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# SYMPOSIUM ON SIGNIFICANT RESULTS OBTAINED FROM EARTH RESOURCES TECHNOLOGY SATELLITE-1

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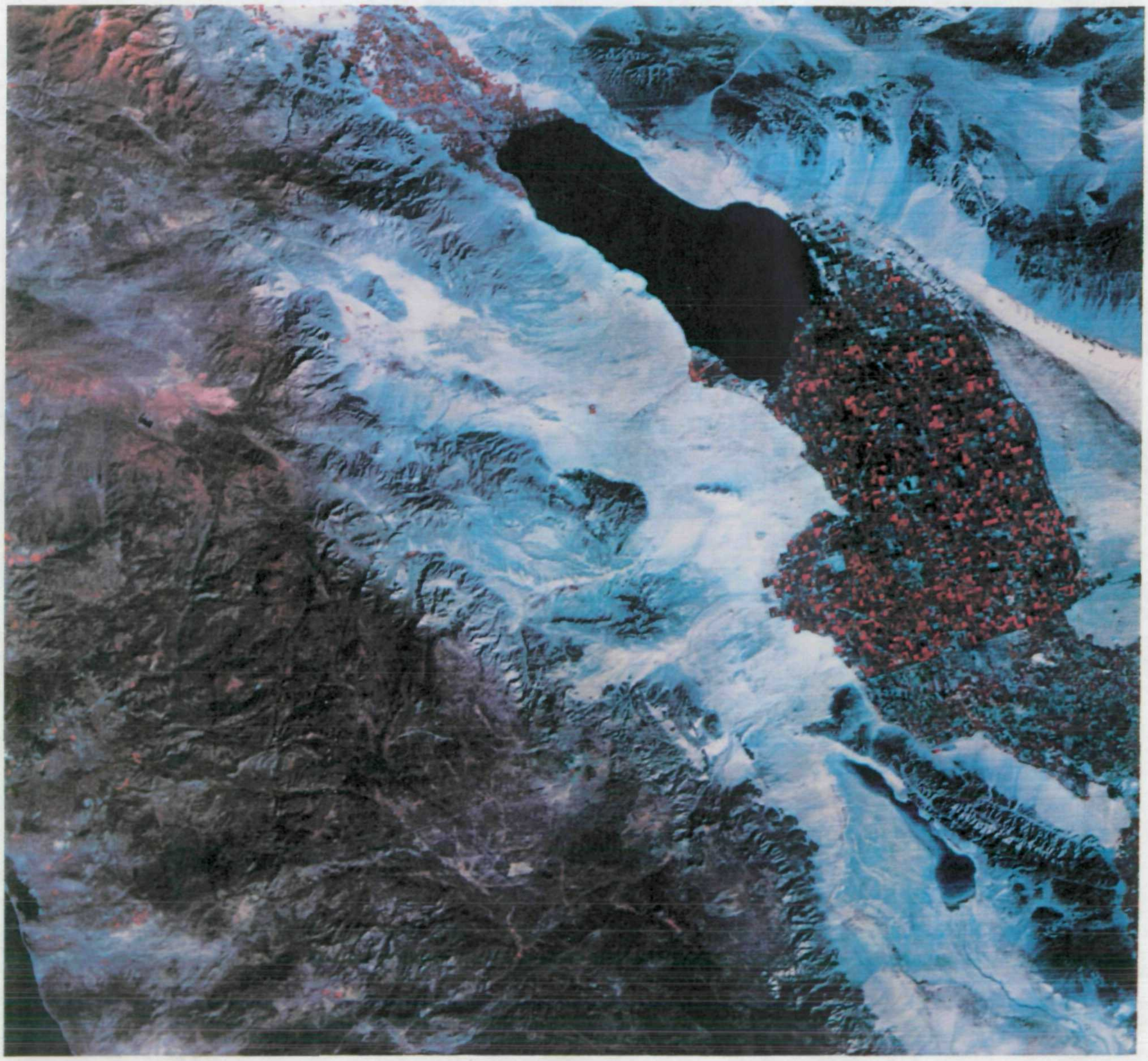
## VOLUME II—SUMMARY OF RESULTS



Goddard Space Flight Center, Greenbelt, Maryland
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Color Illustration. ERTS-1 image of Imperial Valley, California, acquired November 6, 1972 (E-1106-17504). The Salton Sea is in the center. Irrigated farmland borders its northwest and southeast shores. San Diego is on the lower left with San Diego Bay clearly visible.

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# SYMPOSIUM ON SIGNIFICANT RESULTS OBTAINED FROM EARTH RESOURCES TECHNOLOGY SATELLITE-1

**Volume II**
**Summary of Results**

Edited by
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Laboratory for Meteorological and Earth Sciences

and

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May 1973

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

## EDITOR'S NOTE

The papers of Volume II have been derived primarily from oral presentations made during the Thursday Summary Session of the Symposium. Because of this, and in order to achieve a uniform format, a considerable amount of editing was performed. Although contributors were afforded an opportunity to revise their oral transcripts, the time allotted them for this purpose was short in order to expedite the timely publication of this document. Therefore, while care was exercised not to alter a contributor's context, this may have happened inadvertently, in which case the editor assumes full responsibility.

## PREFACE

The first Earth Resources Technology Satellite (ERTS-1) was launched on July 23, 1972. In the seven months since it was activated, over 34,000 scenes of the earth have been obtained, covering all major land masses and about 75 percent of the world's land area. Some areas, such as the United States, have been imaged at least twelve times. The purpose of the ERTS program is to provide an assessment of remote sensing from a satellite as a technique for inventorying and monitoring the earth's resources to provide for better management of these resources.

This Symposium provided the first open forum where the users of the ERTS data had the opportunity to present the significant accomplishments from their investigations. It also provided the first opportunity for representatives of federal, state, and local organizations to present their views on how ERTS data are being used and will be used for solving operational resource management problems.

In order to provide maximum visibility for both the scientific/technological results as well as for the applications results from ERTS, and to provide these results in a relatively concise manner to those who could not be in attendance all week, the Symposium was structured into three parts:

(1) The first three days, after an opening introductory session on Monday morning, were devoted to contributed papers in the various disciplines. A total of 184 papers was presented. These papers are contained in Volume I; they are numbered and presented in the order that they were listed in the Abstracts. Several papers not listed in the Abstracts are contained at the end of this Volume. A summary paper pertaining to the status of the ERTS system, which was given as the first paper because of its general interest to all participants, is contained as the first paper in this Volume.

(2) The Thursday Summary Session of the Symposium was designed to summarize the significant results presented during the first three days and also to present some typical examples of how ERTS results are being applied to solving operational resource management problems primarily at the federal and state levels. Highlighting this Summary Session were addresses by Dr. James C. Fletcher (Administrator, National Aeronautics and Space Administration), the Hon. James Symington (Representative, U. S. Congress, State of Missouri), and the Hon. Ed Reinecke (Lieutenant Governor, State of California). These were followed by a summary paper on the ERTS-1 status and then by four key papers selected from the presentations made during the first three days. On Thursday afternoon, four papers were presented which summarized the significant results from the first three days in selected disciplines. Five papers exemplifying the applications of ERTS results to meeting selected

federal and state program objectives and some resource management objectives in several disciplines were then presented. The proceedings of the Thursday Summary Session are contained in Volume II.

(3) Volume III contains the reports of the Working Groups which were convened on Friday to summarize and critique the ERTS results in the various disciplines. These working groups were chaired by the respective discipline session chairmen and were composed of selected specialists in the disciplines. Opinions and recommendations expressed in these reports are those of the panel members and do not necessarily reflect an official position of NASA.

Stanley C. Freden
*Symposium Chairman*

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## INTRODUCTION TO SUMMARY SESSION

**Dr. James C. Fletcher**
*Administrator*
*National Aeronautics and Space Administration*
*Washington, D. C.*

It is indeed my pleasure to address this summary meeting on ERTS-1 results. Few here need to be convinced of the importance of observations of the earth from space. There is great concern among people in this country and abroad about the quality of life on earth. One particularly important aspect of observing the earth from the moon and long distances is that we begin to realize that this is our home. It is finite; and we have to do all we can to take care of it and to make it the best home we possibly can. The ERTS-1 satellite, launched just eight months ago, is certainly a major step forward in an attempt to decide what we can do to provide the data that are necessary to improve the quality of life here on earth.

There are, as you know, more than three hundred different ERTS-1 investigations underway. Almost two hundred investigators have made presentations during the first three days of this Symposium. We are here to learn, in an informal way, what can be, or what is the potential for the ERTS imagery that we are beginning to accumulate.

We will hear not only summaries today, but also some specific applications which have been selected to show the usefulness of ERTS-1 for the ultimate benefit of mankind.

There cannot be much question, I believe, of the general concern in this country with the quality of life, particularly with the problems of the pollution of water, air, and land. We also are very concerned about the availability of energy sources and natural resources throughout the world. We are also beginning to be concerned on a broader national and global basis with the problem of growth of urban areas and the impact of the industrial age on what used to be rural and wilderness areas. All these problems are of major concern to informed people throughout the world. The question, of course, naturally arises: "Can ERTS help in this regard?"

I do not believe there is much doubt in the minds of the people here that the answer is a resounding "yes." However, we often hear a common remark about new technology: "Yeah, promises, promises." We must turn those promises into reality.

In order to do this, it is not sufficient simply to understand what things like ERTS can do for technology, for improving the quality of life, or for improving our gross national product. It is not enough for only experts to understand what ERTS can do. It is vitally important that the user understand what it can do.

If the user is alert, on his toes, and enterprising, he will find ways of using these data very quickly. But not all users have these qualities. Because most users tend to continue the way they have been, for that is the easiest way, we have to secure the attention of those entrepreneurs, those enterprising individuals, who can see new ways of doing things to greatly improve the output relative to the responsibilities which they have.

And this holds for all user aspects of our society. It certainly holds for local governments. NASA has been working with local governments, using high-flying aircraft, for some time. It also applies to state governments, to the Federal Government, and to other countries; and we cannot omit that important segment of society which we call American industry. Industry, in those areas having to do with resources and resource management, has a very great interest, and in some ways, at the present time, constitutes the real entrepreneurs in the ERTS or the remote sensing area. Industry has been using remote sensing over the years in mineral exploration and in many other applications, particularly agriculture.

We have to establish contact with the urban planners, state agencies, and other agencies of the Federal Government to help them to understand the real value of remote sensing, and particularly the ERTS kind of remote sensing. It is the latter in which there are obtained large quantities of data over large territories in four different spectral bands, precisely recorded in longitude and latitude. We must use this knowledge and transfer to the real users not only the understanding of this knowledge but, in some manner, the potential value of it.

I believe this is our challenge at NASA and the challenge in today's session.

## GENERAL REMARKS

**Hon. James W. Symington**
*Representative, U.S. Congress*
*State of Missouri*

It is a somewhat awesome responsibility for me to be considered in any way an authority of a scientific program, or any portion of it. I was an English major in college, and I had a great difficulty with scientific subjects. If there is a paper shredder around, I hope it takes care of my academic record in that regard.

Dr. Fletcher referred to the problems inherent to understanding the things that are happening around the world, and made reference to a common thought—that is, that the scientist learns more and more about less and less, until finally he knows everything about nothing. But, if that is true, and of course it isn't—but if it is, then the corollary is certainly true concerning members of Congress. We get to know less and less about more and more—eventually we know nothing about everything.

My predecessors, Congressmen Joe Karth of Minnesota and Tom Downing of Virginia, former chairmen of the subcommittee on Space Sciences and Applications, were enthusiastic and articulate spokesmen for this program in general, and the Earth Resources Survey program in particular. I want you to know that I am equally enthusiastic.

One aspect of the ERTS project which has special appeal for those of us on the House Subcommittee on Space Science and Applications and for me in particular, having worked in the vineyards of diplomacy for some years, is that it lends itself so readily, so effectively, to international cooperation. There are, for example, many principal investigators involved in this experimental program from nations all over the world. I understand a good many of them are with us today. We welcome their participation, and we are grateful for their contribution to the success of this program.

The deeper significance of the ERTS project lies in the fact that we view it as the first step leading to future operational systems which we are persuaded will help mankind solve some of the most pressing social and economic problems from one end of the earth to the other. With the success thus far of ERTS-1, the brilliant promise of this new technology becomes clearer. The usefulness of the imagery produced by these extraordinary instruments orbiting the earth 500 miles up has already been demonstrated in many scientific disciplines.

Still, we have much to learn. In spite of some remarkable achievements, some of which were described to our subcommittee only yesterday, we sense that we have only scratched the surface of knowledge which this technology promises. No doubt there are many ingenious uses for ERTS data that are but dimly perceived at this stage, and I think our intuition should tell us that many uses have not yet been revealed.

I think it is no exaggeration to say that my colleagues in the Congress have given unstinting support to NASA's space applications program. We are well aware that the taxpayers of this country wish to see some practical consequences to their large investment in space exploration. I cannot emphasize that point too much.

Any one of the 435 members of Congress on the House side, and any one of the 100 members of the Senate who goes home to his district or his state will inevitable be confronted by the question: "Why this, when we have this? Why up there, when it's all happening down here?"

Now, it is up to us in some way to translate what NASA is doing into terms and concepts that are readily understood by the average citizen in this country who is paying for the program. How well I remember going to the Century Plaza Hotel in Los Angeles to greet the returning astronauts (Neil Armstrong and his colleagues), driving up to the hotel, being invited to the President's state dinner as a member of the Committee, and seeing it ringed, virtually, by three or four thousand young Americans chanting, "Down with the moon." I thought, at that time, that rather than go inside and share in the champagne which I was sure would last, I would stop and talk with these youngsters. I got out of the car, and they came around noticing that I was dressed in a tuxedo. I identified myself to them as a Congressman from Missouri.

"What do you think of all this?", they asked. I said, "Well, I think it's great." Their response was, "Well, why—with all of the poverty and suffering and so forth." I asked them if they knew anything about earth resources, weather, communications, lives saved, a planet served and helped, and we talked for about one hour. Later, I received letters from many of those youngsters saying, "Thanks for spending some time with us." We in Congress must spend time with people and explain what it is that their nation ought to do with its resources.

This message can only be brought home to them with your help. I feel, in talking with Mr. Mathews over the past few days, that we are going to get that help. He has done a tremendous job in presenting testimony to us on behalf of ERTS and other space applications programs. I am confident that Congress will continue to provide resources particularly for space applications programs, because they indeed do promise to enrich human life everywhere. So, we are grateful, Dr. Fletcher, for this opportunity to say what is in our hearts and on our minds about what may well prove to be one of the greatest contributions of the space program to mankind.

## KEYNOTE ADDRESS

**Hon. Ed Reinecke**
*Lt. Governor,*
*State of California*

When I became Lieutenant Governor of California in 1969, I suggested to Governor Reagan that we really needed to make better use of the great resources in California. Through the entire aerospace industry and the great research capabilities of our university, we had a mechanism to accomplish the mission of being a science advisor to the Governor.

Typical of those who use the suggestion box, I became the head of that department. Since that time, we have been trying to find ways to bring to the state government, and now to local governments, some of the methods, the techniques, and the ways in which we can realistically become aware of the many great bits of information, evidence, and techniques to bring science a little closer to the decision-making process of government.

Thus, I find myself very much involved with the programs in which you are interested today. It would be, of course, not very profound for me to say that we are living in complex times, and I suspect that because of the complexity, we sometimes almost forget how complex they really are. We take life for granted. We all, from time to time, should sit back and allow ourselves to be amazed at the world in which we live, and what we are really doing with it and accomplishing by it.

Only four years ago, the entire world almost ground to a halt with awe and amazement when the first human being stepped onto the surface of the moon. Yet it seems that just a few months ago many people were almost disinterested in the concluding mission of the Apollo project. It is a very human reaction, I think—but one that we all share to some extent.

As an engineer, and now as a politician, I was excited at the possibilities of the Earth Resources Technology Satellite when I first heard about it, although I must admit that I had no idea of all of the possible applications that might come from such a spacecraft.

The excitement, to me, was the concept of having something out there getting a good objective look at what we are doing and of understanding that we could get a different perspective on the resources of this great nation. But the implementation has gone far beyond any of the original expectations, and I am confident that there are many applications of which we have yet to dream.

The average Californian is not truly aware of just how much ERTS is going to mean to him, or has already meant to him. There is nothing very strange about this. For example, the tribesman in Laos or New Guinea need not have heard of Mr. Sikorsky in order to ride in his helicopter.

A friend recently said to me, "If the money that has been spent going to the moon were put into research, most certainly we would have a cure for cancer." We have all heard this too many times, particularly those of us in office, and all too many people—politicians in particular—seem to think that money is the solution to all problems. The more money spent, the faster the solution. It is true that without money, many problems would not be solved, but I do not think we should look solely to money as an end in itself for this purpose.

As scientists and as engineers we must be pragmatic. We are faced with a problem. If we can identify the problem, we must look for a solution, and in order to accomplish that solution, it may be necessary to invent a particular tool, and so on. Both the search for the solution and the effects can be very far-reaching. For this we need the far-reaching, farsighted policies that we have seen and that have been the policies of NASA.

It takes more to reach people, however, than just talking in terms of money and in terms of scientific papers and presentations such as you have made here the last few days. I believe what we really need is to demonstrate what can be achieved in tangible, visible results through science and technology, and through ERTS in particular. California, fortunately, took a part in this program right from the very beginning, and has become a formal ERTS investigator. There are a number of reasons why we look upon this program as an extremely important one to the state.

We represent, as we see it, a microcosm—or some call it a macrocosm—of the United States. We are a slice of approximately 10 percent of the people, 10 percent of the income, and a little more than 12 percent of the taxes, nationally. We have a real interest in everything that goes on. We have a state with the varying ranges of geography and geology, with a coastline, with deserts, with mountains. We have a massive agricultural industry that requires tender care and feeding. In short, we have almost everything but a real tropical climate and thus we can do a great deal without ever leaving the state.

A growing population in California is no longer growing quite so fast. Stressed time and time again there is as throughout the rest of the nation, concern for the status of the environment, the need for its protection, and the need for recognition of its nonrenewable resources.

And, of course, there is an extensive industrial development. We feel that we have, in many respects, something more than other states: a great scientific and engineering community, brought about primarily by the focus of the aerospace industry in California, along with the great laboratories of universities within the state, and of NASA's Ames Research Center.

All of these produce a requirement to create and to utilize our land, our resources, and our water, and to provide a protective environment for our people.

The ERTS program can potentially provide better information on our water storage as well as on its distribution and control, and can provide agricultural statistics which are needed for the effective utilization of this very scarce resource. ERTS imagery can identify geological hazards which exist in California, particularly the location and the identification of earthquake fault lines which bear importantly on our earthquake problem.

We have a long and a beautiful coastline which is continuously subject to erosion and change. This generates a great need for accurate land-use surveys which hopefully can be obtained through the ERTS program.

The state started photomapping the entire coastline of California in 1969. Now we are able to tie this all together in a much different, much improved method, by utilizing the ERTS satellite imagery.

The population pressures on California's urban areas have created this country's most extensive use of automobiles, which are now conceded to be the major contributors to our air-pollution problem.

The development of computer models will effectively predict and assist us in tracing the smog sources, and obviously will be very helpful in designing legislative controls and administrative procedures to attack this most critical of all problems in California.

We recognize that ERTS imagery in its present form may not directly apply to this problem. But it is our hope that continuous development of remote-sensing techniques, utilizing high-altitude aircraft as well as ERTS imagery, will make the satellite a major tool in the detection and monitoring of the air quality in California.

ERTS has already resulted in some direct actions being taken by the state executive branch, and I would like to cite a few of these: Our involvement with the University of California has produced computer-generated information on the entire land use of the San Joaquin Valley. This is a valley about 200 to 250 miles long and 50 miles wide. It is the breadbasket of California, where most of our vegetables, produce, and other agricultural products are raised. California's principal industry—its largest industry—is agriculture. Dr. Colwell of the University of California has undertaken an ERTS investigation of this industry and is doing a magnificent job in showing a direct application of the utilization of the ERTS satellite.

We have used imagery produced by the high-altitude aircraft of NASA's Ames Research Center to survey a number of disastrous events that have occurred in the state during the past year. For example, we had an aqueduct break; the photographs from the aircraft helped us to establish the effects and the potential liabilities of this particular incident.

One project which shows considerable promise is the use of these or similar aircraft to provide information on the extent and the spread of forest fires and the best deployment of our fire-fighting resources. Photographs taken in the infrared region show the location of a fire very effectively through the smoke, and are particularly useful when the fire occurs in some of the more remote and rugged areas of the coastal regions of California.

With such photographs, we have determined the extent of fires and have identified access routes, hot spots, and the terrain with which we could generate backfires and execute other effective countermeasures. Most of all, we have been able to identify the type of fuel being burned, permitting us to modify the firefighting techniques to the greatest possible advantage.

Our experience during last summer's fire in the Big Sur area indicated that remote sensing resulted in a substantial savings, estimated at $1 million, to the state. We hope that in the future the state will be able to equip its own aircraft with equipment that will make it possible for us to fight fires more effectively.

The specific figure of $1 million was based on better information about the hot spots of the fire, on the terrain, and on the logistical deployment of equipment and men. Due to this improved information, we estimated that we were able to shut the fire down two to three days faster than it would have been shut down had we not had this information. The cost of the deployment of men and equipment was estimated to be $1 million for those two days. That is a pretty hard figure, is very specific, and is a direct benefit.

We are also in the process of utilizing both aircraft and ERTS data by local government groups to prepare land-use maps of our cities and towns as well as the agricultural areas and the countryside of the state.

The effective preservation of open land can proceed on a rational basis only with data such as these furnished by ERTS. We want to generate recognition at all levels (in the state, in other states, and in other nations) of the need for better use of science and technology by all governments.

With the best of intentions, governments have too long overlooked the use of science and technology to predict problems before they occur, to find ways of preventing some of the problems, or at least to find logical solutions to those that cannot be prevented.

In order to make the best possible use of ERTS data and to plan for the use of data coming from other programs such as this, California has requested and received a grant from the National Science Foundation. Under the requirements of this grant, Mr. Earl Davis of my office sent a dozen people from a dozen departments of state government to the University of California, and to the Ames Research Center. We had, in effect, an ERTS user workshop.

The workshop participants are now the remote-sensing lead men in each of their departments of state government, and I am happy to say that, through the cooperation with NASA at Ames and the University, we are now moving ahead towards bringing some of these bits of information into the policy-making decisions of state government.

This was actually planning ahead; ERTS data was not even available when some of these things were going on. Thus, the high-altitude aircraft (U-2) data were used for these classes. As a result, these departments are making good use of the ERTS data as they become available.

Infrared imagery has been used also to detect marijuana fields growing close to the international border in Mexico. I am involved in the Commission of the Californians which meets several times a year on either side of the border. One of the major problems is the drug traffic. The one that we felt could be handled best was the location and destruction of marijuana fields in the northern provinces of Mexico.

We have had excellent cooperation from the Mexican government and from our own federal government. The federal government appropriated five helicopters and three fixed-wing aircraft which are now being used to scan the northern fields of Mexico. This, in a very real sense, is a direct benefit from remote-sensing technology.

In California, we have undertaken a survey of all of the basic applied research through the University and through some 6000 independent investigators for the University of California, as well as all of the research being done within the state government itself. This is a result of a National Science Foundation grant.

We were pleased to learn that the state was carrying on, within its own departments, about $150 million worth of research annually. The survey will assist not in limiting research, but in enabling us to coordinate the hundreds of programs involved. We will also be in a better position to set priorities for state-sponsored research and development, and to look for the answers to problems that we have identified as being pertinent and major to the society of our state.

Perhaps for the first time since California became a state, we will actually know what is going on in the fields of basic research through the University, through the state government, and through the private universities and the industry of California. We are able to do this thanks to this research grant which is sponsored by the National Science Foundation and supplemented with the cooperation and information coming through NASA.

All of this involves the compilation of vast amounts of material. Too often in the past, bureaucracy has seen the collection and storage of such data as an end in itself. We do not intend to let this happen in California.

One of the great tragedies of our times is that men of great capability, such as yourselves, meet frequently to discuss the great benefits and the great values of programs such as ERTS, and go away with the knowledge of what other people are doing. Unfortunately, the policy makers and the policy implementers of our state, local, and federal governments too seldom get the benefits of meetings such as this.

It is our intention to keep this information alive, to do what is necessary to incorporate these great benefits into the administrative and the legislative programs that we will see in years to come. The data collected from ERTS and from all other resources will be made available for use not only by the State of California, but by anyone throughout the entire United States who wishes this information. Particular emphasis will be placed on providing the information to city and county governments which are going to be encouraged to make all possible use of these data and to suggest other material that might be used if it is available.

One of the first intensive uses that we plan for the data from the ERTS and other programs is land-use planning, with particular emphasis on coastline protection. You have been discussing this the past several days, but I daresay that very few of the planners, the policy implementers, the city councilmen, or the county supervisors anywhere in the state have the benefit of the papers that were offered here today.

Those of you familiar with California politics know that this has been an extremely important issue. Last November we passed an initiative on the ballot, and we now have an intensive land-use planning concept, controlling, if not actually eliminating growth within a thousand yards of the mean hightide line.

This will remain in effect at least until we know where the fragile areas of the coastline are, and what developments will or will not affect the environment. This is a focal point of the environmental efforts in the state of California. I think we, as a state, are fortunate to have been involved in the ERTS program early, for ERTS data will make it possible for us to carry out the orders of the people more quickly.

And now let me turn to look at what potential benefits could come from state involvement in federal programs such as this. The joint use of federal laboratories and people, together with the great resources of the states, represents to me a tremendous opportunity to utilize these precious natural talents in the most effective way.

I believe the advent of large computers, and our ability to use them, will allow us to manage effectively our resources on a rational basis, and will improve the quality of our environment while minimizing the economic impact of restrictive controls.

With the advent of this new technology, represented by satellite information and aircraft imagery, and with the use of the powerful new computers that we have, we have in our hands the tools to do a great and effective job for all of the people of California.

We are making good progress in applying the results of this technology to the solutions of the real problems of today. I confidently expect that in years to come we will derive great benefits from ERTS and similar programs; benefits which have not even yet occurred to us, but which are waiting for us to discover.

In summary, I think what we can say, in terms of utilization, that we have an obligation. We–the Congressmen, the state governments, the local governments–have an obligation for success, out of a fantastic program that was not even conceived of a few years ago.

Yesterday, I was talking with Mr. Roy Ash, Director of the President's Office of Management and Budget. Economists, as you know, talk in terms of cost push and demand pull. I'm not sure what all that means, but I know I hear it quite often. Mr. Ash is a very unique person. He built the Litton Industries, and as such, was involved in remote-sensing many years ago. He is truly a eminent scientist as well as a top-grade economist.

In his discussion, he pointed out very clearly that what we need is not so much reseacrh "push" as a "demand pull," to use his language. He meant that it is not enough to do research and to gather in groups like this. What we–and the obligation is on "we" in government–must do is to create the demand, create the market, for this information.

Science has always been able to provide more data than government could use. We are not a bureaucracy making a project of simply accumulating data. Nor do we want thick volumes of reports, whether they are extremely innovative and intelligent, or not.

We want applications transferred into policies and administrative implementations that will provide day-to-day visible physical benefits from the ERTS program. As Mr. Ash pointed out, if you can create the demand, then the research will follow. It will be pulled through the eye of the needle. But all of the great resources of research in the world will not be able to push it through until there is the demand on the other side.

And so it is up to you, it is up to me, it is up to our Congressmen, to be certain that that demand exists and is understood by the public, beginning in grade school. At such time as we have the demand for the benefits, the benefits of this research will flow quite readily.

To do this, we in government must establish the organization and the implementation, the method by which the benefits of this research can flow. Sometimes we get in our own way and we step on our own toes, because our own organizations are more interested in accumulating the research and the data than in seeing the benefits passed on to the people.

In California we are establishing priorities, priorities of what we need first and most, and in so doing, we are hoping to attract private-sector research, interest on the part of the university for basic research, and implementation through the funding of programs–state, federal, and local–to demand and to pay for the applications of this research. In short, we are looking for user benefits. It is only when those benefits become realistic that ERTS can be considered successful.

As a salesman when I was in business–and once you are in politics, you are always a salesman–the sale was never completed until the customer reordered. This is exactly the situation we have here.

The success of ERTS will never be complete until the customer–the taxpayer–demands more information and more benefits from ERTS. This will happen as soon as we can establish a benefit-cost ratio, not in charts, graphs, and papers, but in terms of improved legislation, improved executive orders, better automobiles or less smog, or better control of water, or snow depth, or agricultural production, or pesticide. So these are the benefits that we must compare to the costs that we are now bearing. When that ratio becomes something in excess of one, we then have a successful program.

And so, as we move for organization within the state, to implement and to pass on the benefits of this program, we are hopeful that those in the federal government will recognize this need and those of other states as well.

Finally, in another project that I have, the possible reform of local government, an element of the applications of science and technology will be strongly urged and recommended upon all levels of government. Whether they themselves establish research mechanisms is beside the point; they must establish the use of the benefits of these research mechanisms, whether they be at the state, university, or the federal level.

In conclusion, when state government, local government, or the private sector establishes its own financial commitment to the utilization of these benefits, then a market will be developed, a demand will be created, and research will be pulled through.

NASA, as you know, by its charter cannot be an operational agency. Until such time as Congress reconsiders this, we in the private sector and in the governmental sector, must assist by creating the opportunity for the benefits of this great program to be demanded, to become real, to carry this on to become the true benefit of our scientific world of today, and for the benefit of our children tomorrow.

I thank you very, very much for the opportunity of being with you. I can assure you that we in California are vitally interested in anything that you have found that has a direct application to benefit society today and tomorrow.

## REVIEW OF ERTS-1 STATUS

**Dr. William Nordberg**
*Chief, Laboratory for Meteorology*
*and Earth Sciences*
*NASA Goddard Space Flight Center*
*Greenbelt, Maryland*

I would like to give a very brief description of the ERTS-1 system and a review of the status of ERTS-1. ERTS is indeed a system; it consists of a spacecraft and a very complex ground operation. The ground operation, to a large extent, outweighs the spacecraft in complexity and significance. The spacecraft is not a new development but an outgrowth of and very similar to Nimbus meteorological satellites. Many of the subsystems on the spacecraft are the same as those on Nimbus.

The spacecraft carries sensors which measure and image sunlight reflected by the earth. The sensors are: (1) three return beam vidicon (RBV) television cameras and (2) a multispectral scanner subsystem (MSS). The two sensors are designed to measure sunlight in three spectral bands which are nearly the same for both sensors; namely in the green and red portions of the visible spectrum, as well as in the infrared, which is invisible to the eye. The MSS is also sensitive to a fourth band in the infrared, near one-micrometer wavelength.

When the satellite is not within receiving range of one of four stations which are distributed over North America, measurements from each sensor are recorded on wideband videotape recorders.

The sensors acquire images of approximately 6½ million square kilometers of the earth's surface every day.

The satellite also carries a data collection system (DCS) which acquires data transmitted from ground platforms distributed over North America. The satellite retransmits the messages from these platforms to a central data analysis facility at the Goddard Space Flight Center. These messages consist of measurements such as water quality, rainfall, snow depth, and seismic activity, which are made by the platforms directly and automatically at remote and inaccessible sites.

During daytime passes of the satellite, the optical measurements made by the return beam vidicon cameras and the multispectral scanner are transmitted to receiving stations located at the Goddard Space Flight Center; Goldstone, California; Fairbanks, Alaska; and to a Canadian station in Saskatchewan. The government of Brazil is constructing a fifth station, which is expected to be in operation later this year. During nighttime passes of the satellite over the three U.S. stations, the measurements recorded on the spacecraft tape recorders over other parts of the world are transmitted.

The daily observations over 6½ million square kilometers of the earth are converted into about 1350 photographic images at the Data Processing Facility at Goddard Space Flight Center.

Approximately ten copies of each of these images are made and distributed to several U.S. Government agencies: the U.S. Army Corps of Engineers, the Department of Commerce, the Department of Interior, and the Department of Agriculture. Both the Department of Commerce and the Department of Interior maintain archives of all the photographs which they receive at their data centers, and ERTS-1 photographs may then be purchased from these data centers by the general public. The Canadian pictures may also be purchased through the archives of that country.

In addition, and very significantly, NASA has reached agreements for analysis of ERTS images with about 320 investigators throughout the world, 220 of whom are within the United States. These investigators analyze ERTS-1 observations for specific applications in various disciplines, including oceanography, meteorology, geology, hydrology, agriculture, forestry, and land use. Investigators are affiliated with the Federal Government, with state and local governments, with universities, and with private industrial organizations, as well as with organizations in other countries.

The satellite is in a near-polar orbit, and makes 14 daylight passes each day. Due to this orbit, ERTS-1 overflies every point on the earth's surface between approximately 80 degrees south latitude at least once every 18 days. All passes occur at approximately the same local time at each location, namely, between 9:30 and 10:00 in the morning every day.

The fields of view of the two sensor systems are identical and cover a strip 185 kilometers (100 nautical miles) wide directly underneath the spacecraft. Images are taken along selected portions of these orbital strips. At the Equator the centers of these strips are 1800 kilometers apart, as fourteen of them occur around the world every day. The orbit is adjusted so that a strip observed on one day, in one location, advances westward by about 180 kilometers on the next day. In this fashion, as these strips advance from day to day contiguously, almost the entire world can be covered by observations from ERTS once every 18 days.

Power and data transmission capacities of the spacecraft and the limited capacity of the data processing facility on the ground prevent acquisition of images over the entire world during every 18-day period; we acquire such contiguous images every 18 days only over the North American continent. For the rest of the world, portions of the strips are imaged every day; these strips amount to about 26,000 kilometers in length, and of course, 185 kilometers in width. The strips outside North America are chosen on the basis of cloud cover forecasts received from the National Oceanographic and Atmospheric Administration, and on the basis of having investigators in these areas who have expressed interest in ERTS-1 coverage, or who have reached agreements with NASA.

The status of ERTS can be summarized by making the following five points:

(1) With the exception of three days during early August last year, the ERTS-1 system has operated and acquired images on every single day since activation on July 25, 1972.

Thus, in little more than six months of operation, nearly 33,000 scenes throughout the entire world have been imaged in each of the four spectral bands. A "scene" is an area 185 kilometers wide and 185 kilometers along the orbital path. This, on the average, amounts to 188 scenes per day, which was our goal when the system was designed.

(2) Most of the major land masses of the world, portions of the oceans, and both polar caps have been mapped with the ERTS-1 system.

(3) More than 50 percent of all the images obtained for the more than 300 primary users are shipped within one month after acquisition of the images.

(4) Significant features such as agricultural fields, surface water, snow and ice cover, various types of land forms, and patterns of urban development or of other human activities extending over no more than about 70 meters can be mapped, in general, very well on a scale of 1:250,000 without substantial loss of definition. Such features can be recognized and analyzed in images representing scales of up to approximately 1:30,000. This, I believe, exceeds the expectations that were held by even the most optimistic before the launch of ERTS-1.

(5) Judging from the reports received from many of the 320 investigators during the past five months, and on the basis of the sessions which have been held during this Symposium, methods have been demonstrated to successfully apply the ERTS observations to at least the following:

- The planning of land use in agricultural, urban, and uncultivated regions. The assessment of stresses or damages imposed on soils, crops, forests, and range lands by fires, insect infestation, human intervention, and climatic or topographic conditions.
- The assessment and possible prediction of available water supply on scales covering very large regions.
- The detection of natural or man-made processes affecting the quality of water, the quality of wetlands areas, and the deterioration of coastlines. Such detection could form the basis of possible action required to conserve these resources.
- The exploration of mineral deposits and ground water and the recognition of hazards to major construction activities, all based on a better understanding, gained from the ERTS images, of the processes that have shaped the surface of the earth.
- The exploration of marine resources and a better understanding of the dynamic interactions between different types of water masses, especially in the coastal zones.

It should be kept in mind that the ERTS-1 system has never been intended to provide such applications on a routine and operational basis. Instead, the primary objective of ERTS-1 was to obtain multispectral images periodically over the United States and to apply these images experimentally to investigations dealing with various parameters relating to earth resources. The fact that after six months of operation of ERTS-1, we are almost beginning to take for granted the applications to which I have just referred, reminds me of my experience with the first weather satellites, about 13 years ago. At that time we intended simply to demonstrate that photographing clouds from TIROS-1 would permit the mapping of weather systems. Yet, two weeks after that demonstration the first weather forecasts were made on the basis of those cloud pictures. The similarity of this to what we are now experiencing with the ERTS-1 results certainly speaks for the success of this first experiment and for the viability of earth resources surveys from space.

# IDENTIFICATION AND MAPPING OF SOILS, VEGETATION, AND WATER RESOURCES OF LYNN COUNTY, TEXAS, BY COMPUTER ANALYSIS OF ERTS MSS DATA

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Results of the analysis and interpretation of ERTS multispectral data obtained over Lynn County, Texas, are presented (Figure 1). The test site was chosen because it embodies a variety of problems associated with the development and management of agricultural resources in the Southern Great Plains. Lynn County is one of ten counties in a larger test site centering around Lubbock, Texas.

The purpose of this study is to examine the utility of ERTS data in identifying, characterizing, and mapping soils, vegetation, and water resources in this semiarid region. Successful application of multispectral remote sensing and machine-processing techniques to arid and semiarid land-management problems will provide valuable new tools for the more than one-third of the world's lands lying in arid-semiarid regions.

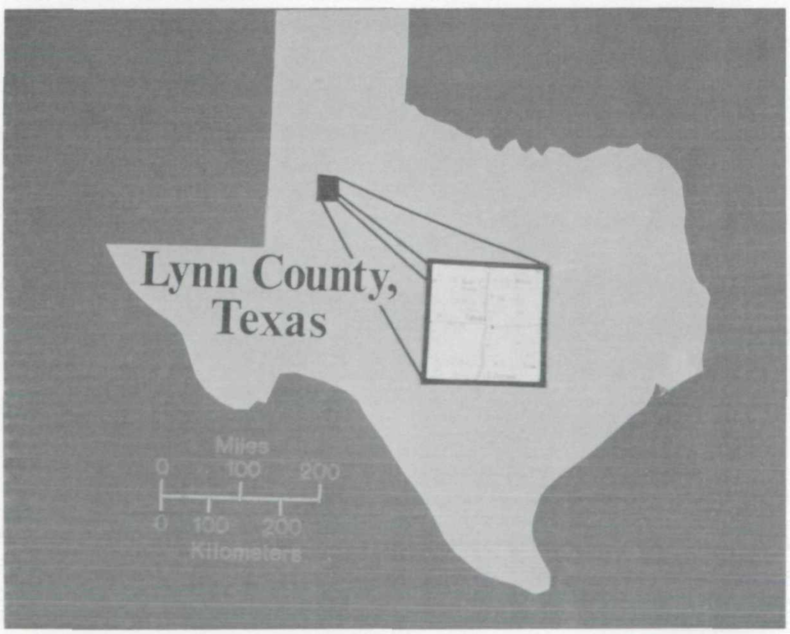


Figure 1. Lynn County, Texas.

Preliminary results from this study suggest that ERTS data can be used successfully in semiarid regions to accomplish the following tasks:

- Map and measure croplands
- Identify and map vegetative species and management differences in rangelands
- Map gross soil patterns and differences which may be related to agricultural and land-use management problems and practices
- Map and measure areas of surface water and indicate changes occurring with the passage of time which may be related to ground water recharge
- Map and measure areas of crops damaged or destroyed by hail and windstorms
- Map and measure areas of bare soil and related problems of erosion, and determine conservation needs

The question arises, "Who wants and can use such information?"

1. Information relating to areas of crops planted and harvested:
   - Various agencies of the U. S. Department of Agriculture
   - Federal Crop Insurance Agency
   - Agricultural industries, especially agricultural chemical industries
2. Areas of crops damaged and destroyed by hailstorms and wind storms:
   - Federal Crop Insurance Agency
   - Private insurance companies
   - The Plains Cotton Growers, Inc.
3. Soil patterns and delineation of soil differences:
   - Soil Conservation Service
   - Land-use planning agencies
   - County, regional, and state planning groups
   - State and regional agencies concerned with natural resources
4. Surface-water maps delineating seasonal changes:
   - U. S. Geological Survey
   - Texas Water Development Board

- High Plains Water District
- All other agencies concerned with water resources management

Lynn County is a part of the High Plains lying south of the Canadian River. Known as the Llano Estacado, the High Plains is essentially a plateau bounded on the north, east, and west by prominent escarpments rising from stream-eroded lower lands (Figure 2). On the south the High Plains merges physiographically with the Edwards Plateau.

The Plains surface is quite flat (Figure 3) and except for a few canyons is devoid of topographic features. The most prominent topographic and hydrologic characteristics of the Llano are the great number of shallow depressions, ranging in size from a few hectares to more than 15 square kilometers (Figures 4 and 5). These "prairie potholes" or "playas" accumulate drainage from local watershed areas that range in area from less than 100 hectares to several hundred hectares. Most of the playas contain ephemeral fresh-to-alkaline water during part of the year.

The principal income of Lynn County is derived from agriculture and ranching. The major problems associated with the development and management of the agricultural and rangeland resources of the county are drought, wind erosion (Figure 6) hailstorms, soil productivity, and invasion of rangelands by mesquite, a spiny deep-rooted leguminous tree or shrub.

Figure 2. A segment of caprock escarpment.

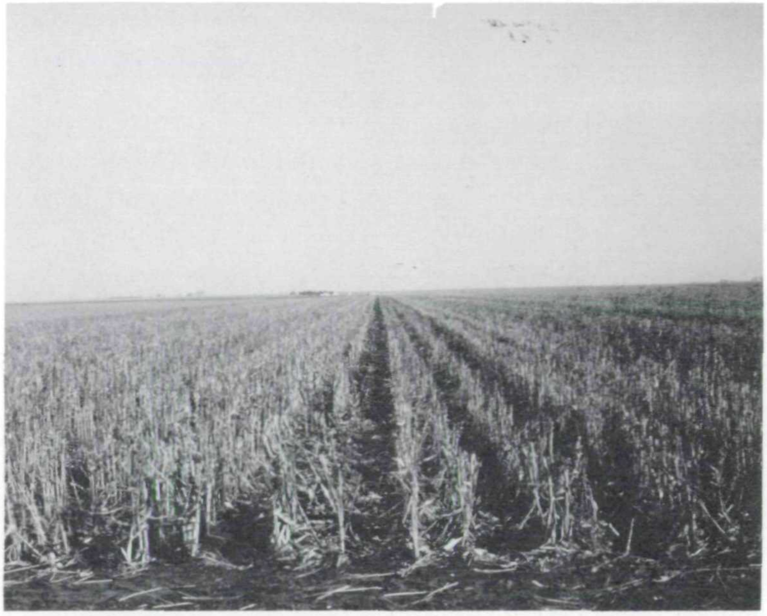

Figure 3. A grain sorghum field in a flat area of Lynn County.

Several months ago a group of prominent farmers and agricultural scientists in the Lubbock, Texas, region became very interested in the ERTS program. They volunteered to provide the Laboratory for Applications of Remote Sensing with ground observations which are vital to the analysis and interpretation of ERTS data. Six Lynn County farmers, as well as six farmers in each of the nine other counties in the Lubbock Regional Test Site, are making and reporting ground observations along segments, each 8 to 10 kilometers long, of county roads at the time of each ERTS-1 overflight. Fields along each segment are numbered, and information on crop type, crop conditions, soil conditions, planting pattern, row direction, and ground cover are reported. These data, from segments well distributed over the test site, have been used for training purposes in the computer-implemented analysis of ERTS data. The light colored north-south strip in the center of Figure 7 is a portion of one of the segments reported by a cooperating ground observer. The light areas are cultivated lands; the dark coloration represents rangeland.

On September 12, 1972, aircraft data were obtained over the center of Lynn County on a single north-south pass at an altitude of 6000 meters. Color infrared photographs (Figure 8) from this mission were very useful in the interpretation of patterns of rangelands shown in the classification from the computer analysis of ERTS multispectral scanner (MSS) data. The large areas represented by mixed brown and green (Figure 9) are rangelands of the T Bar Ranch. Interpretation of the aerial photography suggests that the spectral differences of the rangeland shown in ERTS data may be related to the degree of mesquite infestation. Computer tapes of MSS data from ERTS passes over Lynn County on October 9, November 14, and December 2, 1972 were used in this study.

Figure 4. A typical playa in a cultivated area.

Figure 5. The east bank of Tahoka Lake.

An examination of a soils map of Lynn County reveals four major soil associations, differing primarily in the quantity and depth of sands (Figure 10). Those soils coded yellow along the north and east are deep, moderately permeable loams and clay loams; those coded green are deep, permeable, fine sands; the blue represents soils that are deep, moderately permeable, sandy loams. In a simulated color infrared ERTS image obtained on November 14, 1972, these broad soils patterns can be seen (Figure 11).

Results to date suggest that well-chosen training samples for computer analysis of ERTS data, obtained at a time when a maximum percentage of soil is without cover, could greatly refine and improve the capability to delineate the soil boundaries of Lynn County.

The two major land uses in Lynn County are agriculture and ranching. Of the total agricultural land, little is under irrigation. Approximately 58 percent of the agricultural land in the county was devoted to cotton in 1 972. Other cultivated crops include grain sorghum and forage sorghum. Vegetation of rangelands consists primarily of native grasses and mesquite.

Ground observation data obtained on October 9, 1972 were used for training sets for the computer-implemented analysis of October 9, November 14, December 2, 1972 ERTS data. A classification of October 9 data shows row crops in green, pasture in yellow, fallow in red, and water in blue (Figure 12). The field boundaries and homogeneity of the classes lose definition in the November 14 data (Figure 13); still more definition is lost in the December 2 data (Figure 14). With the computer capability to combine or overlay data from all three dates, a classification was obtained using the best combination of four multispectral scanner bands from the three dates. A classification from the four best bands was produced from the visible red and the longer of the two ERTS near infrared bands for October 9 and November 14 (Figure 15).

The highest percent correct recognition was 89.6 for the October classification. Accuracy declined for the November 14 and December 2 data. For the temporal overlay (combining the data from different dates) the classification accuracy approached that of the classification for the October 9 data.

It was not expected that this late in the growing season the temporal overlay would improve classification results. A killing frost early in November, excessive autumn rains, and late summer weed growth contributed to much confusion in classification results from the November and December data. Experience in identification of summer crops indicates the most significant contributions of temporal or sequential ERTS coverage will be made during the active growing season, before the crops have reached full maturity.

(The classification results from ERTS data obtained on August 9, 1972 over northern Illinois provide an example of more timely crop identification. In Dekalb, Lee, and Ogle Counties, corn, soybeans, and all other features were identified with approximately 90 percent accuracy.)

Since water has very low reflectance in the near infrared wavelengths, it is easy to separate and map playas and reservoirs containing water. Water was separated spectrally from all other categories for three ERTS overflights. It was found that many of the playas containing water on October 9, 1972 (Figure 16) contained no water on November 14, 1972 (Figure 17); many with no water on November 14, held water on December 2, 1972 (Figure 18).

Examination of the precipitation records revealed a record high rainfall for August and September. At the time of the October 9 ERTS overflight, essentially all playas were full. During the three weeks prior to the November 14 overflight, very little rain had fallen in Lynn County. Water in the playas had been partially or completely depleted by evaporation or seepage to groundwater recharge. The period from November 12 to December 2, 1972 was characterized by cloudy days, high humidity, and several light rains. On the basis of the computer-implemented classification and separation of water from other surface features, an estimate was made of the total of surface water for the three dates. These results are presented in Table 1.

Temporal-overlay capabilities provide a significant advance in the machine-processing of multispectral scanner data. It is no longer necessary to go through the tedious exercise of locating ground observation sites on digital data from each ERTS overflight. Once the address of a ground observation site has been located on any ERTS digital tape, the overlay technique can be used to locate the same address on a computer tape of scanner data from any other pass over the same scene. The temporal-overlay technique also adds a valuable dimension for identifying and mapping changes in vegetation, water, and other dynamic surface features.

Table 1.
Estimated Changes in Water Surface
Area in Lynn County, Texas.

| Date | Points | Hectares |
|---|---|---|
| October 9 | 4374 | 1924 |
| November 14 | 3735 | 1643 |
| December 2 | 5120 | 2252 |
| | Total Area = 197,683 Hectares | |

In conclusion, these early results from the computer-implemented analysis of ERTS data suggest several valuable applications in the semiarid-arid regions of the world:

- Assessing conditions of croplands and rangelands
- Mapping and measuring crops and ranges
- Monitoring water resources
- Delineating soil boundaries

Figure 6. Active wind erosion in Lynn County.

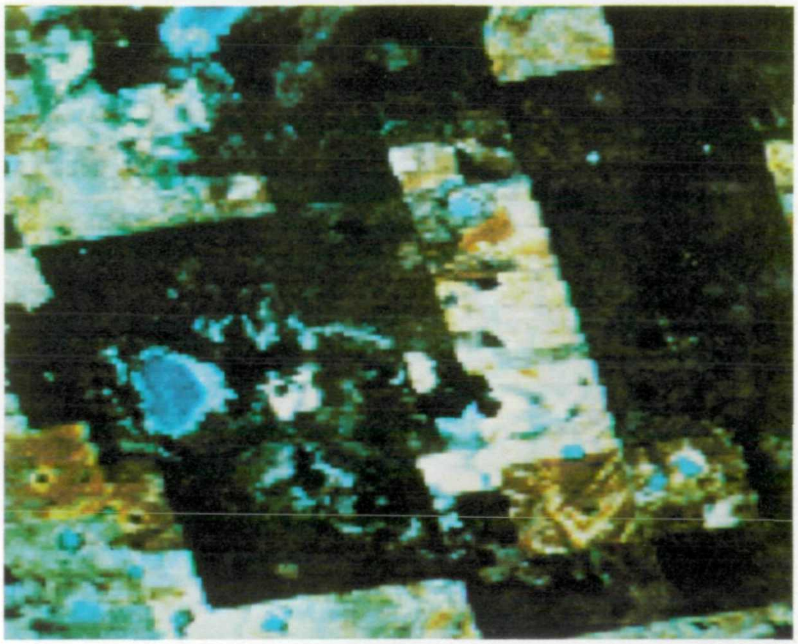

Figure 7. Eight spectral classes produced by computer-implemented analysis of T Bar Ranch area.

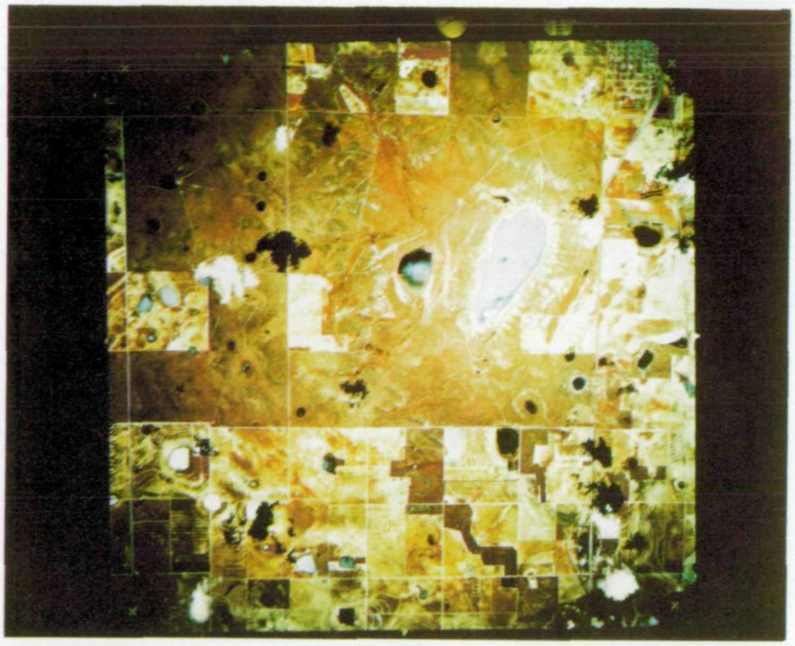

Figure 8. Aerial color infrared photograph of the area around Guthrie Lake in Lynn County.

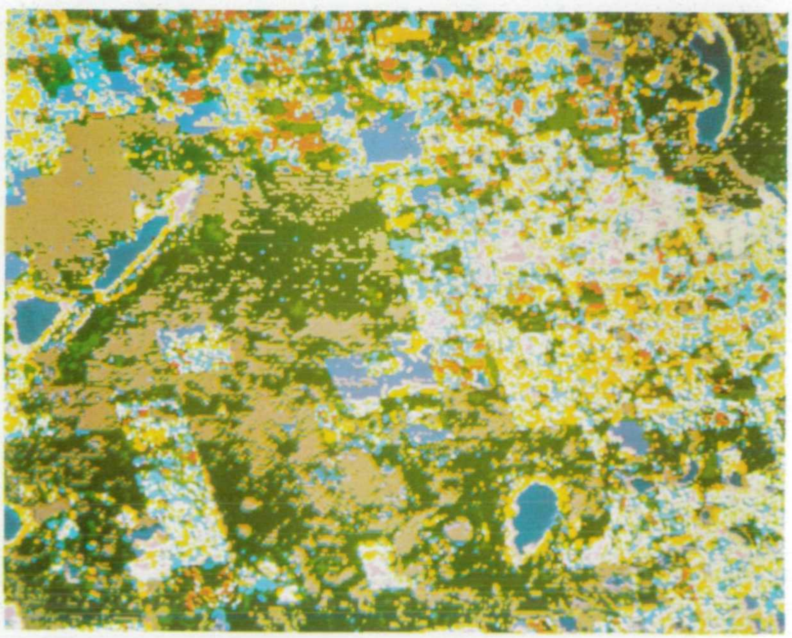

Figure 9. Computer-implemented classification of a portion of Lynn County.

