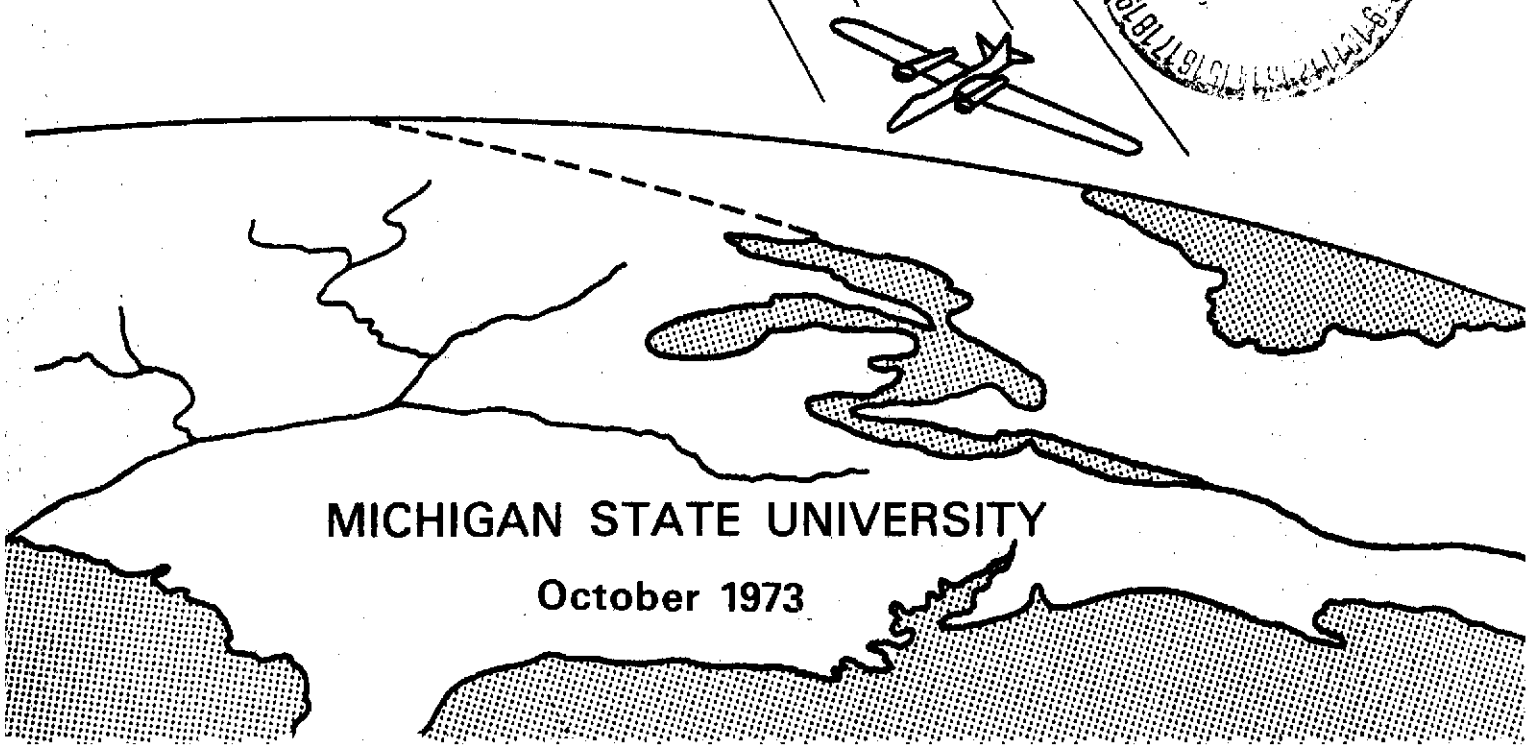
Project for the use of Remote Sensing
in Land Use Policy Formulation

UPPER KALAMAZOO WATERSHED LAND COVER INVENTORY



MICHIGAN STATE UNIVERSITY

October 1973

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This report on the Upper Kalamazoo Watershed Land Cover Inventory was authored by Benjamin Richason III with assistance by William Enslin. The inventory and mapping project described by this report was carried out by the staff of the Michigan State University Project for the Use of Remote Sensing in Land Use Policy Formulation under the direction of Stephen Schar. Mary Daup provided overall supervision for the Kalamazoo research with William Enslin in charge of the photo interpretation completed by Benjamin Richason III, George Martin, Ron Hannes, Mark Wilson, and Ken Keiffenheim. The cartography was completed by Peter Gibson and Patricia Hagedon. Guidance on research procedures and technical advice were provided by the Project's faculty investigators, Dr. Delbert Mokma of the Department of Crop and Soil Sciences and Dr. Wayne Myers of the Department of Forestry at Michigan State University.

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I. INTRODUCTION

The Upper Kalamazoo River Watershed constitutes one third of a 3000 square mile area currently the subject of a three year resource planning effort. A broad range of federal, state, local and regional agencies are participating in the study, which is designed to culminate in a series of action programs for the wise use of land and water resources in the multi-county area.

The principal unit behind the effort is the River Basin Planning Group (RBPG) of the U.S. Department of Agriculture. Several units of the U.S.D.A. are cooperating in this study. Included in the RBPG staff are individuals from the Michigan Watershed and River Basin Planning units of the Soil Conservation Service, the Economic Research Service and the Forest Service.[1] Close cooperation is maintained with the Michigan Water Resources Commission through a series of four policy, advisory, technical, and educational committees. These committees incorporate a large number of local interests in their membership.

The objectives of the RBPG are to achieve coordinated and orderly conservation, development, use and management of water and land resources in the Kalamazoo, Blacks, and Paw Paw River Basin. The RBPG seeks to provide the largest level of long-term benefits to people of the area and adjacent communities. To accomplish this goal the RBPG felt it necessary to develop a detailed land cover inventory to guide their planning.

In the past, such an inventory has been inferred from the Conservation Needs Inventory prepared by the Soil Conservation Service from agricultural statistics. The RBPG did not consider this statistical sampling - inferral method adequate for their needs, however, and thus sought other sources for their information. One of these sources was the Michigan State University Remote Sensing Project. The Project agreed to undertake the interpretation of approximately 1000 square miles of the eastern portion of the study area as a demonstration to the RBPG of the potentials of using remote sensing imagery in such land cover inventories.

The remainder of this report deals with the development of the demon-

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[1]The River Basin Planning Group was organized in June 1972 under the authority of Section 6, Public Law 566 and in accordance with a Memorandum of Understanding dated May 1968, between the administrators of Development Services Division of the State of Michigan's Bureau of Water Management.

stration's classification scheme and its definitions, the imagery and interpretation procedures used, the restrictions and limitations of the interpretations, and a cost analysis and summary of the work done by the staff of the Remote Sensing Project.

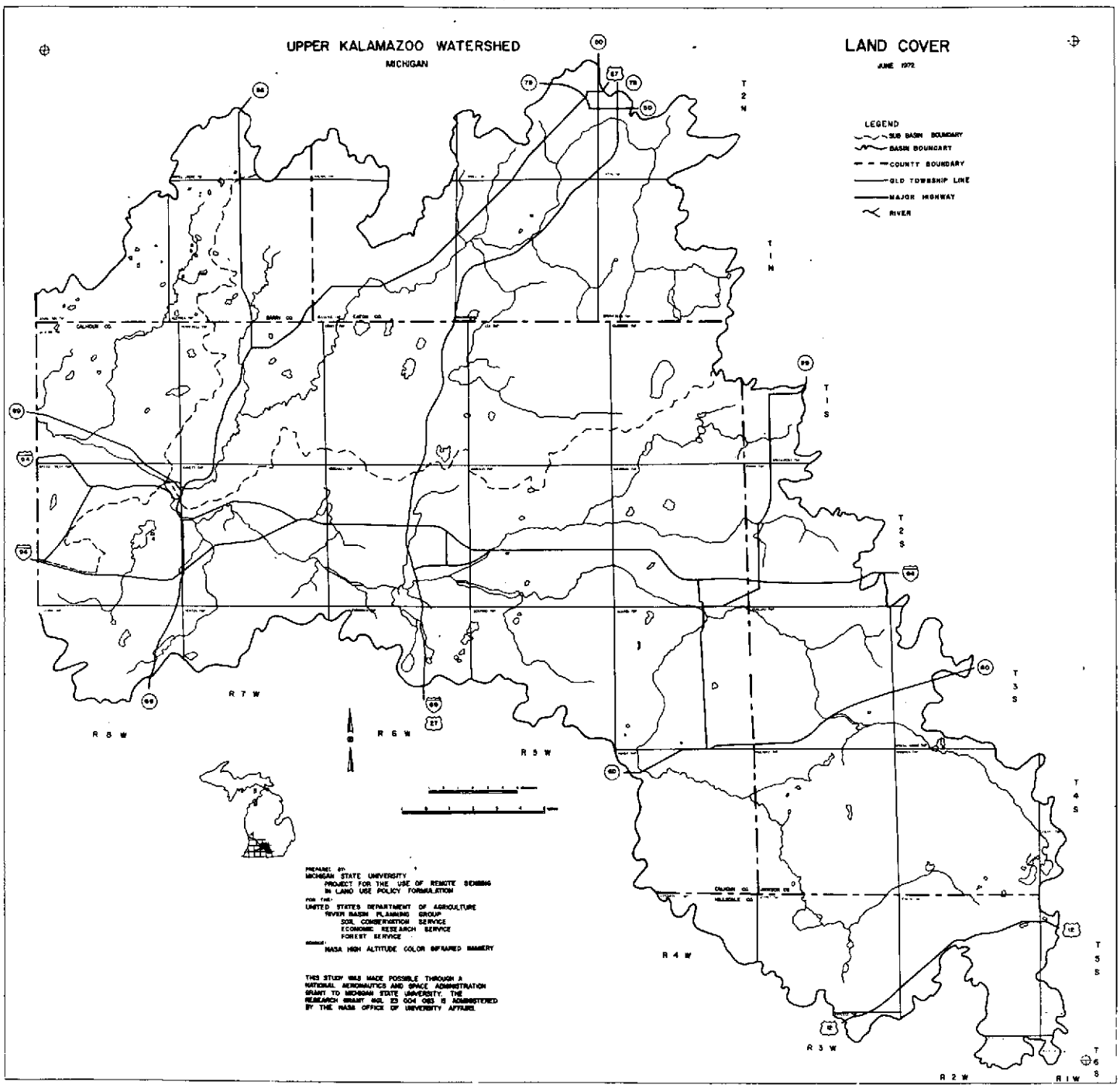

Figure 1. Base Map of the Study Area

II. PROCEDURES

Imagery

The imagery used for identifying the land cover of the Upper Kalamazoo River Watershed was NASA RB-57 color infrared photography. This photography was obtained from cameras mounted in a NASA RB-57 aircraft flown at an altitude of approximately 18,000 meters (60,000 feet).

