053076

SEMI-ANNUAL STATUS REPORT

Reporting Period: December 1, 1975 - May 31, 1976

Grant No. NGL 15-005-186

Title of Investigation:

The Application of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana

Principal Investigator:

R. A. Weismiller
Purdue University
Laboratory for Applications of Remote Sensing
West Lafayette, Indiana 47906

Submitted to:

The Office of University Affairs
Code P
National Aeronautics and Space Administration
Washington, D. C. 20546

TABLE OF CONTENTS

	Page
I. INTRODUCTION	1
II. PROJECT REPORTS	2
A. WATER RESOURCES	
Power Plant Siting and Thermal Discharge	2
B. DATA BASE APPLICATIONS	
Yorktown, Indiana	10
Boone County, Indiana	24
C. FORESTRY APPLICATIONS SECTION	
Forestry Demonstration Project	26
Coastal Zone Mapping Project	33
D. SOIL INVENTORY PROJECT	
Jasper County, Indiana	36
Clinton County, Indiana	37

INTRODUCTION

This semi-annual status report covers the period from December 1, 1975 to May 31, 1976 and contains a review of the research and applications, completed or in progress, as funded by the Office of University Affairs, NASA and conducted by Purdue University, Laboratory for Applications of Remote Sensing.

This reporting period marks the second half of the third year of funding for a proposal entitled "The Applications of Remote Sensing Technology to the Solution of Problems in the Management of Resources in Indiana." As indicated in this title, the purpose of this work is to introduce remote sensing into the user community within the state of Indiana. The user community includes those local, regional and state agencies involved in the decision monitoring and/or managing processes of the state's resources.

In order to carry out this work it is not only necessary to initiate projects with these agencies but also it is necessary to meet with and provide information to as many people and groups as well as agencies as possible. During the past six months numerous meetings were held with ten different groups.

Among the groups that were contacted and received information about this program were:

- Area Planning Commission, Boone County
- Indiana Heartland Coordinating Commission
- Indiana Geological Survey, Industrial Minerals Section
- U. S. Forest Service
- Yorktown, Indiana Town Board
- Yorktown, Indiana Plan Commission
- Yorktown, Indiana Board of Zoning
- Delaware County - Muncie Metropolitan Department of Planning and Zoning
- Save the Valley Organization
- Tipton County Commissioners and Engineers.

Listed below are the projects that are in progress and reported in this document:

- Water Resources - Power Plant Siting and Thermal Discharge
- Data Base Applications
- Forestry Applications
- Soil Inventory Project.

WATER RESOURCES
POWER PLANT SITING AND THERMAL DISCHARGE

R. E. Bailey and J. K. Cochran

There are three aspects to this project wherein multispectral scanning techniques are used in the process of siting energy facilities in general and power plants in particular.

Aspect 1. In regard to cooling water discharge from a power plant, the goal is to develop a mathematical model which will allow the calculation of below surface temperature profiles, given the temperature field on the surface of the water is acquired from MSS techniques.

Aspect 2. In regard to decisions, particularly in the public domain (concerning the siting of energy facilities and/or power plants), the goal is to use the data handling capabilities of the Regional Inventory Analysis Technique Data Base Program (RIAT) to handle demographic, economic, engineering, environmental and institutional data required for siting decisions. Naturally, this same system can be used for surveillance once the facility is built.

Aspect 3. In regard to helping public policy-makers use and understand the information developed, the goals are:

a. Make the data acquired available to all levels of the public,
b. Teach the users and potential users how to apply the information available, and the significance of the information itself.

The progress on these three aspects to date is as follows:

Aspect 1.

The computer program THRM3D5 (3-Dimensional Thermal Simulation Program Version 5) has been completed, and it has run successfully. THRM3D5 solves the partial differential equation which characterizes the conservation of heat in bodies of water in free surface turbulent flow subject to the boundary condition of remotely sensed water surface temperatures. The result is a 3-D map. The final technical alterations since the last reporting are fourfold:

1. An output (OUTPUT) has been written which interfaces with the results disk file from THRM3D5. OUTPUT provides point by point temperature information, or planar photos of the 3-D temperature profiles across a given body of water.

2. The numerical techniques have been accelerated to increase the economy of the program. Specifically, internal convergence rates are checked locally and the convergence of the planar array is checked relative to the previously calculated array.

3. Multiple thermal discharges into a body of water may now be modelled. This may represent either power plants discharging into each others plumes, or multiple dumping ports by a single plant.

4. The upstream boundary conditions are now calculated using a combination of the remotely sensed surface temperatures and a jet mechanics model. This represents an improvement over macroscopic heat balance conditions.

The model has been successfully employed on two sets of MSS data acquired from aircraft. The first set analyzed was the thermal plume downstream of the Gallagher Power Plant operated by Public Service of Indiana at mile 610 of the Ohio River. The data were collected at 6:19 A.M. in the morning of July 31, 1974 at an altitude of 8900 feet. The data in the thermal channel were analyzed by documented LARSYS techniques. (1) The resulting water surface temperature map was input with operating data supplied by the power plant engineers into THRM3D5.

Concurrent with LARS data collection, WAPORA, Inc. personnel collected 3-D field data at the same site. (2) Four transects A, B, C, and D of the Ohio River were established at 100-, 500-, 2000- and 4000-foot intervals, respectively, from the Gallagher discharge. Tables 1 through 4 show a detailed point by point temperature excess (i.e., temperature above ambient) comparison between the THRM3D5 output and the WAPORA data. Of the 224 points compared in these four transects, it is most encouraging to note that 216 or 89% are within 0.2°C of each other, i.e., the measured and the predicted values.

The second set of data was simularly analyzed and acquired at the same time approximately 3½ miles downstream from the Gallagher Plant. The data included the plume developed by the Cane Run Plant of Louisville Gas and Electric. The results were equally encouraging. The field data for the Cane Run Plant was collected by LARS personnel.

In addition to this completion and testing of the model, there has been an effort to get this technique documented. This has involved the writing of

a. a LARS Information Note 070576, (3)
b. a thesis for the completion of a Master of Science in Nuclear Engineering, (4) and
c. a paper for publication. (5)

Plans for the future include seminars on the technique for utility personnel and people from EPA and various state agencies such as the Board of Health, Department of Natural Resources and the Environmental Management Board. Plans also include the development of a time dependent model as an extension of this work (this development is already under way.), and the use of this model in an actual decision process. This will entail the collection and processing of a new set of data associated with yet a third power plant.

Aspects 2 and 3

As a result of continued negotiations with the USEPA, environmental groups along the Ohio River Basin and Senator Bayh's office, a group of six universities - Ohio State, Indiana, Illinois, Louisville, Kentucky and Purdue - joined together and developed proposals for estimating the impact of energy facilities in the lower Ohio River Basin. EPA estimated that the awards will be announced by the end of July 1976, and that the study will go for a three-year period. A technology assessment approach will be used.

As a result of the work reported herein, Purdue will be given the responsibility in the EPA study of estimating the movement of air and water borne pollutants from energy facilities. The results of the study will be given to all those in the public domain concerned with energy facility siting decisions.

BIBLIOGRAPHY

(1) Bartolucci-Castedo, L. A., R. M. Hoffer and T. R. West, Computer-Aided Processing of Remotely Sensed Data for Temperature Mapping of Surface Water from Aircraft Altitudes LARS Note 042373 (1973).

(2) Wapora, Inc., Thermal Plume Ground Truth Project No. I-73 (1974).

(3) Cochran, J. K. and Bailey, R. E., Computer-Aided Extension of Digitized Remotely-Sensed Water Surface Temperatures into the Third Dimension LARS Note 070576, Purdue University, 1976.

(4) Cochran, J. K., Three Dimensional Time-Invariant Computer Simulation of Thermal Discharges as a Remote Sensing Boundary Value Problem, MSNE Thesis, Purdue University (May 1976).

(5) To be published.

Table 1

Transect A - Comparison of Calculated and Measured Values

Depth (feet)	Crosstream Distance (feet) 050	100	150	200	250	300	350	400	450	500	550	600	650
1	-1.1	-0.1	-0.1	0.0	0.0	0.1	-0.1	-0.1					
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
2	-0.9	-0.1	-0.1	-0.1	0.0	0.0	-0.1	0.1					
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
3	-0.8	-0.1	-0.1	-0.1	0.0	0.0	-0.1	0.0					
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
6	-0.7	-0.1	-0.2	0.0	0.0	0.0	-0.1	0.0					
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
9	-0.6	-0.1	-0.1	0.0	0.0	0.0	0.0	0.0					
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0					
12		-0.1	-0.1	0.0	0.0	0.1	0.0	0.1					
		0.0	0.0	0.0	0.0	0.0	0.0	0.0					
15			-0.1	0.0	0.0	0.0	0.0	0.0					
			0.0	0.0	0.0	0.0	0.0	0.0					
18			-0.1	0.0	0.0	0.0	0.0						
			0.0	0.0	0.0	0.0	0.0						
21													

Transect A		
Total Grid Points	58	100%
Points with E-0.2°C	53	91%
0.2-E-0.4	0	0%
0.4-E-0.6	1	2%
0.6-E-0.8	2	3%
0.8-E-1.0	1	2%
1.0-E	1	2%

Note: All values shown are relative to the ambient temperature (°C). The upper number is the measured value while the lower number is the calculated value.

Table 2

Transect B - Comparison of Calculated and Measured Values

Depth (feet)	Crosstream Distance (feet) 050	100	150	200	250	300	350	400	450	500	550	600	650
1	3.7	3.9	2.9	0.1	0.0	0.0							
	3.7	4.1	1.9	0.3	0.0	0.0							
2	3.7	2.9	2.6	0.0	0.0	0.1							
	3.3	2.7	1.7	0.3	0.0	0.0							
3	3.0	2.7	1.9	0.0	0.0	0.1							
	2.3	2.3	1.4	0.0	0.0	0.0							
6	2.1	0.9	0.2	0.1	0.0	0.0							
	1.4	1.1	0.3	0.0	0.0	0.0							
9	3.0	0.5	0.0	0.0	0.0	0.0							
	0.8	0.5	0.3	0.0	0.0	0.0							
12	0.6	0.1	0.0	0.0	0.0	0.0							
	0.4	0.2	0.2	0.0	0.0	0.0							
15		-1.0	0.0	0.0	0.0	0.0							
		0.2	0.0	0.0	0.0	0.0							
18					0.0	0.0							
					0.0	0.0							
21					0.0								
					0.0								

Transect B		
Total Grid Points	44	100%
Points with		
E-0.2°C	33	74%
0.2-E-0.4	4	9%
0.4-E-0.6	1	2%
0.6-E-0.8	2	5%
0.8-E-1.0	2	5%
1.0-E	2	5%

Note: All values shown are relative to the ambient temperature (°C). The upper number is the measured value while the lower number is the calculated value.

Table 3

Transect C - Comparison of Calculated and Measured Values

Depth (feet)	Crosstream Distance (feet) 050	100	150	200	250	300	350	400	450	500	550	600	650
1	-0.1	0.8	1.0	1.7	1.9	1.7	0.1	0.0	0.0				
	0.6	1.0	1.3	1.7	1.7	1.4	0.2	0.1	0.0				
2	0.1	0.9	0.9	1.3	1.7	1.7	0.1	0.0	0.0				
	0.3	0.9	1.2	1.5	1.4	1.4	0.2	0.1	0.0				
3	0.1	0.8	0.7	1.1	0.9	0.9	0.1	0.1	0.0				
	0.3	0.7	0.9	1.2	1.1	1.0	0.2	0.1	0.0				
6	0.3	0.6	0.3	0.8	0.8	0.7	0.2	0.1	0.0				
	0.2	0.4	0.5	0.9	0.9	0.9	0.2	0.1	0.0				
9	0.5	0.3	0.2	0.3	0.3	0.3	0.1	0.1	0.1				
	0.2	0.1	0.1	0.3	0.4	0.4	0.2	0.1	0.0				
12	0.3	0.3	0.2	0.3	0.3	0.2	0.1	0.1	0.0				
	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.0				
15		0.2	0.3	0.2	0.2	0.1	0.1	0.0	0.0				
		0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.0				
18				-0.8	0.2	0.1	0.1	0.1	0.0				
				0.0	0.1	0.1	0.2	0.1	0.0				
21						0.1		0.1					
						0.1		0.1					

Transect C		
Total Grid Points	71	100%
Points with		
E-0.2°C	64	91%
0.2-E-0.4	5	7%
0.4-E-0.6	0	0%
0.6-E-0.8	1	1%
0.8-E-1.0	1	1%
1.0-E	0	0%

Note: All values shown are relative to the ambient temperature (°C). The upper number is the measured value while the lower number is the calculated value.

Table 4

Transect D - Comparison of Calculated and Measured Values

Depth (feet)	050	100	150	200	250	300	350	400	450	500	550	600	650
	Crosstream Distance (feet)												
1	-0.1	0.1	0.5	0.5	0.5	0.7	0.1	0.3	0.7	0.1	0.1		
	0.1	0.1	0.6	0.6	0.5	0.6	0.3	0.3	0.7	0.5	0.1		
2	-0.1	0.2	0.5	0.6	0.6	0.7	0.1	0.4	0.6	0.1	0.1		
	0.1	0.1	0.5	0.6	0.5	0.5	0.3	0.5	0.6	0.3	0.1		
3	0.0	0.3	0.5	0.6	0.7	0.7	0.3	0.3	0.6	0.1	0.1		
	0.0	0.1	0.5	0.5	0.5	0.5	0.3	0.4	0.4	0.2	0.1		
6	0.0	0.3	0.5	0.6	0.7	0.7	0.3	0.2	0.3	0.1	0.2		
	0.0	0.0	0.5	0.5	0.5	0.5	0.3	0.4	0.4	0.1	0.1		
9	0.0	0.4	0.5	0.6	0.7	0.6	0.3	0.1	0.1	0.0	0.1		
	0.0	0.0	0.5	0.5	0.5	0.5	0.2	0.3	0.3	0.1	0.1		
12	0.0	0.4	0.6	0.6	0.7	0.7	0.2	0.0	0.1	0.1	0.1		
	0.0	0.0	0.5	0.5	0.5	0.5	0.2	0.3	0.3	0.1	0.1		
15						0.6	0.2	0.1	0.1	0.1	0.2		
						0.5	0.2	0.2	0.2	0.1	0.0		
18							0.1	0.0	0.0	0.1	0.1		
							0.2	0.2	0.1	0.1	0.0		
21								0.1	0.1	0.1	0.1		
								0.1	0.0	0.1	0.0		

Transect D		
Total Grid Points	81	100%
Points with		
E-0.2°C	77	95%
0.2-E-0.4	4	5%
0.4-E-0.6	0	0%
0.6-E-0.8	0	0%
0.8-E-1.0	0	0%
1.0-E	0	0%

Note: All values shown are relative to the ambient temperature (°C). The upper number is the measured value while the lower number is the calculated value.

DATA BASE APPLICATIONS

Background

The data base project is an attempt to provide a wider range of information to resource planners and managers than available from strictly remote sensing data. The basic assumption in the data base project is that ground collected data must be registered with remote sensing data and presented to users in a coordinated manner if full use is to be obtained from either type of data.

To pursue this concept a multivariable data storage and retrieval software system has been employed which is based on the GRID program developed by Harvard University. Ground collected and remote sensing derived information has been registered for small data base test sites in Indiana to develop and test user response to this approach. Figure 1 shows the locations of the data base test sites in Indiana.

Yorktown, Indiana Site

P. E. Anuta, H. Roepke, B. Dahl, D. Adams

Status

The initial experimentation with the data base approach was directed to a 10 by 14 km block in eastern Tippecanoe County, Indiana. Software developments were made using this site as a test case. Program facilities were developed to input manually extracted data from maps, and LANDSAT data classification files to a data base grid. Data base interrogation and output product generation capabilities were included.

The data base capabilities were then applied to a test case in Yorktown, Indiana. The Yorktown Town Board is the planning body concerned with the area encompassed by the data base. The area is 2 miles N-S by 3 1/2 miles E-W and is gridded into .5 acre cells producing 7680 cells. The village of Yorktown, Indiana is in the southwest portion of the data base as shown on the map in Figure 2. The data variables which have been assembled thus far are all ground collected. Remote sensing (LANDSAT) data for land use input will be analyzed when work is complete on ground variable data input.

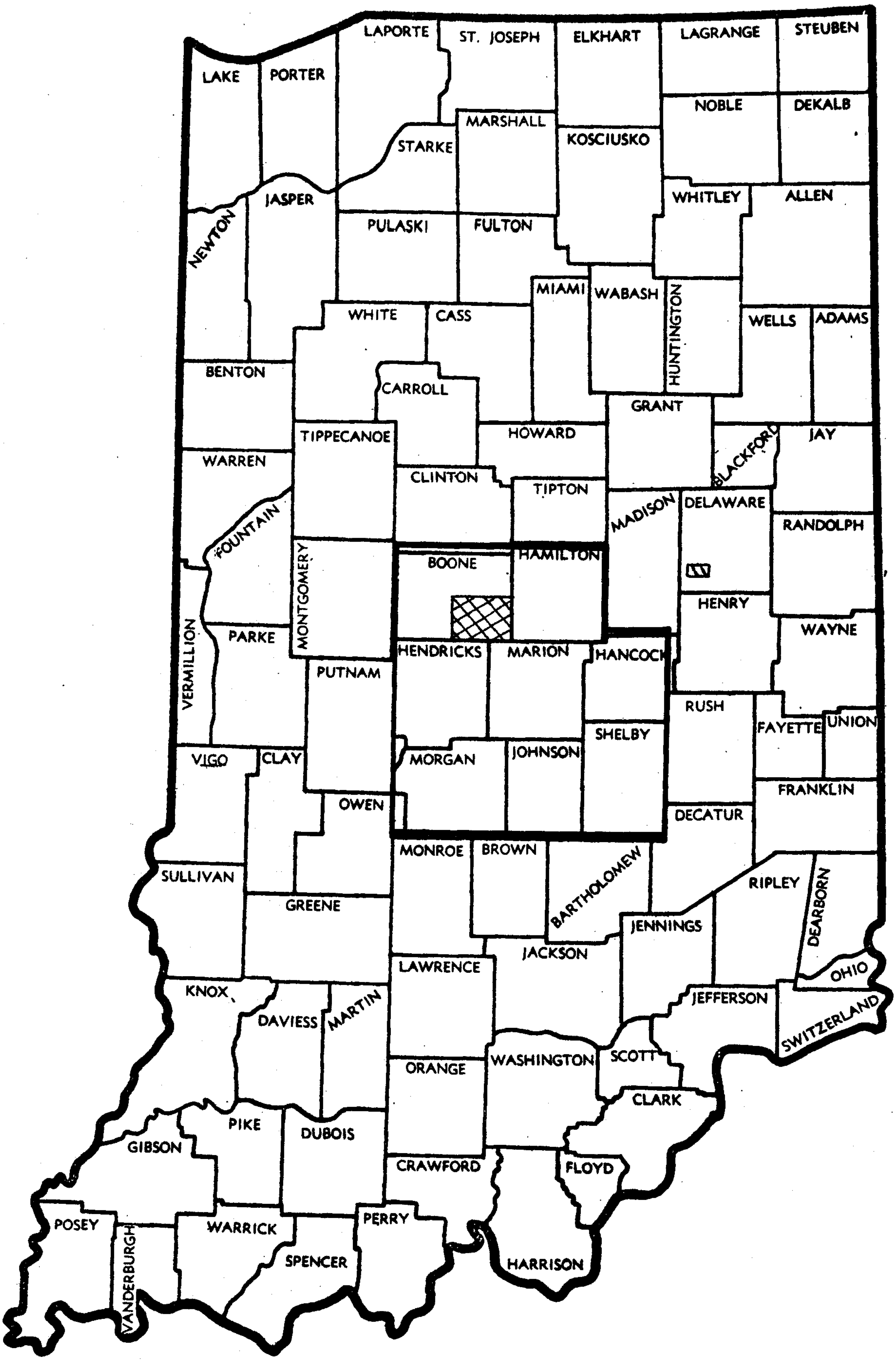


Figure 1. Location of data base sites in Indiana.

