741	0	0

TOTAL ACRES IN COUNTY 402039

Fig. 3. Summary Data (2).

SUMMARY FOR FAYETTE CONTINUED

LANDUSE PERCENTAGE AS COMPARED TO TOTAL COUNTY

PERCENTAGE	URBAN	AGRICULTURAL	FOREST	WATER	BARREN	WETLAND
0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10	0.0061	1.9176	0.0922	0.1045	0.1168	0.0000
20	0.0123	2.8273	0.3073	0.0860	0.0983	0.0000
30	0.0553	2.6552	0.7560	0.0184	0.0553	0.0000
40	0.0246	1.8193	1.3768	0.0000	0.0492	0.0000
50	0.0307	1.3329	1.3829	0.0000	0.0000	0.0000
60	0.0369	1.9545	2.9871	0.0000	0.0000	0.0000
70	0.0430	1.6779	6.2815	0.0000	0.0430	0.0000
80	0.0000	1.1309	11.5058	0.0000	0.0000	0.0000
90	0.0000	0.6638	17.2588	0.0000	0.0000	0.0000
100	0.1229	0.1844	40.9342	0.0000	0.0000	0.0000
TOTAL	0.3319	16.2139	82.8826	0.2090	0.3626	0.0000

NO. OF LANDUSE CODES PER CELL	0	1	2	3	4	5	6
IN TERMS OF PERCENTAGE	0.0000	41.2415	56.3614	2.2125	0.1831	0.0000	0.0000

Fig. 4. Summary Data (3).

SUMMARY FOR FAYETTE CONTINUED

DISTRIBUTION OF DOMINANT LANDUSE

	URBAN	AGRICULTURAL	FOREST	WATER	BARREN	WETLAND	INVALID
NUMBER OF DOMINANT CELLS	6	176	1443	0	2	0	0
PERCENTAGE	0.3687	10.8174	88.6908	0.0000	0.1229	0.0000	0.0000
ACRES	1482	43490	356572	0	494	0	0

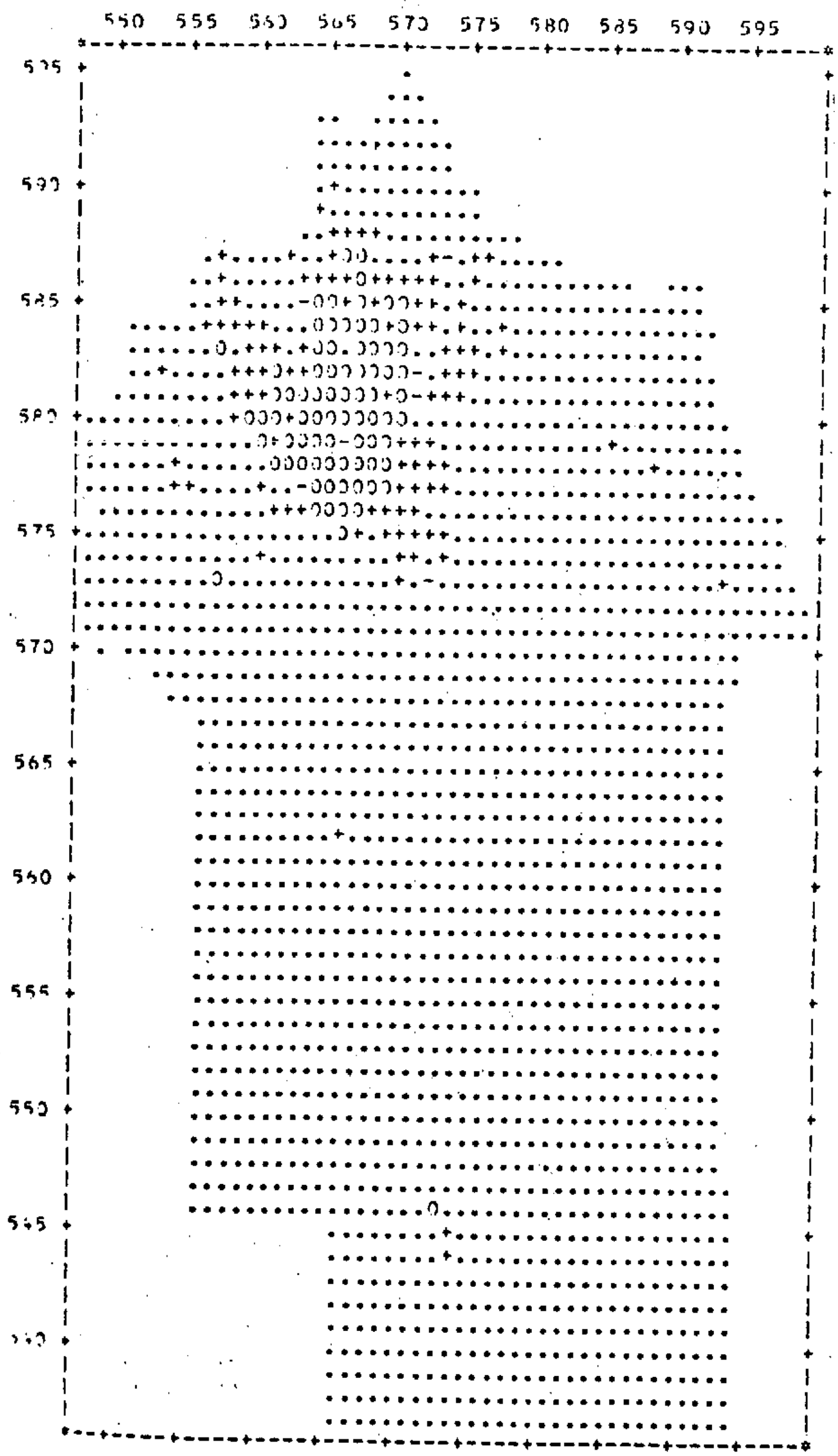
Fig. 5. Summary Data (4).

considerably less time to produce than the original maps, but the map is elongated in the north-south dimension.

The program shows changes in any one of the six primary land use categories between any two sets of data. It compares the earlier data set with that recorded from the later data set. The symbol period (.) appears in a cell location to indicate that the dominant land use of that cell did not belong to the classification being mapped in the base data set and also does not belong to this classification in the base data set and still retains this classification in the comparison data set. A plus symbol (+) indicates that in the base data set the cell was not in the classification being mapped but was classified with this land use in the comparison set; and a minus symbol (-) indicates that it was classified as the class being mapped in the base data set but was given another classification during the comparison data set. Sample land use change maps produced for Montgomery County comparing the historical data with the land use classified from ERTS imagery are included as figures 6 through 8.