Color infrared imagery (CIR) collected by this aircraft was chosen for this study because of its immediate availability, and added usefulness for identifying different types of vegetation.[2]

CIR photography also provides a measure of haze penetration and thus generally provides a sharp, clear image from high altitudes. Because the high altitude photographs cover a relatively large area, few were needed to analyze the study area and thus the time spent on interpretation was reduced. In addition, the use of this imagery for a project of this magnitude provided the MSU Remote Sensing Project with an opportunity to assess the value and costs of this imagery for land cover analyses.

The imagery used in this study was taken from several different RB-57 research flights, at scales of 1:60,000 and 1:120,000. The smaller scale imagery (1:120,000), collected in June 1972 and September 1972 covered the entire study area. The larger scale imagery of these missions, however, did not provide such coverage because there was no sidelap between the photos. This, in turn, necessitated using 1:120,000 imagery to supplement the larger scale imagery. Three flight lines, centered approximately over the cities of Battle Creek, Marshall, and Concord, were flown over the study area.

Classification Scheme

The classification scheme and its categories were developed by the River Basin Planning Group. The definition of each category was jointly agreed upon by the MSU Remote Sensing Project and the RBPG. Problems in

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[2]CIR photography records most of the visible energy and some infrared radiation reflected from the earth. The CIR film is sensitive to green, red, and infrared radiation, rather than the blue, green, and red of conventional color films. Thus, a false color image is produced from the infrared film. Green vegetation, for example, is shown red because vegetation reflects larger amounts of infrared radiation than green.

definition which arose during the interpretation were likewise resolved jointly. The items agreed upon, and eventually mapped, were these:

1. Cropland. All areas of 4 hectares or larger in size devoted exclusively to agricultural row crops and small grains were classified as cropland. To accurately identify cropland, the tonal signatures on the June and September imagery were compared. In June most spring planted crops are not mature enough to be distinguishable from each other. Most fields still have a bare field appearance with light to dark tones within fields marked by faint parallel lines superimposed on soil mottling. An exception is winter wheat which can be identified by medium to dark tones throughout the field, closely spaced parallel lines, and a distinct mottling.

On September imagery, some row crops, like corn and soybeans, appear dark with a coarse texture resembling corduroy. A thin shadow line is sometimes evident on the edge of a cornfield, while soybeans have a finer texture with no shadow. In the case of soybeans, if harvesting has started, concentric swath marks may be apparent instead of the parallel ones usually associated with corn harvesting.

In September, harvesting of small grains, like wheat, oats and rye, has usually started, and tones and textures vary according to what has been done to the field after harvesting. If the field was left in stubble, tones would normally be light and swath marks may appear finer than the row crops. Tones would appear light to dark within fields with a dsitinct soil mottling, and parallel lines may be evident if the field has been plowed. If new hay was planted, tones would be darker with indistinct mottling and swath marks.

Many fields classified as cropland had reflectance characteristics typical of bare fields on both the June and September imagery. Seasonal comparisons are strongly recommended when identifying croplands. This category was generally more difficult to identify than the others due to the difficulty in differentiating between small grains and forage cover. Croplands also require more extensive ground truth than other categories in the classification scheme.

2. Orchards. All areas of 4 hectares or larger devoted exclusively to active fruit orchards were so classified. Orchards were easily identified by their evenly spaced trees in uniformly spaced rows, giving a grid pattern appearance. Orchards were distinguished from conifer plantations by their

bushier tree crowns, and usually greater distance (20 feet) between trees. The main distinguishing factor, however, was the dark blue magenta color of the conifers as opposed to the brighter magenta color of the orchard vegetation.

3. Vineyards. All areas of 4 hectares or larger devoted to the production of vine fruits were classified as vineyards. Vineyards are characterized by a uniformly linear pattern different than the grid pattern of orchards. The alignment and spacing of the plants is approximately 10 feet, and can be differentiated from row crops by their wider row spacing.

4. Small Fruits. All areas of 4 hectares or larger devoted exclusively to strawberries, blackberries, raspberries, blueberries, and similar fruits were classified as small fruits. These crops have a linear pattern like vineyards, but are not as bushy, and may exhibit a pattern similar to row crops. Irrigation pipes and drainage tiles are also frequently evident in these fields.

5. Pasture, Fallow Land, Forage Crops, Sod, and Other. All areas of 4 hectares or larger and devoted to pasture, fallow land, forage crops such as alfalfa, and sod production were assigned to this category. Pastures, fallow land and forage crops included here were alfalfa, clover, fescue and other pasture grasses. Pastures frequently present a rougher texture than forage crops; in some, livestock trails could be identified. Sod farms were also included in this category and could be identifed by their uniformly smooth texture and bright red color. Patterns were sometimes discernible on these fields where they had been mowed.

Also included in this category, though in extremely small quantities, were rural golf courses, rural drive-in theaters, rural industrial areas, and rural cemeteries. These uses were assigned to this category only when they were not part of a clustering or built up area of more than one use, and when under 6 hectares in size. Less than 1% of the land in the category was so classified.

6. Deciduous Forest. All areas of 4 hectares or larger and covered by broadleaf deciduous forest were so classified. These forests are easy to identify by their coarse texture, height, presence of shadow, and distinctive edge definition with other land cover types. They appear as a magenta color on the imagery. Most forest vegetation in the study area is in the form of

woodlots that farmers have not cut. Because they are surrounded by fields in other land cover types, these woodlots usually have a definite square or rectangular shape.

7. Coniferous Forest. All areas of 4 hectares or larger in coniferous tree cover were so classified. These forests appear as a dark blue magenta color with a rough texture and spiked crowns as opposed to the bushy crowns of deciduous foliage. Normally, coniferous forests are not naturally distributed to any extent in this latitude. Therefore, their numbers, as pure stands, are limited to areas devoted to conifer plantations. In such plantations these conifers are in an orderly arrangement (typical row type pattern) because of the cultivation method employed.

8. Mixed Forest. Mixed forests in areas of 4 hectares or larger are identified by an intermix of deciduous and coniferous types. To be classified as a pure stand of either conifers or hardwoods, 70% of the forest was required to be of the respective type. If no type covered 70% or more of an area, the forest was classified "mixed."

9. Brushland. Areas of 4 hectares or greater were classified as brush if it had less than 50% forest cover. Brush usually has photo characteristics similar to those of deciduous forests except that they have a lower density and differentiation. Brush is relatively easy to identify when viewed stereoscopically because of the relative difference in height between it and more heavily forested areas.

10. Marshland. Areas of 4 hectares and larger in swampy or wetland condition, and non-forested were classified as marshland. This appeared on the imagery as a light pink to pink color and was roughly textured. Open water was evident where there was a high water table. When this was the case, the vegetation had darker colors like brown, reddish-brown and green. Marshlands are often found in geomorphic depressions or on low-lying land near a stream or river.

11. Urban Residential or Commercial. This category included all areas of 4 hectares or larger where residential or commercial structures were found in concentrated patterns in urban areas. This category was characterized by its built-up, clustered nature and definitely urban or suburban street patterns.

12. Urban Industrial. All areas of 4 hectares or larger devoted to or closely associated with industrial or warehousing uses were classified as

such. Structures in this category most frequently are recognized by their size and shape. Large parking areas, proximity of transportation routes, railroads, presence of smoke stacks, outside equipment, stockpiles of raw materials, and the extent of a complex of associated structures were used as indicators of industrial activities.

13. Urban Construction. This category includes urban areas of 4 hectares or larger which appeared to be under construction. These areas appeared white on the imagery and resembled the characteristics of open pits, except without the depression. Evidence of construction or earthmoving activity was relied upon heavily.

14. Rural Built-up. Areas of 4 hectares or larger were identified as rural built-up when they contained three or more dwellings lined up or clustered, and which were not associated with or identified as farmsteads. Subdivisions located near an urban area were not included in this cateogry even though they might not be within the continuous space of the urban area; they were mapped as urban residential or commercial.

15. Water. All areas of open water larger than 4 hectares and not included in the open pit or marshland categories were classified as water. Included in this category were lakes, ponds, streams, rivers, reservoirs, and all other artificial drainage. Areas of water less than 4 hectares were put into the category of the dominant land use surrounding the water.

16. Open Pits. This category included all sand, gravel and other quarry areas of 4 hectares or larger in size. These areas were identified by their very light, white color, a depression visible in stereo, and road networks. Machinery was also sometimes discernible on the larger scale imagery.

17. Sand Dunes. Barren or slightly vegetated areas of 4 hectares or larger and identified as sand beach or sand dunes are classified as sand dunes. Like open pits, sand dunes also have very light, white tones, except when covered with vegetation. The difference between the two is the lack of quarrying machinery present on the sand dunes.

