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EVALUATION OF THE APPLICATION OF ERTS-1 DATA TO THE REGIONAL LAND USE PLANNING PROCESS

James L. Clapp
Principal Investigator, GSFC ID UN 040
1204 Engineering Building
University of Wisconsin
Madison, Wisconsin 53706

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PROJECT PERSONNEL

Project Leader

James L. Clapp, Professor of Civil and Environmental Engineering, and Director, Environmental Monitoring and Data Acquisition Group

Principal Investigators

Theodore Green III, Professor of Meteorology and Civil and Environmental Engineering

George F. Hanson, State Geologist and Director, Geological and Natural History Survey

Ralph W. Kiefer, Professor of Civil and Environmental Engineering

Bernard J. Niemann, Jr., Professor and Chairman, Department of Landscape Architecture

Steering Committee

Carroll D. Besadny, Chief Research Coordinator, Wisconsin State Department of Natural Resources

Thomas O. Haig, Executive Director, Space Science and Engineering Center

George F. Hanson, Director, State Geological and Natural History Survey

Philip H. Lewis, Jr., Professor of Landscape Architecture, and Director, Environmental Awareness Center

Orie L. Loucks, Professor of Botany, and Project Leader, Lake Wingra Project of International Biological Program

Robert A. Ragotzkie, Professor of Meteorology and Director, Marine Studies Center

John E. Ross, Professor and Associate Director, Institute for Environmental Studies

Project Coordinators

J. Wayne Aderhold, Project Specialist, Institute for Environmental Studies

William W. Kuhlow, Project Specialist, Institute for Environmental Studies

Michael M. McCarthy, Project Specialist, Institute for Environmental Studies

Research Staff

Umit Basoglu, Research Assistant

Bruce E. Frazier, Project Specialist

Edward L. Kuhlmey, Research Assistant

Barbara L. Kenny, Project Specialist

Doron Nof, Research Associate

Sarah L. Wynn, Research Assistant

Administrative Staff

Linda J. Quirk, Administrative Secretary

Roseann Schaye, Typist

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16. Abstract

The lack of reliable, spatially-based physical resource data is a principal cause of inadequate land use planning and plan implementation. To meet this need, remote sensing from aircraft and satellite platforms must be considered, evaluated and utilized when and where appropriate. This report presents: (1) spatial comparisons of land resources data extracted from ERTS, RB-57 and conventional sources; (2) an evaluation of the effect of the source of the data upon the resulting land use decision; and (3) a recommended management structure designed to provide for the management needs imposed by the interagency and interdisciplinary nature of the application of ERTS data to the land use planning process.

Employing simple and economical extraction methods ERTS can provide valuable data to the planners at the state or regional level with a frequency never before possible. Interactive computer methods of working directly with ERTS digital information show much promise for providing land use information at a more specific level since the data format and production rate of ERTS justifies improved methods of analysis.

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PREFACE

The objectives of this investigation, as presented in the original proposal are: (1) to compare ERTS-1 imagery to specific natural and cultural data at varying scales over time; (2) to determine and document the usefulness of ERTS-1 data for environmentally based regional land use planning in Wisconsin; and (3) to determine the need and usefulness of ERTS-1 data for various state and university groups to obtain interagency and interdisciplinary involvement in data analysis, interpretation and application to current environmental problems and land use planning policies.

The investigation was broad based. It includes an evaluation of ERTS, RB-57 and conventional data sources; an evaluation of the effect of the data source at the level of the land use decision; and evaluation of the methods by which information may be extracted from ERTS-generated data; and an examination of the management problem inherent in the application of ERTS generated to the land use planning process as performed in operational agencies. University units cooperating in the investigation include the Environmental Monitoring and Data Acquisition Group, the Space Science and Engineering Center, and the Environmental Awareness Center. State agencies cooperating in the investigation include the Department of Administration and the Department of Natural Resources. Numerous regional planning agencies and concerned private groups cooperated in an advisory role.

Based upon the results of this investigation, it may be concluded that the ERTS system can provide valuable data to the planners at the state level with a frequency never before possible. The mechanics of the system make it a unique data source. The true value of ERTS as a data source cannot be realized employing processes used for conventional aerial photography. Computer-based methods of data extraction, with emphasis on an interactive mode, show great promise for fulfilling the more refined data needs of regional planners. The data format and production rate of the satellite justify improved methods of data extraction. In order to effectively apply the data generated by ERTS to land use planning it is highly desirable to develop a management system which provides for the operational involvement of many diverse agencies and a required response review process.

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1.0 INTRODUCTION

1.1 THE NEED FOR REGIONAL PLANNING DATA

In their continual interaction with the land use planning process through teaching, research and professional experience, the investigators have encountered a lack of spatial physical land use and resource data. Previous decades of environmental alteration and mismanagement, coupled with a change in perception of what constitutes life quality, have led to requirements that physical planners predict and document environmental impact before plan implementation. Physical planners are being asked to predict environmental consequences in quantified terms prior to construction. In addition, the generation and quantification of alternatives is being required and, therefore, environmental alterations (e.g., highways, urban expansion, energy transmission systems, etc.) must be located and quantified in terms of environmental impact. The requirement to provide location alternatives and quantify impact requires that physical resource data be available in a form which provides for manipulation, both spatially and quantitatively.

In addition to experience gained from long-term interaction with land planning procedures, the investigators in 1972 participated in a university-wide faculty land use seminar which was charged with assisting the Governor of the State of Wisconsin in determining land use planning policy and legislation.* The faculty seminar concluded after examination of twenty-seven individual land use planning problem areas (e.g., urban sprawl, wetland loss, flooding, transportation planning, etc.), that lack of sound, spatially-based physical resource data was a principle cause of inadequate land use planning and plan implementation. This lack affected every level of management and planning effort for private lands, public lands, and public facilities. The lack of physical resource data and a means of data manipulation has prevented the formulation

*Faculty Land Use in Wisconsin: A Preliminary Description of Problems and Preventive Efforts, 1972. University of Wisconsin, Institute for Environmental Studies, Madison, Wisconsin.

of sound overall policies, the examination of planning and management concepts, and the evaluation of individual projects. States and regions endowed with extensive physical resources which desire to plan for the purpose of assuring environmental quality, must quantify, monitor and assess their physical environment. To meet this need, various forms of remote sensing must be considered, evaluated and utilized when and where appropriate. Therefore, the potential use of ERTS-1 data to assist in supplying information required for regional land use planning was explored.

Involvement in the ERTS-1 investigation was based upon experience in other forms of remote sensing research including the use of remote sensing for water quality monitoring and resource data acquisition for input into geo-information systems. In this investigation geo-information systems serve in part as both the basis for ground truth comparisons with ERTS-1 data and as the structure for determining relevant land use planning resource data and variables. The investigation was pursued by a diversity of disciplines including the planning professions and the remote sensing disciplines. Review of the effort was accomplished through an advisory council consisting of representatives of concerned governmental and private agencies. These working relationships provided contact between the researchers and the potential data users thereby forming a system for interactive research, and a mechanism for examining the management problem associated with the application of ERTS generated data to the land use planning process.

1.2 PROJECT OBJECTIVES

The three objectives of this research effort, as presented in the original proposal, were:

a) to compare ERTS-1 imagery to specific natural and cultural data at varying scales and over time.

b) to determine and document the usefulness of ERTS-1 data for environmentally based regional land use planning in Wisconsin.

c) to determine the need and usefulness of ERTS-1 data for various state and university groups to obtain interagency and interdisciplinary involvement in data analysis, interpretation and application to current environmental problems and land use planning policies.

1.3 PROJECT DATA BASE

1.3.1 TEST SITES

The investigation and documentation of the application of ERTS-1 data to the regional planning process was based upon the utilization of representative geographical regions. These regions are shown in Figure 1.3.1. The entire state of Wisconsin was employed as a test site for the portion of the investigation dealing with statewide land use policy. The Northeastern Wisconsin Test Site and the REMAP Test Site were employed in the portion of the investigation dealing with more specific land use decisions. Subdivisions of the REMAP Site, shown in Figure 1.3.2 "Green Bay Test Site" and Figure 1.3.3 "Sheboygan Test Site," were employed in that portion of the investigation dealing with more site specific decisions. These test sites represent:

a) a variety of natural and cultural resource data,
b) different regional planning problems facing Wisconsin, and
c) three varied scales of data.

These sites were determined to be representative of the types required by the various planning levels within the state.

The data base for the State of Wisconsin was developed by the Wisconsin Geological and Natural History Survey and the University of Wisconsin's Marine Studies Center. Small scale soils and geologic maps are available for the entire state. The Marine Studies Center has provided information concerning the current patterns in Lakes

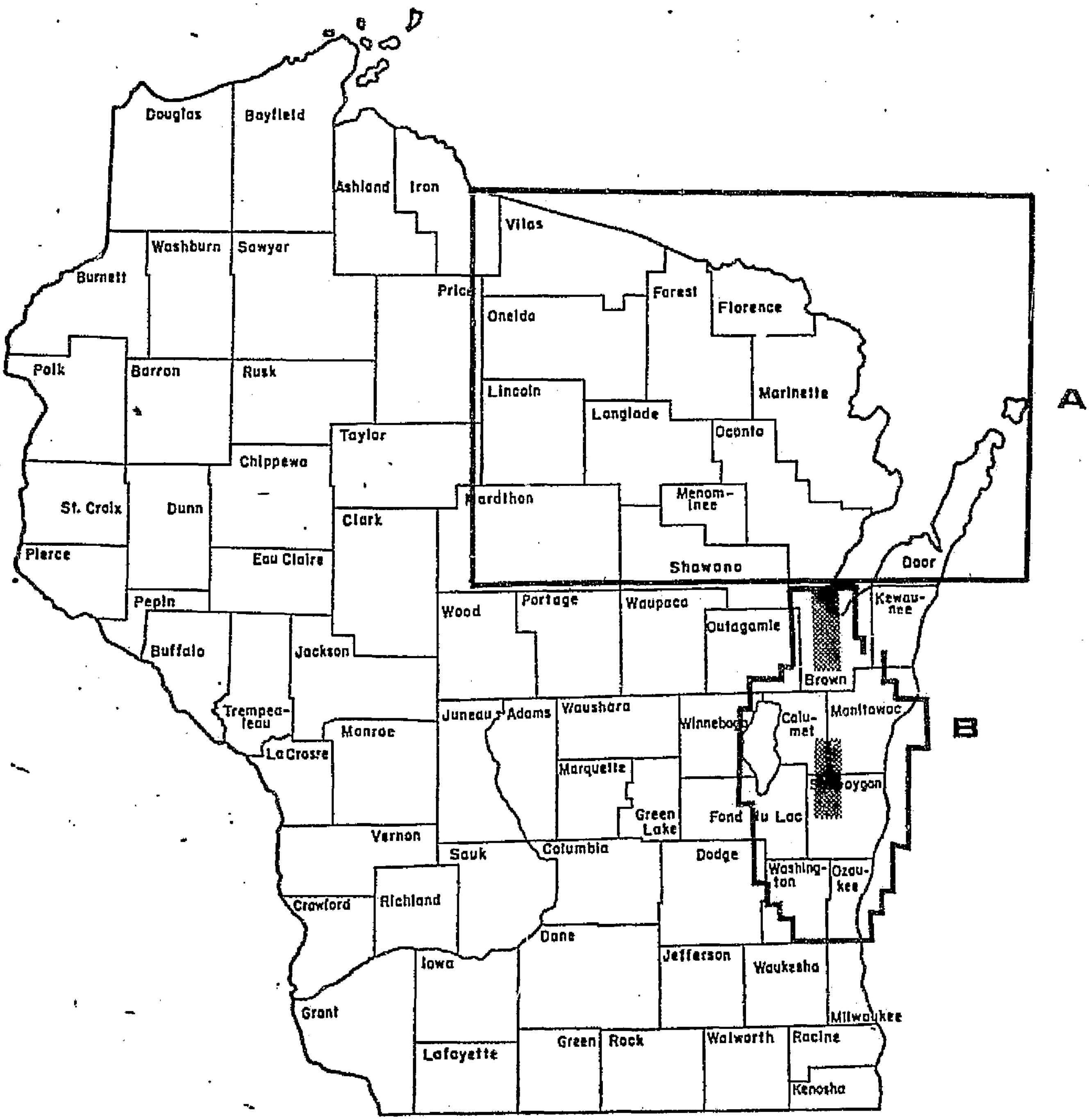

FIGURE 1.3.1 Wisconsin Test Sites.
Area A is the Northeastern Wisconsin Test Site; Area B is the REMAP Site. The two small cross-hatched areas in the REMAP Site are the Green Bay Test Site (northern part) and the Sheboygan Test Site (central part).

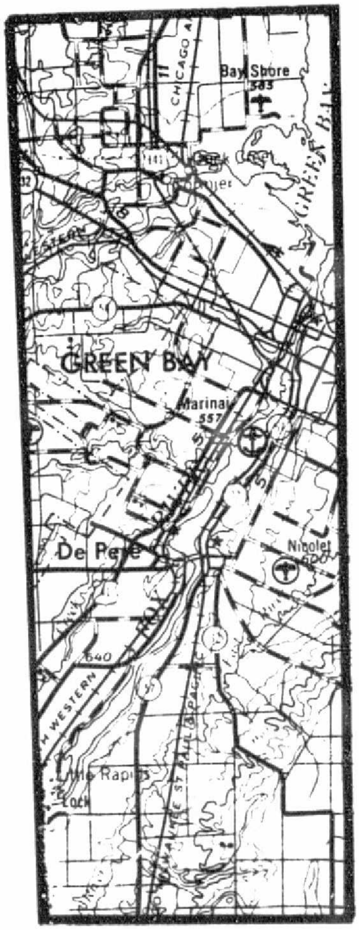

FIGURE 1.3.2 Green Bay Test Site

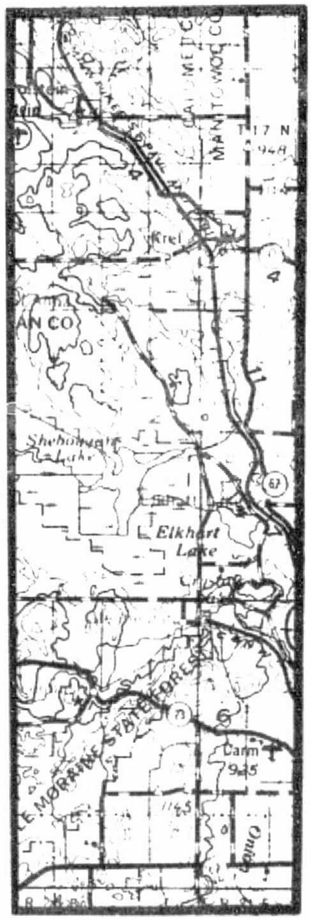

FIGURE 1.3.3 Sheboygan Test Site

Michigan and Superior as well as near shore circulation characteristics.

The data base for the Northeastern Wisconsin Test Site was developed by the Wisconsin Geological and Natural History Survey. Data on the soils, structure, geology, glacial features and drift thickness were generated from published and unpublished reports of the Survey.

The REMAP (Regional Environmental Management Allocation Process) Test Site data base was developed by the University of Wisconsin's Environmental Awareness Center. This is a computer-based data bank developed to provide for the economic storage, analyses, and display of natural and cultural resources for regional planning purposes. The system is geographically referenced on a Universal Transverse Mercator (UTM) base. This geo-information system was specifically developed to assist the Wisconsin Division of Highways in locating and assessing environmental impact from a proposed Interstate Highway between Milwaukee and Green Bay, Wisconsin. The format of this data bank provides for its direct comparison with ERTS-1 data in order to determine:

a) the discernibility of various natural and cultural data from ERTS-1 imagery;
b) the times of year the data can be efficiently inventoried and interpreted from ERTS-1 imagery;
c) the degree of accuracy to which they can be inventoried from ERTS-1 imagery; and
d) the smallest limit of measure at which the data are discernible.

1.3.2 VARIABLES STUDIED

For the purpose of evaluating the utility of ERTS-1 for supplying needed resource information, a list of variables was chosen as a basis of comparison of data sources. The variables were chosen from those already stored in the REMAP data bank to produce a significant representation of both natural and cultural data considered to be of importance in planning decisions. The complete list of these variables together with their definitions is contained in Appendix A.

1.3.3 RB-57 COVERAGE OF WISCONSIN

As an initial phase of the ERTS-1 investigation, work was begun toward interpreting information from the RB-57 high altitude (60,000 ft.) imagery which had been provided by NASA. The purpose of this phase was twofold:

a) to compare data interpretations from RB-57 imagery to the existing REMAP data bank to determine the optimum source of "ground truth" for the ERTS investigation, and

b) to develop a methodology for interpretation of ERTS-1 data. The results of this phase proved to be very significant in the determination of ground truth as indicated later in this report.

The RB-57 coverage consisted of four separate flights over the general area of the REMAP data bank on the following dates:

6 August 1971,
29 September 1971,
4 June 1972,
22 September 1972.

The Northwest portion of the state was flown by NASA on 18 and 20 September 1973, but this imagery has not yet been used for direct interpretation comparison. Figure 1.3.4 shows the extent of the RB-57 coverage used in this investigation.

1.3.4 ERTS-1 COVERAGE OF WISCONSIN

ERTS-1 passes over Wisconsin in a NNE to SSW direction as indicated in Figure 1.3.5. The passes take place on five successive days, with each pass occurring at approximately 10:00 AM CST. The orbital characteristics of the satellite result in an approximate sidelap of 38 percent at Wisconsin's geographic latitude. Summary maps

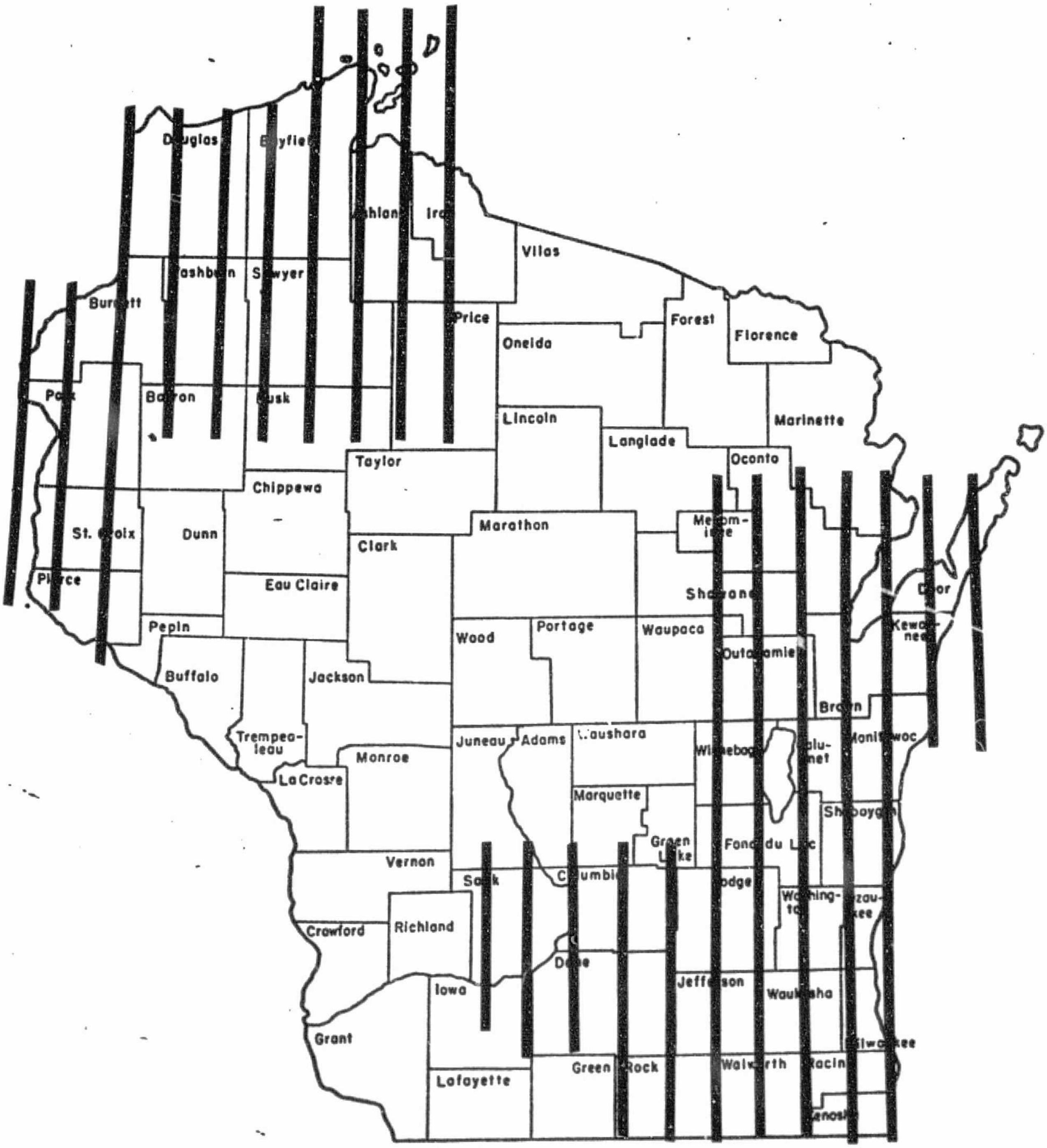

FIGURE 1.3.4 Approximate RB-57 Coverage of Wisconsin

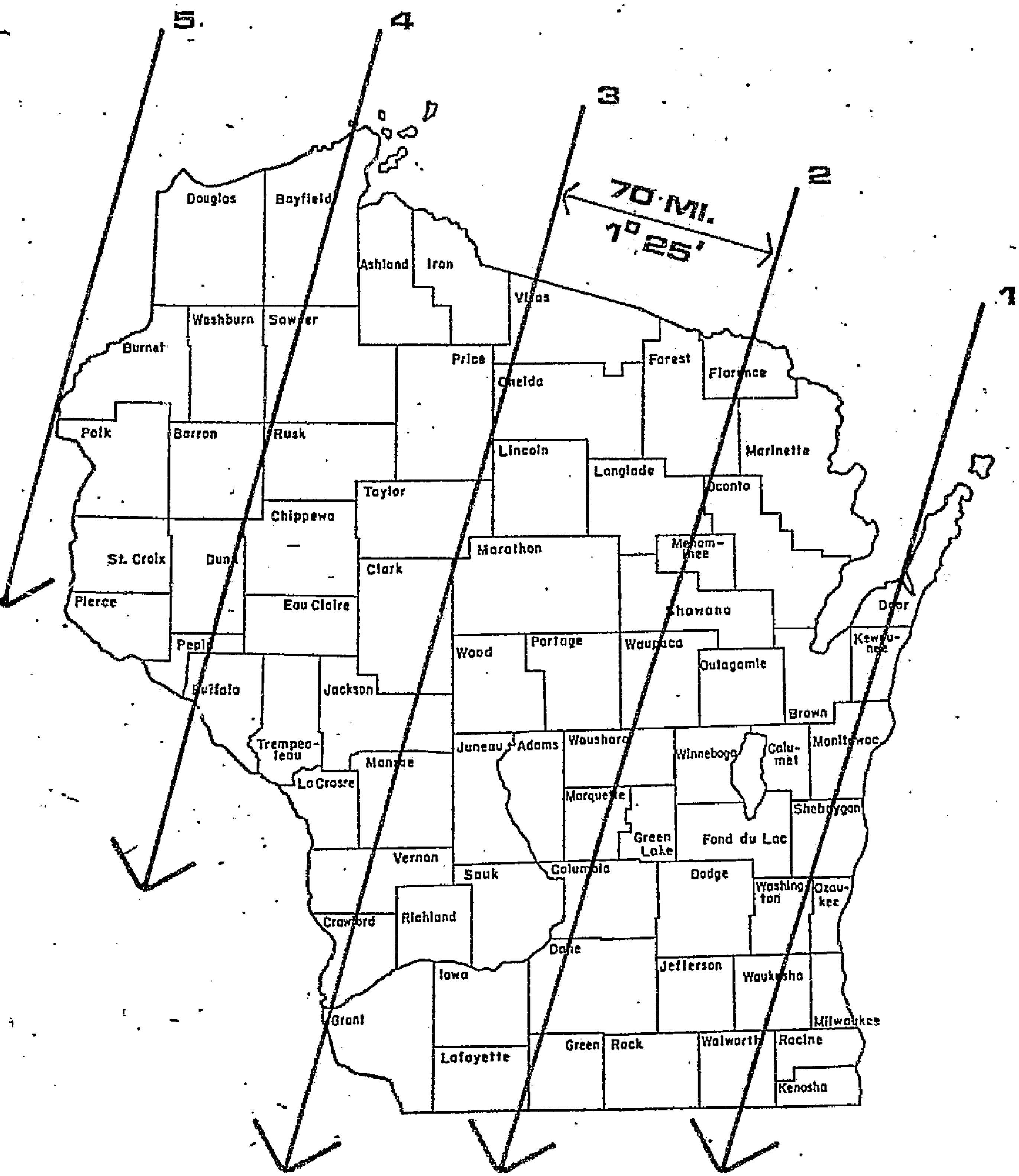

Figure 1.3.5 - The Approximate Paths of ERTS-1 Satellite Over Wisconsin.

of ERTS coverage available to the investigation are indicated in Appendix B.

1.4 PROJECT STATUS

This investigation has been extended by Modification No. 6 to Contract No. NAS5-21754 to terminate on 23 September 1974. A second final report covering the entire investigation will be submitted on 23 October 1974.

1.5 REPORT ORGANIZATION

Section 2 of this report presents the research results of this investigation to date. Subsection 2.1, "Comparison to Conventional Data," presents results for the first objective of the original proposal. Likewise subsections 2.2, "Determination of Usefulness of ERTS-1 Data for Regional Land Use Planning and Allocation Decisions," and 2.3, "Requirements for Interagency Involvement," present results for the second and third objectives of the original proposal. Section 3.0 presents the summary, conclusions and recommendations of the project. Supporting evidence is provided in the appendices.

2.0 PROJECT RESULTS BY OBJECTIVES

2.1 COMPARISON WITH CONVENTIONAL DATA

2.1.1 INTRODUCTION

In order to arrive at acceptable alternatives through a land use planning process, it is of primary importance that data of sufficient accuracy and specificity be made available to the decision makers. The involvement of the Environmental Awareness Center at the University of Wisconsin in the Interstate-57 location process constituted an attempt to provide a specific group of planners with all of the data deemed necessary for an environmentally sound decision.* Throughout the execution of the study, the researchers were constantly faced with the problem of obtaining satisfactory data sources. Often, the sources were either too outdated to be reliable or didn't exist, while the time required for compiling data from conventional sources approached a prohibitive level.

Consideration of these problems encourages the exploration of ERTS-1 data as an alternate source of input to the planning process for two basic reasons:

(1) the earth orbital characteristics of ERTS allow for a near real-time system of data acquisition, a feature which makes it vastly superior to conventional methods;

(2) ERTS has the potential to provide from a single source the same amount of data which previously required a number of different sources.

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*A.H. Miller, B.J. Niemann, An Interstate Corridor Selection Process, Environmental Awareness Center, Department of Landscape Architecture, University of Wisconsin, Madison, Wisconsin, 1972.

It is apparent that because of these characteristics ERTS-1 would be a superior system if the quality of its data could be proven equal to or better than that of conventional systems.

For this reason, work was undertaken to compare ERTS-1 derived data to conventional data in the form of that compiled for the I-57 study in the REMAP data bank. Initially, RB-57 imagery was also interpreted and compared with the REMAP data to determine the best source of ground truth so that the ERTS-1 data could ultimately be evaluated in terms of the highest available. The following sections describe the methods and results of these comparison procedures.

2.1.2 DATA EXTRACTION FROM PHOTOGRAPHIC IMAGERY

2.1.2.1 REMAP Data Identifiable on ERTS Imagery

The REMAP I and II data banks were developed by the University of Wisconsin's Department of Landscape Architecture to assist the State of Wisconsin Department of Transportation in selecting a satisfactory corridor for Interstate 57 between Milwaukee and Green Bay. The data banks consist of natural and cultural resource data, computer stored on a cellular basis for 1 square kilometer (REMAP I) and 1/9 square kilometer (REMAP II) cells. These variables were developed during this investigation as a comprehensive list (based upon available information) of the data types necessary and typically used for large-scale regional planning decisions and are therefore a good basis for assessing the value of ERTS-1 data. Even though the data bank was developed for highway corridor location, the organization of the data objectively provides a basis for answering other regional planning questions.

A basic test of the ERTS system consists of determining the degree to which these data can be identified on ERTS imagery. The comprehensive list of REMAP data was condensed to 33 variables as defined in Appendix A considered to be most significant for decision-making for land use allocations of one kilometer or larger such as transportation corridors, power plant sites, power transmission systems, large industrial concentrations and similar impact-producing phenomena. The interpretation was performed on 9-inch ERTS transparencies of the REMAP area at a scale of 1:1,000,000 using a Bausch and Lomb Model 240 Zoom Stereoscope and Richards Series MIM Light Table. This is a simple and inexpensive system but does not provide for image enhancement or manipulation. Individual "REMAP Data Interpretation Matrices" were tabulated for each variable for each date between 9 August 1972 and 26 October 1973 for which imagery was available for the Milwaukee-Green Bay corridor. The results of these individual tabulations have been condensed into the summary contained in Table 2.1.1, "ERTS Data Interpretation Summary", which indicates which variables could be properly identified by this simple visual inspection of the imagery available during this time period. These results should not be used to draw absolute conclusions in all cases because the interpretability was often influenced by image availability for the optimum time period, image quality and interpretation technique. The lack of satisfactory imagery is documented in Appendix B. However, the results also show this technique lacking in the resolution properties necessary for extraction of these types of data with confidence. For much of the data which were identifiable, it is evident that the identifiability varies with the time of the year and that there is a characteristic optimum time, especially for dynamic variables such as vegetation.

For comparison purposes, Table 2.1.2 ("RB-57 Data Interpretation Summary") has been constructed from inter-

TABLE 2.1.1

ERTS DATA INTERPRETATION SUMMARY[1]

X - Data identifiable without difficulty

O - Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
AGRICULTURE	O	X	X	X	Identified most readily in summer with composite or MSS 5; rectangular grid pattern of fields is good indicator; circular irrigation pattern
BEACH RIDGE					Not identifiable
COMMUNICATIONS, AIRFIELDS	O	X		X	Identified best on MSS 5 when surrounded by dense, healthy vegetation
DRUMLINS	X	X	O		Identified most readily during winter when snow cover exists which produces a "shaded" effect to highlight topographical features
END MORAINE	X	X	X	X	Contrast in characteristic vegetation of moraine with agricultural areas results in easy identification in southeastern areas; identification in more heavily forested northwest is possible but more difficult due to similarity of surrounding vegetation
ESKER					Positive identification is not possible without three-dimensional viewing

[1] See Appendix A: Definitions of Variables.

TABLE 2.1.1 (cont.)
ERTS DATA INTERPRETATION SUMMARY

X - Data identifiable without difficulty.

O - Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
ESCARPMENT			X		Can be identified with previous knowledge of the local geography
FOREST, LOWLAND		X		X	Can be identified but only with color composite image and proper ground truth
FOREST, UPLAND		X		X	Can be identified but only with color composite image and proper ground truth
FOREST, CONIFEROUS		X		X	Can be identified but only with color composite image and proper ground truth
FOREST, DECIDUOUS		X		X	Can be identified but only with color composite image and proper ground truth
FOREST, DECIDUOUS/CONIFEROUS		X			Readily identified

TABLE 2.1.1 (cont.)

ERTS DATA INTERPRETATION SUMMARY

X - Data identifiable without difficulty

O - Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
GLACIAL LAKE BED					Characteristic features require much lower altitude for identification
INTERCHANGES	X	X		X	MSS 5 or color composite provide relatively easy identification in contrasting surroundings of heavy vegetation
GROUND MORAINE			X		Some areas of ground moraine can be detected by their proximity to end moraine
LAKES	O	X		X	Boundaries most well-defined in MSS 6, 7 or color composite due to absorption of infrared radiation
LAKE MICHIGAN	X	X	X	X	Shoreline most well-defined when water is not frozen
LAKES, LESS THAN 50 ACRES	X	X		X	Identified most readily on MSS 6, 7 or color composite

TABLE 2.1.1 (cont.)

ERTS DATA INTERPRETATION SUMMARY

X - Data identifiable without difficulty

O - Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
LIMITED ACCESS HIGHWAY	X	X	X	X	Cannot be identified during winter when snow cover exists
MARSH	X	O	X	O	Identifiability depends on species composition and hydrologic conditions; early spring and late fall are best time for maximum community distinction; ground truth necessary for community distinction
OPEN SWAMP	X	O	X	O	Distinct boundaries are difficult to identify especially during winter
RESIDENTIAL, RURAL					Not readily identifiable
RESIDENTIAL, SUBURBAN	O	X		X	MSS 5 or color composite best; discrete boundaries (urban/suburban) not identifiable
RESIDENTIAL, URBAN	O	X	X	X	MSS 5 or color composite best, discrete boundaries (urban/suburban) not identifiable

ERTS DATA INTERPRETATION SUMMARY

X - Data identifiable without difficulty

O - Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
RIVERS	O	X		X	Only large rivers (unfrozen) identifiable in winter; boundaries are most readily delineated in summer on either infrared band
RIVER OR LAKE ZONING	X	X		X	Color composite best for identification
ROADS	O	X	X	X	MSS 5 or color composite best for identification; identifiability depends on contrast in reflectance of surroundings
SAND DUNES					Not identifiable in Wisconsin due to minute size
SHRUB CARR		X			Requires coverage during a specific time (late fall) and some ground truth
STREAM	X	X		X	Only larger streams can be identified - color composite is best

TABLE 2.1.1 (cont.)

ERTS DATA INTERPRETATION SUMMARY

X - Data identifiable without difficulty

O - Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
STREAM, INTERMITTENT					Not identifiable
TERRACES					Not identifiable
UTILITIES, RAILWAY LINES					Can only be identified where large forest cuts exist

TABLE 2.1.2

RB-57 DATA INTERPRETATION SUMMARY

* Not available

X - Data identifiable without difficulty

O - Optimum time

	SUMMER	FALL	WINTER *	SPRING	Comments
AGRICULTURE	X	X		X	Agricultural fields are easily distinguished; with proper ground truth some crop differentiation is possible
BEACH RIDGE	X	X		X	Can be distinguished along Lake Michigan shore, especially at Point Beach; high altitude provides better discrimination between beach ridges and sand dunes then low altitude (4000-8000 feet)
COMMUNICATIONS, AIRFIELDS	X	X		X	Easily identified; also possible to classify according to size and image by determination of runway length and type
DRUMLINS	X	X		X	Easily identified with stereoscopic viewing
END MORAINE	X	X		X	Possible to identify by vegetational and hydrologic characteristics alone; more positive identification by topographic characteristics with stereoscopic viewing
ESKER	X	X		X	Identifiable but stereoscopic viewing necessary

TABLE 2.1.2 (cont.)

RB-57 DATA INTERPRETATION SUMMARY

X - Data identifiable without difficulty

O - Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
ESCARPMENT	X	X		X	Identifiable but stereoscopic viewing necessary
FOREST, LOWLAND	X	O		O	Identifiable on color-infrared film when ground truth is available; stereoscopic viewing helps by providing relative elevation of forest; distinct tonal characteristics exist for this type of vegetation
FOREST, UPLAND	X	O		O	Identifiable on color-infrared film when ground truth is available; stereoscopic viewing helps by providing relative elevation of forest; distinct tonal characteristics exist for this type of vegetation
FOREST, CONIFEROUS	X	O		O	Identifiable on color-infrared film when ground truth is available; optimum time for distinction is during periods of emergence and senescence of deciduous vegetation
FOREST, DECIDUOUS	X	O		O	Identifiable on color-infrared film when ground truth is available; deciduous vegetation has a characteristically higher infrared reflectance than coniferous
FOREST, DECIDUOUS/CONIFEROUS	X	X		X	Easily identifiable during any season

TABLE 2.1.2 (cont.)

RB-57 DATA INTERPRETATION SUMMARY

X - Data identifiable without difficulty

O- Optimum Time

	SUMMER	FALL	WINTER	SPRING	Comments
GLACIAL LAKE BED		X		X	Can be identified in some areas but requires bare soil conditions to detect the characteristic soil texture pattern; this altitude is generally too extreme for identification of this feature
INTERCHANGES	X	X		X	Easily identified monoscopically
GROUND MORAINE		X		X	Can be identified in some areas but requires bare soil conditions to detect the characteristic soil texture pattern; stereoscopic viewing increases the accuracy of interpretation
LAKES	X	X		X	Easily identified; bottom effects, turbidity and suspended solids affect the photo tone
LAKE MICHIGAN	X	X		X	Easily identified; effects of shore currents can be seen in turbid conditions
LAKES, LESS THAN 50 ACRES	X	X		X	Easily identified

TABLE 2.1.2 (cont.)

RB-57 DATA INTERPRETATION SUMMARY

X -Data identifiable without difficulty

O -Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
LIMITED ACCESS HIGHWAY	X	X		X	Easily identified
MARSH	X	O		O	Can be identified on color-infrared film; vegetation associations can be distinguished best during periods of emergence and senescence
OPEN SWAMP	X	X		X	Easily distinguished from other wetland components on color-infrared film
RESIDENTIAL, RURAL	X	X		X	Identifiable monoscopically
RESIDENTIAL, SUBURBAN	X	X		X	Identifiable but transition from suburban to urban is hard to define precisely
RESIDENTIAL, URBAN	X	X		X	Identifiable but transition from suburban to urban is hard to define precisely

TABLE 2.1.2 (cont.)

RB-57 DATA INTERPRETATION SUMMARY

X - Data identifiable without difficulty

O - Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
RIVERS	X	X		X	Easily identifiable on either color or color-infrared film
RIVER OR LAKE ZONING	X	X		X	Easily identifiable
ROADS	X	X		X	Primary and secondary roads are easily identified; some lesser roadways can be distinguished depending on the surface type
SAND DUNES					Lower altitude required for magnitude of dunes encountered in Wisconsin
SHRUB CARR	X	O		O	Identified best on color-infrared imagery
REAM	X	X		X	Streams as small as a few feet in width are readily identified; identification of smaller streams is aided by stereoscopic viewing

TABLE 2.1.2 (cont.)

RB-57 DATA INTERPRETATION SUMMARY

X - Data identifiable without difficulty

O - Optimum time

	SUMMER	FALL	WINTER	SPRING	Comments
STREAM, INTERMITTENT	X	X		X	Large intermittent streams can be identified by erosion evidence; stereoscopic viewing necessary
TERRACES	X	X		X	Easily identified with stereoscopic viewing
UTILITIES, RAILWAY LINES	X	X		X	Readily identifiable over most terrain types; confusion with roadways sometimes occurs in rural areas

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pretation performed on RB-57 imagery for the same list of 33 variables. The major differences in the two systems, (1) platform (12 miles vs. 500 miles) and (2) sensor (photographic vs. scanner), are evident in the much greater utility of the RB-57 imagery for interpretation of resource data. However, research by other investigators has indicated a cost ratio of ERTS to other data sources at 1:9 to 1:20 (Poulton, 1973); the cost of ERTS to RB-57 and conventional image acquisition as determined by this study (U/W) has substantiated this ratio.

2.1.2.2 Data Bank Comparisons by CROSTAB Routine

Prior to receiving the initial ERTS data, a study was undertaken to compare data interpreted from high altitude RB-57 imagery with the REMAP I data which was derived from conventional sources. The purpose of this endeavor was to establish the value of a high altitude aircraft platform in deriving resource data of the type needed for regional land use planning. A secondary objective was to establish the validity of the REMAP data as ground truth.

Comparison of RB-57 high flights with data derived from conventional data sources shows that RB-57 data correlates closely with conventional sources for the certain types of data categories. The University of Wisconsin computing center has statistical analysis packages available which enable rapid statistical computations to be performed. The principle analysis done was the cross-tabulation of data obtained from interpretation of the RB-57 color infrared photographs and data from the REMAP I data bank. The CROSTAB program compares two equivalent matrices element by element to determine the degree of correlation between the values of the elements. The correlation value is determined as the percentage of elements in one matrix which agree, within a given range of values, with the elements of the second matrix. Thus, if two matrices with 10 rows and 10 columns (100 elements) are compared element by element and found to agree for 75 elements then they are said to have a correlation of 75 percent (75/100). It should be noted that this simply establishes the correlation and does not indicate which source contains the greatest error.

The CROSTAB program calculates this correlation value for two matrices and also provides further information about their similarities or differences. Figure 2.1.1 is a sample output from a CROSTAB analysis of two data banks each composed of 300 one square kilometer cells. The variables in Table 2.1.3 are referred to by number in the CROSTAB printouts. In the sample shown in Figure 2.1.1, the value assigned to each cell was the percent of cell covered by the variable lowland forest, ranging from 0 to 100. The diagonal line in the figure indicates the correlation between the two data sources for each of ten ranges of interpreted value of lowland forest. The results indicate that in a comparison of corresponding cells of the data matrices the computer found that:

> 62.0% of the cells agreed that there was 0 to 10% lowland forest
>
> 1.0% of the cells agreed that there was 10 to 20% lowland forest
>
> 0.7% of the cells agreed that there was 20 to 30% lowland forest
>
> 0.3% of the cells agreed that there was 60 to 70% lowland forest

therefore 64.0% is the "correlation value" for lowland forest.

The remaining numbers in the CROSTAB output are significant because they give an indication of the distribution of the remaining data which did not correlate particularly well. In the ideal case that both matrices

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TABULATION NUMBER 1

PERCENT OF TOTAL TABLE

RB-57

LOWER BOUNDS OF INTERVALS OF VARIABLE 2	LOWER BOUNDS OF INTERVALS OF VARIABLE 1										
	0	10	20	30	40	50	60	70	80	90	TOTALS
0	62.0	8.3	2.7	1.7	1.3	.3	1.7	1.0	1.3	1.7	82.0
10	5.0	1.0	.3	.0	.7	.3	.0	.0	.0	.3	7.7
20	3.0	.0	.7	.0	.0	.0	.3	.3	.0	.0	4.3
30	1.3	.0	.3	.0	.0	.0	.0	.0	.0	.0	1.7
I-57 40	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.3
50	.3	.3	.0	.0	.0	.0	.0	.0	.0	.0	.7
60	.3	.0	.0	.0	.0	.0	.3	.3	.0	.3	1.3
70	.3	.0	.0	.0	.0	.0	.0	.0	.0	.0	.3
80	1.0	.3	.0	.0	.3	.0	.0	.0	.0	.0	1.7
90	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0	.0
TOTALS	73.7	10.0	4.0	1.7	2.3	.7	2.3	1.7	1.3	2.3	100.0

END OF ANALYSIS

Sheb-25

Figure 2.D.1 - SAMPLE CROSTAB OUTPUT

TABLE 2.1.3. CROSTAB RESULTS

	VARIABLE NUMBER	VARIABLE	CROSTAB VALUE
I	16	Intermittent Streams	99.5
	17	Streams	97.2
	20	Lakes (less than 50 acres)	99.3
	21	Lakes	94.4
	22	Lake Michigan	95.4
	98	Limited Access Highway	100.0
	99	Interchanges	100.0
	115	Railway Lines	96.4
	160	Roads	100.0
	161	Rural Residential	95.9
II	24	Upland Forest	53.5
	25	Lowland Forest	77.2
	26	Open Swamp	77.0
	57	Residential Suburban Areas	84.9
	58	Residential Urban Areas	77.2
	65	River and Lake Zoning	77.2
	147	Rivers	87.2

agreed on every cell value, all numbers on the output would lie on the diagonal line and would total 100%. Since this is seldom the case, it is necessary to understand the meaning of the other numbers which occur on the printed output. In Figure 2.1.1 the number "1.7" has been circled in the first row. This value is interpreted to mean that for 1.7% of the total cells in the matrix (300 cells) the RB-57 derived data indicated that there was between 30 and 40% lowland forest while the I-57 indicated a value between 0 and 10%. The rest of the numbers in the table are interpreted in a similar manner. Thus, a good correlation between two matrices would be indicated by a clustering of all the values in the output table around the diagonal line of perfect correlation.

As a test of correlation between RB-57 derived data and the data gathered by conventional methods for the I-57 study, two sample areas were chosen within the Green Bay-Milwaukee REMAP data bank. These areas are shown in Figures 1.3.2 and 1.3.3 (section 1.0). A CROSTAB analysis was then performed for a group of variables to determine the reliability of RB-57 data compared with conventional sources. Table 2.1.3 "CROSTAB Results", shows the "average correlation values" which were arrived at through the cross tabulation process for each of the two sample areas. The complete listing of the CROSTAB output is available in the Type II NASA Report (GSFC ID UN 040), 15 December, 1972.

The variables with a CROSTAB value above 90% have been placed in one group (I) and those with a value below 90% in another (II) with the arbitrary assumption that this represents a significant confidence level for comparing the two data sources. The investigators feel that RB-57 imagery (1:120,000 scale) can replace conventional data sources for the variables in group I with enough accuracy for many planning purposes. This type photography would be especially useful for "corridor" determinations similar to those required for highway alignments by the Wisconsin Department of Transportation and transmission corridors by the Public Service Commission.

The variables in group II displayed enough disagreement between data sources to warrant investigation into the accuracy of each source. After considerable ground surveillance, it has been concluded that RB-57 data represent a more accurate source for vegetation and developed land use categories and constitute a better reflection of actual ground conditions than conventional data sources. Particular study was devoted to the distinction between upland and lowland forest categories and in all cases the RB-57 data proved to be more accurate.

There are many possible reasons for the variances. Since the I-57 data bank was constructed in part from 1967 photography, some of the land use variances are due to additional development since 1967. Other reasons are the weaknesses of conventional data which in many cases are incorrect and archaic, but unfortunately represent the best available information.

2.1.2.3 Data Bank Comparisons by Spatial Location

Correlation of ERTS data with existing spatial data banks was a primary facet of this research program since the major purpose for utilizing remote sensing methods is the improvement of the planning process. The same two 300 square kilometer areas used in the CROSTAB analysis program were chosen for this spatial comparison. The sample areas are identified as the "Sheboygan Test Site" and the "Green Bay Test Site", in reference to geographical locations in Wisconsin. Computer methodologies were developed and software written to compare spatial interpretations from

1) ERTS imagery,
2) RB-57 imagery,
3) conventional data sources (REMAP).

This type of spatial comparison offers a distinct advantage over the CROSTAB comparison since the spatial comparison not only detects discrepancies but also pinpoints their locations.

The following is a list of the variables studied in this process and a comprehensive definition of each.

Agriculture - The percentage of the area of the cell occupied by land which is used directly or indirectly for the growth of food products, including crop, animal or poultry farming. Lands within the agricultural area which are apparently idle are included in this category.

Escarpment - The percentage of the area of the cell occupied by a steep slope caused by the displacement of the earth's surface in a predominantly vertical direction.

Forest - The percentage of the area of the cell occupied by upland forest plus lowland forest.

Forest, Lowland - The percentage of the area of the cell occupied by swamp hardwoods, white cedar, tamarack, black spruce, balsam and lowland birch.

Forest, Upland - The percentage of the area of the cell occupied by upland hardwoods; white, norway and jack pines; popple; white birch; oak, hickory and pin oak.

Lake - The percent of the area of the cell occupied by any lake in excess of 50 acres which is not one of the Great Lakes.

Lake less than 50 acres - The percent of the area of the cell occupied by any pond or lake covering less than 50 acres of surface water as a basic management guideline for the restriction in use of power boats.

Lake Michigan - The percentage of the area of the cell occupied by Lake Michigan.

Open swamp - The percentage of the area of the cell occupied by tagalder, willows, dogwoods; cattail marshes, grass or sedge meadows; leather leaf and cranberry bogs; or weedy peat. Also called "Open Wetlands".

Residential, Suburban - The percentage of the area of the cell occupied by residential units usually on the periphery of population centers as indicated by the lower densities, single-family units, curvilinear street patterns, a dotting of open spaces, and a separation from commercial or industrial land uses. Suburban residential units may also be classified as such if separated from the population center but located adjacent to highways, granting rapid access to the urban center.

Residential, Urban - The percentage of the area of the cell occupied by higher-density housing, including multi-family units located within the population centers and generally with an intermingling of commercial and industrial land uses. Street patterns tend to be geometric.

River - The percent of the area of the cell occupied by a Major River or a Minor River.

River, Major - The percent of the area of the cell occupied by a primary artery of a major river sub-basin. Major river sub-basins have been derived from hydrologic studies done by the U.S. Department of Agriculture in conjunction with the U.S.G.S..

River, Minor - The percent of the area of the cell occupied by a secondary artery of a river sub-basin drainage area as designated by hydrological analysis.

Road - The number of roadways existing within a cell including paved and unpaved town roads, county roads, state highways, federal highways, limited access highways. and interchanges.

The ERTS information was interpreted from a 1:1,000,000 scale positive transparency of Band 5, 14 September 1972 ERTS image while RB-57 interpretations were made from 1:120,000 scale color infrared positive transparencies (29 September 1971). A Bausch and Lomb Zoom 240 stereoscope and Richards MIM series light table were used for ERTS and RB-57 interpretations.

The information for the REMAP data bank was obtained from many sources, principal among which were: (1) USGS topographic maps (1:62,500) from 1954-55; (2) "Wisconsin Land Inventory" maps (1:15,840) which were prepared in the 1930's; and (3) small-scale panchromatic aerial photography flown in 1966 (mono-coverage).

The original intent was that the 10,000 square kilometer REMAP data bank would serve as "ground truth" against which the results of RB-57 and ERTS interpretations would be compared. Results indicate that the interpretations from RB-57 color infrared photography are a better representation of "ground truth" than the REMAP data bank for most of the resources under consideration in ERTS-1 study. Since the REMAP data bank was assembled from a variety of conventional sources, including maps, photographs, reports and statistical information of varying vintages (from about 1910 to 1970), at varying scales, and using various formats and presentation methods, these sources represent conditions as they existed at varying points in time and are not entirely accurate today. The cumulative effects of such source problems required correction by a laborious homogenizing process of updating, restructuring, varifying and scaling information into a common format. This process was eventually successful, but the scope of the data stored in the REMAP data bank were still largely predetermined by the type, scope and accuracy of the information in the source documents. The information utilized does represent the best information available for regional scale decision making. The RB-57 and/or ERTS imagery, on the other hand, provides data at a uniform scale at a recent point in time. For those natural and cultural resource parameters that can be interpreted from these sources, the use of RB-57 and ERTS images as data sources appears feasible and desirable.

The results of the comparisons of these variables for these two test sites are contained in Appendix C and are summarized in Table 2.3.1 which presents the areal estimates interpreted for each of the three data sources. Four of these comparisons appear in Figures 2.1.2 - 2.1.5. These four land cover/activity parameters (Agricultural Land Use, Forest Land Cover, Open Water and Wetlands, and Residential Land Use) account for nearly 90 percent of the land in this test site and are the variables which change most significantly with time.

Agricultural land use: Figure 2.1.2 shows spatial/ statistical comparisons for the amount of land in the Sheboygan Test Site devoted to agricultural land use (land used directly or indirectly for the growth of food products, including crop, animal and poultry farming; includes both cropland and grazing land). There is close agreement among all three data sources and ERTS imagery appears to be very useful for the determination of lands devoted to agricultural use. Because of the continuing change in use of agricultural type lands, there is a need to monitor and assess agricultural use.

Forest land cover: Figure 2.1.3 shows spatial/ statistical comparisons for the land covered with forests (those land areas with at least 50 percent tree canopy cover). Upland Forest and Lowland Forest were treated as separate variables in the original REMAP-1 and RB-57 data extractions, but are combined into the one category "Forest" in the case of ERTS. There is reasonable agreement among all three data sources, but it should be emphasized that the ERTS interpretation contains less discrete information than RB-57 and REMAP-1. It is

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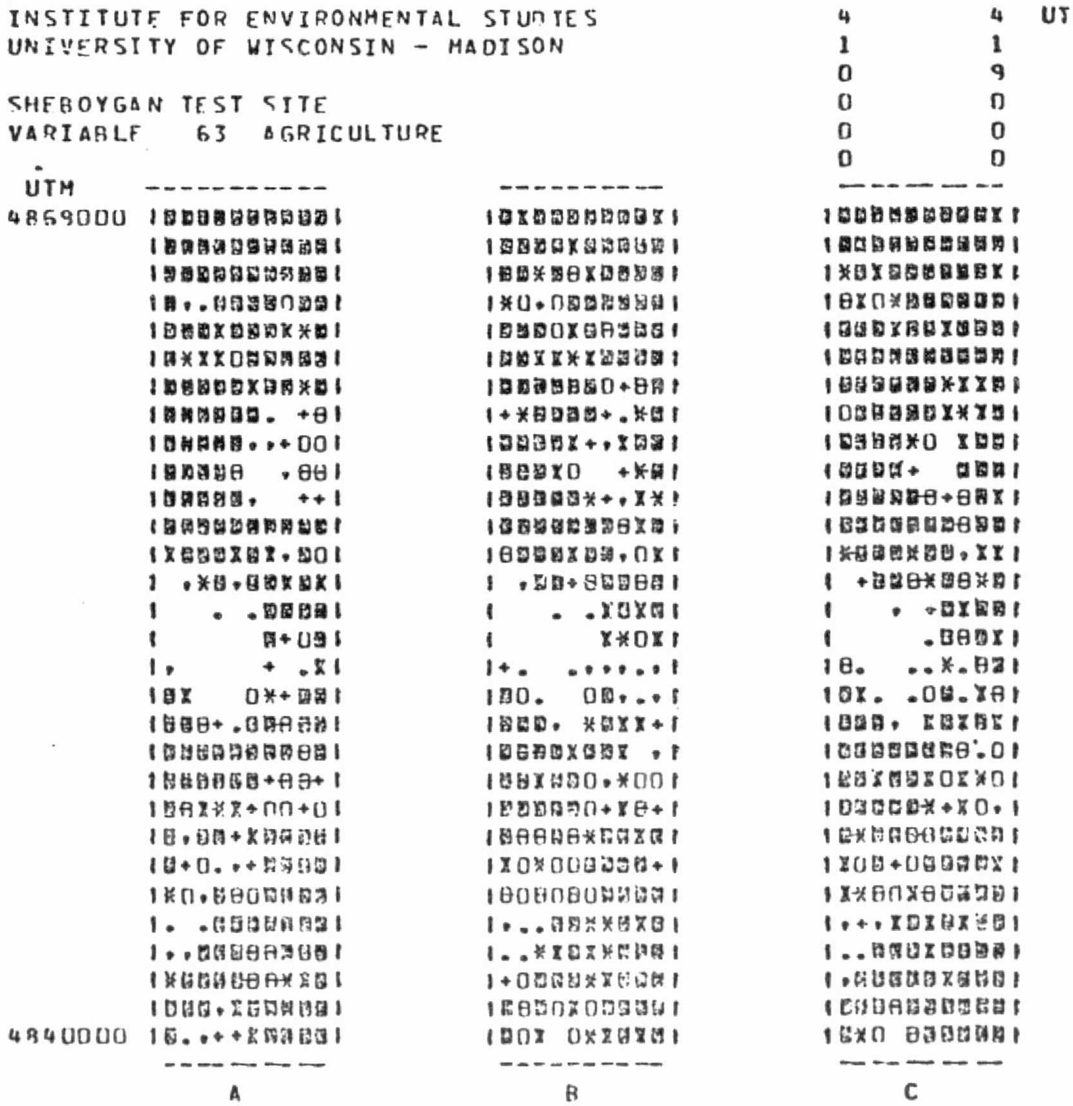
SHEBOYGAN TEST SITE
VARIABLE 63 AGRICULTURE



TOT. SQ.KM	183.630			181.600				198.110		
LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	,,,,,	+++++	00000	88888	XXXXX	XXXXX	88888	88888	88888
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR A	10	16	17	13	15	9	18	39	49	88
OCCUR B	12	15	13	24	15	19	35	33	51	63
OCCUR C	11	7	7	12	17	15	34	42	66	71
SQ.KM A	.47	1.97	3.70	4.05	6.12	4.70	11.35	28.60	40.33	82.34
SQ.KM B	.68	2.20	3.12	8.34	6.43	10.44	22.55	24.81	43.46	59.57
SQ.KM C	.63	1.08	1.65	3.99	7.50	8.24	21.74	31.28	55.97	66.03

ERTS BAND 5   14.SEPTEMBER.1972   1053-16093-5

FIGURE 2.1.2. AGRICULTURAL LAND USE

ERTS and RB-57 INTERPRETATIONS vs
REMAP-I DATA BANK

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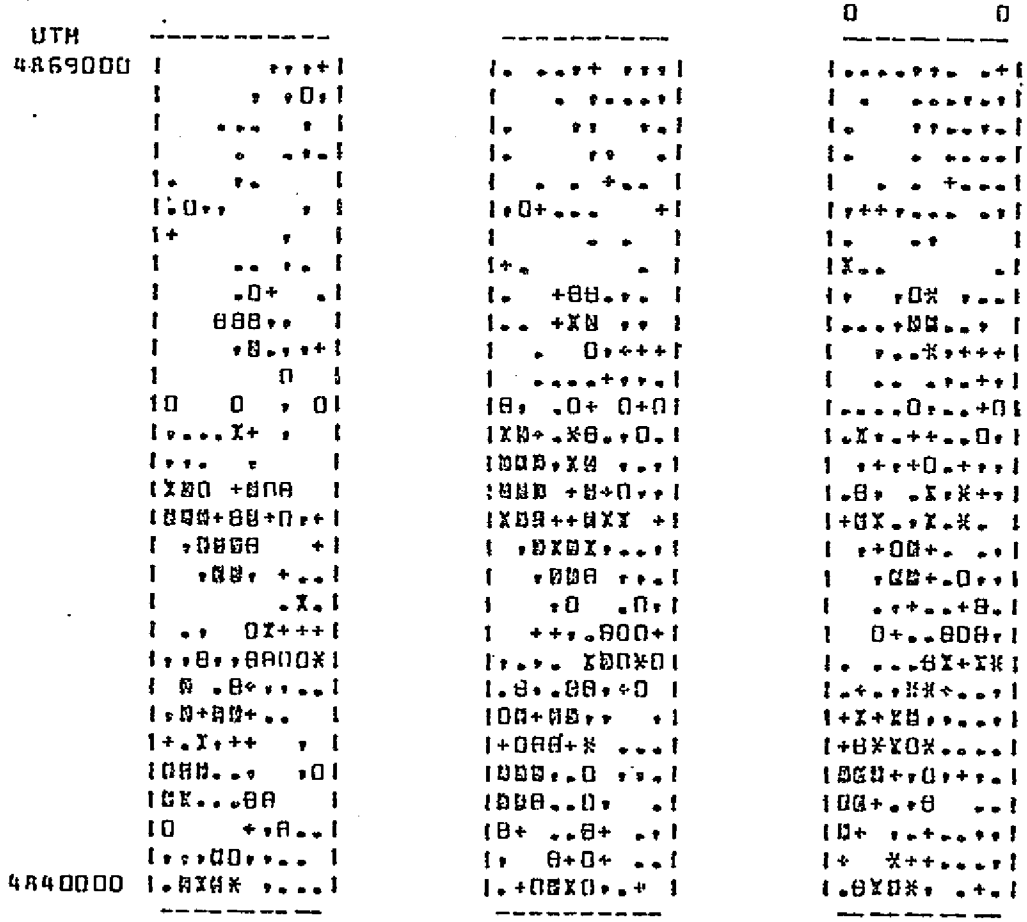
SHEBOYGAN TEST SITE
VARIABLE 24+25 FOREST

UTM 410000 — 419000



UTM 4869000 — 4840000

	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	48.830	59.470	51.990

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	ØØØØØ	XXXXX	ØØØØØ	ØØØØØ	ØØØØØ	ØØØØØ
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	43	48	21	16	13	2	7	7	9	7
	B	62	48	32	21	15	3	10	9	8	10
	C	100	52	37	11	8	11	11	3	9	2
SQ.KM	A	2.36	6.38	4.73	5.30	5.42	1.10	4.48	5.13	7.43	6.50
	B	2.84	5.96	7.39	6.79	6.35	1.58	6.27	6.40	6.55	9.34
	C	4.33	7.10	8.92	3.62	3.39	5.85	7.09	2.16	7.62	1.91

ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

FIGURE 2.1.3 FORTEST LAND COVER

ERTS and RB-57 INTERPRETATIONS
vs REMAP-I DATA BANK

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possible that the ERTS-derived data could be refined by (1) coverage over an entire season, and (2) more sophisticated methods of data extraction.

Open water and wetlands: Figure 2.1.4 shows the spatial/statistical comparisons for land covered with open water and wetlands. Four resource variables, "rivers", "lakes", "lakes smaller than 50 acres", and "open wetlands" were individually analyzed for ERTS, RB-57 and REMAP. They have been combined here to represent that component of the land covered by open water (rivers and lakes) and wetlands (principally areas occupied by such biotic communities as those dominated by grasses, sedges, emergent aquatics, dogwoods, shrub-willows, and alders; such communities are variously called wet meadows, marshes, bogs or swamps). Due to the REMAP data source problems described earlier, the REMAP data bank does not adequately represent the area presently occupied by wetlands in the REMAP area. There is reasonable agreement between ERTS and RB-57 in identifying the major open water and wetland areas in the test site. However, in many cases where only a small percent of each cell is occupied by open water and/or wetland, detection was not made using the ERTS imagery and simple interpretation techniques as shown by the number of occurences. There is not a good agreement between the REMAP areas and the RB-57 and ERTS areas for open water and wetlands. In order to investigate the possible reasons for this discrepancy, a field check was undertaken. It showed that many areas classified as "open wetlands" in the REMAP data bank are now covered by "lowland forest" tree species. Such areas are, therefore, shown as "forest" on the ERTS and RB-57 printouts and as "open wetlands" on the REMAP printout. When printouts for "lowland forest" and "open wetlands" were compared for RB-57 and REMAP, they indicated that the total areas of "lowland forest" plus "open wetlands"

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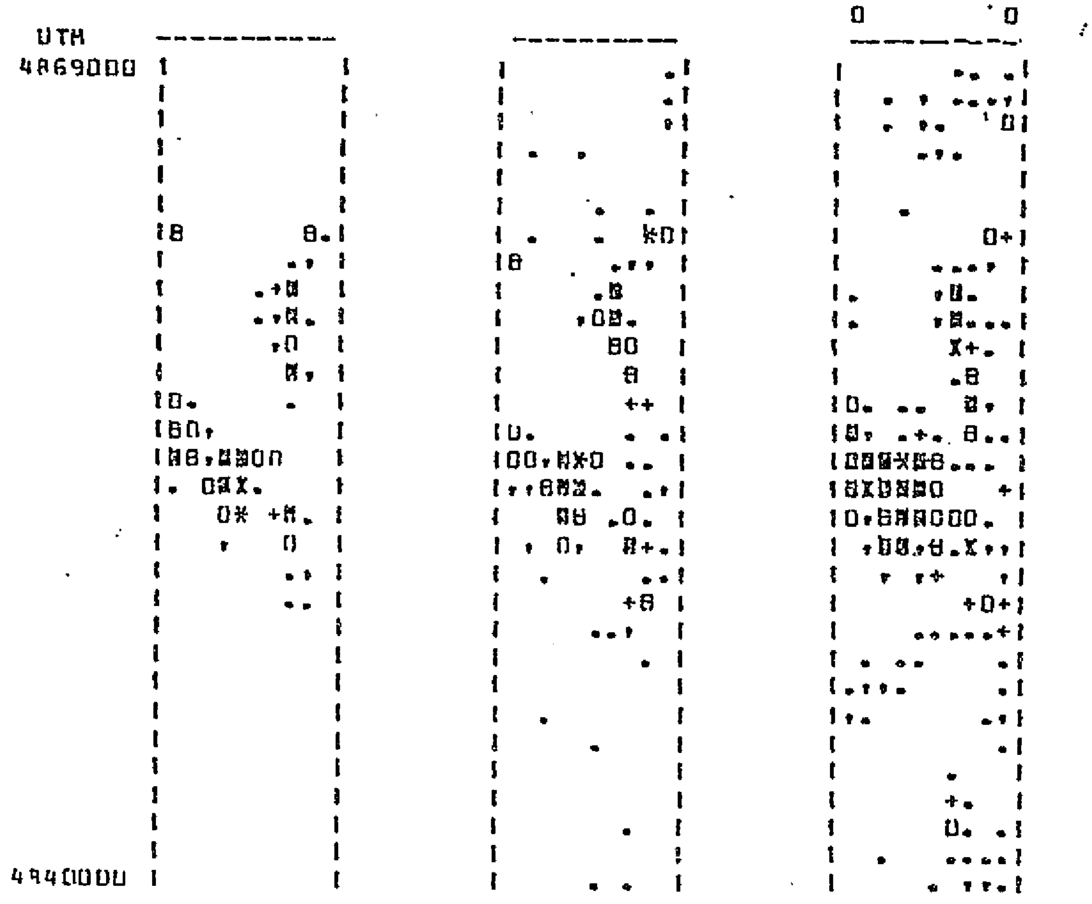
SHEBOYGAN TEST SITE
VARIABLE 20+21+26+147 OPEN WATER AND WETLANDS

UTM 410000 — 419000



		A	B	C
		ERTS	RB57	REMAP I
TOT. SQ.KM		14.070	16.740	29.460

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	OOOOO	BBBBB	*****	XXXXX	ØØØØØ	ØØØØØ	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	13	6	2	8	4	1	1	4	3	1
	B	32	11	4	9	6	2	0	2	1	4
	C	61	23	9	10	5	1	3	6	2	8
SQ.KM	A	.80	.97	.41	2.69	1.78	.52	.68	2.90	2.42	.90
	B	1.05	1.39	.95	3.09	2.57	1.05	.00	1.40	.80	4.44
	C	2.23	3.00	1.95	3.58	2.21	.53	1.95	4.56	1.71	7.84

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

FIGURE 2.1.4 OPEN WATER AND WETLANDS

ERTS and RB-57 INTERPRETATIONS

vs REMAP-I DATA BANK

are quite close for these two data sources.

WETLANDS VERIFICATION

Variable	Total Km^2 as derived from		
	ERTS	RB-57	REMAP
Open Wetlands	10.8	9.2	20.8
Lowland Forest		31.9	18.9
TOTAL		41.1	39.7

This example clearly illustrates that (1) land cover changes with time and 40-year-old data are generally outdated; (2) field checks are an essential part of remote sensing data extraction studies; and (3) resource definitions must be carefully drawn.

Residential land use: Although there are no true urban areas in the Sheboygan Test Site, there are several nodes of urban and rural residential land use, as shown in Figure 2.1.5. The settlements of New Holstein (popl. 3000), Kiel (popl. 2800), and Elkhart Lake (popl. 800) occur within the test site and each can be identified on the ERTS image. There appears to be the tendency to underestimate the area of residential land use when interpreting from ERTS images of predominantly rural areas. This is due to the inability to detect the presence of characteristics which occupy only a small portion of the one-kilometer cells, as previously described in the case of open water and wetlands.

In order to make the interpretations shown in the preceeding examples, only black-and-white transparencies of individual ERTS bands were employed for the ERTS interpretations. Multiple bands or multiple dates were not employed. An additive color viewer (International Imaging Systems Model 6040PT) has been acquired to provide for more discrete and comprehensive ERTS data extraction.

