N73-32282

MASTER Cy.

REMOTE SENSING IN MICHIGAN FOR LAND RESOURCE MANAGEMENT:

Annual Report, 1 June 1972 to 1 June 1973

Report No. 193400-2-F, July 1973

ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN
Ann Arbor, Michigan

Prepared for
Office of University Affairs
National Aeronautics and Space Administration
Washington, D. C.

NOTICES

Sponsorship. The work reported herein was conducted by the Environmental Research Institute of Michigan* for the National Aeronautics and Space Administration, Office of University Affairs, under Grant NGR 23-005-552. Technical Monitor is Mr. Joseph A. Vitale. Contracts and grants to the Institute for the support of sponsored research are administered through the Office of Contracts Administration.

Disclaimers. This report was prepared as an account of Government-sponsored work. Neither the United States, nor the National Aeronautics and Space Administration (NASA), nor any person acting on behalf of NASA:

(A) Makes any warranty or representation, expressed or implied with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

(B) Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used above, "person acting on behalf of NASA" includes any employee or contractor of NASA, or employee of such contractor, to the extent that such employee or contractor of NASA or employee of such contractor prepares, disseminates, or provides access to any information pursuant to his employment or contract with NASA, or his employment with such contractor.

Availability Notice. Requests for copies of this report should be referred to:

National Aeronautics and Space Administration
Scientific and Technical Information Facility
P. O. Box 33
College Park, Maryland 20740

Final Disposition. After this document has served its purpose, it may be destroyed. Please do not return it to the Environmental Research Institute of Michigan.

---

*Environmental Research Institute of Michigan, P. O. Box 618, Ann Arbor, Michigan 48107.

NASA CR- .
ERIM 193400-2-F

Annual Report
1 June 1972 to 1 June 1973

REMOTE SENSING IN MICHIGAN FOR LAND RESOURCE MANAGEMENT

by

I. J. Sattinger, A. N. Sellman, L. B. Istvan, and J. J. Cook
Infrared and Optics Division

ENVIRONMENTAL RESEARCH INSTITUTE OF MICHIGAN
FORMERLY WILLOW RUN LABORATORIES,
THE UNIVERSITY OF MICHIGAN

prepared for

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

August 1973

Grant NGR 23-005-552

Office of University Affairs
Washington, D.C.
Mr. Joseph A. Vitale, Technical Monitor

Page Intentionally Left Blank

FOREWORD

This project was performed for the Office of University Affairs, National Aeronautics and Space Administration, by the Environmental Research Institute of Michigan (ERIM) in cooperation with Michigan State University (MSU). The Environmental Research Institute of Michigan is a non-profit corporation which was established on 1 January 1973 as successor to the Willow Run Laboratories of The University of Michigan. This report covers work performed from 1 June 1972 through 1 June 1973; it is one of a series presenting the results of the program.

The goal of this project is to develop and apply earth resource survey technology to problems in land resource management of current concern to public agencies. The successful introduction of the technology calls for parallel efforts to:

- provide potential user agencies with the necessary evidence of the value of remote sensing technology for their purposes,
- develop the necessary scientific and technical background within the agencies to take full advantage of remote sensing information, and
- provide the necessary remote sensing services and facilities to support a statewide remote-sensing capability.

The investigations described herein were carried out under NASA Grant NGR 23-005-552. Joseph A. Vitale, Chief, Engineering Design Branch, Office of University Affaris, acted as Technical Monitor. The work was performed under the direction of Richard R. Legault, Director of the Infrared and Optics Division at ERIM. The program was coordinated with a similar one conducted by Michigan State University under a separate grant. At MSU, direction was provided by Myles G. Boylan, Director of the School of Urban Planning and Landscape Architecture, and Dr. Raymond D. Vlasin, Chairman of the Department of Resource Development.

ACKNOWLEDGMENTS

Project staff members at the Environmental Research Institute of Michigan who participated in this program are listed below. Their areas of responsibility or specific task assignments are indicated.

Richard R. Legault, Director, Infrared and Optics Division

Donald S. Lowe, Deputy Director, Infrared and Optics Division

Fabian C. Polcyn, Head, Technology Applications Group

Irvin J. Sattinger, Research Engineer (highway impact assessment, commercial site selection)

A. N. ("Buzz") Sellman, Research Associate (state and regional land use management, Lake Erie shoreline flooding, ERTS-1 applications)

Laurence B. Istvan, Research Assistant (waterfowl habitat assessment, Lake Erie shoreline flooding)

Jerald J. Cook, Associate Research Engineer (natural gas eruptions, deer habitat)

Philip G. Hasell, Research Engineer (aircraft facility supervision)

Leo Levereault, Research Associate (aircraft flight coordination)

Roland D. Kistler, Associate Research Engineer (multispectral scanner data processing)

ABSTRACT

The Environmental Research Institute of Michigan continued a program whose goal is the large-scale adoption, by both public agencies and private interests in Michigan, of NASA earth-resource survey technology as an important aid in the solution of current problems in resource management and environmental protection. During the period from June 1972 to June 1973, remote sensing techniques were applied to the following tasks:

(1) mapping Michigan's land resources
(2) waterfowl habitat management at Point Mouillee
(3) mapping of Lake Erie shoreline flooding
(4) highway impact assessment
(5) applications of the Earth Resources Technology Satellite, ERTS-1
(6) investigation of natural gas eruptions near Williamsburg, and
(7) commercial site selection.

Page Intentionally Left Blank

CONTENTS

FIGURES

TABLES

1
SUMMARY

This report describes the work performed during the second phase of a program presently being conducted by the Environmental Research Institute of Michigan in close consultation and cooperation with a similar project at Michigan State University. The goal of this program is the large scale adoption, by both public agencies and private interests in Michigan, of NASA earth-resource survey technology as an important aid in the solution of current problems in resource management and environmental protection.

In the first phase of the program initial contacts were made with a large number of agencies, and useful applications were undertaken on behalf of several of them. During the second phase, extending from June 1972 through June 1973, the remote sensing tasks initiated during the first phase were completed and several new tasks undertaken. The criteria for selecting new tasks stressed those problem areas in which remote sensing could contribute to clear and identifiable action on the part of the user. Consideration was also given to the degree of participation by the user and opportunities for transfer of technology resulting from the remote sensing activity. The objectives and results of these applications are summarized in Table 1.

By the end of the second phase, the data acquisition and analysis for most of the selected tasks had been substantially completed and communicated to the agency personnel involved. In several of the applications, certain action was taken as the result of the remote sensing findings. Results discussed in this report are for the most part short-range. But for many of the applications, the observable results will require longer periods to achieve because of the time interval inherently necessary for the agencies to reach conclusions and take action. The project will continue to follow these analysis and decision-making activities and will provide assistance wherever further use of the remote sensing data is called for. However, it is expected that no major effort will have to be devoted to further data processing and analysis. Instead, future activities will be devoted largely to developing new applications.

In Section 2, project activities are summarized with emphasis on the results achieved in decision making, the transfer of technology, and an analysis of future opportunities. Subsequent sections discuss each application in greater detail.

TABLE 1. SUMMARY OF REMOTE SENSING APPLICATIONS

Application	User	Results
State and Regional Land-Use Management	State Planning Division, Bureau of Programs and Budget Land Use Office, Department of Natural Resources	State land-use maps. Urban and regional change-detection maps. Adoption of land classification and evaluation methods for statewide land-regulation program.
Waterfowl Habitat Management	Wildlife Division, Department of Natural Resources	Contribution to legislative hearings, government planning and decision-making for marsh protection and replacement. Marshland vegetation mapping for improved habitat management.
Lake Erie Shoreline Flooding	Monroe County Planning Commission	A-95 review recommendations. Modifications to zoning ordinances and shoreline planning.
	Monroe County Drain Commission	Planning optimum location of floodwater pumping units.
	Monroe County Civil Defense	Improved planning of disaster response.
	Department of State Police	Improved planning of disaster relief.
	Bureau of Water Management, Department of Natural Resources	Identification of floodplain and high-risk areas. Land use review. Waterfowl habitat assessment.
	Bureau of Outdoor Recreation, U. S. Department of the Interior	Review of past recommendations for recreational use of shoreline.
Highway Impact Assessment	Environmental Liaison Unit, Department of State Highways	Redesign of drainage system for Fleming Creek wetlands. Adoption of color IR photography and impact analysis methods.
ERTS-1 Applications	Statewide Transportation Analysis Unit, Transportation Planning Division, Department of State Highways	Incorporation into highway corridor modelling.
	Forest Service, U. S. Department of Agriculture	Forest type-mapping and regional land-use analysis.
	Forest Wildlife Research Unit, Research and Development Division, Department of Natural Resources	Analysis of deer habitat application.
Natural Gas Eruptions	Department of Natural Resources, AMOCO Production Company	No data acquisition undertaken: Post-disaster remote sensing being considered.
Commercial Site Selection	Trenton State Bank	Selection of branch bank sites.

2
INTRODUCTION

2.1. PROJECT OBJECTIVES

During the second phase of this program, the project continued to meet the following major objectives:

(1) provide information needed for taking action on the problem at hand,
(2) transfer technology to the user agency, and
(3) encourage the agency to consider additional remote sensing applications under its own initiative and with its own resources.

In pursuit of these objectives, the project continued its activities in defining those problems of public concern in which remote sensing information can be used effectively. Through discussions with the responsible agency about such problems and related information requirements, the project staff can identify the appropriate role of remote sensing and the types of information it can supply. Educational activities, both informal and formal, provide the user with the necessary background to take advantage of remote sensing technology. The project also assists in making available the necessary remote sensing imagery and the facilities necessary for its processing and analysis. Here, the degree of participation depends on the circumstances surrounding specific tasks. In some cases, merely necessary advice and assistance are sufficient, with prosecution of the work left to the user staff. In other cases, we have assumed major responsibility for remote-sensing data acquisition and analysis in support of the total problem-solving effort.

2.2. PROGRESS IN ADOPTION OF TECHNOLOGY

All agency personnel with whom we have dealt show consistent interest in considering the usefulness of remote sensing technology for their purposes. However, in employing the new methods made available to him, the user faces several problems. He must not only learn to analyze and interpret unique and unfamiliar kinds of information, but must also be prepared to reexamine and modify his current methods and models to accommodate this new information. After appropriate methods of data illustration are determined, the user must also adapt his personnel and reallocate his financial resources to support the new procedures.

For these reasons, it is more realistic to look for steady progress toward adoption of this technology than to expect instantaneous adoption.

In spite of these constraints, we have succeeded in stimulating and encouraging a number of agencies to undertake their own remote sensing activities. The most noticeable progress has been made by the Michigan Department of State Highways (in highway corridor selection and environmental analysis), by certain units of the Department of Natural Resources (in land use inventory and analysis), and by the Lake Central Region of the Bureau of Outdoor Recreation (in recreation site evaluation). Many other agencies have also become acquainted with remote sensing opportunities and are considering useful applications.

Continued contact has been maintained with many agencies originally approached during the first program phase. In the continuation of these contacts, we usually try to provide more detailed analyses of their problems and better definition of remote sensing opportunities than in the initial general discussions. Not only do these continuing contacts assist the agencies in understanding remote sensing, but they also give the project staff a fuller appreciation of the technical and political character of the problems with which the agencies are concerned.

2.3. DISSEMINATION OF INFORMATION

In cooperation with Michigan State University, we have been able to disseminate information to a large number of potential users on the availability of RB-57 photography and ERTS-1 imagery for the State of Michigan. This information has described how photographic products may be obtained (either directly or with the assistance of ERIM and MSU) through the EROS Data Center in Sioux Falls. The easy availability of these photographic products of course stimulates their use.

ERIM personnel participated in a number of meetings with personnel of various government agencies to discuss remote sensing applications. Compared with the initial ones reported during the first year, these meetings went into greater depth on applications of remote sensing to specific problem areas. Two such participations are mentioned below.

A Conference on Practical Applications of Remote Sensing was held on May 15 and 16, 1973, at the Kellogg Center on the Michigan State University campus in East Lansing, Michigan. This joint-participation conference was financially supported through both the MSU grant and the ERIM grant. The audience included representatives from a number of state and local government units within Michigan. The agenda was planned to provide general background information on remote sensing techniques and capabilities as well as on practical applications. The second day of the meeting was devoted to a series of workshops to give the audience practical experience in the use of remote sensing products and techniques, with an emphasis on RB-57 photography and ERTS imagery.

ERIM also arranged another opportunity for disseminating information to representatives of the Department of Natural Resources. On 16 April 1973, the regular monthly meeting of DNR Region III (consisting of the Southern half of Michigan's Lower Peninsula) was held at ERIM. During the morning, before the regular meeting began, a presentation was made to 24 DNR personnel on remote sensing applications of the C-47 multispectral scanner data, RB-57 photography, and ERTS-1 imagery. The presentation developed continuing interest on the part of Region III personnel. Also, Mr. David Jenkins, Deputy Director of DNR, has requested that a similar presentation be made to members of the National Resources Commission. Subsequent to the meeting of 16 April, DNR personnel have discussed with ERIM, through oral and written communications, their specific responsibilities for protection and management of forests and wetlands, and for development and maintenance of deer habitat. As a result, information requirements for these application areas are being analyzed by ERIM so that specific uses can be proposed for remote sensing information in planning and management activities.

2.4. STATE AND REGIONAL LAND-USE MANAGEMENT

The State of Michigan faces critical policy decisions on how it can effectively protect its land and water resources. In 1972, the State Planning Division of the Bureau of Programs and Budget undertook, at the direction of the Governor, the task of defining the land management policy to be adopted by the state [1]. Because of our project's early participation in overall planning, the State Planning Division provided separate financial support to ERIM so that work could be carried on in direct support of State objectives. (This work was one part of a larger effort by several organizations, including the State Planning Division.)

The resulting group of projects has provided a uniform land-classification system for use throughout the entire state. This system includes general classification levels for statewide inventory as well as more detailed classification levels for uniform inventory of individual counties, municipalities, and other local government units. To provide the means for this inventory, a set of base maps was prepared, sources of remote sensing and other data were surveyed, and methods of using these sources for environmental analysis have been developed. The work performed by ERIM contributed substantially to the survey of remote sensing sources and the development of feature identification and mapping procedures.