18. Roadway System. This category includes all federal interstate highways, state highways, and county roads in the study area. These transportation routes, with their linear and grid patterns, were easily recognized on the imagery and appeared in light tones. Mean right-of-way widths mapped, and

supplied by the Michigan Department of State Highways, were 200 feet for I-94 and M-66, 400 feet for I-69, and 66 feet for all rural and county roads.

Personnel

The analysis of the imagery for the study was done by five students with varying degrees of skill and speed in photo interpretation. Errors which might result from this difference in experience were hopefully minimized by providing all of the interpreters with a short training period in identification of the various categories.

When the interpreter began his analysis, he was supplied with a key which he could use as a check-off list to increase his interpretive accuracy. If there was a problem in identification which the interpreter felt he could not solve, it was taken to a more experienced interpreter who also performed a quality control function by having the final determination in all interpretive problems.

The Use of September, 1:60,000 Imagery

Each interpreter was assigned a flight line of the September 1972 imagery in the study area for interpretation. Since non-stereoscopic interpretation was to be used, every other photo collected along the flight line was selected for analysis.

The actual interpretation of the imagery was begun by taping two 10" x 10" sheets of clear acetate together so that they formed a sort of envelope, and then slipping the photograph inside. Using 10X hand lenses, and occasionally stereoscopes, the imagery was then analyzed according to the various land covers on it.

Road and water features were delineated first on the photograph to form a rough grid pattern. This enabled the interpreter to analyze systematically the land cover on the imagery. The delineation was done with a double zero rapidograph pen, red ink being used for roads, blue ink for water features and black ink for other land covers. All areas on the imagery were classified and delineated.

Most land covers were easily identified with the 10X hand lenses; whenever a problem arose, however, the imagery could be viewed stereoscopically for a

more precise interpretation. The imagery possessed no sidelap, but it did have enough endlap for stereovision. Once a photo was interpreted and the delineation complete, the "next one" in the flight line was selected and the same procedure was followed until the entire flight line was completed.

The Use of September, 1:120,000 Imagery

Since the 1:60,000 imagery did not provide complete coverage of the study area, it was necessary to supplement the photography with the concurrent 1:120,000 imagery. The 1:120,000 imagery was not used for interpretation of the whole study area because field boundaries at this scale are too small for as precise a delineation as could be supplied by the 1:60,000 photography. Thus, for purposes of interpretation, the 1:120,000 imagery was increased in scale approximately 2 times with a Bausch and Lomb Projector-Enlarger.

The enlarged image was projected onto tracing paper where the land cover types identified were delineated with red, blue, and black lead pencils (colors corresponded with those of the ink colors used on the clear acetate sheets.) Procedures in classification and delineation of the 1:120,000 imagery were identical to those of the 1:60,000.

The Use of June Imagery

The majority of the interpretation for the study was done with the September 1972 imagery since at that time of the year crops had matured and were ready for or were being harvested. Tonal variations, at a maximum at that time of year, and a variety of harvesting techniques, made this imagery an excellent source for a study of land cover types.

When questions arose on the September imagery, however, especially concerning the differentiation between small grains and pasture, the June photography was referred to for additional information. In addition, the June imagery, with a lessened amount of foliage evident made possible a more accurate delineation of roads and water courses. The comparisons of the seasonal 1:60,000 and 1:120,000 photography, the June and September imagery were studied side by side on a light table.

LAND COVER CATEGORIES

Rural Built-Up

Marshland

Orchard

Pasture or Fallow Land

Brushland

Urban Industrial

Urban Residential
or Commercial

Open Pit

Deciduous Forest

Coniferous Forest

Cropland

Not Shown on this Photograph are:

Vineyards
Small Fruit Areas
Mixed Forest
Urban Construction
Sand Dunes

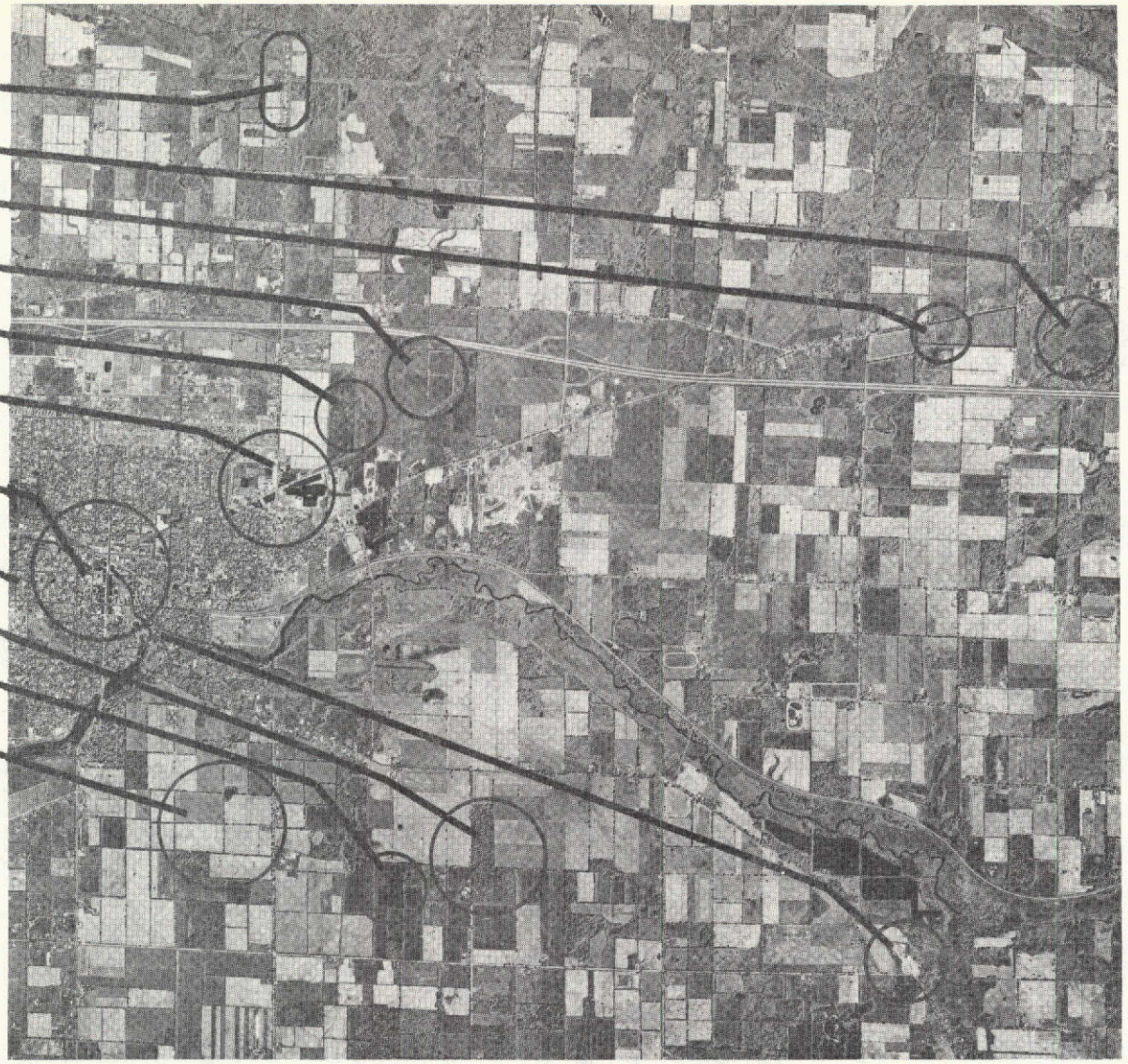
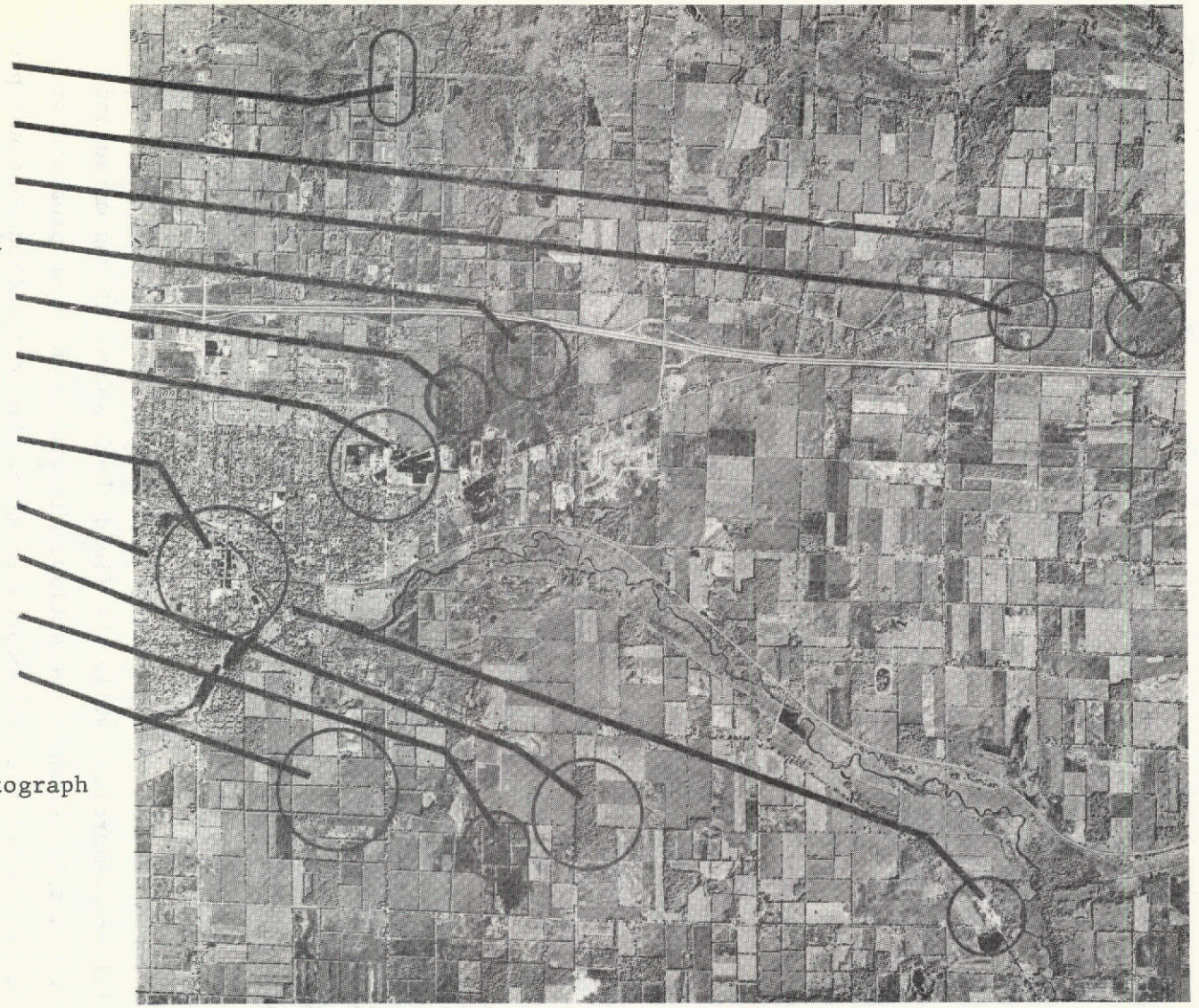