Assuming that the RB-57 derived data represent "ground truth", certain conclusions can be made about

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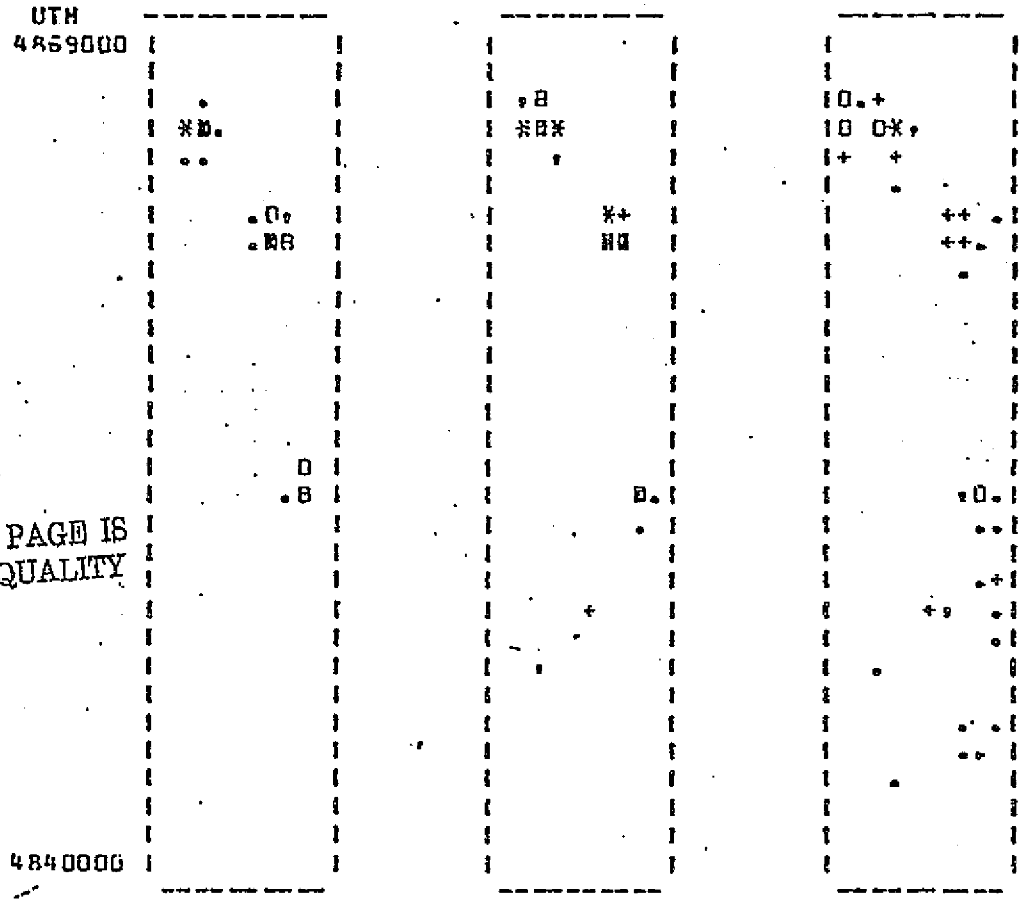
INSTITUTE FOR ENVIRONMENTAL STUDIES                 4          4  UTM
UNIVERSITY OF WISCONSIN - MADISON                   1          1
                                                    0          9
SHEBOYGAN TEST SITE                                 0          0
VARIABLE  57 + 146 RESIDENTIAL, URBAN+SUBURBAN      0          0
                                                    0          0
```



	A		B		C
	ERTS		RB57		REMAP I
TOT. ACRES	1160.90		1842.62		1714.18

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	,,,,,	+++++	00000	88888	*****	XXXXX	00000	00000	00000
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99

		1	2	3	4	5	6	7	8	9	10
OCCUR	A	7	1	0	2	2	1	0	0	2	0
	B	2	3	2	0	1	3	0	0	1	3
	C	17	3	9	4	0	1	0	0	0	0
ACRES	A	86.	49.	0.	196.	247.	148.	0.	0.	432.	0.
	B	44.	138.	148.	0.	114.	442.	0.	0.	222.	734.
	C	388.	143.	647.	395.	0.	141.	0.	0.	0.	0.

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FIGURE 2.1.5- RESIDENTIAL LAND USE

ERTS and RB-57 INTERPRETATIONS vs RELAP I DATA BANK

ERTS-1 as an information source from this preliminary study.

In general, the ERTS-1 interpretation resulted in a higher total area than the other sources. This (1) suggests that interpreters must recognize the resolution capabilities of ERTS and develop skill in estimating percentage occurrence of given variables and (2) indicates the need for the use of machine assistance for extraction.

In general, there exists a closer correlation between the RB-57 derived data and the stored conventional data of REMAP 1 than with ERTS-1 derived data. It is important to recognize that in comparing ERTS results with existing conventional data sources the best utility of ERTS may not be realized. The fact that these types of data (agriculture, roads, cities, etc.) have been mapped previously may suggest that the best utility of ERTS-1 data is in determining measurements of data not traditionally mapped or those data which can be more economically mapped. It is these variables, either insufficiently mapped or totally unmapped, which are not available when needed in the present regional planning and decision-making process.

It must also be realized that the interpretability of a certain variable may vary with geographic location. The results for the interpretation of agricultural land use for the two test site locations demonstrate this point. In the Sheboygan Test Site there was close agreement among all three data sources as to the amount of land used for agricultural purposes as shown in Figure 2.1.2. However, Table 2.1.4 shows that ERTS interpretations for agricultural land use were much lower than the values from the RB-57 and conventional sources. The most satisfactory explanation for this variation lies in the differing compositions of the two areas. The Sheboygan Test Site is almost entirely made up of either

TABLE 2.1.4. SUMMARY OF INTERPRETATION RESULTS

Areal Interpretation Comparison

	Area, Sq. Km.		
Green Bay Test Site:	ERTS	RB-57	REMAP
agriculture	98.75	161.37	159.47
escarpment	10.00	9.00	9.00
forest	31.56	25.69	35.80
Lake Michigan	13.59	9.50	8.52
lakes	0.00	1.78	0.00
lakes less than 50 acres	0.00	0.46	0.42
open swamp (open wetlands)	0.00	3.38	13.90
residential - urban	61.78	48.50	37.19
rivers	10.25	8.69	11.01
Sheboygan Test Site:			
agriculture	183.63	181.60	198.11
forest	48.83	59.47	51.99
lakes	2.11	4.33	4.47
lakes, less than 50 acres	0.15	1.07	0.63
open swamp (open wetlands)	10.84	9.17	20.76
residential - urban	4.70	7.49	7.88
rivers	0.97	2.17	3.60

agricultural land or natural forested areas - two variables which tend to show high contrast on ERTS imagery. On the other hand, the Green Bay Test Site is largely composed of either agricultural or urban land - both forms of "impacted" land and often appearing similar on ERTS imagery. It is extremely important, therefore, that consideration be given to the composition of a geographical area in assessing the accuracy with which certain variables can be interpreted.

2.1.3 DATA EXTRACTION FROM ERTS COMPUTER COMPATIBLE TAPES

2.1.3.1 Conventional Data Tape Analyses

Although the extraction of information from ERTS imagery by visual techniques has the advantage of simplicity and availability, it is apparent that the original ERTS data contains a significantly greater quantity of information than can be extracted by these simple techniques. Therefore, a portion of the investigation was directed towards the application of computer technology to the 800 bpi (9 track) digital ERTS tapes. The REMAP I study area was again used as the test site. This portion of the investigation was conducted in cooperation with the UW Space Science and Engineering Center (SSEC) and was partially funded by a NSF-RANN Grant to the Institute for Environmental Studies.

800 bpi (9 track) system corrected computer tapes of the REMAP I study area of 6 August 1972 have been transformed to formats compatible with the local computer system. MSS bands 4, 5 and 7 have been reformatted for the vicinity of the Sheboygan Marsh (see map in Figure 2.1.6). The area is 270 ERTS data elements wide and 129 records long, or 15.4 km by 9.8 km.

The data elements for this scene were printed with numbers from 0 to 64 representing the brightness values of the data elements. Due to the printout of the

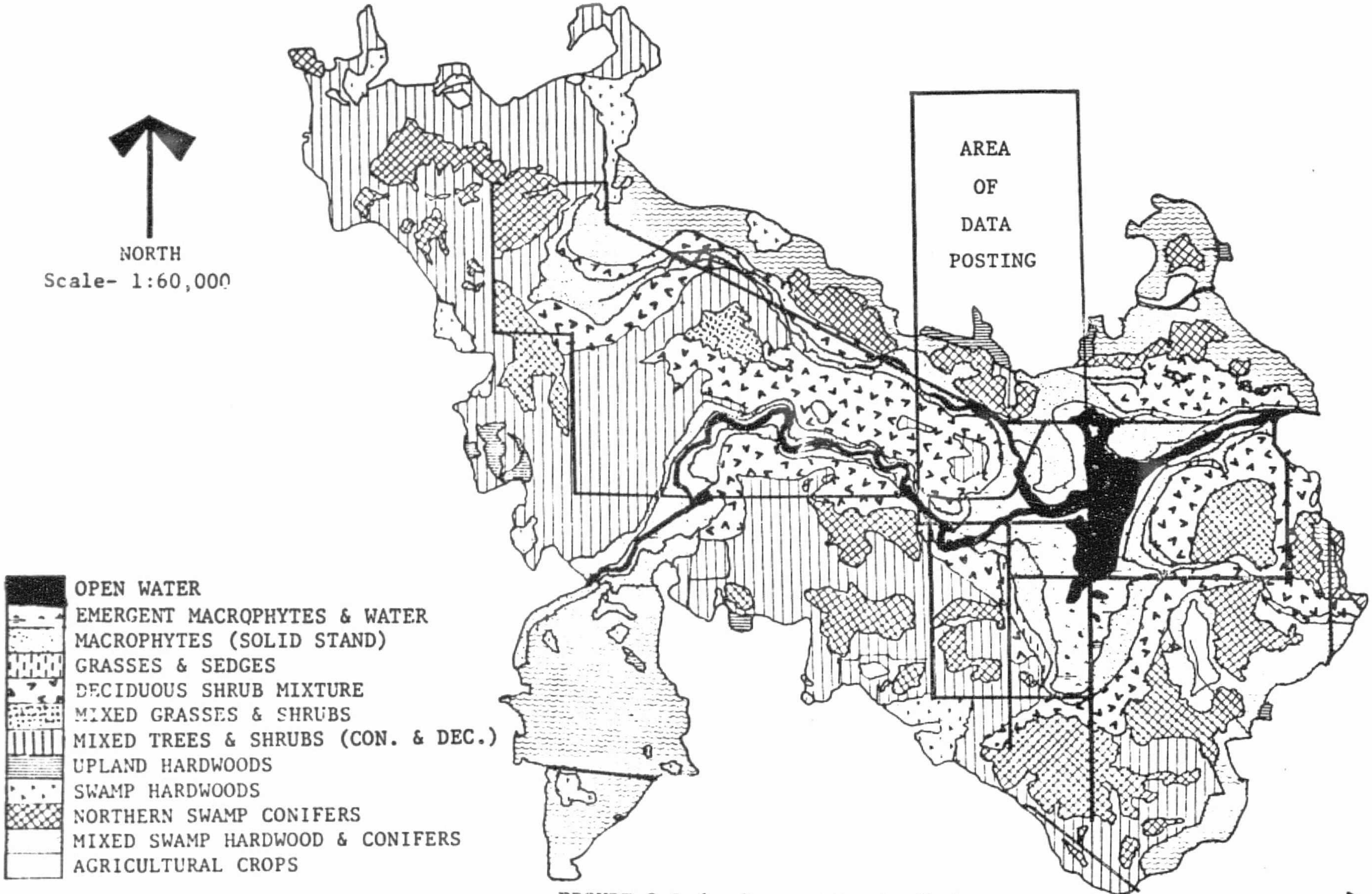

FIGURE 2.1.6 Components in Sheboygan Marsh.

brightness value for each data element, the shape of the marsh is exaggerated 6 times horizontally. This posting of the digital data for MSS bands 4, 5 and 7 for a small area (see Figure 2.1.6) of the Sheboygan Marsh is shown in Figures 2.1.7 to 2.1.9. The 6x horizontal distortion makes comparison of the posting of this small area and the map (Figure 2.1.6) difficult. This could be economically removed if a large volume of work were to be undertaken. Nevertheless, very low brightness values corresponding to open water can be perceived in all three bands. Delineations of open water, macrophytes interspersed with water, and macrophytes in solid stands can be made by consulting the map in Figure 2.1.6. These postings of the data were useful in gaining an initial understanding of the general coincidence of brightness values and known features in the marsh.

The range of data elements for the entire 15.4 km x 9.8 km scene are displayed in Figure 2.1.10. Close analysis of these histograms for each band explains the visual differences perceivable in the overall grayish tone of Band 4, the sharp cultural distinctions in Band 5, and sharp water delineation with otherwise bright tones for most other features were noted on Band 7.

The histogram for Band 4 shows the dynamic range of Band 4 data to lie at 18 to 27 on the range of 0 to 64. The range of Band 5 is 10 to 21. The lower position of the dynamic range of Band 5 explains the overall darkness of Band 5 compared to Band 4. The narrow base of the curve of Band 4 (i.e., a narrow range of brightness values) explains the narrow range of perceivable gray tones in Band 4 for this scene on 9 August 1972. The position of the curve for Band 7 is towards the brighter end of the 0-64 range. This and the upward tail of the curve at brightness values 1-3 is consistent with the overall brightness of land features and the darkness of open water as perceived in an MSS 7 image.

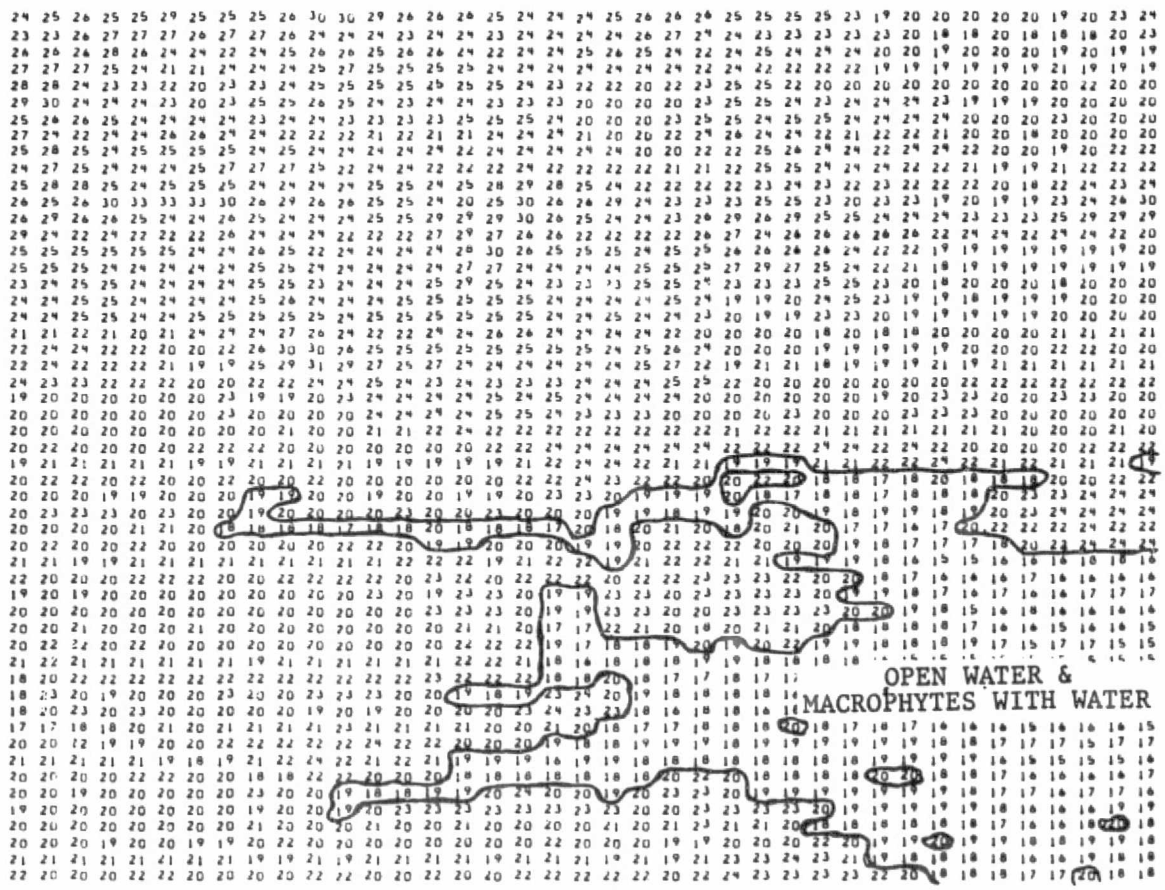

FIGURE 2.1.7 Data Posting, Sheboygan Marsh, MSS Band 4 (.5 to .6μ), 9 August 1972.

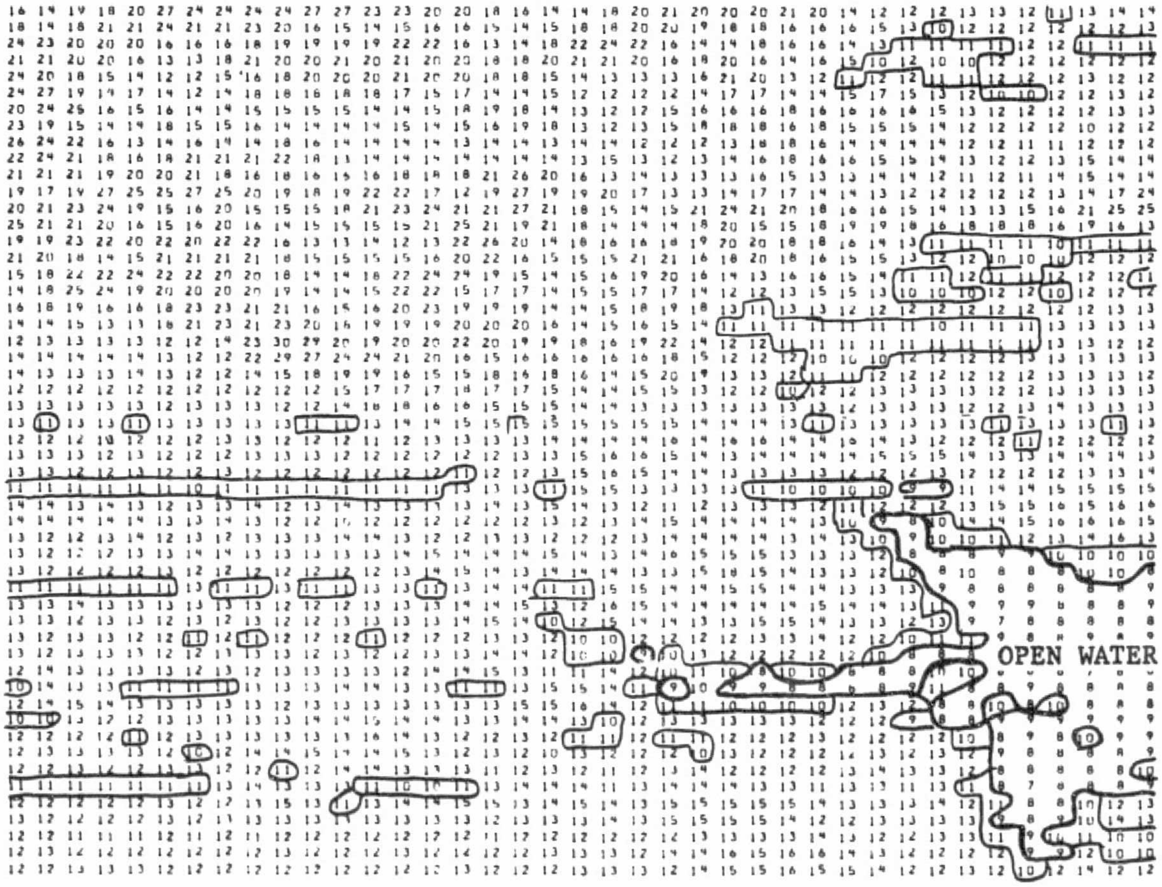

FIGURE 2.1.8 Data Posting, Sheboygan Marsh, MSS Band 5 (.6 to .7μ), 9 August 1972.

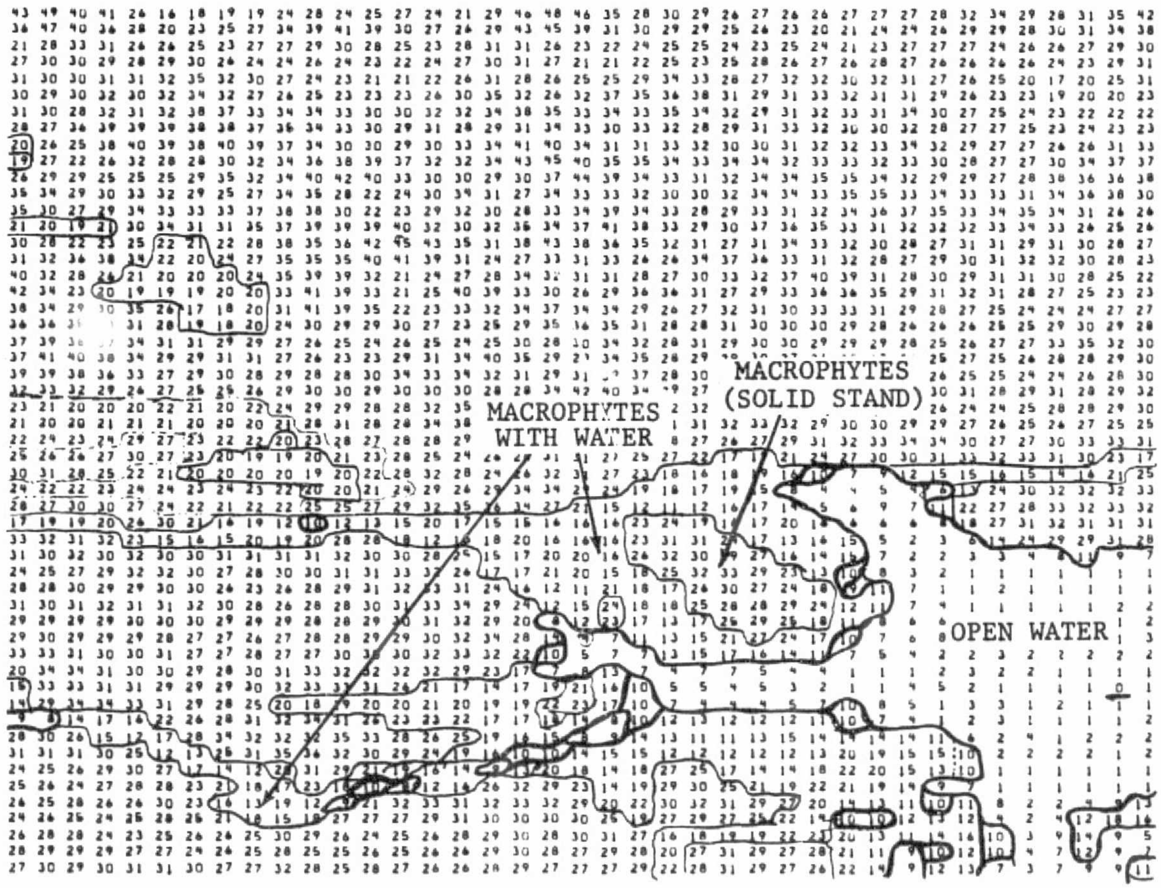

FIGURE 2.1.9 Data Posting, Sheboygan Marsh, MSS Band 7 (.8 to 1.1μ), 9 August 1972.

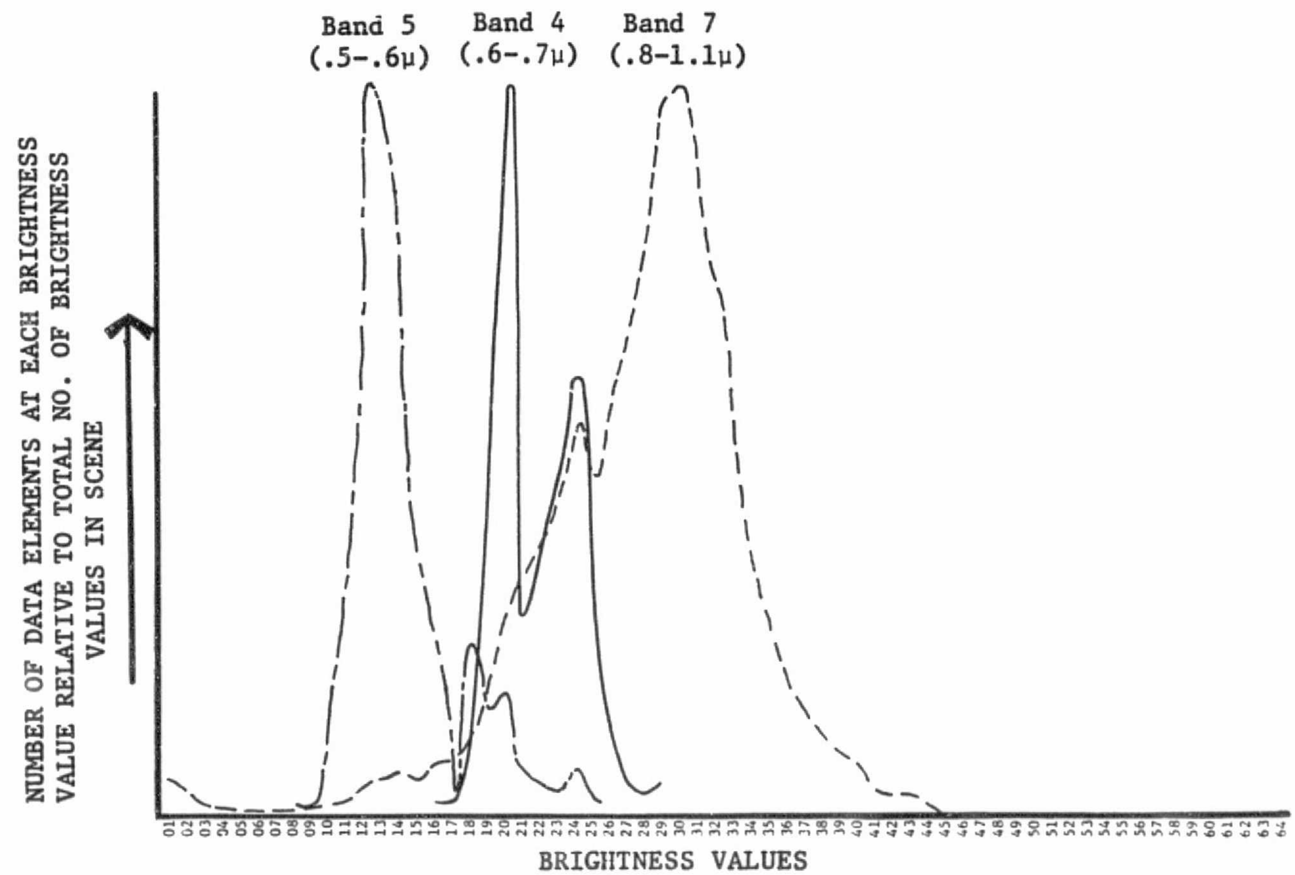

FIGURE 2.1.10 Histograms of Brightness Values for 7.69 km x 6.48 km Scene of Sheboygan Marsh, 9 August 1972.

One technique useful in displaying the digital data has been to display the various brightness levels in discrete ranges. These ranges represented by symbols of a computer overprint gray scale provide a representation of the scene made up of a 10 gray level display. Figures 2.1.11 to 2.1.13 are line printer displays of the brightness value data for Bands 4, 5 and 7 for the Sheboygan Marsh scene of 9 August 1972. The darker symbols represent darker brightness values for each band; lighter symbols represent brighter values.

For each band, the data postings and histograms discussed earlier were used to select the ranges of brightness to display as a single printout symbol. The data postings (Figures 2.1.7 to 2.1.9) showed that on Band 4 open water coincided with brightness values of 15 or less. Accordingly, the darkest symbol was assigned to the 0 to 15 range. The histograms were used to assign single printout levels to single brightness values in the steeper areas of the curve. In the flatter areas of the curves, one printout level was assigned to 3 or 4 brightness values. The brightness values assigned to each printout level are:

ERTS BRIGHTNESS VALUES

Printout Level	Band 4	Band 5	Band 7
1	0-15	0-10	0-10
2	15-18	11	11-18
3	19	12	19-23
4	20	13	24-26
5	21	14	27-28
6	22	15	29
7	23	16	30
8	24	17-18	31-32
9	25-26	19-20	33-25
10	27-29	21-25	36-45

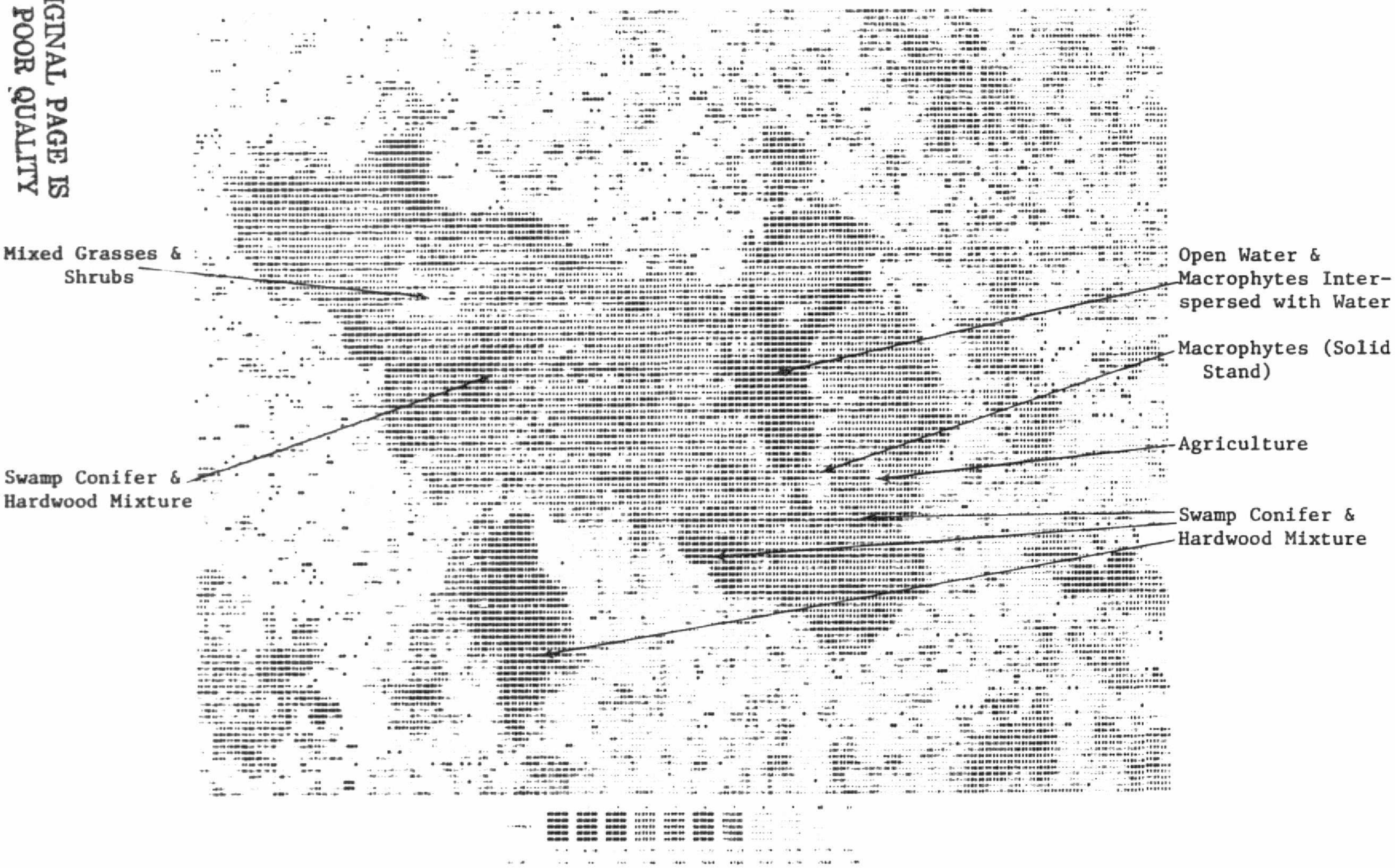

FIGURE 2.1.11 Sheboygan Marsh, MSS Band 4 (.5 to .6μ), 9 August 1972.

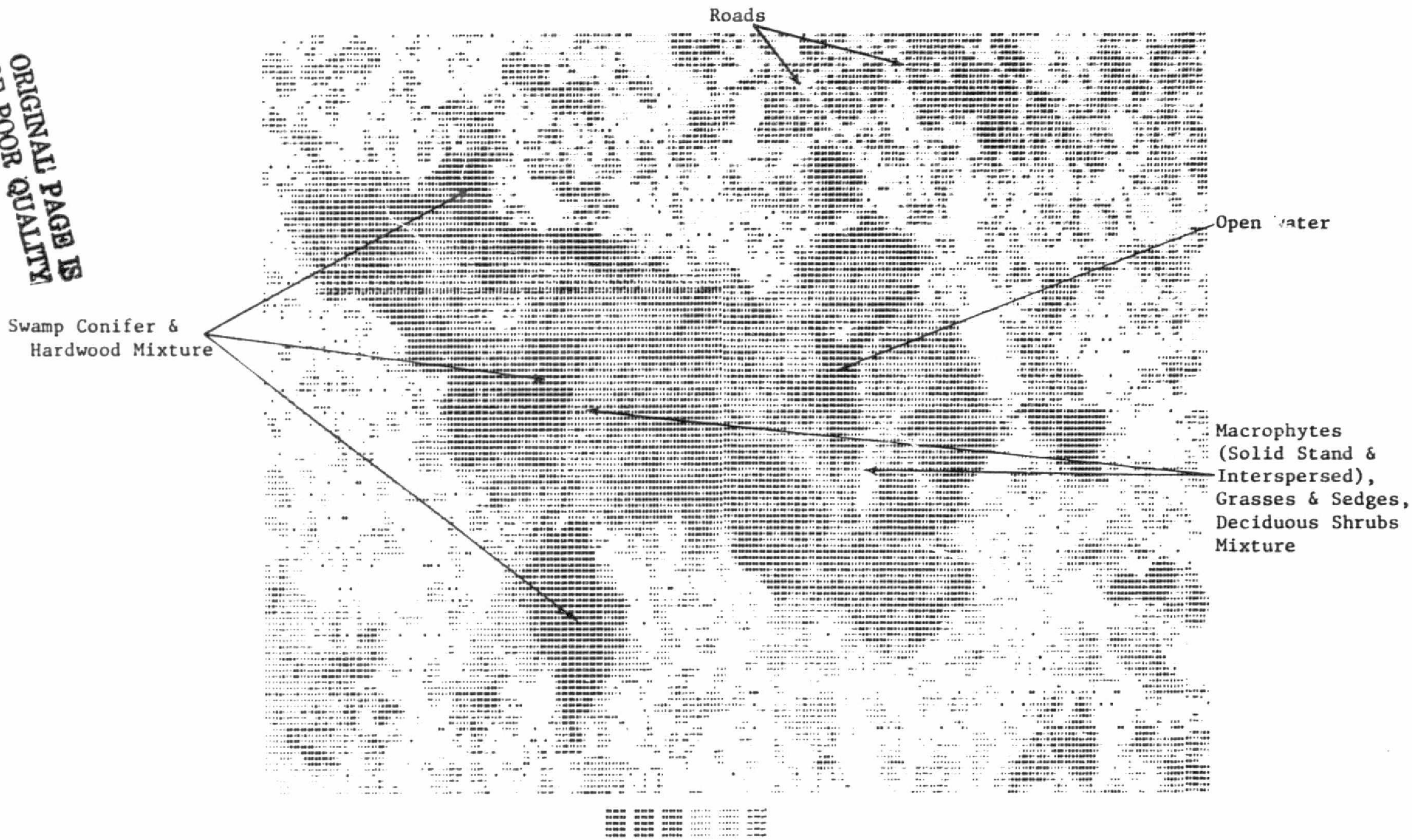

FIGURE 2.1.12 Sheboygan Marsh, MSS Band 5 (.6 to .7μ), 9 August 1972.

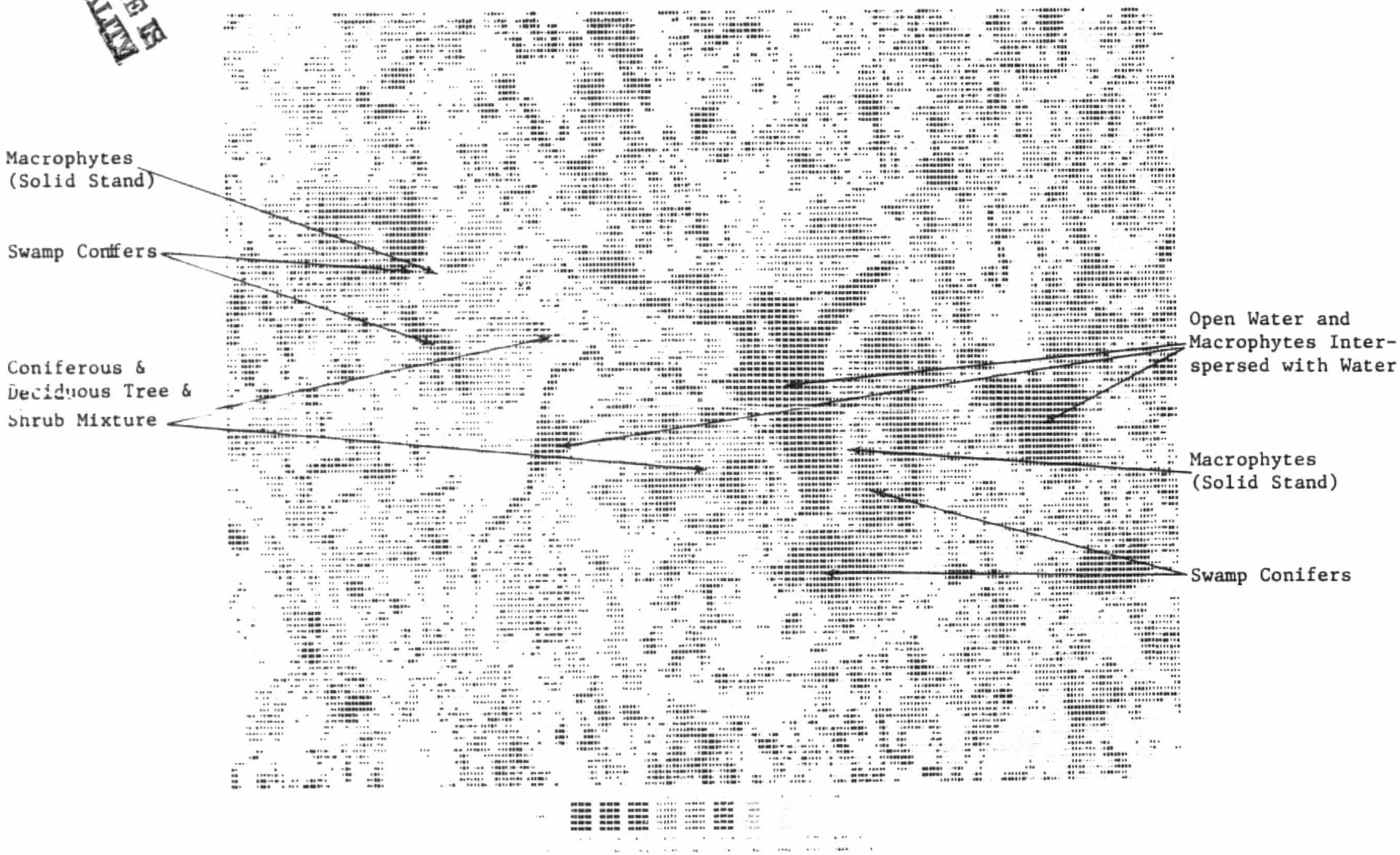

FIGURE 2.1.13 Sheboygan Marsh, MSS Band 7 (.8 to 1.1μ), 9 August 1972.

The printout maps in Figures 2.1.11 to 2.1.13 were compared to the map in Figure 2.1.6 and interpretations of the printouts made. These interpretations are shown in Figures 2.1.11 to 2.1.13. To provide a printout with geometry as close as possible to the true scene, every other ERTS data element was printed. This still does not yield printout geometry the same as that in the map in Figure 2.1.6. Since a direct overlay comparison of the map and printout was not possible within the limits of the budget, only an interpretative comparison is possible. However, NASA and the USGS have established that ERTS data, with proper manipulation, can meet national map accuracy standards at 1:1,000,000.

In Band 4, the perimeter of the marsh is distinguishable from the surrounding farmlands. Within the marsh open water, emergent macrophytes interspersed with water, and swamp hardwood and conifer mixes can be distinguished from other plant groups (Figure 2.1.11).

The perimeter of the marsh and open water can be distinguished in Band 5 (Figure 2.1.12). More of the forested areas appear as dark tones but little separation of vegetation types is possible. Roads are also visible.

In Band 7, the perimeter of the marsh is not detectable (Figure 2.1.13). The open water and small river channels with emergent macrophytes interspersed with water are much more evident than in Bands 4 or 5. The swamp conifer forests are recognizable as a lighter value than open water and emergent macrophytes interspersed with water. Deciduous shrub and shrub-tree mixtures are evident but not distinguishable from each other. In general, there seem to be greater numbers of distinctions possible in Band 7, although the overall pattern is more complex, This is consistent with an earlier observation that Band 7 contains more raw data in digital format than Bands 4 and 5. Digital manipulation of Band 7 data also yields more information than Band 7 in image format.

2.1.3.2 A Semi-Interactive Data Analysis System

Another enhancement procedure has been performed on the 9 August 1972 ERTS digital data. 9" x 9" Muirhead Copy Facsimile prints have been produced from a manually enhanced program and generated by a Muirhead Photofax Receiver. In this process the operator selected, via a teletype keyboard, any level of brightness values of raw ERTS data. Any level (out of the 64 possible levels) was then transformed to any brightness level within the range of the Murifax Copier (256 levels).

Figures 2.1.14 to 2.1.17are examples of output for the Sheboygan Marsh demonstrating the transformation of brightness values of raw ERTS data to varying brightness levels on the Murifax Copier. The pictures are 135 ERTS data elements wide and 90 ERTS data elements long, or 7.69 km x 6.48 km respectively. The western portion of the marsh is omitted. The assignment of brightness values was done with *a priori* knowledge of the Sheboygan Marsh developed by studying the map in Figure 2.1.6 and the postings of raw ERTS data in Figures 2.1.7 to 2.1.9.

In Figure 2.1.14, a result from Band 4, the entirety of the marsh is visible as the gray tone. The open water is black. The white is a representation of not only surrounding agricultural lands but unexplainable patterns within the marsh. This suggests that various features within the marsh have the same brightness values as surrounding agricultural lands. Based on *a priori* knowledge of the area, an interpretor interacting with this display can separate the agricultural from wetland components even though the range of brightness values is sufficiently broad to encompass many features.

In Figure 2.1.15, a result from Band 7, the water is black, macrophytes interspersed with water are dark to medium dark gray, swamp conifers are medium light gray. These are the only distinctions possible within the marsh; the remainder of the plant communities cannot be distinguished from the light gray to white values.

In Figure 2.1.16, also Band 7, the water is black, macrophytes interspersed with water are dark gray, swamp conifers are medium light gray. The remainder of the plant communities in the marsh cannot be distinguished from the light gray and white values.

In Figure 2.1.17 the water is again black, but macrophytes interspersed with water and swamp conifers are gray. The remainder of the marsh cannot be distinguished from the surrounding agricultural lands in the white value.

This process of assigning new values to raw ERTS data, a form of contrast stretching, has been viewed as a learning process for the researchers and demonstrates that significantly more information can be extracted by computer techniques than by light table techniques. The capabilities of the McIDAS system expand this area considerably and are discussed in the following section.

2.1.3.3 McIDAS: A Totally Interactive Data Analysis System

McIDAS (Man-Computer Interactive Data Access System) is a pictoral data analysis system developed by the University of Wisconsin's Space Science and Engineering Center. Developed primarily for wind measurement using satellite observed cloud motion, McIDAS is sufficiently versatile that a number of diverse users have been investigating its application. These include efforts concentrating on land use and resource identification.

McIDAS, described in Appendix D, consists basically, of a medium-scale computer, a color TV display, video disk data storage, digital disk storage for system control data, and high-speed communication links between the

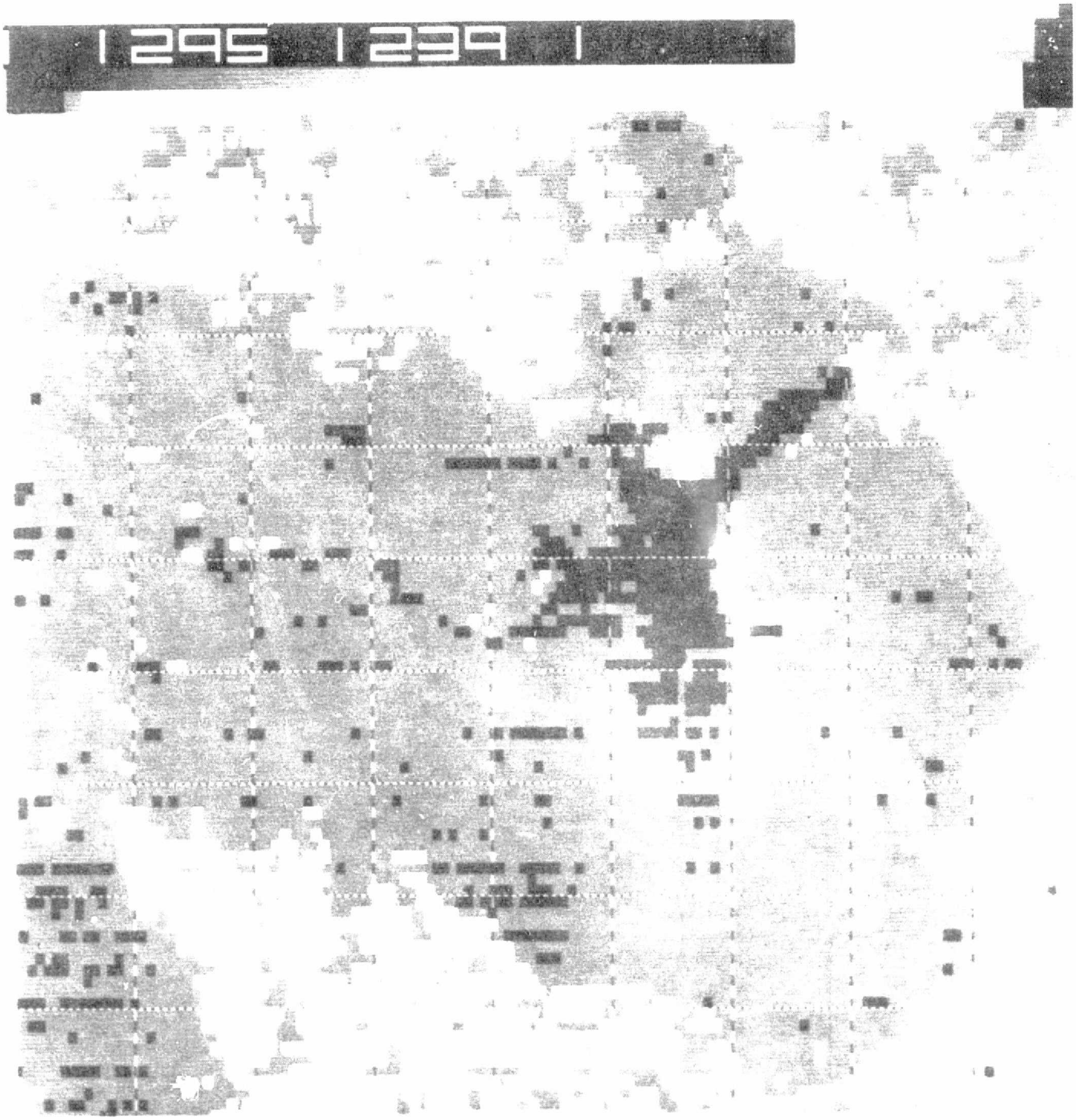

Figure 2.1.14 - Murihead Copy Facsimile, August 9, 1972, Band 4
Level 0, Black = ERTS Brightness Values 0-18
Level 60, Grey = ERTS Brightness Values 19-23
Level 255 White = ERTS Brightness Values 24-64

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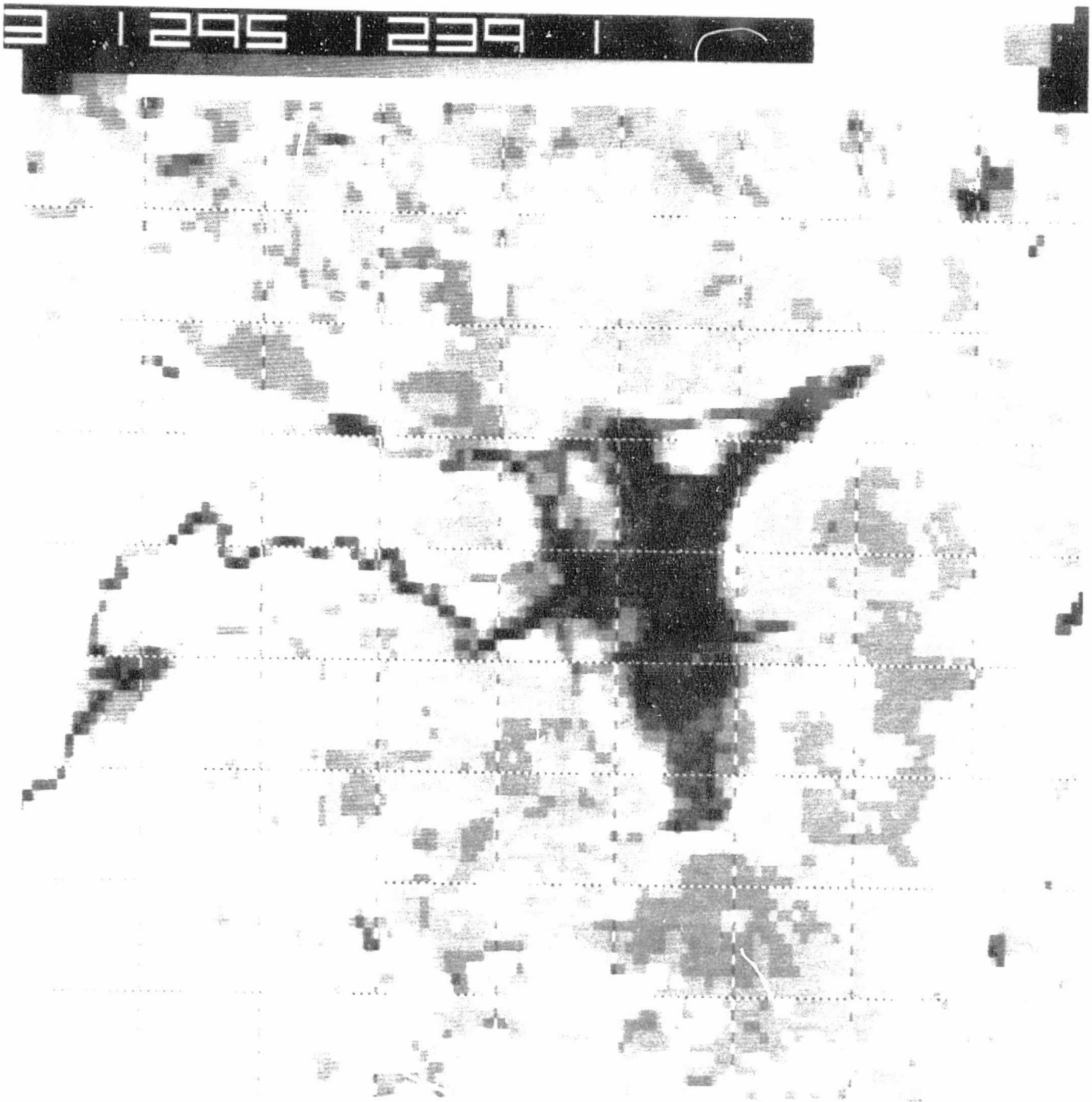

Figure 2.1.15- Murihead Copy Facsimile, August 9, 1972 Band 7
Level 0, Black = ERTS Brightness Values 0-9
Level 20, Dark Grey = ERTS Brightness Values 10-12
Level 40, Med. Dark Grey = ERTS Brightness Values 13-16
Level 70, Med. Light Grey = ERTS Brightness Values 17-22
Level 100, Light Grey = ERTS Brightness Values 23-30
Level 255, White = ERTS Brightness Values 31-40

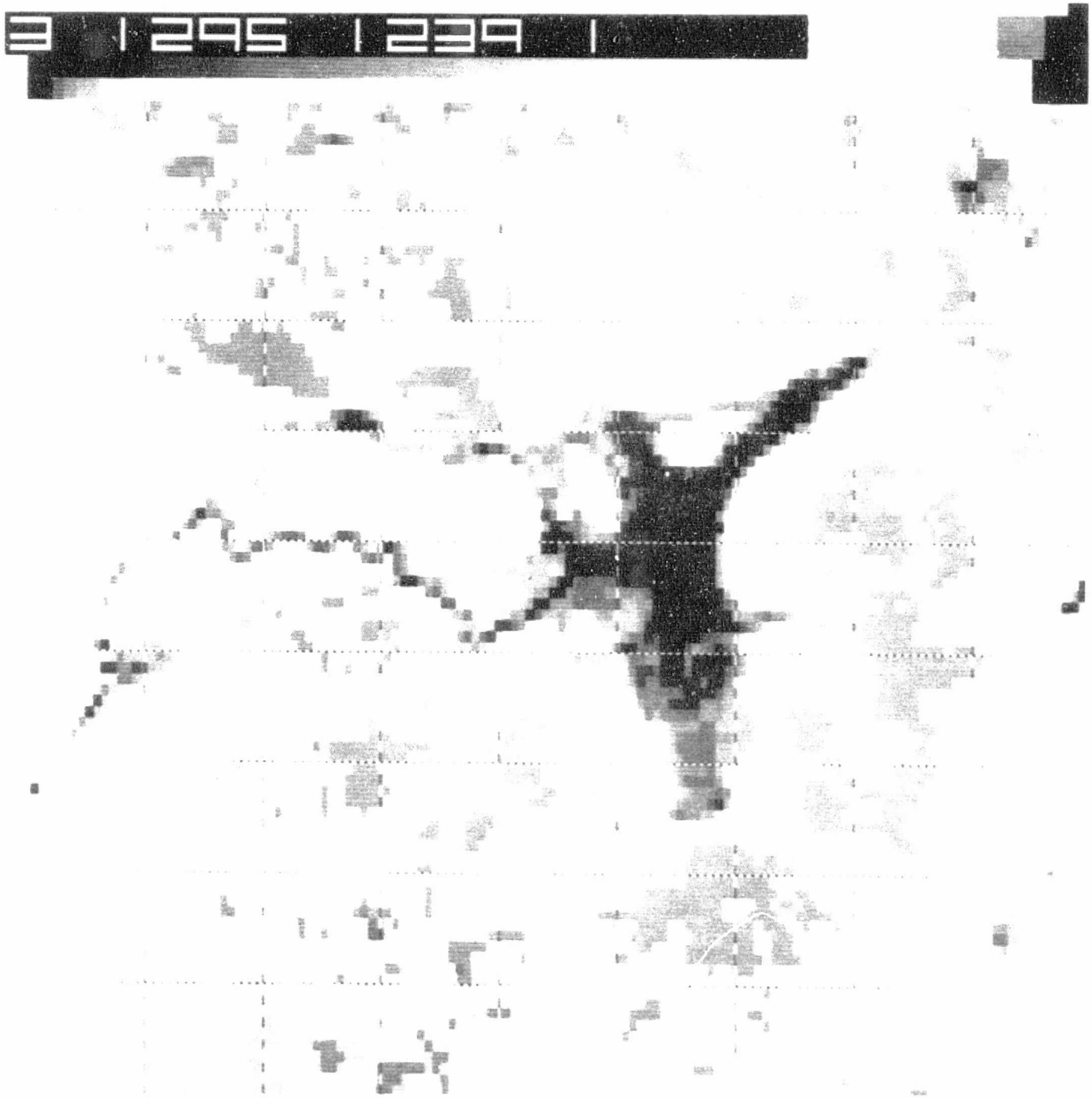

Figure 2.1.16 - Murihead Copy Facsimile, August 9, 1972, Band 7
Level 0, Black = ERTS Brightness Values 0-9
Level 50, Dark Grey = ERTS Brightness Values 11-13
Level 70, Medium Dark Grey = ERTS Brightness Values 14-16
Level 95, Medium Light Grey = ERTS Brightness Values 17-22
Level 145, Light Grey = ERTS Brightness Values 23-30
Level 255, White = ERTS Brightness Values 31-64

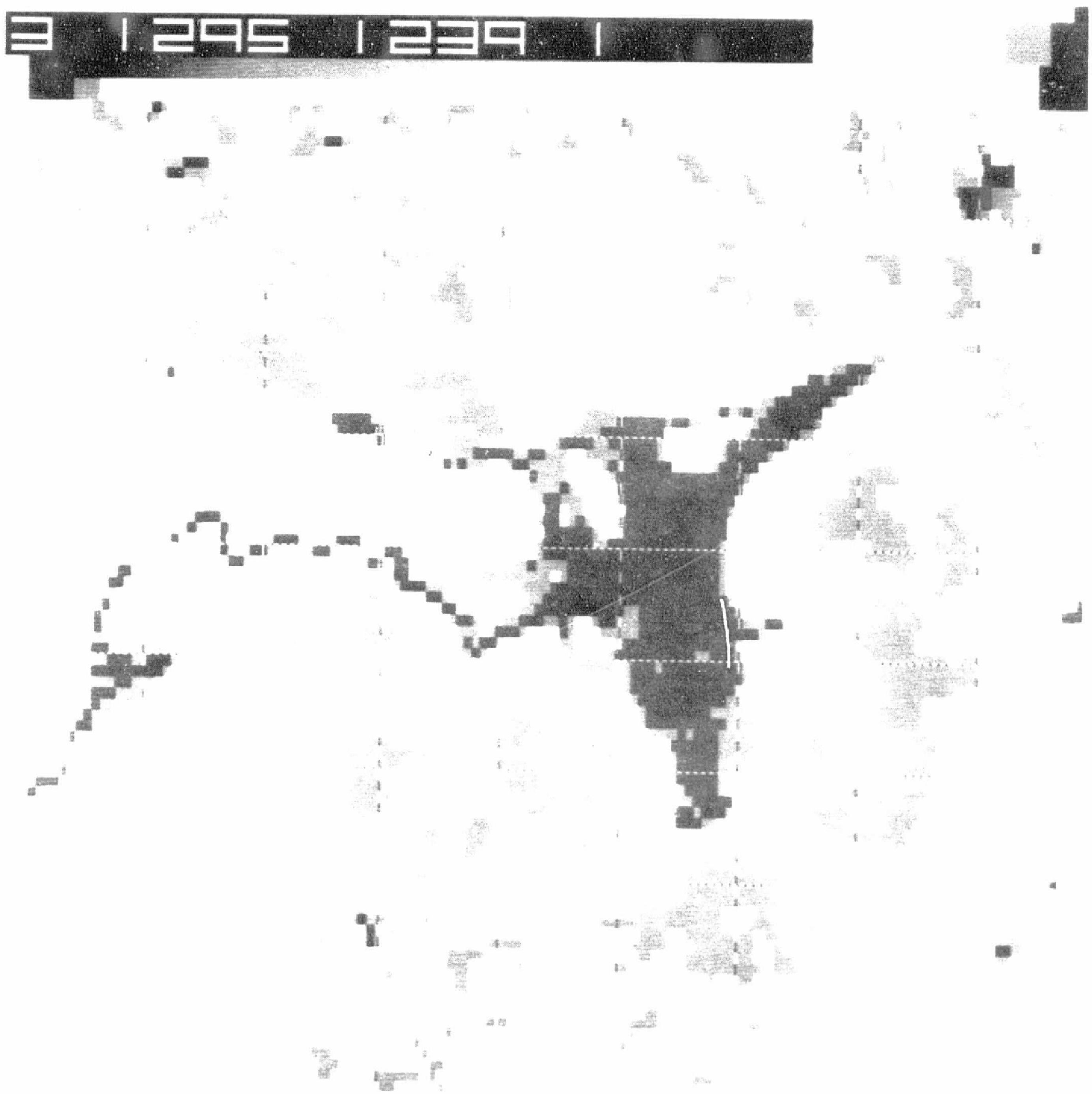

Figure 2.1.17- Murihead Copy Facsimile, August 9, 1972, Band 7
Level 0, Black = ERTS Brightness Values 0-9
Level 60, Grey = ERTS Brightness Values 16-22
Level 255, White = ERTS Brightness Values 23-64

system and display. Data enhancements can be performed simply and quickly utilizing hue and chromaticity as interpretive tools in addition to black and white brightness.

Some rudimentary studies were first conducted using a prototype system (WINDCO) which utilized only black and white display with very inefficient data transfer capabilities. In spite of these limitations, the following conclusions were apparent:

a) With digital data there is more information existent in each band than in the associated photograph.
b) Raw digital data has not been transformed to another form for display and is therefore a more objective data source than ERTS image formats.
c) Digital data may be easier than photographic image data in archiving, retrieving, interpreting and extracting information.

System development of McIDAS (Appendix D) has presently reached the point where some of the capabilities superior to WINDCO are now operational. Preliminary investigations using the same ERTS CCT tapes as used on WINDCO lead to the following conclusions and comments:

a) Proficiency in using the system from an operational point of view was easily attained.
b) The system is very efficient in accessing the desired image and the data associated with that image. Scenes can also be blown up to observe selected areas within a single image. This allows the user to start at a very large scale to gain general impressions of an area. Large patterns and areas of interest can be identified, then one can focus down upon a desired smaller area for a detailed inspection of more subtle

resource patterns. This is a great advantage in allowing both a general and detailed view of an area.

c) The color enhancement capabilities allow for quick and easy immediate color enhancement of a scene using the joystick. The user can interact in the enhancement process, using his knowledge of the resource patterns to maximize the subtle differences in resource patterns for identification. Color enhancement allows one to view more patterns since the eye sees more colors than shades of gray. By several trials of enhancement one can arrive at a display which will maximize the contrast between resource types. In the near future the McIDAS system will have the capability of doing interactive overlays from separate spectral channels each of which can be separately color enhanced.

d) The present capabilities of McIDAS allow an area to be traced out, the trace displayed on the image, and the area in picture elements calculated within seconds. At this writing plans are underway to navigate RB-57 and ERTS data so that the area will be in actual physical dimensions. This capability is presently available for the ATS-III (Applications Technology Satellite) data. An additional extra-conventional feature consists of being able to extract all the data enclosed by the cursor overlaying the image for all or a subset of the spectral channels associated with that image, and to calculate and display on the CRT monitor the means and covariance of the data sets. The cross-hair cursor can be directed to any point on the displayed image by inputting the TV coordinates, the satellite tape coordinates and/or in the case of ATS-III, the ground coordinates.

2.2 DETERMINATION OF USEFULNESS OF ERTS-1 DATA FOR REGIONAL LAND USE PLANNING AND ALLOCATION DECISION

2.2.1 INTRODUCTION

In section 2.1 of this report, explanation was given of efforts to evaluate the utility of ERTS-1 data on the basis of direct comparison with data derived by conventional methods. This method of evaluation is legitimate but not complete. In order to obtain a more complete judgement of ERTS-1 as a source, the data must be tested in the context of actual planning processes.

Attempts were made to accomplish this by utilizing ERTS-1 derived data in various formats for some practical methods of resource information analysis and manipulation. Some of the methods outlined in the following sections are accepted planning techniques which have been previously used. Proving ERTS-1 to be a satisfactory input alternative to these techniques would place great value on the satellite as a land use planning tool. Other methods covered are relatively new to planning disciplines. The utility of ERTS-1 as a valuable source for these techniques can only be ascertained as the techniques themselves are accepted. The study of these methods is justified by the rationale that the ability of ERTS-1 to collect data is so revolutionary that it could allow techniques which would be otherwise unworkable for lack of a satisfactory data source.

2.2.2 DATA BANK COMPARISONS BY MANIPULATION WITH THE LINEFINDER SIMULATION TECHNIQUE

This research seeks to determine the utility of ERTS-1 data in the planning process. The fundamental question can be expressed as "what effect does the data source have upon the planning process?" Inasmuch as the planning process must exist at several levels from site specific to regional, the utility of a data source is a function of the level of planning. In order to test the relationship between a data source and the decision on a regional basis, a portion of an Interstate Highway corridor was located based upon (1) ERTS generated data, (2) RB-57 generated data, and (3) conventional data. The three data banks for each of two test areas were used in the Sheboygan and Green Bay test sites. Two new models were developed to complement an existing model developed with the REMAP I data bank.*

The models are linear summations of the product of resource values for each cell in the 300 km^2 data banks with weights assigned by expert opinion. The LINEFINDER routine (Appendix E) sums products of weights and variable values for each cell. The program then starts at an established starting point and finds the "least cost" or lowest assemblage of coefficients through the data array. LINEFINDER finds linear routes, such as highway or power transmission corridors. Other available software finds optimum areas.

Two policies, which could be real land use decisions determined by policy makers, were run through each data bank:

Policy 1: Least disruption to the ecological system (Table 2.2.1, Figures 2.2.1-2.2.4)

Policy 2: Greatest scenic value (Table 2.2.2, Figures 2.2.5-2.2.8)

Model 1 in each policy uses weights established by experts. Model 2 in each policy uses weights made up by the researchers to demonstrate the effect of weight

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*The REMAP I data bank was developed in 1970-72 by the University of Wisconsin Department of Landscape Architecture with funding from the Wisconsin Department of Transportation. The computer program LINEFINDER was written by Dennis Bunde, UW Department of Computer Science.

POLICY 1

LAND ALLOCATION MODELS

"LINEFINDER" ROUTINE

DATA DERIVED FROM	VARIABLE USED	WEIGHTS	
		MODEL 1	MODEL 2
ERTS	Rivers	20	2
	Lakes	9	2
	Lake Michigan	9	2
	Forest	4	20
	Open swamp	4	20
		46	46
RB-57 and REMAP 1 DATA BANK	Stream, intermittant	100	3
	Stream	90	3
	Rivers	20	3
	Lakes	9	3
	Lake Michigan	9	3
	Lowland forest	4	75
	Upland forest	4	75
	Open swamp	4	75
		240	240

TABLE 2.2.1

POLICY 1: Least Disruption to the Ecological System

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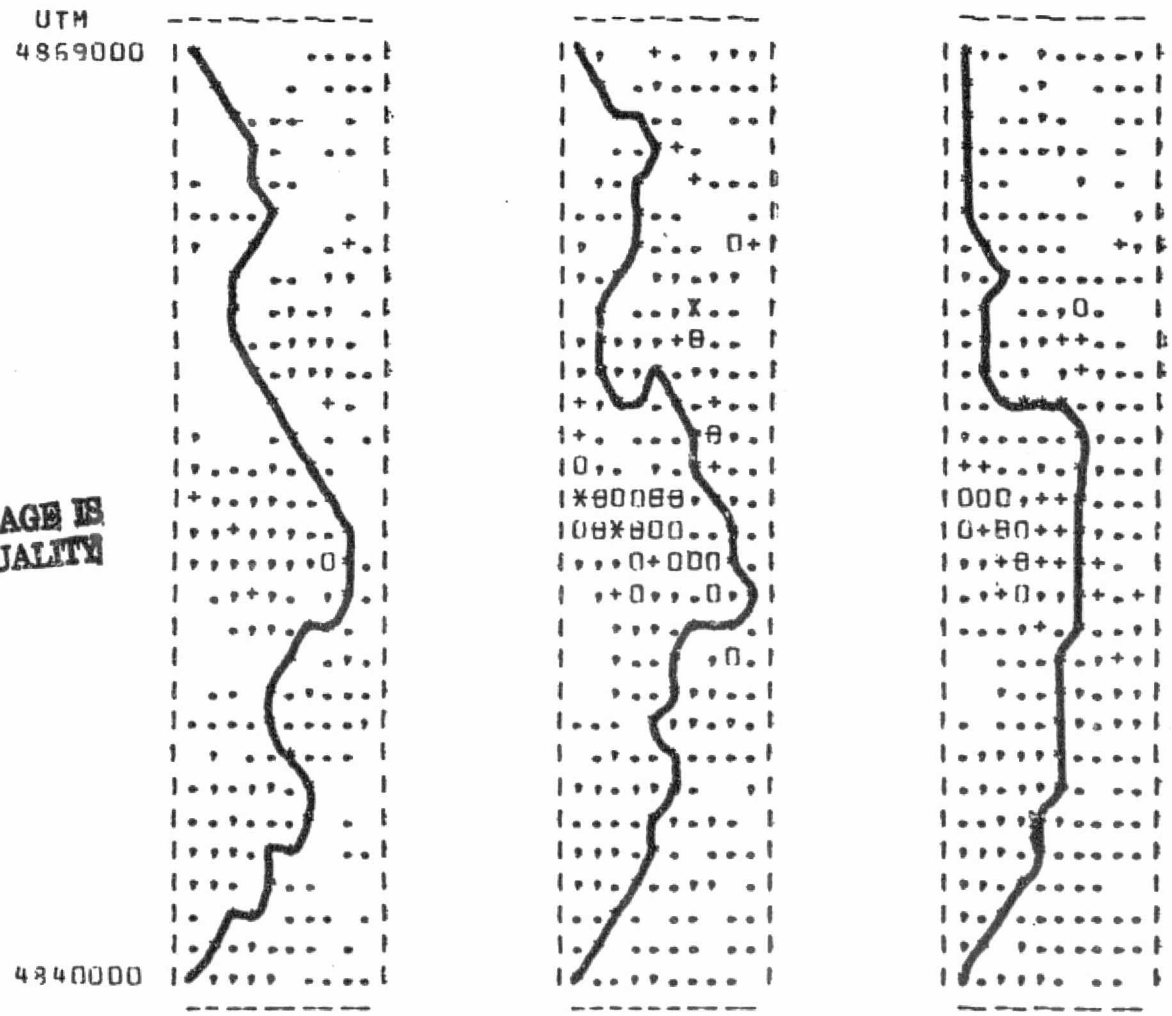
SHEBOYGAN TEST SITE
VARIABLE ECOLOGICAL SYSTEM

UTM 410000 419000



	A		B		C				
	ERTS		RB57		REMAP I				
TOT. SQ.KM	13.250		26.260		22.780				

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	88888	*****	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	108	52	5	1	0	0	0	0	0	0
	B	115	63	11	14	7	2	1	0	0	0
	C	142	60	20	7	2	0	0	0	0	0
SQ.KM	A	3.93	7.73	1.21	.38	.00	.00	.00	.00	.00	.00
	B	4.74	9.08	2.64	4.95	.14	1.03	.68	.00	.00	.00
	C	6.36	8.23	5.04	2.34	.81	.00	.00	.00	.00	.00

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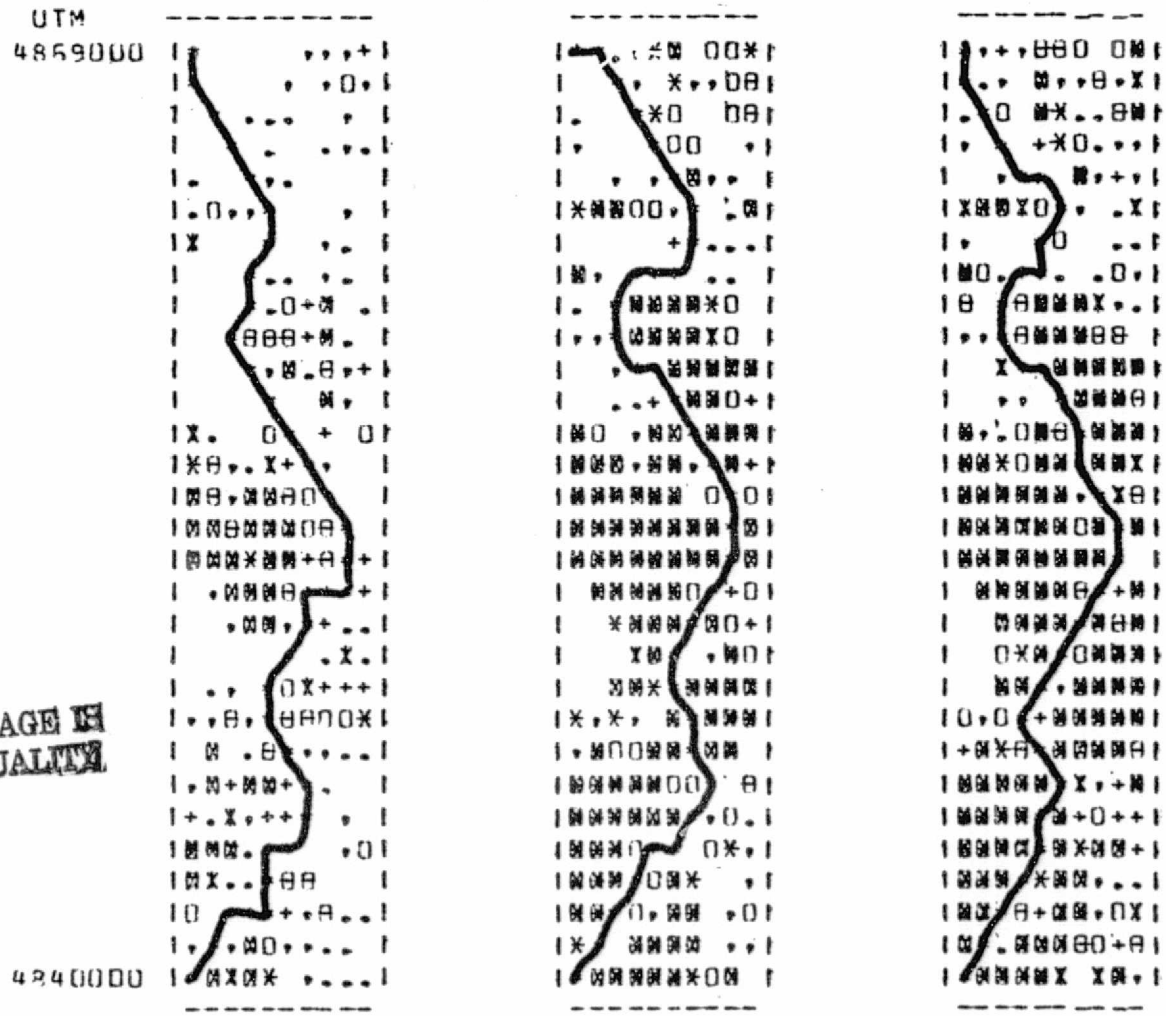
VARIABLE ECOLOGICAL SYSTEM

UTM 410000 — 419000



		A ERTS			B RB57			C REMAP I		
TOT. SQ.KM		59.090			251.220			266.550		

		1	2	3	4	5	6	7	8	9	10
LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	OOOOO	θθθθθ	*****	XXXXX	ØØØØØ	ØØØØØ	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	39	39	19	13	18	4	8	9	14	10
	B	12	29	6	30	3	14	2	13	4	98
	C	16	28	13	18	19	7	12	10	7	106
SQ.KM	A	2.22	5.33	4.51	4.30	7.65	2.15	5.13	6.58	11.67	9.55
	B	.71	4.53	1.44	10.51	1.41	7.80	1.27	9.71	3.44	210.40
	C	.72	3.96	3.12	5.92	8.46	3.80	7.57	7.61	5.82	219.57

FIGURE 2.2.2 - Policy 1, Model 2, Sheboygan Test Site

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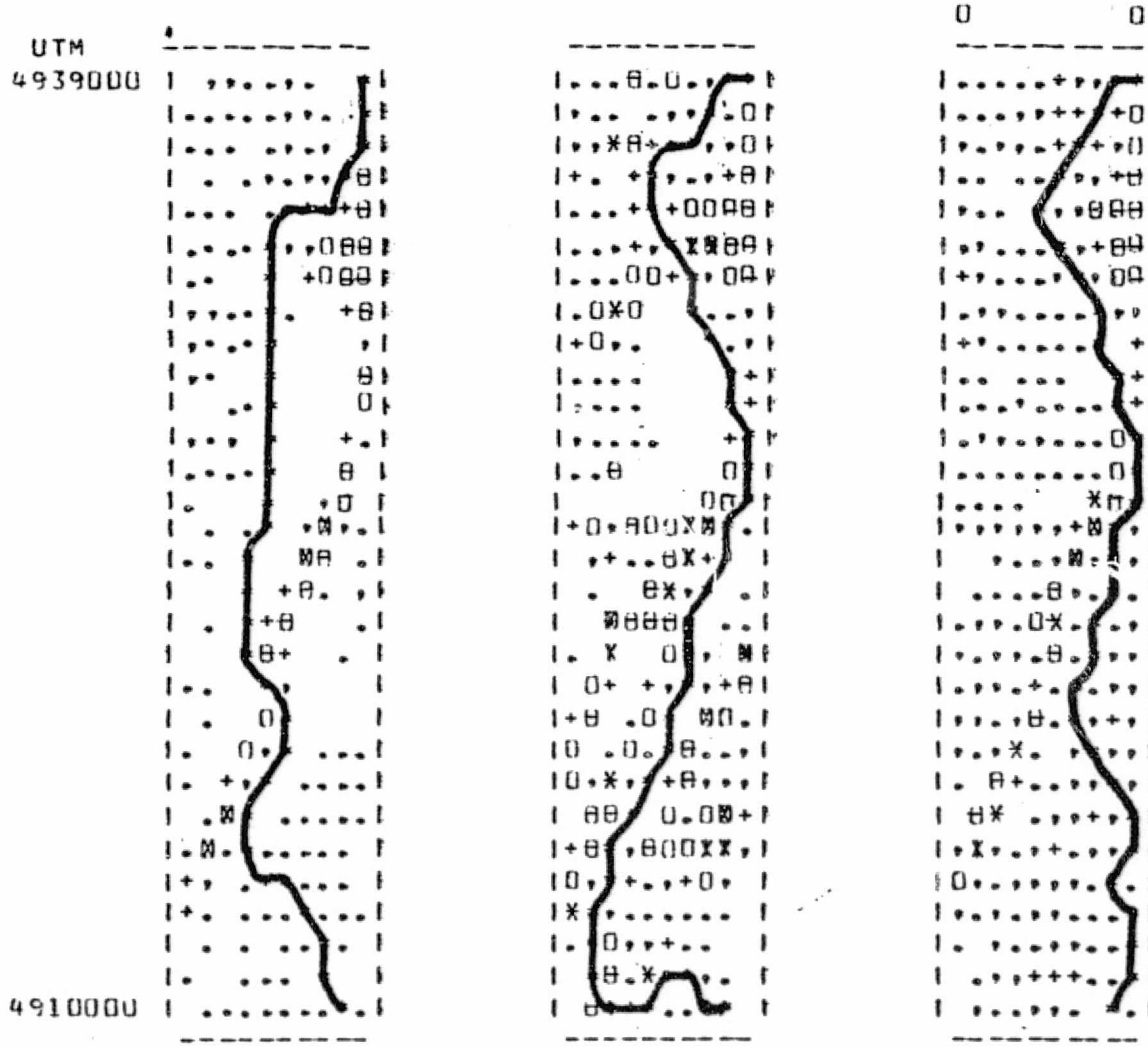
GREEN BAY TEST SITE
VARIABLE ECOLOGICAL SYSTEM



	A ERTS	B RB57	C REMAP I
TOT. SQ.KM	21.920	47.680	36.670

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	,,,,,	+++++	00000	θθθθθ	*****	XXXXX	▓▓▓▓▓	▓▓▓▓▓	▓▓▓▓▓
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR A	106	27	10	5	15	2	0	3	1	0
OCCUR B	66	39	25	30	26	6	6	3	0	3
OCCUR C	110	90	22	7	13	4	1	2	0	0
SQ.KM A	3.10	3.87	2.48	1.76	6.58	1.03	.00	2.30	.80	.00
SQ.KM B	2.60	5.51	5.82	10.22	11.39	3.18	3.88	2.19	.00	2.89
SQ.KM C	6.55	12.15	5.54	2.47	5.77	2.07	.65	1.47	.00	.00

FIGURE 2.2.3 - Policy 1, Model 1, Green Bay Test Site

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GREEN BAY TEST SITE
VARIABLE ECOLOGICAL SYSTEM

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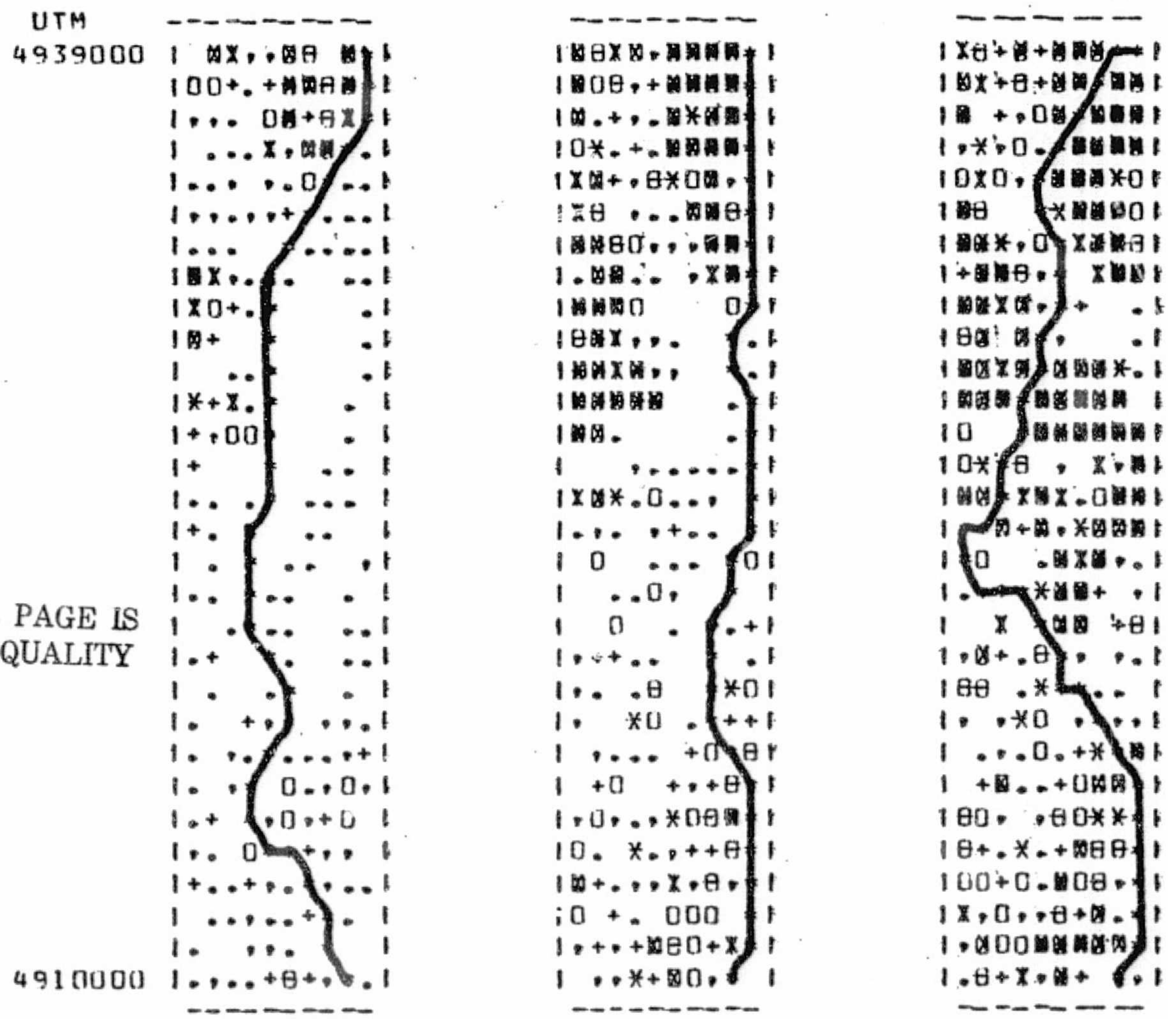

	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	32.960	106.460	178.800

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	θθθθθ	*****	XXXXX	▣▣▣▣▣	▦▦▦▦▦	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	93	34	21	12	4	1	6	2	3	6
	B	48	37	22	24	14	9	9	8	6	35
	C	23	31	20	23	19	14	14	17	7	66
SQ.KM	A	4.84	4.10	4.69	3.82	1.60	.55	3.84	1.50	2.51	5.51
	B	2.04	5.65	5.16	7.97	6.31	4.94	5.71	6.18	4.92	57.58
	C	1.17	4.70	4.70	7.58	8.62	7.69	9.00	12.53	5.84	116.97

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FIGURE 2.2.4 - Policy 1, Model 2, Green Bay Test Site

POLICY 2

LAND ALLOCATION MODELS

"LINEFINDER" ROUTINE

DATA DERIVED FROM	VARIABLES USED	WEIGHTS MODEL 1	WEIGHTS MODEL 2
ERTS	Forest	1	6
	Open swamp	1	6
	Agricultural	1	1
	Urban	10	1
	Escarpment	2	1
	Lakes	1	1
	Lake Michigan	1	1
	Lakes less than 50 acres	1	1
	Rivers	1	1
		19	19
RB-57 and REMAP-1 DATA BANK	Agricultural	1	1
	Escarpment	2	1
	Lowland forest	1	4
	Upland forest	1	6
	Lakes	1	1
	Lake Michigan	1	1
	Lakes less than 50 acres	1	1
	Open swamp	1	2
	Rivers	1	1
	Stream	1	1
	Stream, intermittant	1	1
	Urban	10	1
		21	21

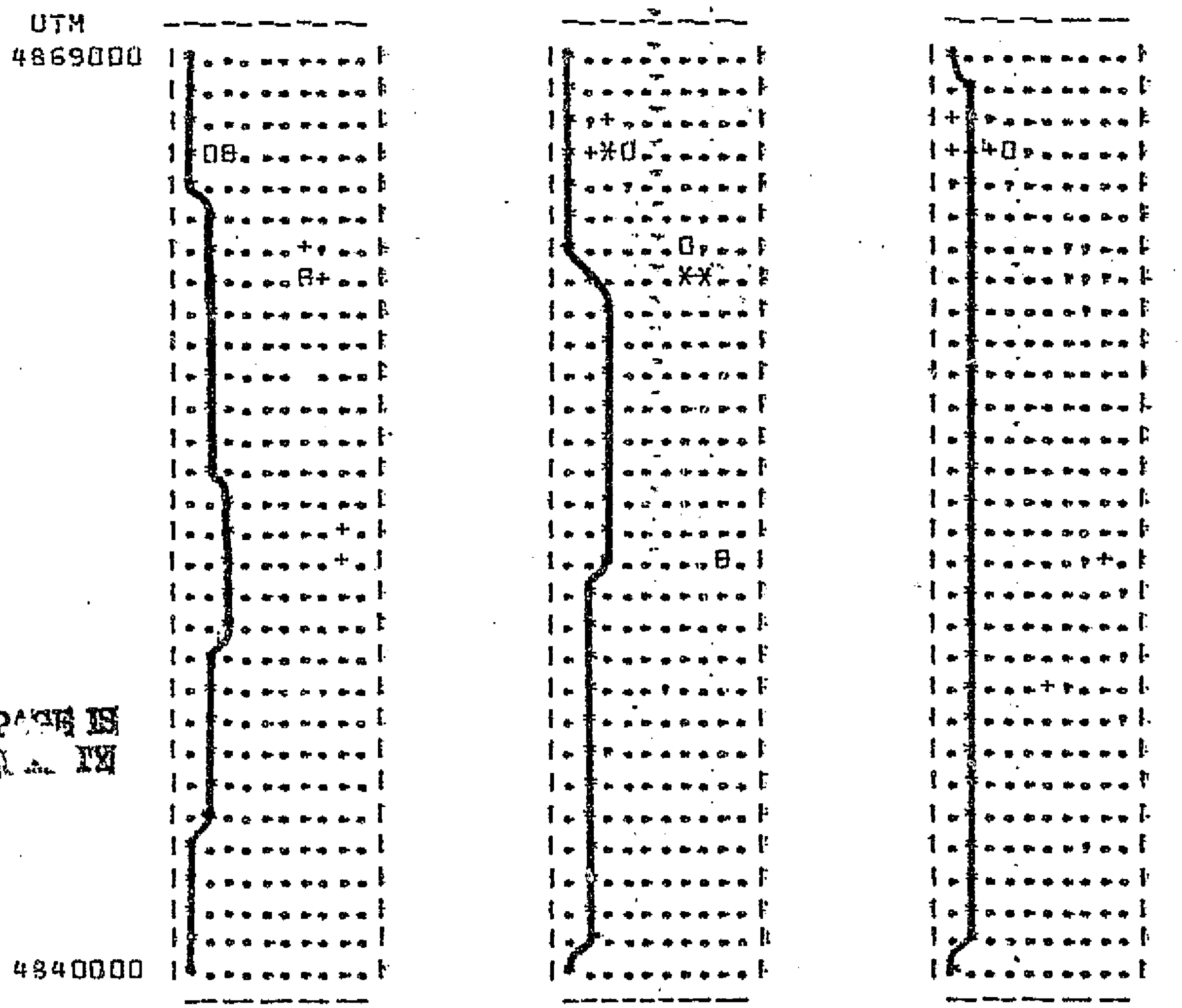
TABLE 2.2.2

POLICY 2: Greatest Scenic Potential

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE SCENIC POTENTIAL

UTM 410000 419000



	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	12.160	14.020	15.020

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	88888	XXXXX	XXXXX	88888	88888	88888
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	261	1	4	1	2	0	0	0	0	0
	B	257	5	2	2	1	3	0	0	0	0
	C	248	16	5	1	0	0	0	0	0	0
SQ.KM	A	9.89	.14	.96	.30	.87	.00	.00	.00	.00	.00
	B	10.22	.67	.54	.64	.45	1.50	.00	.00	.00	.00
	C	11.35	2.28	1.08	.31	.00	.00	.00	.00	.00	.00

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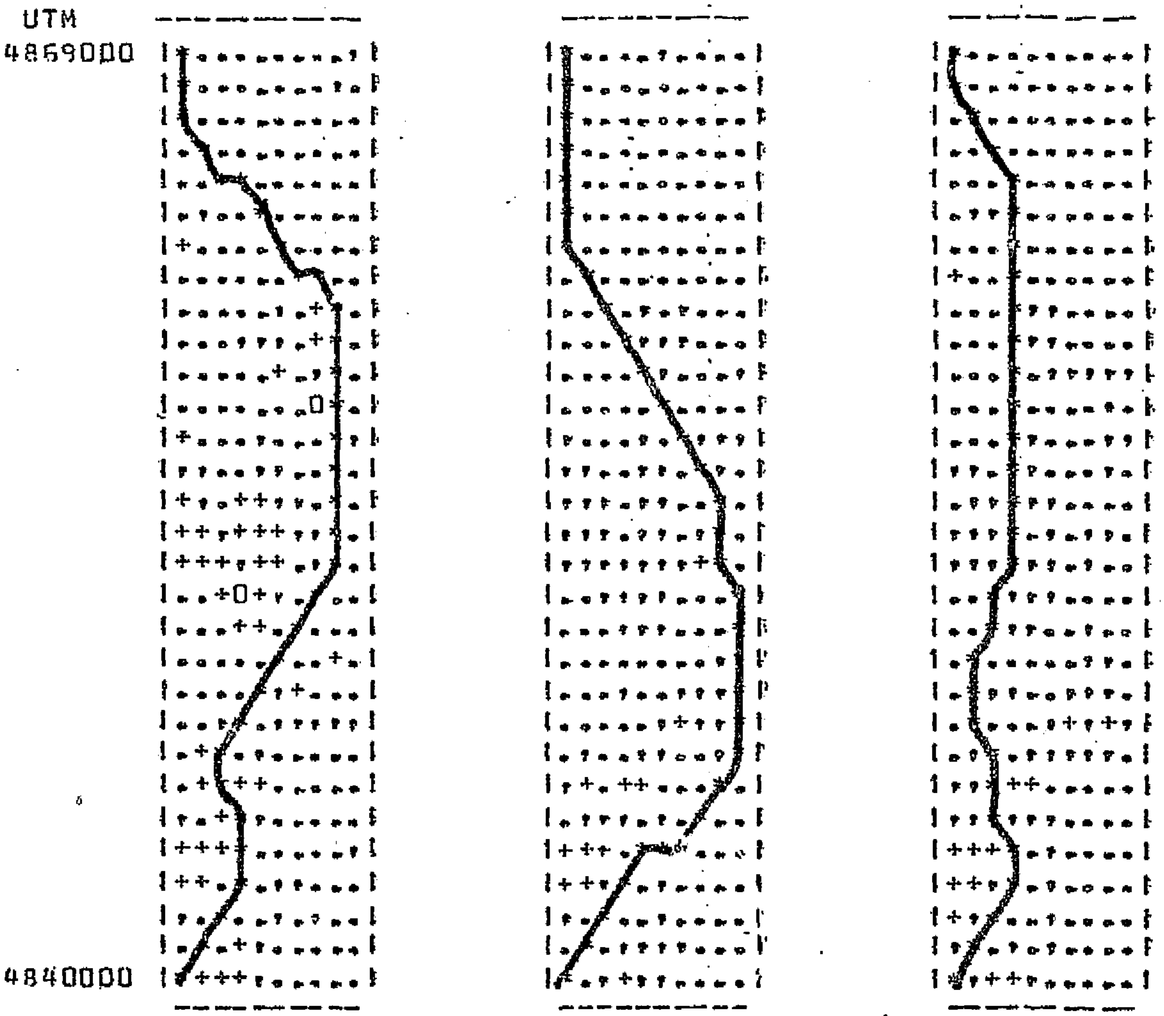
FIGURE 2.2.5 - Policy 2, Model 1, Sheboygan Test Site

ERTS-1 INVESTIGATION; CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE SCENIC POTENTIAL

4	4	UTM
1	1	
0	9	
0	0	
0	0	
0	0	



	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	24.720	22.560	23.380

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	88888	XXXXX	XXXXX	88888	88888	88888
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	187	41	38	2	0	0	0	0	0	0
	B	186	71	11	0	0	0	0	0	0	0
	C	183	74	13	0	0	0	0	0	0	0
SQ.KM	A	9.45	5.45	9.15	.67	.00	.00	.00	.00	.00	.00
	B	10.07	9.82	2.67	.00	.00	.00	.00	.00	.00	.00
	C	10.74	9.57	3.07	.00	.00	.00	.00	.00	.00	.00

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
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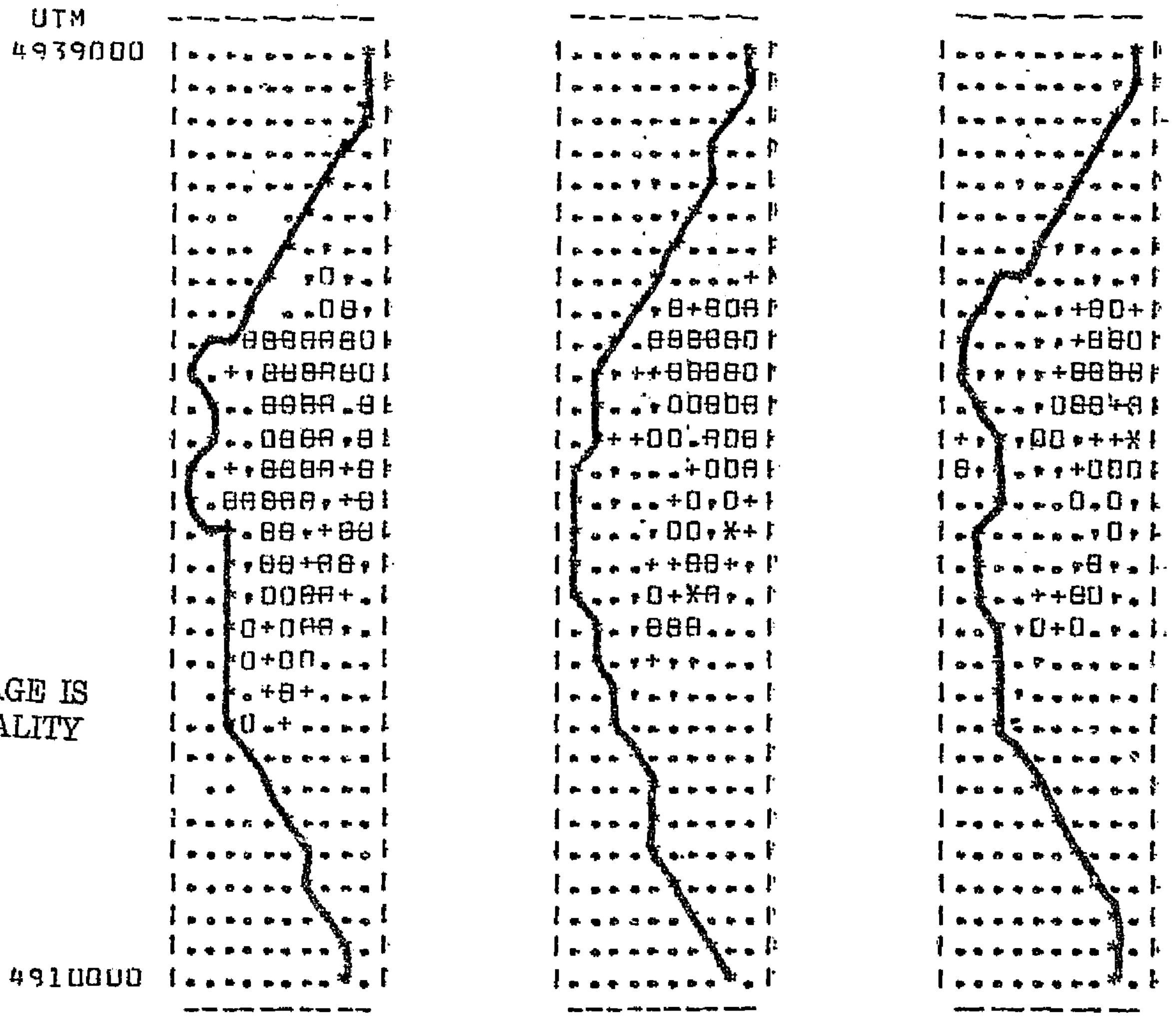
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE SCENIC POTENTIAL

UTM 410000 – 419000



	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	36.930	32.560	27.370

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	88888	XXXXX	XXXXX	MMMMM	MMMMM	MMMMM
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	177	13	13	13	45	0	0	0	0	0
	B	194	20	15	16	23	2	0	0	0	0
	C	198	31	12	14	13	1	0	0	0	0
SQ.KM	A	6.35	1.85	2.90	4.53	21.30	.00	.00	.00	.00	.00
	B	8.76	2.73	3.87	5.53	10.67	1.00	.00	.00	.00	.00
	C	9.09	4.37	2.93	4.69	5.78	.51	.00	.00	.00	.00

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FIGURE 2.2.7 - Policy 2, Model 1, Green Bay Test Site

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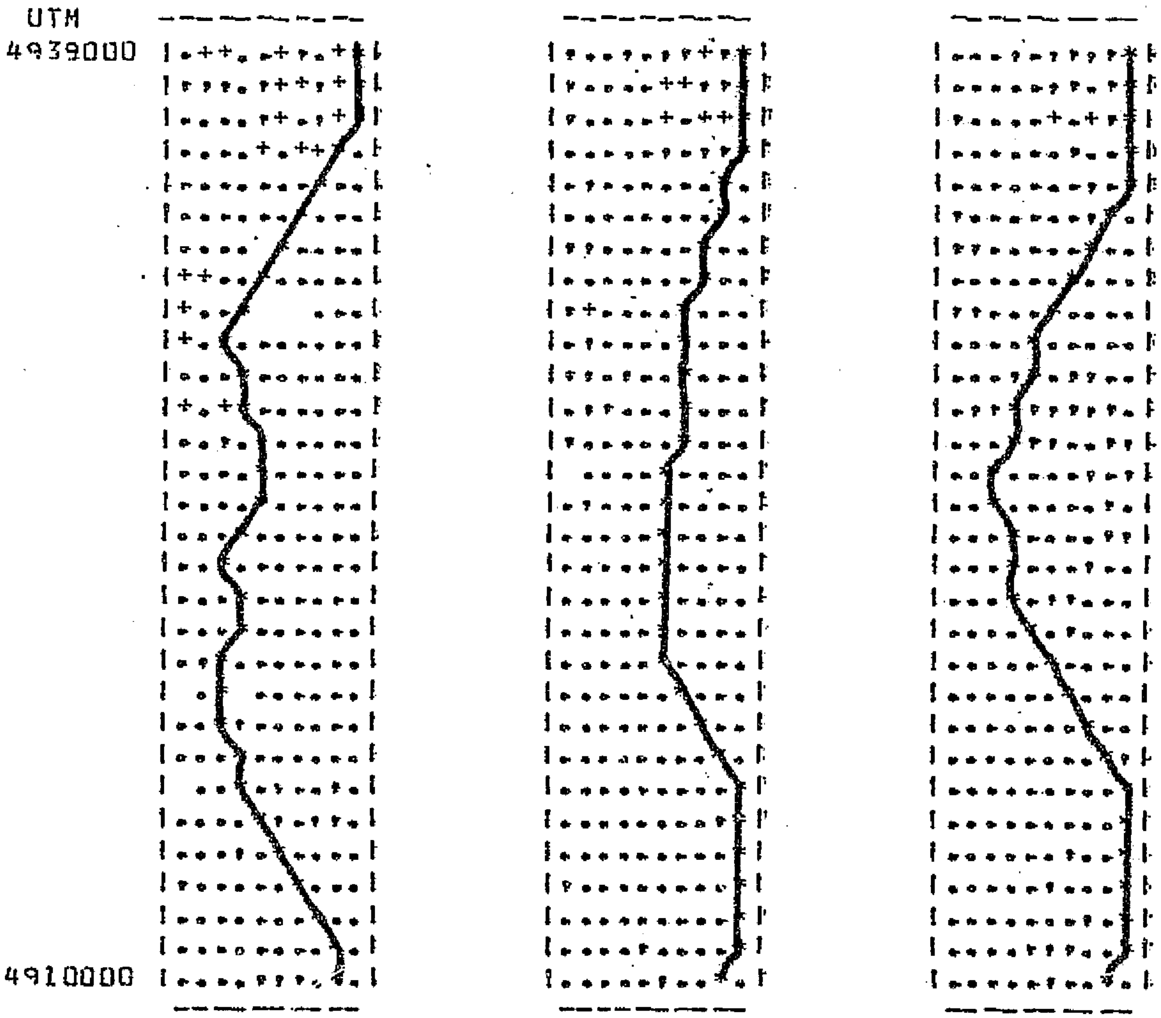
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE SCENIC POTENTIAL

UTM 410000 — 419000



	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	16.610	16.970	18.990

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	'''''	+++++	OOOOO	88888	XXXXX	XXXXX	ØØØØØ	ØØØØØ	ØØØØØ
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR A	224	21	18	0	0	0	0	0	0	0
OCCUR B	234	28	7	0	0	0	0	0	0	0
OCCUR C	219	49	2	0	0	0	0	0	0	0
SQ.KM A	9.77	2.49	4.35	.00	.00	.00	.00	.00	.00	.00
SQ.KM B	12.19	3.21	1.57	.00	.00	.00	.00	.00	.00	.00
SQ.KM C	12.54	6.04	.41	.00	.00	.00	.00	.00	.00	.00

FIGURE 2.2.8 - Policy 2, Model 2, Green Bay Test Site

changes. Since it is realistic to assume that different experts may disagree on weights, two weighting schemes were used to demonstrate the effect of different viewpoints. The ability of this method to accept varying weights and display the results is a great asset.

An inspection of Figures 2.2.1 through 2.2.8 reveals several significant points. Although there is agreement in a few areas among selected corridors there are significant variations. It is apparent after a cursory examination that the variations between the ERTS corridor and the other two are caused in part by inclusion of additional variables in the case of RB-57 and REMAP I (Niemann, 1974; Miller and Niemann, 1972). However, the comparison between the RB-57 and the REMAP I data bank is directly attributable to the discrepancy between the data values stored in those systems since the same variables are included. Inasmuch as field checks have consistently indicated the superiority of the RB-57 data source for these variables the conclusion must be drawn that the conventional REMAP I data base incorrectly biases the decision based upon these variables. The significance of this to the planning process cannot be overestimated.

This investigation is continuing and will be reported on further at a later date.

2.2.3 CRITICAL RESOURCE INFORMATION PROGRAM (CRIP)

Assessing the condition of natural and cultural resources on a statewide basis is rapidly becoming a tenet of sound planning. In response to this need, Wisconsin initiated a study--the Critical Resource Information Program--to define, organize and describe the state's critical resources. During the investigation, a rather sophisticated and multifaceted assessment methodology was developed to evaluate the relative criticality of resource areas within the state. The methodology accounts for the complex nature of the resource base as well as the complications arising from the determination of what constitute criticality.

The term critical, as defined by the CRIP investigators, applies to geographically defined areas within which one or more significant resources are found. The relative criticality of a resource area (from not critical to very critical) is based on such factors as resource quality and size, location, cost of maintenance, and degree of present or future scarcity.

The CRIP investigators have attempted to make objective and where possible, quantify the resource assessment procedure. At the same time, the constraints of time and finances which the state will face in the implementation of such a program are recognized. Consequently, a multiple approach strategy has been developed (Figure 2.2.9).

Potentially critical areas will be delineated through one of two general level assessment procedures. The general level subjective process will solicit and utilize input from county governmental bodies, regional or county advisory committees, local resource experts, interest groups, and local residents to delineate potentially critical areas. This subjective process will be implemented in each county through a series of workshops that will identify potentially critical areas.

The general level objective methodology relies on data of a general nature available over the entire county under investigation. Such data include ERTS imagery, highlevel aerial photographs, maps of resource distribution and data from relevant local, state or federal agencies. These data will be analyzed by resource analysts to objectively identify potentially critical areas. Figure 2.2.9 is a simplified diagram of the overall procedure.

The areas identified through implementing the two

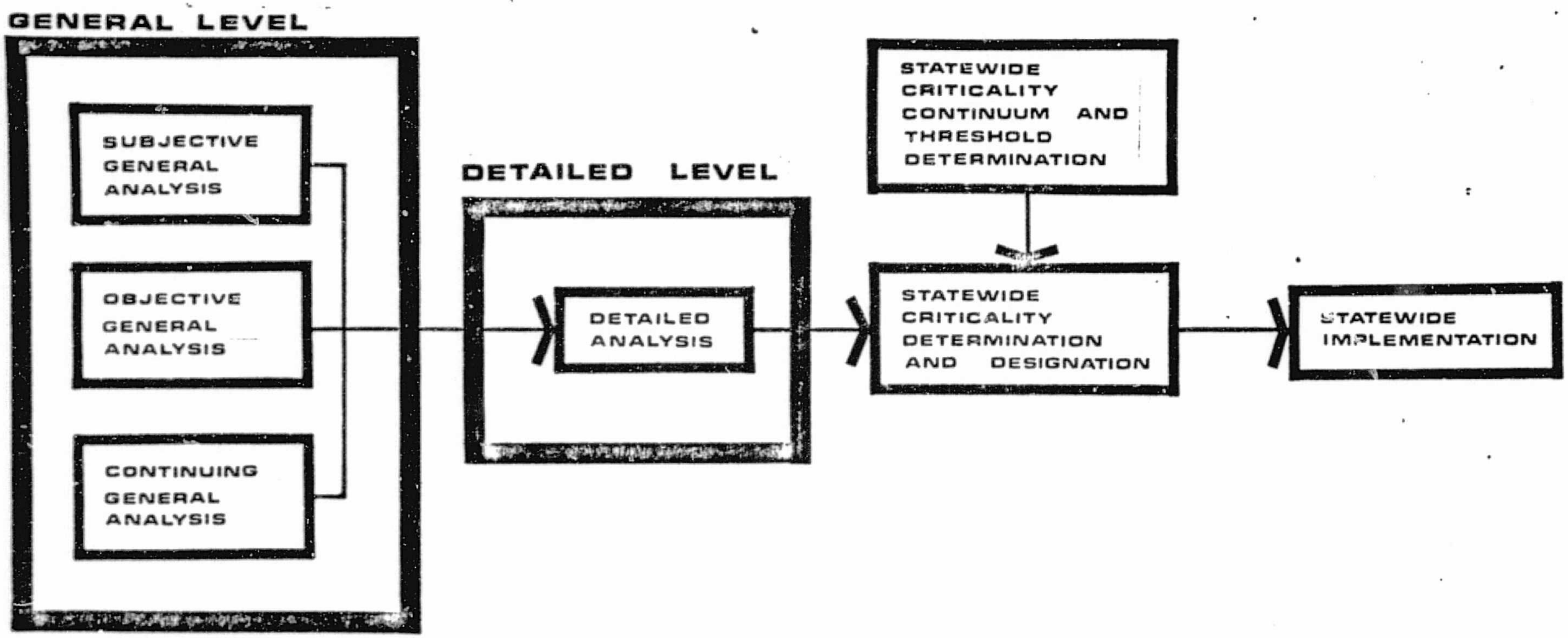


FIGURE 2.2.9 Critical Resource Information Program (CRIP) Assessment Sequence

parallel processes will be combined into one set of potentially critical areas in each county. Each set of potentially critical areas will be submitted to the state agency charged with implementation of the program for review and eventual official designation as potentially critical areas. This agency will select those areas most in need of criticality assessment at the detailed level. The selection of areas for detailed analysis may consider the degree of immediate threat, the availability of funding and other considerations.

The areas selected for criticality assessment will be evaluated by the detailed level objective process. A potentially critical area is evaluated in terms of each of its significant resource components. Each significant resource will be analyzed by use categories, each use being independently evaluated. Thus, criticality is highly use dependent.

Each use will be evaluated on the basis of a set of questions which are either intrinsic (resource related) or extrinsic (man related). The questions are broken down into specific quantifiable variables, such as water pH, number of plant communities, presence of rare plant or animal species, intensity of human pressure, etc. Numerical values which these variables can assume are ranked on a relative scale from 1 (indicating low quality) to 5 (indicating high quality). Each of the variables is independently weighted according to its relative importance within the particular use category.

For some resources in some parts of the state sufficiently accurate data are available to allow the detailed analyses to be made by the administering agency without field work. In most cases, the detailed level assessment will require on-site data acquisition by a qualified resource analyst in the potentially critical area.

An effort has been made to utilize ERTS-1 data for the data collection aspects of this program. Initially, manual interpretation methods with simple viewing and drafting methods were used to identify and delineate significant areas from ERTS-1 images at a scale of 1:1,000,000. These methods proved to be insufficient for the task of extraction of critical resource data mainly because of the small scale of the imagery in comparison with the detail of the data required. However, recent work with the raw data on magnetic tapes through the use of the McIDAS (Man-Computer Interactive Data Access System) system (Appendix D) has shown that much more specific information may be derived from the ERTS-1 data. Further work with the system is required before any specific inventory application of ERTS-1 may be made to the CRIP program.

Another facet of the program involves the communication of the results of CRIP to a widely varying audience. In this area ERTS-1 imagery appears to be potentially very effective due to its large areal coverage which enables general resource categories to be mapped and displayed. Figures 2.2.10 to 2.2.13 are reproductions of resource patterns which were extracted from ERTS-1 images (1:1,000,000) and transformed into 1:500,000 overlays to accompany a mosaic of the State of Wisconsin produced for the Department of Administration. These four patterns: forests, open water, agricultural and open areas and urban areas demonstrate the advantage of ERTS for mapping general feateres economically on a statewide basis and suggest that similar mapping of more specific resource data could be accomplished using more refined technique which are presently being developed.

2.2.4 LAKE EUTROPHICATION STUDY

Since 1 March 1974, a cooperative investigation has been underway with the Wisconsin Department of Natural Resources (DNR) to assess the applicability of using ERTS

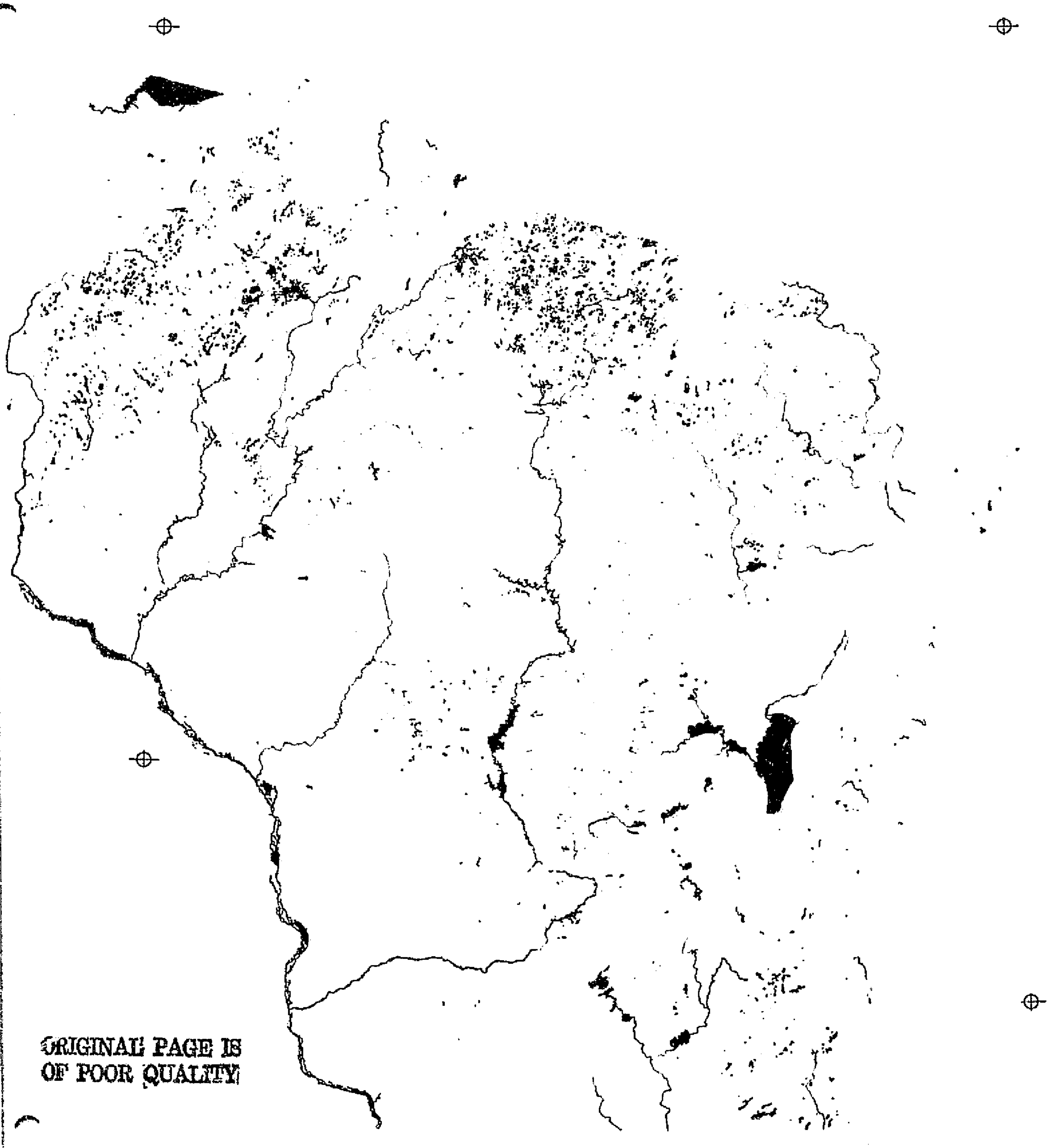


FIGURE 2.2.10 Surface Water in Wisconsin.

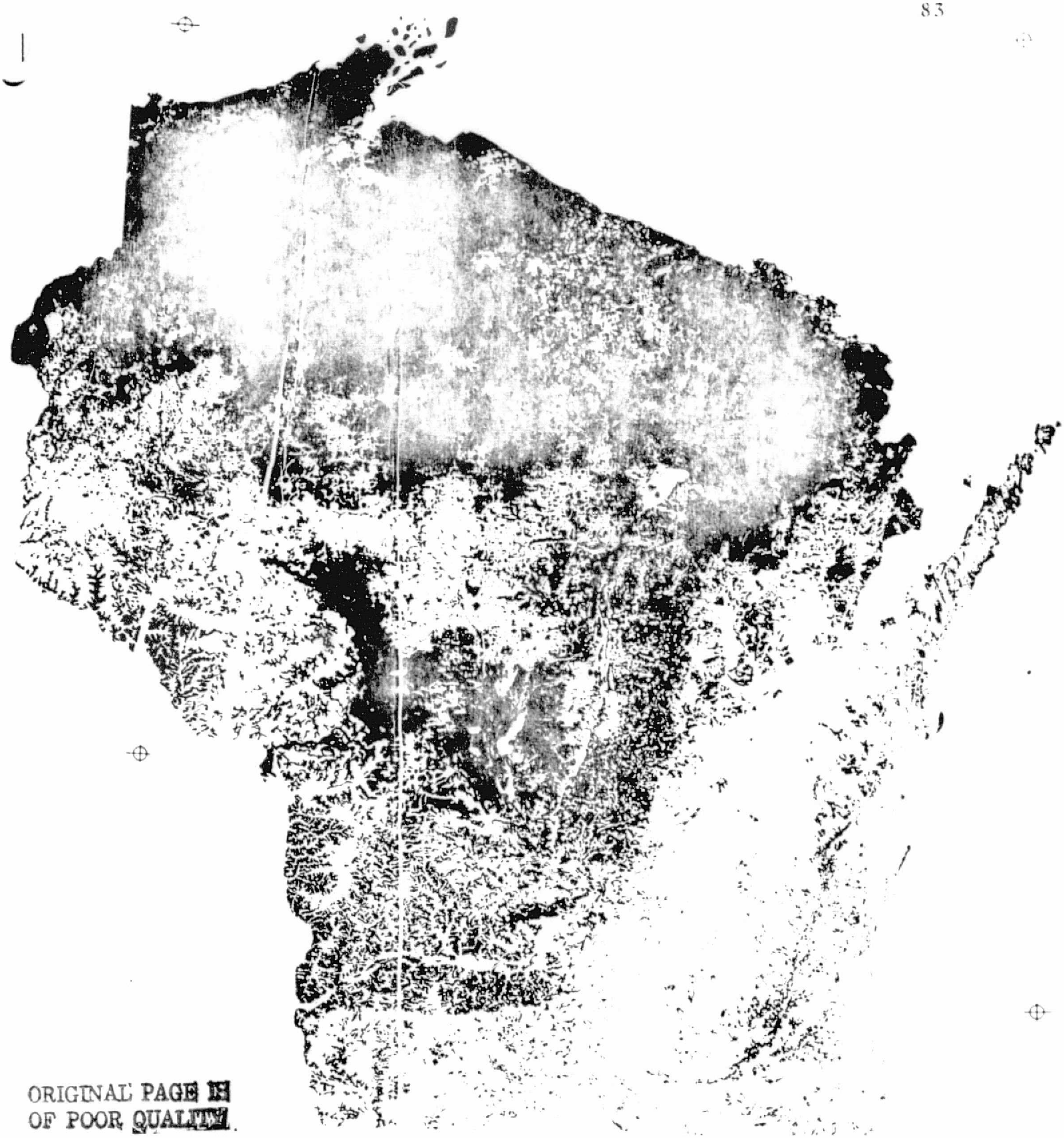


FIGURE 2.2.11 Forested Areas in Wisconsin.

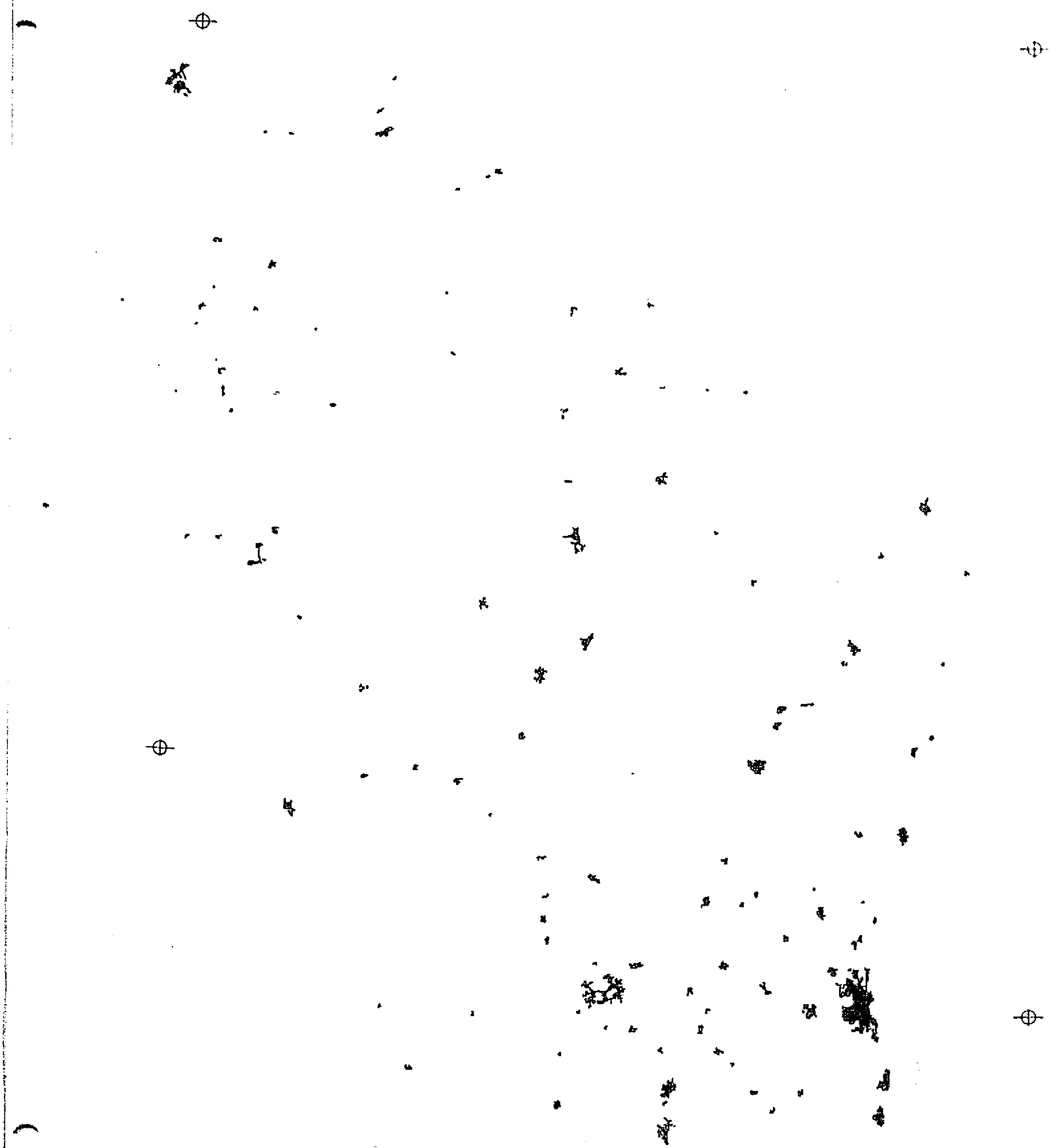


FIGURE 2.2.12 Urbanized Areas in Wisconsin.

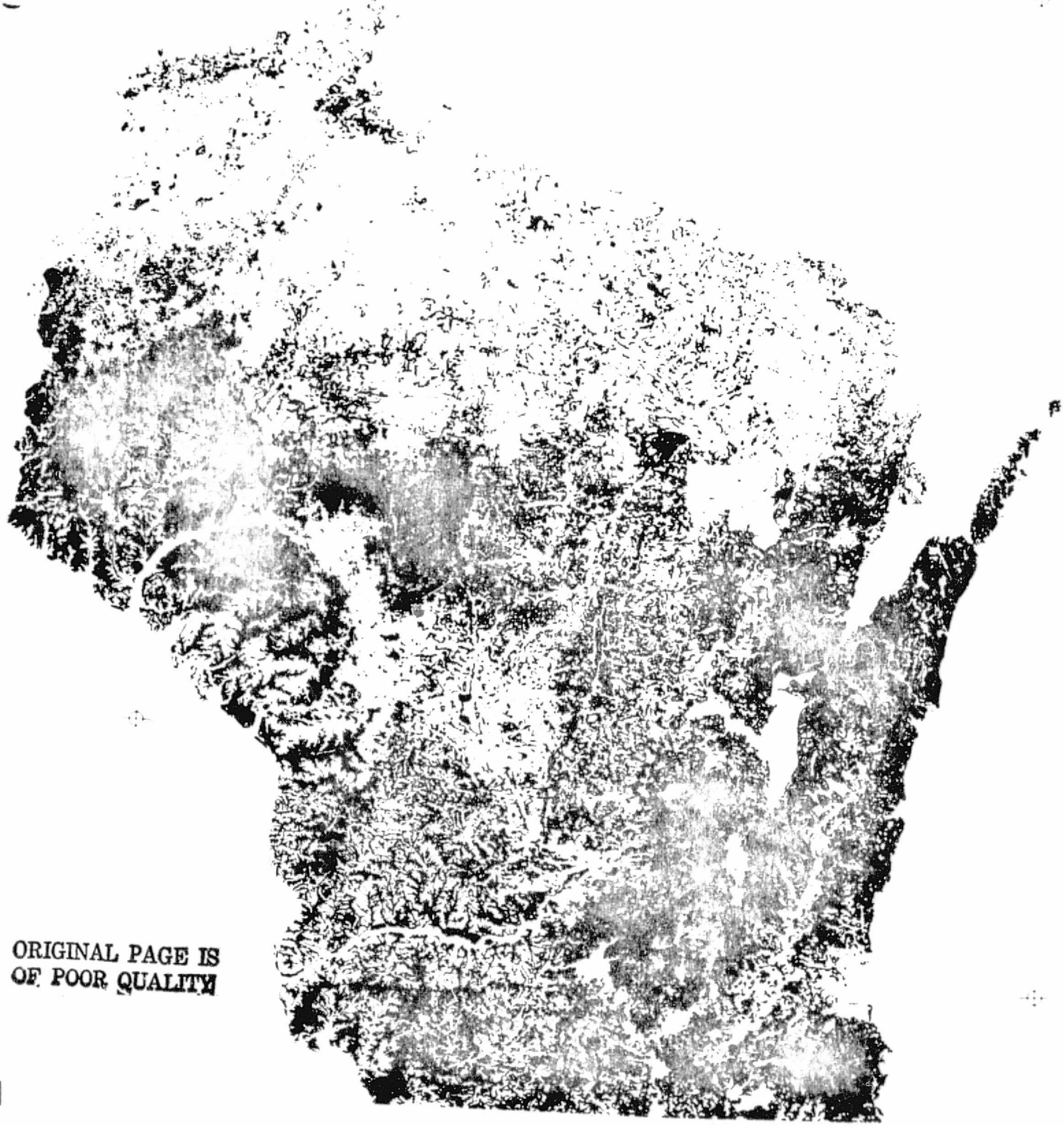


FIGURE 2.2.13 Agricultural Land and Other Open Areas in Wisconsin.

imagery to classify the eutrophic status of inland lakes in Wisconsin.* The DNR has allocated $6000 for partial funding of personnel and supplies for the project. The DNR is also supplying ground truth in the form of water quality parameters for 200 lakes during the summer of 1973. It is anticipated that similar ground truth will be gathered during the summer of 1974.

The imagery used are the ERTS 9" x 9" positive transparencies from bands 5 and 7. Densitometric values for each of the lakes in Wisconsin over 100 acres in size are being determined. Preliminary analysis has indicated that the ratio of the exposure from band 5 to band 7 is a good indicator of turbidity. Turbidity in turn seems to be a good indicator of eutrophication.

Densitometric analysis of the imagery has been rapid. To date measurements have been made on 1100 lakes from bands 5 and 7. Measurements for 20 lakes on five different dates have also been made. The correlations of the measurements from the transparencies to the ground truth from the 200 lakes monitored by the DNR are being made. It is anticipated that a report will be submitted to DNR by 1 June 1974 dealing with a preliminary classification of all the lakes in Wisconsin over 100 acres in size. Further work is anticipated with the DNR to refine the lake classification scheme with an increase in funding from the DNR.

2.2.5 REGIONAL GEOLOGICAL STUDIES

The Geological and Natural History Survey of the University of Wisconsin-Extension is the state agency assigned by statute to study the State's mineral

*The data analysis is under the direct supervision of an investigator at the University of Wisconsin, Dr. Frank L. Scarpace.

C-2

resources, soils, waters, plants and animals and act as a repository for this information. As natural resource management, land use planning and solutions to environmental problems require an extensive and accurate base of geologic and natural resources information, the Survey, a "non-auditable contributor not to be paid by NASA", is a participant in the "Evaluation of the Application of ERTS-1 Data to the Regional Land Use Planning Process".

To date the Survey has not been able to undertake an intensive study to critically evaluate ERTS imagery as a geologic tool for Wisconsin. As is true with any small state survey, priority must be given to on-going and funded projects. Nevertheless, one of the Survey geologists chose a 12 county area and a portion of 3 additional counties in northeastern Wisconsin for preliminary study as reported here. This area was chosen primarily for 5 reasons, namely:

a) The area is comprised of glacial, sedimentary and igneous terrain.

b) Much of the Precambrian area is the site of active exploration for metallic minerals by major mining companies.

c) The area may be considered "geologically remote" as the most detailed maps of the entire area are at a scale of 1:500,000 with many sections labeled only as "granite and undifferentiated igneous and metamorphic rock".

d) The Survey has an active geologic mapping project, at a scale of 1:24,000, in Marathon County located in the southwest portion of the study area.

e) The investigator would not be biased by previous familiarity with the area.

Ten 9" x 9" 1:1,000,000 scale film transparencies of Bands 5 and 7 representing fall, winter, and spring imagery were employed:

Date	Identification Number
12/13/72	E 1143-16095-5
12/13/72	E 1143-16095-7
2/25/73	E 1217-16211-5
2/25/73	E 1217-16211-7
3/31/73	E 1251-16095-5
3/31/73	E 1251-16095-7
4/18/73	E 1269-16095-7
8/04/73	E 1377-16084-7
8/05/73	E 1378-16144-5
8/05/73	E 1378-16144-7

Geologic work has shown the presence of "greenstone" belts in the Precambrian rocks of northern Wisconsin. These belts are often sites of mineralization. However, most of the study area is covered by a mantle of glacial drift. Thus much of northern Wisconsin, including the study area, has unknown mineral potential.

Recent reports such as those by N.F. Day (1974) indicate that there is a high degree of correlation between linear and curvilinear features observed on ERTS images and sites of mineralization. That Wisconsin does have mineral potential is indicated by the presence of "greenstone" belts and the recent discovery of commerical copper deposit outside the study area. Therefore, a map of linear and curvilinear features observed on ERTS imagery might be important to delineate future exploration sites. Additionally, LaBerge and Myers (1972) state that linears in the form of shear zones "must be recognized as a dominant feature of the Precambrian geology of Northern Wisconsin".

With only the aid of a light table and a 3" reading glass, each of the transparencies were studied. All linear or curvilinear data observed by the investigator was plotted on a clear film overlay that was registered to a 1:1,000,000 U.S. Geological Survey

Minimum Culture Base Map Transparency diazo copy of the area. Obvious culture features, such as the section line roads in Marathon County, that would not be related to geologic or hydrologic conditions were not included on the overlay. Figure 2.2.14 is a map showing the linear and curvilinear features observed on the ERTS images.

The next step was to compare the data from Figure 2.2.14 with the best available ground truth. A series of transparent overlays as a scale of 1:1,000,000 showing distribution patterns were constructed from published and unpublished reports of the Survey, namely:

Overlay	Map Source
Soils	Soils of Wisconsin, 1968 scale 1:710,000
Structure	Map of Northern Wisconsin Showing Areal Geology of Precambrian Rocks, 1970 scale 1:500,000
Geology	Preliminary Geologic Map of the Iron Mountain Sheet, 1973, scale 1:250,000 Preliminary Geologic Map of Green Bay Sheet, 1973, scale 1:250,000 Field Trip Itinerary and Geologic Map of the Precambrian Terrain in Northeastern and Northcentral Wisconsin, 1973, scale 1:500,000
Glacial features	Glacial Features of Wisconsin, 1956-unpublished, scale 1:1,000,000
Drift Thickness	Thickness Map of Unconsolidated Surficial Deposits in Wisconsin, in press scale, 1:1,000,000

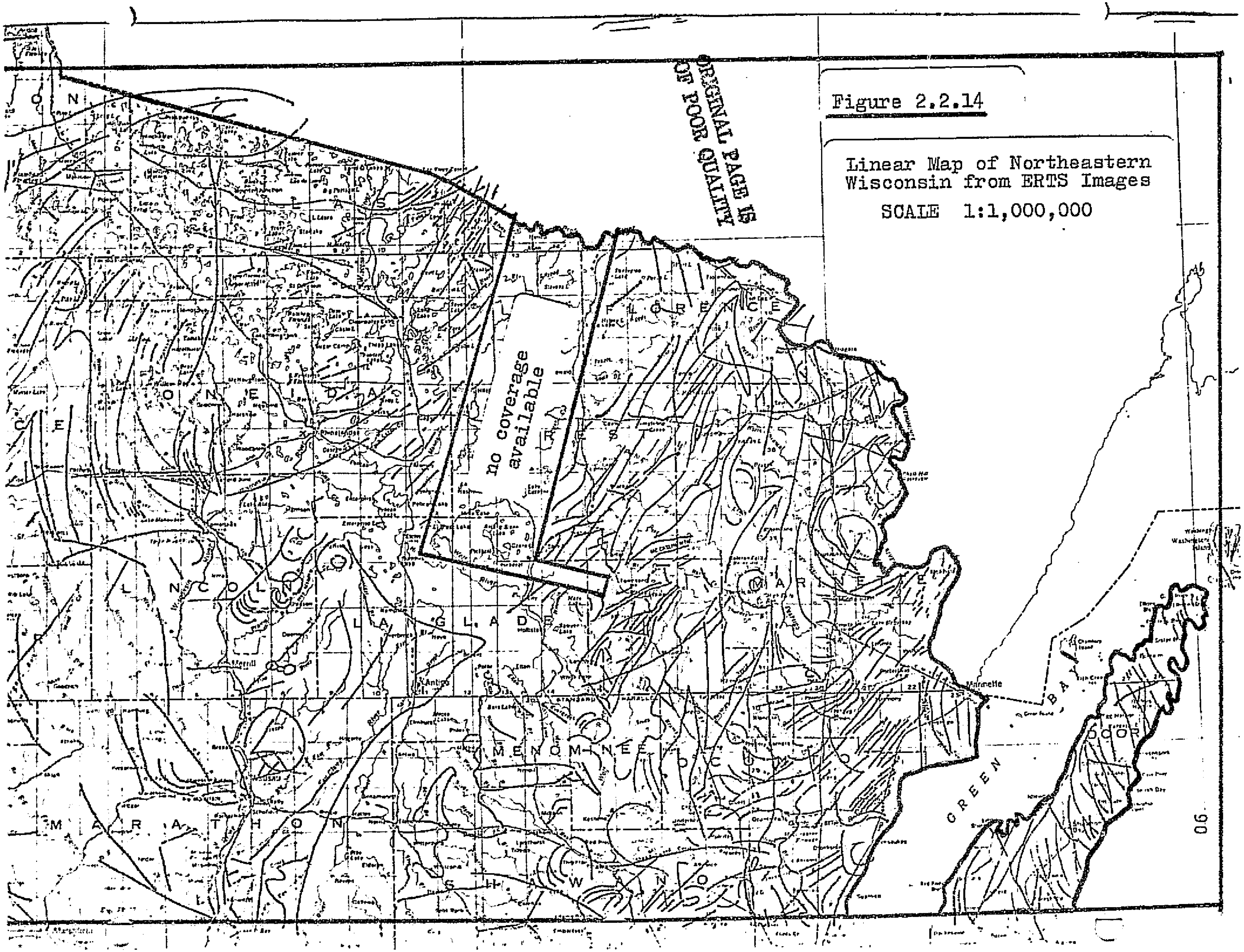


Figure 2.2.14

Linear Map of Northeastern Wisconsin from ERTS Images

SCALE 1:1,000,000

The "Map of Northern Wisconsin Showing Areal Geology of Precambrian Rocks" is a compilation using all available, published and unpublished, data concerning the Precambrian rocks of northern Wisconsin. Likewise, the map of "Glacial Features of Wisconsin" includes the glacial information published at 1:250,000, on the "Pleistocene Geology of the Door Peninsula, Wisconsin", and the "Pleistocene of Part of Northeastern Wisconsin" and other reports. The maps fromthese reports were also used in making visual comparisons but were not reduced to a 1:1,000,000 overlay.

Comparison of these overlays and other maps to Figure 2.2.14 indicates a poor correspondence, with minor exception, between the "ground truth" and data derived from the ERTS imagery. The primary reasons for this discrepancy are that at a scale of 1:1,000,000, the ERTS imagery contains more detail than is presently available on our best available maps and that the area has not undergone any intensive or extensive field study as to structure, glacial features, or geology in the last 50 years. Certainly Wisconsin's accurate base of geologic and natural resource information is lacking in the study area. ERTS imagery may be of considerable value in enhancing this much needed but presently inadequate information base.

Although the correspondence between maps available and the data derived from the ERTS imagery is poor, most of the linear trends found on the imagery do correspond to the known glacial trends of the area. A few of the ERTS linears can be ascribed to known end moraines and many additional linears seem to lie in areas where drumlin fields and/or fluted ground could be expected to occur. Also, many of the longer linears and curvilinears recognized occur in areas presently mapped only as "thin ground moraine" and "pitted outwash". Presumably these linears may represent buried moraines or bedrock highs. Inspection of topographic maps of the area would aid in the delineation of the features but unfortunately much of the study area has only planimetric coverage. Topographic coverage by 7 1/2 quadrangles will be available though, in the near future.

In order to separate the linear features caused by glacial activity from those that are bedrock controlled, detailed surficial and glacial geology maps would be most useful. Fortunately, a detailed preliminary reconnaissance airphoto analysis study was done for the U.S. Navy Underwater Sound Laboratory's "Project Sanguine" using airphotos at a scale of 1:20,000 and 1:66,000. This study, "An Airphoto Analysis of a Portion of Wisconsin & Michigan for 'Project Sanguine'" (1969) includes most of the area covered in this report.

A preliminary spot check of ERTS derived linears and curvilinears with the "Project Sanguine" airphoto analysis maps of landforms, soils, and rocks shows good correlation. By using the airphoto analysis maps as "ground truth" it may be possible to separate the glacial linears from the bedrock linears. Also, as overburden thickness does not exceed 50 feet in many parts of the study area, the linears of bedrock origin expressed through the drift should be especially helpful in the study of the Precambrian geology and mineral exploration in the study area. At the same time, this separation of linears also would enhance definition of glacial features and ultimately could result in resource pattern maps of both glacial and bedrock materials which are so important to resource management and planning.

As the utility of ERTS imagery in solving earth problems is becoming more widely known through reports in professional journals, Wisconsin workers in the geologic fields are becoming increasingly interested in the use of ERTS imagery to their area of concern. The Survey views ERTS imagery as another useful tool for mineral exploration, geologic, land use, and resource problem solving and definition. Although the Survey cannot under present budgetary restrictions use ERTS to its ultimate advantage, it is hoped that the Survey can provide basic information on ERTS derived data to professional users for substantiation in the field and thereby add to Wisconsin's base of geologic and natural resource information.

2.3 REQUIREMENTS FOR INTERAGENCY INVOLVEMENT

2.3.1 INTRODUCTION

The third objective of the research effort, as stated in the original proposal, was; "To determine the need and usefulness of ERTS-A data for various state and university groups to obtain interagency and interdisciplinary involvement in data analysis, interpretation and application to current environmental problems and land use policies." The principal mechanism developed to investigate this objective was the ERTS Advisory Council. This Advisory Council was organized to bring together the various land use interests within the state of Wisconsin in order that they might interact with the Principal Investigators of the project. This was an attempt to involve the land use data users in the evaluation of the application of data generated from satellite and high altitude aircraft platform for regional and state land use planning. Members of the Advisory Council were selected to represent:

- Agriculture
- Conservation and Preservation
- County Planning
- Forestry (Public and Private Sectors)
- Recreation (Public and Private Sectors)
- Regional Planning
- State Department of Natural Resources
- State Environmental Affairs

State Planning
State Transportation Planning
University Extension
Utilities Planning

Table 2.3.1 entitled "ERTS Advisory Council" presents the members and their affiliation.

During the duration of the project the Advisory Council met as a body, on three occasions. The first meeting was a half day presentation of the characteristics, capabilities, and limitations of the ERTS system. The second and third were full day workshops directed towards the evaluation in user terms of the research investigation to date. In addition to these formal meetings of the entire council, many informal meetings were held with sub-groups to examine elements of the research effort which were not of general concern.

2.3.2 RESULTS

2.3.2.1 Basic

There are two categories of results under this objective. The first is application by operational agencies of the ERTS and RB-57 generated data. The second is the development of a more effective management mechanism for coordinating and focusing the research activity to the needs of the user community.

2.3.2.2 Application by Operational Agencies

Based upon the introduction provided by the Advisory Council many of the represented agencies are currently using ERTS and RB-57 generated data in their operational programs. These include, the Southeastern Wisconsin Regional Planning Commission which is employing the data to update information relating to vegetational conditions within the region; the West Central Regional

Planning Commission which is in the process of employing the data to generate a land use and land cover inventory of their region; the newly created Bay Lakes Regional Planning Commission which is considering the use of the data as an integral component of their information system; the State Department of Administration which has utilized ERTS data in overview assessments of the state land resources and is considering the use of this type of data as an integral component of their "Path of Development" approach to determine geographic areas in need of refined inventory and regulation; and the State Department of Natural Resources which in cooperation with the University is using ERTS data to generate a first level inventory of the Eutrophication level of the Lakes in Wisconsin.

Although these specific functional applications are being undertaken and funded by the operational agencies indicated, the initial linkage of problems to methods was largely accomplished through the functioning of the Advisory Council.

2.3.2.3 Development of a More Effective Management Mechanism

Although the Advisory Council, as indicated above, did perform a valuable function in linking problems to methods, an examination of the areas of operational application above indicates that only one is specific, namely the classification of eutrophication levels. The remainder are all general in character and largely consist of simply employing ERTS and RB-57 generated data for general inventory. The Advisory Council has been relatively ineffective for delineating and evaluating specific areas of application of satellite data. This failing of the Council has been examined by the Principal Investigators with sub-groups of the Council, in order to determine causes and to recommend a more effective mechanism for the future.