ERIM's final report for the state-funded program was submitted in June 1973 [2]. The state is now reviewing this report and those provided by other participants before implementing further steps in its land management program. Since this program will depend on the passage of enabling legislation both at the national and state levels, it is necessarily long-range and continuing. The project staff will continue to work with the state on its land management responsibilities. In the near future, this work may include membership on a committee set up by the state to further define remote sensing and land classification methods.

A number of other short-range steps can be taken. As a result of growing concern about the effects of unrestrained growth, considerable political action is already evident at the local level on the question of balancing economic growth and environmental protection. The report submitted to the state recommended a series of two- or three-day workshops for regional and local agency personnel as a means of enabling them to map, inventory, and evaluate land resources in their areas. As a result, they will be able to set up or improve the land-resource data bases needed.

2.5. WATERFOWL HABITAT MANAGEMENT

Preliminary results of the work at the Pointe Mouillee site were reported in Ref. [3]. Since the time of that report, additional effort devoted to analysis and use of the remote sensing data has produced the following results:

(1) Information has been prepared for DNR (and presented to a legislative committee) concerning the amount and character of marshland that would be lost through the conversion to a dredge dumping site proposed by the Corps of Engineers.

(2) Measurements have been made of the additional destruction of waterfowl habitat resulting from recent high water levels and major storms occurring during late 1972 and early 1973. This information indicates the need for replacement of lost waterfowl habitat in the Pointe Mouillee area.

(3) Adjacent land has been evaluated with respect to its suitability as the replacement for present and future losses of marsh habitat.

Future Pointe Mouillee test site effort will be limited to continued application of the results obtained from past remote-sensing data analysis.

2.6. LAKE ERIE SHORELINE FLOODING

During March and April, 1973, a combination of high lake water-levels and strong east winds resulted in extensive flooding along the western shorelines of Lake Erie, Lake St. Clair, and Lake Huron. Extensive flood damage occurred, and disaster relief was made available to residents of the area.

ERIM's C-47 aircraft was flown over the flooded areas along the Lake Erie shoreline within 36 hours after the peak of the flooding to collect photography and scanner imagery for a variety of purposes. Photomosaics were made for studying the extent of flooding, and scanner processed data were used to identify the land-water boundaries under high water conditions. Several meetings were arranged to present the results to a number of federal, state, and local agencies. Our purpose was both to assist the agencies in meeting their immediate responsibilities and to introduce them to the types of information which could be provided in the event of future flooding occurrences.

At the local level the information provided was directly used for the following purposes: improved planning and zoning of shoreland use; relocation and redesign of waste disposal sites, water pumping stations, and county drain systems; and adoption of improved procedures for flood disaster response and relief. At the state and federal levels the data are most useful for longer-term activities concerned with land use planning and zoning.

2.7. HIGHWAY IMPACT ASSESSMENT

During the first year of this program, ERIM and MSU jointly undertook the task of applying remote sensing to assessment of the environmental impact likely in highway construction and to the preparation of environmental impact statements. Reference [4] describes application of these techniques in connection with the planned extension of the M-14 freeway between Ann Arbor and Plymouth, Michigan.

The environmental data on the M-14 site provided to the Highway Department were used to advantage as a basis for changing the drainage pattern at a point where the new highway would traverse wetlands feeding the headwaters of Fleming Creek. In the original design complete drainage of the area had been planned. This would have affected the viability of the wetlands area and the flow of water to Fleming Creek. Maps of the area provided by the M-14 study were used to redesign drainage factors so that only partial drainage is accomplished. The resulting change not only lessens the environmental damage but saves the Highway Department $10,000 in earth-moving costs.

The M-14 impact assessment was also used in helping the Environmental Liaison Unit of the Michigan Department of State Highways develop effective methods of impact assessment for other highway projects throughout the state.

The major factors which must be considered in assessing the ecological impact of highway construction were described in Ref. [4]. Since the time of that report, the Environmental Liaison Unit has been rapidly developing and adopting criteria and procedures for impact assessment. Development of the remote sensing methods covered by the report paralleled to a considerable extent the Unit's continuing development of improved procedures of impact assessment. It is likely that the adoption of those procedures was influenced to a considerable extent by the interaction of the two separate efforts.

Reference [4] reported preliminary information on the extent of adoption of the proposed remote sensing methods by the Unit. Since issuance of that report, the Unit has further implemented some of the recommended methods. Color infrared photography is now being acquired and used by the Highway Department for ease and speed of photointerpretation. There is also increasing use of the concept of assessing environmental impact through the study of a coordinated set of maps or overlays useful for noting direct relation among various features. The trend is toward increasing the variety of information and the amount of detail presented and analyzed. In vegetation mapping, for example, both the use of major vegetation categories and the mapping of individual species or communities of sensitive vegetation appear to be required for full impact assessment.

As a result of favorable experience with color infrared photography of the M-14 corridor provided by the RB-57 flights, the Highway Department is now taking steps to obtain extensive color infrared photography of other state areas in which future highway construction is being considered. Specifically, the Highway Department has contracted with a private company to supply this type of coverage for sizable areas in Northern Michigan. Existing RB-57 photography and additional photography requested under our program will also be used for highway corridor selection and impact assessment in covered areas.

The application of the airborne multispectral scanner in providing impact assessment data is still in the developmental stage and not yet considered adoptable for operational use. Since aerial photography is generally available for any highway corridor under study, scanner data must be justified on two counts: the value of the additional information provided, and the reduced effort such information permits. Once the information requirements on vegetation categories and communities are sufficiently well defined, the additional experience gained in mapping these categories via scanner data will lead to the demonstration of reliable mapping procedures. Similarly, additional experience with soils mapping will allow the mapping of soils drainage and texture for those areas in which adequate soil survey data are not otherwise available.

The development of airborne multispectral scanner methods of information gathering and analysis for impact assessment and other highway planning functions is being carried forward under other remote sensing projects. In the continuation of this project, emphasis will be placed on the processing of multispectral scanner data from the ERTS-1. Preliminary experience indicates that this approach has prospects for operational use in the near future. Data obtained from ERTS-1 provide up-to-date and frequently repeated coverage of large areas. Land use and land cover maps prepared efficiently and economically by computer processing of ERTS data can provide data needed in the impact assessment process associated with initial corridor selection. The application of ERTS technology for highway planning is covered in Section 7.

2.8. MICHIGAN APPLICATIONS OF ERTS-1 DATA

Current studies at both ERIM and MSU under the NASA ERTS-1 Program are developing ERTS technology for a wide variety of applications in resource management and environmental monitoring. Taking advantage of this experience, the project assisted several government units in the investigation of ERTS-1 potential for Michigan applications. For this purpose, ERTS imagery of an area in the Upper Peninsula was processed to produce a land use and land cover map. This map and other ERTS-1 products for Michigan areas were shown to the staffs of a number of federal, state, and local government agencies (including units of the Michigan Department of State Highways, the Department of Natural Resources, the U. S. Department of

Agriculture, and the Bureau of Outdoor Recreation). Review of these mapping results indicates that ERTS data can be of major assistance in the work of these agencies.

Based on this favorable response, ERTS data utilization for land use and land cover mapping is now being expanded to develop one of the most encouraging prospects for user participation initiated under this contract. The Statewide Transportation Analysis Unit of the Highway Department's Transportation Planning Division is developing a preliminary highway-corridor location model which can be used for the selection of routes based on regional environmental characteristics. A statewide land-use model is also being developed and calibrated. Both the computerized corridor-location model and land use models require up-to-date land use information in a quickly accessible form. In the past, up-to-date information of this type has been difficult to obtain and include in the data base needed for transportation analysis. Now the answer to this problem appears at hand in the form of ERTS data processed by multispectral pattern recognition to delineate land use categories. As a first step in this applicational development, we have processed an ERTS-1 data tape of the area previously discussed and supplied it for use in the Highway Department's existing computerized model. Programmers and other researchers in the Statewide Transportation Analysis Unit are currently working with this land-use recognition tape to test the requirements for formatting it and other such tapes into their computerized information systems. Once this objective is achieved, the Highway Department will be able to use the combined data in an improved corridor-selection process. The resulting capability will also be useful for many other agencies.

One of these potential applications is related to deer habitat management, a responsibility of the Department of Natural Resources. A direct and immediate goal of this department is the production by 1981 of a deer herd numbering one million (more than twice its present size). To accomplish this goal, DNR has begun an extensive program to reestablish the intolerant-tree stage of ecological succession that constitutes good deer habitat but which has been declining in recent years. ERTS-1 imagery holds out the prospect of providing the repetitive coverage of Michigan's extensive forested areas needed to identify potential deer habitat. Although the exact character of suitable habitat still requires better definition, analysis of ERTS data can provide an initial screening of candidate areas so that further investigation can be efficiently accomplished by concerted aerial photography or ground survey. The data will be immediately valuable for mapping and identifying the overstory (and if possible, the understory), as well as for mapping cleared areas within forests and nearby surface water. Over a period of time, ERTS data will also make it possible to observe alterations in available habitat resulting from forest clearing, fire, or change in successional stage.

2.9. NATURAL GAS ERUPTIONS AT WILLIAMSBURG

In April and May, 1973, numerous natural gas eruptions occurred near Williamsburg, Michigan (in the Northern half of the Lower Peninsula). Most if not all outbreaks of high pressure gas were accompanied by a large quantity of ground water, which carried subsurface soil and surface debris into numerous streams feeding both inland lakes and Grand Traverse Bay. Dangerous concentrations of gas forced local officials to evacuate residents from several square miles of the affected area. These gas eruptions may have been caused by drilling operations in the vicinity, by AMOCO Productions Co., Inc.

With encouragement from the Michigan Department of Natural Resources and the Michigan Public Services Commission, ERIM conducted a ground-based investigation to assess the potential of remote sensing in the pre-eruption detection of gas and water outbreaks. If this detection were judged feasible, a flight over the area would be proposed to assist the State of Michigan and AMOCO in predicting the location of new outbreaks. The ground investigations indicated that the probability of providing useful information by remote sensing was not high enough under the existing circumstances to justify the collection and analysis of remote sensing data.

Consideration is currently being given, however, to the possibility of using remote sensing in a post-disaster study to look for the following: damage to vegetation throughout the area, undermined areas subject to subsidence, and effects on water quality from discharged ground water. If it is decided that these effects need to be examined further, a remote sensing flight will be proposed to the Department of Natural Resources or to AMOCO.

2.10. COMMERCIAL SITE SELECTION

High-altitude aerial photography acquired in 1969 and in 1972 was furnished to the Trenton State Bank to assist it in identifying potential sites for new branches within 40 km of its main office. The photography was used as a basis for analyzing the following: major concentrations of industrial, commercial, and residential areas; growth trends in these areas; and the location of these areas with respect to major transportation arteries. On the basis of this analysis, several possible sites for new branches were recommended to the bank's Board of Directors. These recommendations are presently under consideration.

2.11. RECREATION SITE SELECTION

The Lake Central Region of the Bureau of Outdoor Recreation is increasing its use of NASA photography for many purposes throughout its area of responsibility. A study of future needs for park and recreation space in a 10-county area in Southeast Michigan was recently completed by the Bureau and made available to local units of government as a planning aid. The study made extensive use of RB-57 photographs taken over the area in September, 1969

(Mission 103) and purchased from ERIM. This study projected future requirements totalling 600,000 acres for park and recreation space within the 10-county area. The 10 counties presently have some 200,000 acres in their parks system. The RB-57 photography was specifically used to identify 596 sites (426,185 acres) possibly available as future parks. The sites, all in rural settings, either have frontage on lakes, streams, or reservoirs (and future reservoirs), or are sufficiently wooded and large enough to be considered for use as parks.

3
STATE AND REGIONAL LAND USE MANAGEMENT

3.1. PROJECT ACTIVITY

Both formulation and implementation of a state-wide land use policy are being actively undertaken in Michigan. In 1971 the Governor's Special Commission on Land Use issued its recommendations for a program of land management by the state (see Ref. 1). At the direction of the Governor, the State Planning Division in the Bureau of Programs and Budget then undertook the task of defining the land management policy to be recommended for statewide adoption.

Because of the growing urgency of land management problems, the ERIM staff actively assisted the State Planning Division in its early efforts toward developing a state-wide policy for land management. After advising the use of remote sensing for developing and implementing such a plan, ERIM staff members recommended a short-range program of land use mapping as a means for making an initial record of the state's land use and natural resource distribution. Because of the project's early participation in formulating the overall land-use plan, the State Planning Division provided separate funding to ERIM so we could directly support its objectives.

Since this land-use mapping program grew directly out of the preliminary work performed under NASA support, and because the objectives of the state-funded program are based to a considerable extent on technology derived from NASA'S Earth Resources Survey Program, the results obtained under the state-supported effort are summarized below. This summary is extracted largely from Ref. [2], the final report submitted to the State Planning Division.

3.2. COMPREHENSIVE STATE PROGRAM

The State of Michigan faces critical policy decisions as to how it can most effectively monitor and control development of its land and water resources. These policies should provide for the establishment of institutions and comprehensive programs designed to protect Michigan's land resources; they should also prepare the state to respond to, and work effectively within, federal guidelines concerning existing and proposed national land-use policy legislation. The state must be in a position to meet the numerous and often conflicting demands placed on its resources with the limited supply of those same resources. To do so, it must have the capability to draw upon or generate valid information concerning the location and disposition of its own land and water resource base.