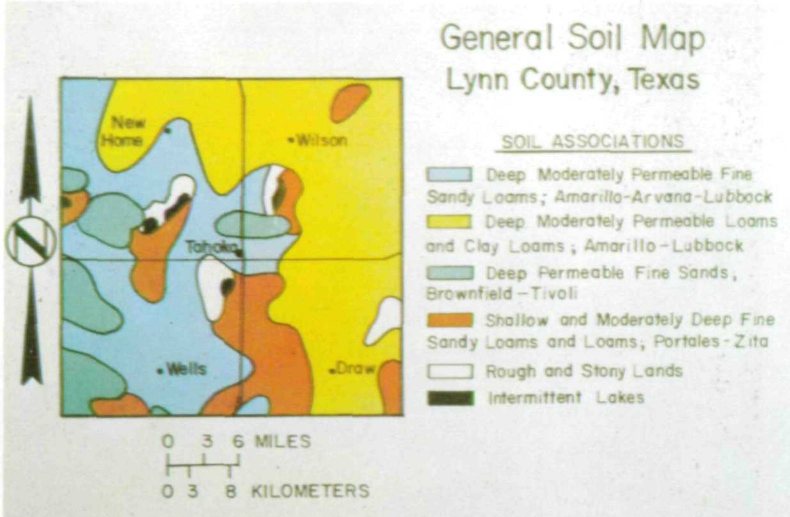


Figure 10. The general soil map of Lynn County.

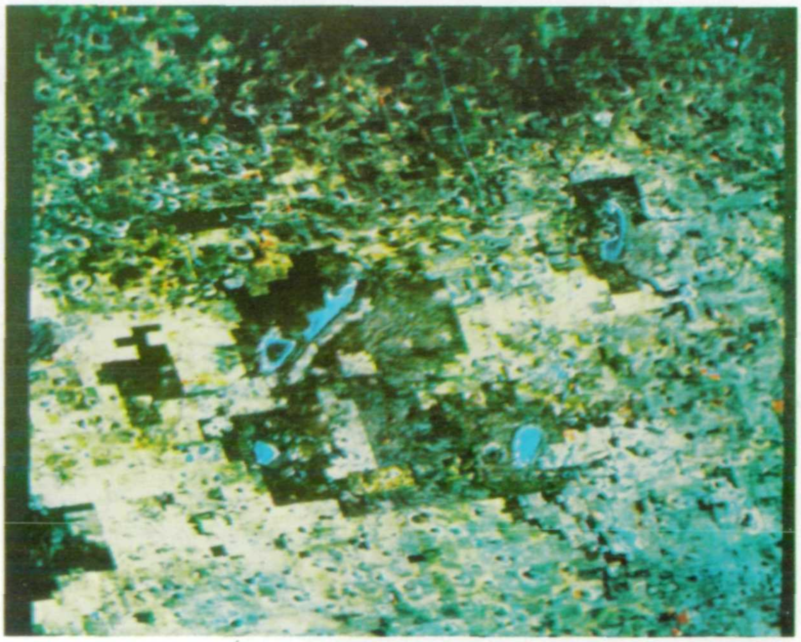

Figure 11. A computer-implemented simulated color infrared image of Lynn County from the November 14, 1972 ERTS digital tape.

Figure 12. Seven spectral classes produced by computer analysis of data from October 9, 1972 ERTS pass over Lynn County, Texas.

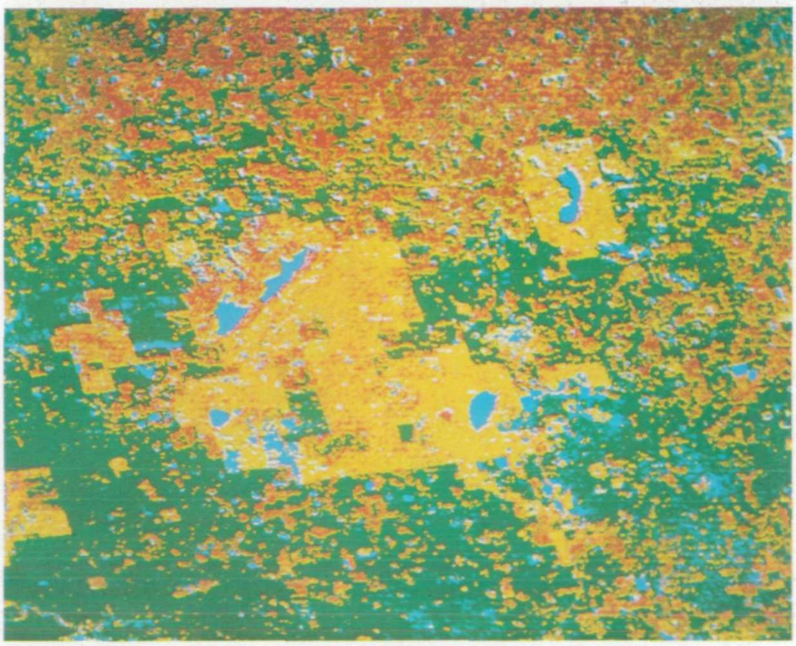

Figure 13. Seven spectral classes produced by computer analysis of data from November 14, 1972 ERTS pass over Lynn County, Texas.

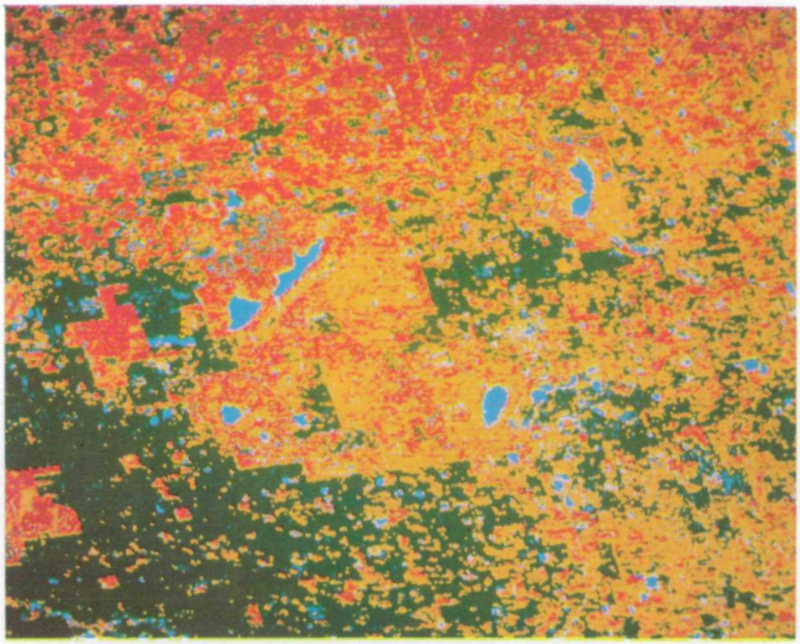

Figure 14. Seven spectral classes produced by computer analysis of data from December 2, 1972 ERTS pass over Lynn County, Texas.

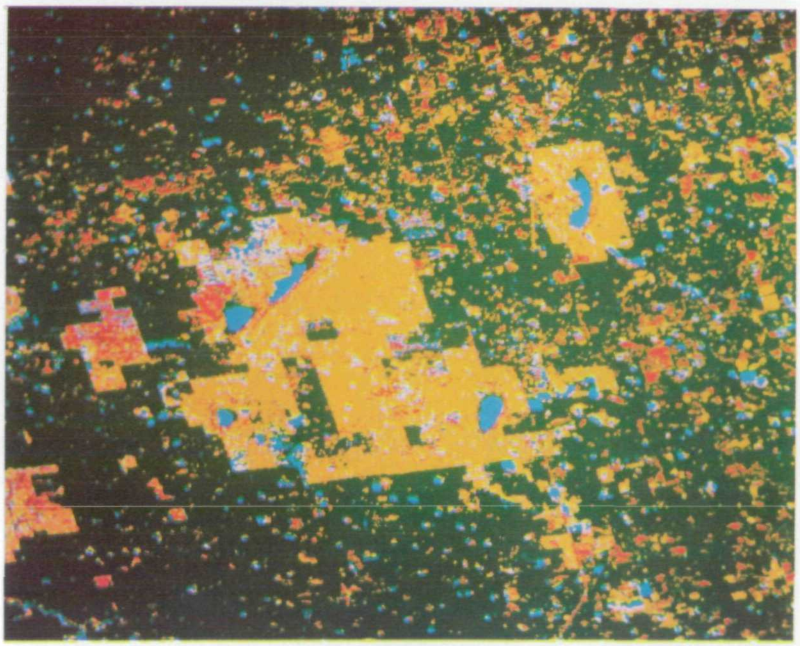

Figure 15. Seven spectral classes produced by computer selection and analysis of the best four of twelve wavelength bands from ERTS passes on October 9, November 14, and December 2.

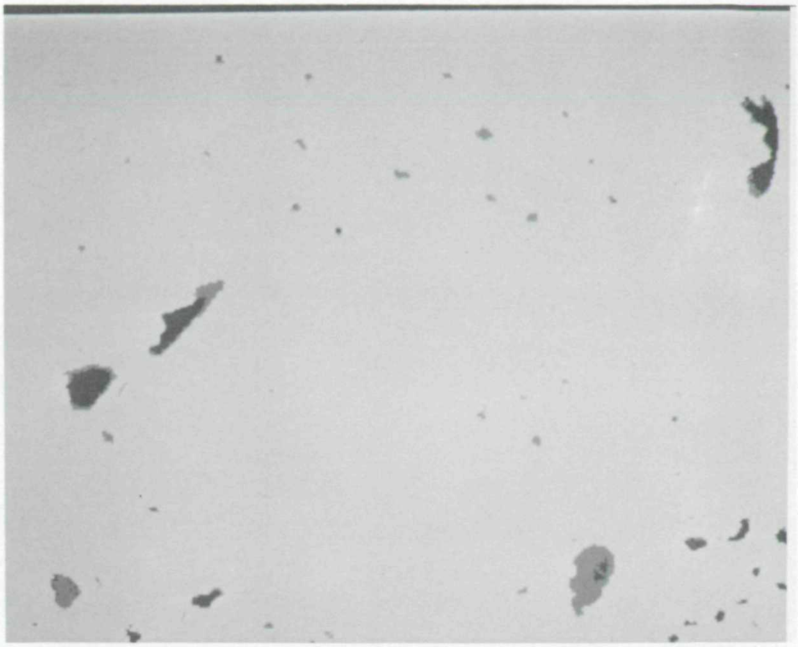

Figure 16. Identification and mapping by computer of playas and lakes containing water at the time of the October 9 ERTS overflight.

Figure 17. Identification and mapping by computer of playas and lakes containing water at the time of November 14 ERTS overflight.

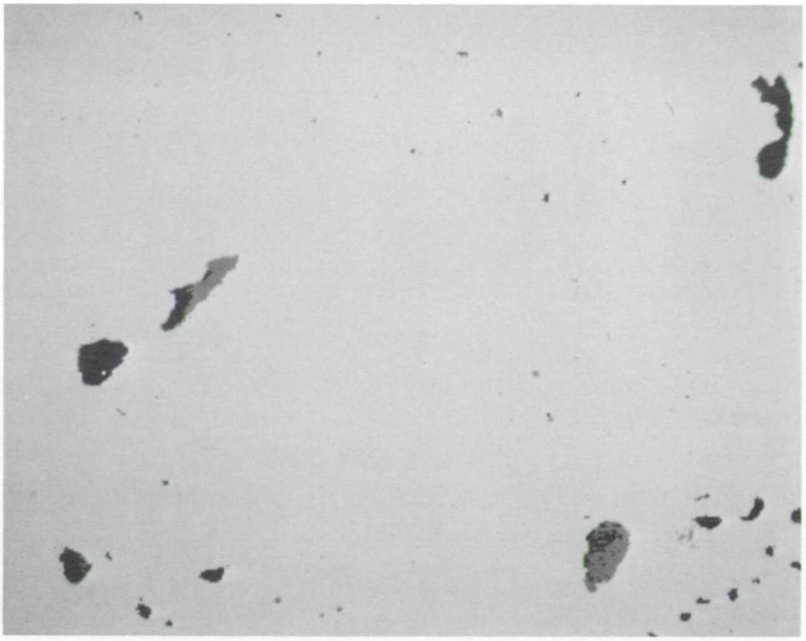

Figure 18. Identification and mapping by computer of playas and lakes containing water at the time of December 2 ERTS overflight.

# PRELIMINARY GEOLOGIC APPLICATION OF ERTS-1 IMAGERY IN ALASKA

**Ernest H. Lathram, Irvin L. Tailleur,**
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*Washington, D. C.*

The results of this investigation are relevant to three national problems: the need to accelerate the identification of minable minerals, the need to accelerate the finding and development of sources of petroleum and gas, and the need to preserve the environment. In addition, this investigation is an interesting, and perhaps unique case history in the synergistic use of images of varying aerial coverage and spatial resolution.

The initial objectives of the study were to improve geologic knowledge and theories as they relate to mineral resource potential, and to improve medium- and small-scale geologic mapping and to extend geologic mapping into unknown areas. These objectives have been accomplished.

To a geologist, a metallogenetic map is a tool with which he synthesizes information from geological surveys and empirical observations of mineral distributions that have been made by many people, and combines this information with a theory that accounts for the observed distributions. Traditionally, geologists have used stabilistic models and theory to guide projections of mineral occurrences on these maps.

The current metallogenetic map of Alaska is based on a stabilistic model that relates to an earlier theory concerning the generation of geosynclines in the earth's crust. Recent plate tectonic theory, which postulates a continuing mobility of the earth's crust, is now being blended with information derived from space images to produce a new metallogenetic map of Alaska.

Prior to the launch of ERTS-1, a Nimbus image, largely cloud-free, was obtained over the whole of Alaska (Figure 1, top). Close inspection reveals numerous dark linear features that proceed great distances across the image in a generally northeast and northwest direction. These linear features were mapped and Figure 1 (bottom) shows the net result of the initial investigation. Many of these structural features were not previously known or had not been put together and recognized as continuous structures in the earth's crust. Their very length led us to conclude that they were probably of a fundamental, crustal nature, and, thus, important in reaching an understanding of metallogenetic relationships throughout Alaska.

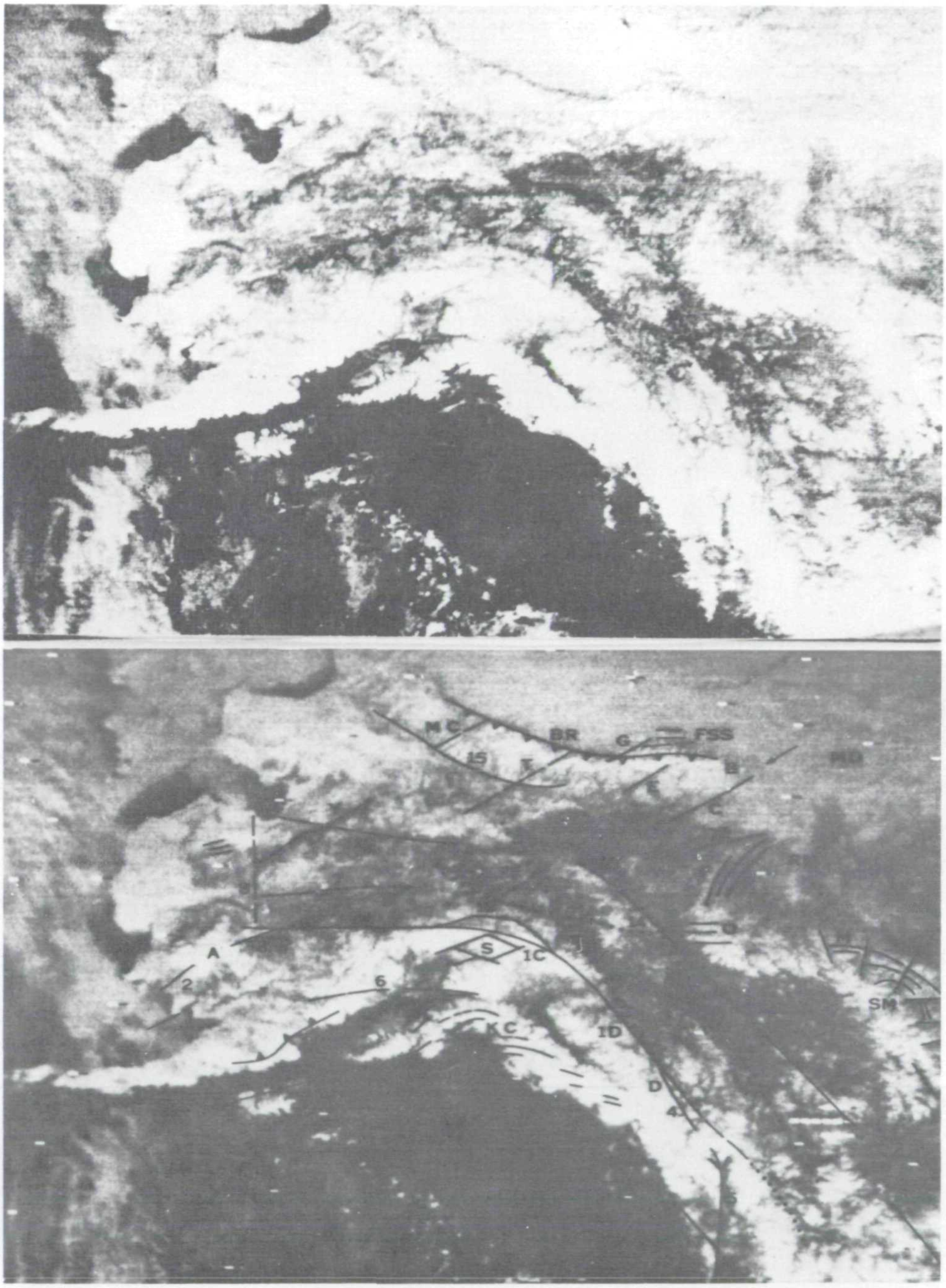


Figure 1. At the top of the figure is an essentially cloud-free image of Alaska and adjacent parts of Canada, taken March 29, 1971, with the image dissector camera system (IDCS) aboard the Nimbus-4 satellite. At the bottom is the same image as annotated by the U.S. Geological Survey, identifying major faults and earth fractures, many for the first time.

Figure 2(a) shows the current metallogenetic map of Alaska. Figure 2(b) is a new metallogenetic map of Alaska that takes into account plate tectonic theory blended with observations from Nimbus and subsequently reinforced and refined by observations made from ERTS. The new map suggests that mineralization in much of Alaska fits more closely with a newer stabilistic theory than with plate tectonic concepts. Nevertheless, a comparison of these maps demonstrates that there has been a significant change in our thinking as a result of satellite observations, and with this a significant change in the identification of areas that deserve investigation for mineral resources.

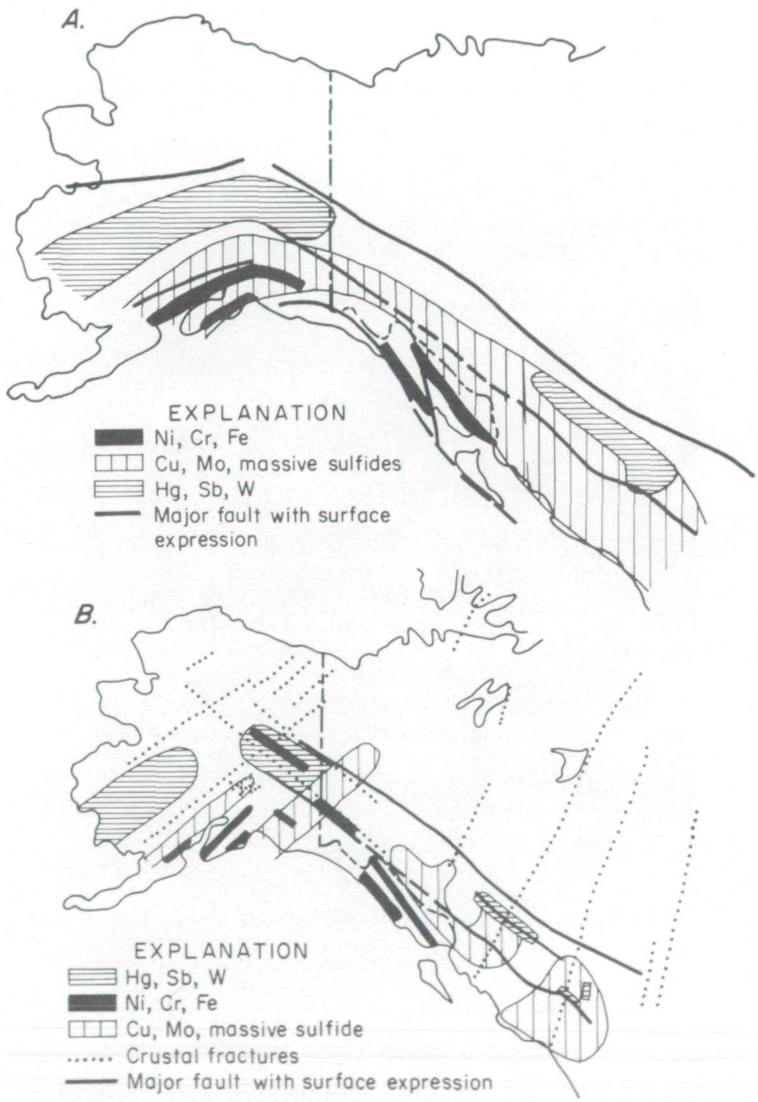


Figure 2. Areas of Alaska and western Canada considered favorable for location of deposits of selected metals based on extrapolation of geologic conditions at known occurrences: *(A)* conventional concept guided by north-convex arcuate distribution of lithologic belts; *(B)* postulated alternative assuming linear features seen on Nimbus-4 image are crustal fractures and have influenced mineralization.

The question remains how, specifically, did ERTS help in arriving at these conclusions? Most metallic mineral deposits are associated with faults or fractures. Figure 3 is an ERTS image of the Alatna Hills of west-central Alaska showing a previously unknown series of closely spaced northeast-trending fractures. These fractures support the conjecture that the Kobuck fault zone, clearly shown on the Nimbus image, is a major east-trending zone of strike-slip faulting.

Not only is the orientation of faulting critical to this analysis, but the direction of movement is likewise critical. From this image (Figure 3), we can tell that there has been significant fracturing, probably extending deep down into the crust, and while we cannot be certain of the direction, we can make an inference. The cross-faults are either sheer faults or tension faults. If they are tension faults, the movement is left lateral; if they are sheer faults, the movement is right lateral.

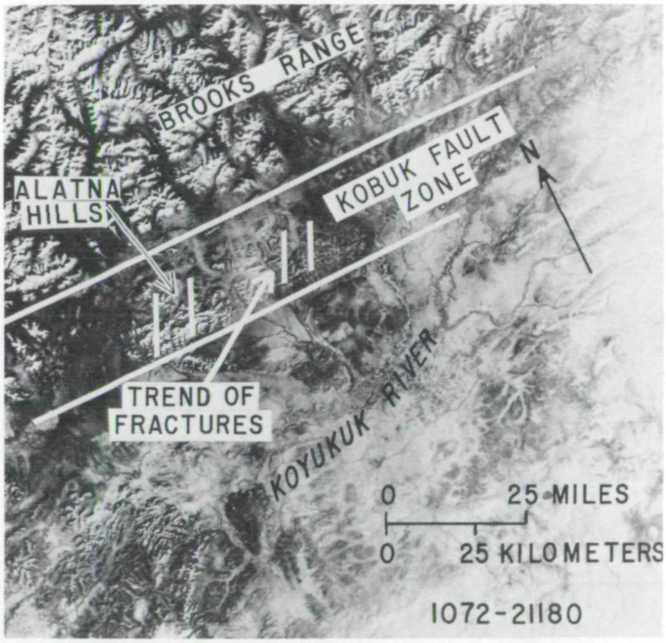


Figure 3. ERTS-1 image (MSS Band 5) showing closely spaced fractures in the Kobuk fault zone.

This area was visited in the field, and these cross-faults were not recognized, probably because there appears to be no large-scale offset along them. Therefore, they may be tension faults, and the movement is left lateral. Thus, we can make an inference from ERTS as to the direction of movement.

Moreover, this image shows us exactly where we will have to go in the field and what we must observe to fully answer this question of direction of movement. Thus, ERTS both poses questions and adds to the efficiency of answering these questions.

Figure 4 is an ERTS image that gives a unique perspective of geologic structures, which must be understood if the petroleum potential of the northern Alaska and Yukon Koyukuk petroleum provinces is to be evaluated. The intricate nature of the complex folds in the foothills northwest of the De Long Mountains is portrayed comprehensively for the first time and contrasts markedly with the broad folds in younger rocks to the north. Folded flat-thrust plates in the De Long Mountains are clearly shown, marked by limestone and by remnants of an ultramafic layer. An understanding of features such as these, and their significance in the regional geologic framework, is essential in analyzing the mineral potential of Alaska.

Perhaps the most significant result with respect to regional analysis of resource potential was achieved in the study of the northern Alaska petroleum province that is shown, in part, in the northern section of Figure 4.

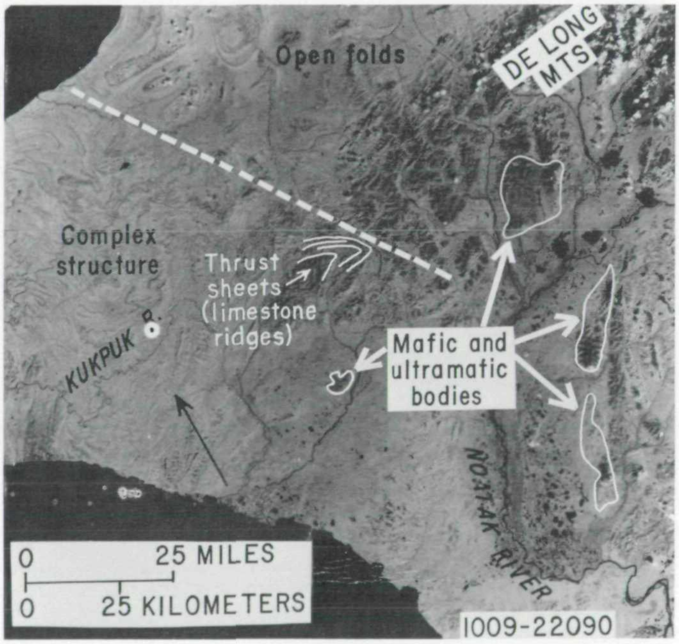


Figure 4. ERTS-1 image (MSS Band 7) showing differing structures and the aspect of some known lithologic types in the western De Long Mountains.

Figure 5 is an ERTS image of the central part of the northern Alaska petroleum province; the figure shows the contact between the relatively young (Gubik formation) rocks to the north and the older rocks to the south, the trends of structures in the older rocks, and the trends of lakes and interlake areas in the younger rocks to the north. The Umiat oil field lies approximately 275 kilometers (170 miles) southeast of Point Barrow and 170 kilometers (105 miles) southwest of the major oil field at Prudhoe Bay.

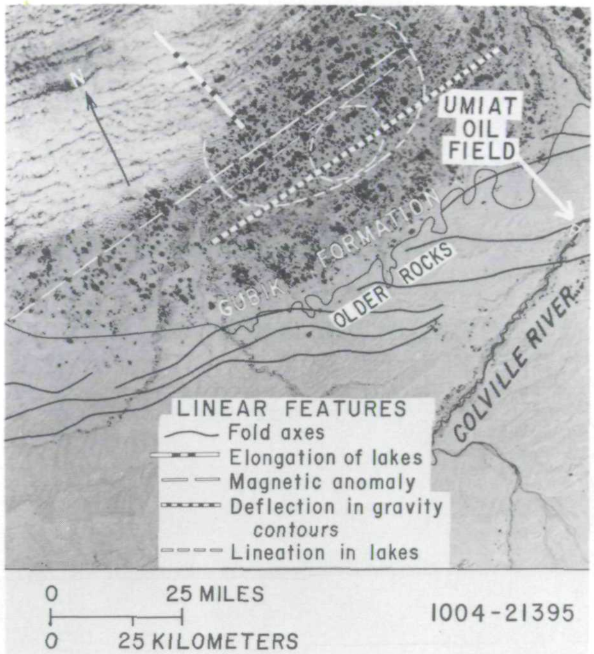


Figure 5. ERTS-1 image (E-1004-21395) showing lineation in lakes, trends in magnetic anomalies, deflections in gravity contours, trends of previously mapped folds, and generalized contact between Gubik Formation and older rocks.

The mapping of geologic structure is a critical part of the petroleum exploration process. Structures shown in the southern part of Figure 5 were mapped by both ground and photogeologic methods. Some structures in the transitional zone between the older and the younger rocks were mapped with aerial photographs using photogeomorphological methods, but could not be mapped on the ground because of the paucity of outcrops. There was, and is, no method of mapping structures in the lake area of the north either by conventional ground geological methods or from aerial photographs.

Lakes in the Arctic Coastal Plain are dominantly elongate, with their long axes parallel and trending about N 9° W. On the ERTS-1 image an additional strong east-trending regional lineation not previously recognized on aerial photographs or in field study is expressed by elongation of some lakes, alignment of others, and by linear interlake areas. The trend of this lineation is parallel to the trend of deflections in contours of the magnetic and gravity fields in the area, and parallel to westerly deflections in the northwest ends of northwest-trending folds mapped to the south. In addition, the alignment of many small lakes forms a large and a small ellipse superimposed on the regional lineation. Sparse seismic profiles show periodic reversals in dip and regional arching in shallow strata beneath the lineated area. These data suggest that heretofore unsuspected structures may be concealed beneath the Quaternary mantling Gubik Formation in the area of the image. The strata in shallow folds are younger than those tapped by the oil wells of the Umiat field to the south, and favorable reservoir beds may occur in the area. Furthermore, the folds in the shallow rocks in this area may reflect structural conditions conductive to oil accumulation in older strata at or near basement.

If this interpretation is correct, we have derived previously unobtainable geologic structural information that may possibly accelerate the finding of a sorely needed energy resource. Many have expressed great concern regarding the environmental impact of producing and transporting oil in an arctic permafrost environment. Figure 6 shows the same area as Figure 5 but is a color composite of bands 4, 5, and 7 of the multispectral scanner data. Figure 6 emphasizes the distribution of vigorously growing vegetation (shown as red). The area

Figure 6. An ERTS color composite (E-1004-21395), taken July 27, 1972, of the same area shown in Figure 5, made from bands 4, 5, and 7, the multispectral scanner. Vigorously growing vegetation on the Arctic tundra shows as bright red. The east central part of this area was the scene of intensive exploration and drilling in the late 1940's and early 1950's. Scars related to this activity are not visible in this image.

south of the lakes was the scene of intensive exploration and drilling in the late 1940's and 1950's. These activities left many scars on the tundra surface. Careful examination of this image reveals no indication of man's scarring of the delicate tundra. This does not mean that the scars are gone, for I am confident they are not wholly healed and could be observed on the ground or from a low-flying plane, but it does mean that they are not spreading like cancer, as some purport, over the northern tundra.

In addition to these specific results, we are now using the ERTS data operationally at scales of 1:250,000 to serve as bases for field and photogeologic mapping and as aids in the interpretation of the geology. We are using ERTS data operationally to refine the geologic map of northern Alaska at a scale of 1:1,000,000 and to refine the entire geologic map of Alaska at a scale of 1:2,500,000.

Therefore, I think we can conclude that ERTS data, coupled with Nimbus data, have helped us to better understand fundamental geologic theory. I think it will improve the efficiency of exploration for mineral deposits and petroleum. It is unquestionably good data from which to evaluate environmental impact, and it has immediate operational use in mapping the geology of Alaska.

# A MULTIDISCIPLINARY SURVEY FOR THE MANAGEMENT OF ALASKAN RESOURCES UTILIZING ERTS IMAGERY

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The most crucial problem in Alaska today is a great environmental knowledge gap, which impedes planning and adversely affects the decision-making process at a critical juncture in Alaska's economic and social development. This problem has been recently and forcefully manifested in several ways:

- o Controversy surrounding the proposed construction of the trans-Alaska pipeline from the Arctic coast to the southern port of Valdez, and the recent U.S. Appellate Court decision denying the permit for its construction.
- o Deterioration of fisheries resources in the Alaskan coastal zones and continental shelf. This results partly from a poor environmental knowledge of these regions.
- o Establishment by the Congress and the Alaska State Legislature of the Joint Federal–State Land Use Planning Commission. This Commission has the awesome task of recommending by 1975 a comprehensive land use plan for Alaska's 1.52 million $km^2$ (375 million acres), thereby assisting the State of Alaska, the Federal Government, and the Alaska native corporations with the selection of 550,000 $km^2$ (220 million acres) of public domain lands.

The basic data for informed land use research and planning in Alaska are sparse and often outdated. Therefore, even the first task of planning on a broad, regional basis labors under severe handicaps. Alaska is so vast, and the arctic environment is so varied, that this environmental knowledge gap will not be bridged soon by conventional means with normal dollar resources. Thus, the ERTS program with its demonstrated capability for *economical,* large scale surveys (see Figure 1) affords a unique opportunity to narrow this knowledge gap.

Alaska's land mass covers 1.52 million $km^2$ (586,000 $mi^2$), encompasses 20° of north latitude, and includes four distinct climatic zones. Seasonal temperature differences as great as 85° C (150° F) are possible in the interior of Alaska.

Cultural activities are dispersed along the major river drainages as small villages, and concentrations of populations occur chiefly in the south central Anchorage–Matanuska Valley and the Fairbanks–Tanana Valley in the interior. These two urban regions account for over half of Alaska's total population. Surface transportation includes a modern railroad from the southern coast to the interior and a skeleton network of paved roads from the interior to various ice-free ports in the south coastal region, such as Valdez, Seward, Haines, and Anchorage.

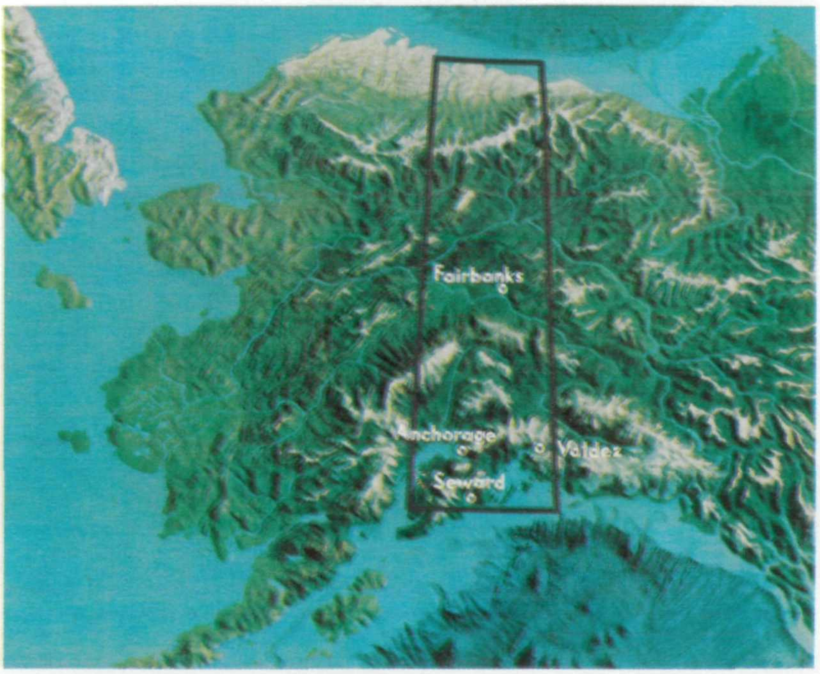


Figure 1. Alaskan land mass showing ERTS study region along 148th meridian.

A prime objective of Alaskan planners is a transportation corridor from the interior rail and highway head at Fairbanks to the resource-rich northern region, including service to the Prudhoe Bay oil fields of the North Slope. It is becoming increasingly evident to many of us that a transportation corridor is inevitable, whether or not the North Slope oil is marketed, or by what means it is marketed. This corridor could include a secondary highway and/or railroad and, perhaps, the proposed 48-inch pipeline for shipping crude oil from Prudhoe Bay on the Arctic Coast to the southern port of Valdez.

## UPDATING THE ENVIRONMENTAL DATA BASE

How to survey the environmental impact of such a transportation corridor, and particularly of the pipeline, is a matter of intense debate and controversy at present. It is clear that no single approach to environmental surveys will be acceptable to groups with highly divergent viewpoints upon the subject of Alaskan oil and what to do with it. In this context, ERTS-1 data form a politically neutral base from which resource surveys can be made without necessarily arousing suspicions from groups which have mutually conflicting goals.

The University of Alaska is performing multidisciplinary surveys of a north-south transect centered on the 148th meridian, which includes the proposed transportation corridor. Twelve ERTS projects in ten disciplines are closely coordinated with cooperating federal, state, and borough government agencies to deal with an extremely wide range of environmental problems.

One area of environmental concern is the northeast Alaska caribou population with special reference to oil pipeline facilities and other natural factors that are not clearly understood. These animals may number 150,000 at present, but there have been large fluctuations in herd sizes over the past 50 years which apparently are unrelated to human activity. Migration routes and winter dispersal patterns are not well enough known to significantly improve management of the caribou resource at the present time. Snow cover has long been recognized as a major factor influencing the biology of caribou, but aerial surveys to obtain data over the vast areas are *prohibitively* costly.

ERTS-1 images are being used in two ways to monitor herd activity. One is to map habitat favorable to caribou and the other is to locate and map environmental features that arise from large caribou aggregations. Typical winter grazing habitat (Figure 2) includes mixed patterns of open spruce stands and treeless bogs, such as those near Anvil Lake on this low-oblique aerial view. The caribou tend to bed down in open spruce stands for wind protection and to use the nearby treeless regions for feeding. The multiform pattern of spruce and bogs is detectable on ERTS images (Figure 3) even by visual analysis, but digital computer techniques are being used to identify and map these habitat landforms.

Animals may winter in loose aggregations of several hundred to a thousand animals and such aggregations typically remain in a drainage area and feed intensively several days to a week before moving on. These feeding areas and the extensive network of trails are expected to be identifiable on ERTS imagery acquired in April, when there is maximum snow

Figure 2. Low-elevation oblique aerial view of Anvil Lake. Open forest mixed with treeless bogs is favored caribou habitat.

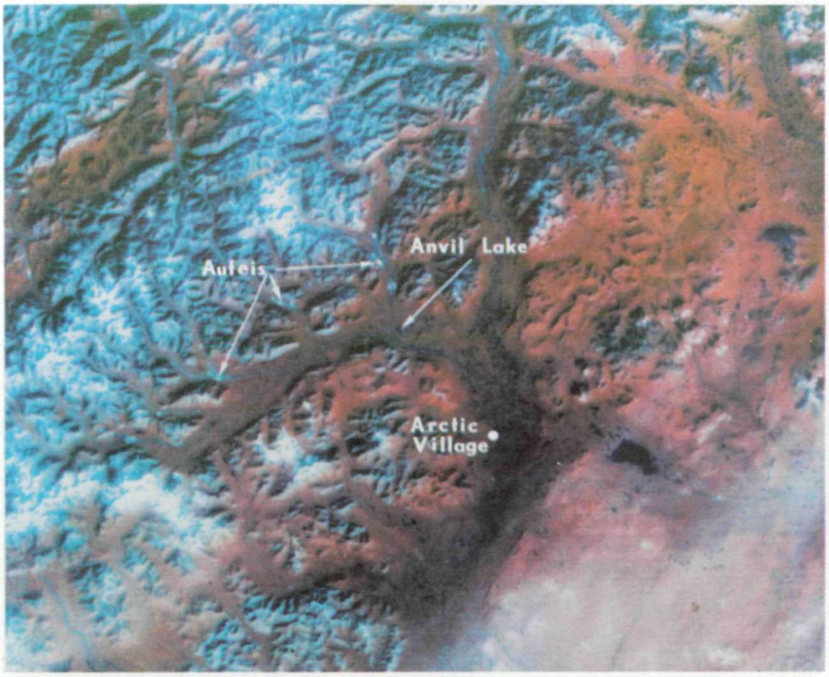


Figure 3. Anvil Lake region enlarged from ERTS scene 1051-21002. Many *aufeis* deposits appear along stream beds. These are accumulative ice formations so massive that they remain unmelted throughout the summer.

accumulation and insignificant melt. There also is some evidence that caribou wintering areas, thus disturbed, melt off much sooner than other areas. This may be due to premature exposure of vegetation, to a decrease in spectral reflectance, and to disturbance of the natural nival characteristics resulting from the trampling activities of the herds. ERTS will help significantly to evaluate this aspect of caribou ecology for the first time (Figure 4).

Available snow data generally do not allow sufficiently detailed mapping for many applications in research, planning, and construction of civil structures and roads. The climatic differences are very pronounced along any north-south transect, and these differences are reflected in the amount, physical characteristics, and duration of seasonal snow cover. Snow has a great many adverse effects on man's activities in arctic and subarctic regions because it remains on the ground for long periods. It also is beneficial in that it thermally insulates the soil-atmosphere interface and affords protection to plants and animals and stores huge quantities of water. From ERTS imagery we can for the first time produce maps of snow lines across Alaska during the initiation and decay of the seasonal snow cover.

A resource survey of a 34,000 $km^2$ (13,000 $mi^2$) area has been prepared from an ERTS scene of the remote and inaccessible Anaktuvuk Pass region (Figure 5) of the Brooks Range for purposes of land use planning. Color and black-and-white prints were visually analyzed by the Resource Planning Team of the Federal-State Land Use Planning Commission for


Figure 4. ERTS scene 1050-20541 (MSS bands 4, 5, and 7) on September 11, 1972, shows the first snowfall in the Brooks Range. Snow on the northern foothills are significantly more affected by katabatic wind than on the southern slopes. Aufeis deposits along rivers can identify additional summertime sources of fresh water.

Alaska. A multidisciplinary team with only a few hours orientation to ERTS images spent only about 25 man-hours to prepare a regional resource survey of this undeveloped area of Alaska.

The output included maps (such as Figure 6 to 9) of the three predominant types of vegetation (moist tundra, low brush, and high brush), ten watershed drainages, geologic features indirectly relatable to economic minerals, and potential use classifications in an area that is susceptible to development of a transportation corridor.

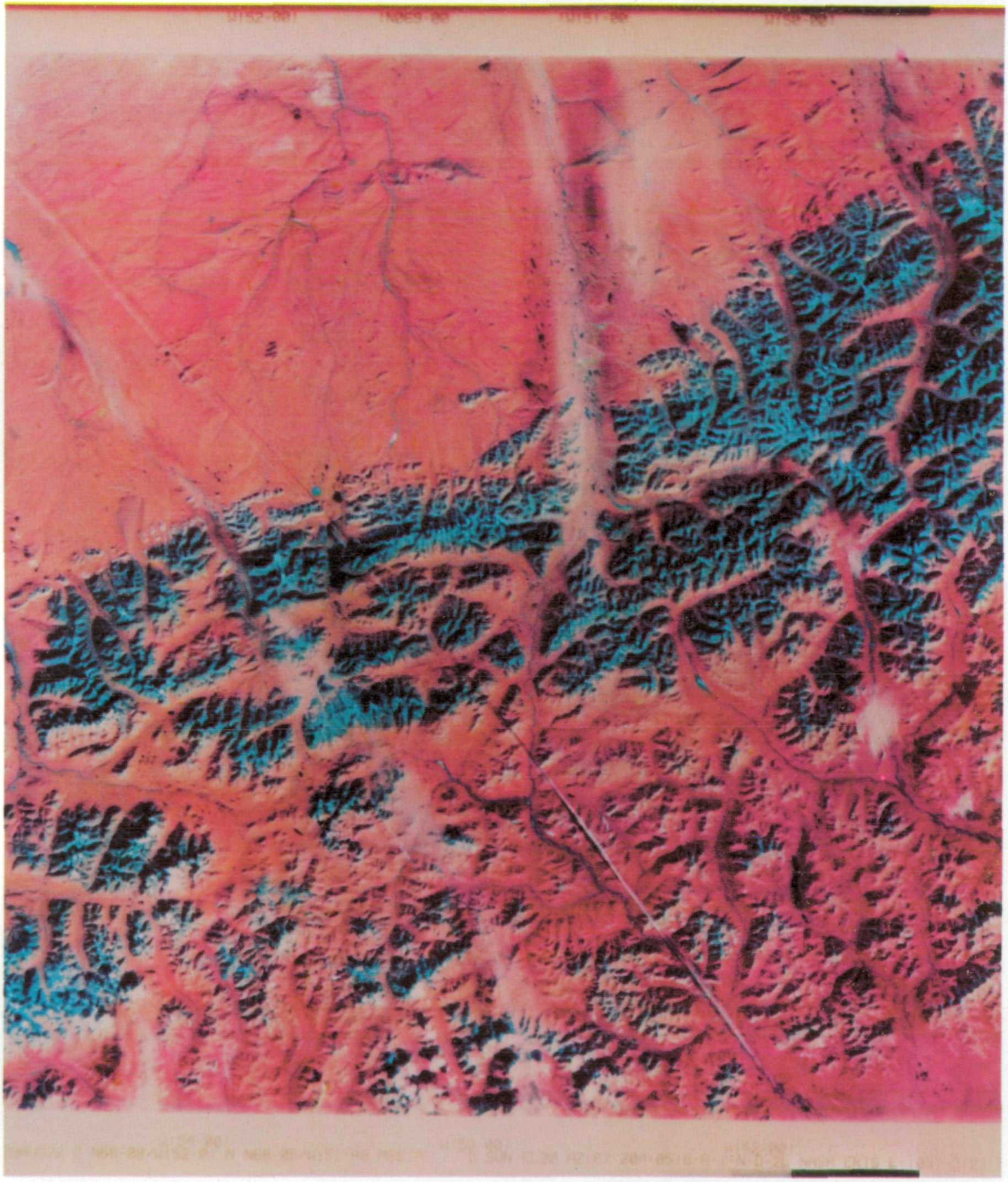

Figure 5. Remote Anaktuvuk Pass region of Brooks Range on August 29, 1972. This ERTS scene (1037-21231, MSS bands 4, 5, and 7) was among those analyzed by the Land Use Planning Commission to produce a broad resource survey. Note jet aircraft contrails.

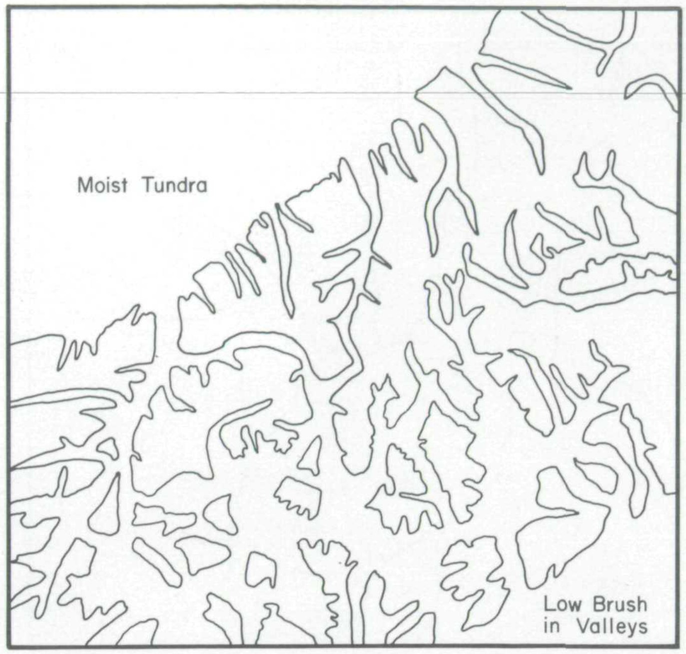


Figure 6. Three vegetation types were mapped in the central Brooks Range.

Such regional resource surveys applied to 19 Alaskan regions of critical interest are primary data base objectives of the Planning Commission. These objectives can be achieved as timely inputs to the deliberation process of the Commission only by the direct use of ERTS imagery. Comprehensive vegetation maps are also being prepared by the University of Alaska for much of the north-south transect of Alaska to aid the formulation of land use plans for this region, which is subject in the southern part to imminent development.

In particular, the Matanuska and Susitna Valleys (Figure 10), adjacent to metropolitan Anchorage, are presently bearing high developmental pressures because of the needs of the population heartland of Alaska. The Matanuska Valley contains the most valuable agricultural land in the state, and along with the Susitna Valley has considerable undeveloped land. However, speculative pressures force sales of these lands at prices that prohibit fulfillment of any agricultural potential. The limited amount of land that is suited to agriculture must be quickly identified and integrated into a long-range planning structure if agriculture is to continue both its material and intangible benefits to Alaskan society. The coupling of ERTS data as a resource survey tool in these large, undeveloped areas with difficult access problems is particularly welcomed by planning agencies.

In the southern part of the transect, type mapping from ERTS has outlined the broad features of mixed woods, coniferous forest, mixed herb-shrub and sedge associations, tidal flats, subalpine shrub-grass, alpine tundra, low elevation grasslands, and agricultural croplands. Use of computer processing has also delineated silty water from clear-water lakes,

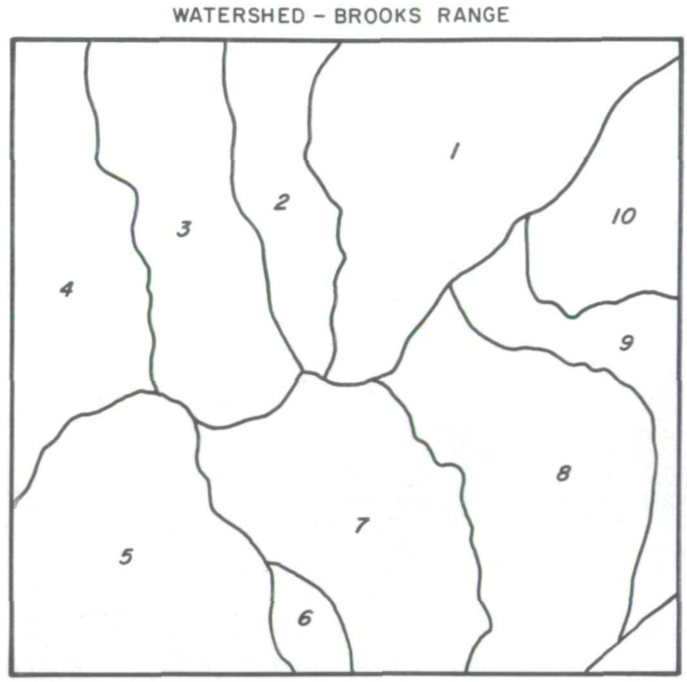


Figure 7. Watershed drainage map prepared from ERTS image. Watersheds 1 to 4 drain into the Arctic Ocean, while 5 to 10 drain into the Yukon and Koyukuk Rivers.

shallow waters from deeper waters, tidal flat vegetation from muskegs, and identified stands of birch-aspen.

In a joint effort with the U.S. Forest Service and the State Department of Natural Resources, we have just recently applied multispectral ERTS data to the surveillance of a 800-km$^2$ (200,000-acre) spruce beetle infestation near the Tyonek Indian Reservation and on the Kenai Peninsula in the Cook Inlet Basin. An estimated two billion board feet of white spruce has been killed or damaged by the spruce beetle, but the large areal extent of the spreading infestation presents a difficult task in maintaining surveillance of affected trees. Techniques are being implemented using ERTS data to stratify damage to white spruce into three levels—healthy, new kill, and old-kill stands.

Geologic applications of ERTS imagery also are aiding the planning for the development of Alaska. The synoptic view (Figure 11) is particularly beneficial in mapping new tectonic features. Seismic data plus the identification of previously unknown fracture zones recognized from ERTS (Figure 12) is an important input to the transportation corridor and to bridge design across the Yukon River.

The University of Alaska also is using ERTS images to study circulation patterns and sediment transport in key estuarine environments in Alaska. The Cook Inlet is one of the largest estuaries in North America, and two successive ERTS scenes are required for

POTENTIAL PETROLEUM PROVINCES

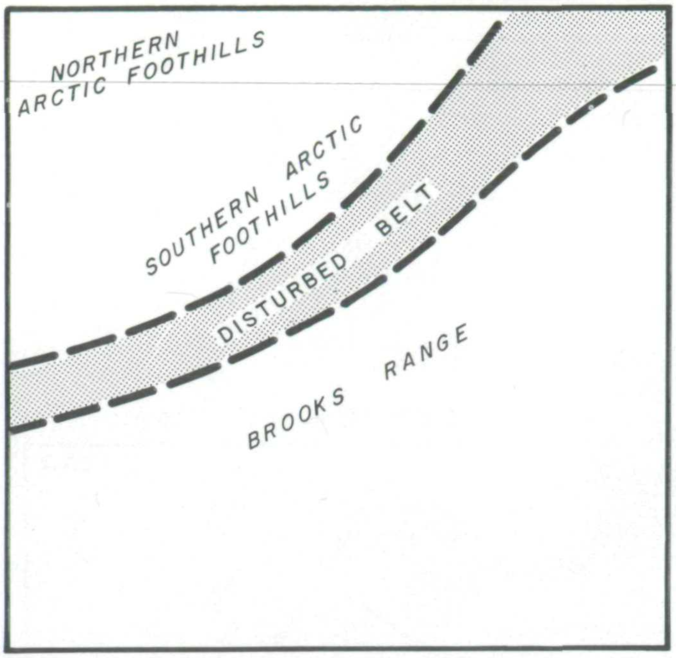


Figure 8. Gross geologic features of central Brooks Range which are related to economic mineral potential.

complete coverage. This inlet has been especially well documented for the first time using ERTS data–an impossible task by any conventional means. The identification of tidal rip currents and pollutant trajectories is useful for planning off-shore oil production and marine terminal facilities and to tell us where to sample for Anchorage pollution monitoring. Inlet overall circulation patterns and sea/turbid water boundaries are also important to the lower-inlet fishing industry. The fish tend to congregate near the interface between the sea water and the turbid water coming down from the glacier-fed rivers in the north end of Cook Inlet.