The Advisory Council has had procedural problems throughout its existence which has severaly limited its effectiveness. Those which could be identified are: the lack of definition of the responsibilities of the Council; the diversity of the expertise of the membership and size of the group; the inability of the users of land use data to articulate specific data needs; and the inadvertant mixing of data requirements for land use related research with that required for regulation and control.

Based upon this assessment of the functioning of the Council the entire Interagency Involvement research objective was re-examined by a subset of the Council in an effort to: (1) more precisely define the problem of the effective interfacing of the multiple agencies, and (2) define a management organization which would be structured to meet the problem as defined.

Four basic elements of the management problem were identified. These are:

1. Administration and Coordination: Those functions associated with the operational support of any complex research activity including: (a) fiscal administration, (b) orderly receipt, storage and retrieval of data, (c) effective coordination of personnel and equipment, and (d) resolution of problems of priorities.
2. The Data/Information Flow Sequence: In any remote sensing activity, be it operational or research, four basic functions can be identified. These are illustrated in Figure 2.3.1 entitled "Data/Information Flow Sequence" as they apply to this ERTS investigation. Insuring that each of these functions operate smoothly is a management responsibility. In the past, the function most difficult to recognize and achieve has been information analysis.

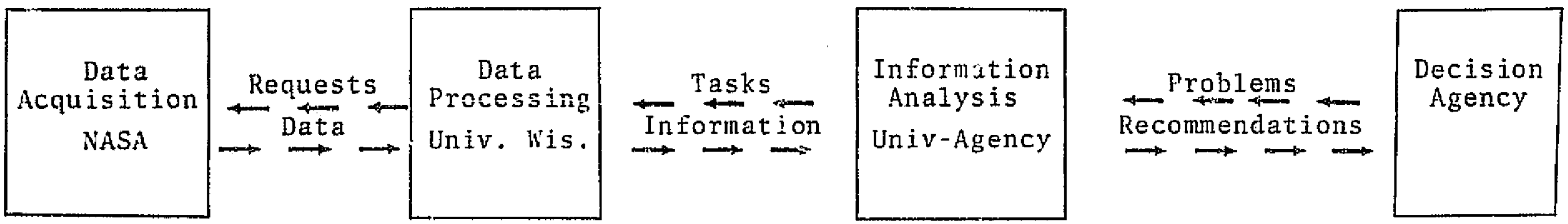


FIGURE 2.3.1 Data/Information Flow Sequence

TABLE 2.3.1

ERTS ADVISORY COUNCIL

Mr. Farnham Alston
Governor's Asst. for Environmental Affairs
Governor's Office
Madison, Wisconsin

Mr. David A. Anderson
Hydrologist/Forester
U.S. Department of Agriculture
Forest Service, Eastern Region
Milwaukee, Wisconsin

Dr. Marvin T. Beatty
Center for Resource Policy Studies
University of Wisconsin-Extension
Madison, Wisconsin

Mr. Harland E. Clinkenbeard
Assistant Director
Southeastern Wisconsin Regional Planning Commission
Waukesha, Wisconsin

Mr. Arthur Doll
Director, Bureau of Planning
Wisconsin Department of Natural Resources
Madison, Wisconsin

Mr. Jonathan P. Ela
Midwest Representative
Sierra Club
Madison, Wisconsin

Mr. Fred Goold
Mt. Telemark Four Seasons Development
Hayward, Wisconsin

Mr. George Gundersen
Division of Planning
Wisconsin Department of Transportation
Madison, Wisconsin

Mr. Arthur R. Kurtz
Assistant Secretary
Wisconsin Department of Agriculture
Madison, Wisconsin

Mr. E. Jack Schoop
Assistant Director for Planning
Wisconsin Department of Administration
Madison, Wisconsin

Mr. Bernard M. Slick
Chief, Environmental Management
U.S. Department of Agriculture
Forest Service, Eastern Region
Milwaukee, Wisconsin

Mr. Thomas C. Webb
Director of Data Processing
Wisconsin Power & Light Company
Madison, Wisconsin

Prof. James L. Clapp*
Dept. of Civil and Environmental Engineering
University of Wisconsin
Madison, Wisconsin

Prof. Ralph W. Kiefer
Dept. of Civil and Environmental Engineering
University of Wisconsin
Madison, Wisconsin

Mr. Michael M. McCarthy
Project Coordinator
ERTS Project
University of Wisconsin
Madison, Wisconsin

Prof. Bernard J. Niemann, Jr.
Dept. of Landscape Architecture/Environmental Awareness Center
University of Wisconsin
Madison, Wisconsin

Prof. Theodore Green III
Dept. of Civil and Environmental Engineering
University of Wisconsin
Madison, Wisconsin

Mr. Meredith Ostrom
Director
Wisconsin Geological and Natural History Survey
Madison, Wisconsin

*also Director, Environmental Monitoring and Data Acquisition Group

At times this has been neglected entirely with the data processing function directly linked to the decision function. At other times, although the function has been recognized, it has not had significant input from both the data processing and decision function. In the case of this ERTS investigation the Advisory Council was in a position to, and had the personnel to perform this function. The fact that it did not perform the function adequately was due to the procedural problems discussed above and the insufficient level of involvement of the Council.

3. The Interagency Interface: Although this aspect of the management problem is not present in all remote sensing operations it is very much an element in this investigation. The basic responsibility of the University is educational while the basic responsibility of a state or local agency is operational. On any cooperative research effort between these units, the interface must be constantly monitored in order to insure that the proposed focus of the research is maintained. Further, if during the course of the investigation it becomes necessary or desirable to change the direction of the research, this interface must function to insure that the new direction is compatible with both the requirements of the agency and the basic educational mission of the University. If, in some cases, differences cannot be resolved at this interface, there should be a mechanism to resolve differences at some other level.

4. Technology Shove-Need Pull Interface: Because this investigation relates to the application of ERTS generated data to problems confronted by state and local agencies, the investigation is involved in the transfer of technology. In

those cases where technology transfer has been most effectively accomplished in the past, a clear linkage between the technology and the need was present. This requires a working-level contact between the researcher who knows the technology and the operational person who knows the need. The Advisory Council, meeting at periodic intervals, was not effective in solving this aspect of the management problem.

2.3.2.4 Recommended Management Structure

After the elements of the management problem associated with the interrelationships between an operational agency federal, state and local governments and a university research unit, and those between the user of remote sensing data and the acquisition unit had been identified, the following management structure was designed. This structure was designed to meet the management needs imposed by these elements as they apply to a multiple component ERTS research program and to be consistent with the capabilities and limitations of the existing organizations involved. The management structure developed is shown diagramatically in Figure 2.3.2 entitled "Recommended Management Structure".

The Institute for Environmental Studies (IES) is an administrative unit of the University of Wisconsin-Madison which has as its objectives: (1) providing leadership in interdisciplinary environmental research by initiating and coordinating research programs; (2) initiating and supporting cross-disciplinary undergraduate and graduate courses and degree programs; and (3) providing for internal communication among groups and individual faculty members involved in environmental research, training and extension programs. The IES has the capability of drawing upon the resources of the entire University of Wisconsin-Madison.

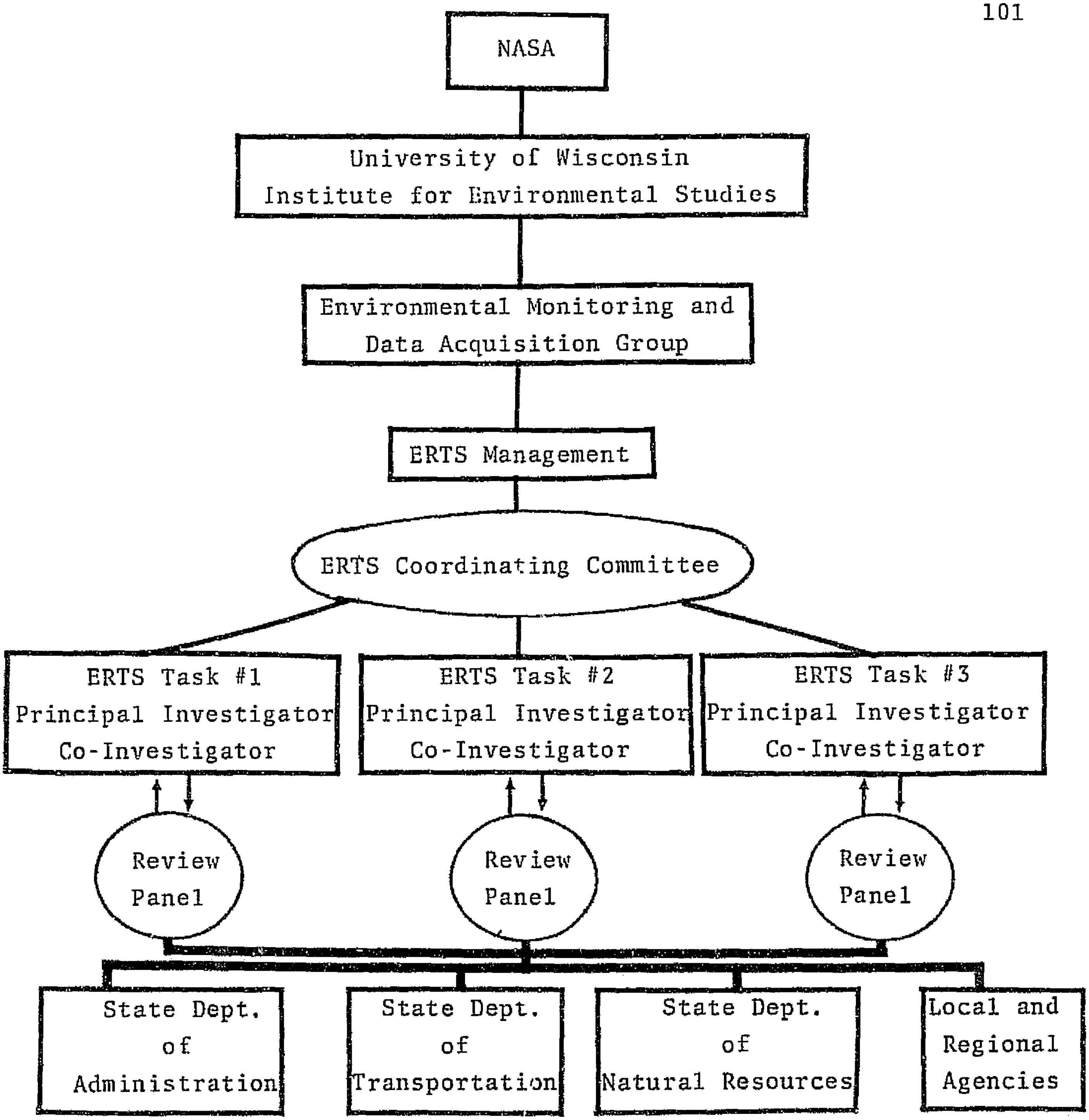


FIGURE 2.3.2 Recommended Management Structure

The Environmental Monitoring and Data Acquisition Group (EMDAG) is one of seven research centers and groups under the direction of IES. The EMDAG is a formally structured ongoing, composite effort focused upon the enhancement, extension and coordination of the monitoring and data acquisition efforts of the IES and the University at large.

In this recommended structure the Director of the Environmental Monitoring and Data Acquisition Group would be responsible for the administration and coordination of the ERTS investigations. In order that maximum coordination be achieved, he would be assisted by a Coordinating Committee. The Coordinating Committee would consist of the Principal Investigators of the separate investigations plus a representative of the Department of Administration, the Department of Natural Resources, the Department of Transportation and appropriate regional and local agencies. The Director of EMDAG would act as chairman of the Coordinating Committee. The Coordinating Committee, in addition to tis responsibilities for coordination, would be charged with resolving problems of priorities.

The Director of EMDAG would be responsible for receipt of data/information from NASA and its orderly and timely distribution to the Principal Investigators. In addition, he would be responsible for maintaining an effective storage and retrieval system for all data/information in order that it be available to all related investigations. Each Principal Investigator, upon receipt of data/information from the Director, would be responsible for the flow as it applies to his investigation. In particular, the Principal Investigators would be responsible for assuring that the appropriate state, regional and local agency personnel are a part of the flow sequence.

In order that the University research effort be directed and maintained constant with the needs of the operational agencies, a Review Panel would be established for each investigation. These Review Panels would have three functions:

(1) to participate in establishing the project definitions and objectives,
(2) to maintain the direction and the focus of the project upon the agencies needs via a review process, and
(3) to evaluate the results of the project at the conclusion of the funding period.

It is anticipated that the panel members may carry a benefit to their respective agencies by becoming more knowledgeable of the capabilities and limitations of satellite remote sensing.

In order to meet these functions, the panels would be required to meet with the research team a minimum of three times during the funding year, typically at the beginning, mid-point and end, to review the project to date and to consider future direction. As a product of each review, the panel would be required by letter of agreement with the appropriate agencies to prepare a report which would include its evaluation and recommendations. Copies would be sent to: (a) the Principal Investigator; (b) the agencies involved; (c) the Director of EMDAG; and (d) NASA, by inclusion as an appendix in the appropriate periodic report. This procedure is designed to force real dialogue between the researchers and the user agencies. By this process, problems, both defined and undefined, would be exposed as they develop during the course of the investigations. In the past, some problems have not been brought to light until after the submission of the final project report.

Although the technology shove-need pull interface element is closely related to the University-State Agency element of the management problem, it cannot be met by the same mechanism. Since the Technology Shove-Need Pull Interface specifically deals with the transfer of technology, contact at the working level is required at a frequency much greater than the Review Panel meetings. Therefore, each investigation would identify Co-Investigator (or Co-Investigators) from the appropriate units of the involved agencies. These Co-Investigators, along with the Principal Investigators, would be responsible for the day-to-day efforts to meet the objectives of the project as monitored by the review panels.

3.0 SUMMARY, CONCLUSIONS, RECOMMENDATIONS AND FURTHER WORK

3.1 INTRODUCTION

In order to assess the applicability of a satellite such as ERTS to the statewide and regional planning process it is necessary to define the needs of the system. At the present time, state and regional planners are being required to predict the effects of environmental alterations such as highways, urban expansion and energy production systems in definite quantitative terms. In addition, data describing many of the state's important resource systems in a statewide content are not available. To accomplish prediction of impact plus statewide inventories, planners need physical resource data in a form which provides for manipulation, both quantitatively and qualitatively. Comprehensive and accurate resource information is lacking. Existing information simply is not sufficient to solve or defend existing or future environmental problems.

The potential strength of ERTS-1 lies in the fact that it has the capabilities to monitor the entire state of Wisconsin, to a certain degree as often as every eighteen days. This fact alone justifies the study of its feasibility as a data source since no other method has been implemented or proposed to date which has the potential to produce this amount of data for large areas at a comparable frequency. Aircraft methods of remote sensing, both low and high altitude, are economically prohibitive at this time to achieve the same spatial coverage as ERTS-1. The existence of ERTS-type coverage is therefore justified by the magnitude of the present data requirements alone.

The sensing abilities of the satellite in terms of the output data products are not revolutionary. Similar uses of scanning instruments have been successful at much lower aircraft altitudes. Many methods of data analysis have already been developed to deal with the types of sensors on board ERTS. ERTS is the first remote sensing instrument with its specific sensor-platform combination.

This ERTS program has been investigating three principal areas: (1) the comparison of ERTS-derived data with data derived from more conventional sources; (2) an inquiry into the usefulness of ERTS-1 data for the regional land use planning process; and (3) an investigation of the management problems associated with interdisciplinary and interagency application of ERTS-generated data to the land use planning process.

3.2 COMPARISON OF ERTS-DERIVED DATA WITH CONVENTIONAL DATA

Section 2.1 described our investigation using both ERTS imagery and ERTS computer compatible tapes as data sources for the construction of resource "data banks" which could be utilized in regional land use planning and allocation decision making. The investigation was concerned with the use of ERTS-1 data as a source for extraction of resource information the nature of which had already been shown to be necessary for data bank construction. Even though the comparison utilized a data bank constructed for an interstate highway location problem, the data are reflective of statewide needs. The study was based on the premise that the benefits of repetitive satellite coverage could make ERTS a superior data source if the quality of its data could be proven sufficient.

Interpretation of resource data was performed on ERTS imagery with methods similar to those often used to extract information from lower altitude aerial photography (i.e. light table and optical magnification). The extracted data were then compared with the most accurate ground truth available to determine the reliability of the ERTS data. It was concluded that ERTS-1 imagery could not produce the resolution necessary for the extraction of the required data to the degree of accuracy provided by the lower altitude imagery. The accuracy of ERTS data was comparable to that of the high-altitude RB-57 imagery for some large patterns such as forests and agricultural land, but finer distinctions of smaller sub-categories could not be made. Therefore, although the ERTS imagery does provide a large area coverage and overview not attainable from aircraft platforms, it does not provide a suitable substitute for RB-57 photography in the process of natural resource data extraction.

In order to obtain maximum resolution of small ground elements, it has been shown that the ERTS digital tapes should be used. This implies the use of a man-machine interface such as the McIDAS system for manipulation of data. The McIDAS system is still in the development stage and its applicability to this phase of the research cannot be fully evaluated at this time. There is, however, little question that without some form of man-machine interface the full usefulness of ERTS-type data cannot be realized.

3.3 USE OF ERTS DATA FOR REGIONAL LAND USE PLANNING

Section 2.2 described the investigation of the use of ERTS data for regional land use planning and allocation decisions and included a consideration of: (1) highway corridor location using a LINEFINDER simulation technique using ERTS and conventional data; (2) the utility of ERTS data to the Wisconsin Critical Resources Information Program; (3) the use of ERTS images in a quantitative Lake Eutrophication Study; and (4) regional geologic studies using ERTS imagery.

The investigation of a highway corridor location using the LINEFINDER simulation technique using ERTS and conventional data was directed towards the fundamental question "what effect does the data source have upon the planning process?" In order to test the relationship between a data source and the decision on a regional basis, a portion of an Intersta Highway corridor was located using computer simulation techniques based upon: (1) ERTS-generated data;

(2) RB-57 generated data; and (3) conventional data. Corridors were located through two approximately 300km^2 test sites (Figures 2.3.2 and 2.3.3) for each data source for each of two policies. Although there is some agreement in the corridors selected, there are significant variations. The variations between the ERTS-based corridors and those based upon RB-57 and conventional data are caused in part by the inclusion of additional variables in the latter two data bases. However, the variations between the RB-57 and the conventional data based corridors must be directly attributable to the discrepancy between the data values stored in those systems since the same variables are included. Inasmuch as field checks have consistently indicated the superiority of the RB-57 data source for these variables, the conclusion must be drawn that the conventional data base incorrectly biases the decision. This investigation is continuing and will be reported on further in October 1974.

The Critical Resources Information Program is one of several current and potential State of Wisconsin programs in the general area of land resource assessment, planning and management. It is the program with the most specific data needs and, as such, can best serve as the means to evaluate the utility of the ERTS program in land resource planning activities. The CRIP effort could provide a partial basis for the configuration of states open space; for additions to the scenic easement programs, for scientific, wilderness and research and educational natural area protection programs; and for a state perception of the extent and quality of its physical resource systems.

It is important to examine the utility of ERTS as a data source within the contexts of both the short run and the long run objectives.

In the short run (1974), CRIP is providing: (1) a methodology to assess the criticality of land and water areas within the state; and (2) an information system to store, manipulate and retrieve critical resource data.

Short run considerations imply reliance on manual data extraction using ERTS transparencies viewed on a light table or with a color additive viewer. ERTS images, in combination with other data sources such as USGS topographic maps, are being used in some cases to spatially locate and provide context for the significant resources identified by CRIP (e.g. wetlands, forests, lakes and shorelands). ERTS also is being considered to serve as the base document for the purpose of sampling these resources. This sampling effort is to establish a basis for measuring criticality, provide an initial approximation of the states critical resources, and test the assessment methodology. The potential usefulness of ERTS in this endeavor is based on the results of the ERTS, RB-57 and REMAP data bank comparisons and preliminary attempts to delineate resource types on clear acetate overlays of ERTS images, as previously discussed.

In the long run (1975+), CRIP will undertake the actual delineation and monitoring of critical resource areas on a statewide basis. We anticipate that the interactive manipulation of ERTS digital tapes could provide a means to acquire detailed data on selected resource variables. The Sheboygan Test Site results reveal the ability to delineate the overall structure of a wetland area and to identify wetland vegetative communities. Utilizing more sophisticated techniques such as image enhancement, density slicing and pattern recognition which McIDAS will offer, it may be possible to obtain detailed data on such variables as surface water pollution (algal blooms, turbidity), forest vegetative type, the extent of exotic species, the extent of flooding, surface water level fluctuations (especially important in identifying wetlands), and the extent of resource buffer areas.

ERTS appears as potentially the best medium for large scale resource monitoring. ERTS must therefore be considered most applicable to the "general objective" scale in the CRIP overall methodology. At present, the sensor does not appear to be spatially discrete enough for the "detailed assessment" procedure. However, with the looping and flicker techniques to be provided by the McIDAS system, sequential images of one area can be viewed rapidly with emphasis on spectral changes. These changes may be suggestive of resource alteration, of phenological phenomena, and of changes in urban and rural development (which is especially important to the extent that development presents a threat to resource integrity). The use of ERTS as a monitoring device becomes even more attractive when comparisons are made with the alternatives (high/low altitude aerial photography and ground surveys) on the basis of cost, time and frequency of updating.

ERTS can also be used as an aid for communicating the purpose and need of the CRIP study. The ability to visualize the limited and threatened nature of the state's resources is greatly facilitated by displaying individual ERTS images or ERTS mosaics of the state. The capability of presenting a time series display of dynamic environmental features using McIDAS could enhance the use of ERTS output as a communication device.

The investigation of the Use of ERTS images for quantitative Lake Eutrophication is being conducted in cooperation with the State of Wisconsin Department of Natural Resources. This investigation was undertaken due to the requirement of the Department of Natural Resources to classify the lakes in Wisconsin by levels of eutrophication. Preliminary results indicate that the ratio of exposure of band 5 to band 7 is a good indicator of turbidity which seems to be an indicator of eutrophication. This investigation is continuing and a preliminary classification of all lakes over 100 acres in Wisconsin will be completed prior to October 1974.

The investigation dealing with Regional Geologic Studies using ERTS images is being conducted in cooperation with the Wisconsin Geological and Natural History Survey. Ten 9"x9" 1:1,000,000 scale ERTS film transparencies of bands 5 and 7 representing fall, winter and spring imagery were employed to prepare a map (Figure 2.2.14) showing linear and curvilinear features of a natural origin observed on the ERTS images. Many of the linear trends correspond to the known glacial trends of the area. Other linears should be related to bedrock fracture patterns. Because an accurate base of geologic and natural resource information is lacking in the study area, it was not possible to ascertain the nature of all the linear and curvilinear features found in this test area. One important conclusion of this study is that the features observed on ERTS images have served to point out the lack of sufficient geologic information for much of the State. Although the Survey cannot under present budgetary restrictions use ERTS to its ultimate advantage, it is hoped that the Survey can provide basic information on ERTS derived data to professional users for substantiation in the field and thereby add to Wisconsin's base of geologic and natural resource information.

In summary, ERTS-1 has the potential to provide extremely valuable data to planners at the state level with a frequency never before possible. The mechanics of the system make it a unique data source. Research has been concentrated in the area of evaluation of the data quality as compared to data needs. Initial attempts at analyzing ERTS-1 data with processes used for conventional aerial photography have shown that the true value of the data cannot be realized with these methods alone. Computer methods of working directly with the digital information have shown much promise towards fulfilling many of the needs of statewide planning. At this point in time, however, the McIDAS system is still in its early stages. Its potential appears to be an important element in assessing the value of ERTS since the data format and production rate of the satellite requires improved methods of analysis.

3.4 DEVELOPMENT OF A RECOMMENDED MANAGEMENT STRUCTURE

Section 2.3 describes our investigations of the management problems associated with the interdisciplinary and interagency application of ERTS-generated data to the land use planning process. The principal mechanism developed to investigate this objective was the ERTS Advisory Council. This Council was organized to bring together the various land use interests within the State of Wisconsin in order that they might interact with the Principal Investigators of the project. The Council and sub-groups of the Council examined the functioning of this project as well as past related projects in order to identify the elements of the management problem. Based upon this examination the following elements were defined: (1) Administration and Coordination; (2) the Data/Information Flow Sequence; (3) the Interagency Interface; and (4) the Technology Shove-Need Pull Interface. After these elements were defined, a recommended management structure was developed which was specifically designed to meet the management needs imposed by these elements as they apply to a multiple component ERTS research program and to be consistent with the capabilities and limitations of the existing agencies involved. This management structure was endorsed by the agencies involved by letters of agreement and was fully incorporated into the ERTS Follow-On Investigations proposed by the University of Wisconsin-Madison in cooperation with the State of Wisconsin Departments of Administration, Transportation, Natural Resources, and the Office of Emergency Energy Assistance.

3.5 CONCLUSIONS AND RECOMMENDATIONS

As a result of the work performed to data on the investigation of the utility of ERTS-1 at the statewide and regional planning levels, the following represent the specific conclusions and recommendations of the investigators based on the present status of the investigation.

(1) Land resource data/information, regardless of source, must be spatially referenced to be of maximum value for planning.

(2) It is essential to establish precise definitions of land resources and the parameters which determine them.

(3) It is essential to establish precise criteria and data required for the assessment of land resources.

(4) Optimum land resource measurement techniques for a data source such as ERTS must be evaluated in terms of economics, requirements of resolution, spatial location and accuracy of identification.

(5) ERTS is the only physical resource imaging system now available which can cover state-size areas at frequent intervals.

(6) Composite ERTS imagery (mosaics) is superior to any other data/information source for perceiving and delineating macro landscape units.

(7) Composite ERTS imagery (mosaics) is an effective device for communicating to non-planners the directions and significance of land use impact on state and regional resources.

(8) The identification and extraction of reliable resource information from ERTS generated data are functions of the variable being extracted, the time of year, and the MSS band employed.

(9) For broad land cover assessments, data/information derived from ERTS by non-sophisticated methods (interpretation using light table and magnifying lens), is sufficient for initial resource assessments at the state or regional policy level.

(10) ERTS derived data/information is superior to conventional land use data for those items (a) which change rapidly with time, and (b) for which conventional data are not available.

(11) Employing non-sophisticated data/information extraction techniques with ERTS imagery tends to yield overestimates of the size of large resource patterns. This overestimation is caused by the relatively large instantaneous field of view of the MSS system and should be reducible by proper interpreter training.

(12) Land resources smaller than 1/10 square kilometer

in area are usually overlooked by interpreters employing non-sophisticated techniques for ERTS image analysis.

(13) The identification and extraction of reliable resource information from RB-57 generated data are functions of the variable being extracted, the time of year, and the type of sensor employed.

(14) High altitude aircraft (RB-57 photography, scale 1:120,000) derived data/information is superior to ERTS as a data source in terms of resolution and accuracy of identification.

(15) Machine-based analysis techniques applied to ERTS-generated data/information yield much more specific information than non-sophisticated visual techniques.

(16) Machine-based data extraction systems should be interactive, employing the man to identify and the machine to analyze, measure and store.

(17) Regardless of what type of extraction system is employed an interpreter with a broad resource knowledge of the geographic area under study can extract significantly more information than an interpreter who is unfamiliar with the area. The optimum combination is a knowledgeable resource expert and supporting interactive machinery.

(18) An optimum state or regional data/information system will encompass a hierarchy of data sources including satellites, high altitude aircraft, low altitude aircraft, ground surveys and other conventional sources.

(19) ERTS can provide a focus from which the regional land use planning data/information needs can be defined as specific requirements for more detailed information by individual variables and decision level.

(20) Any effort directed towards the implementation of ERTS (or any other system) as a data source for a regional information system must be inter- and

multi-disciplinary.

(21) It is essential to integrate development funds from multiple sources in order to develop and implement a comprehensive data/information system for state and regional planning.

(22) The effective implementation of a state or regional data/information system requires the assignment of responsibility, authority and adequate funds to a single agency.

(23) The successful implementation of a state or regional data/information system requires interagency cooperation and may require interagency reorganization.

3.6 FURTHER WORK - SHORT RANGE

This ERTS investigation has been extended until October 1974, at which time a second Final Report will be submitted. Work planned for the period May-October 1974 is outlined below.

3.6.1 DATA EXTRACTION FROM PHOTOGRAPHIC IMAGERY

An additive color viewer, the International Imaging Systems Model 6040PT is recently available to the project. Utilizing 70mm ERTS film chips, viewing on screens attached to the viewer can be done at scales of 1:1,000,000 and 1:500,000. Using the projection feature of this viewer, viewing on a detached ground-glass screen can be accomplished at a scale of 1:250,000. Two principal investigations with this viewer are planned.

(1) Data Bank Comparisons by Spatial Location

Data for each of the data types listed in Section 1.2.3 will be extracted on a percent-of-cell basis for both the Green Bay Test Site and the Sheboygan Test Site using the additive color viewer at a scale of 1:250,000. These results will be compared with the original data extraction from ERTS transparencies using individual MSS bands at a scale of 1:1,000,000.

(2) Land Cover Maps

In Section 2.2.3, it was reported that statewide land cover maps were prepared showing four basic land cover classes (surface water, forested areas, urbanized areas, and agricultural land and other open areas). Data for these maps were extracted from ERTS transparencies at a scale of 1:1,000,000, fitted into a mosaic, and enlarged to a scale of 1:500,000. Using the additive color viewer at a scale of 1:250,000, land cover maps will be prepared showing the four basic land cover classes for at least one ERTS frame and reduce these maps to a scale of 1:500,000 for comparison with our original maps.

3.6.2 DATA EXTRACTION FROM ERTS COMPUTER COMPATIBLE TAPES

Section 2.1.3 described data extraction efforts to date using ERTS computer compatible tapes. The bulk of the work could be described as pre-McIDAS since only the McIDAS prototype (WINDCO) was available for most of the period. McIDAS is still under development and the exact nature of our involvement with McIDAS will depend to some extent on its developmental timetable. However, the following McIDAS work is anticipated: (1) interactive pattern recognition using a maximum liklihood classifier with a fast table look-up approach; (2) interactive full-color scene overlays from separate spectral channels; (3) scene navigation using ERTS and RB-57 data so that delineated areal output will be in actual physical dimensions (square kilometers) rather than tape-machine dimensions (numbers of pixels).

3.6.3 DATA BANK COMPARISONS BY MANIPULATIONS WITH THE LINEFINDER

Building on the work reported in Section 2.2.2, two areas of additional work are planned concerning the

LINEFINDER technique:

(1) To run additional routines using different policy weightings through at least one of the 10 x 30 km test sites.

(2) To analyze the routes selected by LINEFINDER to ascertain which data types caused the greatest difference in routes selected among the three data sources (ERTS, RB-57 and REMAP).

3.6.4 CRITICAL RESOURCE INFORMATION PROGRAM

Only limited involvement with the CRIP program is planned during the next 6 months as a part of this investigation. A proposal has been submitted for an ERTS Follow-On Investigation which is titled "The Use of ERTS Data to Inventory and Monitor Critical Land Resources for Statewide Planning and Management" (Proposal 2097A). If the proposal is funded, work will commence immediately to study in great depth the utility of ERTS to the CRIP program.

3.6.5 LAKE EUTROPHICATION STUDY

The lake eutrophication study described in Section 2.2.4 is continuing with partial financing from the Wisconsin Department of Natural Resources. The results of this study will be reported in our October 1974 Final Report.

3.6.6 REGIONAL GEOLOGIC STUDIES

A geologic analysis of linears from ERTS images of Northeastern Wisconsin was reported in Section 2.2.5. Geologic analysis of this area, and also an area in Northwestern Wisconsin, using ERTS images is continuing and will be reported in our October 1974 Final Report.

3.6.7 ECONOMIC ANALYSIS

Based upon this investigation an analysis will be made comparing the cost of extracting land use data from conventional sources to both ERTS and RB-57 generated data. This will be examined for: (1) simple visual extraction procedures; (2) multispectral viewing procedures (I^2S); and (3) data extraction employing computer compatible tapes. This will be reported in the October 1974 Final Report.

3.6.8 INTERAGENCY INVOLVEMENT

A conceptual framework for interagency involvement in ERTS investigations was set forth in Section 2.3 While no changes are anticipated to these concepts during the period May-October 1974, it is planned to involve the various agencies, as follows:

(1) A copy of this report will be sent to each member of the Advisory Council and feedback from Council members will be requested. This will probably involve a full-day Advisory Council meeting during Summer 1974.

(2) As mentioned above, the lake eutrophication study is being funded in part by the Wisconsin Department of Natural Resources.

(3) The Wisconsin Department of Administration is interested in funding additional ERTS work dealing with: (a) the preparation of statewide land cover maps, and (b) a further investigation of the monitoring aspects of ERTS data analysis. This work is under development.

3.7 FURTHER WORK - LONG RANGE

Five proposals for ERTS follow-on investigations were submitted from the University of Wisconsin-Madison in December 1973. These proposals deal with:

2097A The Use of ERTS Data to Inventory and Monitor Critical Land Resources for Statewide Planning and Management

2097B Lake Eutrophication and Turbidity Studies in Wisconsin

2097C Computer Accessing of ERTS Data to Monitor Snow Albedo for Estimating Statewide Allocation of Distillate Fuels

2097D Computer Applications of ERTS Data to Detect, Inventory and Map Wetlands and Related Resources for Planning, Management and Regulation

2097E Management of Multidisciplinary ERTS-B Projects, University of Wisconsin

Proposal 2097A (The Use of ERTS Data to Inventory and Monitor Critical Land Resources for Statewide Planning and Management) is a direct outgrowth of the ongoing ERTS-1 project described in this report. Future directions of ERTS research at the University of Wisconsin-Madison will depend on the nature of future ERTS funding.

APPENDIX - A

DEFINITION OF VARIABLES

APPENDIX - A

DEFINITION OF VARIABLES

This Appendix consists of a definition of 33 variables considered to be most significant for decision-making for land use allocations of one kilometer or larger such as transportation corridors, power plant sites, power transmission systems, large industrial concentrations and similar impact-producing phenomena.

APPENDIX A: DEFINITION OF VARIABLES

AGRICULTURAL	Land which is used directly or indirectly for the growth of food products, including crop, animal, or poultry farming. Lands within the agricultural area which are apparently idle are included in this category. Indicated by farm structures, cultivated fields, pasture land and the absence of residential, commercial or industrial development.
BEACH RIDGE	A ridge or rim-like area of stratified gravelly and sandy deposits which formed the beach of a lake at an earlier period.
COMMUNICATIONS, AIRFIELDS	Land used for airfields, roadways, highways, interchanges, telephone cables, gas lines and power transmission lines.
DRUMLINS	Long cigar-shaped hills formed by glaciers and oriented axially in the direction of glacial advance.
END MORAINE	A line of hills which mark the margin of a glacier or glacial stage.
ESKERS	Long, steep, sinuous ridges of coarse, somewhat stratified, glacial material which were formed by the deposition of material by rivers which ran within the glaciers.
ESCARPMENT	A long precipitous cliff-like ridge of land or rock commonly formed by faulting or fracturing of the earth's crust.
FOREST, LOWLAND	Forest characterized by swamp hardwoods, white cedar, tamarack, black spruce, balsam, and lowland birch.
FOREST, UPLAND	Forest characterized by upland hardwoods; white, norway and jack pines; popple; white birch; oak, hickory and pin oak.
FOREST, CONIFEROUS	Forest characterized by hemlock, white pine, red pine, jack pine, black spruce, white cedar, tamarack and balsam fir.
FOREST, DECIDUOUS	Forest characterized by southern or northern Wisconsin hardwoods.
FOREST, DECIDUOUS, CONIFEROUS	Forest characterized by northern or southern Wisconsin hardwood and conifer species

APPENDIX A (cont.)

GLACIAL LAKE	A flat area formed beneath bodies of impounded glacial meltwater and often characterized by fine chalky sediments of sand.
INTERCHANGE	The number of highway structures which allow access to high-standard highways without disrupting the flow of traffic on either of the intersecting highways.
GROUND MORAINE	An area of unstratified glacial material which was deposited behind the margin of a glacier when it melted.
LAKES	Any lake in excess of 50 acres which is not one of the Great Lakes.
LAKE MICHIGAN	Lake Michigan
LAKE OR POND LESS THAN 50 ACRES	Any pond or lake covering less than 50 acres of surface water as a basic management guideline for the restriction in use of power boats.
LIMITED ACCESS HIGHWAY	Highways which consist of two separated travelways with an absence of right-angle intersections. Access provided by interchanges. May be state or federal highways.
MARSH	A tract of low wetland often treeless and periodically inundated and characterized by grasses, sedges, cattails and rushes.
OPEN SWAMP	An area occupied by tagalder, willows, dogwoods, cattail marshes, grass or sedge marshes, leather leaf, cranberry marshes, and weedy peat.
RESIDENTIAL, RURAL	An area occupied by non-farm residences located away from population centers and recreational areas, indicated by the grouping of small numbers of units (5-10) with property size of approximately 10-20 acres or less.
RESIDENTIAL, SUBURBAN	An area of the cell occupied by residential units usually on the periphery of population centers as indicated by the lower densities, single-family units, curvilinear street patterns, a dotting of open spaces, and a separation from commercial or industrial land uses. Suburban residential units may also be classified as such if separated from the population center but located adjacent to highways, granting rapid access to the urban center.

APPENDIX A (cont.)

RESIDENTIAL, URBAN	An area occupied by higher-density housing, including multi-family units located within the population centers and generally with an intermingling of commercial and industrial land uses. Street patterns tend to be geometric.
RIVERS	A primary artery of a major river sub-basin. Major river sub-basins have been derived from hydrologic studies done by the U.S. Department of Agriculture in conjunction with the USGS.
RIVER OR LAKE ZONING	Lands adjacent to and within 300 feet of rivers or 1,000 feet of a lake which, by state statute, requires protective zoning.
ROADS	Roads may be defined as including paved and unpaved town roads, county roads, state highways, federal highways, limited access highways and interchanges.
SAND DUNES	Area of medium to coarse-grained materials deposited by the wind.
SHRUB CARR	A wet ground plant community dominated by tall shrubs other than alder with an understory intermediate between meadow and forest in composition.
STREAM	A stream channel with a year-round flow of water, indicated on USGS maps by a single solid line.
INTERMITTENT STREAM	A stream channel which has only a seasonal or periodic flow of water, indicated on USGS maps by a broken line (----..----).
TERRACES	A series of level areas descending the sides of a river valley which indicate past changes in river level and gradient.
UTILITIES, RAILWAY LINES	Land used for telephone cables, power transmission lines, high pressure oil lines, gas lines and railway lines.

APPENDIX - B

SUMMARY OF CLOUD COVER FROM ERTS IMAGERY FOR WISCONSIN

APPENDIX - B

SUMMARY OF CLOUD COVER FROM ERTS IMAGERY FOR WISCONSIN

This Appendix consists of summary maps derived from ERTS imagery of cloud cover over Wisconsin for the period August 1972 through October 1973 according to the seasons: summer, fall, winter and spring.

The shaded areas represent the areas for which at least one good image was obtained during that particular season. These maps are significant because they give an indication of the availability of the imagery required for identification of a particular variable which may require coverage at a specific season of the year. It is important to note the lack of good fall coverage up to this time as this is considered the optimum season for the identification of many resources.

FIGURE 1 Summary of Coverage of Wisconsin: Summer, 1972, 1973.

(Note: Shading Represents Areas of Good Coverage)

ORIGINAL PAGE IS
OF POOR QUALITY

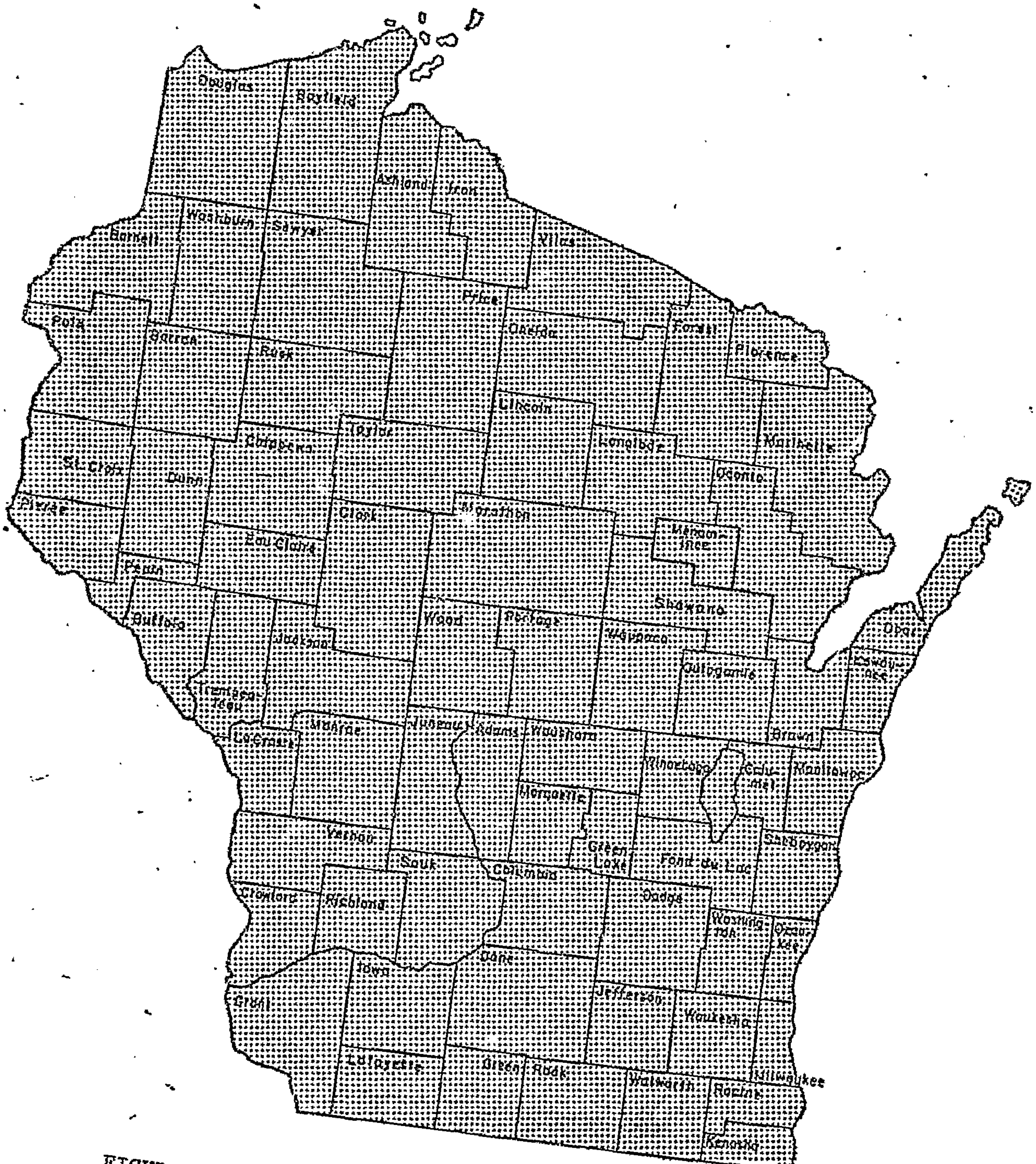


FIGURE 1 Summary of Coverage of Wisconsin: Summer, 1972, 1973.

(Note: Shading Represents Areas of Good Coverage)

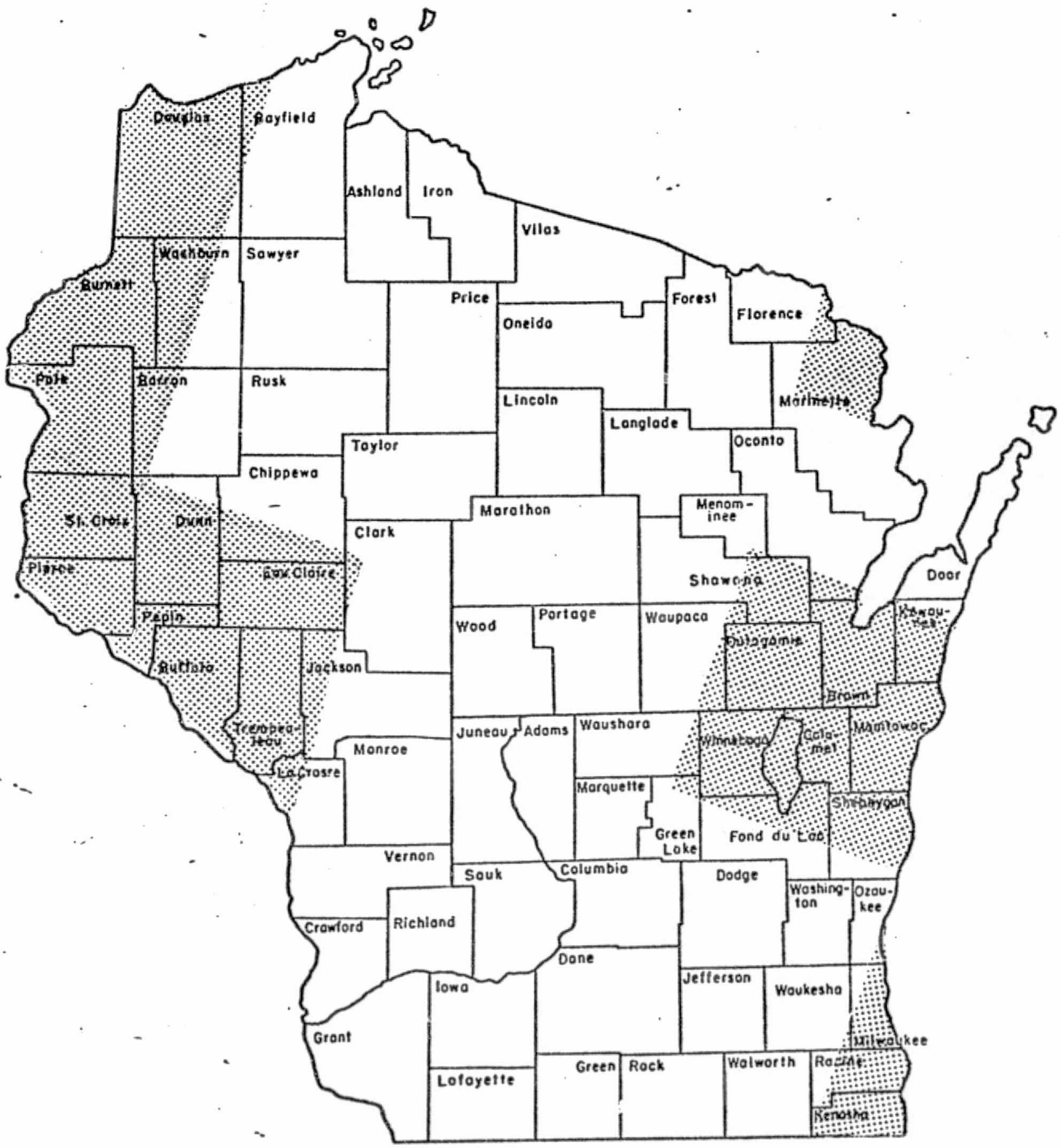


FIGURE 2 Summary of Coverage of Wisconsin: Fall, 1972, 1973.

(Note: Shading Represents Areas of Good Coverage)

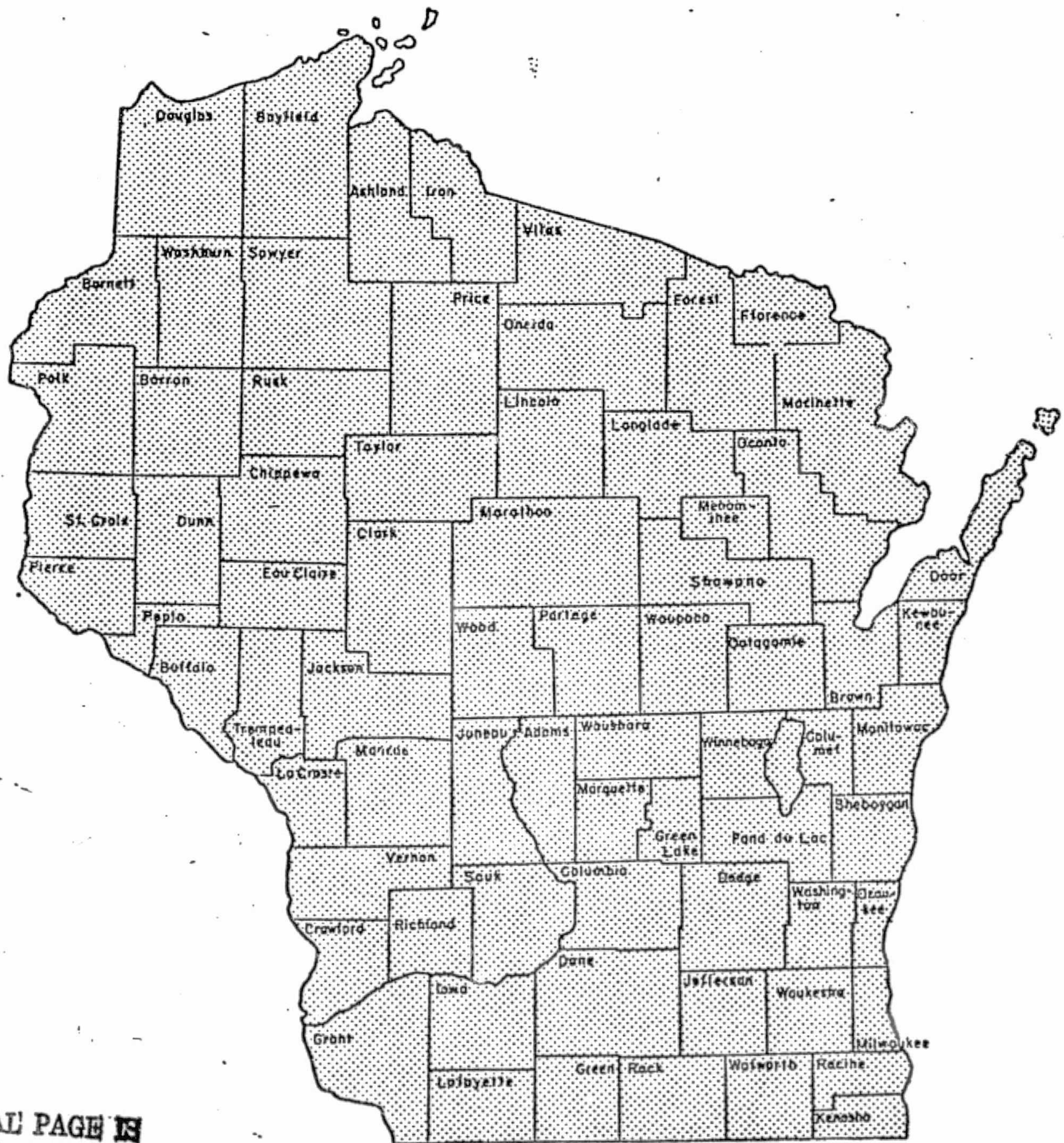


FIGURE 3 Summary of Coverage of Wisconsin: Winter, 1972, 1973.

(Note: Shading Represents Areas of Good Coverage)

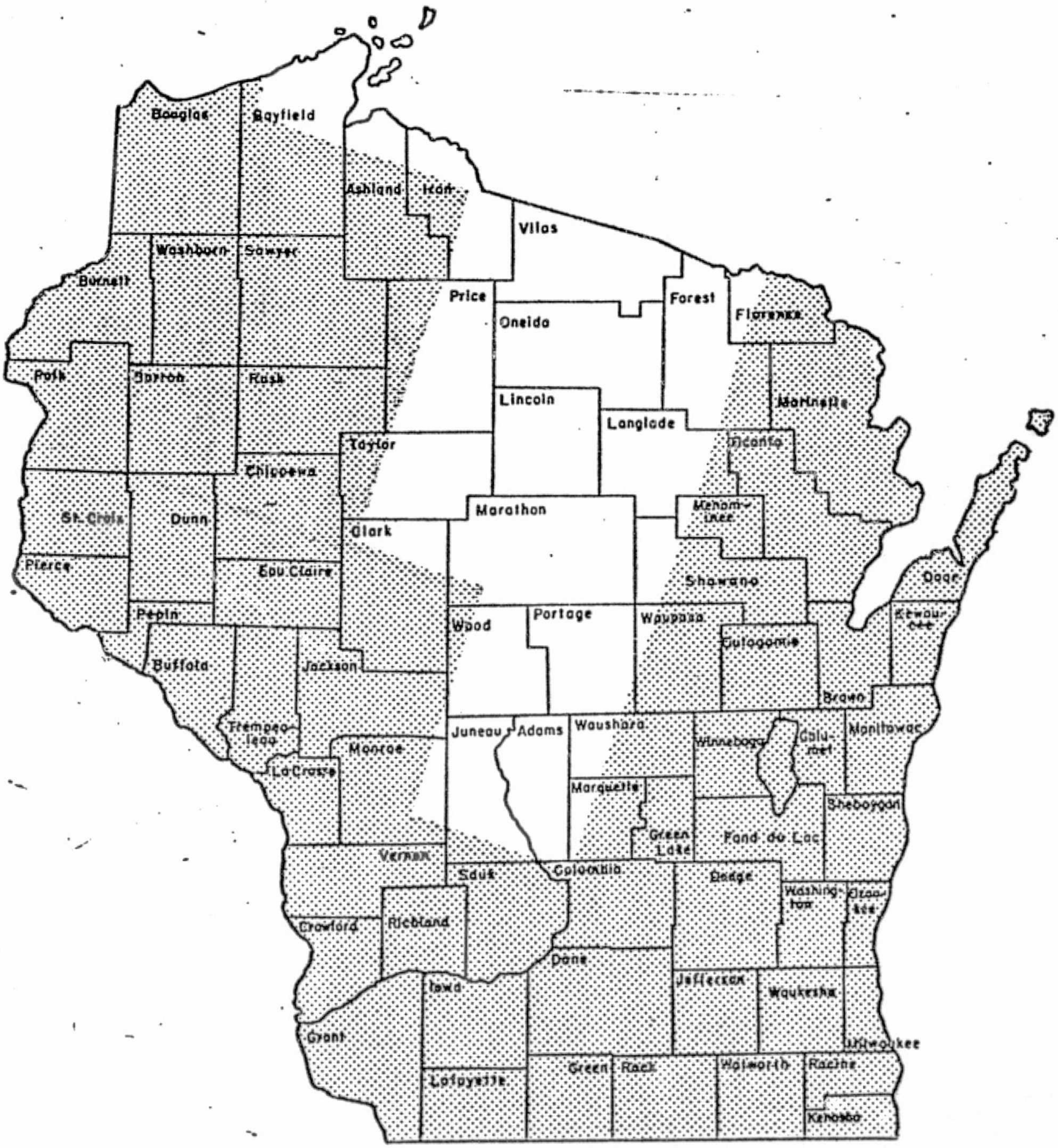


FIGURE 4 Summary of Coverage of Wisconsin: Spring, 1973.

(Note: Shading Represents Areas of Good Coverage)

APPENDIX - C

SPATIAL PRINTOUTS

APPENDIX - C

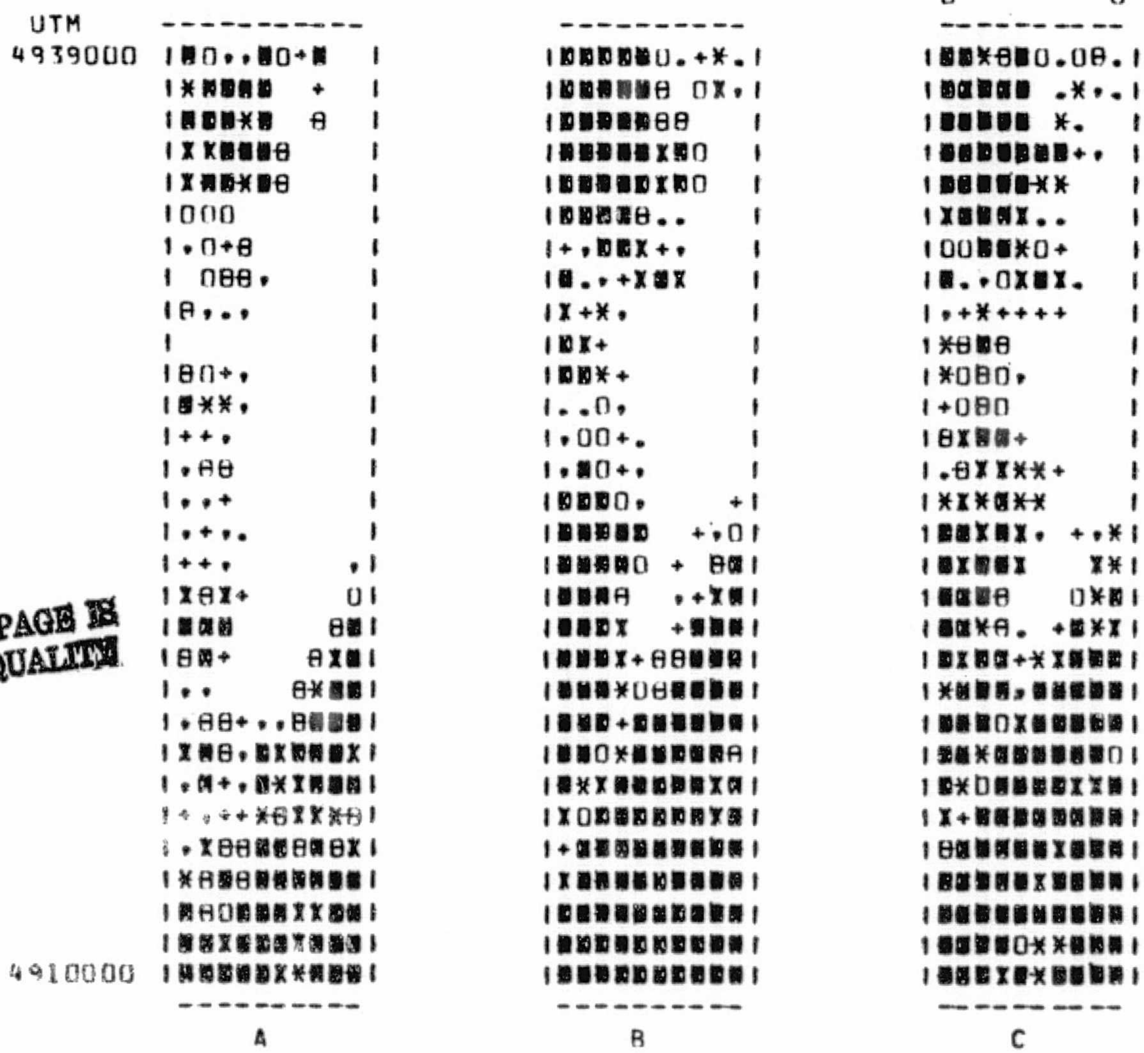
SPATIAL PRINTOUTS

This Appendix consists of maps of a particular variable or value surface over the area specified by a data file. The value present in each cell is represented by a printed character. A variable may be mapped into up to ten defined data levels which are indicated through the use of overprint symbols.

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 63 AGRICULTURE

UTM: 4 1 0 0 0 0 — 4 1 9 0 0 0



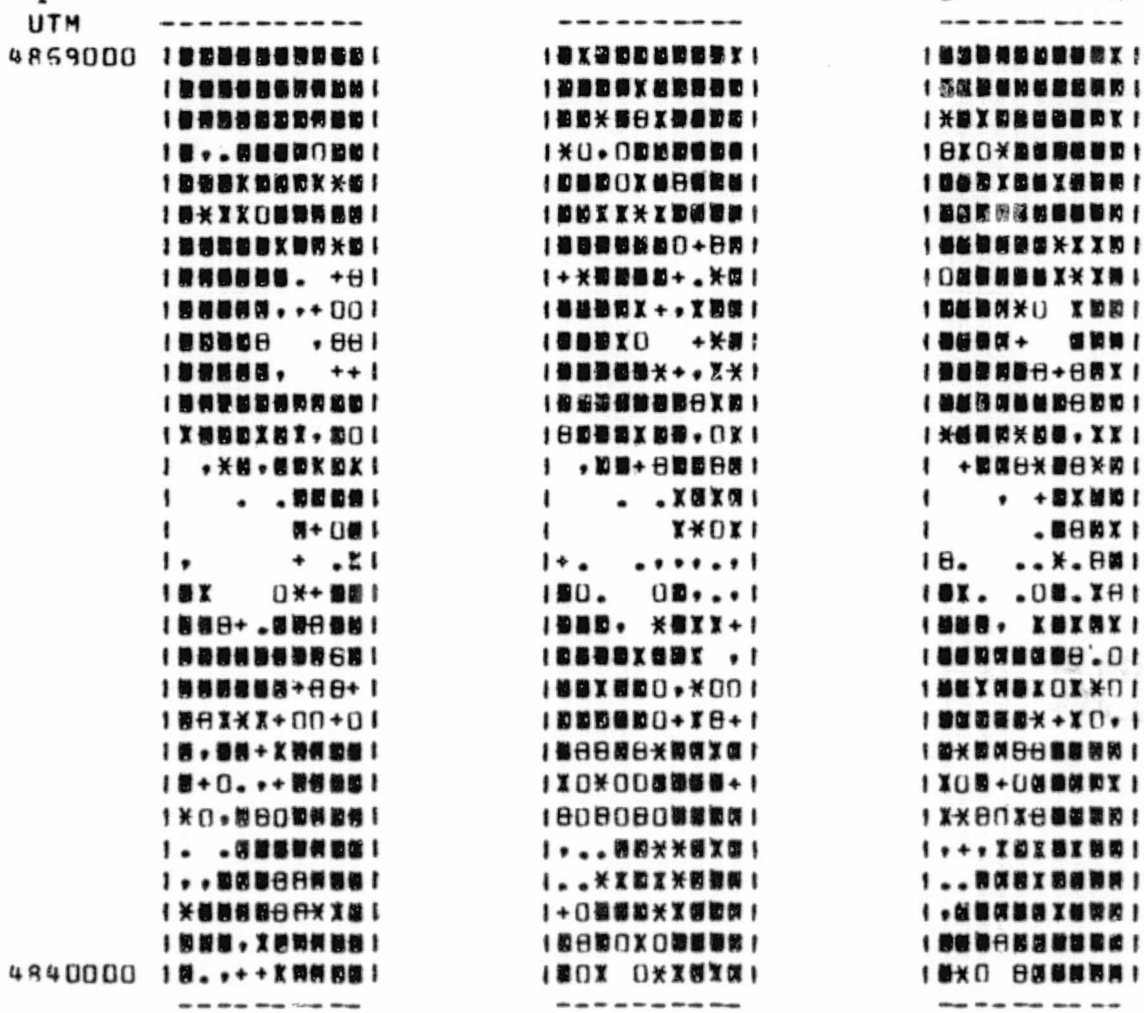
TOT. SQ.KM	A 98.750	B 161.370	C 159.470								
LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	θθθθθ	*****	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	2	26	17	10	28	11	19	19	25	27
	B	8	12	17	14	10	6	16	26	36	91
	C	11	8	14	15	11	27	23	32	65	38
SQ.KM	A	.13	3.44	3.55	3.05	11.65	5.90	11.85	13.65	20.55	24.98
	B	.38	1.42	3.69	4.50	4.00	3.00	9.75	18.75	29.70	86.18
	C	.66	1.11	3.50	5.07	4.85	14.83	15.05	24.04	55.07	35.29

ERTS BAND 5   14.SEPTEMBER.1972   1053-16093-5

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 63 AGRICULTURE

UTM 410000 — 419000



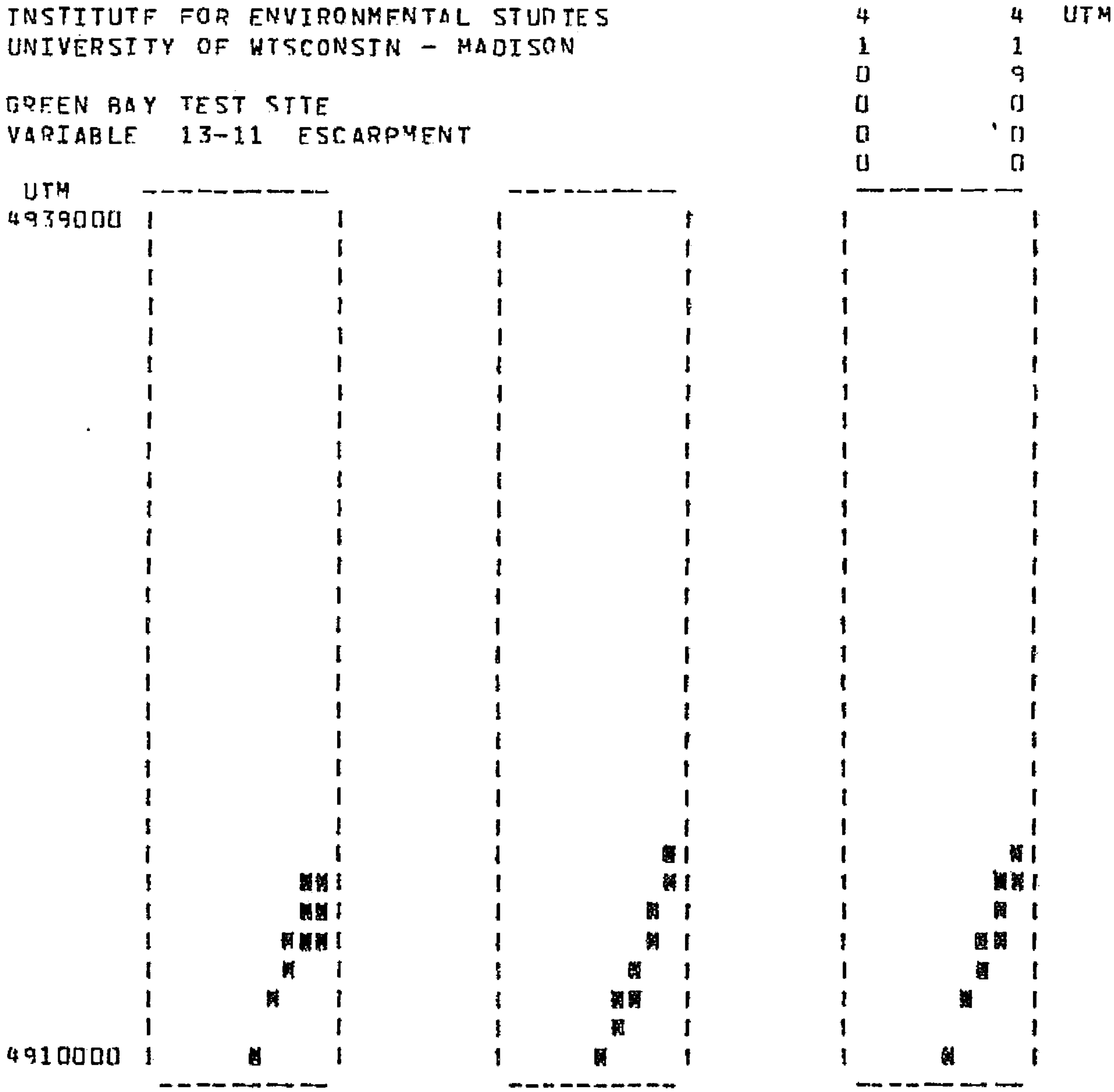
	A		B			C		
	ERTS		RB57			REMAP I		
TOT. SQ.KM	183.630		181.600			198.110		

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	θθθθθ	*****	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	10	16	17	13	15	9	18	39	49	88
	B	12	15	13	24	15	19	35	33	51	63
	C	11	7	7	12	17	15	34	42	66	71
SQ.KM	A	.47	1.97	3.70	4.05	6.12	4.70	11.35	28.60	40.33	82.34
	B	.68	2.20	3.12	8.34	6.43	10.44	22.55	24.81	43.46	59.57
	C	.63	1.08	1.65	3.99	7.50	8.24	21.74	31.28	55.97	66.03

ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

ERTS-I INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 13-11 ESCARPMENT



	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	10.000	9.000	9.000

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	88888	XXXXX	XXXXX	#####	#####	#####
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	0	0	0	0	0	0	0	0	0	10
	B	0	0	0	0	0	0	0	0	0	9
	C	0	0	0	0	0	0	0	0	0	9
SQ.KM	A	.00	.00	.00	.00	.00	.00	.00	.00	.00	10.00
	B	.00	.00	.00	.00	.00	.00	.00	.00	.00	9.00
	C	.00	.00	.00	.00	.00	.00	.00	.00	.00	9.00

ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 13-11 ESCARPMENT

UTM 410000 – 419000

UTM
4869000

4840000

	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	.000	.000	.000

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	OOOOO	BBBBB	XXXXX	YYYYY	▩▩▩▩▩	▩▩▩▩▩	▩▩▩▩▩
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0
SQ.KM	A	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	B	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	C	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

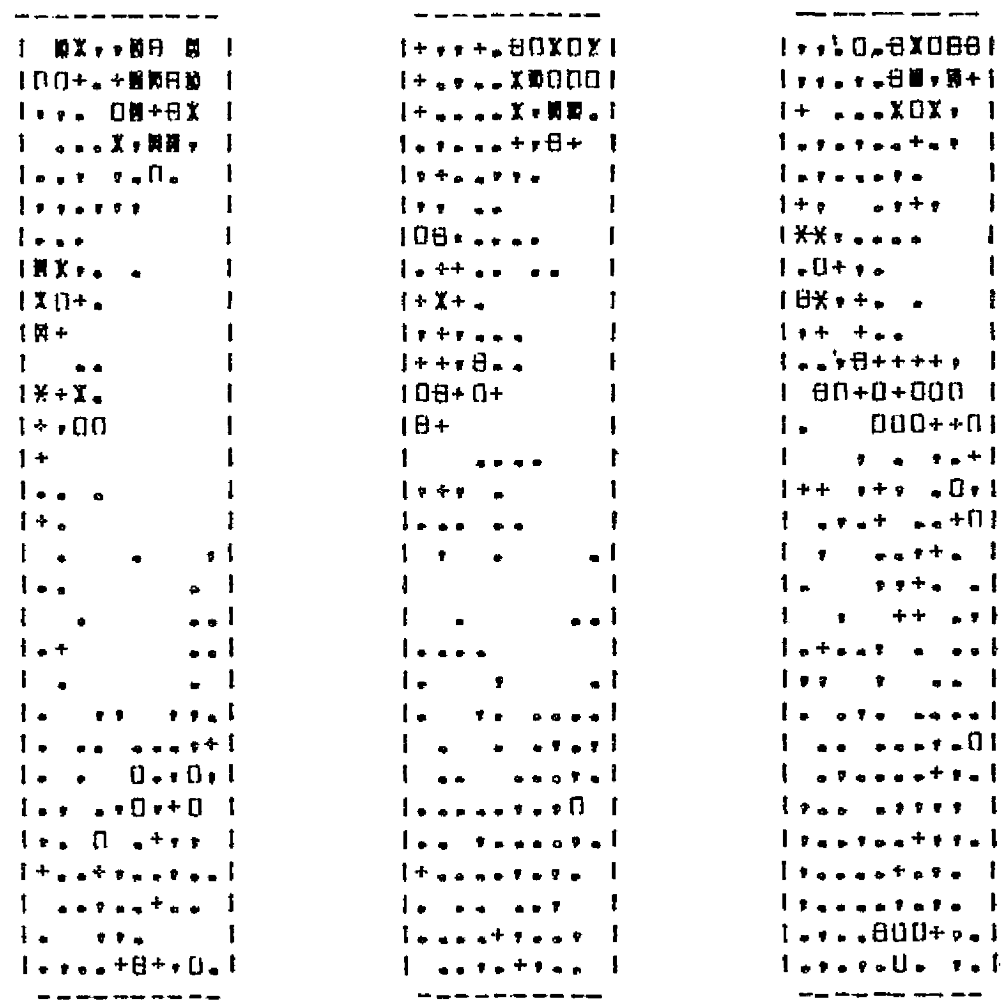
ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 24+25 FOREST

UTM 410000 — 419000

UTM
4939000



4910000

	A	B	C
	ERTS	9857	REMAP I
TOT. SQ.KM	31.560	25.690	35.800

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	'''''	+++++	00000	88888	XXXXX	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99

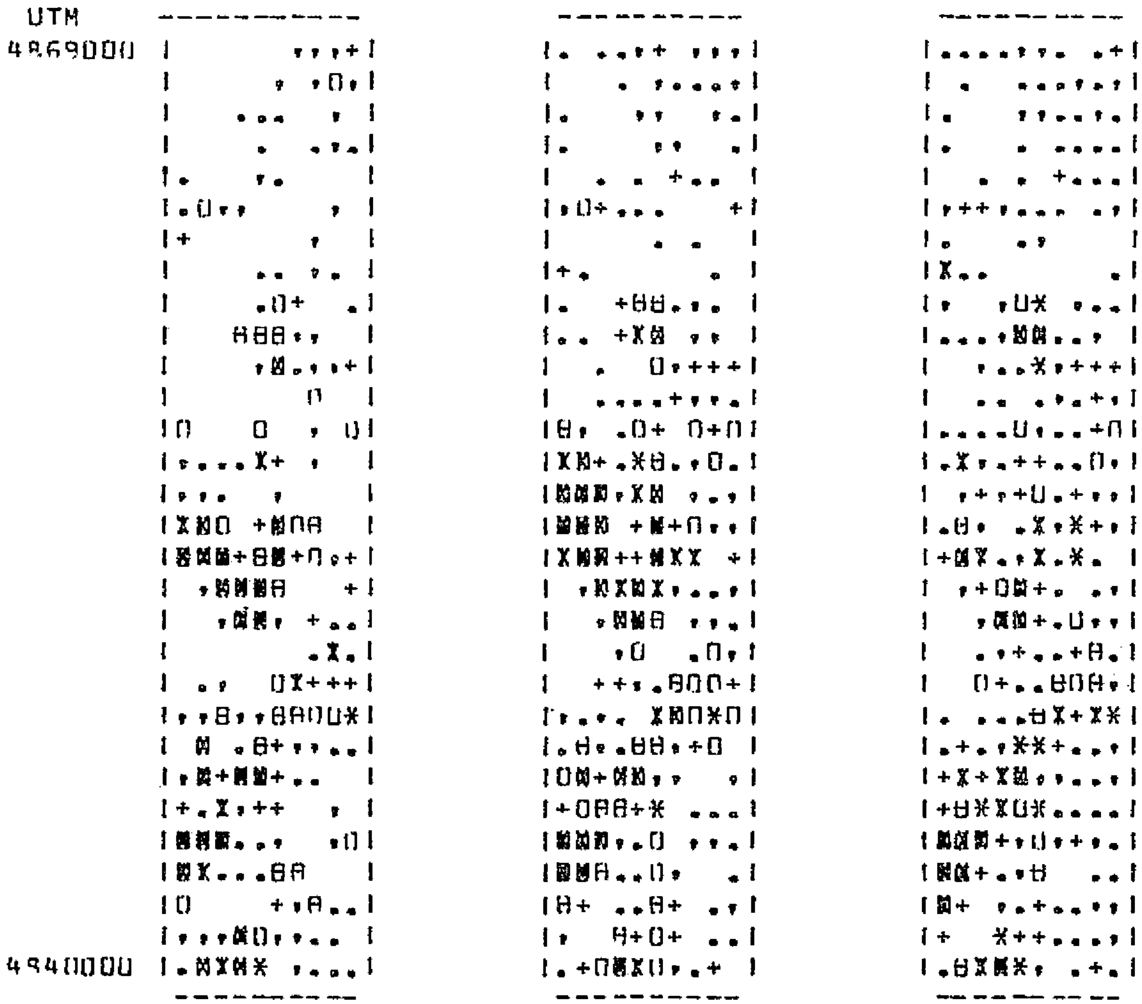
		1	2	3	4	5	6	7	8	9	10
OCCUR	A	69	36	18	13	4	1	6	2	5	4
	B	105	34	21	9	6	0	5	0	3	0
	C	101	60	32	19	8	3	3	1	0	1
SQ.KM	A	3.65	4.44	4.05	4.14	1.60	.55	3.75	1.50	4.21	3.67
	B	4.88	4.63	4.93	3.03	2.54	.00	3.19	.00	2.49	.00
	C	4.93	8.73	7.51	6.07	3.51	1.57	1.91	.73	.00	.94

ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 24+25 FOREST

UTM 410000 ... 419000



	A	B	C
	ERTS	9857	REMAP I
TOT. SQ.KM	48.830	59.470	51.990

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	88888	XXXXX	XXXXX	▓▓▓▓▓	▓▓▓▓▓	█████
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUP	A	43	48	21	16	13	2	7	7	9	7
	B	62	48	32	21	15	3	10	9	8	10
	C	100	52	37	11	8	11	11	3	9	2
SQ.KM	A	2.36	5.38	4.73	5.30	5.42	1.10	4.48	5.13	7.43	6.50
	B	2.84	5.96	7.39	6.79	6.35	1.58	6.27	6.40	5.55	9.34
	C	4.33	7.10	8.92	3.62	3.39	5.85	7.09	2.16	7.52	1.91

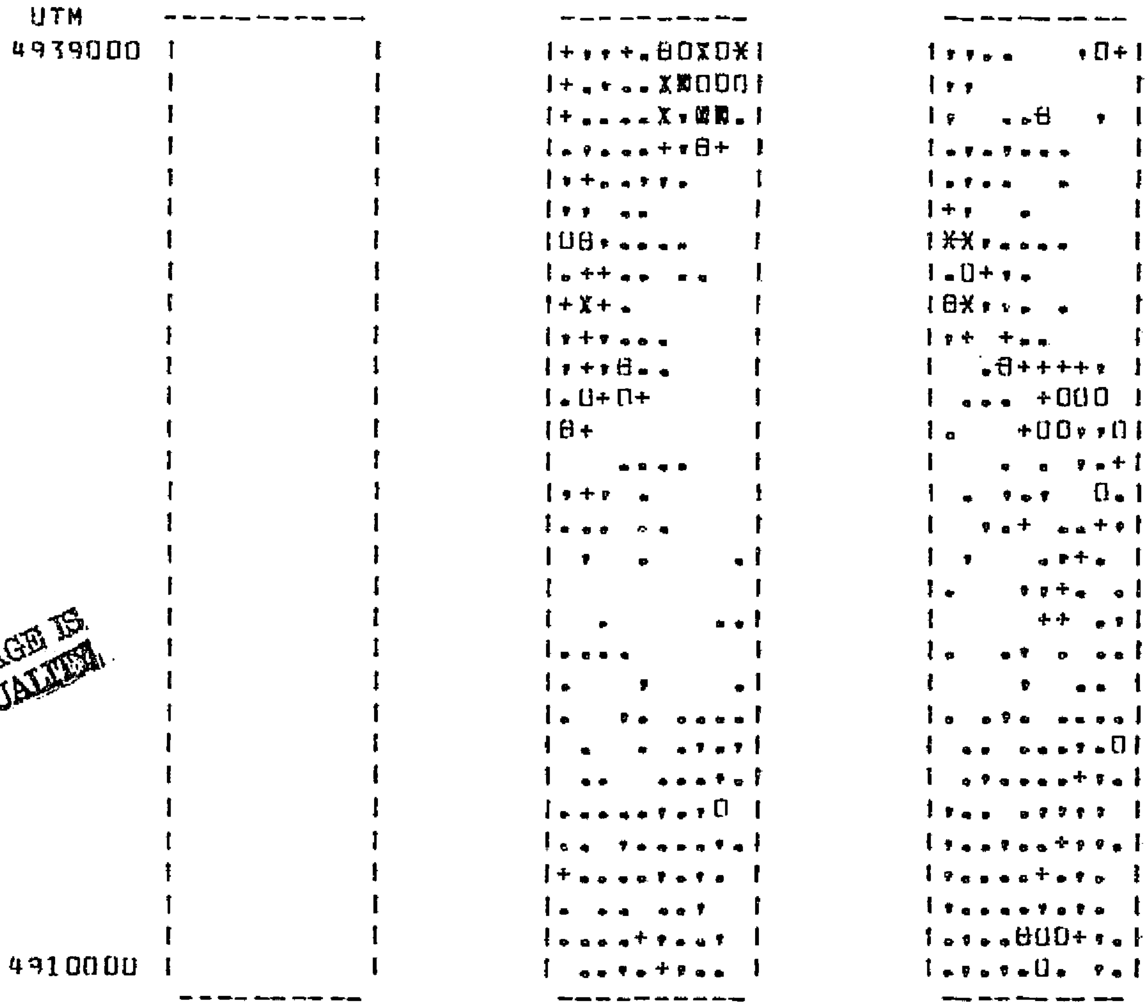
ERTS BAND 5 14-SEPTEMBER-1972 1053-16093-5

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 24 UPLAND FOREST

UTM 410000 — UTM 419000

UTM 4939000 — 4910000



	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	.000	25.120	24.600

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	,,,,,	+++++	00000	88888	XXXXX	XXXXX	▩▩▩▩▩	▩▩▩▩▩	▩▩▩▩▩
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR A	0	0	0	0	0	0	0	0	0	0
OCCUR B	106	35	20	9	5	1	4	0	3	0
OCCUR C	93	54	22	13	4	3	0	0	0	0
SQ.KM A	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
SQ.KM B	4.93	4.75	4.69	3.03	2.14	.55	2.54	.00	2.49	.00
SQ.KM C	4.37	7.70	5.06	4.10	1.80	1.57	.00	.00	.00	.00

ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

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ERTS-1 INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                    4        4   UTM
UNIVERSITY OF WISCONSIN - MADISON                      1        1
                                                       0        9
SHEBOYGAN TEST SITE                                    0        0
VARIABLE   24  UPLAND FOREST                           0        0
                                                       0        0
 UTM      -----------       ----------       ---------
4859000  I          I      I. ..++  . I     I......+. ..I
         I          I      I    . +... I     I .    ..+..I
         I          I      I.    .   . I     I.     .....I
         I          I      I           I     I.   .   .. I
         I          I      I     .     I     I  . .   ...I
         I          I      I           I     I.++   .   .I
         I          I      I       . . I     I.     ..   I
         I          I      I         . I     IX..       .I
         I          I      I.       .. I     I.      ...I
         I          I      I..      .. I     I ....    . I
         I          I      I  .  .  ++I     I   .... .++I
         I          I      I  .... ...I     I  .. .  .+.I
         I          I      I    ... .+0I     I ..... .+0I
         I          I      I      ..0.I     I   ..   ..+.I
         I          I      I        ...I     I        .+..I
         I          I      I        0 .I     I         X+.I
         I          I      I.    +  .X .I     I         X. I
         I          I      I ..     .. I     I        . ..I
         I          I      I  .     ...I     I        .0..I
         I          I      I        .0.I     I   .   ..+8.I
         I          I      I  ++..00+.I     I  0+..808  I
         I          I      I. .   X80X+I     I. ...8X+X8I
         I          I      I...  88.+0 I     I ...XX+++.I
         I          I      I.8.88..   .I     I.0+X8.....I
         I          I      I+008+X     I     I+8X0X..   I
         I          I      I888..0    .I     I888+.0.. .I
         I          I      I888..0    .I     I88+..8   ..I
         I          I      I8+  ..8.  ..I     I8+  ..+....I
         I          I      I     8+0+ ..I     I+   X++....I
4840000  I          I      I.+08X+.  . I     I.8X88.   ..I
          ----------        ----------        ---------
```