Figure 2. NASA RB57 Imagery of the Albion, Michigan Area

a. June 1972 Imagery

LAND COVER CATEGORIES



Not Shown on this Photograph are:

Vineyards
Small Fruit Areas
Mixed Forest
Urban Construction
Sand Dunes

Figure 2. NASA RB57 Imagery of the Albion, Michigan Area
b. September 1972 Imagery

Quality Control

Even the most experienced photo interpreters allow for some value judgments in their interpretative decisions. This expected variance in the interpretations made by different individuals made necessary the use of certain quality control procedures and checks. This quality control was provided by the most experienced photo interpreter in the group who randomly checked portions of the interpretations of all of the larger scale imagery. This was done by selecting a limited number of areas on each photo and verifying that the interpreter was classifying the area correctly, and that all other interpreters were classifying similar areas in the same way.

Another element of quality control involved field checking 100 plots randomly selected located throughout the study area. These plots were accurately located on U.S.G.S. topographic maps, and then visited to verify that the interpreter had correctly classified the area. Of the 100 randomly selected plots, 9 were in error, roughly measuring the interpretations' accuracy as 91%. Of these 9 errors, 5 were misinterpretations while the remaining 4 were mistakes which resulted from definitional problems.

The definitional errors were of several types. In 3 of the plots, brush was identified by the interpreter, while the field check showed the area was a deciduous woodlot. Brush and forest lands were differentiated from each other in terms of percent of ground cover, with 50% assigned as the boundary value between brush and forest. It was the individual value judgment of the interpreters and field checkers as to exactly what constituted a 50% cover.

The fourth definitionally incorrect plot was classified as urban, residential or commercial, while the field check showed it was marsh and brushland. In this instance the wetland was within an urban area and of only slightly greater than 4 hectares in size. The definitions had not provided for uncharacteristic uses inside generally recognized urban areas. The definitions have since been corrected.

Cartography

Once the imagery interpretation was completed, rough interpretation maps were combined and redrawn by two experienced cartographers at a scale

of 1:63,360. This scale was selected by the Soil Conservation Service so they could use their county highway maps, which were at this scale, as base maps. When this preliminary landcover map had been completed it was drafted onto a series of four stabiline overlay maps. The types of cover mapped on each overlay were grouped into somewhat similar categories: cropland; urban areas; forest areas; and pasture, idle and marsh lands. A fifth map, indicating civil divisions, major surface water and the road system was used as the base map for these overlays.

Area Calculations

Once the cartographic work was completed, the original map of land cover types was analyzed to determine the total area of each land cover category within the study area. These values were aggregated by sub-basins, counties, and townships within the Upper Kalamazoo Watershed.

A 16 hectare dot grid was then placed over the map. The land cover type on which each dot fell was noted, and recorded as the predominant cover type for the entire 16 hectare section. Because the dot grid procedure would significantly under count the area in the narrow, lineal road system right-of-ways, a base area per township figure, using data supplied by the Department of State Highways, was applied for rural roads in a standard township. In the case of interstate freeways, a Dietzgen Map Measurer was used to measure the total length of freeway in each township. This distance was then multiplied by the average right-of-way of each interstate highway, as supplied by the Department of State Highways.

Two members of the staff performed the area calculations. One read aloud the dominant land cover type; the other recorded the figures on a tally sheet. Township areas within the individual sub-basins were calculated first. These figures were summed for county totals within the sub-basins. These values were in turn added to determine value for the entire Upper Kalamazoo Watershed.

After these area calculations were finished, a Keuffel & Esser polar planimeter was used to compute from the SCS base map, the total area within the Upper Kalamazoo Watershed for a comparison with the total land cover area calculation. An underestimate in the land cover area of less than 3,200