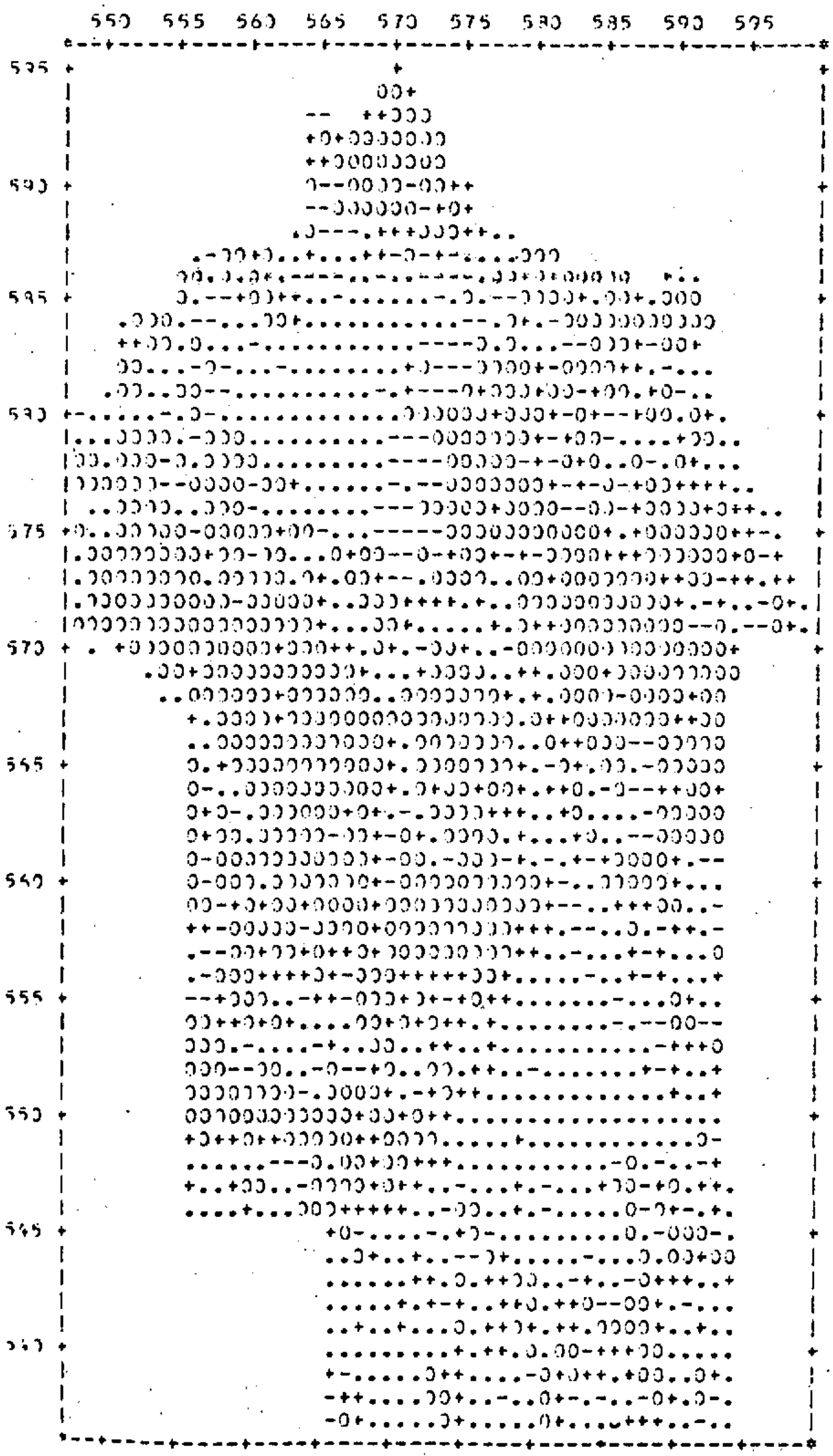
Another program was developed to enable the automatic application of the algorithms developed in the thesis written by Paul Wilms concerning the use of ERTS photographs to predict an optimum site for the placing of industry in the State of Alabama. A test area in the lower southeastern corner of Alabama was chosen as his study area and the calculations were made by hand. This same area was considered as a test area for the development of the computer program.

The algorithm for finding the optimum site location operates using a ten kilometer square area (or macro-cell) instead of a one kilometer square area. Seven factors are taken into consideration



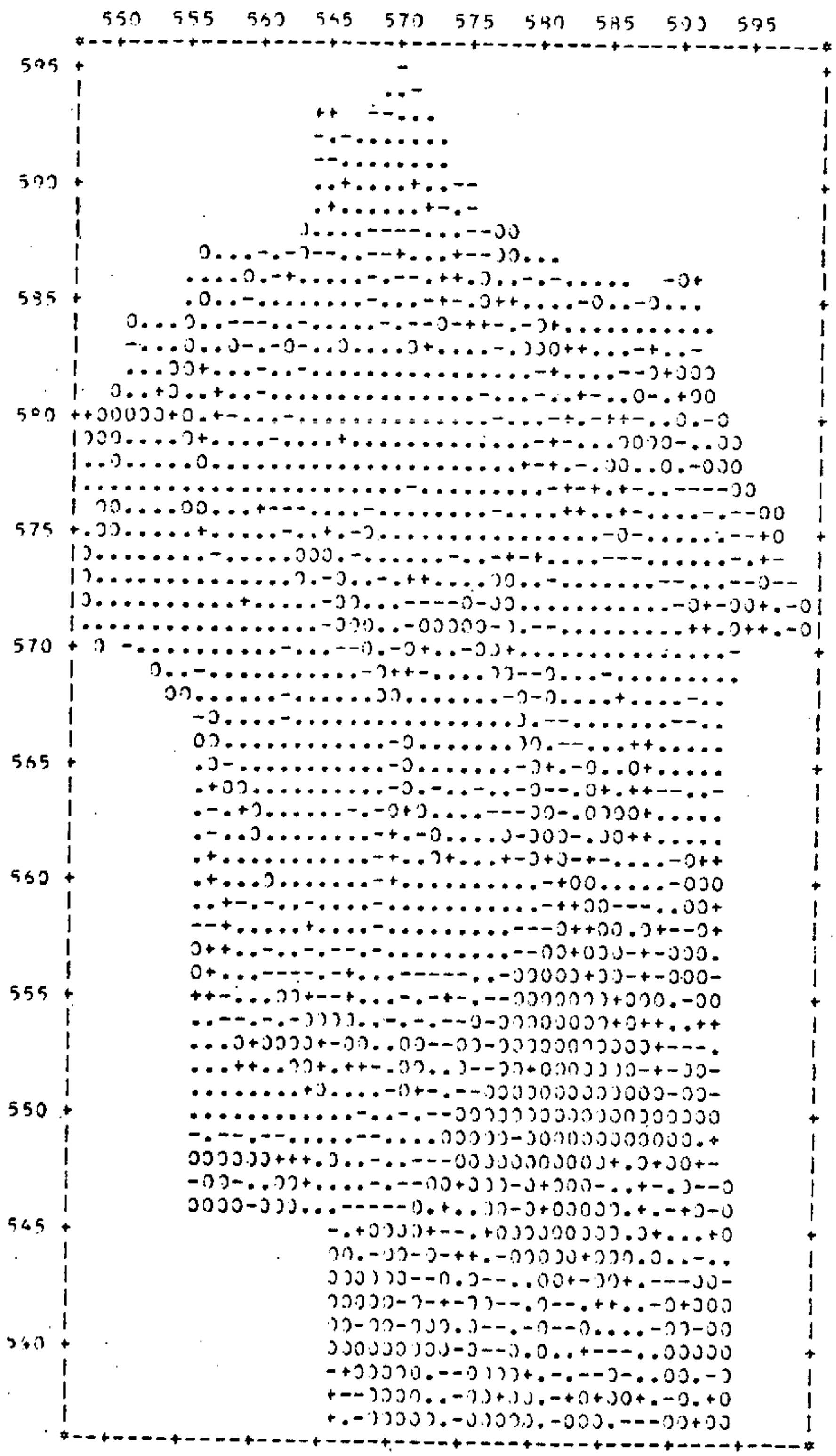
MAP OF URBAN CHANGE
THIS MAP PREPARED FOR MONTGOMERY COUNTY
AERIAL PHOTO DATA 12/64 * ERTS DATA POSITION 3 * CODE