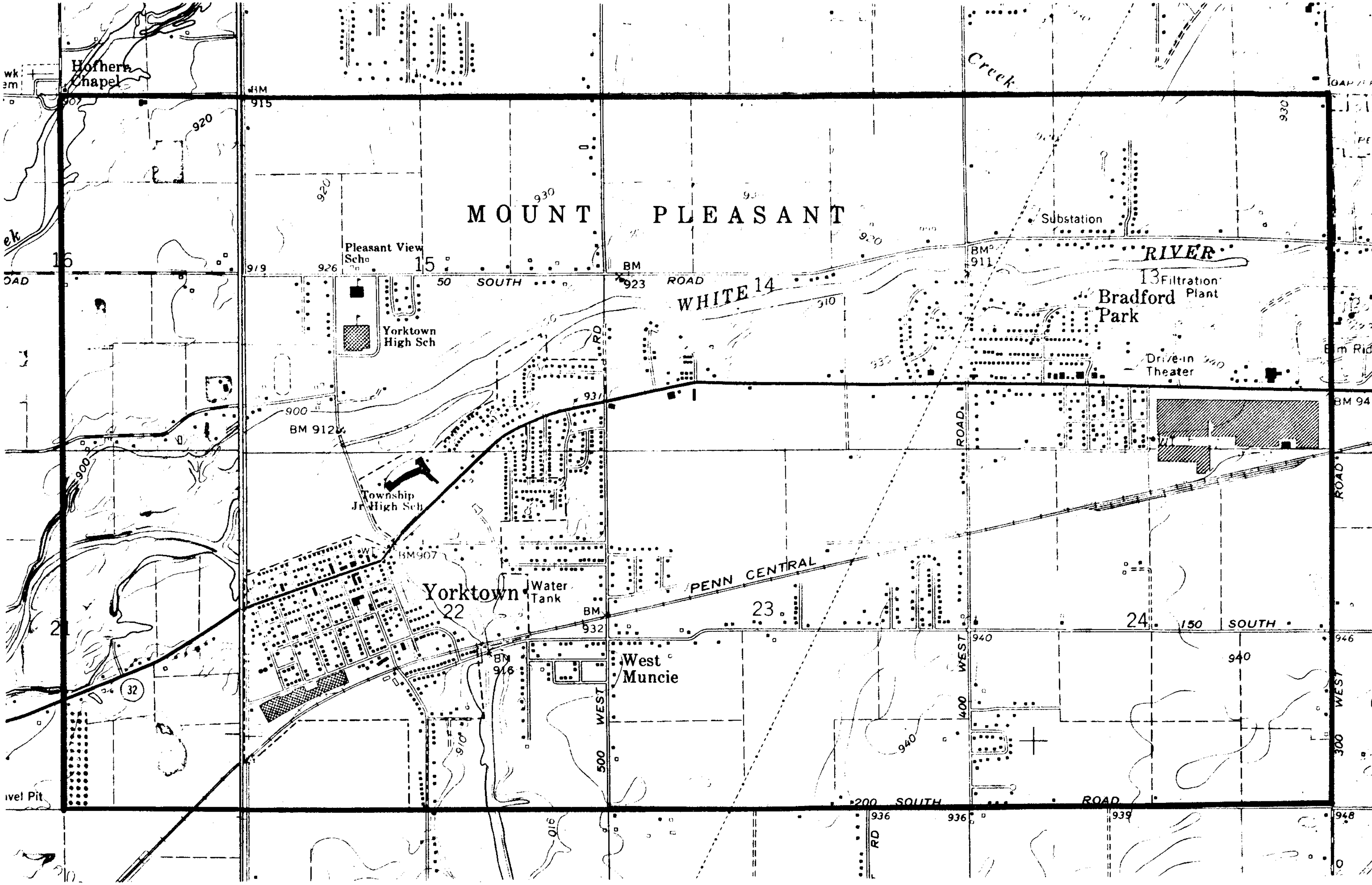


Figure 2. Location of Yorktown data base. The data grid consists of 64 rows and 140 columns of cells measuring 132 feet wide and 165 feet high. The site straddles the west edge of the Muncie west 1:24,000 scale U.S.G.S. topographic map and extends into the Gilman quadrangle.

The variables currently included in the Yorktown data base are as follows:

1. Texture of Underlying Material

The unconsolidated, glacier-deposited sediments found at the earth's surface in Delaware County, have been modified to depths of about 10 to 30 inches by biological activity, weathering and erosion. Below this modified interval, called the soil zone, the sediments are little altered from the characteristics they had when they were first deposited. The texture of the sediments underlying the soil zone are described here in terms that indicate particle size and the various proportions of mixed sizes. The term 'clay' is used for particles less than 0.002 mm, 'silt' is 0.002-0.05 mm, 'sand' is 0.05-2.00 mm, and 'gravel' is coarser than 2mm.

The textural data is recorded in 9 levels, as follows:

0 = No data. Man-made fill and water-covered sites.
1 = Muck. Decomposed plant material with varying amounts, generally less than 6, of silt and clay mixed in.
2 = Clay loam. A mixture of sand, silt, and clay that is more than 4% clay.
3 = Silty clay loam. Loam with little sand.
4 = Silt loam. Loam with more than 4 silt.
5 = Loam.
6 = Sandy loam. Loam with more than 5% sand.
7 = Sand.
8 = Gravelly loam. Loam with more than 2% gravel.
9 = Gravelly sand. Various proportions of gravel and sand.

2. Drainage

Four classes of soils are recognized in terms of relative ease with which the land surface is drained. The two factors contributing to drainage are topographic position and permeability of the soil. Thus, many depressions are poorly drained even when underlain with highly permeable material, and uplands are commonly well drained even when composed of materials of low permeability.

Drainage classes are:

0 = No data.
1 = Poorly drained.
2 = Somewhat poorly drained.
3 = Moderately well drained. This class is not recognized in the Yorktown area.
4 = Well drained.

3. Permeability of Upper Soil

The upper 10 to 30 inches of soil (approximately equivalent to the A and B horizons of the Solum) varies in terms of the rates at which water will flow through. The velocity of flow, in inches per hour, is classed as follows:

0 = No data.
1 = SL, 0.06-0.2 inches per hour
2 = MS, 0.2-0.63 inches per hour
3 = MO, 0.63-2.0 inches per hour
4 = MR, 2.0-6.3 inches per hour
5 = R, 6.3-20 inches per hour

4. Permeability of Lower Soil

Between the upper soil and the lower limit of soil sampling (60 inches) permeability values, commonly greater than in the overlying soil, are classed just as in the preceding variable.

5. Topographic Position

The surface terrain is subdivided into three categories:

0 = No data.
1 = U, Upland soils that tend to drain well because they are higher than surrounding areas.
2 = D, Depression soils that are temporarily covered by standing water after moderate to heavy rains and rapid snow melt.
3 = B, Bottom land soils that are on floodplain of streams and thus occasionally flooded, unless protected by artificial levees.

6. Flood Potential

This is essentially equivalent to the bottom land category of the preceding variable, but is limited to the major streams (White River and Buck Creek in the Yorktown area). The classes are:

0 = No data.
1 = No
2 = Yes

7. Productivity Index

The value of crops that may be produced by good agricultural practices varies from one class of soil to another. These values, normalized to a scale of 0 to 100, have been calculated for each soils class. In Delaware County the values range from 0 to 93. These values are grouped into 10 classes, as follows:

0 = No data
1 = 0-9.3
2 = 9.3-18.6
3 = 18.6-27.9
4 = 27.9-37.2
5 = 37.2-49.5
6 = 49.5-55.8
7 = 55.8-65.1
8 = 65.1-74.4
9 = 74.4-83.7
10 = 83.7-93.0

8. Unified Soils Classification, Upper Soil

The unconsolidated sediments are classified on the basis of grain size and the atterburg tests of moisture contents into the units of the unified system. A standard engineering classification used for evaluating unconsolidated sediments for various engineering applications. Sediments in which gravel or sand are free from appreciable fine material are classed as GP or SP, poorly graded (that is, well sorted) gravel or sand. Where fine material is dominant the sediment is tested to determine the moisture content at which a sample is just moist enough to be plastic (plastic limit) and also the moisture content at which the material begins to flow (liquid limit). The difference between the plastic limit and the liquid limit (PL-LL) is called the plasticity index. This value, together with the liquid limit, is used to distinguish between clays and silts of high and low plasticity. Soils that are high in organic matter are classed separately as organic soil or peat. The classes used in this report are:

0 = No data.
1 = PT, Peat
2 = OL, Organic soils, low plasticity
3 = CL, Clay, low plasticity
4 = ML, Silt, low plasticity
5 = SC, Clayey sand
6 = SM, Silty sand
7 = SP, poorly graded sand
8 = GM, Silty gravel
9 = GP, Poorly graded gravel

9. Unified Soils Classification, Lower Soil

The same system used for variable 8 is applied to the lower soils as well.

10. Depth to First Sand or Gravel

Data collected from 36 water well records in the study area were analyzed for several data items, reported here as variables 10 through 12. Coordinates of the well locations were determined with a table digitizer. Depth values of sand and gravel horizons and the bedrock surface were taken from the well records and entered on computer cards with the digitizer. These data were then submitted to a program called UNGRID which interpolated between well locations and assigned appropriate values to each grid cell. These values have been grouped into several levels, representing equal segments of the range of values in each variable. Low values indicate sand or gravel at shallow depths which can be a problem that requires extra expense for construction projects that require excavation.

Depth to first sand or gravel is encoded as follows:

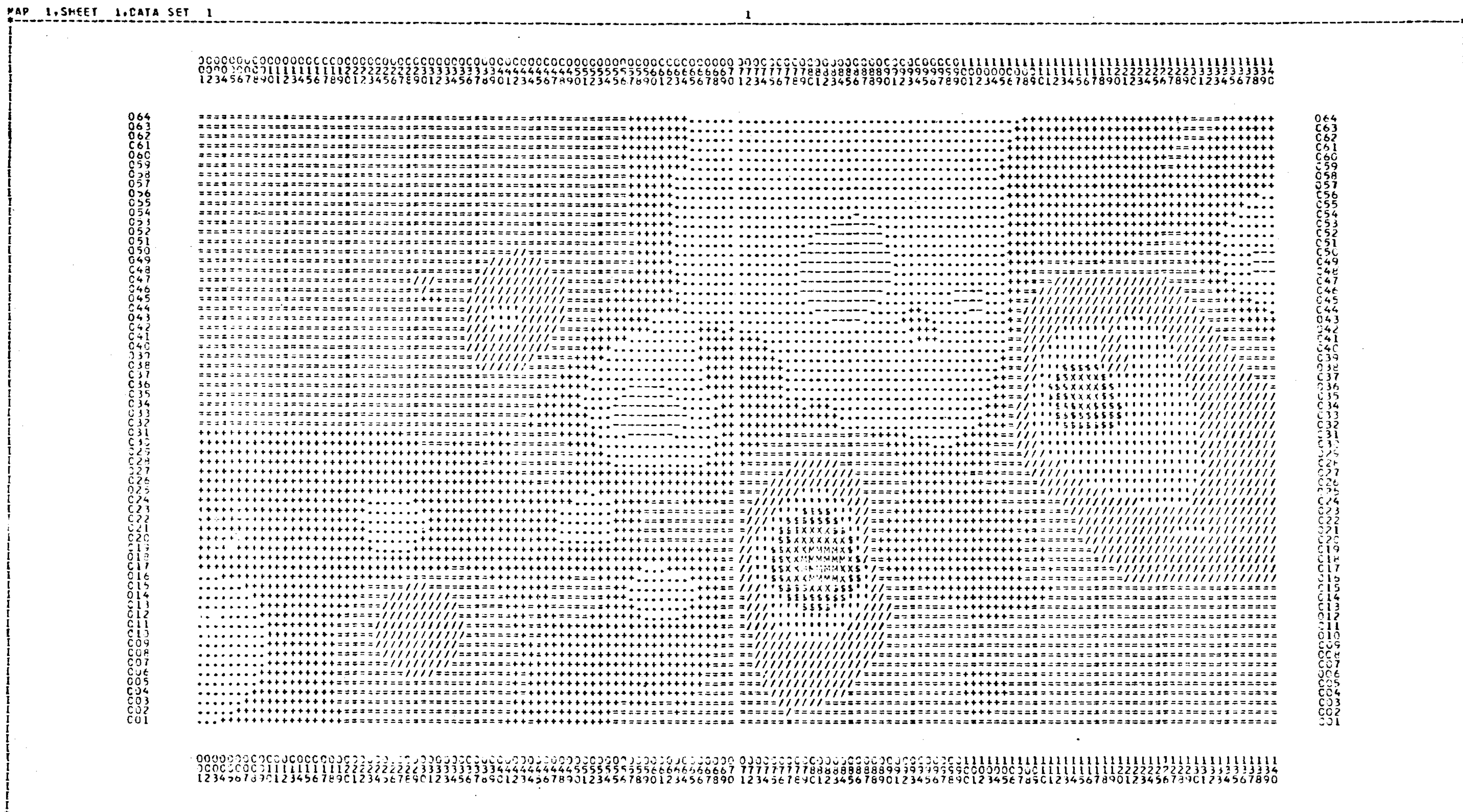
0 = Less than 5 feet
1 = 5-10 feet
2 = 11-15 feet
3 = 16-20 feet
4 = 21-25 feet
5 = 26-30 feet
6 = 31-35 feet
7 = 36-40 feet
8 = 41-45 feet
9 = More than 45 feet

A computer printout for the depth to first sand variable is presented in Figure 3. The GRID data base interrogation program used ten symbols as shown in the legend below the printout to define the ten categories listed above.

11. Percent Sand/Gravel

From the well records mentioned above, the total thickness of sand plus gravel was divided by the total depth from the surface to bedrock. High values of percent sand or gravel are a guide to areas in which shallow wells can be expected to be productive and are at the same time an indication that waste disposal procedures that would threaten the purity of ground water might endanger existing wells. The range of percentages is subdivided as follows:

0 = 0-10 percent
1 = 11-20 percent
2 = 21-30 percent
3 = 31-40 percent
4 = 41-50 percent
5 = 51-60 percent
6 = 61-70 percent
7 = 71-80 percent
8 = 81-90 percent
9 = 91-100 percent



LEVELS	0	1	2	3	4	5	6	7	8	9
SYMBOLS		-------	....	+++++++	=======	///////	'''''''	$$$$$$$	XXXXXXX	MMMMMMM
FREQUENCY	0	170	1561	2501	3236	966	372	92	43	19

Figure 3. Printout of <u>depth to first sand</u> variable from Yorktown data base.

A printout of the data base file for variable 11 is presented in Figure 4. The highest percentage areas are M's and the lowest are blanks.