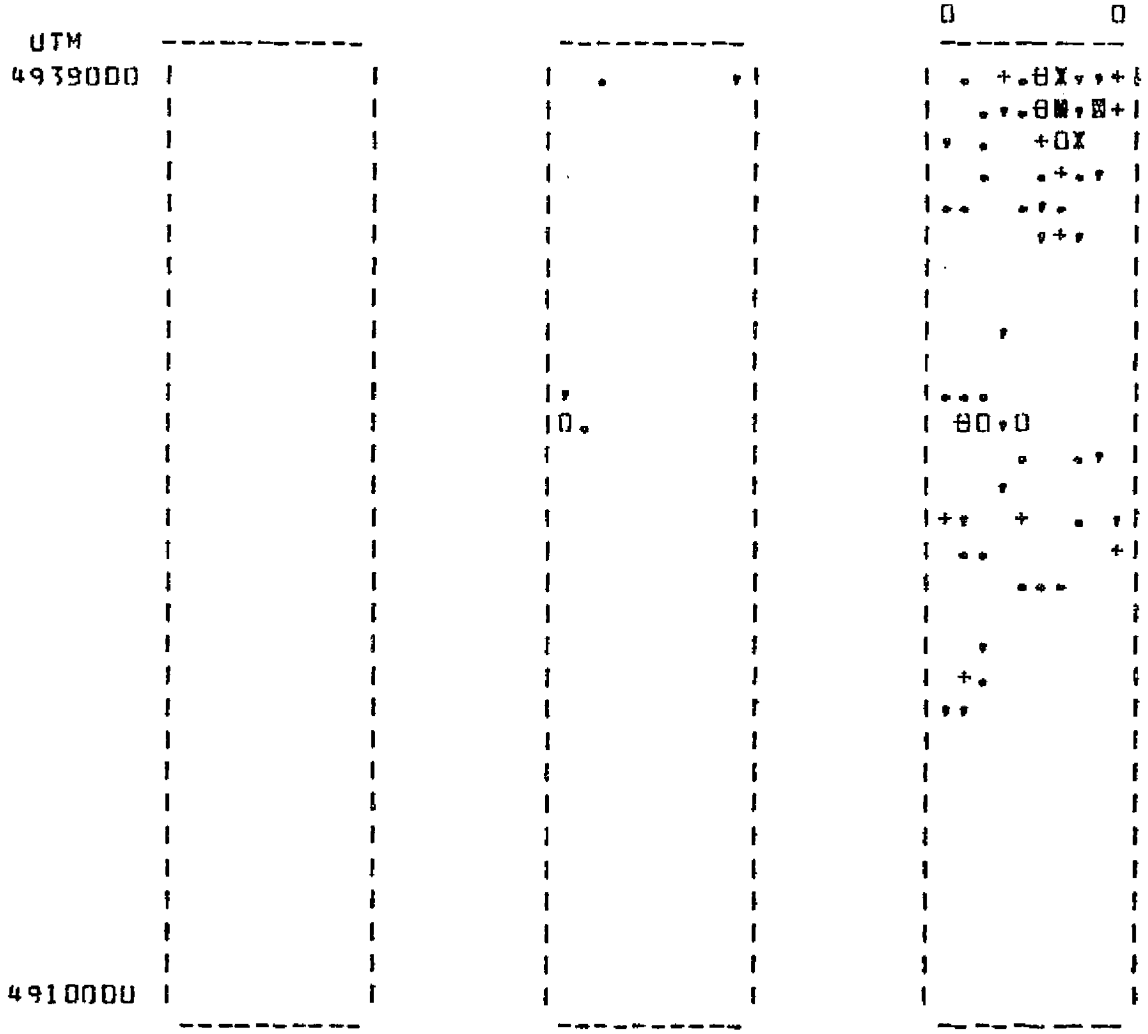
	A				B			C		
	ERTS				9857			REMAP I		
TOT. SQ.KM	.000				27.620			33.560		
LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	'''''	+++++	00000	88888	XXXXX	XXXXX	88888	88888	88888
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR A	0	0	0	0	0	0	0	0	0	0
OCCUR B	61	26	17	13	9	2	3	3	3	3
OCCUR C	97	27	24	7	9	8	5	2	4	2
SQ.KM A	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
SQ.KM B	2.53	3.12	3.34	4.10	3.80	1.00	1.85	2.10	2.50	2.78
SQ.KM C	4.13	3.63	5.63	2.22	3.77	4.23	3.31	1.40	3.43	1.91

ERTS BAND 5   14.SEPTEMBER.1972   1053-16093-5

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 25 LOWLAND FOREST

UTM 410000 – 419000



	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	.000	.570	11.200

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	•••••	+++++	00000	θθθθθ	XXXXX	XXXXX	▩▩▩▩▩	▦▦▦▦▦	▨▨▨▨▨
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	0	0	0	0	0	0	0	0	0	0
	B	2	2	0	1	0	0	0	0	0	0
	C	24	18	10	3	3	0	2	1	0	1
SQ.KM	A	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	B	.07	.20	.00	.30	.00	.00	.00	.00	.00	.00
	C	1.26	2.42	2.38	.95	1.27	.00	1.25	.73	.00	.94

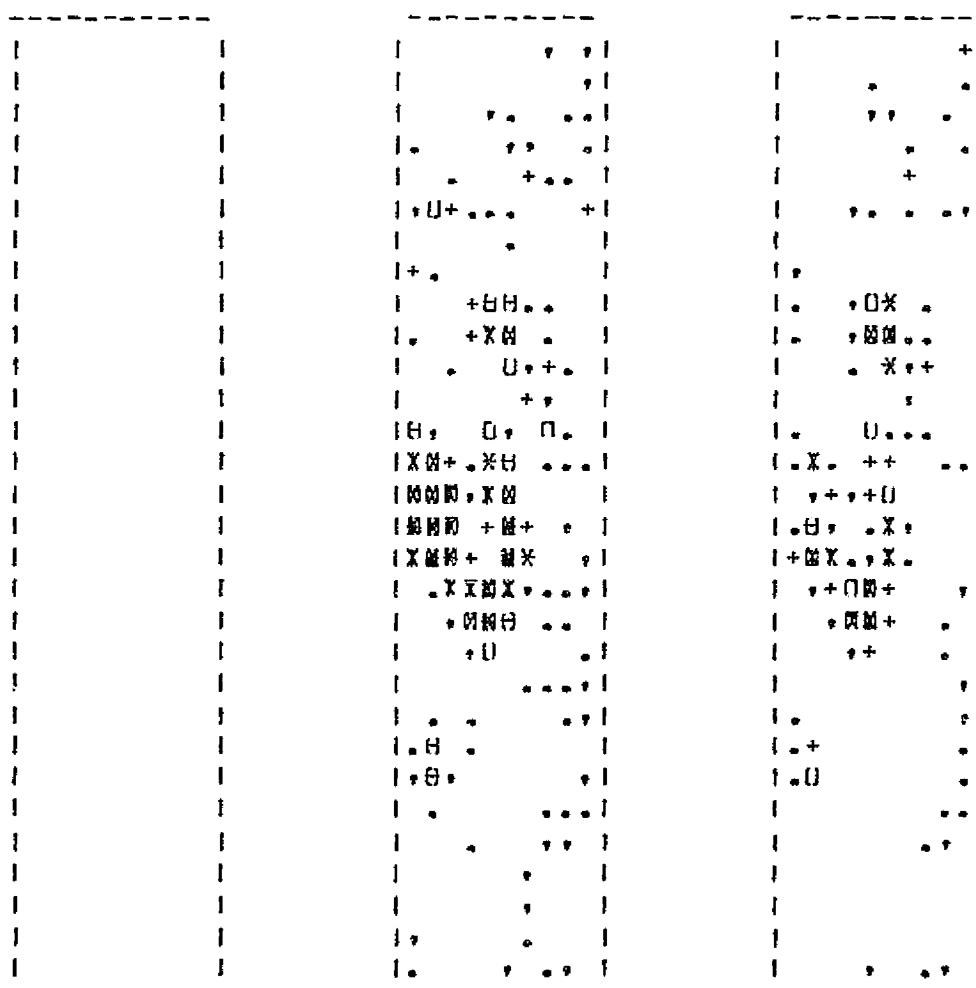
ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 25 LOWLAND FOREST

UTM 410000 — 490000 (vertical: 4 1 0 0 0 0 / 4 1 9 0 0 0 UTM)

UTM
4869000



4840000

	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	.000	31.850	18.920

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	,,,,,	+++++	00000	88888	*****	XXXXX	▩▩▩▩▩	▩▩▩▩▩	▩▩▩▩▩
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR A	0	0	0	0	0	0	0	0	0	0
OCCUR B	46	30	12	5	7	2	7	5	4	7
OCCUR C	37	23	13	5	1	2	4	1	5	0
SQ.KM A	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
SQ.KM B	2.01	3.84	2.76	1.50	2.93	1.05	4.40	3.55	3.25	6.56
SQ.KM C	1.75	3.30	3.26	1.69	.44	1.02	2.54	.73	4.19	.00

ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 21 LAKES

UTM 410000 — 419000

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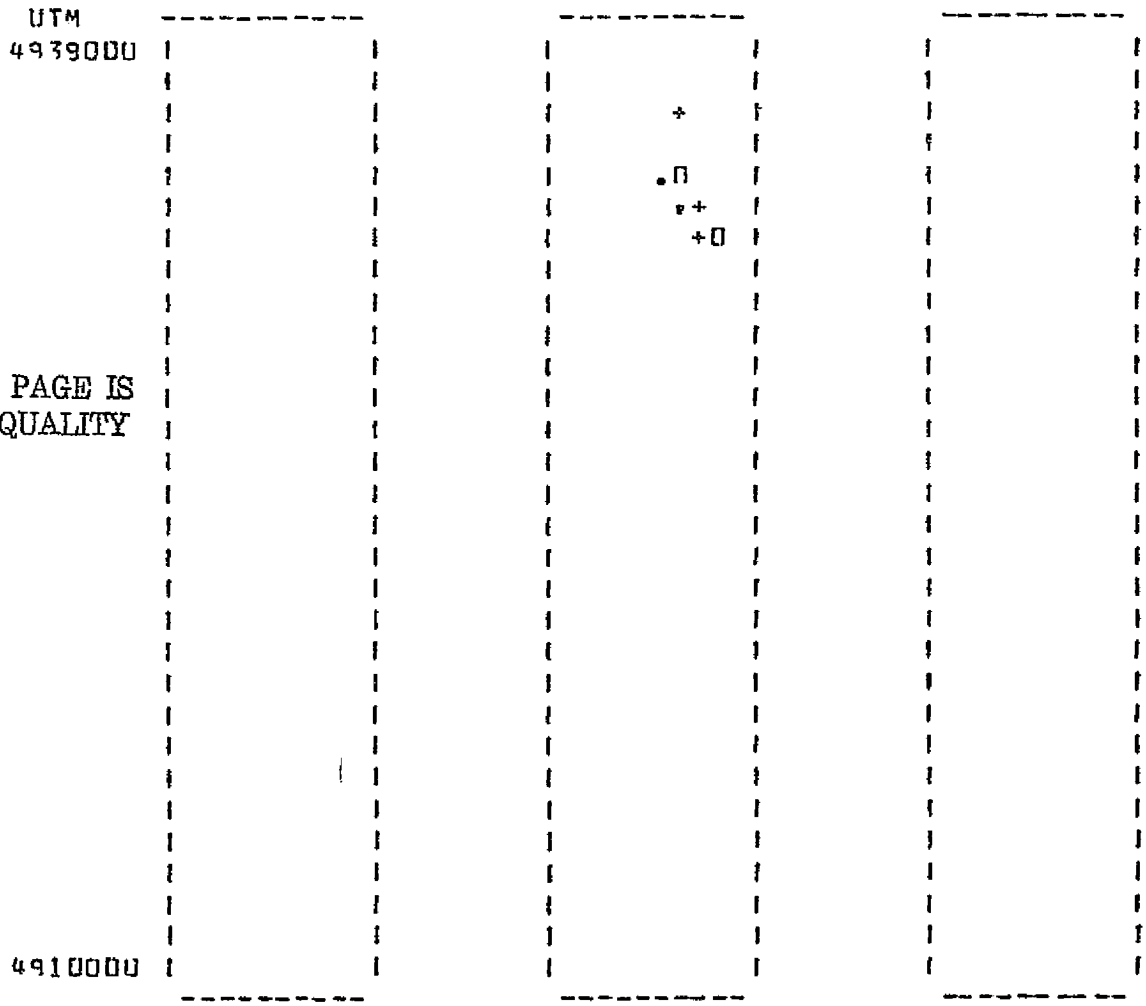


	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	.000	1.780	.000

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	'''''	+++++	00000	88888	XXXXX	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR A	0	0	0	0	0	0	0	0	0	0
OCCUR B	1	1	3	2	0	0	0	0	0	0
OCCUR C	0	0	0	0	0	0	0	0	0	0
SQ.KM A	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
SQ.KM B	.08	.18	.84	.68	.00	.00	.00	.00	.00	.00
SQ.KM C	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

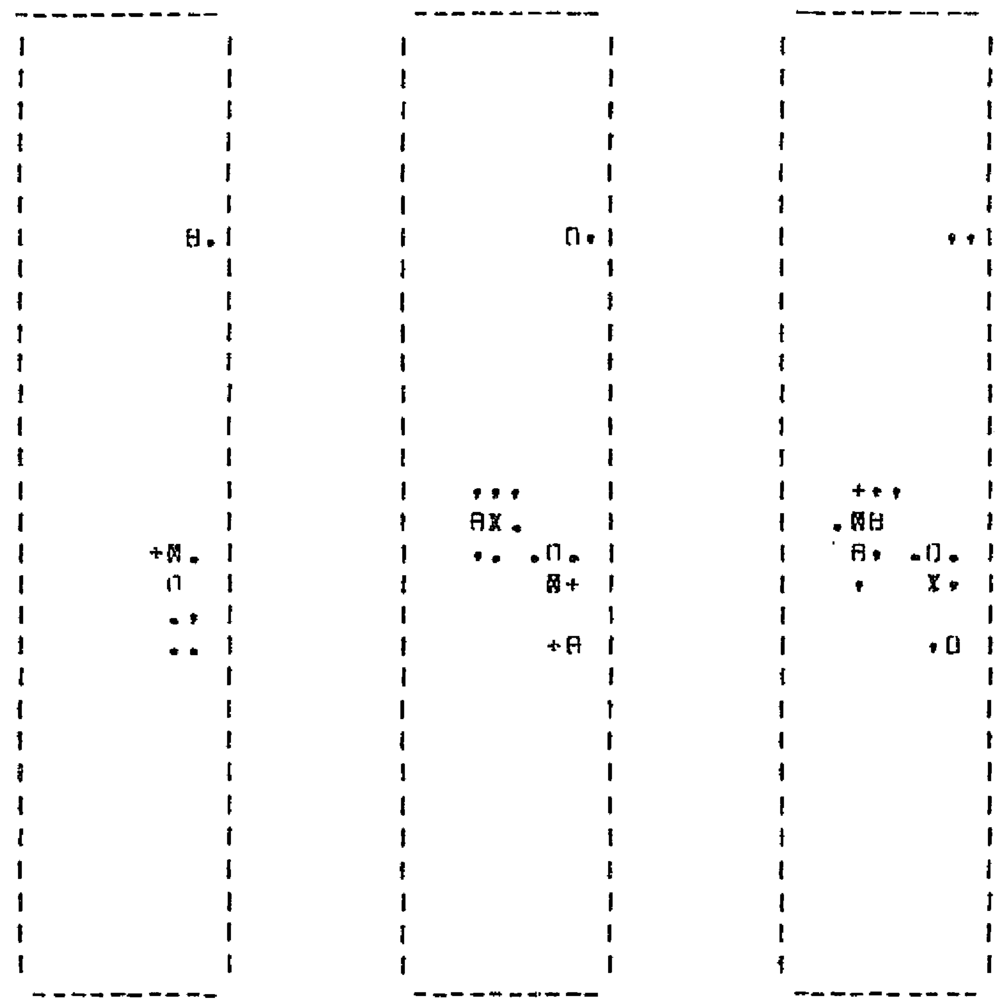
* ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 21 LAKES