Another key marine environment study involving ERTS is located in Prince William Sound and the port of Valdez, which is subject to possible intense oil terminal and shipping activities. Here the application is toward sound ecological management in the face of heavy traffic with the potential for contamination. Valdez is a deep-water port, neither tide-dominated nor bearing a heavy silt burden as does Cook Inlet. The continuing protection of important fisheries resources in this region is the primary goal of this ERTS application.

## SUMMARY

Broadly structured, multidisciplinary environmental surveys of Alaskan resources are underway by the University of Alaska and cooperating agencies using ERTS data as a primary input. These results are coupled to a maximum extent to ten federal and state agencies charged with operational responsibilities. Applications of ERTS data are playing an ex-

tremely vital and timely role in planning for the imminent, and hopefully, orderly de-
development of Alaska.

## ACKNOWLEDGMENTS

The authors appreciate the many contributions to this paper made by the ERTS principal investigators at the University of Alaska, and by the Resources Planning Team of the Federal-State Land Use Planning Commission for Alaska.

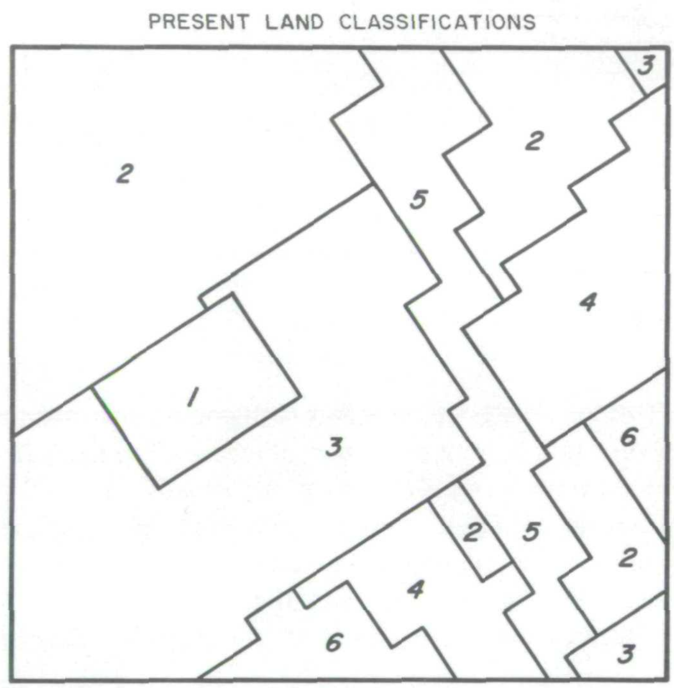


Figure 9. Land use classification map of central Brooks Range. Category 1–native village withdrawals 2–regional deficiency area 3–national interest study area 4–public interest area 5–utility corridor 6–state selection pending.


Figure 10. South Central Alaska on September 10, 1972 from ERTS scene 1049-20505 (MSS bands 4, 5, and 7).

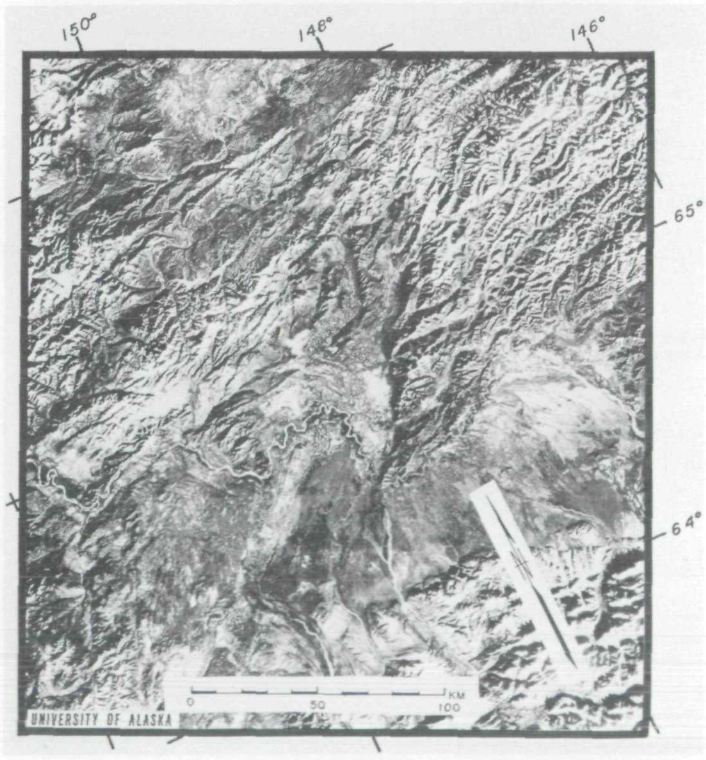


Figure 11. Winter mosaic at low sun angle of six ERTS scenes (1104-20554/20560/20563 and 1105-21012/21015/21021). A complex fracture zone and many new faults are recognized.

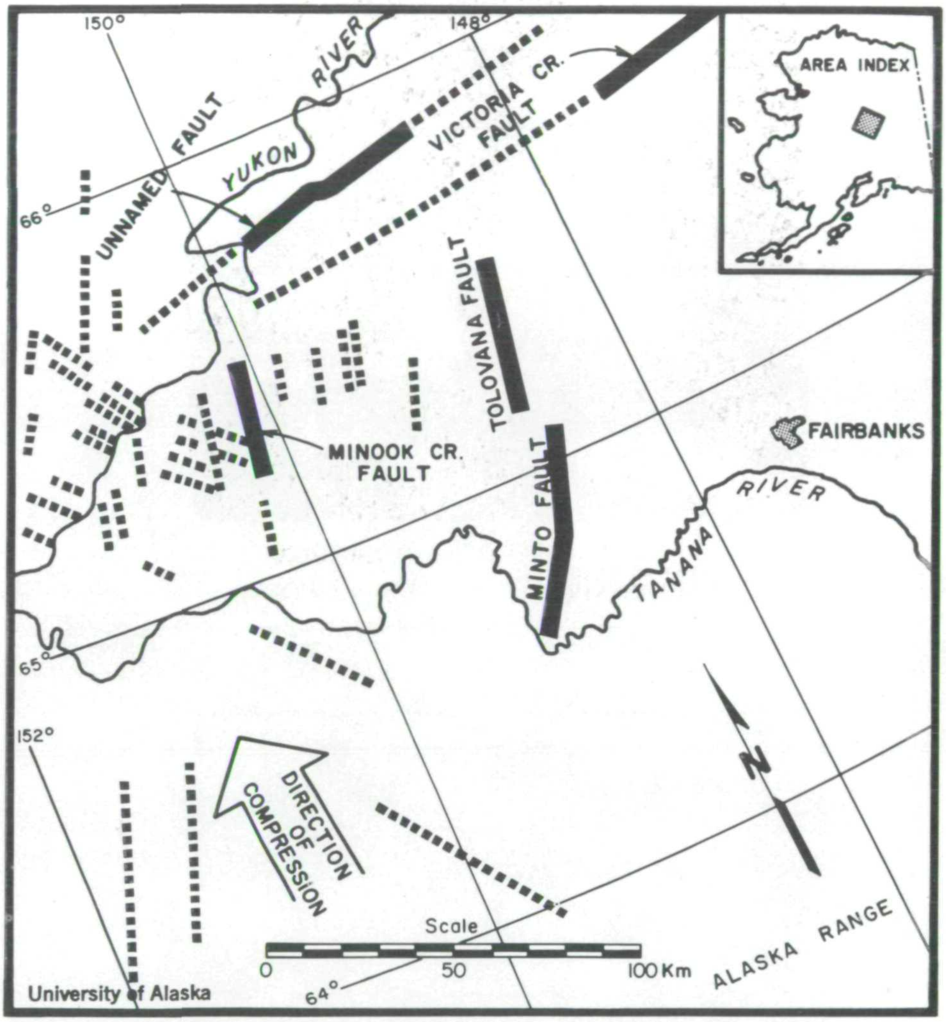


Figure 12. Tectonic map keyed to same scale as Figure 11. Dashed lines are confirmed faults or fractures. Solid lines mark newly recognized major faults from ERTS images.

# APPLICATION OF ERTS-1 IMAGERY TO FLOOD INUNDATION MAPPING

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## ABSTRACT

In September, 1972, heavy rains initiated major flooding in southwestern Iowa throughout the East and West Nishnabotna River basins. The flood crest moved downstream between September 11 and 15. A cooperative program to evaluate the possibility of mapping flood inundation by using remote sensing techniques was initiated jointly by the Iowa Geological Survey Remote Sensing Laboratory (IGSRSL), and the U.S. Geological Survey Water Resources Division. Ground data and a variety of low-altitude multispectral imagery were acquired for the East Nishnabotna River on September 14 and 15. This successful effort concluded that a near-visible infrared sensor could map inundated areas in late summer for at least three days after flood recession. ERTS-1 multispectral scanner subsystem (MSS) imagery of the area was obtained on September 18 and 19. Analysis of MSS imagery by IGSRSL, USGS, and NASA reinforced the conclusions of the low-altitude study while increasing the time period critical for imagery acquisition to at least 7 days following flood recession. The capability of satellite imagery to map late summer flooding at a scale of 1:250,000 is exhibited by the agreement of interpreted flood boundaries obtained from ERTS-1 imagery to boundaries mapped by low-altitude imagery and ground methods. (Figure 1 shows the coverage of a typical low-altitude oblique photograph.) The synoptic coverage of ERTS-1 allowed extension of the flood mapping to the West Nishnabotna River. Satellite imagery allows rapid appraisal of the areal extent of flood inundation for entire river systems. This satellite flood mapping should prove valuable to federal and state agencies involved in regional floodplain management and planning.

## INTRODUCTION

Floods are one of the worst natural hazards in the Midwest. Each year the Midwest experiences flooding caused by the spring thaw and frontal rainstorm activity. Annually, millions of dollars' worth of damage results to homes, businesses, public works, and crops. Much time and energy is devoted by government agencies to study floods, to assess immediate damages, and also to gain a perspective from which to base future decisions concerning floodplain management. Current information about many physical parameters of

Figure 1. Aerial oblique showing flood waters of the Nishnabotna River encroaching on Hamburg, Iowa; September 15, 1972.

both the river and adjoining floodplain is needed to help avert disasters. This information must be rapidly acquired and produced in a format readily useable by many federal, state and local agencies concerned with floodplain planning and management. In Iowa, the paucity of large-scale topographic maps makes flood hazard mapping and regional flood control evaluation difficult. Last fall the Iowa Geological Survey Remote Sensing Laboratory (IGSRSL), and the U.S. Geological Survey Water Resources Division, began developing a remote sensing technique capable of providing data suitable to meet some of the immediate and future planning and management needs of communities located along Iowa's rivers. Low-altitude conventional and multiband photographic techniques were utilized in southwestern Iowa and resulted in an aerial photographic technique capable of fulfilling many of these data requirements. Analysis indicated that infrared sensitive film can be utilized to map late summer flood inundation for a minimum of three days following flood recession. Interpretation based on ERTS-1 imagery of this same region by IGSRSL, NASA, and USGS supported this conclusion. ERTS flood inundation mapping also increased the time allowable for data acquisition to a minimum of seven days following flood crest, while providing regional flood inundation data and flood control assessment.

## AERIAL PHOTOGRAPHY

### Low-Altitude Photographic Study

A large storm system produced 50 centimeters (20 inches) of rain locally in west-central Iowa, on September 10 to 12, 1972 (Figure 2). Flood stages were recorded in the Boyer, Grand, Nodaway, and East and West Nishnabotna Rivers. Extensive overbank flooding occurred only in the Nishnabotna River basin where record flow rates were recorded at Atlantic and Red Oak on the East Nishnabotna River and at Hancock on the West Nishnabotna River (Table 1).

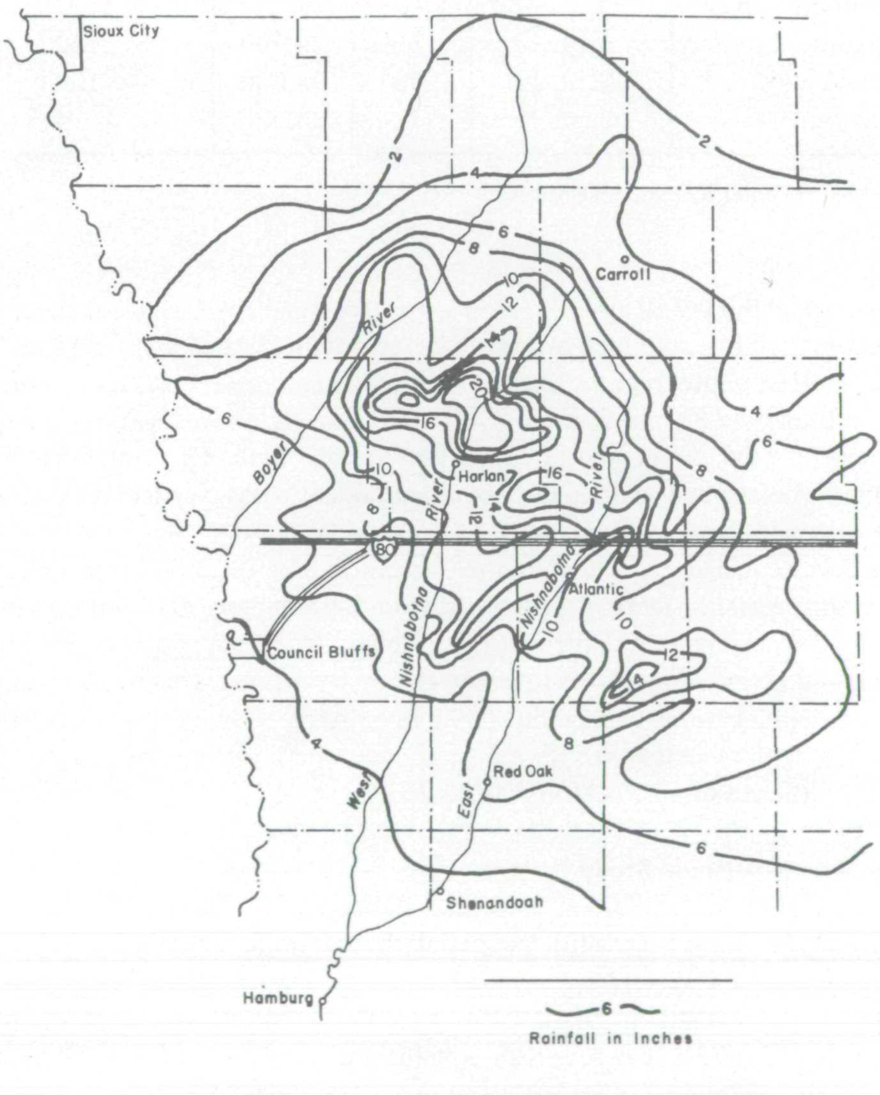



Figure 2. Precipitation pattern for west-central Iowa, September 10 to 12, 1972.

Table 1

Flood Crest Data for September, 1972,
Flood Along Nishnabotna Rivers.

| River | Crest Date | Discharge | | Recurrence Interval (years) |
|---|---|---|---|---|
| | | $m^3/s$ | (cfs) | |
| West Nishnabotna River | | | | |
| At Hancock | Sept. 13 | 746 | 26,400 | 100 |
| Near Randolph | Sept. 14 | 524 | 18,500 | 7 |
| East Nishnabotna River | | | | |
| Near Atlantic | Sept. 12 | 755 | 26,700 | 120 |
| At Red Oak | Sept. 13 | 1075 | 38,000 | 100 |
| Near Hamburg | Sept. 15 | 712 | 25,200 | 4 |

Data from U.S.G.S. Water Resources Division.

The Iowa Geological Survey Remote Sensing Laboratory and the U.S. Geological Survey Water Resources Division combined efforts to develop a method of mapping flood inundation utilizing aerial photography. Imagery was obtained on the East Nishnabotna River between Interstate 80 and Hamburg. Simultaneous field investigations were conducted to document the extent of inundation with ground data. On September 14, color (Kodak 2445) and black-and-white panchromatic (Kodak 2405), vertical, stereoscopic imagery was obtained from 2400 meters above ground level (AGL) with a Wild RC-8 camera. The black-and-white imagery was acquired with a minus blue filter (Wratten 12). On September 15, multispectral imagery was obtained from 2400meters AGL with an $I^2S$ multiband camera and black-and-white infrared film (Kodak 2424). In addition, 35mm color (Ektachrome) and color infrared (Ektachrome infrared), oblique, stereoscopic imagery was obtained at selected locations from about 500 meters AGL. Conventional imagery was analyzed visually with stereoscopic viewing equipment and multispectral imagery was interpreted with the aid of an $I^2S$ Mini-Adicol viewer.

### Conclusions of Low-Altitude Study

The low-altitude study was successful. An aerial photographic technique was developed that can map late summer midwestern flood inundation. All known ground data agree with this mapping. This technique should prove valuable for floodplain management and planning (Hoyer and Taranik, 1973). The summary conclusions are illustrated with imagery in Figures 3 through 5. The basic conclusions of the study are as follows:

- Infrared radiation (740 to 900 nm) proved most important for flood inundation mapping (Table 2). Saturated soils and standing water resulting from flooding reflect less infrared radiation than adjacent nonflooded areas. Likewise, many plants affected by the flood reflect less radiation in the infrared band than comparable plant types that are not inundated. River bottom tree species did not show this decrease in infrared reflectance.

- Blue radiation (400 to 465 nm) was reflected more strongly from flooded areas than from comparable surrounding areas. The green (480 to 570 nm) and red (595 to 685 nm) radiation bands were found to be least definitive for delineating the flooded areas.

- Color imagery aided interpretation both in the visible and near-visible infrared portions of the spectrum. The best flood delineation was provided by multispectral color-additive viewing utilizing the blue and infrared bands. For maximum usefulness the imagery should also be suitable for photogrammetric purposes to allow the production of topographic maps. Of commercially available films suitable for flood mapping and photogrammetric purposes, color infrared film (Kodak 2443) was most successful.

- Stereoscopic viewing was found to be helpful for flood interpretation. The ability to view surface relief is helpful for extrapolating the flood boundary into areas for which tones or colors are not completely definitive. This was common in very flat areas where the flood boundary may be very complex.

- Flood inundation mapping can be accomplished in late summer for at least 3 days following flood cessation in the Midwest.

## ANALYSIS OF ERTS-1 IMAGERY

The low-altitude and ground study has been summarized to show the degree of control available when the ERTS imagery was evaluated. The criteria developed in the low-altitude study were extended to the ERTS MSS imagery. Figures 6 and 7 show a portion of the lower Nishnabotna Rivers from the red (MSS-5) and infrared (MSS-7) bands. As in the low-altitude study, the red and green bands did not contain significant information, but the infrared band distinctly revealed the inundated area.

Since the launch of ERTS-1 several high quality images of southwestern Iowa have been received (Table 3). Analysis of this repetitive imagery, acquired from July through October, allowed a positive determination that the Nishnabotna flood is shown on the imagery. July (Figure 8) and August (Figure 9) imagery show that all the major perennial stream valleys in southwestern Iowa appear very similar in all spectral bands. The Nishnabotna valleys do not appear different from any other stream-valley complexes of comparable size.

Table 2

Suitability of Multispectral Photographic Images For Late Summer Flood Mapping in the Midwest (See Figures 3 to 5).

| Spectral Band | Appearance of Flooded Areas Versus Appearance of Unaffected Areas | Suitability For Flood Mapping |
|---|---|---|
| Blue | Lighter | Fair |
| Green | Lighter or darker | Very poor |
| Red | Lighter or darker | Poor |
| Infrared | Darker | Good |
| Color infrared composite: | | |
| Green, red, and infrared–false colored as blue, green, and red, respectively. | Mottled red, grading to green, blue, or grey | Very good |
| Blue and infrared–false colored as blue and red, respectively. | More blue to purple | Excellent |

On the October imagery (Figure 10) all the floodplains show a reduced infrared response. The Nishnabotna valleys appear similar but are darker than the others, and this may be due to some lingering effects of the flood, nearly three weeks after flood recession.

The September 18 and 19 images were taken 6 and 7 days after the crest of the Nishnabotna flood (Table 3). The major valleys in the area again have similar densities and general appearance in the green (MSS-4) and red (MSS-5) band images. However, the flooded areas in the Nishnabotna valleys and in other areas are readily apparent on the infrared bands, MSS-6 and -7. The inundated areas have sharply reduced infrared reflectance because of surface water, excessive soil moisture, and stressed plants. The flooded areas are most clearly defined on the MSS-7 image, and this was the imagery utilized for mapping the inundated area (Figure 9).

Analysis of the ERTS-1 imagery, by IGSRSL and NASA, reinforced the basic conclusions of the IGSRSL low-altitude, multispectral analysis: Near-visible infrared sensing systems can be used to map the extent of major midwestern floods in late summer. The green and

Table 3

ERTS-1 Satellite Imagery of Southwestern Iowa Utilized by IGSRSL.

| Date (1972) | Cloud Cover (percent) | NDPF I.D. Number | Comments |
|---|---|---|---|
| July 26 | 20 | 1003-16334 | Stream valleys uniform in |
| | 30 | 1003-16341 | appearance on all bands. |
| Aug. 14 | 0 | 1022-16382 | Best defined on band 5. |
| | 0 | 1022-16384 | |
| Sept. 18 | 5 | 1057-16315 | Flood inundated areas |
| | 0 | 1057-16332 | are apparent on |
| Sept. 19 | 10 | 1058-16383 | infrared bands. |
| | 0 | 1058-16390 | |
| Oct. 7 | 0 | 1076-16384 | All floodplains apparent |
| | 0 | 1076-16381 | on infrared bands. |

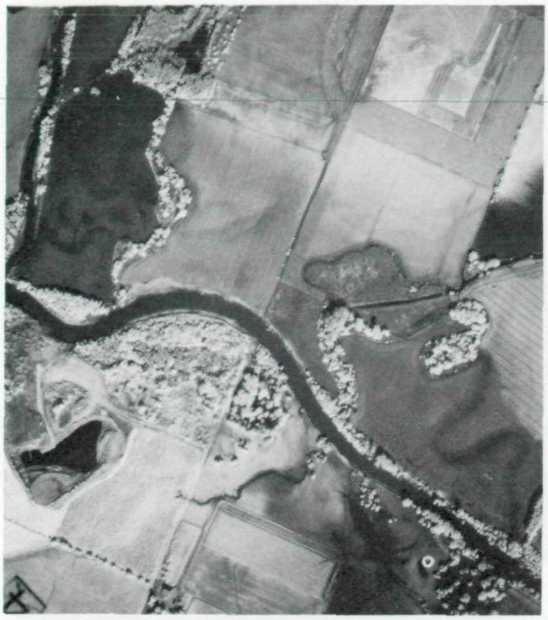
All images taken at approximately 10:30 A.M. CST.

A

C

B

Figure 3. Multispectral images of September 1972, East Nishnabotna River Flood. The area pictured is 16 kilometers (10 miles) south of Atlantic, Iowa. The image was taken two days after recession of flood waters. These are the three bands used in normal black-and-white panchromatic aerial photography. Such films record the portions of the reflected energy least important for photographically mapping floods, after flood cessation. Often the blue wavelengths are filtered out, to reduce atmospheric scatter, and of these three bands, blue is the most useful in delineating inundated areas. Compare these images with the following images which detected reflected infrared radiation. (a) Blue band (400-465 nm) flooded area appears lighter toned and can be easily traced in some areas (b) Green band (480-570 nm) flooded area is not easily identified. The amount of reflected energy is not affected by the flood (c) Red band (595-685 nm) Like the green band, the flooded area is not well defined



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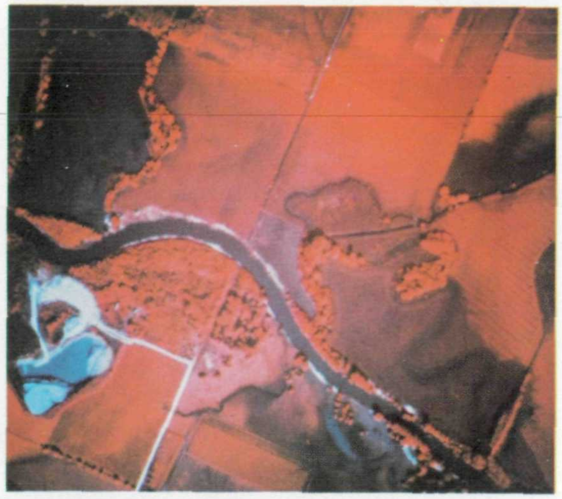

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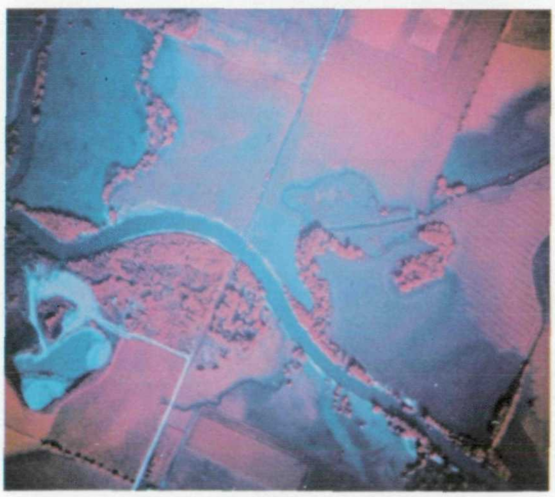

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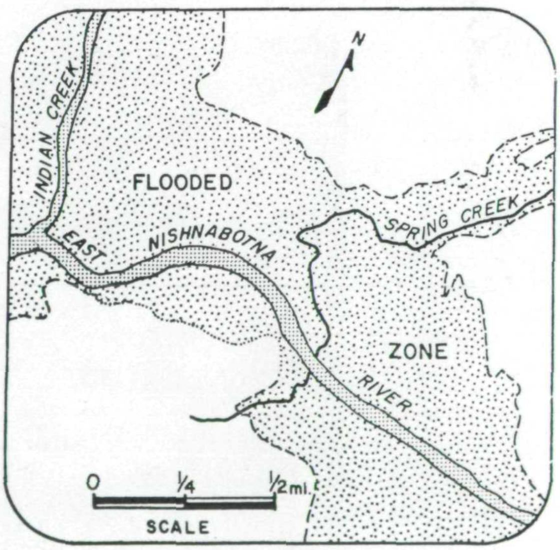


D

Figure 4. Continuation from Figure 3 of multispectral and false color images, produced from an I²S Mini-Addcol viewer (Model 6040). (a) Infrared band (740-900 nm) darker tones delineate where flood waters stood two days before this image was taken (b) Color infrared composite; green, red, and infrared bands false colored to simulate color infrared film (see Table 2). Addition of color aids interpretation. Color infrared film would be the best film for operational mapping of late-summer floods (c) False-color composite: This combines the blue and infrared bands in color (see Table 2). This is the best discriminator of the flooded area, which appears blue to purple (d) Map of the flooded area in the multispectral images

A

B

Figure 5. 35mm aerial oblique images obtained 2 days after flood crest with Ektachrome-X and Ektachrome Infrared films. These films are similar to films available for metric aerial cameras. The inundated area is much more clearly defined on the color infrared image. (a) Ektachrome aerial oblique of the East Nishnabotna River, between Red Oak and Shenandoah. The town of Essex (see Figure 11) appears in this picture (b) Color infrared oblique of the same area

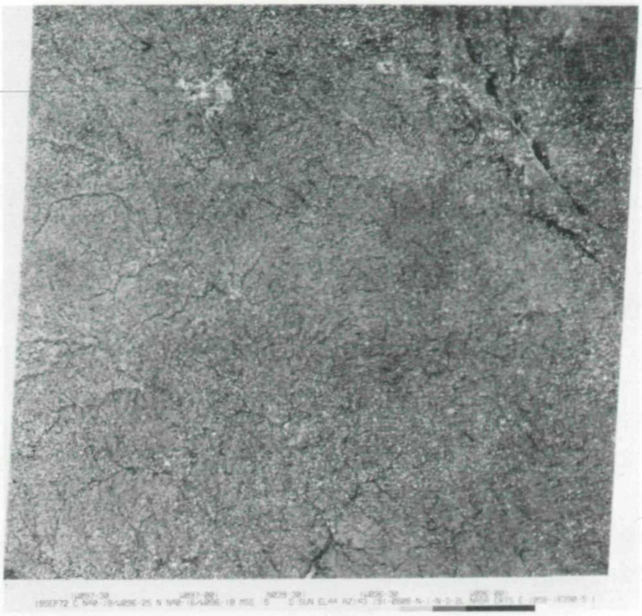

Figure 6. Portion of September 19, 1972, ERTS image 1058-16390-5, showing the junction of the East and West Nishnabotna Valleys and the Missouri River Valley. The MSS 5 band (red spectral region; 600-700 nm) does not reveal any significant information about the area flooded.

red bands were not helpful for delineation of the flood. The MSS does not have a blue channel, so no comparison can be made with the multiband camera for this band. ERTS data demonstrated that flood mapping can be accomplished one week following the recession of high water.

## FLOOD INUNDATION MAPPING—COMPARISON OF RESULTS

After initial analysis of the low-altitude imagery a map of the flooded area along the East Nishnabotna River was prepared, utilizing multispectral imagery and metric black-and-white panchromatic photography. Problems in interpretation of the low-altitude imagery were encountered in some areas because of the incomplete photographic coverage over the entire width of the flooded area. The accuracy of the mapping of the inundated area by low-altitude imagery was substantiated where ground observations were available. After the low-altitude analysis was completed, the interpretations of the inundated area were transferred to base maps at a scale of 1:126,720 (1 inch ≈ 2 miles). The ERTS imagery was then used to produce a map of the inundated area. The interpretation was done directly from prints, enlarged from 70mm positive transparencies to 1:250,000 scale (1 inch ≈ 4 miles). The two maps were produced independently by the IGSRSL interpreters.

The investigators prepared a composite map at a scale of 1:250,000 to compare the low-altitude and the orbital imagery interpretations. A preliminary version of this map is shown in Figure 11. The two interpretations were comparable at this scale, with 80 percent of the area mapped in complete agreement (shaded area). However, small areas of discrepancy exist. These differences should be considered in light of certain factors: The low-altitude mapping was accomplished with incomplete photographic coverage and the multispectral imagery did not include the full width of flood inundation in many areas. At these locations the boundary had to be interpreted from stereoscopic black-and-white panchromatic imagery filtered to include only green and red reflected energy—the least informative spectral bands for flood mapping. Interpretive errors are possible with any imagery in flat lowland areas where the border of the flooded area is very complex. Transferring interpreted data to base maps was difficult because of the almost total lack of topographic maps along the East Nishnabotna River. Several areas of difference have resulted from this problem (Figure 11, at A, for example). A further mapping complication resulted from the acquisition of the low-altitude imagery below Shenandoah up to 24 hours before flood crest. Obviously, differences in mapping had to occur here (Figure 11, at B).

For this study, ERTS imagery resulted in fewer problems because it provided comprehensive coverage with an infrared sensitive system. In places the boundary was not sharply defined and was marked only by slight tonal differences on band 7 which caused some interpretive problems. Tonal differences were especially small in the upper portion of the basin (where flooding was earliest), in the broad floodplain of the West Nishnabotna River (where flooding was slight), and near urban areas (especially Red Oak). Another interpretive difficulty of ERTS imagery resulted from the large amount of infrared energy reflected from lowland tree species located within the flooded region. These trees are particularly apparent near Riverton (Figure 11, at C; Figure 12, at A). It is assumed that these bottomland trees, some of which are phreatophytes, were not stressed as a result of inundation. This response was not a problem for low-altitude imagery, but proved troublesome for ERTS imagery interpretation, especially when a single band (MSS-6 or -7) black-and-white image is used. A false-color image aids in the evaluation of this problem (Figure 12). Where mapping differences occur between low-altitude and satellite imagery, some refinements of one method by the other is possible based on the interpreter's judgement and reevaluation. The map presented does not show these possible refinements, but rather indicates the total area of dispute to eliminate interpretive bias.

Flood inundation mapping was continued into the West Nishnabotna basin because of the agreement of data in the East Nishnabotna basin. The criteria used for interpretation in the East Nishnabotna basin were extended to the West Nishnabotna basin, where mapping in the northern portion was readily accomplished.

However, no flooding could be interpreted throughout much of the southern portion (Figure 12, at B; Figure 13, at A), except in two highly questionable areas. Ground data supplied by the U.S. Geological Survey coinvestigators indicates that the West Nishnabotna did not breach its levees in the Malvern-Randolph area. Flood gauging records suggest this as well (Table 1). The crest of the flood at Randolph was associated with a recurrence frequency of only 7 years–indicating a very minor flood stage. The crests measured along the upper portions of the West Nishnabotna and along the East Nishnabotna indicated a 100-year flood or greater.

Flood stages were also recorded on the Boyer River and in Mosquito Creek, but inundated areas are not apparent on the imagery (Figure 13). The flooding in Mosquito Creek was equal to a 200-year flood near Earling, but this took place in a small local area (drainage area of only 83 square kilometers–32 square miles). This particular area is obscured by clouds on both the September 18 and 19 ERTS images, so no assessment of the capabilities of the ERTS imagery was possible in this area. The Boyer River was imaged on September 19. This river has been highly channelized, and the 30-year flood recorded at Logan was contained with no significant overland flooding.

Utilizing the ERTS imagery, an even larger region can be analyzed (Figure 14). The September 18 imagery revealed apparent flood inundation along other stream systems, notably in the Nodaway River and Grand River basins. U.S. Geological Survey, Water Resources Division data indicate that moderate flooding ocurred in these areas also.

A 1:250,000 scale map was prepared from the ERTS imagery by the NASA coinvestigators at Goddard Space Flight Center. General agreement existed between the maps along the East Nishnabotna, but some gross differences ocurred in the interpretation of the West Nishnabotna. The flooded area mapped by NASA was significantly larger than that mapped by the IGSRSL staff. These differences may be a function of the IGSRSL investigators' correlative low-altitude and ERTS flood-mapping experience on the East Nishnabotna. The experience gained using the East Nishnabotna flood as training allowed more confidence in their regional interpretation. After discussions with the IGSRSL investigators about the interpretive criteria and the characteristics of these valleys, the NASA coinvestigators were able to produce a map very similar to Figure 11.

The correlation of the orbital data with ground and low-altitude data indicates the feasibility of regionally analyzing midwestern, late summer, flood inundation utilizing satellite imagery. Analysis of the MSS imagery reinforced the conclusions of the low-altitude study while increasing the time period critical for imagery acquisition to at least 7 days. In addition reasonable measurements of flood acreage seem possible for entire river systems. The total flooded area mapped in the Nishnabotna basins from the ERTS imagery was 305 $km^2$, or 78,000 acres (Hallberg and Hoyer, 1973). In the East Nishnabotna basin 214 $km^2$ (55,000 acres) were mapped and 91 $km^2$ (23,000 acres) were mapped in the West Nishnabotna basin. The adequacy of existing levee systems can be evaluated on a regional basis. Interpretation of the West Nishnabotna Valley between Malvern and Randolph and the Boyer River Valley indicated that the levees were generally adequate for this flood. Evaluation of ground studies later confirmed this interpretation. With the lack of small-scale topographic maps of the area, and because the flood along the East Nishnabotna was essentially a 100-year frequency flood, the ERTS-interpreted inundation map on the 1:250,000 scale topographic base is also a flood hazard map, on the only available topographic base.

The time requirements for the various methods of mapping floods in Iowa are noteworthy. At present floods are mapped by actually going into the field and marking the high water level. These high-water marks are surveyed later, and from these data a series of profiles are constructed. This method takes weeks for data acquisition and analysis. Even then the profiles produced are only a series of datum points and not a map of the inundated area. For the Nishnabotna flood, the high water marks will not be surveyed and the profiles constructed until the summer of 1973. So in this case it will be at least one year until the data will be usable.

In the low-altitude study it took one of the investigators, who had first hand knowledge of the flood area, several days to map the inundated area of only the East Nishnabotna River. This involved analysis of multispectral imagery and stereo panchromatic black-and-white imagery. This could have been accomplished in one day with stereoscopic, color infrared imagery.

From the ERTS imagery, which covered the entire area in just two frames, it was possible for one of the investigators, also with first hand knowledge of the area, to interpret and map the entire Nishnabotna basin in about 2 hours. In another 2 hours the entire region (Figure 14) was analyzed.

The utilization of satellite imagery to assess floods could become an important tool, particularly in poorly mapped, sparsely settled, or inaccessible areas. The satellite imagery allows rapid appraisal of the areal extent of flood inundation and the adequacy of existing levees for entire river systems. Satellite flood evaluation should prove valuable to federal and state agencies involved in regional floodplain management and planning.

## REFERENCES

*Climatological Data: Iowa, September 1972.* 83, no. 9, U.S. Dept. Comm., N.O.A.A., 133–149.

Hallberg, G. R., and B. E. Hoyer, 1973, *Flood Inundation Mapping in Southwestern Iowa, A Preliminary Report, Analysis of ERTS-1 Imagery,* Iowa Geol. Sur., Remote Sens. Lab.

Hoyer, B. E., and J. V. Taranik, 1973, *Aerial Flood Mapping in Southwestern Iowa, A Preliminary Report,* Iowa Geol. Sur., Remote Sens. Lab.

## ACKNOWLEDGMENTS

Many persons have contributed support in this flood study. Especially helpful were Sulo Wiitala, Walter Steinhilber, Ivan Burmeister, and Oscar Lara, all from the U.S. Geological Survey, Water Resources Division. They arranged financial support for data acquisition, helped plan the study, supplied ground data, and provided editorial guidance. Special appreciation is extended to Morris Deutsch, EROS Project Office, U.S.G.S., for alerting us to examine the ERTS-1 imagery of the flooded area. Some of G. R. Hallberg's time and some of the ERTS imagery utilized in this project were made available via Project SR238, An Evaluation of ERTS-1 Imagery for Mapping Quaternary Deposits and Landforms in the Great Plains and Midwest. Publication of results from the Iowa Geological Survey was authorized by the Director.

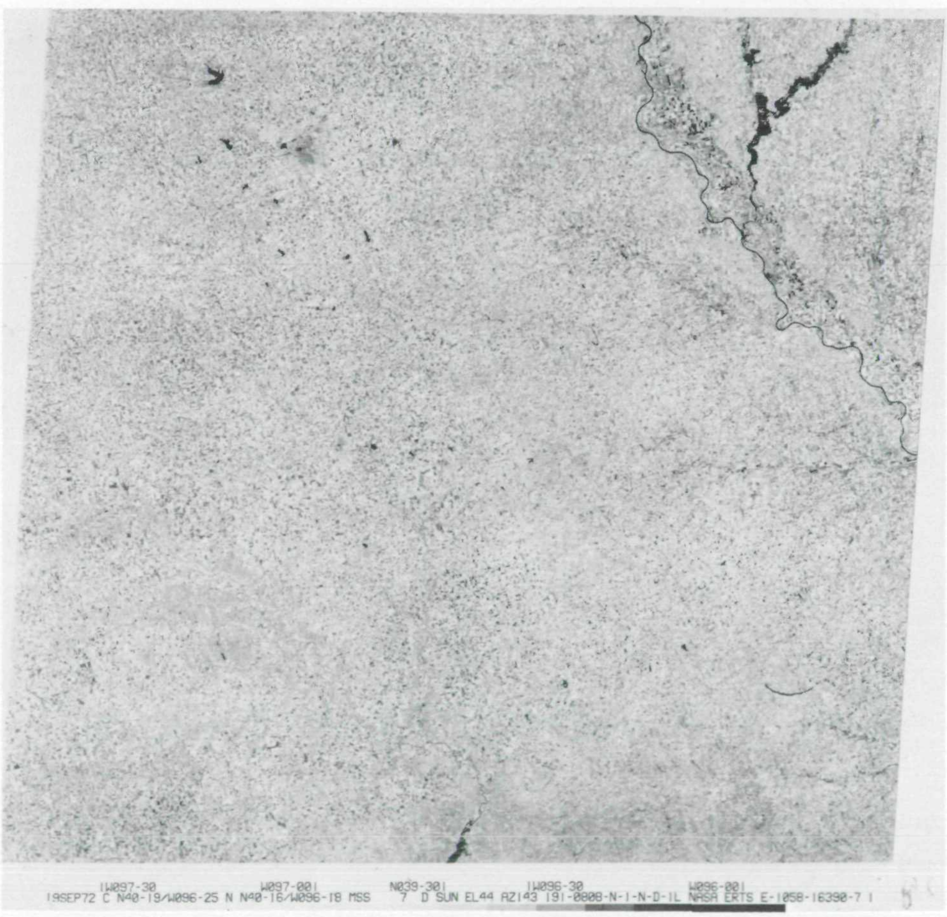


Figure 7. Same image as in Figure 6, except MSS 7 band (800-1100 nm). As in the low-altitude study the infrared bands clearly delineate the area inundated by the flood, 4 to 6 days after recession of flood waters.

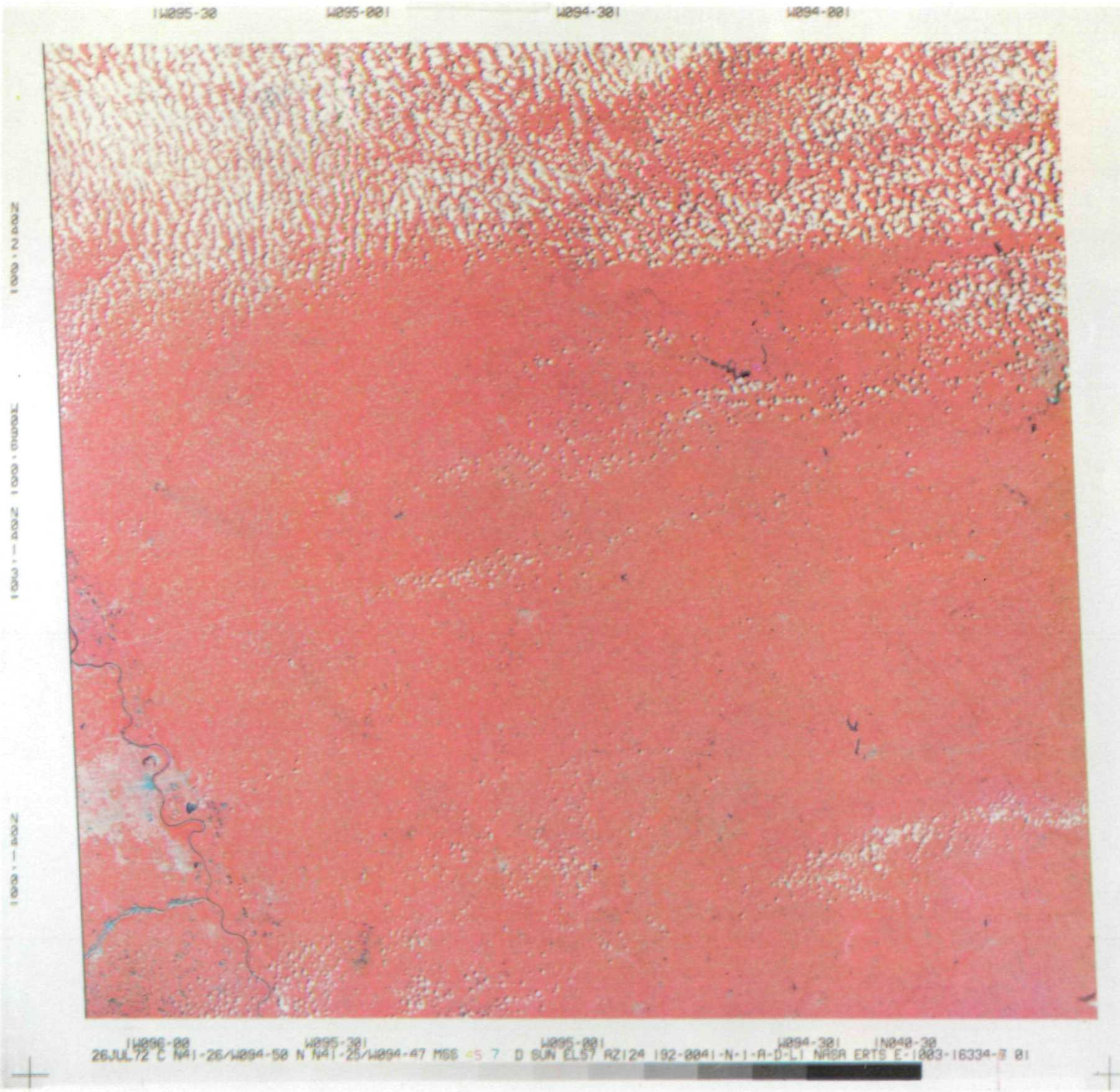

Figure 8. Color infrared composite of July 26, 1972, ERTS image 1003-16334, bands 4, 5, and 7. All the rivers and valley systems comparable to the Nishnabotna have a similar appearance. Omaha, Nebraska and the Missouri River are at the west edge of image.

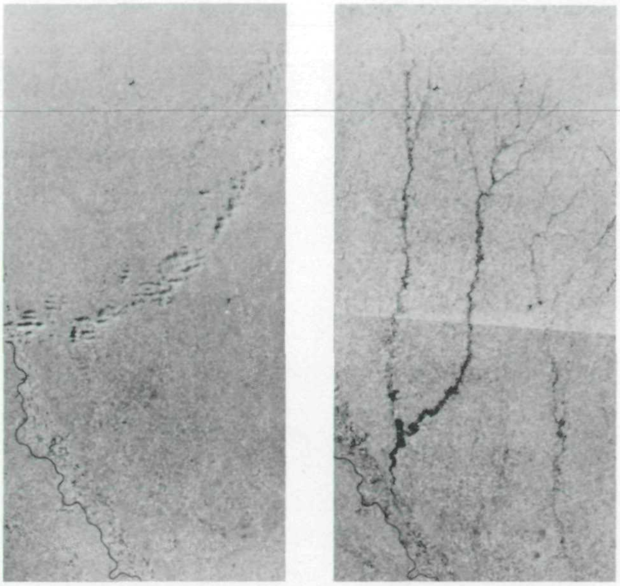

Figure 9. ERTS MSS-7 images of the Nishnabotna basin area. Missouri River is in southwest portions of images. Left image was taken August 13, 1972. Except for the Missouri River no streams or valleys are apparent. In the right image, taken September 18, the inundated areas along the West and East Nishnabotna Rivers are readily apparent. Some flooded areas are also noticeable in the Nodaway River valley to the east.

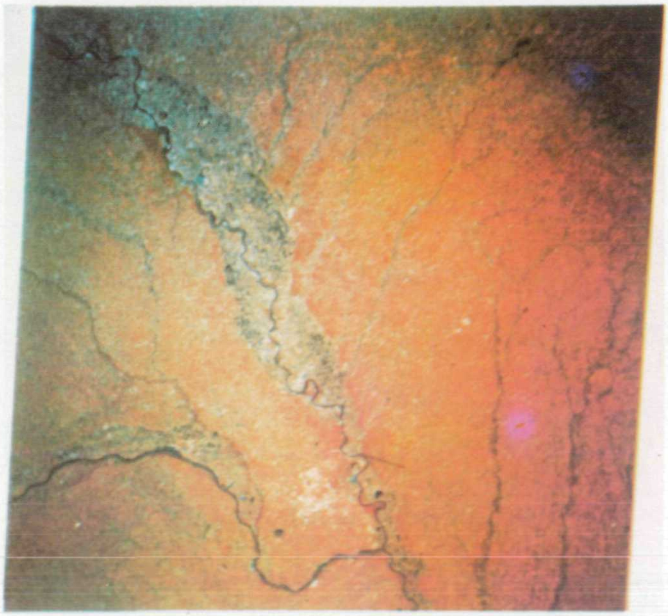

Figure 10. Color infrared composite of October 7, 1972 ERTS image 1076-16384. All major alluvial valleys show reduced infrared reflectance. This response appears more pronounced in the Nishnabotna valleys, and this may be some lingering effect of the flood. Comparison with Figures 11 and 13 indicates that areas on the West Nishnabotna that were not flooded also exhibit this reduced infrared reflectance.

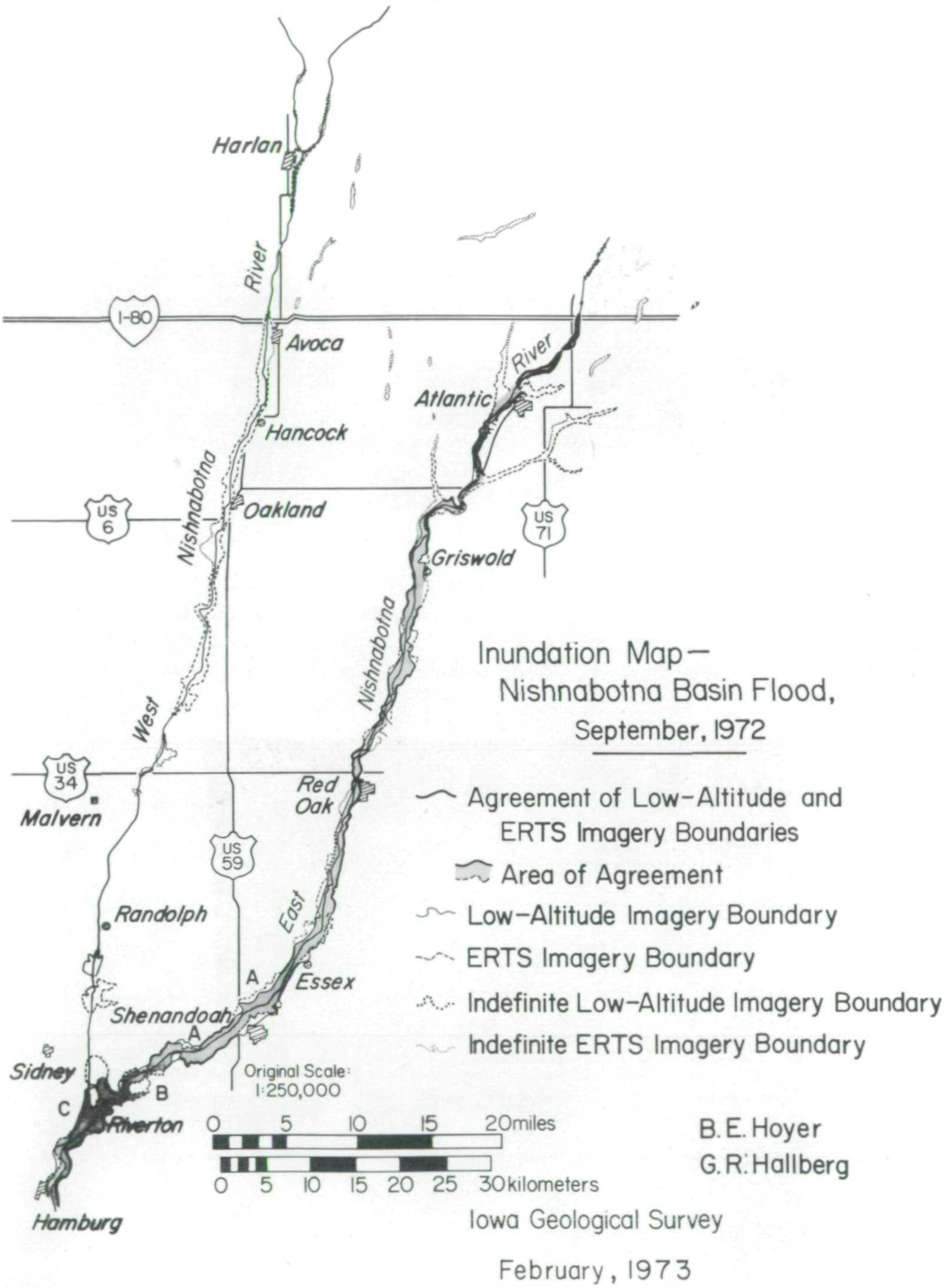


Figure 11. Flood inundation map showing of low altitude and ERTS-1 imagery of the Nishnabotna Basin flood.

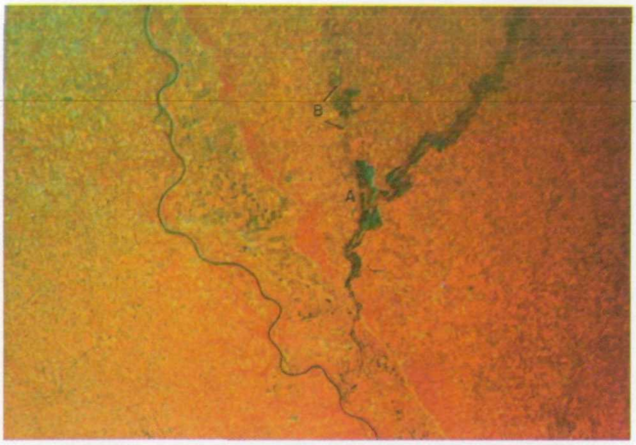


Figure 12. Color infrared composite, of the same area in Figures 6 and 7. The red area near A is a stand of lowland trees which were flooded, but were not stressed enough to reduce their infrared reflectance. This is a potential source of error in flood mapping from ERTS imagery, especially when using the black-and-white infrared band alone (see Figure 11, at C and Figure 7). Areas at B on the West Nishnabotna were not flooded.