Fig. 6



MAP OF AGRICULTURE CHANGE
THIS MAP PREPARED FOR MONTGOMERY COUNTY
AERIAL PHOTO DATA 12/64 * ERTS DATA POSITION 3 * CODE

Fig. 7



MAP OF FOREST CHANGE
THIS MAP PREPARED FOR MONTGOMERY COUNTY
AERIAL PHOTO DATA 12/64 * ERTS DATA POSITION 3 * CODE

Fig. 8

in order to give the square a desirability rating. Four of the factors are determined by the dominant land use for each macro-cell, the number of urban, agricultural, forest, and water cells within the macro-cell. These were given a weight in the equation of 0.2, 0.15, 0.2, and 0.05, respectively. Three other factors were added to the base file for each section which were growth potential, availability of roads, and availability of railroads. These were given a weight of 0.2, 0.15, and 0.05. The resulting equation is:

$$\text{(weight for macrocell)} = 0.2(\#\text{URBAN}) + 0.05(\#\text{AGRI}) + 0.2(\#\text{FOREST}) + 0.05(\#\text{WATER}) + 0.2(\text{GP}) + 0.15(\text{ROADS}) + 0.05(\text{RAILS})$$

The resulting number was mapped to a letter of the alphabet so that trends could be seen on the map, i.e. 0-5 became "A" 6-10 became "B", 11-15 became "C", etc. The central area of each macro-cell was left blank to permit the highlighting of the actual numeric weight which was printed in the cell's center. The resulting map is shown as Figure 9 in this report.

One of the investigators on the project, Mr. Lee S. Miller, was engaged in a project which has been reported separately on the validity of automatic land use classification systems using the ERTS data. Since the Marshall Space Flight Center, a co-investigator on the project, had undertaken the development of an automatic composite sequential clustering technique for the automatic accumulation of ERTS data points into land use classes, the decision was made to utilize their computer program and computer facilities to produce the analyses of the data required by Mr. Miller's thesis. When applied to small study areas in Tuscaloosa, Alabama vicinity, the technique proved to be useful in classifying land use automatically. However, some difficulties

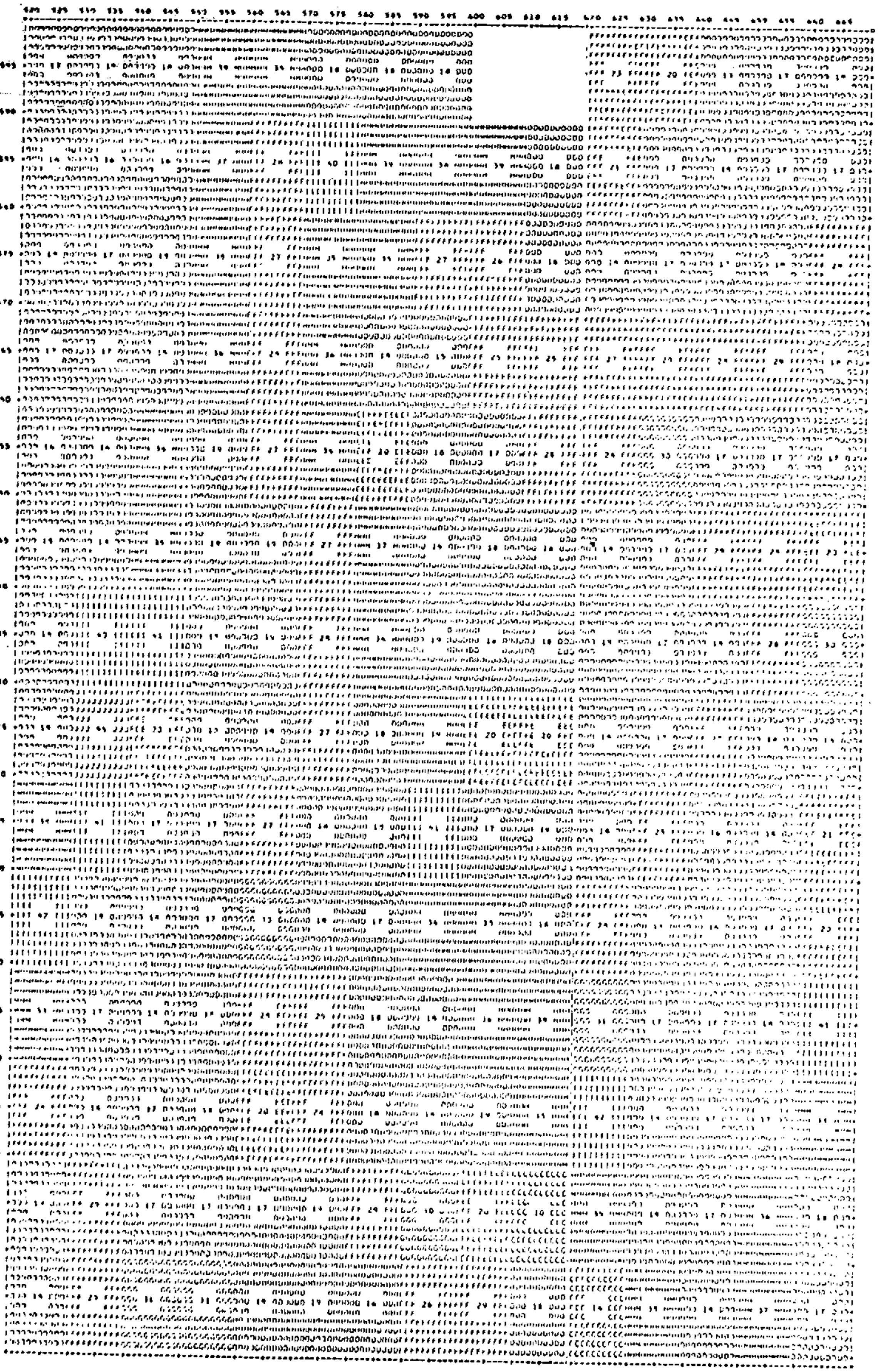


Fig. 9. Optimum Site Location Map.

were noted in Mr. Miller's presentation regarding the algorithm to distinguish between different land use categories where the land use is highly variable. The data processing section gave support to Mr. Miller in his efforts to analyze the automatically classified data.

Another major area of activity for the data processing section was that associated with the data collection platform (DCP) system. Information from the DCPs relayed through the satellite to the NASA ground data processing stations was sent to the project in the form of punched computer cards. A computer program was developed locally to take the information from these card images as received from NASA, edit them, and place them on a magnetic disc file so that the information could be stored conveniently and accessed readily. Additional computer programs were developed to analyze the data thus stored.