12. Bedrock Elevation

Beneath the unconsolidated glacial sediments that constitute the surface materials in the Yorktown area, is hard rock of a kind locally referred to as limestone. In some places it is thick bedded and in others it is slabby and interbedded with shale. The surface of the bedrock, as interpreted by ungrid from the well records is recorded in 20-foot intervals of elevation:

0 = Less than 760 feet
1 = 760-780 feet
2 = 781-800 feet
3 = 801-820 feet
4 = 821-840 feet
5 = 841-860 feet
6 = 861-880 feet
7 = 881-900 feet
8 = 901-920 feet
9 = More than 920 feet

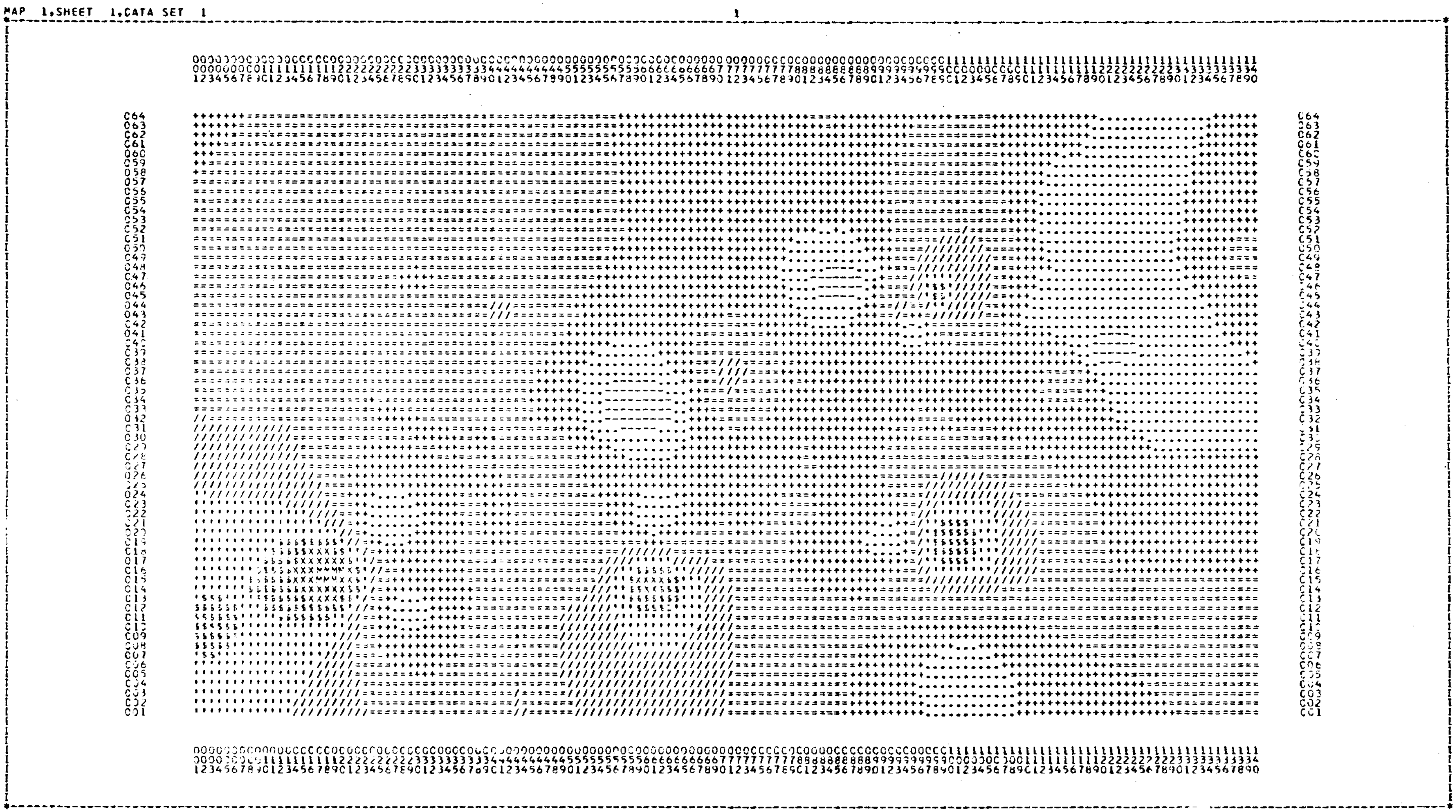
A data base printout for bedrock elevation is presented in Figure 5. Depths 760 to 780 feet to bedrock is indicated by dashes and 781-800 feet by periods. A small area of deeper rock 801 to 820 feet down is shown in + signs in the center of the site.

13. Surface Topography

The elevation of the ground surface in the Yorktown area was determined by digitizing the elevation contours of a U.S. Geological Survey topographic map. These data were interpreted by the UNGRID program and the elevation of each grid cell was stored in the data base. The range of elevations is encoded as follows:

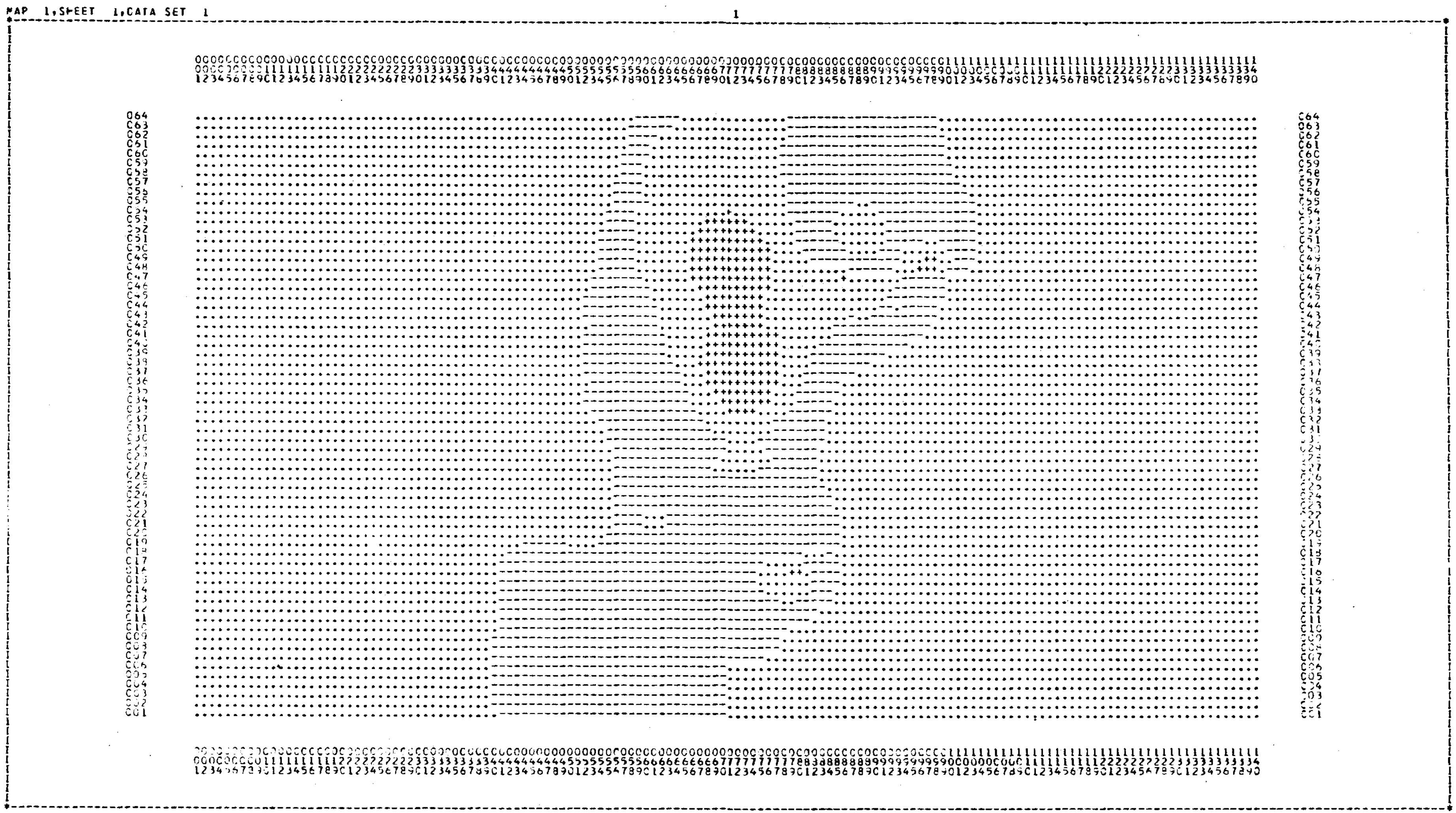
0 = Less than 890 feet
1 = 890-900 feet
2 = 901-910 feet
3 = 911-920 feet
4 = 921-930 feet
5 = 931-940 feet
6 = 941-950 feet
7 = More than 950 feet

Figure 6 shows the topographic data in the data base. Higher elevations are darker symbols. The elevation ranges run from 890 feet (dashes) to over 950 feet ($).



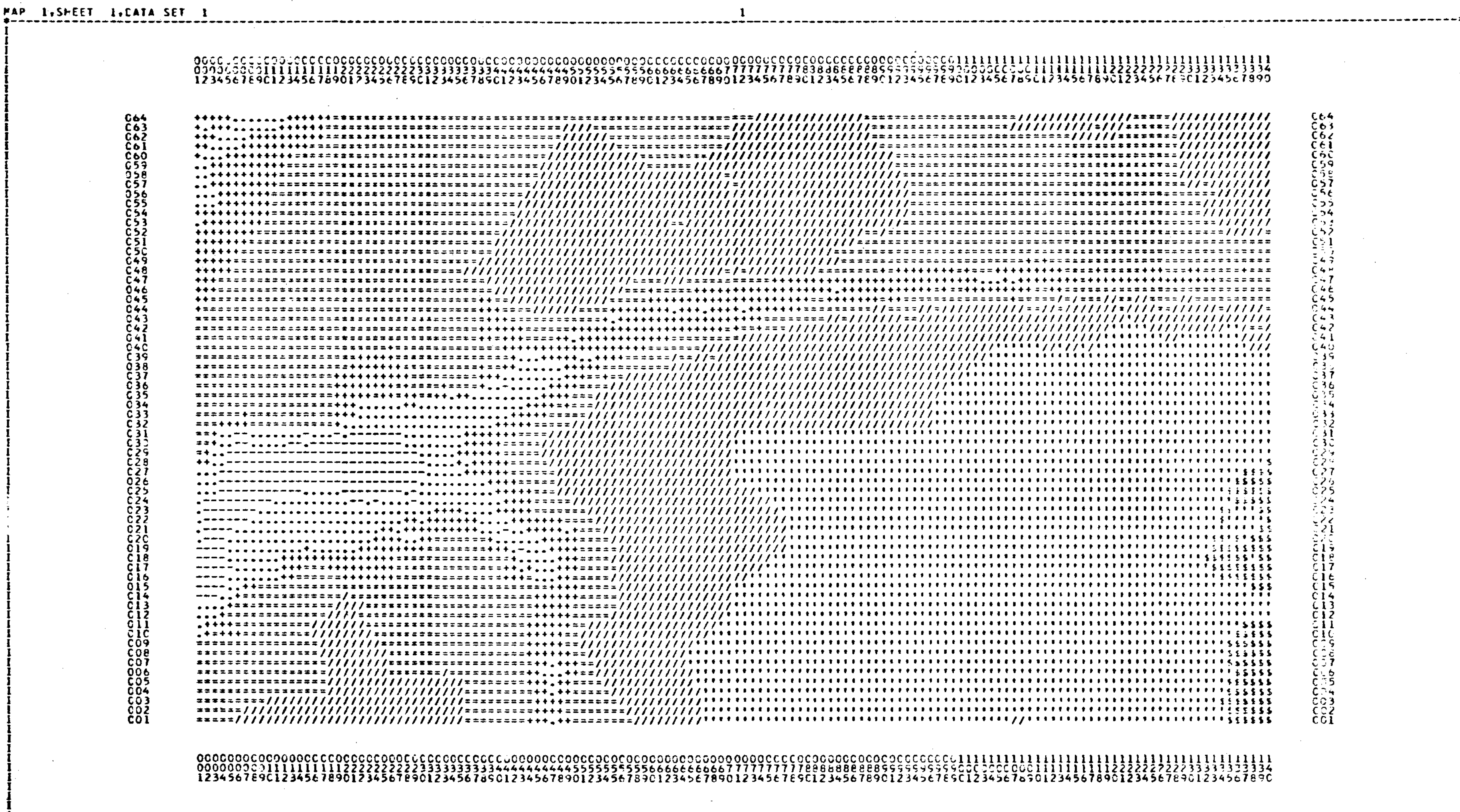
LEVELS	0	1	2	3	4	5	6	7	8	9
SYMBOLS		-------	....	+++++++	=======	///////	'''''''	$$$$$$$	XXXXXXX	MMMMMMM
FREQUENCY	0	88	1317	2974	3615	661	405	159	34	7

Figure 4. Printout of percent sand/gravel variable from Yorktown data base.



LEVELS	0	1	2	3	4	5	6	7	8	9
SYMBOLS		-------	....	+++++++	=======	///////	'''''''	$$$$$$$	XXXXXXX	MMMMMMM
FREQUENCY	0	1710	7053	197	0	0	0	0	0	0

Figure 5. Printout of depth to bedrock variable from Yorktown data base. (-) indicates 781 to 800 feet, (+) indicates 801 to 820 feet.



LEVELS	0	1	2	3	4	5	6	7	8	9
SYMBOLS		-------	....	+++++++	=======	///////	'''''''	$$$$$$$	XXXXXXX	MMMMMMM
FREQUENCY	0	211	442	792	2696	2272	2415	132	0	0

Figure 6. Printout of topographic elevation channel from Yorktown data base. (-) indicates 890 to 900 feet, $ indicates over 950 feet.

Additional variables are being added as data becomes available. Land use will be derived both from aerial photography and LANDSAT data for comparison.

Applications tests have been made in support of Yorktown Town Board decision making. In one case a sanitary sewer route under study by the Board was evaluated. Data base printouts showing areas having soils which would make sewer excavation difficult were presented to the Board. Their comparison of this data and the proposed route indicated that the route did indeed bypass the problematic areas and as a result approval of the route was reinforced. The response of the Board is discussed in a letter which is included as an attachment here.

TOWN OF YORKTOWN

(INCORPORATED)

YORKTOWN, INDIANA 47396

July 22, 1976

Mr. Paul Anuta
L. A. R. S.
Purdue University
West Lafayette, Ind. 47907

Dear Mr. Anuta:

We are writing to confirm a conversation with Mr. Roepke on the recapping of your Computer Data Base Program.

Yorktown's Town Board and Planning Commission wish to express their thanks for the excellent presentation given to us on the computer program. It was very enlighting and established interest in several areas. The study which was performed on the proposed routing of Yorktown's new sewer program did verify and also point out some problems on the routing used by the engineers.

Due to the success evaluation of the engineers sewer proposal, Yorktown's Planning Commission would like to suggest the appointment of a subcommittee to work with Mr. Roepke. The purpose of this subcommittee would be to investigate and recommend areas for study which would enable us to adopt a long range plan in the Yorktown area. If this suggestion is attractive to you please acknowledge by letter and we can set up an agreeable time schedule to continue this program.

Thank you again for your help and interest in our town.

Sincerely,

Hal E. Glass

Hal E. Glass
Pres: Planning Commission

CC: Mr. Roepke
File

A second activity is progressing which is part of the IHCC (Indiana Heartland Coordination Commission) data base applications project. A small area in southeastern Boone County, Indiana is being studied using the data base approach. This work is a pilot effort in preparation for including the entire nine county IHCC are shown in Figure 1. Detailed topographic, soils and geological information is being assembled and digitized for approximately a 15 by 15 mile area which includes the twon of Zionsville, Indiana.

Data Base Study, Boone County, Indiana

T. R. West, S. E. Hasan, S. G. Jordan

Boone County, Indiana is one of the eight counties within the Indiana Heartland Region (Figure 1). Discussions with the Planning Director of Boone County, in June 1975 indicated a need in obtaining geology and soils information to develop zoning regulations and for area planning and guidance in local rezoning. Previous work by Wilkerson, Sette and West, 1974 and Wilkerson and West, 1975 had proven useful; however, additional information was needed. One concern, however, was that local officials commonly need help in interpreting the technical, physical data supplied to them. With this situation in mind it was proposed that a data base be developed for an area in Boone County with capabilities for weighing physical data and yielding recommendations for decision making.

The study area consists of the southeastern quarter of Boone County and includes the major urban area of Zionsville (most rapidly growing city in the county) and Lebanon (the county seat) plus the agricultural area between them. The site is 13.7 miles E-W and 13.8 miles N-S with a total area of some 189.6 square miles.

Two major aspects of research are involved in the study: 1) selection of physical and cultural data to be included in the data base, and 2) determination of the cell size which comprises the primary unit for the data base.

The following list of significant variables to be input into the data base or calculated from that data were selected for inclusion in the study:

1. Slope of ground surface
2. Surface relief
3. Soils types including their physical and engineering characteristics
4. Ground water conditions
5. Geologic features including surficial geology, bedrock geology, seismic activity, flood potential, and slope stability

6. Vegetation characteristics
7. Urban areas
8. Transportation systems
9. Geographic locations

These data must be put into computer-compatible form, either by digitizing contour maps or manual encoding of individual valves for each data cell. The final phase prior to producing output information is the development of weighting factors for the parameters so that their significance can be shown relative to various proposed uses of the land relative to zoning and planning.

Selection of the cell size for the data base is a critical matter as too large a cell yields a gross and generalized data base which may be useful only to regional planning, and too small a cell involves so much time and effort to accomplish the data input that it proves uneconomical. Another requirement is a compatibility between the remote sensing data, other physical data and the geographic base used by the governmental agency involved.

A cell size of 500 feet square or about 5.8 acres was selected. This allows for the incorporation of every other line and column of LANDSAT data. The cell is sufficiently large to keep the data encoding volume within reason and sufficiently small to be useful for a detailed local study. Selection of the cell size makes it possible to provide meaningful information for local levels of government where many of the basic decisions are made.

About one-half of the digitization/encoding work has been accomplished. The remaining information should take from 10-12 weeks time for digitization/encoding. Following keypunching of the information the analysis of the data can begin. Land suitability classification for various intended uses will be performed thereafter with weighting factors developed based on published information and experience of the researchers. It is proposed that this work be completed in May 1977.

FORESTRY APPLICATIONS SECTION

R. P. Mrocyznski

A. Forestry Demonstration Project

Introduction

During the spring of 1975 LARS staff became involved with the U.S. Forest Service in an applications demonstration project on the Brownstown Ranger District of the Hoosier National Forest. Preliminary results of this activity were reported in the Semi-Annual Status Report for the period June 1, 1975 to November 30, 1975. This report reviews the activities during the past semi-annual period. The project status matrix in Figure 1 indicates the status of the potential applications demonstrations.

Mapping Activities

A critical part of this project is the production of general resource maps and then specific timber stand maps. The area in Figure 2 is a computer-assisted classification of Township 7 North, Range 1 East. The map has been prepared on a CalComp drum plotter from a standard LARSYS results tape. This product is considered to be more useful than either an alphanumeric printout or photograph which would contain the same amount of information. Minor changes in map classes are easily made on the CalComp product, by drafting the correction or amplification on the map. Such changes are not possible on either of the other products. Modifications in these situations would require costly reselection of training areas and use of more computational time.

Figure 3 is a base map of the Brownstown Ranger District showing which townships have been mapped. Area E corresponding to Figure 2 is the area reported during the previous semi-annual period.

During this reporting period an ancillary data channel containing Forest Service land ownership boundaries was created. Figure 4 is an example of the ownership boundaries overlaid on a LANDSAT data set. Being able to access data specifically by ownership will be valuable to the Forest Supervisors Office for both planning and fire control purposes.

Results Evaluation

The initial objective of this demonstration project was to develop a LANDSAT classification to compare with the Forest Service land use map. The classification was completed and reported during the last semi-annual period. Table 1 shows a comparison between six classes of cover. The comparison,

PROJECT STATUS MATRIX

WAYNE-HOOSIER NATIONAL FOREST STUDY

Demonstrations	Feasible	Important to User	User Defined Objective	Analysis Phase	Evaluation Phase	Application Phase	Application
	Current Status						
Timber - Cover type maps - Density class maps - Slope Aspect maps - Change detection	X	X	X	X	X		Decisions will be made regarding timber production through improved estimates of productivity. Information will also allow better allocation of resources for timber production activities.
Fire - Type maps - Slope Aspect maps - Fire hazard maps - Change detection	X	X	X				Information in these areas will be used to make decisions regarding the size and deployment of fire crews, based on the location of hazardous fire areas.
Wildlife - Cover type maps	X	X	X				This information will be useful in determining habitat diversity and will allow for decisions concerning location of wildlife openings and waterholes.
Planning - Type maps - Data base - Watershed overlays	X	X	X	X			General information as above will help in settling tentative output targets for the forest plan. Watershed information will be useful in locating and protecting impoundments and wetlands.
Land Acquisition	X	X	X	X			General land use maps will be helpful in assessing where parcels of land are and their suitability for acquisition.