The ERIM project is an integral part of a comprehensive plan developed by the State Planning Division to meet these objectives. The Division performed or funded several projects to provide guidelines and to detail specific means for coordinating disparate land use activities throughout the state. One of these projects established a uniform mapping base for use by all state and regional planning groups (see Ref. 5). A study completed by Johnson, Johnson, and Roy of Ann Arbor, Michigan, provides analytical techniques for identifying and mapping critical environmental areas on a statewide basis (see Ref. 6). Areas sensitive to incursion from physical development or unique as a land or water resource are included. The State Planning Division has also prepared a uniform land-classification system for statewide agency use (see Ref. 7). This system relies heavily upon the New York State Land Use and Natural Resources Inventory System (LUNR) (see Ref. 8) and the U. S. Department of Interior classification system proposed for use with remote sensor data (see Ref. 9). The purpose of the state-supported project undertaken by ERIM was to review and organize current information on land and water resources and to prepare specific products from remote sensing that could be incorporated into the operational phases of the state planning process.

While many state agencies are concerned with land use and land development issues, their programs have not always benefitted from the efficiencies of a common or uniform approach to data collection, analysis, and storage/retrieval systems. The work summarized below is one attempt to analyze and organize existing information sources, principally those related to land use, so that future work and research can contribute in a more coordinated way to our knowledge in the vital area of land use and management.

ERIM's tasks under this project include the following:

(1) Construct a State Land Use Map (1:500,000 scale) depicting these classifications: (a) Urban, (b) Forest, (c) Water, and (d) Agriculture and Other.

(2) Construct a photomosaic of the State of Michigan (1:500,000 scale) using ERTS-1 photography.

(3) Prepare land use maps and photomosaics (1:62,500 scale) for the Tri-County Planning and Development Region (Eaton, Ingham, and Clinton counties).

(4) Prepare a map of urban land-use as of 1963 for comparison with statewide urban land use in 1970.

3.3. STATE LAND-USE MAP

The first task undertaken by ERIM was to map land use for the entire state at a scale of 1:500,000. Four land-use categories were mapped: Urban, Forest, Water, Agriculture and Other. The map was prepared using all available sources of information—primarily aerial photography and USGS topographic sheets. The procedure was to overlay a base map of the state with a square grid, each cell corresponding to approximately one square mile, and to allocate the entire square to that land use category which dominated the cell. Figures 1 and 2 show the completed land use maps for the Upper Peninsula and Lower Peninsula, respectively.

In addition to preparing this land use map, we established the accuracy and utility of existing information for statewide planning objectives and indicated what information would be needed to improve the accuracy and timeliness of the land use map. In preparing the map, ERIM

FIGURE 1. STATE OF MICHIGAN LAND USE - 1972 (UPPER PENINSULA)

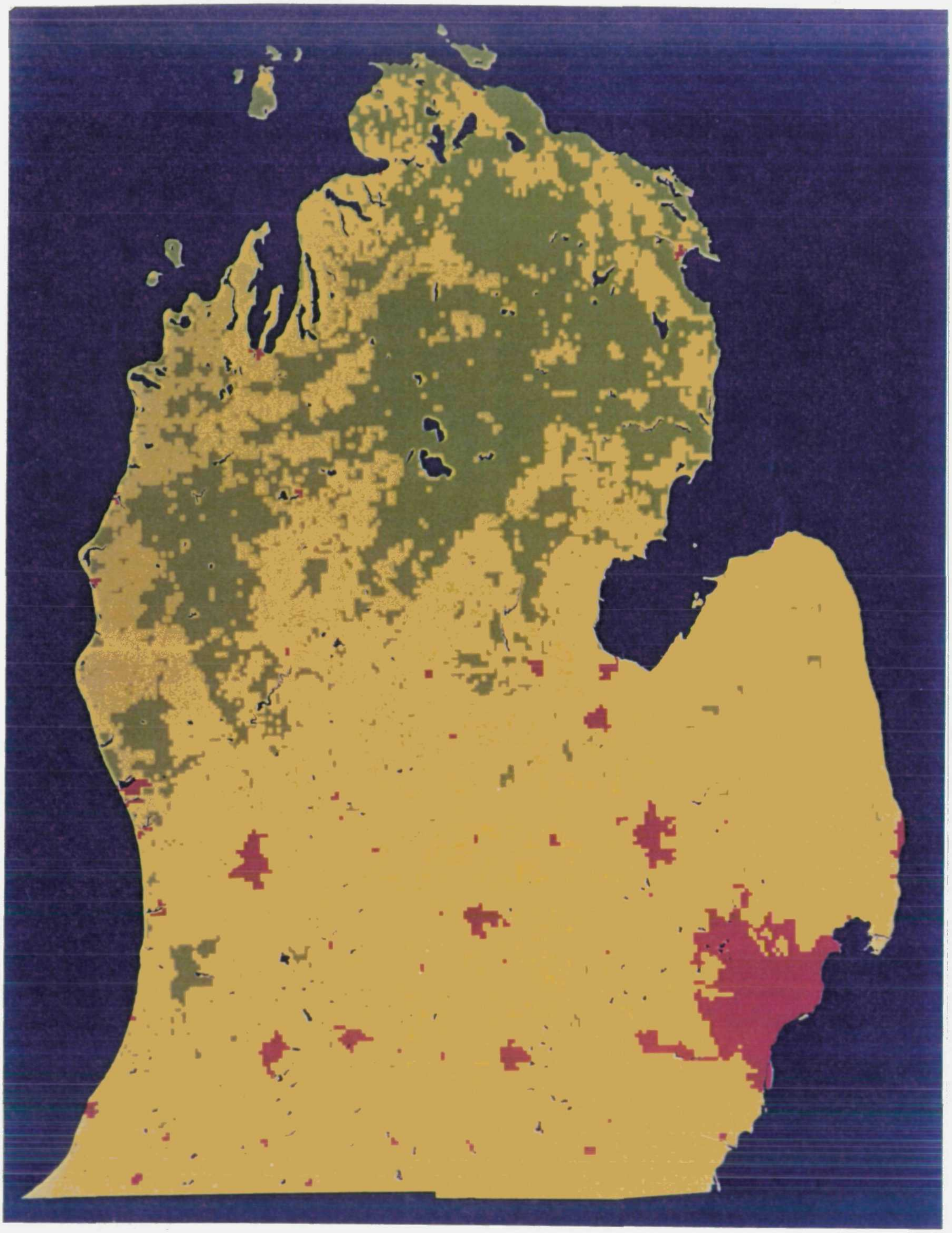


FIGURE 2. STATE OF MICHIGAN LAND USE - 1972 (LOWER PENINSULA). Prepared from such information sources as topographic maps and available aerial photography. Red - urban, green - forest, blue - water, yellow - agriculture, and other.

conducted a thorough review of county land-use maps to determine the extent to which they might serve as a primary information source for the inventory. This review was greatly aided by several ongoing State Planning Division studies. It was found that less than one-third of Michigan's 83 counties have a current land use map, and only four or five had mapped the classes selected for the statewide mapping program. Information sources at the state level also posed problems; most had to be excluded because they were out of date or because the accuracy of mapped materials could not be adequately validated.

Representation of total areal extent of each of the four classes on the State Land Use Map is somewhat biased because of the grid system used in map construction. This bias,which is influenced by several interrelated factors, is the result of classifying each grid cell as the dominant land use type within that cell, when often it is a mixture of several categories.

An auxiliary study was performed to determine the optimum requirements for future mapping efforts. A portion of Branch County, Michigan, was selected for an investigation into the effects of grid cell size on map accuracy and detail. County land use was type-mapped on grid bases of three different sizes and the results compared. The classification system used was the same as on the State Land Use Map. The type-mapping for Branch County was done from high-altitude (RB-57) color IR photography imaged on a VARISCAN viewer.

The study shed light on various aspects of a grid-base land-use mapping system. The major problem is that a predominant class of land use will be over-emphasized, especially with the use of larger grid-cell sizes. This bias is a function of the classification process itself, which discriminates against land use types having small, non-contiguous spatial structures. However, as grid cell size is reduced to near-threshold value for each land-use type, this discrimination is nullified.

The study also showed that a four-fold decrease in grid cell area does not significantly increase the photointerpretation work necessary for classification. It virtually took no longer to completely classify an area for a grid size of 1/16 sq mi (0.162 sq km) than for 1/4 sq mi (0.648 sq km). Although the actual interpretation time was the same, the increase in number of grid cells did make the map preparation time somewhat longer.

Resolution of the RB-57 photography used is such that individual houses can be identified. This means that extremely detailed classification (0.5 hectare or less) can be produced, although the time and effort needed increase with finer grid size.

The photointerpreters also noted that a separate category termed Other could easily have been created with virtually no increase in time or effort. The division of Urban into various categories (such as Commercial and Residential) could also have been made, although interpretation time would have probably increased somewhat.

The conclusions reached concerning available land-resource data and optimum methods of land use mapping have been reported to the State Planning Division (see Ref. 2) so that they can be taken into account in future planning for land-resource inventory mapping.

3.4. LAND USE AND LAND USE CHANGE-DETECTION MAPS

The research staff at ERIM also prepared other imagery products of particular value for local and regional land-use and land-resource studies. The photomosaics constructed from NASA high-altitude photography are particularly appropriate for county and even regional land-use assessments and can be effectively used to map considerable ground detail.

In particular, as a supplement to the State Land-Use Map, a map was prepared of all urban areas as they existed in 1963, using the same techniques and criteria. A change detection map of this type can be useful for monitoring urban development trends. Corridors and regions of rapid growth are visible, as well as areas in which little development has taken place. The resulting comparison of 1963 and 1970 data indicated that population density in the Detroit Metropolitan area decreased by 10% over the seven years. This trend was exhibited to a lesser degree over the entire state, in which a 5.8% decrease in urban population density was noted. These results could connote an increase in the development of low-density suburban communities. In any case, the change detection process illustrated the method of obtaining quantitative measurements of this important trend.

3.5. MAPPING LAND USE FROM SPACE

NASA initiated the Earth Resource Technology Satellite (ERTS) Program to demonstrate the feasibility of utilizing satellite data in earth-resources management programs. This section deals with the potential of ERTS as a data source for the mapping of land use in Michigan using photographic interpretive methods.

The value of ERTS lies in its systematic, repetitive coverage of large geographical areas under constant observational conditions. Every eighteen days (contingent on weather) the satellite furnishes complete coverage of the State of Michigan within nineteen frames. This frequent repetition not only allows the monitoring of land use activities over short periods, but also provides the capability of utilizing optimum seasonal variations in object reflectance for analysis of surface phenomena.

As one contribution of this NASA project to the state-supported program, a photomosaic of the state is to be prepared using ERTS imagery as soon as ERTS coverage is available for the entire state.

As a first step in evaluating the use of ERTS imagery, the State Land-Use Map discussed previously was compared to a type map produced by photographic interpretation of ERTS imagery to determine if ERTS can provide similar information. A grid type map of an area of 2,000 sq mi (5,177 sq km) in Western Michigan was constructed from ERTS imagery employing the same classification scheme, grid base, and scale used in the State Land-Use map. Forest and Urban types were classified from band 5 imagery, while band 7 was used to delineate Water areas. All areas not classified as Urban, Forest, or Water were typed as Agriculture and Other.

Visual comparison of the State Land-Use Map with the ERTS Map indicated a high spatial correlation between classes. Table 2 shows the classification results obtained by comparing the two data sources.

TABLE 2. COMPARISON OF STATE LAND USE AND ERTS MAP

	ERTS		State Land-Use Map	
	Square km	(%)	Square km	(%)
URBAN	230	4.0	207	3.7
FOREST	450	8.0	445	7.9
WATER	55	0.8	41	0.7
AGRICULTURE & OTHER	4,911	87.2	4,942	87.7

The results listed in Table 2 are encouraging not only from the standpoint of areal comparison, but also because of the fact that the test area, which is approximately 3.5 percent of Michigan's total land area, was classified in less than two hours. This is merely a fraction of the time necessary to obtain equivalent information utilizing the procedures involved in constructing the State Land-Use Map.

This classification scheme, however, does not indicate the informational detail that can be obtained from photographic interpretation of ERTS imagery. In terms of the classification system described in Ref. [9], all nine classes of Level I can be classified and many classes of Level II can be identified under optimum circumstances. For the separation of these types, however, conditions must be optimum because not all types are separable on data collected at any one time of the year.

Further work is necessary to establish the accuracy of delineating actual boundaries between Level II classes and optimum conditions for their separation. Photointerpretation of ERTS imagery presently can provide land use information equivalent to current sources at the state level; in addition, it offers the capability for mapping land use on a more detailed basis.

3.6. CONCLUSIONS AND RECOMMENDATIONS

The state-supported project attempted to demonstrate how remotely sensed data and the information derived from various analysis techniques might be put into operational use by all levels of government within the state. To explore the value of remotely sensed data, two similar information outputs were compared in the form of two state land-use maps, one prepared from existing data sources, the other from ERTS-1 photography.

Researchers at ERIM also prepared other imagery products of particular value in local and regional land-use studies. The photomosaics constructed from NASA's high-altitude photography are particularly appropriate for county and even regional land-use assessments; they can also be used effectively to map considerable ground detail.

The work reported is only a first step toward informing and educating a larger public-service audience as to the value of using remote sensing as an information source in both a planning and decision-making context. The state-supported project, therefore, recommended that a series of workshops be set up at different sites in the state so that operational use of the techniques and products resulting from the State Planning Division programs could be further explored and amplified. Possible locations for the workshop, which could be programmed for two full days of intensive work, are Escanaba, Traverse City, and Lansing. The workshop could act as a forum for the exchange of ideas, issues, and problems that confront local, regional, and state planning staffs; at the same time they could provide for an exchange of information on available map materials and remote sensing imagery, land classification systems, and environmental analysis techniques.

4
WATERFOWL HABITAT MANAGEMENT AT POINTE MOUILLEE

The Pointe Mouillee State Game Area is an important waterfowl feeding and resting area on seasonal migration routes, a nesting area, and one of the few duck hunting areas in Southeast Michigan. Its viability is being increasingly threatened by both natural forces and man's activities. Within this area large sections of marshland have been destroyed by wind and wave action associated with recent high-water levels in the Great Lakes. In addition, there is a threat of further loss of suitable habitat because of proposed plans to use a part of the area for dumping material dredged from the Detroit River Channel. Thus, unless action is taken soon—certainly within the next few years—it will cease to serve as a recreation area for hunters and will eventually decline in value as a waterfowl refuge.