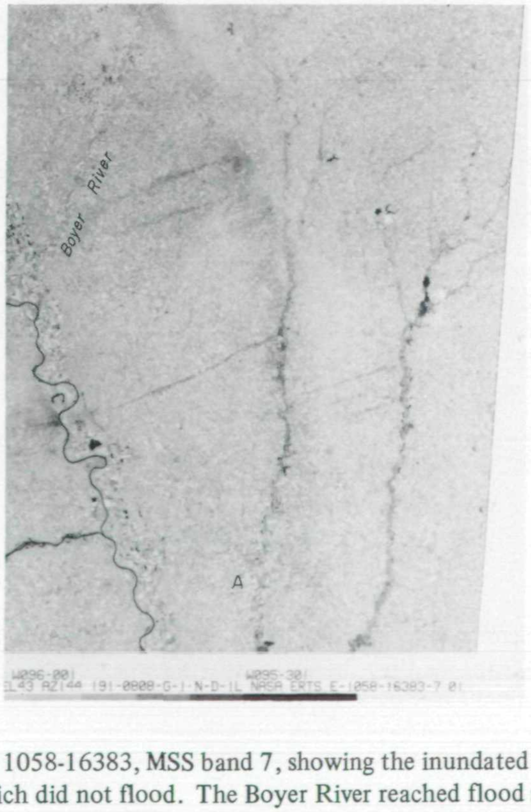


Figure 13. Portion of image 1058-16383, MSS band 7, showing the inundated areas, and areas along the West Nishnabotna (at A) which did not flood. The Boyer River reached flood stage but no overland flooding can be interpreted from the imagery. This interpretation was substantiated by ground data.

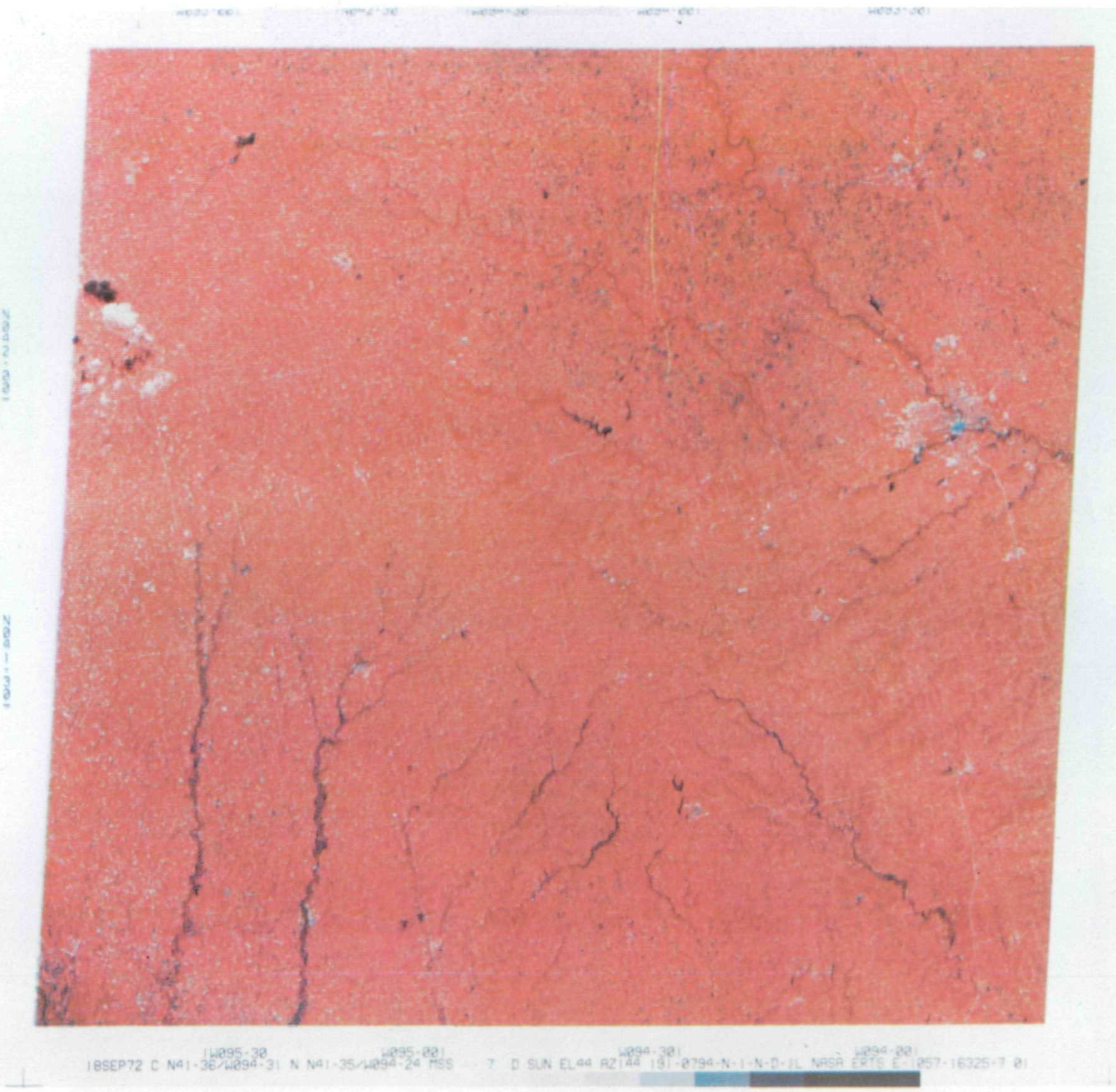

Figure 14. Color infrared composite of September 18, 1972 ERTS image, 1057-16325, showing the inundated areas in the Nishnabotna River Basins (southwest area of picture), the Nodaway River Basin (south-central), and the Grand River Basin (southeast).

# AGRICULTURE, FORESTRY AND RANGELAND RESOURCES

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It is particularly appropriate at this time, as we are approaching a new crop year, to consider what has been possible in the application of Earth Resources Technology Satellite imagery to real and practical problems.

Examples will show that, in the areas of agriculture, forestry, and rangeland resources, data from the ERTS-1 satellite are beginning to be of substantial significance. The reports presented here at the Symposium on Significant Results Obtained from ERTS-1 establish that we are on the threshold of a great new era of better response to the informational needs of these three essential resource areas. These are results from just the end of one growing season; the full power of the ERTS-1 system has not yet had an opportunity to perform.

In our reviews, we are concerned with a major part of an informational system designed to facilitiate rational decision-making in all disciplines related to earth resources. The large area coverage of a single scene from the ERTS-1 satellite provides a perspective of county, state, and regional problems never before possible. In addition, the repetitive coverage of the system is especially well-suited to the seasonally changing scene so important to the analysis and understanding of agricultural, forestry, and rangeland resources problems. In its total form, the ERTS is an intimately interactive system of satellite, aircraft, human beings, and computers, each playing an essential role.

Twenty-five investigators reported in the Agriculture, Forestry, and Rangeland Resources Section. A summary of the subjects on which they reported provides a perspective of the scope of the conference. Table 1 classifies the work of these investigators as they considered various aspects of agricultural crop, rangeland, and forestland production and use. Twenty-two papers were concerned with agricultural crops problems, fourteen with rangeland questions, and thirteen with forestry questions or problems.

Table 2 classifies some of the papers in terms of more specific resource considerations or approaches. Four of these applications are narrow–essentially points of single-discipline concern. Five investigators reported on the use and application of an integrated, multidisciplinary approach to resource inventory and evaluation. I labeled this group Ecological Resource Inventory because it provides an information base broad enough to fill many of the needs of a diverse user clientele which must make decisions on agriculture, forestry, and rangeland problems.

Table 1

Number of Investigators Concerned with Broad Classes of Features.

INVENTORY

| Resource Area | Recognition | Acreage Estimate | Production | Monitoring | Insects and Disease |
|---|---|---|---|---|---|
| Agricultural Crops | 12 | 7 Investigators | 2 | | 1 |
| Forestry | 8 | 8 Investigators | 1 | 3 | 1 |
| Rangeland | 9 | 9 Investigators | | 5 | |

Table 2

Number of Investigators Concerned with Specific Resource Features.

| Soil Mapping | Ecological Resource Inventory | Fire-Related | Water Resources | Erosion |
|---|---|---|---|---|
| 4 | 5 | 3 | 5 | 1 |

It is also informative to consider the interpretive approaches of various investigators. Table 3 shows the number of investigators who utilized only ERTS data, as compared to both ERTS and aircraft imagery in mutual support. The summary also groups those who applied purely human interpretation techniques in image analysis as compared to those who used a human-computer interrelating system to derive the needed information from data provided by the satellite. From this, it is obvious that much of value can be learned from the ERTS data without expensive and complicated analytical equipment; a knowledgeable individual with a problem to solve is the main requisite.

The selection of exemplary reports was made by a panel of three persons. The following works provide a perspective of the scope and depth of accomplishment of all ERTS investigators in the primary renewable land resource areas–agriculture, forestry, and range. In the agricultural crops area, considerable attention is given to development of a new technology to better serve the statistical information needs for food production planning, distribution, warehousing, and marketing.

The initial agricultural crops inventory work is being done on two bases: (1) identification by matching the image changes over time for a specified field with an agronomic crop calendar; and (2) computer analysis of the way in which the image of a specified field changes as one views it with the four separate kinds of energy recorded by the satellite

Table 3

Systems Used for Interpretation by the Reporting Investigators.

| ERTS Alone | ERTS With Aircraft | Human PI | Computer Interpretation |
|---|---|---|---|
| 12 | 13 | 19 | 13 |

Table 4

Imperial Valley Crop Calendar for ERTS-1 Detected Field Conditions

| Crop Type | Field Condition Code by Date | | | |
|---|---|---|---|---|
| | August 26 | October 1 | November 6 | December 12 |
| Field Crops | | | | |
| Barley (Pasture) | 4 | 2 | 1 | 1 |
| Barley (Grain) | | 4 | 3 | 2 |
| Sorghum | 1 | 5 | 5 | |
| Oats | | 4 | 3 | 2 |
| Wheat | | 4 | 4 | 3 |
| Corn (Grain) | | | 4 | 3 |
| Grass (Bermuda and Alicia) | 2 | 2/1 | 1 | 1/5 |
| Grass (Rye) | 4/3 | 3/2 | 2 | 1 |
| Grass (Sudan) | 1/5 | | | |
| Alfalfa | 1/4 | 1/2 | 1/2 | 1/2 |
| Sugar Beets | 3 | 2/1 | 2/1 | 1 |
| Cotton | 1 | 1 | 5/4 | 5/4 |
| Rape | 3 | 2 | 1 | 1 |
| Vegetable Crops | | | | |
| Lettuce | 3 | 2 | 2/1 | 1 |
| Mustard | 3 | 2 | 1 | 1 |
| Cabbage | 4 | 2 | 1 | 1 |
| Cantaloupe (Fall) | 1 | 1/5 | | |
| Cantaloupe (Spring) | | 4 | 3 | 2 |
| Cucumbers (Fall) | 2 | 1/5 | | |
| Cucumbers (Spring) | | 4 | 3 | 2 |
| Watermelon | | | 4 | 3 |
| Tomatoes | | | 4 | 3 |
| Carrots | 3 | 2 | 2/1 | 1/2/5 |
| Onions (Bunching) | 2 | 1 | 1 | 1/5 |
| Onions (Dry) | 4 | 4 | 2 | 2 |
| Squash (Summer) | 2 | 1/5 | | |
| Field Condition Code Legend: | 1 - (Red) growing crops; 2- (Purple) wet soil seeded crops; 3- (Lavender) plowed soil; 4- (White) bare soil; 5- (Yellow) harvested stubble). | | | |

sensor system. These view the subject in green light, red light, and in reflected energy from two separate near-infrared regions just beyond the visible part of the electromagnetic spectrum.

Figure 1 shows the Imperial Valley location where successful identification of a large variety of crops (as shown in Table 4) was reported by Johnson and Coleman.[1] By matching the field condition interpreted from the imagery for the four dates shown in Table 4 with a crop calendar, the investigators were able to achieve high success in crop identification. With refinement, they expect to achieve 90 percent accuracy. With use of the ERTS-1 imagery, the authors reported inventorying 8,865 fields in 465,000 acres (1860 $km^2$) of the Imperial Valley, in 40 manhours spread over three days' time. The identification system worked well enough so that they detected and inventoried a new crop, Alicia grass (a variety of Bermuda grass) for the first time. They confirmed the presence of the new crop by the interpretation of highflight photography in conjunction with minimal ground checking.

Also working in the area of Figure 1, Coleman[2] reported an inventory of cotton plow-down status for 800,000 acres (3200 $km^2$) of cotton in the Imperial Valley, California. Pink cotton bollworm is controlled only by carefully regulating the period during which all cotton plant material is plowed under. Supervision of this control program requires accurate and timely determination of plow-down effectiveness. With current ground enumeration methods, this inventory requires an average of 128 manhours, and completing the task on time is a continuing problem. Coleman reported completing such an inventory in 16 man-


Figure 1. An ERTS-1 image of the agricultural region of the Imperial Valley, California, overlayed by a field grid to facilitate analysis.

hours of image interpretation to yield the 9:1 benefit in favor of using ERTS imagery over conventional ground methods.

As an example of computer analysis of crop type and acreage, Figure 2 and Table 5 are illustrated by the work of Bauer.[3] With the accuracy levels indicated in Table 5, he reported the identification and acreage of corn shown in green and of soybeans shown in red, and of other crops shown in yellow. This computer rendition of the analytical results is from the satellite data in digital tape form. The author reported 80 percent or greater accuracy of classification and found one set of samples used to "train the computer" to be applicable over a distance of 15 to 25 miles (24 to 40 km). As time can be entered

Table 5

Comparison of Area Estimates.

| | ERTS | USDA |
|---|---|---|
| | (Percent of Total Area) | |
| CORN | 40 | 40 |
| SOYBEANS | 23 | 17 |
| OTHER | 37 | 43 |

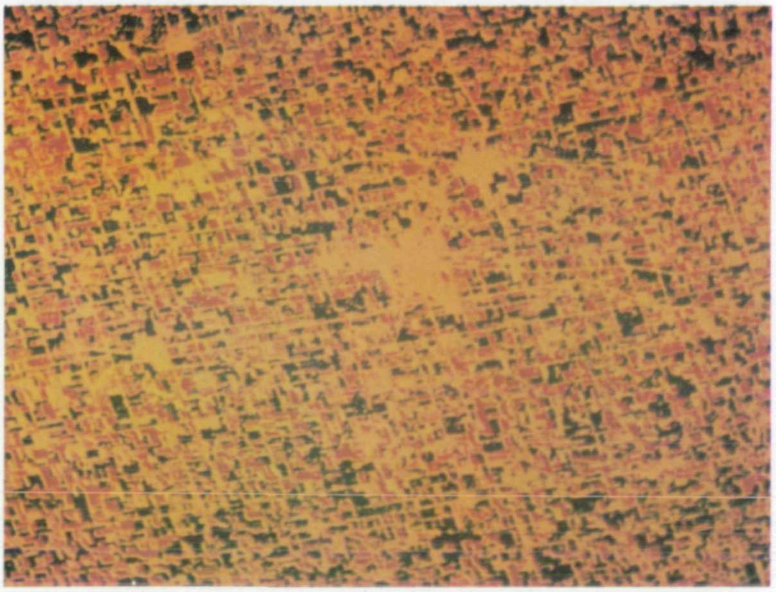


Figure 2. A computer classification from the digital satellite record. Areas classified as corn are shown in green, soybeans in red and other crops in yellow.

as a variable to utilize the crop calendar approach in addition to the multispectral signature analysis from which these data were derived, greater levels of accuracy and discrimination of more crop types should be possible.

Bizzell, et al.,[4] reported the computer recognition of corn and popcorn crops with 90 percent and 70 percent accuracy, respectively. The successful separation of these two closely-related crops fesults from a sharp difference in their tasseling time. This developmental difference produces a sharp contrast in image characterisitcs. Most investigators on related topics reported accuracy levels ranging from 70 percent to 90 percent, with many seeming to cluster in the 80 percent region.

Figures 3 and 4 illustrate the way land-use and crop-type maps can be quickly updated from ERTS imagery. The map on the left side of Figure 4 is an updated and improved version. In Figure 3, notice how the cropping patterns, and thus the combinations of crop types, produced on the various soils and geologic materials in the Sacramento River delta area are easily detected and mapped. Improved and updated crop-type stratifications such as these could be an initial step in sampling studies to sharpen and improve crop production statistics.

The digital tape data from the ERTS-1 satellite permits one to analyze, by computer methods, the unique signatures for areas only slightly in excess of 1 acre (0.4 hectare). The po-

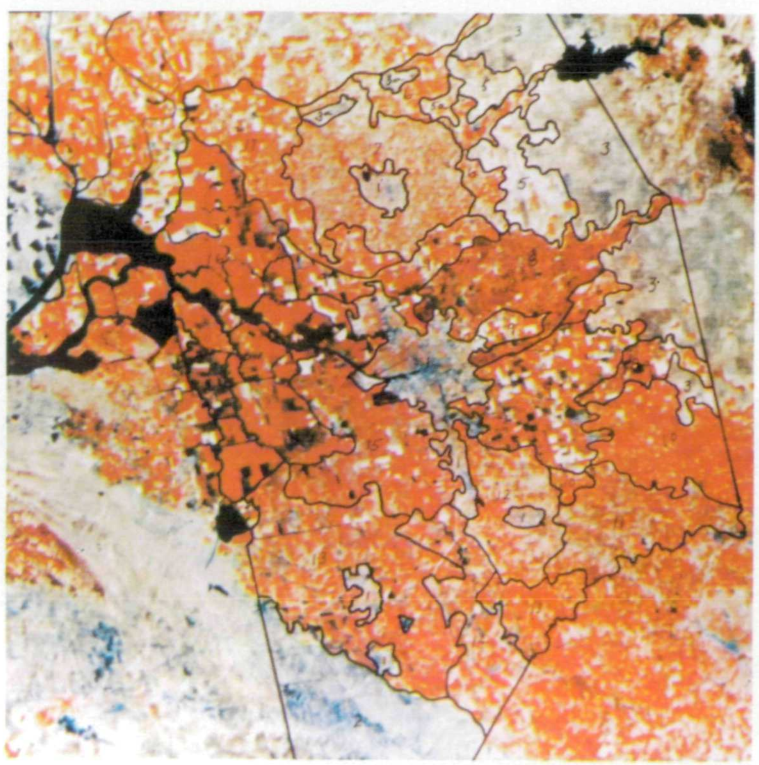


Figure 3. Agricultural land use and crop type discrimination on ERTS-1 color reconstituted imagery.

tential power of the digital data systems illustrated in this next example. At the proper season of the year, rice was shown by four investigators, Thomson[5], Poulton and Welch[6], and Heydt[7], to have a highly identifiable, unique signature (Figure 5). In the initial phase of an experiment by Thomson, the rice acreage in the area covered by Figure 5 was estimated at 1030 acres (41 $km^2$), with a true acreage from USDA records of 1221 acres (49 $km^2$). Instead of the apparently uniform, deep red fields shown in Figure 5, critical examination of the digital data revealed field patterns as shown in Figure 6. The lineations through the field in this figure are the ditches, canals, and non-producing field borders typical of rice cultures in this California study area. Following the initial area estimate, Thomson performed a revised analysis in which he considered both the crop recognition algorithm and also a special analysis to evaluate the field border problem. This analysis yielded a revised estimate of 1218 acres (48 $km^2$), comparing favorably with the true acreage, 1221 (49 $km^2$) as shown in Table 6. While these were not reported as final or best estimates, this example is certainly illustrative of the power and flexibility of the digital data system in agricultural crops inventory.

The ERTS-1 system enables both stratification and sampling estimates of relatively small areas such as counties or subregions within a state. This suggests that one of the significant benefits of the ERTS will be through development of local crop statistics not now available Even if the accuracy level should remain in the range of 70-80 percent, having such data particularly relevant to the local scene should be of substantial value to growers in their planning, production, and marketing activities.

Table 6
Comparison of Rice Field Acreages Estimated by Recognition and by Recognition Plus Convex Mixtures.

| Rice Field | True Acreage | Recognition Estimate | Recognition Plus Conmixed |
|---|---|---|---|
| 1 | 150 | 119 | 144 |
| 2 | 212 | 174 | 205 |
| 3 | 106 | 71 | 95 |
| 4 | 159 | 130 | 163 |
| 5 | 176 | 149 | 179 |
| 6 | 194 | 173 | 196 |
| 7 | 224 | 214 | 236 |
| TOTAL | 1221 | 1030 | 1218 |

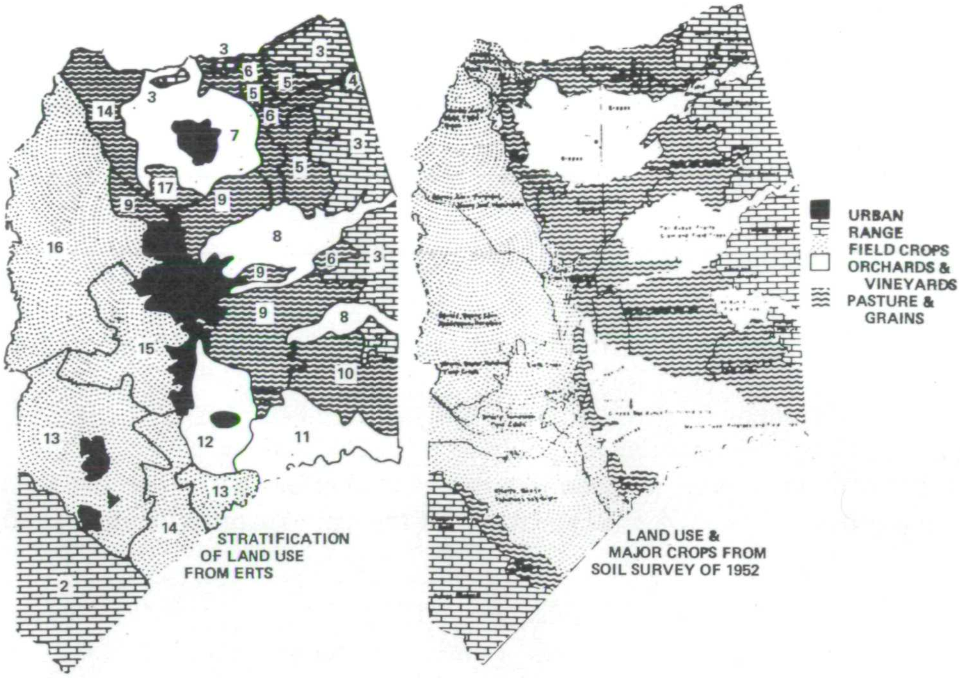



Figure 4. An updating of crop type maps from ERTS-1 imagery interpretation.

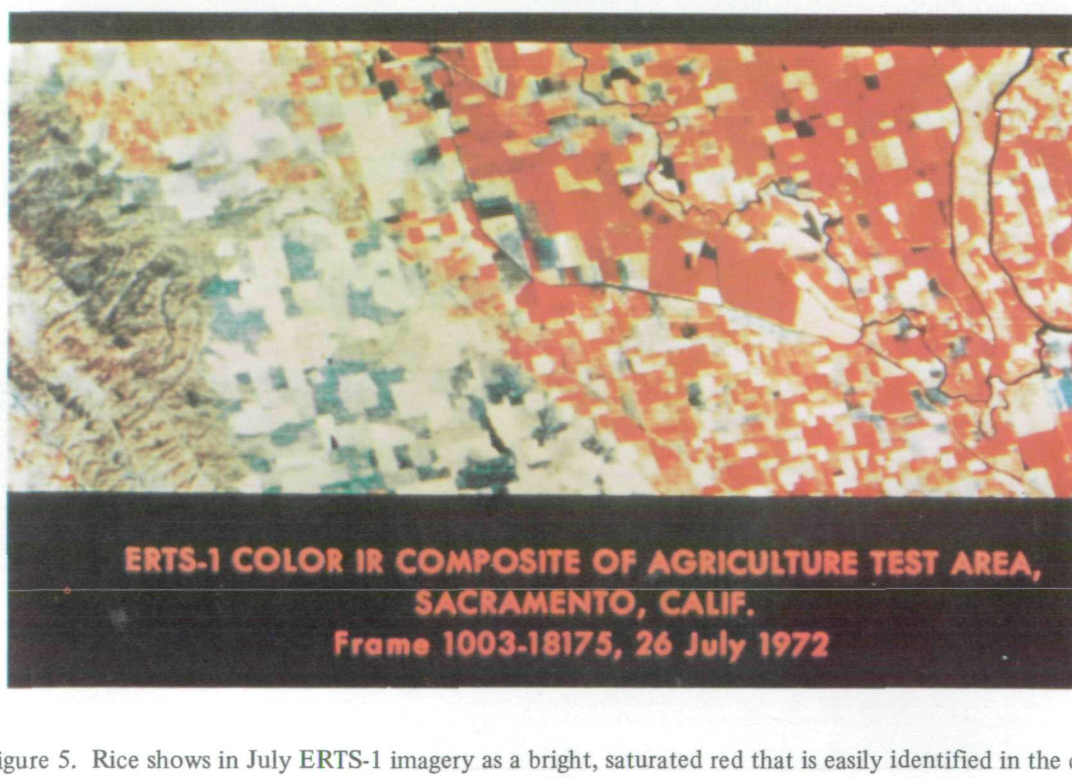



Figure 5. Rice shows in July ERTS-1 imagery as a bright, saturated red that is easily identified in the color reconstituted product.

1973. These investigators learned to read the ERTS images and to draw reliable soils inferences therefrom by comparing the ERTS-1 photographic imagery with an existing soils map in a similar known region (Figure 8). Figure 9 shows the generalization of the same area made by the interpretation of the ERTS "photograph" of the training area. This training area was sampled with aircraft photography to improve on the ability to interpert the space images. Figure 10 shows the generalized soils reconnaissance map produced for previously unknown area by interpretation of the ERTS image. This reconnaissance-level soils map is already being used by the Colombian Transportation Department in making a first approximation of new routing through the study area.

The ERTS system is proving to be an excellent way to engage in foreign aid by helping nations help themselves through the capability of earth resources satellites. This is only one of a number of comparable foreign reports presented in other sessions.

Not all little-known, developing lands are in foreign countries. Anderson, Shapiro, and Belon [11] reported a valuable application of ERTS imagery in improving the natural vegetation and geological map of an approximate 7000-square mile (28,000 $km^2$) area on the tip of the Seward Peninsula. In the newly developing lands program in Alaska, this improved information has a virtually inestimatible value because Alaska lacks the comprehensive resource inventories that would be desirable for its land and resource allocation activity.

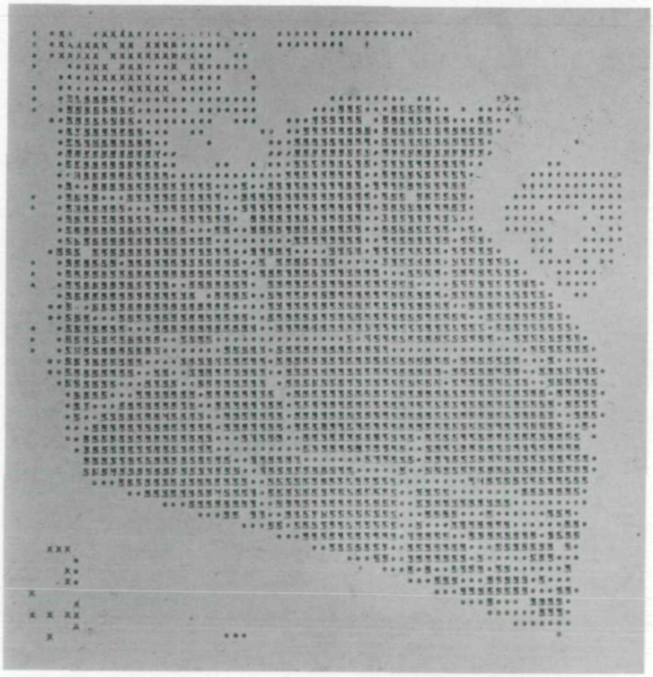


Figure 6. A digital data printout of one of the larger rice fields in Figure 5 showing the complicated "border effects" involved in productive area estimation.

One of the most critical problems in the United States is the disappearance of prime agricultural land that results from essentially unplanned and unguided urban and industrial sprawl. A critical region in this category is the Phoenix vicinity in northern Maricopa County, Arizona. This next example combines work from two investigators, Schrumpf[8], and Draeger[9]. Schrumpf, in discussing new work with the ERTS-1 data, called attention to resource inventory work done by his team with Apollo IX and its supporting highflight photography (Figure 7). In this analysis of the urban-agriculture conflict, the dark brown areas show the available rangelands particularly suitable for new agricultural development if urban sprawl continues to take up the existing agricultural land. The red areas in Figure 7 depict the locations where urban development would not adversely impact future agricultural production. In approaching this problem, Draeger compared the urban area from Apollo IX space photography to the ERTS-1 imagery. Table 7 shows the tremendous acreage of agricultural land that has become urbanized in slightly over three years between Apollo IX and ERTS-1. This table is suggestive of the ease with which certain statistics on land-use change can be documented from space. The impact that such statistics could have on public awareness and on the establishment of land-use policy and necessary controls in critical areas should be self-evident.

In the steppe region of eastern Colombia, Elbersen[10] reported completion of a useful reconnaissance-level soils map in a previously unmapped area west of Puerto Carreño between the Meta and Orinco Rivers in the eastern Colombian savanna region. The project was begun and completed in the period between December 1972 and through February

Table 7
Urban Change In Phoenix Area.

| Town or City | 1969 Urbanized Area (Acres) | 1972 Urbanized Area (Acres) | Amount of Agricultural Land (Acres) Lost |
|---|---|---|---|
| Chandler | 1,920 | 2,880 | 960 |
| Glendale | 4,000 | 6,240 | 2,240 |
| Mesa | 8,320 | 13,440 | 5,120 |
| Phoenix* | 56,680 | 64,680 | 8,000 |
| Scottsdale* | 6,400 | 9,600 | 3,200 |
| Tempe | 7,200 | 15,840 | 8,640 |

*1972 urbanized area totals do not include sparse residential developments in wildland areas.

Figures 11A, B, and C tell the story of what was done to improve and virtually double the understanding of the tip of the Seward Peninsula with only 10-15 man-hours of interpretation time on one ERTS frame. Figure 11A shows the existing resource map of this area, broken into six major types of land. This inventory was completed over a period of a few years and it represented very arduous work. By comparing this map to the ERTS image (Figure 11B) and drawing on local familiarity of knowledgeable scientists, it was possible to increase from six to twelve the kinds of land and resources (Figure 11C) inventoried from the ERTS frame. Notice how the accuracy of type delineation is greatly improved in addition to the recognition of the twelve landscape features as compared to the maps in Figure 11A. After learning to read the images, less than 2 man-days were required to do the interpretation, and the entire task was completed in only a few months.

While the operating scanner system aboard ERTS-1 was not designed for maximum geometric fidelity (map accuracy), the photographic images from the scanner—at a scale of 1:1,000, 000—are surprisingly good in this respect. Tueller[12] and associates in the State of Nevada were the first to lay an uncontrolled mosaic of the entire state. This is shown in Figure 12. It is important that people relate effectively to and fully understand the maps that are required for the cartographic presentation of background information and zoning proposals as well as resource decisions, especially in the area of resource allocation and land use planning. One of the greater values of this kind of photographic rendition is found in the ease with which people unfamiliar with cartography principles and maps relate to information presented or explained on a photographic base. Development of these kinds of mosaics for the nation as a whole should go a long way toward reducing emotionalism in the solution of many natural resources problems and in facilitating regional and national planning. This

Figure 7. A land use and resource capability analysis for from high flight photography projecting lands most suitable for new agricultural development in northern Maricopa County, Arizona.

is but a glimpse of what is to come through a USDA program to produce even better state-wide mosaics for the entire country.

In addition to these values, the speed with which certain kinds of resource information can be extracted by an analysis of the color-reconstituted ERTS images is illustrated by one example from the work of Tueller. In much of the semi-arid and arid west, an important question is, "How much work has been done to rehabilitate and maximize the production from the rangelands that are so important both to the domestic livestock industry, wildlife production, watershed protection, and to the economy of the included rural communities?" Working from the ERTS imagery of the entire State of Nevada, Tueller developed an updated assessment of rangeland seeding for the whole state with just 3 man-days of interpretation time (Table 8). There are two important points to note with respect to this table. While reasonably good statistics are available for range improvement activity on public lands, it is a laborious and time-consuming job to extract and summarize the information from the records of the diverse managing agencies. Thus, state-wide statistics are rarely kept up-to-date. In addition, it is almost impossible to get an accurate assessment of similar work done by private landowners. The statistics generally are available through a combination of county agent and ASCS offices, but the labor and correspondence required to draw them together are almost prohibitive. While the accuracy of these statistics was not reported, they certainly give a perspective of the activity sufficient for many policy-related decisions, and clearly show that the private sector in land ownership is concerned and doing something about resource rehabilitation.

Seevers and Drew[13] used visual interpretation of space and highflight aircraft photography to monitor the expansion of center pivot irrigation systems and to inventory range sites in the Sand Hills of Nebraska. Figure 13 shows, in the upper right-hand corner, how effectively and accurately land-use change from grazed rangeland to irrigated agriculture can be monitored in this kind of environment. The pattern in the natural vegetation in the lower half of the photograph is exemplary of the "sand hills" site in this region of Nebraska. It consists of a steppe vegetation on the convex, sandy uplands and wet meadows with interspersed lakes in the depressional areas between the old dunes. The nature of this space image was positively confirmed by the examination and interpretation of aerial photography (Figure 14). The appearance of the "sand hills" and other sites on space imagery was confirmed by comparison with highflight aerial photos over known areas. This illustrates one of the many ways aircraft photography supports the interpretation of ERTS imagery. The ability to make these kinds of assessments from the synoptic coverage of space imagery greatly facilitates the coordinated land and resource planning and development in areas such as this where the vegetational, soil, and landform contrasts are distinct.

Figure 15 illustrates one of two nationwide studies reported at the symposium, neither of which could be successfully conducted without the rapid, nationwide, repetitive coverage of the ERTS system. This study depicts the corridors being used in a plant development and growth study. For this purpose, it is imperative to record repetitively and in a relatively short time-span, the greening, maturing, and drying of vegetation both from east to

Table 8
Crested Wheatgrass Seedings
State of Nevada

| | Acres | % Total Arid |
|---|---|---|
| Public Land | 743,407 | 74.9 |
| Private Land | 249,579 | 25.1 |
| Total | 992,986 | 100.0 |


Figure 8. The existing soils map from the Savanna region of Eastern Colombia that was used to train for the interpretation of ERTS-1 imagery in an unknown region of the Savanna region.


Figure 9. A generalized soils map prepared as a step in training for the previously mapped area of Figure 8.

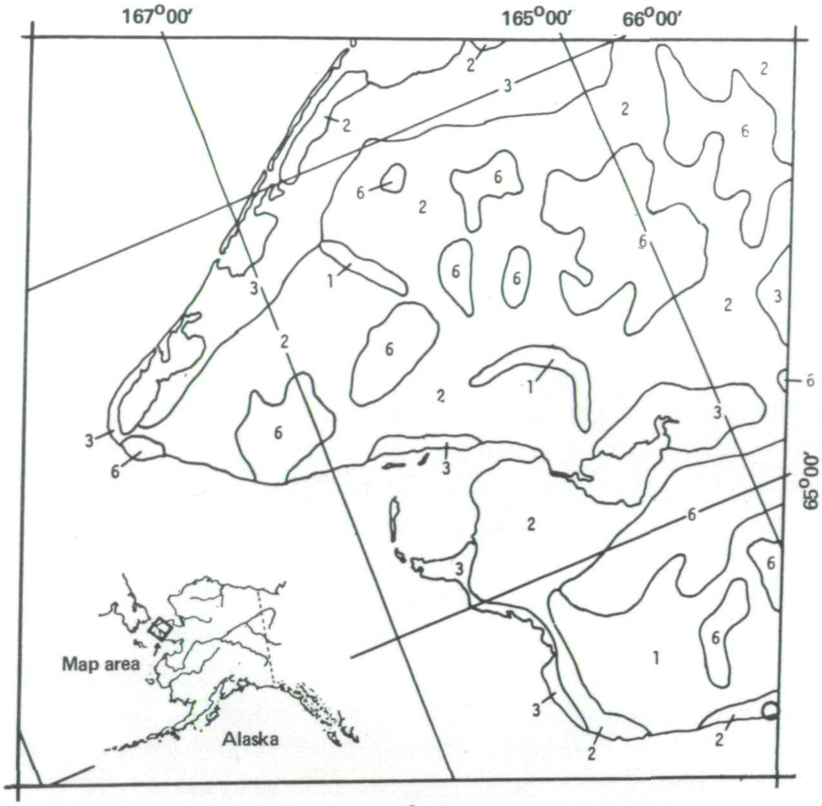
Figure 10. A generalized soil reconnaissance map of a new region of the Colombian Savannas produced by interpretation from the ERTS-1 imagery.

west and south to north. The transects of Figure 15 have been laid out to intersect known gradients, and a nationwide team of collaborators in assisting with the project under the leadership of Deithier[14]. With cloudfree weather, the ERTS system is sure to document vegetation growth conditions on one or more of these corridors in each overpass period.

A more local study of vegetational development in a rangeland environment is illustrated by the work of Carneggie [15]. Here, the concern is in the timing, amount, and rate of development in the California winter-annual grassland type. Determination of this development rate is important in the scheduling of livestock grazing of these ranges and in planning for fire control in periods of unusually lush growth. In the winter of 1972, a series of storms moved into the central interior valley, California, and the San Francisco Bay region generally from a northwesterly direction. This caused an unusual and early flush of growth on the annual vegetation. Carneggie demonstrated how the timing and rate of greening could be monitored with the ERTS system (Figure 16). Figure 17A shows this region prior to appearance of greening of the winter-annual vegetation. Emphasizing the area of particular concern, Figure 17A shows the San Pablo Reservoir area; the upper view is taken prior to greening and the lower view is picking up the winter flush of growth. Note the yellow color in the areas that were previously blue to cream-colored grassy hillsides in dormant condition. Detection of greening by this technique is important in the anticipation and planning of range utilization, especially in areas remote from easy ground-access. Similar observations can lead to the identification of potential drought conditions on the regional and national scale. Putting these two bits of information together, one could more effectively plan the interregional movement of livestock to avoid drought or short feed supplies in one area and to capitalize on abundance in others. Such practices of interregional movement of animals for grazing is not infrequently done under modern management.

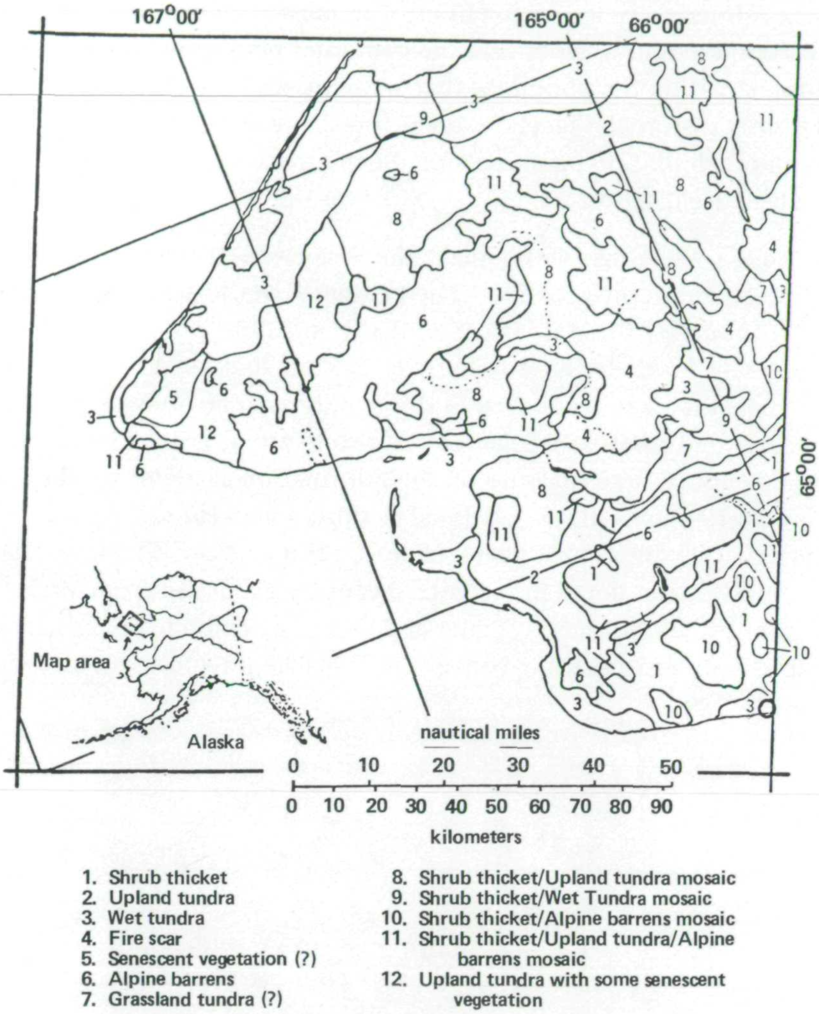
Unusually severe cold weather in the San Francisco Bay region killed thousands of acres of introduced eucalyptus trees. Because of their high oil content and normally heavy ground litter, dead eucalyptus in an area such as this could be catastrophic. The fire risk has always been high and the economic impact of wild fires has been staggering because of the interspersion of suburban dwellings throughout the scenic hillsides. Figure 17B shows extensive areas of dead eucalyptus (creamy white) on color infrared film. They are interspersed with healthy conifers (red color). Millions of dollars will have to be spent to minimize fire hazard from this extremely flammable fuel. A first-stage assessment of the location of the most critical areas could easily be done from ERTS with such contrasty signatures. These ERTS evaluations could then form the basis for more detailed assessment by efficiently locating aerial photography subsamples to derive information for use in developing a fire prevention and control strategy as well as rehabilitation programs. When knowledge obtained on this kind of problem from ERTS evaluation is combined with that exemplified by the green wave evaluation of Carneggie, it is possible to see quickly how a total fire prevention strategy could be more effectively developed in high risk areas such as these.

Forest and range files show very clearly in the ERTS imagery. Forest fires in progress have, in fact, been imaged by ERTS-1. Two investigators reported advantages of more accurate




A

B




C

Figure 11. Maps produced from an ERTS-1 image of the Seward Peninsula, Alaska to improve resource definition for land-use planning, resource allocation, and resource development decisions.

mapping of wild fires in both rangeland and forest environments from the ERTS than had been done by conventional methods. Seevers and Drew reported improved accuracy in mapping a $1,000,000 burn in Nebraska. Substantial errors in estimates where this magnitude of value is involved can have strong impacts on insurance rates as well as being generally misleading as to local economic impact. Lauer and Krumpe[16] demonstrated improved accuracy and timeliness as well as a 10:1 cost advantage in mapping forest fire areas ERTS-1 imagery. Figure 18 shows the comparative maps for one of the 1972 forest fires they analyzed. The left-hand map is a copy of the actual operational map produced to assess the damage of the burn and to project some preliminary rehabilitation and peripheral damage prevention measures. The right-hand map is a computer-generated map from the digital record of the burned area. There was a 3000-acre (12-$km^2$) difference in the two acreage estimates, or a 22 percent error in burned acreage determination by the conventional ground method. Note that the computer map shows considerable acreages of unburned forest within the perimeter that were missed by the ground crew's mapping. These errors greatly distort the facts on direct forest fire impact to say nothing of the indirect effects on rehabilitation planning, etc. Such errors are intolerable, especially in situations involving legal action.

As a final example, I would like to highlight the best cost-effectiveness study reported in the Agriculture, Forest, and Range Session. The Feather River watershed in California is critical to the economy of the state because of a tremendous project to transfer water from the Sacramento River drainage to users in the San Joaquin River drainage. The Feather River watershed is a key watershed in this supply system. Obviously, the maintenance of vegetation cover and careful management of its use are of critical importance. Success in these areas depends in large measure on the information available on the resources of the watershed. Figure 19 shows the vegetational resources map for the Feather River watershed that was prepared after some three years' of work prior to the ERTS investigation. Figure 20 shows the much greater detail in resource inventory produced from aircraft highflight imagery and from ERTS-1 imagery. Lauer and Krumpe conducted a cost effectiveness study of the inventory process using conventional black-and-white photography as compared

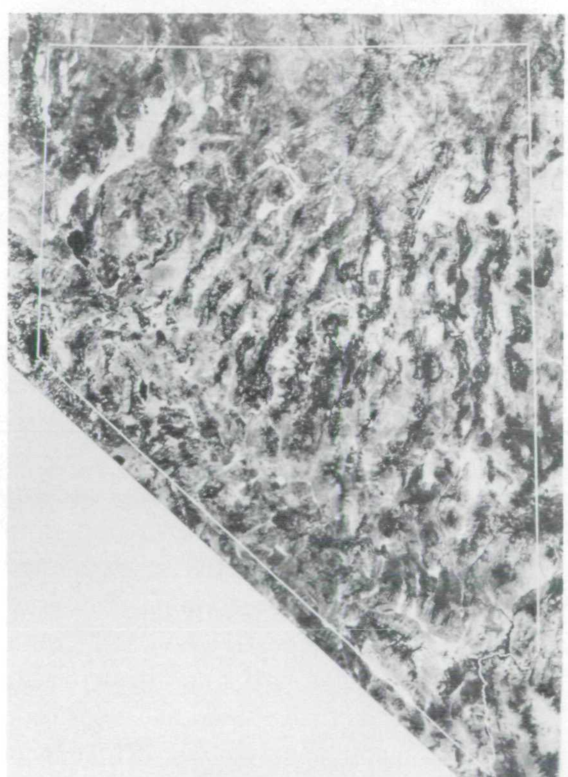


Figure 12. An uncontrolled Mosaic of the State of Nevada laid from ERTS-1, red band imagery.

to the highflight and the ERTS interpretations. The cost-effectiveness comparison of this study is shown in Table 9. The cost-effectiveness of 1:9 and 1:20 for ERTS in comparison to highflight and conventional method is substantial.

This rather carefully conducted study and many of the others that addressed themselves to cost-effectiveness in time and/or dollars strongly suggests two major benefits potentially derivable from an ERTS based resource inventory system in the areas of agriculture, forestry, and rangeland resources. The first will be in the improved cost-effectiveness and the second in the short time lapse (speed of accomplishment) between initiation and completion of inventory projects and timeliness of the results. These advantages are most likely to be realized where the inventories are conducted by knowledgeable people with

Table 9
Interpretation Time and Costs Associated with the Bucks Lake Study
(50,000 acres)

| Task | B/W Photography | Highflight CIR Photo | ERTS False-Color Image |
|---|---|---|---|
| Delineation of watershed boundary | 6 hours | 1 hour | 0.5 hour |
| Plotting effective areas on photos | 5 hours | 0 hours | 0 hours |
| Interpreter training and testing | 3 hours | 3 hours | 0.5 hour |
| Type delineation and classification | 30.5 hours | 17 hours | 1.25 hours |
| Total time required | 44.5 hours | 21 hours | 2.25 hours |
| Hourly wage | $7.00/hour | $7.00/hour | $7.00/hour |
| Total interpretation costs (time) | $311.50 | $147.00 | $15.75 |
| Total cost per acre | 0.622 | 0.294 | 0.032 |
| Cost ratio | 20 | 9 | 1 |

Figure 13. An ERTS-1 color reconstituted image of a section of the Nebraska Sand Hills where domestic range livestock production and pivot center irrigated agriculture are important land uses.

sufficient local experience to minimize ground truth investigations before going operational with an inventory program.

In conclusion, this symposium seems to point to some very definite and worthwhile benefits derivable from an earth resources satellite system as it is applied to the solution of problems in agriculture, forestry, and rangeland resources.

First is the improved perspective that the unusual synoptic coverage provides. Problems can now be put in a regional perspective never before possible.

Secondly, people relate much more effectively to a photo map than to line maps and drawings. Thus, understandability and communication will be enhanced wherever ERTS and highflight "photo maps" can be used as a working base. Citizen confidence in and acceptances of public programs should result.

Thirdly, the synoptic coverage of the system is not a respector of jurisdictional, agency, and political boundaries. Because of this intergrative view, the effective interpretation of the imagery requires a team effort and will, no doubt, act as a unifying force to cause various groups concerned with natural resources within a region to work more closely together as they strive to realize maximum information and benefit from this new technology.

Fourth, no decision is better than the knowledge that supports it or the rationality and perspective with which it is approached. An interactive spacecraft and aircraft information system, coupled with the capability of knowledgeable human beings and computer science and technology, has the potential of vastly increasing the knowledge base and thus of increasing the rationality and tempering the emotionalism with which many natural resources problems tend to be approached. Man and environment will surely be the beneficiaries in this setting.

Fifth, it is important to recognize that the big investment of putting the ERTS-1 vehicle in orbit has been made. It is impossible to equate that cost equitably and fairly against any specified problem because every time one makes a new use or application of imagery derived from ERTS-1, the real cost to all of the rest drops.

New uses and applications and new users are appearing every day.

Sixth, this symposium has clearly shown that it does not require highly sophisticated, expensive equipment or a high level of education to convert ERTS data into highly practical and useful information. In my judgment, some of the most significant papers in

Figure 14. A high flight aircraft photograph of the "Sand Hills Range Site" used as confirming ground truth for ERTS image interpretation.

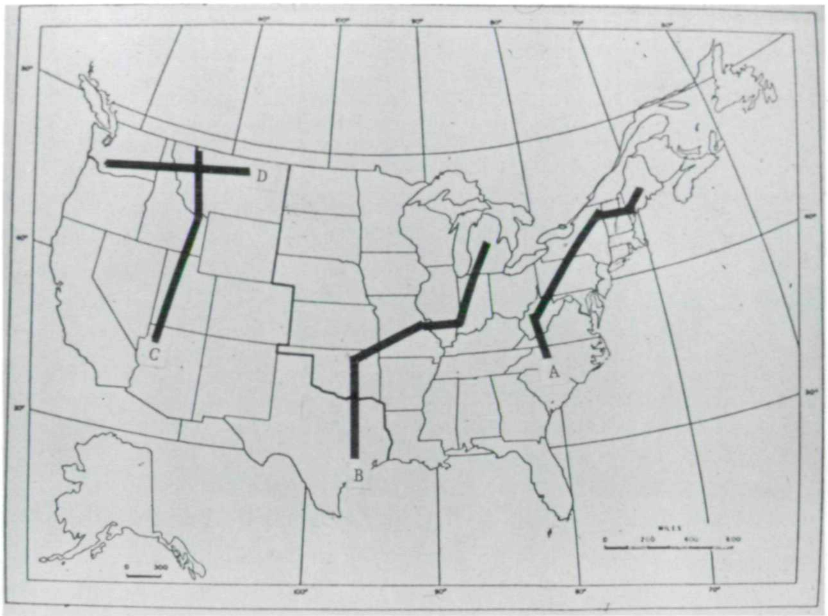



Figure 15. Transects established throughout the Nation to study the "Green and Brown Wave" in natural vegetation and crop plants.

this symposium have reported results simply derived visually by the good eyes and brains of knowledgeable people who are oriented to the solution of real-life problems.

Seventh, the Apollo program drew together one of the most diverse and stimulating national teams of scientists that our time has seen. Now ERTS promises to have the same impact on the international scene as is evident by the international participation in the ERTS program. We are truly on a new horizon with a new door opened to the future which, if fully explored and developed, will see man successfully cope with his environmental problems and meet more skillfully the challenges of the future.

Figure 16. Frost killed Eucalyptus groves in the heavily populated East Bay area near Berkeley, California.