UTM	410000	419000
	4 1 0 0 0 0	4 1 9 0 0 0

UTM
4869000



4840000

	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	2.110	4.330	4.470

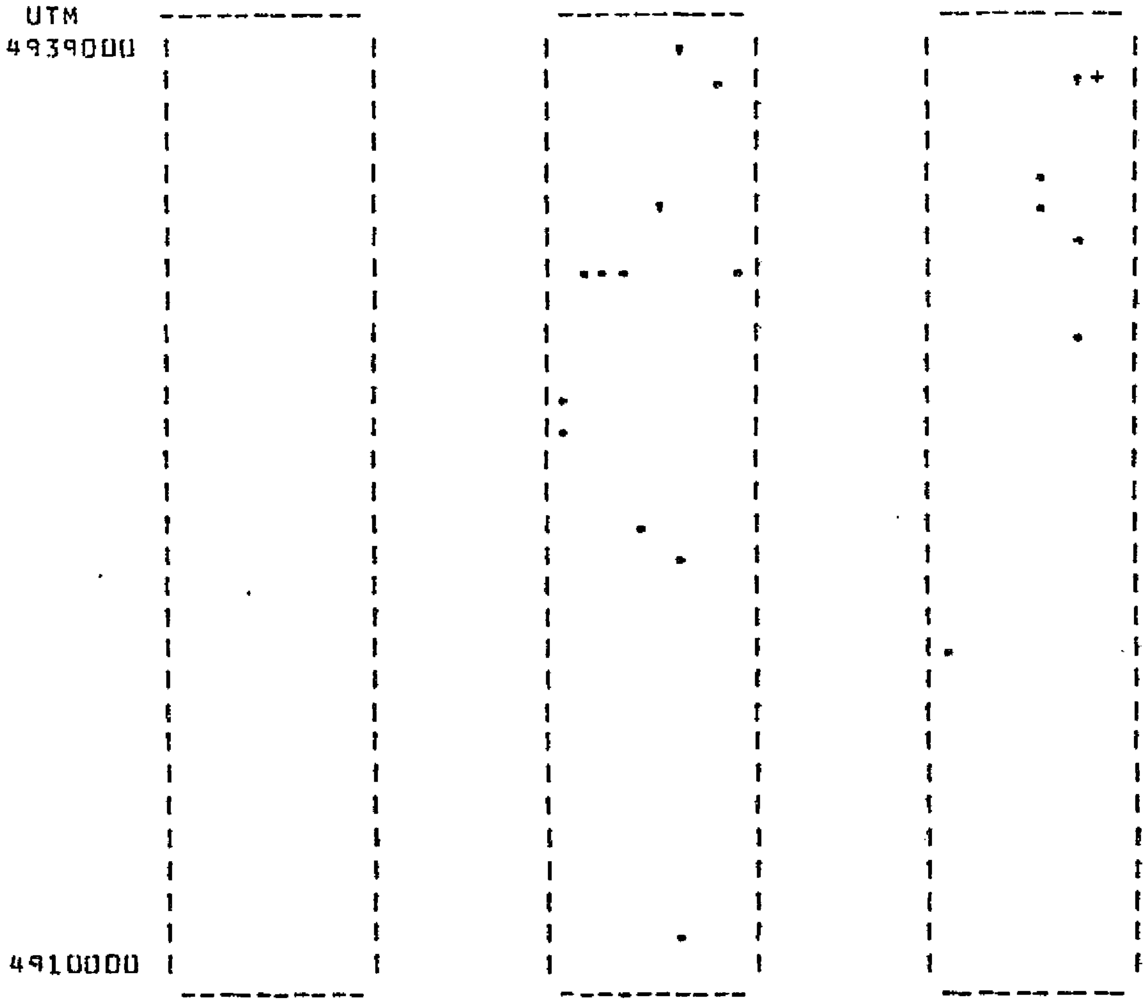
LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	.....	+++++	00000	88888	XXXXX	XXXXX	#####	#####	#####
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	5	1	1	1	1	0	0	1	0	0
	B	4	5	2	2	2	0	1	1	0	0
	C	3	8	1	2	2	0	1	1	0	0
SQ.KM	A	.33	.10	.20	.38	.40	.00	.00	.70	.00	.00
	B	.23	.76	.52	.62	.90	.00	.60	.70	.00	.00
	C	.15	1.19	.20	.68	.86	.00	.62	.77	.00	.00

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 20 LAKES LESS THAN 50 ACRES

4	4	UTM
1	1	
0	9	
0	0	
0	0	
0	0	



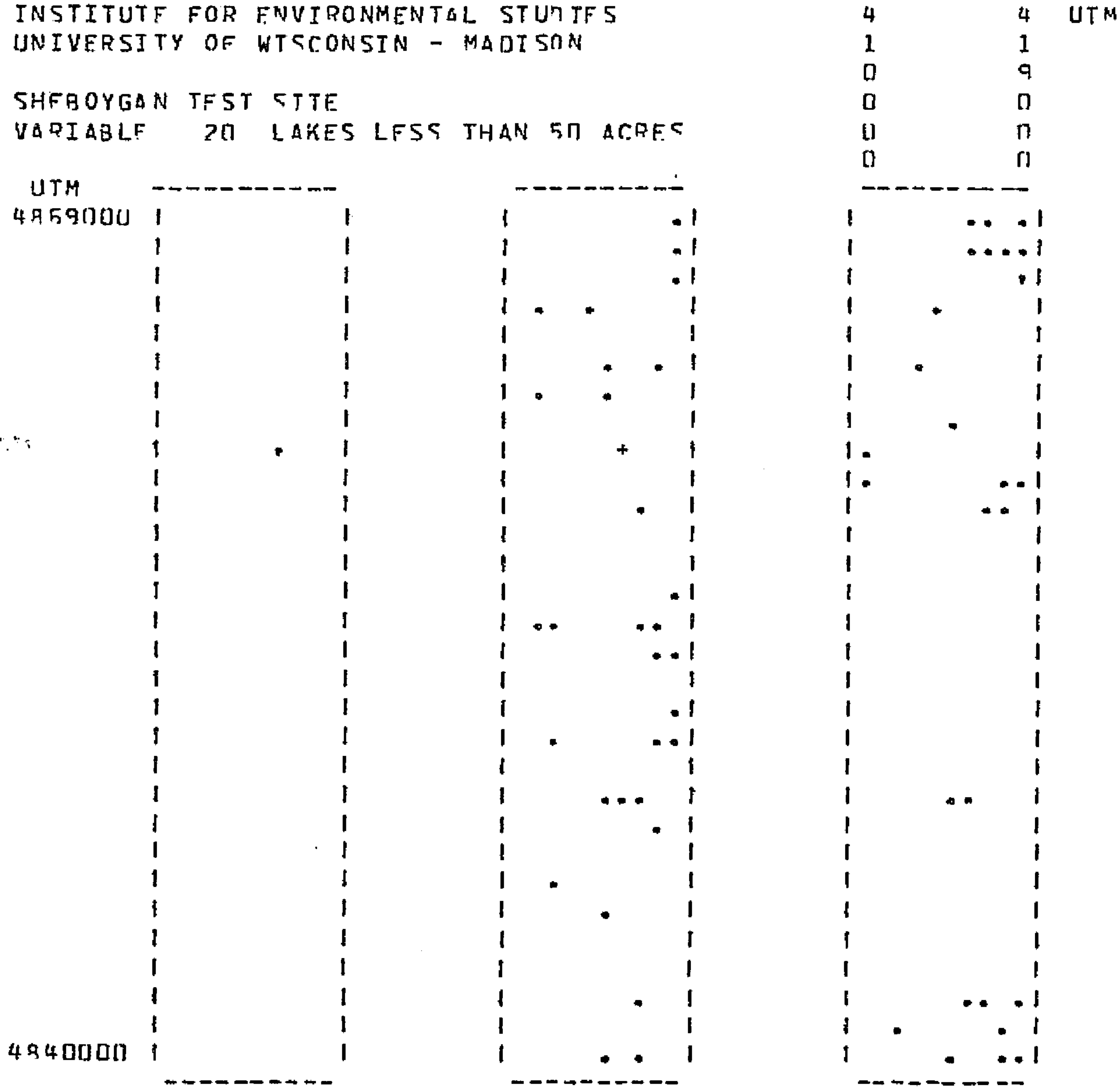
	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	.000	.460	.420

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	88888	XXXXX	XXXXX			
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	0	0	0	0	0	0	0	0	0	0
	B	10	2	0	0	0	0	0	0	0	0
	C	5	1	1	0	0	0	0	0	0	0
SQ.KM	A	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	B	.24	.22	.00	.00	.00	.00	.00	.00	.00	.00
	C	.10	.12	.20	.00	.00	.00	.00	.00	.00	.00

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 20 LAKES LESS THAN 50 ACRES



		A	B	C							
TOT. SQ.KM		.150	1.070	.630							

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	88888	XXXXX	XXXXX	#####	#####	#####
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	0	1	0	0	0	0	0	0	0	0
	B	30	0	1	0	0	0	0	0	0	0
	C	26	1	0	0	0	0	0	0	0	0
SQ.KM	A	.00	.15	.00	.00	.00	.00	.00	.00	.00	.00
	B	.87	.00	.20	.00	.00	.00	.00	.00	.00	.00
	C	.47	.16	.00	.00	.00	.00	.00	.00	.00	.00

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

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ERTS-1 INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                     4        4   UTM
UNIVERSITY OF WISCONSIN - MADISON                       1        1
                                                        0        9
GREEN BAY TEST SITE                                     0        0
VARIABLE    22  LAKE MICHIGAN                           0        0
                                                        0        0
 UTM
4939000 I        ■ I           I        0 I       I        8 I
        I        ■ I           I        8 I       I        8 I
        I       .■ I           I        X I       I        * I
        I       +■ I           I      +0■ I       I      .8■ I
        I       X■ I           I      ■■■ I       I      X■■ I
        I    +0■■■ I           I      0■■ I       I      .■■ I
        I     *■■■ I           I       0■ I       I       +■ I
        I       8■ I           I        0 I       I        + I
        I        8 I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
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        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
        I          I           I          I       I          I
4910000 I          I           I          I       I          I

               A                     B                 C
              ERTS                 RB57             REMAP I
TOT. SQ.KM   13.590                9.500             8.520
```

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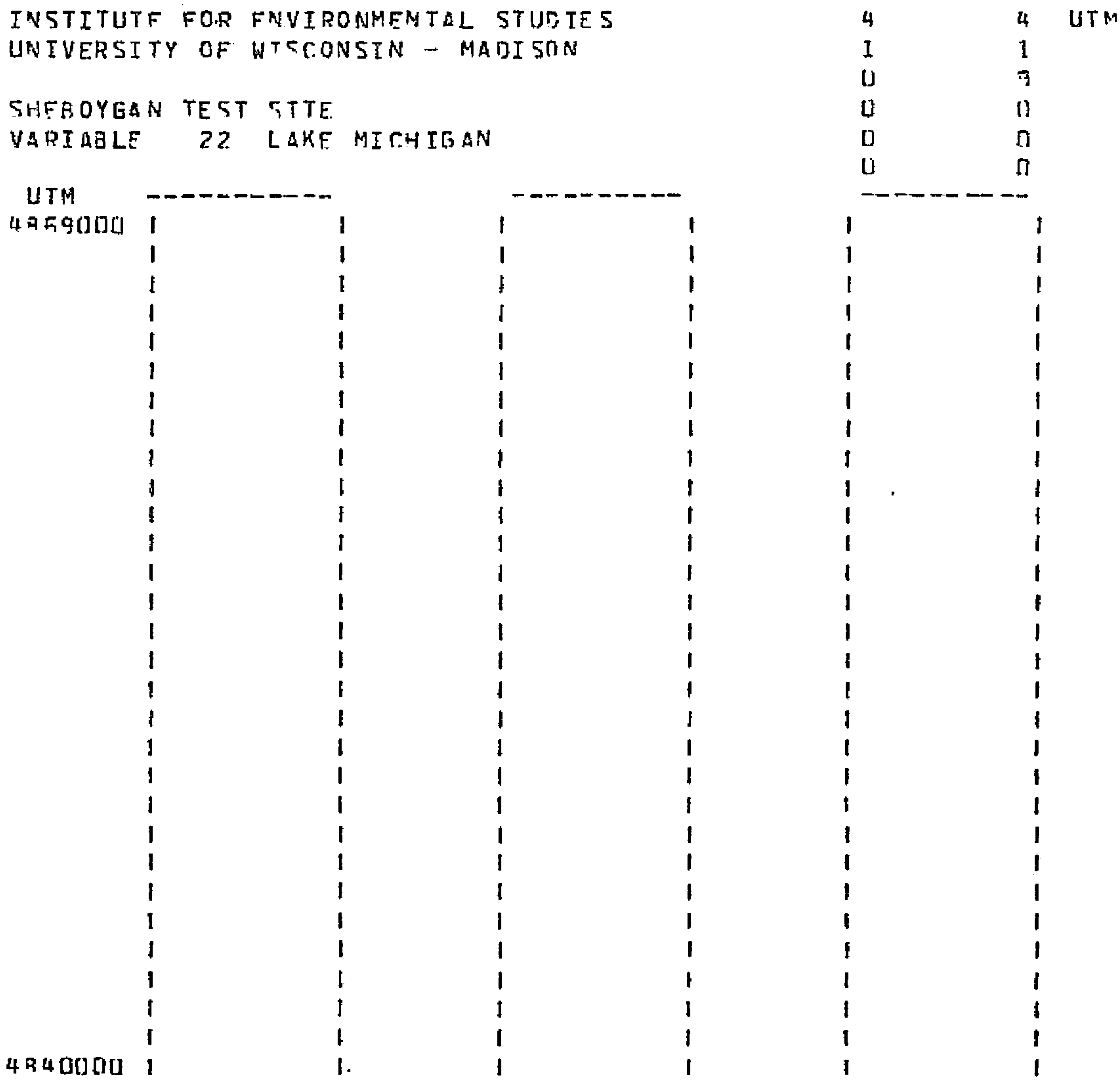
LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	88888	XXXXX	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	1	1	1	1	2	1	1	2	2	8
	B	0	1	0	5	1	0	1	1	0	6
	C	2	0	2	0	3	1	1	1	1	4
SQ.KM	A	.05	.10	.20	.30	.85	.55	.65	1.45	1.60	7.84
	B	.00	.11	.00	1.75	.45	.00	.60	.70	.00	5.89
	C	.10	.00	.48	.00	1.33	.57	.61	.70	.89	3.84

ERTS BAND 7   14.SEPTEMBER.1972   1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 22 LAKE MICHIGAN



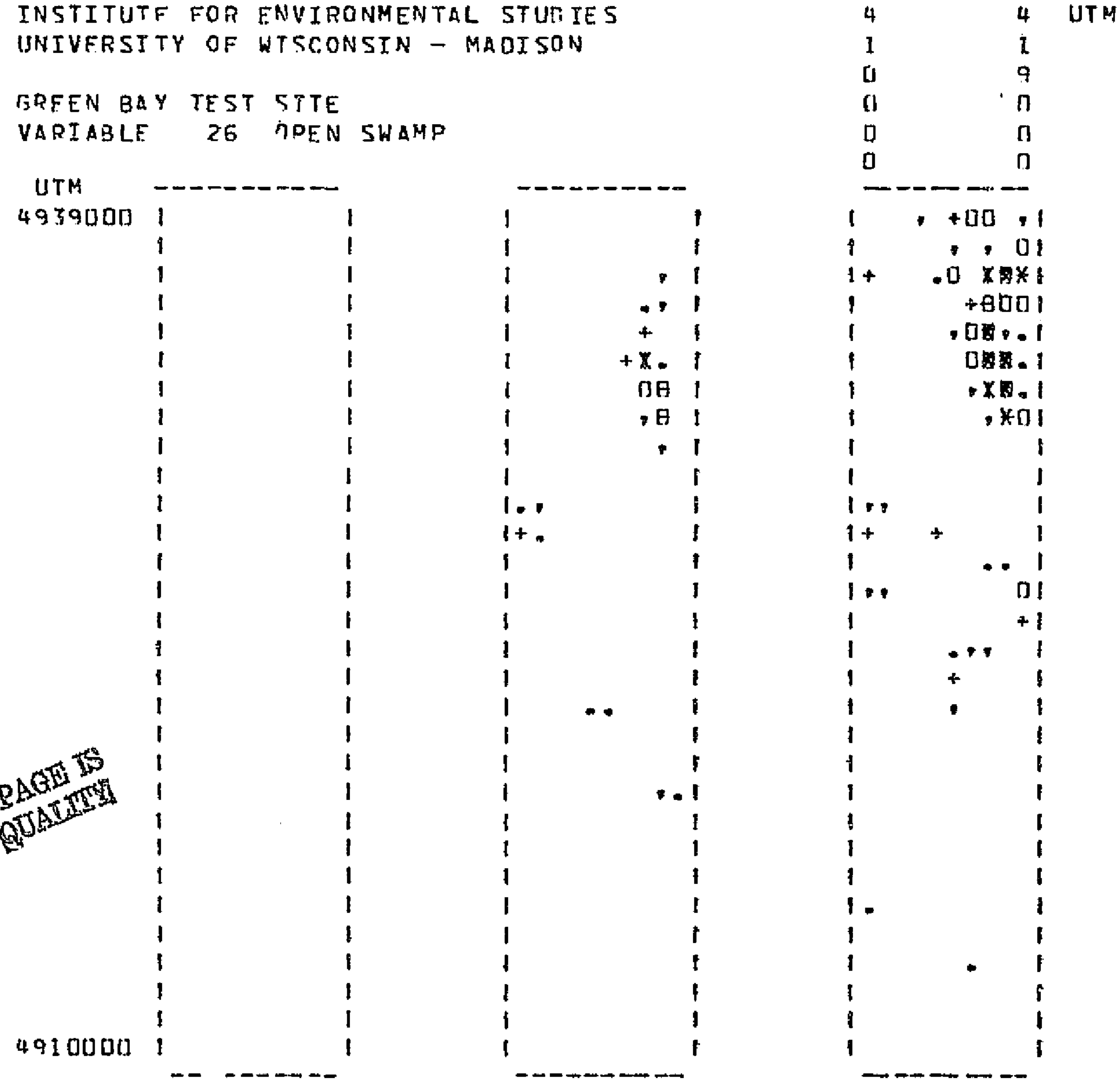
	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	.000	.000	.000

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	.....	+++++	00000	88888	*X*X*	XXXXX	▩▩▩▩▩	▩▩▩▩▩	▩▩▩▩▩
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	0	0	0	0	0	0	0	0	0	0
	B	0	0	0	0	0	0	0	0	0	0
	C	0	0	0	0	0	0	0	0	0	0
SQ.KM	A	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	B	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	C	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 26 OPEN SWAMP



		A			B			C			
		ERTS			RB57			REMAP I			
TOT. SQ.KM		.000			3.380			13.900			
LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	88888	XXXXX	XXXXX	#####	#####	#####
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	0	0	0	0	0	0	0	0	0	0
	B	7	6	3	1	2	0	1	0	0	0
	C	9	15	7	10	1	2	2	4	1	0
SQ.KM	A	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
	B	.33	.75	.60	.30	.80	.00	.60	.00	.00	.00
	C	.44	2.13	1.55	3.26	.45	1.07	1.27	2.93	.80	.00

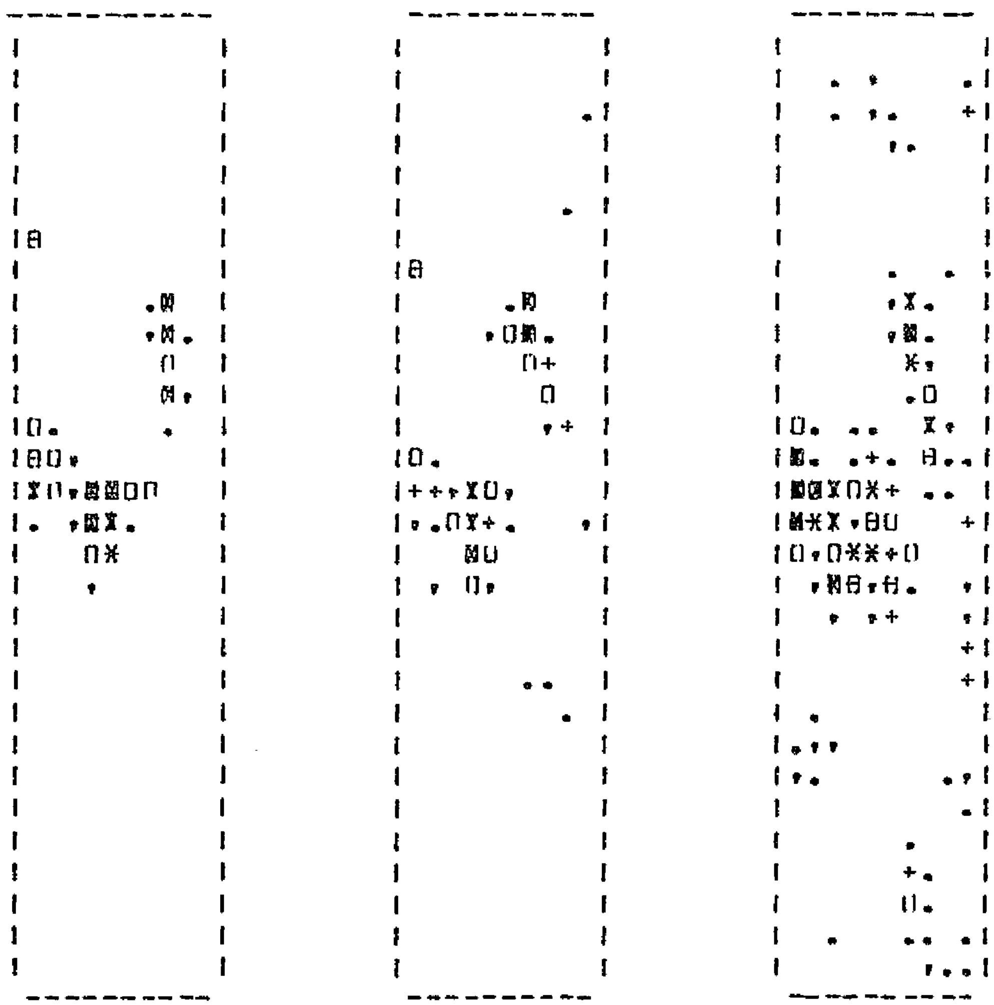
ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 26 OPEN SWAMP

UTM 410000 419000

UTM 4869000 — 4840000



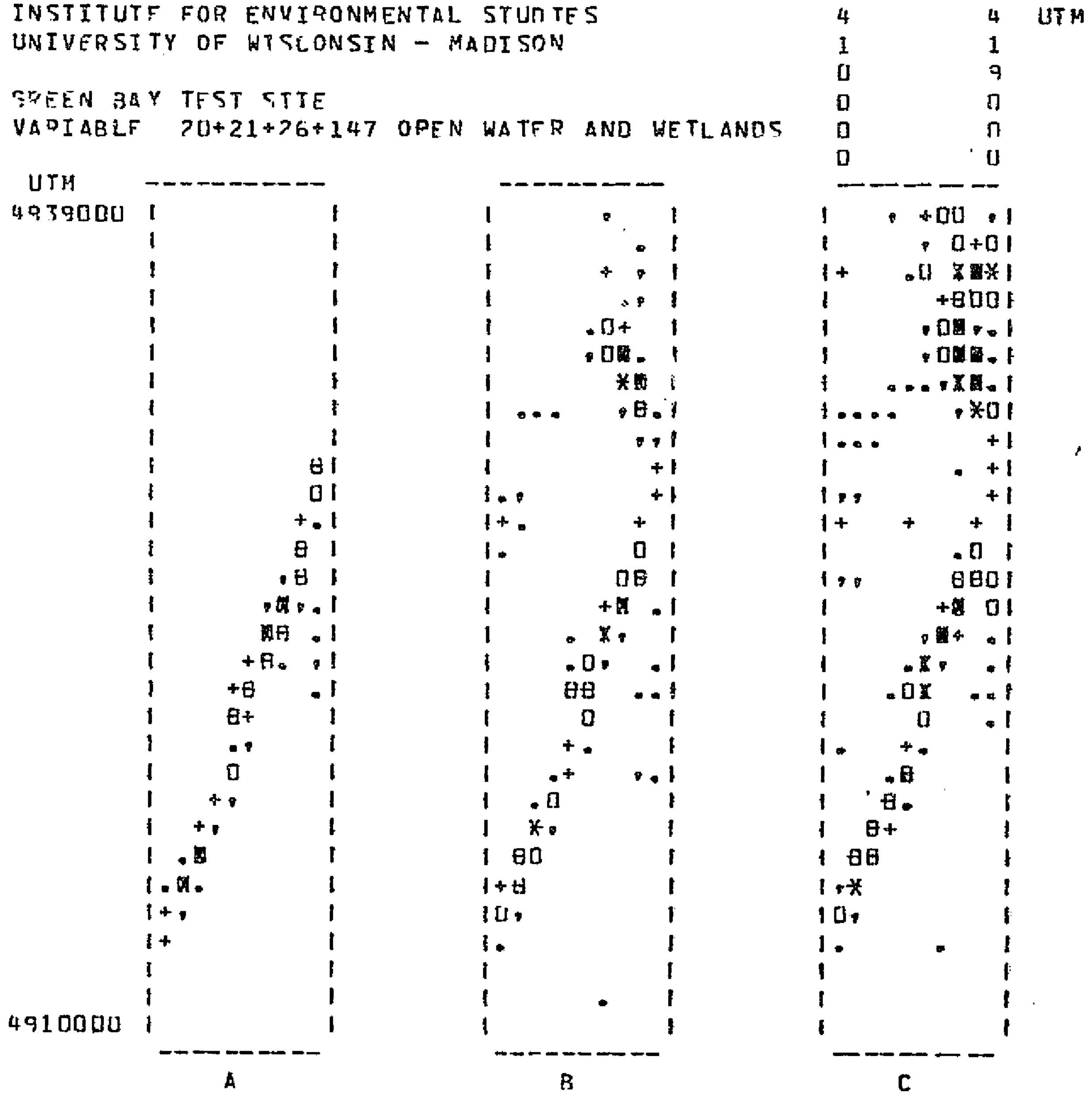
	A	B	C
	FRTS	RB57	REMAP T
TOT. SQ.KM	10.840	9.170	20.760

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	θθθθθ	XXXXX	XXXXX	▩▩▩▩▩	▩▩▩▩▩	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	6	6	0	7	2	1	2	2	4	0
	B	10	8	5	8	1	0	2	2	0	1
	C	35	20	9	8	4	5	4	2	3	1
SQ.KM	A	.33	.74	.00	2.30	.90	.52	1.33	1.42	3.30	.00
	B	.46	.97	1.00	2.60	.45	.00	1.20	1.50	.00	.99
	C	1.48	2.63	1.97	2.70	1.73	2.67	2.63	1.45	2.57	.93

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 20+21+26+147 OPEN WATER AND WETLANDS



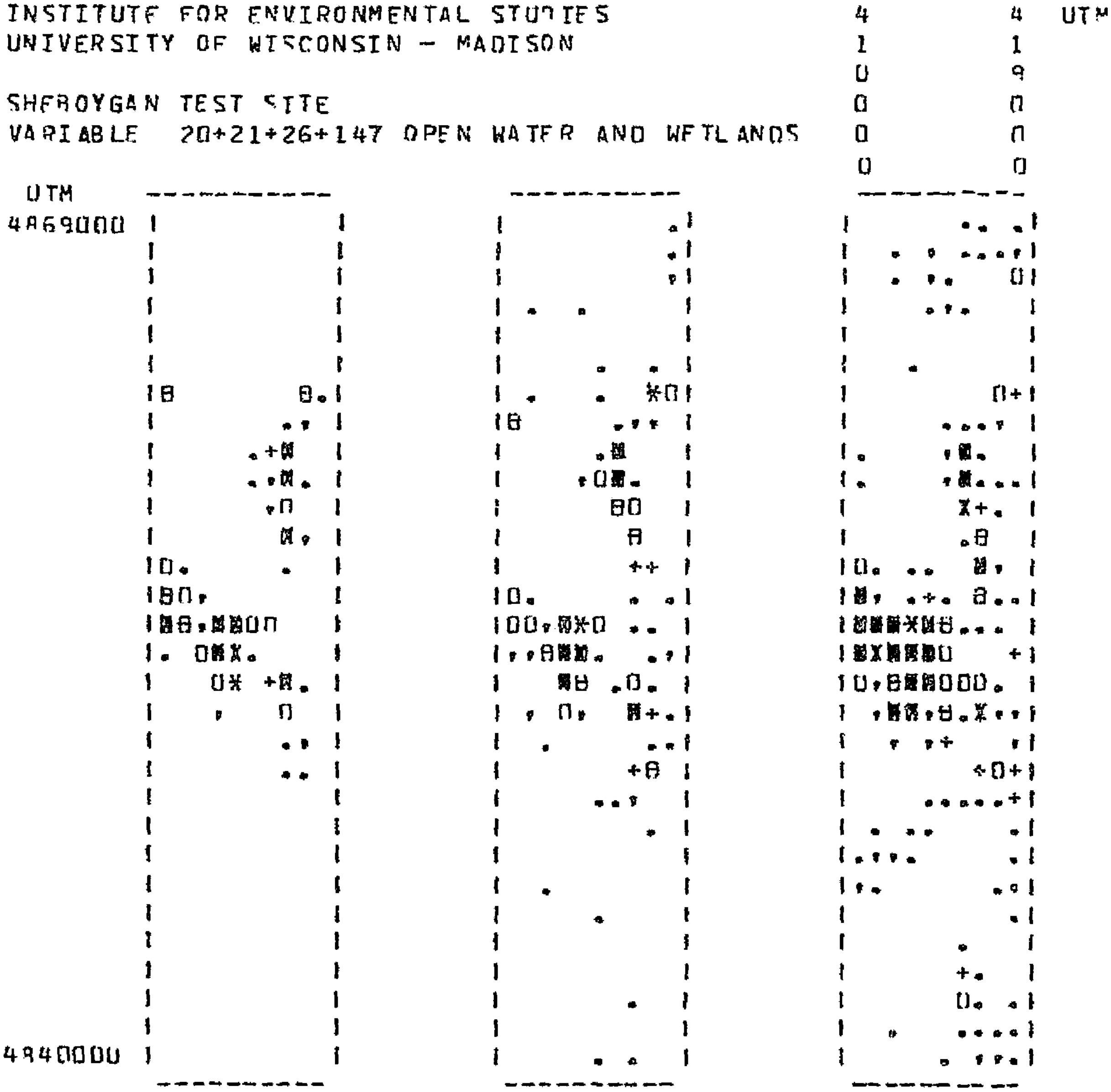
		A	B	C							
TOT. SQ.KM		10.250	14.310	25.330							

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	88888	XXXXX	XXXXX	▓▓▓▓▓	▓▓▓▓▓	▓▓▓▓▓
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	9	8	8	2	7	0	0	3	1	0
	B	23	13	10	9	6	2	1	2	1	0
	C	29	16	14	16	8	3	4	5	2	0
SQ.KM	A	.46	1.02	1.96	.73	3.02	.00	.00	2.26	.80	.00
	B	.85	1.64	2.18	3.00	2.54	1.13	.60	1.48	.89	.00
	C	1.32	2.19	3.29	5.44	3.55	1.61	2.58	3.72	1.63	.00

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 20+21+26+147 OPEN WATER AND WETLANDS



	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	14.070	16.740	29.460

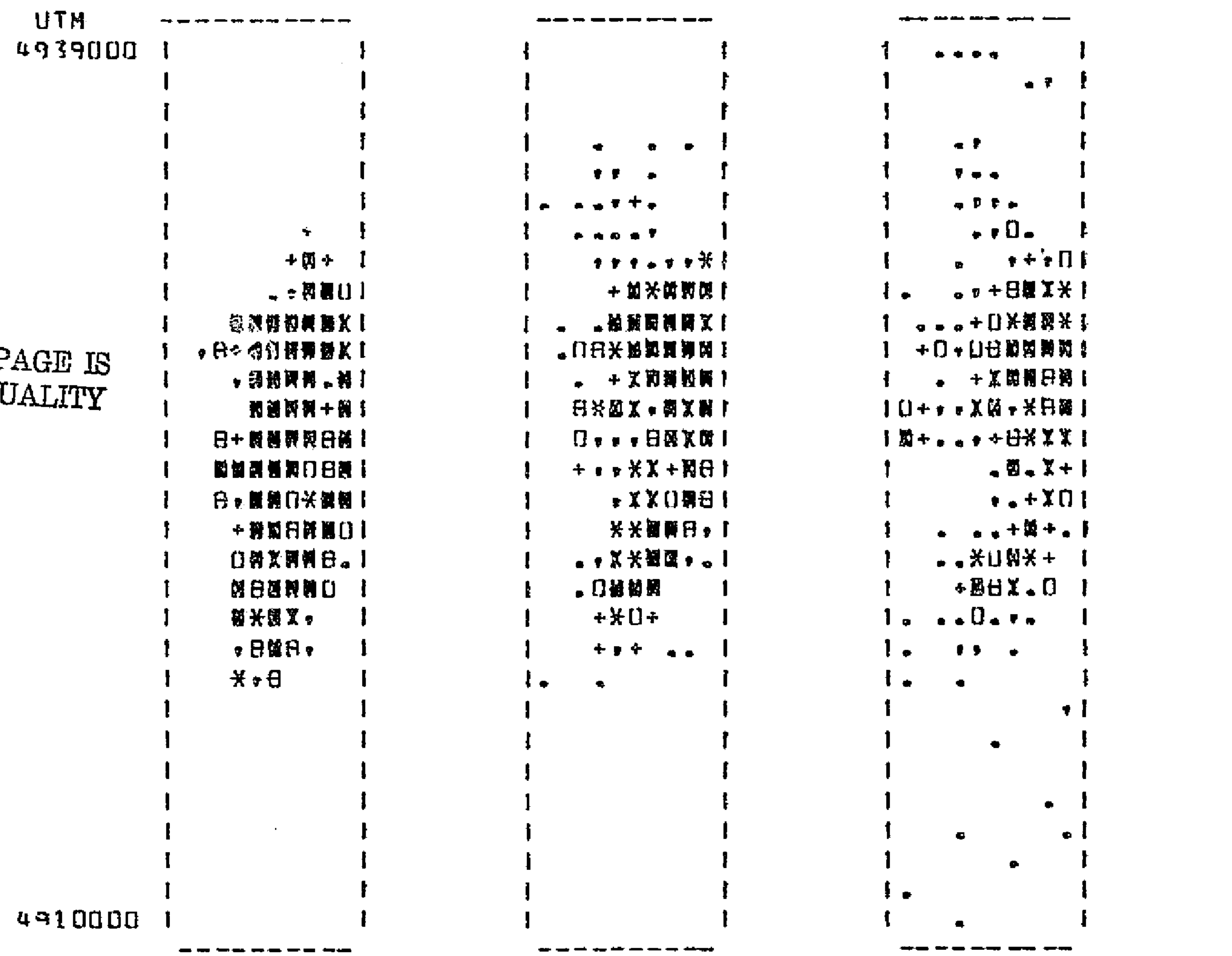
LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	88888	*****	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	13	6	2	8	4	1	1	4	3	1
	B	32	11	4	9	6	2	0	2	1	4
	C	61	23	9	10	5	1	3	6	2	8
SQ.KM	A	.80	.97	.41	2.69	1.78	.52	.68	2.90	2.42	.90
	B	1.05	1.39	.95	3.09	2.57	1.05	.00	1.40	.80	4.44
	C	2.23	3.00	1.95	3.58	2.21	.53	1.35	4.56	1.71	7.84

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 57+146 RESIDENTIAL,URBAN

4 4 UTM
1 1
0 9
0 0
0 0
0 0



	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	61.780	43.500	37.190

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	,,,,,	+++++	00000	BBBBB	*****	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99

		1	2	3	4	5	6	7	8	9	10
OCCUR	A	3	8	7	6	11	3	4	8	8	37
	B	24	20	9	5	6	9	9	7	7	18
	C	47	19	14	10	6	7	8	4	6	7
SQ.KM	A	.18	.95	1.40	1.85	4.45	1.65	2.55	5.80	6.70	36.25
	B	.63	2.64	1.98	1.58	2.67	4.82	5.66	5.18	5.72	17.67
	C	1.72	2.50	3.48	3.28	2.61	3.91	5.11	2.94	4.98	6.66

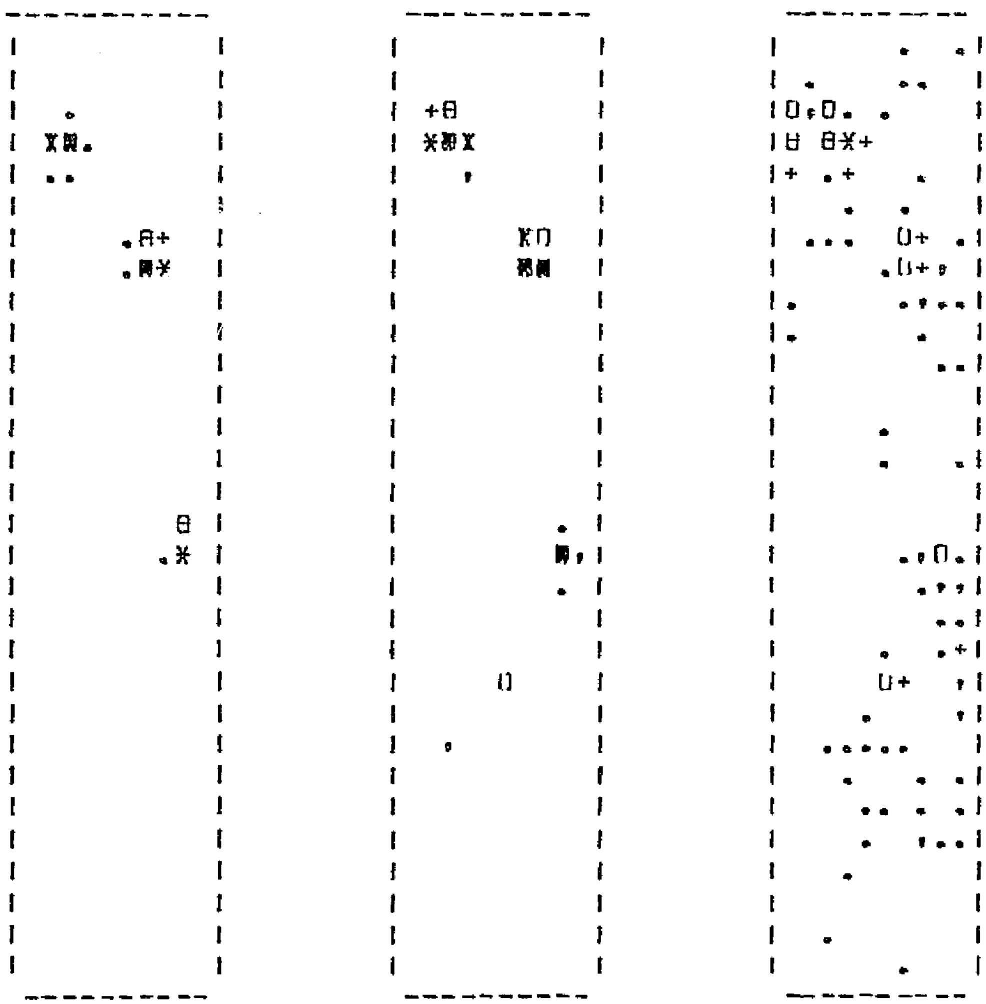
ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

ERTS-I INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 57+146 RESIDENTIAL,URBAN

UTM 410000 419000

UTM
4869000



4840000

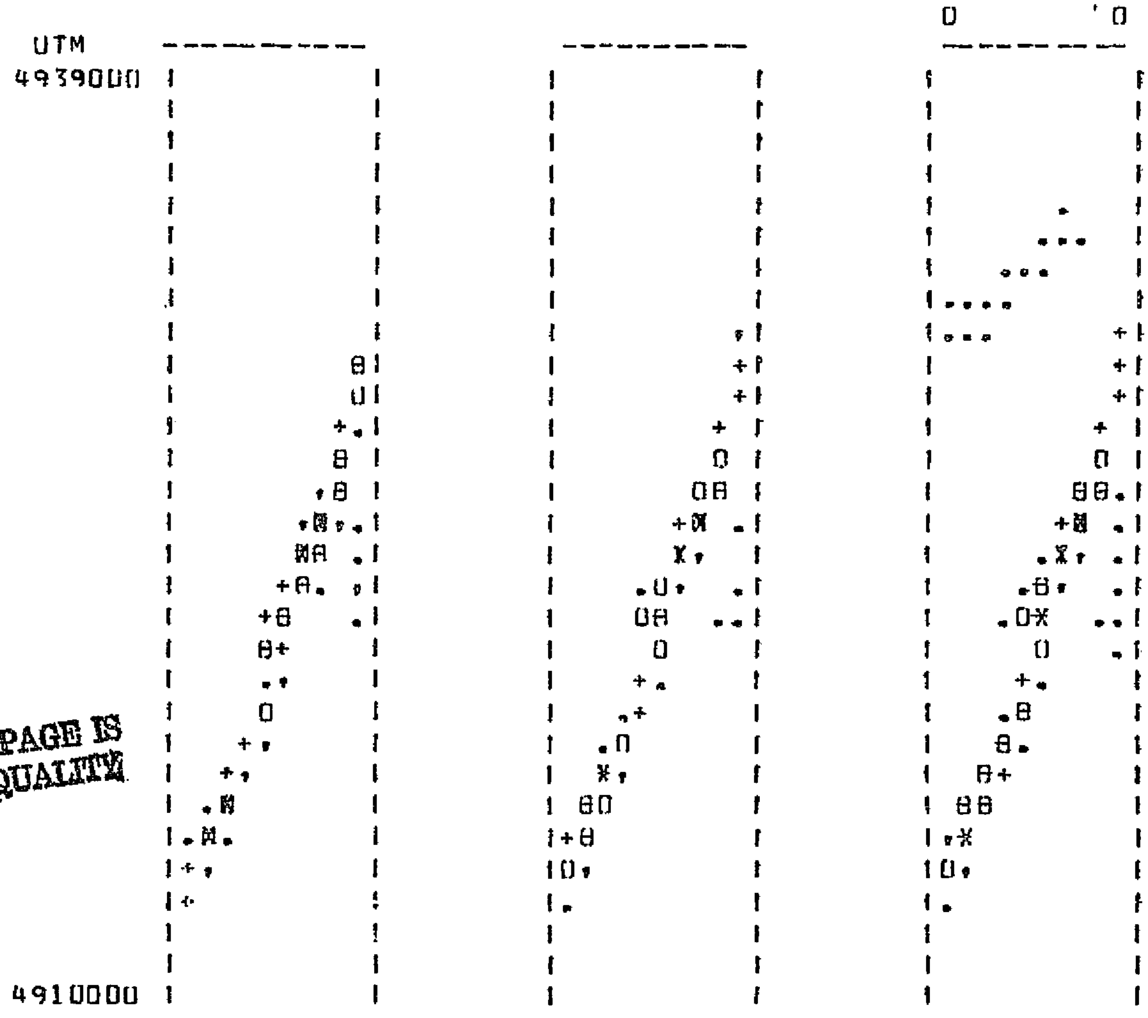
	A	B	C
	ERTS	RB57	REMAP I
TOT. SQ.KM	4.700	7.490	7.880

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	88888	*****	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	7	0	1	0	2	2	1	0	1	1
	B	2	3	1	2	1	1	2	0	0	4
	C	53	9	7	6	2	1	0	0	0	0
SQ.KM	A	.35	.00	.20	.00	.80	1.00	.60	.00	.85	.90
	B	.08	.49	.20	.60	.46	.56	1.23	.00	.00	3.87
	C	1.51	1.16	1.76	2.03	.85	.57	.00	.00	.00	.00

ERTS BAND 5 14.SEPTEMBER.1972 1053-16093-5

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE 147 RIVERS



	A		B		C				
	ERTS		RB57		REMAP I				
TOT. SQ.KM	10.250		8.690		11.010				

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	'''''	+++++	00000	88888	XXXXX	XXXXX	▩▩▩▩▩	▩▩▩▩▩	■■■■■
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99

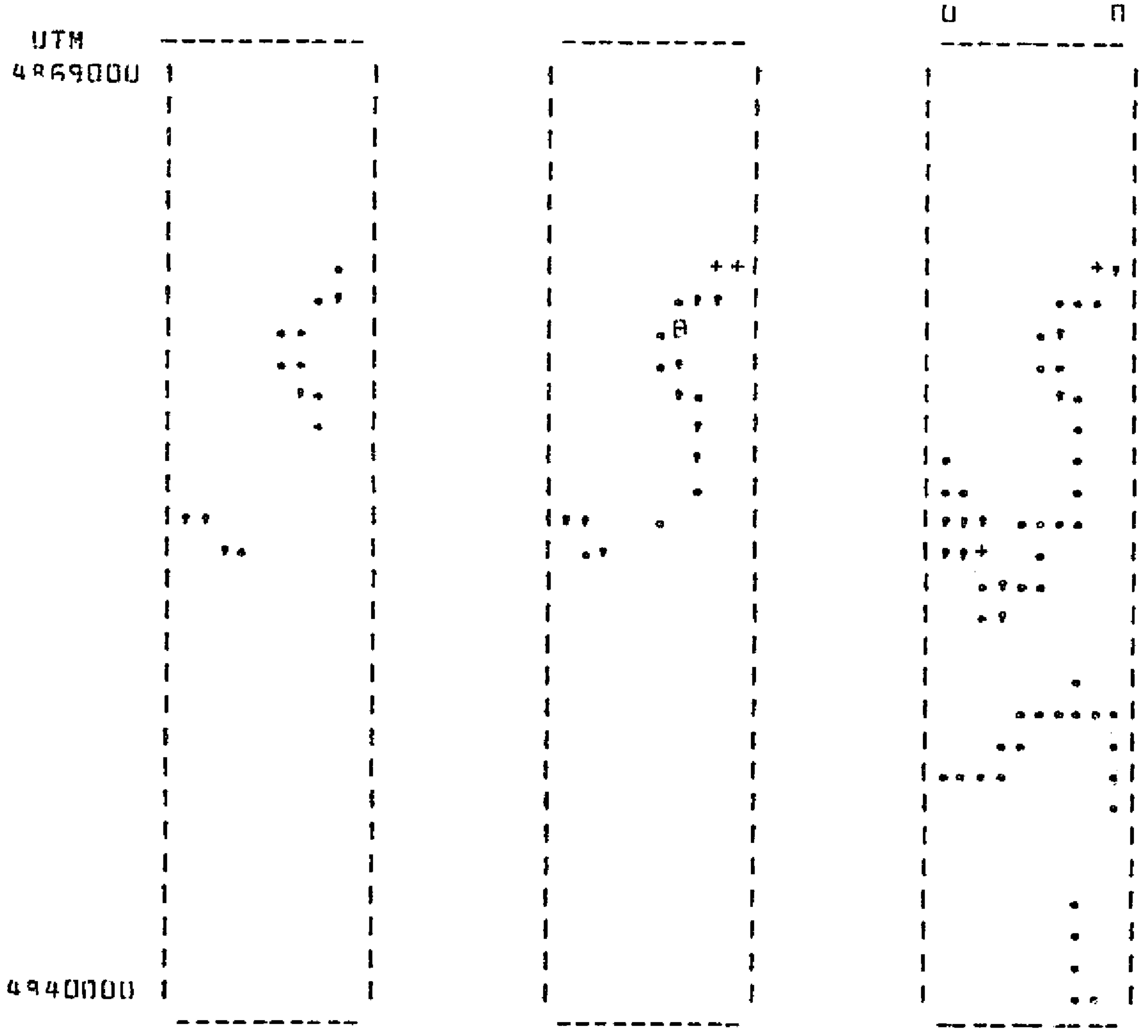
OCCUR	A	9	8	8	2	7	0	0	3	1	0
	B	9	5	7	8	4	1	1	1	0	0
	C	28	4	7	4	8	2	1	1	0	0
SQ.KM	A	.46	1.02	1.96	.73	3.02	.00	.00	2.26	.80	.00
	B	.37	.62	1.50	2.62	1.68	.55	.60	.75	.00	.00
	C	1.37	.47	1.79	1.37	3.53	1.04	.68	.76	.00	.00

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE 147 RIVERS

4	4	UTM
1	1	
0	9	
0	0	
0	0	
0	0	



	A	B	C
	ERTS	3857	REMAP I
TOT. SQ.KM	.970	2.170	3.600

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	88888	*****	XXXXX	■■■■■	■■■■■	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUP	A	9	5	0	0	0	0	0	0	0	0
	B	7	9	2	0	1	0	0	0	0	0
	C	43	10	2	0	0	0	0	0	0	0
SQ.KM	A	.39	.58	.00	.00	.00	.00	.00	.00	.00	.00
	B	.25	1.07	.45	.00	.40	.00	.00	.00	.00	.00
	C	1.81	1.34	.45	.00	.00	.00	.00	.00	.00	.00

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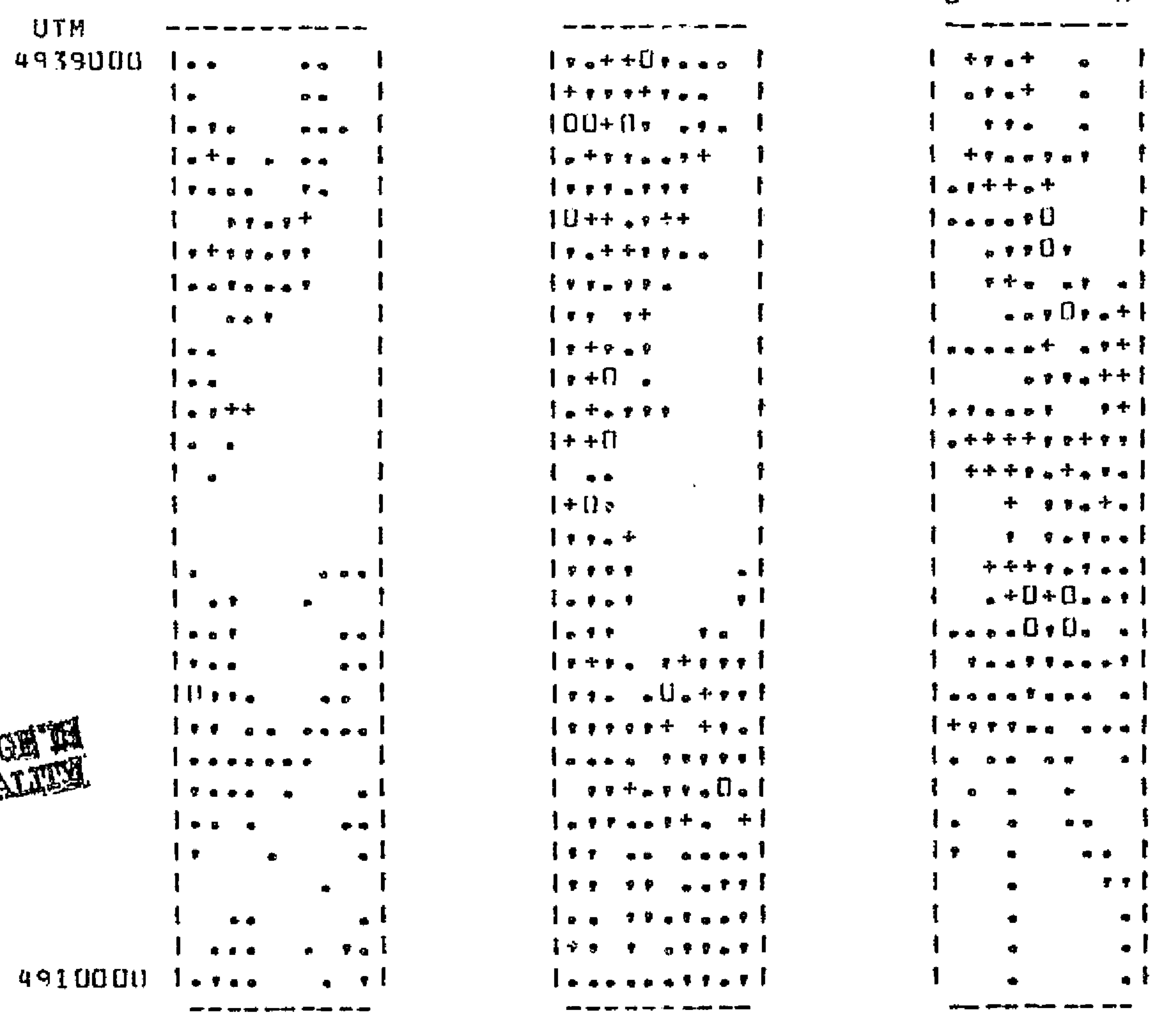
GREEN BAY TEST SITE
VARIABLE 160 ROADS



A
ERTS

B
8857

C
REMAP I

		1	2	3	4	5	6	7	8	9	10
LEVELS		1	2	3	4	5	6	7	8	9	10
		.....	,,,,,	+++++	00000	88888	XXXXX	XXXXX	■■■■■	■■■■■	■■■■■
SYMBOLS		.....	,,,,,	+++++	00000	88888	XXXXX	XXXXX	■■■■■	■■■■■	■■■■■
		.....	,,,,,	+++++	00000	88888	XXXXX	XXXXX	■■■■■	■■■■■	■■■■■
	A	93	27	5	1	0	0	0	0	0	0
OCCUR	B	68	96	30	10	0	0	0	0	0	0
	C	97	48	31	7	0	0	0	0	0	0

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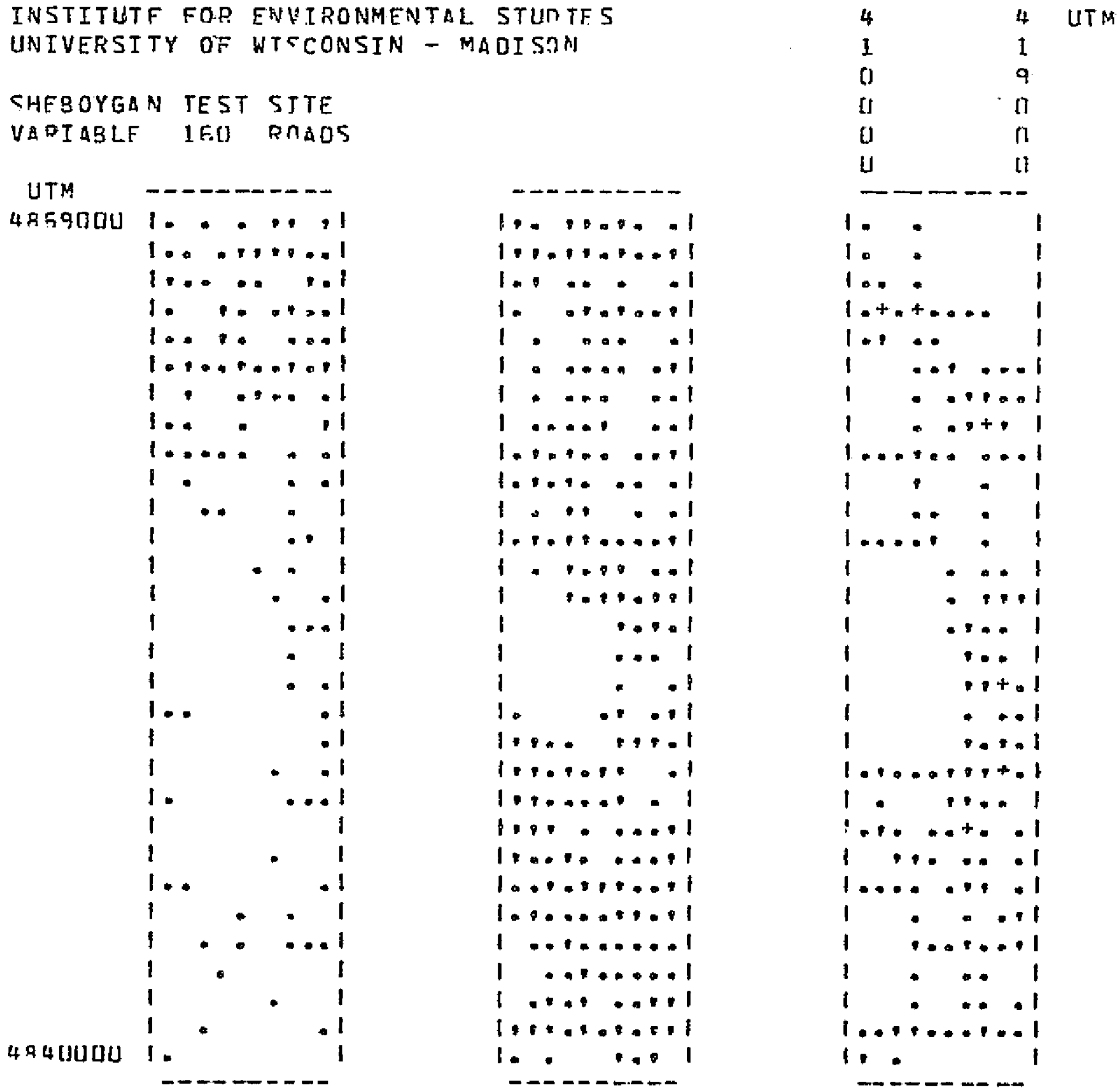
SHEBOYGAN TEST SITE
VARIABLE 160 ROADS



A	B	C
ERTS	RB57	REMAP I

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	'''''	+++++	00000	88888	*****	XXXXX	#####	#####	#####
OCCUR A	87	20	0	0	0	0	0	0	0	0
OCCUR B	135	33	0	0	0	0	0	0	0	0
OCCUR C	105	37	0	0	0	0	0	0	0	0

ERTS BAND 7 14.SEPTEMBER.1972 1053-16093-7

APPENDIX - D

McIDAS

APPENDIX - D

McIDAS

1) INTRODUCTION

McIDAS (Man-Computer Interactive Data Access System) is a pictoral data analysis system developed by the University of Wisconsin's Space Science and Engineering Center. Developed primarily for wind measurement using satellite observed cloud motion, McIDAS is sufficiently versatile that a number of diverse users have been investigating its application. These include efforts concentrating on land use and resource identification.

2) HARDWARE DESCRIPTION

Major components of McIDAS (Figure 1) include a high quality color television monitor, a medium size (1 microsecond cycle time) Datacraft 6024/5 computer, and an AMPEX video disk for storage, in analog form, of 250 video frames. Video information is not displayed directly on the monitor but is converted back into 6-bit digital form by high speed analog-to-digital (A/D) converters. (A single A/D converter is in use at this time, a second will be installed soon, and a third is planned.) The high speed stream of digital information is applied to small "look-up table" memories whose outputs are reconverted to video form to supply drive signals to the monitor. This arrangement allows nearly instantaneous alteration of enhancements, chromaticity, and hue merely by changing contents of the look-up tables.

One-hundred-fifty megabits of disk storage are provided for the operating system, program libraries, and 4 video frames of digital data; this storage will soon be tripled and will allow up to 18 digital TV frames. Other hardware includes a tape drive, cursor-control joystick and electronics, a keyboard/console for operator communication, card reader, and line printer.

3) SOFTWARE FEATURES

McIDAS' operating system is a Datacraft-desinged DMS-3 (disk monitoring system), modified by the McIDAS designers. FORTRAN-IV is available. However, an operator has at his disposal a very simple and convenient two-mode command structure which makes interactive operation simple and which can be learned quickly by a person without programming background. One class of operations are invoked by single-character operands entered on a console keyboard. 'A' and 'B', for example, advance or back-up the frame selected for display from the video disk. 'F' prints the displayed frame number.

A "line feed/character/character/return" sequence invokes another class of more complex operations. A few examples of this are illustrated in Section 4.

4) APPLICATION OF MCIDAS FOR REMOTE SENSING

Utilization of remotely-sensed data requires at least two distinct data analysis steps. First, data must be somehow processed to permit sufficiently accurate interpretation -- perhaps of ground cover types, land use or whatever. Second, some effective means must be used to retrieve the interpreted data and place it into some usable form. This may be a hard-copy map, or perhaps simply a tabulation of cover, type percentages or areas.

McIDAS, with its comparatively small computer, is ill-suited to large-scale "number smashing" numerical and statistical analysis. On the other hand, it allows a high degree of man-machine interaction so we are striving to solve the interpretation problem by taking best advantage of this capacity. Largely, this utilizes the extremely easy gray scale and color enhancement capabilities of McIDAS.

One enhancement program, E1, allows a linear enhancement over a specified range of input values; this is done by loading the look-up table to map the selected range of input values into the entire range of output values. Another procedure, SC, which we are finding especially useful for resource interpretation allows an operator to trace a curve with the display cursor across the face of the display. The ordinate represents output brightness, the abscissa, input level, so the curve defines an enhancement. The image in question is continually visible during this process, so one can instantly inspect and alter enhancements. A related program allows color displays with hue replacing output brightness on the ordinate.

Any enhancement can be saved for a given frame and recovered later. Or, a fixed enhancement can be retained for an arbitraty number of frames.

With installation of a second A/D converter in the near future and later a third, these programs and others will be expanded to allow true multi-spectral analysis.

Data extraction can be facilitated if statistical properties of the data are known. One useful tool is a routine called CURGRAM (operand code CG), which retrieves data points bounded by an adjustable rectangular cursor and prints brightness-value histograms.

"Zooming" capability is provided by repeating rows and picture elements. Because of the high-speed data transfers of the digital disk, this process is rapid, requiring approximately a minute to completely redisplay an expanded image.

Data utilization is expedited by several programs which have been developed. Image navigation, or precise computation of geographic position, was essential for the cloud motion studies which led to the system. Appropriately modified, these techniques are readily applied to ERTS data so that latitude/longitude can be listed for selected points of interest.

Another useful and simple procedure calculates surface area bounded by the display cursor. Most recently we have produced software to allow manual manipulation of the cursor (reduced, in this case, to a point) around a closed boundary. Area calculations are then performed and printed on a CRT.

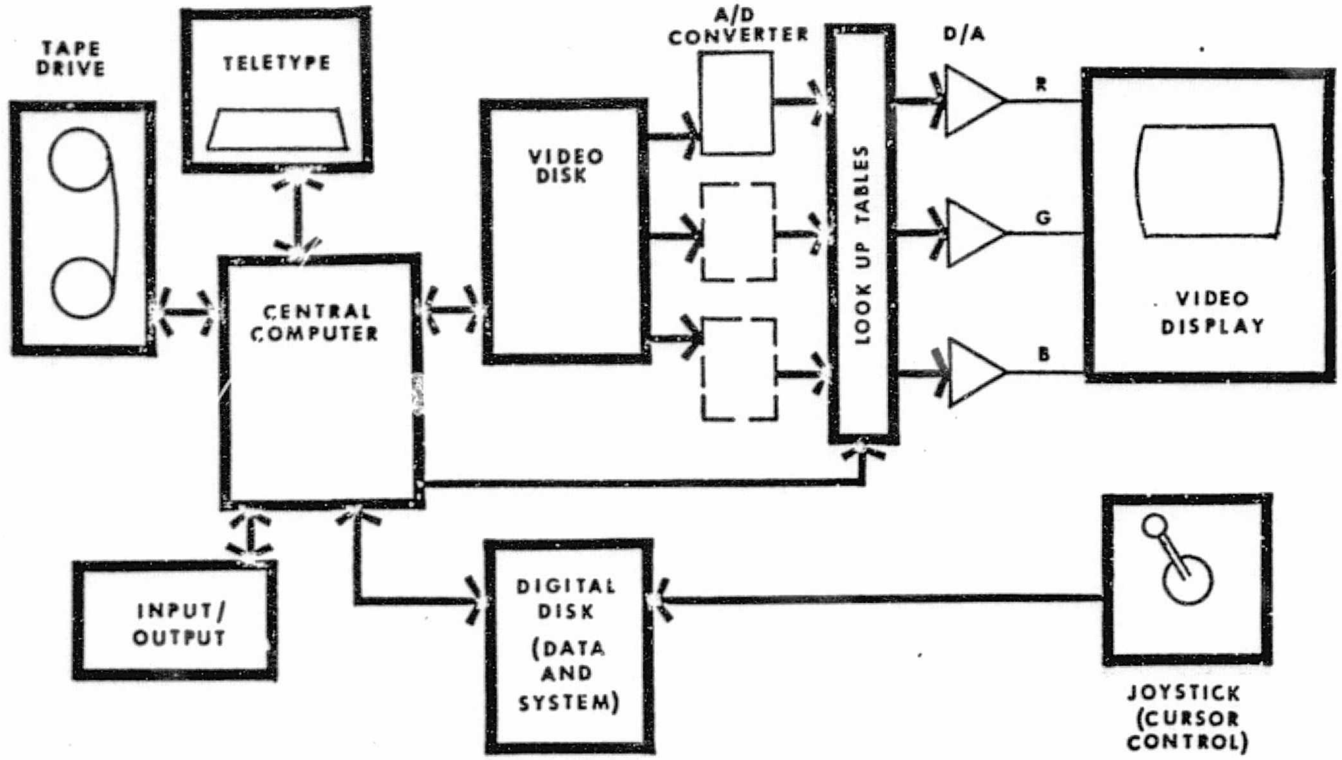


FIGURE 1 - SCHEMATIC OF McIDAS

APPENDIX - E

LINEFINDER

APPENDIX E

LINEFINDER

Introduction

The LINEFINDER procedure was developed by the Department of Landscape Architecture/Environmental Awareness Center with support by the Wisconsin Department of Transportation by Denis Bunde, research assistant and Mike Andersen, research assistant. Adaptations and documentation was supported by the USDT-Bureau of Outdoor Recreation (Contract no. 2-14-07-6) and with HATCH support (142-1900).* The initial program was developed for the allocation of interstate 57 corridors between Green Bay and Milwaukee Wisconsin (REMAP I and II).

Allocation of land for construction of a linear feature such as a powerline or highway was based on a model in the original REMAP application. The original model was constructed to account for as many interests as possible. For example it included sub-models of engineering feasibility, visual effect, disruption to the natural system, disruption to the cultural system, etc. The approach taken in the REMAP study was to construct models which represent the cost from the modeler's point of view of running the linear element through a given cell. For example, from the farmer's point of view (agricultural model), it should cost a great deal to run through agricultural land, while from the engineer's point of view (engineering feasibility model), it would cost very little due to the relative flatness of the land. Once the sub-models were created they were weighted to represent the relative importance of different points of view and combined.

---

*Niemann, B.J. Jr., Rose R.A., and Marcus, P.A., et al., Handbook: Applications of Remote Sensing and Computer Techniques for Recreation Planning, Vol. 2 & 3. Department of Landscape Architecture/Environmental Awareness Center, University of Wisconsin-Madison: March 1974.

The LINEFINDER Program

To the previously mentioned model is applied the line-finding algorithm which, given a model, a starting cell, and a finishing cell, finds the lowest cost route from start to finish in terms of that model. The algorithm consists of two parts:

a) Find the minimum cost of going from the starting point to all other points in terms of the model (subroutine DISTR).

b) Follow the path from the finish to the start that will minimize the total cost accumulated by passing through cells (subroutine FINDR). Note: If the cost of going through each eell were the same, the minimum cost route would be the shortest route. However, since cell values, the minimum cost route is not necessarily the shortest.

DISTR and FINDR

The output of DISTR is a matrix which specifies the cost of the minimum cost path from every cell to the origin. Subroutine FINDR is an implementation of Algorithm CHEAP described below. Its output is the array JPATH which indicates which cells are included in the minimum cost path from the starting point to the origin specified to subroutine DISTR. These subroutines are described below:

DISTR (COST, TOT, XINIT, YINIT)	DISTance Route Generates the Distance Matrix TOT with the integers XINIT and YINIT specifying the origin. The real matrix COST contains the effective cost of running the corridor horizontally or vertically through that cell.

FINDR (TOT, X, Y, ROUTE)	<u>FIND Route</u> Finds minimum cost ROUTE from integer coordinates x, y to the origin of array TOT. The output of FINDR is in a format such that it can be fed directly into the corridor impact routines.

The program listings for DISTR and FINDR (Figure 1) comprise the LINEFINDER program. DISTR creates an array of relative "costs" to get from any cell to a derived cell (XINIT, YINIT) (one of the end points). FINDR, given a cell (the other endpoint) follows the path of least cost thru all cells back to the "first" endpoint. A general discussion of the LINEFINDER algorithm follows the figure.