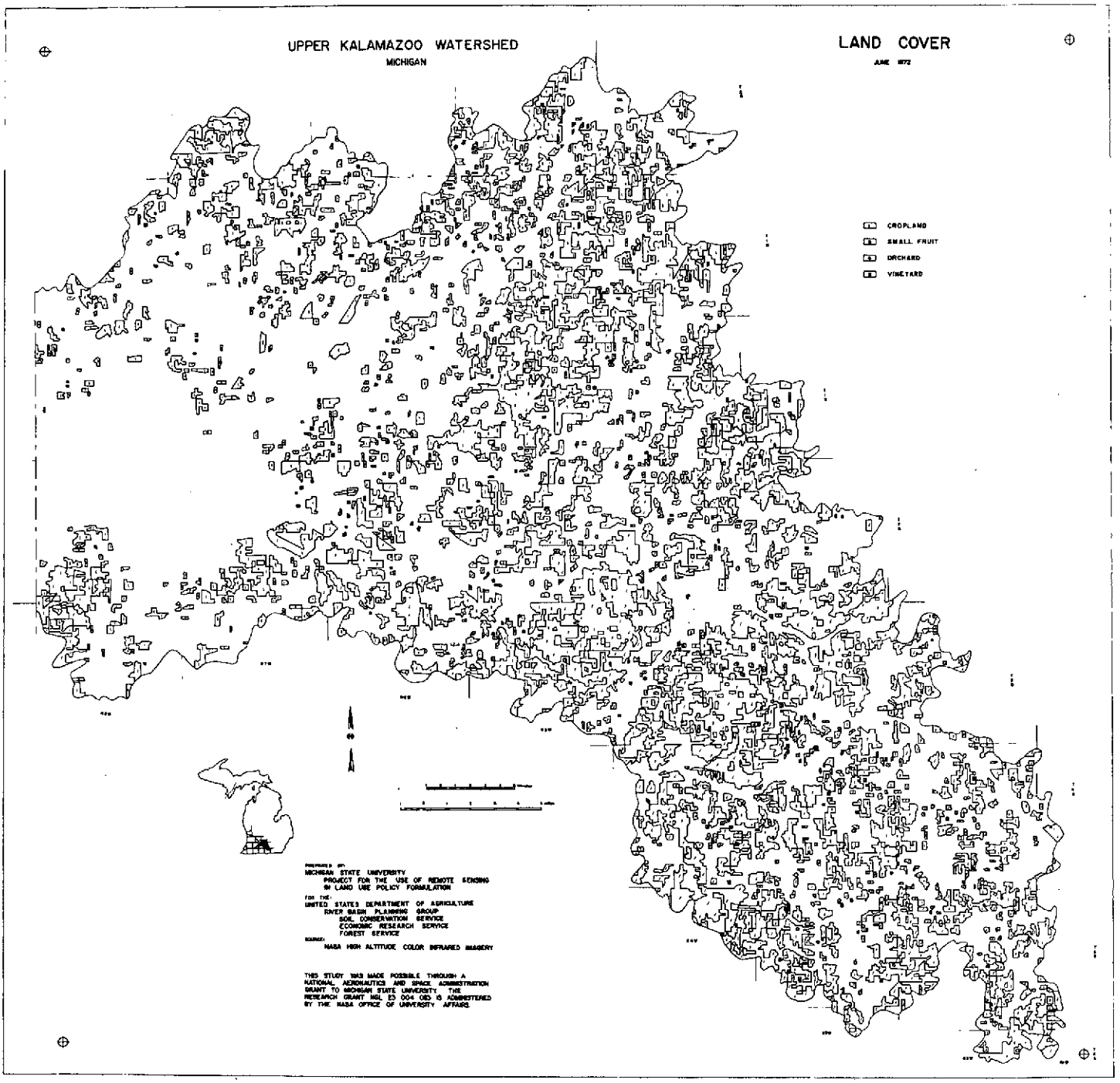


Figure 3. Land Cover: Active Agricultural Land Use

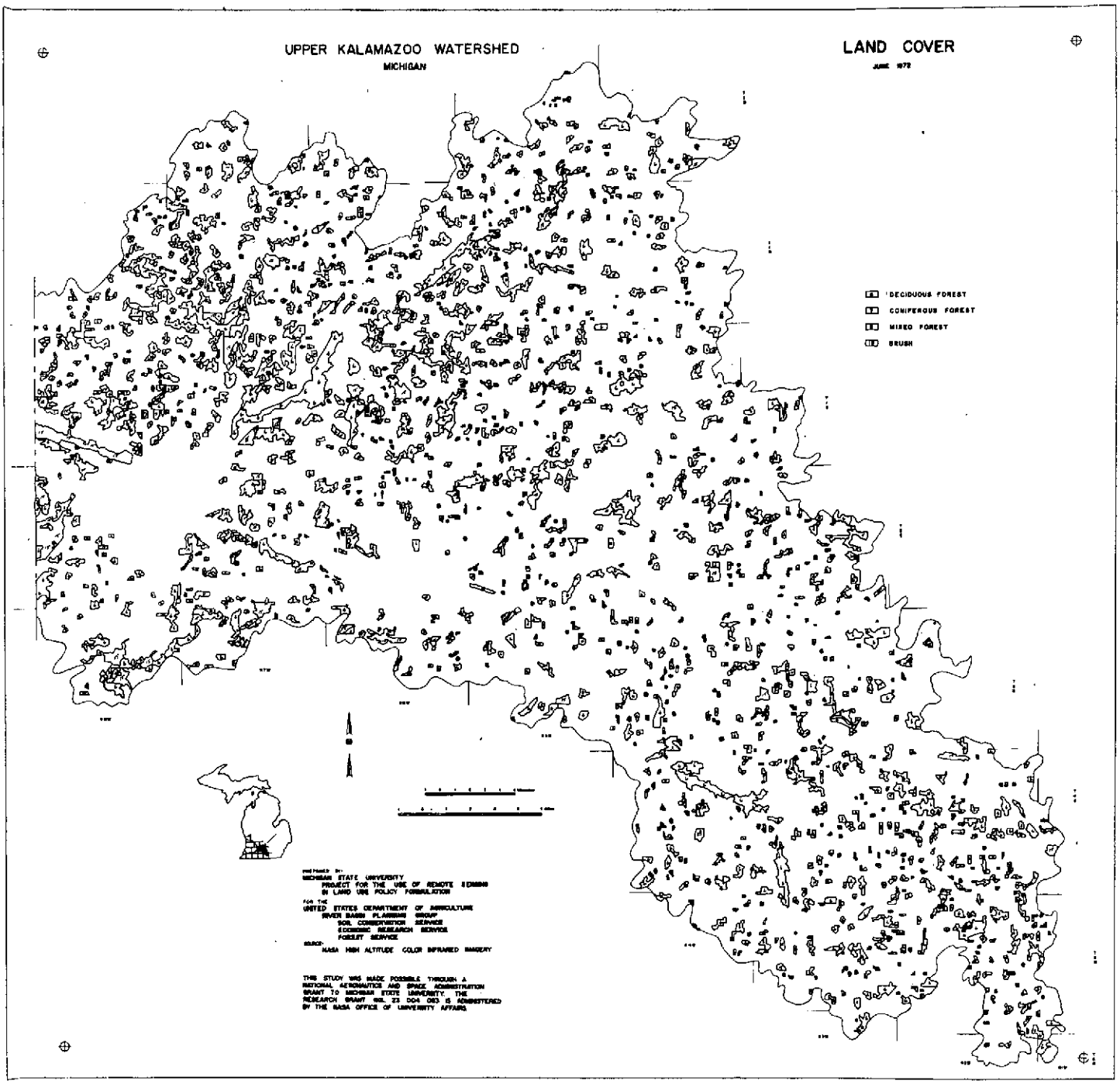


Figure 4. Land Cover: Forested Land

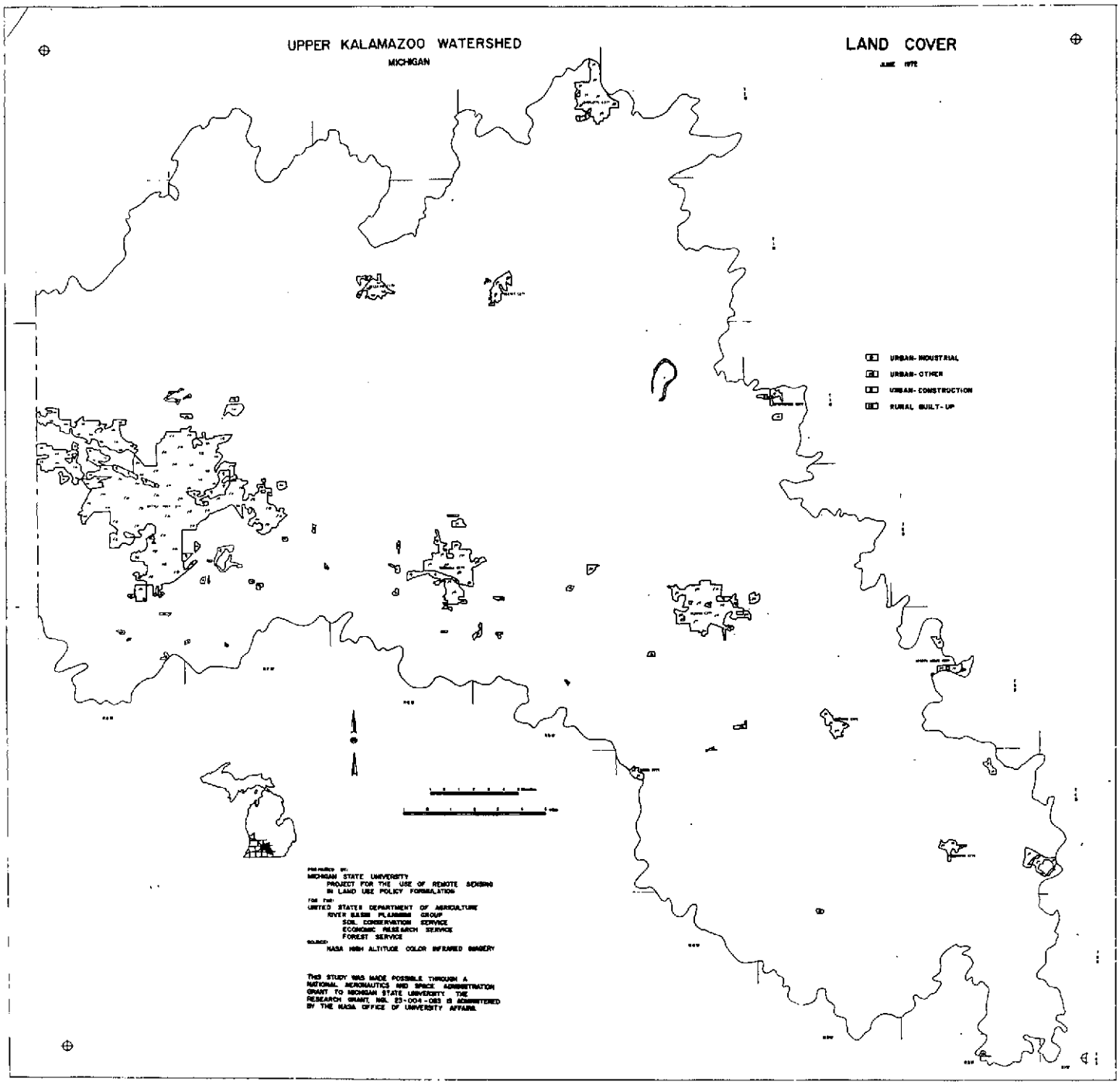


Figure 5. Land Cover: Developed Land

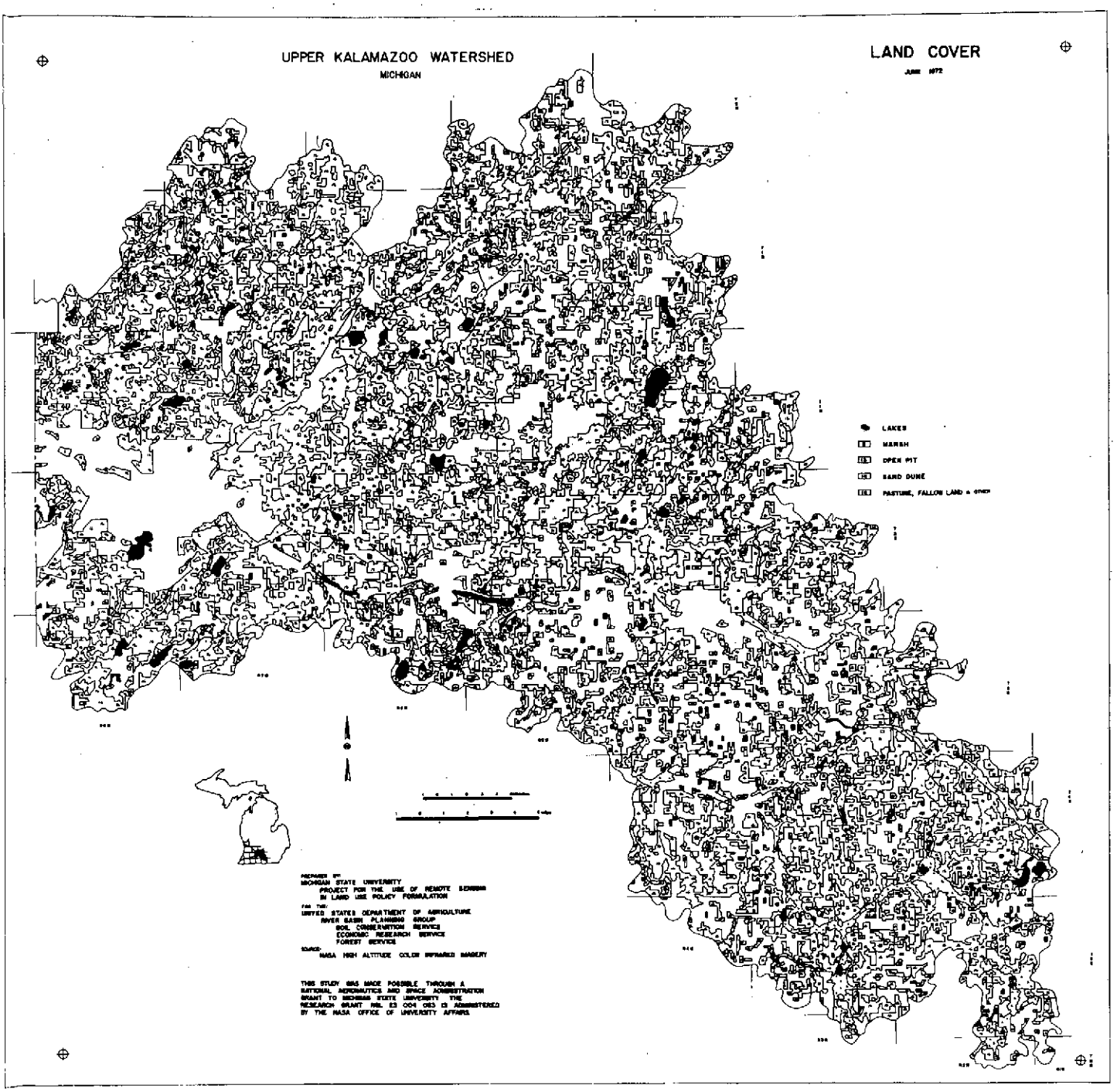


Figure 6. Land Cover: Other Open Lands

hectares, or 1.4%, was found in this comparison.

Some Limitations on Quality

Several factors affected the accuracy and quality of the interpretative and planimetric results. Some interpretative inaccuracies may have been caused by the use of two scales of imagery. The entire watershed might have been interpreted with the smaller scale, 1:120,000, imagery. It was thought, however, that greater accuracy could be achieved over the majority of the watershed with use of the larger scale imagery supplemented by the 1:120,000 photography in the "gaps."

The varying levels of experience of the five interpreters working on the study affected interpretative accuracy as well. But such errors were probably kept to a minimum by the frequent quality control checks. The time limitations may also have caused inaccuracies.

Finally, the amount of ground truth available also affected results. Extensive ground truth usually increases interpretative accuracy. However, not enough time or personnel were available for as extensive a series of ground truth checks as might have been desired.

Like the interpretative results, there is also the possibility of errors in the planimetric precision of the study. Two scale changes had to be made from the imagery to the preliminary map, and once this map was completed, it had to be redrafted onto the final maps. Such scale changes and redrafting procedures frequently result in planimetric inaccuracies. In addition planimetric errors, like interpretative ones, may have resulted from such factors as the differences in the scales of imagery, the experience of the interpreters, and time limitations. For example, aerial photography contains some planimetric distortion, especially on its borders, because of altitudinal changes of the aircraft in flight. The imagery used in this study was no exception. Such planimetric distortions are normally corrected for by the equipment used in this study, but malfunctions occasionally made such corrections difficult and far from automatic.

Errors in identification were also introduced by misuse or misunderstanding of the cover type classification scheme, or by its inadequacies. Perhaps the largest problem encountered in use of the classification scheme was

recognizing the difference between some kinds of cropland, pasture and fallow lands because of their similar texture and pattern characteristics. Identifying the difference between sod farms and some specialty crops is one such example of this problem.

It was also difficult to differentiate between marsh, brush and fallow lands (all have fairly rough textures). Differences in classification were based primarily on the tonal signatures of these vegetation types.

Another problem occurred in trying to decide exactly what was rural built-up and what was urban. Each interpreter's judgements were relied on to make the distinction. If he felt a residential concentration was too far removed from an urban area to be classified as such, it was called rural built-up. If, on the other hand, a residential concentration was considered to be relatively near an urban area it was classified urban.

The interpreter's task in judging the percent composition of a particular forested area was also difficult. For example, if an area was covered with less than 50% forest cover, it was classified brushland; the interpreter had to decide what constituted forest cover. Hopefully, errors resulting from such interpretative problems were corrected by the quality control check.

III. COSTS

The total cost of the study was based on the wages paid to project staff, the number of hours of equipment use, the cost of the imagery and cartographic supplies, printing costs, and miscellaneous expenses such as indirect wages paid to administrative staff. A 61% overhead of total related gross wages charged to the project by Michigan State University was also included in the study costs. This charge includes such things as the use of office space, lighting, etc.

The number of hours spent on interpreting any imagery varies with the interpreter's skill, the equipment available, the quality and scale of the existing imagery of the study area, the number of interpreters working on the study, and numerous other factors. Based on the time sheets maintained by staff members working on this project, the interpretation of the imagery, including training time for the interpreters, took 620 hours to complete (approximately 36 minutes for each square mile).