One such program, a water quality information system, was produced using GIS (Generalized Information System). The data used in this project was the water quality data from the Warrior River. GIS was used to create a generation data group consisting of two entries for ease of updating and changing records. This type of file is sequential in organization making it faster to access than an indexed sequential type file. The two entries provide two copies of the data, the -1 generation and the 0 generation. When the data set is processed and updated, the update becomes the +1 generation. Future generations of the data set would automatically cause the oldest data in the system to be deleted. This program was used to update the file when new information is received from the data collection platforms and to modify the file when errors in transmission or data errors caused by known hardware failures were identified.

A general program for the plotting of observed data was also developed for the project use. This program is capable of producing a plot of any or all of the sensors by month and/or DCP number and a specific type, either orbital, night time, daytime, or monthly averages. This routine is very versatile in application, as a very flexible input data set, and has been extensively used in this segment of the project produced graphs of the type shown in Figure 10.

Because of the difficulties identified in the classification of land use in Lee Miller's thesis research, the data processing section has undertaken a scholarly investigation of clustering techniques in an effort to produce a computer algorithm which is capable of classifying land use satisfactorily while overcoming some of the operational difficulties encountered in the composite sequential clustering technique algorithm used on Mr. Miller's research work. One of the goals of this aspect of the project is to produce an algorithm which would classify those points which were left unclasified by the composite sequential clustering technique. The second goal was to produce an algorithm which would be far simpler in operation and, therefore, produce substantial gains in processing time required to operate the algorithm. The third goal was to accomplish the two goals just enumerated without any significant loss in classification accuracy in the areas that were correctly classified by the composite sequential clustering technique. Sam Schillaci, a graduate student in Industrial Engineering, has made substantial progress in this area. The results of his investigation can be found in Volume II.

PH
(ORBIT AVERAGES)
Night Only

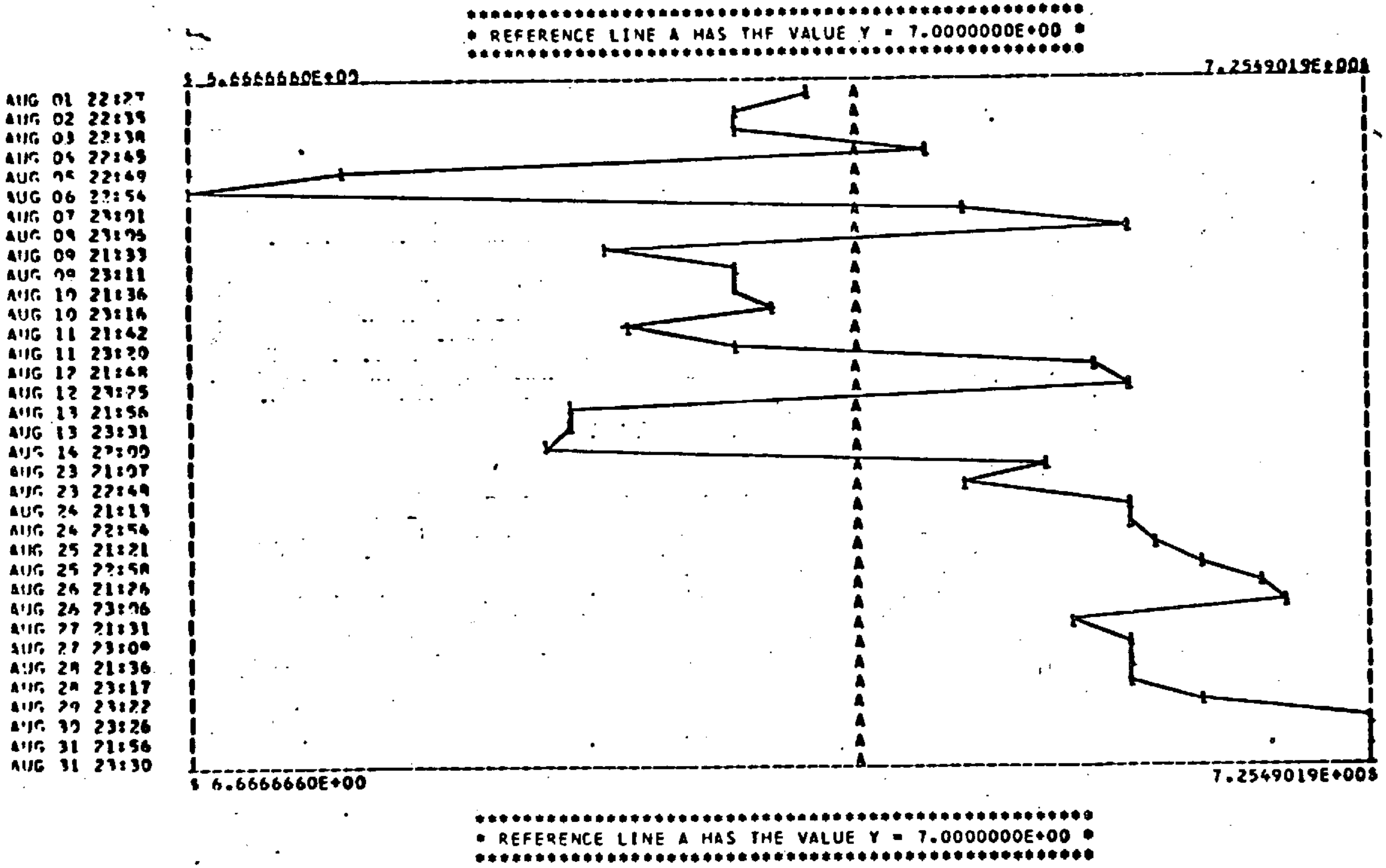


Figure 10 Averaged Orbital pH Values Collected by DCP No. 6060 for the Month of August, 1973.

ECONOMIC CONSIDERATION AND USER LIAISON SUPPORT

John F. Vallery

and

Larry Davis

SECTION FIVE

of

VOLUME ONE

INVESTIGATIONS USING DATA IN

ALABAMA FROM ERTS-A

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ECONOMIC CONSIDERATIONS AND USER LIAISON SUPPORT

Toward the end of realizing ERTS's mission "... to demonstrate that remote sensing from space is a feasible and practical approach to efficient management of the earth's resources," two essential elements of the project were to provide a format and staff support for reporting on the economic considerations and to provide user liaison. In this section, the activities of two economists providing secondary or support services to the several primary investigators are reported. A semi-independent task of the economist was to assist in providing user liaison with governmental agencies and other potential users of the final products. The basic support assignment was to assist others with the technicalities of an economic evaluation.

User Liaison

In early discussions of project organization, plans were made to systematically evaluate and make recommendations relative to information flows to actual users of ERTS data. An earlier project had identified a number of "potential users" of ERTS information. Contacts with several of these governmental agencies and private firms were maintained and data were offered to these users. Our emphasis, however, was focused on the Alabama Development Office (ADO), as the agency primarily responsible for statewide land use planning under existing and proposed legislation, and several multi-county regional agencies as potential users with direct and immediate applications. We were especially interested in their response to the availability of data and the offer of various amounts of experimental support on actual agency problems, and how these data and assistance would be utilized in the absence of an incentive to use the data through funded participation.

One major problem was anticipated in providing ERTS output to such agencies for their use or evaluation of use in the missions of their agencies, then finding that further processing or other work would be requested by the agency before they could evaluate an actual application of the data. Part of the liaison function was to facilitate and later evaluate the interchange between project investigators providing data and experimentation and these ultimate users.

