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

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16. Abstract

This project is concerned with the application of ERTS-1 satellite data to the regional land-use planning process. During this reporting period (1 June 1973 to 1 December 1973) the extraction of resource and land-use data from ERTS 9-track digital tapes was initiated. In this period various other modes of data extraction have been explored: percentage of a grid cell, manual delineation of patterns interpretation from numerical printouts of ERTS digital data, interpretation from density over-print displays of ERTS digital data, interpretation from display of an interactive data access and display system.

Conclusions regarding each of these extraction modes are reached. Use of ERTS data in realistic land allocation processes is illustrated. The optimum dates for detection of various resource variables are also included.

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II PREFACE

A. OBJECTIVES, SCOPE OF WORK

Efforts are being made to determine the efficiency of data interpreted from ERTS-1 imagery (of both natural and cultural resources) in comparison with resource data conducted by conventional methods. General objectives of the research are:

1. Compare ERTS-1 derived data to specific types of natural and cultural data at varying scales and during different dates of the year.
2. Determine the usefulness of ERTS-1 data for regional land use planning and allocation decisions.
3. Assist the total community of government and private groups involved with aspects of regional planning by making recommendations as to the usefulness of satellite imagery to the types of land allocation decisions which are relevant to each group.

To achieve the general objectives of this project, the specific research objectives are to compare the ERTS-1 imagery with existing geo-information systems to determine to what extent: 1) specific data can be interpreted, 2) the data acquisition techniques are affected by scale 3) the data acquisition procedure is affected by temporal effects, and 4) spectral variance affects data discernibility.

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V. INTRODUCTION

A. SCOPE OF REPORT

This report for the period June 1 to December 1, 1973 covers the third six months of an investigation of the application of ERTS data to regional land-use planning. As reported in earlier type II reports, the project is composed of 5 phases of research.

Phase I consists of organizational arrangements and meetings with an Advisory Council to discuss applications of ERTS data to land use planning problems.

Phase 2 consists of investigating the effects of scale and temporal changes.

Phase 3 includes development of new means of interpretation and data classification.

Phase 4 is the documentation of evaluations and results to date.

Phase 5 will consist of recommendations to various government and private groups on the usefulness of ERTS data for regional land-use planning.

This report documents the extent to which these phases have been investigated during the 6-month period.

B. SUMMARY OF WORK PERFORMED DURING REPORTING PERIOD

This report documents the extent of work completed for the five research phases noted in section A. In the previous period, spatial computer generated maps derived from ERTS, RB-57 and conventional data were illustrated for several variables. Two 300 km^2 test areas in Southeastern Wisconsin were used. In this reporting period no Advisory Council sessions were held as efforts concentrated on research phases 2-5.

Data extraction from ERTS digital tapes was initiated. Use of a Man-computer Interactive Data Access System continued. Extraction of resource patterns with a fine drafting pen was investigated. Two reports were submitted to state agencies. The first, to the Wisconsin Department of Natural Resources, documents the utility of RB-57 imagery for the mapping of wetlands in Wisconsin. The second, to the Wisconsin Department of Administration, documents the use of ERTS data for statewide planning in Wisconsin.

VI MAIN TEXT

A. DISCUSSION OF PROGRAM DURING REPORTING PERIOD

PHASE 1

Although no Advisory Council sessions were held during the six-month period, a NASA site visit was conducted by Dr. Louis Walter, NASA-GSRC and Mr. Daniel Mooneyhan, NASA-MTF. All Advisory Council members were invited to witness the review of our investigation.

PARTICIPANTS ERTS SITE VISIT AUGUST 2, 1973

Dr. Louis Walter	- NASA Goddard Space Flight Center
Wayne Mooneyhan	- NASA Mississippi Test Facility
Dean Robert Bock	- Dean, Graduate School, U.W.
Dr. James Clapp	- Director, EMDAG, Univ. of Wisconsin
Dr. Ralph Kiefer	- Dept. of Civil & Environmental Eng. U.W.
Prof. Ben Niemann	- Chairman, Dept. of Landscape Architecture, U.W.
Ed Kuhlmey	- Graduate student, Dept. of Land. Arch. U.W.
Wayne Aderhold	- Graduate student, Dept. of Civil & Environ. Eng. U.W.
Dale Keyes	- EMDAG, IES
Dr. William Kuhlow	- EMDAG, IES
Dr. Larry Fisher	- Dept. of Electrical Engineering, U.W.
Dr. Alden McClellan	- Space Science & Engineering Center, U.W.
Tom Krauskopf	- Wisconsin Department of Administration
Craig Adams	- Wisconsin Department of Administration
George Gunderson	- Wisconsin Department of Transportation
Richard Lorang	- Wisconsin Department of Natural Resources
Charles LaGrand	- U.S.D.A. Statistical Reporting Service
Perry Alcott	- Wisconsin Geological Survey
Alan Voss	- EMDAG, IES
Evelyn Howell	- Graduate student, Department of Botany, U.S.
Ron Hennings	- Graduate student, Department of Geology, U.W.
Mike Rhyner	- Graduate student, Department of Land. Arch. U.W.
Mike Winter	- Graduate student, Department of Land. Arch. U.W.
Aschi Ishaq	- Graduate student, Department of Civil & Env. Eng. U.W.
Richard Thompson	- Dept. of Electrical Engineering, U.W.
Dave Eibish	- University of Wisconsin Information Service
Hanna Pavlik	- University of Wisconsin Information Service

PHASES 2 & 3

As noted previously, phase 2 is concerned with the comparison of

ERTS-1 data to data acquired by conventional means and data acquired by RB-57. Manual interpretations were made from ERTS and RB-57 data on a cell format by overlaying a grid of 1 km^2 cells over ERTS and RB-57 image data. The results of this effort were described in the previous type II report. In this period, investigation has proceeded on four other types of data extraction methods:

1. Line delineation of patterns
2. Digital data displays on a computer line printer.
3. Color additive viewer displays.
4. Man-computer Interactive CRT displays of digital data.

1. Line delineation of patterns:

The University of Wisconsin Environmental Monitoring and Data Acquisition Group (EMDAG) is being funded by the Wisconsin Department of Administration in an effort to define and inventory critical resources in Wisconsin. A first phase report of the Critical Resource Information Program (CRIP) was released on July 15, 1973. It describes several significant natural and cultural resources which must be considered in their spatial setting and condition to determine the criticality of that resource.

A brief study has been made to determine the utility of ERTS data to provide information on the resources or variables outlined in the Phase I CRIP report. The following variables identified in the report were extracted in pattern form from the best date, band, and format of ERTS data we have available:

Resource or Variable	Date	Image Type
1) Forest Cover	20 Oct. 72	Color
2) Forest Cover	14 Sept. 72	Color
3) Conifer Swamp	20 Oct. 72	Color

Resource or Variable	Date	Image Type
Cont.		
4) Surface Water (normal stage)	14 Sept. 72	Color
5) Surface Water (flood stage)	14 March 72	MSS 7
6) Islands	28 Aug. 72	MSS 7
7) Surface Water	28 Aug. 72	MSS 7
8) Wetland	9 Aug. 72	Color
9) Wetland	20 Aug. 72	Color
10) Urban Areas	9 Aug. 72	MSS 5
11) Urban Areas	14 Sept. 72	MSS 5
12) Algae Bloom	9 Aug. 72	MSS 6 & 7
13) Algae Bloom	9 Aug. 72	Color

Examples of the actual pattern interpretations are included in Appendix A. All patterns were extraced by overlaying an acetate sheet over an ERTS 1:1,000,000 transparency and tracing the pattern with the smallest drafting pen point available (0000 point).

2. Digital data displays on computer line printer:

800 bpi (9 track) system corrected computer tapes of the REMAP study area of 6 August, 1972 have been transformed to useable formats. MSS Bands 4, 5 and 7 have been reformatted for the vicinity of the Sheboygan Marsh (see map in Figure 1). The area is 270 ERTS data elements wide and 129 recoreds 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 format, the shape of the marsh is exaggerated six times horizontally. This posting of the digital data for MSS bands 4, 5 and 7 for a small area (see Figure 1) of the Sheboygan Marsh is shown in Figures 2 through 4. The 6 X horizontal distortion makes comparison of the posting of this small area and the map (Figure 1) difficult. 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 1. 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 5. 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.

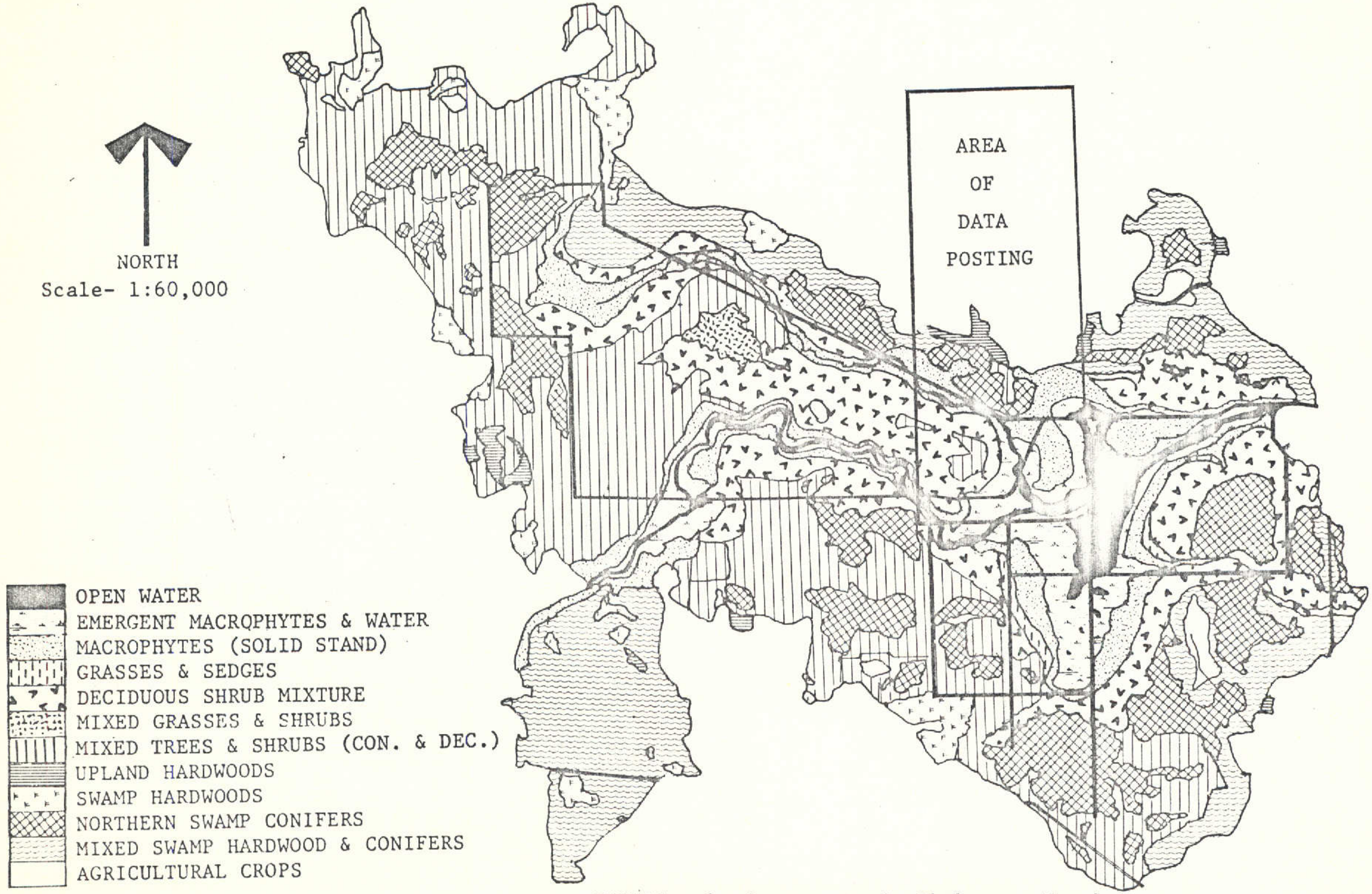

FIGURE 1 Components in Sheboygan Marsh.

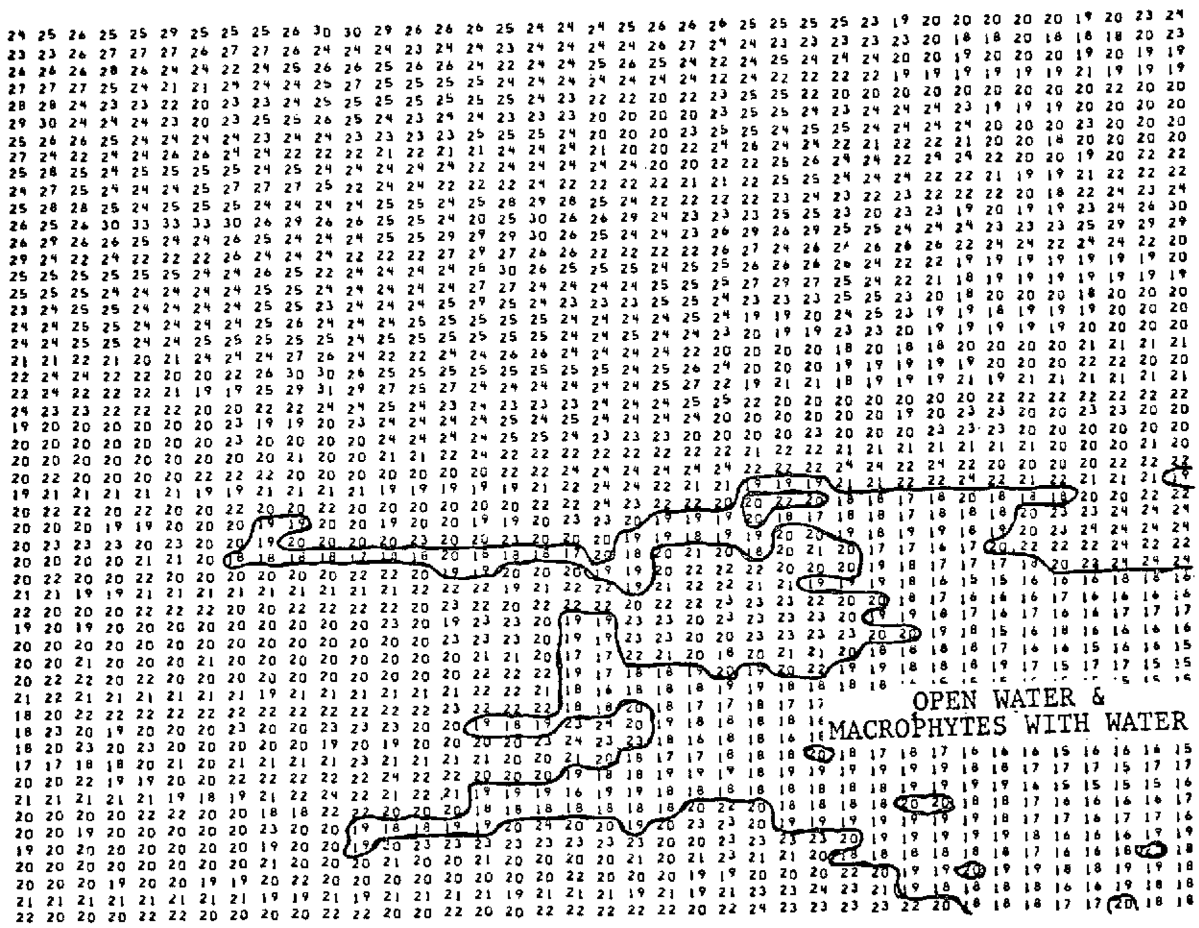

FIGURE 2 Data Posting, Sheboygan Marsh, MSS Band 4 (.5 to .6μ), 9 August 1972.

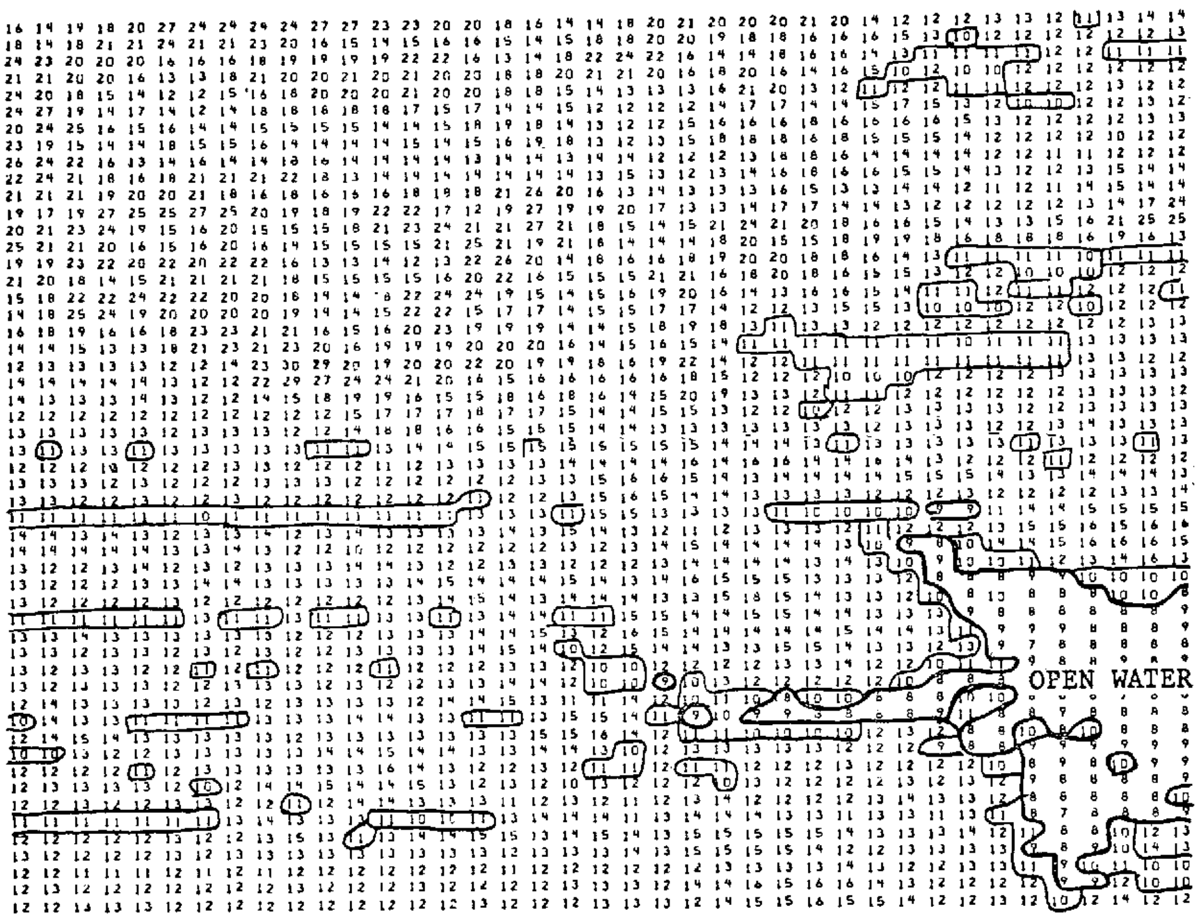

FIGURE 3 Data Posting, Sheboygan Marsh, MSS Band 5 (.6 to .7μ), 9 August 1972.

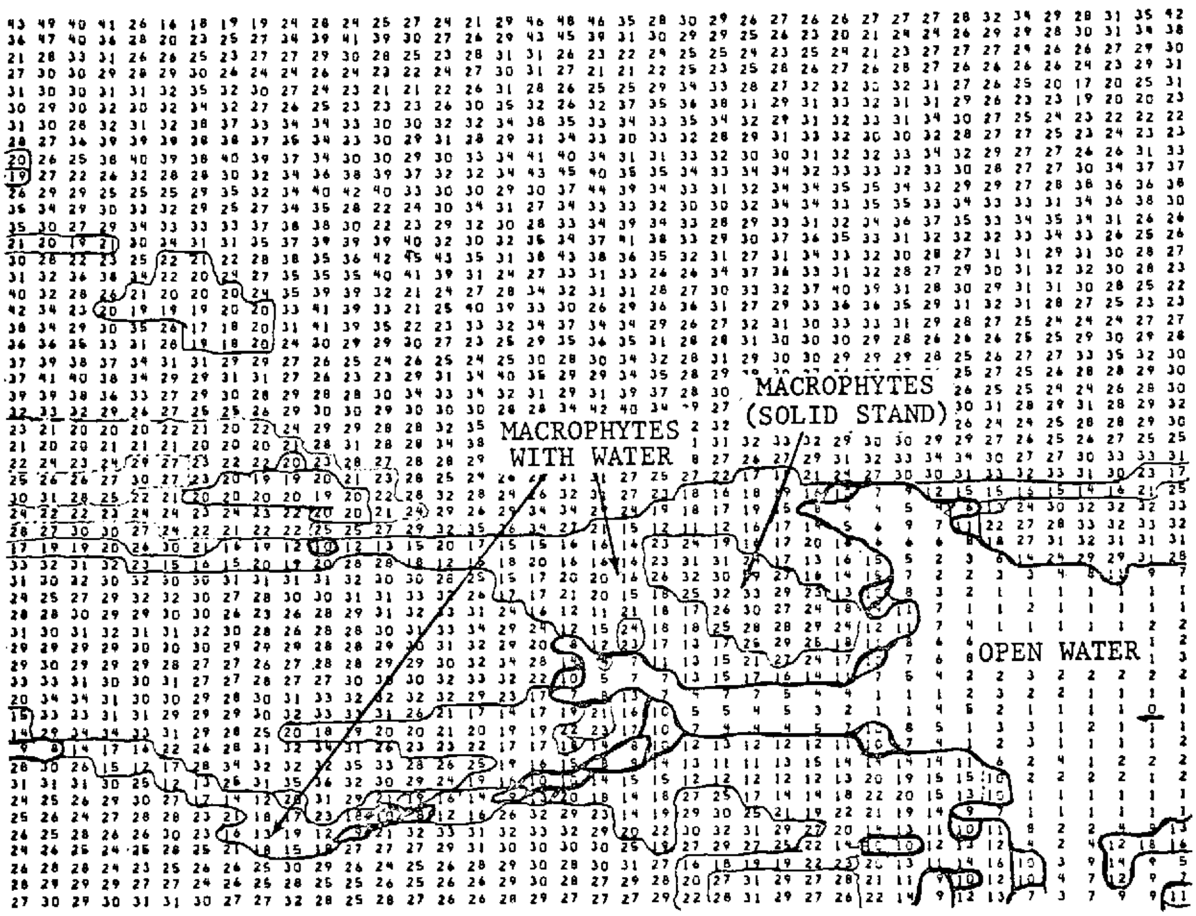

FIGURE 4 Data Posting, Sheboygan Marsh, MSS Band 7 (.8 to 1.1μ), 9 August 1972.

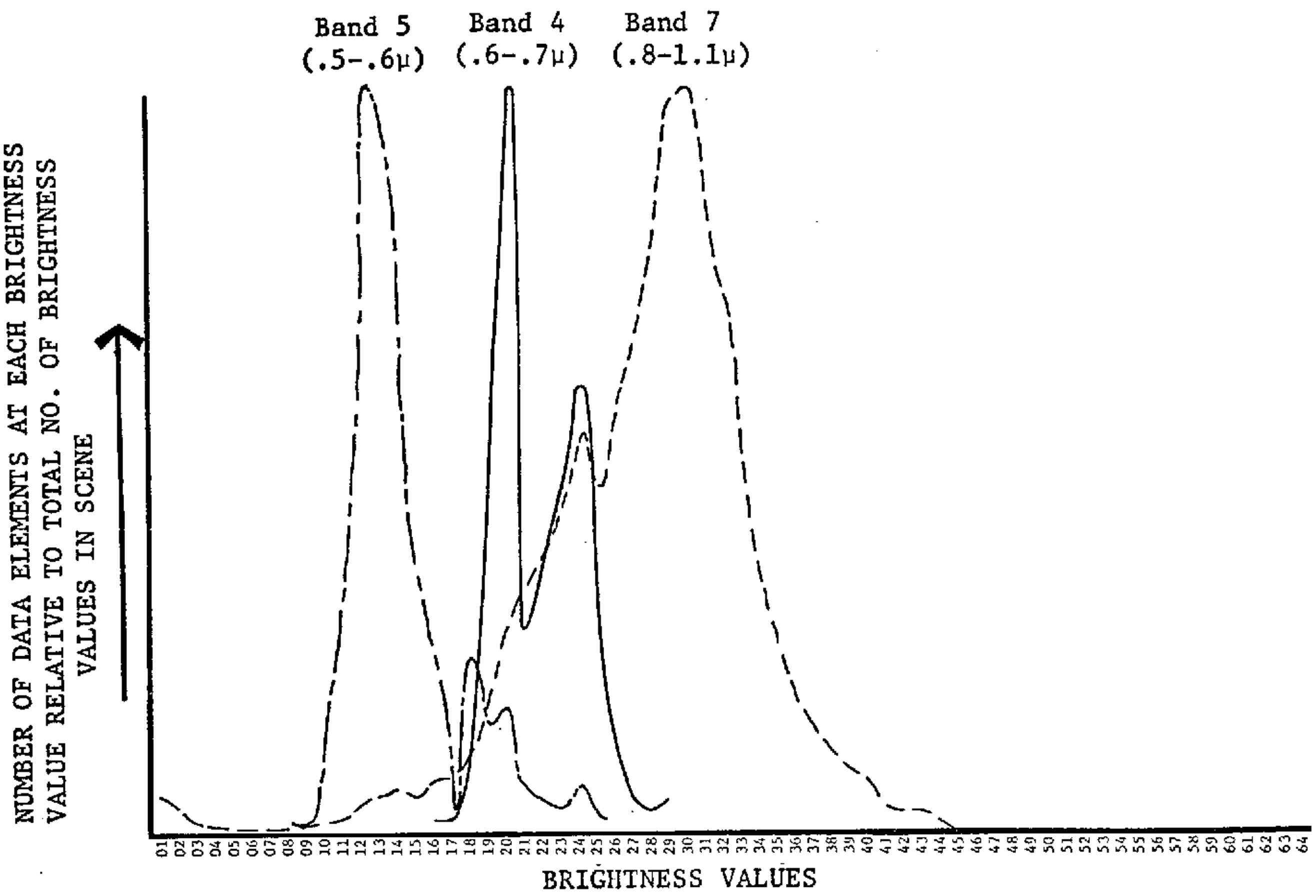

FIGURE 5 Histograms of Brightness Values for 7.69 km x 6.48 km Scene of Sheboygan Marsh, 9 August 1972.

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 gray level display. Figures 6 to 8 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; the lighter symbols represent brighter values.

For each band, the data postings nad histograms discussed earlier were used to select the ranges of brightness to display as a single printout symbol. The data postings (Figures 3 to 4) 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 at single brightness values in the steeper areas of the curve. In the flatter areas of the curve, one printout level was assigned to 3 or 4 brightness values. The brightness value 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	33-35
10	27-29	21-25	36-45

The printout maps in Figures 6 through 8 were compared to the map in Figure 1, and interpretations of the printouts were made. These interpretations are shown in Figures 6 through 8. 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 1. Since a direct overlay comparison of the map and printout was not easily available, only an interpretative comparison was made.

In Band 4, the perimeter of the marsh is distinguishable from the surrounding farmlands. Within the open water of the marsh, emergent macrophytes interspersed with water and swamp hardwood and conifer mixes can be distinguished from other plant groups (see Figure 6).

In Band 5, the perimeter of the marsh and open water can be distinguished. More of the forested areas appear as dark tones but little separation of vegetation types is possible for this date and imagery. Roads are clearly visible (see Figure 7).

In Band 7, the perimeter of the marsh is not detectable (see Figure 8). 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 than Bands 4 and 5. Digital manipulation of Band 7 also yields more information than Band 7 in image format.

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

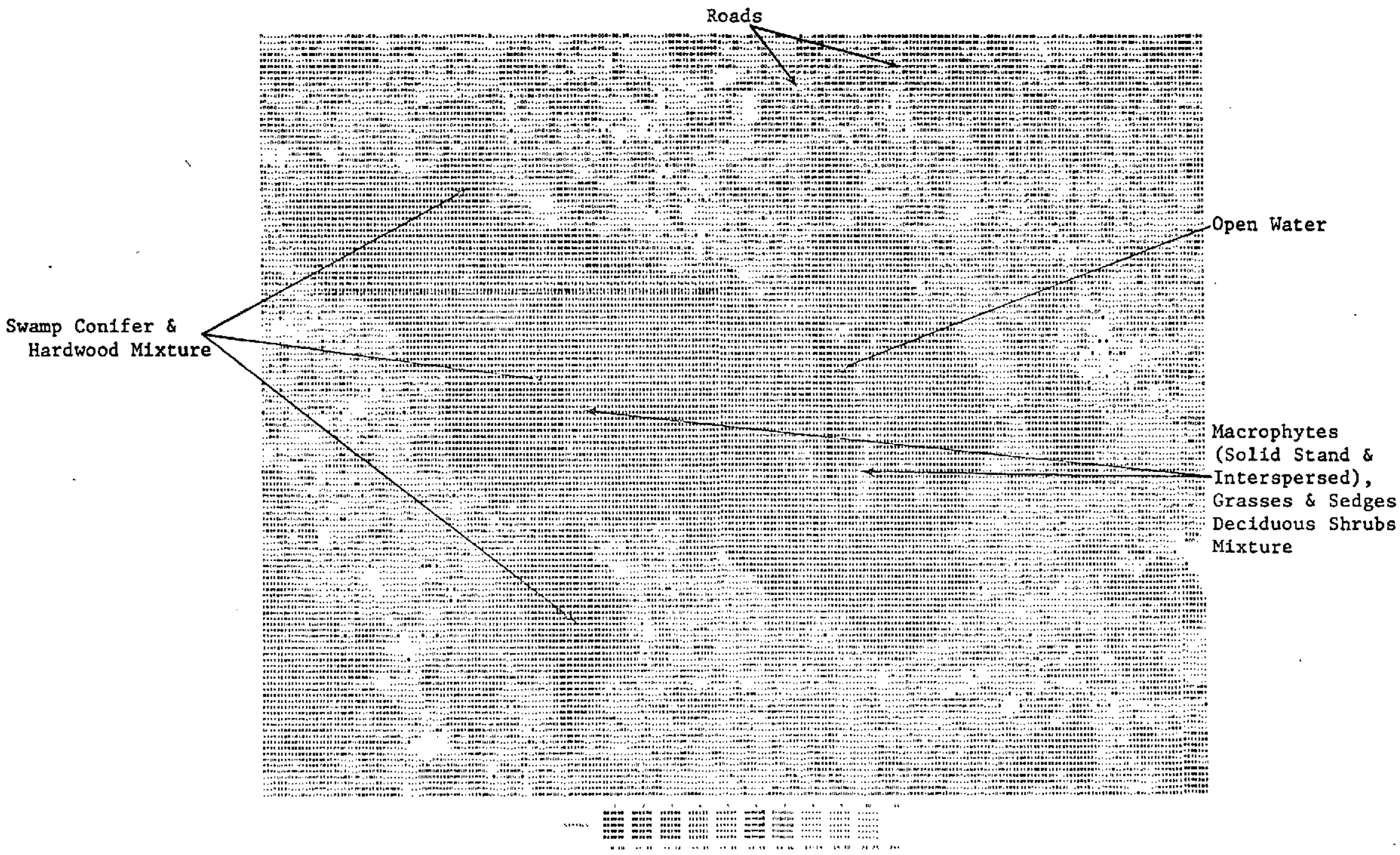

FIGURE 7 Sheboygan Marsh, MSS Band 5 (.6 to .7μ), 9 August 1972.