Figure 1. The project status matrix indicates which demonstrations have been identified by the Forest Supervisor's staff as important. The matrix also indicates the status of accomplishments for each demonstration.

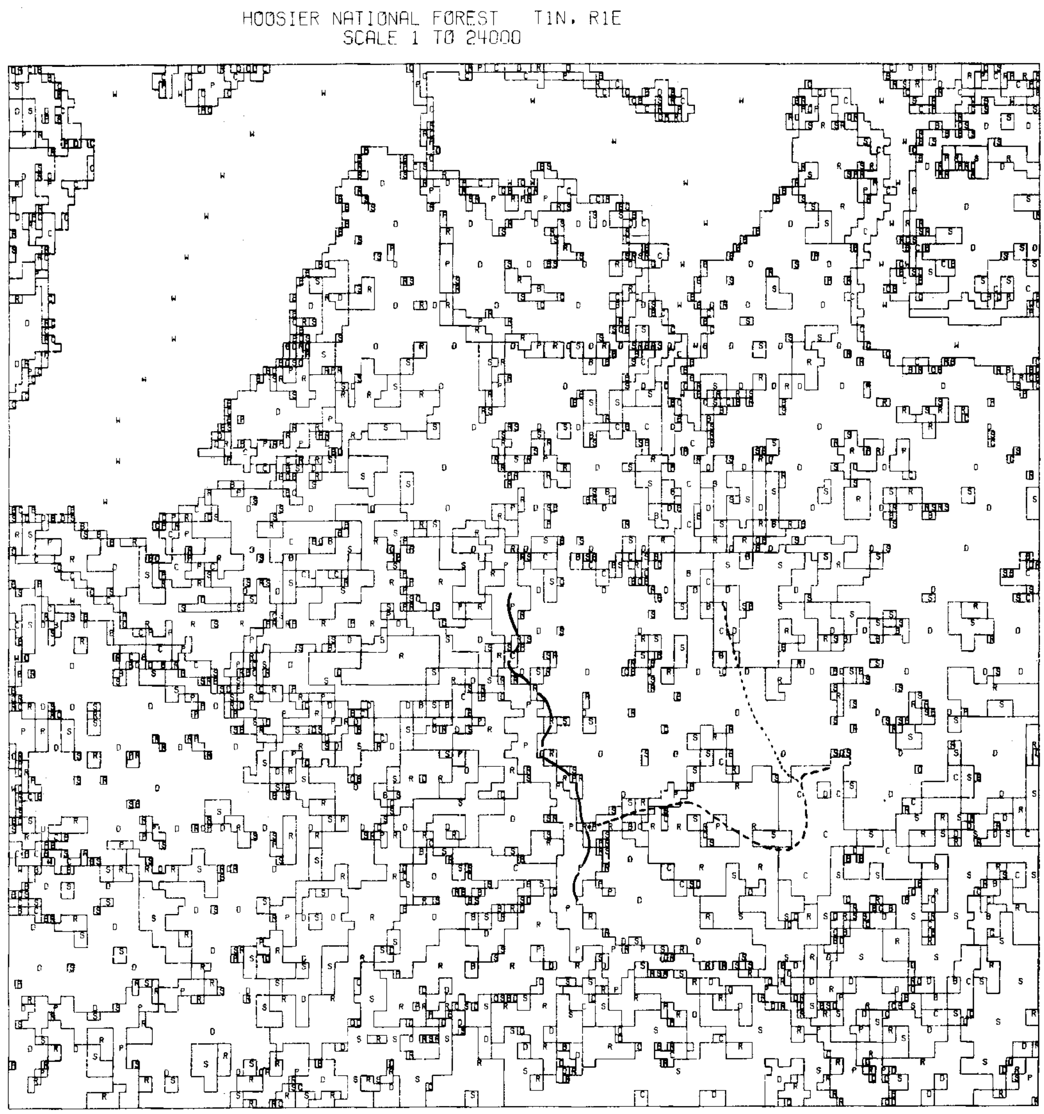


Figure 2. CalComp classification map of Township 7 North, Range 1 East. The classes include

R = Brushland
P = Pastureland
D = Dense Deciduous Forest
S = Sparse Deciduous Forest
W = Water
C = Conifer Stands
B = Bottomland Deciduous Forest

The outlined area represents the approximate location of Timber Stand Compartment 32.

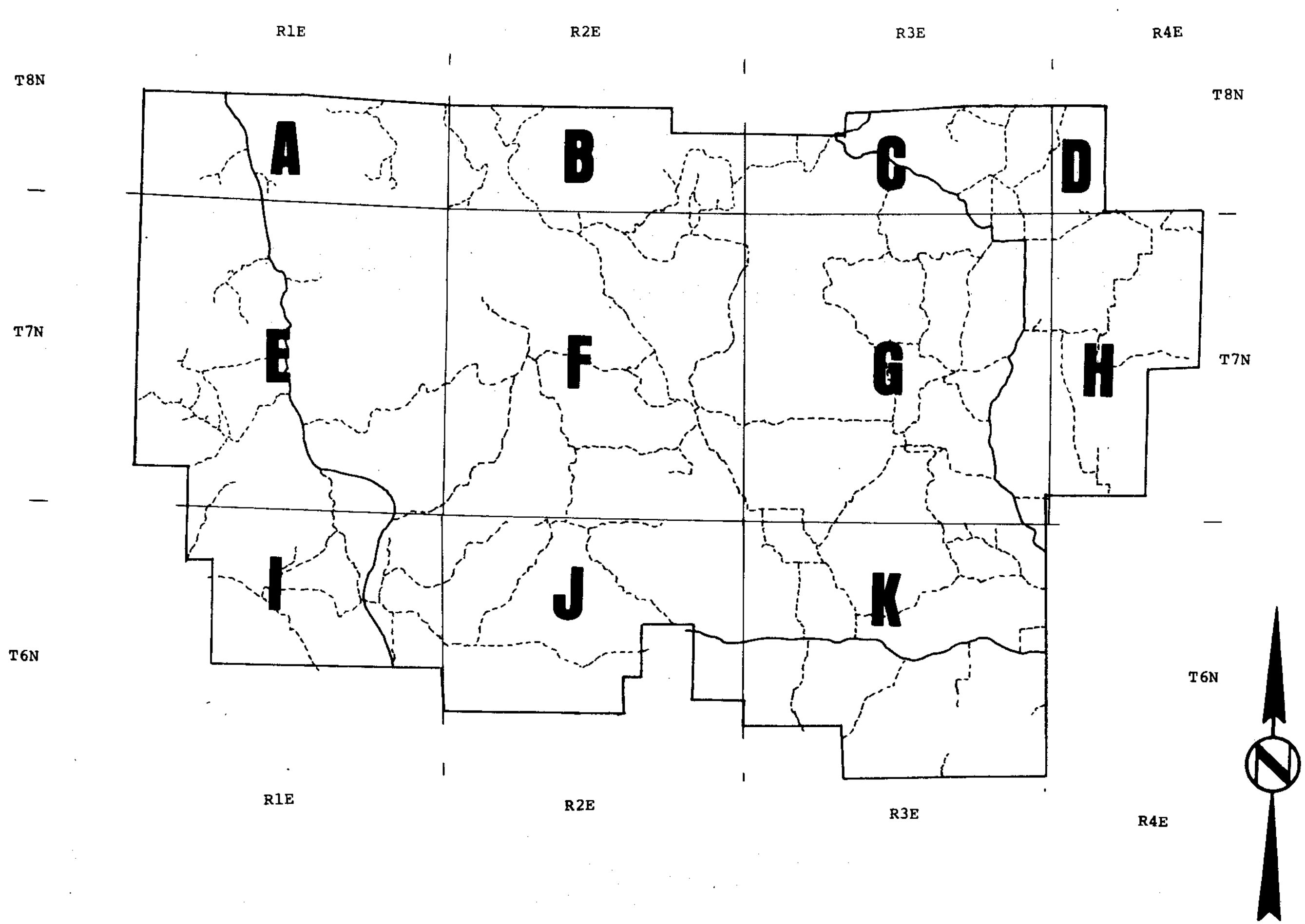


Figure 3. Base map of the Brownstown Ranger District of the Hoosier National Forest. Township boundaries and main and secondary roads have been included for reference. The townships are keyed by letter code.

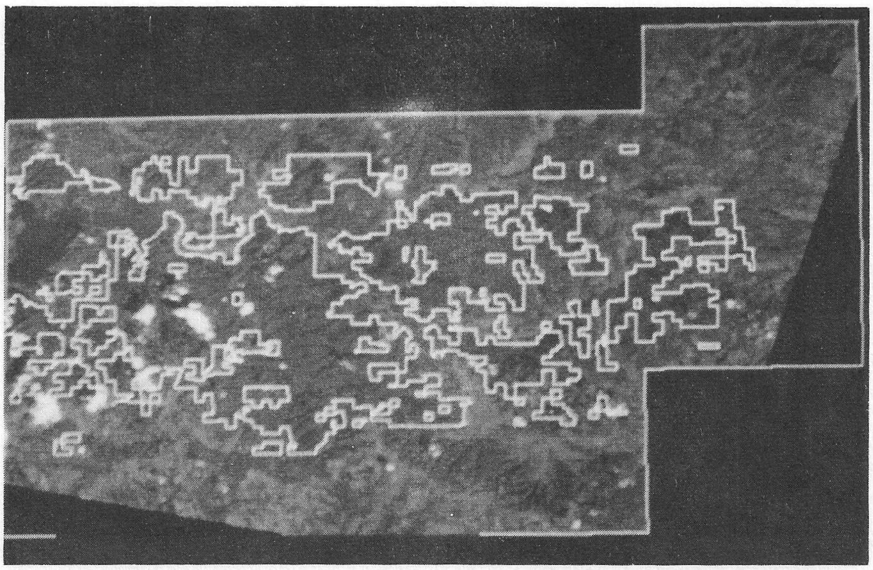


Figure 4. U.S. Forest Service ownership boundaries overlayed on LANDSAT data.

Table 1. Comparison of Acreage Estimates

Class	Percent Area in Class		Difference
	Forest Service	Computer	
Hardwood	77	57	+20
Conifer	<5	7	- 2
Brush	1	11	-11
Crop and Pasture	13	20	- 7
Water	5	5	0
Urban	<1	0	0

by percent area, is between the Forest Service land use map and the LARS computer classification. The last column indicates the magnitude of the difference between the classifications. An explanation of these differences is warranted.

The biggest difference between the two classifications lies in the hardwood class. The Forest Service map is designed to identify all areas in hardwood cover greater than 21 acres in size. This would include areas of low or understocked stands as well as adequately and well-stocked stands. Stocking, as expressed as crown density, is possibly the most important variable in the spectral response of a forest stand. In other words, brushy understocked areas identifiable on aerial photographs by their spatial and textural qualities, might share similar spectral characteristics with understocked commercial hardwoods. Since we are dealing with a continuum, the analyst had to develop a decision boundary to separate brush from hardwood. Probably that decision boundary was positioned to include a greater portion of understocked commercial hardwood than desirable.

Another explanation of the difference rests with the mapping unit utilized for each classification. The Forest Service classification is based on a 40-acre mapping criteria. As such, only areas 21 acres or greater are mapped as identifiable units. Therefore, small areas (anything 20 acres or less) such as openings or understocked areas are included with an adjacent class. The computer results are from a pixel-by-pixel classification where each pixel represents slightly more than one acre on the ground. With this mapping unit, the computer classification is considerably more sensitive to small areas on the ground. This might help explain the inflated estimates for the brush and crop/pasture class.

Planned Future Activity

Future activity as planned for this project includes the following:

a. Complete mapping of the Brownstown District on a township by township basis.
b. Evaluate classification results against 1:20,000 resource photography available through the supervisor's office.
c. Document application of the information to Forest Service needs.

B. Coastal Zone Mapping Project

Introduction

During mid-January 1976, members of LARS staff met with personnel from the Division of Forestry within the Indiana Department of Natural Resources (IDNR). The purpose of this meeting was to determine if computer-analyzed LANDSAT data could benefit the IDNR inventory of the forest resources of the state. An outgrowth of this meeting was a request (attachment) by the State Watershed Forester for assistance in mapping the forests and wetland resources of the Lake Michigan Watershed. This area included portions of Lake, Porter and LaPorte counties in northwestern Indiana.

Objective

Since the LANDSAT data was available at LARS, and the IDNR had a real need for assistance in collecting information about the area, both groups agreed to cooperate. The objective:

> "To provide information about the resources of the Indiana Coastal Zone utilizing machine-assisted analysis of LANDSAT data."

Anticipated Use

Under provisions of the Coastal Zone Management Act of 1972 (Public Law 92-583), states must develop plans for utilization and management of coastal zone areas. A prerequisite for any planning activity is knowledge about the resource to be managed. At the time LARS staff were contacted the IDNR had very little information about the nearly 400K acres encompassing the Coastal Zone Management Area.

Classifications of LANDSAT data by LARS will provide the IDNR with information about:

1. The forest and wetland resource base within the watershed boundaries.
2. Specific information relating to the classification of forest lands.

The ultimate application of this information would be in the creation of legislation regulating the uses of the land within the coastal zone.

Intermediate Application

Results from the preliminary mapping activity (Phase I) will be used to guide the collection of field data (Phase II). Results from both phases will be part of a comprehensive study that the State of Indiana is conducting for the Coastal Zone

Area. Legislation is expected to be developed which will regulate the uses of this unique area.

Results

Results from the Phase I activity are presented in the attachment entitled:

> Application of LANDSAT analyzed data to the mapping of the forest and wetlands resources of the Indiana Coastal Zone management area-preliminary progress report - Phase I.

Planned Future Activity

The Division of Forestry in IDNR is planning on placing two students in the Coastal Zone area to collect field data. The basis for this data collection will be the LARS-developed classifications. Members of LARS staff hope to be able to participate in the field data collection in order to become more familiar with the area. Additionally, an attempt will be made to correlate field data with the spectral data in order to help assess the accuracy of the classification.

 Attachment

STATE of INDIANA

INDIANAPOLIS, 46204

DEPARTMENT OF NATURAL RESOURCES
JOSEPH D. CLOUD
DIRECTOR

Division of Forestry
613 State Office Building

February 2, 1976

Richard A. Weismiller, Ph.D.
Purdue University
1220 Potter Drive
West Lafayette, IN 47906

Dear Mr. Weismiller:

As you are aware, we have been working with your organization in an attempt to devise a forest inventory and associated forest land use suitability guide to be used as a part of regional planning efforts throughout the state. During a meeting with John Berkibour and Dick Mroczynski last week, I mentioned that the Division of Forestry is presently involved in researching forest related information for the Coastal Zone Management Study of the Indiana shoreline of Lake Michigan. I was pleased to learn that you may have already performed some studies of the area and may have some forest inventory information available.

We are in the preliminary phase of the study and are concerned with an inventory and analysis of the forest land within the Indiana watershed boundaries of Lake Michigan. Enclosed is a map outlining our study area.

Presently, the only forest inventory information available to us is that found in the 1959 U.S.D.A. Forest Service Resource Bulletin NC-7, "Indiana's Timber". Since this publication was prepared on a county basis, it is of little benefit in inventorying the forest resource within the watershed boundaries.

We are interested in an inventory of the extent and nature of the forest resource within the watershed boundaries. A map delineating the extent of forestland to the smallest, feasible acerage and a map delineating major cover types would fulfill much of the inventory needs. In addition, we hope to be able to assign productivity and importance values to the commercial, aesthetic, recreational, and soil and water conservation aspects of the forestland. Finally, we hope that an analysis of forest related problems and needs can be compiled.

Any information that your office may have and would be able to make available to us on any aspect of our study, especially the inventory, would be most appreciated.

Sincerely,

Thomas M. Lyons
Thomas M. Lyons
Watershed Forester

TML/rp

ATTACHED

INDIANA COASTAL ZONE MANAGEMENT STUDY

Preliminary Report

PHASE I

Application of LANDSAT Analyzed Data to the Mapping of the Forest and Wetlands Resources of the Indiana Coastal Zone Management Area

Work performed for the

Indiana Department of Natural Resources

Division of Forestry

by

The Laboratory for Applications of Remote Sensing

Purdue University

West Lafayette, Indiana

under

NASA Office of University Affairs

Grant NGL 15005186A

Introduction

Personnel from Purdue University's Laboratory for Applications of Remote Sensing (LARS) in cooperation with the Division of Forestry Indiana Department of Natural Resources (IDNR) have been involved in a project to map Indiana's coastal zone resources. The IDNR is interested in obtaining current forest and land inventory information which can be used as input to developing management plans and alternatives for the area.

Currently the most reliable information about the forest resources in the coastal zone area is available in the publication "Indiana's Timber"(USDA Forest Service Resource Bulletin NC-7, 1959). Because the material presented in this bulletin is in excess of 15 years old, the IDNR was interested in obtaining more timely information.

LARS had available LANDSAT-1 data which included a major portion of Southern Lake Michigan (Figure 1). In addition, 1:120,000 scale aerial photography - collected during 1971 as part of the Corn Blight Watch Experiment - was also available. The aerial photography would provide important ground truth information.

The project, of which this report is the first phase, grew from the desire of the user (IDNR) to obtain current information and the need of the scientist (LARS) to apply remote sensing technology to a real situation. Therefore, the objective of this activity as developed by these two groups was to:

> Provide current information about the forest and wetlands resources of the Indiana Coastal Zone through application of computer-assisted analysis of LANDSAT data.