A partial solution to the problem of evaluating actual applications, the inability of agencies such as ADO to devote sufficient staff time for the evaluation, was included in the project design. The Geological Survey (GSA) had been incorporated in the project as part of the research staff. This agency was also to serve as an example of final user of the data and analyses independent of their role of funded investigators. This stronger tie assured a significant amount of direct feedback from at least one operational agency.

Detailed output of GSA appears elsewhere in this report. For purposes of this evaluation, it is sufficient to note that the scope of applications by this agency greatly exceeded the scope of their official funded participation. ADO's participation was much greater than most non-funded participants in the sense that they maintained contact throughout the project, made numerous suggestions, and spent a great deal of time reviewing the potential of the work of project investigators. Little effort was made by ADO or other agencies, including some non-governmental agencies, to utilize the data independently, however, and these agencies were unable to provide independent reports for the overall economic evaluation.

Moreover, as the results of limited independent or interactive uses of ERTS data by unfunded participants, it was not possible to evaluate and make recommendations on a processing and distribution system for future ERTS output. Analyses of problems and insights from observing the data flows and usage are presented as part of evaluations of the several reports on land use applications where direct interaction with ADO was maintained. The several accomplishments and problems related to the liaison function are reported more appropriately in the introductory section of this Volume, where a more comprehensive evaluation of user interrelationships is provided.

Conceptual Framework for Economic Evaluations

In order to accomplish our primary objective of providing information suitable for an evaluation of economic benefits from an ERTS system, we set forth a methodological approach which was designed to facilitate the study, measurement, and transference of the creation and transmission of knowledge through technological progress. Early in the project an interim report was completed describing an optimization model for ERTS information flow and a tool for analyzing the cost and benefits, and cost-effectiveness of the users output. Furthermore, we proceeded to follow an interative questionnaire methodology which would elicit the maximum information from users of ERTS information and provide a conceptual framework for determining the feasibility and practicality of employing remote sensing in the efficient management of earth's resources. These approaches are spelled out in greater detail in Appendix I.

Some significant problems were encountered in the execution of the framework. The initial step of data collection proved to be a significant barrier since most of the individual investigators had developed a research design which excluded explicit consideration of cost or benefits of their findings. Therefore, it would have proven to be a major task to elicit this data, and so, for budgetary reasons, the structure of the research design of the investigators, the long lead time necessary to familiarize the users with the cost-benefit approach, and most importantly, the entry of EarthSat as the central organizer for cost/benefit input, our role was redefined as data suppliers as opposed to evaluators.

Methodology

Our final contribution in devising an appropriate methodology was based upon an evaluation of the results obtained from our own questionnaires, the questionnaire circulated by NASA, and a number of in-depth discussions with both project researchers and several other experimenters either under separate funding or those voluntarily utilizing data from either the ERTS or EROS programs. From the preliminary and first-draft reports, we concluded that specialists in engineering, geography, geology and other hard sciences were no better equipped to handle the technical problems in an economic evaluation than we would have been to handle a technical evaluation of the capabilities of the satellite technology.

The modified research design implemented at that stage of the project was for each scientific investigator to incorporate both cost benefit and cost effective observations in his report. (See Appendix II.) The benefit of this methodology was that the investigator has the highest level of expertise on the particular subject and is most aptly prepared to report the findings of his investigations. Then the project economists who are relatively unfamiliar with the technical findings and language of the investigator may interface with the users through both formal and informal seminars and direct collaboration to provide the means for users to enumerate and evaluate the relevant costs and benefits of these observations. Thus, the resulting information has been evaluated quantitatively in terms of a dollar cost (or an effort expended) or qualitatively in terms of some subjective estimate (or subjective expression) of the possible usefulness of the findings for future evaluation.

Results, Evaluation and Conclusions

The results of the modified methodology are reported in the researchers bi-monthly reports and final reports. However, some general comments seem relevant. The overall study provided a major, general conclusion which can be evaluated in the narrow context of the cost-benefit appraisal; the physical outputs themselves (e.g., maps, data collection and processing programs, new technology, and specific works) were more applicable to large scale as opposed to detailed observations and, thus, the management of earth resources via ERTS data must generally be complimented with conventional methods. There are few examples of substitute output. From this finding, we conclude that a speculative description of future applications, or "benefits," in addition to or perhaps instead of cost analysis will be essential in a comprehensive evaluation. The unprovable potential of the Earth Resources Program appears much greater than results which can be clearly demonstrated at this time. For this reason, conventional measuring tools (e.g., cost benefit or cost effectiveness) allow for only a limited number of potential applications, and emphasize only a small portion of the actual and potential uses.

Furthermore, the implications of a scientific economic evaluation are misleading and almost as harmful as the omissions associated with this emphasis. We wish to emphasize that in reviewing the individual reports for program evaluation one should look beyond the cost comparisons. The general non-comparatibility of cost effectiveness is brought out in the repeated conclusions of both experimenters and applicators. The usefulness of remote sensing from ERTS data is based primarily on the uniqueness of the synoptic view and repetitive coverage. There are no conceptually valid comparisons to the unique aspects of ERTS technology with conventional recording methods where the emphasis is primarily on a highly detailed small area at infrequent intervals.

Several specific examples support these conclusions. The reports summarized in Section One of this Volume have immediate potential demand by state agencies.[1] Land use maps have been generated through the use of ERTS imagery and the output has a favorable cost-effectiveness to existing A.S.C.S. photos, the comparison being 1:5.[2] However, this estimate of relative high cost mosaics for a synoptic overview in land use distracts from the unique identification of faults and other geological phenomena which could not be recreated withmosaics. Furthermore, as pointed out by the investigator, the benefits available through ERTS data (the synoptic view, the continuous coverage, and the rapid availability of computer compatible tapes) are not presently available from any other source thus no substitutes are present.

Cost-effectiveness analyses can also overstate the benefit of an application. A land-use cost estimate generated by Paul Wilms, with our assistance, was actually only a rough <u>ex post</u> evaluation by a scientific investigator.[3] Wilms observed that using ERTS-I imagery and his technique to generate land-use inventory for a county gave a 1:10 cost advantage for ERTS versus air photo mosaics, and that an entire county's land-use inventory could be generated in one and one-half hours with ERTS's imagery whereas air photo mosaics would require fifteen hours.[3] The basic problem with this cost estimate is the quality of the output varys, and, therefore comparative cost evaluation is inappropriate. One must first determine the degree of resolution that the potential user needs and then compare comparable output. The map produced is actually "cheaper" only for a broadgaged application in state or regional work--it would be high-cost (or unusable) in conventional applications.

Another specific example is J. A. Drahovzal's seventh bi-monthly report[4], wherein we find that ERTS data has been helpful in obtaining the boundary between Little Mountain and Moulton Valley. This finding is very important but the evaluation of its benefits are not clearly defined. Other similar examples are contained in the report (e.g., lineament show possible correlation with many of the known hydrothermal mineral deposits of the Valley and Ridge and Piedmont provinces or salt marshes were delineated from ERTS MSS band 7 image 1158-15564)[5] but the investigator is unable to compute either cost-benefit or cost effective values because no comparable data exist.

In the area of data processing and data management, we note that certain new benefits accrue to the ERTS project with potentially very large demand by ERTS users such as the program developed by Gary Darby. This program is capable of producing a plot of any or all of the sensors by month and for DCP number and a specific type, either orbital, night time, day time, or monthly averages. This program will be useful to compare historic data to that collected by ERTS and DCP's and also to help validate the proposed river model of Lamar Larrimore.[6] Again, one is impressed by the potential usefulness of these findings, but actual cost comparison are simply not feasible.