Initial findings on the Pointe Mouillee project were presented in our 1972 Report [3]. The present account is limited to presenting, in summary form, the additional results obtained since the time of that report. A complete review of the project and its results is being prepared for publication as a separate report.

Information derived from remote sensing data previously acquired under this NASA-supported project has been used to assess the rate of marshland destruction and to provide information needed for the evaluation of adjacent land which might be acquired to compensate for past losses. In recognition of this and other past project activities, the Michigan House of Representatives' Committee on Conservation and Recreation invited Buzz Sellman, Research Associate at ERIM, to present on 3 April 1973, information derived from our studies. This committee was at the time considering a resolution aimed at preventing the Department of Natural Resources from transferring certain marshlands north of the Huron River to the Army Corps of Engineers for use as a site for disposal of channel spoil. The objectives of the NASA-supported project, together with results of the analysis, were presented to the committee. Of particular importance were data describing the loss of marsh habitat and concerning acreage measurements tied to specific habitat characteristics. Acreages of emergent vegetation, upland areas, trees, and water have been measured from remote sensing data acquired during Mission 63M, flown on 29 August 1972. This information provided the quantitative data needed for accurate assessment of the amount and character of marsh habitat presently available and also for determining the fraction of this total in danger of being converted to a disposal site.

Because of increasing public interest in Pointe Mouillee, additional work was performed to complement the information analysis already supplied to public agencies. Related management problems have been greatly magnified by recent storm damage resulting from lake water levels reaching their highest point in 20 years. Information on the extent of this damage is necessary so that existing plans for acquisition of new land to replace lost marshland can be updated. Revised decisions must be made with respect both to the amount and suitability of land needed for acquisition and development.

The extent of storm damage during the winter and spring of 1972-73 was determined from interpretation of aerial photography acquired during C-47 flights made in March and April 1973. (This information will be further discussed in Section 5.) It was noted that many of the islands surrounding Pointe Mouillee previously used as duck cover and duck blinds were destroyed by the storms and high water, increasing the urgency of replacing the lost habitat. Interpretation of this aerial photography allowed us to map and measure the areas destroyed by flooding, as well as additional areas subject to flooding. Permanent changes in land/water boundaries cannot be determined from the aerial photography of near-high-water conditions, but at least a preliminary estimate of these changes was possible. We supplied such an estimate to James Foote, Game Biologist at Pointe Mouillee, to aid him in the management and decision-making needed for maintaining the continued viability of the area.

Our continuing effort also led to the evaluation of adjacent land for conversion to marsh habitat. This evaluation was based on data concerning vegetation, soils, topography, and land use provided by remote sensing and other data sources, such as photography, showing the extent of flooding shortly after the peak of the April storm. Used in further analysis, this information can suggest the dike construction and vegetation management measures necessary in the conversion to marshland.

Mapping of vegetation, a task already completed under the project, has been used as an aid in managing the food and cover needed by waterfowl. We have also discussed the further application of this work with the Department of Natural Resources. Since the types of information collected and analyzed for Pointe Mouillee are typical of data generally needed for waterfowl habitat assessment, it is likely that DNR can use this operational study as a prototype for other remote sensing investigations by its Wildlife Division in many other areas for which the department is responsible.

The remote sensing data already gathered and analyzed for the Pointe Mouillee vicinity will be made available for continuing analysis of the game-area management problems previously discussed. However, additional major remote-sensing data acquisition and analysis are not presently planned for this area.

5
LAKE ERIE SHORELINE FLOODING

During March and April, 1973, a combination of high lake water-levels and strong east winds resulted in extensive flooding along the western shorelines of Lake Erie, Lake St. Clair, and Lake Huron. Extensive flood damage occurred in many shoreline communities in Southeast Michigan and Northern Ohio. As a result of the storm of 9 April, the entire shoreline area of western Lake Erie was officially declared a disaster area, and residents became eligible to receive cash grants and loans from the Department of Housing and Urban Development and the Small Business Administration.

5.1. DATA ACQUISITION AND PROCESSING

Based on early reports from the Michigan State Police, the Army Corps of Engineers, and the DNR Bureau of Water Management, the ERIM project staff made a decision on 9 April to collect imagery of Lake Erie's western shore in order to analyze and document the extent of flooding and assess the resulting damage.

On 11 April, ERIM's C-47 aircraft was flown along the western Lake Erie shoreline from the mouth of the Huron River, just south of Detroit, to the Erie Game Marsh, on the north side of Maumee Bay (see Fig. 3). The following kinds of imagery were collected: 70 mm color infrared-photography; 70 mm black-and-white photography; 9 in. × 9 in. black-and-white infrared-photography; and MSS 12-channel data, later subjected to thermal processing and analysis.

The 9 in. × 9 in. black-and-white infrared-film was processed immediately and photomosaics of the shoreline were compiled on the same day. These data offered an immediate look at the extent of the flooding and graphically recorded those areas still inundated 36 hours after the peak of the flood (see Fig. 4). In addition our personnel were in the field taking ground photos on both 10 and 11 April—that is, before and during the overflight. The information they supplied effectively complemented the airphoto interpretation.

Because of the different reflective properties of water and land in the near infrared, both the color IR and the black-and-white IR film readily show the extent of standing water. In addition many light, irregular patches are visible in fields above the standing water line. Ground checking confirmed the interpretation of these patches as debris left by the receding floodwaters. It was determined that the farthest inland extent of flooding could be approximated by plotting these lines of jetsam and then connecting them along equivalent contours. This was done as an overlay on available USGS 7-1/2-minute-series topographic maps. The 575-ft contour line was also plotted as a reference. Examination of these maps shows that in no case did the water level rise above the 580-ft elevation. It is also easy to identify areas in which water had flooded over roads and through culverts to spread out across inland areas.

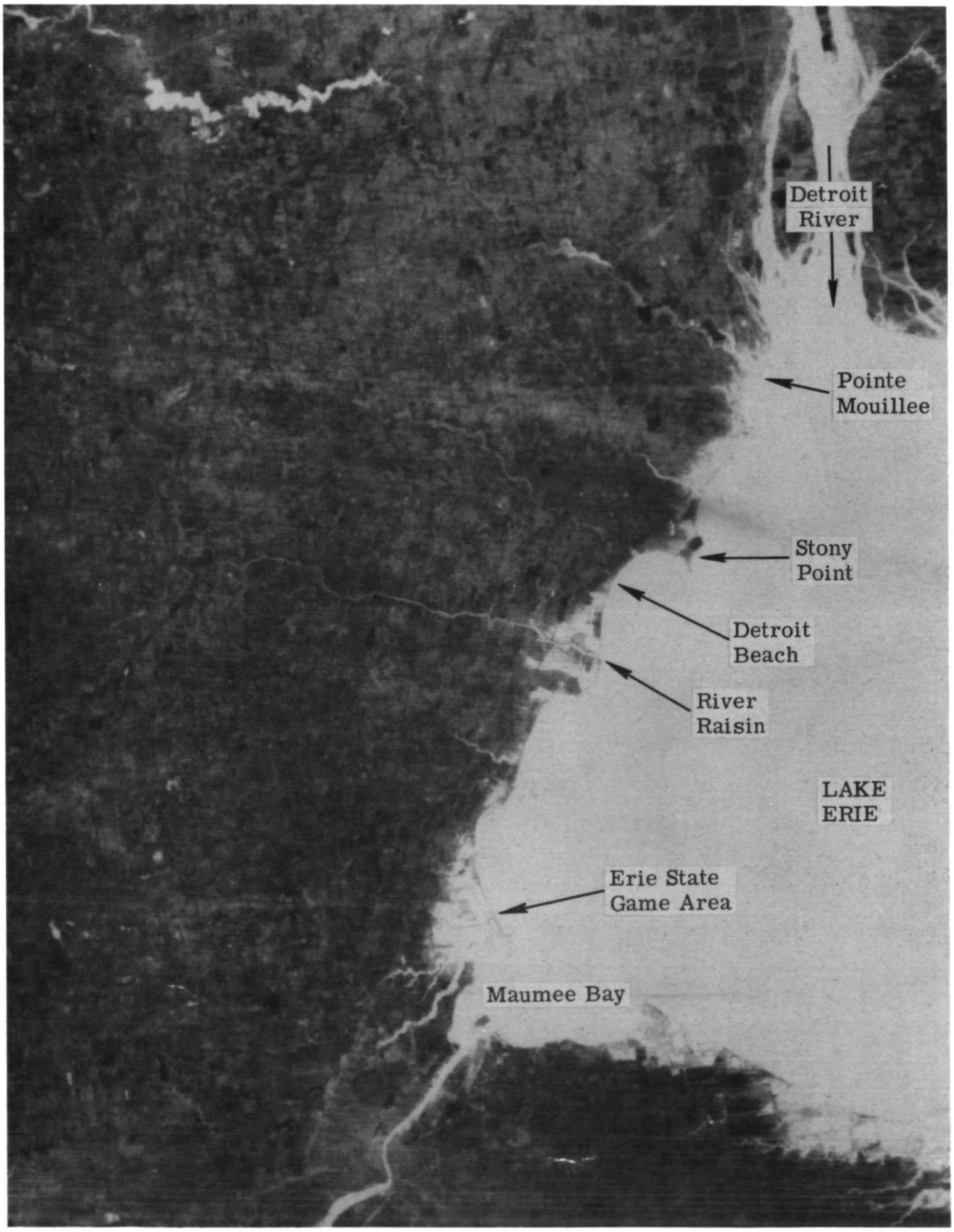


FIGURE 3. MICHIGAN'S LAKE ERIE SHORELINE. This image was taken from ERTS-1 Frame No. 1265-15480, Band 7, acquired on 14 April 1973, five days after the storm of 9 April. Some areas in Michigan and Ohio still remain flooded. (On 11 April ERIM'S C-47 aircraft collected photographic and scanner imagery for the shoreline between Pointe Mouillee and the Erie State Game Area.)

FIGURE 4. FLOODING AT DETROIT BEACH. This photograph was taken on 11 April 1973, some 36 hours after the peak of the Lake Erie shoreline flooding. Those areas of Detroit Beach which appear dark are still underwater. Jetsam indicates the probable high-water mark, just above the 575-ft contour.

In another attempt to map the extent of flooding, we performed level slicing on a near-infrared MSS channel (1.0-1.5 μm). The more important of these quantized levels were then color-coded and sandwiched together. Inspection of this slicing showed that standing water was accurately mapped. In addition, several intermediate levels between water and dry land were differentiated (see Fig. 5). These levels have been interpreted as areas which had been flooded with water and at the time of the flight were (1) still completely saturated or thinly covered with water, and (2) areas still wet but no longer saturated. However, various anomalies were found in this interpretation. For instance, several fields were included in the saturated category, although they appeared from the aerial photography to be dry and were actually above the estimated high-water line. Unique drainage patterns or high-ground water levels may account for some of these discrepancies. In any case, the utility of multispectral scanner (MSS) data for the quick mapping of flooding over a large area was clearly demonstrated.

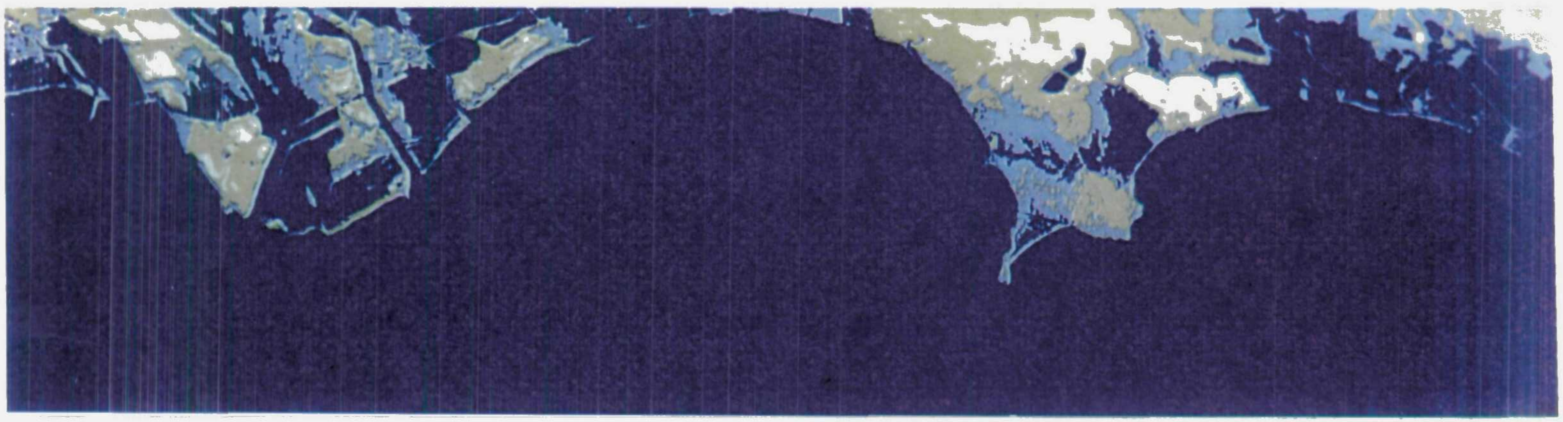
5.2. APPLICATION OF RESULTS

ERIM staff members have made three formal presentations of the results of our shoreline imagery analysis. One was given in Lansing, Michigan for the Department of Natural Resources and the State Police Department. The other two were given in Monroe, Michigan, for the following audiences: officials from local and county planning agencies, road and drain commissions, county civil-defense personnel, and private citizens. The meetings with Monroe County officials generated more immediately demonstrable results than the meeting with state agencies. The immediate interest of local officials and citizens in our flooding data was in contrast with that evidenced by state agency personnel, who are involved with more general responsibilities and longer term activities. Therefore, tangible results from the use of our flood mapping data are more likely to develop as a result of extended contact with local agencies.

Given below, in outline form, is a brief summary of the uses these agencies made of our flooding data and the possible benefits from a continued review of such imagery with them. Additional information on some of these uses is contained in two letters sent to us by Monroe County officials (see Appendices B and C).