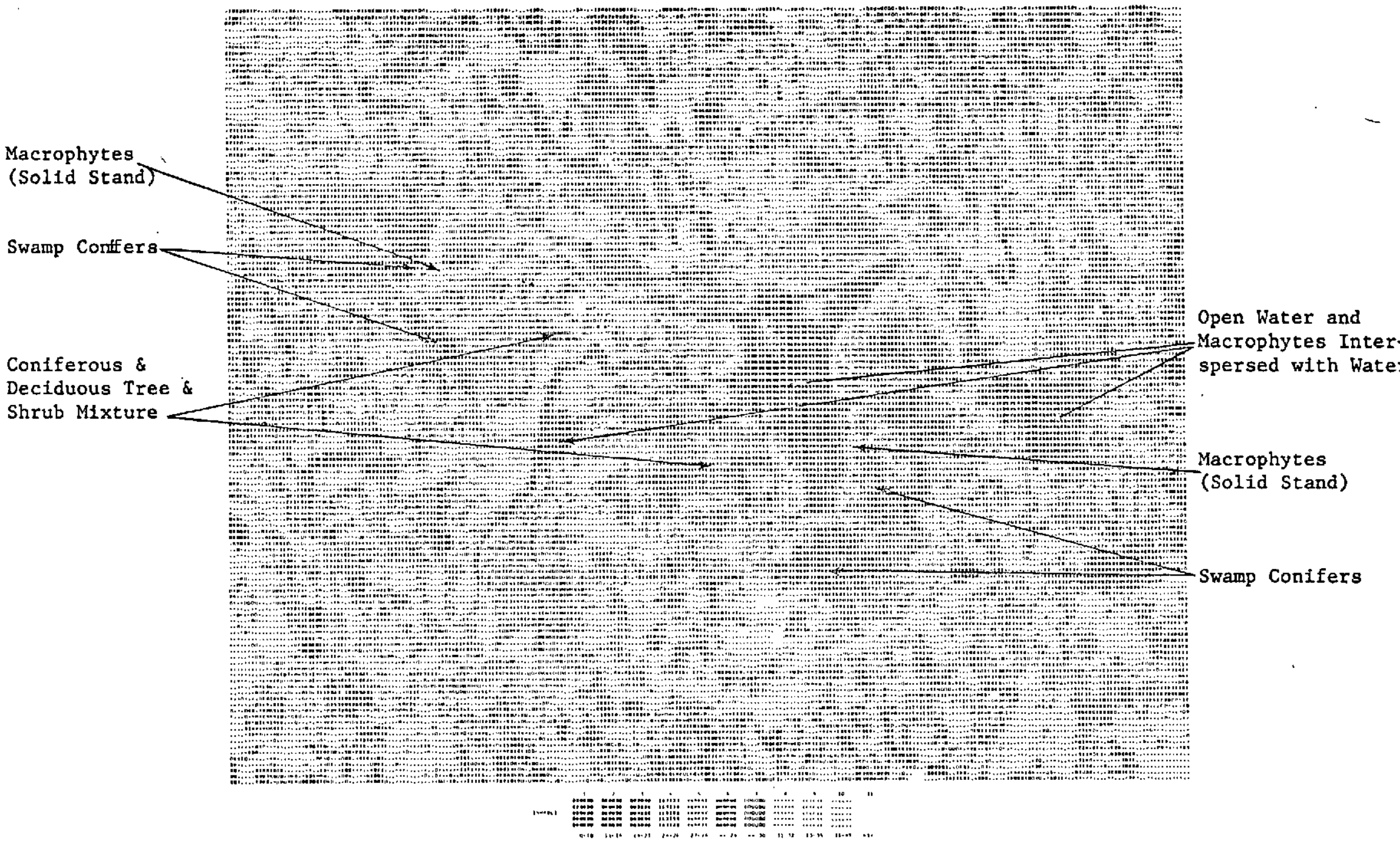

FIGURE 8 Sheboygan Marsh, MSS Band 7 (.8 to 1.1µ), 9 August 1972.

3. Color Additive Viewer Displays

An IES Mini-Addcol Additive Color Viewing System Model 60305 was ordered by the University in June 1973. It was received in late October but did not become operational until late November. Several scenes have been displayed to observe temporal effects. Cell and line extractions of patterns are planned but have not yet commenced.

4. Man-Computer Interactive CRT displays of digital data:

The Space Science and Engineering Center (SSEC) at the University of Wisconsin is presently developing a Man-Computer Interactive Data Access System (McIDAS). (For full explanation, see Appendix A.) While no funding under this contract is involved in the development of McIDAS, it is being explored as yet another data manipulation and extraction mechanism.

At the present time, density displays have been achieved for several ERTS scenes. Colors have been assigned to various ranges of brightness values as one enhancement technique. (See Appendix B for more capabilities.) Researchers on this project are coordinating with SSEC in performing interpretations from the CRT display.

Sincer ERTS data are available in many formats, several modes of data extraction are possible. This project has used several techniques ranging from crude to sophisticated. Some conclusions have been reached with respect to the advantages and disadvantages of each.

Extraction of resource and land-use data on a cellular basis is performed by overlaying a grid over an image. The trained interpretor calls out the percent of the cell (1 km^2 in this study) occupied by a particular pattern or calls out the predominating pattern in each cell. This technique is fast and since the data are extracted on a cell-by-cell basis, it is easy to put into a computer file for further use. Use of a grid cell of the same size as that desired for the intended purpose (1 km^2 in this study) is also an efficient concept. This method is subject to error since it is difficult to correctly align the grid on the imagery. To compound this problem, the true locations of the control points are not known. One solution would be to use control points with "known" locations. However, this does not solve the manual grid positioning problem. We have used both single band MSS data and color composites at a scale of 1:1,000,000. The color infrared composites are preferred for extraction of most variables.

Patterns can be extracted by tracing them with a fine drafting pen on a mylar overlay. It has b_en determined that even the smallest drafting pen (0000) is unsatisfactory fot he delineation of even large features (several hundred square miles). Qualitative delineations for visual display are acceptable using this method but quantitative procedures such as calculating areas are subject to great error. Color infrared composites are best for extraction of most patterns.

Color composite constructed on the screen of the I^2S color additive viewer will pose many of these same extraction problems. The 1:1,000,000 scale will pose the same grid positioning and line delineation problems. The degree to which the additive color process will sophisticate scene rendition is still unexplored in this research.

The success of extraction of information from digital tapes depends on the type of software and hardware available to display the data. Computer line printer displays of each data element for each MSS band (from 9-track tapes) enabled each data element to be examined. However, this is time-consuming and navigation on the printout without corrective software is difficult. Interpretation is facilitated by assigning line printer overprint symbols to various ranges of data elements. This produces a display of ten levels of gray values which often enables the interpretor to perceive patterns from single MSS band printouts. However, this process does not sophisticate the

Table 1 - Data Availability Summary

X - Data identifiable without difficulty

0 - Best time

	SUMMER	FALL	WINTER	SPRING	Comments
1. AGRICULTURE	0	X	X	X	Identified most readily in summer with composite or MSS 5
2. BEACH RIDGE					Resolution too poor for identification
3. COMMUNICATIONS, AIRFIELDS	0	X		X	Identified best on MSS 5 when surrounded by vegetation
4. DRUMLINS	X	X	0		Identified most readily during winter when snow cover exists
5. END MORAINE	X	X	X	X	Contrast in characteristic vegetation of moraine with agricultural areas results in easy identification throughout year
6. ESKER					Positive identification is not possible without stereoscopic viewing
7. ESCARPMENT			X		Can be identified with previous knowledge of the local geography
8. REST, LOWLAND		X		X	Can be identified but only with color composite image
9. FOREST, UPLAND		X		X	Can be identified but only with color composite image
10. FOREST, CONIFEROUS		X		X	Can be identified but only with color composite image
11. FOREST, DECIDUOUS		X		X	Can be identified but only with color composite image
12. FOREST, DECIDUOUS/CONIFEROUS		X			
13. GLACIAL LAKE, BED					Characteristic features require much lower altitude for identification
14. GROUND MORAINE			X		

X - Data identifiable without difficulty

0 - Best time

	SUMMER	FALL	WINTER	SPRING	Comments
15 INTERCHANGES	X	X		X	MSS 5 or composite provide relatively easy identification in contrasting surroundings
16. LAKES	X0	X		X	Boundaries most well-defined in in MSS 6, 7 or color composite
17. LAKE MICHIGAN	X	X	X	X	Shoreline most well-defined when when water is not frozen
18. LAKES, LESS THAN 50 ACRES	X	X		X	Identified most readily in MSS 6, 7 or color composite
19. LIMITED ACCESS HIGHWAY	X	X	X	X	Cannot be identified during winter when snow cover exists
20. MARSH	X	X0	X	X0	Identifiability depends on species composition and hydrologic conditions
21. OPEN SWAMP	X	X0	X	X0	Distinct boundaries are difficult to identify especially during winter
22 RESIDENTIAL, RURAL					Requires lower altitude for identification
23. RESIDENTIAL, SUBURBAN	X0	X		X	MSS 5 or color composite best boundaries (urban/suburban) not identifiable
24. RESIDENTIAL, URBAN	X0	X	X	X	MSS 5 or color composite best boundaries (urban/suburban) not identifiable
25. RIVERS	X0	X		X	Only large rivers (unfrozen) identifiable in winter
26. RIVER OR LAKE ZONING	X	X		X	Color composite best for identification
27. ROADS	X0	X	X	X	MSS 5 or color composite best for identification
28. SAND DUNES					Requires lower altitude for identification

X - Data identifiable without difficulty

0 - Best time

	SUMMER	FALL	WINTER	SPRING	Comments
29. SHRUB CARR		X			
30. STREAM	X	X		X	Only larger streams can be identified - color composite is best
31. STREAM, INTERMITTENT					Requires lower altitude for identification
32. TERRACES					
33. Utilities, Railway lines					Can only be identified where large forest cuts exist

process of storing interpreted patterns in a computer file for further use. Rather, it only convinces one that better means are needed to work with ERTS digital tapes.

The most useful tool for data display, enhancement and extraction appears to be the McIDAS systems. Its capabilities as yet are largely unexplored; however, see Appendix B for a discussion of the system's capabilities.

5. The Effect of Temporal Change on ERTS Data Utility

Throughout this research, a record of the effect of temporal change on ERTS data utility has been kept. This information has been compiled in a matrix format that is difficult to interpret because of its length (9 pages). This record, dated August 9, 1973, to the present, is summarized further. Table 1 shows the seasons and data types most suitable for providing information on 33 variables from the REMAP I & II data banks, based upon data received to date.

6. The Use of ERTS Data in the Planning Process

The goal of the research is to determine the utility of ERTS-1 data in the planning process. To demonstrate one application, the routing of an interstate highway, existing computer software was utilized. The three data banks (ERTS, RB-57, and conventional data) 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.[1]

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 sums the products of weights and variable values for

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1 The REMAP-1 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, U.W. Department of Computer Science.

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. The 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 (Figures 9-12);

Policy 2: Greatest scenic value (Figures 13-16).

Model 1 in each policy uses weights established by "experts,"[2] Model 2 in each policy uses weights made up by the researchers to demonstrate the effect of weight 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. In reality the ability of the method to accept varying weights and display the results is a great asset.

The effect of models, weights, and the data used cannot be fully explained at this time. It must be emphasized that the purpose of this effort is to demonstrate how ERTS data might be used in the planning process. The alternative routes change when run through each data bank and with the varying weights.

7. <u>The Use of ERTS Data for Analyzing Lake Circulation</u>

ERTS imagery of Lakes Michigan and Superior was examined to determine its usefulness in determining the circulation patterns of the Great Lakes. Because of cloud cover, only a few clear images of these lakes were obtained during the period of the grant (August 1972 to June 1973). Of these, only the Lake Superior imagery of August 12, 1972, showing the western arm of the lake showed water with sufficient traces (clay, silt, etc., due

[2] In the REMAP-1 study, highway planners established the weights based on their "expert" judgement.

POLICY 1

LAND ALLOCATION MODELS

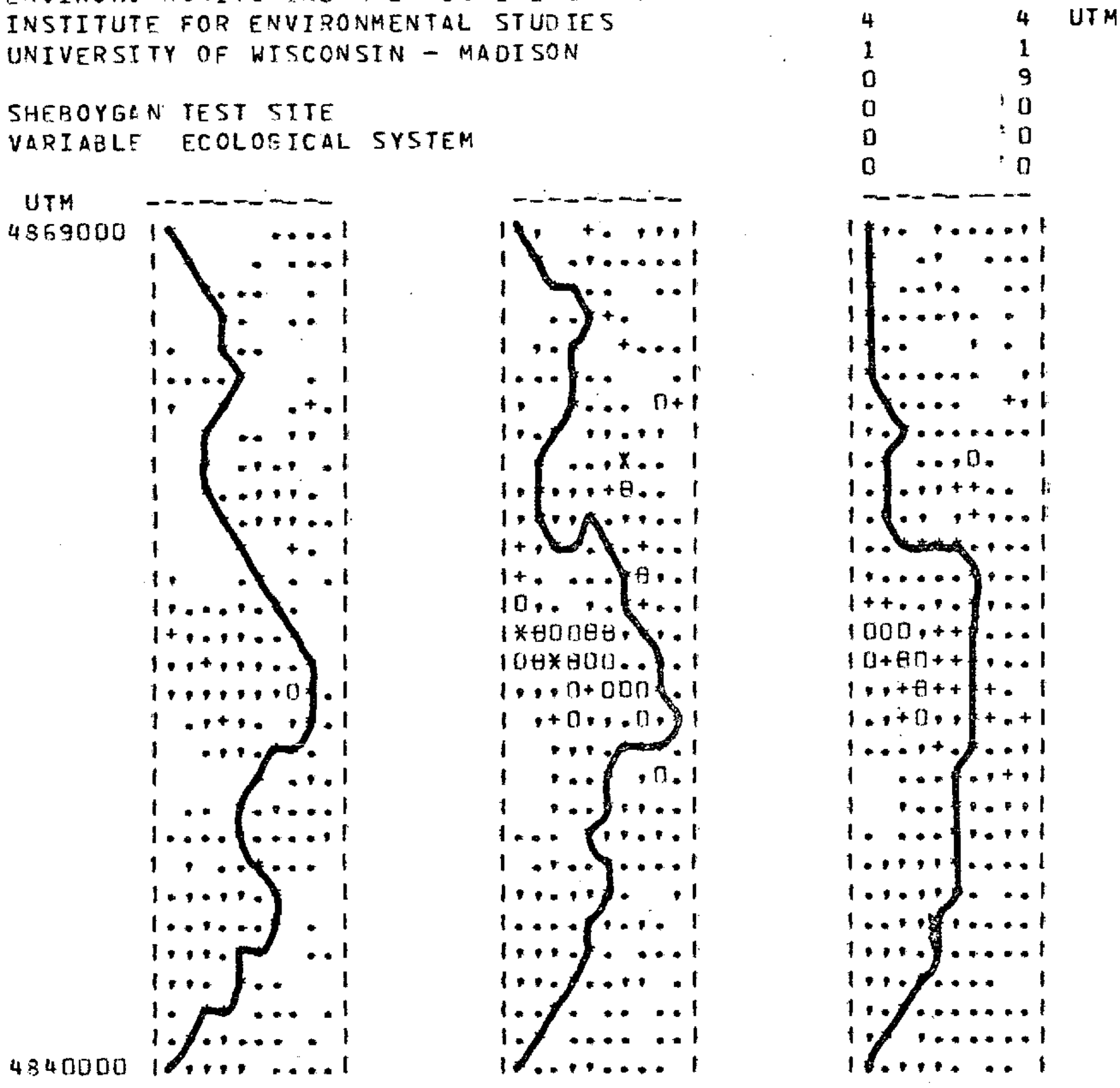
"LINEFINDER" ROUTINE

POLICY 1: LEAST DISRUPTION TO THE ECOLOGICAL SYSTEM

DATA DERIVED FROM	VARIABLE USED	WEIGHTS MODEL 1	WEIGHTS MODEL 2
ERTS	Rivers	20	2
	Lakes	9	2
	Lake Michigan	9	2
	Forest	4	20
	Open swamp	4	20
		$\Sigma = 46$	$\Sigma = 46$
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
		$\Sigma = 240$	$\Sigma = 240$

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

SHEBOYGAN TEST SITE
VARIABLE ECOLOGICAL SYSTEM



	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	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	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	3.14	1.03	.68	.00	.00	.00
	C	6.36	8.23	5.04	2.34	.81	.00	.00	.00	.00	.00

Figure 9 - Policy 1, Model 1, Sheboygan Test Site

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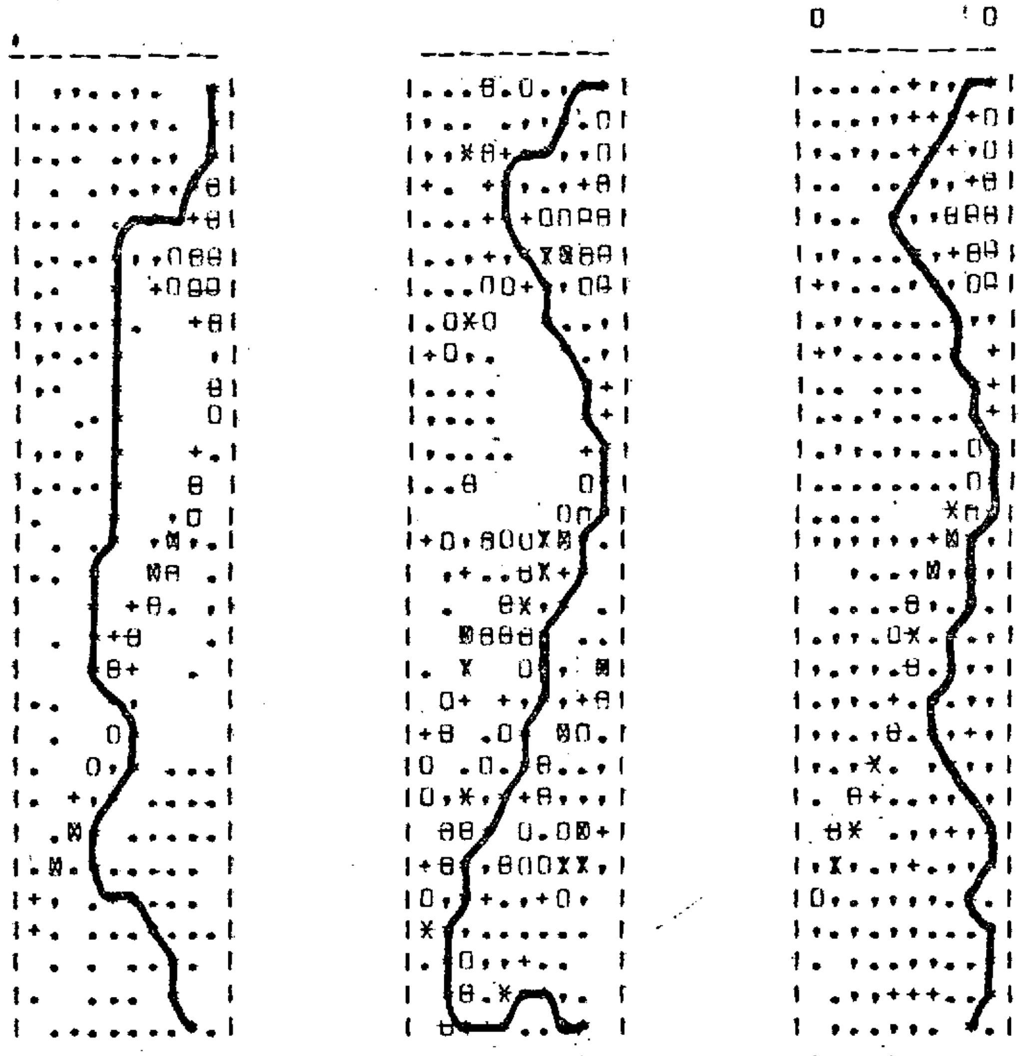
ENVIRON. MONITORING AND ACQUISITION GROUP
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE ECOLOGICAL SYSTEM



		1	2	3	4	5	6	7	8	9	10
TOT. SQ.KM		21.920 (A)				47.680 (B)			36.670 (C)		
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	106	27	10	5	15	2	0	3	1	0
	B	66	39	25	30	26	6	6	3	0	3
	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
	B	2.60	5.51	5.82	10.22	11.39	3.18	3.88	2.19	.00	2.89
	C	6.55	12.15	5.54	2.47	5.77	2.07	.65	1.47	.00	.00

Figure 10 - Policy 1, Model 1, Green Bay Test Site

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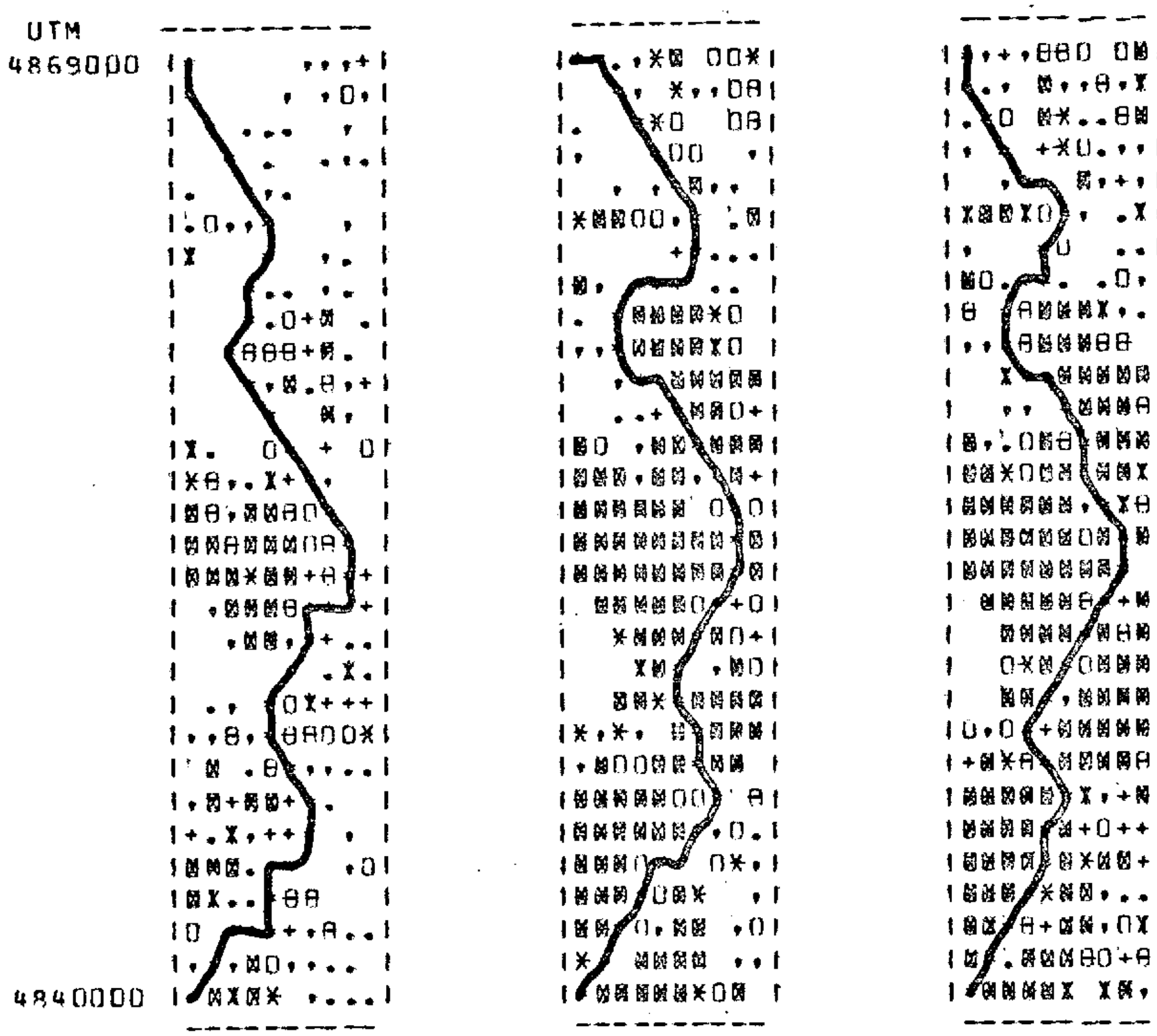
UNIVERSITY OF WISCONSIN - MADISON

SHEBOYGAN TEST SITE
VARIABLE ECOLOGICAL SYSTEM



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

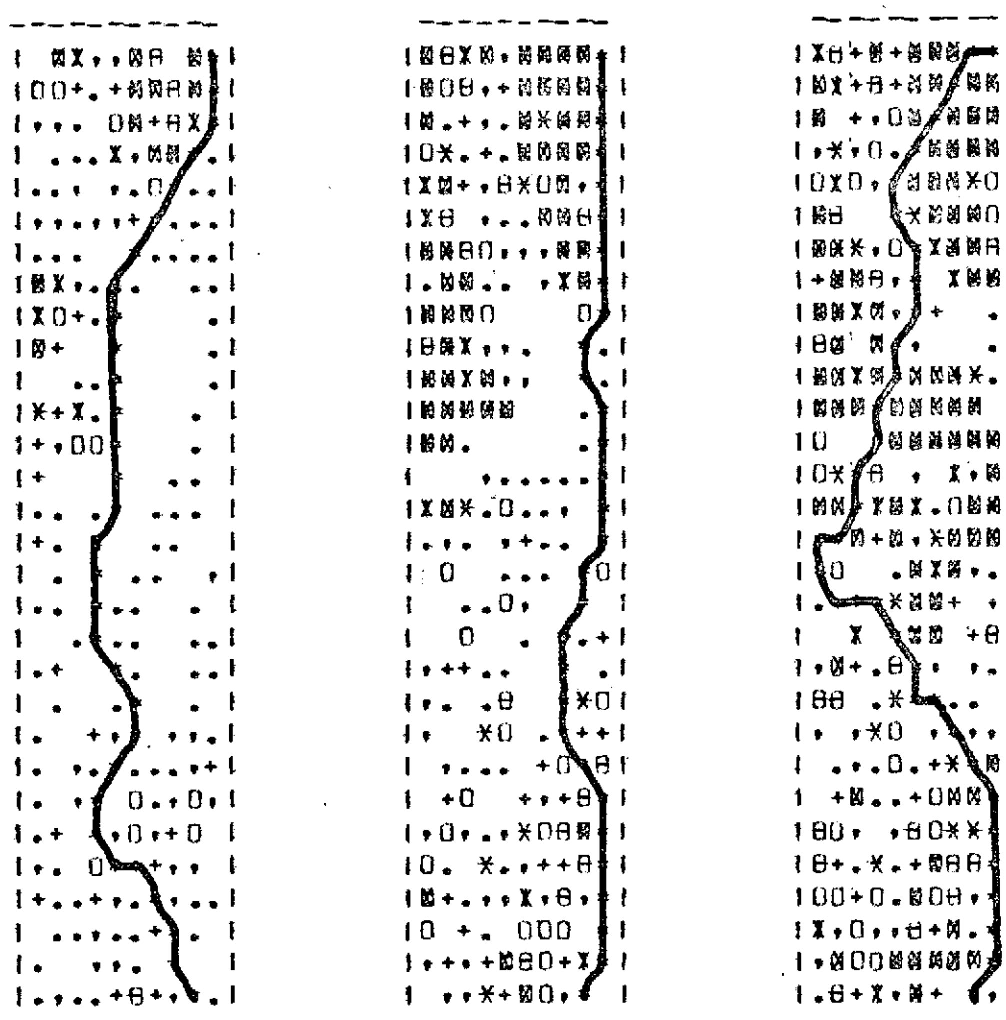
LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	OOOOO	ΘΘΘΘΘ	*****	XXXXX	ØØØØØ	ØØØØØ	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	39	39	19	13	18	4	8	9	14	10
	B	12	29	6	30	3	14	2	13	4	98
	C	16	28	13	18	19	7	12	10	7	106
SQ.KM	A	2.22	5.33	4.51	4.30	7.65	2.15	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 11 - Policy 1, Model 2, Sheboygan Test Site

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 ECOLOGICAL SYSTEM

UTM 410000 419000



	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	ØØØØØ	▩▩▩▩▩	■■■■■
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	116.37

Figure 12 - Policy 1, Model 2, Green Bay Test Site

POLICY 2

LAND ALLOCATION MODELS

"LINEFINDER" ROUTINE

POLICY 2: GREATEST SCENIC POTENTIAL

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
		Σ=19	Σ=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
		Σ=21	Σ=21

ERTS-1 INVESTIGATION: CONTRACT # NAS 5-21754
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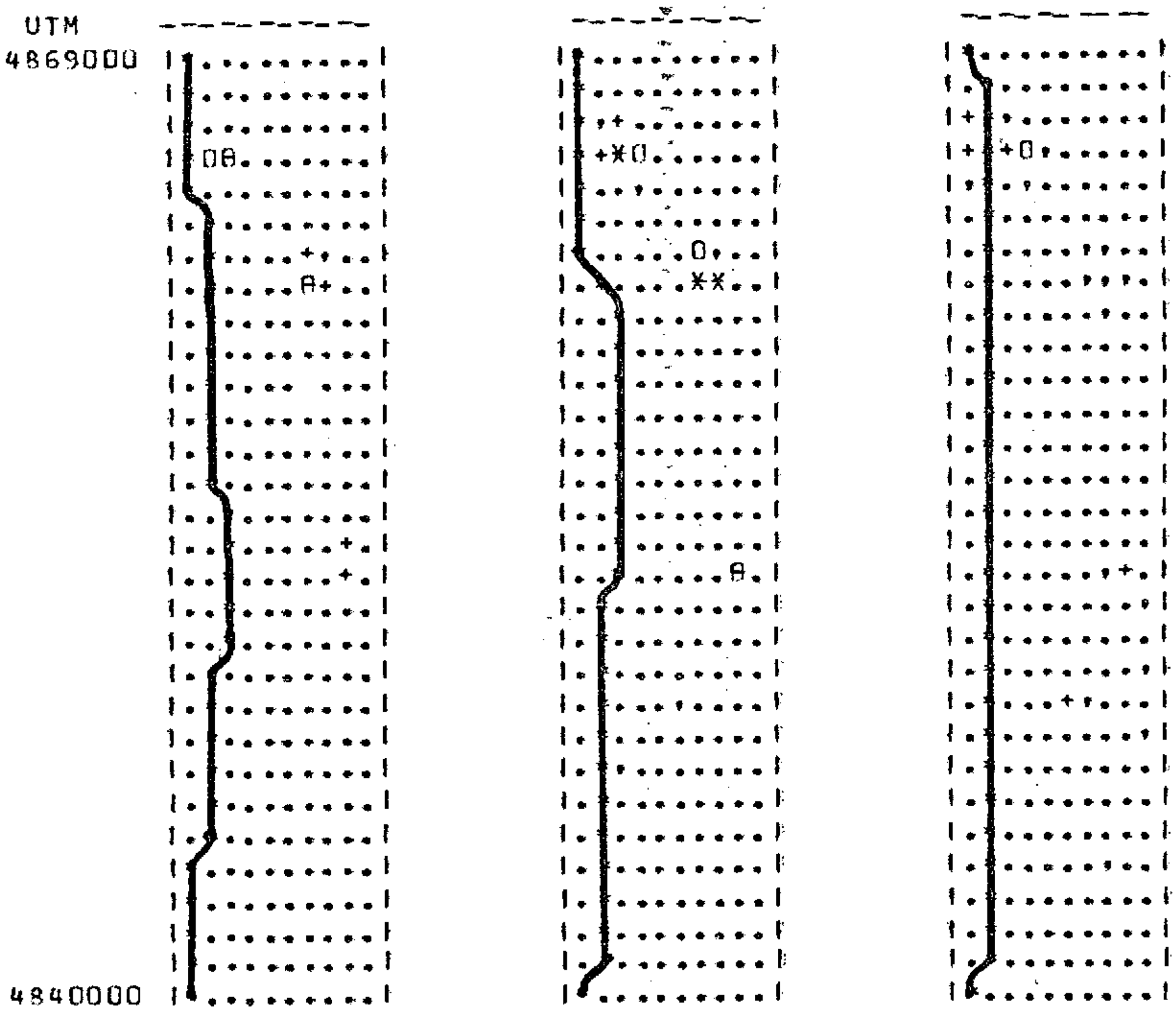
SHEBOYGAN TEST SITE
VARIABLE SCENIC POTENTIAL

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



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

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	261	1	4	1	2	0	0	0	0	0
OCCUR B	257	5	2	2	1	3	0	0	0	0
OCCUR 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
SQ.KM B	10.22	.67	.54	.64	.45	1.50	.00	.00	.00	.00
SQ.KM C	11.35	2.28	1.08	.31	.00	.00	.00	.00	.00	.00