A

B

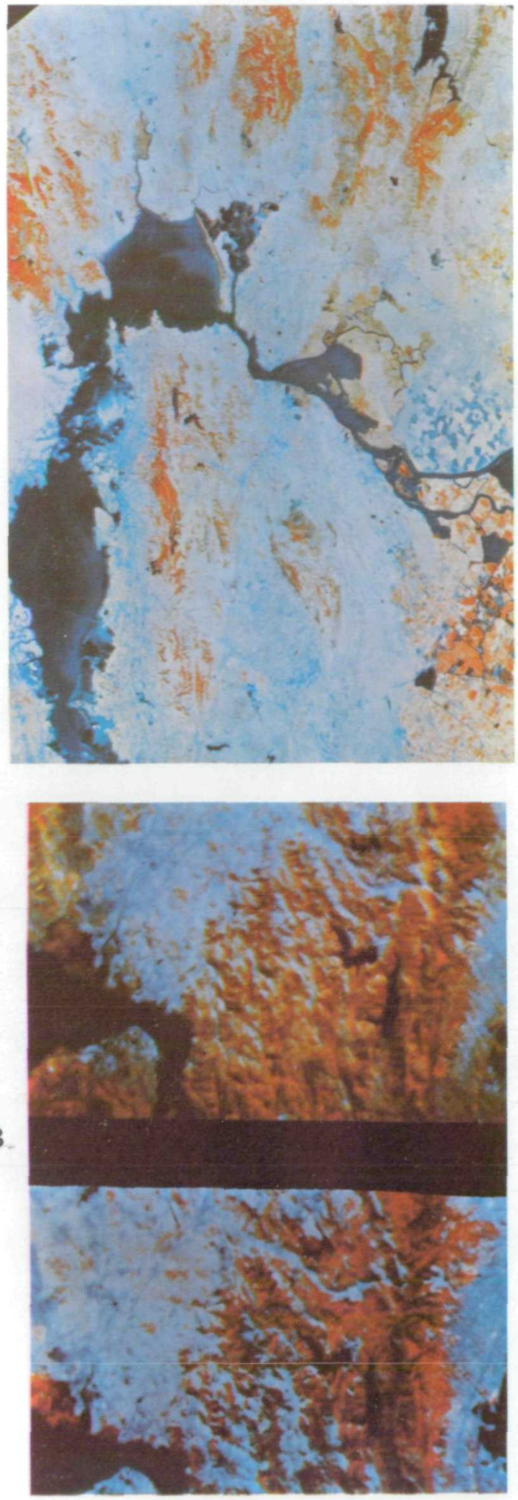


Figure 17. Monitoring the flush of growth on rangeland vegetation in the San Pablo test site, California. (A) San Francisco Bay, Sacramento Delta region. (B) Sequential pair of ERTS photos, San Pablo Reservoir area east of Berkely

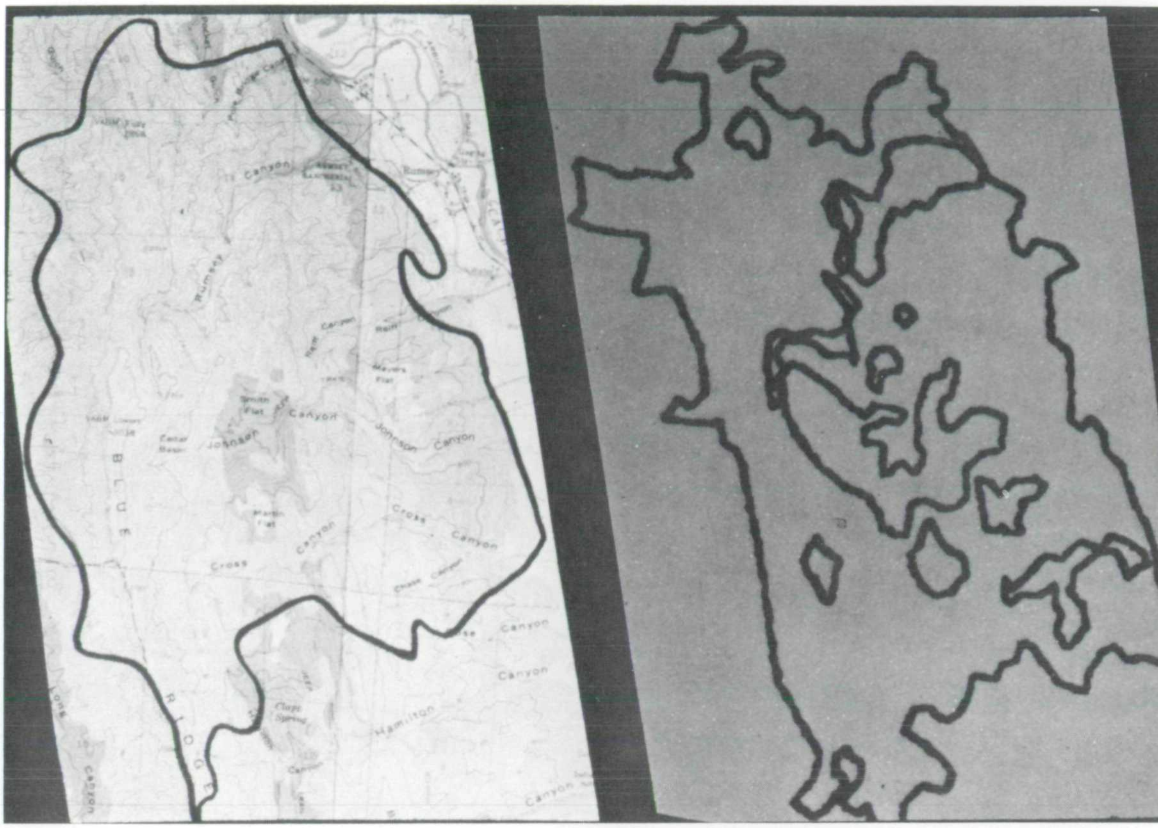



Figure 18. Conventional map of burned area by ground methods (on left) and a computer generated map of the same area from ERTS-1 (on right).

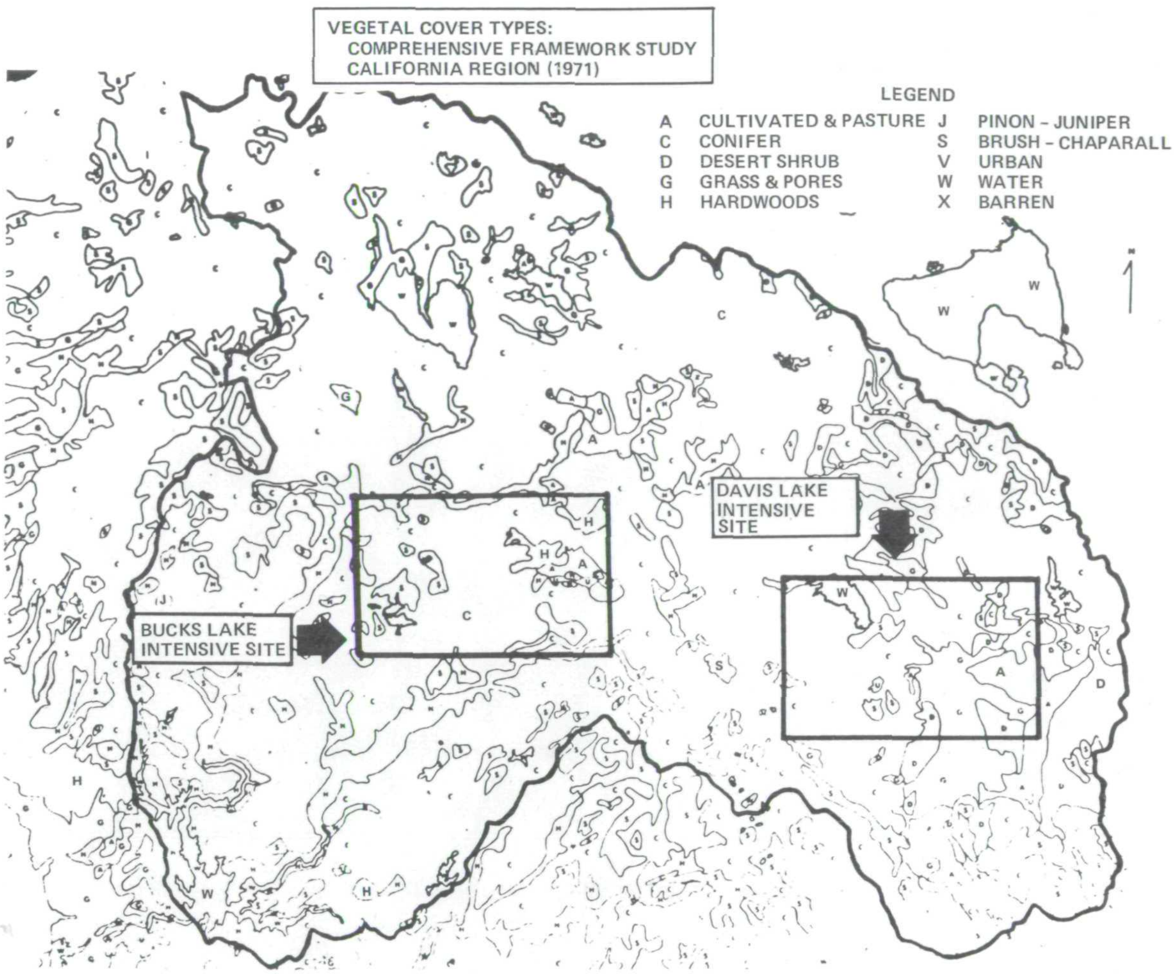



Figure 19. Pre-ERTS resources map of the Feather River Watershed prepared after about three years of work. Includes ten classes of land and resource conditions.

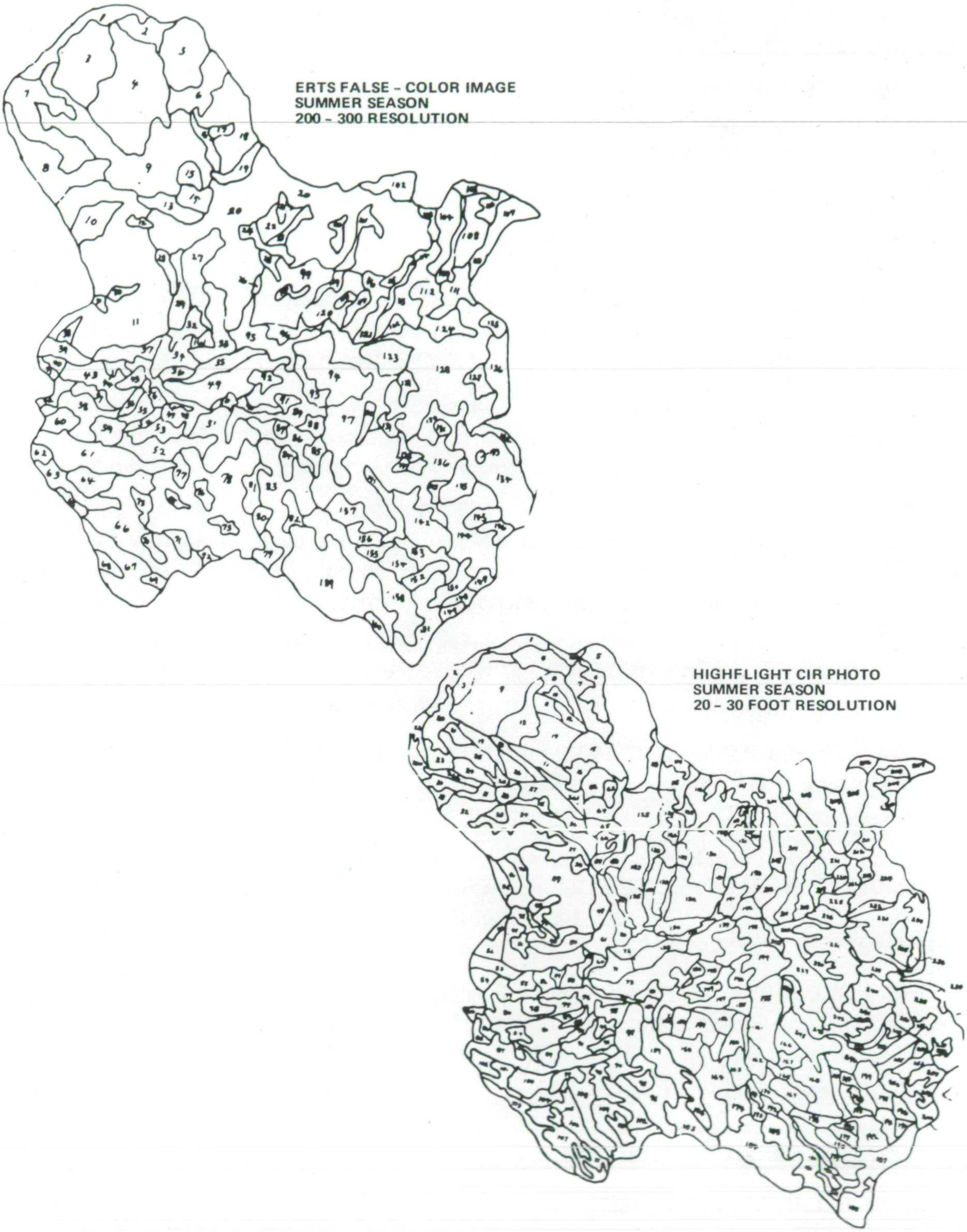



Figure 20. State-of-the-art resource inventory map of Feather River Watershed prepared from high flight (on the left) and from ERTS-1 (on the right). Compare the delineation density as an index to the amount of information developed by the various techniques.

## REFERENCES


1. Johnson, C. W., and Coleman, V. B., 1973, Semi-automatic Crop Inventory from Sequential ERTS-1 Imagery. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

2. Coleman, V. B., 1973, Evaluation of Remote Sensing in Control of Pink Cotton Bollworm. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973.)

3. Bauer, M. E., 1973, Identification of Agricultural Crops by Computer-Processing of ERTS MSS Data. *Abstracts, Symposium on Significant Results Obtained from ERTS-1.* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

4. Bizzell, R.M., Wade, L.C., Prior, H.L., and Spiers, B., 1973, The Results of an Agricultral Analysis of the ERTS-1 MSS Data at the Manned Spacecraft Center. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

5. Thomson, F. J., Crop Species Recognition and Mensuration in the Sacramento Valley. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

6. Poulton, C.E., Welch, R.I., 1973, An interregional Analysis of Natural Vegetation Analogues Using ERTS-1 Imagery. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

7. Heydt, H. L. and McNair, A. J., 1973, Engineering Analysis of ERTS Data for Southeast Asian Agriculture. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

8. Schrumpf, B. J., 1973, Natural Vegetation Inventory: An Abstract of a presentation to the Agriculture/Forestry/Range Resources Session (Oregon State University, Corvallis, Oregon). *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

9. Draeger, W.C., 1973, Agricultural Applications of ERTS-1 Data. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

10. Elbersen, G. W. W., 1973, Interpretation of ERTS-MSS Images of a Savanna Area in Eastern Colombia. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

11. Anderson, J. H., Shapiro, L., and Belon, A. E., 1973, Vegetative and Geologic Mapping of the Western Seward Peninsula, Alaska, Based on ERTS-1 Imagery. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

12. Tueller, P. T., 1973, ERTS-1 Evaluations of Natural Resources Management Applications in the Great Basin. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

13. Seevers, P. M., and Drew, J. V., 1973, Evaluation of ERTS-1 Imagery in Mapping and Managing Soil and Range Resources in the Sand Hills Region of Nebraska. *Abstracts, Symposium on Significant Results Obtained form ERTS-1.* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

14. Deithier, B. E., 1973, Phenology Satellite Experiment. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

15. Carneggie, D. M., 1973, Monitoring California's Forage Resource Using ERTS-1 and Supporting Aircraft Data. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

16. Lauer, D. T., and Krumpe, P. F., 1973, Testing the Usefulness of ERTS-1 Imagery for Inventorying Wildland Resources in Northern California. *Abstracts, Symposium on Significant Results Obtained from ERTS-1* (Sponsored by NASA/Goddard Space Flight Center, March 5-9, 1973).

# LAND USE AND MAPPING

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## INTRODUCTION

The almost inevitable establishment of a national land-use program has stimulated many states to begin thinking in terms of developing their own land management programs. One of the critical elements of such a program, however, is a land-use data acquisition and storage system capable of providing planners with up-to-date land-use information. In the past, the financial and manpower requirements for the acquisition of land-use data have made the creation of such a system an impossibility for most states. However, with the successful orbiting of the ERTS system, the situation has changed; many state and county agencies are beginning to view ERTS as a potential method for acquiring the timely land-use information they need. The papers presented have illustrated in a variety of ways the capability of the present ERTS system to provide such information.

## TECHNOLOGY

From the standpoint of technology, the most encouraging thing about ERTS has been the level of land-use identification. Land-use detail has exceeded the expectations of the Interagency Steering Committee and the requirements of land-use classification proposed by the Department of Interior. Whereas in the latter instance it was anticipated that only nine classes of land use would probably be identifiable, in fact some 14 to 18 classes have been identified.

The success in the level of land-use identification results primarily from the various attributes of the ERTS system. These include the ability to provide repetitive coverage, and in particular seasonal coverage; the ability to image in four bands of the electromagnetic spectrum (green, red, and two near-infrared), which allows for manipulation of various combinations of bands; and the provision by the ERTS system of computer-compatible tapes for machine processing of data. Furthermore, the resolution of ERTS imagery has been better than expected. Although there is some question as to its exact resolving power, it is safe to say objects as small as 100 meters (300 feet) in diameter have been identified. Linear features as narrow as 16 meters (50 feet) can be detected (Figure 1).

The aforementioned attributes of the ERTS-1 system have made possible the production of an 11-category land-use map of Rhode Island, a map which, incidentally, was turned out in a matter of 8 man-days (Figure 2).

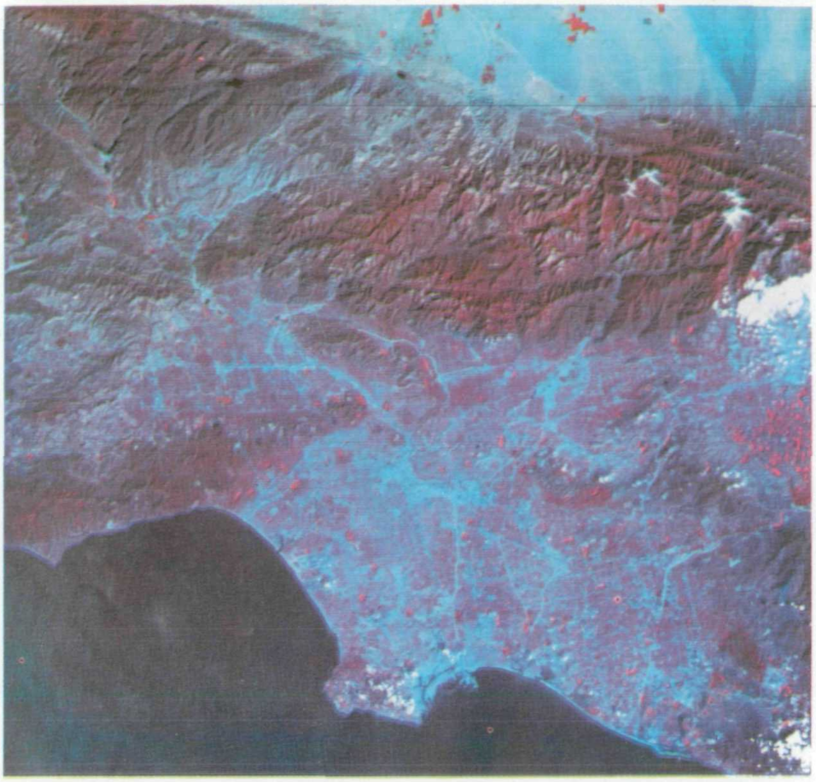

Figure 1. ERTS-1 multispectral scanner image of Los Angeles. The linear street patterns are clearly visible.

Furthermore, the land-use maps produced from ERTS data have displayed considerable accuracy, as illustrated by two maps of the Houston Area Test Site (Figure 3). One of these maps was compiled from high-altitude RB-57 aircraft imagery, the other from ERTS.

Imaging separately in the green, red, and two near-infrared bands allows for manipulation of the imagery as illustrated by photos of Washington, D. C. (Figure 4) and Houston (Figure 5). Such manipulation can be a considerable aid in land-use identification.

Finally, the ability to produce automated land-use maps such as this one of Milwaukee (Figure 6) implies even greater economies in the production of future land-use maps.

## APPLICATIONS

It has become apparent from the discussions of the past two days that the major concern of land-use planners is the rapid destruction of open space by urban expansion. The threatened open space ranges from the deserts of southern California to the beaches and barrier islands of the Atlantic coast. The value of ERTS to this problem is its ability to acquire land-use data for large areas in a short period of time—data that can be used to formulate policy, or at a later date to enforce policy. Using ERTS, the data can be assembled in common format and scale so rapidly that in most cases the resultant action can be initiated months or

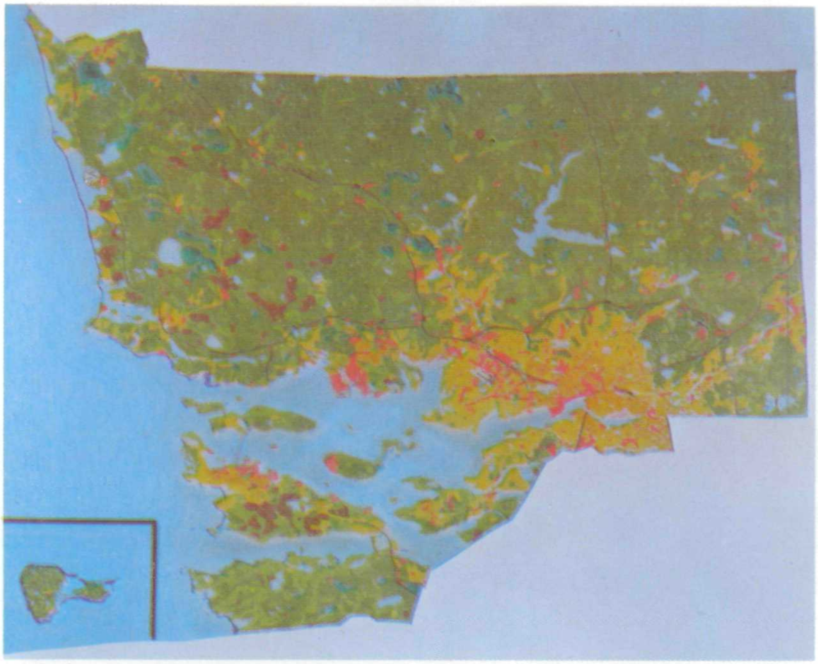

Figure 2. Land-use map of the state of Rhode Island, produced from a single ERTS multispectral scanner (MSS) image in eight man-days (December 1972).

even years earlier than would otherwise be the case. Thus, at county, state, or interstate levels, relatively complex policy can be hammered out and implemented within one or two years' time.

Many states are inventorying their land resources as a first step in the policy formulation process. Michigan, for example, has recently produced a state land-use map of four categories. It has been demonstrated that ERTS can provide additional land-use data to strengthen the Michigan program. Other states, including Wisconsin and Minnesota are also attempting to integrate ERTS data into their land inventory programs. Once a land-use inventory is completed, the repetitive coverage of ERTS provides the opportunity to constantly update that inventory, while at the same time noting the type and direction of land-use change.

As for policy enforcement, several examples have been discussed. In Ohio, the state government may soon use ERTS to monitor the reclamation activities of strip miners, while in Vermont an ERTS photo has been introduced as evidence in court in a suit against the State of New York and the International Paper Company for alleged polluting of Lake Champlain.

It should be emphasized that so far we have discussed primarily applications within the United States. However, the value of ERTS to the countries of the developing world is inestimable. In some locales, the ERTS images are better than any existing maps, so people in these areas eagerly look forward to the production of photo-base metric maps from ERTS imagery.

A

B

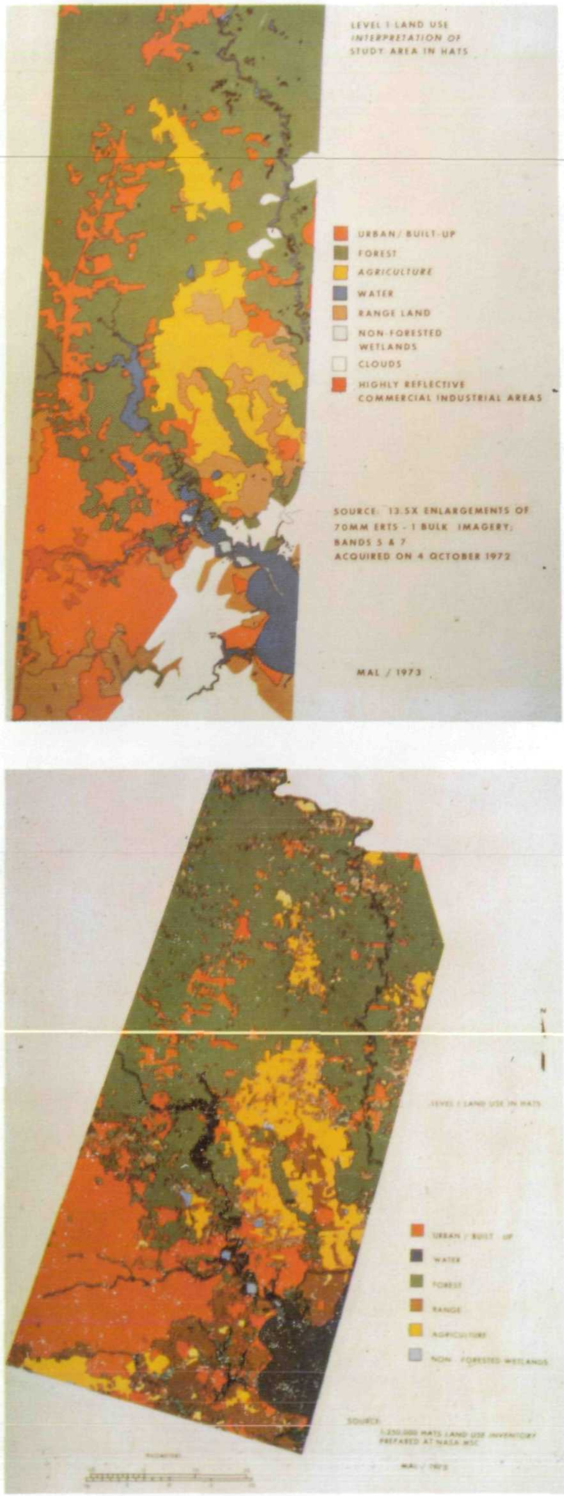


Figure 3. Comparison of land-use maps derived from ERTS-1 and from high-altitude aircraft imagery: (a) the ERTS-1 MSS compilation; (b) the high-altitude aircraft photo version.

Finally, ERTS is cost-effective. By the most conservative estimates, land-use mapping by satellite is cheaper by more than an order of magnitude over land-use mapping from conventional medium-altitude aerial photography. For example, preparing a simple 10- or 12-category land-use map of an average-size state such as Iowa or Illinois by medium-altitude aircraft would cost approximately a million dollars. For the same map legend, and assuming that the cost of mapping is proportional to the scale of the map, to do the same job by high-altitude aircraft would cost only 1/5 as much–about $200,000. By utilizing ERTS imagery the job can now be done for less than 1/12 as much, or approximately $80,000.

In conclusion, it is for the first time economically possible to acquire land-use data quickly and efficiently over large areas. This is an indispensable capability if we are ever to control urban growth and protect our land resources.

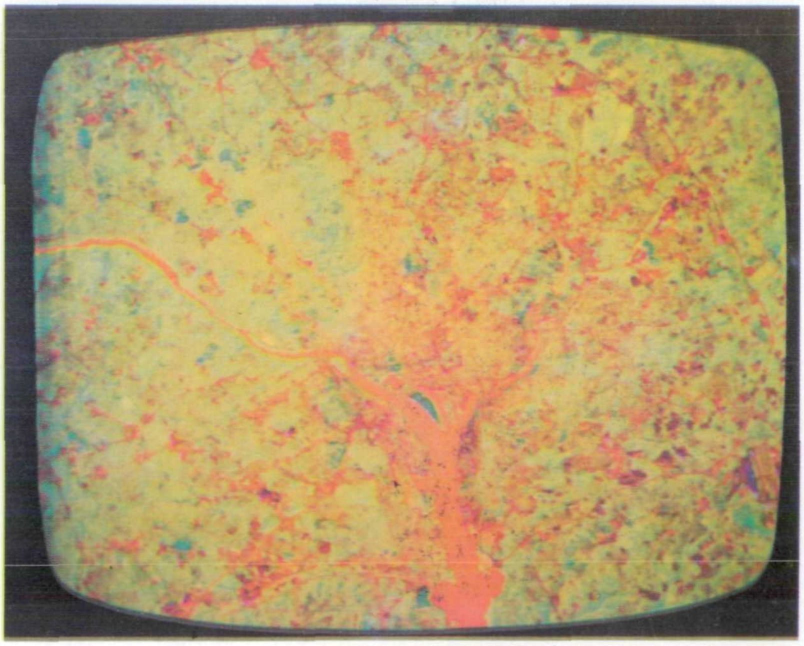

Figure 4. "Density-sliced" image of part of the Washington, D. C., area. The image is from an MSS band 5 (red band) scene acquired on October 11, 1972. Colors have been subsituted here for the different gray-scale values of the original black-and-white image.

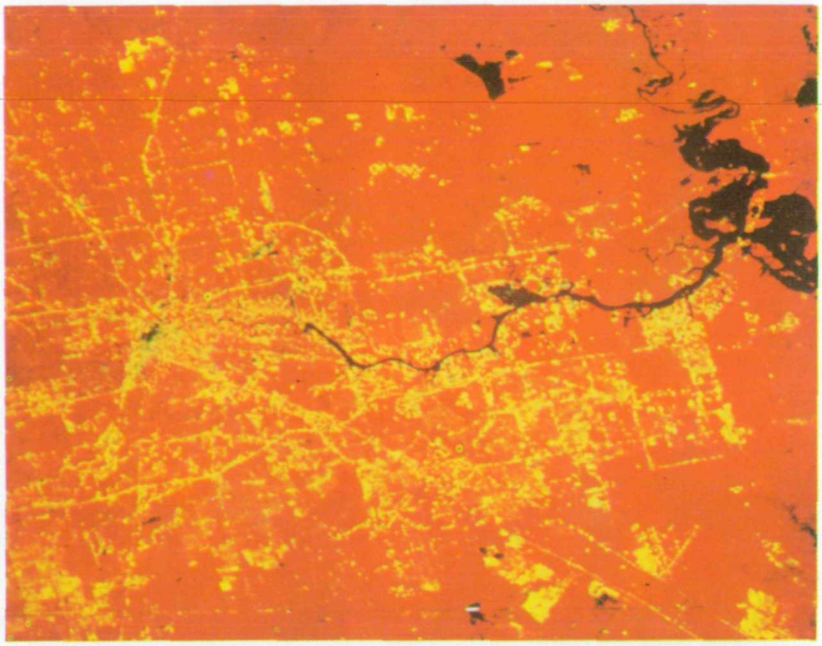

Figure 5. Composite color image of the Houston, Texas, area. Here MSS bands 5, 6, and 7 have been used to produce the composite image, rather than the customary bands 4, 5, and 7.

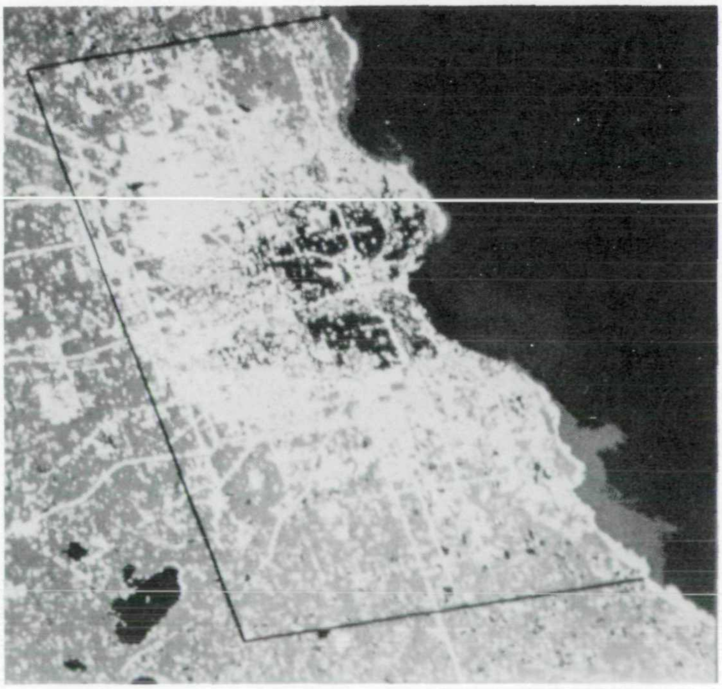

Figure 6. Land-use map from digital tapes. This map of Milwaukee, Wisconsin was produced from MSS digital tapes rather than from visual imagery, using automated computer-implemented, pattern-recognition processes.

# MINERAL RESOURCES, GEOLOGIC STRUCTURE, AND LANDFORM SURVEYS

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We can summarize the results of three days of presentations in the geological and mineral resources field in four categories: four categories in which ERTS has already contributed significantly.

Category one is rather subtle; it has to do with the thinking of the geologist. The availability of ERTS imagery has broadened the scale of geological thinking to a more regional format than it has commonly had in the past. Speaker after speaker at this Symposium has dealt with thousands of square miles, as against the usual reporting by 15-minute U.S.G.S. quadrangles. This change in scale of thinking does not have an immediate, obvious impact, but in the long run it may be one of the most valuable contributions of ERTS, because it may turn out that the solution of many of our problems is based on regional rather than local thinking.

Category two where ERTS has contributed immediately and significantly is in the upgrading of geologic maps. Figure 1 is an example of a new conceptual model of tectonics and metallogenic provinces of southern Alaska, based in part on ERTS imagery. A geologic map, which shows the distribution of rock types at and immediately below the surface of the earth is the basic tool of the geologist. In order to upgrade maps, the primary work in the past has been done in the field, supplemented by aerial photography.

Figure 2 is of an area in Rhodesia, a rather remote area with a very complicated geological structure. Existing geological maps of this area did not differentiate the granitic basement rocks nor the subtle extensions of the mineralized greenstone belts that are apparent on the ERTS imagery. Mining is important in the rich metallogenic provinces of southern Africa, and many of the mineral deposits are associated with the juxtaposition of certain types of rocks. Figure 2 is the geologic map which resulted directly from the interpretation of an ERTS image, based on a model of crustal evolution worked out by a South African investigator. This image gives new meaning to mineral exploration in this area. In addition, the ERTS imagery, which shows a continuity to some granite bodies not previously apparent, enabled the investigator to reinterpret these bodies as a large batholith not previously known from any reconnaissance study.

Additional examples of the extension of known geological structures derived directly from ERTS imagery of Alaska and California are shown in Figures 3 and 4 respectively. Obviously, surface and subsurface methods must be used to check out these extensions, but at

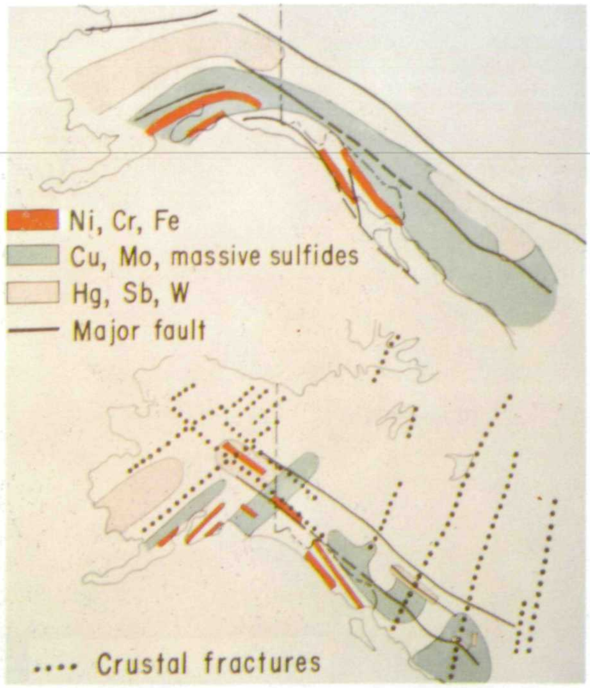



Figure 1. This tectonic and metallogenic-province model of southern Alaska is based in part on analysis of ERTS data.

least geologists know where to go to look for them, based on interpretation of the ERTS imagery.

The seasonal repetition of ERTS imagery is a tremendous advantage, because the presence or absence of vegetation has a real effect on our ability to map geologic boundaries. In addition, one investigator has demonstrated very effectively that light snow cover also aids geologic mapping by etching out microrelief, so that in the course of repetition, those images which show slight snow cover are of real geologic value.

Category three is direct application, consuming about 75 percent of the effort reported by the investigators. The most striking features visible on ERTS imagery, which are difficult to map on ordinary photography, are regional lineaments, or linear patterns in the topography, which have been believed for some years to reflect major fracture zones extending upward from the basement of the earth. It had been previously postulated that such regional lineament patterns might localize ore deposits, the foci of earthquakes, and other geological hazards.

The mapping of lineaments is done almost effortlessly on ERTS imagery. Figure 4*(a)* is a map of the Big Horn Mountains, showing the lineaments that have been derived directly by one investigator from the ERTS image in Figure 4*(b)*. He reported a substantial increase in the number of lineaments that could be mapped in this area, versus those known from field work or larger-scale, smaller-coverage aerial photography. The mapping of such lineaments can be done very rapidly with ERTS and has real potential in locating ore deposits.

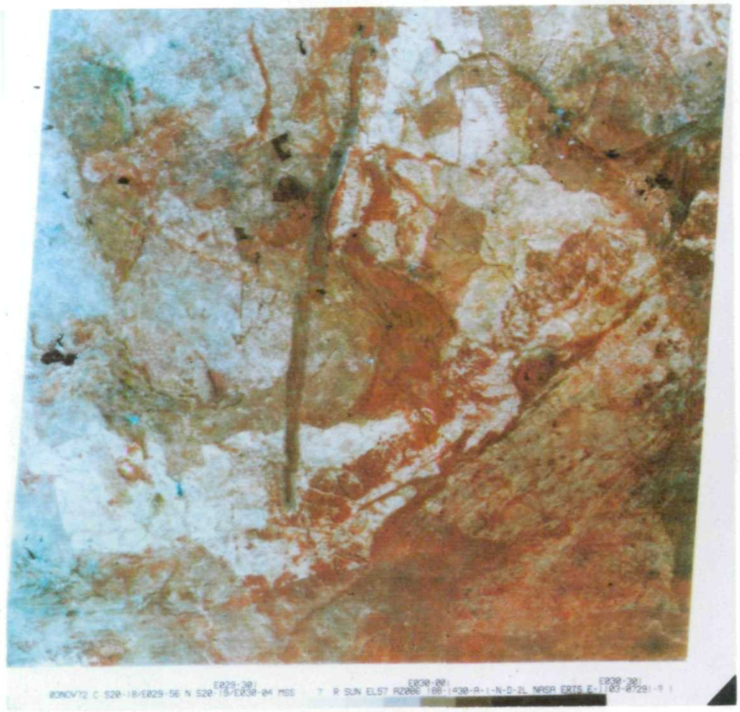
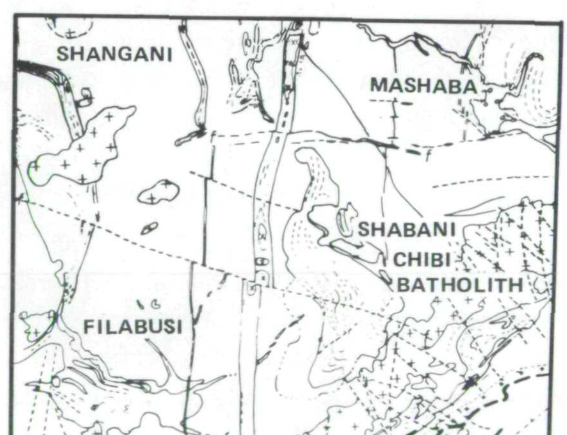


Figure 2*(a)*. ERTS color composite (Nimbus) of Rhodesia, showing the southern portion of the Great Dyke. The greenstone belts (greenish tone) occur marginally to the granite batholiths (light tones). Land use is evident in the rectangular patterns.

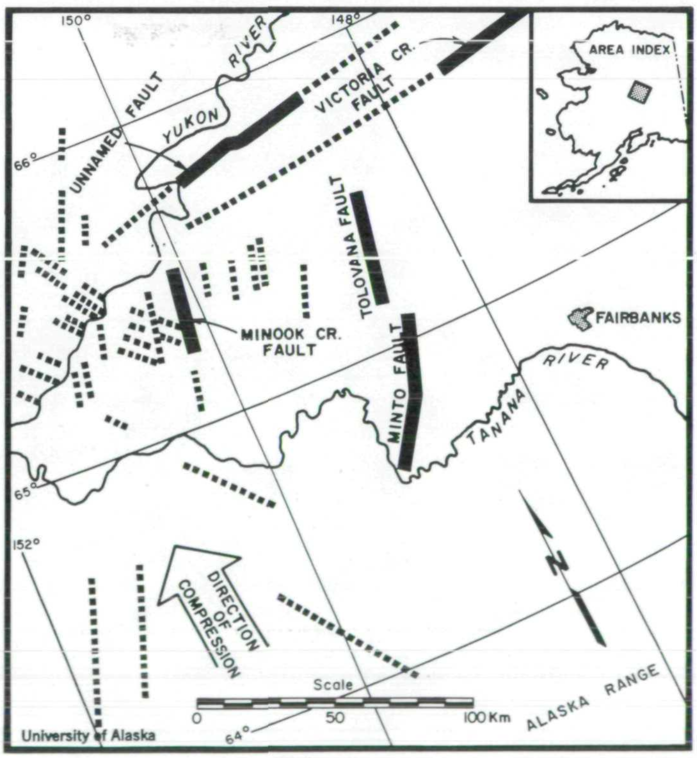



Figue 2*(b)*. Geologic interperetation of Rhodesia based on a crustal evolution model. Note the younger potash-rich granite body intrusive into both the older granite and the greenstone belt.

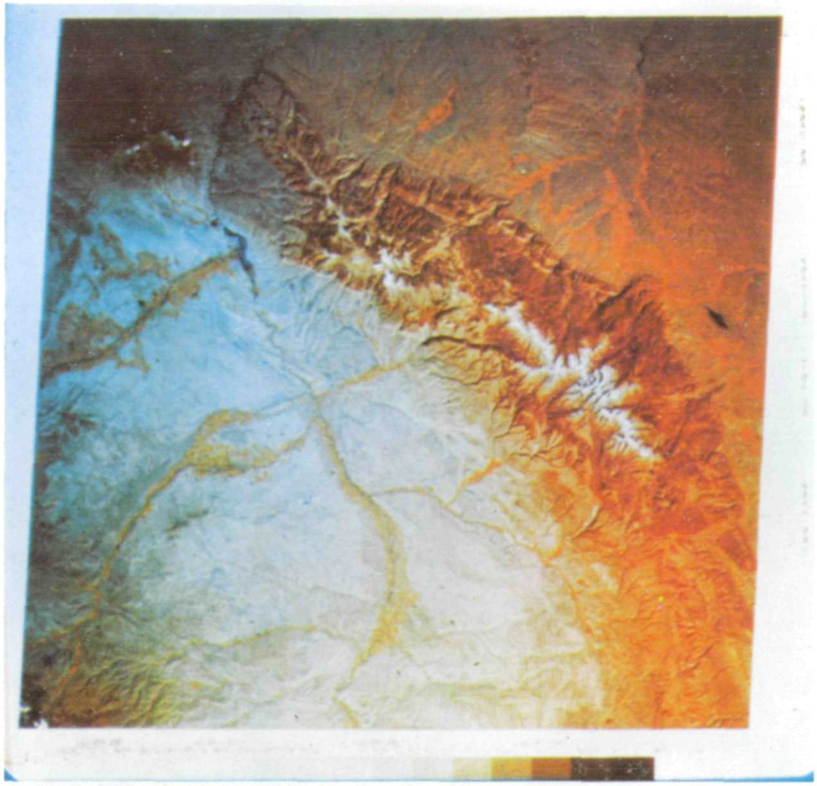
Figure 5*(a)* is an ERTS image of the Las Vegas, Nevada, area. Lake Mead is on the upper right of the image, and Las Vegas is just to the west of Lake Mead. The Las Vegas shear zone comes right through Lake Mead trending northwest-southeast, and this zone of shearing has ore mineralization associated with it. The investigators reported several tens of miles of extension of the Las Vegas shear zone from the ERTS image, an extension not previously known, and therefore a new high-priority area for mineral exploration.

Coming south from Lake Mead, of course, is the Colorado River drainage, the dark line going down the right hand side of Figure 5*(a)*. The map (Figure 5*(b)*) shows the localization of ore deposits (gold, copper, molybdenum, lead, zinc, and silver) along major fracture zones paralleling the Colorado River drainage. Based on the ERTS image (Figure 5*(a)*) a fracture map (Figure 5*(c)*) was prepared of that same area of Arizona and Nevada. Notice the previously reported faulting versus the unreported faulting which has been mapped from ERTS imagery and which again can concentrate mineral exploration efforts. The same type of structural mapping applies, of course, to petroleum exploration, where even at the scale of ERTS imagery, the information can be used to aid and target the more precise, but more expensive subsurface tools, such as seismic exploration and test drilling.

Figure 6*(a)* and 6*(b)* depict the geology and ERTS-1 imagery of a remote area in southern Morocco. Notice the remarkable parallelism between the image and the map in Figure 6*(a)*.




Figue 3. Tectonic interpretation of parts of Alaska. Red lines represent known faults, blue dotted lines are faults and lineaments nearly mapped from ERTS imagery.



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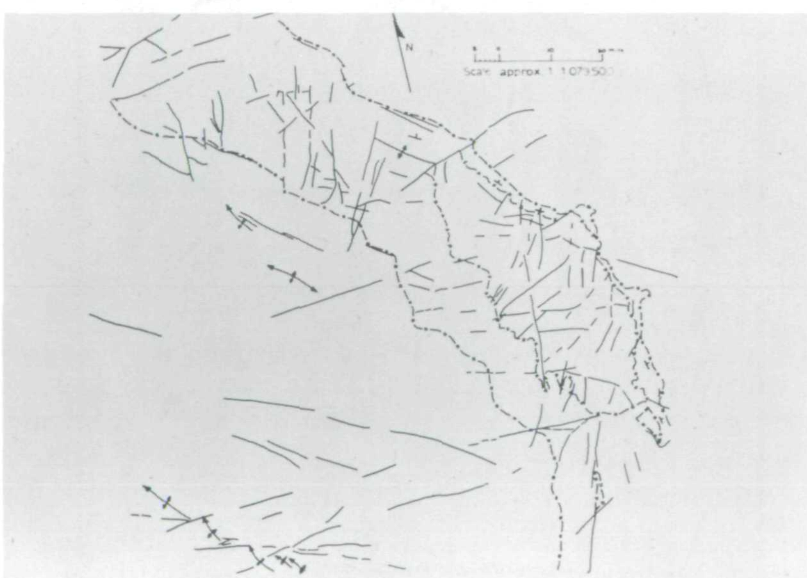



B

Figure 4. The Bighorn Mountains: *(a)* color composite of Bighorn Mountains and the southwest part of the Bighorn basin; *(b)* lineament map of the Bighorn Mountains.

Figure *6(b)* shows the lineaments and structures mapped in this area, along with known mineral deposits.

The point here is that if relationships are found between known mineral deposits and certain types and directions of lineaments, then, obviously, lineaments of similar expression and direction would be first priority areas for continuing exploration. I might add that, for a long time, lineaments have been believed to present an engineering hazard. They commonly are the trace of faults on zones of crushed rock, and in the course of building aqueducts, tunnels, dams, or any large structures which could be affected by weakened or moving rock, the accurate location of lineaments across the projected site of such construction is critical.

Another investigator discussed the location of buried valleys beneath the glacial drift that covers much of the north central United States. The ability to map these buried valleys is critical in evaluating ground water supply, because the gravel contained within them makes one of the finest aquifers in the central United States. Mapping of buried valleys is not only important in determining sources of water, but in some areas is also critical in selecting the location of sanitary landfill; improper location of a landfill may lead to contamination of a water supply.

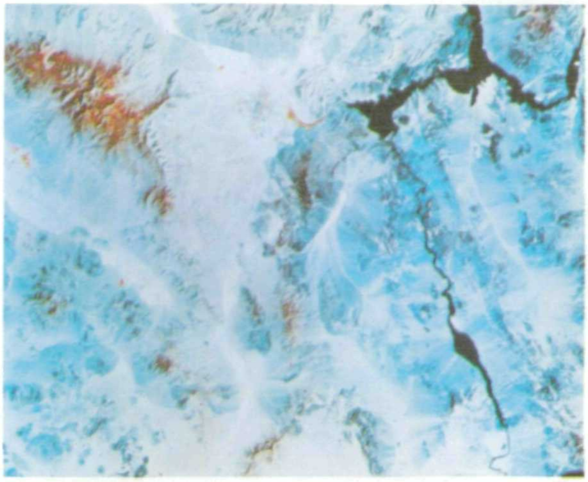
Category four deals with monitoring geological hazards. Here, of course, the repetitive nature of ERTS is critically important. One of the most obvious monitoring applications does not deal, however, with ERTS imagery, but with ERTS as a communications satellite—volcanic monitoring. The U.S. Geological Survey has placed two devices in inaccessible places, sensitive tilt meters and seismometers that record prenuncial activity in volcanoes, activity which precedes activism and volcanic eruption.

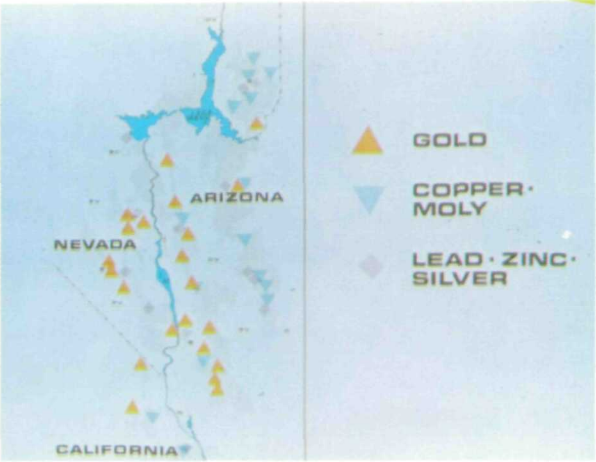
These instruments transmit the information to ERTS which in turn transmits it to Goddard, where it is sent by telephone or teletype to the Geological Survey's Menlo Park center, where the information is very rapidly collated. We are thus able to monitor selected volcanoes for signs of increasing activity, perhaps preliminary to an eruption.

Additionally, work is being done on plotting the epicenters of earthquakes. The plotting of epicenters in relation to lineaments mapped by several investigators in California shows suggestive relationships not yet proven.

In southern Arizona, one investigator reported the use of ERTS in the study of accelerated erosion. Accelerated erosion, which commenced about 1880 or 1890, is tearing apart extremely valuable grazing land in southern Arizona. He pointed out that if we are going to study the causes and the growth of accelerated erosion, we must monitor it continuously. ERTS imagery is well suited to such a study. By successive ERTS plotting, it may be possible, perhaps within a decade, to determine the actual rates of accelerated erosion in this area, and from this, to make a meaningful study of the underlying causes, instead of the educated guesses we make now.

A



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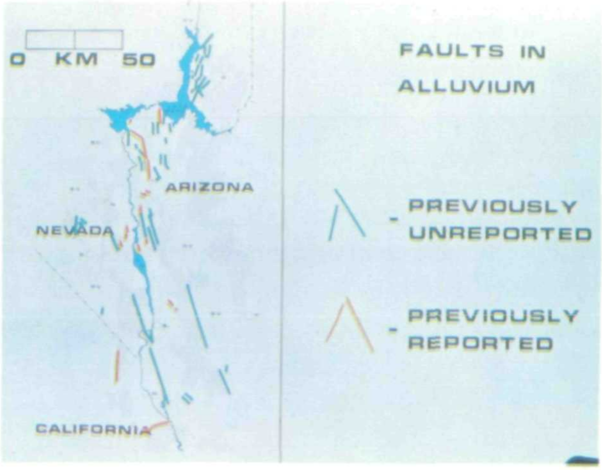


Figure 5. *(a)* ERTS color composite showing Lake Mead and Las Vegas; *(b)* ore deposits; *(c)* fracture map made from the ERTS image.


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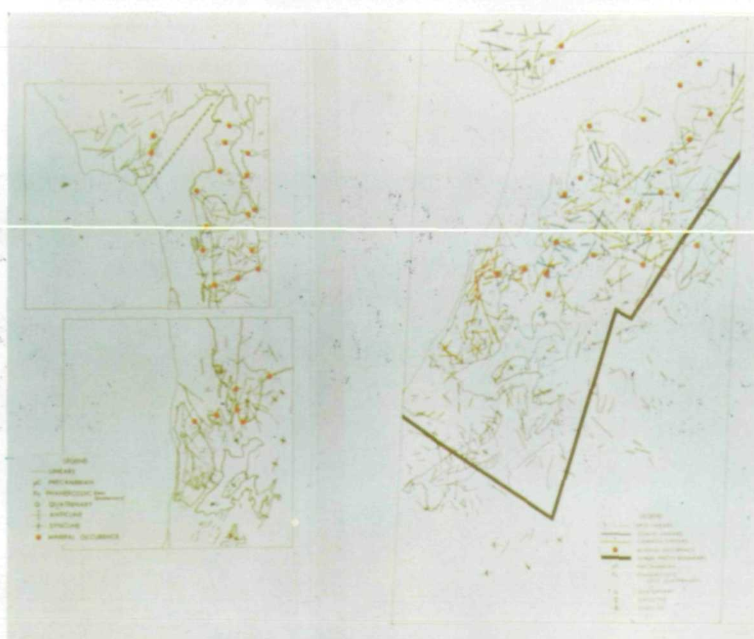

B

Figure 6: Southern Morocco: *(a)* Comparative views of the geological map and ERTS-1 image of southern Morocco; *(b)* maps showing the locations of mineral deposits and their geometric association to the general geology and folds, and to the lineaments mapped from ERTS.

Figure 7 is an ERTS image of part of Iceland, together with a topographic map. Notice the glaciation which appears here. Such map features can be updated by repetitive ERTS imagery. The topographic map, of course, is an instant in time, and as the glaciers retreat or advance, the map becomes obsolete.

More importantly,.one glacier shows a very steep front. The investigator reported that this is a surging glacier. The early recognition of surging glaciers can represent a valuable use of ERTS in the study of geologic hazards.

To repeat, the four categories are:

- the regional thinking of the geologist
- the upgrading and correction of geologic maps
- direct applications (particularly the use of lineaments in the localization of ore deposits, analysis of oil structures, and engineering hazards)
- hazard monitoring, such as accelerated erosion, surging glaciers, and epicenters controlled along lineaments

It is very difficult to speak about cost effectiveness because some of the extensions of lineaments being done on ERTS literally cannot be done by any other device. Some lineaments evident on ERTS imagery do not even show on U-2 imagery. In the case of our extended ability to map, the cost effectiveness is infinite. In conclusion, most investigators are of the opinion that ERTS has indeed provided a new view, a regional view, and an important time view to geology—a view which was simply unavailable heretofore.

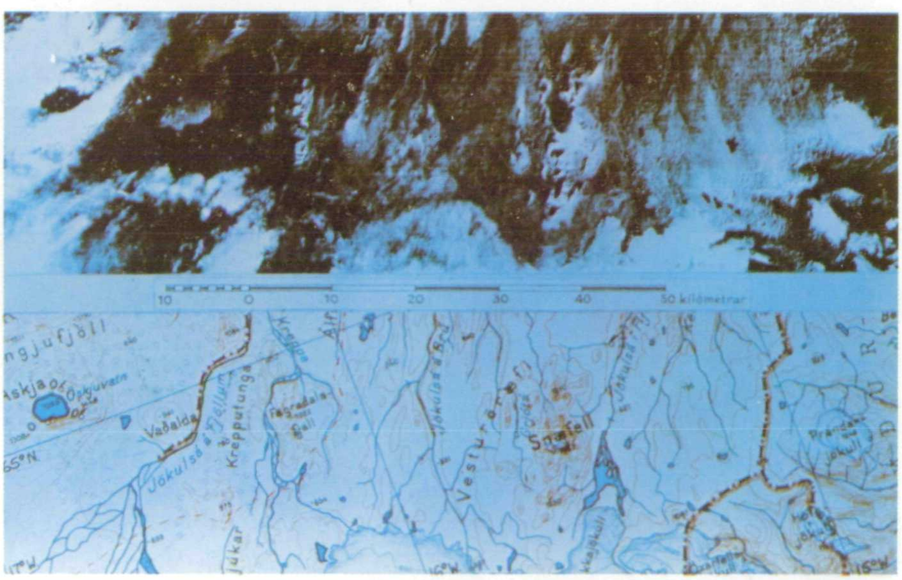

Figure 7. Topographic map and ERTS 1 image of part of Iceland showing a temporal variation in the ice margin.