```
      SUBROUTINE DISTR(COST,TOT,XINIT,YINIT)
      PARAMETER MX=60,MY=58
      PARAMETER MX2=MX-1
      DIMENSION COST(MX,MY),TOT(MX,MY),COEFF(6),XINC(6),YINC(6)
      INTEGER X,Y,X2,Y2,XINC,YINC,XINIT,YINIT
      DATA/XINC/-1,0,1,-1,0,1/YINC/1,1,1,-1,-1,-1/
      DATA/COEFF/.707107,.5,2*.707107,.5,.707107/
      LOGICAL ISW
C INITIALIZE
      N=0
      DO 10 Y=1,MY
      DO 10 X=1,MX
      IF(COST(X,Y).GT.0.0)GO TO 10
      N=N+1
      COST(X,Y)=1.E-5
10    TOT(X,Y)=1.E10
      IF(N.GT.0)PRINT 12,N
12    FORMAT(1H0,I3,' CELLS WERE FOUND THAT WERE LESS THAN ZERO BY SUBRO
     *UTINE DISTR')
      TOT(XINIT,YINIT)=0.0
      Y=YINIT
* C CONSIDER MOVING FROM CELL(X,Y) TO CELL(X-1,Y)
15    DO 20 X=2,MX
      A=TOT(X,Y)+.5*(COST(X,Y)+COST(X-1,Y))
      IF(A.GE.TOT(X-1,Y))GO TO 20
      TOT(X-1,Y)=A
20    CONTINUE
C CONSIDER MOVING FROM CELL(X,Y) TO CELL(X+1,Y)
      DO 30 X=1,MX2
      A=TOT(X,Y)+.5*(COST(X,Y)+COST(X+1,Y))
      IF(A.GE.TOT(X+1,Y))GO TO 30
      TOT(X+1,Y)=A
30    CONTINUE
C UPDATE TOT MATRIX FOR ROWS Y-1 AND Y+1
      ISW=.TRUE.
      DO 45 X=1,MX
      DO 40 I=1,6
      X2=X+XINC(I)
      Y2=Y+YINC(I)
      IF(X2.LT.1.OR.X2.GT.MX.OR.Y2.LT.1.OR.Y2.GT.MY)GO TO 40
      A=COEFF(I)*(COST(X2,Y2)+COST(X,Y))+TOT(X,Y)
      IF(A.GE.TOT(X2,Y2))GO TO 40
      TOT(X2,Y2)=A
      IF(I.GT.3)ISW=.FALSE.
40    CONTINUE
45    CONTINUE
      IF(ISW)GO TO 50
C THE PREVIOUS ROW (Y-1) MUST BE REPROCESSED
      Y=Y-1
      GO TO 15
C IF Y POINTS TO ROW MY, THE ALGORITHM IS DONE
50    IF(Y.EQ.MY)RETURN
C PROCESS THE NEXT Y ROW
      Y=Y+1
      GO TO 15
      END
```

```
      SUBROUTINE FINDR(TOT,X,Y,ROUTE)
      PARAMETER MX=60,MY=58
      INTEGER X,Y,ROUTE,XINC(8),YINC(8),TEMP
      DIMENSION ROUTE(MX,MY),COEFF(8),TOT(MX,MY)
      DATA/XINC/1,1,0,-1,-1,-1,0,1/YINC/0,-1,-1,-1,0,1,1,1/
      DATA/COEFF/.5,.707107,.5,.707107,.5,.707107,.5,.707107/
      INTEGER TYPE(8)/1,4,1,3,1,3,1,3/
C FIND A MINIMUM PATH FROM X,Y TO THE ORIGIN OF THE TOT MATRIX.
C INITIALIZE
      DO 5 J=1,MY
      DO 5 I=1,MX
5     ROUTE(I,J)=0
      JX=X
      JY=Y
C DONE YET
100   IF(TOT(JX,JY).LT.1.E-4)RETURN
C FIND THE NEXT CELL ON THE MINIMUM PATH BY SUCCESIVELY TRYING ALL 8
C SURROUNDING CELLS.
      AMAX=0.0
      DO 110 I=1,8
      J=XINC(I)+JX
      K=YINC(I)+JY
      IF(J.LT.1.OR.J.GT.MX.OR.K.LT.1.OR.K.GT.MY)GO TO 110
      A=(TOT(JX,JY)-TOT(J,K))/COEFF(I)
      IF(A.LE.AMAX)GO TO 110
      TEMP=I
      AMAX=A
110   CONTINUE
C UPDATE COEFF, XCOORD, YCOORD
      ROUTE(JX,JY)=ROUTE(JX,JY)+TYPE(TEMP)
      JX=JX+XINC(TEMP)
      JY=JY+YINC(TEMP)
      ROUTE(JX,JY)=TYPE(TEMP)
      GO TO 100
      END
```


FIGURE 1 LINEFINDER -- Subroutines

*NOTE: Statement 15 should read: DO 20 X = MX,2

LINEFINDER

GENERAL CONSIDERATIONS

The program LINEFINDER finds the minimum cost corridor of a given width between two points on a matrix representative of a map. It is assumed that the corridor runs through the center of the cells, and may proceed to the next cell only horizontally, vertically or diagonally. There are three parameters which the user specifies: RATIO, RATIO2, and SQUARE.

The parameter RATIO, which must be less than or equal to one, determines the width of the corridor with respect to the width of the cells. For example, if RATIO is one, then the corrido' 'sed will be as wide as a cell. If RATIO is .5, it will be half as wide, *et cetera*.

The parameter RATIO2, which must be one or greater than one, allows consideration of corridors with effective costs greater than the minimum. For example, if RATIO2 is 1.01, all corridors are considered that have an effective cost no more than one per cent greater than the minimum cost corridor. This gives some idea of alternative corridors that have nearly the same effective cost, and of how constraining the corridor is.

The third parameter is SQUARE. This determines how the input map is transformed. If SQUARE is false, then a constant is added to every cell in the map so that all costs in the map range from zero upward. This is done to prevent the LINEFINDER from going into an infinite loop which can occur if a negative cost is associated with a cell. If SQUARE is true, then not only is a constant added to every cell in the map, but in addition, all the cell values are squared. This emphasizes the relatively high valued cells. This mode of operation effectively simulates what a human does in drawing a corridor on a map.

The output of the LINEFINDER program is a symbolic map. All cells which fall in a minimum cost corridor are printed with an "x." All cells which belong to the union of slightly more expensive corridors are printed with a plus (+). All other cells are printed with a period. An example of LINEFINDER output is shown in Figure 15 of the text.

COMPUTER FORMAT

The input map is read by the standard subroutine UNPACK. The input file is UPFILE, which must be in the standard system format except by subroutine UNPACK.

The coordinates used by the program LINEFINDER are the ones used internally to identify the x and y location of each record. In the one-kilometer data bank, the coordinates are represented by the three digits before the decimal place. In the 1/3-kilometer data bank, each coordinate is multiplied by three and then rounded off to an integer. For example, a coordinate of 433.3 is represented internally as the integer 1270.

LINEFINDER CONTROL CARDS

One card is needed for each minimum cost route which is to be found. Each card is written with the following format.

Column	Field Name	Description
1-5	Location	A right justified integer indicating the location of the input data in each record read by UNPACK. A 1 will cause variable 1 to be mapped, a 2 will cause variable 2 to be mapped, etc.
6-10	X_1	The internal x-coordinate of the desired corridor's starting location written as a right justified integer.
11-15	Y_1	The internal y-coordinate of the desired corridor's starting location written as a right justified integer.
16-20	X_2	The internal x-coordinate of the desired corridor's terminal location written as a right justified integer.
21-25	Y_2	The internal y-coordinate of the desired corridor's terminal location written as a right justified integer.

Column	Field Name	Description
26-30	Ratio	The ratio of the width of the corridor compared to the width of each cell written as a floating point number. The assumed decimal point which may be overridden by an explicit decimal point is to the left of the field. This number must be less than or equal to one.
31-35	Ratio2	A ratio of the greatest cost corridor to be considered compared to the lowest cost corridor. The ratio must be greater than or equal to one, and is written as a floating point number. The implied decimal point which may be overridden by an explicit decimal point, is just to the left of the field.
36	Square	If this field contains a "T", the input map values will be squared before LINEFINDER is run. If "F", they will not be squared.

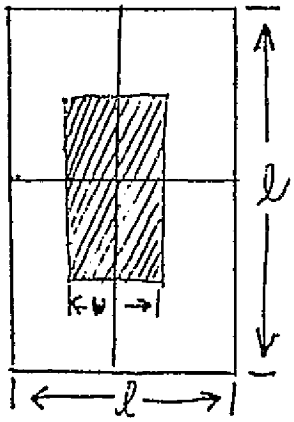
DESCRIPTION OF THE ALGORITHM

The input value map is read into a two-dimensional matrix called COST. A constant is added to all cells in the matrix COST so that every cell is greater than or equal to zero. This is done so that there will be no negative costs. A negative cost may cause the LINEFINDER to go into an infinite loop. If the variable SQUARE is true, all the values in the COST matrix are then squared.

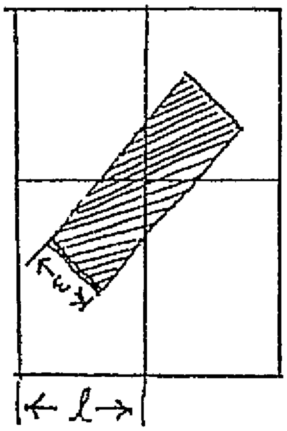
The goal of the algorithm is to find the minimum cost corridor connecting two end points on the COST surface. Before we can discuss how the algorithm works, we must first discuss how the effective cost of a corridor is found.

The cost of a corridor through a cell is the proportion of that cell covered by the corridor times the cost of the entire cell. This relation assumes that the attributes of each cell are evenly distributed within that cell. The effective cost of the entire corridor is the sum of the costs for the individual cells.

Each corridor segment is assumed to run from the center of one cell to the center of an adjacent cell. Only two orientations need be considered: vertical and diagonal. All other segments can be obtained by rotating these two basic orientations.



Vertical Line Segment



Diagonal Line Segment

Assume that the width of a corridor is w and the length of a cell is L. Consider a vertical segment which runs from (x,y) to cell (x,y+1). The area impacted in cell (x,y) is $\frac{wL}{2}$. The area of cell (x,y) is L^2. Let VERT be the fraction of the cell impacted. Then:

$$VERT = \frac{wL}{2L^2} = \frac{w}{2L} = 1/2\ RATIO$$

where $RATIO = \frac{w}{L}$

Let $IC(x_1, y_1, x_2, y_2)$ be the incremental cost of getting from cell (x_1,y_1) to cell (x_2, y_2)

Then the impact of this corridor segment is:

$$IC(x,y,x+1,y+1) = VERT * COST\ (x,y) + VERT * COST\ (x,y+1)$$

In general, the impact of any corridor segment which runs horizontally or vertically is VERT times the cost of the first cell plus VERT times the cost of the second cell.

Consider a diagonal cell running from cell (x,y) to cell (x+1,y+1). The area impacted in cell (x,y+1) is:

$$AREA_{x,y+1} = \frac{1}{2}\ \frac{w}{2}\ w = \frac{w^2}{4}$$

Let CUT be the fraction impacted. Then

$$CUT = \frac{w^2}{4L^2} = \frac{RATIO^2}{4}$$

Similarly, the fraction impacted in cell (x+1,y) is also Cut. Let DIAG be the fraction impacted in cell (x+1,y). Then:

$$DIAG = \frac{w\sqrt{\frac{L^2}{4} + \frac{L^2}{4}}}{L^2} - CUT$$

$$= \frac{\sqrt{2}}{2}\ \frac{w}{L} - CUT$$

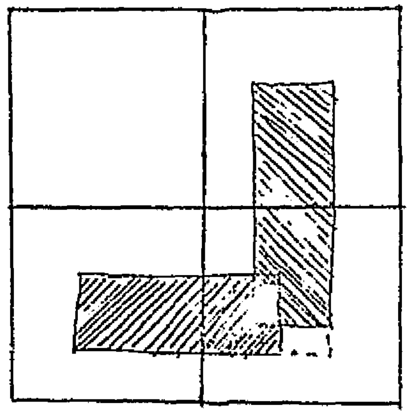
$$= \frac{\sqrt{2}}{2}\ RATIO - CUT$$

The cost of this diagonal cell is:

IC(x,y,x+1,y+1) = DIAG * COST (x,y) + CUT * COST (x+1,y) + CUT * COST (x,y+1) + DIAG * COST (x+1,y+1)

In a similar way, the cost of all the other diagonal corridor sections can be computed.

It is not obvious that the total effective cost of a corridor made up of two corridor segments is the sum of the costs for each section. Consider a corridor which runs from cell (1,1) to cell (2,1) and then to cell (2,2). This corridor is shown below.



A Corridor Running From Cell (1,1) to Cell (2,2)

It will be seen that the small square in cell (2,1) belongs to both segments, and hence is counted twice. In addition, the square enclosed by the dotted line is not counted at all. However, it can be shown that the area in the dotted square is exactly the area contained in the solid square. Hence, the corridor from cell (1,1) to cell (2,2) is the sum of the separate corridor segments. It can be shown that the area of corridor overlap within a cell equals the area of required fill for all pairwise combinations of corridor segments, except for the case where one segment lies on top of another. This exception case will never occur as part of a reasonable corridor.

It can now be seen that the cost of a corridor is simply the sum of the cost of each corridor segment.

DISTRANCE MATRIX

The DISTANCE Matrix (D) is a matrix the same size as the COST Matrix which, when the following algorithm is complete, will contain in each cell the total effective cost of the minimum cost corridor from that cell to the origin cell. Let the origin cell have coordinates (x,y). For ease of exposition, we will assume that the following operations are done only when all cells used in each operation lie within the study area.

1. (Initialize) Fill all the cells in the Distance Matrix with an extremely large number, which is larger than any minimum cost route on the cost surface. Let (x,y) be the origin, and let D(x,y) = 0.
2. [Consider moving from cell (x,y) to cell (x-1,y)]
   Do for x = minimum (x) step 1 until maximum (x) in row y:
      If D(x-1,y) > D(x,y) + IC(x,y,x-1,y) then
         D(x-1,y) ← D(x,y) + IC(x,y,x+1,y)
3. [Consider moving from cell (x,y) to cell (x+1,y)]
   Do for x = maximum (x) step 1 until minimum (x) in row y:
      If D(x+1,y) > D(x,y) + IC(x,y,x+1,y) then
         D(x+1,y) ← D(x,y) + IC(x,y,x+1,y)
4. [Try moving from row y to row y-1]
   If y = 1, go to step 7.
   ISW ← True
   Do for all x in row y:

```
        If D(x,y-1) > D(x,y) + IC(x,y,x,y-1) then
           D(x,y-1) <- D(x,y) + IC(x,y,x,y-1)
           ISW <- False
        If D(x-1,y-1) > D(x,y) + IC(x,y,x-1,y-1) then
           D(x-1,y-1) <- D(x,y) + IC(x,y,x-1,y-1)
           ISW <- False
        If D(x+1,y-1) > D(x,y) + IC(x,y,x+1,y-1) then
           D(x+1,y-1) <- D(x,y) + IC(x,y,x+1,y-1)
           ISW <- False
5.  [Check to see if Row (y-1) must be reprocessed].
    If ISW = False, then
        y <- y-1
        Go to step 4.
6.  [Consider moving from row (y) to row (y+1)]
    If y points to the top of study area, then STOP.
    The Algorithm is completed.
    Do for all x in row:
        If D(x,y+1) > D(x,y) + IC(x,y,x,y+1) then
           D(x,y+1) <- D(x,y) + IC(x,y,x,y+1)
        If D(x+1,y+1) > D(x,y) + IC(x,y,x+1,y+1) then
           D(x+1,y+1) <- D(x,y) + IC(x,y,x+1,y+1)
        If D(x-1,y+1) > D(x,y) + IC(x,y,x-1,y+1) then
           D(x-1,y+1) <- D(x,y) + IC(x,y,x+1,y+1)
           y <- y+1
           Go to step 2.
```

WHY THE DISTANCE ALGORITHM WORKS

After the Distance Algorithm stops, D(x,y) for all x and y contains the smallest value of $D(x_a,y_a)$ plus $IC(x_a,y_a)$ where x_a, y_a are the coordinates of a cell adjacent to x,y. We will prove that D(x,y) contains the effective cost of the minimum cost corridor from cell (x,y) to the origin. We will do this by first describing an algorithm which defines a corridor from cell (x,y) to the origin. Secondly, we will show that the effective cost of this route is D(x,y). And thirdly, we will show that there is no less expensive corridor.

Algorithm CHEAP constructs a corridor from cell (x,y) to the origin. The algorithm is as follows:

1. Set pointer "P" to point to the starting cell (x,y)
2. Mark cell P. If P points to the origin, Stop.
3. Set P to point to the minimum D(x,y) adjacent to the cell now pointed to by P. If there is more than one minimum, arbitrarily pick one. Go to Step 2.

When the algorithm stops, the route is the line connecting all the marked cells.

The algorithm CHEAP is guaranteed to stop for the following reason. If P points to the origin, then D(P) = 0, and the algorithm will stop. If P points to a cell not the origin, and if the next cell chosen in Step 3 is $\hat{P}$, then $D(\hat{P}) < D(P)$. This is true since the cost of very cell is greater than or equal to zero, hence $IC(P,\hat{P}) > 0$, and hence step 3 by the way that matrix D was constructed, $D(\hat{P}) < D(P)$. Hence D(P) for every new P chosen in Step 3 will be smaller than the last. Since there are only a finite number of cells in the matrix, in a finite number of steps, a P will be chosen such that D(P) = 0. Pointer P will now point to the origin and the algorithm will stop.

The effective cost of the corridor found by algorithm CHEAP from cell P is D(P). Let P_1 be the cell adjacent to P on the corridor found by algorithm CHEAP. Then $D(P) = D(P_1) + IC(P,P_1)$. By induction, it can be found that $D(P) = IC(P,P_1) + IC(P_1,P_2) + \ldots + (P_n, \text{origin})$. From this it can be seen that D(P) is the effective cost of the corridor from P to the origin.

We will now show that algorithm CHEAP gives the minimum cost corridor from cell P to the origin. Let us call this CHEAP corridor Corridor C_o. The effective cost of corridor C_o is D(P). Consider an alternative corridor A which connects cell P and the origin, which is not an algorithm Short route. We will construct a series of corridors C_i connecting P and the origin such that length $(C_m+1) > Cost(C_m)$ for $m < n$, and that C_n is alternative corridor A.

We will now show how to construct corridor C_m+1 from corridor C_m. Follow route C_m starting from point P to the origin. Let P_1, be the last cell on which corridor C_m and corridor A agree. Corridor C_m+1 is a new route which follows corridor C_n from cell P to cell P_1, follows corridor A from cell P_1 for one cell, cell P_2, and then takes an algorithm CHEAP corridor from this cell to the origin. Since $D(P_1)$ is the minimum of $D(P_j) + IC(P_1,P_j)$, where P_j is any of the cells adjacent to P_1, it is clear that $D(P_1) < D(P_2) + IC(P_1, P_2)$. Hence, cost $(C_m) <$ cost (C_m+1). This is true for all m, less than or equal to n. Hence we have:

$$\text{COST } (C_o) < \text{COST } C_1 < \cdots < \text{COST } (C_n) = \text{COST } (A)$$

Because of the transitive property of the relation, less than, COST $(C_o) <$ COST (A).

We have shown that any corridor from an arbitrary point P to the origin which is not an Algorithm CHEAP corridor has a greater cost than the Algorithm CHEAP corridor. Hence, the minimum cost corridor from P to the origin being entirely within the surface will be found by Algorithm CHEAP.

DETERMINING THE CORRIDOR

One way of locating the optimum corridor is to put the origin of the Distance Matrix at one end point of the desired corridor, use the Distance Algorithm to generate the Distance Matrix, and then start Algorithm CHEAP at the other end point of the desired corridor. Theere are two further capabilities which were desired.

1. If there is more than one minimum corridor, it is desirable to locate all of them. Algorithm CHEAP can be modified to do this.
2. It is desirable to print out the union of all corridors which are only slightly longer than the minimum cost corridor.

In order to accomplish this, the following algorithm was employed.

Call the beginning point of the desired corridor E_1 and the end point E_2. The Distance Algorithm is used to determine the first Distance Matrix D_1 with its origin at E_1, and Distance Matrix D_2 with its origin at E_2. Consider any point P. The minimum cost corridor from E_1 to P is $D_1(P)$, and the minimum cost corridor from P to E_2 is $D_2(P)$. The minimum cost route from E_1 to E_2 through point P is $D_1(P)$ +

c-3

$D_2(P)$. The minimum cost route from E_1 to E_2, which may or may not go through point P, is $D_1(E_2)$. If $D_1(P) + D_2(P) = D_1(E_2)$, then point P is on a minimum cost route from E_1 to E_2. If $D_1(P) + D_2(P) < \text{RATIO2} \cdot D_2(E_2)$ where RATIO2 > 1, and if P is not a member of the minimum cost corridor then point P belongs to the union of corridors which are less than RATIO2-1 times more expensive than the minimum cost corridor.

SAMPLE LINEFINDER RUN STREAM

Assume that the generated model is on tape U8086, and that the programs are on tape U6944.

RUN name,account-number,page-limit	RUN CARD
@ASG,T UPFILE.	Assign Fortrand file space.
@ASG,T PROG.	
@ASG,TH TAPE.,T,U8086/U6944	Reserve one tape drive on which to mount these tapes, the first tape is mounted.
@COPY,G TAPE.,UPFILE.	Copy tape U8086 into file UPFILE.
@TSWAP TAPE.	Mounts the second tape on the tape drive.
@COPY,G TAPE.,PROG.	Copy tape U6944 onto file PROG.
@FREE TAPE.	Release the tape drive.
MAP,I TPF$.LINEFINDER IN PROG.DLINE	Collect the LINEFINDER relocatable elements into an absolute element.
LIB PROG.	
@XQT TPF$.LINEFINDER	Causes execution of LINEFINDER
LINEFINDER Control Cards	The cards which control the operation of program LINEFINDER
@FIN	End of control deck.

GLOSSARY TERMS

<u>Conventional sources for data extraction</u>: Those used in the REMAP data bank consist of:

1. USGS topo maps (15 minutes) 1:62,500 scale;
2. Wisconsin land inventory maps 1:15,840 scale dating from the 1930's;
3. Small scale panchromatic aerial photographs flown in 1966 (monocoverage); and
4. Maps, photographs, reports and statistical information of varying vintages (1910-1970).

<u>CRIP</u>: Critical Resources Information Program: A program of the Department of Administration of the State of Wisconsin to define, organize and describe the critical resources of the state. A multifaceted assessment methodology was developed to evaluate the relative criticality of resource areas within the state. The criticality of a resource is based on such factors as resource quality, size, location, cost of maintenance and degree of the present or future scarcity. Most of the current CRIP research is being done by EMDAG with funding by the State of Wisconsin.

<u>CROSTAB</u>: A computer program out of the University of Wisconsin-Madison computer center that compares two equivalent matrices element by element to determine the degree of correlation between the values of the elements. The correlation value is determined as the percentage of elements in one matrix which agree within a given range of values with the elements of the second matrix. This program simply establishes the correlations and does not indicate which source contains the greater error.

<u>Cultural Resource Data</u>: Includes data elements on

1. land use systems,
2. population distribution systems,
3. communication systems, and
4. cultural landscape units

EMDAG: Environmental Monitoring and Data Acquisition Group, one of seven research centers and groups under the administration of the Institute for Environmental Studies, University of Wisconsin-Madison. The EMDAG is a formally structured, ongoing composite effort focused upon enhancement, extension and coordination of the monitoring and data acquisition efforts of IES and the University at large.

I-57 study: Study done by the University of Wisconsin Environmental Awareness center in 1972 entitled "An Interstate Corridor Selection Process: The Application of Computer Technology to Highway Location Dynamics", by F.J. Niemann, Jr. and A.H. Miller.

I^2S: A color additive viewer (International Imagery Systems Model 6040PT).

LINEFINDER Routine: A computer routine written by Mr. Denis Bunde, U.W. Department of Computer Sciences, that sums the products of weight and variable values for each cell. The program then starts at an established starting point and finds the "least value" or lowest assemblage of coefficients through the data array. The LINEFINDER finds linear routes, such as highway or power transmission corridors.

McIDAS: (Man-computer Interactive Data Access System): A highly interactive man-machine system currently being developed by the University of Wisconsin's Space Science and Engineering Center, created primarily for quick access to large volumes of digital data generated by satellites such as ATS-III, SMS, and ERTS-1.

Muirhead Photofax Copier: A computer controlled copier by which a photographic image can be produced from imagery stored on digital data tapes.

Natural Resource Data: includes data elements relative to:

1. hydrologic systems
2. ecological systems
3. physiographic systems

4. pedalogical systems, and
5. natural landscape units (watersheds).

Physiographic Patterns: Patterns made up of topographic orientations, topographic slope, and various land forms such as outwash plain, ground moraine, till plain, etc.

RB-57 Imagery: Color and color-infrared photography flown at 60,000 feet to give scales of 1:60,000 and 1:120,000.

REMAP: A computer program entitled Regional Environmental Management Allocation Process, developed by the University of Wisconsin Environmental Awareness Center to provide for the economical storage, analysis and display of natural and cultural resources for regional planning purposes using a Universal Transverse Mercator Base. This geoinformation system was specifically developed to assist the Wisconsin Division of Highways in locating and assessing environmental impact from proposed Interstate-57 between Milwaukee and Green Bay, Wisconsin. Data banks consist of natural and cultural resource data, computer stored on a cellular basis for one square kilometer (REMAP I) and 1/9 square kilometer (REMAP II).

VARIABLE: A data type whose amount varies relative to a given criterion. Appendix A lists and defines the 33 variables (e.g., upland forest, river, agricultural land, etc) which are considered to be most significant for decision making for land use allocations of one square kilometer or larger such as transportation corridors, power plant sites, power transmission systems and similar impact producing phenomena.

WINDCO: The McIDAS prototype with the capability for displaying digital tape data on a TV monitor as a black and white image and performing enlargements and contrast adjustments via external controls and software.

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4.0 ADDENDUM - WORK COMPLETED AFTER 23 MARCH 1974

4.1 DATA EXTRACTION FROM PHOTOGRAPHIC IMAGERY

ERTS images were used for two data extraction studies using the International Imaging Systems Model 6040 PT additive color viewer, as reported below.

4.1.1 DATA BANK COMPARISON BY SPATIAL LOCATION

4.1.1.1 Introduction

A study of the Sheboygan Test Site was undertaken to compare land cover data extracted using 70mm positive ERTS transparencies in an International Imaging Systems Model 6040 PT color additive viewer at a scale of 1:500,000 with land cover data extracted using ERTS 9x9 positive transparencies (1:1,000,000). RB-57 color-infrared photography at a scale of 1:60,000 of the test site provided ground truth data for each of the four land cover types. From the above data (Table 4.1.1) we sought to determine if there was any advantage in using the 70mm ERTS chips color enhanced in the I^2S as opposed to ERTS (9x9) positives, and if there might not be greater variability among individual interpreters than among the data sources.

Data Source	Land Cover Type	Interpreters
RB-57	Agriculture	1
ERTS (I^2S)	Forests	2
ERTS (9x9)	Structures	3
	Water	

Table 4.1.1: Data Sources, Land Cover Types and Interpreters.

The Sheboygan Test Site (see Figure 1.3.3) is a portion of the larger REMAP test site which has been consistently used as a test site in ERTS investigations at the University of Wisconsin-Madison. This site includes a variety of natural and cultural resources -- agricultural fields and pastures, upland and lowland forest, wetlands, quarries, two small towns and their supporting communications and transportation systems.

4.1.1.2 Methodology

For purposes of this study the test site was gridded into 300 one square kilometer cells (ten cells wide by thirty cells long) at a scale appropriate for each of the three data sources. One interpreter placed the grids on all the imagery in order to make their placement as consistent as possible.

Previous studies with ERTS determined four land cover types that can be considered all inclusive in Wisconsin. These are:

1) agriculture - agricultural areas, open fields and pastures;
2) forests - upland and lowland forests;
3) structures - man-made structures and disturbances such as cities, roads, gravel pits and quarries; and
4) water, here defined as open water only, not including heavy macrophyte growth.

One land cover type at a time was interpreted for the 300 cell test area by the interpreters on a percent-of-cell basis. After percent forests, structures and water were interpreted, the percent of each cell remaining was designated agriculture. With three data sources (RB-57, ERTS [I^2S], ERTS [9x9]), four land cover types and three interpreters, thirty data matrices emerged.

Data were first extracted from 70mm chips using the I^2S. Table 4.1.2 lists the date of imagery, image number, bands, illumination and filters used on the I^2S for the land cover types. "Agriculture" is not shown on this table since the percent of each cell designated Agriculture was determined by subtraction.

Land Cover Type	Date	Image #	Band #	Illumination	Filter
Forest	12/13/72	1143-16095	5	full	green
			7	7.5	red
Structure	8/9/72	1017-16100	5	full	none
			7	5.5	red
Water	6/11/73	1323-16100	4	full	blue
			5	full	blue
			7	full	none

Table 4.1.2: ERTS 70mm Film Chips and Settings Used with I^2S.

Next the forests, structures and water were interpreted by each of the three interpreters for the test site using RB-57 color-infrared photography (1:60,000) flown on 4 June. Two months later the three interpreters determined percent land cover type per cell for the test area using ERTS (9x9)s on a light table with approximately 10 power magnification (Table 4.1.3).

Land Cover Type	Date	Image #	Band #
Forest	12/13/72	1143-16095	5
Structures	8/9/72	1017-16100	5
Water	6/11/73	1323-16100	7

Table 4.1.3: Date, Image Number and Band Number for ERTS (9x9) Transparencies at a Scale of 1:1,000,000.

4.1.1.3 Results

The data from the above interpretations were punched onto computer cards and run on a program that output two types of cell-by-cell correlation analyses. Table 4.1.4 gives percent correlation between interpreters by data sources. Correlation values are expressed as a percent range from 100% to -100% where 100% equals perfect correlation, 0% equals no correlation, and -100% equals perfect negative correlation. NV stands for number of vectors (cells), always 300, in this study.

	Land Cover	NV	Interpreters 1-2	1-3	2-3
ERTS (I^2S)	Forests	300	85.9	79.4	67.4
	Structures	300	81.7	-1.8	-9.0
	Water	300	39.2	83.5	50.5
	Agriculture	300	76.8	59.8	52.6
RB-57	Forests	300	89.7	78.0	66.9
	Structures	300	78.8	83.2	75.0
	Water	300	92.7	96.2	94.8
	Agriculture	300	85.2	72.7	60.7
ERTS (9x9)	Forests	300	92.9	94.8	87.5
	Structures	300	55.8	60.5	53.4
	Water	300	88.5	95.3	83.9
	Agriculture	300	89.9	90.7	83.5

Table 4.1.4: Percent Correlation Between Interpreters by Data Sources - ERTS(I^2S), RB-57, and ERTS(9x9).

Table 4.1.5 gives percent correlation between ERTS (I^2S) and RB-57, between ERTS (9x9) and RB-57, and ERTS (I^2S) and ERTS (9x9), by interpreter. It compares each interpreter's ground truth data to that extracted from the two ERTS sources and compares his consistency in interpreting ground cover types from ERTS (I^2S) and ERTS (9x9).

Used together, Tables 4.1.4 and 4.1.5 tell what cover types were difficult to interpret accurately and where interpreter inconsistencies exist. In analyzing Tables 4.1.5 and 4.1.5 it should be remembered that since agriculture was originally derived by subtraction, it will always reflect the total correlations of the other three land cover types. Therefore it is more to the point to consider only the correlations of forests, structures and water.

	Land Cover	NV	Interpreters 1	2	3
ERTS(I^2S) vs. RB-57	Forests	300	89.8	63.4	78.6
	Structures	300	66.0	63.9	2.6
	Water	300	96.1	42.9	84.6
	Agriculture	300	81.5	74.2	58.5
ERTS(9x9) vs. RB-57	Forests	300	88.1	90.2	66.0
	Structures	300	58.8	36.6	55.3
	Water	300	92.1	77.4	85.9
	Agriculture	300	85.2	86.0	61.2
ERTS(I^2S) vs. ERTS(9x9)	Forests	300	83.5	80.4	72.2
	Structures	300	84.4	59.1	-2.2
	Water	300	91.7	40.7	87.3
	Agriculture	300	79.8	75.9	57.6

Table 4.1.5: Percent Correlation Between ERTS (I^2S) and RB-57; ERTS(9x9) and RB-57; and ERTS(I^2S) and ERTS(9x9) by Interpreter.

4.1.1.4 Correlations Between Interpreters

RB-57 imagery is considered to yield ground truth since its larger scale yields more detail than the ERTS imagery. For forests, there was 89.7% correlation between interpreters 1 and 2, 78.0% correlation between interpreters 1 and 3, and only 66.9% correlation between 2 and 3. Interpreter 3's interpretation seems to bring down both correlations, indicating an inconsistency in his interpretation as compared to the other interpretations. For structures, agreement between 1 and 2 is 78.0%, between 1 and 3, 83.0%, and between 2 and 3, 75.0%. Interpretation of open water is best correlation, being between 92.7 and 96.2%. From the above it would appear interpreter 3 did not interpret forests in the same manner as 1 and 2, nor did interpreter 2 interpret structures as did 1 and 3. Consistency exists among interpreters only in their extraction of open water data.

Using the ERTS(I^2S), interpreter 3 again shows a low percent correlation in forests. Interpreter 3's correlation of structure with both interpreters 1 and 2 is slightly negative. As this did not occur using ERTS (9x9)s, a mechanical error of some sort such as grid slippage is suspected here. Interpreters 1 and 2 show an 81.7% correlation on structures. On water, while interpreters 1 and 3 show an 83.5% correlation, it drops to 39.2% between interpreters 1 and 2, and 50.5% correlation between interpreters 1 and 3, indicating interpreter 2 was not consistent with the other two. Referring to Table 4.1.5, we find only 42.9% correlation between interpreter 2's ERTS(I^2S) and RB-57 data for water. Going back to the RB-57 data in Table 4.1.4 we see interpreter 2's data is in close agreement with that of interpreters 1 and 3 which would indicate his I^2S interpretation is at fault.

Using the ERTS (9x9)s we find a high correlation between interpreters for forests (87.5-84.8%). The correlation on structures is considerably poorer than with the RB-57 (being between 53.4 and 62.5%) and the ERTS(I^2S), discounting the grid slippage error. The interpreters correlations on water while not quite as high as on the RB-57, are far better than those using the ERTS(I^2S).

4.1.1.5 Correlations Between Data Sources

Table 4.1.5 shows interpreter 1 to have the highest correlation between ERTS(I^2S) and RB-57 data. Interpreters 2 and 3 showed reasonable correlation on forests between their ground truth data and ERTS(I^2S); interpreter 3 shows reasonable correlation on water. Interpreter 3's mechanical failure on structures shows up as no correlation between ERTS(I^2S) and RB-57 while interpreter 2 shows poor correlations on both structures and water.

On the ERTS(9x9) vs. RB-57 data, both interpreter 1 and 2 show a high positive correlation between their

ERTS(9x9) and ground truth forest data while interpreter 3 does not. All three interpreters show poor correlations on structures, indicating structures was poorly defined. Since structures are generally small, they are difficult to pick up on ERTS imagery. Where they do show, the high reflectance which makes them stand out can lead to an over-estimation of this cover type. Interpreters 1 and 3 show high correlations on water; interpreter 2's correlation is down but not as much as on the I^2S.

Comparison between the ERTS(I^2S) and ERTS(9x9) by interpreters shows a medium high correlation on forests (72.2-83.5%), a high correlation on structures for interpreter 1 (84.4%) and only a 59.1% correlation for interpreter 2. Interpreter 3's mechanical failure makes his correlation meaningless. Interpreters 1 and 3 showed high correlation on water. Interpreter 2's problem interpreting water on the I^2S is reflected in his low correlations here. One suspects correlations can only be considered to show reasonable agreement among interpretations if they are 75% or greater.

4.1.1.6 Correlations by Interpreters for Each Land Cover Type by the Three Data Sources (Table 4.1.6).

Table 4.1.6 (Table 4.1.5 data rearranged) gives the percent correlation between data sources for each land cover type for each interpreter. As such, it shows interpreter 1 has the highest correlations and is most consistent among the data sources for each land cover type. All interpreters show poor correlations between all sources on structures with the exception of interpreter 1. He shows agreement between his ERTS(I^2S) and ERTS(9x9) interpretation but the accuracy is questionable as neither his ERTS(I^2S) or ERTS(9x9) correlate well with his RB-57 (ground truth) interpretation. Interpreter 2 is fairly consistent in his forest interpretations; interpreter 3 in his water interpretations. Interpreter 1 has had the greatest amount of experience in image interpretation. As his results are very consistent within themselves, we will take them as being most reliable. Thus the better the other two interpreter's data correlates with his, the more accurate they may be considered.

	Data Sources Correlated		
	I^2S vs RB-57	9x9 vs RB-57	I^2S vs 9x9
Interpreter 1			
Forest	89.8	88.1	83.5
Structure	66.0	58.1	84.4
Water	96.1	92.1	91.7
Agriculture	81.5	85.2	79.8
Interpreter 2			
Forest	83.4	90.2	80.4
Structure	64.9	36.6	59.1
Water	42.9	77.4	40.7
Agriculture	74.2	86.0	75.9
Interpreter 3			
Forest	78.6	66.0	72.2
Structure	2.6	55.3	2.2
Water	84.6	85.9	87.3
Agriculture	58.5	61.2	54.6

Table 4.1.6: % Correlation by Interpreters for Each Land Cover Type by the Three Data Sources.

4.1.1.7 Data Extraction Time

Interpreters kept track of time spent extracting data. Table 4.1.7 gives data extractions in minutes per square kilometer for each land cover type. Since water is very discrete and there is little of it in the test site, it took the least amount of time to interpret, followed by structures and forest. Structures, while not being . . . . .

numerous on ERTS, were hard to interpret as they were the most evenly distributed cover type other than agriculture. Agriculture times are the same for all three data sources as they were derived by subtraction. ERTS (9x9)s can be interpreted slightly faster than ERTS(I^2S) while RB-57, at a larger scale and with far greater detail, takes more than twice the time to interpret.

	Data Extraction Time[1] In Minutes/Square Kilometer		
	ERTS 1:500,000/I^2S	ERTS 1:1,000,000	RB-57 1:60,000
Forest	.20	.22	.60
Structures	.13	.10	.22
Water	.10	.07	.22
Agriculture/Open	.17	.17	.17
TOTAL	.60	.56	1.21

[1]Includes set up and extraction, but does not include computer encoding, printout/data display, or analysis.

Table 4.1.7: Data Extraction Time in Minutes/Square Kilometer

4.1.1.8 Conclusions

1) As indicated by the consistently low correlations with ground truth (RB-57), structure as a land cover type was poorly defined on both ERTS(I^2S) and ERTS(9x9). Water appearing in discrete units was easiest to define with high agreement among interpreters except for interpreter 2 using the I^2S.

2) For both interpreters 1 and 3, the I^2S gave a slightly more accurate interpretation of forests and and structures. Water was interpreted approximately the same for both ERTS(I^2S) and ERTS(9x9). Using the I^2S takes slightly more interpretation time (Table 4.1.4) and certainly more preparation (set up) time than using the ERTS(9x9)s. Nonetheless, in the case of a well trained interpreter, use of the I^2S seems to bring forth slightly more accurate data for slightly more time spent interpreting.

3) In this study error stems primarily from three sources: a) lack of visual understanding of ground cover types; b) grid shrinkage, expansion and shifting; and c) interpreter's lack of experience. (a) While the three interpreters had a verbal and written definition of the land cover types, the three did not spend enough time together visually comparing and making consistent one another's interpretations before interpreting the 300 cell area. The grids were painstakingly located by one individual on all the imagery, but some grid shifting was unavoidable when the imagery was handled. This spplies particularly to the ERTS(9x9) and the RB-57 interpreted on the light table where, over time, the table heats up.

(b) Grid slippage was particularly severe with the RB-57. The test site covers three frames and grid sections stretched and shifted when the imagery was rolled up between times of use. As the RB-57 was used to locate the ERTS(I^2S) and ERTS(9x9) grids, shifts of the grid on one created shifts of the grid on the others. While a fraction of an inch frid shift does not greatly affect the RB-57 cell-by-cell interpretation at 1:60,000, on the vastly smaller scales of the ERTS(I^2S)(1:500,000) and the ERTS(9x9)(1:1,000,000), such a shift may be highly significant. (c) Lack of experience is well-documented by the correlation analyses of this study. Inexperienced interpreters 2 and 3 show little consistency in their interpretations by data source, while interpreter 1, with the most experience in interpreting ERTS as well as a variety of larger-scale imagery, shows high consistency among data sources. While interpreting a 300 cell area is entirely manageable, interpreting an area the size of the State of Wisconsin (145,400 one square kilometer cells) would be a tedious job.

4) Far greater variability seems to exist in the interpreters' ability to interpret consistently among themselves than among data sources. It would seem that both extensive expe nce and interpreter training and care in

interpretation are necessary to derive optimal data from either ERTS(I^2S) or ERTS(9x9)s. There is no substitute for an experienced, careful interpreter. If more than one person is going to make interpretations for a project, the interpreters must work together until each can interpret given cover types with only a small degree of deviation from the other's interpretations.

4.1.2 LAND COVER MAPS

Following extensive consultation with planners of the Wisconsin Department of Administration (DOA) to define their needs and using funds provided by the Wisconsin DOA, Bureau of Planning and Budget, land cover maps were prepared for the State of Wisconsin at a scale of 1:500,000.

4.1.2.1 Definition of Land Cover Classes

The land-use classification system being developed by USGS for use with remote sensor data (Anderson, Hardy and Roach) was applied with modification to this project. The classes developed were forest-brushland, agricultural-open land, structures-barren land and surface water.

1) Forest-Brushland: The forest-brushland class is made up of the USGS forest land including deciduous, evergreen and mixed, plus the shrub-brushland range which includes the Eastern brushlands -- former agricultural clearings. Forest land is defined as an area having a tree crown areal density of 10% or more. Areas within forest land showing evidence of recent clear cutting are included with forest land.

2) Structures-Barren Land: The structures-barren land class is a combination of the USGS urban and built-up land and barren land classes, except for transportation and communication networks which extend into rural areas. Salt flats and strip mines in the USGS barren land class do not occur in Wisconsin.

3) Surface Water: Surface water includes all areas of water visible on the ERTS imagery. Unlike the USGS definition, if emergent aquatics were present but in quantities insufficient to change the spectral signature then the area was called surface water. If emergent aquatic vegetation was dense enough to cover the water, the area was included in the agricultural and open land class.

4) Agricultural and Open Land: The land areas that have been designated agricultural and open land include the USGS agricultural land class plus such open areas as non-forested wetland, golf courses and others.

4.1.2.2 Data Extraction Techniques

Data extraction was accomplished at 1:500,000 scale using an International Imaging Systems Model 6040PT additive color viewer. The viewer utilizes 70mm ERTS images and has the capability of overlaying four bands with filter and intensity variations available to each one.

Distortion problems, common to all ERTS imagery used, were overcome by extracting data onto a Kronoflex copy of the 1:500,000 USGS Lambert Conformal Conic Projection Map of the State of Wisconsin. The cultural features and water bodies shown on the map permitted adjustment to alleviate distortion as it occurred for each township.

4.1.2.3 Results

The following categories of land cover data were extracted in units of 160 acres or larger: 1) forest and brushland, 2) structures and barren areas, 3) surface water, and 4) agricultural and open land.

Final versions of the four land cover maps are being drafted as color separation plates and the Wisconsin DOA will publish a four-color Land Cover Map of Wisconsin at a scale of 1:500,000 in early 1975.

Three of these color separation plates have been completed and are contained herein as Figure 4.1.2.1 (Forest and Brushland), Figure 4.1.2.2 (Structures and Barren Areas), and Figure 4.1.2.3 (Surface Water).

1) Forest and Brushland: Forest and brush areas were best seen on winter imagery where they appeared in dark tones on the white snow background. Care was taken to exclude open water and certain urban areas which also appear dark toned. Snow cover in southeast Wisconsin was insufficient to separate tall herabceous plants from brush and trees; therefore, it is likely that some open areas were included with forest and brushland in that area.

Using RB-57 color-infrared photographs as ground truth, it was determined that a wide range of canopy densities were included. Dense canopies such as conifer forest at 100% appear black while lesser canopy densities appear respectively lighter.

Imagery combinations useful for forest and brushland included band 5 with no filter and full illumination and band 7 with a red filter and full illumination. Any date when deep snow covers the ground but not the trees is useful.

2) Structures and Barren Areas: Structures and barren areas were best identified in late summer (July and August) imagery because of the high contrast in reflectance between structures and full growth vegetation.

Ground truth studies showed that urban densities of less than one structure per acre, with accompanying pavement, and older, small communities having mature tree canopies were not seen.

Band 5 used with no filter and full illumination combined with band 7, a red filter and 5.5 illumination provided the best results.

3) Surface Water: Surface water systems were best identified on early June imagery after wet soil areas had

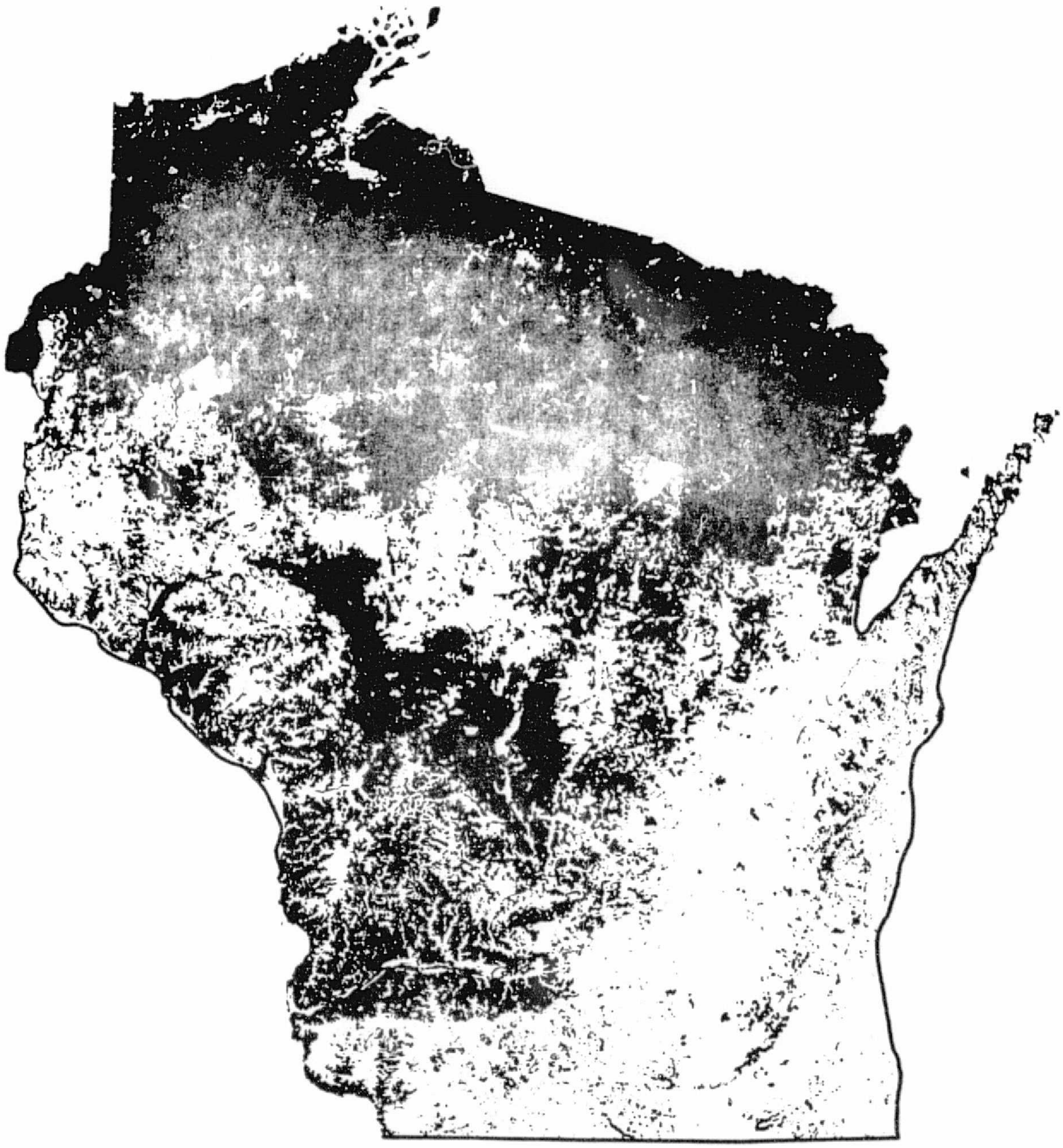

FIGURE 4.1.2.1 - LAND COVFR MAP OF WISCONSIN: Forest-Brushland
SCALE: 1:3,000,000

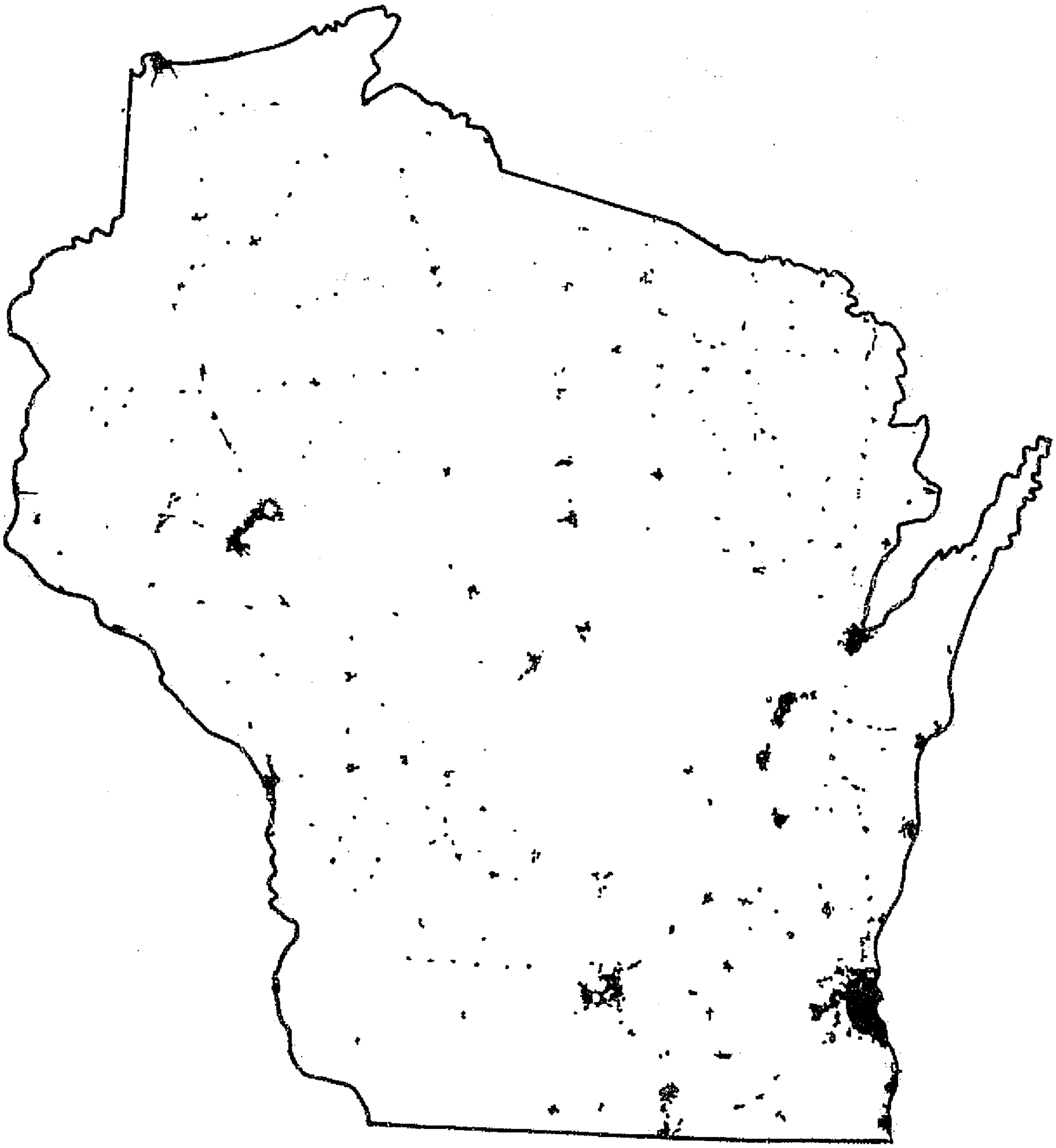

FIGURE 4.1.2.2 - LAND COVER MAP OF WISCONSIN: Structures-Barren Land
SCALE: 1:3,000,000

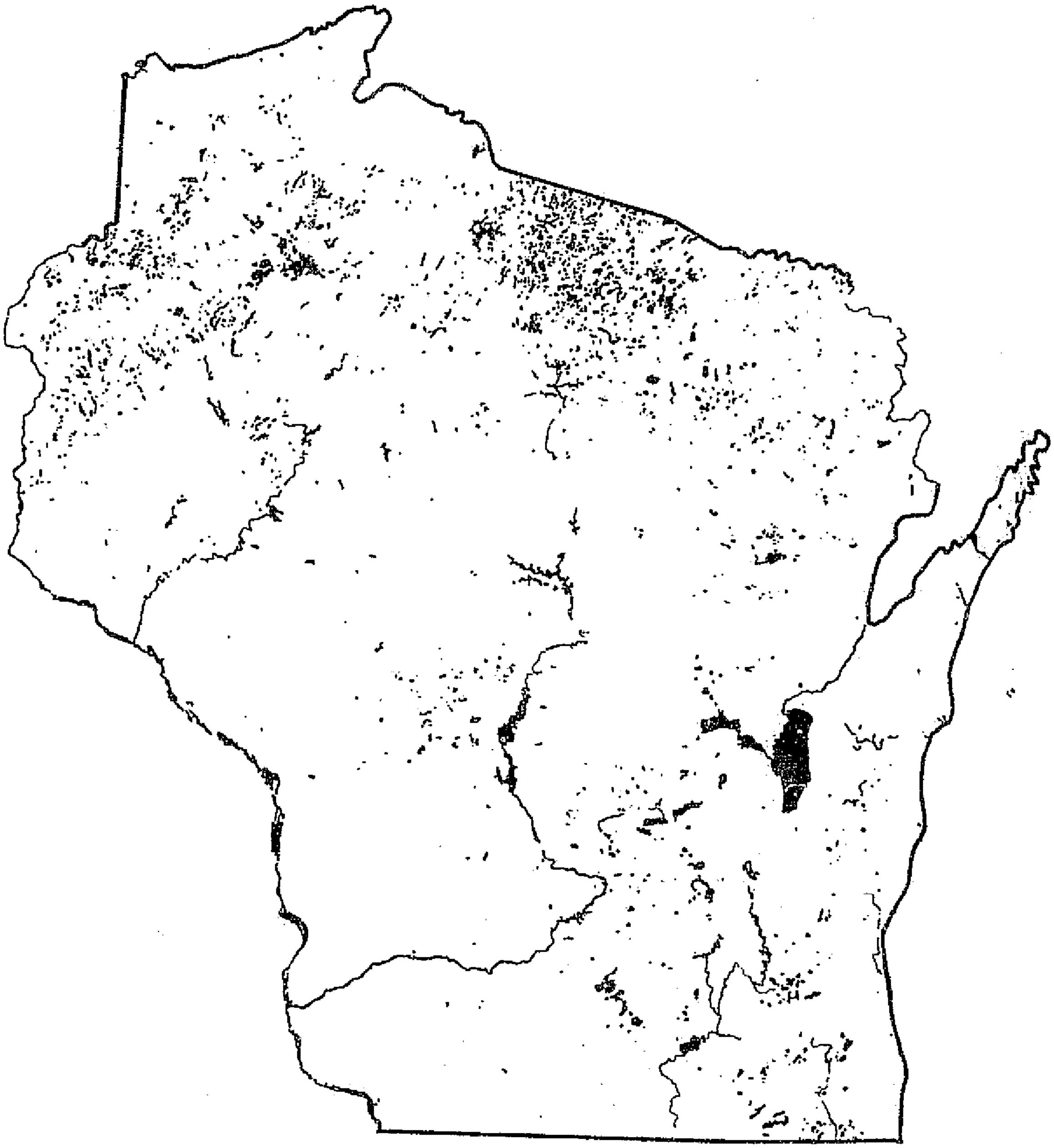

FIGURE 4.1.2.3 - LAND COVER MAP OF WISCONSIN: Surface Water
SCALE: 1:3,000,000

dried but before shallow water bodies evaporated or were overgrown with emergent aquatic vegetation. Extreme care was necessary to separate cloud shadows from lakes.

The most useful imagery combination was band 5 with a blue filter and full illumination and band 7 with no filter and full illumination.

4) Agricultural and Open Land: Agricultural and open lands were considered to be all land not delineated under one of the other categories.

4.1.2.4 Summary and Conclusions

Four land cover categories were defined and delineated over the entire area of the State of Wisconsin using ERTS imagery. Delineations were recorded on a 1:500,000 scale Kronoflex copy of the USGS map of the state. Approximately 60% of the total project time (1.5 man-months excluding map drafting) was spent with actual delineations of the four categories. Another 40% was used to select imagery, study the appearance of the four categories, compare to ground truth, and write the paper describing the project.

This project has been extended in order to prepare a wetlands map of Wisconsin at a scale of 1:500,000 using the additive color viewer techniques developed during the progress of this land cover mapping project.

4.1.3 COST ANALYSIS FOR LAND COVER MAPPING

Based on the results reported in Sections 4.1.1 and 4.1.2, it was determined that data extraction for four land cover classes using ERTS imagery at a scale of 1:500,000 and an additive color viewer required 1.56 minutes per square mile in the case of data extraction using a grid overlay and 0.28 minutes per square mile in the case of continuous line drawings. These times include set-up and extraction times but do not include computer encoding or map drafting time.

At a pay rate of $5.00 per hour, the data extraction costs would be as summarized in Table 4.1.8.

	Data Extraction Costs for Land Cover Mapping in 4 Classes 1:500,000 ERTS/additive color viewer	
	Cost per Square Mile	Total Cost for State of Wis.[3] (56,154 sq.mi.)
1 km grid overlay[1]	13.0¢	$7280
Continuous line drawing[2]	2.3¢	1290

1 - using data extraction by percent of cell.

2 - delineating, in general, only areas of 160 acres or larger.

3 - calculated at a rate of $5.00/hour.

Table 4.1.8: Data Extraction Costs

4.2 DATA EXTRACTION FROM ERTS COMPUTER COMPATIBLE TAPES

The value of ERTS data to the environmental work of State regulatory and management agencies comes from the breadth of view possible (the whole State from a new perspective), from the quantity of data (four channels each with at least 64 levels), and from the frequency of repeat views. But these require so much data, with so much potential for analysis, that conventional methods of data manipulation, light table and photo analysis, can neither exploit the materials nor meet the need.

In 2.1.3.3 the McIDAS system was described as a feasible means for manipulation and interpretation of large volumes of digital data. Up to this point the capability of the Space Science and Engineering Center has been used to instrument the system to the point where it has been possible to test the manipulation of various examples of ERTS data. One research associate in the past year has demonstrated the capabilities of the system in extracting the kinds of data required for environmental monitoring and resource inventory. He has demonstrated the value of the McIDAS system to

(1) digest large amounts of data at a high rate of speed,

(2) go directly to digital data without need for reduction to another form,

(3) display subtle characteristics of the data by color enhanced density slicing,

(4) increase recognition of features of land and water by visual display,

(5) produce greater versatility of interpretation through the interactive capabilities of the system,

(6) locate features accurately by longitude and latitude,

(7) display accurately overlaid images in chronological order to aid in detection of temporal changes,

(8) compute areas having selected characteristics or within described bounds, and

(9) store and recall enhanced images.

(The capability will soon be developed to find locations for which the coordinates are known.)

In its present form the McIDAS system displays one channel of the ERTS data at a time. Additions to the system in the next few months will produce the capability of analyzing two channels simultaneously allowing real time analysis of multispectral data. A third is planned for the future. These additional channels will allow multispectral analysis with greater speed and versatility.

The McIDAS system is just now ready for practical use to analyze ERTS data on problems specifically related to the work of the Department of Natural Resources, the Department of Administration, and the Public Service Commission of the State of Wisconsin.

a) Remote sensing has been shown to be of value for the measurement of the biomass of macrophytes in lakes. In connection with the research of Prof. Michael S. Adams, imagery will be analyzed in the next few weeks to determine macrophyte quantities.

b) In research on algae concentrations in lakes, Prof. William Woelkerling is ready to use image analysis that will be carried out on the McIDAS system.

c) The Wisconsin Critical Resources Information Program, funded by the State Department of Administration, is preparing to make use of the McIDAS system in its pilot study to identify and measure a variety of resources in selected areas of the State. This research is expected to show the feasibility of an inventory of the whole State. A system like McIDAS appears to be essential to such an inventory.

d) Projected research on power plant siting is expected to be dependent on McIDAS analysis of the many factors impinging on plant and transmission line decisions by the Public Service Commission and public utilities.

e) Research on power plant plumes in Lake Michigan is expected to begin to use the McIDAS system for analysis in the near future.

f) The project on determination of the eutrophic status of lakes described in 3.6.5 requires the capability of the McIDAS system or a similar system to extract the data for interpretation.

Development of the McIDAS system in connection with this ERTS research has brought the capability of the applications described. Since this development cannot be interrupted now, funds have been secured from the National Science Foundation to continue one Research Associate who will work for seven months (until 30 April 1975) on the applications of the McIDAS system to these State environmental problems and to generate clearer outlines for further research in the application of this system. (For more detailed description, see Appendix 4B.)

4.3 DATA BANK COMPARISONS BY MANIPULATIONS WITH SYNOP

4.3.1 INTRODUCTION

Building on the work reported on in Section 2.2.2, a computer program SYNOP has been developed and tested. Its primary purpose is that of a versatile analytical tool to aid in the determination of the effects of different data sources on the selection of a minimum-cost corridor within a selected test site. The data sources, ERTS, RB-57 and REMAP I, used were from the same data banks reported on in Sections 2.1.2.1 and 2.1.2.3. For this study the test site was restricted to the 300 square kilometer Sheboygan Test Site described in Section 1.3.1 and for simplicity and clarity the same terminal points, the left-uppermost and left-lowermost one kilometer cells, were used whenever a corridor was produced. The techniques described here, of course, are applicable to any test site and data sources assuming the data is in a computer-compatible format.

4.3.2 BACKGROUND

To aid in the understanding of the various forms of SYNOP output a few basic concepts need to be reviewed. A minimum cost corridor between two terminal points is minimum in the sense that it is the smallest sum of corridor segments between the two points where a corridor segment is a positive definite number derived from the data bank values of two adjacent cells. A cell in the data bank not on the boundary of the test site would thus have eight corridor segments associated with it. In more physical terms this number represents the cost of a corridor segment from the center of one cell to the center of an adjacent cell. A further discussion of this concept appears in Appendix E. How this "cost" is actually computed depends on the type of minimum corridor a policy maker is interested in. For example in SYNOP, two different methods are available. In the first the cost of the corridor segment is simply the sum of the two adjacent cell values where off-diagonal cell values are ignored when the two adjacent cells in question are along a diagonal. The second method computes the cost by adding the cell values times the fraction of the cell covered by the corridor segment. Thus, a horizontal or vertical corridor segment would be the average of the two cell values while a diagonal corridor segment would be the sum of four contributions, two from the off-diagonal cells (see Appendix E for a quantitative description). A corridor segment width of one kilometer is assumed. The effect on the nature of the path for these two methods on corridor segment calculations on the minimum cost corridor for identical data sources is discussed below. Note: This difference in the paths of the corridors has nothing to do with the differences in paths which results when different data sources or data "variables" are taken into account.

4.3.3 DISCUSSION OF SYNOP OUTPUT

In a single computer run, SYNOP can produce all or any combination of the various forms of output shown in Figures 4.3.1 to 4.3.7. Although the single variable FORESTS is illustrated here the input/output could be any weighted linear combination of the variables discussed in Section 2.1.2.3.

1. Figure 4.3.1 is a normal spatial printout of the percentage of each variable in increments of 10% on a cell-by-cell basis. The frequency of occurrence for each increment for each data source appears at the bottom of the figure. This form of output is essentially the same as that which appears in Appendix C.
2. The disadvantages of the old LINEFINDER routine

as used to generate the routes in Section 2.2.2, were: a) alternative minimum cost routes, if they existed, were not displayed; b) routes only slightly greater in cost were unavailable; and c) no meaningful manner of comparing the different routes resulting from the same variables but different data sources was available. The SYNOP output in Figures 4.3.2 and 4.3.3 represents an attempt to remove some of these disadvantages. In Figure 4.3.2, the symbol "0" represents the path of all minimum cost corridors; more specifically any cell in which an "0" appears is a cell through which a minimum cost corridor can be found. Any cell in which the symbol "θ" appears is a cell through which a corridor greater than (.GT.) minimum cost but less than or equal to (.LE.) 1% above the minimum cost can be found. The same interpretation applies to the other symbols in the legend of the figure. In general each cell symbol represents the minimum corridor cost possible for a route passing through that cell. The meaning attached to the numerical values MINIMUM and MAXIMUM under each cost array printout is that, for example in the case of ERTS (Figure 4.3.2), the MINIMUM corridor cost is 71.785. The MAXIMUM value 214.964 means that there is at least one cell somewhere in the 300 Km ERTS FOREST data bank through which the cheapest route that could be found passing through this cell would be 214.964, i.e. for each of the 300 cells in the data banks there exists a minimum cost route which connects the two terminal cells and passes through that cell; the range of these minimum cost routes varies from a MINIMUM of 71.785 to a MAXIMUM of 214.964 for this particular data set.

It is evident upon examining Figure 4.3.2

that the ERTS and RB-57 minimum cost routes agree quite well while the REMAP I route differs substantially, although in the case of the latter a route about 10% above the minimum seems to follow the same course as the former. A second feature to be noted which serves as an advantage over the conventional LINEFINDER output is that in the present display it is apparent where in the test site severe restrictions exist in the location of the corridor and where the restrictions are not so severe. For example in the ERTS and RB-57 arrays there is very little leeway in the lower half of the test site for relocating the minimum route without incurring a large increase in cost, while on the upper half the route could be shifted several kilometers without encountering more than a 1% increase.

Figure 4.3.3 is an "overlay" by pairs of the results shown in Figure 4.3.2. This is achieved simply by printing the symbol associated with the larger cost for each pair of spatially identical cells. It is seen that for the ERTS and RB-57 overlay there is fair agreement between the location of the minimum cost corridors for the two data sources implying that for the case of FORESTS, the ERTS data source would lead to the same corridor selections as the RB-57 data bank would.

3. Figures 4.3.4 and 4.3.5 are similar to Figures 4.3.2 and 4.3.3 except that the second method discussed above, where off-diagonal elements are involved in the calculation of the corridor segments, was used. Comparison of Figures 4.3.2 and 4.3.4 demonstrates the characteristic features of the two calculations. The first method (Figure 4.3.2) where off-diagonal cells are not accounted

for results in a corridor with smooth curves suggestive of a highway designed to handle a large traffic flux at moderate speeds; the large number of right angle turns in Figure 4.3.4 is typical of the lower speed, leisure-type corridors found in Federal and State Parks where efficient traffic flow is often secondary to the design of a scenic route. These two different types of corridors resulted from identical data sources and the choice of one over the other would depend primarily on the goals of the decision makers. There are an almost unlimited number of ways in which corridor segments can be calculated; the final choices, of course, must be made by those in charge of policy.

4. In analyzing the various corridors, it is sometimes helpful to have an understanding of how closely the data banks agree with each other. The normal spatial printouts as in Figure 4.3.1 contain that information but it is difficult to easily compare the data banks. Figures 4.3.6 and 4.3.7 serve as an aid in this goal. In Figure 4.3.6 all spatially identical cells are compared by pairs and those which exceed a threshold value of 10% are printed out. The symbol "0" refers to the data bank which has the smaller value. For example in comparing ERTS and RB-57, 70 ERTS cells contained at least 10% less of the variable FOREST than the same geographical RB-57 cells, while 28 RB-57 cells contained more than 10% of the variable FOREST than the corresponding ERTS cells. Various conclusions can be reached with this technique: if the number of "0"s and "θ"s are approximately equal, this implies a random error; if a large preponderance of one over the other exists, this implies some kind of bias. The latter point is

demonstrated in Figure 4.3.7 where the threshold value is 50%. It is clear that located around the Sheboygan Marsh County Park, the forests were greatly underestimated from the ERTS data relative to the RB-57; referring back to Figure 4.3.6 the occurrence of 70 to 28 tends to imply that in general forest is underestimated from ERTS data.

5. Figures 4.3.8 through 4.3.14 for the variable AGRICULTURE are identical in technique to Figure 4.3.1 through 4.3.7 for FORESTS. Figures 4.3.15 and 4.3.16 likewise demonstrate that the same analysis can be compared to linear combinations of variables.

4.3.4 CONCLUSIONS

It is apparent from the work done earlier on data bases described in this report as well as the later results derived from the SYNOP routine that in spite of some gross differences between the ERTS and RB-57 variable estimates that, assuming the RB-57 to be "ground truth," there is almost always better agreement between the ERTS and RB-57 data banks than between the REMAP-I and the RB-57. The REMAP-I data bank is typical of most Wisconsin data banks which are removed from the higher populated areas in that they are usually too outdated to serve as reliable data base in the decision making process. For relatively sparsely populated areas such as the Sheboygan Test Site, the macroscale ground cover variables such as agricultural and forested areas tend to play a dominant role in the choice of selecting a minimum cost corridor. It is these variables which can be extracted from ERTS imagery.

Furthermore, with systems such as McIDAS (Appendix D), improvements in the ERTS data extraction process are inevitable. In addition, thought is being given to adapting the SYNOP routine to the McIDAS system so that corridors can be selected and varied in real time.

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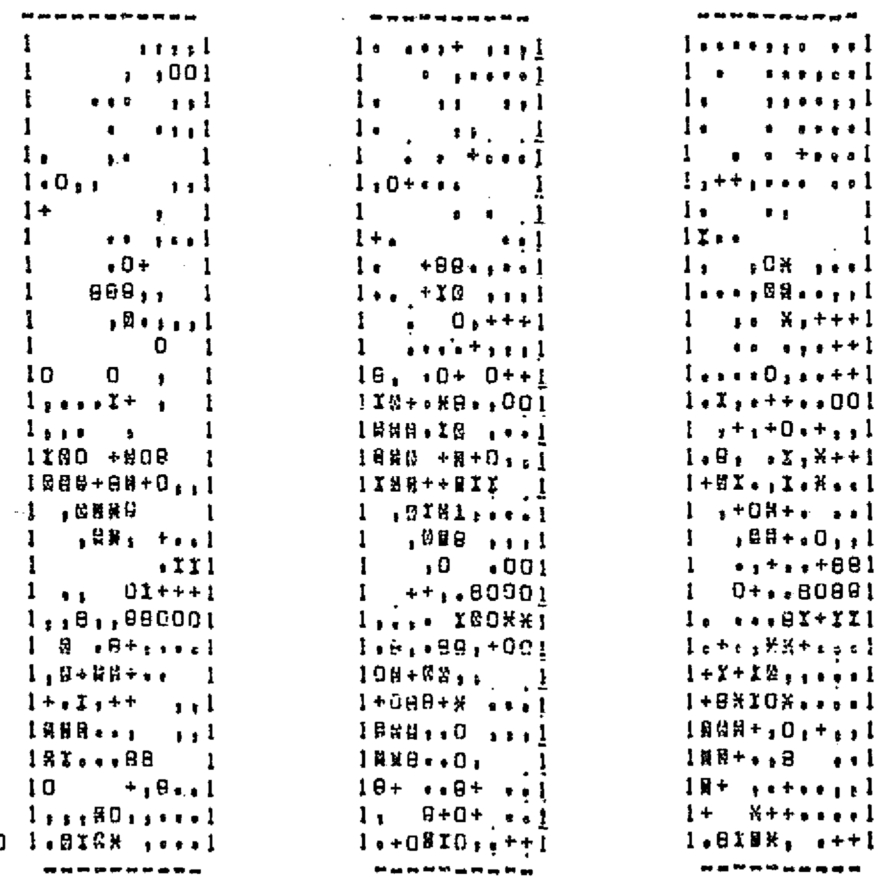
SHEBOYGAN TEST SITE
VARIABLE : FORESTS

UTM 410000 – 419000



A ERTS | B RB57 | C REMAP I

LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	;;;;;	+++++	00000	88888	XXXXX	IIIII	ØØØØØ	HHHHH	ĦĦĦĦĦ
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR A	42	55	17	16	13	1	8	7	9	7
OCCUR B	62	47	31	23	15	4	10	9	8	10
OCCUR C	103	45	40	11	10	10	12	3	9	2

FIGURE 4.3.1 - SPATIAL PRINTOUT - FORESTS.

ORIGINAL PAGE IS
OF POOR QUALITY

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ERTS-I INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                    4       4  UTM
UNIVERSITY OF WISCONSIN - MADISON                      1       1
                                                       0       9
SHEBOYGAN TEST SITE                                    0       0
POLICY :  AVOID FORESTS                                0       0
                                                       0       0
 UTM      ----------        ----------        ----------
4869000  I08866GH9AHI      I00++HHHHHHI      I0+++X9HX8HI
         I0066@HAHXHI      IH80+6HHHHHI      I0688+++XH8I
         I800XHHH8EHI      I8@8CHX*XHHI      I0068XX8+EHI
         I860CN68*AHI      I+869OHHXXXI      I+808+8X+*XI
         IX86CH*8RA9I      I9H+6+0H+++I      IP8+C00H++XI
         I*HHHC88FPHI      I8HH*X+0808I      IXHHX+90888I
         IH8ACC88H66I      I8S856+0+86I      I+6669X0688I
         I880CHHHHHHI      I8+AC0068++I      IHX6C008668I
         I6800*HH688I      I+W0HHH+HHXI      IX80XHH8X++I
         I680#HHHHP6I      I++6HHH+HHHI      IP80XHHH*HHI
         I8PACHHH9HHI      I8A+C0HHHHHI      I80H+XHHHHNI
         I8AP506@HH8I      I8A+++0HHHHI      I80++XXHHHHI
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         IHH+XHX0R98I      IHHH+8H0+HHI      I0HH+HHXXHHI
         IHHH#YH6CEHI      IHHNPHH60+XI      I0XH*HHXHH0I
         IHHH*HHHX08I      IHNHKHHH*0+I      I0HHXXHXHHHI
         IHHHHHHHN08I      IHHHHL*HH08I      I0HHXHHXHHHI
         I8XHHHHAC8SI      IHHHHHH*0++I      I0HXHHHHXHHI
         I88HHEH0HX*I      IHHHHHH0HHHI      I00XHHHXHH0I
         I8AF580AHRHI      IHHHHH0H+HHI      I00+HHXHHHHI
         I8XH8CHHHHHI      IHHHH*CHHHHI      I00HH*HHHHHI
         IHHH8CHHHHHI      IHHH+0HHHHHI      IX0H+HHHHHHI
         IHHHHHJHHXAI      IHHH*+0HHHHI      I+H0XHHHPHHI
         IHHHHH50+H8I      I0H*HH0*HHXI      IHHCHHHHHHHI
         IHHHHHH09HHI      IHHHX0HXHHHI      IHH6C3HHHHHI
         IHHHHX0H6HHI      IHHH+0XXHHHI      IHHH9CHHHHHI
         IHHH+CHH968I      IHHH0XXHX#XI      IHHHCXHHHHHI
         IH800EHHH*XI      IHH0X+HHXHHI      IH90X+HHHHHI
         IX0HHHHHHHHI      IHC6HHHH*HHI      IHC8HHHHHHHI
4840000  I0HHHHHHHH8I      I0HHHHHHHHHI      I0HHHHHHHHHI
          ----------        ----------        ----------
              A                 B                 C
             ERTS              R857             REMAP I
MAXIMUM     214.964           352.419           285.668
MINIMUM      71.785           119.279           147.799

OVERPRINT SYMBOLS REPRESENT PER CENT COST ABOVE MINIMUM COST

                SYMBOLS ASSOCIATED WITH COST RANGE

                RANGE (PER CENT)           SYMBOL
           0  .EQ.  COST  .EQ.  0            0
           0  .GT.  COST  .LE.  1            6
           1  .GT.  COST  .LE.  5            +
           5  .GT.  COST  .LE.  10           X
          10  .GT.  COST  .LE.  100          ■
```


FIGURE 4.3.2 - MINIMUM COST ARRAYS - Off-diagonal cells not included in corridor segment calculations.

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ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                  4        4   UTM
UNIVERSITY OF WISCONSIN - MADISON                    1        1
                                                     0        9
SHEBOYGAN TEST SITE                                  0        0
POLICY :  AVOID FORESTS                              0        0
                                                     0        0
 UTM      ----------         ----------          ----------
4869000  IO8++HHHHHHI       IO+++XHHHHHI        IO+++HHHHHHI
         I88H+8HHHHHI       IO888+8+HHHI        I888++HHHHHI
         I888XHX*XHHI       I8O8XHX8+HHI        I8888HXXXHHI
         I+888HXXXH8I       I+8O8H8XXHHI        I+888+XXXXXI
         IXH+8HXH+++I       IXH+OHXH++XI        I88+8+OH++XI
         IHHHHX+88HHI       IXHHH+888HHI        IHHHXX+O888I
         IH8888+8888I       IH8888XHH88I        I+888XO+88I
         IH+8OHH8HHHI       IHX8OHHHXHHI        IHX8OOO88++I
         I+8OHH8HHHXI       IX8OXHHHX++I        IX8OHHH+HXXI
         I++OHHHHHHHI       I88OHHHHHHHI        I+,OHHH+HHHI
         I88+OHHHHHHI       I8HH+HHHHHHI        I88H+XHHHHHI
         I88+++8HHHHI       I88++XXHHHHI        I88++XXHHHHI
         IHX8+HH8HHHI       IH88+HHXHHHI        IHX8+HHXHHHI
         IHHHXHHOHHHI       IHHHXXXXHHHI        IHHH+HHXXHHI
         IHHHHHHHO+XI       IHHHXHHXHHHI        IHHHHHHHHHHI
         IHHHHHHHHO+I       IHHHXHHHHHHI        IHHHHHHHHHHI
         IHHXHHHHHO8I       IHXHHHHHHHHI        IHHHHHHHHHHI
         IHHHHHHXO++I       I8HHHHHHXHHI        IHHHHHHHXHHI
         IHHHHHHOHHHI       I8HHHHHXHHHI        IHHHHHHXHHHI
         IHHHHOOHXHHI       I8H+HHXHHHHI        IHHHHHXHHHHI
         IHHHHXHHHHHI       I8XHHXHHHHHI        IHHHHXHHHHHI
         IHHHHOHHHHHI       IHHHHHHHHHHI        IHHH+HHHHHHI
         I8HHHHOHHHHI       IHHHHHHHXHHI        IHHHXHHHHHHI
         IHHHHHHXXXXI       IHHHHHHHHHHI        IHHXHHHHHHHI
         IHHHHHHXHHHI       IHHHHHHHHHHI        IHHHXHHHHHHI
         IHHHHXXXHHHI       IHHHHXHHHHHI        IHHH+OHHHHHI
         IHHH+XHHXXXI       IHHH+XHHHHHI        IHHHOXHHHHHI
         IHHOX+HHHHHI       IHHOX+HHHHHI        IHHOX+HHHHHI
         IHOHHHHHHHHI       IHOHHHHHHHHI        IHO8HHHHHHHI
4840000  IOHHHHHHHHHI       IOHHHHHHHHHI        IOHHHHHHHHHI
          ----------         ----------          ----------
              A                  B                   C
          ERTS & RB57        ERTS & REMAP        RB57 & REMAP

              * * OVERLAYS OF MINIMUM COST ARRAYS * *

              SYMBOLS ASSOCIATED WITH COST RANGE

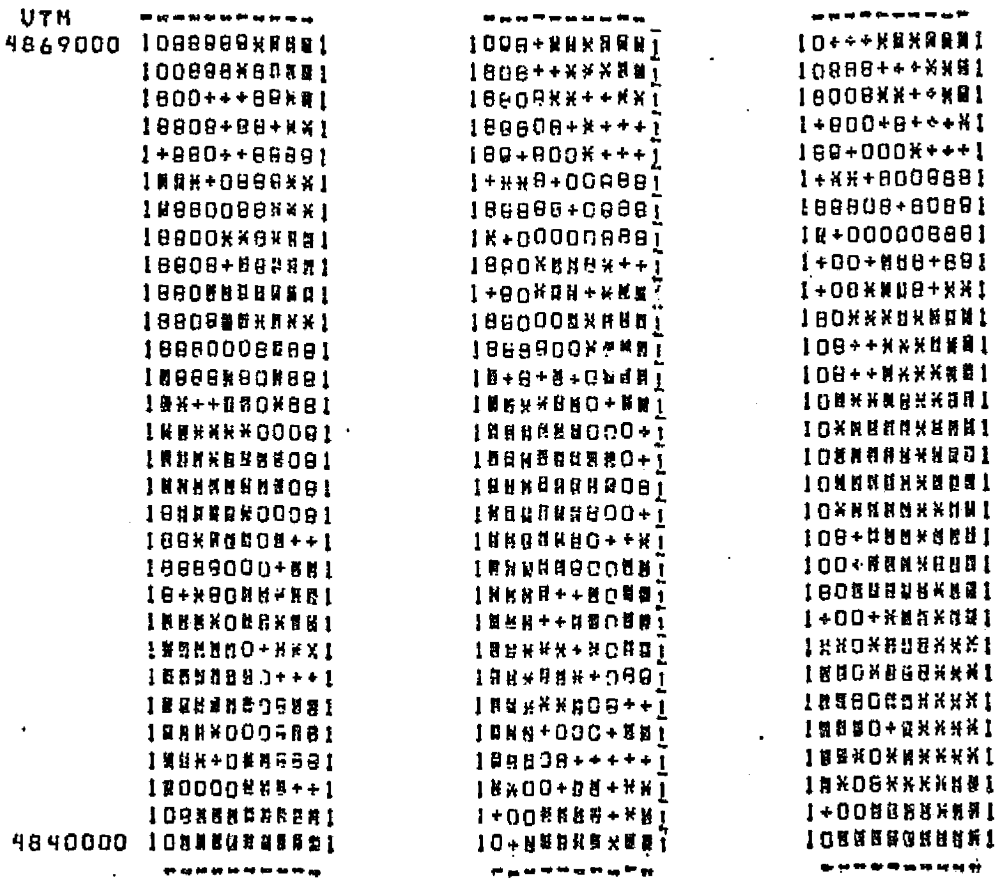
                  RANGE (PER CENT)          SYMBOL
              0   .EQ.  COST  .EQ.  0         O
              0   .GT.  COST  .LE.  1         0
              1   .GT.  COST  .LE.  5         +
              5   .GT.  COST  .LE.  10        X
             10   .GT.  COST  .LE.  100       H
```

FIGURE 4.3.3 - OVERLAYS OF MINIMUM COST ARRAYS OF FIGURE 4.3.2.

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
POLICY : AVOID FORESTS

UTM 410000 419000



	A	B	C
	ERTS	RB57	REMAP I
MAXIMUM	298.036	503.577	378.930
MINIMUM	124.866	230.625	230.914

OVERPRINT SYMBOLS REPRESENT PER CENT COST ABOVE MINIMUM COST

SYMBOLS ASSOCIATED WITH COST RANGE

RANGE (PER CENT)	SYMBOL
0 .EQ. COST .EQ. 0	0
0 .GT. COST .LE. 1	Θ
1 .GT. COST .LE. 5	+
5 .GT. COST .LE. 10	X
10 .GT. COST .LE. 100	M

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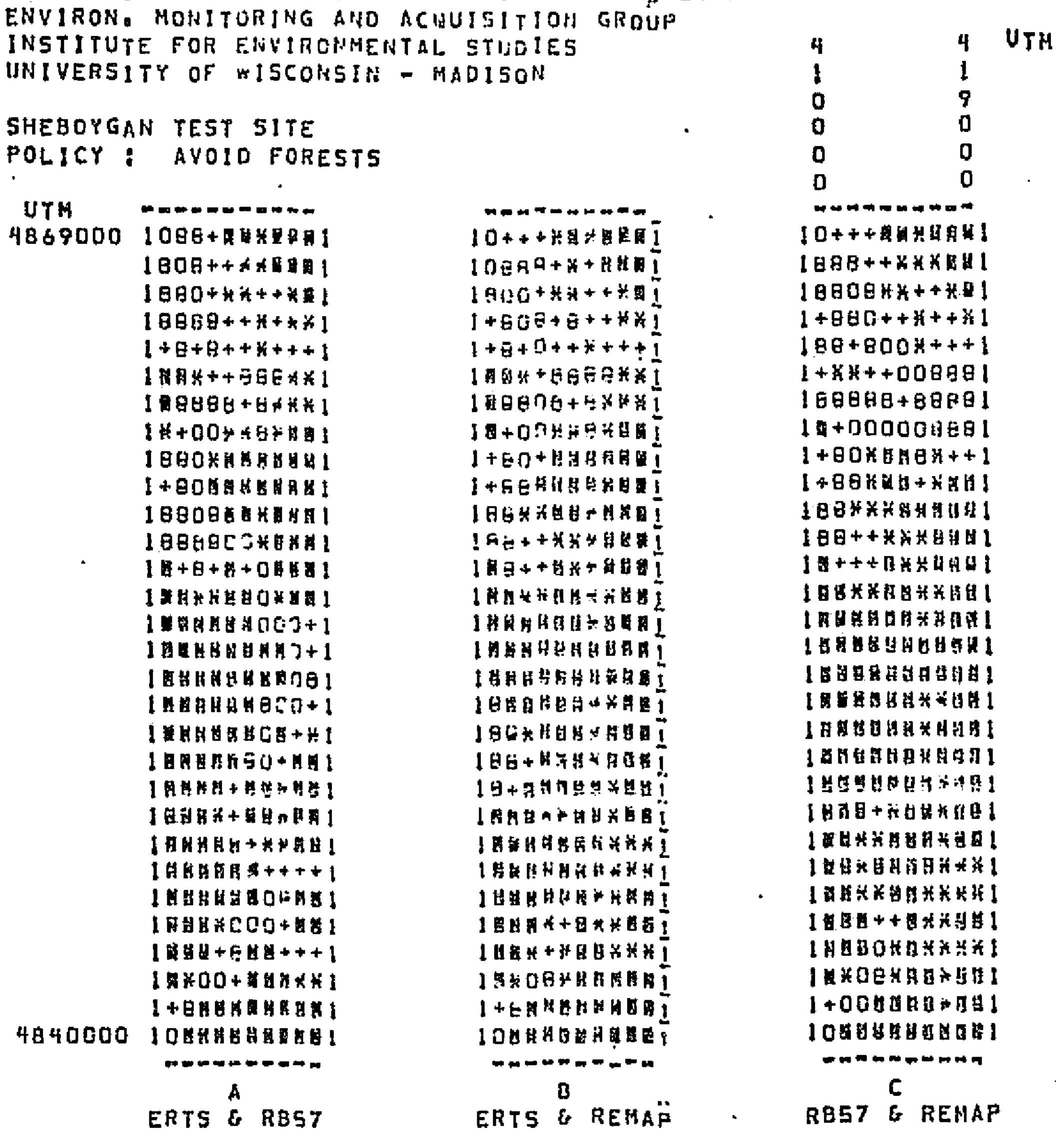
OF POOR QUALITY

FIGURE 4.3.4 - MINIMUM COST ARRAYS - Off-diagonal cells are included in corridor segment calculations.

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
POLICY : AVOID FORESTS



* * OVERLAYS OF MINIMUM COST ARRAYS * *

SYMBOLS ASSOCIATED WITH COST RANGE

RANGE (PER CENT)					SYMBOL
0	.EQ.	COST	.EQ.	0	0
0	.GT.	COST	.LE.	1	8
1	.GT.	COST	.LE.	5	+
5	.GT.	COST	.LE.	10	X
10	.GT.	COST	.LE.	100	■

FIGURE 4.3.5 - OVERLAYS OF MINIMUM COST ARRAY OF FIGURE 4.3.4.