Figure 13 - Policy 2, Model 1, Sheboygan Test Site

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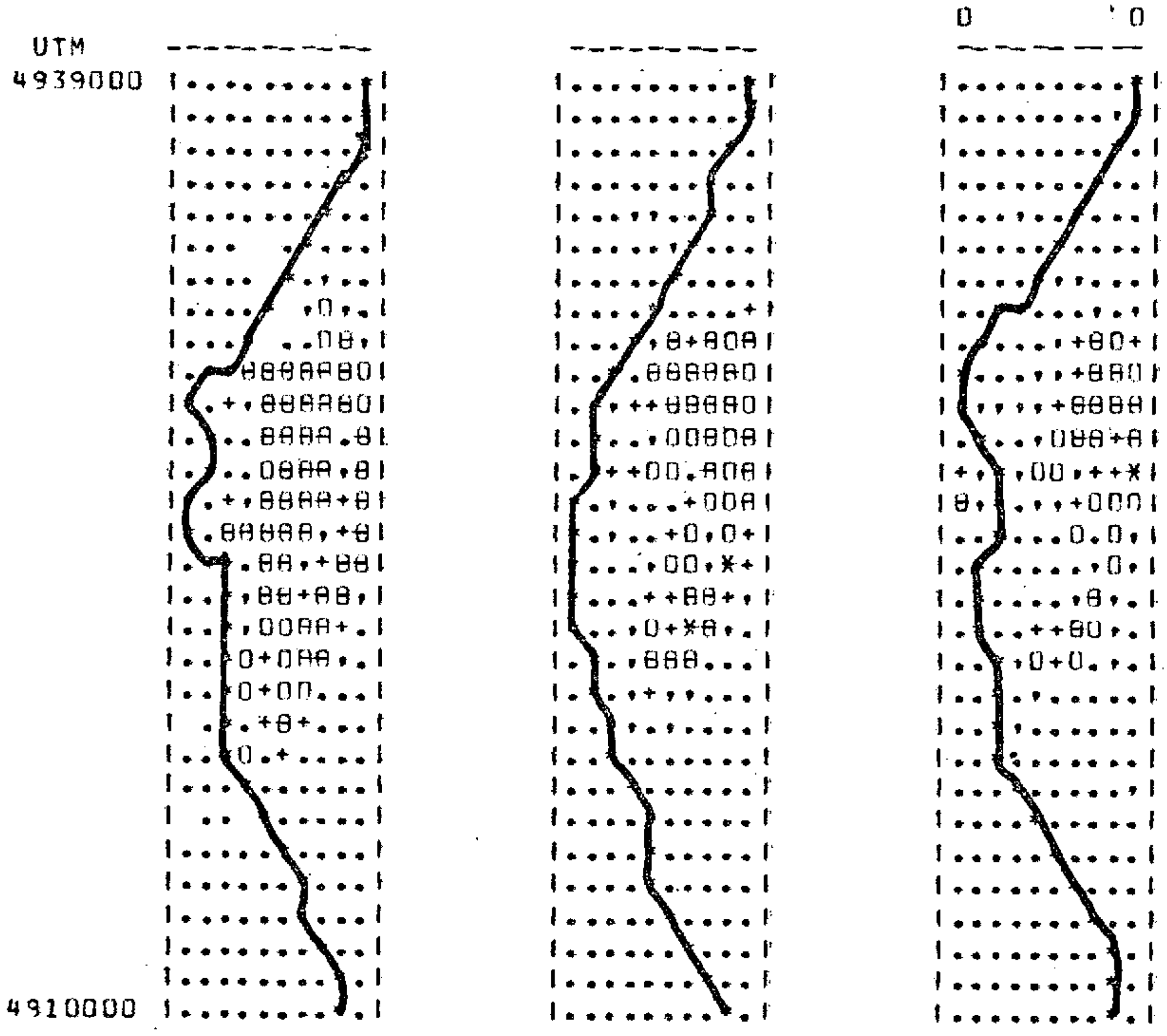
INSTITUTE FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF WISCONSIN - MADISON

GREEN BAY TEST SITE
VARIABLE SCENIC POTENTIAL

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



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

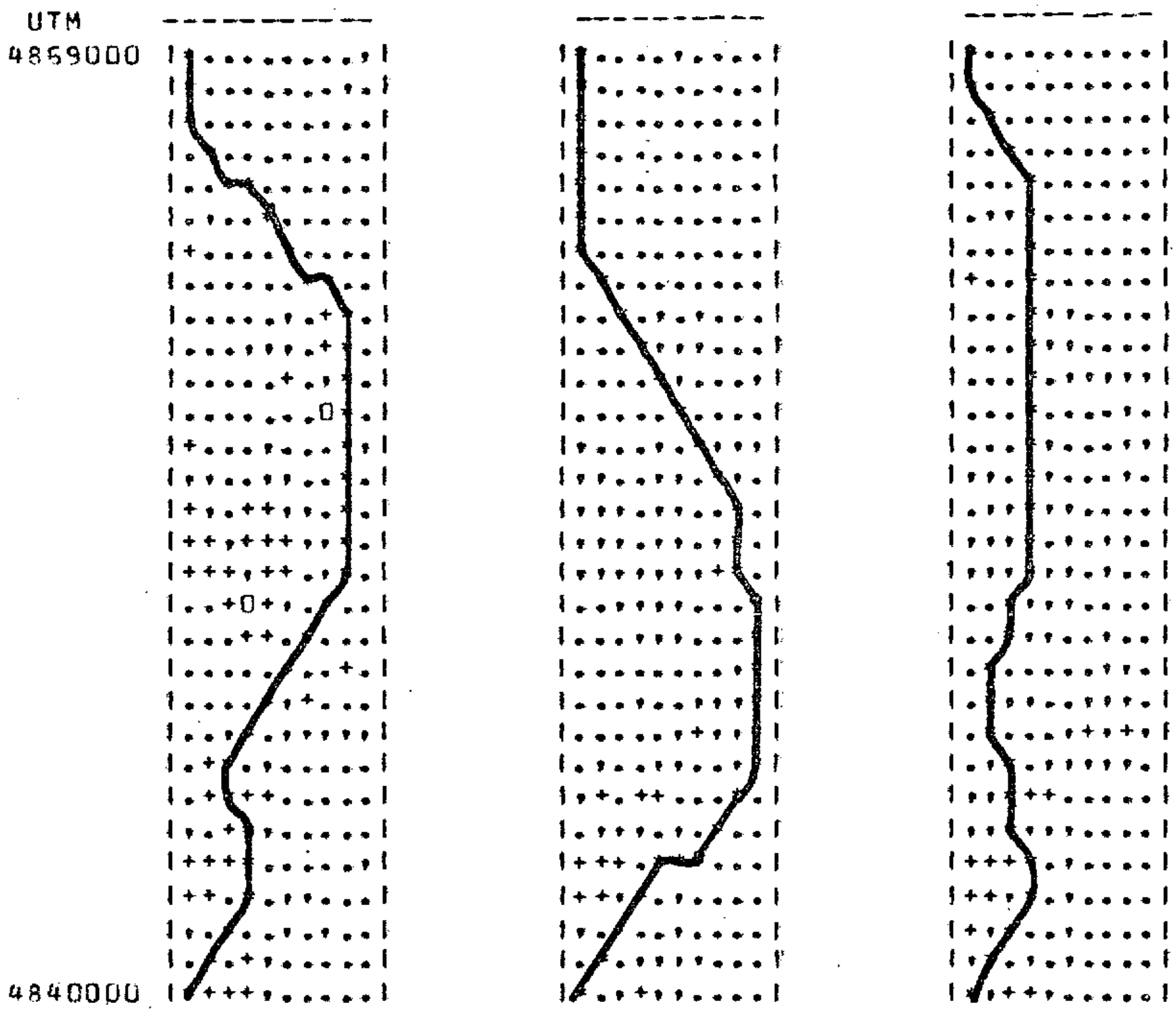
LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	,,,,,	+++++	00000	88888	XXXXX	IIIII	▩▩▩▩▩	▩▩▩▩▩	▩▩▩▩▩
RANGE (%)	1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR A	177	13	13	13	45	0	0	0	0	0
OCCUR B	194	20	15	16	23	2	0	0	0	0
OCCUR C	198	31	12	14	13	1	0	0	0	0
SQ.KM A	6.35	1.85	2.90	4.53	21.30	.00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

Figure 14 - Policy 2, Model 1, Green Bay 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

UTM 410000 — 419000

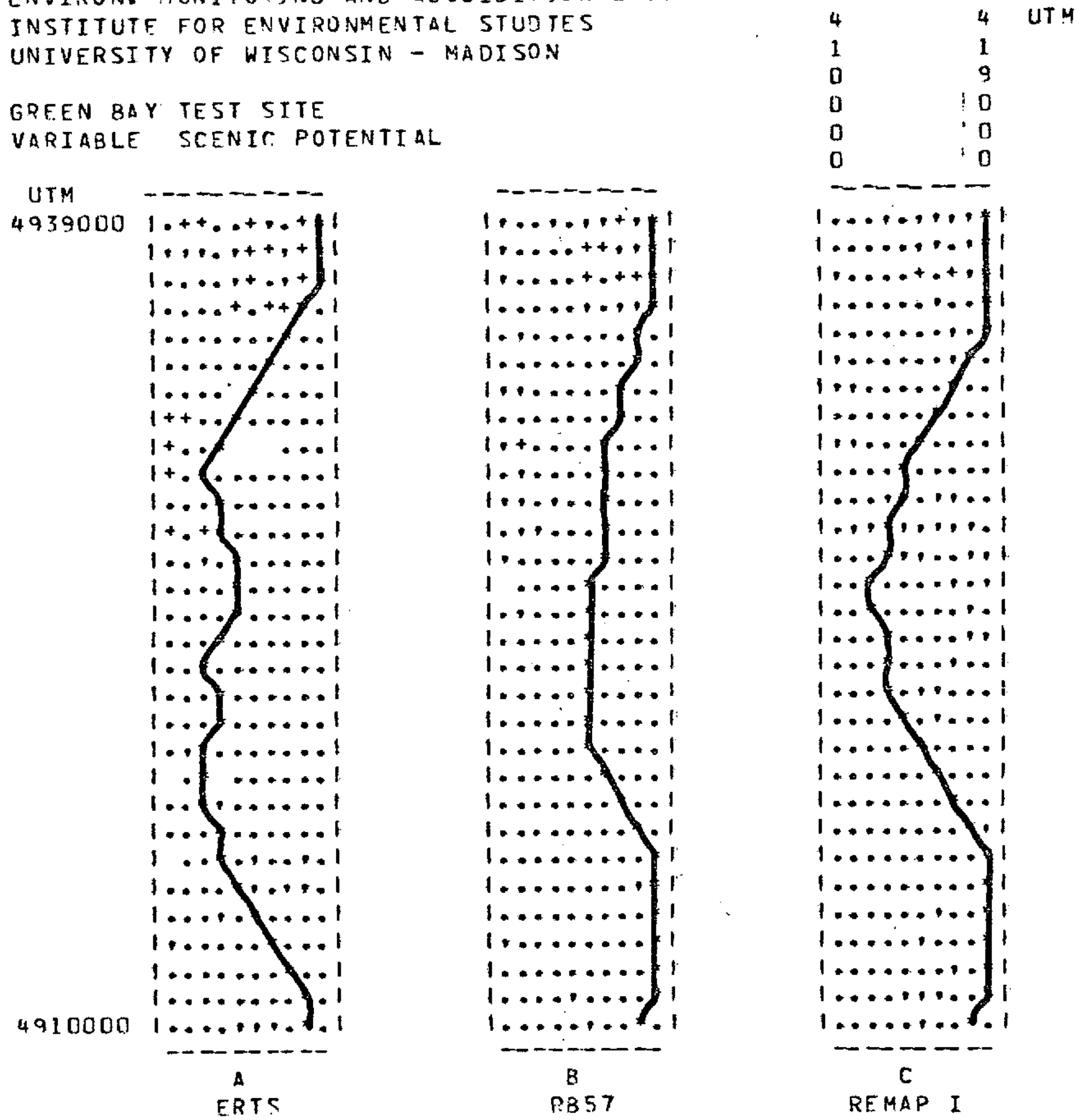


		A		B		C					
		ERTS		RB57		REMAP I					
TOT. SQ.KM		24.720		22.560		23.380					
LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	00000	BBBBB	*****	XXXXX	[illegible]	[illegible]	[illegible]
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
OCCUR	A	187	41	38	2	0	0	0	0	0	0
	B	186	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

Figure 15 - Policy 2, MOdel 2, Sheboygan Test Site

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 SCENIC POTENTIAL



		A	B	C
TOT. SQ.KM		16.610	16.970	18.990

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	OOOOO	θθθθθ	XXXXX	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	224	21	18	0	0	0	0	0	0	0
	B	234	28	7	0	0	0	0	0	0	0
	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
	B	12.19	3.21	1.57	.00	.00	.00	.00	.00	.00	.00
	C	12.54	6.04	.41	.00	.00	.00	.00	.00	.00	.00

Figure 16 - Policy 2, Model 2, Green Bay Test Site

to heavy rainfall) to suggest circulation patterns. A large counter-clockwise gyre seems to be present (on that day) in the western arm. Ground-truth measurements taken (using a transmissometer) in the western arm at the same time as the overflight showed good correlation with the ERTS imagery. This, however, is not especially surprising.

While suggesting an interesting circulation pattern, the August 12 data tell us little or nothing about the persistence or frequency of occurrence of such features. Until daily or twice-daily data are available, this will probably be generally true, and the use of ERTS data to directly determine water circulation patterns will be quite limited.

The data can be quite useful, however, in determining the extent of both natural and man-made near-surface turbidity in lakes. For example, the data referred to above were used in the case of the United States vs. Reserve Mining Company to show the extent of natural discoloration of the surface waters of Lake Superior. In another court case, the use of ERTS data to show man-made pollution of Lake Winnebago (Wisconsin) was examined. However, the case was settled out of court before the data could be introduced into the record.

The usefulness of ERTS data in determining water motions is closely related to the time scale of these motions. It is quite certain that the most important motions in the Great Lakes are wind-driven, and have a time scale directly related to that of local weather patterns, i.e., a few days. In order to gain informaiton regarding these motions from satellites:

(i) a tracer must be available (surface turbidity, in most cases),

(ii) the satellite must pass overhead at least once a day

(iii) the satellite data must be supported by an extensive field sampling program, so that the full cycle of the transient circulation patterns can be ascertained, at least in a few places.

The data are more useful to simply document the aerial extent of surface-water turbidity. If this relates to an "aesthetic" problem, such data can probably stand on their own. If, however, the data are being used to infer the presence of certain substances in the near-surface waters, an extensive set of ground-truth measurements is required.

To a certian extent, criterion (ii) above can be met by using aircraft to supplement the ERTS coverage in time. We are proposing to do this along the western shore of Lake Michigan, and in the western arm of Lake Superior.

In meeting criterion (i), it would be very helpful to have a thermal scanner (i.e., 8-14 micron radiometer) aboard the next ERTS satellite. Water temperature can often be used as a tracer when turbidity is not present.

PHASE 4

The documentation of evaluations and results to date is contained in two articles published in the reporting period:

1) Clapp, J.L., B.J. Niemann, R.W. Kiefer, and E.L. Kuhlmey, "The Application of ERTS-1 Data to the Land Use Planning Process," Presented at the 3rd ERTS Symposium, NASA-GSFC, Washington, D.C., December 10-14, 1973 (Appendix C).

2) Niemann, B.J., A.H. Miller, R.W. Kiefer, D.L. Keyes, and E.L. Kuhlmey, "Critical Land Resources Inventory Using ERTS Data," Symposium Proceedings: Management and Utilization of Remote Sensing Data, the American Society of Photogrammetry, Sioux Falls, D.S., Oct. 29 - Nov. 1, 1973, pp. 573-592 (Appendix D).

PHASE 5

1. Recommendations to the Wisconsin Department of Administration (DOA)

Recommendations on the use of ERTS data have been made to the Wisconsin Department of Administration, Bureau of Planning and Budget. One product generated for the DOA was the extraction of surface feature patterns from an ERTS mosaic 1:500,000 overlays on the ERTS mosaic and constituted part of the product presented to the DOA. Figures 17-20 are reductions of these patterns. The remainder of the product is a report not yet published.

FIGURE 17. Surface Water in Wisconsin.

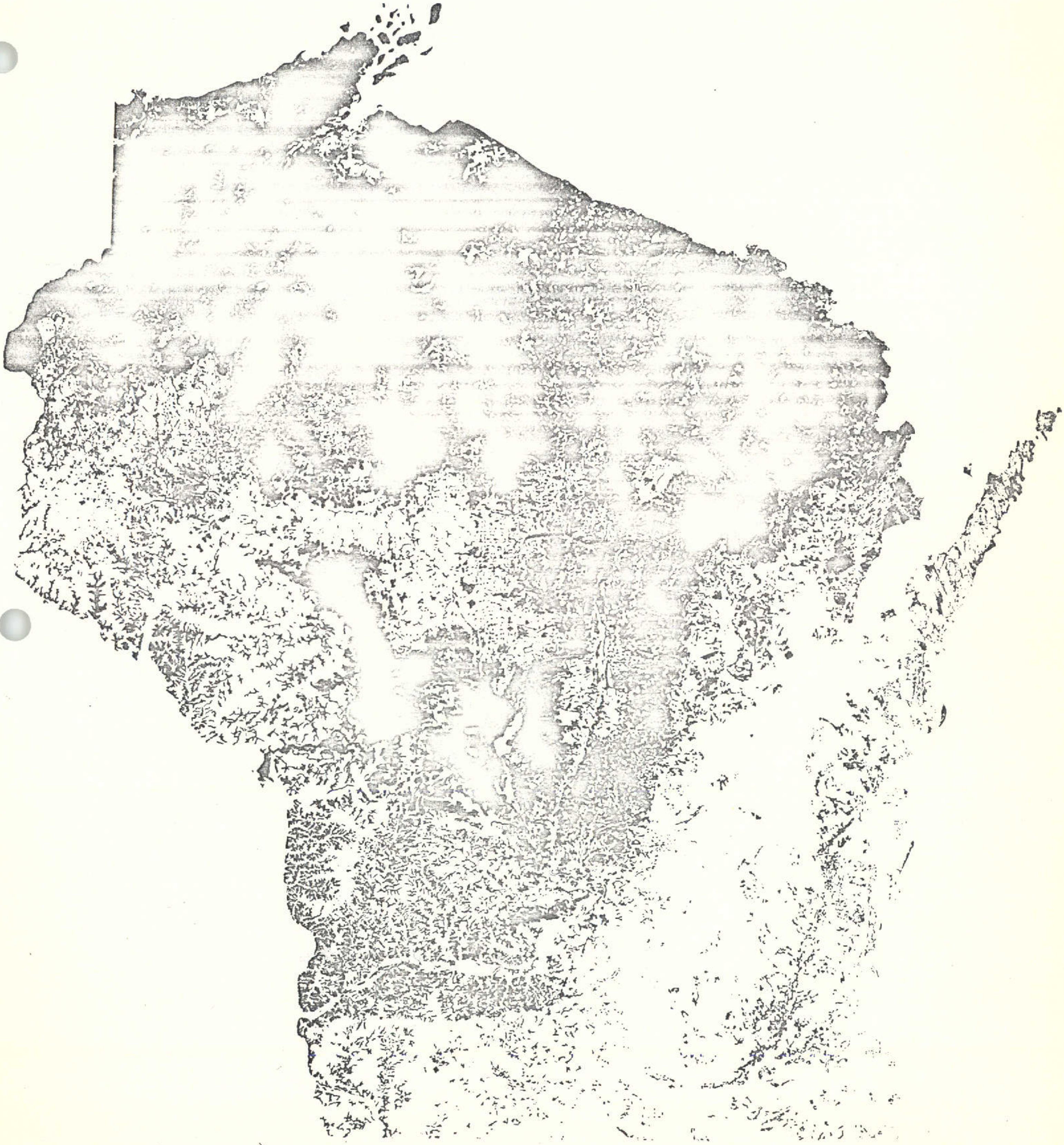


FIGURE 18. Forested Areas in Wisconsin.

FIGURE 19. Urbanized Areas in Wisconsin.

FIGURE 20. Agricultural Land and Other Open Areas
in Wisconsin.

2. Recommendations to the Wisconsin Department of Natural Resources (DNR)

A paper on the utility of ERTS and RB-57 data for wetland mapping in[1] Wisconsin has been completed. The report recommends RB-57 data as the base from which mapping can be done sufficient to meet most of DNR's needs (See Appendix E).

VII PROGRAM FOR THE NEXT REPORTING PERIOD

The same variables previously extracted from ERTS image data will be extracted from the screen of the I^2S additive color viewer. Similar attempts are planned for the McIDAS system.

VIII CONCLUSIONS

ERTS data can be used in the land planning and allocation process through the use of dynamic computer modeling. This process uses the most sophisticated techniques available to planners today. While ERTS can provide data suitable for gross land use decisions, only the planning practitioners in the field can attest to the adequacy of land use allocations formulated from ERTS data.

Other preliminary conclusions reached thus far:

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 critical land resources and the parameters which determine them in terms of measurement techniques economically available.

3. It is essential to establish precise criteria and data required for the establishment and measurement of the relative quality of critical resources.

4. ERTS derived data/information is potentially superior to conventional land use data for those items (which) 1) change rapidly with time, and (2) for which conventional data is not available.

5. For broad land cover assessment, data derived from ERTS by non-sophisticated methods is sufficient for initial resource assessments at the state or regional policy level.

6. More specific land resource information is available from ERTS if machine-based analysis techniques are employed.

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

8. A state or regional data/information system must encompass a hierarchy of data sources including satellites, high-altitude aircraft, low-altitude aircraft, and ground-based surveys.

9. ERTS has provided a focus from which the regional land use planning data/information problem can be approached.

10. Any effort directed toward the implementation of a data/information system for regional land-use planning must be multidisciplinary.

11. 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.

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

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

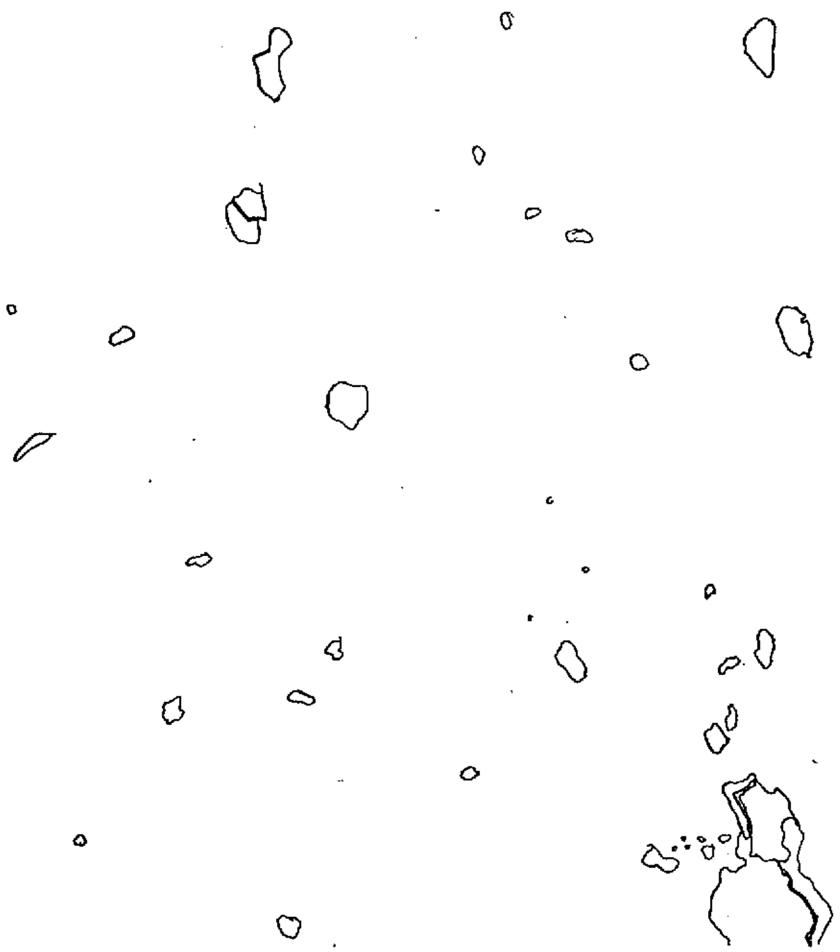
APPENDIX A

PATTERN EXTRACTIONS FROM

ERTS 1:1,000,000 IMAGES

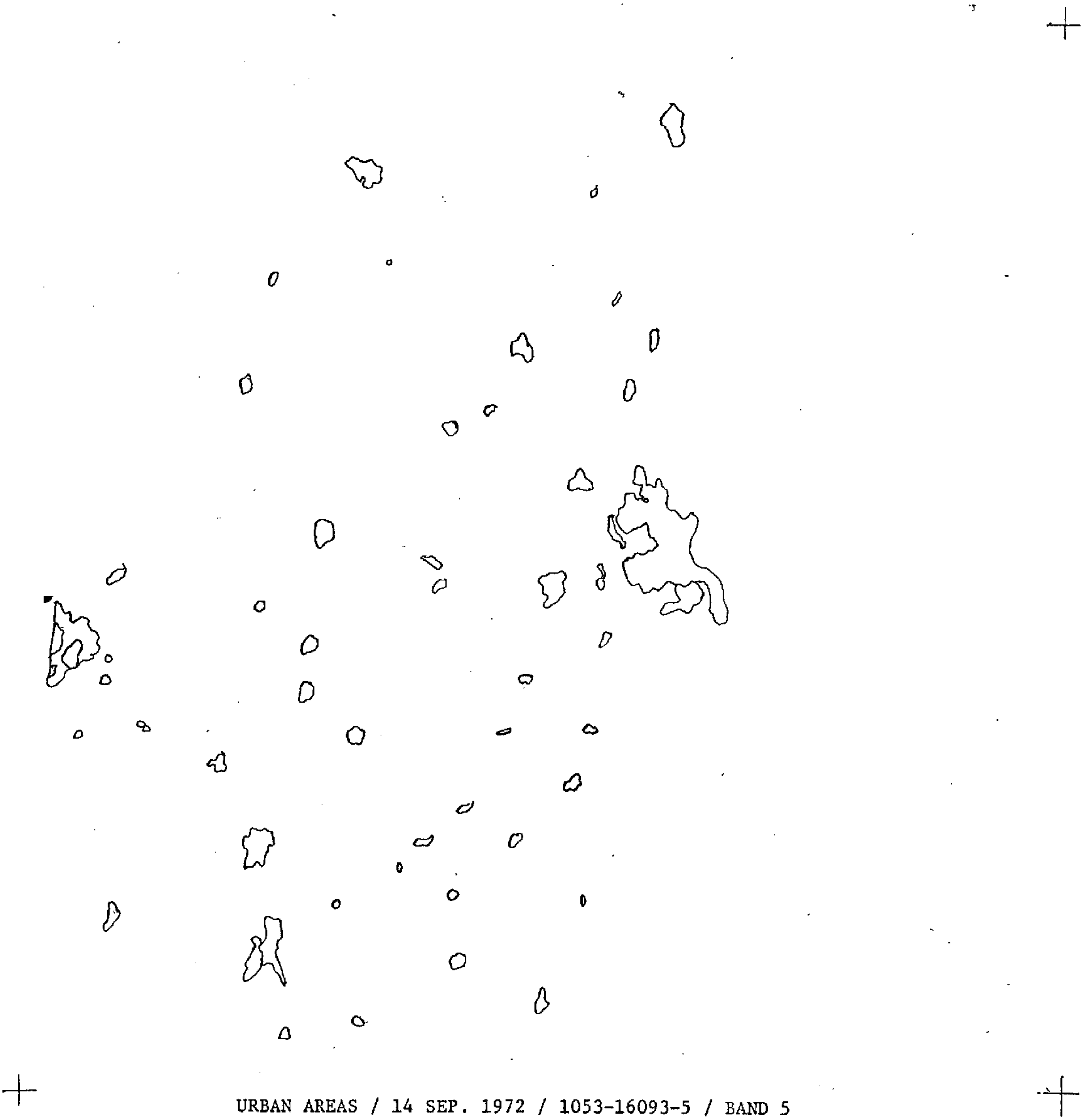
ALGAL BLOOM / 9 AUG. 1972 / 1017-16090-7 / BAND 7

ALGAL BLOOM / 9 AUG. 1972 / 1017-16091-6 / BAND 6



URBAN AREAS / 9 AUG. 1972 / 1017-16091-5 / BAND 5

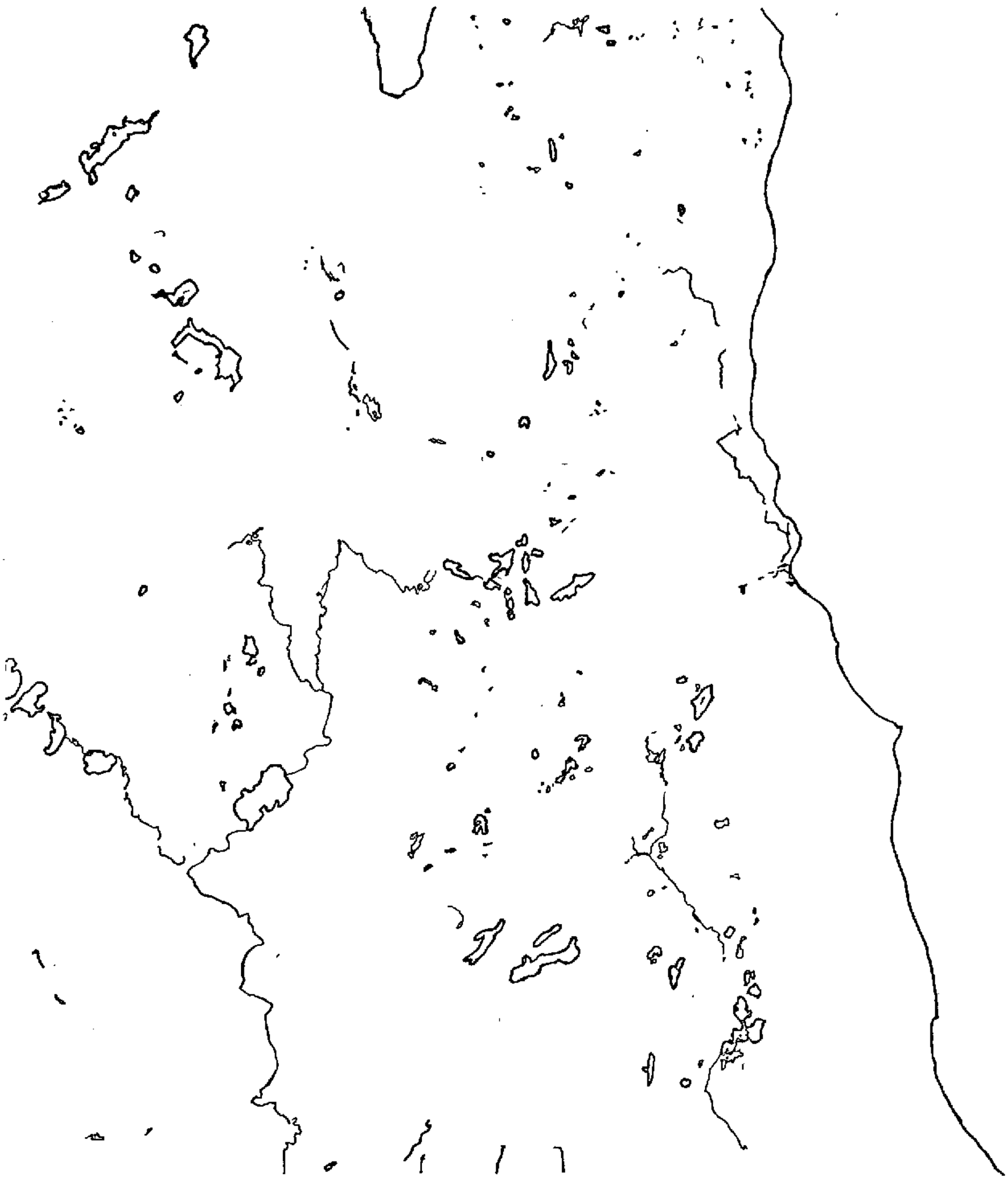
ALGAL BLOOM / 9 AUG. 1972 / 1017-16091-IR / COMPOSITE