COSTS INCURRED IN THE UPPER KALAMAZOO RIVER BASIN LAND COVER STUDY

Description of Cost Item	Cost
I. Development Costs	
none	
II. Operational and Acquisition Costs	
Color infrared transparencies	$ 802
Wages - administrative indirect	112
MSU overhead %	59
III. Processing Costs	
none	
IV. Interpretive Costs	
Light table (pro-rated cost)	161
Work table (pro-rated)	19
Magnifier & reducer (pro-rated)	419
Stereoscopes	9
Field survey tools	15
Wages - interpreters	2325
Wages - field surveyors	114
Wages - indirect	112
MSU overhead %	1548
V. Application & Presentation Costs	
Drafting table (pro-rated cost)	20
Light tables	7
Tools	25
Wages - cartographer	431
Wages - analysts	392
Wages - clerical	75
Wages - indirect	121
MSU & Commercial printing	255
Drafting supplies	25
MSU Overhead %	578
TOTAL PROJECT COST	$7524

The finished cartographic presentation, including quality control measures, took 100 hours, while ground truth required 35 hours to complete. The area calculations took 55 hours to finish. The first draft of the study report was written in 32 hours with revisions and corrections taking 25 hours. Typing the report took a total of 40 hours which included 8 hours for typing the area calculation tables.

Indirect administrative hours which included project coordination and supervision, totaled 40 hours. Finally, 2 hours were spent on determining the format of the report and 4 hours in duplicating, collating, and binding the report.

IV. SUMMARY

Several conclusions concerning the effect of the Kalamazoo Watershed study can be made. First, the study demonstrated the value of NASA RB-57 color infrared imagery in the interpretation of land cover over an extensive area (approximately 1000 square miles). Imagery at a larger scale would have cost considerably more and taken longer to interpret. Imagery at a smaller scale (ERTS or Skylab), while it might cost less and taken less time to interpret than RB-57 imagery, could not provide the detail that the study's classification scheme demanded.

Second, the study provided the users with a detailed land cover map of the study area as well as fairly accurate area measurement statistics. Due to its scale, for this study the RB-57 imagery demonstrated its value in preparing maps with accompanying area calculations inexpensively and in little time.

In addition, the study's success has persuaded the RBPG to complete land cover inventory of the western 2,000 square miles of the basin area, using commercially acquired color infrared imagery comparable to NASA's. Because this was a demonstration study, such an action is extremely heartening, for the advantages of such remote sensing imagery at these scales has been proven to a user agency.

Finally, this study has provided a usable, necessary product. Not until now has such an extensive land cover inventory using remote sensing been accomplished in Michigan. This study has provided basic land cover data at a scale, consistency, and economy which has not been available before.

V. APPENDIX

AREA CALCULATIONS

FOR THE KALAMAZOO WATERSHED

LAND COVER INVENTORY

Table I

Summary of Land Cover Types in the Upper Kalamazoo Watershed by Sub-Basin, in Acres, Hectares, and Percent of Total

Land Cover Type		Total Kalamazoo Watershed	Upper Kalamazoo Sub-Basin	Battle Creek Sub-Basin	Middle Kalamazoo Sub-Basin
Pasture Fallow Land Forage Crops Other	acres	217,964	127,466	71,138	19,360
	hectares	88,245	51,606	28,801	7,838
	percent	37.8 %	37.4 %	39.7 %	35.0 %
Cropland	acres	164,940	109,450	49,272	6,218
	hectares	66,777	44,312	19,947	2,517
	percent	28.6 %	32.1 %	27.4 %	11.2 %
Deciduous Forest Coniferous Forest Mixed Forest Brushland	acres	85,994	41,058	32,432	12,504
	hectares	34,815	16,623	13,130	5,062
	percent	15.0 %	12.0 %	18.1 %	22.6 %
Marshland Swampland	acres	52,170	32,686	12,072	7,412
	hectares	21,121	13,233	4,887	3,001
	percent	9.1 %	9.5 %	6.7 %	13.4 %
Urban Industrial Urban Residential, and Commercial Urban Construction Rural Built-Up	acres	28,336	14,824	6,152	7,360
	hectares	11,472	6,002	2,491	2,980
	percent	4.9 %	4.3 %	3.5 %	13.3 %
Transportation Right-of-Way	acres	16,299	9,527	5,346	1,426
	hectares	6,599	3,857	2,164	577
	percent	2.8 %	2.8 %	3.0 %	2.6 %
Lakes and Ponds	acres	8,562	5,432	2,090	1,040
	hectares	3,466	2,199	846	421
	percent	1.5 %	1.6 %	1.0 %	1.9 %
Open Pits	acres	1,200	280	880	40
	hectares	486	113	356	16
	percent	0.2 %	--	0.5 %	--
Orchard Vineyard Small Fruit Area	acres	720	560	160	--
	hectares	291	227	65	--
	percent	0.1 %	0.1 %	0.1 %	--
TOTAL Land Area	acres	576,185	341,283	179,542	55,360
	hectares	233,273	138,171	72,689	22,413
	percent	100.0 %	100.0 %	100.0 %	100.0 %