The first phase of this study focused on providing broad-level in-

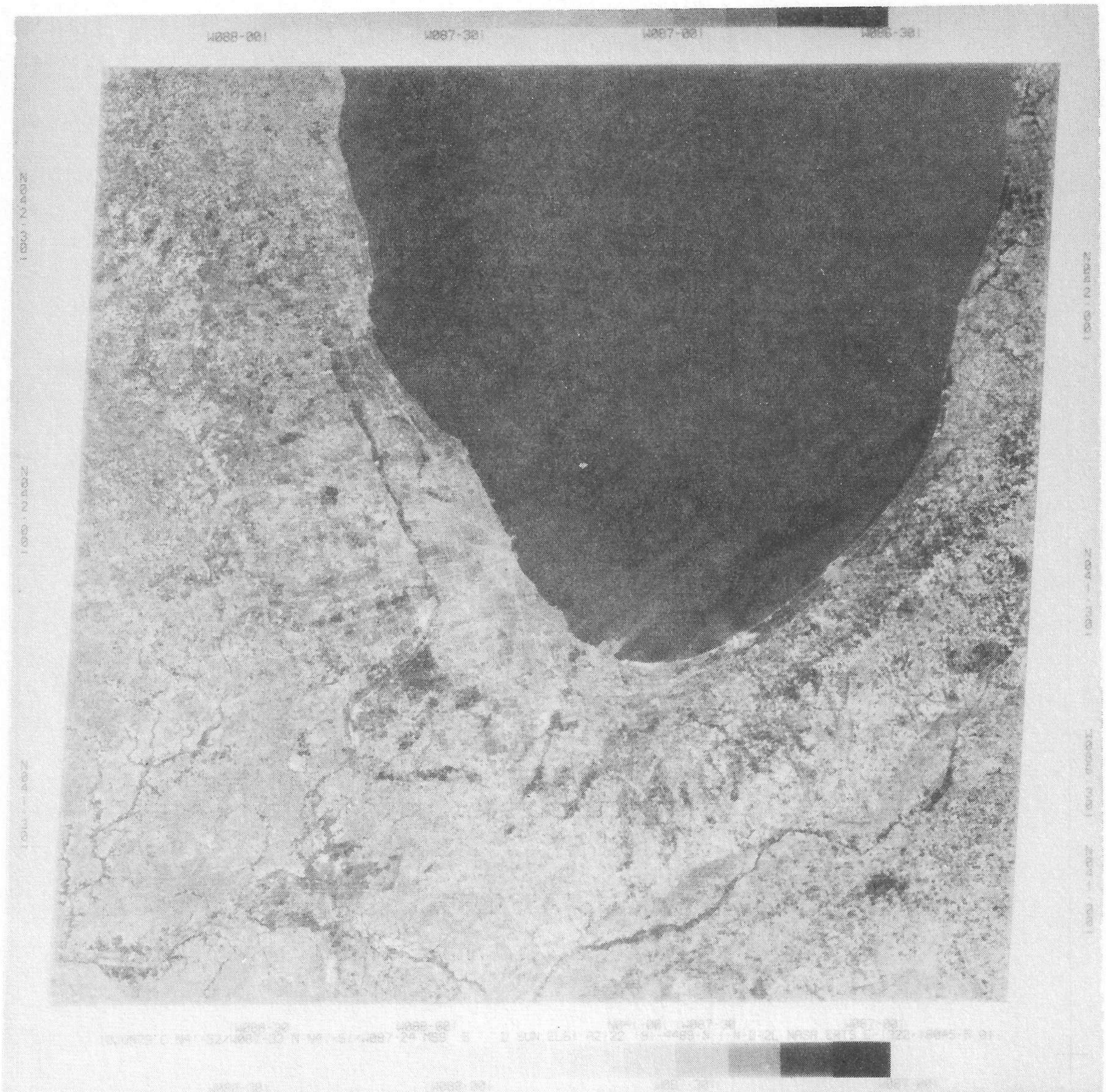


Figure 1 - LANDSAT-1 Scene ID; 1322-16045 collected 10 June 1973. This is one visible band, Channel 5 (.6-.7 um) which was available for analysis at LARS. The frame includes all the Coastal Zone Management Area.

formation for the Coastal Zone which includes portions of Lake, Porter and LaPorte counties. This report will address results of that study. Subsequent phases will involve detailed mapping of the forest and wetland communities, overlay of soils and topographic data and development of a multi-tiered sampling scheme.

Materials and Methods

LANDSAT-1 data collected over northern Indiana on 10 June 1973 (Scene ID: 1322-16045) was the primary data source. Analysis of this data was supported by small-scale high-flight photography collected as part of the Corn Blight Watch Experiment, in July of 1971. Due to the proximity of the test site to LARS, one field trip was made to allow for a preliminary check of the classification.

The procedures used in classification were those described by Berkebile, et.al. (1976) in "A Forestry Application Simulation of Man-Machine Techniques for Analyzing Remotely Sensed Data". Figure 2 is an annotated flow-chart indicating the analysis steps required in the production of the final map and tabular products. The final products from the first phase of this study were maps of the forest and wetland associations produced by a CalComp drum plotter at a scale of 1:125,000. Acreage tables were also provided for each 7½ minute U.S.G.S. quadrangle or portion of a quadrangle that was included in the Coastal Zone Area.

Because of the time factors associated with the project, adequate training samples could not be located throughout the Coastal Zone Area. Since the area is relatively small - no more than 43 miles east - west and only half as deep at the extremity of a north-south point (Figure 3) - we

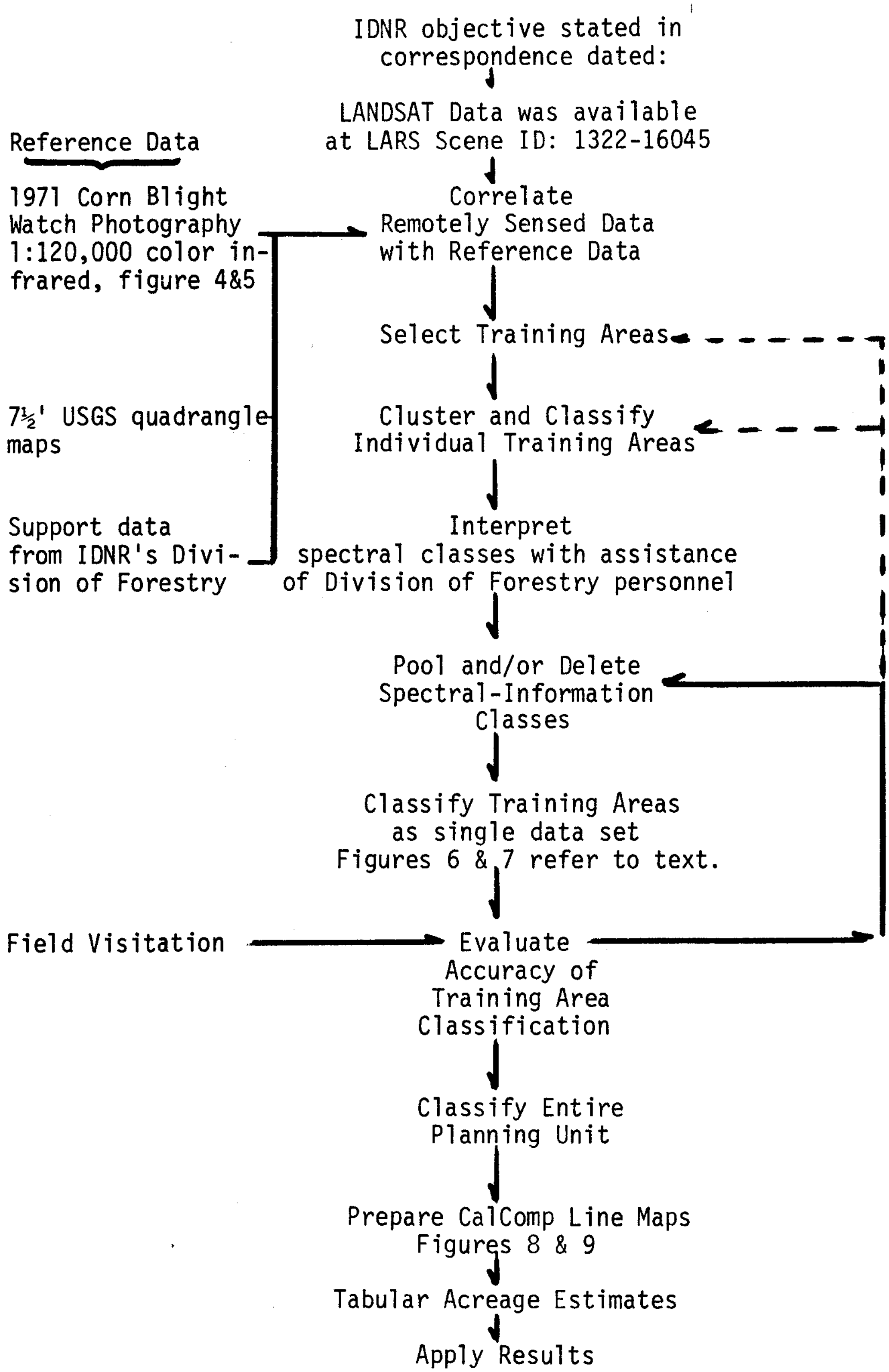


Figure 2. Specific Analysis Steps followed in the Classification of the Indiana Coastal Zone Management Area.

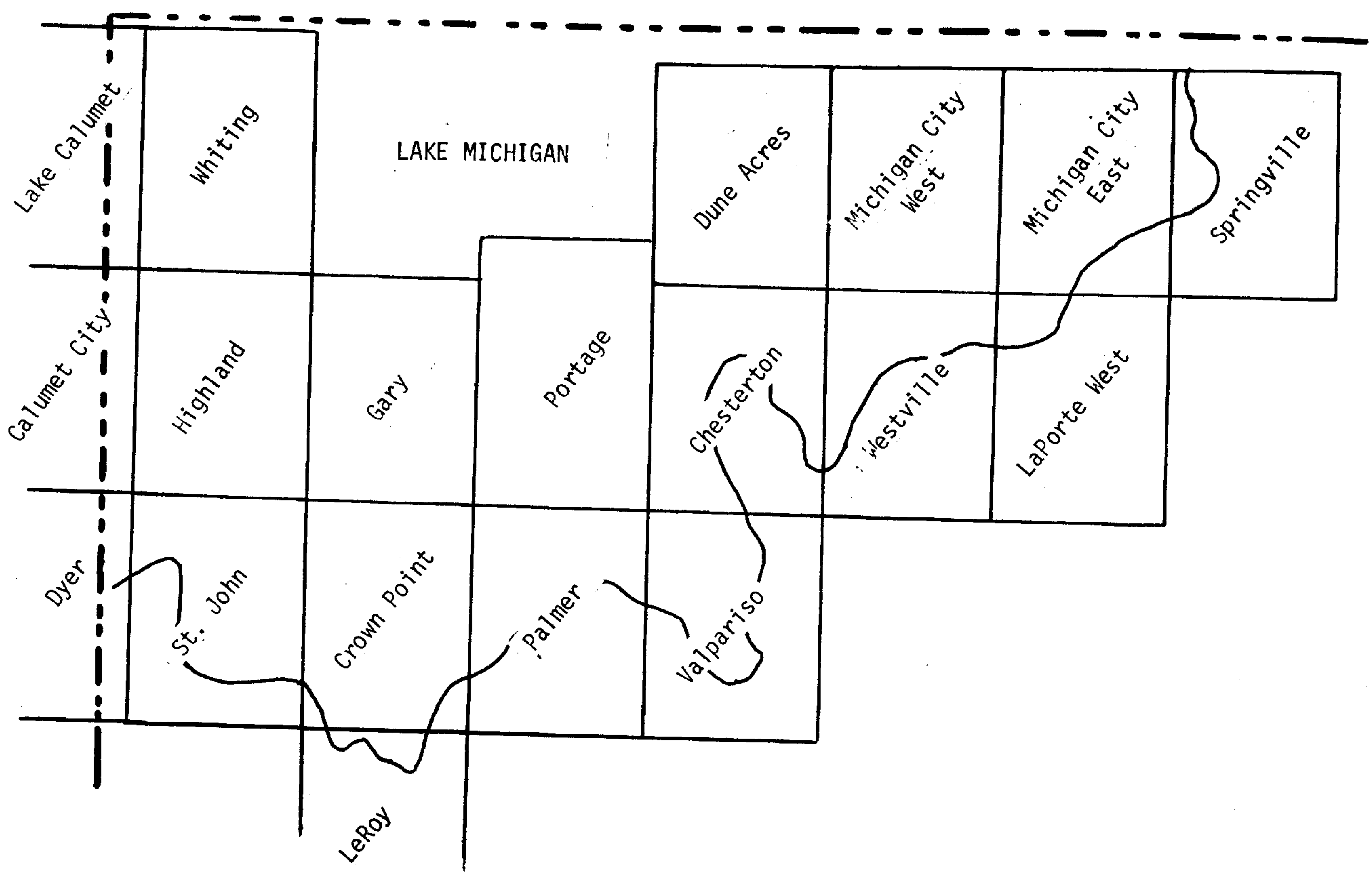


Figure 3. Indiana Coastal Zone Management Area

assumed that the vegetative cover was relatively homogenous. This meant that the training sites - seven total - were located only in Lake County. We felt that this area was the most diverse and therefore offered the widest range of training samples.

The seven training sites were located on two U.S.G.S. 7½' quadrangle maps, the Gary and Crown Point sheets. Figures 4 and 5 are black and white reproductions of the color infrared photos encompassing the two quads. The numbered areas are the training site locations. Table 1 gives a general description of these seven areas.

Table 1 - Description of Training Sites

Site No.	General Characteristics
A-1	Heavy industry predominantly concrete, asphalt and man-made materials. Minimal vegetation along highway corridor and older residential areas. Water representative of settling basins, harbors and channels.
A-2	Remnant lake beaches, alternating ridge and swale topography representing both dry and moist vegetation. Beach sands, industrial spoil and old residential areas are also included in this site.
A-3	Newer residential including recreational site (golf course) and some agriculture land. This site would represent the majority of residential areas close to the lake but located in older communities.
A-4	Suburbia; higher cost residential housing, mixed woodlot, subdivision and agricultural lands. Lake typical of the other larger inland water bodies in the watershed.
B-1	Interior wetland site with mixed ag lands and subdivisions Woodlots are generally small with ag-lands predominating.
B-2	Typical of northern Indiana ag-land, except for wetland association highlighted by small woodlot. Area represents rural landscape.
B-3	Terminus of watershed boundary, high cost residential areas mixed with larger woodlots, small ag-lands, wetland classes.

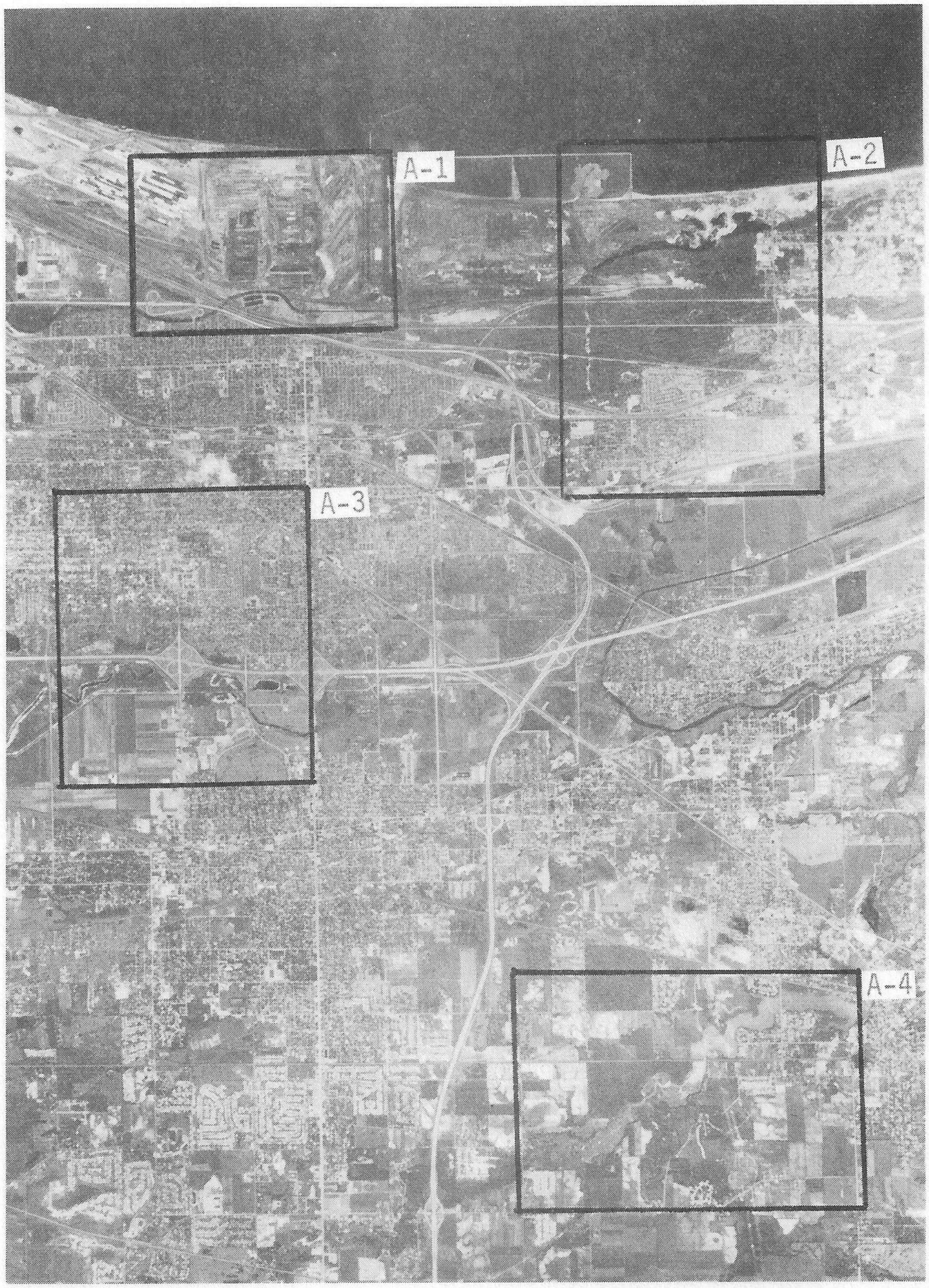


Figure 4. Approximate photographic coverage of the U.S.G.S. 7½' Gary quadrangle in northwestern Lake County. The black and white was made from a 1:120,000 scale color infrared transparency. The outlined areas indicate location of training sites which are referred to in Table 1.