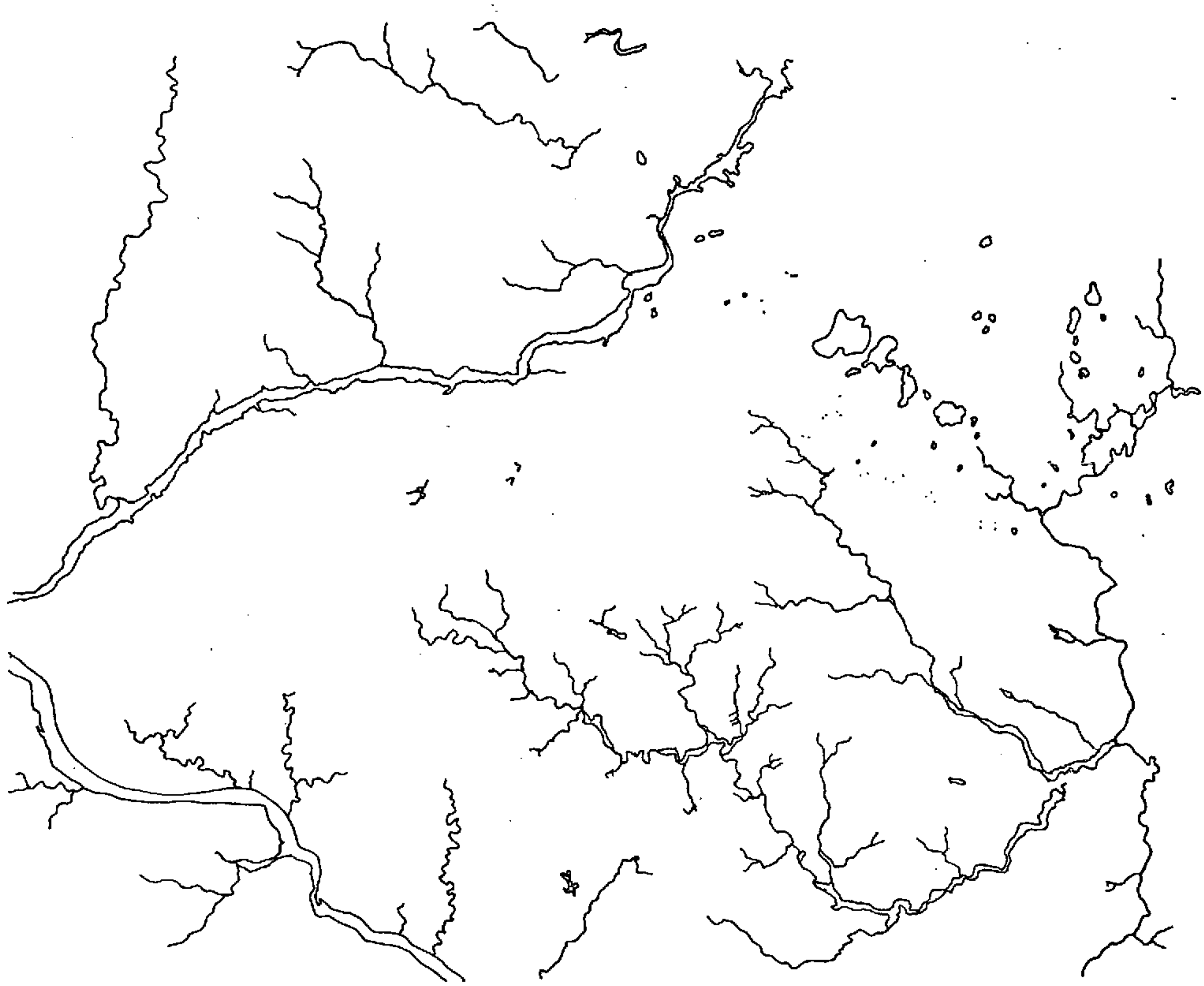
URBAN AREAS / 14 SEP. 1972 / 1053-16093-5 / BAND 5

WETLANDS / 20 OCT. 1972 / 1089-16093-IR / COMPOSITE

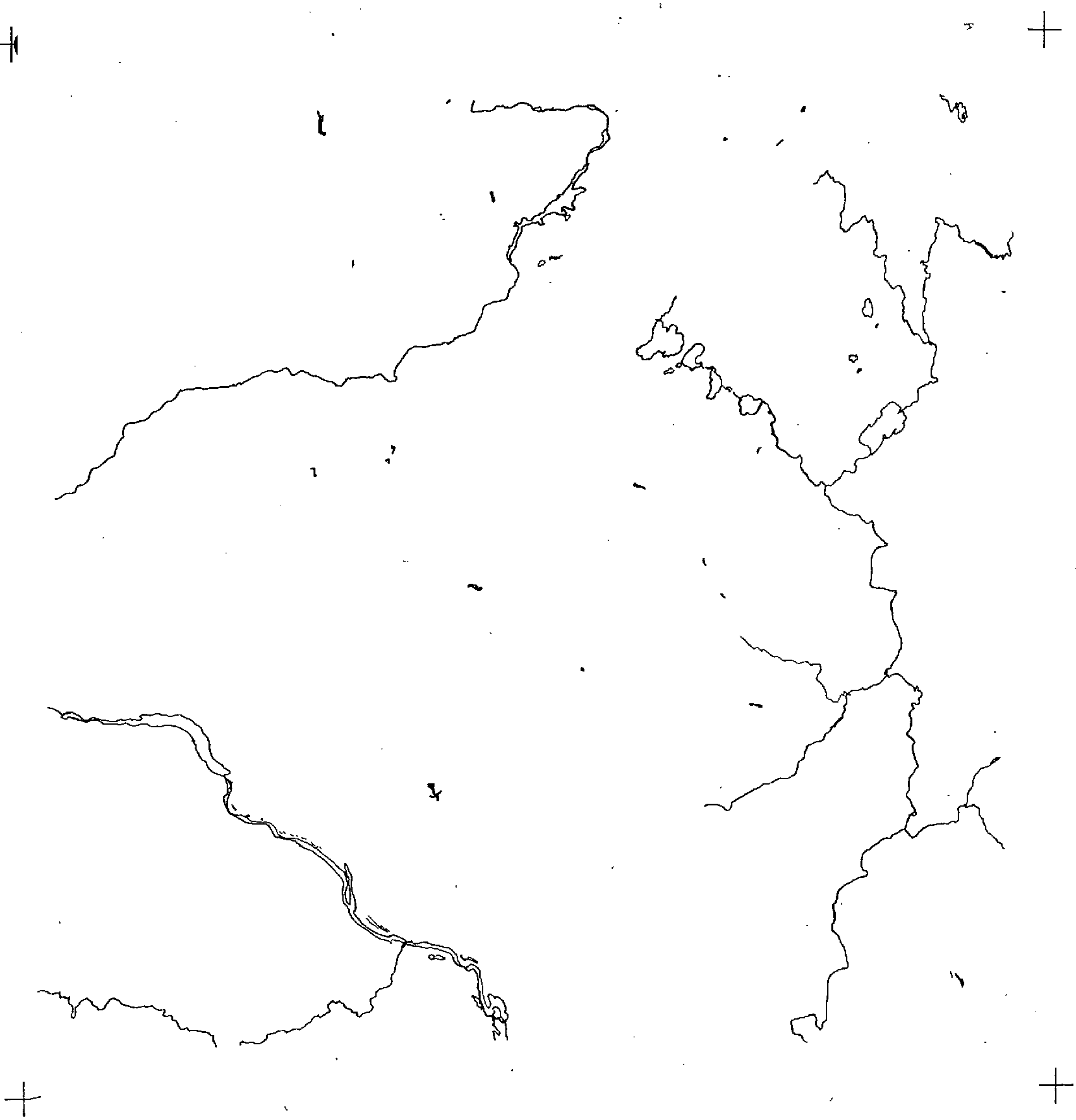
WETLANDS / 9 AUG. 1972 / 1017-16091-IR / COMPOSITE



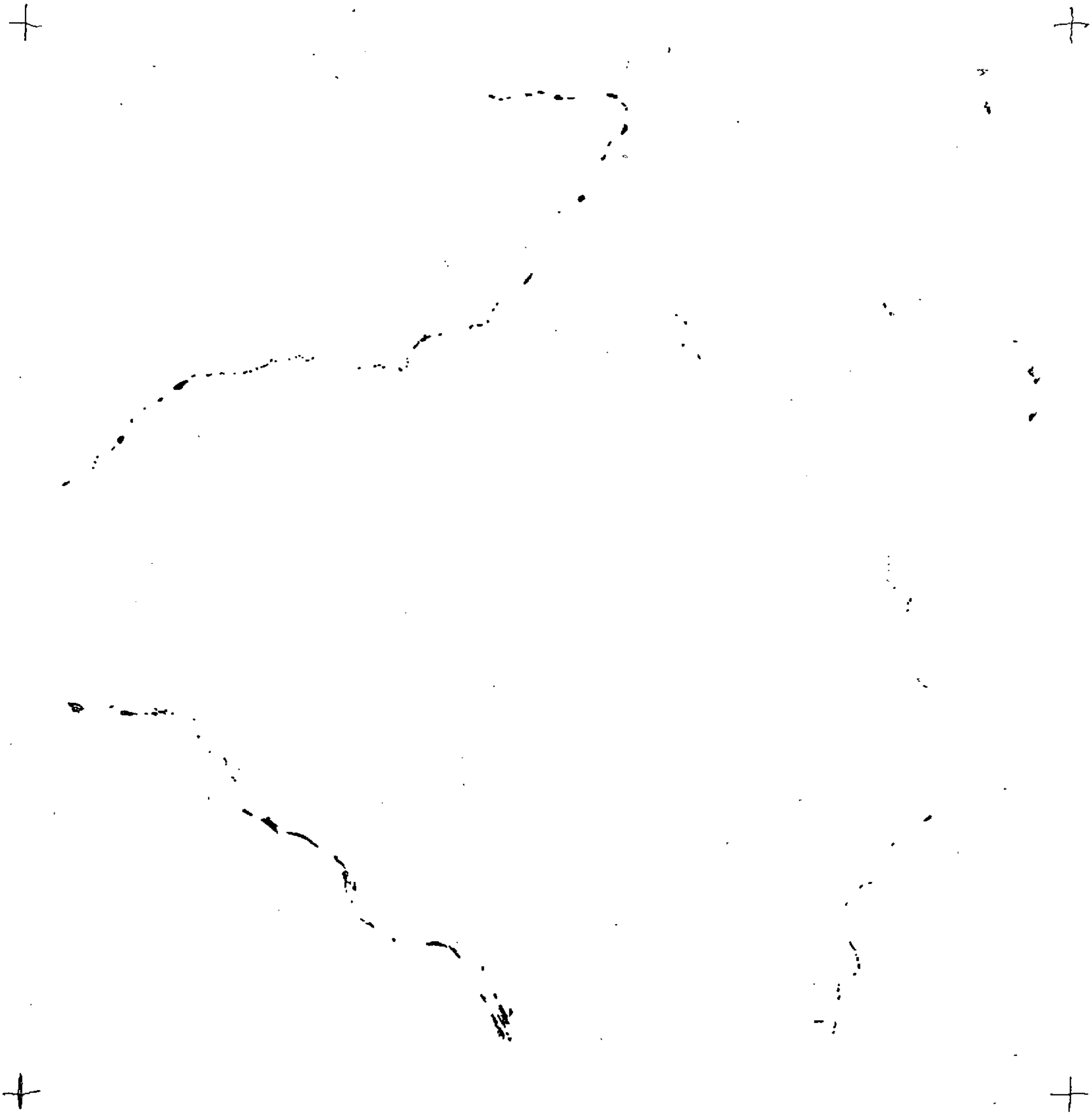
SURFACE WATER / 14 SEP. 1972 / 1053-16093-IR / COMPOSITE



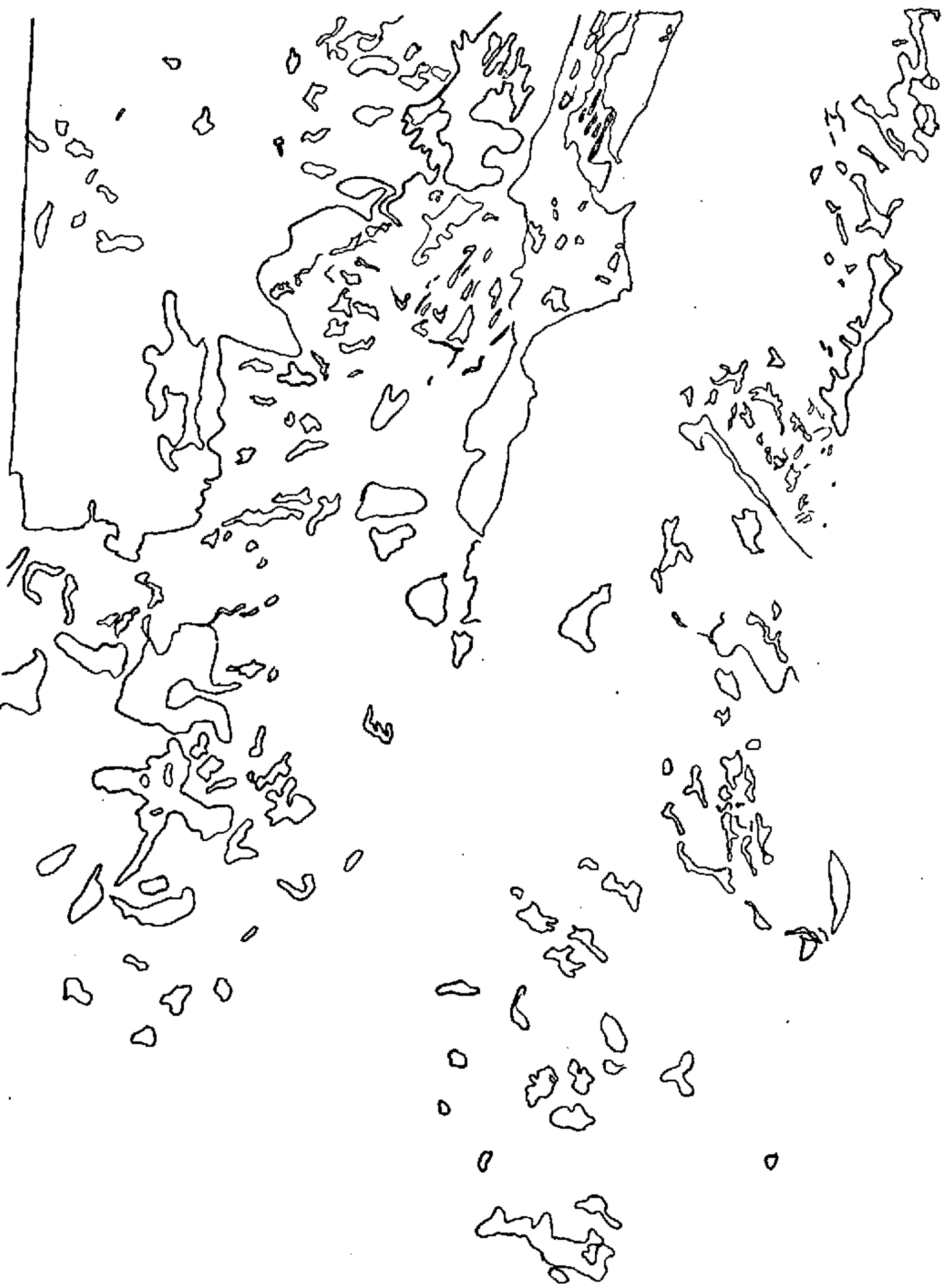
SURFACE WATER / 14 MAR. 1973 / 1234-16162-7 / BAND 7



SURFACE WATER/28AUG.1972/1036-16152-7/BAND 7



ISLANDS / 28 AUG. 1972 / 1036-16152-7 / BAND 7



FOREST COVER / 20 OCT. 1972 / 1089-16093-IR / COMPOSITE

FOREST COVER / 14 SEP. 1972 / 1053-16093-IR / COMPOSITE

CONIFER SWAMP / 20 OCT. 1972 / 1089-16093-IR / COMPOSITE

APPENDIX B

McIDAS

CHAPTER IX

MAN-COMPUTER INTERACTIVE DATA ACCESS SYSTEM (McIDAS)

PRESENTED BY: W. W. Kuhlow[1]

REPORTED BY: E. L. Kuhlmey[2] and D. R. Laux[3]

ABSTRACT

The Man-Computer Interactive Data Access System (McIDAS) is an interactive display and access system being developed by the Space Science and Engineering Center, University of Wisconsin, Madison, Wisconsin. The system will allow many kinds of data enhancement and analysis procedures to be performed by varying users. The capabilities of the system will be developed as specific tasks are required by the user.

INTRODUCTION

Investigators dealing with remote sensing data are becoming aware of the inadequacy of conventional means for handling it. There is a widening gap between the rate at which remote sensing data is being acquired and the rate at which it is being analyzed, assimilated, and displayed in a useful manner. A system called McIDAS (Man-Computer Interactive Data Access System) is currently being developed at the University of Wisconsin's Space Science and Engineering Center (SSEC) which promises to be a useful tool for accessing large quantities of digital data. SSEC's principal effort has been directed towards developing McIDAS to obtain wind data sets. McIDAS TV display prototype hardware and the navigation and cloud wind computation (WINDCO) has been in operation since April 1972. While algorithms to obtain wind data sets are not directly applicable to other remote sensing groups, research is proposed to investigate and develop man-computer algorithms useful to other remote sensing applications. Data handling techniques found to solve one problem will most likely have a counterpart solution to a similar problem in another field.

GENERAL DESCRIPTION OF McIDAS

McIDAS is a member of a family of interactive data access systems developed elsewhere. Similar installations have been developed by the Laboratory for Applications of Remote Sensing (LARS) at Purdue University, the Stanford Research Institute (SRI), NASA-Houston, General Electric, and

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2 - Graduate Student, Department of Landscape Architecture, The University of Wisconsin, Madison, Wisconsin.

3 - Graduate Student, Department of Landscape Architecture, The University of Wisconsin, Madison, Wisconsin.

Philco. McIDAS is one of the more sophisticated of these systems combining features from these into one system.

The system will allow digital data to be displayed in visual form on a color TV which is controlled by a Datacraft 6024/5 computer (Figure 1). This arrangement, which allows the raw or processed digital data associated with each pixel (picture element) to be available at all times to the computer, makes McIDAS superior to many of the aforementioned interactive display systems. The operator manipulates the visual data by communicating with the computer via a teletype keyboard. The keys on the teletype keyboard will not only function in their conventionally alpha-numeric level, but are presently being modified to serve as function switches. In this "function switch level" of operation an entire program (for example, one whose "function" is to remove some of the noise from the raw data displayed on the TV) can be called into action and implemented by depressing one or two keys. This feature relieves the operator from needing a computer programming background.

In addition to the teletype keyboard, the console also has a joystick to steer a rectangular cursor superimposed on the TV screen to any area on the screen. Once the cursor is in the desired place, the operator can instruct the computer to consider only the area within the cursor and magnify it to full screen size or select specific coordinates which can be immediately referenced to its geographical coordinates. The system also is designed to incorporate two black and white TV monitors to record the commands the operator gives the computer to display digital results, histograms of scene brightness values, and other record keeping and archival procedures.

FUNCTIONS

The present capabilities of the system are being developed to meet the needs of the meteorological community in wind vector analysis of ATS and SMS satellite data. Investigation is proposed to develop operator options and man-computer algorithms which will be most useful to remote sensing groups in other fields of study. The capabilities of the system are such that it can accept data other than satellite data. There are several programs and techniques tried and tested elsewhere that can be obtained to aid in ecological and natural resource inventory and monitoring studies, air pollution detection, water pollution and quality monitoring, and other areas. The system operates entirely with digital input; there are no optical capabilities at present, although an image could be densitized elsewhere for input into the system. A TV camera might also be used for input.

Because of the selection and interfacing of the hardware which make up McIDAS, the limitation of McIDAS in addressing the remote sensing groups' needs is primarily its software capabilities. This means that if one encounters a problem in getting a better "handle" on his data, it is likely that in most cases his problem can be alleviated by making available additional functions to the operator via the teletype keyboard.

The following are examples of the functions or procedures that can be handled by McIDAS:

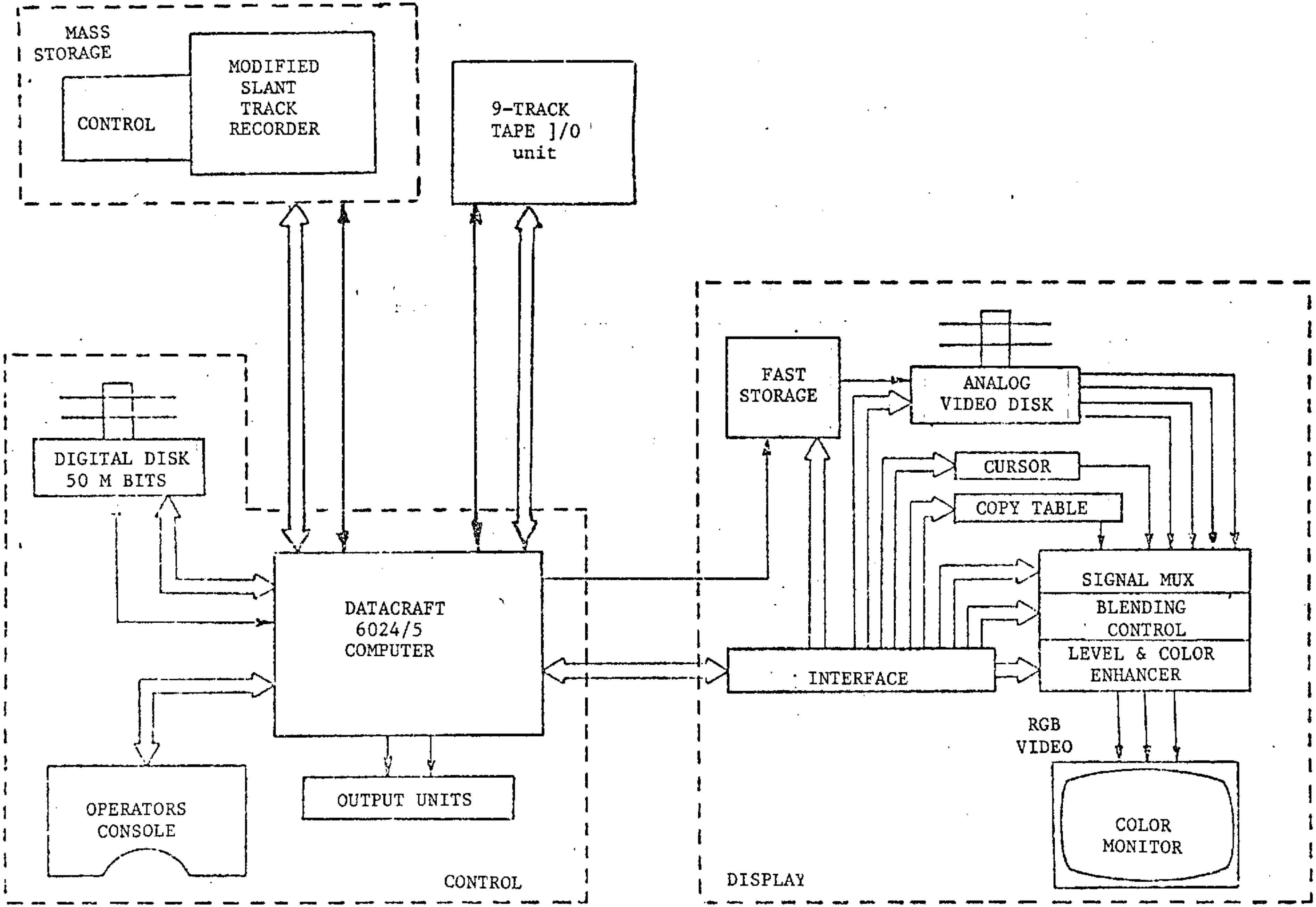

Figure 1. Wisconsin McIDAS System Block Diagram.

1. Image Enhancement - intensity, hue and chromaticity
   a) Density slicing and contouring
   b) Contrast stretching
   c) Image addition and subtraction
   d) Image smoothing
   e) Image sharpening
   f) Color additive viewing
2. Image Restoration
3. Image Segmentation
4. Pattern Recognition
5. Data Smoothing
6. Edge Matching
7. Projection Change
8. Looping or sequential display of images in proper registration

HOW THE SYSTEM WORKS

The image is entered in the TV monitor via magnetic tape. The image is a mosaic of small squares of varying shades of intensity which are resolution elements or picture elements. These squares build up gray levels into a picture. Up to 64 gray levels can be manipulated and displayed compared to the 22-25 gray levels which can be perceived by the human eye. In image processing each gray level can be converted to any other gray level.

In contrast stretching, for example, a narrow range of the gray scale can be expanded by spreading the range out over the entire gray level range. The eye response of a human is that of perceiving ratios of gray levels. Realizing this, a processing function can be performed where density levels can be expanded to yield a perceivable representation of a feature. In this way, areas with low contrast can be enhanced by increasing the contrast to enhance features.

Pattern recognition is another example of the capability of the system. A pattern or feature of interest can be displayed, the cursor placed on the pattern, and a statistical distribution of the density range of that area can be recognized by the computer as the theme of that area. A histogram of this distribution can be displayed on one of the black and white TV monitors. The entire scene can then be searched to find other areas of same theme. Once found and properly recognized, the area of any feature can then be calculated by totaling the number of picture elements in any one pattern. The pattern recognition capability may require a back-up computer in addition to the DATACRAFT; a lot depends on the sophistication of the pattern recognition algorithm.

The McIDAS system will allow multiple data inputs and blending. The analog disc will have four independent information channels which will allow, for example, simultaneous display of ERTS visible channel data, ERTS infrared data, and grids, etc. These data sources (and many other possible sets) can be blended in a variety of ways to aid in analysis. Among these are tri-color displays in which each of three data channels controls one of the three red, green or blue guns of the color monitor. Another feature is matting in which one data channel controls the display of another channel. In this way it is possible to cause infrared displays to appear for only those areas exceeding a specified visible channel radiance threshold, thus aiding in the location of high emissivity surfaces.

The system also provides the operator with the ability to set up a digitally controlled loop of up to several hundred TV frames. The system will then automatically display the pictures in sequence, retrace back to the beginning and repeat. The speed can be controlled by the operator from about 10 frames per second to one frame every 2 seconds. Manual operation is also possible. These functions thus allow the operator to play back the data fast enough to produce a "movie" effect. This allows the operator to go from raw digital data to a dynamic display without the time delay and registration problems inherent in hard copy and film loop methods.

McIDAS provides interactive digital color and level enhancement where a digitally specified enhancement, updated by computer at TV frame rates, can convert any set of data levels to a new set of data levels, a set of hues, or a combination of both. Digitally specified enhancement offers great flexibility in data manipulation over analog enhancement because contour intervals can be arbitrarily and instantaneously delineated by changing data levels to intermediate intensity values. For example, changing intermediate intensity values to zero results in a black border to clearly outline each color line. Spectral signatures can be discovered quickly by the operator because color and level enhancement can be performed in real time. Since the image is digitally enhanced and the new enhancement values computer specified, the automated pattern recognition technique is greatly simplified.

Interactive computations and rapid access of up to 6 TV frames of digital data allows any one of the 6 frames to be observed on the TV monitor. A portion of an image frame selected by the cursor can be almost immediately "magnified" to fill the TV screen. Rotating and stretching of images of a scene can provide image registration that is far more accurate than by optical means. Stretching might also require a larger computer.

ARCHIVE DATA STORAGE

In addition to the conventional 7 or 9 track magnetic tape input, the McIDAS computer will be interfaced with two slant track video tape recorders which can archive input from high density video tapes. These recorders can record digital information on the tapes to a capacity of 75 billion bits per tape. This capacity is equivalent to digital data from:

1. 400 ERTS-1 MSS scenes (4 bands per scene). This is equivalent to 2 years coverage of the state of Wisconsin. 50 to 60 TV frames will be required for one scene (100 x 100 miles) at full resolution. Thus, each ERTS-1 display will be about 14 miles on a side on the TV screen.

2. ERTS-1 scenes for the continental United Stated for 1 year on 12 such tapes.

3. Over 1000 images from 9"x9" photographs digitized into 100 micron cells at 256 gray levels available per cell (encoded to 8 bits).

A maximum of 3 minutes is required to access any image on the tape.

SUMMARY

McIDAS will be capable of accepting remote sensing data either as digital tape or densitized images, aligning, displaying in color, and performing designated recognition or measuring processes. The ability to display frames alternately or in rapid succession as a time sequence with various forms of enhancement will provide a powerful tool for analysis, limited only by the ingenuity of the experimenters.

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APPENDIX C

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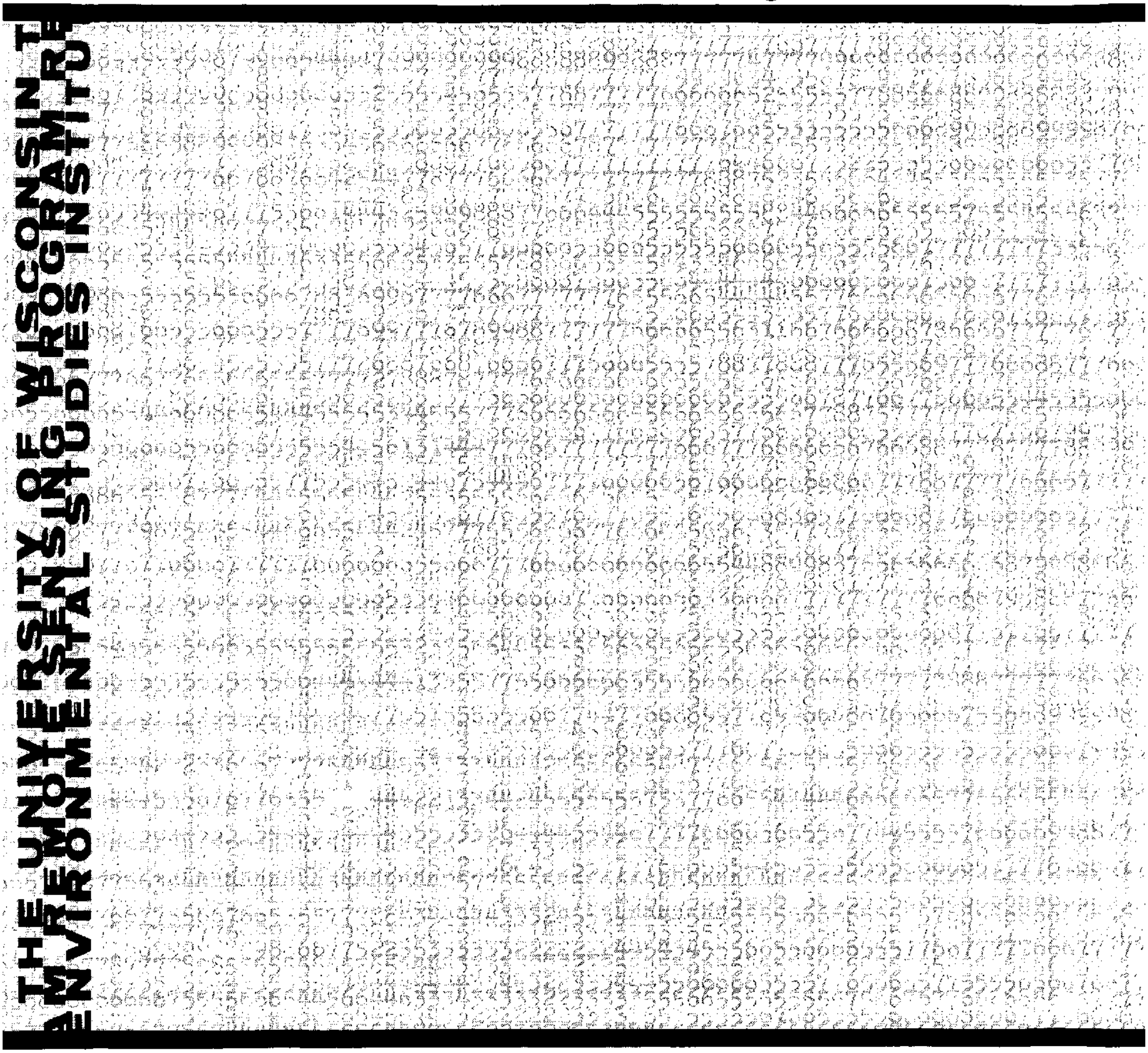
D. L. Keyes, E. L. Kuhlmey

THE UNIVERSITY OF WISCONSIN
REMOTE SENSING PROGRAM
ENVIRONMENTAL STUDIES INSTITUTE



CRITICAL LAND RESOURCES INVENTORY USING ERTS DATA

70<

CRITICAL LAND RESOURCES INVENTORY USING ERTS DATA

R. W. Kiefer, A. H. Miller, B. J. Niemann, Jr.,
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University of Wisconsin—Madison
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Remote Sensing Program
Report No. 25

November 1973

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BIOGRAPHICAL SKETCHES

Ralph W. Kiefer is Professor of Civil and Environmental Engineering at the University of Wisconsin—Madison. Allen H. Miller is the Land Use Coordinator of Wisconsin's State Planning Office. Bernard J. Niemann, Jr., is Professor and Chairman, Department of Landscape Architecture, University of Wisconsin—Madison. Dale L. Keyes is Project Coordinator for the Critical Resources Information Program (CRIP) research project at the University of Wisconsin--Madison. Edward L. Kuhlmey is Project Coordinator for the Earth Resources Technology Satellite (ERTS) research project and Project Investigator on the CRIP research project, both at the University of Wisconsin—Madison.