Table II

Distribution of Land Cover Within
the Upper Kalamazoo Watershed and
its Sub-Basins, in Acres

Land Cover Category	Upper Kalamazoo River Basin	Battle Creek Sub-Basin	Middle Kalamazoo-Kalamazoo Area	Total for Upper Kalamazoo Watershed
Cropland	109,450	49,272	6,218	164,940
Marshland	31,574	12,072	7,412	51,058
Rural Roadways R.O.W.	9,527	5,346	1,426	16,299
Orchard	480	160	0	640
Vineyard	80	0	0	80
Deciduous Forest	30,352	21,932	6,232	58,516
Coniferous Forest	240	680	680	1,600
Mixed Forest	560	200	400	1,160
Urban Industrial	710	466	320	1,496
Urban Other	12,954	5,686	6,280	24,920
Urban Construction	40	0	560	600
Swampland	1,112	0	0	1,112
Rural, Built-Up	1,120	0	200	1,320
Open Pits	280	880	40	1,200
Pasture, Fallow Land, Other*	127,466	71,138	19,360	217,964
Brushland	9,906	9,620	5,192	24,718
Water (Lakes only)	5,432	2,090	1,040	8,562
Total	341,283 Acres	179,542 Acres	55,360 Acres	576,185 Acres

*This category, (pastures, fallow land, other) contains all areas of land identified as in use as pasture, forage crops, fallow land, rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries. Less than one percent of the land in this category 15 was identified as devoted to rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries.

Table III

Distribution of Land Cover Within
the Upper Kalamazoo Watershed and
its Sub-Basins, in Percent of Total

Land Cover Category	Upper Kalamazoo River Sub-Basin	Battle Creek Sub-Basin	Middle Kalamazoo-Kalamazoo Area Sub-Basin	Total for Upper Kalamazoo Watershed
Cropland	32.1	27.4	11.2	28.6
Marshland	9.2	6.7	13.4	8.9
Rural Roadways R.O.W.	2.8	3.0	2.6	2.8
Orchard	0.1	0.1	-	0.1
Vineyard	-	-	-	-
Deciduous Forest	8.9	12.2	11.3	10.2
Coniferous Forest	-	0.4	1.2	0.3
Mixed Forest	0.2	0.1	0.7	0.2
Urban Industrial	0.2	0.3	0.6	0.3
Urban Other	3.8	3.2	11.3	4.3
Urban Construction	-	-	1.0	0.1
Swampland	0.3	-	-	0.2
Rural, Built-Up	0.3	-	0.4	0.2
Open Pits	-	0.5	-	0.2
Pasture, Fallow Land, Other*	37.4	39.7	35.0	37.8
Brushland	2.9	5.4	9.4	4.3
Water (Lakes only)	1.6	1.0	1.9	1.5
Total	100.0%	100.0%	100.0%	100.0%

Note: The dash (-) indicates less than one-tenth of one percent of land identified in that use.

*This category, (pastures, fallow land, other) contains all areas of land identified as in use as pasture, forage crops, fallow land, rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries. Less that one percent of the land in this category 15 was identified as devoted to rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries.

Table IV

Distribution of Land Cover Within
the Upper Kalamazoo River Sub-Basin
by County, in Acres

Land Cover Category	HILLSDALE	JACKSON	CALHOUN
Cropland	18,562	31,518	59,370
Marshland	4,436	10,276	16,862
Rural Roadways R.O.W.	1,094	2,562	5,871
Orchard	80	120	280
Vineyard	0	0	80
Deciduous Forest	4,766	9,814	15,772
Coniferous Forest	0	40	200
Mixed Forest	400	0	160
Urban Industrial	0	40	670
Urban Other	40	1,726	11,188
Urban Construction	0	40	0
Swampland	0	1,112	0
Rural, Built-Up	0	40	1,080
Open Pits	40	0	240
Pasture, Fallow Land, Other*	13,222	36,396	77,848
Brushland	760	2,684	6,462
Water (Lakes only)	360	1,610	3,462
Total	43,760 Acres	97,978 Acres	199,545 Acres

*This category, (pastures, fallow land, other) contains all areas of land identified as in use as pasture, forage crops, fallow land, rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries. Less than one percent of the land in this category 15 was identified as devoted to rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries.

Table V

Distribution of Land Cover Within
the Upper Kalamazoo River Sub-Basin
by County, in Percent of Total

Land Cover Category	HILLSDALE	JACKSON	CALHOUN
Cropland	42.4	33.16	29.75
Marshland	10.1	10.48	8.45
Rural Roadways R.O.W.	2.5	2.61	2.94
Orchard	0.182	0.12	0.14
Vineyard	-	-	0.04
Deciduous Forest	10.9	10.01	7.90
Coniferous Forest	-	0.04	0.10
Mixed Forest	0.09	-	0.08
Urban Industrial	-	0.04	0.33
Urban Other	0.09	1.76	5.60
Urban Construction	-	0.04	-
Swampland	-	1.13	-
Rural, Built-Up	-	0.04	0.54
Open Pits	0.09	-	0.12
Pasture, Fallow Land, Other*	30.2	37.14	39.01
Brushland	1.73	2.73	3.23
Water (Lakes only)	0.82	1.64	1.73
Total	100.00%	100.00%	100.00%

Note: The dash (-) indicates less than one-tenth of one percent of land identified in that use.

*This category, (pastures, fallow land, other) contains all areas of land identified as in use as pasture, forage crops, fallow land, rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries. Less than one percent of the land in this category 15 was identified as devoted to rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries.

Table VI

Distribution of Land Cover Within
the Battle Creek Sub-Basin
by County, in Acres

Land Cover Category	CALHOUN	EATON	BARRY
Cropland	18,104	27,628	3,540
Marshland	5,612	4,860	1,600
Rural Roadways R.O.W.	2,324	2,664	358
Orchard	120	40	0
Vineyard	0	0	0
Deciduous Forest	9,630	10,262	2,040
Coniferous Forest	320	200	160
Mixed Forest	120	80	0
Urban Industrial	426	40	0
Urban Other	3,440	2,166	80
Urban Construction	0	0	0
Swampland	0	0	0
Rural, Built-Up	0	0	0
Open Pits	200	520	160
Pasture, Fallow Land, Other*	31,506	33,680	5,952
Brushland	5,668	3,300	652
Water (Lakes only)	1,690	360	40
Total	79,160 Acres	85,800 Acres	14,582 Acres

*This category, (pastures, fallow land, other) contains all areas of land identified as in use as pasture, forage crops, fallow land, rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries. Less than one percent of the land in this category 15 was identified as devoted to rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries.

Table VII

Distribution of Land Cover Within
the Battle Creek Sub-Basin
by County, in Percent of Total

Land Cover Category	CALHOUN	EATON	BARRY
Cropland	22.87	32.20	24.27
Marshland	7.08	5.66	10.97
Rural Roadways R.O.W.	2.93	3.10	2.45
Orchard	0.15	0.04	-
Vineyard	-	-	-
Deciduous Forest	12.16	11.96	13.98
Coniferous Forest	0.40	0.23	1.09
Mixed Forest	0.15	0.09	-
Urban Industrial	0.53	0.04	-
Urban Other	4.34	2.52	0.54
Urban Construction	-	-	-
Swampland	-	-	-
Rural Built-Up	-	-	-
Open Pits	0.25	0.60	1.09
Pasture, Fallow Land, Other*	39.79	39.25	40.81
Brushland	7.16	3.84	4.47
Water (Lakes only)	2.13	0.41	0.27
Total	100.00%	100.00%	100.00%

Note: The dash (-) indicates less than one-tenth of one percent of land identified in that use.

*This category, (pastures, fallow land, other) contains all areas of land identified as in use as pasture, forage crops, fallow land, rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries. Less than one percent of the land in this category 15 was identified as devoted to rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries.

Table VIII

Distribution of Land Cover Within
Middle Kalamazoo River-Kalamazoo Area Sub-Basin
by County, in Acres

Land Cover Category	CALHOUN	BARRY
Cropland	2,418	3.800
Marshland	3,552	3,860
Rural Roadways R.O.W.	898	528
Orchard	0	0
Vineyard	0	0
Deciduous Forest	3,132	3,100
Coniferous Forest	360	320
Mixed Forest	320	80
Urban Industrial	320	0
Urban Other	6,280	0
Urban Construction	560	0
Swampland	0	0
Rural, Built-Up	160	40
Open Pits	0	40
Pasture, Fallow Land, Other*	12,000	7,360
Brushland	3,520	1,672
Water (Lakes only)	640	400
Total	34,160 Acres	21,200 Acres

*This category, (pastures, fallow land, other) contains all areas of land identified as in use as pasture, forage crops, fallow land, rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries. Less than one percent of the land in this category 15 was identified as devoted to rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries.

Table IX

Distribution of Land Cover Within
Middle Kalamazoo River-Kalamazoo Area Sub-Basin
by County, in Percent of Total

Land Cover Category	CALHOUN	BARRY
Cropland	7.07	17.92
Marshland	10.39	18.20
Rural Roadways R.O.W.	2.62	2.49
Orchard	-	-
Vineyard	-	-
Deciduous Forest	9.16	14.62
Coniferous Forest	1.05	1.50
Mixed Forest	0.93	0.37
Urban Industrial	0.93	-
Urban Other	18.38	-
Urban Construction	1.63	-
Swampland	-	-
Rural, Built-Up	0.46	0.18
Open Pits	-	0.18
Pasture, Fallow Land, Other*	35.12	34.71
Brushland	10.30	7.88
Water (Lakes only)	1.87	1.88
Total	100.00%	100.00%

Note: The dash (-) indicates less than one-tenth of one percent of land identified in that use.