We found even the best examples of a cost-effectiveness calculation to be misleading. Data Collection Platform experiments approximate a data collection technique producing a "product" almost perfectly comparable to conventional methodology in terms of quality of output. In this sense, a preliminary calculation of the relative cost of data bits under alternative methods was submitted as "proof" of the low cost position of the ERTS approach. As skeptics, we also challenged the finding that valuable use would be made of data simply because ERTS information was being utilized by a regulatory agency, Alabama Water Improvement Commission,[7] and that the use of remotely sensed data in modeling verification offers unique advantages in water resource management. We emphasized again that no relevant substitute is available for cost comparison, and cost ratios may be very misleading.

The "devil's advocate" role of the above evaluation, presented earlier in seminars, led to what we believe to be the outstanding example of the appropriate type of economic evaluation. In Dr. Whittle's final draft (SECTION THREE, this VOLUME), a narrative description and major conclusion gave emphasis to what can be done with a large volume of data, the flexibility of moving the data collection stations, and other unique and noncomparable uses of ERTS data. It might also be noted that uses have already been extended beyond the scope of this project in both the work of Dr. Whittle and in data collected in Mobile Bay.

Other cost analysis in the various papers of this report have come closer to indicating general directions with narrative conclusion than in generating valid cost-effectiveness comparisons. In general, we believe that the output approximates the best which could be expected without a one-to-one ratio of cost-benefit technicians to scientific investigators. In conclusion, moreover, we believe that the really relevant "benefit" is much too speculative to assign a dollar figure. Land use maps will produce the technically correct "benefit" only when better resource management creates some economic windfall to society. This may come, sooner or later, or may never materialize regardless of technical capabilities. The <u>potential</u> benefits clearly exceed extremely high hardware and developmental cost. There are simply no means available to measure the extent to which these benefits will actually be realized within the scope of the funding available.

for such analysis and the current state of operation evaluation techniques.

FOOTNOTES

[1]Interview with Alabama Development Office, Tuscaloosa, June 1973.

[2]Neal G. Lineback, "Final Report on Determination of Applications and Uses of ERTS-I Data," unpublished preliminary report prepared for Geological Survey of Alabama.

[3]Richard Paul Wilms, Sec. 6, Vol. II, The Feasibility of Using Remotely Sensed Data From ERTS-I for land-use inventory, Management, and Planning.

[4]J. A. Drahovzal, "Appendix VII-A," Investigations Using Data in Alabama from ERTS-A, Seventh Bi-Monthly Progress Report, pp. 55-63.

[5]Ibid., p. 59, 57.

[6]E. T. Miller and Sam Schillaci, "Data Management and Data Processing," Investigations Using Data in Alabama from ERTS-A, Seventh Bi-Monthly Report, pp. 44-47.

[7]G. P. Whittle, "Water Resource Management," Investigation Using Data in Alabama from ERTS-A, Seventh Bi-Monthly Report, pp. 31-37.

APPENDIX I

A Conceptual Framework for Evaluating
Costs and Benefits from the Utilization of
ERTS-Aquired Data

APPENDIX I*

Systems Approach to ERTS Information Flow

In designing an optimization model for Earth Resources Technological Satellite (ERTS) information flow, it was recognized that the problem was sufficiently complex that a broad approach was required for analysis and solution. This suggested the use of a systems approach. A systems approach requires that the phenomena being studied can be conceptually described as a set of parts coordinated to accomplish a set of goals.[1] Furthermore, a systems approach focuses on achievement of a specific purpose or goal simultaneously seeking: to organize technology, manpower, and available funds within a time constraint; to incorporate dynamic characteristics which respond to changes in the environment of goals, needs and values; and to yield a framework for benefits and costs evaluation.[2] Thus, this approach recognizes that many factors which may be stated explicitly or included implicitly in the formulation of the problem play a role in determining the final output. Among the primary factors are: ERTS information demands (users), suppliers, available technology, management framework, data-gathering facilities, and feedback responses. One further assumption

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*This appendix only contains portions of the original reports. Parts I and II reflect the revision made to incorporate the questionnaire distributed by NASA June, 1973.

was adopted before deciding to explore the systems approach as opposed to various other optimization techniques. That is, the ERTS information flows depend on social and political factors and no realistic procedure to assign values to these factors was available. Therefore, their effect upon the ERTS information flows as a whole system was handled as constraints.

With this as background, we may move directly to a description of the systems approach to ERTS information flow. In general, the main objective of the model is the maximization of user information flow. A user is defined as scientific researchers, field professionals, and interested individuals. The reason for tri-secting the term, user, is that the purpose, needs, and quality of information of these users, in general, vary. Thus, this division yields subsystems within the context of ERTS information flow where the market for information for research "sake," whereas field professionals are operational oriented for "decision-making" and interested individuals need ERTS information for "decision-making" and general resource information. Also, the quality of information will vary depending on the "sophistication" of users as processor of information flows.

Given the primary objective, the following problems must be considered:[3]

(1) Criteria for the optimal design of the ERTS information technology.

(2) Target outputs for users.

(3) An optimal operating policy, that is, a schedule indicating timing, lags of information flow, and user response findings.

Assuming that the outcome of these problems can be expressed as "benefit" B (where, "costs" are negative benefits), then B is a function of three sets of variables: Y_1, the optimal design; Y_2, target outputs; and Y_3, the optimal operating policy; where Y_i may be a multidimensional vector. Therefore, $B = f(Y_1, Y_2, Y_3)$ and geometrically represents a response surface in multidimensional space, and the solution is the highest peak within the range of admissible values of Y_i. Clearly, the Y_i vectors are not independent. For example, the optimal design and operating criteria have strong interactive relationships. However, at this point, we will consider each of these problems separately. Thus, maximizing for B for $P_{12.3}$ which says maximize B for problems 1 and 2 while considering problem 3 as a parameter.

Consider for a moment the following objective function in which P_1 and P_2 are considered explicitly.

$$\max B = PV(A) - I(A)$$

Here all values are in monetary units and B represents the present value of the net benefits; PV (A) is the present value of A amount of information supplied per year to users; I (A) is the investment necessary for the construction of a system capable of supplying A amount of information per year. Obviously, A is unknown, its value must be determined in order to maximize B. The solution will simultaneously determine P_1 and P_2 by specifying the criteria for designing the system I (A) and the flow information PV (A) and takes the optimal operating policy as a parameter. Notice that different values of A maximizing B may be possible when different operating rules are applied to the system.

Suppose we wish to specify a primary objective of economic efficiency for the total informational flows. Using this systems model, consider n possible forms of information flow having a span of T years of economic life; while every form of information flow j (j=1,2,...,n) generates Bjt (t=1,2,...,T) gross benefits; and during any year the information flow (jth) generates Mjt monetary costs for its operation and maintenance; also this information flow (jth) requires a total investment Kj for construction. It follows that in order to maximize economic efficiency for the total information flow, the following criterion must be maximized:

$$Z = \sum_{j=1}^{n} \sum_{t=1}^{T} \frac{B_{jt} - M_{jt}}{(1+i)^{t}} - \sum_{j=1}^{n} K_{j}$$

where i is the prevailing interest rate.