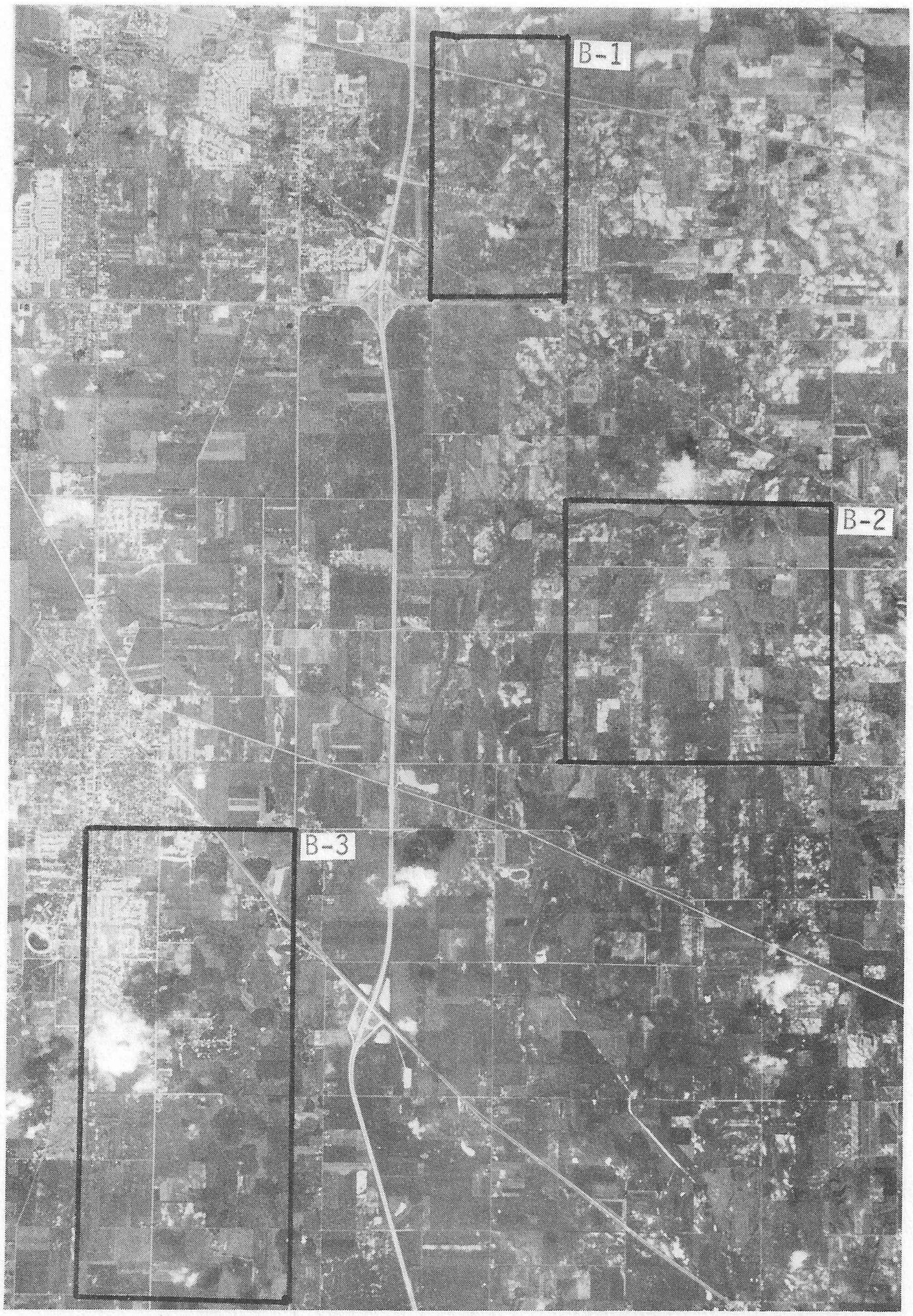


Figure 5. Approximate photographic coverage of the U.S.G.S. 7½' Crown Point quadrangle in southwestern Lake County. The black and white was made from a 1:120,000 scale color infrared transparency. The outlined areas indicate locations of training sites which are referred to in Table 1.

Thirty-two distinct spectral classes were defined from clusters within these seven test areas. Table 2 shows the preliminary breakdown of the spectral classes and a description of their informational value. This table was derived without the benefit of field tests. For purposes of this phase of the study classes other than forest and wetland were not evaluated in detail. Tabular acreage results are presented for each major land use category and are reported by components of the forest and wetland classes. CalComp line map products were prepared only for the general forest and wetland categories.

A discussion of the forest and wetland class descriptions follows.

Discussion

The majority of forests and wetlands in the Coastal Zone Management Area occur in small discontinuous or fragmented blocks. An underlying requirement for the analysis, which is necessary to produce accurate map and acreage estimates for the two classes is the selection of representative training sets.

The initial selection of the seven cluster areas (training sets) was based on an eyeball stratification of the 1971 color infrared photography. These areas were selected by the analyst because they appeared to be representative of the material present in the Coastal Zone site. Once the areas have been defined in the LANDSAT data, the computer analysis can begin. The first activity involves clustering (refer to Figure 2). The cluster function in the LARSYS computer programs makes additional discrimination of the area based on spectral characteristics of the cover classes. The analyst then tries to identify these spectrally separable classes and tag them with meaningful informational names.

Table 2 - Spectral/Informational class relationships derived through Interpretation of high flight photography and LANDSAT data

Class Number	Description
1-5	Urban
6&7	Urban vegetation
8	Shallow water and urban (dark material?)
9	Dark sand and urban and water
10-14	Ag and Urban
15	Grass
16	Light sand
17	Dark sand
18-21	Ag
22	(Mix) sparse forest? (bright objects?)
23	Light forest (lush understory?)
24	Medium forest
25	Dense forest
26	Water and Vegetation
27	Vegetation - wet
28	Wetland
29	Wet - grass
30	Wet - grass
31	Water and Vegetation
32	Water and factory tops
33	Lake water

For this study the cluster maps were compared to the 1:120,000 color infrared photography with the aid of a Bausch and Lomb Zoom Transfer Scope. Cluster classes were identified as to probable information class, then the cluster areas were classified based on those determinations. This classification was again compared to the photography. Figures 6 and 7 are examples of the preliminary classifications for two cluster areas, A-4 and B-3 (Figures 4 and 5).

The black and white photos are enlargements of the high-flight color infrared photography. Overlays are provided for those spectral classes identified as forest (either commercial or urban) and wetlands. Table 3 is the legend for the symbols on the classification map.

Table 3 - Definition of preliminary classification symbols for Figures 6 and 7.

Category	Symbol	Description
	A	Mixture class; sparse forest, residential and vegetation, certain ag classes.
Forest	B	Upland forest, moderate density
	C	Upland forest, dense
	D	Bottomland forest
Wetlands	1-6	Shrub and marsh classes
	7,8	Water classes

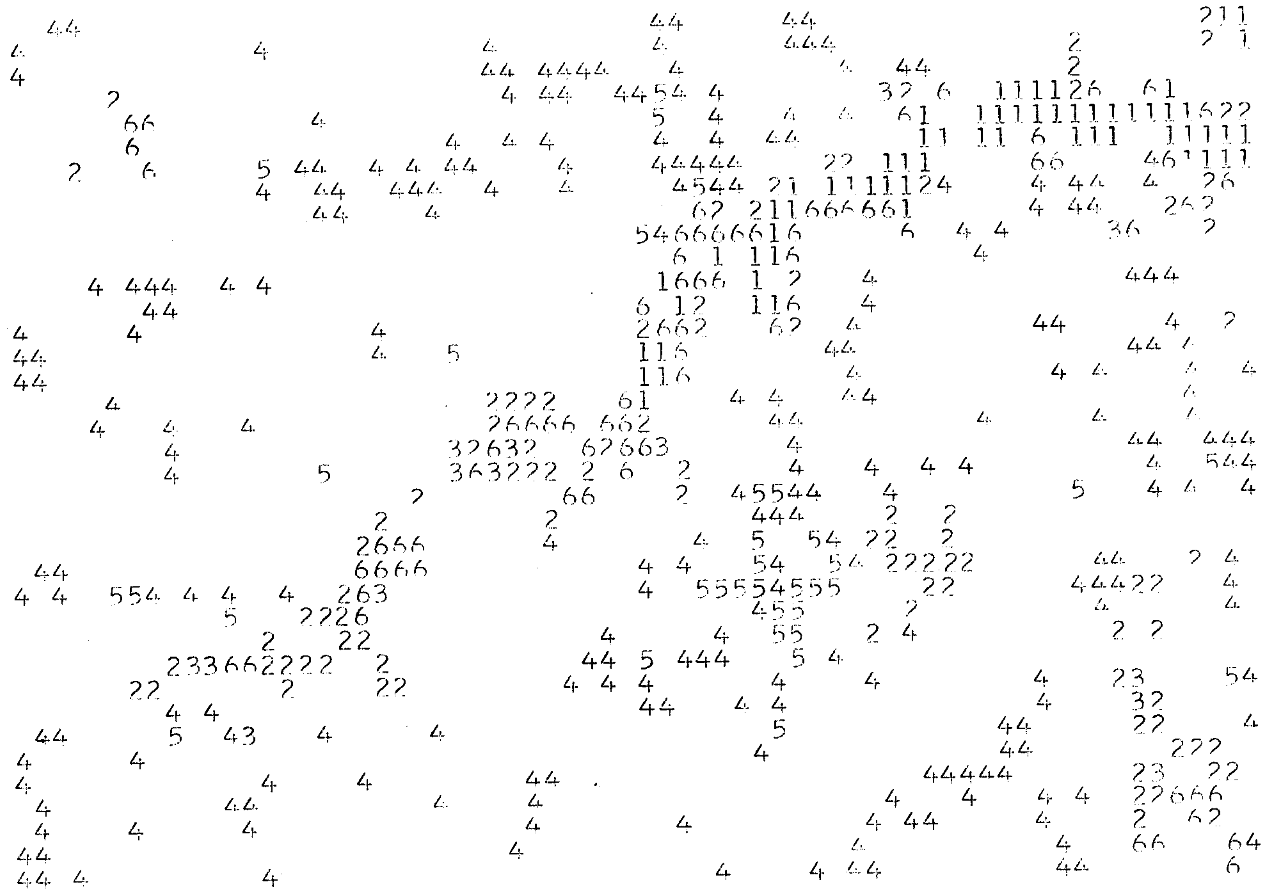
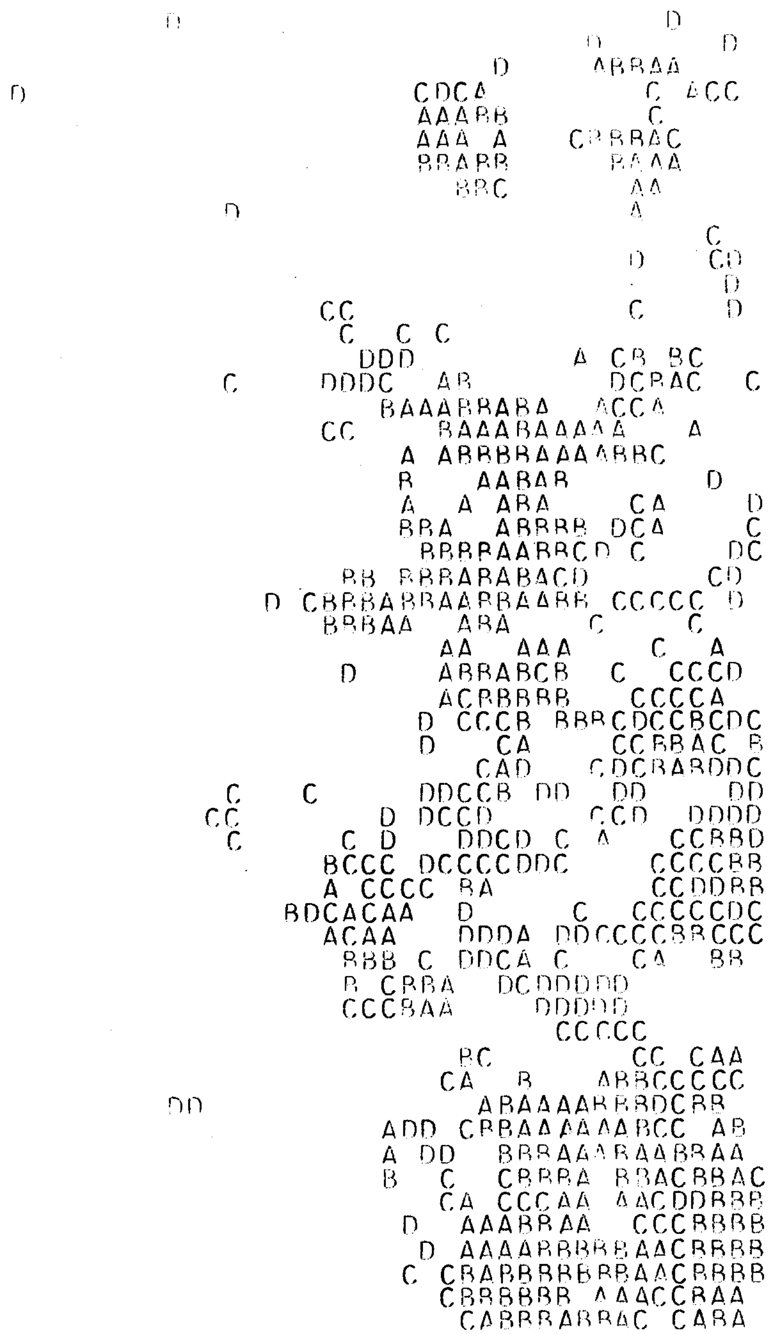


Figure 6. Test Area A-4, Lake George, located in the southeastern corner of the Gary quadrangle. The overlays are preliminary classification results for the wetland and forest-land classes described in Table 3.

4 2 22
44 4 4555
4 4 5 5554
44 44 4 454 4 4
4 4 2 4444
5 44 5 44
4 4 44 55 2
4 4 4 4 4 55
4 4 5 4 2 5544
44 5 4 55
4 4 4 4 4
4 4 55 554 4 4
445 55554 44 6
4 4 54 4 4 6
4 44 5 5
4 4 55 5555544 4
4 4 55 44
4 44 554 44
4 44 4 444
4 4 4 4 4 4 66
4 44 5 554 676
4 4 3 4 62
4 4

4
4 4 5554 4444
4444 4 4 55 5 4
44 44 44 4 5 44 2
44 4 4
4444 443 4 4
4 4 444 44
4 4 4544 4 4
5 2 44 4 44
4 4 4
4444 4 4
44 4544
444 4 4
44 4 4
4 4 4 4
4 4 5 4 4
444 4
4 4
4 4 44 44 4 4 4 44 4 4 4
4 4 4 4 44 4544544 4 5
4 4 4 44 4 4
4 4 4 4 54
4 44 4 4
4 44 4
44 5 4 5
6 4 5
4 54
4 4
4 44 4
4 5 4
3 5



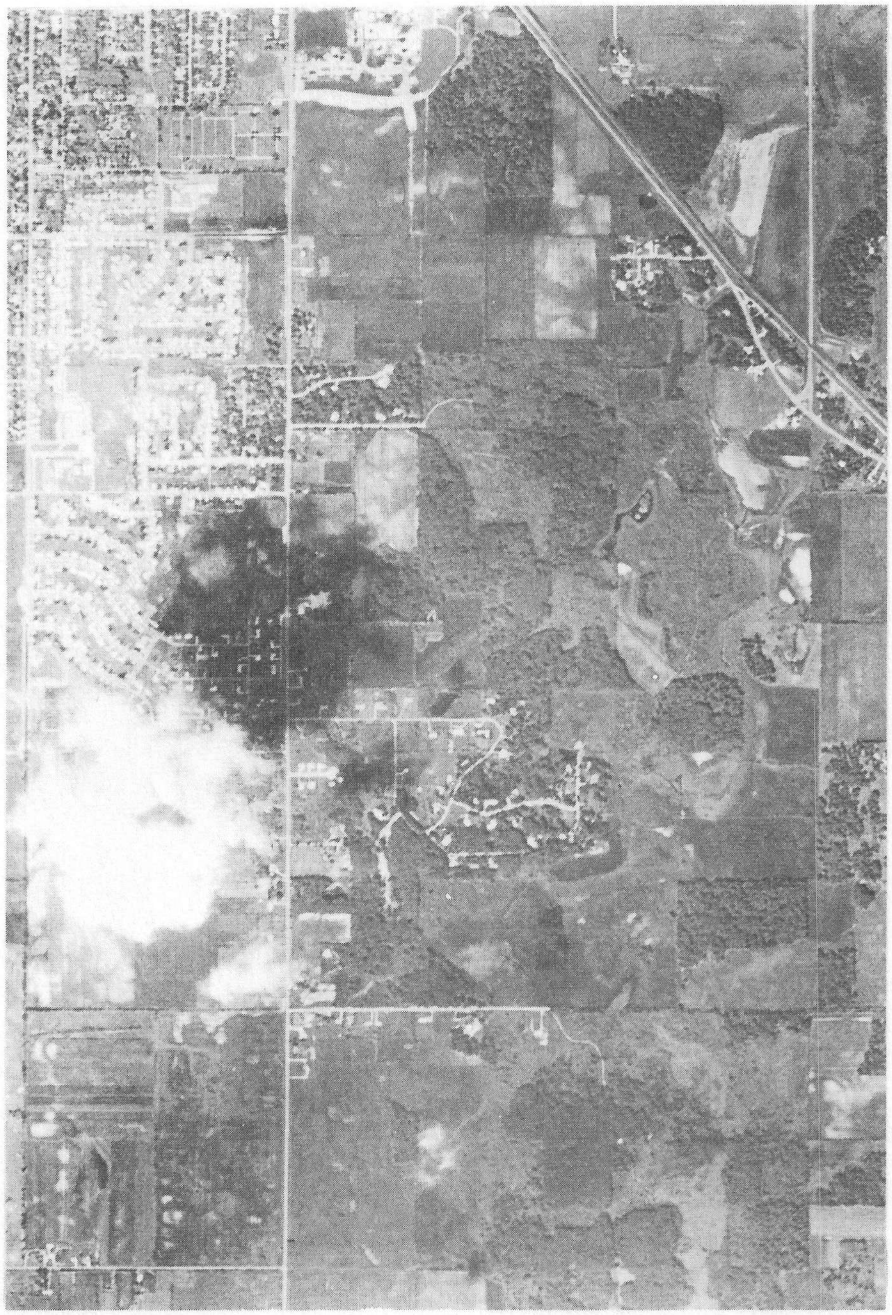


Figure 7. Test area B-3, Crown Point located in the southwestern corner of the Crown Point quadrangle. The overlays are preliminary classification results for the wetlands and forest land classes described in Table 3.