# WATER RESOURCES

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## INTRODUCTION

The fields of water resources and hydrology have been reaping benefits from the application of data from space since the launch of TIROS-1 on April 1, 1960. The improvement of our understanding and ability to monitor atmospheric processes and, in particular, atmospheric moisture, has been very substantially improved by observations which have come from meteorological satellites. In more recent years some significant progress in the application of remote sensing from high altitude platforms to the observation of the terrestrial portions of the hydrological cycle has also been made.

Figure 1 shows in pictorial form the relative amounts of water stored in the major environments of the hydrological cycle. Figure 2 represents the hydrological cycle and the gross magnitudes and interactions of the flux terms comprising the hydrological cycle. Examination of the material in these two figures will reveal that only a relatively small portion of the water in the hydrological cycle is subject to existing management practices. This portion ($\approx$0.01 percent) largely consists of the deposited water that falls on the watersheds of the continents and is stored in lakes, reservoirs, or flows into streams and rivers where it eventually returns to the oceans. Our principal management challenge lies in conserving the quality and quantity of these waters so that they can be used to maximum advantage in the sustaining of our lives and that life upon which we depend. This paper is devoted to reviewing the progress that has been made in applying ERTS-1 data to meet this challenge.

## HYDROLOGY AND LAND USE

In the study of the terrestrial phase of the hydrologic cycle and the general characteristics of runoff from a watershed, one should be aware that these features are affected by the existing geology and land use in the watershed. Other papers (Lattman, Lindgren, Simpson and Poulton) have summarized many of the uses of ERTS-1 data in the geology, agriculture, and land use disciplines and many of the findings have hydrological implications. For instance, mapping of fracture systems from ERTS-1 is allowing hydrogeologists to locate areas of potentially high water yield. This information will allow regional ground water resource development previously not possible in Pennsylvania (Gold et al.) and act as a valuable guide for the drilling for ground water in other areas during the coming year.

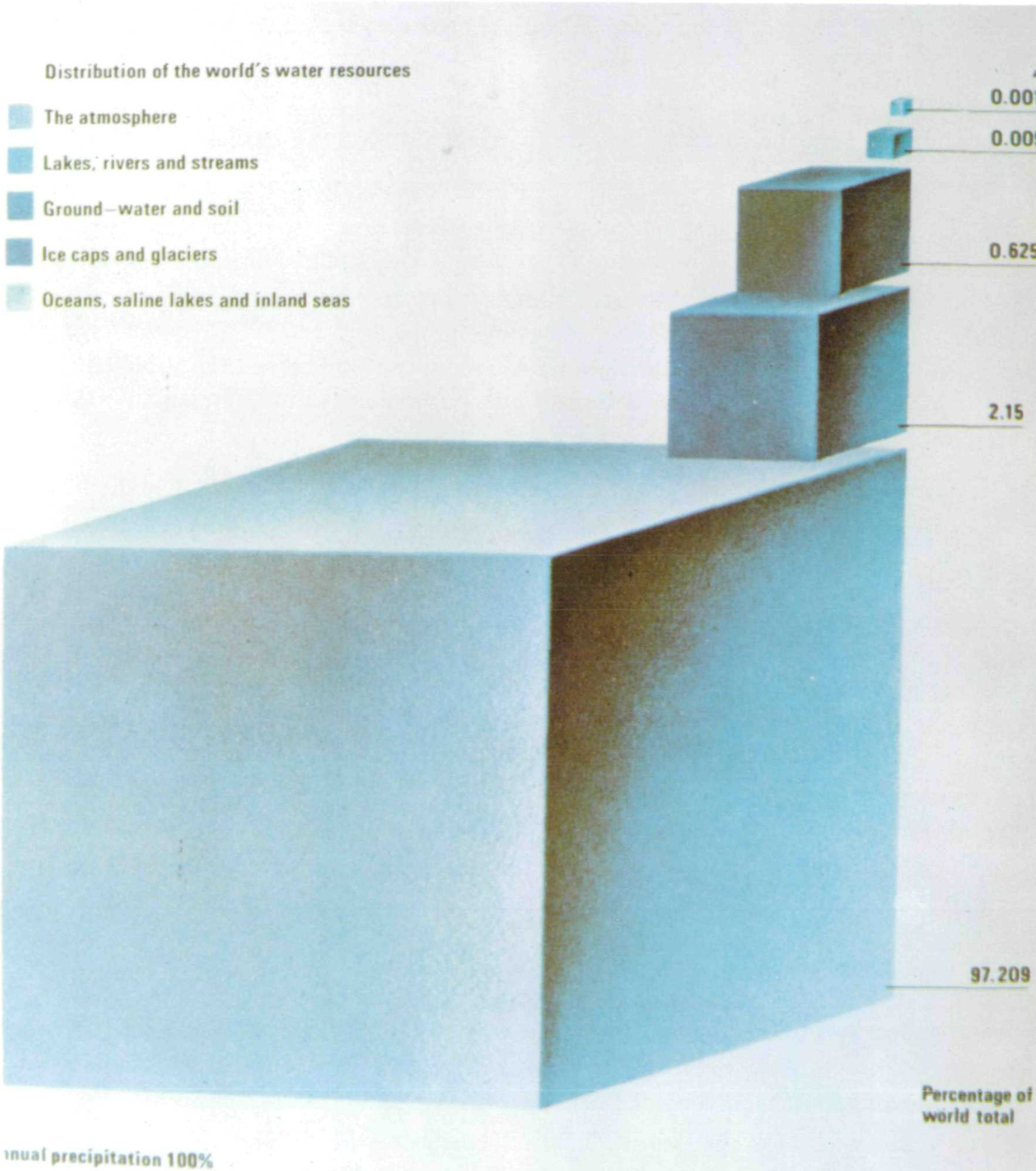


Figure 1. Relative amounts of water stored in the major environments of the hydrological cycle.

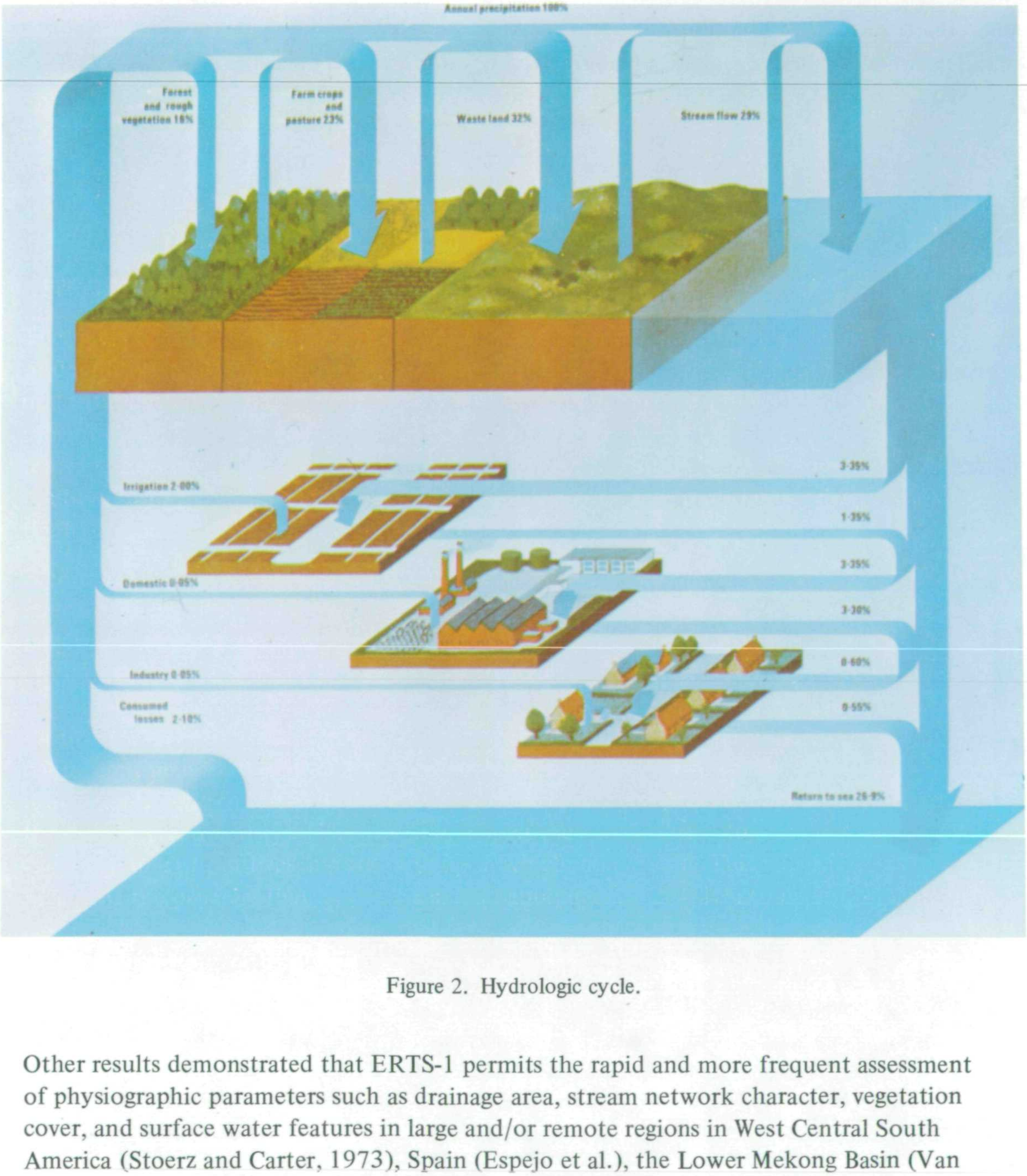


Figure 2. Hydrologic cycle.

Other results demonstrated that ERTS-1 permits the rapid and more frequent assessment of physiographic parameters such as drainage area, stream network character, vegetation cover, and surface water features in large and/or remote regions in West Central South America (Stoerz and Carter, 1973), Spain (Espejo et al.), the Lower Mekong Basin (Van Liere), and the Republic of Mali (MacLeod). For instance, in the 440,000-square kilometer (170,000-square mile) region of South America hundreds of drainage basins were inventoried using 31 images from ERTS-1. With reference to surface water features 36 new lakes were found based on the ERTS imagery. In the Lower Mekong Basin ERTS-1 revealed that 4 million hectares of primary forests have been seriously degraded by war action. This has obviously altered the natural hydrological cycle of the region and particularly the interception and evapo-transpiration characteristics. Surveys of this detail, which are of great value and importance to water resources planning and development, are nearly impossible or completely impractical by conventional methods.

## FLOODING

One of the clearest demonstrations of ERTS-1 sensor applicability concerned the mapping of areas inundated by floods. As was noted by Hallberg et al., the regional extent of the floods on the East and West Nishnabotna Rivers in Southwest Iowa were assessed with accuracies very comparable to methods presently being used. Figure 3 shows how apparent (in the near infrared spectral region) the moist, inundated areas were after the flood as compared to the same area observed by ERTS-1 before the flood. Similar results, were also obtained over the October 1972 Upper Gila River Flood in Arizona (Morrison). (See Figure 4.) In both cases the time required to map the flood-inundated area was an order of magnitude smaller than that required by low-altitude aircraft surveys, and the ERTS-1 area

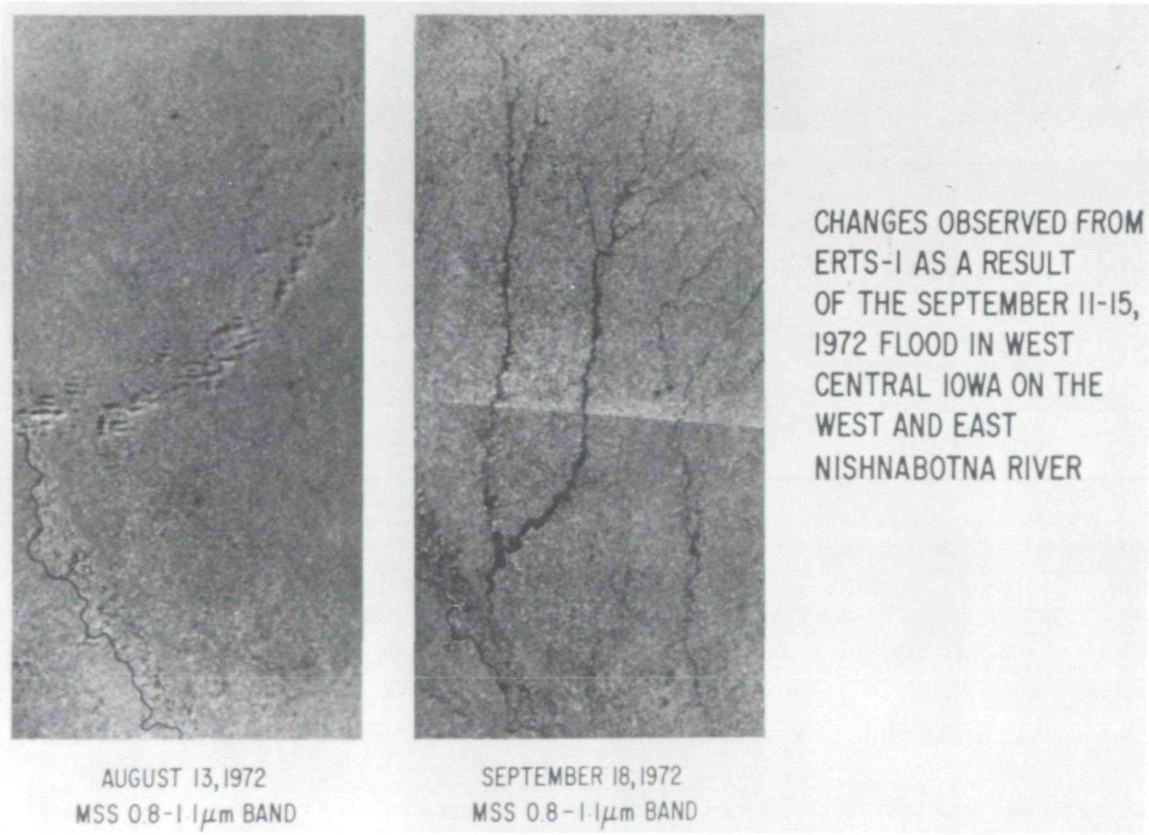


Figure 3. ERTS-1 observations of the East and West Nishnabotna River watersheds before and after the September, 1972 flood.

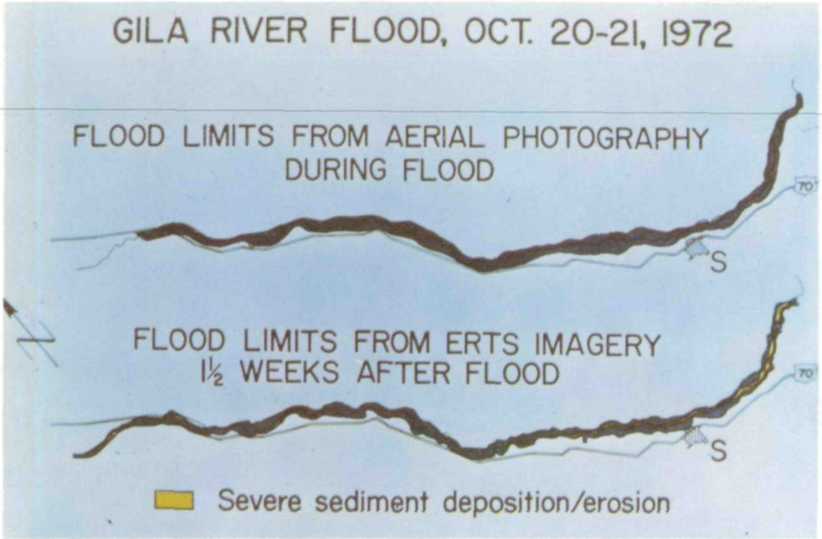


Figure 4. Comparative flood mapping results for the Upper Gila River in Arizona.

coverage permitted extension of the mapping to areas and rivers not covered by the aircraft surveys. It should be emphasized that the satellite information is, therefore, applicable in (a) mapping the extent and location of areas subject to floods for flood planning purposes, (b) areas where damage and insurance claims may be expected, and (c) areas where relief operations may be needed. Assuming it were effectively applied, we can only imagine how much utility ERTS data would have had if it had been available to survey the aftermath of Hurricane Agnes in the Spring of 1972.

## SNOWCOVER

In runoff and flood forecasting the most important variable is the amount and intensity of precipitation. In the western United States a very large percentage of the runoff occurs as a result of snowmelt. This runoff is used for hydroelectric power generation, flood control and irrigation, industrial uses and, of course, human consumption. ERTS-1 has been used to more accurately map the amounts of snow cover to within 1 percent of drainage basin area and the elevations of snowlines to within 60 meters (Barnes and Meier). As a specific instance where available data have been used to relate snow covered area to runoff, the area covered by snow in the Thunder Creek drainage basin in the North Cascades of Washington State (Figure 5) was mapped using ERTS-1 data related to measured runoff (Figure 6). These early results appear to be as accurate and reliable as standard snow course measurements. One should note that when improved snow course measurements were first installed, they saved an electric power utility in a single city in the Northwest $1 million in the first year of operation. The implications of these results are even more far reaching, because the Wilderness Act prohibits installations of conventional snowpack monitoring instrumentation in many regions, such as high alpine areas, where a great proportion of the


Figure 5. ERTS-1 observations over the Thunder Creek drainage basin (A) and the South Fork Cascade River basin (B) at South Cascade Glacier in Washington State.

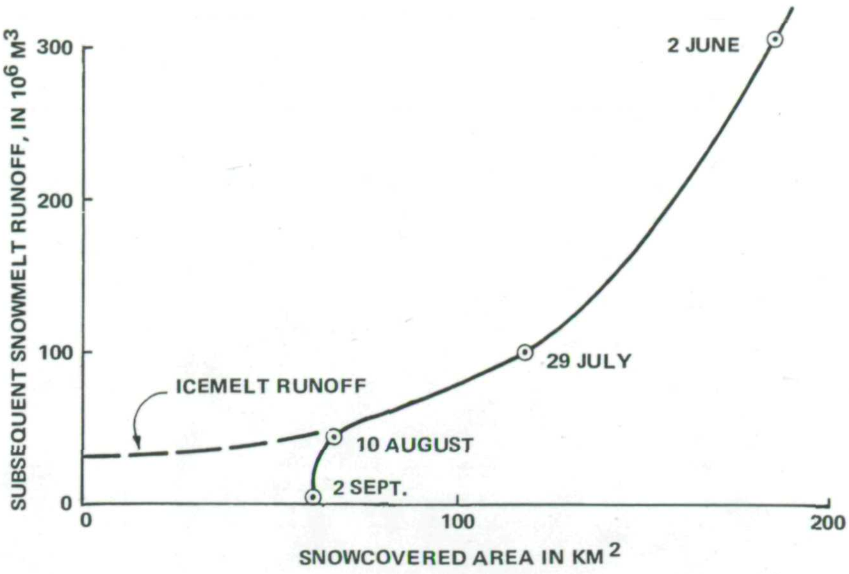


Figure 6. Snowmelt runoff as a function of snow-covered area for the Thunder Creek Drainage Basin in Washington State.

snowpack water resources exist. Therefore, the rapid implementation of these satellite snowmapping procedures on many watersheds where these wilderness areas exist would appear to be especially important.

## GLACIOLOGY

Glaciers constitute 80 percent of the available fresh water on the earth. Snowlines are very easy to identify in ERTS-1 imagery taken over glaciers. These snowlines can be used to indicate whether the glacier accumulation area ratios and their mass balance are changing (Meier). ERTS-1 data can be used to make these determinations even in areas where glaciers are remote and/or as small as 6 square kilometers, such as the South Cascade Glacier in Washington State. Surging glaciers can also be identified. These are glaciers which may advance over large areas and cause devastating floods by blocking and suddenly releasing large quantities of meltwater. Figure 7 shows the wiggly (folded) moraines which characterize surging glaciers on the Yentna Glacier near Mt. McKinley in Alaska. The 1800-meter surge of this glacier in 1972 has been observed on ERTS-1 imagery. ERTS observations show that these kinds of glaciers can now be inventoried and monitored over all areas and proper precautions taken against flooding as well as using the data for planning of water resource development from new sources.

## DATA RELAY

There are many hydrological parameters which are very difficult to obtain via remote sensing. Conventional measurement systems can be installed, but the rapid collection of these

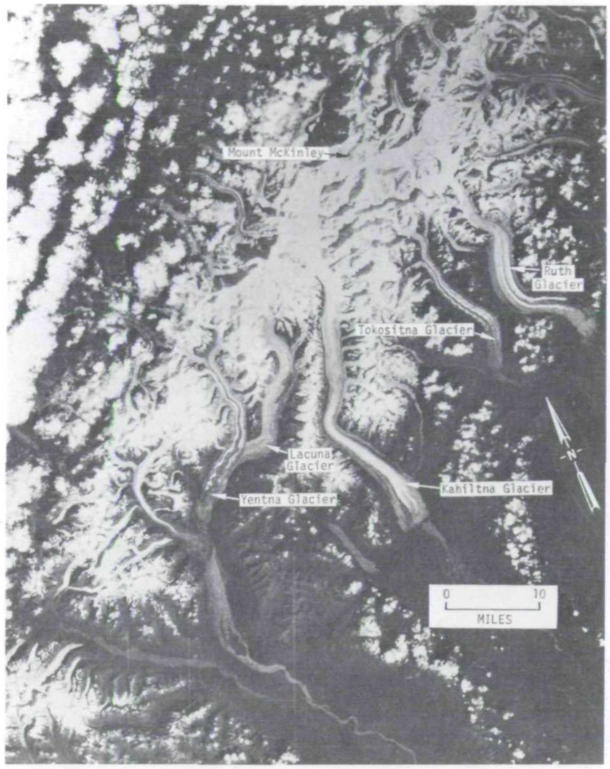


Figure 7. Surging and nonsurging glaciers around Mt. McKinley, Alaska on August 25, 1972.

data over widely separated and remote regions is impossible by conventional data collection methods. The data collection system on ERTS-1 has proven in several instances to date to be a reliable and rapid means of collecting and relaying these data so that it can be used in operational water resources management situations requiring near real-time data. As an example, on February 21, 1973 snowmelt information on the Verde River Watershed in Arizona was needed on an emergency basis (because of a microwave telemetry failure) in order to decide on the amount of water to be released from the Bartlett Reservoir (Schumann). The required information was relayed from the headwater portions of the Watershed via satellite to Goddard Space Flight Center and subsequently to the Salt River Valley Water User's Association in Arizona within 1/2 hour. As a result of this information it was determined that excess amounts of water did not have to be released and therefore highway closures due to flooding were reduced by 40 percent in the Phoenix area.

Data from 20 stations collecting water quality, stream flow, and observation well information are being relayed in near real-time from the Delaware River Watershed via the data collection system on ERTS-1 to the Delaware River Basin Commission (Paulson). Similar activities are being conducted by the New England Division of the Army Corps of Engineers on the Merrimack River Basin. By conventional means, the collection of these data would take weeks.

In Florida, water level and rainfall information is being collected via ERTS-1 and relayed to water resources management agencies in 30 to 45 minutes (Higer et al.). This information when coupled with imagery information giving surface water area allows volumetric estimates to be made for the first time since 1947 when the Central and Southern Florida Flood Control Act was established. The impact of this capability is that it permits definitive assessments to be made on the existing nature of the environment for the multitudes of animals in this region of Florida that are so dependent on water, particularly during drought situations and after hurricanes. It is clear from these efforts that these data are valuable and can be reliably provided if the availability of these data were assured from a satellite so that a management model could be implemented; a preliminary cost benefit analysis indicates that $2.5 million/year could be saved.

## SURFACE WATER

As just indicated surface water features are very clearly expressed on ERTS-1 imagery. The ERTS-1 ability to map surface water and wetlands area is very exciting because it permits the rapid inventorying over large regions of water bodies as small as one hectare in size. This information has great meaning in terms of providing indices of the amount of water available for industrial, agricultural, and recreational use, the amount of water subject to evaporation, and the locations of areas contributing to ground water reckage. As an example of this, Figure 8 shows the playa lake area in an ERTS-1 frame near Lubbock, Texas on the Texas High Plains. Using ERTS-1, a total of 6631 playas have been identified in the area covered by this scene. An inventory of this kind for the whole erea is completely impractical by any other means. Information of this kind is particularly important when one considers that this is a semi-arid area where water must be managed carefully. Time and space changes in the area covered by water in playas can be observed from ERTS-1 (Reeves; Baumgardner et al.). Space change is illustrated by the darker toned strip in the upper left hand corner of Figure 8, where a passing thunderstorm filled the playas in its path but left those on either side untouched.

## WETLANDS MAPPING AND TURBIDITY PATTERNS

Time does not permit the illustration or extended mention of the details of several other instances where surface water area (Van Tries; Gilmer and Klett), wetlands (Flores et al.; Anderson et al.; Klemas and Bartlett; Mairs et al.), vegetation including phreatophytes (Turner), patterns in turbidity (Falconer et al.; Wagner and Polcyn; Pluhowski; Yarger and McCauley; Schubet and MacLeod), and algal features were all clearly expressed in the ERTS-1 imagery. It was demonstrated that coastal and inland wetlands are very important resources for recreational, economic, and environmental reasons. Figures 9 and 10 show a high altitude photograph on the Texas gulf coast and a computer map version from ERTS data showing the wetlands in gray (Flores et al.). The wetlands in this photograph were mapped with accuracies between 86 and 99 percent. Turbidity variations in lakes and reservoirs were imaged very nicely in many situations including Lake Ontario (Pluhowski), reservoirs in Kansas, Utah Lake (Strong) and Lake Champlain (Lind). Figure 11 shows the extent of a paper mill effluent plume originating on the New York side of Lake Champlain and crossing into Vermont waters. This imagery is being used as part of the material collected by the State of Vermont in a suit against the State of New York concerning the pollution of Lake Champlain waters.

## SUMMARY

In summary, we have seen some notable and operationally significant applications of ERTS-1 data made in the areas of flooded area mapping, snowcover measurements for runoff estimates, and the relay of hydrologic data taken over widely separated and remote regions to water resources management personnel. In addition, ERTS-1 provides much improved information on glacier characteristics, the areal extent of surface water and wetlands, and physiographic and land use characteristics. Relative to previous data gathering systems–including remote sensing systems–ERTS-1 provides a much improved combination of repetitive coverage over wide areas coupled with high spatial resolution and consistent viewing perspective over several spectral intervals. This in conjunction with the commendable data analysis efforts of the many ERTS investigators treating water resources themes permits one to say that a clearly valuable and beneficial observational tool is now available to the hydrology and water resources management communities.

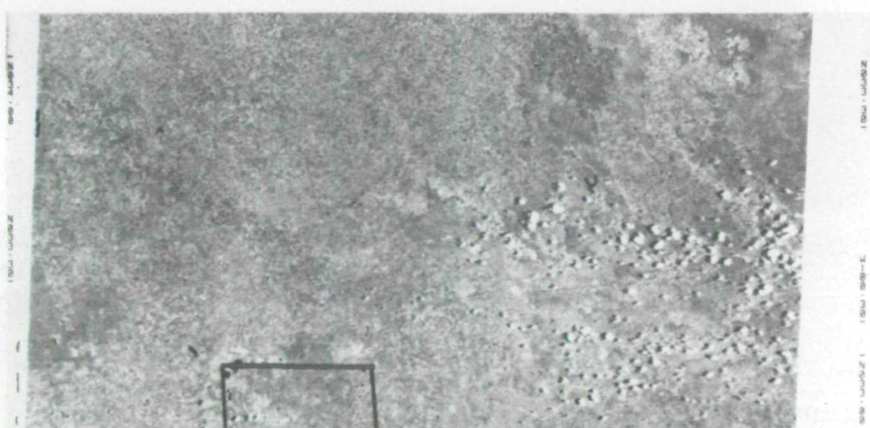

Figure 8. ERTS-1 observation of the playa lake area near Lubbock, Texas; 353 playa lakes contain water in the outlined area.

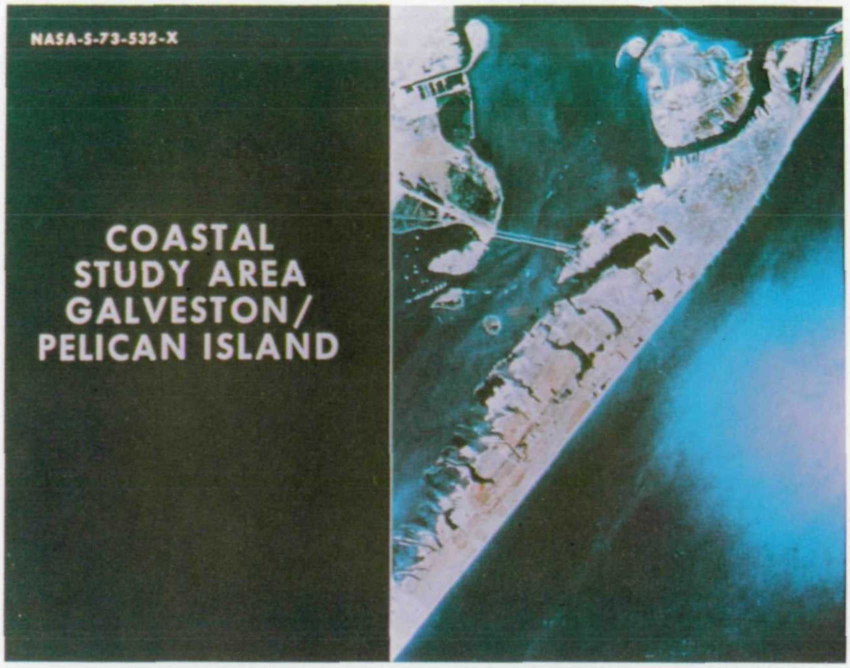


Figure 9. High-altitude aircraft photo on the Texas Gulf Coast.

Figure 10. Computer Classification of area shown in Figure 9 using ERTS-1 digital data wetlands are shown grey color.

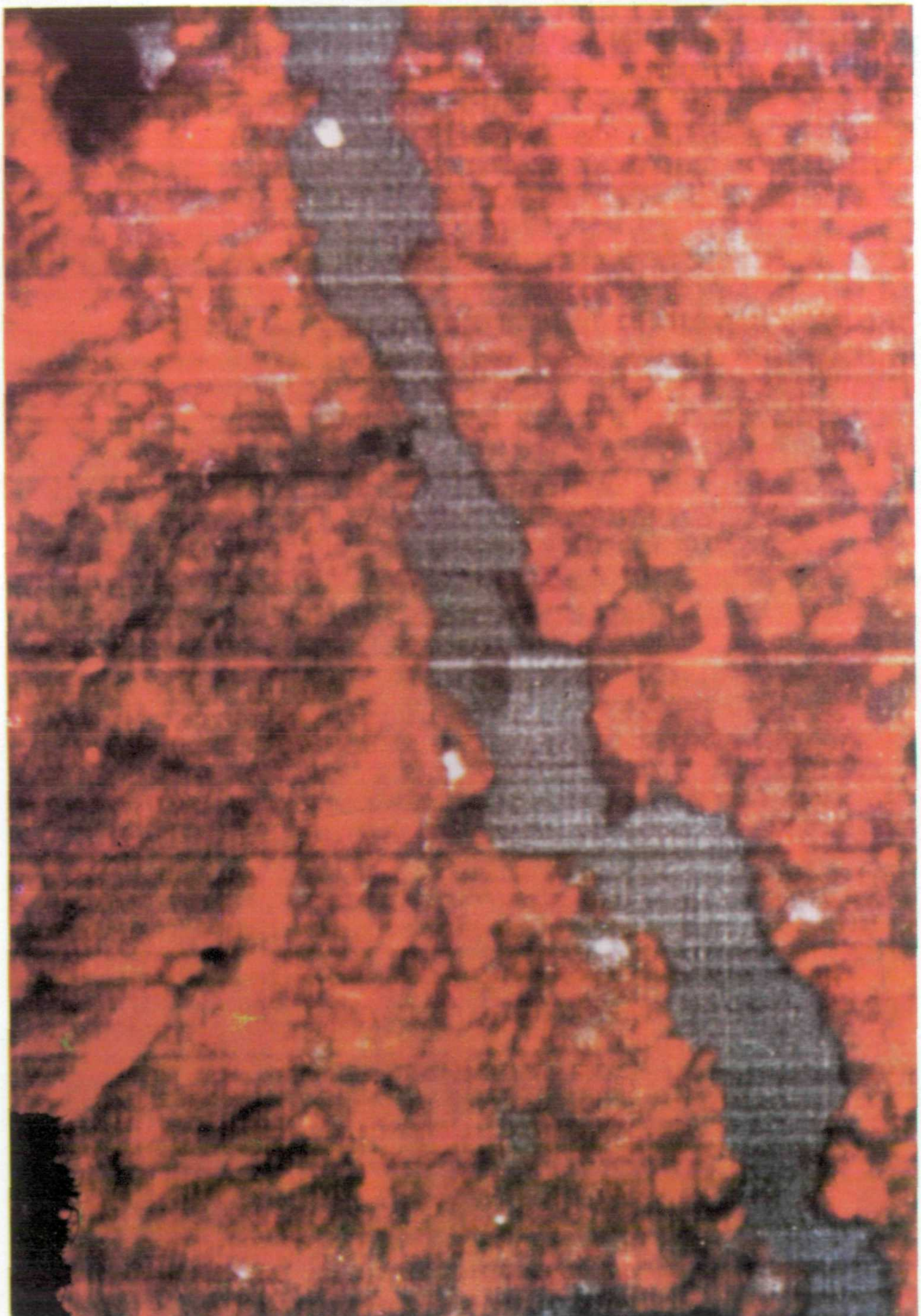

Figure 11. Paper mill effluent plume (left side of Lake Champlain in the middle of the figure) as seen from ERTS-1 on October 10, 1972.

# THE EARTH RESOURCES PROGRAM OF THE CORPS OF ENGINEERS

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The Earth Resources Program of the Corps of Engineers is directed to its civil works mission. This includes planning, construction, operation, maintenance, and real estate activities for water resources development, and administration of laws for protection of navigable waters. Remotely sensed data can facilitate the accomplishment of the mission by providing near-real time data with synoptic coverage, which allows a greater precision in gross evaluations of large ecosystems and a convenient method to monitor change. The Corps has about 30,000 people scattered throughout the country working on earth resources problems, and we feel that there is a great deal of information being obtained from both aircraft and satellite programs which they can use.

The emphasis of the Corps of Engineers program is on technology transfer. One example is the application of available remote sensing systems to problems faced in the performance of our mission. The program does not address basic research in sensor development or in the development of image-processing hardware.

When we first became involved in the program, we sat down and had a brain-storming session. We tried to assess the potential of remote sensing technology to water resource activities and we developed a rather general list. (Figure 1) As we worked on problems, we found that there was more overlap than specificity, but we still found that the list gave us a good framework within which we could establish priorities. In two years we have managed to start projects in many of the high potential areas. The capability of aircraft as well as satellite-borne sensors is being tested in four areas where remote sensing is considered to have potential application to Corps activities–engineering geology, flood control, master planning, and fluid dynamics and interactions. We now have underway a total of 21 research projects within these four areas. In most cases the principal investigator is from a Corps field office. Technical expertise in support of the principal investigator is obtained from Corps of Engineers Laboratories or by contract. We expect to expand into new areas in the FY 1974 period. Some examples of our ongoing programs include the following:

## ENGINEERING GEOLOGY

In the area of engineering geology, topographic information, we have several projects underway. In Alaska we have the Cold Regions Research and Engineering Lab doing research

**ENGINEERING GEOLOGY**

- *TOPOGRAPHIC INFORMATION*
- *MATERIALS LOCATION*
- *SOIL DIFFERENTIATION*

**FLOOD CONTROL**

- *BASIN RUNOFF MEASUREMENT AND PREDICTIONS*
- *SNOW COVER AND MELT RATES*
- *LOCATION, TEMPERATURE, AND DEPTH OF SURFACE WATER*
- *FLOOD DAMAGE ESTIMATION AND PROJECTION*

**MASTER PLANNING**

- *LAND USE PATTERNS*
- *VEGETATION COVER*
- *ENVIRONMENTAL MONITORING*
- *DISASTER RELIEF PLANNING*
- *RIVER, HARBOR AND LAKE POLLUTION*

**FLUID DYNAMICS AND INTERACTIONS**

- *BANK AND BEACH EROSION*
- *RIVER MIGRATION*
- *ICE JAMMING*
- *EARTH, ICE, AND SNOW MOVEMENT*
- *RIVER, SEA AND LAKE ICE COVER*
- *WAVE AND TIDAL DATA*
- *COASTAL STORM DAMAGE ASSESSMENT*
- *SALINE INTRUSION*
- *SEDIMENT LOADS IN RESERVOIRS AND WATERWAYS*

Figure 1. Potential application of remote sensing imagery.

which includes geologic analysis. Figures 2 and 3 show the interpretation of ERTS imagery to identify topographic information such as bedding planes, glacial features, and permafrost regions. We will be using this type of analysis to show geologists in the Corps what can be seen from high altitudes.

Also, in geology, we are developing techniques for showing engineers how to use high altitude aircraft and subsequently satellites, to locate landforms which normally relate to sources of construction materials. Beach ridges are generally good sources of coarse materials, and the interbeach flats are good sources of fine materials. As we move inland (Figure 4), the river bars are traditionally good sources of coarse material, and the abandoned chan-

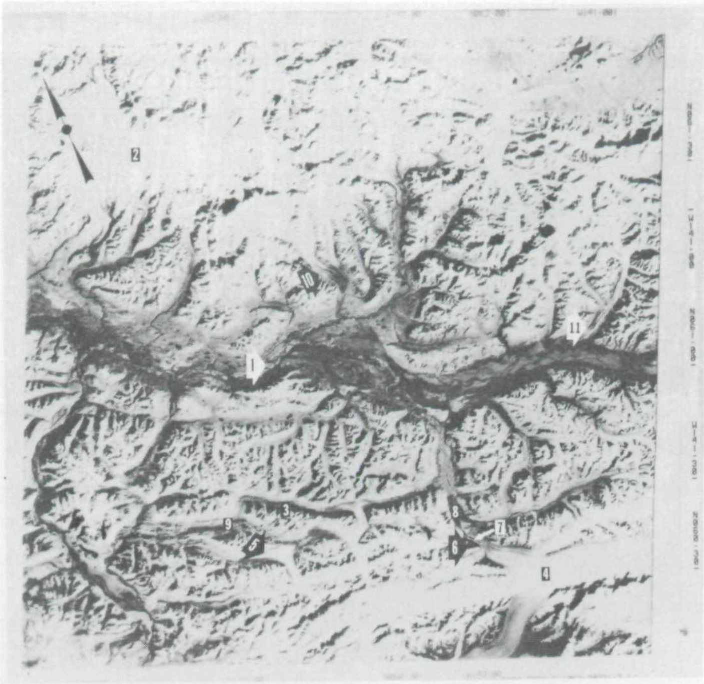



Figure 2. Chitina River east of Anchorage, Alaska.

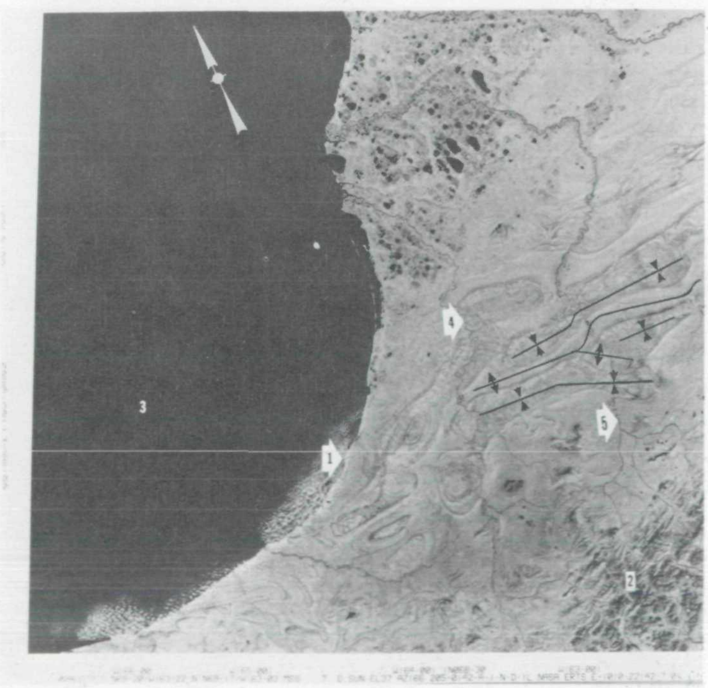



Figure 3. Area east of Cape Beaufort.

nels, since these are flooded only periodically, provide fines. The value of high altitude aircraft and satellite photography results from the fact that frequently these beach ridges and river bars are obvious on the synoptic coverage that is obtained, and yet are not readily apparent from ground investigations or low altitude aircraft.

## FLOOD CONTROL

In the area of flood control, we are extremely interested in data collection platform (DCP) capabilities. In our New England Division, we are instrumenting our hydromet network. We will run the system in parallel with the microwave system, which is also feeding in data. We will compare the ERTS DCP data for cost effectiveness and accuracy with the microwave data. We anticipate the use of satellite data relay systems in reservoir control systems and flood warning systems throughout the country.

In addition to using the DCP, we are working with the University of Connecticut on the interpretation of data to supplement the data from the hydromet network for flood forecasting and for other purposes.

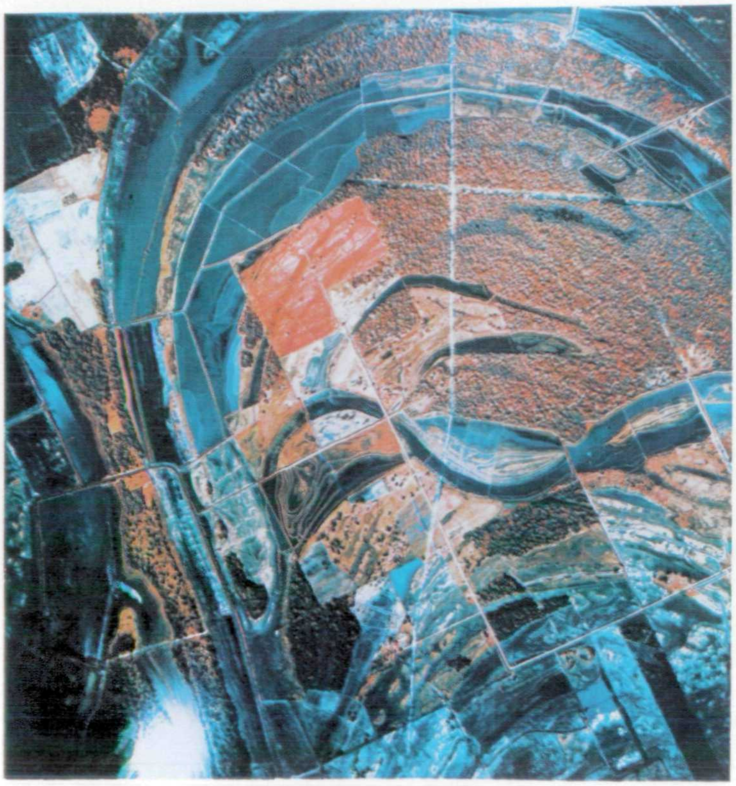


Figure 4. An aerial Ektachrome IR photograph showing relict point bars.

One of our first operational applications came up last August when H. R. 15951 was passed. The Corps has been directed to institute an inspection of dams. This is a spinoff of the Buffalo Creek disaster of approximately a year ago. We are being asked to inventory all dams which have 60,000 cubic meters (50 acre-feet) of storage or a dam height of 2 meters (6 feet) or more. We know that we have a fairly good inventory of the large dams but the location and important statistics about small dams are probably lacking in many parts of the country. We examined the ERTS imagery to determine the smallest water body which could be identified with a reasonable amount of success. We obviously can pick up the large reservoirs, but we felt that if we could locate water bodies with a surface area of 40,000 square meters (10 acres), we had a high probability of spotting all bodies having 60,000 cubic meters (50 acre-feet) of storage. On this Band 7 image (Figure 5) of the Connecticut River Basin we have identified several ponds that are less than 8 acres in surface area, so we are now using ERTS imagery in an operational program for inspection of dams.

Tied into the inspection of dams and to promote the use of this imagery for our other water problems, we are investigating the use of Band 5 and Band 7 (Figures 6 and 7) to show depth or turbidity of reservoirs. On Band 7 the entire surface area of a water body is quite black,

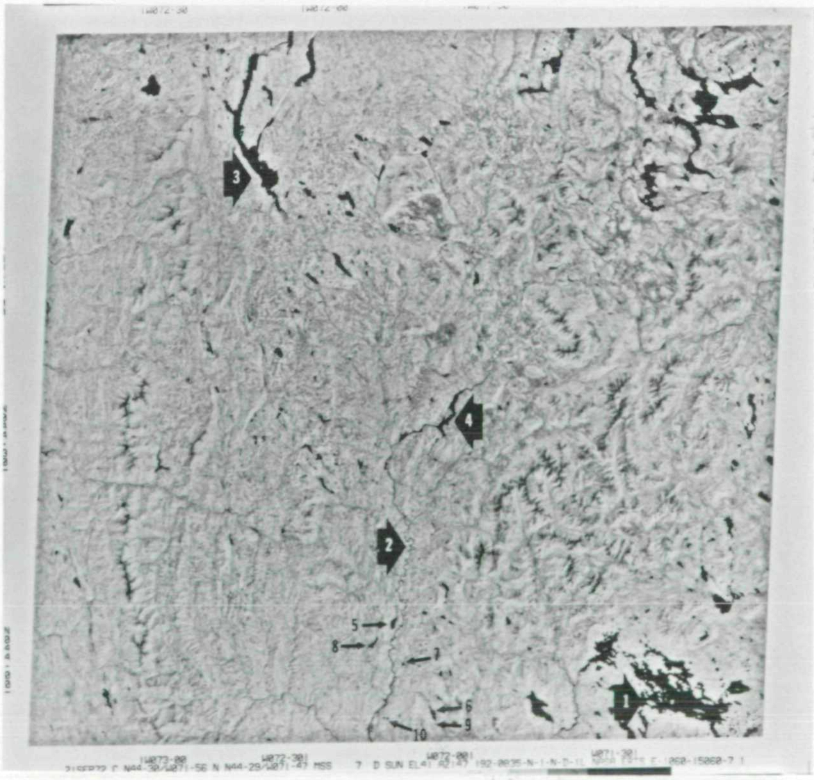



Figure 5. ERTS MSS band 7 of northern New England. The Connecticut River (2) runs north and south through the image. Little Goose Pond (9) is approximately 10 acres in surface area.

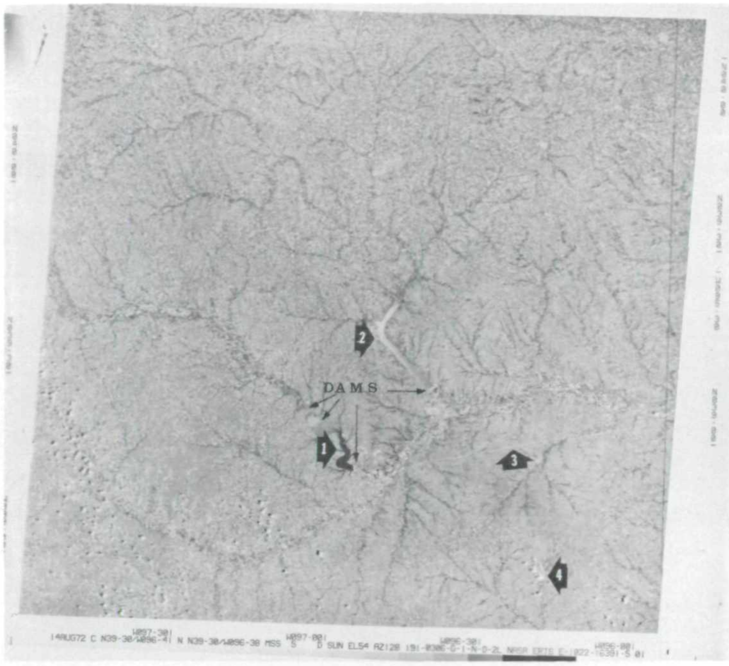



Figure 6. ERTS MSS band 5 of northeast Kansas and southeast Nebraska. Milfred (1) and Puttle Creek (2) reservoir can be seen in the central portion of the image.

Firgure 7. ERTS MSS band 7 of the same area covered by figure 6. Puttle Creek (2) and Milfred (3) also can be seen in this image.

but on Band 5 turbid or shallow areas are less dark. We would like to develop methods of quantifying the turbidity or depth, and methods of determining whether the observed differences result from depths or turbidity.

## MASTER PLANNING

The next category, master planning, is extremely important to us. When we propose a project, we have to know what is going on in the area and what effect that project will have on the area after it is completed. We are interested in both the environmental and the economic impacts.

We are using the land use categories that are being developed by the Department of the Interior. We are developing methods to provide baseline maps rapidly to planners in the district and methods which will allow these planners to monitor changes after project construction.

We are also attempting to correlate changes in land uses with changes in water bodies in terms of pollution or flow patterns or sedimentation.

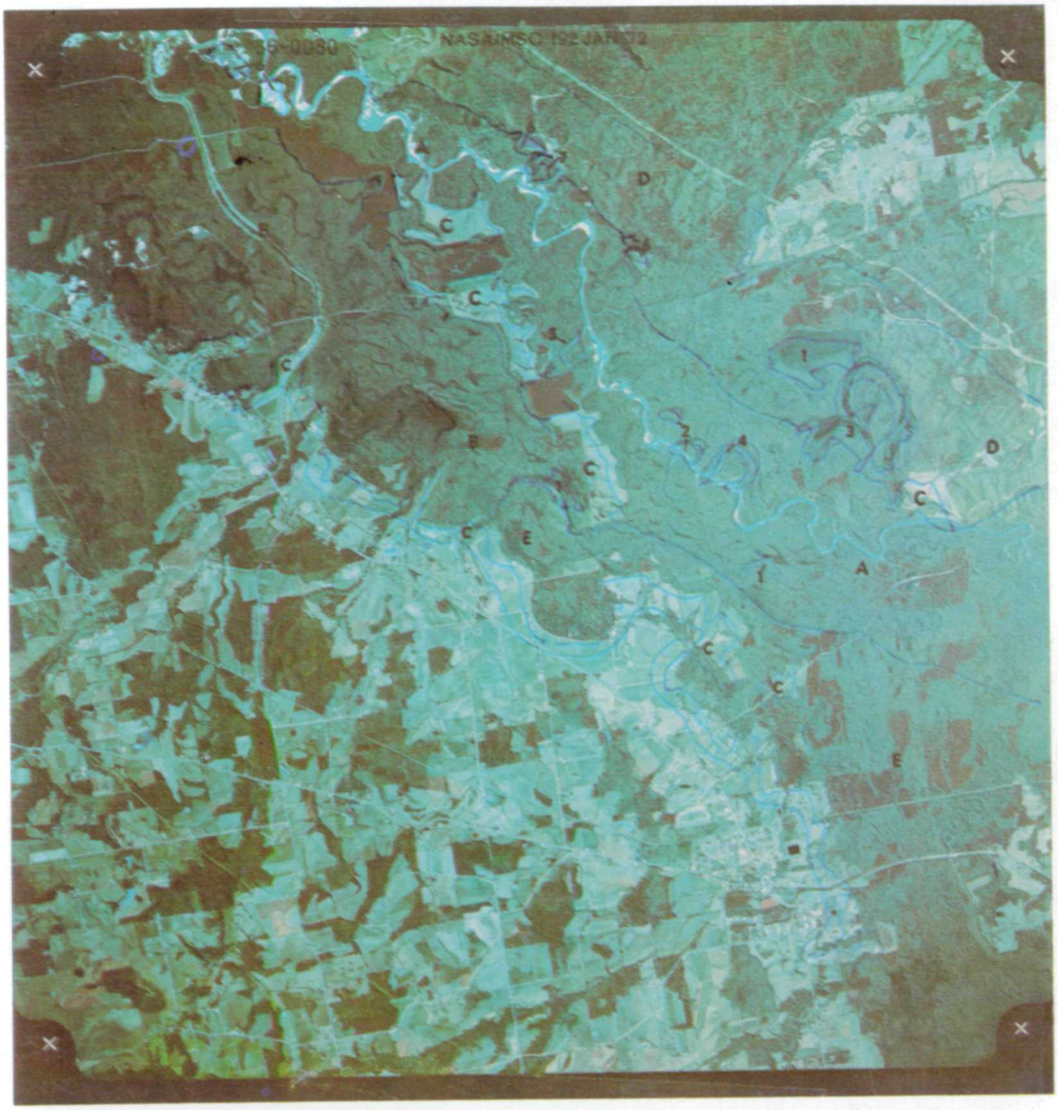
In the area of environmental assessment, we have used remote sensing on several projects. The Tennessee-Tombigbee project is a major project which will connect the Tennessee River with the Tombigbee River, providing for direct movement of material from the Ohio and Tennessee valleys down to the Mobile area. We recognize the fact that there will be a tremendous environmental impact, so we are making environmental assessments to identify not only the borrow areas for construction materials and the spoil areas but also important wildlife habitat, valuable timber stands, and cultural features which should be preserved. Figure 8 is an example of actual imagery obtained to show the location and classification of waterfowl and wildlife habitat along the proposed Tennessee-Tombigbee waterway.