Monroe County Planning Commission

(1) A nearly complete delineation of the extent of flooding is now available based on imagery analysis and map preparation by ERIM staff members.
(2) In performing the A-95 review required by the Federal government for federally supported projects, the Commission recommended rejection of a proposed multiple housing project in Monroe County.
(3) The local power company has agreed to relocate its disposal site for fly ash in order to reduce erosion hazards caused by its proximity to areas subject to flooding.



River Raisin Detroit Beach Stony Point

FIGURE 5. FLOODED AND SATURATED AREAS. A part of Michigan's flooded shoreline of Lake Erie has been mapped by level slicing the 1.0-1.5 μm channel of multispectral scanner imagery. Dark blue areas are offshore. Light blue areas are completely saturated or covered by a thin film of water. Light green areas are those saturated or flooded at the height of the storm.

(4) Recommendations have been made for a federal study to investigate the continuing risks associated with intensive residential and commercial land uses in the floodplain. This study would consider the costs and benefits of major land-use changes in the area.

Monroe County Drain Commission

(1) The "flood-of-record" evidence is to be used for studying whether fixed and mobile water-pumping stations are correctly located with respect to the areas that actually flooded on 9 and 10 April.

(2) A long range review and study is to be undertaken of areas, especially county drains, that continually have standing water indicative of improper or inadequate drainage.

Monroe County Civil Defense

(1) The primary use of the "flood-of-record" imagery will be to evaluate the strategy used by Civil Defense for blocking roads and evacuating citizens.

(2) The Civil Defense Director hopes to create closer cooperation among county officials based on a common interest in, and evaluation of, the imagery supplied by ERIM.

Department of Natural Resources

No action has yet been taken by DNR. We plan to continue our discussions in order to develop long-range planning and research questions arising from our common review of the data. The following items suggest several of the most likely data applications.

(1) The Bureau of Water Management and the Water Resources Commission within DNR can use the flooding data for several purposes. To identify high risk areas the Beach Erosion Section requires information on erosion rates. The Flood Plain Management Section within the Hydrological Survey Division could use remote sensing data collected on these exceptional floods for defining the extent and areas of danger of 50-year or 100-year floods.

(2) Land use changes in flooded areas should be considered. If these areas were to be used for recreational purposes or as wildlife habitat instead of for their present residential and commercial purposes, they would be less subject to flood damage.

(3) A matter of particular concern to DNR is the continuing destruction of the natural marsh areas at the Point Mouillee State Game Area. The severe storms of November, 1972, followed by those of March and April, 1973, caused substantial damage. Our first report (see Ref. 3) described our efforts in cooperation with DNR toward estimating damage and evaluating marsh habitat characteristics at Pointe Mouillee. These efforts, which are summarized in Section 4 of this report, are continuing.

Michigan Department of State Police

We plan to continue with the State Police our discussions arising from common review of the flooding data in order to develop uses of remote sensing in long-range planning and research activities.

(1) One potential application concerns requests for disaster relief funds. In the Department of State Police, Lt. James L. Somers, of the Emergency Services Division, acts as Disaster Coordinator for the State of Michigan and as the local representative for the Office of Emergency Preparedness. He needs rapid access to flooding data so that he can provide accurate estimates when requesting disaster relief funds. It is particularly important that he be able to distinguish actual victims from those not really affected by the flood.

6
HIGHWAY IMPACT ASSESSMENT

To ensure environmental protection, the federal government recently passed legislation, including the National Environmental Policy Act of 1969 and the Federal Highway Act of 1970, which requires the preparation and submission of environmental impact statements for all planned construction of new highways.

The Environmental Research Institute of Michigan and Michigan State University jointly conducted a pilot project in 1972 to determine the applicability of remote sensing techniques for both assessing the environmental impact of highway construction and preparing environmental impact statements. Reference [4] describes this project, which was concerned with a planned extension of the M-14 freeway between Ann Arbor and Plymouth, Michigan.

The report on the pilot project was reviewed and evaluated by staff members of the Environmental Liaison Unit of the Michigan Department of State Highways. They concluded that some of the reported techniques are applicable to the current requirements and practices. Since the initiation of the M-14 project, impact assessment methods have been rapidly developed and information requirements revised and increased. Consequently, conclusions and recommendations concerning the utilization of remote sensing techniques must be reconsidered. The purpose of this section is to review the tentative conclusions discussed in Ref. [4] and to bring them up to date in relation to recent study of the impact assessment process.

6.1. IMPACT ASSESSMENT PROCEDURES

The complete process of planning a new highway may cover a period of five years or more. When the decision is made to build the highway, the project is turned over to the Planning Section. The Environmental Liaison Unit assists in the highway planning process during the entire period by preparing environmental inventories and by assessing the impact of highway construction. For these purposes, the Unit assembles and analyzes data from various sources, including soil surveys, USGS topographic maps, low-altitude aerial photography, and more recently (as a result of previous project recommendations) RB-57 color infrared-photography.

As an initial step, the Planning Section decides on a corridor, typically 10 miles wide, through which the highway is to be routed. The Highway Department has photographic coverage (in some cases not completely up to date) of such areas at scales ranging up to 1:2500 or 1:2000. The Environmental Liaison Unit then takes about three months to prepare a preliminary environmental inventory of the entire corridor. At this early stage, such an inventory is rather broad in nature, providing only general information about topography, geology, drainage, soils, vegetation, land use patterns, and other features. Areas of special sensitivity, such as floodplains and wildlife game areas, are noted.

Next, the Planning Section incorporates this corridor assessment into other information such as traffic projections and social and economic data. From this material it selects two or three alternate corridors (each two to three miles wide) within the larger corridor. The Environmental Liaison Unit then conducts a more detailed study of these corridors, a process which takes three to six months.

Based on all this information, an exact though tentative route is selected through one of the corridors. For route location work such as highway design and construction, the Highway Department uses 1:400-scale photography. Over perhaps a six-month period the Environmental Liaison Unit does a much more detailed study of the corridor, and performs a considerable amount of field checking (including habitat analysis and the measurement of soil properties and ground water table). Recommendations from the Unit and other information are then used by the route-location engineer to settle on a final route for the highway.

After this final route is selected, the Environmental Liaison Unit prepares a Final Alignment Environmental Impact Statement, describing in detail the predicted ecological, economic, and social impact of the highway.

In short, there are at least two distinct stages of impact assessment: the corridor statement prepared during the earlier phases of a highway project covers broad areas of concern; whereas the alignment statement which comes later, is more specific.

Some of the major factors which must be considered in assessing the ecological impact of highway construction were discussed in Ref. [4]. Since that report was prepared, however, methods and procedures of impact assessment have rapidly changed, particularly with regard to the criteria for judging impact significance in terms of ecological change and economic gain or loss. Federal agencies now require impact assessment statements to be much more sophisticated than they were only a year ago. In fact, agencies such as the Environmental Protection Agency, the Soil Conservation Service, and the Bureau of Outdoor Recreation are specifying that particular types of information be supplied. Reacting to these changing requirements, the Environmental Liaison Unit is constantly evolving its methodology.

Our review of the most recent methods of preparing highway impact assessments was based on discussions with Highway Department personnel and study of the Final Alignment Environmental Impact Statement for a section of US-131 to be constructed in Michigan through Mecosta and Montcalm Counties (see Ref. 10). We found that the alignment process now goes into a much more detailed determination of the impact of Highway construction. However, the types of information required do not differ greatly from those assumed in Ref. [4], and the methods of data gathering and analysis have not been materially changed.

Remote sensing can provide much of the information required for impact assessment throughout the entire period of highway planning, including the phases of corridor and alignment selection. The remainder of this section is devoted to an evaluation of the uses of photographic, scanner, and satellite sensors for impact assessment.

6.2. AERIAL PHOTOGRAPHY

The Highway Department makes extensive use of aerial photography in highway planning and design. In addition, high-altitude color and color IR photography (such as that provided by the RB-57 and U-2 in NASA's Earth Resources Aircraft Program) are useful since they provide large area coverage. Color IR photography facilitates data interpretation, particularly for vegetation and soils analysis. There would be an additional advantage if the use of high-altitude aircraft resulted in reducing the cost of data acquisition per unit area.

Since specific methods of implementing aerial photography for highway impact assessment and of displaying the results (by using overlay techniques) were presented in detail in Ref. [4], they are not further discussed here. As indicated in that report, the Environmental Liaison Unit is incorporating some of the methods described into its current assessment procedures.

As a result of its favorable experience with the use of RB-57 color infrared-photography for the M-14 corridor, the Highway Department is now taking steps to obtain and use extensive color-infrared photography for other large areas of the state in which future highway construction is being considered. In fact, the Department has contracted with a private company for this type of coverage in parts of Northern Michigan. Existing RB-57 photography and additional photography requested under our program will also be used for highway corridor selection and impact assessment.

Color or color-IR aerial photography, as well as multiband photography and multispectral scanner imagery, lend themselves to the preparation of thematic maps by means of image enhancement methods. This type of presentation can be used to simplify the interpretation and discrimination of major classes of land use, such as active agriculture, natural vegetation, deciduous forests, coniferous forests, wetlands, water bodies, and built-up areas. While the separation into these classes may be subject to some error, it provides an easily interpreted and relatively inexpensive presentation for preliminary analysis of the type of land use and land cover in a given corridor. The image enhancement technique is certainly worth further investigation to determine its utility in highway design studies.

6.3. MULTISPECTRAL SCANNER

At present, multispectral scanner techniques have a capability to map and measure many earth features significant for impact assessment. For example, surface water, soils, vegetation, wetlands, and built-up areas were classified and mapped in assessment of the M-14 freeway.

6.3.1. SURFACE WATER

Lakes, ponds, rivers, streams, and even intermittent surface water can be accurately mapped over large areas by MSS methods. Observation of small bodies of water or streams, however, may be restricted by overhanging vegetation—unless coverage is obtained when foliage is absent.

6.3.2. SOILS

Up-to-date soil surveys are available for less than 25% of Michigan's counties. In areas for which there are no soil surveys, older survey data or special collections of data associated with the highway planning and design process must be relied upon. Multispectral scanner techniques can be used to collect such special data.

On the basis of our experience with the M-14 site and other feasibility studies, we are able to map natural drainage and organic matter content with fair accuracy. In several recent studies, for example, ratio processing methods have been used (see Ref. 11). Computing and mapping the ratio of a reflective band to a thermal band enhances the soil differences associated with natural drainage and usually correlated with differences in soil moisture and organic matter content.

Moreover,current research indicates that the ability to identify soil texture can also be developed. Ratio processing methods in the thermal infrared can indicate the silicon dioxide content of soil surface. Since silicon dioxide frequently comprises the bulk of the sand-size fraction in weathered soils, a rough correlation can be made between soil texture and a ratio of two thermal bands. As a result, ratio processing can be used to indicate various texture-size classes of soils.

Soils information can best be provided for terrain which is bare at the time of the overflight. Of course, the maximum amount of bare soil varies substantially according to the land use characteristics of a particular region. For example, heavily forested areas will show very little bare soil, while areas dominated by active agriculture may show as much as 80% or 90% bare soil during spring plowing. The data collection period, therefore, is limited to the spring or fall, when more bare soil areas will be present. This limitation is not likely to pose a serious problem, however, since highway planning and construction schedules normally extend over substantial time periods.

The use of ratio processing multispectral-band as a means of discriminating vegetation types has been recently reported (see Ref. 11). This processing may prove useful for studying terrain in which the soil surface cannot be observed directly.

A review of mapping soils via multispectral scanner techniques indicates that they have potential value for highway impact assessment but need further development and refinement before they can be recommended for operational use. Because of the operational character of the M-14 application,the data processing techniques used were arbitrarily restricted to previously developed methods primarily based on likelihood ratio processing. Additional study [11] which followed the M-14 work, indicates that soils mapping can benefit from other scanner processing techniques, particularly ratio processing methods. When fully developed, soils mapping based on ratio processing will require only a relatively simple and inexpensive use of the computer. However, such mapping for highway impact assessment or other purposes will still require ground sampling as a means of confirming remote sensing results and determining subsurface characteristics.

This possible utilization of the multispectral scanner will be studied further under other programs concerned with perfecting methods for automatic soils survey and mapping. These techniques for highway impact assessment will be considered further under this program and others, but some time will probably be required for their development.

6.3.3. VEGETATION

Impact assessment within a projected corridor or alignment requires information about vegetation characteristics and distribution. Such information must indicate all unfavorable impacts on vegetative resources, and include those likely to result in economic loss as well as ecological damage.

The selection of individual classes or physical characteristics of vegetation to be mapped is determined by the criteria adopted for estimating impact. The mapping of specific plant communities or species, for example, would mean concentrating on those classes which are particularly sensitive to air pollution or changes in drainage, or which have unusual ecological significance. Alternatively, the criteria may be related to the economic value of the vegetation or to the cost of removing it, factors depending not only on classification into plant communities and species but also on size, physical characteristics, and successional state.

A general capability for multispectral discrimination of vegetation communities or categories already exists, as indicated by past feasibility studies. Scanner vegetation mapping for the M-14 project emphasized likelihood ratio processing. During the later stages of the project, however, some effort was also directed toward using ratio processing (a simpler method) for the mapping of vegetation categories. Considering that this was an initial and quite limited effort at category mapping, it was fairly successful. For instance, it appears that the broad categories of deciduous forest, coniferous forest, brushland, and wetlands can be distinguished from each other and from all other types of vegetation. Also, bare soil observed during the early part of the growing season can be a good indicator of active agriculture. Individual communities or species of vegetation carrying special ecological or economic significance can also be mapped and measured. For example, as reported in Ref. [4] willow trees in the M-14 Test Site were mapped. And as other feasibility studies have demonstrated, the scanner can be trained to recognize a variety of tree species, crop types, and vegetation communities (see Refs. 12 and 13).

The continuing development of impact assessment criteria will certainly clarify the exact vegetation mapping requirements for information inputs to the assessment process. When determination cannot be made from past feasibility studies of the scanner's capability to discriminate particular types of vegetation, special analysis or measurement may be needed to determine this capability.