Examination of the overlays and the two aerial photos indicate good visual correspondence between the spectral classes and the ground scene. Similar relationships were noted for the remaining five cluster areas. There were, however, some questionable classes. A ground check of a portion of the site was made to resolve any remaining questions. After field examination of a few representative areas, the following class definitions were used for the final classification (Table 4). Note the differences between Tables 2 and 4, specifically outlined below by change in class definitions:

Spectral Class	Was described in Table 2 as	change to	New description in Table 4
22	Mixed sparse forest		dense upland forest
23	light forest		dense upland forest
24	medium forest		sparse, botoomland
25	dense forest		shallow marsh
26	water and forest		dry bottomland forest
28	wetland		shrub association
30	wet grass		shallow water
31	water/vegetation		shallow water
33	lake water		null

The type of changes between Tables 2 and 4 involved nothing more than a change in class definition. In other words, each class had been basically identified correctly on the aerial photography but could not be described in detail on the scale of the photography available. Given this last piece of information the classes were grouped (e.g., all forest associations were combined to form one class called forest), and maps and tables for the forest and wetland classes were produced.

Table 4 - Descriptions assigned to spectral classes after field visit.

Class #	Name/Symbol	Description
1-5	URBAN	Urban classes
6&7	URB-VEG	Urban vegetation - grass, trees, houses, streets
8	SHWA&URB	Shallow water (e.g., Lake George) and dark urban class (probably asphalt, factories, etc.)
9	DS&UR&WA	Mixture of dark objects, e.g., dark sand, urban and water
10-14	AG&URB	Mixture of ag and urban components
15	GRASS	Mixture of grass & ag (probably winter wheat)
16	LITESAND	Light-colored sand
17	DARKSAND	Darker-colored sand
18-21	AG	Agriculture
22	UP-FOR1/A	Dense, upland forest
23	UP-FOR2/B	Dense, upland forest
24	FOREST/C	Sparse, wet, bottomland trees and shrubs OR good crown closure, black oak (no bare sand)
25	SH-MARSH/2	Shallow marsh (e.g., Lake George periphery)
26	DRY-For/D	Drier botoomland forest OR forest sandhill with some bare sand
27	SHR-MSH1/3	Deep shrub marsh
28	SHRUB/4	Shrub association - somewhat wet (some conifers in dry spots
29	SHR-MSH2/5	Deep shrub marsh
30	SH-WA/6	Shallow water (deeper part of Lake George)
31	SHWA&URB/7	Shallow water and some urban
32	LAKE-WA/8	Lake Michigan and deep, open water
33	NULL	Null data due to geometric correction

Results

Figures 8 and 9 are CalComp maps of the Coastal Zone area. The maps were produced at a scale of 1:125,000. Cultural information (i.e., town names, roads, etc.) will be added by personnel from IDNR on the classifications to provide locational data. Figure 8 is the map for the forest class while Figure 9 represents the wetland classes. The smallest mappable unit considered for producing these maps was a block of land approximately 10 acres in size. A unit smaller than 10 acres created a salt and pepper pattern, thus making the map extremely difficult to interpret. Additionally 10 acres is about half the size of the smallest manageable woodlots in the area. Therefore, at this scale, no important forest land will be ignored.

Table 5 lists Level I and II classes and their descriptions. Maps were produced during this phase of the study for only the Level I forest and wetland associations. Tabular information as acres and percent of area by class is presented both for the Level I and II breakdowns in Tables 6 through 9. The tabular information was arrived at by applying the factor 1.145x to the number of pixels (ground resolution elements) tallied for each class.

Conclusions

The results presented in this report are preliminary in nature and therefore subject to change after intensive analysis during the Phase II portion of the study. The reader should, however, be aware of the time frame in which this material was proposed. No more than two and a half months passed from the time of the request for analysis to the completion of maps and tables. This is a significant accomplishment in that there was no reasonable avenue open to the IDNR for collection and analysis of new field data by the deadline they had for preparing the final report. These results support the contention that LANDSAT data analysis can provide information useful to resource managers in a timely manner.

LABORATORY FOR APPLICATIONS OF REMOTE SENSING
PURDUE UNIVERSITY

CALCOMP CLASSIFICATION MAP

CLASSIFICATION STUDY 609109402	CLASSIFIED MAR 31,1976
RUN NUMBER............ 73033504	DATE DATA TAKEN... 6 / 10 / 73
FLIGHTLINE.... 132216045 IND	TIME DATA TAKEN..... 1004 HOURS
DATA TAPE/FILE NUMBER.. 3177/ 1	PLATFORM ALTITUDE. 3062000 FEET
REFORMATTING DATE. MAR 3,1976	GROUND HEADING..... 180 DEGREES

CLASSIFICATION TAPE/FILE NUMBER ... 184/ 2

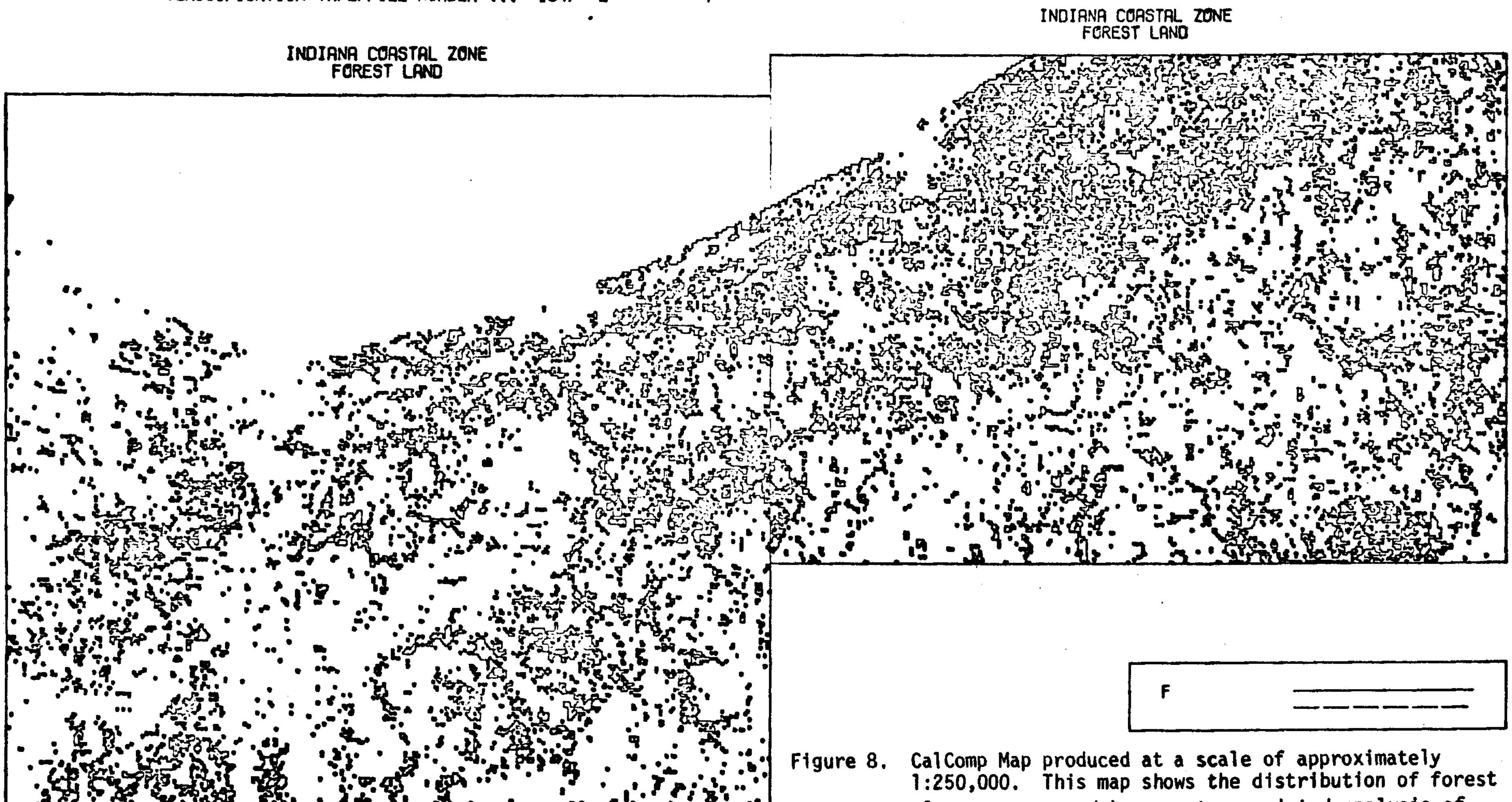


Figure 8. CalComp Map produced at a scale of approximately 1:250,000. This map shows the distribution of forest classes as mapped by computer assisted analysis of LANDSAT 1 data.

LABORATORY FOR APPLICATIONS OF REMOTE SENSING
PURDUE UNIVERSITY

CALCOMP CLASSIFICATION MAP

CLASSIFICATION STUDY 609109402	CLASSIFIED MAR 31,1976
RUN NUMBER........... 73033504	DATE DATA TAKEN... 6 / 10 / 73
FLIGHTLINE.... 132216045 IND	TIME DATA TAKEN..... 1004 HOURS
DATA TAPE/FILE NUMBER.. 3177/ 1	PLATFORM ALTITUDE. 3062000 FEET
REFORMATTING DATE. MAR 3,1976	GROUND HEADING..... 180 DEGREES

CLASSIFICATION TAPE/FILE NUMBER ... 184/ 2

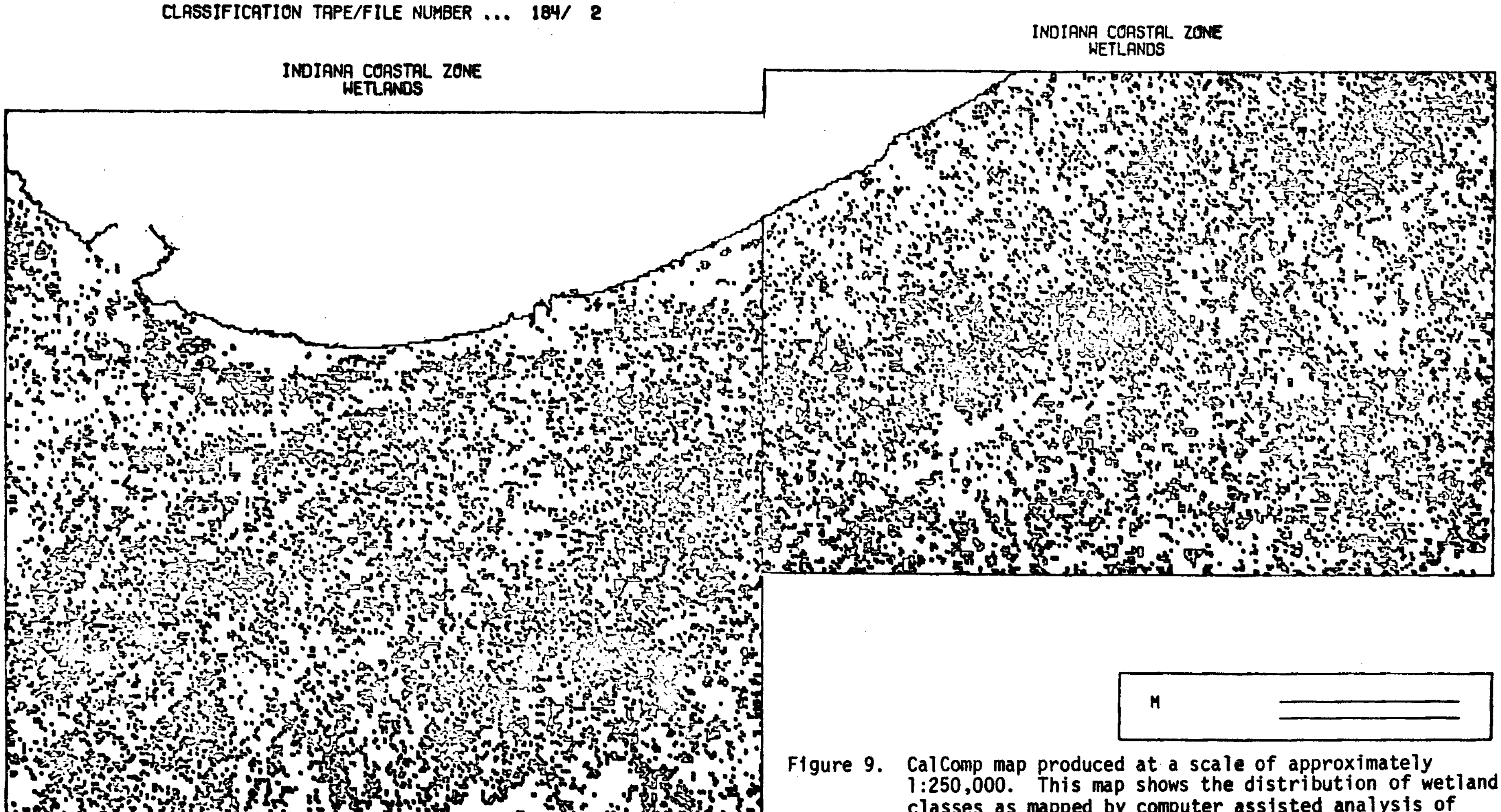


Figure 9. CalComp map produced at a scale of approximately 1:250,000. This map shows the distribution of wetland classes as mapped by computer assisted analysis of LANDSAT 1 data.

Table 5 - Classes of material mapped in the Indiana Coastal Zone Management Project Area

Level I Class	Level II Class	Description
Urban	Urban	Commercial, Industrial, Business and High Density Residential Areas
	Residential	Older residential areas, characterized by having more vegetative cover associated with the "urban" spectral class
	Suburban	Mixed class containing spectral response of cultural development and areas of bare soil and grass
Ag	Rural	Urban spectral characteristics in mixture with spectral classes associated with ag class
	Ag	Bare soil, pasture, grassland
Forest	Upland Forest 1 Upland Forest 2	Dense, upland forests
	Forest	Sparse, wet, bottomland associations mixed with shrubs or dense black oak stands
	Dry forest	Dry bottomland association or sandhill forests
Wetlands	Shallow marsh	Shallow marsh (e.g., periphery of Lake George)
	Shrub	Shrub association somewhat wet, some conifer on drier sites
	Shrub marsh 1 Shrub marsh 2	Deep shrub marshes
Water	Shallow water	Inland waters
	Lake water	Deep lake water

TABLE 6. Level I Cover Classes* Identified in the Indiana Coastal Zone Management Area.

Class	Acres	Percent
Urban	51161	13.2
Ag	173687	44.6
Forest	72516	18.6
Wetlands	56606	14.6
Water	35124	9.0

*Classes identified through computer-aided analysis of LANDSAT Data source LANDSAT Scene Id 1322-16045 collected 10 June 1973.

Table 7. Area Breakdown by Major (Level I) Cover Categories Reported by Quadrangle for the Indiana Coastal Zone Management Area.

Class	Lake Calumet	Calumet City	Dyer	Whiting	Highland	St. John	Gary	Crown Point	LeRoy	Portage	Palmer	Dune Acres	Chester-ton	Valpa-raiso	Michigan City West	Westville	Michigan City East	LaPorte West	Spring-ville
	Area by Percent																		
Urban	33.0	26.8	6.1	32.6	23.1	10.2	24.8	9.5	6.7	13.4	4.0	4.2	6.9	5.1	9.4	4.1	9.9	1.8	10.4
Ag	39.0	61.2	68.0	24.4	43.7	49.4	41.7	64.7	67.3	50.6	54.5	17.1	47.9	54.7	32.0	46.9	33.7	35.2	30.2
Forest	0.6	3.1	6.4	0.4	14.8	15.9	11.6	7.7	6.2	14.5	18.7	33.4	24.8	16.0	25.0	26.1	41.7	36.2	38.3
Wetlands	3.8	7.2	6.0	1.8	14.3	21.7	14.1	16.3	17.8	11.6	19.1	8.1	19.4	23.7	7.7	22.7	13.2	26.3	17.1
Water	24.4	2.0	1.2	40.8	1.8	2.8	7.7	1.8	2.0	9.9	0.7	37.2	1.0	0.5	25.9	0.2	1.5	0.5	4.0

Source: Computer-aided analysis of LANDSAT Scene 1322-16045 collected 10 June 1973

Table 8 - Level II cover classes identified in the Indiana Coastal Zone Management Area from Analysis of LANDSAT data.

Classes	Acreage	Percent Area
Urban (commercial, industrial, new residential)	7034	1.9
Residential (urban mixed with vegetation)	40575	10.4
Mixed Urban (urban, bare soil)	3370	.9
Rural (Ag and urban class mix)	88192	22.7
Ag (cropland, pasture	85495	22.0
Upland Forest 1	10362	2.6
Upland Forest 2	13208	3.5
Forest	22887	5.8
Dry Forest	26059	6.7
Shallow Marsh	11202	2.9
Shrub	29689	7.6
Shrub - Marsh 1	5067	1.3
Shrub - Marsh 2	10648	2.7
Shallow Water	6250	1.6
Lake Water (primarily Lake Michigan)	28874	7.4

Table 9. Level II classes in the Indiana Coastal Zone Management Area Reported by U.S.G.S. quadrangle.