Notice that we have only introduced primary (direct) benefits; however, if we wish to introduce external benefits (secondary) we should expand this criterion to encompass primary benefits B_p and secondary benefits B_s; furthermore, as the model expands to encompass <u>all</u> benefits, the criterion should be expanded to incorporate all other plausible (current and future) benefits B_f. This will account for all of the benefits generated by the information flows to the users, and can be handled by either maximizing total information flow subject to economic efficiency that is maximized

$$Z = \sum_{j=1}^{n} \sum_{t=1}^{T} \frac{(B_p + B_s + B_f)_{jt}}{(1+i)t} - \sum_{j=1}^{n} K_j$$

$$\text{subject to} \quad \sum_{j=1}^{n} \sum_{i=1}^{T} \frac{B_{pjt} - M_{jt}}{(1+i)t} - \sum_{j=1}^{n} K_j \geq 0$$

or maximize economic efficiency with total information flow to a particular user as a constraining condition, i.e., maximize

$$Z = \sum_{j=1}^{n} \sum_{t=1}^{T} \frac{B_{pjt} - M_{jt}}{(1+i)t} - \sum_{j=1}^{n} K_j$$

$$\text{subject to} \quad \sum_{j=1}^{n} \sum_{t=1}^{T} \frac{(B_p + B_s + B_f)_{jt}}{(1+i)t} \geq B_u$$

where B_u is a specified level of benefit to user u.

Since K_j is an investment decision made by the national governmental agencies and B benefits occur to a limited number of users, most of the direct national priorities are explicitly introduced. However, the model does provide useful insights into an optimal systems approach for ERTS information flows. Furthermore, since the derived model is of the form of a linear programming model, a strategy alternative may be chosen when budgetary, administrative and time constraints are specified.

Moving toward a more operational section of this paper, we ask the question, given that certain output currently exists from ERTS's information, how can this output be evaluated for specific sensors?

Cost-Effective Approach for Evaluating ERTS's Output for Specific Sensors

This section provides a framework for the economic evaluation of the utility of selected sensors in providing data for users.[4]

The approach suggested is the comparison of effectiveness and costs of alternative methods. The weighted sum technique was used because of the subjectivity involved in providing an element of datum. The overall cost-effective method for sensors may be calculated in the following way:

$$E_{jku} = \sum_{i=1}^{n} W_{iu} e_{ijku}$$

where E_{jku} = Effectiveness of the k^{th} sensor(s) in providing data at an effective resolution level j for the u^{th} user.

w_{iu} = Relative importance of the i^{th} element of information for the u^{th} user.

$(\sum_{i}^{n} w_i = 1)$.

e_{ijku} = Effectiveness of the k^{th} sensor(s) in providing the i^{th} information element of an effective resolution level j for the u^{th} users.

$i = (1,2,\ldots,n$

A cost-effective comparison may be completed if the cost of each sensor(s) is known. The output of ERTS information may also be compared to conventional means of gathering and presenting sensors information by directly costing the sensors output to conventional methods for identical outputs. Notice that costs would include procurement of sensors and film, operational costs incurred in obtaining the imagery or recorder medium, processing, and other costs incidental to acquiring the finished product for users employment. Notice that, the market price, if one exists, will not, in general, reflect all costs. The weights may be derived from the Goddard questionnaires and the revised responses from the interview technique. (Shown below)

From the standpoint of a user, please rate the following system variables with respect to the degree to which they satisfy the requirements in the application specified above.

Use a scale of 1 to 10 with the following significance:

1 - Variable is useless for this application
5 - Variable generally satisfies requirements
10 - Variable is essential (though not necessarily sufficient to satisfaction of requirement

We recognize and accept the fact that such statements, in relative terms, carry with them appreciable errors but this should not deter you from making your best evaluation in every case. Brief remarks (e.g., concerning the degree of confidence in the rating) can be made in the space provided - but are not required.

Variables	Rating	Remarks
Spectral coverage		
MSS (4 spectral bands)		
MSS (4 bands + thermal channel)		
RBV (1 panchromatic channel)		
RBV (3 spectral bands)		
MSS (4-, 5- channel) + RBV (pan)		
Stereo coverage (using RBV)		
Output Data Requirements		
50-meter spatial resolution		
100-meter spatial resolution		
Better radiometric fidelity		
Geometric fidelity within image		
$\pm$ 400 meters		
$\pm$ 150 meters		
Positional location of scene		
$\pm$ 5000 meters		
$\pm$ 1000 meters		
Ability to overlay from band to band		
$\pm$ 300 meters		
$\pm$ 100 meters		

Variables	Rating	Remarks
Ability to overlay from scene to scene		
± 1000 meters		
± 150 meters		
Computer compatible tapes		
System		
How often are data required		
every day		
every 5 days		
every 20 days		
longer?		
Data collection system capability		
Local receiving station for sensor data		
Local receiving station for DCS data		
Time of day of data acquisition		

The next section of this report delves into the questionnaire methodology.

An Iterative Questionnaire Methodology

This section briefly reviews the conceptual questionnaire methodology whixh was partially implemented in an interview and feedback technique. Dalkey and others at Rand Corporation developed a technique for eliciting expert opinion on future developments in technology, emphasizing speculation as opposed to factual knowledge.[5] In general, the methodology attempts to forecast developments far into the future and has been referred to as the "Delphi Method." In various modifications and experimentation with this basic methodology, attempts have been made to determine institutional goals and otherwise incorporate the impact of subjective value judgments on the ultimate benefits to society of technological developments.[6] A modified "Delphi" approach was tested for application to two of the problems here, (1) the need to project current experimentation into future usefulness in application and (2) to develop a method for identifying and describing and, if possible, establishing values of the benefits to be derived from these future uses.

The conceptual framework for implementing the methodology is outlined below. Financial constraints prohibited full implementation in contacting the range of experts desirable for the experiment, however, and the actual application was limited to the interchange among researchers engaged in the project.

Step 1: Define the problem to be solved and probable outcomes.

(1) Make the answer quantifiable whenever possible.

(2) Direct responses toward weights of sensors among other relevant information.

Step 2: Determine users which bear on the problem.

(1) These can concern the total problem or sectors of it; and may encompass all, some, or none of the known specific needs of the users.

Step 3: Select expert(s) to be used in solving the problem.

Criteria:

(1) Must have requisite knowledge and be able to apply it to problems.

(2) Must have good performance record in their areas.

(3) Must be rational, objective and impartial.

(4) Must be available over a period of time of the study.

(5) Must be willing to participate in the study.

Step 4: Contact experts being considered.

(1) In person.

(2) Explain the total study being undertaken.

(3) Explain the central problem under consideration.

(4) Explain the role they are expected to play in solving the problem. (Responding to questionnaires and analyzing the data between questionnaires.)

Step 5: Distribute the first questionnaire (The Goddard Questionnaire). Begin preparation of second questionnaire.

(1) Restate the problem under consideration in specific terms.

(2) Request a numerical estimate of rating at this time.

(3) Also include questions which bring out:

(a) The respondent's reasoning and feelings (speculations).

(b) The factors which he considers relevant.

(c) Information as to the kind of data he feels would enable him to arrive at a better appraisal of these factors and thereby at a more confident answer to the first question.