ACKNOWLEDGEMENTS

Michael M. McCarthy served as ERTS project coordinator during the period July 1972 to June 1973. Much of the work reported in this paper was performed under his guidance. John Wayne Aderhold performed some of the ERTS and RB-57 interpretations described in this paper. Umit Basoglu wrote the computer programs for the ERTS, RB-57 and REMAP spatial/statistical comparisons (Figures 5-8).

William W. Kuhlow, in cooperation with the University of Wisconsin Space Science and Engineering Center, supervised the computer operations using ERTS digital tapes (Figures 10-12).

ABSTRACT

The State of Wisconsin has embarked on a Critical Resources Information Program aimed at defining, establishing the units of measurement, inventorying, and monitoring natural and cultural spatial resource elements which are of statewide or regional significance. This paper presents the results of using ERTS data to inventory certain significant natural resources, such as agricultural land, forests, surface water and wetlands. Computer-generated spatial and statistical comparisons of resource data derived from conventional sources, RB-57*photographs, and ERTS images of Wisconsin suggest that certain resources can be inventoried and monitored on a statewide basis using ERTS images. Preliminary results of data extraction using ERTS digital tapes are also presented. The interpretation of certain natural and cultural resource information from ERTS images is anticipated to be an operational part of Wisconsin's Critical Resources Information Program.

INTRODUCTION

The years of the 1970's have lead to a growing social awareness of man's environment, a re-awakening of ecological interest, and a perception of the need to manage more wisely our land and water resources. In Wisconsin, the conversion rate of agricultural land to other, primarily urban-related, land uses is 200,000 acres annually. State recreational facilities are overcrowded, leading to a consideration of requiring advance registration for use of public parks. The alteration of wetlands, the development of flood plains and shorelines, the encroachment on the more primitive areas of the state, the pressure for major power generating and transportation facilities, and the consumption of scientific, historic, and unique resources by urbanization, have led to a re-examination of the goals of the citizens of Wisconsin and their effects on the state's finite natural resources.

The above concerns have manifested themselves in dramatically increased public participation in major land use decisions. In the State of Wisconsin, two major study committees were initiated in the summer of 1971: the Governor's Wisconsin Land Resources Committee and the University of Wisconsin Faculty Land Use Problem Definition Seminar. The recommendations of these committees [1,2] have led to two major programs within the State of Wisconsin Bureau of Planning and Budget (Department of Administration). One, the Wisconsin Land Use Information System is directed at the acquisition, storage and analysis of land use related data. The other, the Critical Resources Information Program is directed at the definition, delineation, and methodology required to inventory and monitor resources of statewide and regional concern.

* Refers to a reconnaissance bomber which has been converted for use in high altitude photography.

Both the Wisconsin Land Use Information System and the Critical Resources Information Program (CRIP) respond to major existing and proposed federal legislation, specifically: the National Coastal Zone Management Act of 1972, the Rural Development Act of 1972, and the Land-Use Policy and Planning Assistance Bill (passed by Senate). Each of these federal programs necessitates a means to continually monitor a wide array of natural and cultural data with emphasis on "critical resources". Because of the need for continual monitoring over time and the complexity of the spectral and temporal responses related to specific resource data, the ERTS satellite appears to be a feasible platform-sensor combination for use in continuing inventories of diverse resource data covering large areas.

In this paper is discussed the research which has been undertaken to evaluate the utility of ERTS systems for providing the data necessary for state and federal programs related to land use planning in general and to the identification of critical natural and cultural resource areas in particular. Many approaches have been used throughout the nation to define and identify resources of critical concern to its citizens. Many have sought local governments or special interest groups to assist in defining these special areas. Wisconsin has pursued a different and perhaps more difficult course in attempting to identify the parameters to be used to measure criticality and to establish the measurement thresholds that cause the resource to become critical to the State as a whole.

The CRIP program is in its early stages of development. As a methodology, it is being reviewed by local, regional, and state planners, resource managers, and resource experts. When the resource assessment methodology and the information system to handle resource data are finalized, CRIP will be applied on a statewide basis. Our findings to date on the utility of ERTS as a data source for both the development of CRIP methodology and the statewide application of the developed system are discussed in this paper.

DATA NEEDS

Because of the overlap between planning and regulatory authorities at various governmental levels, and the necessity for statewide protection, the State of Wisconsin is engaging in planning and regulation activities involving physical resources of greater than local concern. These resources are being evaluated as a part of the CRIP program. The CRIP data needs relate to specific natural and cultural resources which have been identified by various groups concerned with the issues of land use and critical resource protection. Principal among these groups are the Governor's Wisconsin Land Resources Committee and the Faculty Land Use Problem Definition Seminar, as mentioned previously. These groups identified numerous resource systems which are of primary statewide importance, including the following: prime agricultural lands; prime forest lands; prime recreational areas; prime scenic lands; prime wetlands; prime wilderness areas; prime mineral resources; prime scientific resource areas; areas of frequent flooding and flood plains; areas subject to serious erosion; areas impacted from urban development; areas impacted from agriculture; areas adjacent to critical resources; and coastal zone areas.

Drawing from this list, the CRIP study has enumerated natural and cultural resources which are of statewide concern and the presence of which will form the basis for ascertaining the criticality of land and water areas in the state. These are: (1) forests; (2) grasslands; (3) wetlands; (4) the ground water reservoir; (5) lakes and shoreland; (6) streams and shoreland; (7) agricultural land; (8) non-metallic mineral deposits; (9) metallic mineral deposits; (10) special geologic features; and (11) historic, archeologic, and architectural features. In addition to these single aspect type resources, composite or combination resource systems will be delineated and evaluated. Resources such as scenic resources and floodplains are mixtures of basic resources and therefore are considered as composite resource systems. Geographical areas containing the single aspect and composite resources will be assessed based on both their value for a variety of activities and the probability of degradation.

An effort has been made to organize the data required to assess the natural and cultural resources listed above. The framework of the resulting "Organization of Environmental Data" is presented as Figure 1.

FIGURE 1

ORGANIZATION OF ENVIRONMENTAL DATA

I. NATURAL COMPONENTS
- A. Abiotic
  - 1. Hydrologic
    - a. Surface Water (name, type, location, quality, quantity, sensitivity)
    - b. Ground Water (name, aquifer location, quality, quantity, seasonal fluctuations, depth to G.W.T., aquifer systems communication, ground water-surface water communication)
  - 2. Lithologic
    - a. Physiography (land form, specific characteristics)
    - b. Unconsolidated Earth Materials (pedological soil descriptors, soil characteristics)
    - c. Consolidated Earth Materials (bedrock name descriptors, bedrock characteristics)
  - 3. Climate (precipitation, temperature, air quality)
- B. Biotic
  - 1. Botanic
    - a. Non-crop (vegetative descriptors, quantity)
    - b. Crop (vegetative descriptors)
  - 2. Zoologic
    - a. Wild, non-game (wildlife descriptors)
    - b. Wild, game (wildlife descriptors)

II. HUMAN COMPONENTS
- A. Land Use
- B. Political Designation
- C. Value
- D. Ownership

This list has been condensed from a three-page list presented in the CRIP Phase One Report [3]. The attempt has been made here to group like data together. For example, all soil data needed to assess the criticality of agricultural lands, wetlands, and forests are grouped together under soil characteristics. The intent of this data list is to provide a unified list of the parameters which must be known to detect, quantify, evaluate and monitor the State's critical resources. Much of the required data are not currently available on a statewide basis, which points out the potential importance and application of remote sensing from high-altitude platforms in providing basic information for assessing statewide resource systems. Without question, assessment data must come from a variety of sources, of which high-altitude remote sensing is just one. The complexity and extent of the data list does indicate, however, that the greater the comprehensiveness of the useable data sources, the greater the efficacy and the higher the probability that a statewide system of assessment and regulation will be maintained.

DATA EXTRACTION

The ERTS-1 project members at the University of Wisconsin-Madison have been investigating the application and use of ERTS imagery as a data source for regional and state resource planning since the summer of 1972. This project has had a close working relationship with the CRIP project since its inception (February 1973). As a part of the ERTS project, a variety of resources are being evaluated and examined to determine the potential for the detection and monitoring of these resources from satellite and high altitude platforms. The initial data extraction was done using RB-57 images while awaiting the arrival of ERTS imagery. Since December 1972, data extraction has been performed using primarily ERTS transparencies. During the summer of 1973, efforts to extract data from ERTS tapes were initiated.

Data extraction from ERTS and RB-57 images

To determine the effectiveness of the ERTS and RB-57 sensors for resource detection and inventory, a sample site in eastern Wisconsin is being utilized. This 10 x 30 kilometer "Sheboygan Test Site", outlined in Figure 2, is part of a larger, 10,000 square kilometer, test area generally located between Green Bay and Milwaukee, Wisconsin. A computer-based data bank, called the "REMAP-I" data bank, was developed for this test area from conventional data sources such as existing maps to assist the Wisconsin Department of Transportation locate a corridor for Interstate-57 [4] and is serving as a comparison basis for the ERTS-1 investigation. Enlarged ERTS and RB-57 images similar to those used for the data extraction reported here are shown for the Sheboygan Test Site as Figures 3 and 4.

Figures 5-8 are computer-processed spatial comparisons which present quantitative information about several resources which occur in the Sheboygan Test Site, as derived from three different sources: (A) ERTS-1 multispectral imagery; (B) RB-57 high-altitude color-infrared photography;

FIGURE 2 - ERTS IMAGE OF GREEN BAY-MILWAUKEE REGION
ERTS Band 5 (MSS-Red), 9 August 1972

FIGURE 3

SHEBOYGAN TEST SITE

ERTS BAND 5 (MSS-red)
9 August 1972

FIGURE 4

SHEBOYGAN TEST SITE

RB-57, Hasselblad
b/w red band, 4 June 72

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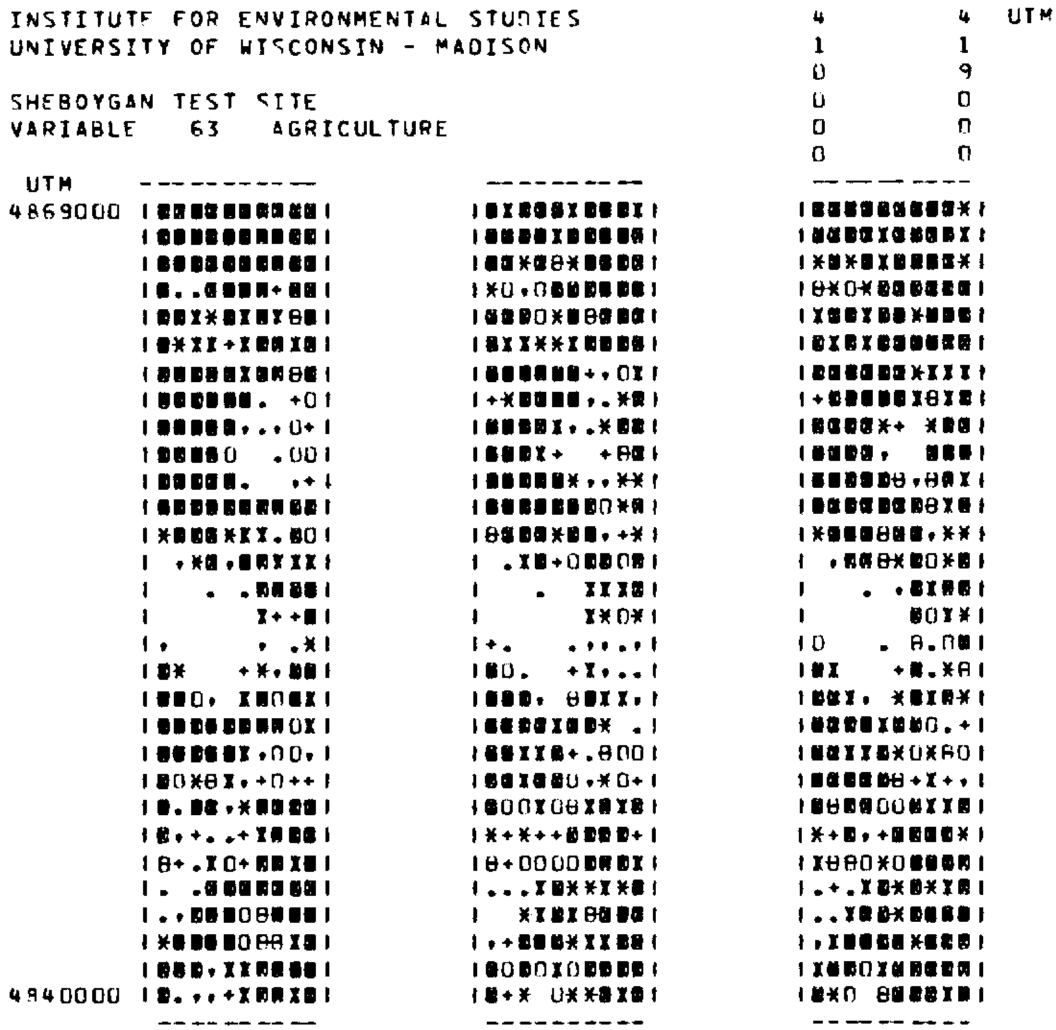
SHEBOYGAN TEST SITE
VARIABLE 63 AGRICULTURE



	A	B	C
	ERTS	RB57	REMAP I
TOT. ACRES	45351.64	44830.47	48893.61

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	OOOOO	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	18	18	16	16	7	11	27	51	61	48
	B	15	15	17	24	9	29	34	36	67	30
	C	9	9	9	14	15	29	33	52	87	20
ACRES	A	338.	803.	1111.	1549.	840.	1581.	4532.	9843.	13326.	11429.
	B	346.	709.	1262.	2337.	1089.	4229.	5790.	7059.	14825.	7185.
	C	215.	445.	672.	1383.	1823.	4347.	5676.	10268.	19328.	4737.

FIGURE 5 - AGRICULTURAL LAND USE

ERTS and RB-57 INTERPRETATIONS vs REMAP I DATA BANK

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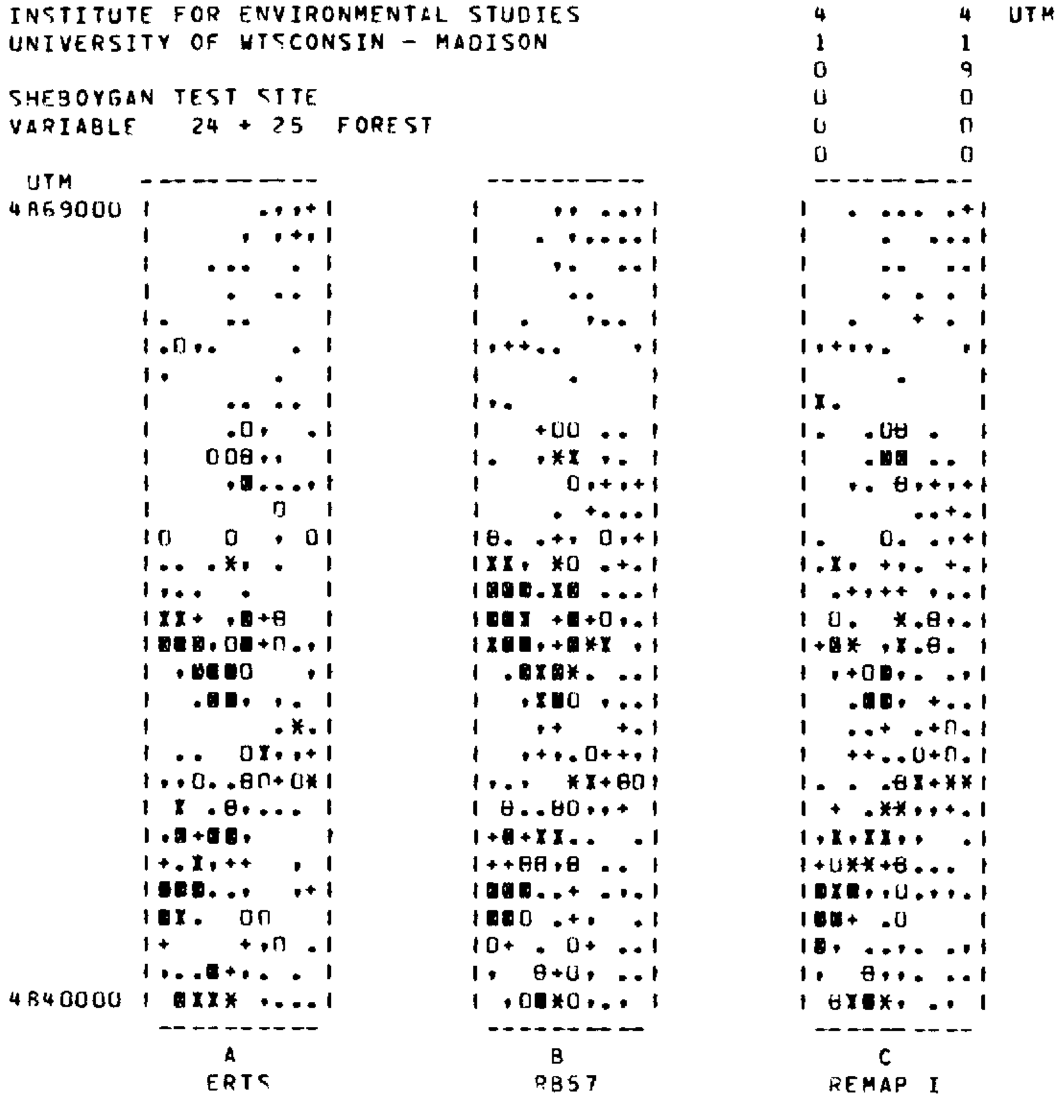
SHEBOYGAN TEST SITE
VARIABLE 24 + 25 FOREST



		A			B			C		
TOT. ACRES		11991.85			14508.77			12599.46		

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	56	37	15	18	4	4	8	9	7	4
	B	64	37	28	16	8	6	12	7	9	4
	C	77	36	26	10	8	9	9	5	6	1
ACRES	A	1141.	1598.	1042.	1680.	445.	563.	1329.	1736.	1514.	933.
	B	1272.	1645.	1974.	1494.	934.	877.	2018.	1358.	1974.	963.
	C	1776.	1743.	1796.	973.	988.	1264.	1492.	990.	1307.	245.

FIGURE 6 - FOREST LAND COVER

ERTS and RB-57 INTERPRETATIONS vs REMAP I DATA BANK

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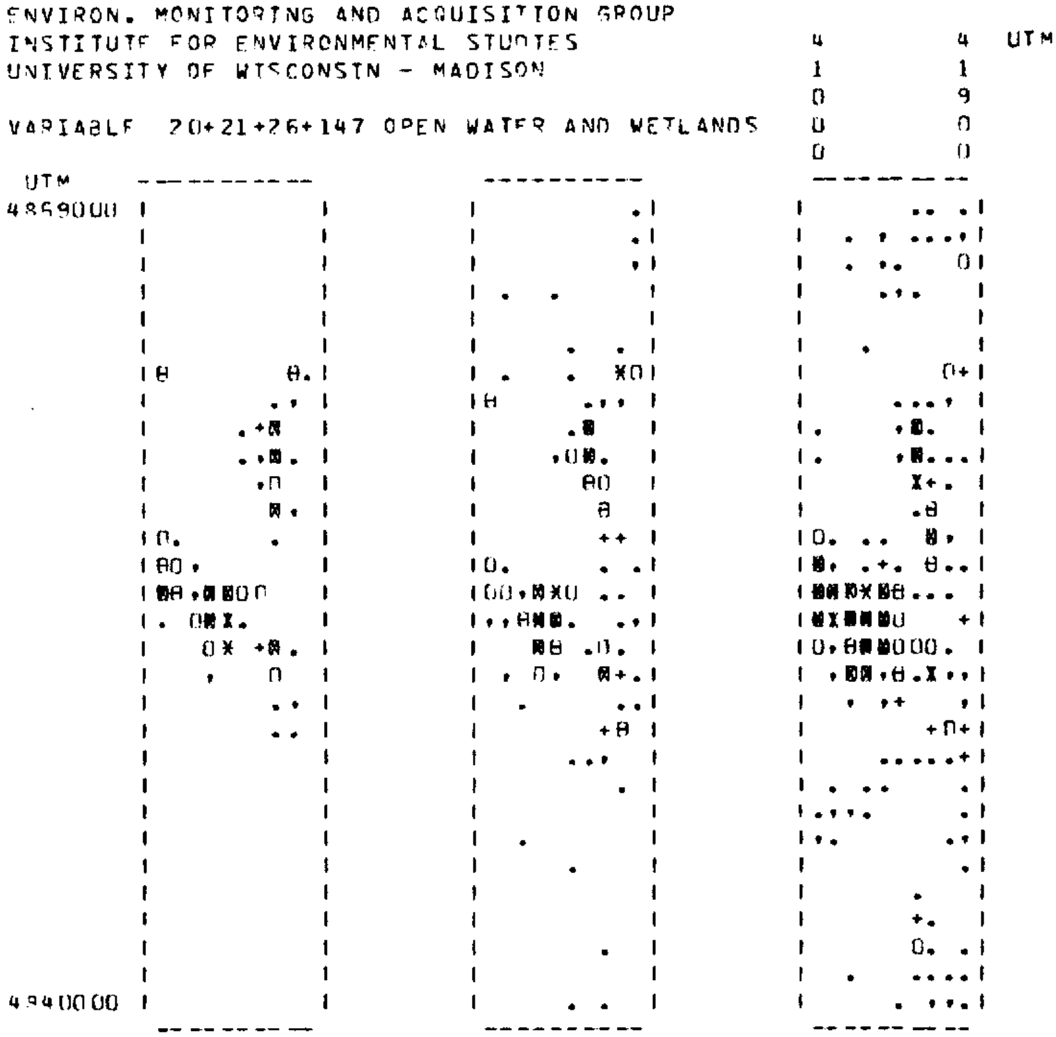
VARIABLE 20+21+26+147 OPEN WATER AND WETLANDS



	A	B	C
	ERTS	RB57	REMAP I
TOT. ACRES	3475.29	4134.78	7276.62

LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	'''''	+++++	UUUUU	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	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
ACRES	A	198.	240.	101.	664.	440.	128.	168.	716.	598.	222.
	B	259.	343.	235.	763.	635.	259.	0.	346.	198.	1097.
	C	551.	741.	482.	884.	546.	131.	457.	1126.	422.	1936.

FIGURE 7 - OPEN WATER AND WETLANDS

ERTS and RB-57 INTERPRETATIONS vs REMAP I DATA BANK

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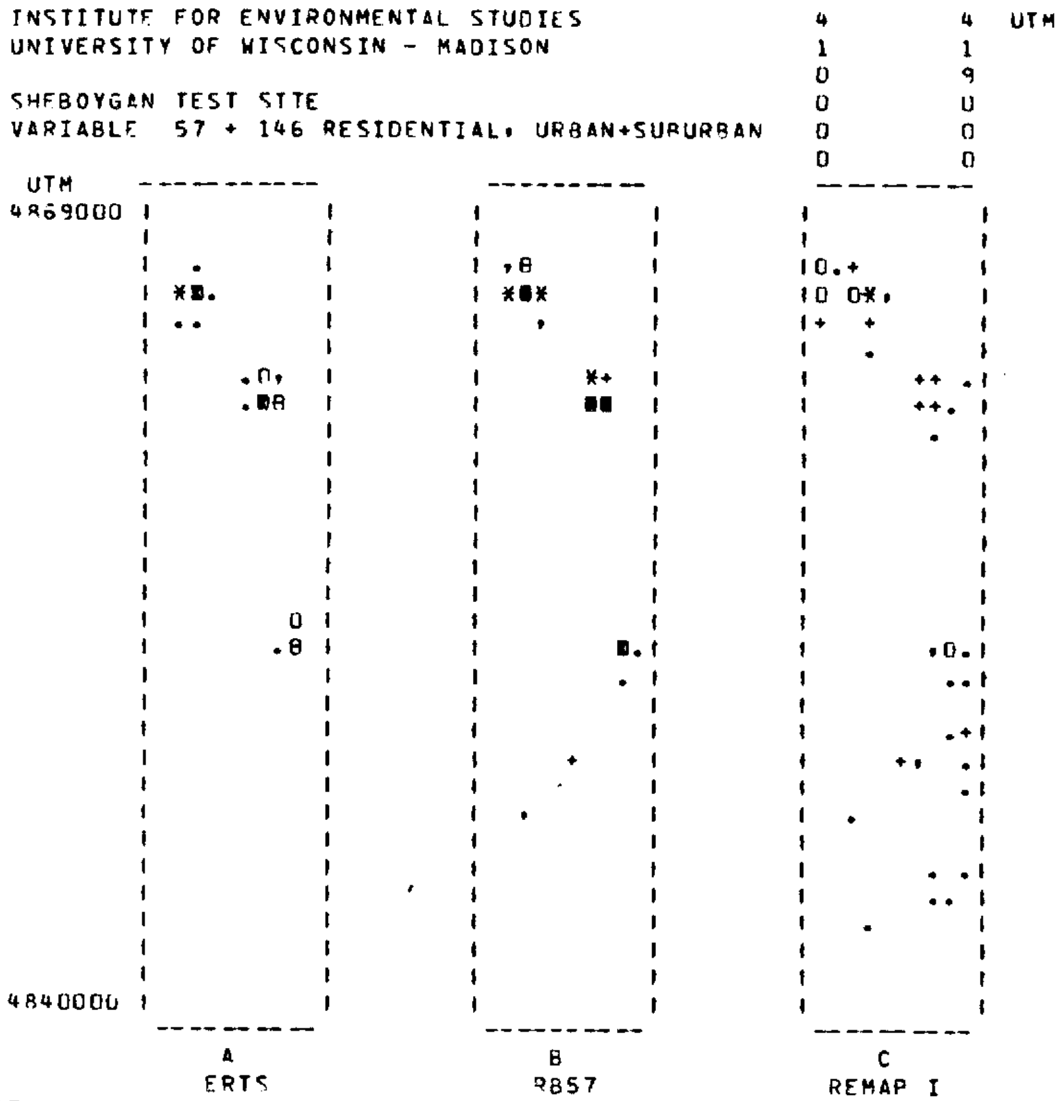
SHEBOYGAN TEST SITE
VARIABLE 57 + 146 RESIDENTIAL, URBAN+SUBURBAN



TOT. ACRES		1160.90				1842.62				1714.18	
LEVELS		1	2	3	4	5	6	7	8	9	10
SYMBOLS		.....	,,,,,	+++++	00000	88888	XXXXX	IIIII	■■■■■	■■■■■	■■■■■
RANGE (%)		1-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90-99
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.

FIGURE 8 - RESIDENTIAL LAND USE

ERTS and RB-57 INTERPRETATIONS vs REMAP I DATA BANK

and (C) the REMAP data bank. Each cell in this sample site is one square kilometer in size, spatially referenced according to the Universal Transverse Mercator (UTM) system. The density of the symbol printed in each cell shows the percentage of that cell occupied by the resource in question (e.g., agricultural land use in the case of Figure 5). Beneath the 300 square kilometer areas shown on Figures 5-8 are given the total acres of each resource as determined from each of the three data sources. Numbers of occurrence and numbers of acres for each of the three types of data source (A, B, or C) are presented for each level of occurrence.

The information derived from ERTS was interpreted from a 1:1,000,000 scale positive transparency of Band 5 of the 14 September 1972 ERTS image and the 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 shown in Figures 5-8 for the REMAP data bank was obtained from three principal conventional sources: (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).

Our 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. Our present feeling is 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 our ERTS-1 study. 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 probably not entirely accurate today. The cumulative effects of such source problems required correction by a laborious homogenizing process of updating, restructuring, verifying, and scaling information into a common format. This process was eventually successful, but the scope and accuracy 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 information available for regional scale decision making. The RB-57 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 aerial images, the use of RB-57 or ERTS images as data sources appears feasible.

Figures 5-8 display the results of our comparisons of information derived from ERTS and RB-57 images and as stored in the REMAP data bank. The land cover/activity parameters displayed in Figures 5-8 (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.

Agricultural land use: Figure 5 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 excellent 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 6 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 are treated as separate categories in the original RB-57 and REMAP data extraction but are combined into one category (Forest) in the case of ERTS data extraction. There is reasonable agreement among all three data sources, but it must be realized that the ERTS interpretation contains less discrete information than RB-57 and REMAP because upland and lowland forests have been combined in the case of ERTS.

Open water and wetlands: Figure 7 shows the spatial/statistical comparisons for land covered with open water and wetlands. Four resource variables, "rivers", "lakes", "lakes smaller than 50 acres", and "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 bogs, wet meadows, marshes, or swamps). For reasons relating to the REMAP data source problems described earlier, and for reasons detailed elsewhere [5], it appears that 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 possible using the ERTS imagery, as shown by the number of occurrences listed near the bottom of Figure 7.

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 8. 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. We are in the process of acquiring an additive color viewer (International Imaging Systems Model 6030S) and feel that this will allow for more discrete and comprehensive ERTS data extraction.

The preceeding examples have illustrated data extraction from ERTS images by use of overlay techniques whereby a one-kilometer grid was placed over ERTS transparencies at a scale of 1:1,000,000 and the percent of each one-kilometer cell occupied by various resource types was estimated. Another data extraction technique is to place clear acetate sheets over the ERTS transparencies and to draw lines around the various resource patterns. We are in the process of using this data extraction technique to map four resource patterns on a statewide basis: (1) agricultural areas; (2) forested lands; (3) surface water; and (4) urbanized areas. We have encountered two major problems in attempting these data extractions from ERTS images on a statewide basis: (1) The only relatively cloud-free ERTS imagery over the entire state within a limited time frame is during the period 13 December 1972 to 2 January 1973. We have found from our experience with RB-57 imagery and lower level imagery that the optimum time of year for interpreting the four resource patterns listed above is either the spring (15 April to 15 June) or the fall (15 September to 31 October). (2) We have found that more information can be seen on ERTS images at a scale of 1:1,000,000 than the human hand can draw lines around using the smallest available pen point. It would appear that larger scale images should be used when attempting to manually draw lines around patterns.

Data extraction from ERTS tapes

The preceding discussion has pointed out some of the problems in data extraction from ERTS images. In an attempt to explore alternate methods of data extraction, we have begun to work with digital tapes of ERTS data covering the REMAP I data bank area in cooperation with the University of Wisconsin Space Science and Engineering Center.

The specific test area to be described here is the "Sheboygan Marsh" test area shown in Figure 9. The eastern 2/3 of this marsh can be seen near the center of Figures 3 and 4. Figure 9 delineates 12 classes of water/vegetation components that were interpreted from RB-57 color-infrared photographs and represents "ground truth" for water/vegetation components in the Sheboygan Marsh.

800 bpi (9-track) "bulk" computer tapes of the REMAP area as sensed on 9 August 1972 have been reformatted for the Sheboygan Marsh test area. This test area is 270 ERTS data elements wide and 129 ERTS data elements long (a total of 34,830 data elements), or 15.4 km by 9.8 km. Histograms showing the distribution of ERTS tape brightness values for MSS bands 4, 5, and 7 associated with the data elements in this scene are shown in Figure 10.