6.3.4. WETLANDS

Wetlands are a particular concern in highway impact assessment because they play an important part in groundwater recharge and serve as habitat for many types of wildlife, especially waterfowl. Evaluation of wetlands requires information about their classification, size, and shape. As mentioned earlier, the area and perimeter of surface water can be delineated accurately. In addition, methods of measuring water depth by ratio-processing have been developed, but their applicability to the specific problem of measuring water depth over diverse types of wetlands has not yet been demonstrated. As for wetland vegetation, it can be classified and mapped by methods already discussed in the section above.

6.3.5. URBAN AREAS

Scanner methods can be used to delineate various types of residential and commercial areas. Vegetative cover is a significant indicator of the structural type, age, and affluence of residential areas.

6.4. DATA FROM THE EARTH RESOURCES TECHNOLOGY SATELLITE

Useful for general corridor assessment is the information obtained from the Earth Resources Technology Satellite (ERTS) which provides up-to-date and frequently repeated coverage of large areas—a single ERTS frame covers an area of 33,000 sq km. Mapping of broad categories of vegetation, built-up areas, water bodies, and other major features provides data needed in the preliminary steps of impact assessment.

ERTS imagery, which is recorded on magnetic tapes, can be processed and studied in the following ways: black and white or color photographic enlargements can be made and directly interpreted; or digital printouts can be produced by computer-processing for examination. The latter form permits multispectral discrimination of a number of classes of land use or land cover. Also, the computer format makes possible the combination of ERTS data with data from many other sources. (Of course, geographic format must be the same.)

The current development status and ultimate potential of ERTS technology are well illustrated by studies of three Michigan test sites (see Refs. 14 through 16). The highway-planning applications of ERTS technology are covered in Section 7.

6.5. CONCLUSIONS

The foregoing review of recent developments in impact assessment procedures and a further examination of remote sensing's present state of development indicate that the conclusions and recommendations presented in Section 3 of Ref. [4] are still valid. An update on some of the tentative conclusions concerning remote sensing applicability is presented below.

The adoption of specific remote sensing techniques for highway impact assessment will depend not only on their accuracy and effectiveness but also on their relation to other sources of information. Where aerial photography, soil surveys, topographic maps, land use maps, and other data make up-to-date information available, special remote sensing methods can be recommended—but only if the additional information they provide justifies the extra cost and time required for collection and analysis. Before making such a judgment, however, we should recognize that much of the information needed for impact assessment can also be used in performing other aspects of highway planning and design, including corridor and route selection. Special methods of data collection and analysis may therefore be justified in situations where they can generate information essential to the accomplishment of several kinds of tasks.

Aerial photography is already widely used for highway planning purposes. In addition, such advances as high-altitude photography, color film, and color IR film are being incorporated into highway planning and design procedures.

We are still developing the use of the airborne multispectral scanner in providing impact assessment data. When fully evolved, the scanner will probably be most suitable for land use and land cover mapping in the corridor selection phase of impact assessment.

Once information requirements on vegetation categories and communities are sufficiently well defined, additional experience in mapping these categories from scanner data will lead to the demonstration of reliable mapping procedures. For vegetation mapping, such procedures must take into account specific vegetation types which are of special economic or ecologic value or which are sensitive to air pollution or changes in water drainage.

Additional experience with soils mapping will generate the ability to map soils drainage and texture for areas in which adequate soil-survey data are not available. Soils analysis, however, will be restricted to those areas in which bare soil can be observed or soil types inferred from a vegetation map.

Because there should be a common format for all data used in impact assessment analysis and reporting, including airborne scanner data, suitable means must be provided for the registration of scanner-processed data with all other sources. Since scanner data are available in electrical form, registration might be accomplished through the use of computer-based methods for the storage and analysis of geographically referenced data.

The use of airborne multispectral-scanner methods of information gathering and analysis for impact assessment and other highway planning functions will not be emphasized in the continuation of this project since such application is being advanced under other programs.

ERIM's experience to date with the processing of ERTS-1 data indicates that it is a likely source of the type of information on land use and natural resources needed in the early stages of highway impact assessment. In addition, information of this type can be efficiently and economically incorporated into computer models permitting parameter manipulation and analysis.

7
MICHIGAN APPLICATIONS OF ERTS-1 DATA

Current studies at both ERIM and MSU under NASA Contracts NAS5-21783 and NAS5-21834 are concerned with developing ERTS technology for a wide variety of applications in resource management and environmental monitoring. Based on this experience, the project assisted several government units in the investigation of ERTS-1 potential for Michigan applications. As a first step in this investigation, ERTS imagery of an area in the Upper Peninsula was processed to produce a land use and land cover map. This map and other ERTS-1 products for Michigan areas were shown to the staff of a number of federal, state, and local government agencies, including units of the Michigan Department of State Highways, the Department of Natural Resources, the U. S. Department of Agriculture, and the Bureau of Outdoor Recreation. Although the potential for computer-processed data has not been fully realized as yet, staff members of these Michigan-based agencies who have reviewed these results indicate that ERTS data can be of major assistance in their work.

This section discusses the Upper Peninsula mapping, which had two major objectives:

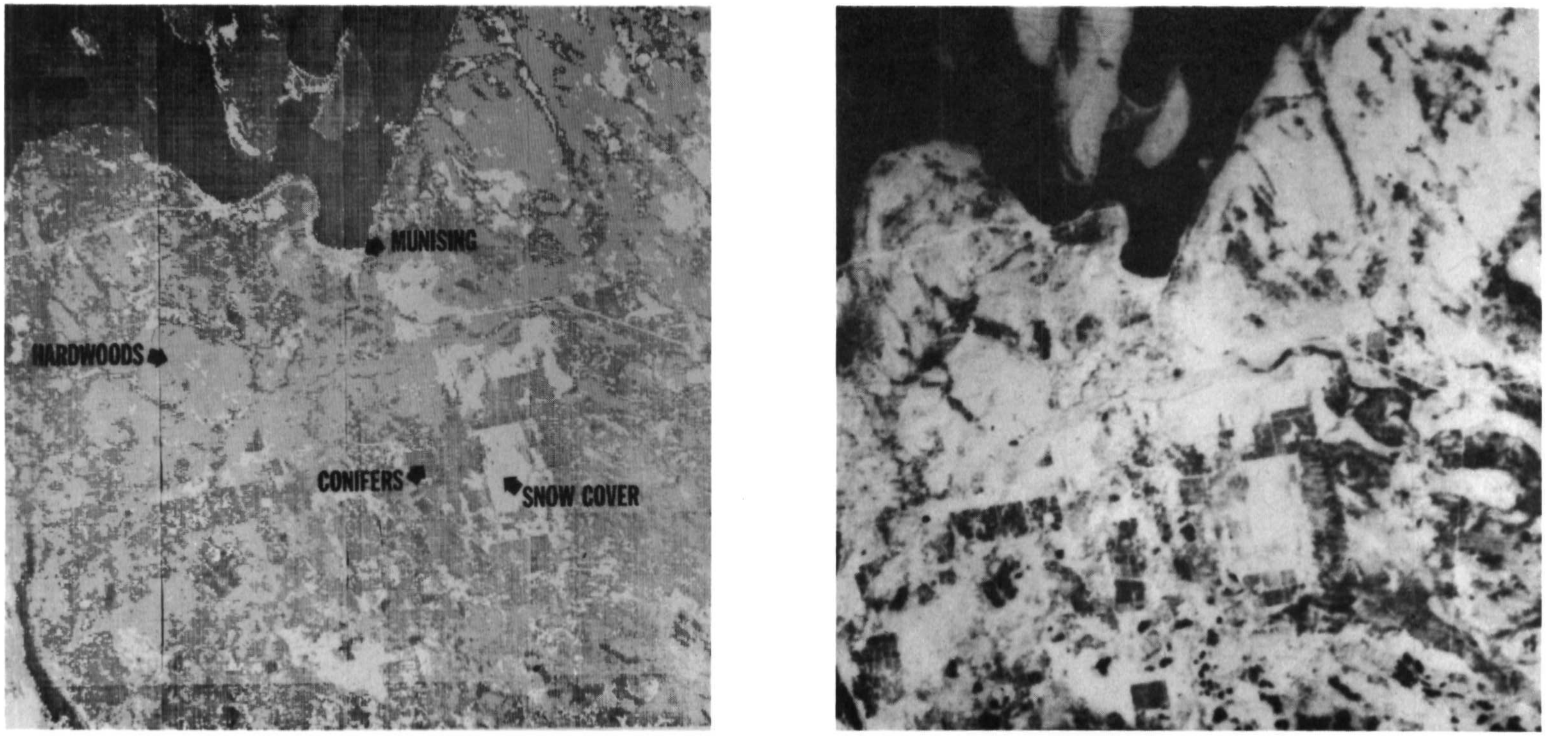
(1) to demonstrate the current capability of ERTS data processing when used to inventory land use and land cover for large areas; and

(2) to adapt the resulting inventory data for use in a computer data storage, analysis, and retrieval system, which can in turn be used for statistical analysis, modelling, and other functions.

7.1. PREPARATION OF LAND USE AND LAND COVER MAP

The Upper Peninsula area chosen for our study is around Munising, just north of the Hiawatha National Forest. This heavily forested region was selected because, with forests as a class covering approximately 50% of Michigan's land area, there is the prospect of working with the U. S. Department of Agriculture's Forest Service and the Michigan Department of Natural Resources in the analysis of forest cover situations. Further, the Highway Department will soon begin several major studies of highways which are to pass through heavily wooded areas in the Upper Peninsula and the northern half of the Lower Peninsula. In short, we are trying to coordinate our work and share our results with as many users as possible.

Figure 6 is a digital recognition map of the Munising area showing four classes of ground cover features. A photograph of ERTS-1 MSS-band 5 has been included for comparison purposes. An area of approximately 920 sq km was mapped to depict water, deciduous and coniferous tree stands, and unforested areas accurately delineated by snow cover. [The area was covered by a uniform background of snow (13 cm), which aided analysis and recognition procedures.] The map has been closely compared to forest-type maps supplied by the U. S.



(a) Forest Cover Analysis

(b) ERTS-1, MSS-5

FIGURE 6. HIAWATHA NATIONAL FOREST, MUNISING, MICHIGAN, 20 OCTOBER 1972. An area of approximately 920 sq km has been mapped from ERTS-1 data to depict water, deciduous and coniferous tree stands, and snow cover (which corresponds to areas without forest cover). The site was covered by 13 cm of snow; this uniform background greatly increased the accuracy of recognition. Comparison with forest type-maps and field checking in specific areas indicate that this initial effort at forest classification was quite accurate.

Forest Service; in addition it has been field-checked in specific areas. A remarkably accurate product, it extends ground cover classification into areas not previously mapped in detail.

A color-coded recognition map of the area has also been prepared showing seven classes: two hardwood types, mature jack pine and red pine stands, marsh, water, and snow cover. A small portion of this map is shown in Fig. 7, together with an annotated aerial photograph taken in July, 1972. As can be seen, there is excellent correspondence between the recognition types and the annotated photograph. Of particular interest is the fact that the hardwood stand (immediately west of the airport) which was thinned for selected individuals (TSI) during the summer of 1972 registers a spectral signature distinguishing it from the rest of the hardwood stands in the area. At first this particular stand was mapped as a separate class, but later ground-truth field checking performed by Forest Service personnel revealed its unique character.

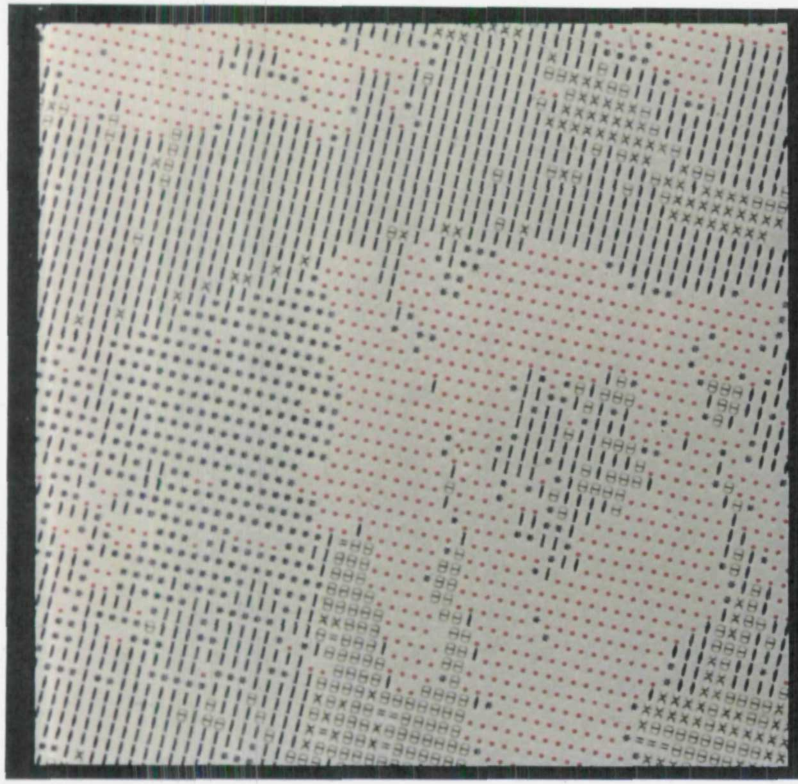
7.2. TRANSPORTATION MODELLING FOR THE HIGHWAY DEPARTMENT

The work in land use and land cover mapping just described promises to be an encouraging prospect for user participation. The Statewide Transportation Analysis Unit of the Transportation Planning Division, Michigan Department of State Highways, has developed a Statewide Traffic Forecasting Model to study traffic flow patterns and the impact of new road construction. The input data currently used in the model include population figures for each of the 547 zones within the state, the existing primary road network, and some of the existing secondary road network. One output of the model is information on future trip volumes and travel characteristics.