```
ERTS-1 INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                        4          4  UTM
UNIVERSITY OF WISCONSIN - MADISON                          1          1
                                                           0          9
SHEBOYGAN TEST SITE                                        0          0
VARIABLE :  FORESTS                                        0          0
                                                           0          0
 UTM      -----------          -----------           -----------
4869000  I    008    I        I    00 8   I         I           I
         I        888I        I     8   88I         I     8     I
         I           I        I           I         I           I
         I           I        I           I         I           I
         I       0   I        I       0   I         I           I
         I           I        I0          I         I           I
         I8          I        I8          I         I           I
         I0          I        I0          I         I0          I
         I   00 80   I        I0  00080   I         I   8 0     I
         I   8008    I        I   8008  00I         I     00    I
         I    88  000I        I  0 88  000I         I  0  0     I
         I       08  I        I       0800I         I       8 00I
         I0     0 000I        I8     0 800I         I8       8  I
         I000   0  00I        I 00 8    00I         I8    88    I
         I000 00     I        I8 0000  000I         I888 88     I
         I000   0  00I        I888 888  00I         I888 8880   I
         I  0 8 00   I        I8 888880   I         I8888 888   I
         I    8 0    I        I  88 8     I         I   88 8    I
         I      0    I        I           I         I    0 0 0  I
         I   00    88I        I   00   088I         I        000I
         I    0088000I        I  00  88000I         I   0       I
         I   8 800 00I        I 88    0 00I         I      8    I
         I  8   0  00I        I 8    00   I         I 8    0 888I
         I0   8      I        I 8  8  0   I         I 8         I
         I 080  0    I        I 0  0 0  88I         I    00     I
         I      0    I        I 8 00000   I         I    00 0   I
         I  00   8   I        I 00  0 8   I         I  8    8   I
         I  0   008  I        I00  0   8  I         I0     88   I
         I   88 00   I        I   88      I         I      88   I
4840000  I 880  0  00I        I 8  0 08 00I         I 00   88   I
          -----------          -----------           -----------
               A                    B                    C
          ERTS & RB57          ERTS & REMAP          RB57 & REMAP

OCCURRENCE  0     8           0      8              0      8
           70    28          70     48             24     44

          COMPARISON OF DATA BANKS ON A CELL-BY-CELL BASIS

                 OVERPRINT SYMBOLS INDICATE AN ABSOLUTE
          DIFFERENCE GREATER THAN 10 PER CENT BETWEEN CELLS
```

FIGURE 4.3.6 - COMPARISON OF DATA BANKS - 10% THRESHOLD.

```
ERTS-1 INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                        4       4  UTM
UNIVERSITY OF WISCONSIN - MADISON                          1       1
                                                           0       9
SHEBOYGAN TEST SITE                                        0       0
VARIABLE :  FORESTS                                        0       0
                                                           0       0
 UTM      ----------          ----------          ----------
4869000  I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I0         I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I00        I        I 0        I        I8         I
         I000 00    I        I          I        I888       I
         I          I        I6         I        I8 8       I
         I          I        I          I        I      8   I
         I          I        I   8      I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I          I        I          I
         I          I        I0         I        I          I
         I          I        I          I        I          I
4840000  I 8        I        I          I        I          I
          ----------          ----------          ----------
               A                   B                   C
           ERTS & RB57        ERTS & REMAP        RB57 & REMAP

OCCURRENCE  0     8          0     8           0     8
            7     1          3     2           0     7

            COMPARISON OF DATA BANKS ON A CELL-BY-CELL BASIS

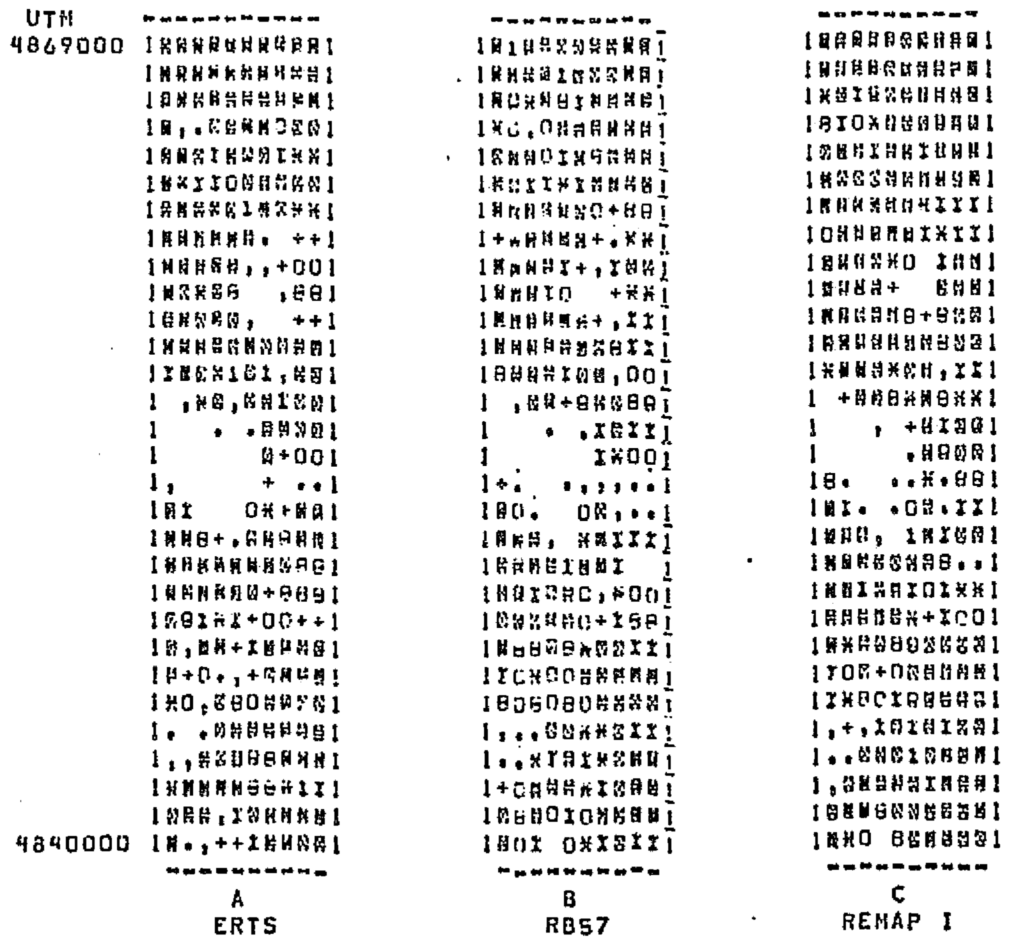
                   OVERPRINT SYMBOLS INDICATE AN ABSOLUTE
            DIFFERENCE GREATER THAN 50 PER CENT BETWEEN CELLS
```

FIGURE 4.3.7 - COMPARISON OF DATA BANKS - 50% THRESHOLD.

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE : AGRICULTURAL LAND

UTM 4100000 4190000



LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	OOOOO	88888	XXXXX	IIIII	00000	88888	88888
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	11	16	18	12	16	11	17	40	44	89
	B	14	12	10	26	18	20	39	30	46	64
	C	12	6	7	11	17	17	31	43	67	71

FIGURE 4.3.8 - SPATIAL PRINTOUT - AGRICULTURE.

```
ERTS-1 INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                    4        4   UTM
UNIVERSITY OF WISCONSIN - MADISON                      1        1
                                                       0        9
SHEBOYGAN TEST SITE                                    0        0
POLICY :  AVOID AGRICULTURAL LAND                      0        0
                                                       0        0
 UTM     ----------             ----------             ----------
4869000 I0*8######I             I0*8######I            I0*#######I
        I08+######I             I+0*######I            I+0#######I
        I80**#####I             I*+0*#####I            I++0*#####I
        I#80*#####I             I8+80#*###I            I*+80*####I
        I#*+0*####I             I##*80*###I            I**+80*###I
        I##8+0*###I             I#*#*80*##I            I8**+80*##I
        I####*0*##I             I#####80++#I           I##*++80*#I
        I####**08+*I            I####**80*#I           I###*++80*I
        I####*808+*I            I####*80+*#I           I####++0+#I
        I####+808+*I            I####+80+*#I           I####+80*#I
        I####*808+*I            I####**80*#I           I8###*+0+*I
        I####*808+#I            I8*###++0+#I           I8##*+++0+I
        I***+80*8+#I            I+*8*+++0+*I           I+***+++0+I
        I8+**0*8*#I             I8**#++0**#I           I8+*+++0+*I
        I88880*###I             I88880*###I            I888800+**I
        I888000***I             I88800****I            I888008***I
        I+88000+++*I            I+88088+**I            I+80088+*#I
        I+*860+**#I             I#+800+***I            I**808+***I
        I#8++0*##*I             I8**+0+###I            I#**80+***I
        I###*+0**#I             I8*8*08***I            I8#**80+**I
        I####*+0*#I             I####*08***I           I8#**+80+*I
        I####*0++#I             I#**#*80*##I           I###*+80*#I
        I###*0*####I            I#***80*###I           I8**#80**#I
        I8++08+###I             I#*#80*####I           I8**80*###I
        I*+0*+*###I             I**80+*####I           I**+0+*###I
        I800*#####I             I880*######I           I++0**####I
        I08*######I             I80**######I           I80**#####I
        I0+8*#####I             I08*#######I           I0+*######I
        I08*8*####I             I+0*#######I           I0+*######I
4840000 I088++####I             I0+*#######I           I0+*######I
         ----------             ----------             ----------
             A                      B                      C
            ERTS                   RB57                 REMAP I
MAXIMUM  1640.696               1631.802               1892.428
MINIMUM   910.154                939.392               1143.002

OVERPRINT SYMBOLS REPRESENT PER CENT COST ABOVE MINIMUM COST

                   SYMBOLS ASSOCIATED WITH COST RANGE

                   RANGE (PER CENT)            SYMBOL
              0   .EQ.  COST  .EQ.  0            0
              0   .GT.  COST  .LE.  1            8
              1   .GT.  COST  .LE.  5            +
              5   .GT.  COST  .LE.  10           *
             10   .GT.  COST  .LE.  100          #
```

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OF POOR QUALITY

FIGURE 4.3.9 - MINIMUM COST ARRAYS - Off-diagonal cells not included in corridor segment calculations.

```
ERTS-1 INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                  4         4   UTM
UNIVERSITY OF WISCONSIN - MADISON                    1         1
                                                     0         9
SHEBOYGAN TEST SITE                                  0         0
POLICY :  AVOID AGRICULTURAL LAND                    0         0
                                                     0         0
 UTM     ----------       ----------       ----------
4869000 I0X########I     I0X########I     I0X########I
        I+8X#######I     I+8X#######I     I+0X#######I
        IX+8X######I     I++8X######I     IX+0X######I
        I#+8X######I     I#+8X######I     I#+80X#####I
        I###8X#####I     I#XX8X#####I     I###80X####I
        I####8X####I     I###X8X####I     I###X80X###I
        I#####8XXX#I     I####X8XX##I     I####X80X##I
        I####XX88X#I     I####XX88X#I     I#####X80X#I
        I####X80+X#I     I####X+0+##I     I####X+0+##I
        I####+80+X#I     I####+80X##I     I####+80X##I
        I####XX88X#I     I####X+0+X#I     I####XX8+X#I
        I####X++8+#I     I###X+++8+#I     I####X++0+#I
        IXX##++X8X#I     I#XXX++X8X#I     I+X#X+++0+#I
        I8+XX+X8XX#I     I8+XX+X8XX#I     I8+XX++0XX#I
        I888888X###I     I888808X###I     I888880XXXXI
        I888808XXXXI     I888088XXX#I     I888808XXX#I
        I+88088+XXXI     I+88088+XX#I     I+88088+XX#I
        I#X#80+X###I     I#X888+XX##I     I#X808+XXX#I
        I##X+0X#X##I     I##X+0X#X##I     I###+0+#XX#I
        I###X+8XXX#I     I###X+0X#X#I     I###X88XXXXI
        I####X+8X##I     I####X+0X##I     I#8XXX88XX#I
        I###X#8+X##I     I###XX8+X##I     I#XXXX80X##I
        I#X#X8X####I     I#X8X8X####I     I#XXX80X###I
        I#XX88X####I     I#XX88X####I     I#XX80X####I
        IX+8X+X####I     IXX+X+X####I     IXX+0+X####I
        I888X######I     I++8X8#####I     I++0X######I
        I88XX######I     I88X#######I     I80XX######I
        I0+X#######I     I0+X#######I     I0+X#######I
        I+8X#######I     I0+X#######I     I++########I
4840000 I0+X#######I     I0+X#######I     I0+X#######I
         ----------       ----------       ----------
             A                B                C
        ERTS & RB57      ERTS & REMAP     RB57 & REMAP
```

* * OVERLAYS OF MINIMUM COST ARRAYS * *

SYMBOLS ASSOCIATED WITH COST RANGE

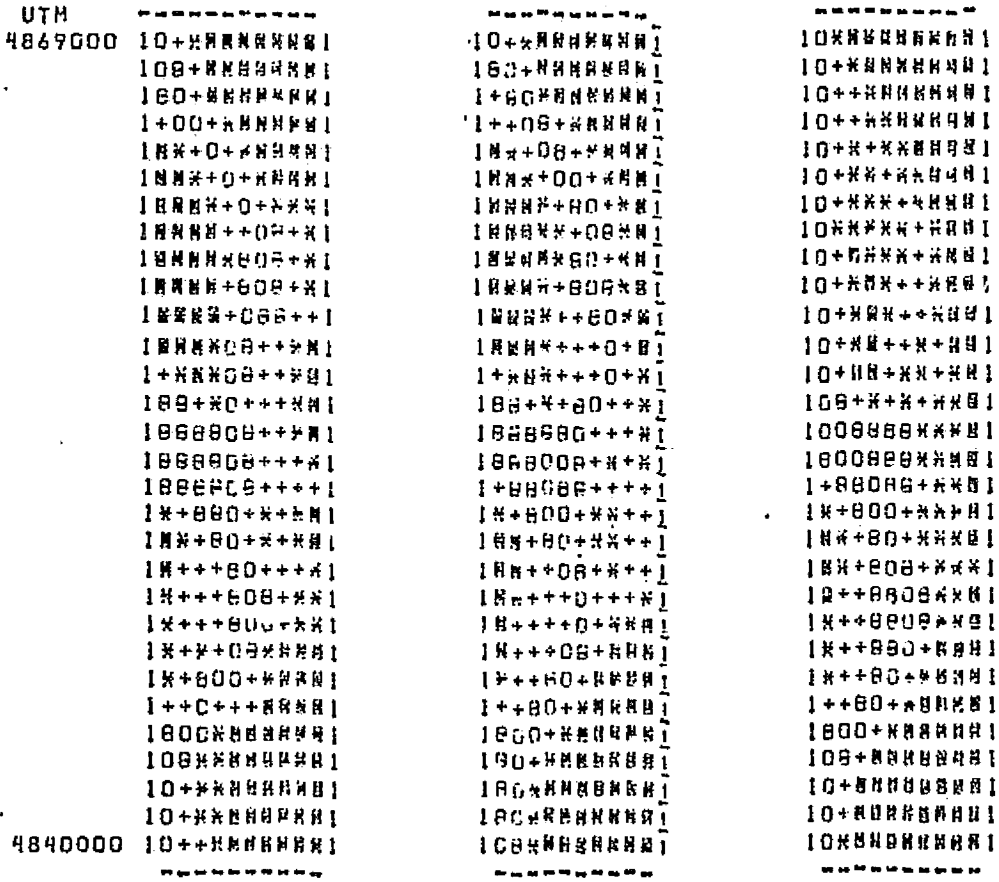
RANGE (PER CENT)	SYMBOL
0 .EQ. COST .EQ. 0	0
0 .GT. COST .LE. 1	8
1 .GT. COST .LE. 5	+
5 .GT. COST .LE. 10	X
10 .GT. COST .LE. 100	#

FIGURE 4.3.10 - OVERLAYS OF MINIMUM COST ARRAYS OF FIGURE 4.3.9.

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
POLICY : AVOID AGRICULTURAL LAND

4	4	UTM
1	1	
0	9	
0	0	
0	0	
0	0	



	A	B	C
	ERTS	RB57	REMAP I
MAXIMUM	2028.584	2123.180	2357.317
MINIMUM	1302.094	1347.752	1527.859

OVERPRINT SYMBOLS REPRESENT PER CENT COST ABOVE MINIMUM COST

SYMBOLS ASSOCIATED WITH COST RANGE

RANGE (PER CENT)	SYMBOL
0 .EQ. COST .EQ. 0	0
0 .GT. COST .LE. 1	8
1 .GT. COST .LE. 5	+
5 .GT. COST .LE. 10	*
10 .GT. COST .LE. 100	#

FIGURE 4.3.11 - MINIMUM COST ARRAYS - Off-diagonal cells are included in corridor segment calculations.

```
ERTS-1 INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                    4        4   UTM
UNIVERSITY OF WISCONSIN - MADISON                      1        1
                                                       0        9
SHEBOYGAN TEST SITE                                    0        0
POLICY :  AVOID AGRICULTURAL LAND                      0        0
                                                       0        0
 UTM      ----------         ----------          ----------
4869000  I0+XMMMMMMMI       I0+MMMMMMMMI        I0XMMMMMMMMI
         I88+MMMMMMMI       I0+XMMMMMMMI        I8+XMMMMMMMI
         I+8+MMMMMMMI       I8++MMMMMMMI        I+++XMMMMMMI
         I++0+XMMMMMI       I+++XXMMMMMI        I+++XXMMMMMI
         IMX+0+XMMMMI       IM+++XXMMMMI        IMXX+XXMMMMI
         IMMX+0+XMMMI       IMMXX+XXMMMI        IMMXX+XXMMMI
         IMMMX+8+XXMI       IMMMXX+XMMMI        IMMMXX+XMMMI
         IMMMMX+08XMI       IMMMMXX+XMMI        IMMMXXX+XMMI
         IMMMMX80+XMI       IMMMMXX+XMMI        IMMMMXX+XMMI
         IMMMM+80X+MI       IMMMMX++XMMI        IMMMMX++XMMI
         IMMMM++88XMI       IMMMMX++XMMI        IMMMMX++XMMI
         IMMMX++++XMI       IMMMM++X+MMI        IMMMM++X+MMI
         I+XMX++++XMI       I+XMM+XX+XMI        I+XMM+XX+XMI
         I88+X++++XMI       I8X+X+X+XXMI        I88+X+X+XXMI
         I888888++XMI       I8+8888XXXMI        I888888XXXMI
         I888888+M+XI       I8+8888XXMMI        I888888XXMMI
         I+88888++++I       I+88888+XXMI        I+88088+XXMI
         IX+880+XXXMI       IX+880+XXXMI        IX+800+XXXMI
         IMM+80+XXXMI       IM++80+XXXMI        IMM+80+XXXMI
         IMM++88+X+XI       IM+++88+XXXI        IMM++08+XXXI
         IMX+++0++XXI       IM+++808XXMI        IMX+++0+XXMI
         IM++++0+XXMI       IX+++808XXMI        IM++++0+XXMI
         IM+X+08XMMMI       IX+X+88XMMMI        IM+++88+MMMI
         IX++80+MMMMI       IX++80+XMMMI        IX++80+MMMMI
         I++8++XMMMMI       I++8++XMMMMI        I++80+XMMMMI
         I800XMMMMMMI       I800XMMMMMMI        I800+XMMMMMI
         I88XXMMMMMMI       I08XMMMMMMMI        I88+MMMMMMMI
         I8+XMMMMMMMI       I0+MMMMMMMMI        I8+MMMMMMMMI
         I8+XMMMMMMMI       I0+MMMMMMMMI        I8+MMMMMMMMI
4840000  I0+XMMMMMMMI       I0XMMMMMMMMI        I0XMMMMMMMMI
          ----------         ----------          ----------
              A                  B                   C
         ERTS & RB57        ERTS & REMAP        RB57 & REMAP

            * * OVERLAYS OF MINIMUM COST ARRAYS * *

              SYMBOLS ASSOCIATED WITH COST RANGE
```

RANGE (PER CENT)					SYMBOL
0	.EQ.	COST	.EQ.	0	0
0	.GT.	COST	.LE.	1	8
1	.GT.	COST	.LE.	5	+
5	.GT.	COST	.LE.	10	X
10	.GT.	COST	.LE.	100	M

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FIGURE 4.3.12 - OVERLAYS OF MINIMUM COST ARRAY OF FIGURE 4.3.11.

```
ERTS-1 INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES                      4         4  UTM
UNIVERSITY OF WISCONSIN - MADISON                        1         1
                                                         0         9
SHEBOYGAN TEST SITE                                      0         0
VARIABLE :  AGRICULTURAL LAND                            0         0
                                                         0         0
 UTM      -----------         -----------               -----------
4869000 I 8  88    I        .I    88 0  I              I 0        I
        I  8 8 8800I         I    8   00I              I        0 I
        I 88 88    I         I8 8 8     I              I80   00   I
        I80 8 88000I         I8008 88000I              I 000      I
        I  08808000I         I8 0  08000I              I    00 0  I
        I80  0  C00I         I800 00 000I              I   0000   I
        I0  00088  I         I0  0008 00I              I      0000I
        I88    0 00I         I8     0000I              I 0     00 I
        I   88  C00I         I8  880 000I              I      0   I
        I 0 8   0  I         I 0  8  000I              I    0  000I
        I0 0 000000I         I0   000000I              I       000I
        I   0   888I         I    0  8  I              I          I
        I8 0   0 68I         I  0   0 88I              I        00I
        I  0008 088I         I  0 08 888I              I 0 800 800I
        I       8  I         I     0 8  I              I      00  I
        I        0 I         I      0000I              I      0800I
        I0     0 0 I         I0     0 00I              I0     0800I
        I 8    0 68I         I      0888I              I 0    0 00I
        I  0  8 088I         I  0    088I              I  8       I
        I8    8 888I         I   88 8888I              I       8  I
        I  8888 0  I         I  88  0000I              I     00 00I
        I 00000 000I         I0000000 0 I              I  0   0   I
        I 0880 8888I         I C88088889I              I  0   8   I
        I8000000   I         I8 0000    I              I  0       I
        I  08      I         I0008000 00I              I00   0    I
        I     88888I         I 0    8 8 I              I 0     0 00I
        I 88  0 8  I         I    0 00  I              I  00   00 I
        I88  200000I         I88  800000I              I 0    0 0 I
        I 8 0 8    I         I 0 0      I              I 0    0   I
4840000 I 0080 68  I         I 00800 8  I              I 08   00  I
          ----------          ----------               -----------
              A                   B                        C
          ERTS & RB57         ERTS & REMAP              RB57 & REMAP
```

OCCURRENCE	0	8	0	8	0	8
	78	75	102	56	77	9

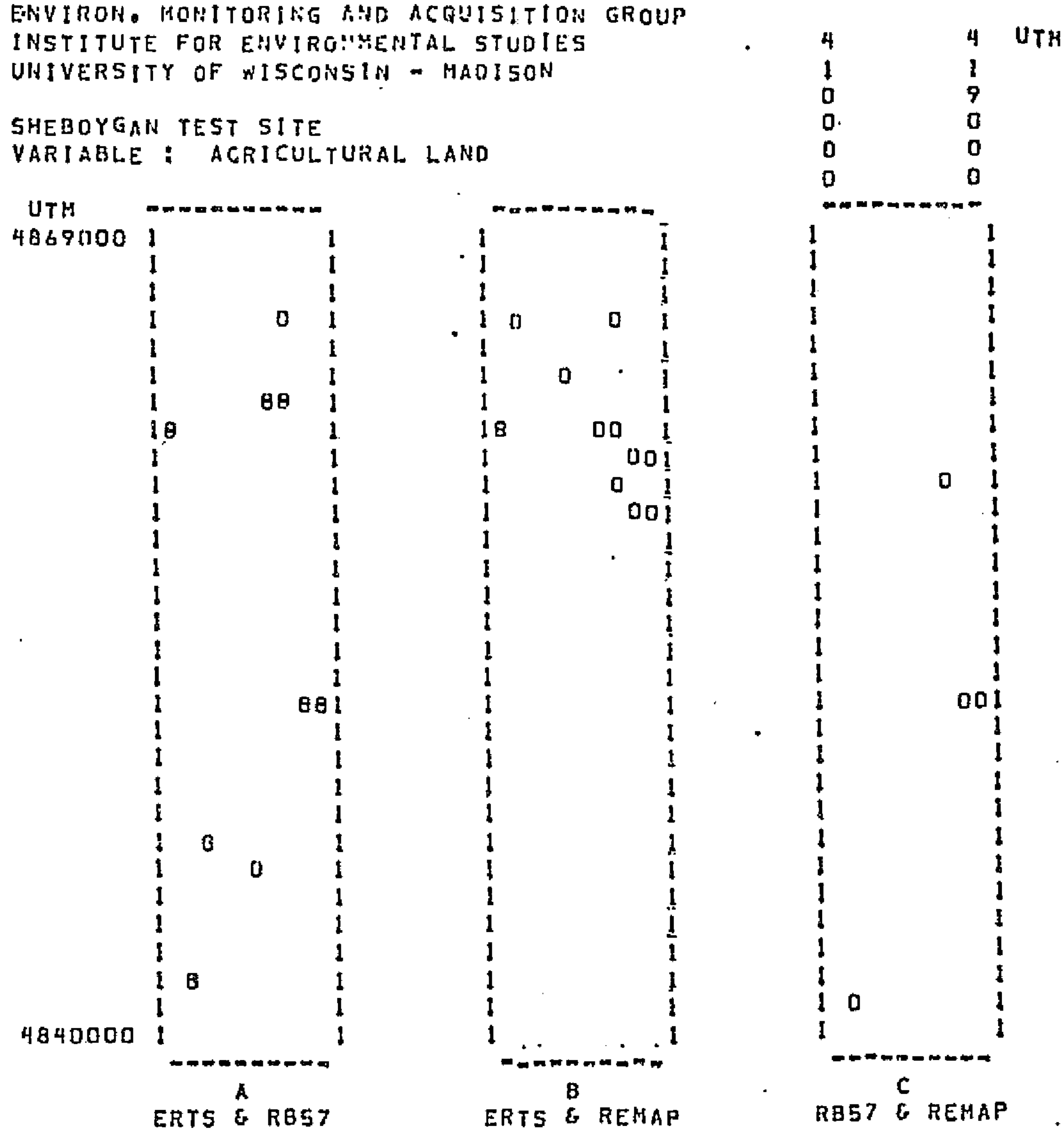
COMPARISON OF DATA BANKS ON A CELL-BY-CELL BASIS

OVERPRINT SYMBOLS INDICATE AN ABSOLUTE
DIFFERENCE GREATER THAN 10 PER CENT BETWEEN CELLS

FIGURE 4.3.13 - COMPARISON OF DATA BANKS - 10% THRESHOLD.

ERTS-I INVESTIGATION: CONTRACT # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE : AGRICULTURAL LAND



	A: 0	A: 8	B: 0	B: 8	C: 0	C: 8
OCCURRENCE	2	7	10	1	4	0

COMPARISON OF DATA BANKS ON A CELL-BY-CELL BASIS

OVERPRINT SYMBOLS INDICATE AN ABSOLUTE
DIFFERENCE GREATER THAN 50 PER CENT BETWEEN CELLS

FIGURE 4.3.14 - COMPARISON OF DATA BANKS - 50% THRESHOLD.

```
ERTS-1 INVESTIGATION:  CONTRACT  # NAS 5-21754
ENVIRON. MONITORING AND ACQUISITION GROUP               4       4   UTM
INSTITUTE FOR ENVIRONMENTAL STUDIES                     1       1
UNIVERSITY OF WISCONSIN - MADISON                       0       9
                                                        0       0
SHEBOYGAN TEST SITE                                     0       0
POLICY :  AVOID OPEN WATER AND URBAN LAND               0       0

 UTM     ----------       ----------       ----------
4869000  1O+XX######1     1O+XX######1     1OOOOO8XX++1
         1O8+XX#####1     1O8+XX#####1     18+X8#OXX++1
         1O8#+XX####1     1O##XXX####1     1###+#XO8#81
         1O###+XX###1     1O###8XX###1     1#8####+O881
         1O##+++X###1     1OO+#XXX###1     1#8X#88O+881
         1OO++++X###1     1OOO+X#####1     1888#8O+8881
         1#OO++#####1     1O#OO+#####1     18+++OO####1
         18OOO+#####1     1#OOO8+####1     18888O#####1
         1+OOOO#####1     18OOO8#####1     1+888O#####1
         1X+OOO#####1     1+OOO######1     1#888O#####1
         1XX+OOO####1     1X+OOO+####1     18888O#####1
         1#XX+OOO###1     1XX+OOO+###1     188888O####1
         1##X#+OO#XX1     1#XX+OOO###1     1#X8XX+O###1
         1###XX+OO+X1     1###X+OO###1     1##88##O###1
         1#####8#O+X1     1######O###1     18#####OX#X1
         1#8####O+##1     1######O+##1     1######O8881
         1#####O####1     1####8O####1     188###OX###1
         1#X##OO####1     1##X##O####1     1X###X8O###1
         1XX+OOO8###1     1#X#+OO8+##1     1XX#X##O#+X1
         1X+OOOO####1     1XX+OOO+X##1     1XXXXXXO###1
         1+OOOOO88+X1     1X+OOO#####1     1XXXXX##OXX1
         1OOOOOO88#X1     1+OOOO8+X##1     1X#X#888O881
         1OOOOOOO8+#1     1OO#OO8#X##1     1####X++O8O1
         1OOOOOO8+X#1     1OO8OO8++X#1     1#+8X#8O+XX1
         1OOOOOO+XX#1     1OOOOO8+XX#1     18#8#X+O#++1
         1OOOOO+XX##1     1OOOOO+XX##1     18888+O+###1
         1OOOO+XX###1     1OOOO+XX###1     1888#O##8##1
         1OOO+XX####1     1OOO+XX####1     188OO###8##1
         1OO+X+#####1     1OO+X######1     18O#88#+###1
4840000  1O+XX######1     1O+XX######1     1O8888++###1
          ----------       ----------       ----------
              A                B                C
             ERTS             RB57           REMAP I
MAXIMUM    114.357          153.384          211.439
MINIMUM       .290             .290           47.340
```

OVERPRINT SYMBOLS REPRESENT PER CENT COST ABOVE MINIMUM COST

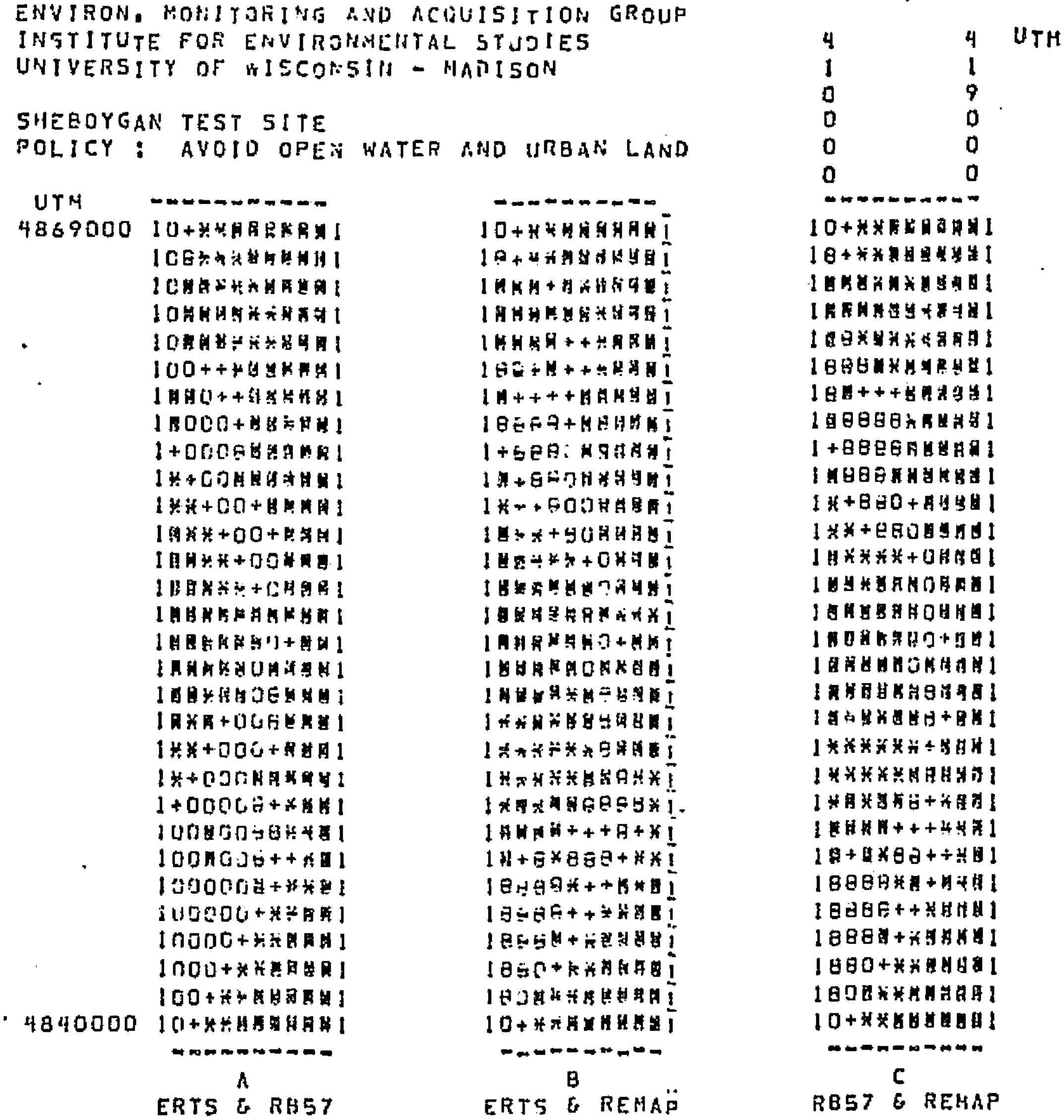
SYMBOLS ASSOCIATED WITH COST RANGE

RANGE (PER CENT)					SYMBOL
0	.EQ.	COST	.EQ.	0	O
0	.GT.	COST	.LE.	1	8
1	.GT.	COST	.LE.	5	+
5	.GT.	COST	.LE.	10	X
10	.GT.	COST	.LE.	100	#

FIGURE 4.3.15 - MINIMUM COST ARRAYS FOR LINEAR COMBINATION OF VARIABLES - Off-diagonal cells not included in corridor segment calculations.