Class	Lake Calumet	Calumet City	Dyer	Whiting	Highland	St.John	Gary	Crown Point	LeRoy	Portage	Palmer	Dune Acres	Chesterton	Valparaiso	Michigan City West	Westville	Michigan City East	LaPorte West	Spring-ville
	Area in class expressed as a percent of area in quad																		
Urban	7.4	2.7	0.4	15.3	1.8	0.2	4.3	0.4	0.5	1.3	0.1	0.8	0.1	0.1	1.0	0.1	0.1	0.0	0.0
Residential	20.6	23.8	5.4	13.6	19.8	9.4	18.8	8.9	5.7	11.2	3.7	3.0	6.3	4.7	7.9	3.8	9.7	1.5	6.8
Suburban	5.0	0.3	0.3	3.7	1.5	0.6	1.7	0.2	0.5	0.9	0.2	0.4	0.5	0.3	0.5	0.2	0.1	0.3	3.6
Rural	24.0	30.0	19.9	18.8	16.8	33.9	15.0	39.6	38.4	15.3	16.2	3.7	34.4	38.6	8.4	32.6	24.3	26.0	22.8
Ag	14.0	31.2	48.1	5.6	26.9	15.5	26.7	25.1	28.9	35.3	38.3	13.4	13.5	16.1	23.6	14.3	9.4	9.2	7.4
Upland Forest 1	0.0	0.0	1.2	0.0	0.3	2.4	0.8	1.4	1.9	1.2	4.5	3.0	5.3	3.6	2.9	7.3	5.5	7.9	4.0
Upland Forest 2	0.0	0.0	1.1	0.0	0.6	2.8	1.1	1.4	0.2	1.6	4.3	6.9	5.3	2.9	4.4	8.1	9.0	8.9	5.7
Forest	0.1	0.3	1.9	0.0	3.8	4.6	3.1	2.3	1.9	4.4	6.5	14.2	7.2	5.7	8.5	7.2	13.5	11.7	13.2
Drysite Forest	0.5	2.8	2.2	0.4	10.1	6.1	6.6	2.6	2.2	7.3	3.4	9.3	7.0	3.8	9.2	3.5	13.7	7.7	15.4
Shallow Marsh	3.0	4.6	1.2	1.3	7.3	3.9	5.0	1.7	2.1	2.7	1.3	0.9	1.9	1.1	2.3	0.6	3.2	0.5	2.5
Shrub	0.2	2.3	12.3	0.2	3.0	12.9	5.7	10.4	10.2	5.9	10.6	4.5	11.9	14.5	3.5	15.0	7.0	15.1	6.2
Shrub-Marsh 1	0.6	0.2	0.1	0.3	3.4	.9	2.1	0.2	0.4	1.4	0.9	1.6	1.4	0.7	0.9	0.4	1.1	3.9	4.9
Shrub-Marsh 2	0.0	0.1	4.7	0.0	0.6	4.0	1.3	4.0	5.1	1.6	6.3	1.1	4.2	7.4	1.0	6.7	1.9	6.8	3.5
Shallow Water	4.6	1.8	1.2	2.8	1.5	2.7	2.7	1.8	2.0	1.1	0.7	0.3	0.7	0.4	1.1	0.2	0.7	0.1	3.3
Lake Water	19.8	0.2	0.0	38.0	0.3	0.1	5.0	0.0	0.0	8.8	0.0	36.9	0.3	0.1	24.8	0.0	0.8	0.4	0.7

REFERENCES

Berkebile, J., J. Russell and B. Lube, 1976. "A Forestry Application Simulation of Man-Machine Techniques for Analyzing Remotely Sensed Data". LARS Information Note 012376, Laboratory for Applications of Remote Sensing, 74p.

Spenser, J.S., 1969. "Indiana's Timber". U.S.D.A. Forest Service, North-Central Forest Experiment Station; Resource Bulletin NC-7, 61p.

State of Indiana, 1976. Application for a Fiscal Year 1975 Grant for Coastal Zone Management Program Development as Authorized by Section 305 of the Coastal Zone Management Act of 1972 (Public Law 92-583). A Proposal submitted to the Office of Coastal Environment, National Oceanic and Atmospheric Administration, U. S. Department of Commerce, 44p.

SOIL INVENTORY PROJECT

F. Kirschner, R. Weismiller and M. Baumgardner

Introduction

During the past year members of the LARS staff have been collaborating with the USDA/Soil Conservation Service (SCS) in Indiana to develop and evaluate remote sensing techniques as an aid in soil survey. LARS proposed in the statement of work for FY76 that LANDSAT data be used as an additional source of reference data for detailed soil mapping. In discussions with State Soil Scientist Ray Sinclair, we jointly decided that satellite MSS data be incorporated into the soil mapping program at three levels. The objectives defined were:

1. To provide a broad view of the landscape and soils differences for initial planning of the survey.
2. To aid in determination of the broad range of soils and in the preparation of the descriptive legend prior to the initiation of detailed mapping.
3. To provide detailed alphanumeric printouts (spectral soils maps) at the same scale as the aerial photographs for use in detailed soils mapping in the field.

Status

Jasper County, Indiana

A detailed soil survey of Jasper County had been scheduled to begin in FY77. Initially, satellite data was to be used to derive the following information:

1. Broad relationships between soils and their physiographic positions;
2. Complexity or degree of homogeneity of the soils as they appear in the landscape;
3. Indications of areas requiring extensive sampling during the reconnaissance survey;
4. Delineation and composition of soil complexes;
5. More adequate and detailed descriptive legends.

Eight study sites, each 4 square miles in extent, had been chosen for analysis of the spectral characters of the soils in the areas.

Currently, all eight areas have been analyzed using a clustering algorithm. Five of these areas have been field checked to ascertain that they represent different soil areas and that differences indicated by the computer analyzed data actually represent differences in soil conditions.

In order to initiate a soil survey, the local community is required to participate financially. Unfortunately, in this instance, the county did not fund the survey during FY77. Thus, this effort has been set back. A minimal effort will continue since the prospects of local participation appear favorable for FY78.

Status

Clinton County, Indiana

With the delay of the Jasper County soil survey, Clinton County, located in west central Indiana, is the site currently being utilized for the detailed mapping study. The initial review for Clinton County has been completed and detailed mapping is underway by USDA/SCS personnel.

In this study site satellite data is being used to derive much of the same information as had been discussed in the Jasper County study:

1. Broad relationships between soils and their physiographic positions;
2. Complexity or degree of homogeneity of the soils as they appear in the landscape;
3. Indications of areas requiring extensive sampling during the reconnaissance survey;
4. Delineation and composition of soil complexes;
5. More adequate and detailed descriptive legends.

In addition, a problem has arisen in Clinton County over how to map an uncorrelated soil series that occurs over large areas of an ancient buried pre-glacial river valley. Soil samples and soil profile observations indicate that the proposed new soil series is found in all parts of the valley; but because it is not evident on the aerial photographs being used as a base map, no attempts have been made to identify and map this series. Thus, an effort is being made to delineate the boundaries of this proposed new soil series utilizing the spectral properties of the soil derived from LANDSAT data. This information along with the laboratory characterization of the soil will be used to decide whether or not to correlate and map the proposed new soil series.

The application of computer-aided classification of multispectral scanner data to the soil survey program is progressing and field tests of the data have been very encouraging.

The validity of separating soil drainage profiles

a. well drained
b. moderately well
c. somewhat poorly
d. poorly
e. very poorly drained

by the clustering mthod has been established. This has been verified on numerous field investigations by both SCS and LARS personnel. This accomplishment alone is a very significant step in providing a tool for the soil surveyor. Drainage characteristics are one of the most important properties used in classifying soils and to have these boundaries displayed, before setting a foot on the land, would be a tremendous advantage to the soil mapper. Not only does it inform the soil surveyorveyor where to take borings in order to identify the soil series, it also points out the extent and nature of other soils he has in his mapping unit. Normally, an individual mapping unit is considered to be at least 85 percent pure or in other words, it does not contain more than 15 percent "other" soils. Heretofore, this was solely a judgment of the soil scientist in the field. However, with spectral data to assist him in making a decision, the soil scientist can more accurately make a determination and do it at a faster pace.

Another potential advantage of utilizing spectral data is in determining when a soil complex should be mapped. Intensive soil investigation has usually been necessary to establish if a soil complex existed in the landscape and in the normal course of mapping, they can easily be overlooked. The complexes involving different drainage profiles can be "flagged" by the use of spectral data, thus informing the soil scientist where to make his investigation.

Appendix 1 includes a computer classification of a four square mile area located in Clinton County, Indiana, a copy of the soils map made by a SCS soil scientist, and the mapping legends. The scale of both the map and the output is 1:20,000 (one square inch equals 63.7 acres).

The classification is based on fifteen spectral classes and these in turn have been grouped into four conventional soil drainage classes and one vegetative class. The test class performance indicates the data to be rather reliable; 97.8 percent of the fields were correctly classified.

In comparing the computer output (transparency) with the copy of the soils map, it is relatively easy to pick out discrepancies or variations between the soil map and the classification. The fields represented by dots are areas that have been field checked and analyzed.

A good example of the use of the classification map is found in field D and the area immediately above and below it. This area (dotted) identified as XeB2 is the mapping unit Xenia silt loam, 2 to 6 percent slopes, eroded. The soil representing this mapping unit should be moderately well drained. The area represented is about 40 acres in extent. Based on the computer classification we can deduce that about half of this unit is moderately well drained and the balance consists of somewhat poorly and poorly drained soils. Spot checks in this field, indicated that the computer classification was most nearly correct and approximately half of the delineation or about 20 acres is made up of poorly and somewhat poorly drained soil which should be separated from the Xenia series. The examination of the other dotted area will reveal situations where boundary lines could be moved in order to better represent the actual soil boundary lines.

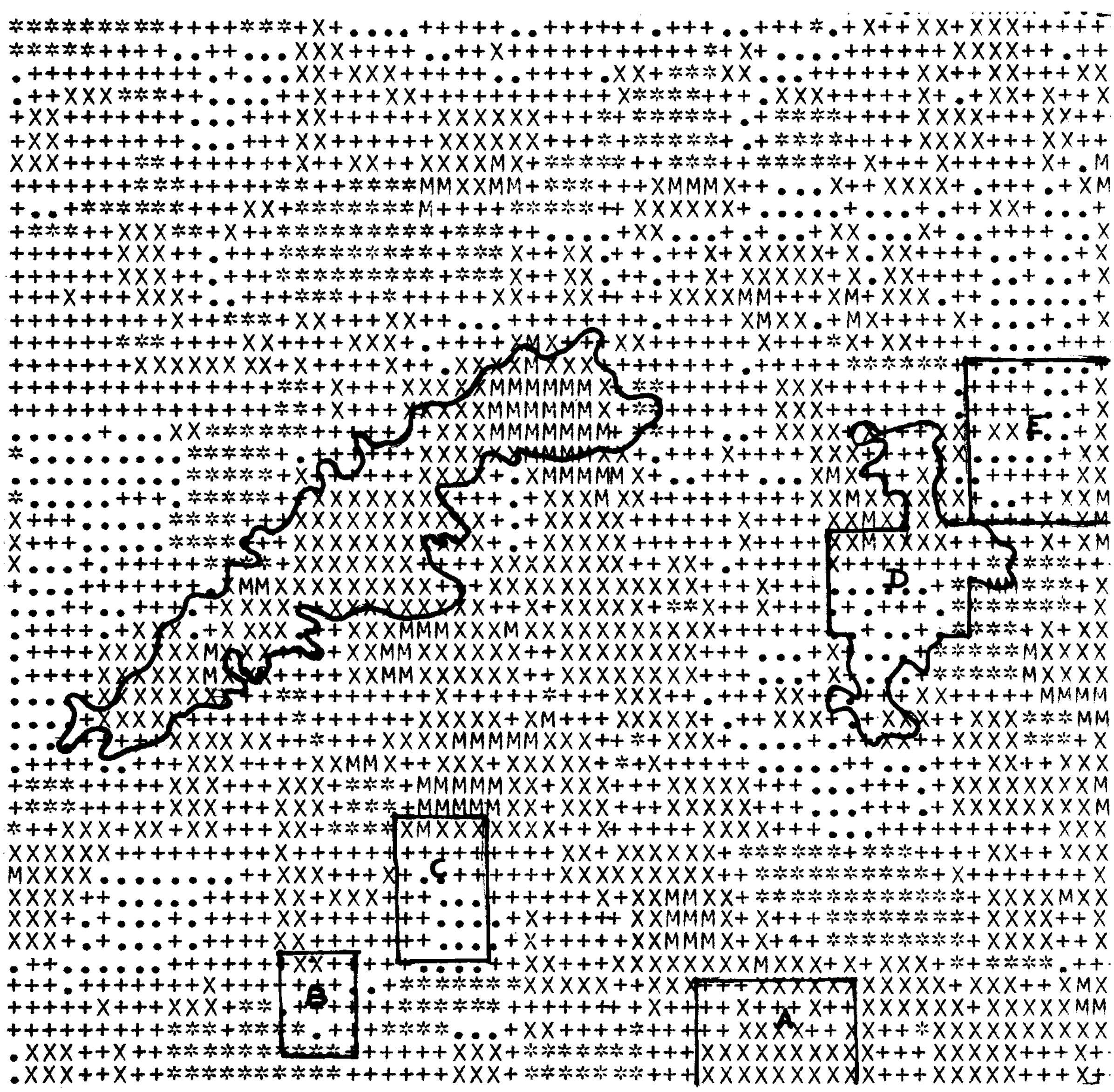
The long narrow delineation, identified by the diagonal lines, is mapped as the Mahalasville series. Approximately 40 acres on the east end have a very different spectral response than the balance of the delineation. Although not field checked, it appears very evident that another soil, other than Mahalasville, could have been mapped at this location based upon spectral response.

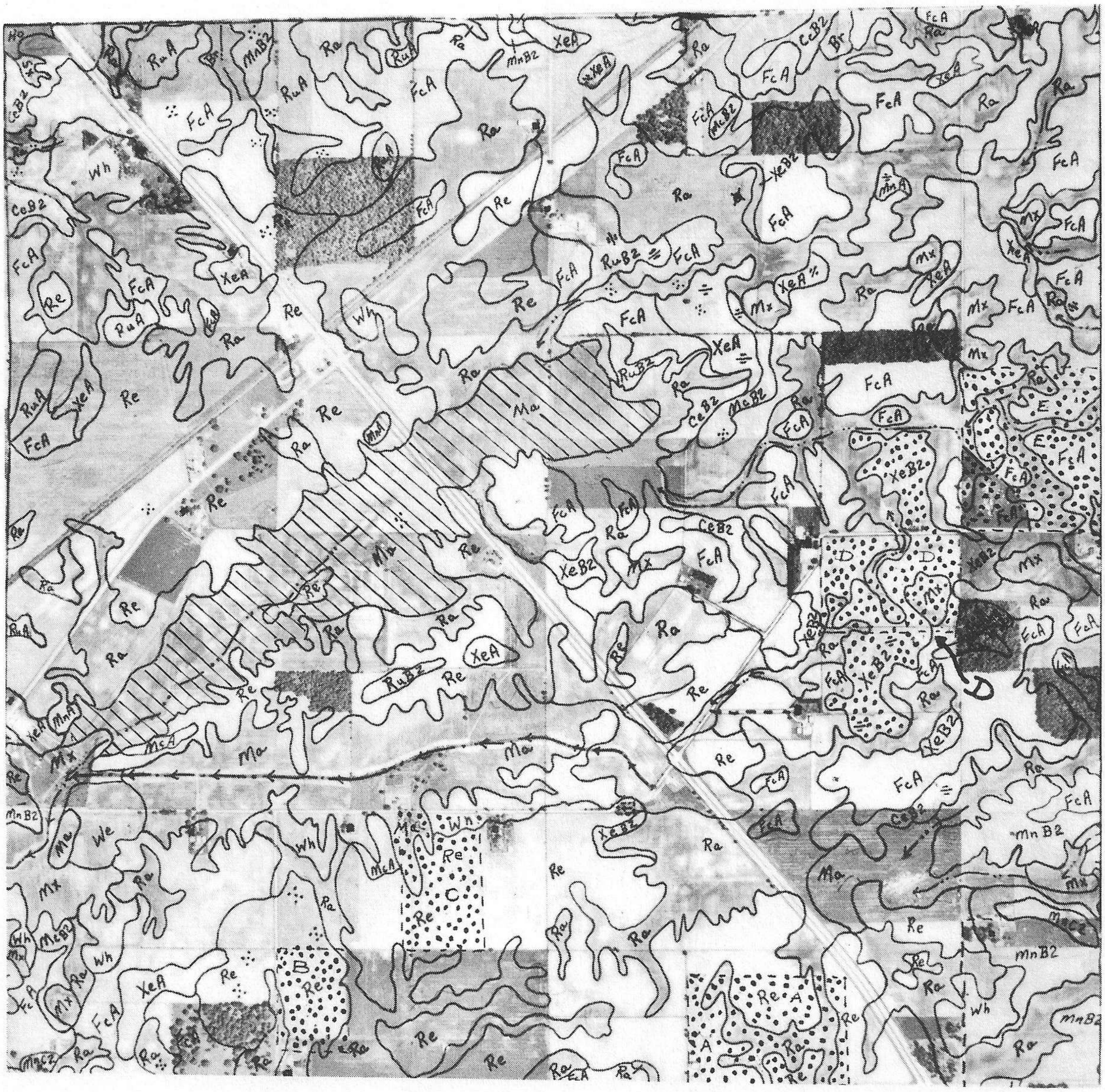
Work on the effort to delineate the boundaries of the new soil series is progressing. This consists of separating the darkest soils in the ancient, filled-in river valley, consisting of molisols, from the darkest soil in the adjacent till plain area, consisting of alfisols. Statistics* indicate that the separation of these soils is a distinct possibility. The work of classifying tha ancient river valley along with the adjacent till plain will be completed in the very near future. This data will provide the necessary information to justify naming an entirely new soil series in Indiana.

---

* Appendix 2

APPENDIX 1


A
B
C
D
E



DRAINAGE CLASSES

· Moderately Well

+ Somewhat Poorly

X Poorly

M Very Poorly

* Vegetation

LEGEND FOR SOILS MAP

Map Symbol	Mapping Unit
CeBz	Crosby-Miami silt loams, 2 to 6 percent slopes, eroded
FcA	Fincastle silt loam, 0 to 2 percent slopes
Ma	Mahalasville silty clay loam
MnA	Miami silt loam, 0 to 2 percent slopes
MnB2	Miami silt loam, 2 to 6 percent slopes, eroded
Mx	Milford silty clay loam
Ra	Ragsdale silty clay loam
Re	Reesville silt loam, 0 to 2 percent slopes
RuA	Russel/silt loam, 0 to 2 percent slopes
We	Westland silty clay loam
Wh	Whitaker silt loam
XeA	Xenia silt loam, 0 to 2 percent slopes
XeB2	Xenia silt loam, 2 to 6 percent slopes, eroded

LEGEND FOR COMPUTER DATA

•	Moderate well drained
+	Somewhat poorly drained
X	Poorly drained
M	Very poorly drained

No classification for well drained was designated since the actual extend of well drained soils on the classification was very small.

APPENDIX 2

CHANNELS	DIJ(MIN)*	AB (10)	AC (10)	AD (10)	BC (10)	BD (10)	CD (10)
1 2 3 4	1652	1980	2000	2000	1985	1997	1652

<u>Glacial Till Plain</u>

A - Darkest Alfisol or timber soil

B - Next darkest Alfisol or timber soil

<u>Filled River Valley</u>

C - Darkest Mollisol or prairie soil

D - Next darkest Mollisol or prairie soil

*The value DIJ represents the separability (D, divergence) of the various classes I,J. A value of 2000 represents complete separability; while a value below 1500 generally indicates the classes are not spectrally separable.

The above data indicate that all classes are separable from one another (e.g., Class A is completely separable from classes C and D).