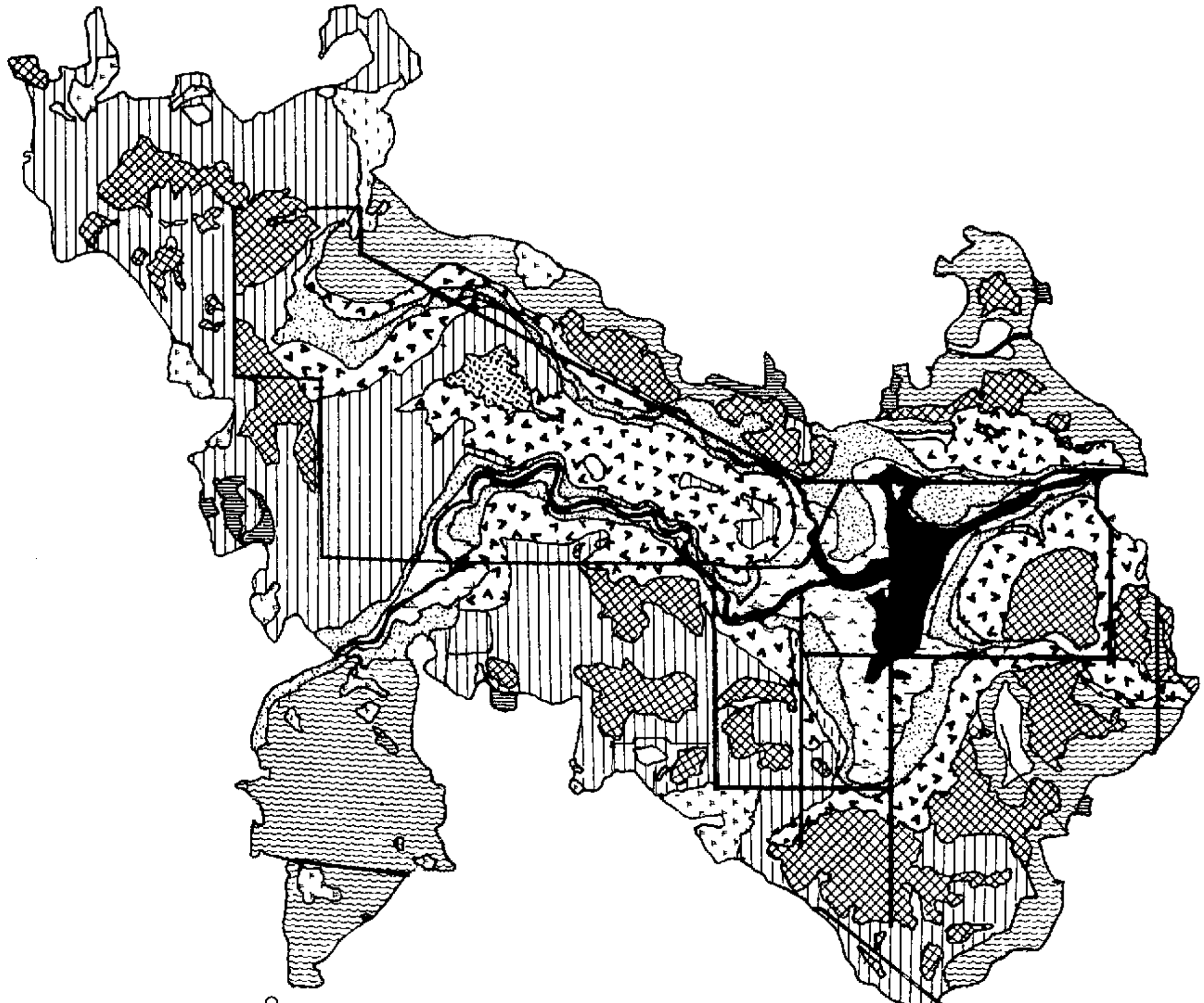
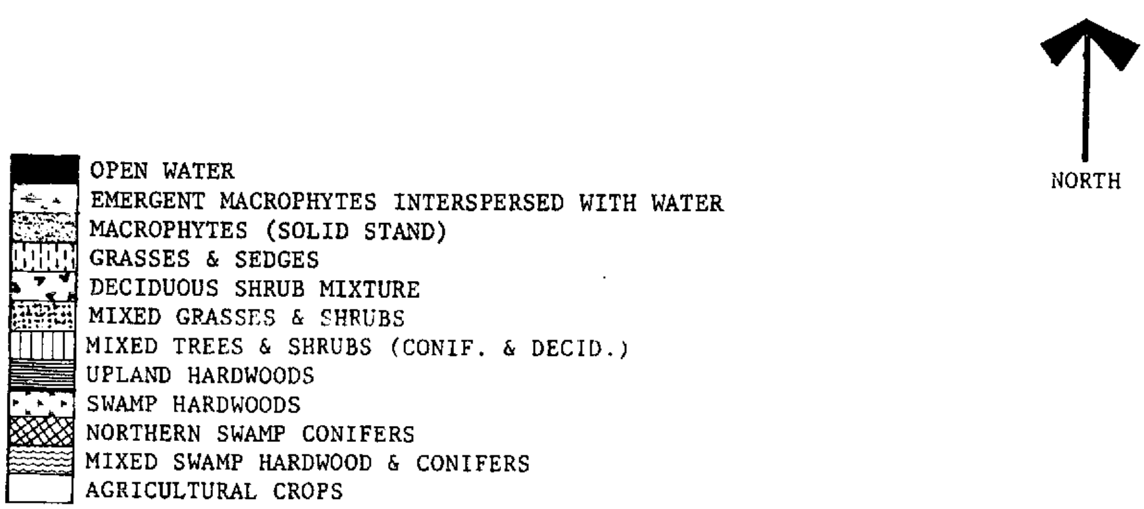
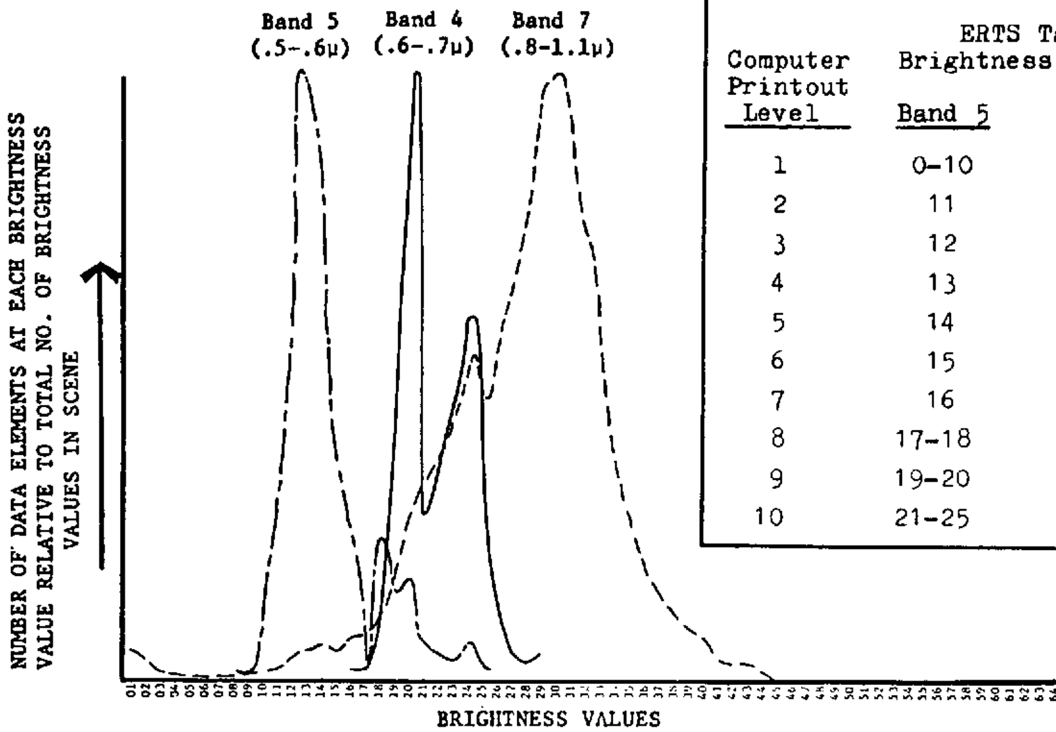


FIGURE 9 Components in Sheboygan Marsh.





Computer Printout Level	ERTS Tape Brightness Values Band 5	ERTS Tape Brightness Values Band 7
1	0-10	0-10
2	11	11-18
3	12	19-23
4	13	24-26
5	14	27-28
6	15	29
7	16	30
8	17-18	31-32
9	19-20	33-35
10	21-25	36-45

FIGURE 10 ERTS TAPE BRIGHTNESS VALUES

One technique useful in analyzing the digital data is to display the various ERTS tape brightness values in discrete ranges. These ranges when presented as symbols of a computer overprint gray scale provide a representation of the scene made up of a 10-gray-level display. Figures 11 and 12 are computer line printer displays of the brightness value data for bands 5 and 7 for the Sheboygan Marsh scene of 9 August 1972. The darker overprint symbols represent the lower (darker) ERTS tape brightness values for each band and the lighter overprint symbols represent the higher (lighter) ERTS tape brightness values. For each band, data postings of the brightness values for each data element (not illustrated) and the histograms shown in Figure 10 were used to select the ranges of brightness values to assign to each single computer printout symbol. The ERTS tape brightness values assigned to each computer printout level are shown in Figure 10. Single printout levels were assigned to single brightness values in the steeper areas of the histogram curves; in the flatter areas at the toe of the curves single printout levels were assigned to a range of up to 10 brightness levels.

The printout maps shown as Figures 11 and 12 were compared with the "ground truth" map shown as Figure 9 and interpretations of the printouts were made. 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 exactly the same as the map in Figure 9, but does allow visual comparisons to be made.

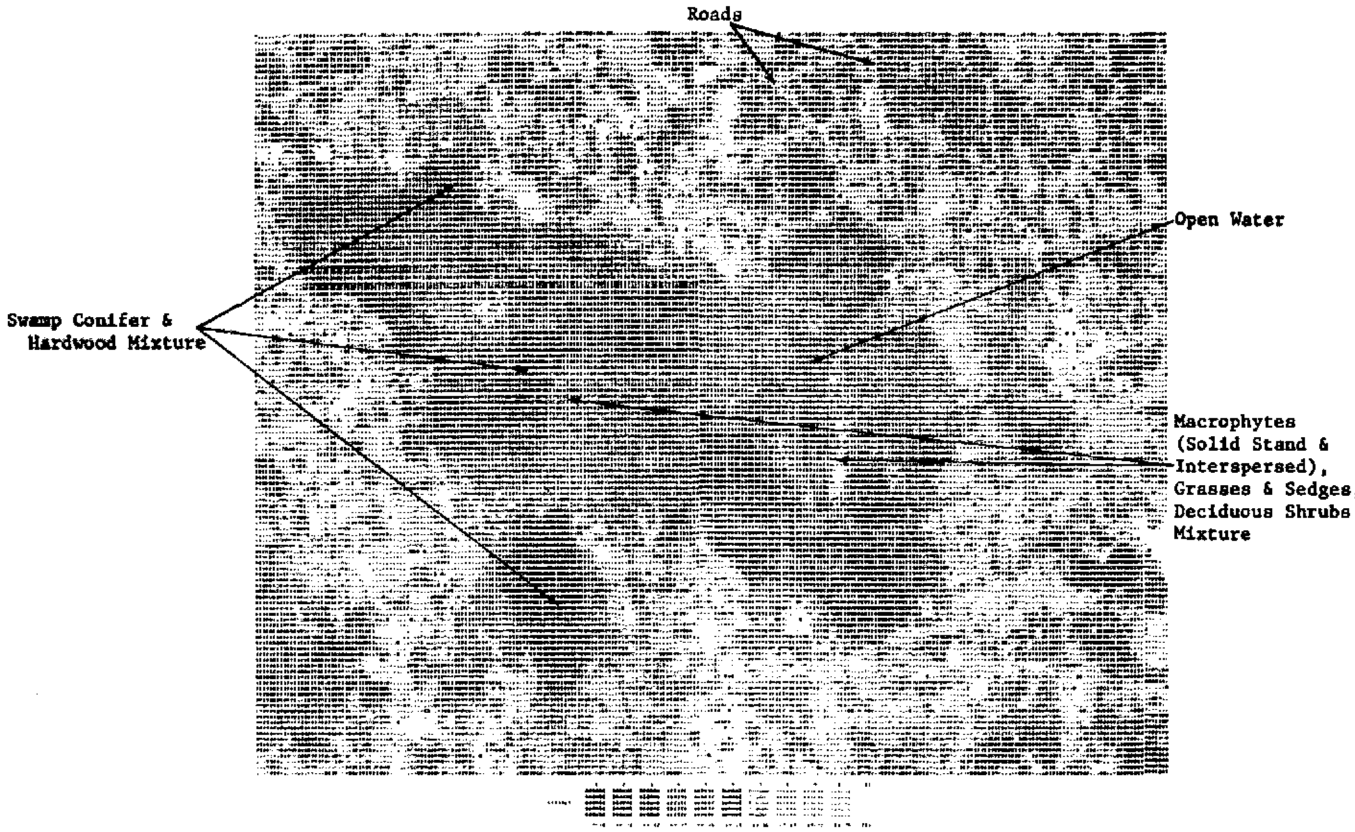


FIGURE 11 Sheboygan Marsh, MSS Band 5 (.6 to .7μ), 9 August 1972.

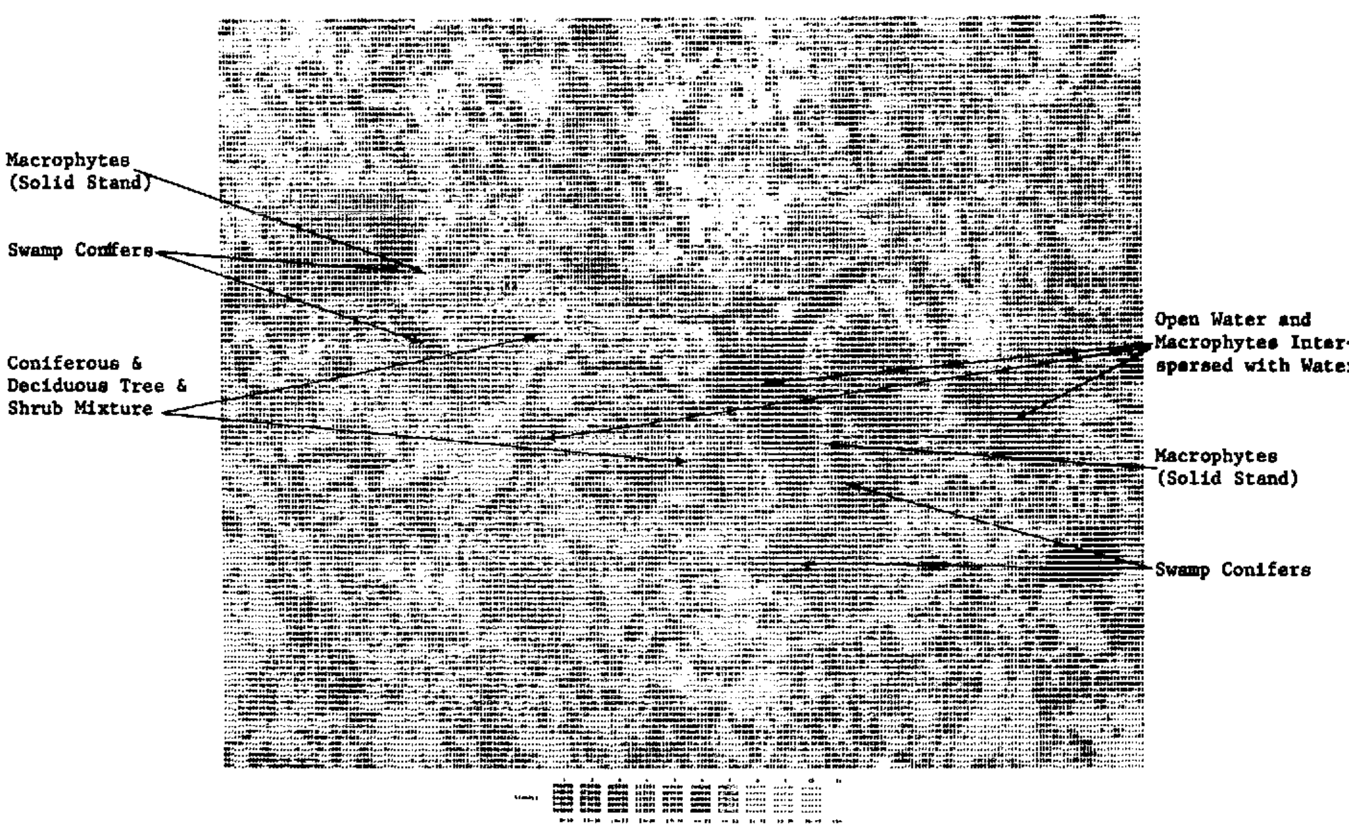


FIGURE 12 Sheboygan Marsh, MSS Band 7 (.8 to 1.1μ), 9 August 1972.

In the Band 5 printout (Figure 11), the perimeter of the marsh and open water can be distinguished. Most of the forested areas appear as dark tones but little separation of vegetation types is possible. Roads are also visible.

In the Band 7 printout (Figure 12), the perimeter of the marsh is not detectable. However, the open water and small river channels with emergent macrophytes interspersed with water are much more evident than in the Band 5 printout. 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 a greater number of distinctions possible in Band 7, although the overall pattern is more complex.

The preceding brief explanation and discussion of the digital data format suggests several inherent advantages of digital data over image data:

(1) With digital data there may be more information existent in each band than in image format.

(2) Raw digital data has not been transformed to another form for display and is therefore a less degraded data source than ERTS image formats.

(3) Digital data may be easier to archive, retrieve, interpret and extract information from with precision than image data.

The ease of use, specificity of information that can be extracted, and spatial fidelity of that information are of utmost importance in advancing the use of satellite data in resource inventories. The ultimate use of large quantities of ERTS data may exceed human capabilities to cope with the volumes of data generated. Means of data handling, enhancement, manipulation, and archiving other than manual operations are required to make maximum use of the large quantities of ERTS data planning applications in Wisconsin.

A Man-Computer Interactive Data Access System (McIDAS) is presently being developed by the University of Wisconsin Space Science and Engineering Center. This system should prove a useful tool for handling large quantities of digital ERTS data. It will accept remote sensing data either as digital tape or densitized images. The digital data can then be displayed in visual form on a color TV screen which is controlled by a Datacraft 6024/5 computer.

The potential capabilities of the system will enable the operator to interact with the system and perform functions such as: color additive viewing, density slicing, contrast stretching, image smoothing and sharpening, pattern recognition, and various measuring processes. The ability to display frames alternately (flickering) or looping in rapid succession as a time sequence with various types of enhancement should prove useful for analysis of spatial and phenological changes of resources.

Those designing McIDAS have made several technological breakthroughs in the areas of mass data storage and retrieval. In addition to the conventional 7 or 9 track magnetic tape input, the McIDAS computer will be interfaced with two slant-track video tape recorders which can archive input from high density video tapes. These recorders can record digital information on the tapes to a capacity of 75 billion bits per tape. This tape capacity is such that 400 ERTS-1 MSS scenes (4 bands per scene) could be stored on one tape. In other words, two years ERTS coverage of Wisconsin could be stored on one tape. Or, complete ERTS-1 coverage of the continental United States for one year could be stored on 12 tapes. One tape could hold over 1000 images from 9 x 9 inch aerial photographs digitized into 100 micron cells at 256 gray levels available per cell (encoded to 8 bits).

McIDAS is not yet fully operational. When the system is complete, it will provide a powerful tool for the storage, manipulation, and analysis of ERTS-1 and other remote sensing data.

THE UTILITY OF ERTS DATA TO CRIP

The Critical Resources Information Program is but one of several current and potential State of Wisconsin programs in the general area of land use planning and management. It is, however, the one with the most definitively specified data needs and, as such, can best serve as the means to evaluate the utility of the ERTS program in land use planning activities. The CRIP effort will provide at least a partial basis for open space and land use planning and regulatory programs; for scenic easement programs; for scientific, wilderness, and natural area protection programs; and for a state urban growth policy project.

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 <u>short run</u> (by February 1974), CRIP is to provide: (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 resource data. Short run considerations imply reliance on manual data extraction using ERTS prints or transparencies viewed on a light table or with a color additive viewer. ERTS, in combination with other data sources such as USGS topographic maps, will be used to spatially locate the significant resources identified by CRIP (e.g., wetlands, forests, lakes and shorelands) and then will serve as the base document for the purpose of sampling these resources. This sampling effort is to provide an initial approximation of a statewide inventory and a test of 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, 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 will 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 that 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 flooding, surface water level fluctuations (especially important in identifying wetlands), and the extent of resource buffer areas.

We view ERTS as potentially the best medium for resource monitoring. 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 an effective device 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 as exemplified by McIDAS would also improve the use of ERTS output as a communication device.

In summary, we view ERTS as one of many data sources to be probed in assessing the quantity, quality, and threatened condition of Wisconsin's resources. The importance of ERTS as a data source should increase considerably as interactive techniques for analysis of ERTS digital data become operational.

SUMMARY

Effective regional and state land resource planning are dependent upon relevant information which presently may not exist, except in inaccurate or archaic forms. Also critical, for use by state and regional planners, is resource information at varying scales, including land resource information for citizen educational purposes, large area planning, public facility planning, and information for legislation and control of land resources. As presented in this paper, the detection, inventory, and monitoring of certain critical land resources appears feasible for the scales of planning just described, except for legal control (which requires accurate property description).

With the advent of statewide data systems, such as New York's LUNR and Minnesota's MLIS, plus the need to inventory specific resources, the extent of applicability and usefulness of satellite sensors is being tested. Definitions and data resolution levels of resource information are being established by planning and governmental agencies. The State of Wisconsin Critical Resources Information Program is aimed at defining, establishing the units of measurement, inventorying, and monitoring of natural and cultural spatial resource elements which are of statewide or regional significance. The desire and need to inventory and monitor land resources during the coming decade is obvious and the extent of applicability of ERTS satellite sensors will be of utmost interest to persons responsible for and interested in the land resource planning and decision processes.

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APPENDIX D

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

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ABSTRACT

The need for the development and implementation of methods for the detection, inventory and monitoring of land resource variables is reflected in present and pending federal and state legislation. ERTS can provide an operational data source for many of the significant land use variables at the policy level.

Land resource data has been extracted on a percent of cell basis from ERTS imagery, RB-57 color infrared imagery and best available conventional sources for a 10,000 square kilometer test area in eastern Wisconsin.

First, the data from the three sources is compared on a spatial basis for a 300 square kilometer portion of the test area. For those land resource variables associated with cover, ERTS derived resource data compared favorably with both the RB-57 and conventional data. In the case of those variables which change with respect to time and are not regularly monitored by conventional means, the ERTS derived data is superior to conventional data.

Second, the effect of the data source on land use decisions is examined. Three interstate highway corridors are located through the same region based upon data extracted from each of the three sources. A policy of preserving natural environmental systems was used as a basis for the corridors selection in each case. The resulting three corridors compare favorably.

INTRODUCTION

The urban population growth, the demands of population centers for recreational resources, the growing need and concern for environmental resource planning, all dictate the need for better data in the land use planning process. This need for a relevant and environmentally responsive regional planning and management data base is crucial to the economic future for an assuring quality of life. At present, the regional decision maker typically lacks relatable basic information on the use, the composition, character, and the temporal change of the region. The most basic forms of these data, such as the extent of vegetation cover, wetlands distribution, urban growth and the ecological well-being of the landscape are examples of data that have been traditionally unavailable in formats directly useable in the regional planning process. The results of this study, while clearly demonstrating that ERTS-generated information will not be a panacea for all regional planning data needs, does offer a technique by which the data acquisition process can be significantly improved.

METHOD OF INVESTIGATION

The investigation was conducted in three basic phases. The first phase consisted of the determination of which land use variables could be extracted from ERTS and RB-57 images. The second phase consisted of the quantitative and spatial comparison of land resource variables extracted from ERTS, RB-57 and available conventional data sources. The third phase, which is still under investigation, compares the spatial effects of the data sources on land use planning decisions.

Test Site

The principal test site employed in the investigation, called REMAP-I, consists of a 10,000 square kilometer area between Milwaukee and Green Bay, Wisconsin, shown in Figure 1. A smaller portion of the area, the 10 x 30 kilometer Sheboygan Test Site, was employed in some of the analyses. A computer-based data bank had been developed for REMAP-I area by the Environmental Awareness Center of the University of Wisconsin from conventional data sources to assist the Wisconsin Department of Transportation in the location of a corridor for Interstate 57. Thirty-eight land resource variables, made up of 132 data items, are stored for each 1 km cell in REMAP-I on a percent-of-cell basis. The cells are spatially organized on a UTM base. Any combination of variables, which can be individually weighted, can be developed as a spatial density printout for comparisons with ERTS and RB-57 derived information. Figure 2 shows a sample printout for the variable "Existing Agricultural Land Use." Figure 3 illustrates the use of the REMAP-I data base to generate a spatial density printout of the study area employing a particular policy. The policy illustrated in Figure 3 is environmental impact. All variables which relate to environmental considerations are weighted high. The resulting lighter areas should be protected under this policy. The policy can be modified by changing the weights assigned to the variables.

In the construction of the REMAP-I data bank significant difficulties were encountered. These centered on the non-availability of compatible data sources. The "best available" sources of appropriate data varied in format, scale, accuracy, vintage, controlling agency and spatial reference. The cost of data

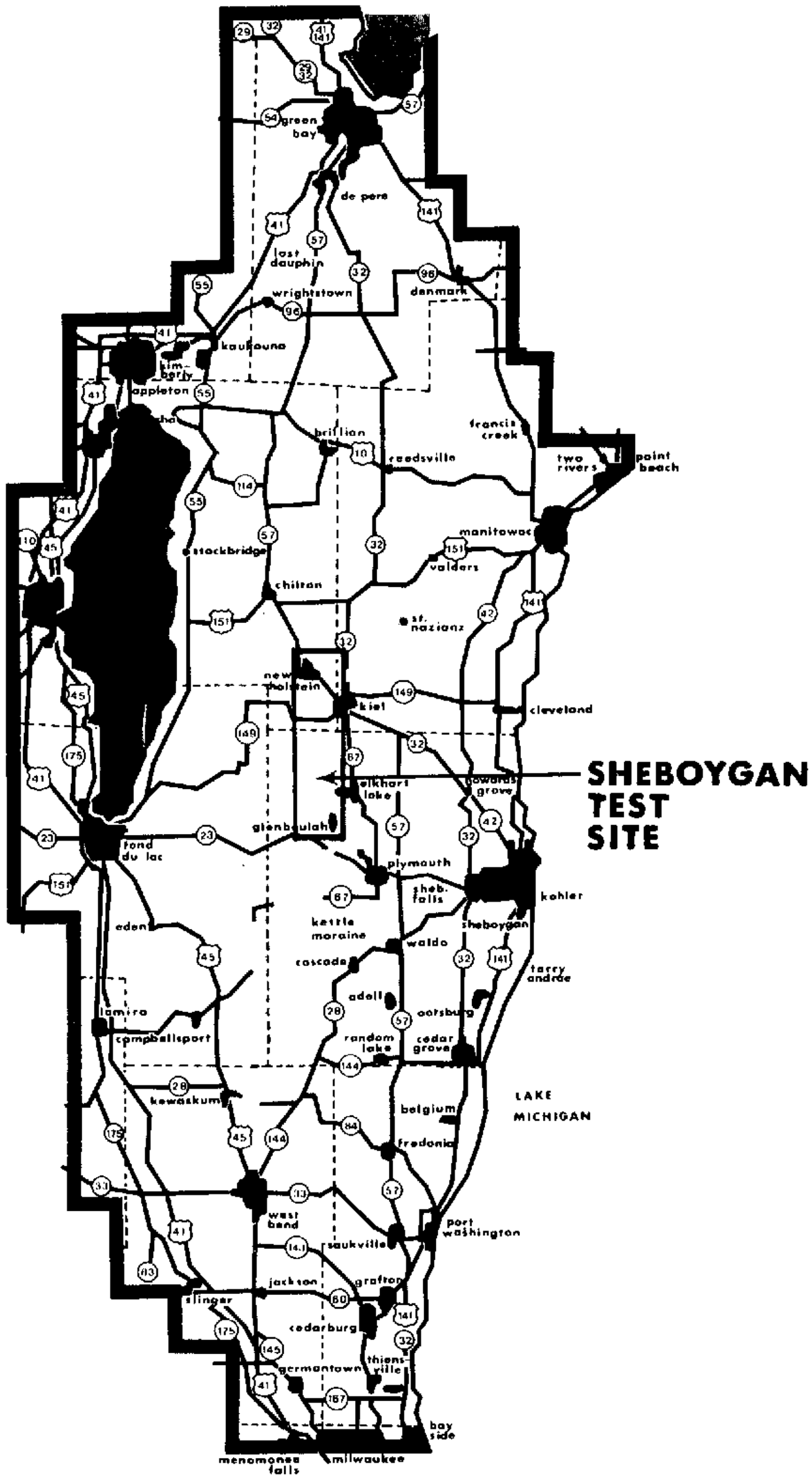

FIGURE 1. **REMAP I TEST SITE**

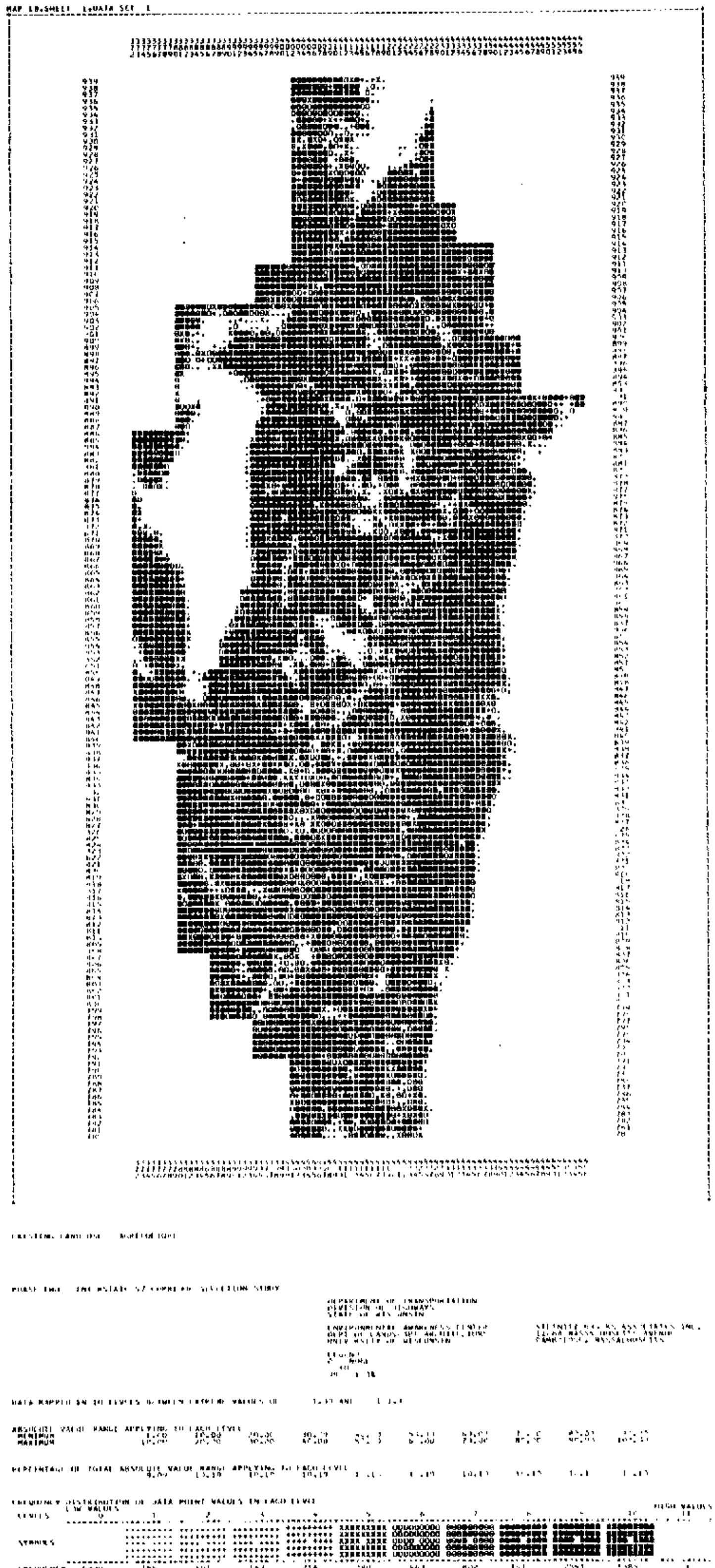

FIGURE 2. REMAP-I DATA BANK
EXISTING AGRICULTURAL USE

FIGURE 3. POLICY MODEL -
WEIGHTED TOWARDS ENVIRONMENTAL CONSIDERATIONS

extraction from these varied sources was estimated at $10 per cell or $100,000 for the entire 10,000 cell REMAP-I area.