Step 7: Analyze the results of the first questionnaire.

Step 8: Make appointments to review first questionnaire and analysis with user.

Step 9: Interview users and hand out second questionnaire.

Step 10: Record new information from interview and feedback response.

(1) Feedback information that was either requested by some one of the experts or which deals with factors and considerations which are considered relevant.

(2) Take care to conceal opinions of the other experts.

(3) Correct misconceptions about empirical factors or theoretical assumptions underlying those factors.

Step 11: Follow steps 1-10 until users exhaust all information and weights are determined by consensus.

Step 12: Report results to users.

Step 13: Discuss results with all users in group meeting.

Step 14: Report new results, if any, in user's reports.

FOOTNOTES

[1] C. West Churchman, The Systems Approach (New York: Delacorte Press, 1960), p. 27.

[2] Sidney Fine, "A Systems Approach to Manpower Development in Human Services," A Systems Approach to New Careers: Two Papers (Kalamazoo, Michigan, W. E. Upjohn Institute, 1969), p. 27.

[3] This section draws heavily from Nathan Buras, Scientific Allocation of Water Resources (New York: American Elserier Publishing Company, Inc., 1972), ch. 2.

[4] This section draws heavily from an unpublished paper by Dr. Greg Butterworth, an unidentified co-author on cost-effectiveness for ERTS.

[5] See T. J. Gordon and Norman Dalkey, "The Delphi Method: An Experimental Study of Group Opinion," RM-5888-PR, the Rand Corporation, 1969, and Richard N. Farmer and Barry M. Richman, Comparative Management and Economic Progress, (Homewood, Illinois: Richard D. Irwin, Inc., 1965), pp. 325-349.

[6] This section draws heavily on work published by William D. Gunther and J. F. Vallery, Jr. "The Delphi Method as Applied to Public Investment Decisions," The Review of Regional Studies, Vol. 1 (2), pps. 127-147, and the subsequent application of the approach by Vallery in the identification of developmental objectives for the State of Alabama.

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*Other than footnote references.

APPENDIX II

Memorandum to Project Staff

on the

Inclusion of Cost-Benefit Considerations in Individual Reports

APPENDIX II

September 27, 1973

MEMORANDUM

TO: Experimenters with Remote Sensing Technology

FROM: Ted Vallery, Project Economic Consultant

Larry Davis and I, in working with several experimenters in ERTS and EROS projects, have reviewed the problems and prospects of evaluating the social and economic impacts in several remote sensing applications. We used a combination of guidelines and questionnaires furnished by the Department of Interior, NASA, EarthSat, and our own ideas. Our initial object was to develop a comprehensive questionnaire format which could meet requirements for both national and Alabama evaluations. This memo is to summarize our observations to date and to review the questionnaire substitute approach which we discussed at several meetings.

In general, we found a uniqueness among efforts of the several investigations which greatly reduced the effectiveness of any single questionnaire. Short and simple formats aimed at check-offs and one-line descriptive statements failed to generate the some of the more important economic observation sought. We believe that the major limitations can be greatly reduced with a modified approach directed toward a narrative description of findings and emphasis on professional insights.

The one pitfall we observed was in describing an "application" of a particular set of data to a specific problem. Most investigators are working from a particular research design with a conceptualization of their problem which is generally not optimal and sometimes not workable for the secondary economic evaluation. We believe that a restatement of the problem (or redescription of the application) directed toward the estimates of data cost, quality evaluations, and proposals for future systems requirements will be quicker, simpler and more effective than force-fitting the evaluation to the experimental mold most relevant for your emphasis. A major problem is that investigators tend to review the utility of data only in terms of the central thrust of their experiment thereby omitting many incidental observations of high potential value for a comprehensive evaluation. In general, the solution is to identify the several data manipulations utilized in your work and summarize the actual and projected usefulness of the data, both as is and as it could be assuming equipment modifications, extended time-series coverage, etc.

The second pitfall we observed stemmed from legitimate but misleading emphasis placed on the need for a numerical calculation of cost savings associated with your applications. The economic concept of "benefit" emerged as a major stumbling block. Most experimenters limited their comments and observation to the "benefit" provided by the experimental product envisioned in the research design. In effect, the benefits perceived were limited to known and proven uses such as land use maps. In such cases, the upshot of the evaluation is to compare cost under alternative methods of producing a product, imputing potential cost savings as the only benefit. These cost-effective analyses, while of great value, clearly speak to only a limited scope of the potential utility of remote sensing data. The solution calls for bold and visionary assessments of potential future uses and application drawing upon the full range of your professional expertise as opposed to your findings from the specific application. Since no one <u>knows</u> future utility, your speculative expert judgment is the best possible source for identifying "benefits" other than cost reductions.

These two limitations can be fully offset by the inclusion of positive result such as those reported to us in interviews. Individual experimenters, especially after some discussion of terminology and probe of the intent of the questionnaires, demonstrated a firm grasp of conceptual problems underlying the cost-benefit approach. Outside of the context of the structured questionnaire, relevant comments and observations were made relative to the information sought. It therefore appears that the short narrative report on cost-benefit aspects of the several experiments can furnish both clearer and more detailed observations than a standardized questionnaire format.

Our emphasis, therefore, is to encourage you to report observations outside the scope of findings directly related to your experimental design. We believe that insights and speculative assessments stemming from your experimentation will be at least as valuable as experimental results. The various questionnaires will be of primary value in suggesting appropriate content for the narrative. Cost-effective examples should be incorporated where appropriate to the fullest extent possible. The narrative allows and hopefully encourages a discussion of the implications of your cost estimates, considering such factors as the quality of estimates used, comparability of new versus conventional findings, and other factors beyond the scope of a numerical example. The general objective should be to provide an evaluation of future potential and to recommend appropriate system modifications, using the cost insights for appropriate support.

There are several other observations which we also offer as a possible aid in structuring the economic section of your report.

Cost effective evaluations contain a pitfall which often calls for subjective and descriptive modification. Ideally, a daily log would be used to record the exact cost of producing a product in terms of man hours and equipment utilized. Such cost, however, would compare efforts required using conventional methodology and standard equipment with costs incurred using the newly developed techniques and equipment. To the extent that producing a product experimentally required greater effort in developing and checking the methodology, cost figures as obtained from actual records of your experiment will be too high and hypothetical estimate of replication cost would be more appropriate.

...(Suggestions deleted)... If the product replaces or serves as a partial substitute for an existing source of information, the benefit can be used as a cost-effectiveness example. If new information is provided (inclusive of greater frequency, broader scope, and other innovative forms), the potential benefits are speculative as opposed to definitive and call for a description of potential users and uses.

Note, however, that identifying whether your experiment produced an old product in a new way or created a new product often is a matter of how you call it. Simply recognizing that most applications have aspects of both, for example, the land-use map which is not really the same as a land-use map produced under older techniques, gives rise to:

> A critical evaluation of the results as a substitute, balancing the discussion in terms of strengths and limitations, and
>
> A probing evaluation of potential new and different uses.

Both should be described, and a sharp distinction should be made between the two descriptions. What is obvious to you and your discipline may not be as readily apparent to evaluators of the system.

When you have completed your draft, at your request, we will review your report for technical accuracy in the use of cost-benefit terminology, make suggestions as to relevance in economic context, etc. We can also provide limited technical support on format, etc. relative to the economic problems.