We are now expanding into the use of ERTS imagery for this type of an assessment. We are working in several areas to develop pilot environmental baseline maps or regions. These maps will be published in forms of environmental baseline inventories, and will be used for future planning to avoid–or at least to alleviate–the adverse impact on the environment through construction or other water resources activities.

## FLUID DYNAMICS AND INTERACTIONS

The Corps has a number of projects underway which are attempting to use remotely sensed data to learn more about the dynamics of fluid systems.

In the Chesapeake Bay area (Figures 9 and 10), the Corps has selected a number of sites that are associated with different tributaries to the Bay. Each has a different type of runoff, for instance, the Choptank River (right of center on Figure 9) drains an area where chicken processing plants represent a major industry. Water samples from several test sites have been collected and analyzed for sediment content. A test of the correlation between the



| | Deer | Squirrel | Turkey | Rabbit | Quail |
|---|---|---|---|---|---|
| A | Good | Good | Mod | Mod | Poor |
| B | Good | Mod | Poor | Mod | Poor |
| C | Good | Very Poor | Poor | Good | Good |
| D | Mod | Mod | Mod | Poor | Poor |
| E | Mod | Poor | Poor | Good | Poor |

Figure 8. Aerial photograph of a portion of the proposed Tennessee Tombigbee Waterway.

Figure 9. ERTS MSS band 5 image of the Chesapeake Bay area.

measured sediment concentration and the spectral response of the sediment as viewed from ERTS reveals that ERTS electronic data can be used to determine range of sediment concentration.

Also, through digital processing, we are attempting to track the various outfalls into the Bay system, and use the movement of these outfalls to learn more about the dynamics of the Bay system.

On the West Coast we have several test sites. There, too, we are developing methods of processing ERTS imagery to bring out sediment movement.

Figure 11 is a standard color enhancement of San Francisco Bay. By adjusting the color enhancement it is possible to show the sedimentation in the Bay. We are able to evaluate the sediment flow patterns and learn more about the dynamics of the San Francisco Bay.

Figure 12 is a data color enhancement of the Bay and shows relative concentrations of sediments. Maximum sediment concentration is denoted by the blue color. The green and yellow areas denote zones of decreasing sediment concentration.

In Figure 13 of the Santa Barbara region, we have again used a color enhancement of Channels 4, 5, and 7, but, since there was very little sediment in the water at the time, we were

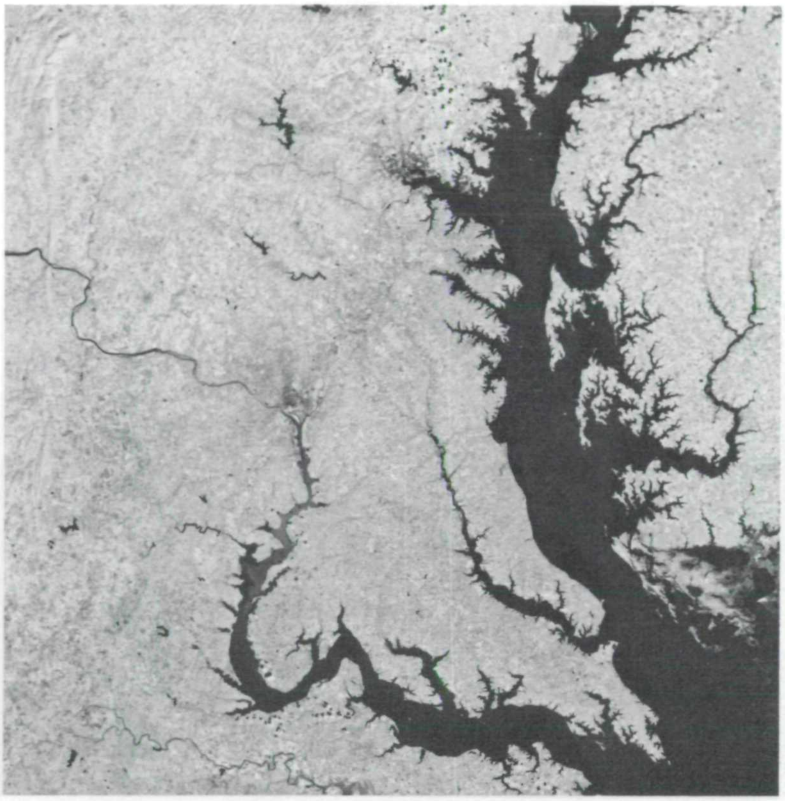


Figure 10. ERTS MSS band 6 of same area in figure 9.

unable to bring out much information about littoral drift. However, by going into digital processing (Figure 14) we find that we are able to bring up a great deal of information on the long shore currents. Data color enhancements of Figure 14 shows relative concentrations and transport path of suspended material from the Ventura and Santa Clara Rivers. The effect of the southeasterly flowing longshore drift is shown by the area of maximum sediment concentration denoted by a light blue color. The dark blue, light green, and dark green areas represent zones of decreasing sediment concentrations in the subsurface water. Entrainment of the sediment plume by the northwesterly flowing Anacapa Current is outlined in dark green. Santa Cruz (lower left) and Anacapa (lower right) islands are light blue. Orange represents the open ocean waters.

We are also developing methods of monitoring bank erosion or river migration. We are using high altitude imagery, and we hope, eventually, satellite imagery, to monitor the changes along the rivers and to evaluate the effectiveness of our revertments and other river control structures in maintaining river channels. (Figure 15)

In the coastal areas, we are developing methods of monitoring shoreline changes. We have lost a large portion of the coastal marshes in the past few years because of the exploitation of mineral reserves, urban development, and recreational development. We hope to use ERTS imagery such as Figure 16 to rapidly assess the changes in the shore areas.

Figure 11. Additive color enchancement of San Francisco Bay area processed to accentuate sediments.

We have similar problems related to inland rivers. Certain land uses; for example, strip mining or major land clearing activities, increase sediment in the rivers. We must determine what is happening to that sediment so that eventually we can start saying something about what will happen to a river before the land use changes occur or before the development takes place.

Baltimore District of the Corps of Engineers is currently managing a $15 million program to study the Chesapeake Bay. One of the by-products of this study will be a fixed-bed hydraulic model. Several specific task groups have been established (Figure 17) and have just completed the preparation of an "existing condition" report. Because of this role in the Bay, the Corps is currently monitoring several ERTS investigations using the Chesapeake Bay as a test site (Figure 18). We are attempting to make the task group aware of the ERTS experiments so that the information from the investigators can be applied to our study.

For example, the economic projection task group should be able to use information from the Alexander study and the McMurtry study; the water quality task group should obtain great deal of information from investigations by Anderson, Grabau, Weaver, Klemas, and so on.

In this way we hope to tie our ongoing activities into the NASA program to make sure that the people in the Corps learn what is going on, and can benefit from the results of research.

In summary, the Corps of Engineers is involved in the transfer of technology learned from experimental programs like ERTS-1 to operational applications. It now appears that remote sensing technology can become a major supporting tool in accomplishing the Army Engineers' civil mission.

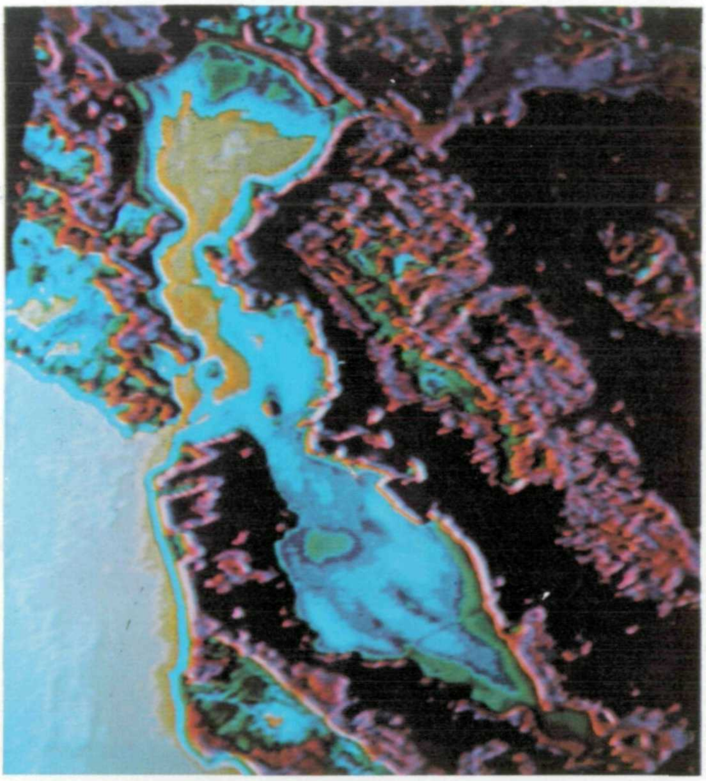


Figure 12. Data color enchancement of MSS band 5 of same areas as figure 11.

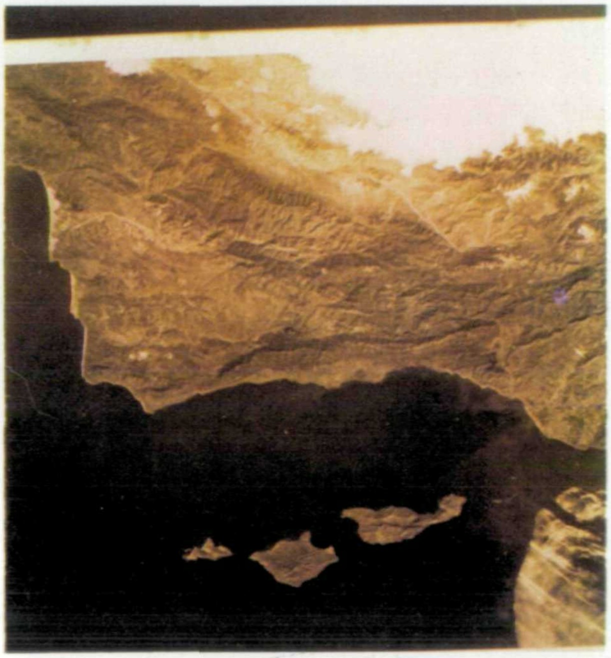


Figure 13. Additive color enhancement of MSS band 4, 5 and 7 of the Santa Barbara, California, area.

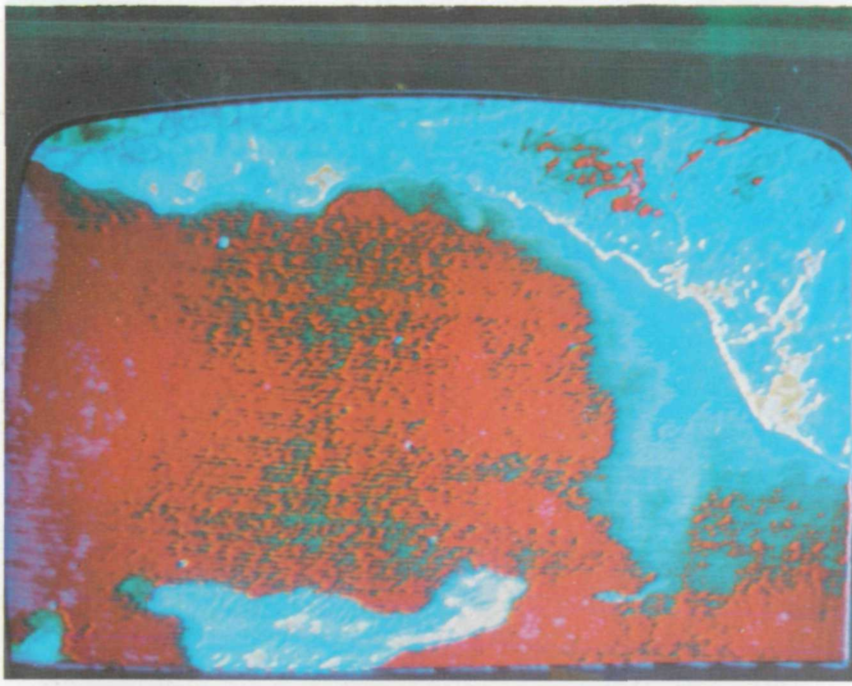


Figure 14. Data color enhancement MSS band 4 of same area as figure 13.

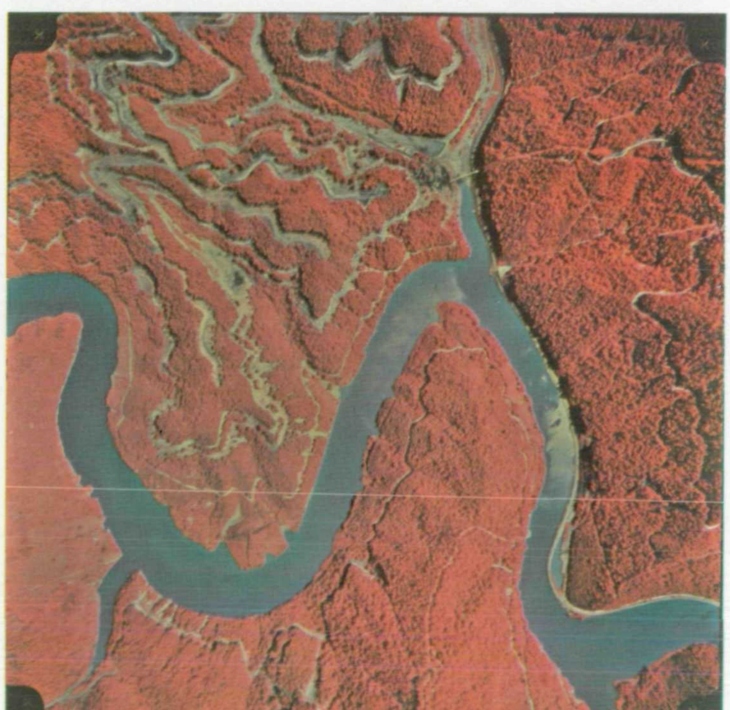


Figure 15. Aerial IR photograph showing river sediments.

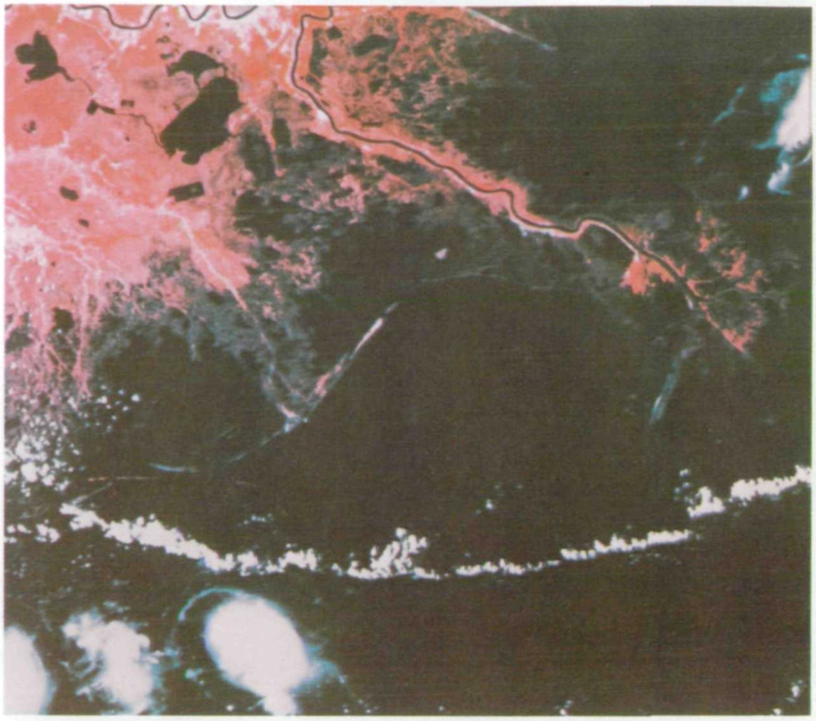


Figure 16. ERTS color eomposite of the Mississippi Delta area.

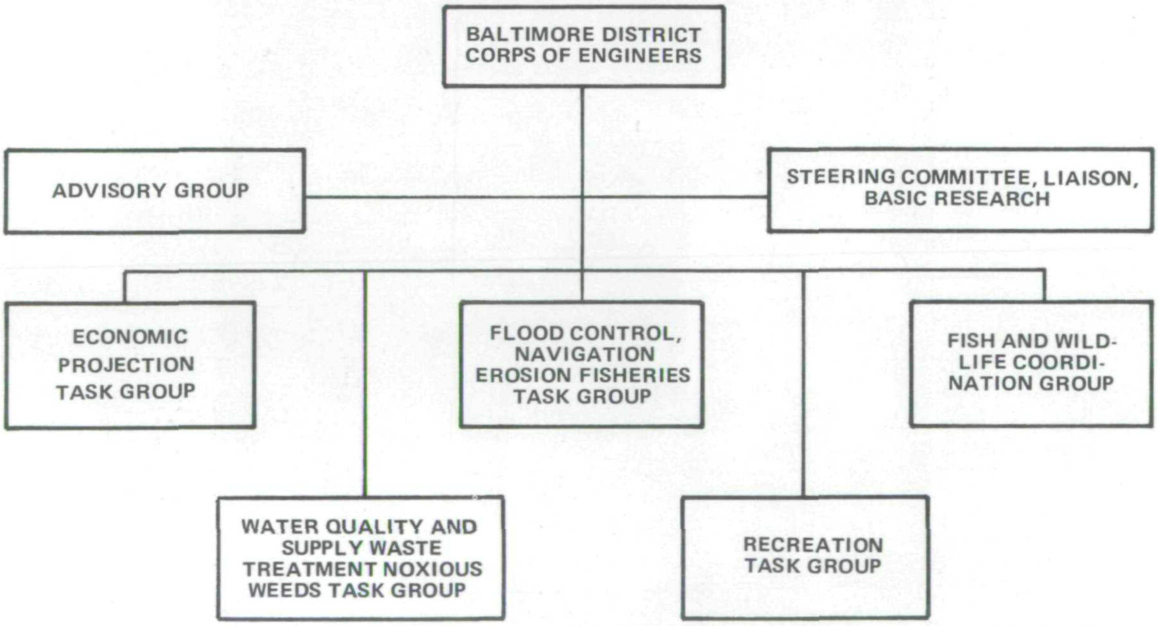



Figure 17. Chesapeake Bay study organization

| PROGRAM | SYSTEM | | | | |
|---|---|---|---|---|---|
| | REGION | WATERSHED | BAY | RIVER | COAST |
| RESOURCE INVENTORY | Weaver | McMurty | Ludwick | | Anderson Marshall Klemas |
| ENVIRONMENTAL IMPACT | Alexander | | | | |
| LAND USE PLANNING | Thomas | | | | |
| WATER CIRCULATION SEDIM. TRANSPORT | | | Grabau | | Berg |
| DATA COLLECTION SYSTEM | Krieger | Paulson | | | |
| MODEL VERIFICATION | | | | Hollyday | |

Figure 18. Chesapeake Bay package.

# APPLICATION OF ERTS-1 RESULTS TO U.S. DEPARTMENT OF INTERIOR PROGRAMS

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The people who have summarized discipline areas have done an excellent job of putting the uses of ERTS into the proper perspective. The illustrations they have used cover many of the basic topics of concern to the Department of Interior. Interior's interests in this program go completely across the board in every discipline area that has been discussed. The reason for our broad interest is that there are some large pieces of real estate in this country whose management is the responsibility of the Secretary of the Interior, and the various bureaus of the Department have many functions in terms of the management of these public lands. In addition, Interior has responsibilities for nationwide information and research activities. Many of these activities are centered in the Geological Survey and are involved with water resources, geologic mapping, topographic mapping, and some management functions concerning the production of mineral resources and assessments of reserves on public lands.

These functions require information. In the past, many decisions were made mainly on the basis of need. In this day and age, the environmental impact becomes much more important as resource demands begin to stress the environment. The trend and the desire of the Secretary is to reach a reasonable balance between use of resources and conservation and recovery practices. This means that much greater care must be taken to assess environmental impacts prior to the initiation of activities. Strip mining is one example. In the past, most strip mining was done without regard to what developed afterward. Now things are being changed; recovery activities are underway at state levels to reclaim many strip-mined areas, and plans to reclaim strip mines are often required before approval for mining is granted.

I think that you can sum up the Geological Survey's–or the Department of Interior's–interest under one major heading: land use in one form or another. Under this heading fall all of the earth resources disciplines that have been discussed at the Symposium. Land use has been used in a very restricted way, but everything that this whole program is about really contributes to this particular objective: land use and resource use.

This objective is now assuming greater importance in terms of thinking in the Department of Interior, because there is much concern and activity regarding land-use legislation. Last year, the Jackson bill was introduced in Congress. Although the bill did not pass, there is a high probability that there will be land-use legislation enacted before too long. The

Administration has proposed a land-use bill—or is proposing one—and Congress may well act on this. This particular bill assigns certain responsibilities to the Department of Interior, to the Department of Housing and Urban Development, and to some other agencies, but it requires that the states do a tremendous amount of work in order to comply with federal law.

It is my own personal opinion that it will be impossible for the states to carry out their land-use inventory and planning activities without a very effective remote-sensing program, including satellite data for nationwide coverage and aircraft data for smaller areas where detail is needed.

The time frames being talked about for making really significant progress in land-use planning are very short; and certainly, if we use the techniques that we have been using for the past hundred years, or even the past decade, we will never meet schedules.

Another area of concern to Interior is renewable resources, especially rangelands, Indian reservations, and other public lands. At this point in time, there has been some significant work done in agriculture and some very promising indications concerning what we might be able to do with rangeland. However, the real experiments in this area are going to have to wait until this spring. I am personally very optimistic that we will be able to do what we think we can do as far as rangeland assessment goes.

Not too long ago, I was briefed on how rangeland capabilities are assessed in some areas. A man rides to the range in a jeep or on a horse; he twirls a loop of wire around his head and lets it go with his eyes shut. He takes his sample where the wire lands. This constitutes random selection. He counts every blade of grass in the sample, describes the species, and then repeats the process a few miles away. If the hoop lands on the side of an arroyo, he obtains one answer. If it lands in a clump of grass, he obtains another one. Decisions have to be made in a very conservative way when this quality of data is used to assess rangeland capability to prevent overgrazing.

I would like to discuss another concern that I have. We have heard a lot about data and data-analysis methods, and I think we have made some tremendous progress in this area. There have been some benefits pointed out in terms of greater efficiency in doing various jobs. There is still another kind of benefit: The real payoff is in the use of the information after it has been analyzed—in other words, the actions people take to produce beneficial results. We have not heard very much about such applications at this Symposium, and I am not sure that we will for a while because they have to be ferreted out. Applications are very hard to find; often, the scientists involved do not like to talk about taking their results to evaluation of tradeoffs by decision makers.

But there are quite a few things going on that I think are relevant to the area of applications. Some actions are being taken. For instance, there is a requirement in the Alaska Native Claims Act for the native Alaskans to nominate large tracts of land for withdrawal, for the use and benefit of the Alaskan natives. The intent here is to withdraw valuable tracts of land, so the land will be worth something to them. The Chairman of the Alaskan Native Claims Commission knew about ERTS-1 and started collecting all ERTS data on Alaska, and the Commission has been determining resources potential from these data. They do not have verified field studies yet; however, they have already picked potentially valuable areas and are selecting these for withdrawal. I think this is a very positive thing in terms of actions that comply with the intent of the nation.

Several states are involved, on their own, in using ERTS data in land-use planning and land-use inventory activities. For instance, the state of Michigan is doing a 1:500,000 land-use map of the entire state, and they plan to use aircraft data to go into more detail in some of the more critical areas.

Another indication of value may be phrased as a question: "Who wants the data outside the experimenter community?" A consortium of petroleum industries and mining companies is purchasing satellite data of the entire country. While I do not know what benefits they will obtain from these data, I think they feel the benefits will be large. This is not the kind of use that is normally reported, but it has the potential of being beneficial to the economy of the country.

Efficiency factors of six, ten, or twenty and in some areas possibly higher, have been reported at this meeting, but the real benefits come from taking actions based on these more efficiently derived results. One type of benefit that I have not heard mentioned is the ability to take action early enough to be effective. Many kinds of data are collected today similar to data that we are getting from ERTS, but the compilation requires so long that effective action is not possible. I want to emphasize the importance of timely acquisition *and* analysis of data. For instance, Schuman's data from the DCS platform, which allowed decisions to be made concerning regulation of a reservoir, is what I am talking about, because the data were available in time for effective action to be taken.

I received a report just about a minute before the meeting started that there has been a volcanic eruption of the Volcano Fuego in Guatemala. The eruption occurred on February 23, 1973. On February 17, 1973, six days before the eruption, a DCS platform was installed on this mountain. For four days, the average number of seismic events ran at a rate of about five per day. A similar level of seismic events was observed at a reference DCS platform 30 kilometers away. The level stayed at this low level at the reference station, but two days before the eruption, the level jumped to 80 seismic events per day on Fuego, and then on February 23, 1973, the volcano did erupt with ash flows and ash ejection.

This is the first time we have had an eruption from a volcano monitored by a DCS platform. We have quite a number of volcanoes instrumented now. Some of them were bound to erupt; we did not know when, but we are beginning to get some data on these events. As far as volcanoes go, there are very few that are well-studied; this DCS capability is making it possible to study a statistically significant number to see whether our old ideas were right and to determine how other volcanoes behave. Why is this important to us? In the East, many people do not realize that there are some active volcanoes in the western states. Mt. Lassen erupted in 1915, and it is not dead by any means. In fact, many of the Cascade volcanoes are potentially active. In Alaska, we have many active volcanoes; there have been numerous historic eruptions there. We also have active volcanoes in Hawaii.

Thus, in its few months of operation, ERTS-1 has already demonstrated its capability to provide resources planners and managers with useful, timely data, and we at Interior expect that further demonstrations will be made in the months ahead.

# A PRELIMINARY ASSESSMENT OF ERTS IMAGERY FOR MARINE RESOURCES

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Two momentous events are being celebrated this year. It was 500 years ago that Copernicus was born. For thousands of years, men thought of themselves as living at the center of the created universe not only philosophically but also physically. Copernicus reasoned otherwise. He knew his discovery about the solar system would shatter the world of thought, and for 18 years he was afraid to publish his book. Also about 500 years ago, his contemporary, Christopher Columbus, set out on perhaps the most momentous oceanographic exploration of all time. He was a master mariner who could read the signs in the sea—the meanings of the Sargassum weed, the sea birds, and the color of the oceans.

The two men offer an instructive contrast in motivation. Copernicus, the mathematician, had no interest in application; Columbus did. I have often wondered whether the cost effectiveness of Columbus' proposal was computed. It probably was, because when Columbus returned without silver, gold, and spices, he was jailed for over-promoting.

We no longer take quite so simplistic a view of a new enterprise. What is relevant to use is that different as these men were, their careers complemented each other to produce a new age of exploration: the fruit of a balanced view of knowledge and application. It is somewhat futile to speculate which comes first and which follows.

Our capacity for surviving on this planet is critically dependent on how we perceive it. The greatest impact of the space program on mankind may well come from the extraordinary first view of earth seen from the moon on December 24, 1968. People will never again perceive the earth in the old way. In retrospect, this will seem like a quantum step in our attitude toward world problems, for it made men ponder what will happen if we continue to plunder and despoil our planet.

The other event we celebrate this year is especially important to oceanographers: 100 years ago the Royal Navy and the Royal Society sent out the first expedition on a ship specifically designed for oceanographic research. HMS Challenger sailed from Portsmouth on December 21, 1872, 96 years to a day before the launching of Apollo 8. The Challenger was a three-masted corvette with a crew of 243 men. She carried a donkey deck engine with rope cable used to lower a newly-designed dredge to the sea bottom. Her scientific director, Professor Wayville Thompson, wanted, among other things, to test a theory of Edward Forbes, Professor of Natural History at Edinburgh University, that no life could exist below

100 meters in the sea. It was a great theory and quite logical in the context of the time. In those days it was implausible to think that knowledge of the ocean could have any practical application. Indeed, the whole concept of freedom of the seas was based on the assumption that the ocean, except as a means of transportation, was just a useless wasteland.

The Challenger stayed at sea for 1000 days and sailed 68,000 miles, crossing the equator eight times and penetrating to Antarctica. She discovered the great intercontinental ridge named after Professor Thcmpson, and explored the deeps of the sea. Her soundings remade our picture of the globe. Each laborious lowering took three hours to make, but they established oceanography as one of the basic earth sciences.

There have been great innovations since the days of the Challenger, notably the underwater sound technology that led to perhaps the greatest discovery of this century—the movement and drifting of the continents riding on huge tectonic plates of the earth's crust. This discovery will undoubtedly find application in our search for minerals and our ability to anticipate earthquakes and disastrous tidal waves. But, however we may profit by applying new knowledge of our world, the men who made the discoveries were not motivated by mercantile ambitions—they just wished to know.

The Challenger established the pattern of oceanographic voyages for the intervening century. Until the advent of the Earth Resources Technology Satellite (ERTS) and other orbital platforms, we were still limited to slow expensive vessels. To be sure, we can now circumnavigate the earth in much less than three years and make individual soundings in seconds. But basically we have been limited to point-to-point reconnaissance at stations far apart in space and time. We have not been able to look at the month-to-month or day-to-day events or to see concurrent happenings in the Atlantic and the Pacific. For example, it has been beyond our grasp to observe the seasonal onset of the spring growing season in the ocean while it occurs.

ERTS promises to solve this problem, at least with regard to processes that take place in the upper levels of the sea. Now we can circumnavigate the globe via satellite in about 90 minutes, or we can station a sensor overhead and observe selected areas continuously. There are many ways in which this new capability can revolutionize oceanography in the next 100 years just as radically as the Challenger did. In recent years, there has been a spectacular proliferation of knowledge about the earth's crust and its hydrosphere, in many instances as a result of the development of new instruments to probe the deep sea and its sediments.

But the sampling plan of fixed stations, widely separated in time and space, has not been significantly altered. To repeat the 68,000-nautical-mile voyage around the world which was accomplished by the Challenger in 1000 days, a modern research vessel equipped for general oceanography with high speed winches and acoustic sounding devices would still require some 300 days. Of the 30,000 one-degree squares of the ocean surface, only about 1100, or less than four percent, would have been sampled at an operating cost approaching one million dollars.

The high cost and low rate at which oceanographic data have been acquired have narrowly constrained the range of phenomena amenable to study. Processes subject to rapid change or or to large variability on a small spatial scale have, for the most part, been studied on an intermittent and local basis, often expanded to planetary scale by speculative extrapolation. Such hazardous procedures have, in the past, frequently led to false conclusions.

An example of such processes is the life cycle of a plankton bloom, which has a characteristic area of two or three square nautical miles and a life expectancy of a fortnight. The scarcity of knowledge about such phenomena, and the consequent lack of understanding is vividly illustrated by our uncertainty about the effects of man's activities on the productivity of the marine environment, now and in the future. The sampling techniques available in the past and still in vogue scarcely offer much hope for significantly alleviating this lack of information. What is required is a network of information much denser in both time and space, particularly for the superficial sunlit layers of the ocean which are the site of all the primary biological productivity, and through which rapid energy exchanges occur.

The newly available capability for rapid and continuous oceanic survey, afforded by both orbiting and stationary satellites, is spectacularly fitted to fill this need. Although it is too soon to forecast future developments in this fast unfolding field, the imagery and quantitative data currently emerging from the ERTS program is already finding ready applicability to varied problems such as:

- Location of large-scale areas of seasonally variable biological productivity
- Measurement of realtive water depth in nearshore areas and shallow seas
- Rapid monitoring of the origin and transport of industrial waste from river and sewer discharges
- Prompt assessment of damage to beaches and shoreline installations by waves and storms
- Navigation through the ice-choked Northwest Passage Alaska

To digress for a moment, let me comment on the fact that we look only at the superficial layer of the sea. Let us consider the ocean geometrically. Just as all biological activity is basically a surface process on land, so it is in the sea. All of the sea's food resources stem from plants grown in the sunlit layer, and nearly all the energy exchanges are through this superficial layer. To make this geometry more vivid, say that the sea is proportioned like a fully opened sheet of newsppaer. Its horizontal dimensions are some 5000 times greater than than the thickness. So besides its capability for speed, ERTS has direct access to the part of the ocean where the action is.

I could not try to guess what this new capability will lead to, but I am certain that it will prove to be another quantum jump in our perception of the ocean. Here are just three of the new vistas which have been exposed at this symposium:

Figure 1 illustrates the ability to reach into inaccessible locations quickly and cheaply. Shown in detail are typical ice floes in the Bering Sea. Let me emphasize the difficulties of monitoring the floes by conventional means, and the role the northwest passage will play in giving access to the new Alaskan oil field. Imagine what it would cost to obtain this information in real time.

We turn next to the more mundane job of catching fish. Thirty percent of the menhaden catch is achieved in Mississippi Sound. These plankton feeders are found in relatively non-turbid shallow water of low salinity. In Figure 2, the density of the ERTS image has been partitioned into high and low categories, depicting areas of high and low turbidity. The black dots shown in the figure at the edge of the turbid water mark the areas where the fish are caught. This type of information is given to the fishermen each morning as they leave port. Since nearly three quarters of the cost of catching fish is expended on scouting, the savings to the fishermen are significant and timely.

The heavily populated Long Island Sound area has been so polluted that the public has demanded that it be cleaned. This is an expensive operation and requires an understanding of the circulation of the Sound—particularly the plume of the Connecticut River. Figure 3 shows the plume mixing into the Sound under four different conditions of wind and tide.

In summation, what we have seen at this Symposium is just a beginning. The future will see more capabilities and more understanding proceeding hand in hand. After ERTS, oceanography will never be the same pedestrian science.

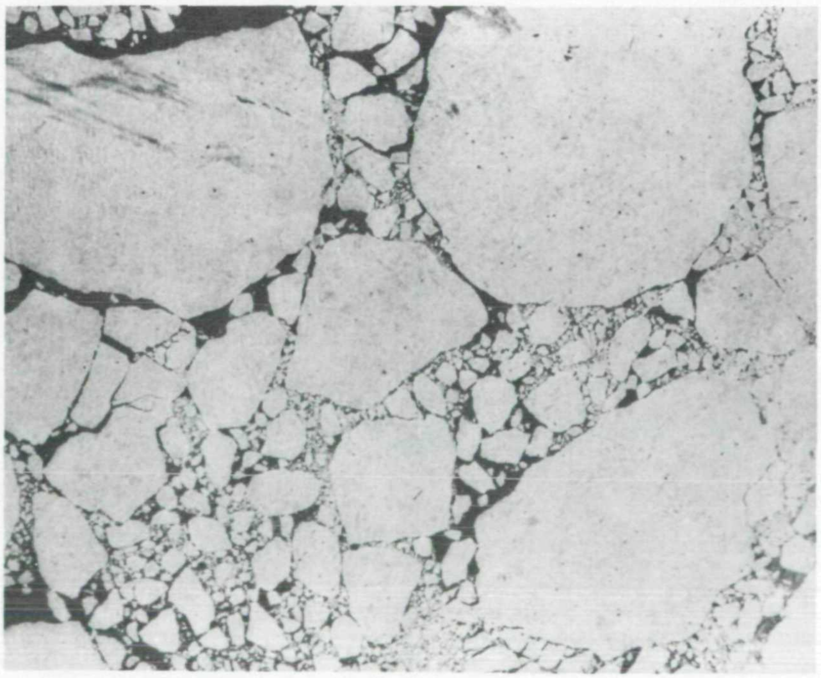

Figure 1. Ice flows in the Bering Sea.

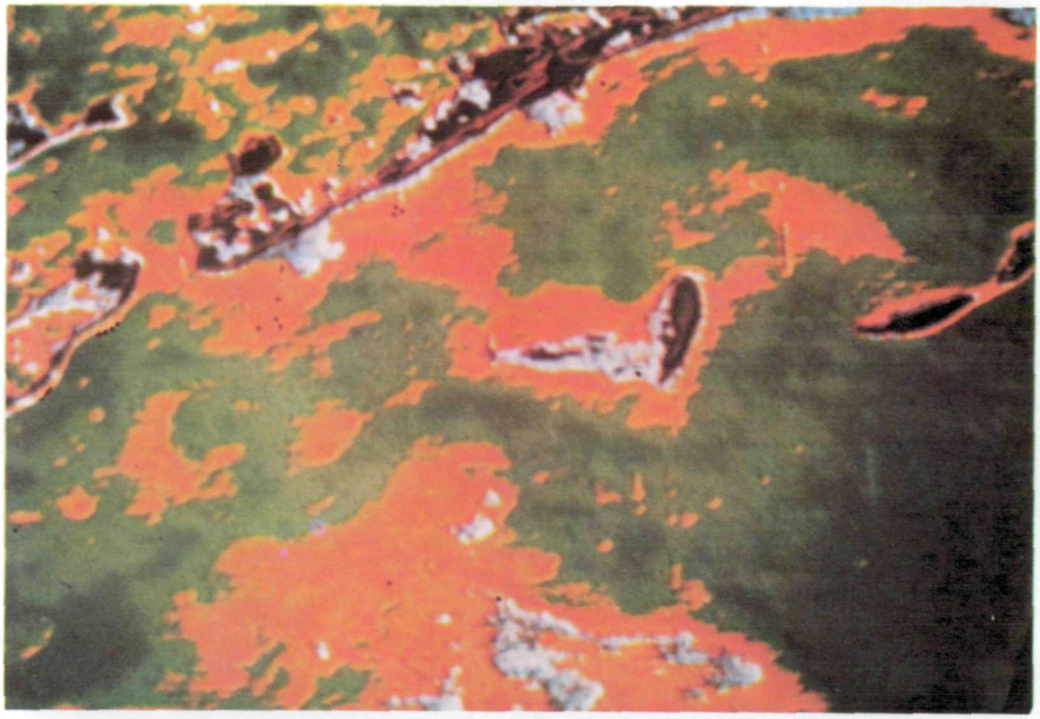

Figure 2. Areas of high and low turbidity in Mississippi Sound.

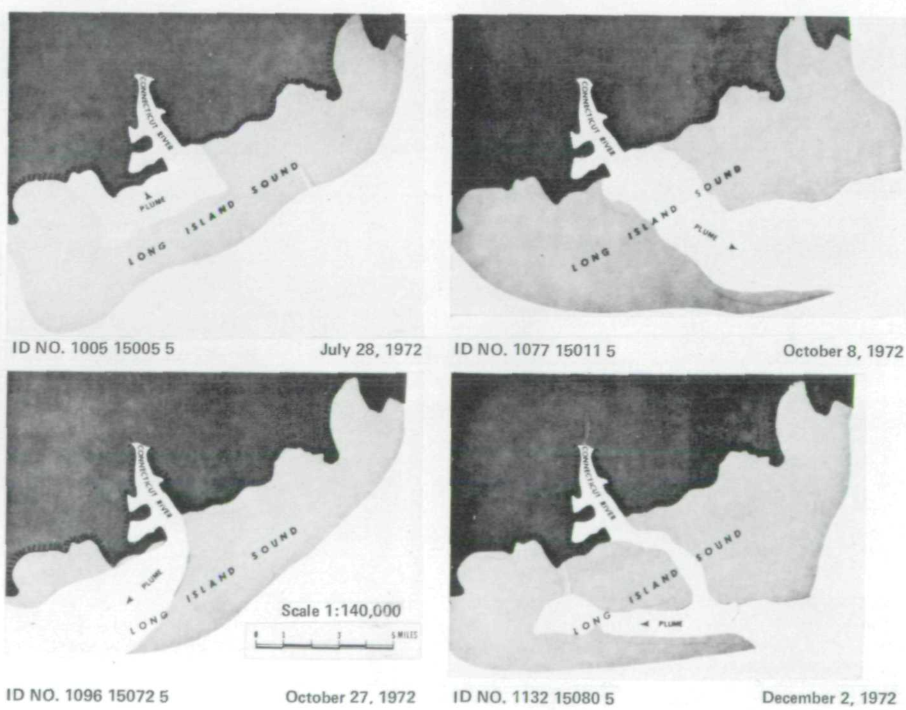


Figure 3. Plume of the Connecticut River mixing into Long Island Sound.

# APPLICATION OF ERTS-1 DATA TO AID IN SOLVING WATER RESOURCES MANAGEMENT PROBLEMS IN THE STATE OF CALIFORNIA

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Hydrologists and water resource managers have eagerly awaited the opportunity to assess the potential of remotely sensed data from a satellite platform for application to a broad array of operational tasks.

Investigations within the State of California have emphasized the direct utilization of the supplemental data source afforded by the Earth Resources Technology Satellite-1 (ERTS-1) imagery. A user-oriented study has been underway for several years to identify and develop application methodology for remotely sensed information available from several platform levels, including low and high flights by NASA's U2 aircraft, and other manned and unmanned devices. The University of California has pursued both basic and applied research in remote sensing, through ongoing studies supported by NASA, and in cooperation with state agencies responsible for water resources and related fields. This report reviews the applications of ERTS-1 and supplementary imagery sources applicable to water resources planning, operations, and management.

At the outset, it was clear that no single device would be available to provide the variety of information and detail needed for hydrologic purposes at the current state-of-the-art in remote sensing. An assessment was undertaken to define the parameters involved in the hydrologic processes and subsystems of the water cycle. Parameters of the subsystems were defined on the basis of the operational tasks, reduced to the fundamental hydrologic process or function performed currently by water resource agencies. This procedure provided a listing of parameters designed to be responsive to the needs of data users. The parameters were further defined in terms of the type of measurement required and the magnitude, resolution, and frequency of data acquisition needed for several levels of intensity in operational tasks.

The continuing phases of this research are currently centered in developing alternative parameters or analytical methods to adapt remotely sensed information to user tasks. ERTS-1 imagery is being studied intensively for these purposes. This satellite provides a synoptic level coverage of study areas in California on a repetitive cycle of 18 days. A series of test areas have been selected in Central California within the region designated as the San Francisco Bay and Sacramento-San Joaquin River Delta Test Site. This site provides a wide variety of conditions and examples of targets of hydrologic and water resource interest. The repetitive coverage throughout the year permits study of seasonal changes, a particularly important factor in the area where precipitation is largely a winter season occurrence, and extended dry periods persist for the balance of the year.

Water requirements for both urban (municipal and industrial) and agricultural uses have led to comprehensive programs of water development. Planning and development of large water systems together with their operation are summarized in terms of where the water is: when, how much, and in what form; and logically where, how much, and when water is needed by users. Remote sensing offers a potential new dimension to this field of endeavor. A strong effort needs to be directed toward concepts of quantification of data derived from remote sensing, especially for water resource and hydrologic use. Remote sensors of the imaging type permit qualitative comparison or evaluation quite readily, and thus are useful for monitoring and for comparative analysis. Many investigations are seeking to provide insight and methodology for useful measurements of water-related phenomena. While these results are not yet fully developed nor in operational use, this objective for the interpretation of ERTS-1 imagery and data extraction is of highest priority.

To illustrate the progress to date in evaluating ERTS-1 imagery and in applying the results to typical water resource problem solutions, some selected samples are presented, based on a partial year of analysis. Completion of the annual cycle is expected to yield additional bases for interpretation. Longer term operational analysis of ERTS-1 data will produce a wider range of experience for hydrologic interpretation and applications, embracing greater extremes of natural processes and increasing the data base for quantification of sensor response with ground truth studies.

Three specific characteristics of this satellite are valuable for the test site conditions:

- Repetitive coverage over seasonal and annual cycles
- The imagery format is readily adaptable to a variety of enhancement procedures to increase derivative results.
- Resolution characteristics and spectral band coverage provide great opportunity for detailed examination of other target subjects and other interpretative techniques.

The test area includes mountain watersheds; foothill and valley basins; snow pack regions; large river systems; flood-water control facilities; deltaic areas; agricultural lands, both irrigated and nonirrigated; dams and reservoirs operated for multiple purposes including water supply, flood control and recreation; urban areas; and lakes, both eutrophic and oligotrophic. It also provides examples of most of the important water conditions of concern to hydrologists.

The illustrations generated from the multispectral scanner (MSS) images supplied from ERTS-1 are controlled for tonal response to certain water-related interpretations only. Detailed discussions of most of the subjects are contained in progress reports issued periodically by the research team.

Figure 1(a,b) are color composite images of bands 4, 5, and 7 made by a diazo process for August 3, 1972 (dry season) and January 4, 1973 (wet winter). All of the aforementioned water-related components are contained in these images and are directly comparable for the two extremes of seasonal effect.

Specific hydrologic elements that can be discerned include:

- Watershed physiography (drainage network) features
- Water body locations (natural and man-made)
- Canals
- Large and small river systems
- Deltaic areas
- Flood control works
- Flooded delta islands
- Snow on higher mountain slopes
- Wet lands (seasonal)
- Irrigated agriculture
- Dry land agriculture
- Many additional water-related features

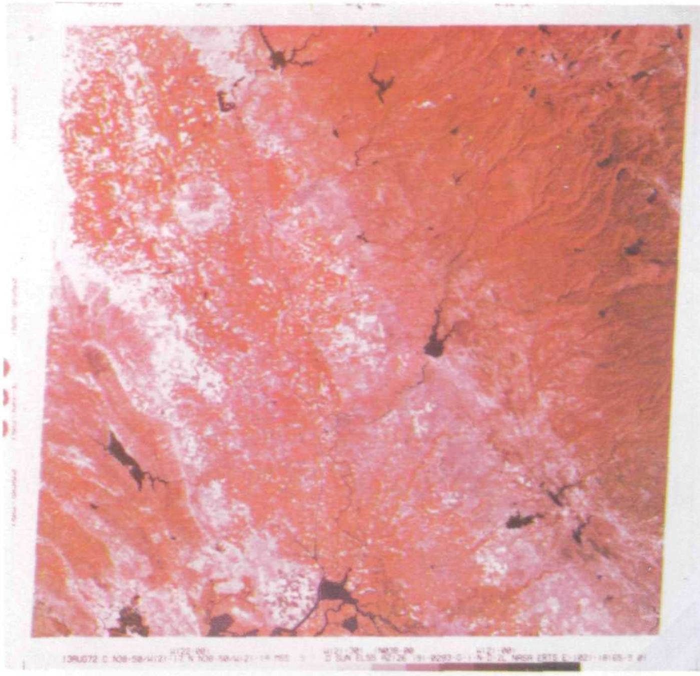
Seasonal effects in terms of both atmospheric attenuation and sun angle tend to reduce the image quality in the winter at this latitude.

Figure 2 extends the imagery to the westerly portion of the test site, and overlaps the area of Figure 1 for this date only, after which orbital adjustments of the satellite track were made. This particular image scene is nearly centered over the specified test site and provides orientation for the illustrations which follow.

Near the center, the flooded area of Andrus Island is obvious. Levee breaks in June 1972 caused the flood (see bottom center of Figures 1(a,b,)). That target has been studied as an illustration of a flood condition with a controlled recession produced by pumped dewatering of the island. Successive coverage, supplemented by detailed low flight imagery is permitting analysis of the spectral characteristics of ERTS-1 MSS bands in relation to delineation of water boundaries, depth of water, and penetration for depth sounding through remote sensor interpretation. The land had been essentially dewatered by the time of Figure 1(b). It appears as a good example of extremely wet soil (high ground water table) and indicates the relative wetness of the general region of the surrounding delta lands. The strip located northward adjacent to the Sacramento River is the alignment of the Sacramento River Flood Bypass (see detail in Figure 7).

Figure 3(a,b,) are enlargements of the Andrus-Brannan Island site showing surface details emerging as the water level declined. The island is situated between the main channels of the Sacramento River (on north) and the San Joaquin River (main channel on south). The figures indicate the myriad cross channels and sloughs characteristic of this complex delta flow regime.

A



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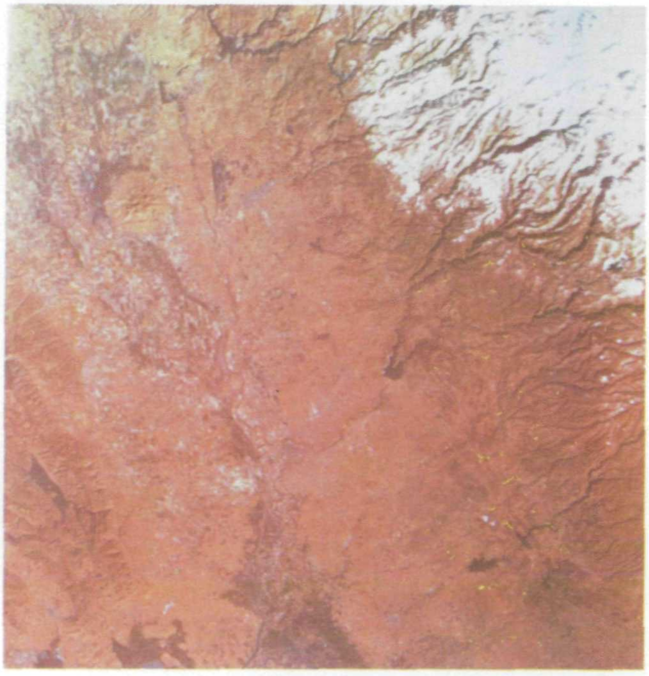


Figure 1. (a) Shown is an infrared ektachrome composite image prepared from ERTS-1 MSS bands 4, 5, and 7, centered on Sacramento, California. The region is the site of the Sacramento-San Joaquin River Delta Test Site used for ERTS-1 Application Studies. (b) The same scene as Figure 1a, depicting the changes in the region in winter. Snow on the mountains and areas of wet (dark) soils lie along river channels.

Referring to Figure 1(a), Folsom Reservoir (Lake), located near the center, exhibits changes in surface configuration as water stage is lowered during seasonal water supply operations. Enlarged views show the summer condition, Figure 4(a), and a lower stage, Figure 4(b), after water demands downstream have been supplied. Prominent shoreline features emerge at the lower stage like the white band of sandy shore on the northerly edge and the extension of the peninsula at the center. A general reduction in the area of the water surface is noted throughout, including the two forks of the American River entering the reservoir from the Sierra Nevada Mountain slopes to the east.

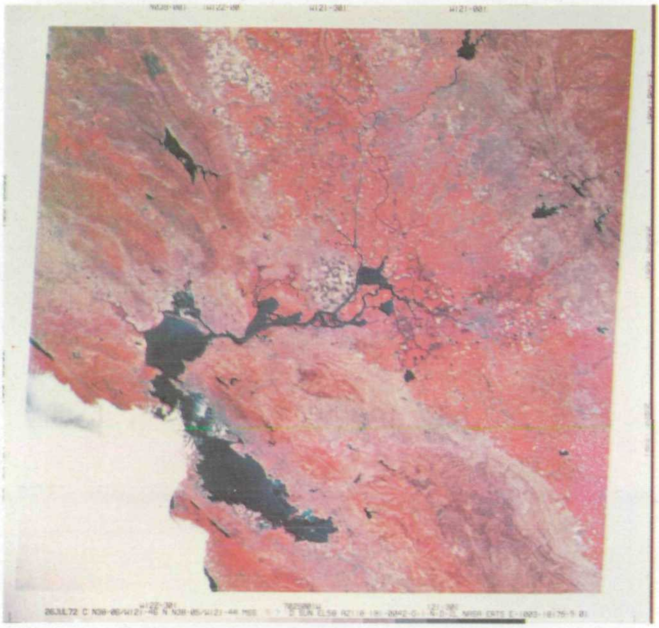
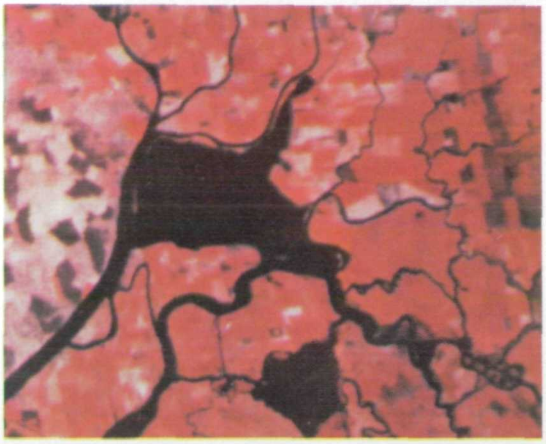


Figure 2. This color composite of the westerly portion of the Sacramento-San Joaquin River Delta Test Site shows the relationship of the area to the San Francisco Bay and lower Sacramento River.

Within regional topographic groups, there have been general similarities observed with respect to shape of stream valleys, general slopes, and orientation. These characteristics can be used to estimate reservoir volume changes if only some data are available.

In the highly developed western United States, most reservoirs are controlled on the basis of a stage-capacity relationship to determine volumes from stage records. No advantage is to be gained by remote sensing for such systems. However, the concept of regional topographic similarity, and the capability to determine surface area differences between sequentially acquired images affords a means of assessment of volume changes in water bodies in unknown areas. The extensions of the concept to remote areas for runoff quantification and estimates is suggested. This technique may be employed by water resource surveyors in assessing dams and reservoirs in a nationwide survey in the near future within the U.S.



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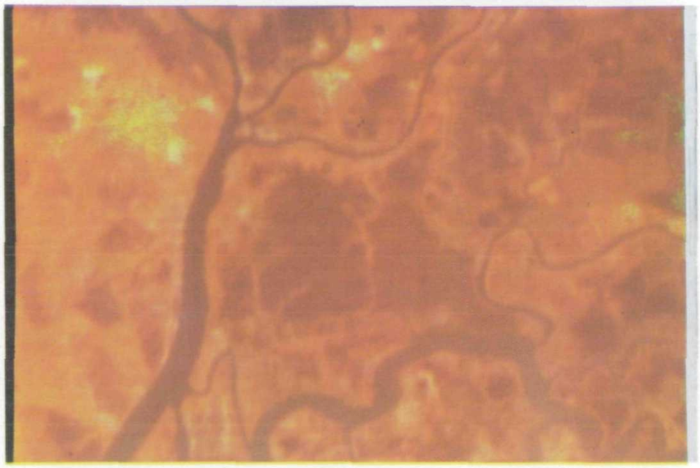

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Figure 3. (a) Andrus-Brannan Island, enlarged from Figure 1a, indicates the flooded island resulting from a levee break in June, 1972. (b) The Andrus-Brannan Island area after repair of the levee and subsequent pumping to remove the water. Most of the land surface is exposed, but wet soil produces the dark tone. The Sacramento River channel lies on the left and the San Joaquin River channel on the bottom (south), where the break occurred. Sequential imagery provides an excellent method of monitoring flood recessions.