Interpretation Technique

Conventional air photo interpretation techniques were employed to extract data from the ERTS and RB-57 images. Nine-inch transparencies were used for both ERTS and RB-57 sources as the basic image format. Data extraction on a percent-of-cell basis was made using a zoom stereoscope. A 1 km cell grid was superimposed on the imagery by navigation with respect to identifiable features on the imagery. Extracted data were keypunched and input to the computer data bank. This procedure was followed for each variable identifiable. An ERTS-1 Interpretation Matrix was prepared which lists the REMAP-I variables, data and coverage interpreted, the band employed, a classification of identification by difficulty, and the image format and date most appropriate for each variable identification. This matrix is viewed as incomplete at this time due to inadequate spring and fall ERTS coverage caused by poor weather conditions.

SPATIAL COMPARISONS OF VARIABLES

Figures 4, 5 and 6 illustrate the spatial comparison of three of the land resource variables for the Sheboygan Test Site, a 10 x 30 kilometer portion of the REMAP-I data bank. The figures are computer-generated spatial-referenced quantitative information as derived from (1) ERTS-1 multispectral imagery, (2) RB-57 high altitude color-infrared photography, and (3) the REMAP data bank constructed from conventional sources. Each cell is one square kilometer in size, spatially referenced to the UTM system. The density of the symbol printed in each cell indicates the percentage of that cell occupied by the resource in question. Beneath the spatially represented areas are given the total area occupied by each resource as determined from each data source. Numbers of occurrence and areas for each of the three data sources are presented for each level of occurrence.

Figure 4, the printout for the variable "Agriculture," shows the spatial/statistical comparison 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 crop land and grazing land). There is excellent agreement among all three data sources and ERTS imagery is useful for the determination of lands devoted to agricultural use. Because of the continuing change in the use of agricultural lands, there is a real need for monitoring this variable on a regular basis.

Figure 5, the variable "Forest," shows spatial/statistical comparisons for the land covered with forests (those land areas with at least 50% tree canopy cover). "Upland Forest and Lowland

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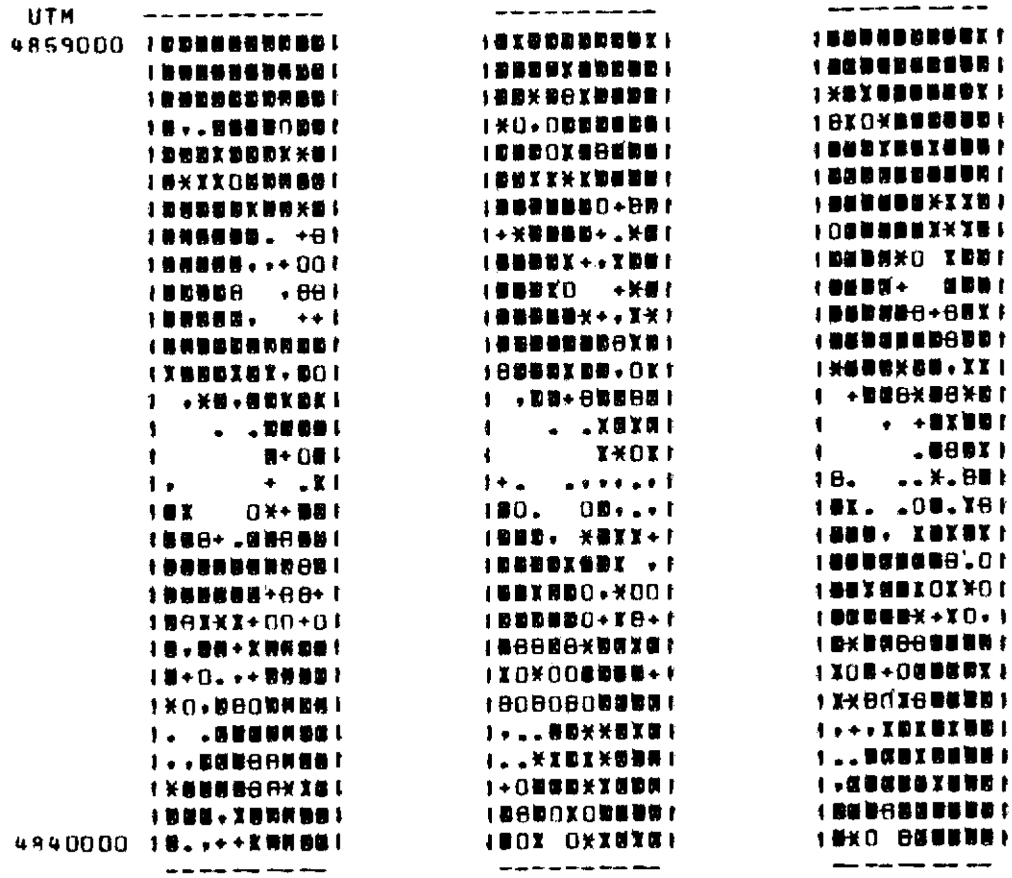
UNIVERSITY OF WISCONSIN - MADISON

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	88888	XXXXX	IIIII	■■■■■	■■■■■	■■■■■
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 4. AGRICULTURAL LAND USE

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

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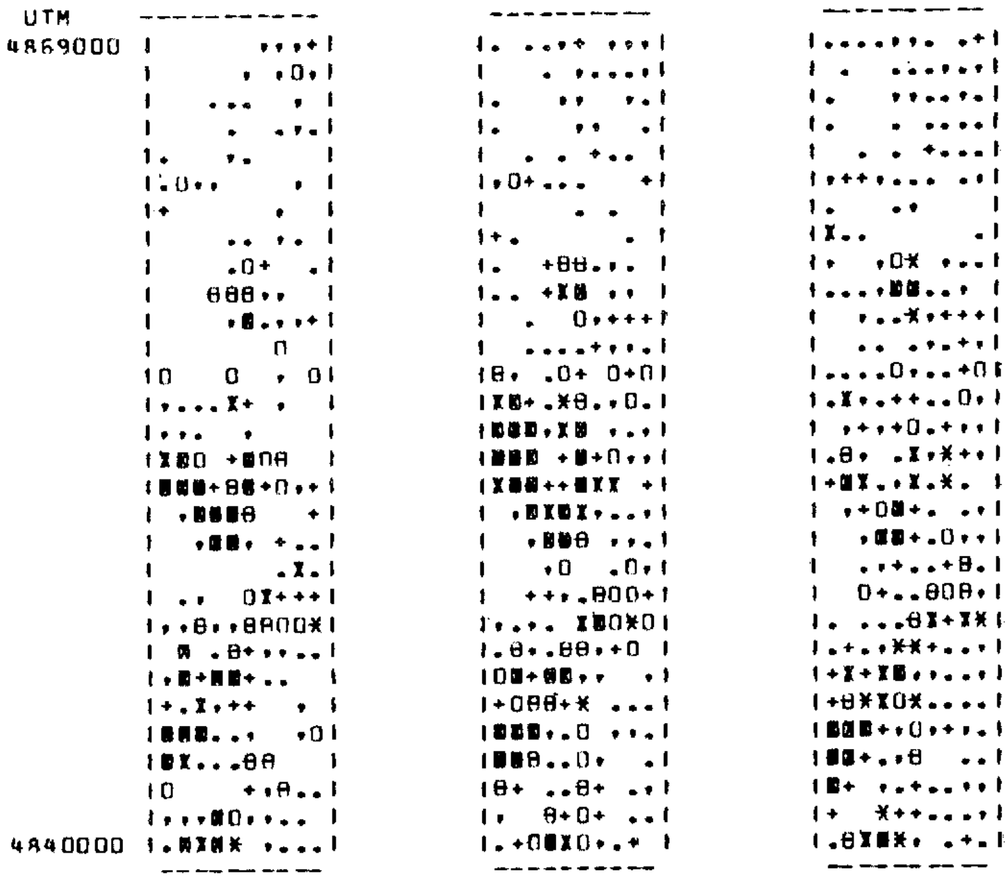
SHEBOYGAN TEST SITE
VARIABLE 24+25 FOREST

UTM 410000   419000



	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	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	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 5. FOREST LAND COVER

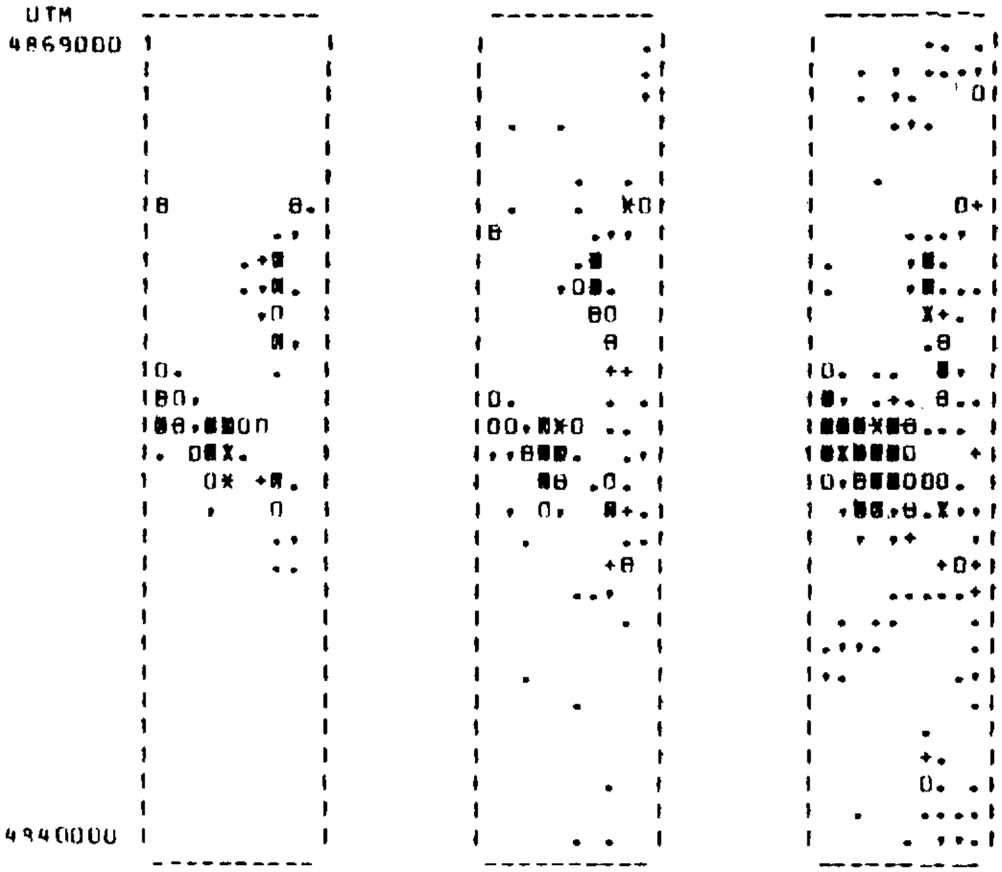
ERTS and RB-57 INTERPRETATIONS
<u>vs</u> REMAP-I DATA BANK

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

UTM 410000 — 419000

UTM 4869000 — 4840000



	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	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
OCCUR B	32	11	4	9	6	2	0	2	1	4
OCCUR 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
SQ.KM B	1.05	1.39	.95	3.09	2.57	1.05	.00	1.40	.80	4.44
SQ.KM 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 6. OPEN WATER AND WETLANDS

ERTS and RB-57 INTERPRETATIONS

vs REMAP-I DATA BANK

Forest" were treated as separate variables in the original REMAP-I 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-I. It is possible that the ERTS derived data could be refined by (1) coverage over an entire season, and (2) more sophisticated methods of data extraction.

Figure 6, the variable "Open Water and Wetlands," 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. For the purposes of this comparison they were combined to yield 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, shrubwillows, and alders). 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 percentage of each cell is occupied by open water and/or wetland, detection was not made on the ERTS imagery, as shown by the number of occurrences.

It can be seen that 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, it indicated that the total areas of "lowland forest" plus "open wetlands" 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 points clearly illustrates that (1) land cover changes with time and 40-year-old data are probably inadequate, (2) field checks are an essential part of remote sensing data extraction studies, and (3) resource definitions must be carefully drawn.

EFFECT OF DATA SOURCE ON LAND USE DECISIONS

A spatial comparison of data derived from the three sources, although valuable, does not approach the more fundamental question of how the source of the data affects the decisions based upon the data.

In order to approach this question, Policy Models were established for the Sheboygan Test Site for each of the three data sources. This was accomplished by resource disciplines assigning weights to each variable according to its significance with respect to that policy. Figure 7 shows the printout for the Policy Minimum Environmental Impact for each of the data sources. The more dense cells represent those areas which have a high sensitivity to impact and should be avoided under this Policy. Note that if there are differing opinions or changes in perception over variable weights to be assigned to a policy, the spatial effect of a change of weights or policy can be quickly examined.

The ERTS model is based upon five variables, the RB-57 model upon eight variables, and the REMAP-I model upon all 38 variables. This reflects the varying degree of discreteness of the respective data sources and the greater dependence upon varying sources required for REMAP I.

In order to examine the effect of the three data sources on land use decisions, a computer optimization program was developed which selects an interstate highway corridor through the test site based upon minimum environmental impact as established by the policy. These corridors are shown in Figure 7 as the dark lines.

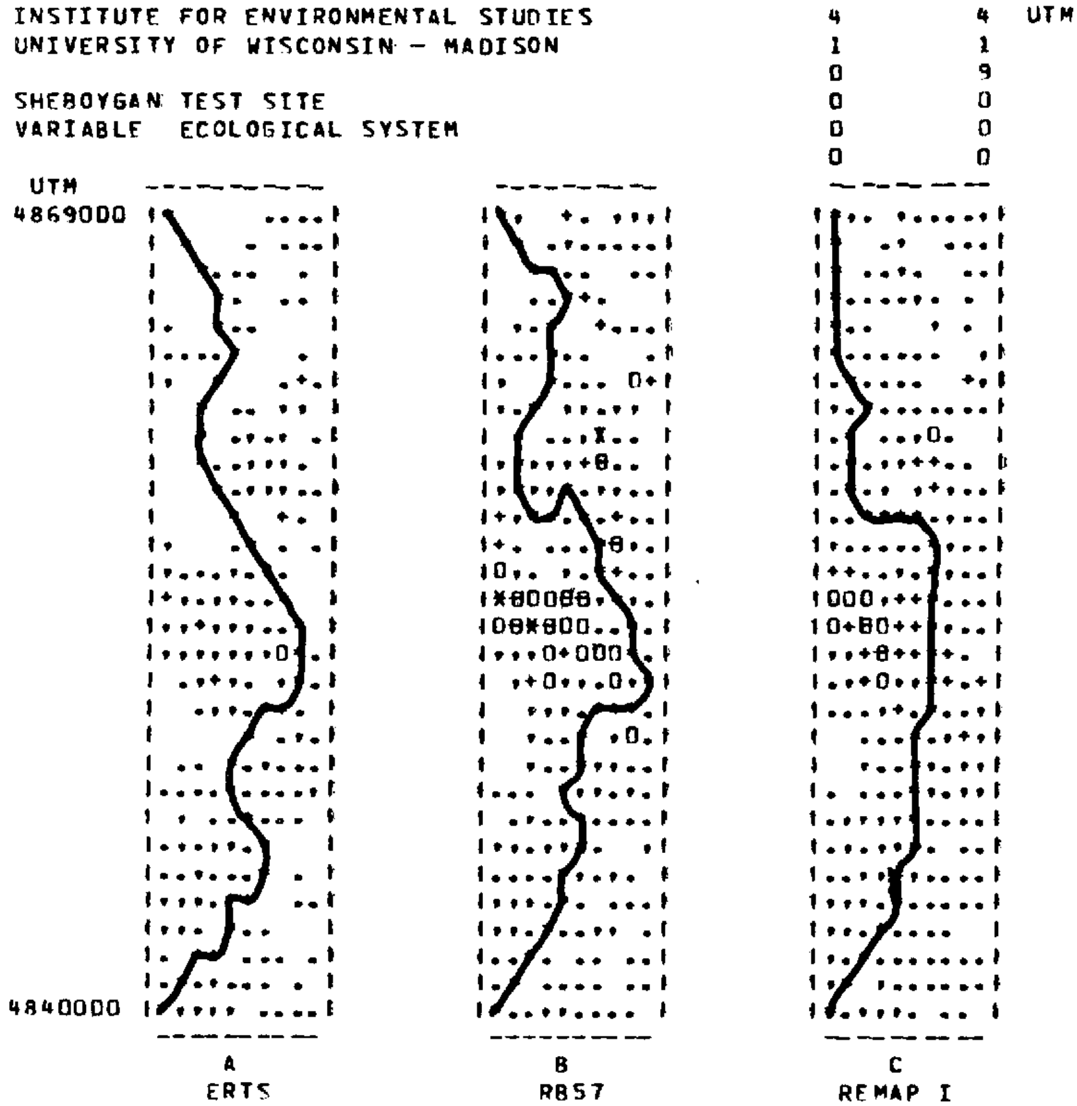
Although this portion of the investigation is only preliminary, an examination of Figure 7 reveals some interesting features. First, all three sources produce corridors which are quite similar. Second, as the data become more discrete, the corridors become less direct. A significant amount of investigation remains to be done on this question, particularly on the optimization of the data base using each source for those variables for which that source is most appropriate.

STATE LAND INFORMATION SYSTEM

In order to meet the data needs of the land use planning process it is necessary that four key elements be represented. These are shown diagramatically in Figure 8. First, there must be a hierarchy of data sources, including earth resources satellites. Second, the data needs and definitions must be established by the user groups. Third, the legislative support must be provided. Fourth, an information system must be designed to be responsive to all these elements. These components must be dynamic and responsive to social and technological change.

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

SHEBOYGAN TEST SITE
VARIABLE ECOLOGICAL SYSTEM



TOT. SQ.KM	13.250				26.260			22.780		
LEVELS	1	2	3	4	5	6	7	8	9	10
SYMBOLS	.....	,,,,,	+++++	00000	88888	XXXXX	IIIII	█████	█████	█████
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
OCCUR B	115	63	11	14	7	2	1	0	0	0
OCCUR 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
SQ.KM B	4.74	9.08	2.64	4.95	3.14	1.03	.68	.00	.00	.00
SQ.KM C	6.36	8.23	5.04	2.34	.81	.00	.00	.00	.00	.00

FIGURE 7. LAND USE DECISION MODEL

"LINE FINDER" HIGHWAY ALIGNMENT.
WEIGHTED TOWARDS ENVIRONMENTAL
CONSIDERATIONS

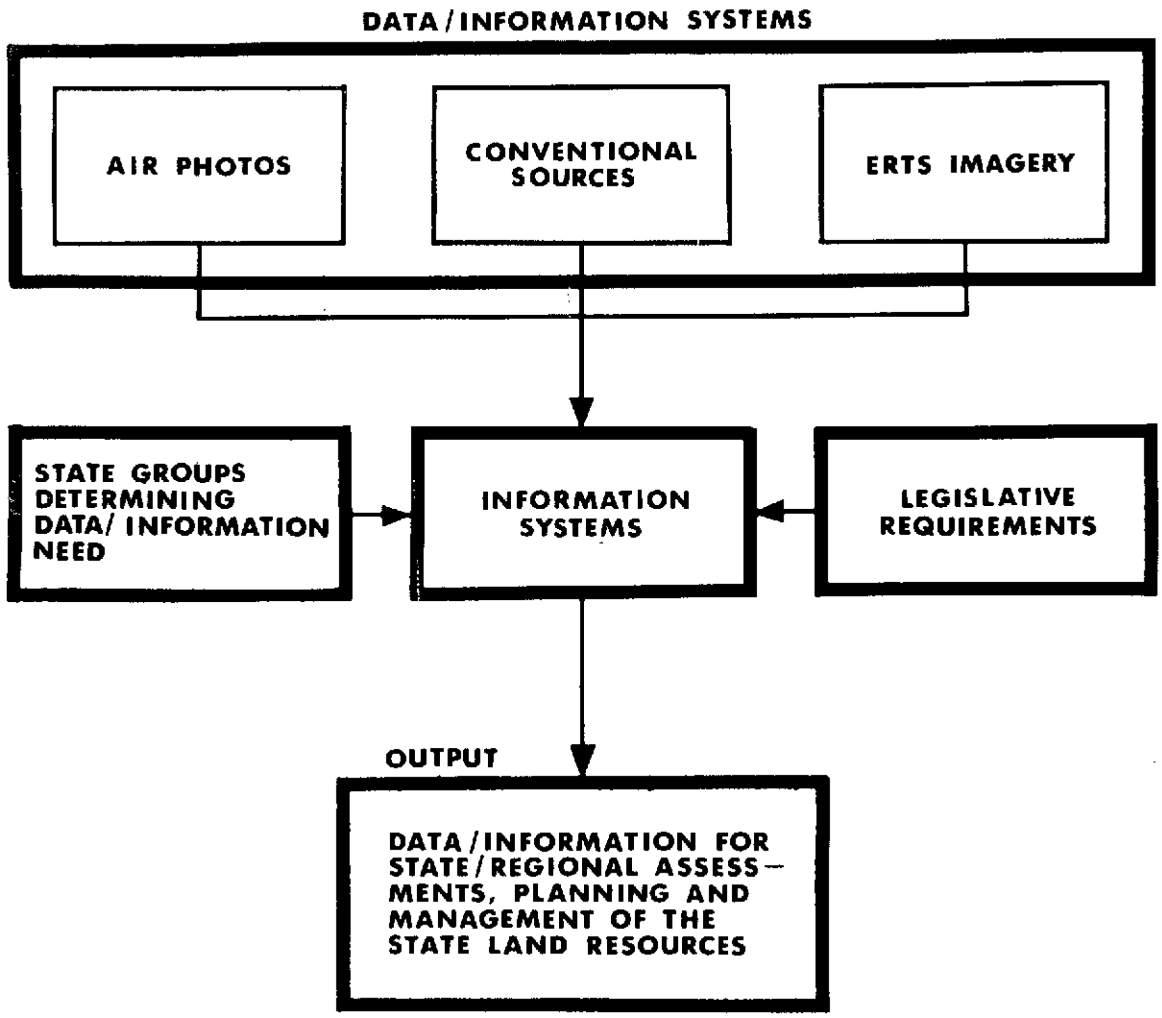


FIG. 8. DATA/INFORMATION AND LEGISLATIVE REQUIREMENTS FOR STATE INFORMATION SYSTEMS

PRELIMINARY CONCLUSIONS

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 critical land resources and the parameters which determine them in terms of measurement techniques economically available.

3. It is essential to establish precise criteria and data required for the establishment and measuring of the relative quality of critical resources.

4. ERTS derived data/information is potentially superior to conventional land use data for those items (1) which change rapidly with time, and (2) for which conventional data is not available.

5. For broad land cover assessments, data derived from ERTS by non-sophisticated methods is sufficient for initial resource assessments at the state or regional policy level.

6. More specific land resource information is available from ERTS if machine-based analysis techniques are employed.

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

8. A state or regional data/information system must encompass a hierarchy of data sources including satellites, high-altitude aircraft, low-altitude aircraft, and ground-based surveys.

9. ERTS has provided a focus from which the regional land use planning data/information problem can be approached.

10. Any effort directed toward the implementation of a data/information system for regional land use planning must be multidisciplinary.

11. 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.

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

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

APPENDIX E

THE APPLICABILITY OF HIGH ALTITUDE INFRARED PHOTOGRAPHY AS A DATA SOURCE FOR WETLAND VEGETATIONAL MAPPING: A TEST

By: David R. Laux
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Critical Resource Information Program
Environmental Monitoring and
Data Acquisition Group
Institute for Environmental Studies
University of Wisconsin-Madison
28 November 1973

INTRODUCTION

The Wisconsin Department of Natural Resources (DNR) is presently considering methods of analysis to inventory the existing wetland communities within the state. Previously wetland surveys have been limited due to the economics of time and money, while limitations of inventory technology have curtailed comprehensive state inventories. The first and last comprehensive inventory of vegetation including wetlands was done using manpower supplied by the 1930 Depression programs. During the 1930's the state was mapped and the results were the Borgnor Series[1]. Because of growing concern within the state agencies pending state legislation (Assembly Bill 813,626,882) and a general public concern, there appears a consensus that wetlands are an important state resource and a need exists to locate, classify and rank these resource areas. In addition, management techniques for wildlife production have been developed for specific wetland areas throughout the state, and the concepts and resultant information needs have implications on statewide planning. However, these management techniques have been based on specific types of information which were obtained to meet the needs of the individual management questions. Management questions are therefore dependent upon a specific level and type of information. The level or discreteness of information must therefore be defined and methods of data accumulation found and implemented if these data and information questions are to be resolved as part of a wetland inventory program.

In its search for wetland data sources and applicable inventory techniques, the DNR has been approached by various research and educational groups from the University of Wisconsin. As a result of previous research (NASA[2], ERTS[3], BOR[4] grants), research has been done on the applicability

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1
2 National Aeronautics and Space Administration
3 Earth Resource Technology Satellite
4 Bureau of Outdoor Recreation

of remote sensing using high altitude photography and ERTS imagery to identify and classify various vegetational patterns throughout the state. It was the consensus of the DNR and University personnel that the participation of the University group could possible aid the DNR in its search for applicable inventory methods and their ability to satisfy the needs of a statewide wetland inventory.

As indicated, high level photography (i.e. 60,000 ft. platform; scale 1:120,000) has been previously studied for its application to a variety of land resource inventory problems. It was determined that a trial wetland mapping project using the high level photography type of data source would be beneficial to both the DNR and the University. It would be beneficial to the University because it could learn which specific types of wetland information the DNR as a state planning agency deem important. It would also provide the DNR with an initial evaluation of the capabilities of high altitude photography as a data collection system for wetland mapping.

This paper is a documentation of an initial trial which was limited to delineating and mapping vegetation within a specific wetland system. Horicon Marsh (Figure 1) was selected as a test site because of (1) the availability of the imagery covering the area, and (2) an existing vegetational map compiled by the DNR personnel using conventional methods of fieldwork and mapping. It was concluded by the DNR and University group that this initial test of high level photography as a data inventory and extraction technique would provide a specific spatial and species comparison to DNR's conventional methods.

TEST SITE - A DESCRIPTION

Horicon Marsh is located in Dodge and Fond Du Lac Counties, to the north of the city of Horicon. The southern portion (10,794 acres) is state-owned and the northern portion (20,924 acres) federally-owned. The ownership patterns are the result of the various land management practices

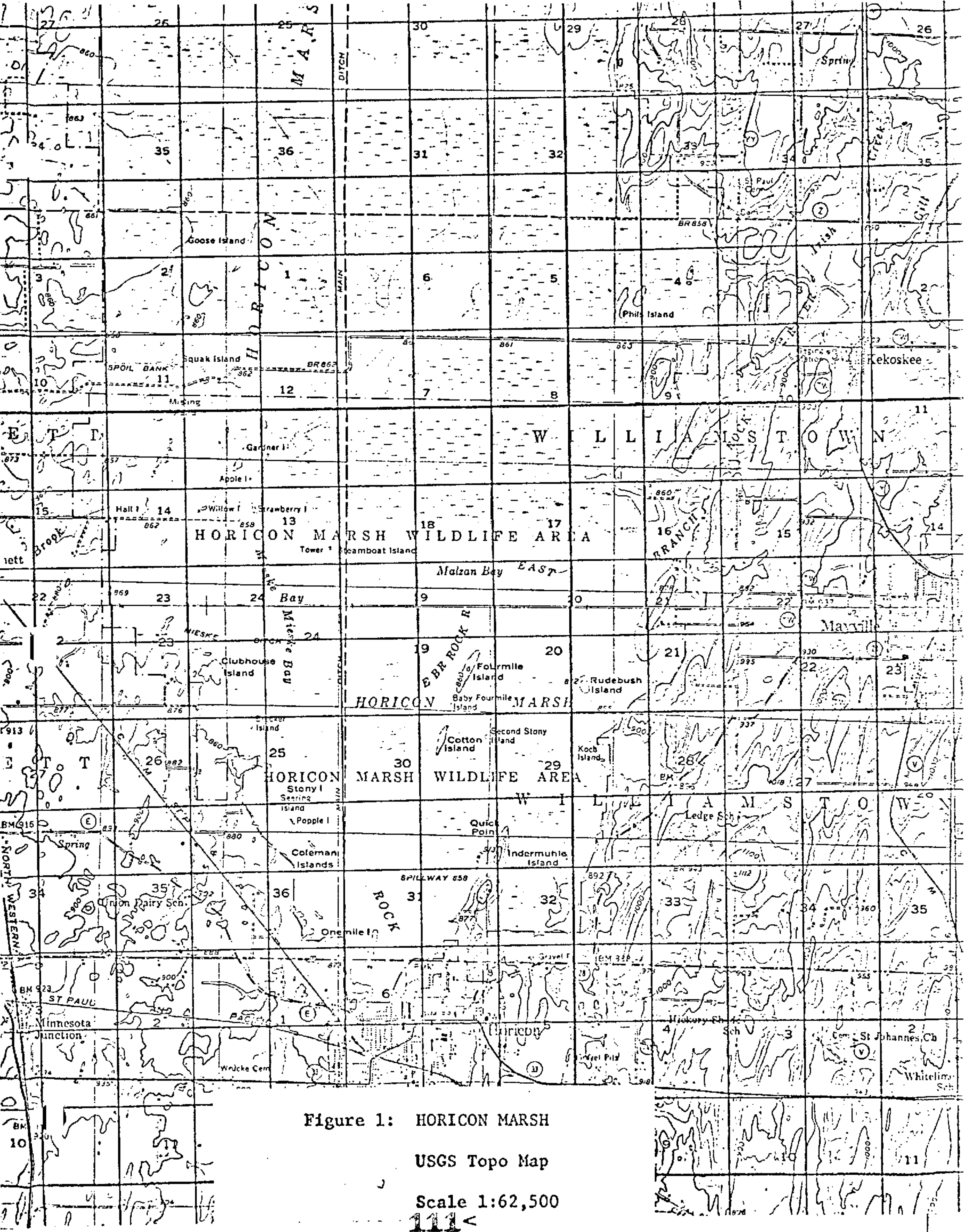


Figure 1: HORICON MARSH

USGS Topo Map

Scale 1:62,500

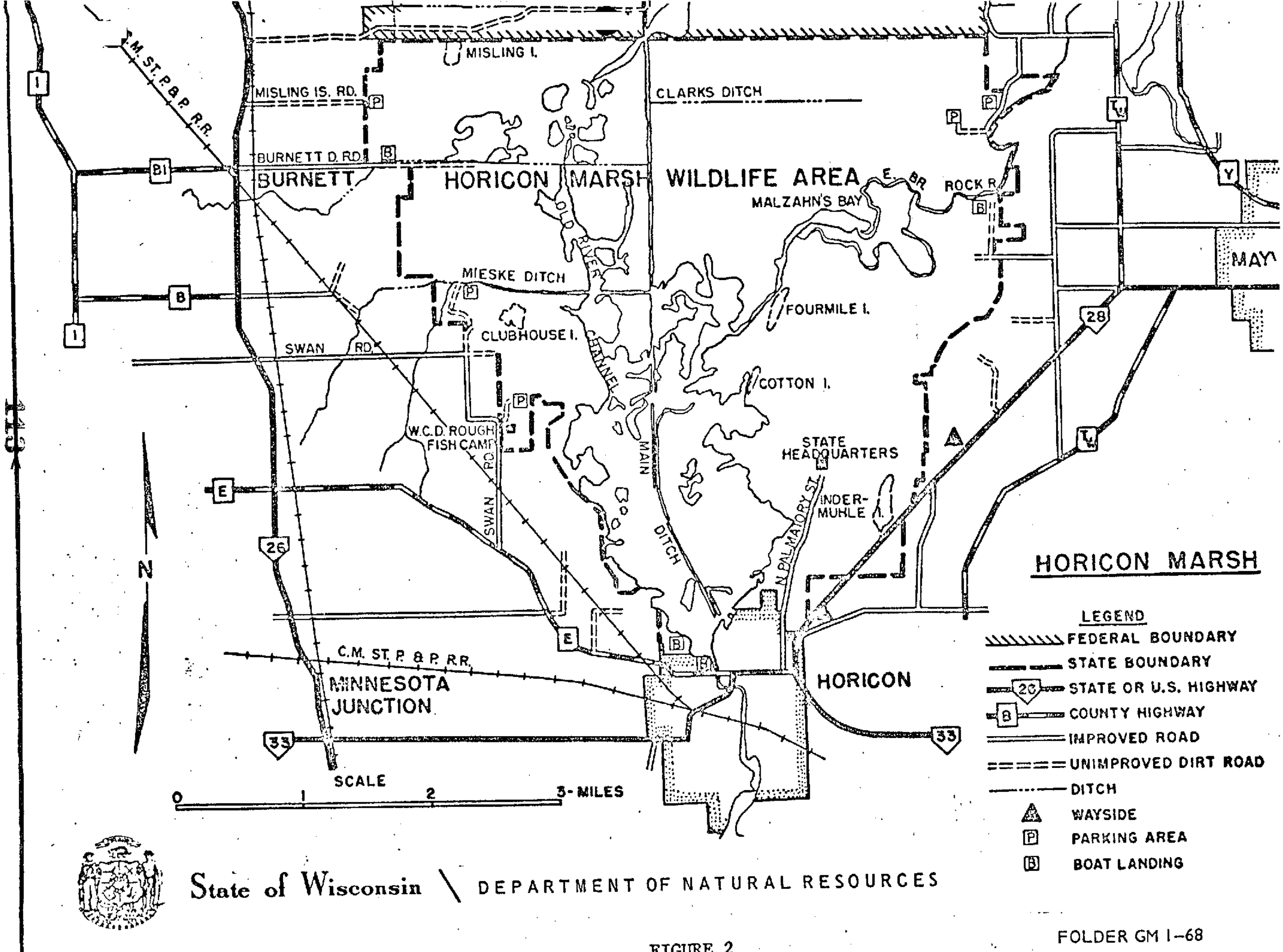
the marsh encountered leading to the passage of the Horicon Marsh Wildlife Refuge Bill in 1927 and the purchases following this in the 1940's. Previous to this the marsh had been dammed in Horicon in 1846 to provide power for a sawmill and gristmill creating a lake approximately 9 feet deep. In 1869 the dam was removed and the area became a phenomenal waterfowl production area until the turn of the century.