```
ERTS-I INVESTIGATION:  CONTRACT  # NAS 5-21764
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
POLICY :  AVOID OPEN WATER AND URBAN LAND
```



* * OVERLAYS OF MINIMUM COST ARRAYS * *

SYMBOLS ASSOCIATED WITH COST RANGE

RANGE (PER CENT)					SYMBOL
0	.EQ.	COST	.EQ.	0	0
0	.GT.	COST	.LE.	1	8
1	.GT.	COST	.LE.	5	+
5	.GT.	COST	.LE.	10	X
10	.GT.	COST	.LE.	100	█

FIGURE 4.3.16 - OVERLAYS OF MINIMUM COST ARRAYS FOR FIGURE 4.3.15.

4.4 CRITICAL RESOURCE INFORMATION PROGRAM

Since our proposal for an ERTS Follow-On Investigation titled "The Use of ERTS Data to Inventory and Monitor Critical Land Resources for Statewide Planning and Management" (Proposal 2097A) was not funded by NASA, it was not possible to devote project time and resources to study further the utility of ERTS to the CRIP program.

4.5 ERTS LAKE WATER QUALITY MONITORING PROJECT

The Wisconsin Department of Natural Resources (DNR) is required to classify the lakes in the state as to their trophic level in response to the federal legislation "Federal Water Pollution Control Act Amendments of 1972," section 314. This project represents an attempt to evaluate the feasibility of using photographic imagery from the ERTS (Earth Resources Technology Satellite) to accomplish this classification. The ERTS satellite passes over the same location on the ground every 18 days. Each ERTS image covers a rectangle on the ground 115 miles by 115 miles. The satellite's sensor systems (multispectral scanner) gather data in four different wavelength bands simultaneously: Band 4 (.5-.6μ); Band 5 (.6-.7μ); Band 6 (.7-.8μ); and Band 7 (.8-1.1μ).

Densitometric readings in band 5 of ERTS 70mm imagery were taken for all lakes in Wisconsin greater than 100 acres (approximately 1000 lakes). For 37 of these lakes, DNR water quality ground truth data was correlated with density readings in all four bands. The lakes in the remainder of the state were classified as to the level of eutrophication by an algorithm developed by a statistical analysis of this correlation.

4.5.1 METHODOLOGY

This project involved four separate experiments: 1) Densitometric analysis of 37 lakes in each of the 4 ERTS bands using 70mm positive transparencies; this data was then correlated with secchi depth readings taken by the Wisconsin Department of Natural Resources; 2) Using specially developed computer programs and an interactive CRT terminal, ERTS digital tapes were accessed and the actual 64 scene brightness values sent back by the satellite were obtained for 14 of the above lakes; 3) A time series densitometric analysis of 20 lakes in southeastern Wisconsin on four different ERTS overflight dates; and 4) Densitometric analysis of approximately 1000 lakes in Wisconsin greater than 100 acres on band 5 of ERTS 70mm imagery.

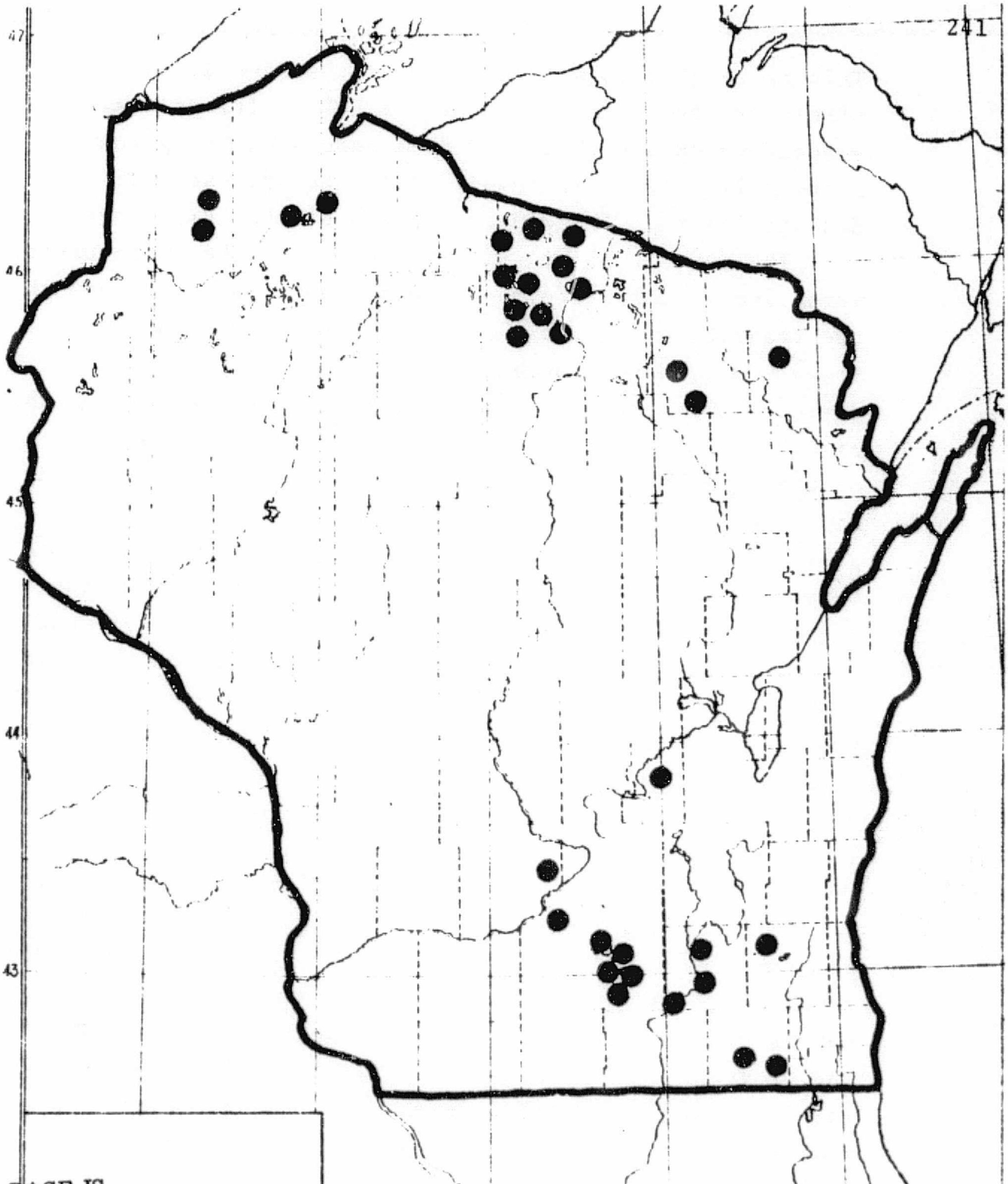
4.5.2 DENSITOMETRIC ANALYSIS OF 37 LAKES USING 70MM ERTS IMAGERY

The primary goal of this study is to evaluate the usefulness of densitometric analysis of ERTS photographic imagery as a tool for a periodic monitoring program of Wisconsin lakes for changes in water turbidity caused by the growth of phytoplanktonic algae. Thirty-seven lakes were selected for densitometric analysis in each of the four ERTS bands. The location of these lakes, which range in fertility from extremely eutrophic lakes in southeastern Wisconsin to very clear oligotrophic lakes in the northern part of the state, is shown on Map 4.5. Eight different ERTS images were required to provide coverage of all 37 lakes. Secchi depth readings were selected as the ground truth measure of lake eutrophication to be correlated with lake exposure calculated from the ERTS image. Secchi depths and various other water quality parameters are sampled quarterly in these lakes as a part of the DNR Lake Water Quality Monitoring Program.

The sampling date of each of these lakes was within 25 days of the ERTS overflight date.* In addition, each lake 1) had no tannin coloring, 2) was at least 20 feet deep to minimize bottom interference, 3) was large enough to insure that the measurement spot of the microdensitometer was wholly within the lake, and 4) was not obscured at all by clouds or atmospheric haze.

A Gamma Scientific spot microdensitometer equipped with a digital readout photomultiplier-picoammeter combination was used for the measurement of the transmitted intensity of light through the film. A measurement spot size diameter of 50 microns, which corresponds to 550 feet on the ground, was selected for the analysis of lake imagery.

*For 30 of the lakes the sampling date was within 10 days of the ERTS overflight. The remaining lakes (sampled within 11-25 days) were included because they were all known to be oligotrophic and were not expected to show much variability in algal turbidity over time.



LOCATION OF LAKES ANALYZED

MAP 4.5

This is large enough to average across several of the pixels or resolution cells of the ERTS multispectral scanner which are about 200 feet across on the ground. A one millimeter measurement spot size was used for densitizing the film wedges on each of the ERTS images.

The raw current readings output from the densitometer were used to calculate the transmittance of light through the transparency for the lake of interest. On any one frame, lake image transmittance might be expected to correlate with secchi depth. However, the transmittances of lakes on different frames are not comparable because of photographic processing differences. These processing differences can be normalized by using the film wedges provided on each frame to calculate the relative exposure of each lake. Relative exposure is proportional to the light energy hitting the ERTS multispectral scanners and is comparable from frame to frame. Each step on the film wedge was exposed during processing by an amount of light proportional to a known exposure. The transmitted light was measured through each step of the film wedge on each frame. A transmittance versus exposure curve was plotted for each frame and this was used to find the exposure related to the densitometric reading for each of the lakes.

All the above calculations were done with computer programs developed for this project. The program includes a graphing subroutine for plotting exposure versus secchi depths. These plots are shown in Figures 4.5.1-4.5.6. The programs include provisions for inputting calculated lake exposures and secchi depths into a non-linear regression curve fitting subroutine for statistical analysis.

Of the four ERTS bands, band 5 and, to a slightly lesser extent, band 4 showed the best resolution between lake image exposure and secchi depth. Band 5 of the multispectral scanner senses red band wavelengths from .6-.7μ. The plot of band 5 exposure versus secchi depth

FIGURE 4.5.1 - BAND 4 EXPOSURE VS. SECCHI DEPTH — ERTS 70MM IMAGERY
EXPONENTIAL REGRESSION REPRESENTED BY SOLID LINE

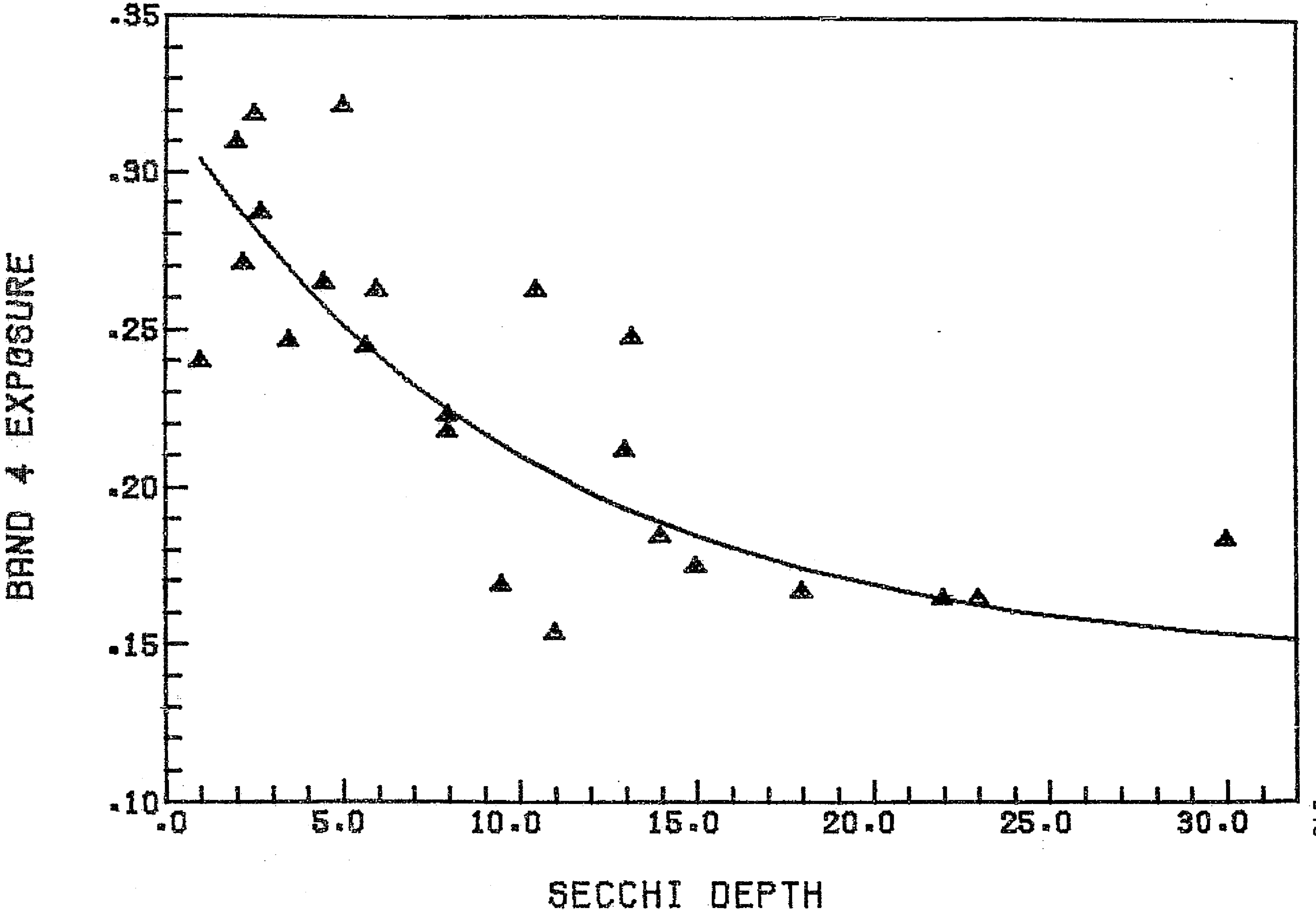
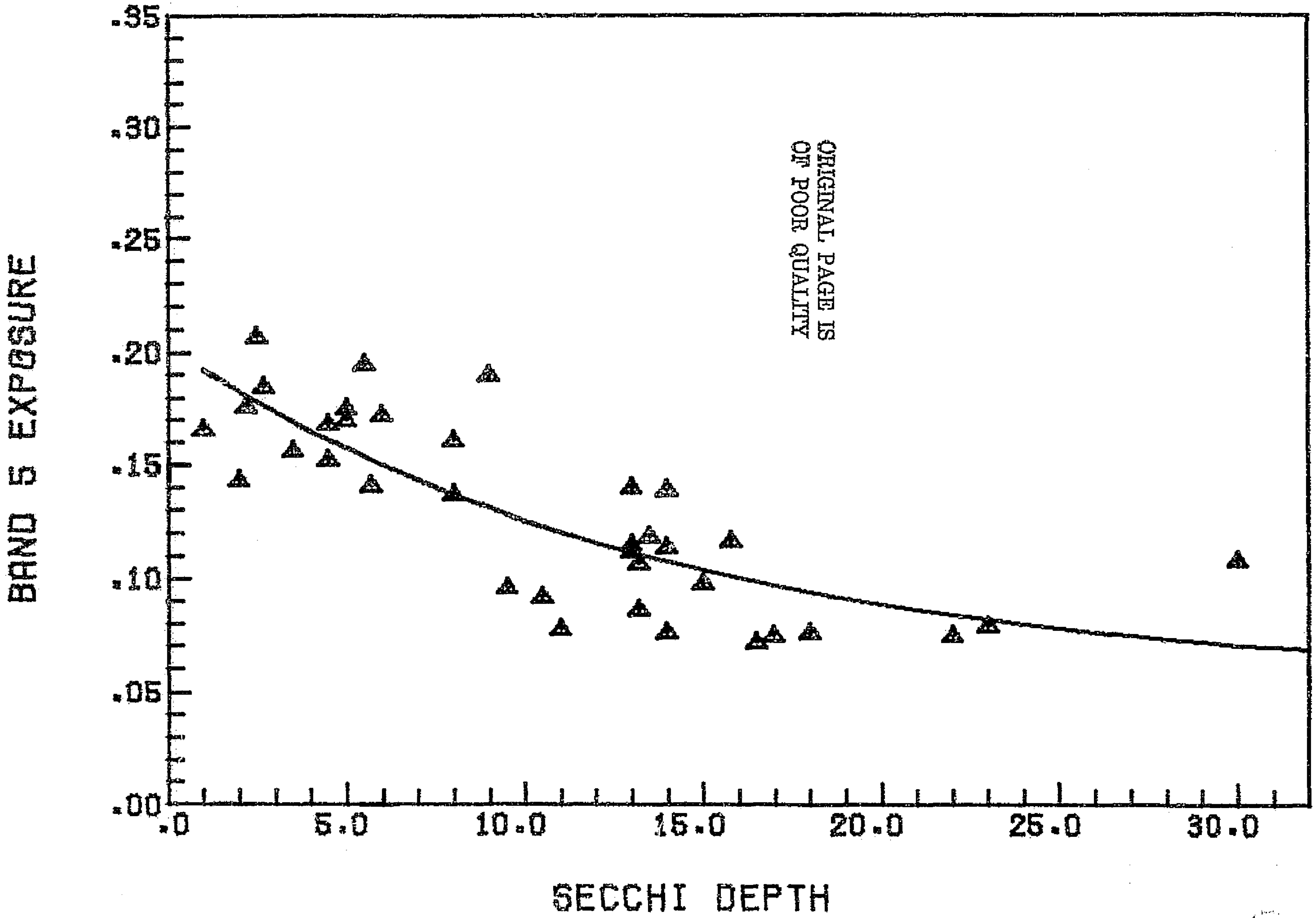


FIGURE 4.5.1 - Band 4 Exposure vs. Secchi Depth -- ERTS 70mm Imagery Exponential

FIGURE 4.5.2 -BAND 5 EXPØSURE VS. SECCHI DEPTH -- ERTS 70MM IMAGERY EXPØNENTIAL REGRESSIØN REPRESENTED BY SØLID LINE



GURE 4.5.2 - Band 5 Exposure vs. Secchi Depth -- ERTS 70mm Imagery Exponential Regression Represented by Solid Line.

FIGURE 4.5.3 - BAND 6 EXPOSURE VS. SECCHI DEPTH - ERTS 70MM IMAGERY

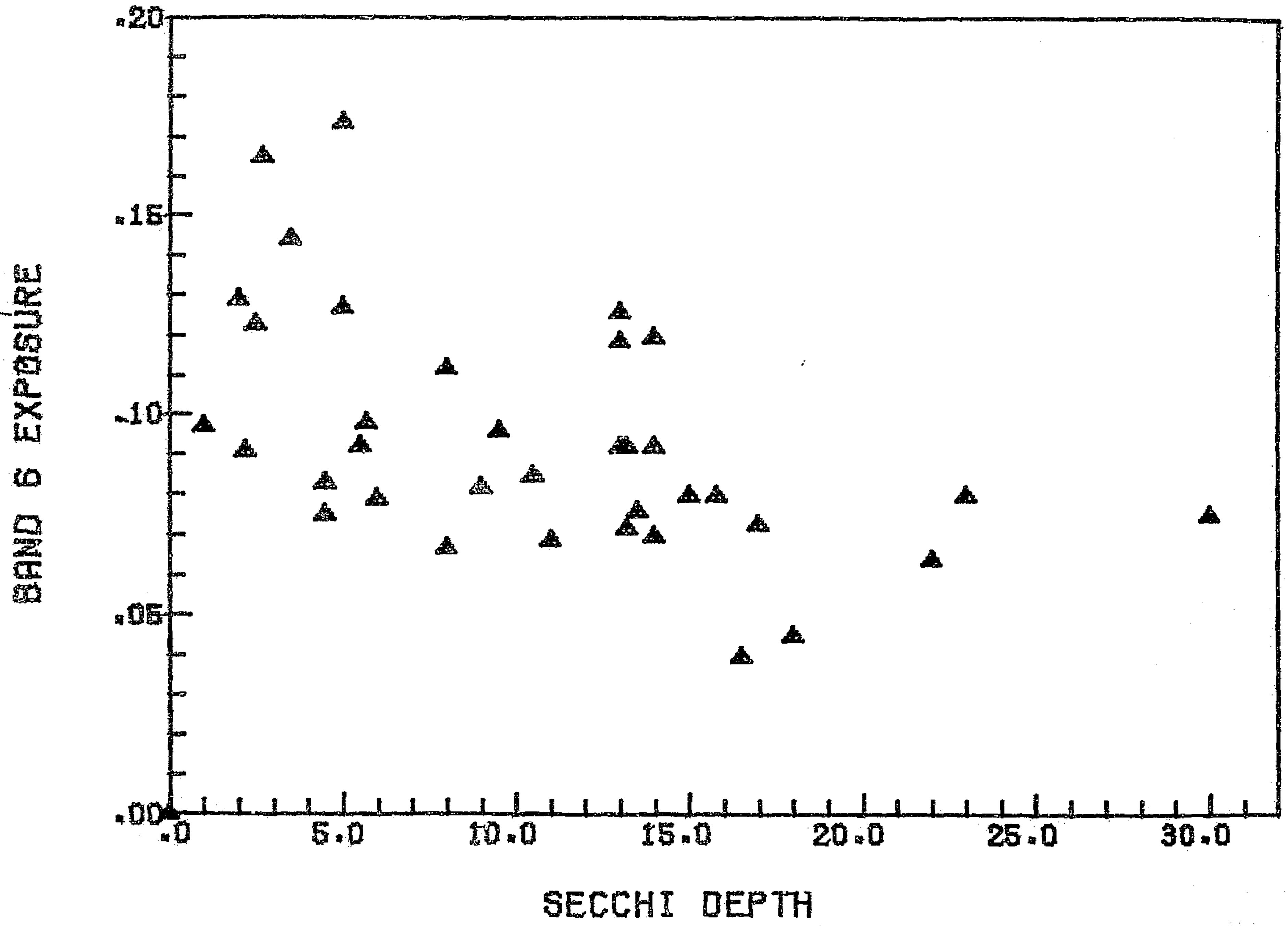


FIGURE 4.5.3 - Band 6 Exposure vs. Secchi Depth - ERTS 70mm Imagery.

FIGURE 4.5.4 - BAND 7 EXPOSURE VS. SECCHI DEPTH -- ERTS 70MM IMAGERY

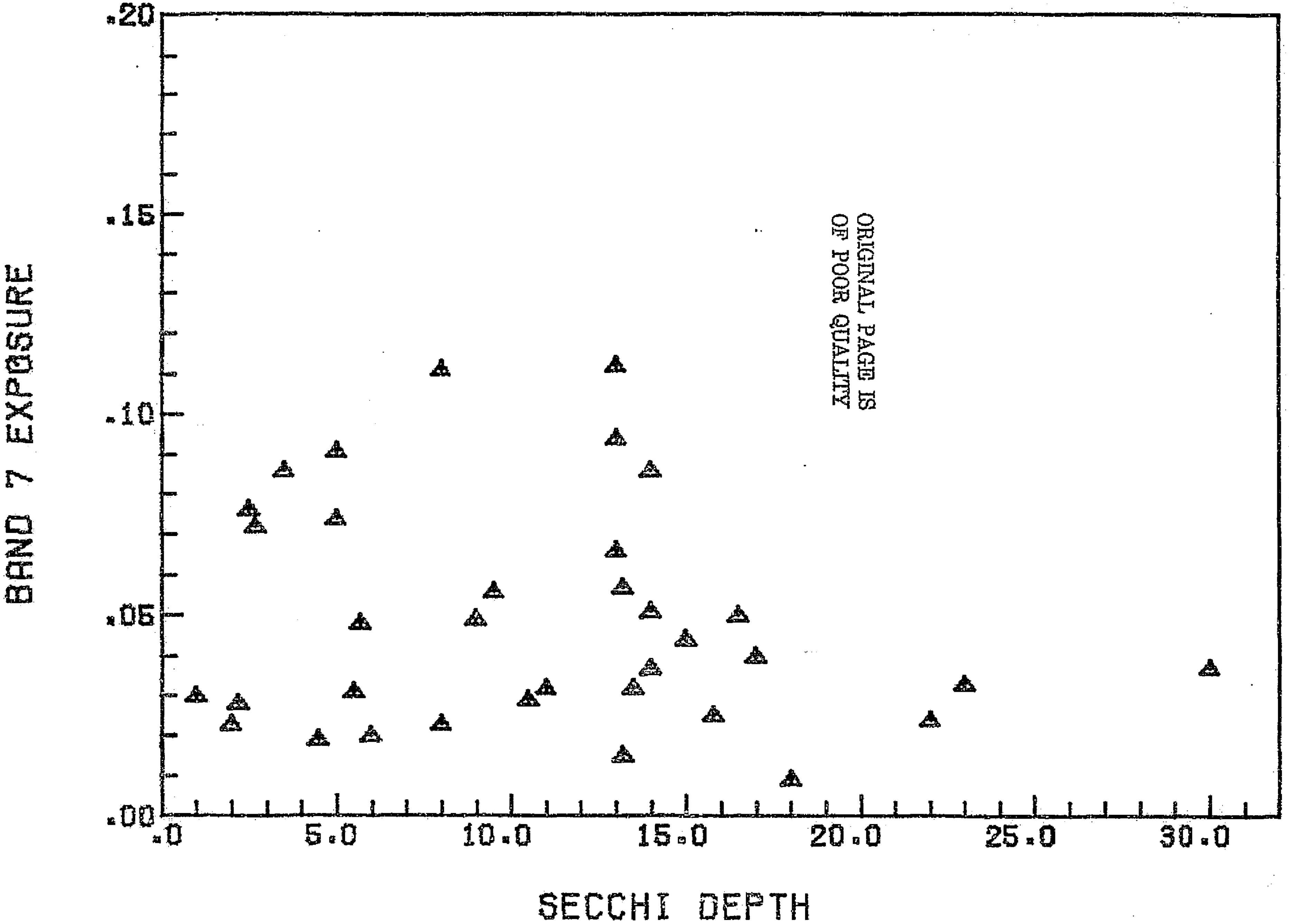


FIGURE 4.5.4 - Band 7 Exposure vs. Secchi Depth -- ERTS 70mm Imagery.

FIGURE 4.5.5 - BAND 5 EXPOSURE -- TANNIN LAKES -- ERTS 70MM IMAGERY

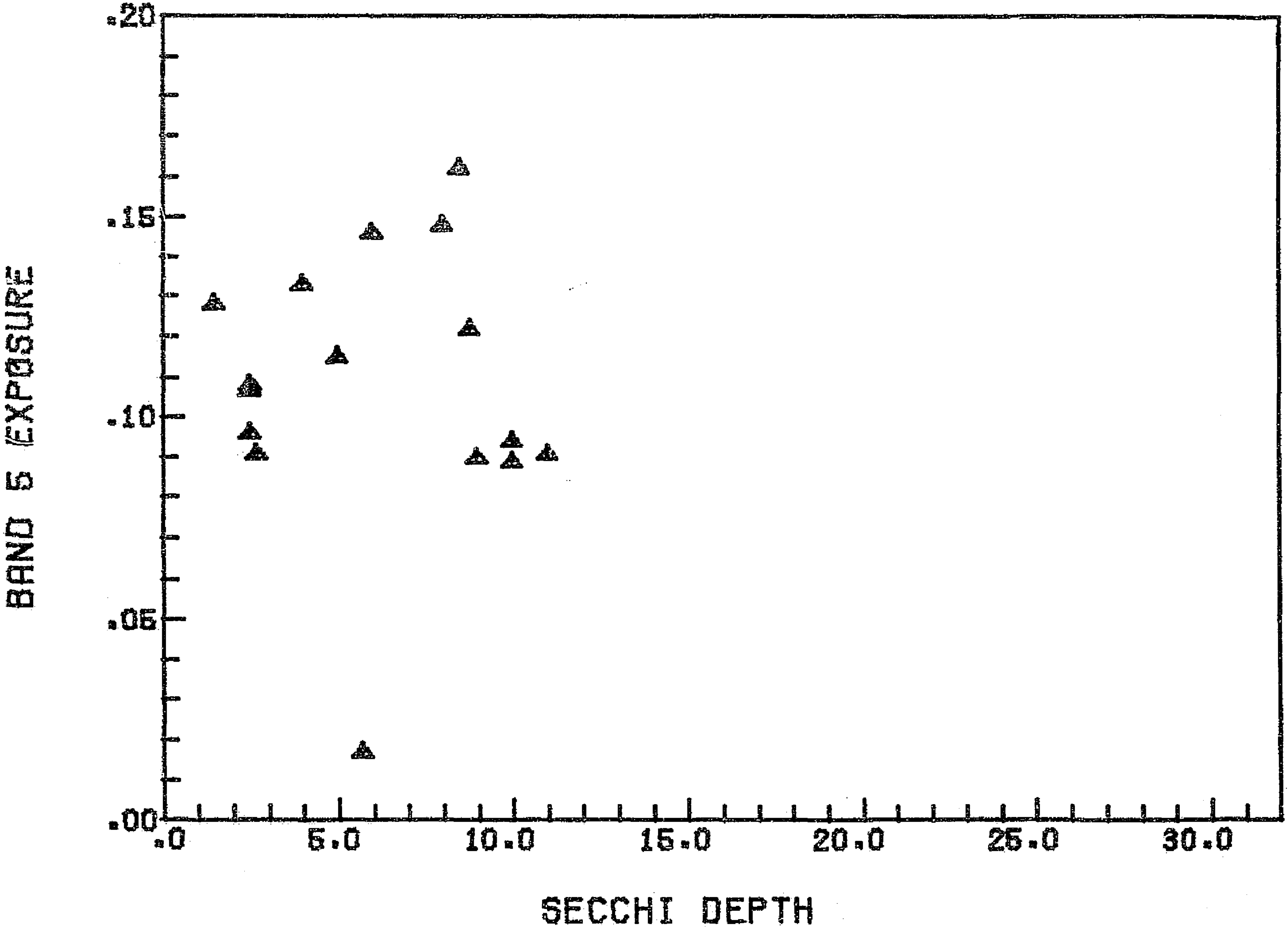
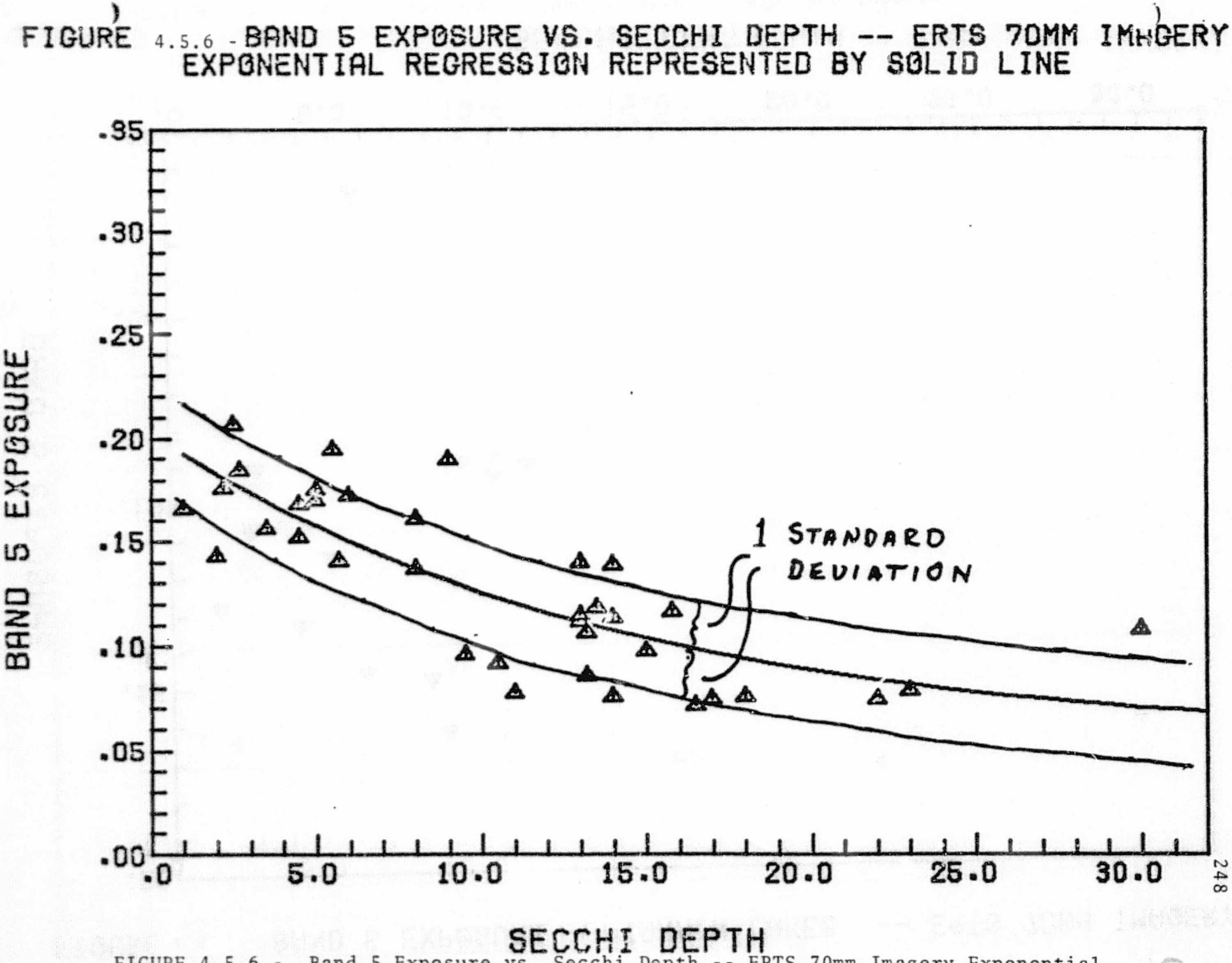


FIGURE 4.5.5 - Band 5 Exposure -- Tannin Lakes -- ERTS 70mm Imagery.



248

FIGURE 4.5.6 - Band 5 Exposure vs. Secchi Depth -- ERTS 70mm Imagery Exponential Regression Represented by Solid Line.

is shown in Figure 4.5.2. An exponential model was used to calculate the least squares regression represented by the solid line. The following equation describes this line:

$$\text{EXPOSURE} = .0543 + .148e^{.073 \text{ secchi depth}}$$

The root mean square residual (standard deviation) about the regression line is .02524. The mean measurement error in band 5 of two replicate sets of 14 lakes was 6.09%. Given this small measurement error, much of the scatter about the regression line can be assumed to be a function of the 1 to 25 day interval between the sampling date and ERTS overflight date. The root mean square residual is an indicator of how reliably the fitted curve predicts a secchi depth for a given exposure. Assuming a normal error distribution, an envelope of one standard deviation (.0254) on each side of the fitted curve can be expected to contain a given lake exposure 68.27% of the time (see Figure 4.5.6). An envelope of two standard deviations (.0508) on each side of the curve will contain a given lake exposure 95.45% of the time.

The plot of band 4 (green band, wavelength .5-.6μ) lake exposure is shown in Figure 4.5.1. There is very little contrast in band 4 between the lake image and the land surrounding it. To reduce the chance of measurement error caused by the inability to distinguish between the two, 12 of the smaller lakes were not analyzed, leaving 25 lakes in the band 4 sample. The exponential equation describing the least squares fit is:

$$\text{EXPOSURE} = .144 + .176e^{.0979 \text{ secchi depth}}$$

The root mean square residual (standard deviation) is .0402. The mean measurement error in band 4, calculated from two replicate sets of 14 lakes, is 4.70%.

The plots of the infrared wavelengths, band 6 (.7-.8μ) and band 7 (.8-1.1μ) exposure versus secchi depths are shown in Figures 4.5.3 and 4.5.4, respectively. There was no significant correlation between lake exposure and secchi depth in either of these two bands.

Figure 4.5.5 shows a plot of band 5 exposure versus secchi depth for tree tannin colored lakes. While exposure values for tannin lakes don't correlate with secchi depths, at a given secchi depth they consistently have lower exposure values than non-colored lakes. One possible explanation for this phenomenon is that turbidity caused by the brown colored tannin dye dissolved in the water absorbs light while the particulate turbidity caused by phytoplankton increases lake reflectivity.

4.5.3 ANALYSIS OF 11 LAKES USING DIGITAL GRAY LEVEL DATA FROM ERTS COMPUTER TAPES

Using computer programs developed in conjunction with Dr. Lawrence Fisher of the University of Wisconsin-Madison Department of Electrical and Computer Engineering, digital brightness values for 13 lakes in south central Wisconsin were extracted from ERTS computer tapes. The technique involves the use of a Princeton Electronic Products (PEP) interactive graphics terminal to display a representation of the area of interest in band 7. The high contrast between the lake image and the land surrounding it in this band allows for easy and positive identification of the lake to be analyzed. Using an electronic "joy stick," a cursor is positioned on the lake surface and the scene brightness value from 0 to 63 in all four bands at that location is accessed and stored on a high speed disk for further manipulation and analysis. This procedure eliminates measurement errors due to densitometer spot size and positioning and data degradation due to photographic processing. In addition, any lake larger than several pixels (200 feet across each) can be analyzed with a high degree of accuracy. Graphs of scene brightness versus secchi depths for bands 4 and 5 are shown in Figures 4.5.7 and 4.5.8, respectively.

The relationship between scene brightness and secchi

FIGURE 4.5.7 - BAND 4 DIGITAL BRIGHTNESS LEVEL VS. SECCHI DEPTH

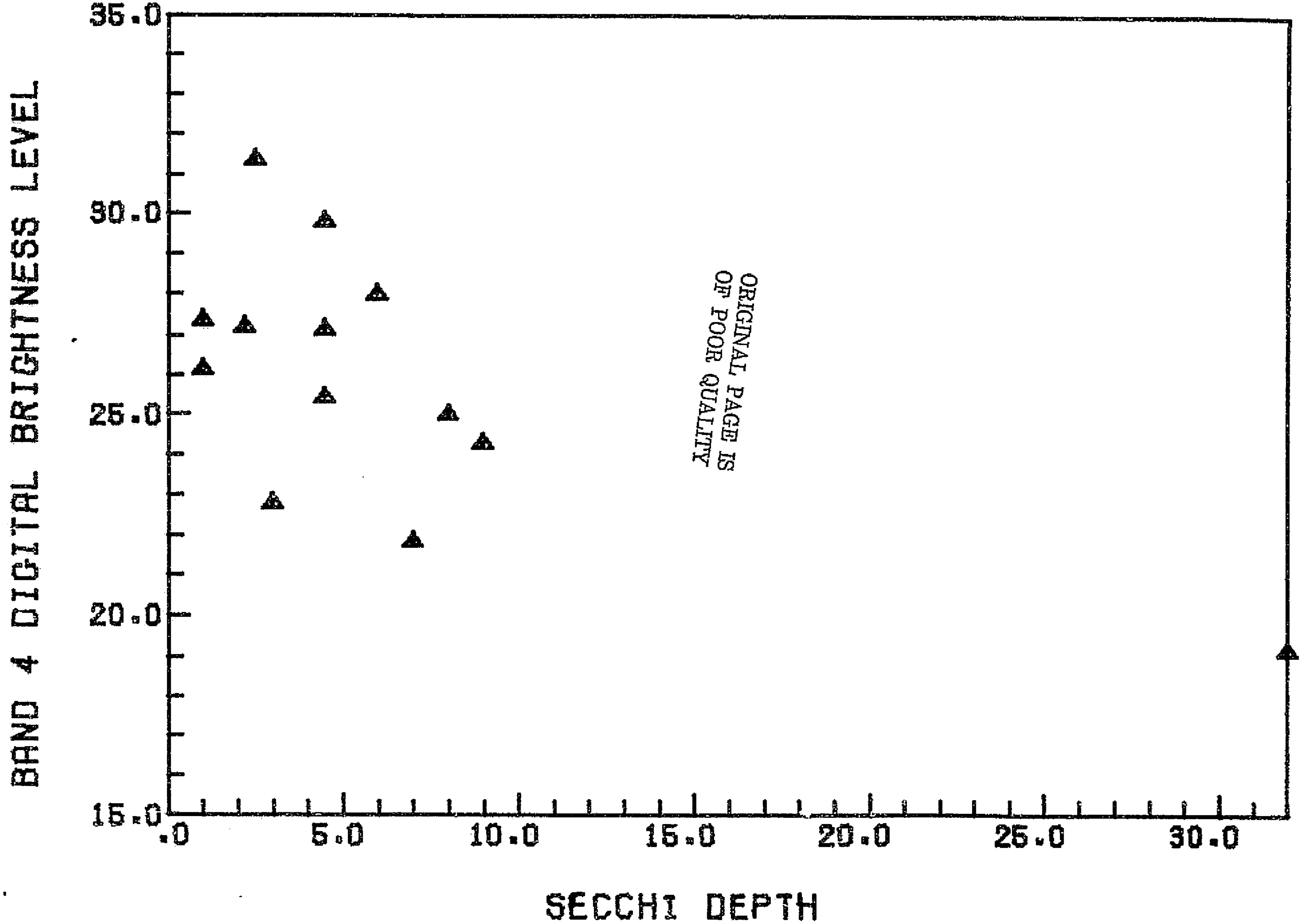
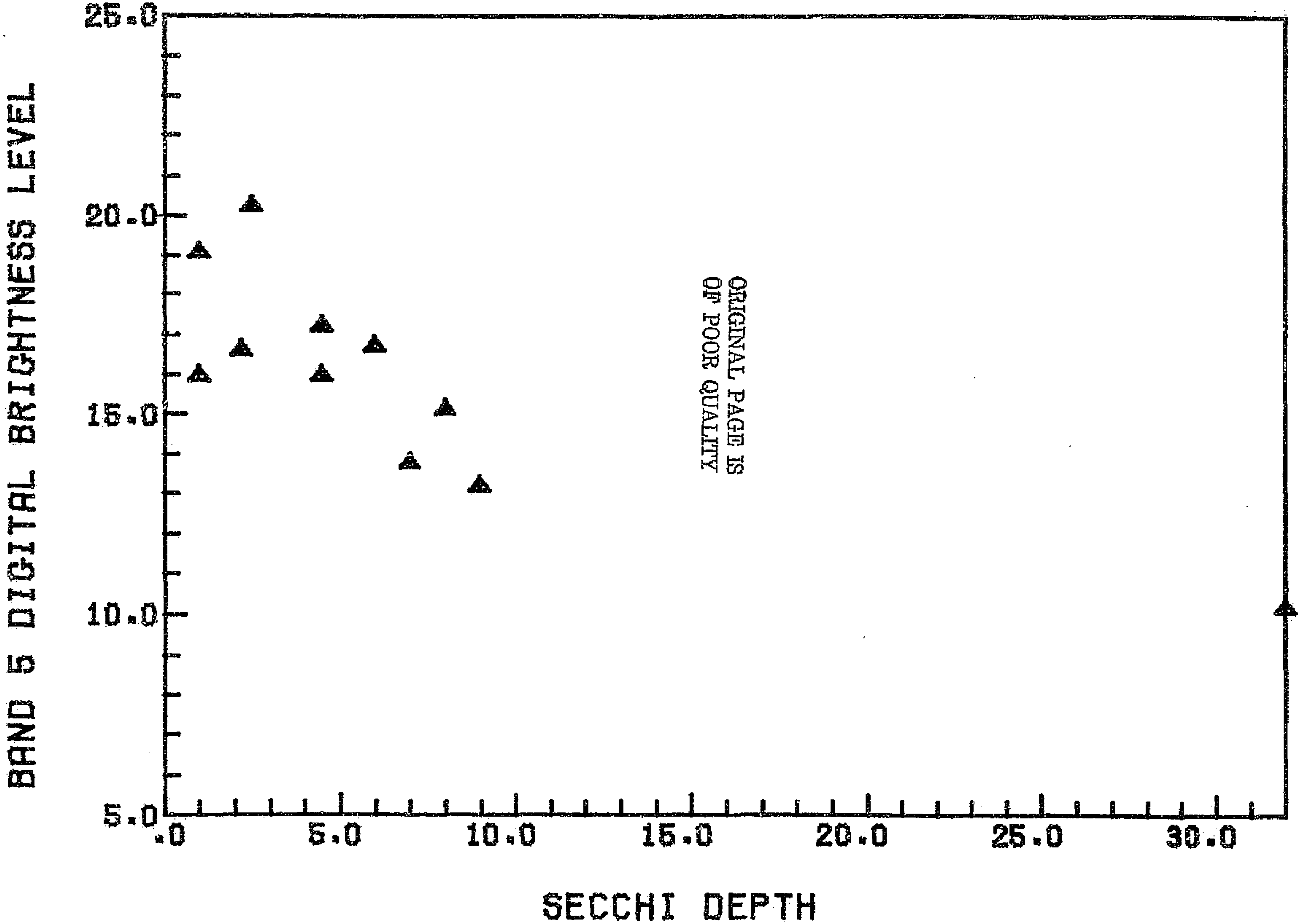


FIGURE 4.5.7 - Band 4 Digital Brightness Level vs. Secchi Depth.

FIGURE 4.5.8 - BAND 5 DIGITAL BRIGHTNESS LEVEL VS. SECCHI DEPTH



ORIGINAL PAGE IS OF POOR QUALITY

F[illegible]URE 4.5.8 - Band 5 Digital Brightness L[illegible] 1 vs. Secchi Depth.

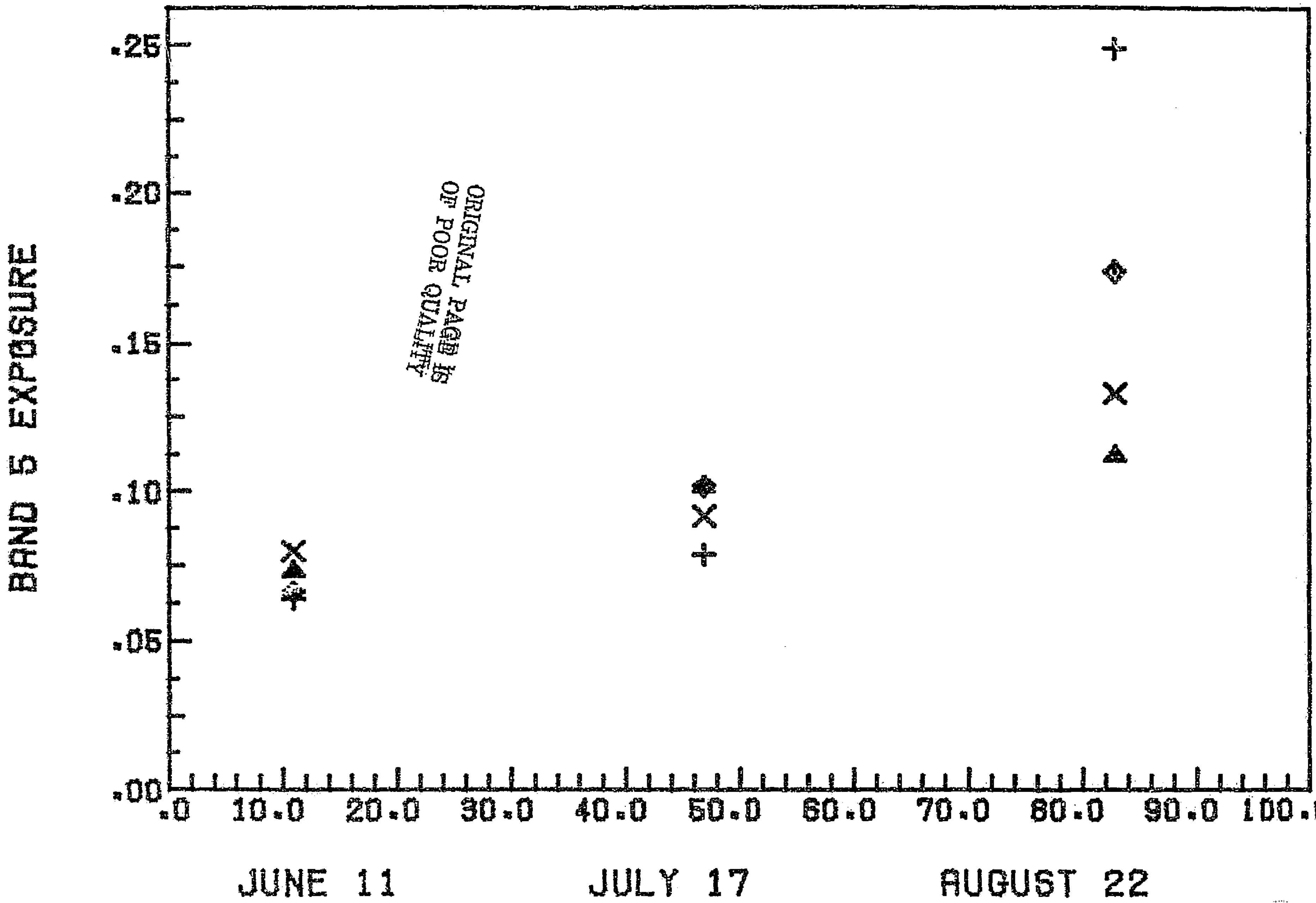
depth as found by this computer analysis are to be compared with Figures 4.5.2 and 4.5.3. The relationship found for band 5 seems to be comparable. The standard deviation is less, but significant scatter occurs. The scatter in the regression suggests that there are either measurement errors or that the conditions in the lakes changed between the time of sampling and ERTS overpass. Measurement errors are almost non-existent when using the PEP terminal. This would suggest that the scatter is due to changing lake conditions.

This past summer secchi depth and other ground truth measures were taken in a number of Wisconsin lakes on the same day as the ERTS overpass. A more reliable relationship between scehe brightness and secchi depth should be available after data from this work has been analyzed. The similarity between densitometric-derived exposures and computer-derived exposures lends confidence to the densitometric measurement of all lakes greater than 100 acres in Wisconsin. When the new exposure versus secchi relationship is derived, secchi depth will be predicted for all lakes greater than 100 acres from the exposure values derived from the measurements on the 70mm imagery.

4.5.4 TIME SERIES ANALYSIS

A time series analysis was performed to evaluate the variability of lake exposure as the algae growing season progresses through the summer. Twenty southeastern Wisconsin lakes were identified on individual frames for the following dates: 9 August 1972, 11 June 1973, 17 July 1973, and 22 August 1972. All of these lakes had known fertility problems, and as would be expected, the exposure in band 5 increased for almost all the lakes as the algal turbidity levels increased as the summer progressed (see Figure 4.5.9). Exposures were consistently significantly higher in August 1972 than in August 1973. This increase in exposure could be attributed to a light atmospheric haze covering the frame.

FIGURE 4.5.9- BAND 5 EXPOSURE TIME SERIES FOR 4 SELECTED LAKES
MENDOTA,WAUBESA,OKAUCHEE,PEWAUKEE



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F'GURE 4.5.9 - Band 5 Exposure Time Series r 4 Selected Lakes -- Mendota, Waubesa, Okauchee, ɪewaukee.

4.5.5 DENSITOMETRY OF WISCONSIN LAKES GREATER THAN 100 ACRES USING ERTS BAND 5 70MM IMAGERY

Based on the preceeding studies, it was decided to densitize ERTS band 5 70mm lake imagery to develop a trophic status ranking of all lakes greater than 100 acres in the State of Wisconsin. This classification is based on the relation between band 5 exposure and turbidity caused mainly by phytoplanktonic algae. Energy detected in band 5 may come from as much as 5 feet below the lake surface, and submerged rooted aquatic macrophytes are probably registered by the satellite's sensors. This study, however, has not directly addressed itself to the relation between lake exposure and the extent of these macrophyte growths.

One hundred acres was selected as the minimum lake size to be densitized based on the need for the micro-densitometer measurement spot to be wholly within the lake. The 50 micron measurement spot used covers an area approximately 550 feet across on a 70mm image. A round 100 acre lake is 2300 feet across, which was felt to be the minimum lake area that could be found and measured with a reasonable degree of accuracy.

Theoretically 17 ERTS images from one 6-day overpass period would provide complete coverage of the State of Wisconsin. However, because of cloud cover and missing imagery, this project used 26 images from four different 6-day overpass periods. The 5-day period from 3 through 7 August 1973 provided the majority of the imagery used.

Densitometer readings for each lake were punched on IBM cards for computer calculation and manipulation. In addition to densitometer readings, IBM cards were also punched with each lake's name and an arbitrary identification number, the lake's latitude and longitude, county location, secchi disc depths when available, maximum water depth, an arbitrary 0,1,2 ranking for atmospheric haze, and an arbitrary 0,1,2 ranking for evaluating cases where the lake shape was such that difficulty was encountered insuring that the measurement spot of the densitometer was wholly within the lake.

Computer programs developed for this project were used to calculate lake exposure, and to rank the 1000 lakes by exposure by county, DNR district, or the State as a whole. In addition, sorting routines will sort the lakes by depth, haze, or size for analysis purposes. The computer printouts presented with this report include: 1) a sort of all lakes by district with the lakes ranked in descending order of exposure; 2) a sort of all lakes by district, with the lakes ranked in order of descending exposure by county within each district; and 3) a sort and ranking by DNR district of all lakes greater than 20 feet in depth, with no haze or clouds obscuring the imagery, and whose size and shape is such that the microdensitometer measurement spot is wholly within the lake.

A rough cost estimate of labor and computing costs for future densitometry of lakes greater than 100 acres in band 5 comes to about $3.00 per lake analyzed. Based on the cost of analyzing the 13 lakes from the ERTS digital tapes, it is hoped that any lake greater than 25 acres can be analyzed in all four ERTS bands for a comparable cost per lake.

4.5.6 CONCLUSIONS

There seems to be a relationship between the exposure value for a lake as measured by ERTS band 5 and secchi disc depth. The exact relationship between exposure and secchi depth is still to some extent in doubt. A better relationship could result from an analysis of the data from last summer.

If a photographic product is to be analyzed, the 70mm positive transparencies are the best approximation to the scene brightness as measured by ERTS. The most reliable data from ERTS can be derived from the ERTS digital tapes. For lakes less than 100 acres, assessment of lake conditions should be made from the digital tapes.

The costs of analysis for lakes in Wisconsin from ERTS are less than $3.00 per lake. Costs for analysis from the digital tapes should be comparable or less than the analysis of the photographic product.

4.6 REGIONAL GEOLOGIC STUDIES[1]

ERTS-1 images of a geologically complex area in northwestern Wisconsin (Figure 4.6.1) were examined to evaluate their potential use as geologic mapping tools. ERTS 9x9 inch transparencies (several dates and several bands) were examined using a light table and magnifying lens. Areas of similar tones and patterns were delineated for each ERTS transparency and the resulting pattern maps (see Figure 4.6.2 for a sample pattern map) were compared with existing soil, glacial geology, bedrock geology, and structural geology maps and the degree of correlation between ERTS-derived pattern maps and existing soil/geologic maps was determined. It is important to note that the pattern analysis was performed without reference to ground truth maps. Patterns were mapped strictly on their spectral similarity without attempting image interpretations.

Table 4.6 summarizes the results of this study. It shows that the best correlations between pattern maps and soil/geologic features occur for soils and glacial geology and the poorest correlations are for bedrock geology and structural geology. This is not unexpected since the entire area is covered by glacial drift of varying thickness.

In addition to pattern mapping, maps were prepared showing linear features. Many previously unmapped linears were delineated. As with the Northeastern Wisconsin area reported in Section 2.2.5, present geologic "ground truth" for this area is inadequate to substantiate the nature of these newly identified linear features.

The use of ERTS imagery for geologic studies in Wisconsin is promising and further studies should be undertaken.

[1]This section is summarized from a term paper titled "Geologic Interpretation of an Area of Northwestern Wisconsin Using ERTS-1 Imagery" by William W. Woessner, Graduate Student, Department of Geology, University of Wisconsin-Madison (prepared for the course CEE-552, Remote Sensing of the Environment, taught by Prof. Ralph W. Kiefer and Dr. Frank L. Scarpace).

Figure 4.6.1 Northwestern Wisconsin Study Area

N

Scale 1:1000000

linear feature

bedrock or glacial positive feature

Figure 4.6.2 Pattern Map of Band 7, June 14, 1973

TABLE 4.6

DEGREE OF CORRELATION BETWEEN PATTERN MAPS DERIVED FROM ERTS IMAGES AND EXISTING SOIL AND GEOLOGIC MAPS

Date	ERTS Band	Degree of Correlation[1] With: Soils Map	Glacial Geology Map	Bedrock Geology Map	Structural Geology Map
8/12/72	4	4	4	4	5
8/12/72	5	3	2	3	5
8/12/72	6	3	2	3	3
8/12/72	7	2	2	3	3
8/12/72	Color 457	2	2	4	4
2/8/73	6	3	3	2	3
6/14/73	7	1	2	3	4

[1] Degree of Correlation

1 - excellent, almost every pattern line matched overlay

2 - good, most pattern lines matched overlay

3 - fair, some pattern lines matched overlay

4 - poor, almost no pattern lines matched overlay

5 - very poor, no lines matched overlay

4.7 INTERAGENCY INVOLVEMENT

In June of 1974 copies of this project's Type III Report for the period June 1972 to April 1974 were sent to all members of the Advisory Committee (see Section 2.3). This report served as background material for a full day Advisory Council meeting held on 9 July 1974 at the University of Wisconsin-Madison campus. This meeting was devoted to an open discussion of the results of this investigation to date and suggestions for future research and applications direction. These discussions were organized around the six major sub-divisions of this project, namely: (1) Comparison of ERTS Derived Data to Conventional Data; (2) Determination of the Usefulness of ERTS Data for Regional Land Use Planning and Allocation Decisions; (3) The Automation of Data Extraction and Manipulation; (4) The Application of ERTS Data to Lake Eutrophication Studies; (5) The Application of ERTS Data to Regional Geological Studies; and (6) Interagency Management Implications. The results of these discussions are included in the appropriate sections of this addendum. Correspondence with members of the Advisory Committee is included in Appendix 4A.

Based upon the early work done under this contract, a cooperative project between the University of Wisconsin-Madison and the State of Wisconsin Department of Natural Resources (DNR) is currently being conducted. This project is funded by the DNR and is directed towards the classification of the lakes in Wisconsin by eutrophic level using ERTS as a data source. This work is reported in detail in 4.5.

Based upon the early work done under this contract, a cooperative project between the University of Wisconsin-Madison and the State of Wisconsin Department of Administration (DOA) is currently being conducted. This project is funded by the DOA and is directed towards the preparation of state-wide land cover maps. This work is reported in detail in 4.1.

4.8 FUTURE WORK - LONG RANGE

Inasmuch as none of the five ERTS Follow-On Proposals submitted to NASA from this group were selected for funding, we anticipate no further work.

4.9 ADDENDUM BIBLIOGRAPHY

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APPENDIX 4A

ADVISORY COMMITTEE CORRESPONDENCE

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JUL 18 1974

Wisconsin Power & Light Company
Investor-owned Energy

222 West Washington Avenue P O Box 192 Madison, Wisconsin 53701 Phone 608/252-3311

July 16, 1974

Mr. James L. Clapp
Director
Environmental Monitoring and
Data Acquisition Group
Institute for Environmental Studies
University of Wisconsin
610 Walnut
Madison, Wisconsin 53706

I found the ERTS Advisory Council meeting very informative and have also reviewed the project report. I would like to share the following thoughts with you regarding the usefulness of ERTS imagery and research being performed by your group.

With regard to the research projects reviewed at the meeting, it is quite apparent that ERTS has been a valuable resource enabling more comprehensive analysis than would otherwise have been attainable. The communication value of ERTS images with respect to the enhancement of man's knowledge of his environment would seem to justify the entire ERTS project in itself. Your group is to be commended in its desire to involve potential users through the Advisory Council. Although user interaction is valuable, it is important that funding agencies recognize that ERTS is currently in the research phase and that its applicability to the needs currently identified by user groups should not be a criteria for the continuance of the project.

In reflecting upon the usefulness of ERTS data with regard to the location of power transmission corridors, some specific suggestions are indicated below:

1. Computer Technology - The use of computer techniques to assist in the location of utility corridors has been established through EDAP and other systems. The comments herein contained assume this computer technology will be applied and further enhanced. It is the interface between ERTS data and the computer technology that is therefore being addressed.

2. Coordination with Traditional Data Sources - In order for ERTS data to be incorporated into computerized models, there would have to be a coordination with traditional data sources; for example, rights of way would have to be identified as to usage levels, functions, widths and agency control. Cultural data would have to be identified, as would land uses. It is understood that certain land uses are identifiable from the imagery per se; however, such categories as "Designated Recreational Areas" must be based on traditional data sources.

3. Applicability to Highly Urbanized Areas - Many of the areas in which utility corridors are located are urban in character and have been extensively covered by traditional data sources. The need for a high degree of spacial resolution is accentuated in these areas. It would therefore appear that ERTS data would have little applicability to corridors selected entirely within relatively urbanized areas.

4. Extent of Data Interpretation - In order for the ERTS data to be valuable in decision models, the level to which data can be interpreted must be more discreet than is indicated in Table 2.1.3. That table indicates that ERTS identified linear systems correlate well with traditional data sources. These linear systems can be identified and stored in computerized models with relative ease using traditional sources. It has been found that the most time-consuming and expensive kinds of data to store in computerized models are those kinds of data that occur over a high percentage of the geographic area in question. Such data categories as Upland Forest, Lowland Forest, Wet 's and other natural data have been the most difficult an` ime-consuming to transfer from traditional sources to computer format. It appears from the correlation analysis made in the study that the raw ERTS data would not provide an answer to this problem. With this concern in mind, the McIDAS system begins to emerge as one of the most significant potential technologies uncovered in the ERTS research project. If the McIDAS system would enable the further identification of data to a more discreet level and subsequently, the storage of the refined data in computer compatible format, the key to the applicability of ERTS to computerized utility corridor location would be provided.

5. Acceptability to Regulatory Agencies - Application of ERTS data to utility corridor selection assumes acceptability of computerized techniques to regulatory agencies. Part of such acceptability would be the underlying data credibility. The use of photographic imagery would probably be inadequate to provide such credibility; therefore, direct interfaces to the computerized data bank are necessary. If the McIDAS system were used, the expertise of interpreters would have to be clearly established.

6. Future Direction of Research - A recurrent concern in both the report and the Advisory Council meeting was that of the spacial resolution capability of ERTS data. If ERTS data is to be used for utility corridor locations, any further spacial resolution is unnecessary. The area of further research should be the enhancement of the capability to identify resources on a discreet level as was indicated above.

I appreciate the opportunity to express my perceptions of the utility industries views regarding the applicability of ERTS research to planning applications.

Sincerely,

John W. Laub
System and Procedures
Supervisor

JWL:lp
020747

cc: Bernard J. Niemann, Jr.
Professor and Chairman
Department of Landscape Architecture
University of Wisconsin
Madison, Wisconsin

cc: Mr. Thomas C. Webb
Mr. William Keepers

SOUTHEASTERN WISCONSIN REGIONAL PLANNING COMMISSION

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July 8, 1974

Mr. James L. Clapp
Director
Environmental Monitoring and
Data Acquisition Group
Institute for Environmental Studies
University of Wisconsin
WARF Building
610 Walnut Street
Madison, Wisconsin 53706

Dear Mr. Clapp:

This is to acknowledge receipt of your letter of June 19, 1974, with which you transmitted a copy of the report entitled "Evaluation of the Application of ERTS-1 Data to the Regional Land Use Planning Process" dated April 23, 1974, and prepared for the National Aeronautics and Space Administration and in which you also invite me, as a member of the ERTS Advisory Council, to a meeting to be held at the WARF Building on July 9, 1974, to assess the highlights of the report and to obtain "...honest reaction to this research and use of ERTS..." We have reviewed the aforementioned report and we do have some questions and comments regarding the conclusions being reached based on the findings of the research as reported.

Preceding any specific comments regarding findings and conclusions spelled out in the report, however, it is worthwhile to provide some background information regarding the work of the Southeastern Wisconsin Regional Planning Commission. We agree wholeheartedly, for example, that high quality mapping and aerial photography is required for the preparation of sound regional plans, which plans must be and are indeed inextricably linked with the natural resource base. Under its legislative charge to prepare a comprehensive plan for the Southeastern Wisconsin Region, the Commission began, in 1961, to prepare the first county base maps for the seven counties in southeastern Wisconsin which were drawn to national map accuracy standards. These county base maps have been compiled at a scale of 1:24000. In addition, the Commission has prepared rectified enlargements of each civil township in southeastern Wisconsin at a scale of 1:24000 from 'high flight' aerial photographs flown by the

Commission in the Spring of 1963 and in the Spring of 1970 and from 'high flight' aerial photographs flown by the Wisconsin Department of Transportation in the Fall of 1967. In addition to the base map program which is annually updated and the 'high flight' aerial photography series which will again be flown in the Spring of 1975 and every five years thereafter, the Commission has prepared ratioed enlargements at a scale of 1:4800 for the entire 2,700 square mile Region from the 'low flight' aerial photographs flown in the Spring of 1963, 1967, and 1970, with each such enlargement encompassing four complete U. S. Public Land Survey Sections. These maps and aerial photographs have been an invaluable tool in the complex planning process utilized in southeastern Wisconsin.

Using the maps and aerial photographs, the Commission began in 1963 the conduct of a number of special resource inventories and investigations including: detailed operations soils studies; woodland inventories including specific woodland use identification and qualitative assessment; wildlife habitat identification delineation and qualitative review; potential outdoor recreation and scenic area identification and evaluation; prime agricultural area identification and delineation; water and wetland identification and delineation; and, conventional urban and rural land use identification delineation and quantification. The information collected by the Commission utilizing the maps and aerial photographs, in addition to being a prime input to the preparation of various regional and subregional plans prepared and adopted to date, has been used by a number of state agencies as well as private industry, private and public utilities, land developers, and individuals in numerous specific studies ranging from highway corridor studies to the location of individual residences. The maps and aerial photographs and the type of data maintained are all essential, we believe, to any regional planning program. It is because of this background of information and experience, we suppose, that the Southeastern Wisconsin Regional Planning Commission staff was initially asked to participate on the ERTS Advisory Council.

As a member of the Advisory Council, we have indicated at two of the meetings of the Council held in Madison, that after reviewing the imagery derived from ERTS-1, along with photographic enlargements prepared from the RB-57 'High Flight' Series that in our opinion the ERTS-1 imagery was essentially useless to Regional Planning and that the RB-57 photography was more useful to regional planning when supplemented with lower flight photography and actual field surveys. We cannot, therefore, agree with the general conclusions reached in your report that ERTS imagery is a valuable tool to regional planning. Perhaps one of the reasons that we disagree in our conclusion is that there appears to be a general difference of opinion as to what regional planning encompasses. Simply stated, regional planning as it is conceived in southeastern Wisconsin is local planning and we believe sincerely that this concept, if reviewed would be found to be universal throughout the State of Wisconsin. Regional planning in the State of Wisconsin is funded by the counties and local units of government who look, and appropriately so, to regional agencies for the technical assistance in local planning matters. Information that can be derived from the ERTS-1 program is much too general and imprecise to use in confronting a city council or village board let alone a judge and jury in a courtroom involved

Mr. James L. Clapp
July 8, 1974
Page 3

in a zoning dispute. In our opinion, the money being spent to project and monitor a space satellite could better be spent, in terms of regional planning, to provide better high flight (RB-57) and low flight aerial photography, including color infrared and conventional color photography.

Following are some comments on your report which will be assessed by the Advisory Council on July 9, 1974:

1. In the comparative evaluation made utilizing the ERTS imagery, RB-57 photographs, and conventional data sources, we question the use of the conventional data if, in fact, as the report indicates, much of the information is 30 or 40 years old. Obviously in viewing forest cover, wetlands, and water areas, these three data sources could not be expected to be compatible with any photographs flown in the last five years. Indication that the RB-57 photography correlates most closely to actual field checks would be the expected result. We would expect for example that the natural resource base information gathered utilizing the Commission's 1970 'low flight' aerial photographs would compare favorably with the 1971 RB-57 photography.

2. The conclusion reached on page 36 of the report regarding the use of RB-57 and ERTS imagery as "feasible and desirable" data sources is not substantiated by the findings reported on the preceding pages as relates to the ERTS imagery.

3. On page 43, it is indicated "...that the best utility of ERTS-1 data is in determining measurements of data not traditionally mapped or those data which can be more economically mapped. It is these variables either insufficiently mapped or totally unmapped, which are not available when needed in the present regional and decision making process." No where can we find an indication of what these variables are or should be or what method has been used to determine the economics of mapping such variables. Economics are indeed a problem and the funding for data collection is indeed limited. Spending money, however, on data collection and retrieval which cannot be used by the traditional user is not at all economical and may indeed be a complete misuse of limited fiscal resources.

4. The comments made in the report on page 66 indicating that "...the planning process must exist at several levels from site specific to regional,..." is an indication as mentioned previously that there is a wide discrepancy in the concept of regional planning. Regional planning is 'site specific' and must be in order to be viable in any kind of changing situation.

5. The first paragraph under the title "Application by Operational Agencies" on page 94 of the report, there is an indication that the Southeastern Wisconsin

Regional Planning Commission is employing data generated from the ERTS and RB-57 series to update information related to vegetational conditions within the Region. The report should be corrected in this regard. No such data is being utilized by the Southeastern Wisconsin Regional Planning Commission. These data are being updated in southeastern Wisconsin utilizing the Commission's 1970 1:4800 scale 'low flight' aerial photographs.

6. In regard to the proposed management structure, we would suggest that the actual users of data to be derived from research programs at the University or operational programs at the state be included in the structure <u>preceding</u> the actual operations or programs and specific studies in order that these users may provide input regarding specific needs.

7. On page 105 of the summary and conclusions section, the statement is made that "The potential strength of ERTS-1 lies in the fact that it has the capabilities to monitor the entire state of Wisconsin, to a certain degree as often as every 18 days." and that "...this fact alone justifies the study of its feasibility as a data source..." The Southeastern Wisconsin Regional Planning Commission updates its information source maps and photographs at a minimum of every five years and while it would be advantageous to have aerial photographic coverage every year, there is some question whether or not the period of time of even one year is large enough to actually monitor changes in the natural resource base, even though the monitoring of urban development at the one year interval would be desirable although expensive. In terms of the resolution of the imagery and utilization of the data received from an ERTS-1 type program, we question the assessment made on page 105 that the ERTS type program is more economical than more conventional aerial photographic methods.

8. Beginning on page 112, specific conclusions and recommendations are spelled out in a total of 23 sentence/paragraphs. Conclusion No. 5 on page 113, indicates that, "ERTS is the only physical resource imaging system now available which can cover state-size areas at frequent intervals". The obvious question here is what kind of information do we in government or at the University want to monitor every 18 days in the State of Wisconsin? Conclusion No. 6, on page 113, indicates that, "Composite ERTS imagery (mosaic) is superior to any other data/information for perceiving and delineating macro landscape units." Depending upon your definition of macro, we must disagree with that statement, if indeed macro is regional and not just statewide. Conclusion No. 7 states that, "Composite ERTS imagery (mosaics) is an effective device for communicating to non-planners the directions and significance of land use impact on state and regional resources." Again we must disagree. As a matter of fact, in speaking to individuals or a group of non-planners, general information such as derived from ERTS may be more harmful to the resolution of problems than having no data at all. Conclusion No. 10 on page 113, states, "ERTS derived data/

information is superior to conventional land use data for those items (a) which change rapidly with time, (b) for which conventional data are not available." We agree wholeheartedly with the statement, however, we reiterate that (a) the problems confronted in regional planning programs are not those which change rapidly in time and (b) the fiscal resources could better be spent on compiling conventional data. In conclusion No. 14 on page 114, it is stated that, "High altitude aircraft (RB-57 photography scale 1:120000) derived data/information is superior to ERTS as a data source in terms of resolution and accuracy of identification." We would agree again wholeheartedly with that statement. Conclusion No. 19 on page 114, states that, "ERTS can provide a focus from which the regional land use planning data/information needs can be defined as specific requirements for detailed information by individuals variables and decision level." That statement could be made about any large coverage mapping or aerial photography program. The problem again is one of resolution and if indeed an overview of a region is needed or required, it is our opinion that high altitude air photography such as RB-57 or the NASA U-2 programs could meet this requirement better and at an appropriate time as relates to a specific study, project, or application.

As has been stated at the previous meetings of the Advisory Council, the Regional Planning Commission staff as users of data derived from aerial photographs and mapping cannot agree that the ERTS-1 program is presently valuable or has any real potential for value in a regional planning program as regional planning is conceived in southeastern Wisconsin due to the fact that such imagery source does not provide the specificity required in truly regional/ local planning programs.

We trust that these comments are helpful to both the University of Wisconsin Institue for Environmental Studies and the National Aeronautics and Space Administration and while they might appear to be negative, we trust that they will be constructive inputs to any future effort by either the IES or NASA in terms of data source studies.

Sincerely,

Harlan E. Clinkenbeard
Assistant Director

HEC/lh

cc: Mr. G. Richard Stonesifer
The 8 Regional Planning Commissions in Wisconsin

IES

INSTITUTE FOR ENVIRONMENTAL STUDIES
Environmental Monitoring and Data Acquisition Group

University of Wisconsin—Madison
WARF Building, 610 Walnut
Madison, Wisconsin 53706
Telephone: 608-263-4789

2 August 1974

Mr. Harlan E. Clinkenbeard
Assistant Director
Southeastern Wisconsin Regional
Planning Commission
916 N. East Avenue
Waukesha, Wisconsin 53186

Dear Mr. Clinkenbeard:

Your letter of 8 July and particularly the time of study and consideration it represents are appreciated. This kind of honest reaction is essential to research which is to apply to community needs. I am responding because, while I believe your comments are extremely important coming from one of the best developed and expertly operated regional planning commissions in the United States, they do not agree with the views of other users nor with the majority of the researchers in some respects.

I understand your viewpoint to be that Regional Planning in Wisconsin is limited to local planning and that research on "Regional Land Use Planning Process" should consider only the needs applicable to local planning. I believe that when you raised this question at our first advisory council meeting it was clear that the researchers and many members of the advisory council did not agree with this limitation of the area of research.

SWERPC has such an enviable history and position that I can see how you feel satisfied with its combined high and low altitude methods of gathering the data it needs. This research, however, is based on the opinion that most levels of government charged with aspects of the regional planning process are not satisfied with the data gathering methods available to them and could not confidently answer the question "How does ERTS data compare with that available from other sources?" It does not appear that SWERPC could have answered that question apriori without research something like what we have conducted with your participation.

The suggestion that I understand you to be setting forth is that the money spent on satellite research would better be spent collecting data by the conventional means used by SWERPC. This would seem to mean that money should be used to operate in a proven manner rather than to search for improved methods. While it may be the objective of SWERPC to operate on proven methods it is the objective of research to question the value of a variety of methods, determine their relative merits, and expand the knowledge of the whole variety of possibilities -- including those that prove not to be useful for a particular purpose as well as those that represent improvements. The funds spent for research seldom are directly comparable with those spent to operate on well known methods. I believe that those who sponsor research are convinced that while many tasks

Mr. Harlan E. Clinkenbeard
2 August 1974
page 2

could be accomplished in the short run if money were spent on operations, in the long run research is invaluable and cannot be sacrificed to short run goals.

I take it from your comments that you believe photo update once a year is too often for detection of changes of interest to SWERPC and that even if ERTS produced data as often as once every 18 days, it could not be economically feasible since it does not produce useful data. It is my belief that the conclusion that less-than-once-a-year coverage is sufficient and that no use could be made of data of the general level of ERTS data is considered premature by our researchers and by some members of the advisory committee. This seems to me to be another case of the general point that while SWERPC is satisfied with its current methods, others are of the opinion that other options must be considered.

You have concluded, as I understand it, that if small scale data is required, U-2 or RB-57 photography would be superior. To the extent that U-2 or RB-57 imagery would be available at a favorable cost, and assuming that for all uses these are shown to be superior to ERTS data, this conclusion might be shared by most of the advisory committee. However, we believe that this conclusion is not wholly supported and that a careful use of both ERTS and RB-57 imagery may better serve some of the users. It is one of our objectives in future research to define more accurately the limitations and strengths of each type of data.

Your comments indicate that it is not correct to state that SWERPC is using RB-57 data. We were lead to this conclusion by the following events. At the second ERTS Advisory Council meeting you inquired concerning the availability of RB-57 coverage of the Southeast Wisconsin area. You were informed that such coverage was available for a portion of the area. On 15 April 1974 Mr. Ed Semrad, who filled out our check-out sheet as an Associate Planner from your office, came to our data center, looked over the available coverage and checked out two samples (MDR-00022 and MDR-00028) to investigate their suitability for update of vegetational conditions within your region. A short time later we were asked to advise your office as to procedures for ordering a complete set of this coverage from EROS to which we responded. The reason given for the order was the above mentioned vegetational update. At the third Advisory Council meeting (after the report was written) you told several of our staff that indeed the coverage had been ordered but because of scratched imagery it could not be used. If this is the correct sequence of events I will see to it that this is reflected in our final report submitted to NASA in October.

Your opinion that the user community should be an integral part of the planning for research is shared by other users and the researchers. I believe we made significant progress in this direction in the preparation of our ERTS follow-on proposals in which four agencies and organizations in addition to the University were involved in the development of the proposal. The needs and interests of these agencies were exposed through the mechanism of the ERTS-1 Advisory Committee.

With regards to your question concerning the specific identification of insufficiently mapped or totally unmapped land use variables, I am only able to

Mr. Harlan E. Clinkenbeard
2 August 1974
page 3

say that an inventory of the status of land resources data for the state was beyond the scope of this project. We are basing this conclusion upon the reports of the Governor's Land Resources Committee, the University's Faculty Land Use Seminars and, more recently, the Critical Resources Information Program of the Wisconsin Department of Administration. I believe that a state-wide inventory to document this point is necessary and desirable.

In conclusion I wish to thank you sincerely for your taking the time to share your thoughts with us. I would be glad to discuss any of these points further at your convenience.

Sincerely,

James L. Clapp

James L. Clapp, Director
Environmental Monitoring and
Data Acquisition Group

JLC/rs
cc: Mr. G. Richard Stonesifer
The 8 Regional Planning Commissions in Wisconsin.

cc · Kiefer
Kuhlmey
Kuhl
Wiersma Jerrell
277

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September 3, 1974

Dr. James L. Clapp
Director
Environmental Monitoring and
Data Acquisition Group
Institute for Environmental Studies
University of Wisconsin
WARF Building
610 Walnut Street
Madison, Wisconsin 53706

Dear Dr. Clapp:

This is to acknowledge receipt of your letter of August 2, 1974, in which you responded to our letter of July 8, 1974, incorporating our comments and suggestions on the report entitled "Evaluation of the Application of ERTS-1 Data to the Regional Land Use Planning Process."

There are two or three points which you made in your letter of August 2 which should be clarified. The first of these relates to your interpretation of our remarks on the second page of our July 8 letter relating to the definition of regional planning. Our comment was that "...regional planning as it is conceived in southeastern Wisconsin is local planning..." We did not say, as you indicated, that we believe regional planning is limited to local planning nor that research on regional land use planning should consider only the needs applicable to local planning. The point here is that regional planning in Wisconsin is specifically defined in the Statutes and, consequently, regional planning commissions in the state must carry on their planning activities within specifically established physical boundaries and cannot arbitrarily change geographic jurisdiction for either the purpose of research or for the purpose of planning. The term 'regional' cannot, therefore, be interpreted or should it be defined as encompassing an area unique to each specific planning project or program. Moreover, because regional planning commissions are advisory under state law, they have no legal authority or power to implement the plans prepared. Implementation must rely certainly on state and federal agencies having authority to provide funds or to actually design and construct works of improvement, but also, and, most importantly, implementation of regional plans lies extensively within the province of the local units of government in the Region, and, therefore, the level of detail in regional planning must be able to be interpeted at the local level--thus, my comment that regional planning is really local planning. This does not mean, certainly, that regional planning should be limited to local planning nor does it mean that all research should be locally oriented. To be more specific, the need and desirability of producing very generalized maps of large land areas such as a statewide or multi-state area of the country such as derived from ERTS-1 imagery is, in our opinion, non-existent in terms of the practical usability of such mapping at the local level. Certainly such mapping is 'nice to have' and, perhaps, is valuable in specific broad area research or monitoring operations.

Our comments should not be interpreted as 'anti-research'. The Southeastern Wisconsin Regional Planning Commission has indeed been involved over the past 13 years in a great deal of planning related research of which a part has been incorporated into specific operations of the Commission and other planning agencies as well as into research programs of universities and governmental agencies throughout the United States and countries in Asia and Europe. The comments and suggestions set forth in our letter of July 8, were directed specifically at the findings and conclusions set forth in the aforementioned ERTS-1 document.

Your comment that 'the comparison of ERTS data with other source information for planning purposes could not have been made without the satellite mapping' is not necessarily a valid statement as it relates to regional planning as defined and established in Wisconsin. Given the specifications of the imagery expected to be provided via ERTS-1, we are confident that a determination could have been made that such imagery would not be of either the resolution or preciseness required in preparing a comprehensive physical plan for a sub-region of the state, which is the legislative charge of regional agencies as set forth in the Wisconsin Statutes. There is no question that such research may be <u>helpful</u> in such planning activities or useful to other types of planning, monitoring, and analyses. The specific point here is that in our opinion, and forgetting both the technical and climatic problems, the ERTS-1 imagery is not of significant value to a regional planning program to warrant the expenditure. In view of the fact that better source information and data can be acquired for such purposes by more conventional means, based on more specific specifications, and within specific time constraints, we would suggest again as we did in our letter of July 8 that the money might better be spent on either producing or finding better ways to produce and provide more conventional photography to regional planning agencies with very limited budgets.

In regard to the comment made in your report that our Commission is utilizing RB-57 data, we would request that that statement be deleted from the text. The RB-57 infra-red photography of southeastern Wisconsin obtained by the staff was used in fact as a part of our own research in an attempt to determin if indeed this high flight aerial photo series would be valuable in helping to better define vegetitative cover. That research has not yet been completed although the RB-57 infra-red coverage might, at some future date, be utilized in conjunction with the Commission's own high flight aerial photographs to assist in natural resource inventories. As already stated on several occasions, the RB-57 photographs may provide a suitable substitute for the Commission's own high flights if such photography can be produced based on very specific specifications relating to resolution, and time of photography, and other general quality improvements. Continued research in these areas may indeed be feasible if such research would result in ways and means of providing high quality, low cost conventional aerial photography for use by such agencies as regional planning commissions.

We hope that these comments serve to clarify the statements in our letter of July 8. We appreciate the opportunity to comment on this research program as it relates to regional planning in Wisconsin and we would also welcome the opportunity to meet with you on this matter to discuss either our comments or the ERTS research program more specifically.

Sincerely,

Harlan E. Clinkenbeard
Assistant Director

HEC/lh

cc: Mr. G. Richard Stonesifer, NASA
The 8 Regional Planning Commission Directors in Wisconsin

APPENDIX 4B

THE APPLICATION OF McIDAS TO REMOTE SENSING NEEDS

c - 4

Final Progress Report to the
NATIONAL SCIENCE FOUNDATION
RESEARCH APPLIED TO NATIONAL NEEDS
(RANN Division)

From
ENVIRONMENTAL MONITORING AND DATA ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES

THE APPLICATION OF McIDAS TO REMOTE SENSING NEEDS
(Phase I)

Prepared by William W. Kuhlow

Principal Investigator: Lawrence T. Fisher
Assistant Professor
Department of Electrical Engineering
University of Wisconsin
Madison, Wisconsin 53706

Co-Investigator: William W. Kuhlow
Project Associate
Institute for Environmental Studies
University of Wisconsin
Madison, Wisconsin 53706

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1.0 INTRODUCTION

There exists an increasing demand to monitor our physical environment and to acquire specific quantitative knowledge about it in such resource areas as land use patterns, air quality, water-wetland quality, soils, surface-subsurface hydrology, and vegetation. To satisfy such demands in a practical and efficient manner, various remote sensing methods have evolved over the past decades. The nature of both the environmental studies and the remote sensing data gathering systems (aircraft and satellites) result in enormous amounts of acquired data. It is evident to anyone who has worked in this area that the conventional means and techniques employed to extract desired information in a reasonable amount of time are disappointingly inadequate. Furthermore, the rate of such data collection is increasing and all present indications are that it will continue to increase for some time to come.

Conventional techniques based on light table analysis of photographs are slow and tedious. Such operations as photograph alignment, while critical, are time-consuming and make inefficient use of investigators; photograph-based measurements and other hand-constructed efforts are slow, repetitious, and monotonous. In many cases computers are used to do these time-consuming tasks, particularly where much of the data is originally acquired in a manner which is directly compatible with a digital computer (magnetic data tapes); however, conventional computer output, such as line-printer material, are impossibly bulky, awkward and are ill-suited to most remote sensing applications. In addition, raw data is seldom analyzed in a single computer operation and the final information extracted, but the data analysis chain must purposely be broken by human intervention in order to select relevant portions of the data and make judgement decisions. Interpreting the line-printer or plotted output, rewriting and updating the old programs and engaging in the logistics of moving them back and forth between users and machines resulting in the "breaks" typically lasting days and sometimes weeks.

A system called McIDAS (Man-Computer Interactive Data Access System) is being developed at the University of Wisconsin's Space Science and Engineering Center (SSEC) which offers great promise as a useful tool to gain efficient access to large quantities of digital data in addressing itself to the problems discussed above. It reduces the interruptions in the data chain from days to minutes and seconds quickly doing the tedious, time-consuming manipulations associated with the analysis of such data while at all times retaining the data in picture form which is the most convenient format for human perception and judgement. Supported primarily for obtaining wind measurements using satellite observed cloud motion, McIDAS has the potential to be useful in many other areas.

The purpose of this study was to investigate the application of McIDAS to efficient resource data extraction, manipulation, and analysis, and to determine the necessary hardware and software requirements to be fulfilled in accommodating potential users interested in obtaining resource information.

2.0 PROJECT OBJECTIVES

To meet the objective of assessing the needs of potential users involved in extracting information from resource-type data, it was originally proposed to utilize existing digital data which were currently being studied by others with more than a passing interest in efficient resource data analysis. A logical choice of such data was the ERTS-1 magnetic tapes associated with the photographic imagery currently under investigation by another group in the Environmental Monitoring and Data Acquisition Group (EMDAG) who had been awarded a grant to evaluate the application of ERTS-1 data to the regional land use planning process (NAS5-21754). In addition to the ERTS data there was available RB-57* false color photographs of the same areas under study utilizing the ERTS data. A portion of this imagery was digitized and also investigated (see next section).

Once the digital information was available, it was proposed to get it into the proper format for display and study on the McIDAS prototype (for a brief description of the prototype, see Appendix A). Having acquired familiarity with the data, system and users needs, a reasonable assessment of where to go from there could be made in developing McIDAS.

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*RB-57 imagery is color and color-infrared aerial photography. The altitude is usually 60,000 feet and the scales are 1:60,000 and 1:120,000.

3.0 METHODOLOGY

INITIAL STUDIES

In the initial phase of the study, four sets of ERTS computer compatible tapes were obtained corresponding to three different dates in eastern Wisconsin. The tapes were reformatted for use on the McIDAS prototype system (see Appendix A) and the Muirhead PhotoFax Receiver, a system for making photographic images from digital data tapes (see Appendix B). The reformatting was done so that the raw ERTS data "looked"like the ATS-III satellite data for which all existing routines were written. Having accomplished this task, the ERTS imagery was examined using blowup routines, black and white contrast stretching routines and flickering techniques in which images of the same area (Sheboygan Marsh in eastern Wisconsin) taken at different times were registered to within a pixel and then "flickered" back and forth to observe any changes which might have occurred. The flickering experiment greatly demonstrated the need for developing routines in which the effects of the satellite detectors on the imagery has to be removed or normalized to make temporal comparisons meaningful, i.e. one must be extremely cautious in attributing any brightness changes observed temporally to "real" changes in the scene without first having thoroughly considered the effects due not only to the satellite detectors changing with time but also changes in sun-scene-detector angle and atmospheric effects. The detector effect observed in this study was the "modulo 6 banding" which was very pronounced for one date but almost non-existent for the other.

In addition to the WINDCO studies, programs were developed using a UNIVAC 1108 to gain further familiarity with the ERTS data since it was at that time quite obvious that it would be the primary data source and, in fact, the most popular one from the users' point of view. The programs developed were those in which data from portions of the ERTS magnetic tape were extracted and histograms plotted for a selected data field, brightness values printed and/or plotted for a series of selected lines and multispectral channels, and contour lines of brightness plotted retaining the geometric configuration of the data. The latter routine was useful for outlining lakes which, in the two IR ERTS channels (MSS 6 and 7), are usually always darker than the surrounding land features.

CONCLUSIONS OF INITIAL STUDY

As the various results discussed above were achieved, they were communicated to the potential users either on a private basis or via seminars and lectures. (The potential users were primarily at that time graduate students and faculty in the areas of Civil and Environmental Engineering and Landscape Architecture.) From the resulting feedback it was apparent that there was one outstanding requirement that the upcoming McIDAS system should address itself to. That requirement was how well could the system classify data. The classification of data is meant here to mean that given an image - in this case displayed on the face of a colored CRT - some operation is performed on the imagery such that a selected feature is made distinct from the rest of the imagery both visually and in a mathematical sense, i.e. that feature is "classified" into some meaningful category. An example of classification was alluded to above in the discussion of the contouring routing in which lakes were separated from their surrounding features on the basis of their low brightness values in the ERTS infrared channels.

A secondary requirement was that once classification was effected that some geometrical operation be performed on the classified data. The operation was either that of computing the land area of the classified data or referencing (navigating) it to some earth-based coordinate system, such as the Universal Transverse Mercator (UTM) system.

Since navigation was well within the capabilities of the system (all the geosynchronous satellite data used on the system are navigated) and since navigation appeared and still appears to be a secondary consideration, it was decided to investigate the classification capabilities of McIDAS, which are discussed later in the report.

FURTHER DEVELOPMENTS

As the McIDAS system was being assembled and its prototype disassembled, investigations proceeded on several fronts. A fair amount of effort went into searching for existing routines which might easily be adapted to the McIDAS system. One area of software support considered was the "LARSYS User's Manual" developed by the Laboratory for Application of Remote Sensing (LARS) of Purdue. The LARSYS package consists of processing functions for operating on multispectral and/or multitemporal image data in digital form and is formatted for use on remote terminals connected to the LARS IBM 360/67 computer. However, after several informal inquiries, it was learned that the manual was intended for those users who subscribed to the LARS remote terminal. A second software system examined was the Algorithm Simulation Test and Evaluation Program (ASTEP)(Detchmendy et al., 1973), an interactive program designed to manipulate and process multispectral scanner data (including ERTS) which was assembled by the Mission Planning and Analysis Division of the Johnson Spacecraft Center. Although designed to operate on a UNIVAC 1110 computer (the University of Wisconsin has a UNIVAC 1110), a fair amount of time was spent in editing changes to make the ASTEP routine conform to the UW UNIVAC 1110 input/output format in order that the various ASTEP subroutines could be utilized to experiment with the ERTS data on that computer. Even then, not all of the routines worked satisfactorily and, since the ASTEP documentation was not thorough enough, it was decided that further efforts towards improvement were not merited. Although small portions of ASTEP were later incorporated into some of the McIDAS routines, a fair amount of time could have been saved if the routines had initially been written from scratch, a practice which is now evident in retrospect.

While the above mentioned routines were being examined, simultaneously as McIDAS was being assembled the basis systems software was being developed to receive the ERTS data. This included developing an internal computer directory code and classification scheme for all data to be used in this project.

Throughout the course of this project, the SSEC-McIDAS developmental and user's meetings were attended. The attendance had a twofold function: to make the SSEC McIDAS engineers and systems programmers aware of the needs of the potential users outside of meteorology in order, when practical, to influence system development favorable to them; and to gain awareness of the present and projected capabilities of the system in order that meaningful plans could be made.

The second part of the project consisted of developing and experimenting with routines on McIDAS which were felt to have the greatest value in demonstrating to the potential users the capabilities of the system. A discussion of these routines follows this section.

4.0 SIGNIFICANT HARDWARE AND SOFTWARE FEATURES OF McIDAS

Major components of McIDAS (see Appendix C for schematic) include a high quality color television monitor (see Figure 1), a medium size (1 microsecond cycle time) Datacraft 6024/5 computer, a tape drive, cursor-control joystick and electronics, a keyboard/console for operator communication, CRT, card reader, and line printer. Four-hundred-fifty megabits of disk storage are provided for the operating system, program libraries, and 16 video frames of digital data. Also included is an AMPEX video disk for storage, in analog form, of 250 video frames. Video information is not displayed directly on the monitor but is converted back into 6-bit digital form by high speed analog-to-digital (A/D) converters. (A single A/D converter is in use at this time, a second will be installed soon, and a third is planned.) The high speed stream of digital information is applied to small "look-up table" memories whose outputs are reconverted to video form to supply drive signals to the monitor. This arrangement allows nearly instantaneous alteration of enhancements, chromaticity, and hue merely by changing contents of the look-up tables which is accomplished via the keyboard or the joystick. Changing the contents of the look-up tables using the joystick has been found to be an extremely useful feature of the system and is the basis of several successful techniques. From the user's point of view one of these techniques works as follows: the bottom of the TV screen is considered as representing the range of input gray scale values (0-63) with increasing brightness going to the right; the left side of the screen represents a continuum of hues from top to bottom and the position of the cursor on the screen indicates the input value-hue pair. Starting with a black and white image on the face of the monitor and the cursor located to the left of the screen, the entire image is transformed to a color image in a matter of seconds simply by moving the cursor via the joystick across the face of the screen in any manner desired by the user to transform any of the gray values of the image to any hue.

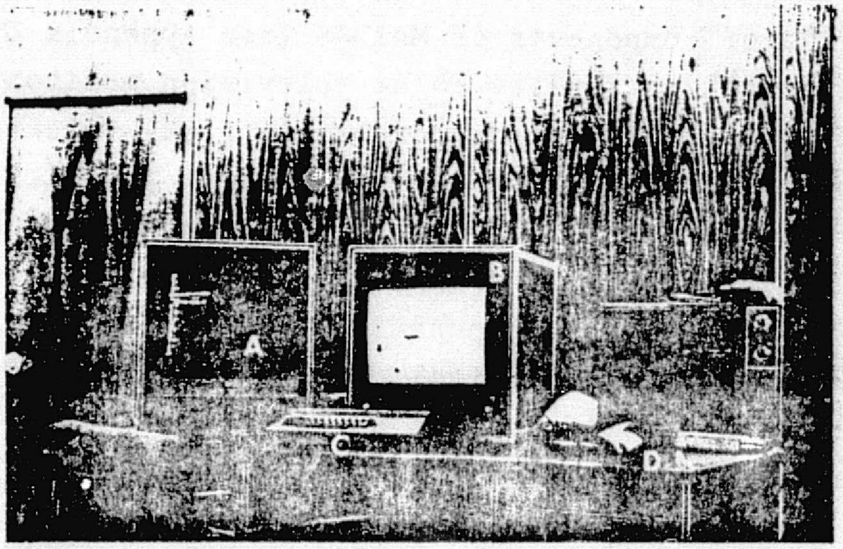

FIGURE 1A - McIDAS CONSOLE

FIGURE 1B - SHEBOYGAN MARSH

Figures 1A and 1B show the McIDAS console and a separate shot of the Sheboygan Marsh, displayed on the color monitor, in Figure 1A. A - CRT display for input/output messages; B - Color TV monitor; C - keyboard; D - joystick. A further description of Figure 1B appears in the text and following figures.

(This transformation is sometimes referred to as density slicing.) Since any input gray scale value can be assigned to a slightly different hue, the texture of the imagery is retained, a distinct advantage over conventional density slicing techniques where for practical reasons, usually large ranges of input values are assigned primary or near-primary colors thus obscuring some of the information in the imagery. In like manner, black and white enhancements, contrast stretching and a variety of other transformations can be effected by this joystick-cursor-look-up table approach, a characteristic of the system which truly is an interactive feature.* Any enhancement can, if desired, be saved in the system's directory and recalled at a later time by a simple key-in command. In addition, a succession of images, each with their own unique enhancements, can be repeatedly displayed in a "loop" where the recycle time of the loop can be controlled by the horizontal position of the cursor. The looping capability is of course most useful for observing changes in a sequence of nearly identical images such as provided by the meteorological satellites.

The programs discussed thus far such as density slicing allow for single spectral channel data classification. A simple example of this is demonstrated in Figure 2 where the open bodies of water (Sheboygan Lake and Elkhart Lake) and a form of vegetation (swamp conifers, primarily Tamaracks) were color enhanced for two types of imagery, ERTS and RB-57. The latter was digitized from a color infrared transparency using three color filters. (This area displayed here in Figure 2 and subsequent figures lies within one of the test sites chosen for the University of Wisconsin's ERTS-1 project (Kiefer et al., 1973; Clapp et al., 1972).) Classification for these two features in this case was amendable to a simple density slicing technique since these features were really inherently separated in the individual images and simply needed some enhancement to "bring them out." However, many

*All these transformations can be performed faster than the user can perceive the results.

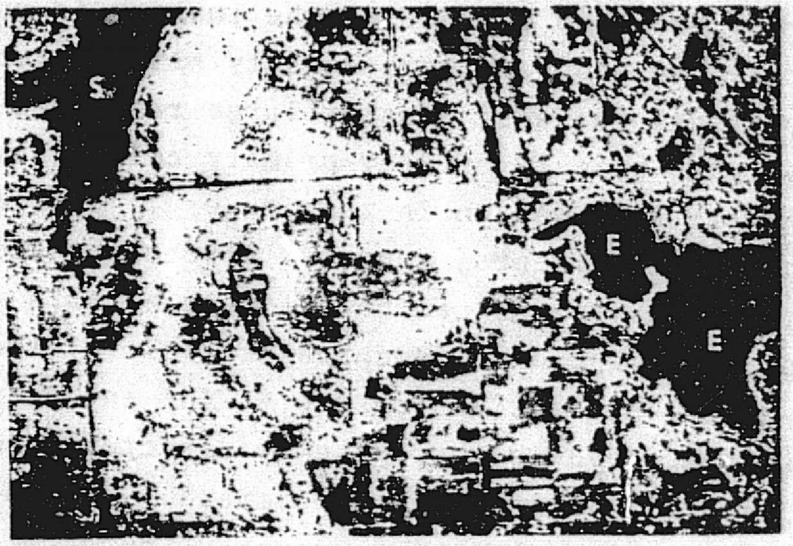

FIGURE 2A - SHEBOYGAN MARSH - RB-57

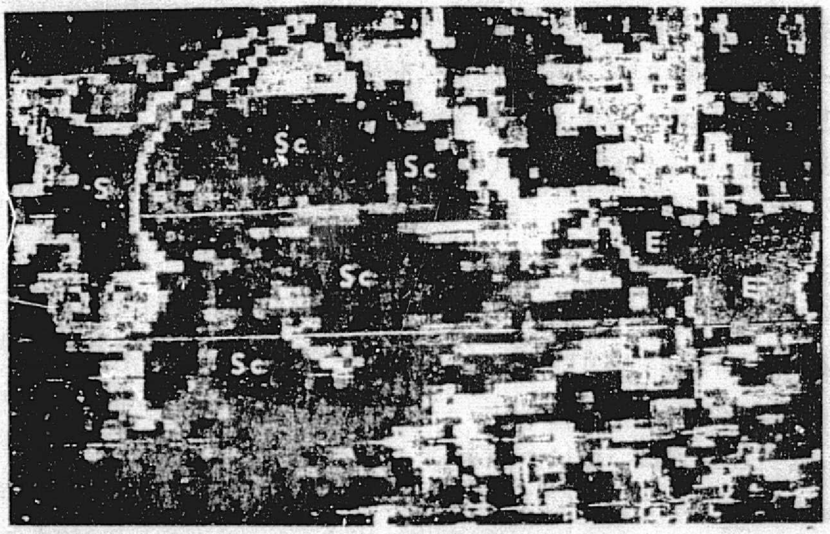

FIGURE 2A - SHEBOYGAN MARSH - ERTS

RB-57 enhanced red channel from imagery collected on 4 June 1972. ERTS enhanced IR channel (0.7 to 0.8 micron) from imagery collected 9 August 1972 (skew in ERTS data not removed). S - Sheboygan Lake; E - Elkhart Lake; Sc - swamp conifers.

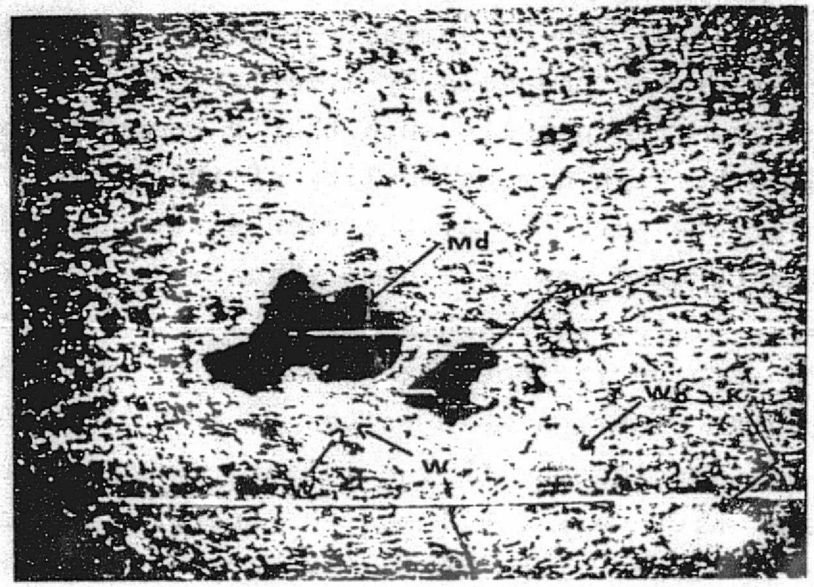

FIGURE 3A - MADISON AND ENVIRONS - MSS-5

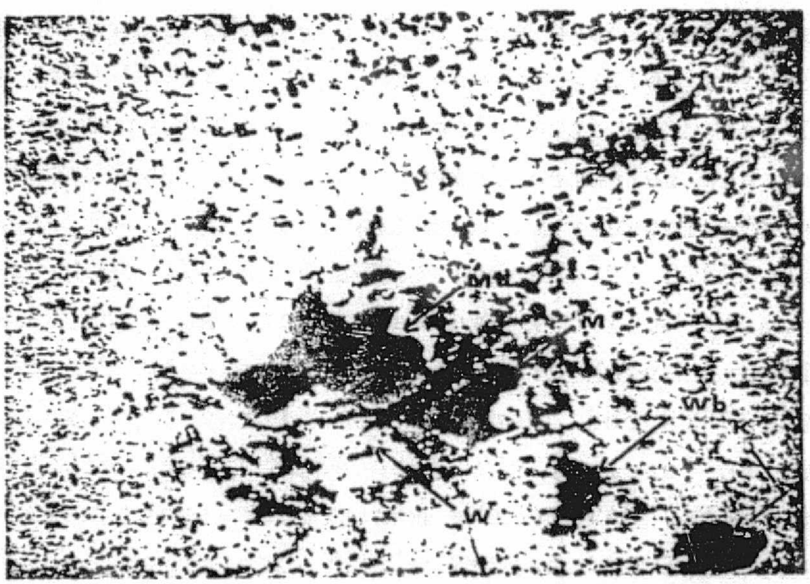

FIGURE 3B - MADISON AND ENVIRONS - MSS-5 & 7

Madison and Environs - 15 Sept. 1972. Figure 3A is enhanced red channel of ERTS in which man-made structures (roads and buildings) show up clearly but open water (Lakes Wingra, Kegonsa and Waubesa) does not. Figure 3B shows results of PATREC (see text) in which ERTS bands MSS-5 and 7 are combined to delineate both man-made structures and open water. Lakes are as follows: Md - Mendota; M - Monona; W - Wingra; Wb - Waubesa; K - Kegonsa.

At present only rectangular training sets can be selected but with a trivial modification of a program called RSTICS to CURGRAM any area on the imagery can be traced out using the cursor-joystick. Figure 4A demonstrates RSTICS where the enhanced Tamarack areas were traced out and numbered. Another feature of RSTICS is that it automatically calculates the areas enclosed and displays the results on a CRT.

The multidimensional scheme in which efforts were concentrated during the last months of the duration of this study was MAXLIK, a maximum likelihood routine based on multivariate normal distributions with thresholding. The threshold value and the channels to be included in the spectral signatures were entered into the McIDAS system with the keyboard, the training areas selected with the cursor, and the classification of the image based on the training sets was carried out on a pixel-by-pixel basis. Figures 4B and 5 demonstrate MAXLIK. Here two training sets were chosen, one centered in Lake Mendota, the other in Lake Kegonsa with the results that the large bodies of open water in the scene were classified into two classes, one for each training set. Any pixel or picture element not falling into either of these two classes was made black. The result of the classification using channels MSS 5 and 7 appears in Figure 5B. Figures 4B and 5A show the best efforts using a density slicing technique on the separate channels MSS 5 and 7, respectively to separate out the lakes into these two classes. From the colored images it is far more obvious that the density slicing on the separate channels alone is inadequate to bring about the same classification using MAXLIK.

The classification scheme MAXLIK presently takes a prohibitively long time (9 minutes for the above classification) because the Datacraft computer does not have floating point hardware. At the termination of this project work was under way to use a table look-up approach for MAXLIK as suggested by Eppler (1974). This program was tested on a set of ERTS data which took less than 1/20 of the time than the LARSYS

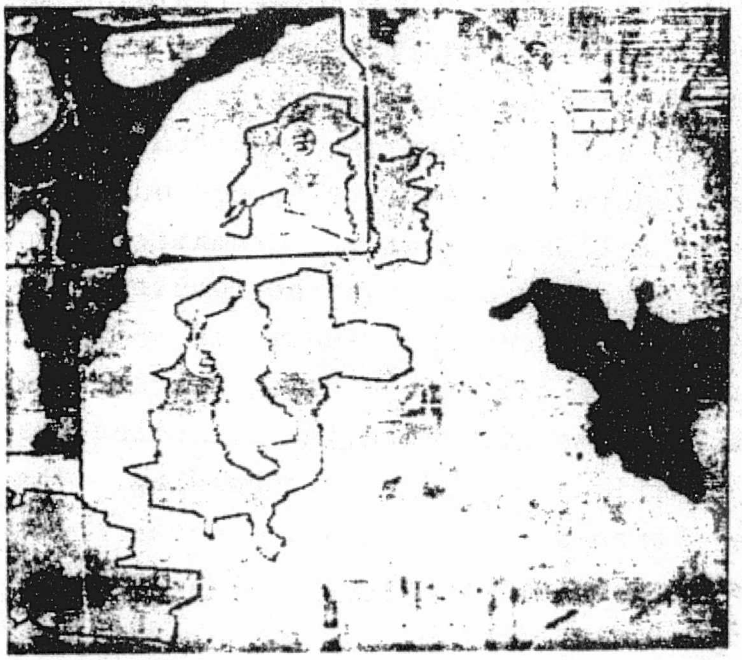

FIGURE 4A - SHEBOYGAN MARSH - AREA STATISTICS

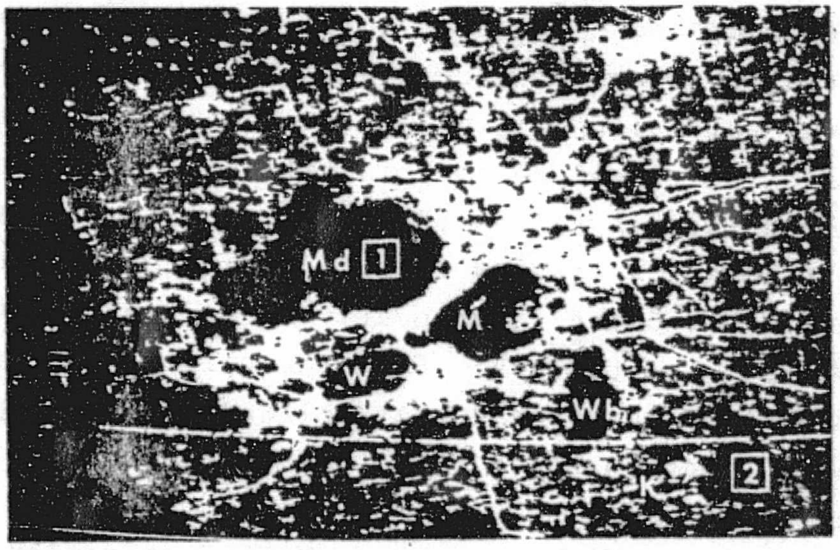

FIGURE 4B - MADISON - MSS-5

RSTICS, a routine to calculate enclosed areas (see text), is demonstrated in Figure 4A for RB-57 imagery. The boundaries - B and area numbers (enclosed by circles) are computer generated after tracing the enclosed areas and superimposed on the image. Calculated areas are displayed on the CRT (not shown). Figure 4B represents the best red ERTS channel (MSS-5) color-enhancement attempt to separate Lakes Mendota (Md) and Monona (M) into one class and Lakes Wingra (W), Waubesa (Wb) and Kegonsa (K) into a second brightness class. The squares show the subsequent "training sets" used in MAXLIK to effect the separation (see text and Figures 5A and 5B).

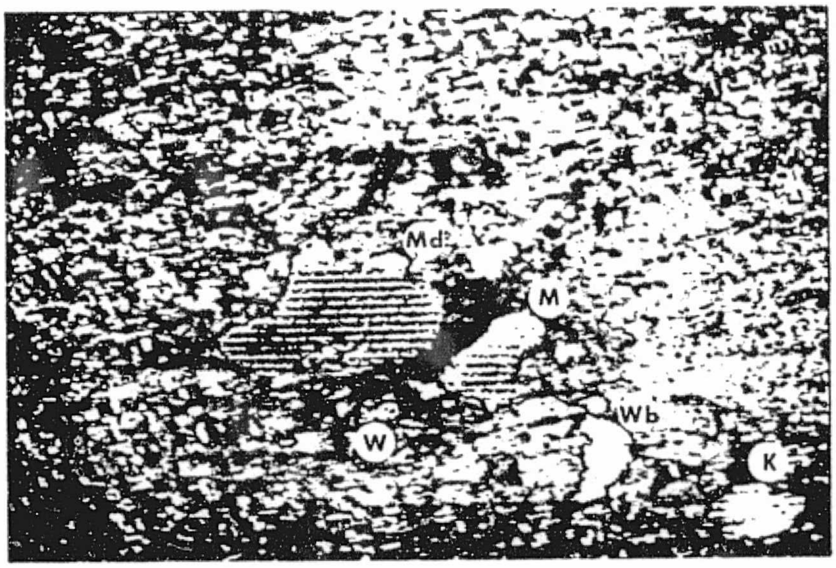

FIGURE 5A - MADISON - MSS-7

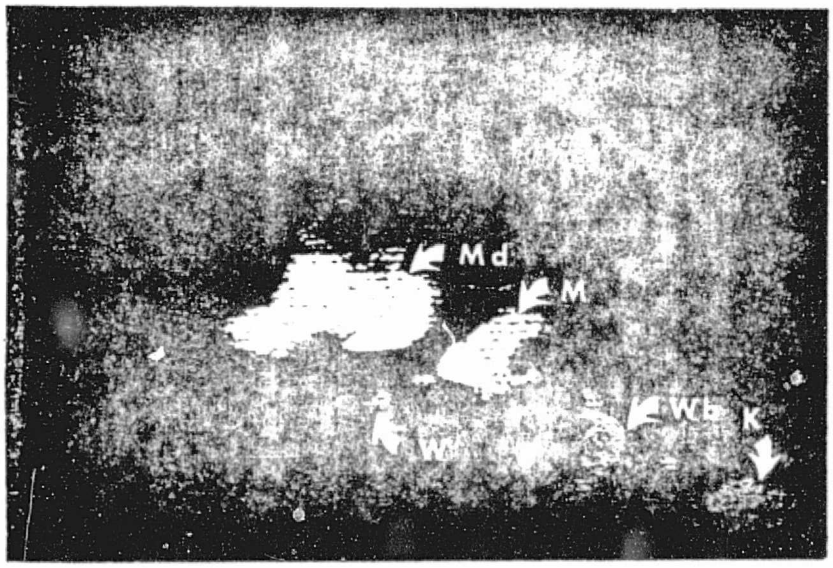

FIGURE 5B - MADISON LAKES SEPARATED INTO TWO CLASSES

Figure 5A represents the best IR ERTS channel (MSS-7) color-enhancement attempt to separate Lakes Mendota (Md) and Monona (M) into Class 1 and Lakes Wingra (W), Waubesa (Wb) and Kegonsa (K) into Class 2. Figure 5B shows the result of the maximum likelihood routine MAXLIK in effecting the separation into the two classes (the threshold class is black) where the training set locations are shown in Figure 4B. Class 2 lakes tend to be shallower lakes.

program of Purdue took on the same computer with identical classification results. It is felt that this approach would make MAXLIK a successful interactive routine on McIDAS for a small number of classes and channels.

5.0 USER APPLICATIONS

The outstanding effect that the NSF/RANN support for this work had was to bring an awareness to a large number of potential users, who are presently engaged in resource data extraction efforts, of an innovative and unique system which has the capabilities or will have the capabilities to offer them a great deal of assistance in helping them to extract information from data in a far more efficient manner. Without the support of this grant there would have been no seminars, lectures, papers delivered and demonstrations given on the capabilities of the McIDAS system to extract resource information from multispectral data such as ERTS and the digitized RB-57 data. Nor would there presently exist in the McIDAS system the basic routines to analyze multispectral data upon which more sophisticated routines may be developed. In short, this support made it possible to lay the foundation upon which further work for potential users can be based. Potential users outside of SSEC who are seriously considering using McIDAS for future work are discussed below.

LAND USE

The State of Wisconsin has embarked on a Critical Resources Information Program (CRIP) aimed at defining, establishing the units of measure, inventorying, and monitoring natural and cultural resource elements which are of statewide or regional significance. The CRIP project has been using both RB-57 and ERTS data to inventory significant natural resources. Presently the CRIP program is a pilot study. Should it blossom into a full-scale project where the entire state will be inventoried and monitored, the capabilities of McIDAS to classify natural fround covers and reference it to a local coordinate system will be of inestimable value.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES (DNR) STUDY OF LAKE EUTROPHICATION

Currently there is a cooperative effort between the Institute for Environmental Studies (IES) of the University of Wisconsin and the DNR to undertake lake eutrophication studies using ERTS data. Commercial organizations involved in this work, such as Bendix, analyze the ERTS data directly from the data tapes but the costs involved are prohibitive. It appears one reason may be that the entire data from each ERTS scene (2×10^8 bits) must be fed through the computer to extract information for the lakes only. It appears very likely that the data associated with the lakes could easily be separated from the rest of the lakes by viewing the imagery on McIDAS and using the RSTICS routine discussed above to extract only the data associated with the lakes, and annotate and store it on a separate tape which could then be analyzed on a larger computer at the investigators' convenience.

CLIMATE/FOOD PROGRAM

Presently IES is involved in a preliminary study to model annual wheat yields worldwide, based on a variety of input parameters, many of them collectively falling under the term "climate." To test the accuracy of the Climate/Food model requires an accurate assessment of wheat yields and wheat acreage. These statistics from Russia, China and many of the South American countries are not always forthcoming and when available are often questionable as to their accuracy. As a long range goal, consideration is presently being given to determine the degree and extent the acreages of the wheat belt regions of the world can be determined by the remote sensing capabilities of a suitably designed satellite. Such a satellite would by necessity generate enormous volumes of data. It appears very likely that such a digital interactive system as McIDAS would be highly suited to access and analyze such resulting data. It is felt that the McIDAS system has evolved and has been tested to the extent by the investigators of this grant that serious efforts can begin to prepare a proposal for a program designed as a support function to the Climate/Food program.

CARTOGRAPHY

Professor P. Muehrcke of the University of Wisconsin Geography Department and his graduate student are considering using McIDAS to develop and test statistical procedures in classifying land types into various themes based on the extent of mixtures with other land types and the scale sizes of the resulting maps.

6.0 CONCLUSIONS AND COMMENTS

With the increasing need to monitor resources and the increasing flow of data, interactive systems such as McIDAS are an essential tool. Technological breakthroughs in the computer industries and other related areas are occurring at such a rate that the capabilities of such systems will increase by orders of magnitude over the next few years.

The strength of this interactive system is that the human user is constantly selecting portions of the relevant data based on such cues as texture and context, something which is very difficult to program in an automated form, i.e. the advantages are that the system is such that human assistance is given to the system in precisely those areas in which computers are weakest.

Finally, concluding on a very specific level, it is recommended that should additional funding become available that the following two tasks be carried out: (1) completion of the table look-up approach discussed above and testing of MAXLIK to determine the practical number of classes and multispectral dimensions to be used in an interactive sense on McIDAS; and (2) development of routines to navigate ERTS data.

The estimated time for developing and testing the first is approximately 3-4 months. The second task can be accomplished in less than one month. This last estimate is based on a preliminary study of ERTS data by D. Phillips of SSEC who has ample experience in the navigation of satellite data and was instrumental in developing the navigation routines presently on McIDAS (Smith and Phillips, 1972).

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