The Unit is also developing a preliminary corridor-location model for use in selecting routes based on regional environmental characteristics. Also, a statewide land-use model is being developed and calibrated. These models constitute a complete transportation-analysis package, which will be used in predicting the future impacts highway construction may have on traffic flow and land use patterns.

These computerized models require up-to-date land-use information in a form amenable to quick access. In the past it has been difficult to obtain such information and then include it in the data base needed for transportation analysis. Data obtained from ERTS and processed by multispectral pattern recognition to delineate land use categories appear to overcome these difficulties. The recognition results we have obtained thus far are sufficiently useful, both in classification content and accuracy, for initial testing in this highway modelling program. To develop this application, we have been working cooperatively with Mr. Richard Esch, Supervisor of the Statewide Transportation Analysis Unit, and his staff.

Highway Department personnel have indicated that they need information about the location of water, forests (further subdivided by species), open grassland, marsh, agriculture, and urban



(a) Digital Recognition Map
20 October 1972

(b) Annotated Aerial Photograph
27 July 1972

FIGURE 7. COMPARISON OF ERTS-1 PROCESSED DATA WITH AERIAL PHOTOGRAPHY, HIAWATHA NATIONAL FOREST. There is excellent correspondence between the recognition map and the annotated aerial photograph taken in July, 1972. Of particular interest is the fact that the hardwood stand immediately west of the airport which has been thinned for selected individuals (TSI) during the previous summer, registered a spectral signature distinct from that of the rest of the hardwood stands in the area. As a result, it was distinguished by the computer as a separate class.

areas. These major categories are consistent with the land-use classification system proposed by the State Planning Division. A further stratification of developed areas may also be extremely useful in future modelling applications. And the stratification of forests into pine, spruce, birch, and hardwood may be useful for indicating forest soil characteristics of importance in assessing highway construction costs.

In order to efficiently utilize land classification information obtained from ERTS-1, a suitable means must be devised for integrating the ERTS-1 data with other data used in the transportation model. This requires that the ERTS-1 data be registered, element-by-element, with geographically registered data from the other sources. To do this, it will be necessary to design and implement a system capable of computing the UTM coordinates of each digitized scene point from ERTS-1 scans and then merging this information on digital tape with land-use classification data from ERTS-1. As an initial step in developing such a system for use in the Highway Department's existing computerized model, we have provided a processed ERTS-1 data-tape of the area previously discussed. Programmers and other researchers in the Statewide Transportation Analysis Unit are currently working with this first land-use recognition tape in order to establish format requirements for the ERTS-1 data tapes to be used in their computerized information systems.

Once these requirements are defined, the Highway Department will be able to merge remote sensing data into its information system rapidly and economically. Undoubtedly, the resulting capability will be examined by many other agencies interested in its possible uses.

7.3. DEER HABITAT MANAGEMENT

Hunting is of major importance to Michigan, and the number of hunters is growing faster than the state's population. Hunting is not only a recreational activity; it also significantly supports the state's economy. Since there are more than 700,000 deer hunters every year, management of the deer herd is an important responsibility of the Department of Natural Resources. A direct and immediate goal of DNR is the production by 1981 of a deer herd numbering one million (more than twice its present size).

The potential uses of remote sensing for wildlife management have been discussed with members of the Forest Wildlife Research Unit of DNR's Research and Development Division. Remote sensing can be utilized both in support of deer research and in the operational stages of deer habitat management. With particular reference to the use of ERTS data, this section outlines potential applications of remote sensing for both long-range and short-range information needs.

The goal of DNR's long-range research program is to determine the most effective and economical management methods needed to build and maintain the deer herd at a level that will meet hunting demands. This research will provide a better understanding of the following: the parameters which govern wildlife-habitat quality; new methods for estimating animal census and condition; and new ways of measuring recreational and non-recreational land use based on information derived from vegetation surveys.

Although much additional research is needed, existing knowledge can be effectively used at present to make important deer-management decisions. One of the most important issues currently facing the state is the threat to available wildlife habitat resulting from conversion to other uses or natural changes in successional stage. Much of the needed information about deer habitat (such as present availability, growth, and decrease) can be provided by remote sensing methods. High-altitude aircraft photography and satellite imagery can be particularly useful in mapping certain vegetation communities known to be especially suitable for support of the deer population. In addition, accurate measurement of the growth or attrition of wildlife-producing lands can be used to make decisions on zoning, development, and management of public and private lands in Northern Michigan. These decisions can then be implemented by legislation or DNR action. Information can also be made available to private landowners to assist them in the development and management of their own land.

Those animals most valuable for Michigan recreational purposes live primarily in an intolerant-tree stage of forest succession. Recreational use of this ecologic stage takes forms other than those directly related to wildlife. Commercial users of this stage, for example, include the paper pulp industry with its ongoing harvests of aspen, oak, and jackpine — our major pulp trees. With the increasing demand for pulp products, more use is being made of these lands. Because of these recreational and non-recreational uses, the intolerant stage is one of the more important stages of forest succession. Consequently, it requires intensive and effective management.

The extent of the intolerant-tree stage in Michigan directly controls the white-tailed deer population. In the late 1940's the deer population was largest in the Northern Lower Peninsula and in the late 1950's in the Upper Peninsula. Since then the herd has steadily declined. The build-up took place because a large portion of Northern Michigan was in an early successional stage (brush and young intolerant trees) caused by heavy logging, followed by innumerable fires, followed in turn by effective fire suppression. The recent absence of logging and fire has resulted in the steady decline of wildlands in this early successional stage; and the attendant reduction in brushy and intolerant tree species has led to a decline in the white-tailed deer herd.

In broad terms the problem is easy to define: the intolerant stage of ecological succession is disappearing, while simultaneously the demand for its products is increasing. DNR has begun an extensive program to reestablish this successional stage in selected areas of the state, and to devise long-range management programs that will ensure the continued availability of adequate intolerant-tree lands to meet future demands.

ERTS-1 imagery offers the prospect of providing repetitive coverage of extensive forested areas in Michigan that constitute potential deer habitat. As indicated previously, the exact character of suitable habitat still needs to be better defined. However, analysis of ERTS data can screen out many unsuitable areas, permitting a concentration of effort on further investigation of the more likely areas via aerial photography or by ground survey. Used over a period of time, ERTS data will also enable the observation of changes in available habitat resulting from forest clearing, fire, or alteration in successional stage.

The immediate value of ERTS data, however, will be for observing the current situation. For example, overstory mapping and identification will give important clues for classifying the suitability of potential deer habitat. If ERTS-1 information can be used to identify and map understory, it will be even more valuable for habitat assessment. The mapping of cleared areas within forests and nearby surface water also enters into the assessment task.

In short, the preliminary mapping of the Upper Peninsula forested area described previously, and which is now being carefully considered by DNR wildlife scientists, is an early indication of the potential offered by ERTS data as a source of much needed management information.

8
NATURAL GAS ERUPTIONS AT WILLIAMSBURG

8.1. BACKGROUND

Beginning on 18 April 1973, numerous natural gas eruptions occurred near the small town of Williamsburg, Michigan. Most, if not all, outbreaks of high pressure gas were accompanied by a large quantity of ground water, carrying subsurface soil and surface debris into the many streams feeding inland lakes and the Grand Traverse Bay of Lake Michigan. The rapidly escaping flammable gas (primarily methane), coupled with subsurface erosion and cratering, immediately created a dangerous situation which forced local officials to evacuate residents and cordon off several square kilometers of the affected area.

There appears to be a direct connection between the gas eruptions and difficulties encountered three days earlier at the site of a gas well being drilled by AMOCO Production Co. some 6 km southeast of the original gas outbreak. Officials on the scene suspect that mud, which fills the borehole and surrounds the drill during normal operations (acting both as a lubricant and as a retainer against cave-in or gas leakage), expanded outward into a porous subsurface layer. Apparently this expansion drained off mud from above until the remaining downward retention force (weight of the mud column) could no longer prevent the upward surge of high pressure gas. According to this hypothesis, gas in large quantities was then released into one or more porous subsurface layers, through which it could rapidly spread over a large area, working its way into the uppermost drift layer. Eventually it reached the surface through countless channels, cracks, and openings (including the many artesian wells in the area and old core holes drilled for previous geologic study).

As Michigan and AMOCO geologists tried to pinpoint the exact cause and relieve pressure through additional drilling, the eruptions rapidly increased in number, intensity, and distribution until more than 100 outbreaks had affected many square kilometers and forced the evacuation of some 70 families. Simultaneously, sediment-laden streams, flowing well above their normal levels, were sending dense cream-colored plumes into and over much of the surface of nearby Elk Lake and the east arm of Grand Traverse Bay. Acme Creek and Williamsburg Creek, normally clear and nearly pollution-free trout streams, became thoroughly colored and visually opaque.

8.2. DISASTER RELIEF ACTIVITIES

Because of the sudden appearance of the gas outbreaks, their rapid spread, and the subsequent high gas-concentration in the area, the primary concern was for the safety of the residents and their orderly evacuation, if and when such action became necessary. Since much of the gas was reaching the surface through artesian wells, many of which are piped into homes as a primary water supply, in several cases the highest gas concentrations occurred within occupied dwellings. Consequently, the earliest possible detection of potentially dangerous conditions was a prime consideration, particularly in locating impending gas/water outbreaks and predicting their direction and rate of spread.

Starting only 13 km away, the eruptions moved closer and closer to Traverse City (the most densely populated urban area in that part of the state). As a result, early indication of their continued spread became a most important matter. At the same time, there was the further concern that undetected outbreaks in the more isolated areas might produce dangerously high gas concentrations in unevacuated homes or structures in which the operation of electrical equipment, pumps, furnaces, farm machinery, and the like could constitute an explosion hazard. Finally, knowing the pattern of outbreaks was important in order to understand the geologic structures and layers involved. Such understanding, in turn, was needed to guide pressure-relief drilling activities and to help predict potential eruptions.

The geology of the area, considered highly complex, was not well understood; also, the exact subsurface layers involved were unknown. Thus, considerable emphasis was placed upon finding known routes through which gas could reach the surface. For example, AMOCO officials, as an aid in their search for potential trouble spots, obtained information on the location of core holes drilled previously for geologic study.

8.3. REMOTE-SENSING APPLICATION ANALYSIS

Since we knew that the gas at the base of the well thought to be the source of the eruptions was at an elevated temperature (about 125°F), we concluded that the time-sequence of events prior to an eruption might create a thermal anomaly detectable at the surface. ERIM, therefore, obtained permission from the Michigan Department of Natural Resources, the Michigan Public Services Commission, and local authorities to conduct a ground-based investigation by a team equipped with portable thermal sensors in order to assess the potential of remote sensing techniques for the pre-eruption detection of gas/water outbreaks. If this detection capability were proven feasible, a flight over the area would be proposed to assist the State of Michigan and AMOCO in predicting the location of new outbreaks.

Accordingly, J. J. Cook, R. K. Vincent, and E. A. Work, all from ERIM, visited the area. Working from 2000 hours on 23 April through 1900 hours on 24 April, they took ground-based radiative and direct temperature measurements in and around three active eruptions and in numerous channels and streams carrying sediment-laden run-off water. In order to cover a larger area and obtain additional information regarding potentially anomalous surface thermal conditions, ERIM researches then made a one-hour flight in a Coast Guard helicopter over the affected area and its environs, taking measurements with hand-held portable instruments. Ground and aerial photographs were also taken to provide additional information.

After analyzing the data collected during this flight, we concluded as follows:

(1) While existing eruptions can be detected thermally, they are not thermally distinguishable from flowing ground water discharged from uncontaminated artesian wells.

(2) This distinction can be made, however, using spectral discrimination based on the unique color (and reflective characteristics) of the water-borne sediment.

(3) A map and record of existing outbreaks and the pattern of eruptions can be derived from remote sensing data.

(4) Considerable geologic information might be derived through study of surface conditions as interpreted from existing aerial photography.

(5) Prediction of potential eruptions is possible, but remains unverified because of a lack of information on the mechanism and time-dependent phenomena involved.

Although detecting pre-eruption conditions by means of remote sensing may be feasible, the unique nature of this application made it impossible to determine its effectiveness in advance. In addition, remote sensing during active eruptions is subject to the rapidly changing nature of the phenomena under observation. Finally, the collection and processing of remote sensing data takes time, which might decrease its value as a solution for the immediate problems facing authorities in such situations. Under the existing circumstances, therefore, it was concluded that the probability of providing useful information by remote sensing was not high enough to justify the collection and analysis of such data.

8.4. REMOTE SENSING IN A POST-DISASTER STUDY

By the end of April, the break in the gas well casing had been sealed off, and shortly afterwards gas leakage in the area started to subside. Further study of information gathered at the Williamsburg site indicates that remote sensing may be useful for investigating some of the harmful effects of such eruptions.

One such effect is the possible damage to vegetation, especially that involving commercial products (crops and orchards) and wildlife habitat. For example, an appropriate oxygen concentration in soil air (particularly the rhizogenous zone) is essential to effective water-uptake by plant roots. It is highly probable in localized areas near surface outbreaks (and perhaps over extensive portions of the entire area) that high gas concentration drastically reduces available soil-air oxygen and consequently inhibits water uptake for many days. Other factors, such as changes in rhizogenous zone moisture-regime, may also have effects on vegetation. Further, the fact that methane is soluble suggests that gas-carrying moisture may have been directly absorbed into plant roots, perhaps having a detrimental effect on vegetation vigor. All these factors could have caused damage to vegetation throughout the area.

Another possible effect of the eruptions is extensive subsurface erosion, which has been indicated by the fact that much ground water carrying considerable subsurface material has been discharged onto the surface. Although much of the area is sandy, it is possible that subsurface layers could be strong enough to bridge caverns and channels, thereby creating the potential for later subsidence or land collapse. (One indication of such subsidence occurred after an initial reduction in surface activity near M-72, where sagging had produced cracks in the highway surface.) Since remote sensing of surface features has been effective for inferring the presence of some types of subsurface caverns, it may be useful in the present situation.