Reservoirs like Folsom are operated for flood control purposes, and the stage is held low to provide winter season flood storage capacity; therefore, the reservoirs continued throughout the winter season of 1972-73 at the lower stage. Late spring runoff from snow melt will be retained to bring the water level (and volume) up to higher levels in the spring and summer.

Another direct use of volume estimates by remote sensing using ERTS-1 images should be noted for lakes and reservoirs. Direct inflow to some water bodies is fully retained, at least for substantial periods of time or until the maximum stage is reached, after which spillage or overflow occurs to downstream channels. Prior to spillage, inflow volumes may be correlated to watershed runoff to estimate yields for the time period. Sequential coverage by the remote-sensing platform may thereby augment the data base for yields prediction in undeveloped areas, or where little hydrologic information is available.

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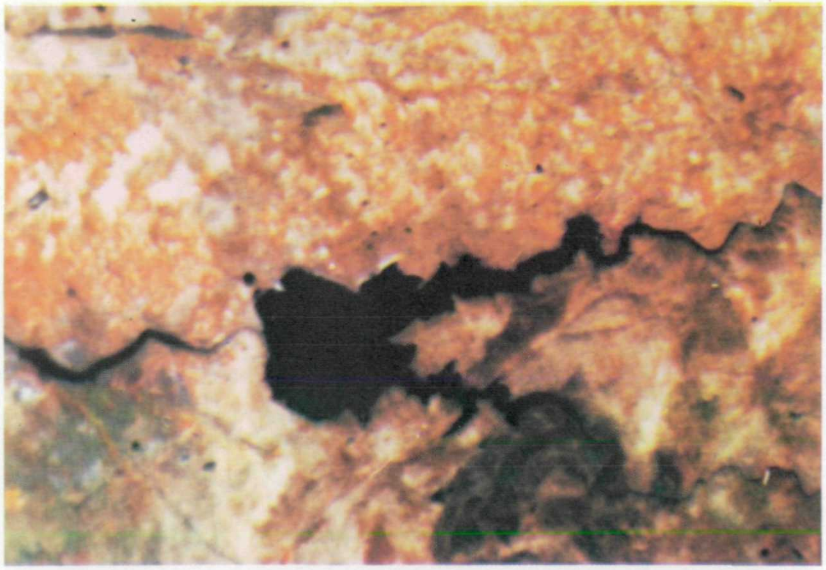

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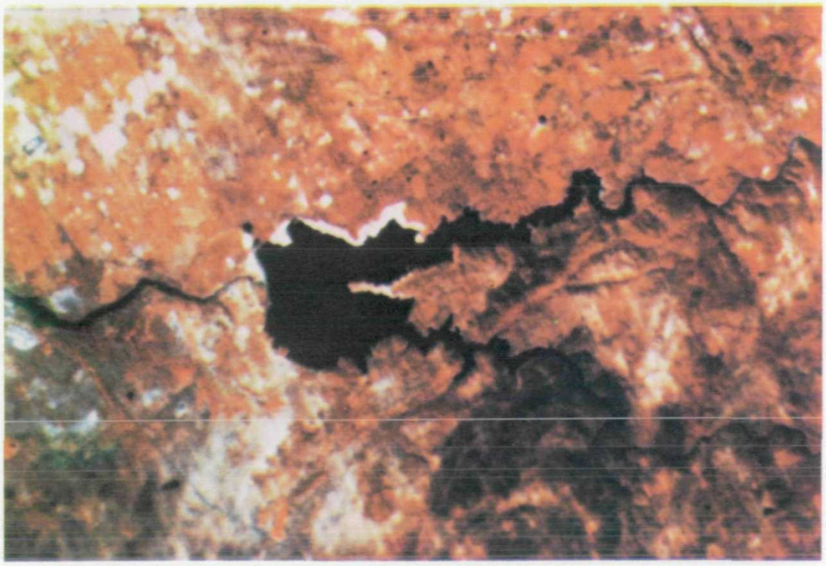


Figure 4. (a) Folsom Reservoir as it appeared in an enlarged view on July 26, 1972. Reservoir water stage is relatively high. (b) Folsom Reservoir on October 6, 1972, when water levels were lower. Note changes in shore line details and beach areas.

Downstream from Folsom Reservoir, the American River joins the Sacramento River at Discovery Park in Sacramento (see Figure 1(a)). Figure 5 is an oblique view of this confluence with the turbid waters of the Sacramento River joined by the clearer waters of the American River from the right. An enlargement of this site, shown in Figure 6 for MSS band 5, reveals the tone difference of the turbid water as contrasted to the clear water inflow. Extensive efforts are underway to quantify the spectral signatures of water for sediment concentration or turbidity. For monitoring purposes, band 5 is useful. At this site, turbidity values were 5 and 25 Jackson Turbidity units for the American and Sacramento Rivers, respectively, and Secchi Disk Transparency of 2.7 and 0.7 meter (8.8 and 2.3 feet), respectively.

The sediment-produced turbidity is apparent throughout a longitudinal (profile) scan of the Sacramento River, moving upstream. This permits isolation of the source region of the contaminant. The utility of this type of imagery, acquired on a regular schedule for monitoring of river water quality and source identification, is great.

Figure 7 depicts a flood condition at the same site as Figure 6, and shows the Sacramento River Flood Bypass in operation. Flood water from the north is being conducted around the urban area, and the flood wave from the American River is being partially diverted through the Sacramento Weir to the Bypass, evidenced by the channel connecting the river to the Bypass due west of the river junction. Water quality effects are noted due to the dilution of flows. Tone differences are quite distinct in the main channel of the Sacramento River downstream from the junction, even on the enlargement of the color composite image.

Figure 5. The junction of the American and Sacramento Rivers at Sacramento, California, on October 6, 1972, shows the characteristic turbidity of the Sacramento River, which receives return flows from irrigated lands upstream.

Figure 6. This image is an enlargement from MSS band 5 of October 6, 1972, at the river confluence shown in Figure 5. Note the tonal differences (gray) due to turbidity in the Sacramento River.

Figure 7. This is an enlarged section of the color composite image produced for January 22, 1973 over the test area. It provides a detailed view of the flood bypass in operation to divert flood runoff around the urban area. Turbidity differences are apparent both in the bypass and in the main river channels.

Characterization of watersheds for hydrologic prediction purposes includes inventory of vegetation for species, composition, density, and density changes, together with relative vigor of vegetative growth. Forestry remote sensing techniques have been extensively developed to permit vegetative identification and relative density evaluations. Within hydrologic regions the ability is being developed to assess the general watershed condition and to predict the relative yield of annual runoff based on precipitation. Such a study area is depicted in Figure 8, for the chaparral-covered foothills lying northwest of Lake Berryessa. Here, forest and range interpretations of ERTS-1 imagery are being correlated to the runoff yields of tributaries. One obvious vegetative change due to wildfire shows clearly. The fire was outside the hydrologic basin under study, but demonstrates the ease with which unique watershed phenomena may be identified.

During the fall and winter seasons of 1972, rainfall exceeded normals by over 150 percent in Northern California, producing heavy runoff and heavy soil erosion, particularly since the previous runoff year was below normal.

Figure 8. Lake Berryessa and the watershed lying northwesterly are shown for July 26, 1972. Vegetation and watershed conditions assessed from the imagery are correlated with runoff predictions at this site.

The opportunity was afforded this year to engage in a cooperative study with scientists from the NASA Ames Research Center, to test intermediate elevation aircraft platform imagery for sediment plumes and dispersion within lakes and reservoirs. Aerial photos produced under direction of Mr. Robert C. Wrigley, NASA/Ames, were coordinated with ground truth for the flood wave depicted in Figure 9, for Putah Creek entering the northwest corner of Lake Berryessa on January 19, 1973.

Figure 9. This aerial photo shows a sediment-laden flood wave discharging into Lake Berryessa.

Three days later, the ERTS-1 pass over the site yielded the pattern of sediment dispersing in the reservoir as shown in Figure 10. The peculiar pattern results from heavy inflows at the upper end of the reservoir in combination with a rapidly rising stage (the dam is about 20 miles downstream in the lower right arm shown in Figure 8). Stratification of inflows have been noted previously in the lake. Ongoing studies are quantifying the movement and dispersion of the sediment wave. The stratification results from warm water inflow spreading over the cooler reservoir water.

The use of ERTS-1 imagery for delineating water depth was noted in connection with the flooding of Andrus Island (Figure 3). Another example was derived on the Lake Berryessa site for low water stage in late fall, as seen in Figure 11. White tones (streaks) reflecting in band 5 result from shallow water where the depth is insufficient to attenuate the red wavelengths. The green wavelength (band 4) penetrates more deeply, but is attenuated by atmospheric components reducing the intensity. Differences between MSS bands 4 and 5 may be used for sounding of water depth. Image enhancement using digital data and computer output has been illustrated by Dr. V.R. Algazi, University of California at Davis, a coworker in the integrated Studies of Remote Sensing in California.

Figure 10. This shows the sediment plume dispersing in Lake Berryessa, three days after the scene in

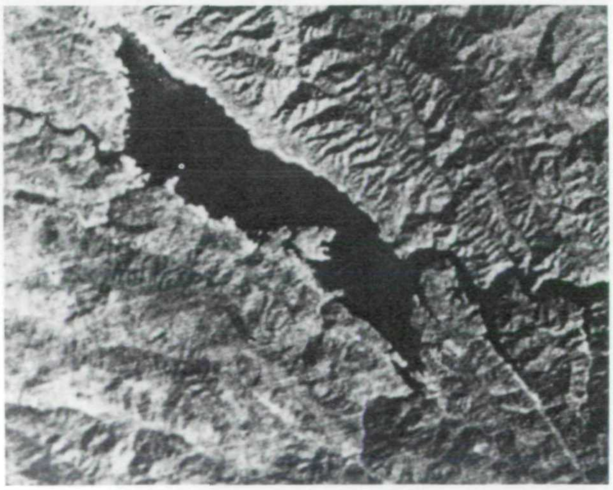


Figure 11. This is an ERTS-1 MSS band 5 scene of Lake Berryessa in October, 1972.

The video display shown in Figure 12 results when all background is suppressed and only the spectral portion of interest is retained. Shallow water is delineated in white. This technique may be used in both color and black-and-white displays and has been described by Dr. Algazi. Enhancement techniques for many water-related phenomena are being tested as digital data becomes available.

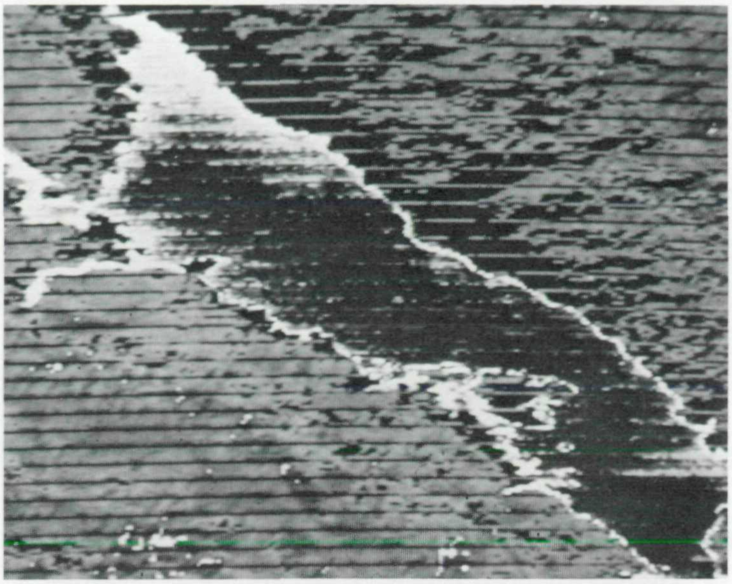


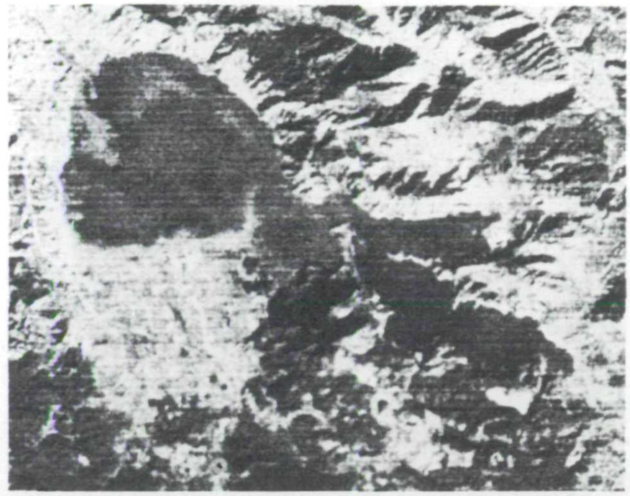
Figure 12. A video display of a computer enhanced digital data image of areas of shallow water is shown.

A final set of illustrations of water quality responses detectable by ERTS-1 image analysis are shown in Figures 13(a,b), views of MSS bands 5 and 7 on Clear Lake, California. This natural lake is an example of an eutrophic water body exhibiting heavy algal growth. The reflectance patterns noted in Figure 13(a) (MSS band 5) are algal growths mixed with turbidity factors. Reflectance in band 7 (Figure 13(b)) shows characteristic white streaks and patterns in certain areas which do not appear in band 5. Infrared reflectance must occur at the surface, indicating the presence of dense algal growth or mats.

One such pattern was photographed from a low flying aircraft on color and infrared color film simultaneously, near an area noted in Figure 13(b). Figures 14(a,b) show the conditions at the site and the infrared reflectance of the green algae. The patterns are the result of wind action and are possibly due to surface mixing by boats. The presence of the white scum and foam piled by wind action is typical of algal blooms, and is associated as a by-product of the bloom. Further examination of this characteristic response is underway.

The infrared reflectance is apparent on subsequent ERTS-1 color composite images. The migration of the patterns from scene to scene may be useful for studies of the motions within the water body.

A



B

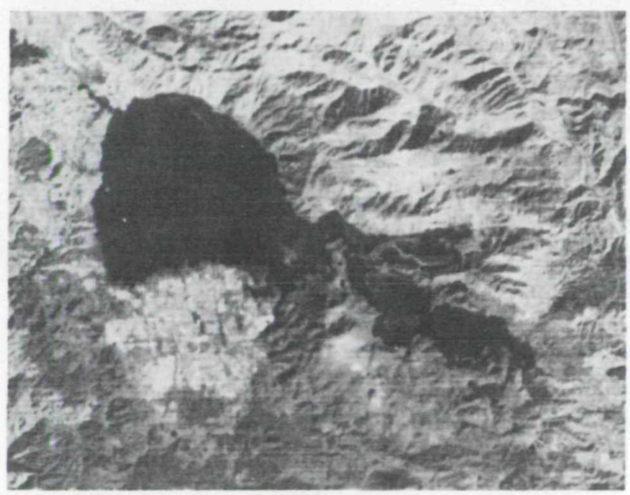


Figure 13. (a) This is an ERTS-1 band 5 image enlargement of Clear Lake, California, taken January 5, 1973. This highly eutrophic lake exhibits dense algal blooms which migrate continuously. Red band reflectance patterns are compared with infrared band in (b). (b) Band 7 of the same date shows infrared reflectance patterns indicating surface response detectable from the concentrated mats formed by wind action. See text and Figures 14 (a, b).

Summarizing the kinds of water resource-oriented uses of ERTS-1, we see that the effective use of the imagery has been demonstrated for a variety of subjects in this test area. The objectives noted include:

- Defining the presence and location of water bodies and watershed delineation
- Defining the quantity of water
- Defining the relative quality of water
- Defining the sources of water quality constituents
- Isolating the time periods of specific elements

A

B

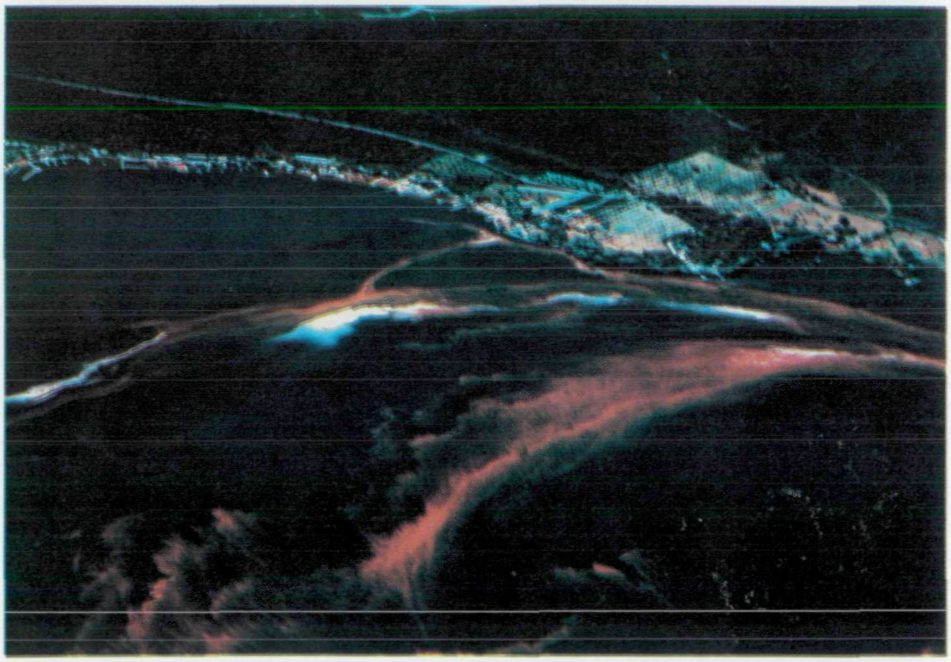


Figure 14. (a) This oblique color photograph of part of the scene shown in Figure 13 (a, b) shows the dense algal concentrations and the foam and scum associated with algal blooms. (b) The companion Infrared Ektachrome photograph shows the red tones associated with infrared reflectance in algal blooms. The white scum and foam streaks are induced by wind action in regions of dense algal blooms (principally blue-green algae). These white streaks are not visible in ERTS-1 images. The response noted in Figure 13 (b) is assesssed as true infrared reflectance from larger masses of the material contained near the water surface.

Examples of each have been studied and early results indicate the great value of the synoptic coverage provided by ERTS-1.

Several significant points derived from the studies may be listed:

- ERTS-1 provides the synoptic coverage of the earth needed for regional water resources planning and operations.
- ERTS imagery is directly applicable for water resources and hydrologic interpretations.
- The spectral ranges (bands) provided are directly useful for both qualitative and quantitative evaluation of water-related parameters.
- The sequential coverage provides the capability to assess and quantify seasonal changes, specific responses, and changes on watersheds in both large and relatively small water system components.
- The potential applications and the data quantification capabilities of ERTS-1 image analysis are extremely broad-scoped. Enhancement techniques becoming available will make the imagery adaptable for many additional uses.
- In combination with intermediate elevation platforms, including the high flights by U-2 aircraft, ERTS-1 should be continued in operation to provide an alternative source of data for hydrologic and water resource applications.

Implementation of programs for the application of satellite-based remote sensing is well underway at both state and local levels as well as by national agencies. Training of key personnel within water resources agencies is an essential factor and is being accomplished through work sessions, university course offerings, and by on-the-job assignments. The new technology of remote sensing and the applications of the new data source will be rapidly integrated into operational status to provide a cost-effective tool for solutions in water resources management.

# APPLICATION OF ERTS RESULTS TO LAND AND RESOURCE MANAGEMENT IN THE STATE OF MISSISSIPPI

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*State of Mississippi*
*Jackson, Mississippi*

When you consider how recently the Earth Resources Technology Satellite-1 (ERTS-1) was launched and realize that the results have been available for use by you and your colleagues for an even shorter period of time, many of the achievements we have seen and heard described here are truly remarkable. With such accomplishments by the scientific community as we have witnessed at this meeting, Lt. Governor Reinecke's observation–"We have an obligation to succeed"–is certainly appropriate. I would like to add a sense of urgency to his statement.

As many of you realize, some people are calling into question the priorities of national expenditures for many scientific and high-technology programs such as ERTS. Within the past few years, we have seen evidence of disillusionment with science and technology by members of Congress and other policy and decision makers as new social problems become matters of national urgency–improved law enforcement, equal education opportunities, better transportation systems, better housing, environmental deterioration, managing the coastal zones, land use, and the energy crisis. Efforts to turn all our new scientific and technological knowledge–knowledge which for the most part was spawned by our advances in defense and space programs–to the solutions of these problems have not always been successful. The results of past efforts to transfer our know-how from war and space to other national needs have been disappointing. The demise of the State Technical Services Act a few years ago attests to the difficulty of getting new technology ingested into the machinery of state and local government.

Within our federal system of shared yet separate responsibilities, the role of the states has become increasingly important during the last few years. In the words of Georgia's Congressman Davis, "The States are where the action is." The broad national policy, whatever it may be at a particular time, must largely be implemented by the States. Increasingly, the problems with which the states must deal are becoming more complex, have a higher technology content, are more costly to solve, and in a very real sense are more difficult to "get a handle on."

I would now like to describe some of the projects that are underway in Mississippi to inventory land and other resources, and to point out what we think are essential elements for a successful technology-transfer process.

The ERTS photomosaic of the State of Mississippi, shown in Figure 1, may be used to illustrate Mississippi's needs, which are similar to those of many other states. You can see the Delta in northwest Mississippi—a very flat, extremely fertile, and intensively cultivated area. The northeastern part of the state, which is an area of gently rolling hills, is relatively underdeveloped except around a few cities. The Gulf Coast region is an area of rapid growth and is subjected to the conflicting pressures of demands for recreation, environmental protection, and industrial development.

While we do not have mountains, deserts, or large urban areas, we do have most of the other resource inventory and management problems found in the southeastern United States.

Before examining some of the ERTS results let me first review the more fundamental data base we are using as a point of departure. We have undertaken a state-wide land-use map project in cooperation with NASA's Earth Resources Laboratory (ERL) and the Department of Interior's Environmental Resources Observation Satellite (EROS) program. In addition to the merits of the final product, this project has easily overlooked but nevertheless important features.

Only after thorough inquiry of various user groups at the state and local level as to their needs—format, scale, frequency of update—was a search undertaken by ERL personnel for an optimum system to meet these needs. The users were involved in a basic way in the definition of the problem.

The Earth Resources Laboratory at the Mississippi Test Facility conducted an experiment utilizing high-altitude aircraft photography with the objective of developing procedures within the technical capabilities of most small governmental agencies and private companies—particularly regional planning or resource census groups. At the outset it was recognized that a large quantity of high-altitude (18,000 m [60,000 ft]), small-scale (1:120,000) photographic data have been gathered over the United States by a number of federal agencies, and the development of centralized public dissemination centers such as the USGS data center at Sioux Falls, South Dakota, made the data available at nominal cost.

The NASA-ERL investigators also realized two additional benefits would derive from a procedure which did not require extensive ground survey teams and utilized high-altitude, small-scale photography for land-use information. First, this is the logical step in going from low-altitude photography (4500 m [15,000 ft] or less) to the eventual orbital-altitude imagery expected from the ERTS and SKYLAB programs. Second, developing a technique that would utilize these photos would help encourage more widespread use of this available data by public and private interests. By and large, relatively little use had been made of such data because of the paucity of small-scale photography and the lack of widespread understanding of the advantages of such imagery by potential user groups outside the research community. With the ERTS and SKYLAB programs in the offing and the establishment of the USGS distribution center at Sioux Falls, it was reasoned that high-altitude imagery would receive much more widespread use in the future.


Figure 1. Uncontrolled mosaic of the State of Mississippi. This false-color IR composite at a scale of 1:1,000,000 was compiled in 1972 from ERTS imagery by NASA Earth Resources Laboratory, Mississippi Test Facility, Bay St. Louis, Mississippi.

Working closely with the Gulf Regional Planning Commission—a four-county planning agency in southern Mississippi, a preliminary map update project was undertaken. Seven Gulf Coast areas of critical concern to the planning agency were chosen as test sites—areas that had been subjected to major land-use changes, including devastation by Hurricane Camille since the last mapping. Previously flown NASA Earth Resources Program small-scale photography (1:120,000) was used to update 1:24,000 base maps of the planning commission. The updating procedure which evolved yielded substantial savings in time and money, required relatively lower-level skills, and virtually eliminated field work and the distortion problems found with low-altitude photography.

As a result of the success of this procedure, an effort to develop and evaluate a simple procedure by which large land areas could be economically categorized using high-altitude small-scale photography was initiated. Developed over the four-county coastal area, the technique was replicated by other planning groups in three counties around the state capitol in central Mississippi. Manpower and cost estimates were verified. In summary, the technique was found to be highly cost effective—approximately one-fifth the cost *and* the time required using photography—requiring but a few months to complete compared to approximately three years for the same area using more conventional technology. The point to be emphasized is that the technique cost and time requirements are within the limitations of personnel capabilities, budget and program deadlines of the operating agencies. This program has now been extended to the entire state. Aimed primarily at producing a state-wide land-use map, the availability of the imagery makes possible a number of other uses and other derivative products, including forest type maps, wildlife habitat maps, and other resource management tools. These tools are expected to be of particular importance and utility in the development of Mississippi's Coastal Zone Management Program and state-wide land-use policy development.

Once this base-line project is completed—within a year or so—we must think of keeping the system updated. The first effort will be completely manual. We hope to be able to utilize ERTS-1 data to update this product and associated information through the use of computerized techniques such as pattern recognition. In the years ahead, it is anticipated that systems and techniques will be developed which will permit automatic annual updates.

Thus, the initial land-use map project should be viewed as the beginning of what can ultimately be a highly sophisticated, satellite-fed, computer-manipulated information system—but we do not have to go that far if circumstances do not warrant additional investment. This is an evolutionary approach that can be stopped at any step, with a usable workable system in hand at that point.

A section of the Mississippi Coast is shown in Figure 2. The land-use map derived from ERTS data using photointerpretation techniques is reproduced in Figure 3. The coastal area of the ERTS image includes Harrison County, the second most populous county in the state, and the cities of Gulfport and Biloxi. Land-use inventory of the county has been

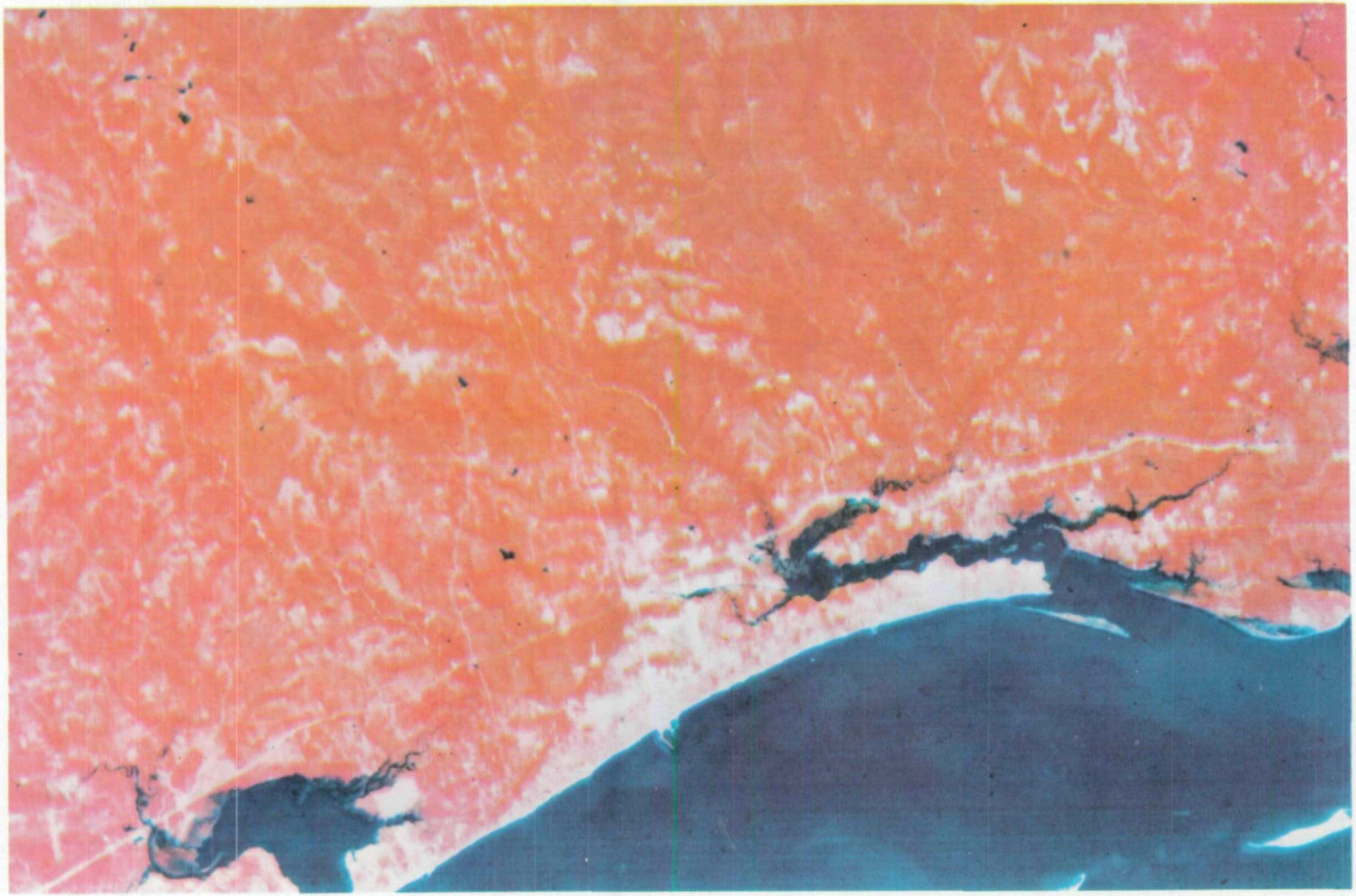

Figure 2. ERTS-1 false-color IR image of the Gulf Coast from Bay St. Louis to Biloxi Bay.


Figure 3. Harrison County, Mississippi, land-use map derived from ERTS data using photointerpretation techniques.

completed to the categories indicated. The Class I level is generally obtainable, and certain Class II classifications are possible.

Derived from ERTS data, Figure 4 illustrates the transportation network of the county. The interstate, primary, and secondary highways and railroads are discernible. Powerline and pipeline rights-of-way can also be delineated.

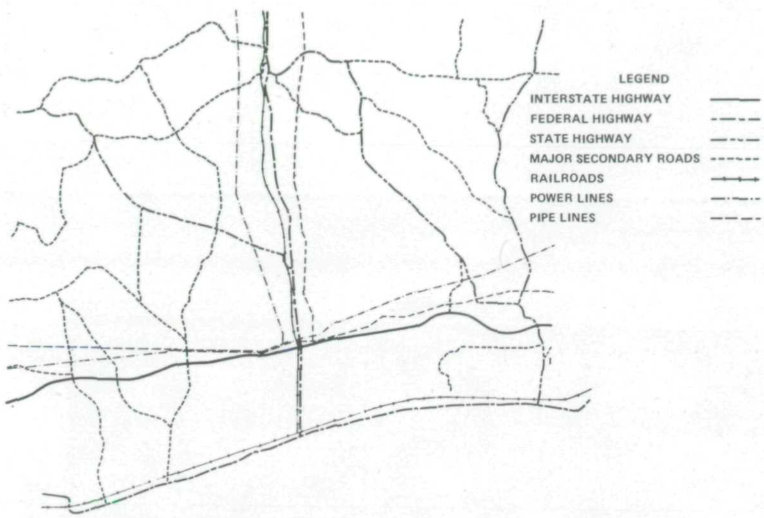


Figure 4. Harrison County, Mississippi, transportation network derived from ERTS data.

For comparison, Figure 5 shows the land-use map derived from false-color IR imagery acquired at an altitude of 18,000 m (60,000 ft). This map covers only part of the area included in the ERTS image and obviously shows a much greater level of detail.

In Figure 6 the color IR image from which Figure 5 was enlarged reveals the sharpness of detail and other characteristics which make this imagery such a valuable tool for interpretive purposes.

It may be concluded that a county or larger political unit is suitable for generalized land-use classification and drainage and transportation network mapping. These results would indicate the possibility of preparing several special-purpose maps—or inventories—needed by natural resource agencies. It is believed that we will be able to derive a wildlife habitat map which requires Class I categories plus several in Class II. Similarly, a first-order inventory of forestry types is a continuing requirement. It is believed that we will be able to achieve both of these from ERTS data.

Figure 7 shows the traditional forest-type map produced from the U.S. Forest Service decenial inventory. The problem of timeliness of this information is well known. In

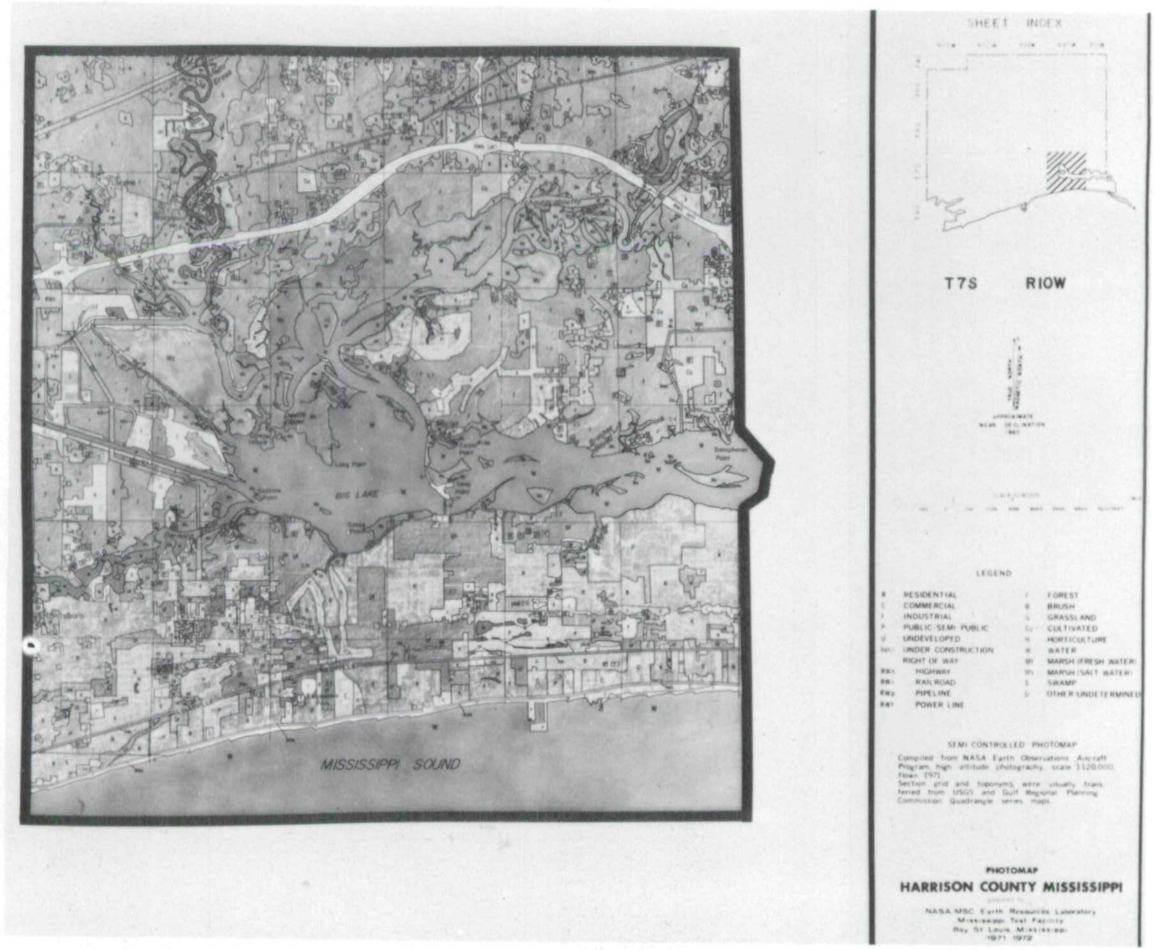


Figure 5. Harrison County, Mississippi, land-use map at a scale of 1:24,000, derived from high-altitude, small-scale aerial photography. (Note range-township format.)

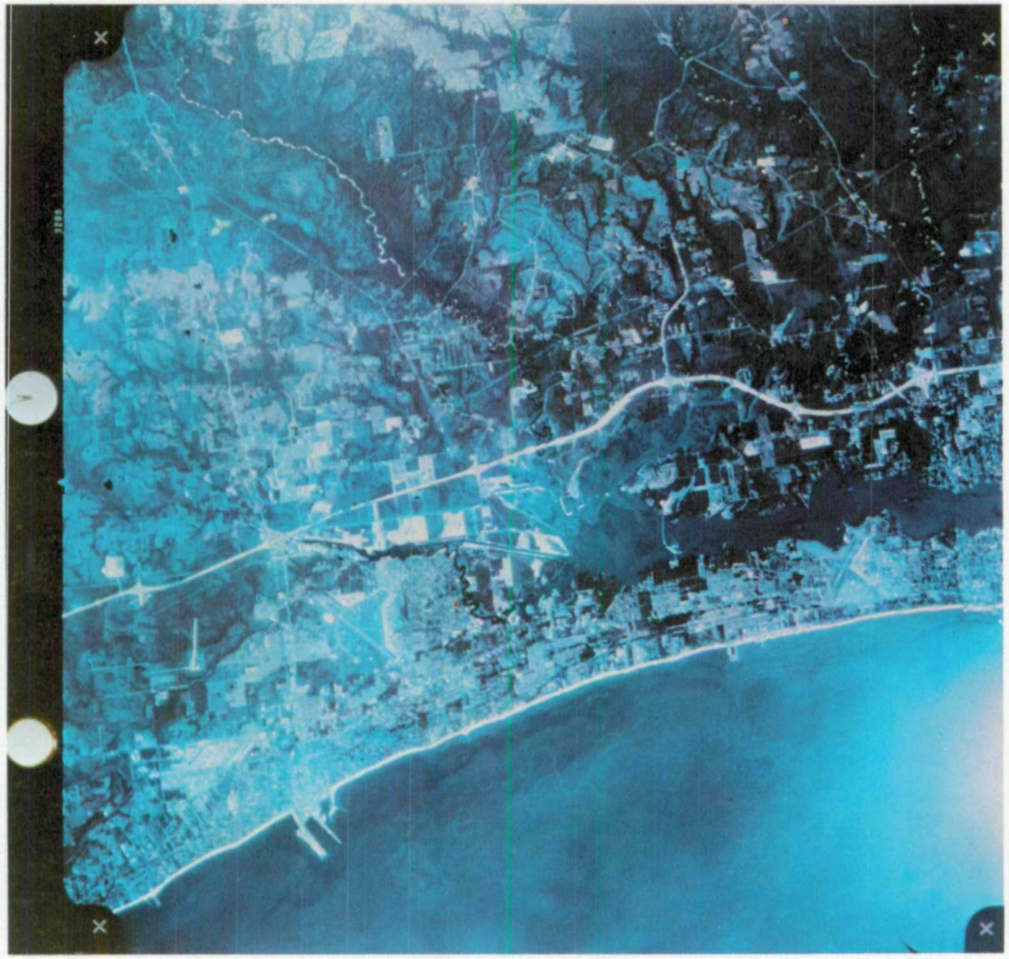

Figure 6. Harrison County, Mississippi, color IR aerial photography (scale = 1:120,000).

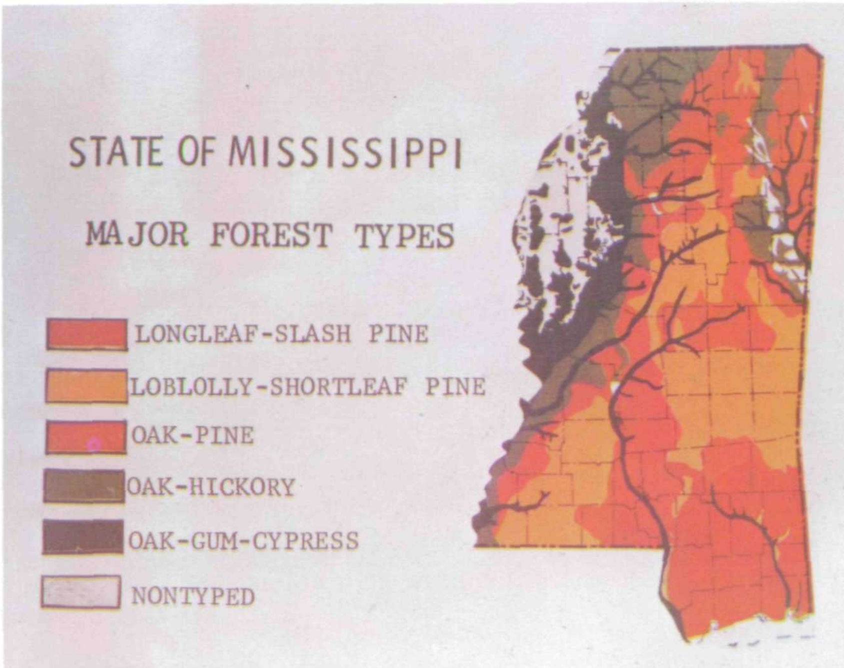


Figure 7. Forest type map–State of Mississippi.

Figure 8, the most recent state-wide wildlife habitat survey of the Mississippi Game and Fish Commission is shown. This map is inferred from land use and vegetative cover. When you know that this map was 11 years in the making, the demand for more timely forestry and wildlife information is understandable.

Figure 9 is an enlargement of an ERTS image (scale 1:208,000) of the area around Hollandale, a region in the Mississippi Delta, an intensively cultivated agricultural region of the state. It is here that the plantation system of cotton culture reached its fullest expression. This image has been used in an initial attempt at classifying the area using automatic pattern-recognition techniques. As other investigators have demonstrated at this Symposium, the use of such techniques would appear to extract the maximum information content from the data and to put it in a form most conducive to further manipulation, as is shown in Figure 10–an automatic surface classification of this area.

From a state viewpoint, the use of the generally distributed ERTS imagery is a reasonable departure point. However, to extract full value from the data it would appear that automated techniques will be required so that we can obtain the full content of the data with less processing; we also must be able to manipulate the data in computers for a variety of purposes.

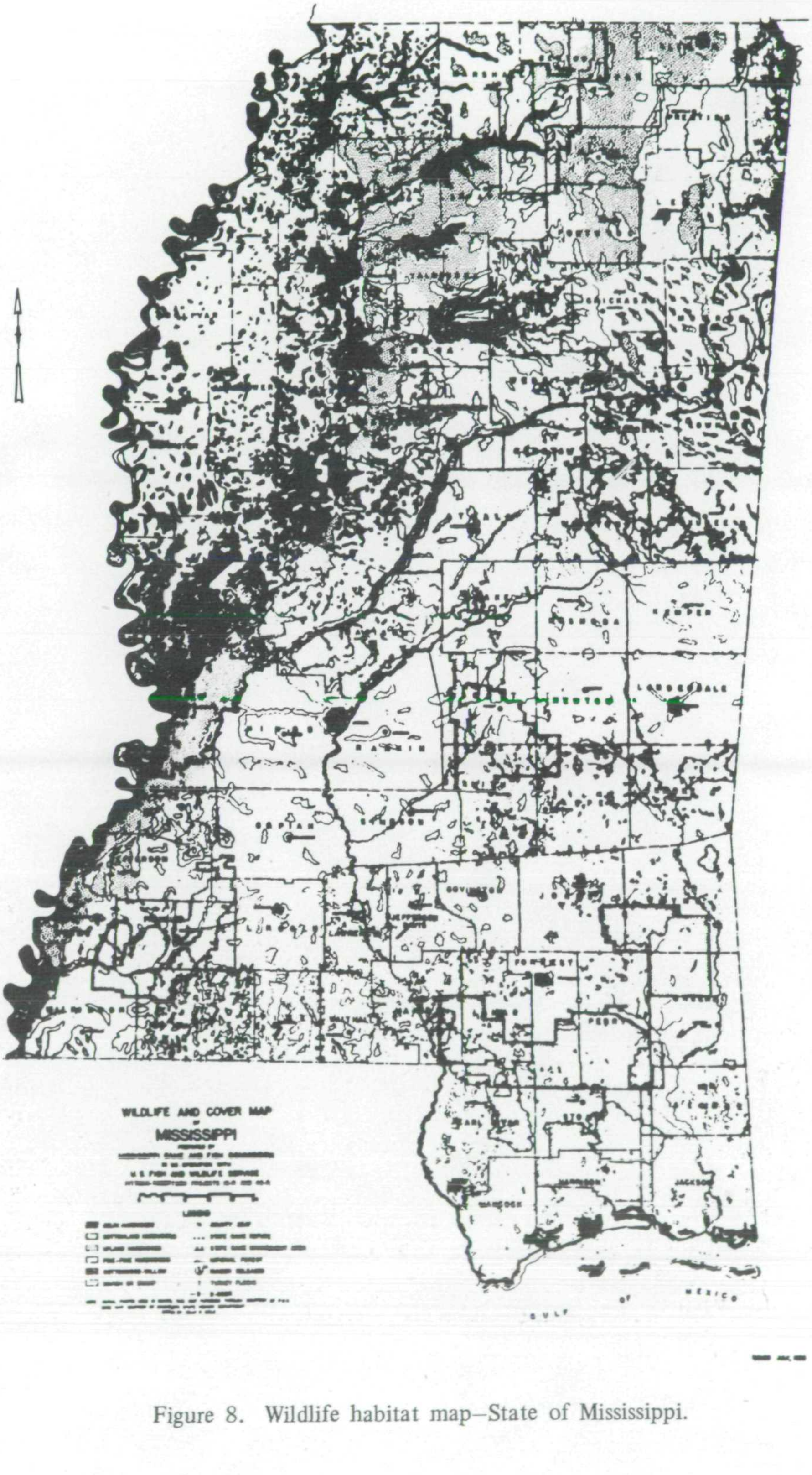


Figure 8. Wildlife habitat map–State of Mississippi.

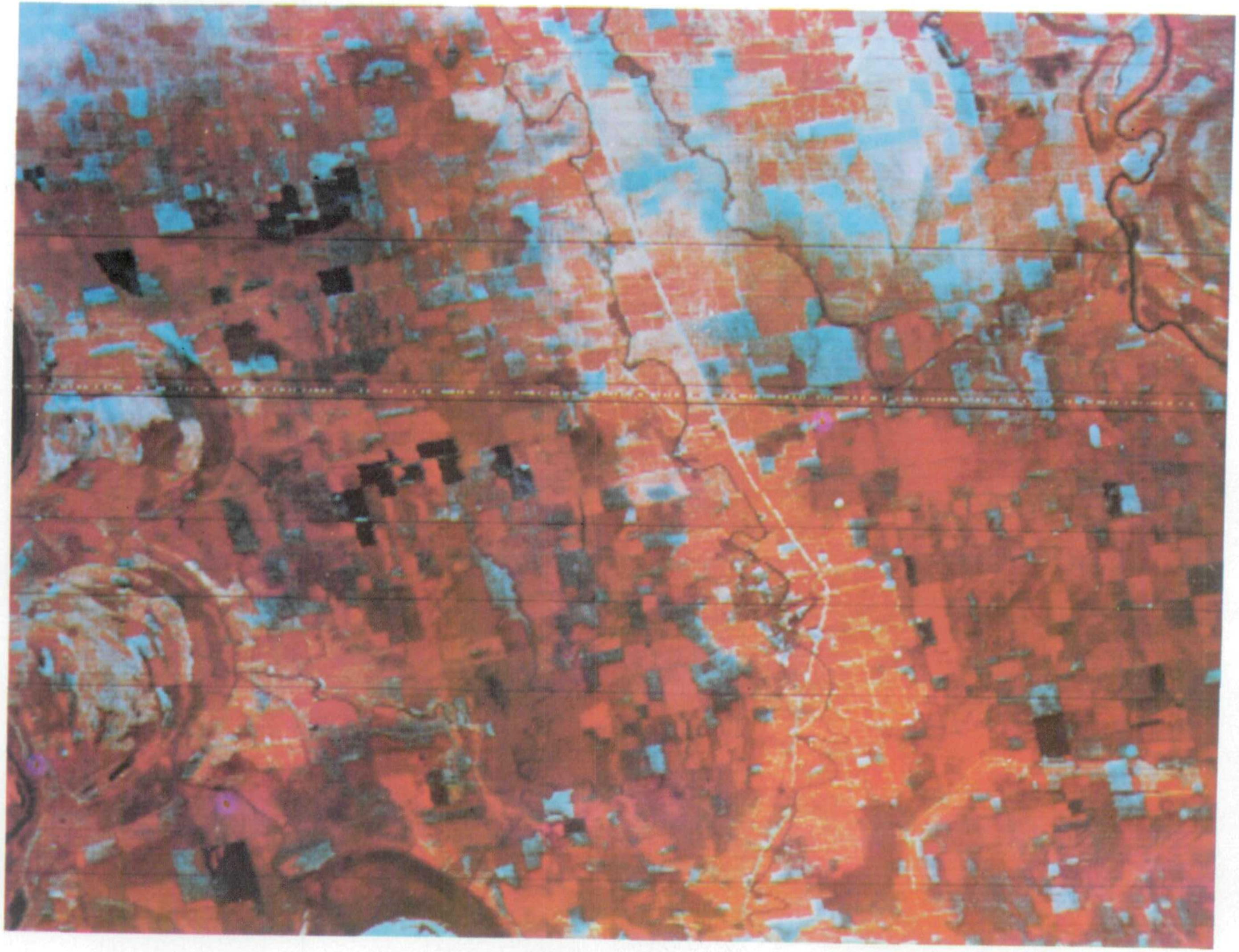

Figure 9. An ERTS enlargement of Hollandale, Mississippi (scale = 1:208,000).


Figure 10. A computer-coded surface classification of the Mississippi Delta, based on the ERTS enlargement in Figure 9.

There is no doubt that ERTS can be useful to the states in planning, resources management, and other important ways. Many examples have been shown in forestry, land use, marine resources, and other disciplines. It seems to me that the problem is to transfer this technology to appropriate agencies in state and local governments. With the exception of a very few states I think the requirements in Mississippi are typical as to what steps must be taken to translate this new technology into operational systems. With this in mind the following observations are offered to facilitate this transfer.

The results of many of these scientific evaluations need to be translated into procedures for use by state governments. These procedures need to be demonstrated and evaluated with regard to cost, time requirements, simplicity, and data availability.

Examination of the data and procedures needs to be made with a view to the normal technical capability of the intended recipient organization's personnel. The transfer mechanism must provide continuing consultation–technical support must be available on an on-going basis.

In many states, extensive information systems are already in existence. As automated techniques are evolved, transferable software packages should be capable of being coupled with these information systems.

The states, on the other hand, must be prepared to accept the new procedures as a way of improving their technical capabilities–they must be prepared to look at new ways of problem solving to meet their new and expanding responsibilities. They must be willing to invest in the future even if initial gains are not always cost beneficial.

While ERTS can be useful, it should be remembered that, to many of us and for many uses, high-altitude aircraft are almost as new as satellites. At least for a time it appears that aircraft are valuable for higher resolution and spot coverage as well as for urban studies and special areas such as wetlands.

In summary, ERTS can prove to be an extremely important tool for use by state and local governments in solving some formidable inventory and management problems. There can be difficulties in gaining widespread acceptance of this important technology by these essential user groups. These difficulties arise from important differences in the respective problem-solving roles of the states and Federal governments. The differences are basically those found when suppliers and users have different concepts of what is specifically wanted and needed to accomplish an objective.

Numerous examples are available from industry in which only hard experience has shown that the buying public is perfectly capable of ignoring some new technology that some firm has confidently believed would receive a warm welcome. Similar supplier-user difficulties can and do exist in Federal-state relationships.

Too often, direct user input into the decision process in Federal research programs and projects is nonexistent. Instead, research-oriented professionals employed by the Federal agencies decide what they believe operating officials should want or need. This control exercised by research-oriented professionals is enhanced by the fact that too often the Federal agency professionals rely on the research proposals of university scientists to develop research programs. The absence of state agency professionals on advisory panels and committees—except in agriculture, highways and LEAA—or other selection groups generally means the states have no formal voice and little informal influence in determining the specific objectives to be pursued, in selecting the projects intended to contribute to the broad objectives, or in determining the dissemination readiness of the results.

A second problem lies in the nature of the research and development product as seen by the user. Frequently a report on a research effort is of such a nature that it is not readily interpreted or applied to state problems. Normal uncertainties about changing an on-going system will cause a state official to hesitate. His expression of opinion may be to wait for something more immediately useful to come along. Many times the research results—the contribution of new science and technology—can present problems to the states. The tasks of interpreting the results, determining relevance, estimating costs and benefits, and integrating into on-going systems may not be worth the trouble to a given state agency or official.

In my opinion the sequence described earlier in the NASA-ERL-Mississippi land-use map project illustrates the elements necessary to create user demand for new technology. I think something like this is necessary in the case of ERTS. The users (states) must be involved in problem definition. They must be involved in the process of choosing between alternatives, they must be involved in evaluating results, they must be provided research results packaged in a manner appropriate to their capabilities (a software package that will fit their computers), and they must have access to continuing technical assistance.

If all these elements can be connected in a system that is focused on targeting this technology to user needs, a significant start can be made toward the solution of many problems which now loom large in the operation of state government.

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