Muck farming was attempted in the early 1900's when a drainage system was constructed to drain the marsh, however the farming attempt failed due to poor soil fertility. This failure led to increased support from conservation minded groups in the 1920's to obtain control for wildlife management which evolved into enactment of the bill. Since the bill's enactment, management practices have been implemented which maintain the marsh for maximum wildlife productivity. Management provisions included were the installation of the east to west dike to maintain 12,000 acres on the federal portion; installation of level ditches to increase open water areas for waterfowl use; maintenance of water levels; and the use of lift pumps and impoundment dikes to create additional marsh area (Figure 2).

IMAGERY AVAILABILITY

Various types of imagery are available for the test area. Figure 3 is a listing of these different sources with information pertaining to their format, date, coverage, etc. As mentioned previously, high altitude infrared photography at a scale of 1:120,000 or 1 inch = 1.9 miles was selected for the initial test. This imagery has been widely used in the University investigations and was most familiar to the investigator. Figure 4 indicates the state coverage of RB-57 imagery. This data is available at the University of Wisconsin, Environmental Monitoring and Data Acquisition Browse File.[5]

[5] For information contact Mrs. Barbara Kenny, Institute for Environmental Studies, 658 WARF Building, 263-4836.



HORICON MARSH WILDLIFE AREA
BURNETT
MISLING I.
MISLING IS. RD.
CLARKS DITCH
BURNETT D. RD.
C.M. ST. P. & P. R.R.
E. BR. ROCK R.
MALZAHN'S BAY
OLD RIVER
MIESKE DITCH
FOURMILE I.
CLUBHOUSE I.
CHANNEL
SWAN RD.
COTTON I.
W.C.D. ROUGH FISH CAMP
SWAN RD.
MAIN DITCH
STATE HEADQUARTERS
N. PALMATORY ST.
INDER-MUHLE I.
MAY
MINNESOTA JUNCTION
HORICON
SCALE
0 1 2 3-MILES
N
HORICON MARSH
LEGEND
FEDERAL BOUNDARY
STATE BOUNDARY
STATE OR U.S. HIGHWAY
COUNTY HIGHWAY
IMPROVED ROAD
UNIMPROVED DIRT ROAD
DITCH
WAYSIDE
PARKING AREA
BOAT LANDING
State of Wisconsin \ DEPARTMENT OF NATURAL RESOURCES
FOLDER GM 1-68

FIGURE 2

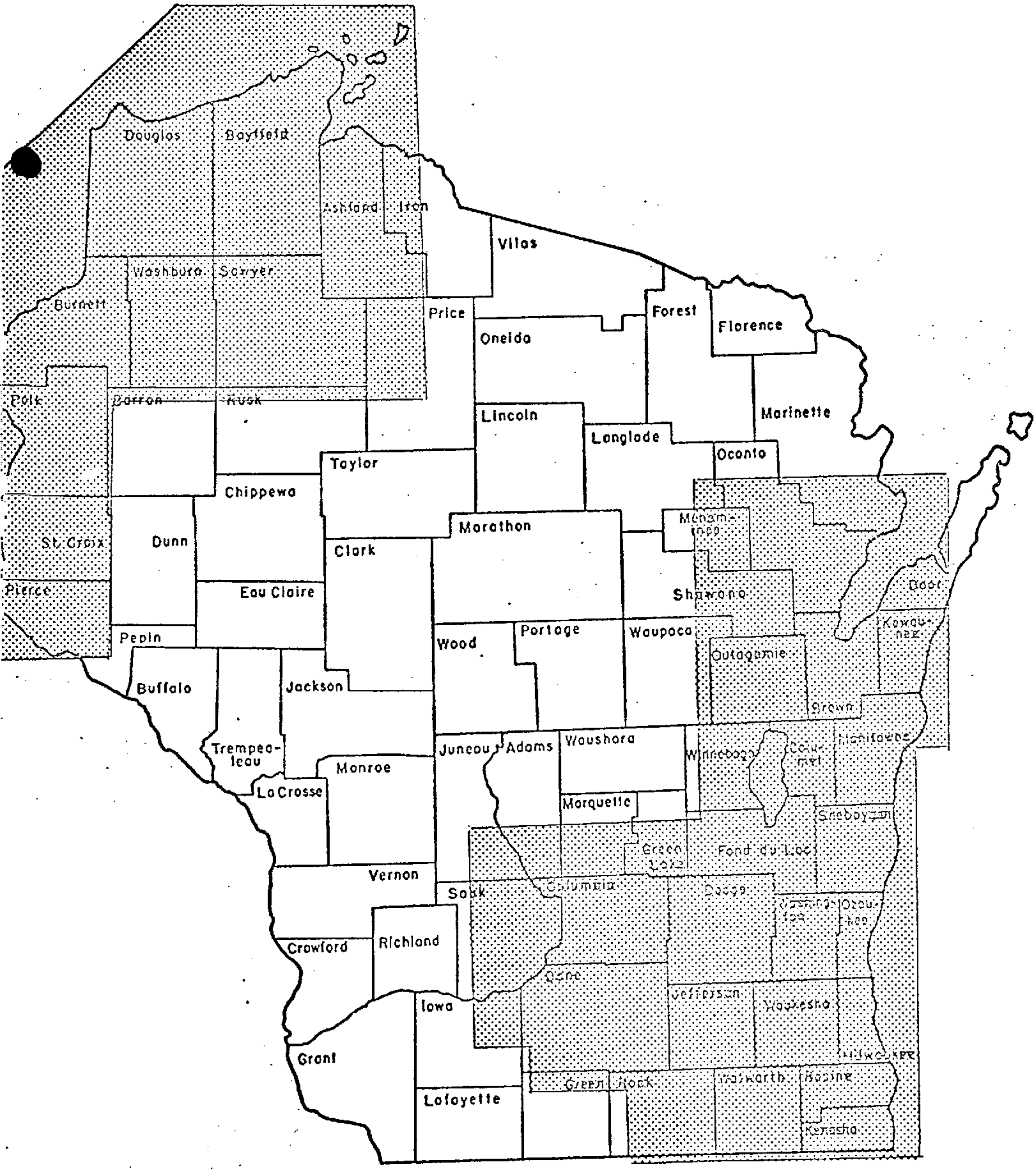


FIGURE 4

RB-57 - STATUS OF HIGH ALTITUDE AERIAL PHOTOGRAPHY IN WISCONSIN
(Shaded areas show coverage)

METHODS OF DATA EXTRACTION

The initial procedure included the analysis, interpretation and extraction of vegetative data which could be identified from RB-57 imagery (Sept. 1971, 1:120,000 CIRT*). This was done using a 4-0 rapidograph on a Richardson light table with a Bausch and Lomb stereoscope. Each form of biotic data considered a variable was extracted separately on individual acetate overlays. Once the extraction was accomplished the overlays were then enlarged to a scale of approximately 1:26,000. Each variable was then assigned a color to distinguish differences in data types by using diazo paper (Spectra Diazo color film for Projection Transparencies) and processing the treated paper through a blueprint machine. These reproduced images were then combined to produce one color composite image which represented the southern Horicon Marsh area (see diazo map).

This type of extraction technique just described produced a number of problems. First, in working at this scale of imagery (1:120,000) there is a considerable error in attempting to put lines around vegetative patterns. An extremely fine rapidograph is not an accurate enough instrument to produce desired detail nor the detail perceptable from the imagery. The error is also multiplied proportionately to the scale increase when these overlays were blown up. This, in turn, negates meaningful interpretations of spatial correlations. Second, the acetate overlays heat up and stretch when placed over the light tables, thus distorting the spatial geometry. This was especially noticeable when working with vegetative groups that required greater amounts of time to extract (e.g., emergent macrophytes). When the color transparencies from the Diazo reproductions were combined to produce a combined image the alignment error is easily noticeable.

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*CIRT: Color InfraRed Transparency.

The following listing is the photo interpretation key developed by the author for RB-57 color infrared imagery used to delineate the vegetative categories shown in the Diazo map.

Open Water: Distinghishable by deep dark blue to black with smooth surface area.

Emergent Aquatics: Gray to pinkish tone with purplish tinge; flat-smooth texture; stands can be solid but usually intermixed with or dispersed by water with the water surface showing through the vegetative pattern; patterns can appear somewhat stringy.

Emergent Macrophytes: Mottled tones of light green and dark green. Tones can also be pinkish to brownish pink depending upon the flowering times and pigmentation of the macrophytes. Usually, even when flowering, pinkish tones will be mottled or intermixed with the green tones. Stands can be quite extensive and solid or intermixed with water creating an interspersion zone of cover water. Texture is fine.

Grasses and Sedges: Usually found upward in gradation of open water to uplands from macrophytes. Water table is at or near the surface. Tone is light dull pink to bright pink and fine textured. Can have some grayish and brownish mottling present.

Deciduous/Coniferous Shrubs: Tone can vary from white or light gray (distinguishing aspen/birch community) to a deep purplish, reddish brown indicating a young stand of tamarack or white cedar. Other deciduous shrubs appear in some tinge or pink varying from light to bright pink. Canopy can be closed and dense or interspersed with grasses and sedges. Texture is medium to coarse with individual tree canopies distinguishable, if dispersed. Most identifying characteristic is by association to grasses/sedges complex and placement in gradation.

Deciduous Trees: Tonal pattern bright red to very bright red with the exception of aspen/birch community which remains white to light gray. Community usually lies on the uppermost gradation pattern. Pattern can be closed and dense, with texture varying from medium to very coarse. When dispersed, canopies of individual species are evident. Can be intermixed or dominated by one species. Aspen and birch associations are usually found along edges.

Coniferous Trees: This category includes tamarack and white cedar associations. Both are purplish or brownish red and dull in color. Texture is medium to fine because of pointed canopies. Stands of tamarack are solid and dense with white cedar intermixed. Can be interspersed with deciduous.

It should be mentioned here that the tonal patterns are those associated with the particular imagery and date (Sept. 1971) used in this experiment. Specific tonal patterns do not always hold true for other dates. Reasons for this can be vegetative differences due to climatic fluctuation, water level differences, film and filter differences, and time of day. However, texture and association remain somewhat constant even when tonal patterns fluctuate.

The amount of time to extract the described variables onto acetate overlays and reproduce them on the diazo transparencies was estimated to be 11 hours.

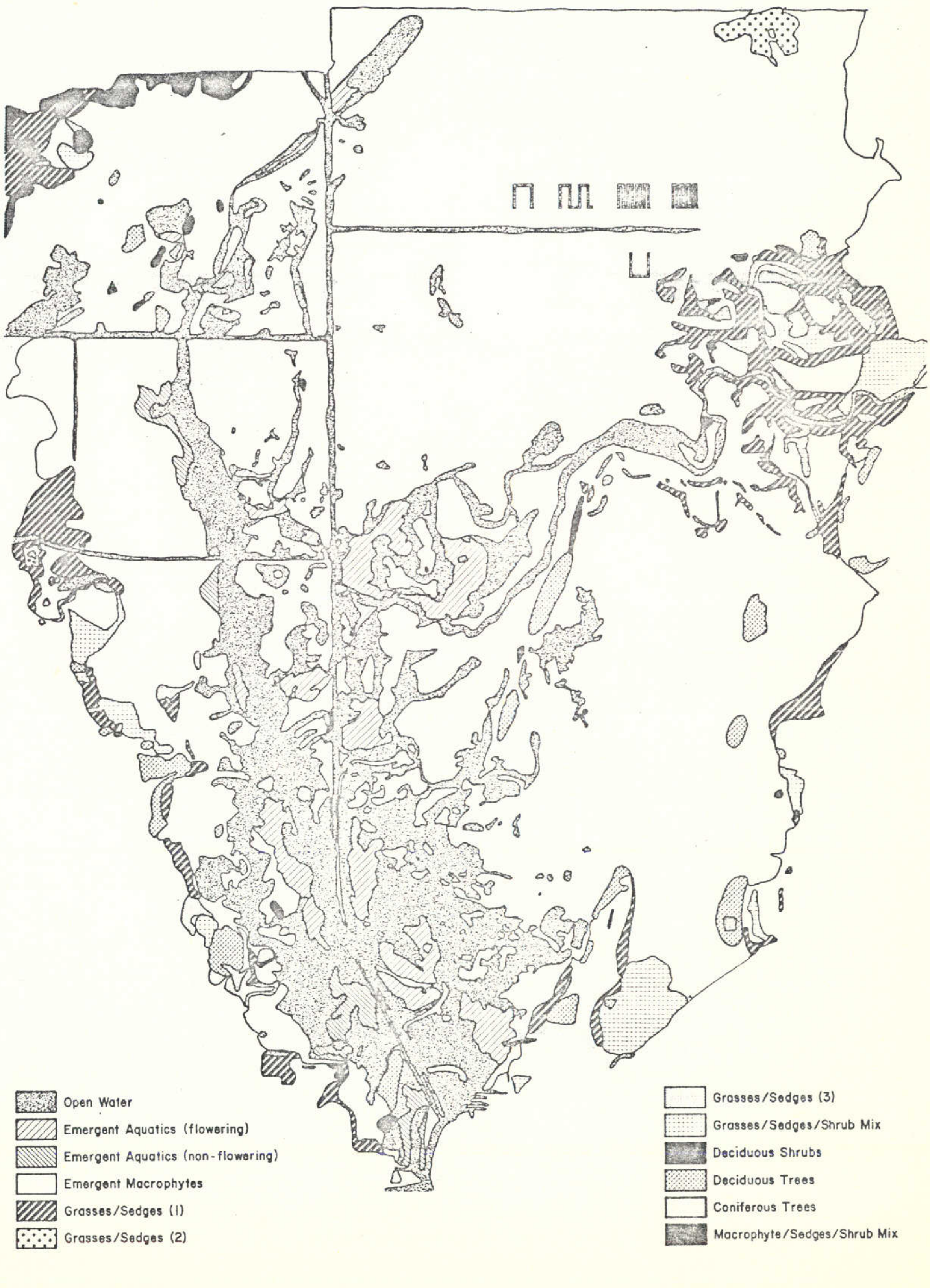
Based upon this initial test, it was decided that this method of extraction would not provide enough discrete detail to meet DNR's needs.

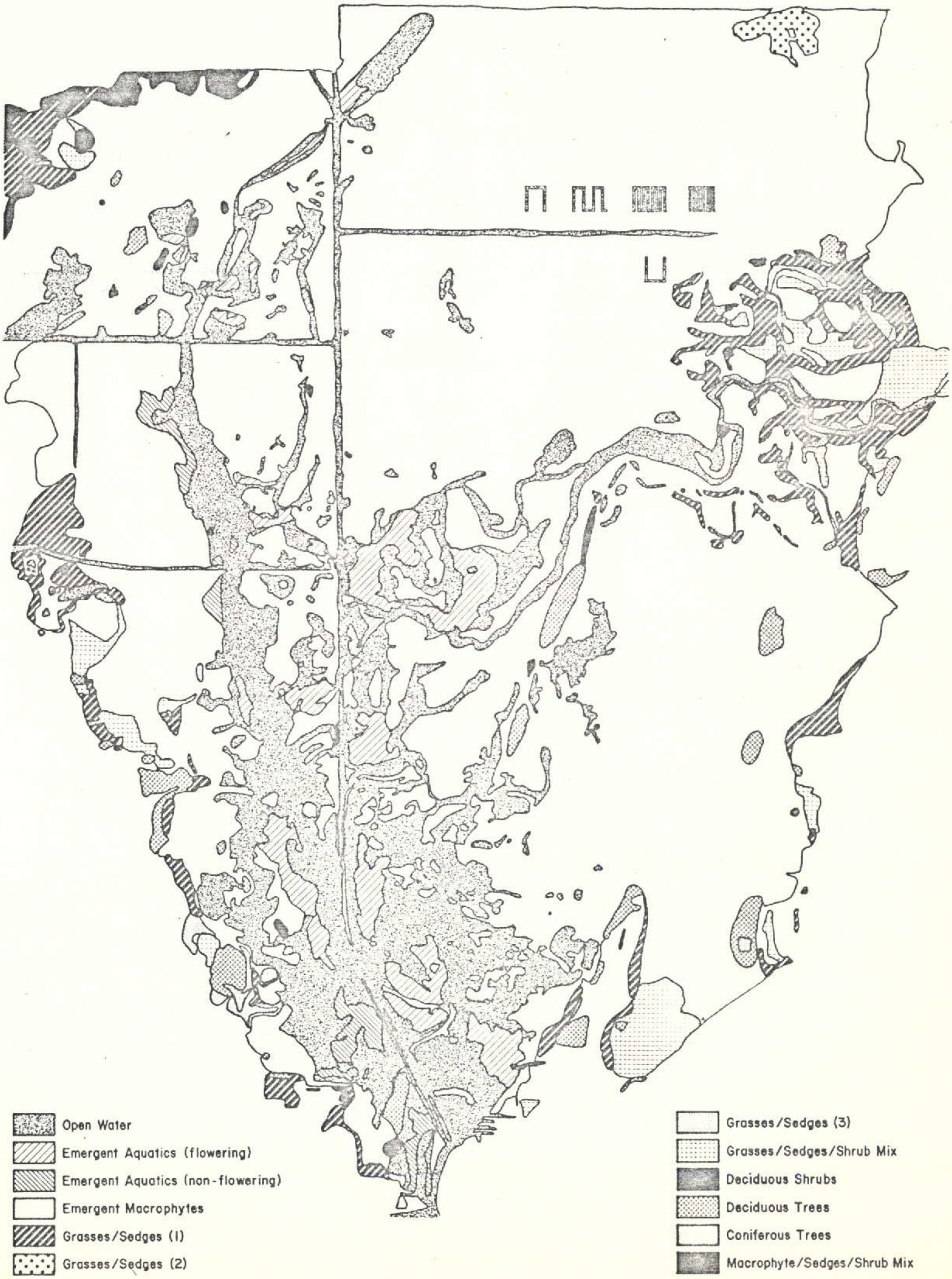
However, because the discrete information could be visually identified on the RB-57 imagery, it was determined that using different photogrammetric techniques the spatial geometry could be corrected.

A second attempt was initiated using a PG-2 stereoplotter. In general, this instrument aligns two consecutive images in stereo and scene corrects photogrammetric errors such as relief displacement, tilt, swing, drift, etc. Extraction was done by placing and moving a dot through a viewing screen around the vegetational patterns which were then machine reproduced on drafting paper at a scale of 1:31,680. These drafting papers were then combined and increased to a scale of 1 inch = 1320 feet (see map). This process greatly reduced the error created in the first extraction procedure. Significant error was then essentially limited to airphoto interpretation of the variables (i.e. placing lines around vegetative patterns). These pattern identification lines by necessity must be somewhat arbitrary because wetland vegetation does not exist within specific defined boundaries, rather within a continuous gradation between open water and upland vegetation.

During this second phase it was decided that other wetland vegetational patterns which could be identified by their differences of tonal reflection should also be included. The following example should explain. During the first attempt grasses/sedges complex was listed as one variable. This was due to the constraints of interpretation using the extraction method previously described. During the second photo interpretation, because of the ability of an instrument like the PG-2 stereoplotter to map fine detail it was found that this group could be broken down into three sub-categories,groups 1, 2 and 3 as listed on the map legend.

These can be photo identified as follows:


Open Water
Emergent Aquatics (flowering)
Emergent Aquatics (non-flowering)
Emergent Macrophytes
Grasses/Sedges (1)
Grasses/Sedges (2)
Grasses/Sedges (3)
Grasses/Sedges/Shrub Mix
Deciduous Shrubs
Deciduous Trees
Coniferous Trees
Macrophyte/Sedges/Shrub Mix


Open Water
Emergent Aquatics (flowering)
Emergent Aquatics (non-flowering)
Emergent Macrophytes
Grasses/Sedges (1)
Grasses/Sedges (2)
Grasses/Sedges (3)
Grasses/Sedges/Shrub Mix
Deciduous Shrubs
Deciduous Trees
Coniferous Trees
Macrophyte/Sedges/Shrub Mix

Grasses/Sedges (1) - Fine textured areas which appear pink to pinkish red on the imagery.

Grasses/Sedges (2) - Fine textured areas which appear whitish and have an interlaced pattern.

Grasses/Sedges (3) - Fine textured areas which appear various tones of gray.

(Both subgroups 1 and 2 appear to be associated with the edges of shrub complexes, where subgroup 3 lies within the macrophytes and therefore seems to require or grow in a greater depth of water.)

The following patterns were also noted and identified:

Emergent Aquatics (1) - Patterns which appear on the surface with a light pink tonal reflection.

Emergent Aquatics (2) - Patterns which appear on the surface with a gray tonal reflection.

Because of the time constraints placed on the author and the availability of the PG-2, these are the categories mapped. However, there are patterns which exist in the general category macrophytes which should be described to give a better description of the information available from the imagery.

Macrophytes (1) - Areas which appear pink.

Macrophytes (2) - Areas which appear gray.

Macrophytes (3) - Areas which appear greenish gray.

As indicated, these areas could have therefore been mapped but were not. Within the categories that were mapped the amount of time required to extract changed significantly, with extraction taking 30 hours. This is due to the specificity of detail with which the patterns could be mapped, plus the time required to orient the images in the PG-2.

RESULTS/CONCLUSIONS

Comparison of different types of mapping techniques showed significant results. By mapping vegetative groupings or associations from high altitude photography, species identification is not possible. This loss of specificity when compared to traditional ground mapping techniques must be recognized. However, depending upon the type of information desired, high altitude photography does provide a large volume of information in a short period of time. Presently, a comparison is underway by the DNR between the categories listed on the RB-57 generated map and the species map done by DNR personnel using conventional ground techniques. When this is accomplished a comparison of DNR species/classification can be compared with the results of this investigation.

It should be mentioned that this mapping attempt was consciously done without the aid of ground truth and without familiarization of the area. This was to determine the amount of information available from the imagery without extensive field work involvement. It was based on the previous experience of the author in attempting to identify wetland plant communities using high level photography. In any attempt to use this type of remote sensing data gathering, eventual ground truth is essential. Only with a combined attempt using both remote sensing and ground techniques can the optimum application of both be realized. Remote sensing techniques do provide an accumulation of data with the ability to recall the raw source for comparison based on later evaluations and/or changes in data requirements. At a minimum, an initial assessment of the state's wetlands with remote sensing can provide a data base from which wetland areas requiring more detail can be spatially delineated for further ground truth information.

DISCUSSION

Presently the DNR is considering the adoption of the federal classification system proposed by the Fish and Wildlife Service, Department of the Interior (Circular #39), to coordinate state surveys with federal classifications. Within the federal system of 20 wetland types, 8 apply to the state of Wisconsin. Those 8, which are included in the category "Inland Fresh Areas," are:

1) Seasonally flooded basins or flats
2) Fresh meadows
3) Shallow fresh marshes
4) Deep fresh marshes
5) Open fresh water
6) Shrub swamps
7) Wooded swamps
8) Bogs

(At the present time the DNR is considering recognizing only groups 3 through 8).

However, a problem remains within Wisconsin in that wetland areas demand an assessment of quality. The federal classification does not inherently provide an assessment of quality given the many uses of a wetland resource (e.g., wildlife vs. educational). This is a critical factor because data gathering will have to meet other state data and planning needs.

The Wisconsin Land Resources Committee in its report to Governor Lucey (Feb. 1973) states that "certain land resources and certain uses of land, selective in number but of great significance, have a wide ranging importance which extends far beyond the immediate community in which the resource or proposed land use is located...The Committee has found that informational gaps exist which alter and even thwart comprehensive planning. Basic data will be essential if standards are to be developed to protect specific resources...The state must assure that it has adequate data for overall state development policies for wisely locating public facilities, identifying, understanding and establishing sound policy on significant state land resources concerns."

Within this framework the Upper Great Lakes Regional Commission, the Department of Administration, and the Institute for Environmental Studies, University of Wisconsin, are developing a Critical Resource Information Program through which the critical resources within Wisconsin will be defined and assessed. It is hopeful that the needed criteria developed in this program will provide an agglomeration of measurement variables by which the federal classifications and others can be delineated.

On 5 April 1973 the Wisconsin State Legislature introduced Assembly Bill 813 which initiated a wetland preservation program to be administered and enforced by the Department of Natural Resources. This bill recognizes wetland areas as being an important critical resource of the state and one that has been heavily misused within the past. In recognizing wetlands as a resource within the "public interest" the legislature authorizes the Department of Natural Resources for "inventory, planning and regulation of wetland alterations including special protection orders adopted for specific wetlands." This authorization implies that wetlands not necessarily be considered just as one entity but individual resources requiring individual management practices.

Recognizing this overall need, the federal classification system does not give adequate information for quality assessment, but rather separates wetlands into general categories. The classification system therefore does not provide for identification of the composition of each individual wetland. Policy decisions using this level of information are therefore thwarted and management decisions impossible.

Appendix I lists a classification system developed previously by the author using high altitude RB-57 imagery. The described components of the classification system provide an indication of the discreteness with which the imagery can be used as a data base. By a systematic ranking of the extractable variables an index or hierarchy of quality could possibly be developed which will be helpful to state agencies in delineating and ranking areas for preservation and forms of management.

It remains for the DNR to establish the information criteria that they require before the state wide inventory is attempted. The various user needs for wetland information should assist in determining what specific data to collect. Hopefully, this paper will somewhat familiarize DNR personnel with the uses and applications of one type of remote sensing technique presently being used at the University. It is also hopeful that the paper will help establish a working relationship between the agency and interested University personnel in solving state land use needs.

APPENDIX I

WETLAND CLASSIFICATION

This wetland classification is based on an existent system developed by Dr. James Zimmerman, University of Wisconsin-Extension, and used by Dr. Zimmerman and Barbara Bedford Putzer in a project financed by the Urban and Regional Planning Commission and the Department of Natural Resources in classifying the wetlands of Dane County. It reflects the extractable information from high altitude RB-57 imagery and is computer oriented for storage and manipulation to coincide with other land resource data classifications. It was developed and has previously been used in a study funded by the Bureau of Outdoor Recreation at the Department of Landscape Architecture/Environmental Awareness Center. This study was based on storing data in 1 km^2 cells as a data base for general state and regional planning.

3100 Water
- 3102 Non-Existent
- 3101 Existent
- 3101.00 Estimated percentage of cell (water quantity)
- 3110 Water occurrence
  - 3111 Occurs throughout the year
  - 3112 Seasonally flooded
  - 3113 Unidentifiable
- 3110.00 Percentage of cell in which water occurs
- 3120 Water depth
  - 3121 0-1 foot
  - 3122 2-5 feet
  - 3123 Greater than 5 feet
  - 3124 Unidentifiable
- 3130 Water quality
  - 3131 Excellent (no visible suspended solids)
  - 3132 Good (few visible suspended solids)
  - 3133 Fair-poor (many identifiable suspended solids)
  - 3134 Unidentifiable

3200 Cover-Water Ratio (Interspersion)
- 3202 Non-Existent
- 3201 Existent
- 3210 Level of interspersion (cover:water)
  - 3211 10:90
  - 3212 20:80
  - 3213 30:70
  - 3214 40:60
  - 3215 50:50
  - 3216 60:40
  - 3217 70:30
  - 3218 80:20
  - 3219 90:10
- 3210.00 Percentage of cell in which interspersion exists (i.e. 3215.76 would indicate 50:50 ratio of cover to water occurring in 76% of the cell)

3300 Gradation
- 3302 Non-Existent
- 3301 Existent
- 3310 Degree of gradation
  - 3311 1 plant community (mono-type)
  - 3312 2 plant communities
  - 3313 3 plant communities
  - 3314 4 plant communities
  - 3315 5 or more plant communities
- 3310.00 Estimated percentage of cell in which gradation occurs

3400 Vegetation
- 3402 Non-Existent
- 3401 Existent
- 3410 Vegetational types
  - 3411 Emergent aquatics
  - 3412 Emergent macrophytes

- 3413 Grasses, sedges
- 3414 Deciduous shrubs
- 3415 Coniferous shrubs
- 3416 Deciduous trees
- 3417 Coniferous trees
- 3418 Deciduous, Coniferous mix
- 3419 Unique species

3410.00 Estimated percentage of cell in which these discernible patterns exist and their percentages. Therefore, two cards may read 3413.08 and 3414.26 for one cell. This would indicate that within the cell, 8% is covered by grasses and sedges, and 26% by deciduous shrubs.

3500 Diversity
- 3502 Non-Existent
- 3501 Existent
- 3510 Number of plant groups represented within a given cell
  - 3511 1 type (mono-type)
  - 3512 2 types
  - 3513 3 types
  - 3514 4 types
  - 3515 5 or more types
- 3510.00 Estimated percent of cell in which diversity exists

3600 Disturbance
- 3602 Non-Existent
- 3601 Existent
- 3601.00 Occurrence time
  - 3601.01 Occurring at present
  - 3601.02 Has occurred in the past
  - 3601.03 Both occurring at present and semblance to the past
- 3610 Type of disturbance
  - 3611 Draining
  - 3612 Grazing
  - 3613 Burning
  - 3614 Erosion
  - 3615 Farming
  - 3616 Filling
  - 3617 Building
- 3610.00 Estimated percentage of cell in which each type of disturbance occurs. This could be represented in the same way as vegetation in a situation where more than one type of disturbance is occurring.

3700 Geographic Relation/Location of Other Wetlands
- 3702 Non-Existent
- 3701 Existent
  - 3711 Critical part of large wetland system
  - 3712 Adjacent to wetland system
  - 3713 Interconnected with other wetland systems
  - 3714 Adjacent to lake greater than 50 acres
  - 3715 Adjacent to lake less than 50 acres
  - 3716 Adjacent to major river
  - 3717 Adjacent to minor river