Major streams in the area carried large quantities of contaminated water heavily laden with subsurface sediment and surface debris into inland lakes and Grand Traverse Bay. This discharge may have a detrimental effect on the animal and plant life and the recreational activities in the area. There is also concern about the effect on distribution of silt by circulation patterns within the larger water bodies. One such possible effect is sediment blockage of the intake pipes along Grand Traverse Bay which provide drinking water for many area residents. Remote sensing has been proven effective in assessing water quality and circulation patterns in such water bodies. It may also be effective in evaluating the potential damage this sediment-laden runoff may cause.

We believe it is desirable to carry on our investigation of the possible uses of remote sensing data for detecting and assessing potential gas-eruption damage. In particular, high-altitude aerial photography scheduled to be collected over the area during the summer of 1973 will be examined for any changes which may have occurred as a result of the gas eruptions. Additional site visits and further analysis of remote sensing methods will also be made, as long as they offer the possibility of identifying useful applications of remote sensing. Finally, if it appears that remote sensing data can be effectively provided, we will recommend—to the State of Michigan and to AMOCO—the collection and analysis of such data.

9
COMMERCIAL SITE SELECTION

A valuable application of aerial photography is in helping commercial and government organizations select good locations for expansion of their activities. Retail stores, banks, and other facilities serving the general public can benefit from this method of site reconnaissance. At the suggestion of Mr. Richard D. Warfel of the Office of Economic Expansion (a division of Michigan's Department of Commerce), Mr. Sheldon Hochstetler and Mr. Gary D. King of the Trenton State Bank visited ERIM to discuss the use of aerial photography for identifying branch bank sites. ERIM made available copies of RB-57 photography for this purpose.

This remote sensing information can be used by the bank in several ways:

(1) It identifies potential sites for new branches over a large area and minimizes the amount of ground checking usually required for site selection.

(2) It can be used in conjunction with other information to justify the new branch to the Banking Commissioner (of the Department of Commerce's Financial Institutions Bureau).

(3) It identifies growth trends in areas already served by bank branches, which can be in turn used to analyze banking service requirements for these areas and to update marketing and advertising plans.

Appropriate sites for a branch bank are determined through an analysis of the concentrations of industrial, commercial, and residential areas and their relation to major transportation arteries. A factor of major significance is the recent growth rate of these residential areas; this indicates future trends in urban growth and, therefore, the locations most likely to need improved banking services. A selection of suitable sites must also take into account the geographic distribution of existing branches of all banks.

At the time this application was undertaken, only the RB-57 aerial photography taken during September 1969 was available. As a result, trends could not be determined. However, a study of this photography made it possible to pinpoint a number of sites (all within 40 km of the main office) which appeared to be good candidates for further consideration. The growth of the area was then determined by on-site inspections, which generally bore out Mr. King's preliminary assessment of site suitability. On the basis of this investigation, several locations for new branch sites were recommended to the bank's Board of Directors, who have taken them under consideration.

At a later date the RB-57 photography collected in June 1972 was supplied to Mr. King so that the original decisions about site selection could be reviewed. In general, both sets of aerial photography helped materially in the assessment of growth trends, particularly regarding the location of new subdivisions and commercial areas. If available earlier, the second set would have reduced to some extent the amount of field checking required.

In short, high-altitude photography provided the regional overview needed for studying extensive areas. Its resolution was adequate for the purpose of identifying major kinds of land use. And the fact that the photographs were in color proved helpful for those individuals with limited experience in photointerpretation.

This type of remote sensing application certainly has value for many other commercial and government organizations concerned with studying their present and potential geographic marketing areas.

Page Intentionally Left Blank

APPENDIX A

Newspaper Accounts of Williamsburg Gas Eruption

Geysers Create Ghost Town

By Quane Kenyon

WILLIAMSBURG, Mich. (AP) —Williamsburg is virtually a ghost town.

The doors of empty houses stand open. Windows are raised. Laundry hung out to dry flaps unattended on a clothesline. The sounds of a community at work and at play have given way to silence.

This village of 200 persons is deserted because of a sudden, inexplicable series of natural gas eruptions.

Since Wednesday, natural gas has broken through the ground in hundreds of places and filled a mile-square area with fumes.

"We first told 'em it would be at least a week before they could get back," said Traverse County Sheriff Richard Weiler of the men, women and children who call Williamsburg home. "Now we're talking at least two weeks."

But other officials said it may be several months before life gets back to normal in Williamsburg. Nearly every structure in the town is over or near one of the many blowholes caused by gas eruptions.

Extensive damage already has been caused in the village. One blowhole erupted near the town hall, seriously undermining the structure, built in 1889. Another is eating away Michigan 72, and the highway probably will have to be rebuilt.

Several neatly trimmed front lawns in the village now feature ugly mud basins as much as 10 feet across and more than five feet deep.

Bill Mullendore, a biologist for the Department of Natural Resources, said the agency had no reports of wildlife killed in the incident.

But he said Acme and Williamsburg creeks, both popular trout streams, may be damaged badly by mud and clay pushed up by the escaping gas.

Meanwhile, the 200 evacuated residents of Williamsburg are living with friends or relatives.

Evidence of a large geyser 3½ miles outside the perimeter ... only 4½ miles from heavily populated Traverse City — was found late Saturday, but Dyer said:

"There have been no fresh outbreaks since ... and this is not a clear indication that there is a westward movement of gas."

But Troy Yoder, another DNR official, said the situation within the perimeter here is more dangerous now because the holes are throwing less water and more gas.

Therefore, patrols seeking new geysers are doing it on foot. If they use machinery they might set off an explosion.

Last week, M-72 through here was closed because sinkholes cracked the pavement. A 15-mile stretch of the highway was shut off and traffic detoured around the town by way of old M-72.

Now a new set of holes is aproaching old M-72. If it is damaged, officials say, that highway also will have to be closed.

Officials said two creeks from here have been pouring silt (small particles of clay mixed with sand) a quarter mile out into Grand Traverse Bay five miles west of here.

There is some uncertainty whether the silt will damage fish, but officials are concerned that it may block intake pipes along the bay which provide drinking water.

As a precaution, Amoco and the DNR announced that they will start building small dams along the two silt-carrying creeks that empty into Grand Travere Bay.

Geologists said yesterday it appears that the gas is seeping through the underground rock strata toward Grand Traverse Bay and beyond. They explained that the definite cause of the gas seepage is not yet determined, although some people have blamed a 6,000-foot gas well being drilled by Amoco Productions Co., a subsidiary of Standard Oil of Indiana, four miles south of Williamsburg.

Area Scientists Probe Eruptions

Scientists at the Environmental Research Institute of Michigan (ERIM) at Willow Run Airport are now analyzing remote sensing data collected April 23 in the Williamsburg area where gas eruptions have forced evacuation of the northwestern Michigan community.

Jerald Cook, ERIM research scientist said today that his organization had asked the Michigan Department of Natural Resources (DNR) if ERIM scientists could make an inspection to determine if remote sensing could be used to locate craters before they broke through the ground.

Cook said that he and fellow ERIM scientists, Edward Work and Robert Vincent, did not find any obvious potential eruptions not yet visible to the eye in ground based studies and in a short helicopter flight with hand-carried infra-red remote sensing equipment.

However, "we think remote sensing could be used in the future to determine what damage the gas eruptions have done to vegetation and lakes and streams in the area," Cook said.

APPENDIX B

Monroe County Planning Commission
COUNTY COURT HOUSE · MONROE, MICHIGAN · 48161
AREA CODE 313 PHONE 241-6066

June 19, 1973

Mr. Albert N. Sellman
Environmental Research Institute
of Michigan
P.O. Box 618
Ann Arbor, Michigan 48107

Dear Mr. Sellman

This opportunity is taken to confirm that you visited our offices on May 16, 1973 and presented staff with black and white infrared photography of Monroe County's portion of Lake Erie Shoreline. You noted that this photography was flown on April 11,1973 on the day following severe flooding of the Lake Erie Shoreline in Monroe County.

Your representation on behalf of the Office of University Affairs headquartered in Washington D.C. was greatly appreciated by myself and members of my staff. Our exposure to infra red photography and its potential use as a planning tool is limited and your visit served to improve that understanding and to whet our appetite to seek increased opportunities to use infra red photography in our work.

As a result of the availability of the photography you left with us we recently were able to bring to bear unmistakable evidence that a proposed public housing site for the elderly and families in the City of Luna Pier was inundated on April 11, 1973 and indeed the entire community was inundated on that date. With this evidence my planning commission responded negatively to the Department of Housing and Urban Development relative to approval of this housing application pursuant to the Office of Management and Budget Circular No. A-95. Furthermore my Commission has taken positive steps to urge the Department of the Interior, Bureau of Outdoor Recreation to initiate a comprehensive cost/benefit study relative to the merits of acquisition of all Lake Erie Shoreline in Monroe County now in residential or vacant use for public or private recreation oriented uses. Your mapping was also used recently to assess the potential hazards in terms of fly ash stock piles eroding into Lake Erie and have discussed this problem with officials of the Detroit Edison Company who have agreed to dispose of their fly ash residue farther removed from the shores of Lake Erie and adequately diked to eliminate erosion to Lake Erie. While we have not had an opportunity to use infra red photography for zoning decisions we certainly see great potential in its application to zoning decision making.

We hope that your efforts will be continued to be supported as we can see real potential benefits to the interpretation of urban development phenomena.

Sincerely

Ronald F. Nino, Director

RFN:mm

APPENDIX C

MONROE COUNTY OFFICE OF CIVIL DEFENSE
MONROE COUNTY COURTHOUSE
106 E. FIRST STREET TELEPHONE CH 1-6400
MONROE, MICHIGAN 48161

HAROLD D. STRAUB, DIRECTOR

June 20, 1973

Mr. Buzz Selman
Environmental Research Institute of Michigan
Willow Run, Michigan

Dear Mr. Selman,

We appreciate the two explaination periods that you had on the pictures taken of the Monroe area.

We also appreciate the ariel photos that we are now in the process of assembling. The photos were able to give us a clear picture of the water level attained on 9 April, 1973, at the height of the flooding. We feel that these will be very useful in future planning for this type of disaster. If this same condition exists again with possible rainfall at the same period, would give us valuable information for planning evacuations etc.

The Drain Commission finds the pictures extremely valuable due to the locations of pumping stations along the flooded area.

This source of information has also been extracted for use by the County Planning Commission. As we derive other information from these photos, or see a need for your department, we will forward the information to you.

Thanking you for the photos and all services rendered, I remain,

Sincerely,

Harold D. Straub,
Director, OCP

HDS/aa

REFERENCES

1. Governor's Special Commission on Land Use Report, Lansing, Michigan, 14 December 1971.

2. A. N. Sellman, T. W. D. Gregg, and L. B. Istvan, Land Use Mapping for the State of Michigan, ERIM Report No. 200100-1-F, June 1973.

3. I. J. Sattinger et al., Remote Sensing in Michigan for Land Resource Management: 1972 Annual Report, ERIM Report 190800-2-F, December 1972.

4. Remote Sensing in Michigan for Land Resource Management: Highway Impact Assessment, ERIM Report 190800-1-T, December 1972.

5. Michigan Base Mapping—Approach to Standardized Base Mapping, Executive Office of the Governor, Bureau of Programs and Budget, State of Michigan Planning Division, Lansing, Michigan, 1973.

6. Michigan Natural Environment Survey, Johnson, Johnson, and Roy, Inc., Ann Arbor, Michigan, 15 January 1973.

7. Land Use Classification System as Recommended by the State Planning Division for the State of Michigan, December 1972, (Unpublished).

8. E. E. Hardy, R. L. Shelton, D. J. Belcher, and J. T. Roach, New York Land Use and Natural Resources Inventory, Vol. II, Center for Aerial Photographic Studies, Cornell University, Ithaca, New York, 1971.

9. J. R. Anderson, E. E. Hardy, and J. T. Roach, A Land Use Classification System for Use with Remote Sensor Data, U. S. Geological Survey 671, 1972.

10. Environmental Impact Statement for US-131 from M-46 to 20-Mile Road, Montcalm and Mecosta Counties, Michigan, Environmental Liaison Unit, Transportation Planning Division, Michigan Department of State Highways, 1973.

11. T. W. Wagner, R. Dillman, and F. Thomson, Remote Identification of Soil Conditions with Ratioed Multispectral Data, in Proceedings of The Second Annual Remote Sensing of Earth Resources Conference, The University of Tennessee Space Institute, Tullahoma, 26-28 March 1973.

12. C. E. Olson, Jr., W. G. Rohde, and J. M. Ward, Study IV: Automatic Recognition of Forest Tree Species from Multispectral Data (pp. 15-25), in Remote Sensing of Changes in Morphology and Physiology of Trees Under Stress, Annual Progress Report, 30 September 1970, performed under auspices of the Forestry Remote Sensing Laboratory, University of California, Berkeley.

13. R. S. Driscoll and M. M. Spencer, Multispectral Scanner Imagery for Plant Community Classification, in Proceedings of The Eighth International Symposium on Remote Sensing of Environment, Environmental Research Institute of Michigan, Ann Arbor, 2-6 October 1972.

14. I. J. Sattinger and R. D. Dillman, Digital Land Use Mapping in Oakland County, Michigan, in Proceedings of The Symposium on Significant Results Obtained from ERTS-1, Goddard Space Flight Center, 5-9 March 1973.

15. G. R. Safir, W. L. Myers, W. A. Malila, and J. P. Morgenstern, Applications of ERTS-1 Data to Analysis of Agricultural Crops and Forests in Michigan, in Proceedings of The Symposium on Significant Results Obtained from ERTS-1, Goddard Space Flight Center, 5-9 March 1973.

16. A. N. Sellman, Land Resources Survey for the State of Michigan, in The Proceedings of The Symposium on Significant Results Obtained from ERTS-1, Goddard Space Flight Center, 5-9 March 1973.

DISTRIBUTION LIST

NASA Scientific and Technical Information Facility
P. O. Box 33
College Park, Maryland 20740 (5 + Repro)

Office of University Affairs
NASA Headquarters
Washington, D. C. 20546

ATTN: Mr. J. A. Vitale, Code PY (10)