* This category, (pastures, fallow land, other) contains all areas of land identified as in use as pasture, forage crops, fallow land, rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries. Less than one percent of the land in this category 15 was identified as devoted to rural golf courses, rural drive-in theatres, rural industrial areas, and rural cemeteries.

Table X
(Sheet 1 of 4)

Distribution of Land Cover Within the Upper Kalamazoo Watershed
by Sub-Basins, County, and Township in Acres

Upper Kalamazoo River Sub-Basin

HILLSDALE COUNTY

	Litchfield Township	Scipio	Fayette	Moscow	Adams	Wheatland	Somerset
1	3,000	6,080	312	7,120	776	194	1,080
2	40	2,220	196	1,540	240	40	160
3	110	430	24	430	38	12	50
4		80					
5							
6		1,910	232	2,230	40	154	200
7							
8	320			80			
9							
10		40					
11							
12							
13							
14							40
15	890	5,640	196	5,600	386	80	430
16	120	480		160			
17		320		40			
Total	4,480	17,200	960	17,200	1,480	480	1,960

CALHOUN COUNTY

	Pennfield	Convis	Lee	Clarence	Battle Creek	Emmett
1	240	200	280	2,360	2,360	4,160
2		80	80	1,574	696	1,546
3	28	18	46	226	423	530
4						
5						
6	266		314	560	800	1,680
7						80
8						80
9					40	80
10					4,800	1,960
11						
12						
13						400
14						
15	546	422	1,120	3,320	7,120	8,600
16	40			400	40	1,506
17				360	520	360
Total	1,120	720	1,840	9,120	16,799	20,982

Note: Row numbers 1-17 refer to the Land Cover Categories of Tables II through IX.

Table X cont.
(Sheet 2 of 4)

Distribution of Land Cover Within the Upper Kalamazoo Watershed
by Sub-Basins, County, and Township in Acres

Upper Kalamazoo River Sub-Basin

CALHOUN COUNTY

	Marshall	Marengo	Sheridan	Leroy	Newton	Fredonia	Eckford	Albion	Homer
1	6,120	6,680	6,200	2,720	650	2,200	8,240	9,200	7,440
2	1,520	1,760	2,360	716	1,080	1,720	1,640	850	1,240
3	970	678	688	284	150	376	420	550	484
4		40						240	
5								80	
6	920	1,400	1,600	1,480	960	392	1,080	1,720	2,600
7			80						40
8		40							40
9	270		240				40		
10	1,920	348	1,040					1,000	120
11									
12									
13	160	40		200		80	80	80	40
14	120	80		40					
15	9,680	9,400	8,160	4,840	2,680	2,480	4,720	7,640	7,120
16	600	534	832	720	360	840	310	440	236
17	240	280	400	360	120	392	230	200	
Total	22,520	21,280	21,600	11,360	6,000	8,480	16,760	22,000	19,360

JACKSON COUNTY

	Liberty	Spring Arbor	Concord	Pulaski	Hanover	Parma	Sandstone	Springport
1	358	2,240	9,200	7,160	5,360	5,200		2,000
2	120	554	2,760	2,600	3,320	842		80
3	42	172	550	590	564	512	4	128
4			40	40		40		
5								
6	40	394	1,800	2,960	2,760	1,400		460
7			40					
8								
9								40
10	200	200	390		596	80		260
11						40		
12						920		192
13				40				
14								
15	640	3,160	6,520	9,480	8,600	6,000	116	1,880
16	160	80	390	450	700	864		40
17	120	80	350	240	620	160		40
Total	1,680	6,880	21,960	23,520	22,520	16,058	120	5,120

Table X cont.
(Sheet 3 of 4)

Distribution of Land Cover Within the Upper Kalamazoo Watershed
by Sub-Basins, County, and Township in Acres

Battle Creek Sub-Basin

	CALHOUN COUNTY					
	Pennfield	Emmett	Marshall	Convis	Lee	Clarence
1	1,068		196	3,360	10,200	2,880
2	1,360			2,492	600	1,060
3	464	68	44	888	590	270
4	80			40		
5						
6	3,440	160	80	2,720	2,050	1,180
7	160			160		
8	80				40	
9		426				
10	1,760	1,680				
11						
12						
13						
14	80	40		40	40	
15	8,680	306	360	9,640	8,200	4,320
16	1,188	40	80	2,560	1,400	400
17	160			840	40	650
Total	18,520	2,720	760	22,840	23,560	10,760

	EATON COUNTY						BARRY COUNTY	
	Kalamo	Bellevue	Carmel	Walton	Eaton	Brookfield	Maple Grove	Assyria
1	428	4,880	4,280	8,720	2,480	6,840	380	3,160
2		620	500	1,164	640	1,936		648
3	64	474	300	996	398	432		10
4			40					
5								
6	348	5,360	920	1,680	802	1,152	40	2,000
7		40		80	40	40		160
8			40	40				
9		40						
10		246	1,160	320	440			80
11								
12								
13								
14		40	40	440				160
15	1,760	9,240	4,400	7,640	4,040	6,600	232	5,720
16		1,060	280	1,640	240	80		652
17				160		200		40
Total	2,600	21,960	12,000	22,880	9,080	17,320	662	13,920

Table X cont.
(Sheet 4 of 4)

Distribution of Land Cover Within the Upper Kalamazoo Watershed
by Sub-Basins, County, and Township in Acres

	Kalamazoo River-Kalamazoo Area Sub-Basin					
	CALHOUN COUNTY			BARRY COUNTY		
	Battle Creek	Bedford	Pennfield	Johnstown	Assyria	Maple Grove
1	280	1,678	460	1,160	920	1,720
2	712	2,640	200	1,320	1,920	620
3	256	562	80	224	184	120
4						
5						
6	32	2,760	340	1,360	1,160	580
7		320	40	280	40	
8		280	40		80	
9	280	40				
10	3,040	3,160	80			
11	280	280				
12						
13	120	40	40			
14						40
15	2,000	8,240	1,760	3,720	2,160	1,480
16	1,440	2,040	2,040	40	696	280
17	160	360	120	200	200	
Total	8,480	22,480	3,200	9,000	7,360	4,840

Table XI
(Sheet 1 of 4)

Distribution of Land Cover Within the Upper Kalamazoo Watershed
by Sub-Basins, County, and Township in Hectares

Upper Kalamazoo River Sub-Basin

HILLSDALE COUNTY

	Litchfield Township	Scipio	Fayette	Moscow	Adams	Wheatland	Somerset
1	1,215	2,462	126	2,883	314	79	437
2	16	899	79	623	97	16	65
3	45	174	10	174	15	5	20
4		32					
5							
6		773	94	903	16	62	81
7							
8	130			32			
9							
10		16					
11							
12							
13							
14							16
15	360	2,283	79	2,267	156	32	174
16	49	194		65			
17		130		16			
Total	1,184	6,964	389	6,964	599	194	794

CALHOUN COUNTY

	Pennfield	Convis	Lee	Clarence	Battle Creek	Emmett
1	97	81	113	955	955	1,684
2		32	32	637	282	626
3	11	16	19	91	171	215
4						
5						
6	108		127	227	324	686
7						32
8						32
9					16	32
10					1,943	794
11						
12						
13						162
14						
15	221	171	453	1,344	2,883	3,482
16	16			162	16	610
17				146	211	146
Total	453	291	745	3,692	6,801	8,495

Note, Row numbers 1-17 refer to the Land Cover Categories of Tables II through IX.

Table XI cont.
(Sheet 2 of 4)

Distribution of Land Cover Within the Upper Kalamazoo Watershed
by Sub-Basins, County, and Township in Hectares

Upper Kalamazoo River Sub-Basin

CALHOUN COUNTY

	Marshall	Marengo	Sheridan	Leroy	Newton	Fredonia	Eckford	Albion	Homer
1	2,478	2,704	2,510	1,101	263	891	3,336	3,725	3,012
2	615	713	955	290	437	696	664	344	502
3	393	274	279	115	61	152	170	223	196
4		16						97	
5								32	
6	372	567	648	599	389	159	437	696	1,053
7			32						16
8		16							16
9	109		97				16		
10	777	141	421					405	49
11									
12									
13	65	16		81		32	32	32	16
14	49	32		16					
15	3,919	3,806	3,304	1,960	1,085	1,004	1,911	3,093	2,883
16	243	216	337	291	146	340	126	178	96
17	97	113	162	146	49	159	93	81	
Total	9,117	8,615	8,745	4,599	2,429	3,433	6,785	8,907	7,838

JACKSON COUNTY

	Liberty	Spring Arbor	Concord	Pulaski	Hanover	Parma	Sandstone	Springport
1	145	907	3,725	2,899	2,170	2,105		810
2	49	224	1,117	1,053	1,344	341		32
3	17	70	223	239	228	207	2	52
4			16	16		16		
5								
6	16	160	729	1,198	1,117	567		186
7			16					
8								
9								16
10	81	81	159		241	32		105
11						16		
12						372		78
13								
14								
15	259	1,279	2,640	194	3,482	2,429	47	761
16	65	32	159	182	283	350		16
17	49	32	142	97	251	65		16
Total	680	2,785	8,891	9,522	9,117	6,501	49	2,073

Table XI cont.
(Sheet 3 of 4)

Distribution of Land Cover Within the Upper Kalamazoo Watershed
by Sub-Basins, County, and Township in Hectares

Battle Creek Sub-Basin

	CALHOUN COUNTY					
	Pennfield	Emmett	Marshall	Convis	Lee	Clarence
1	432		79	1,360	4,291	1,166
2	551			1,009	243	430
3	188	28	18	360	239	109
4	32			16		
5						
6	1,393	65	32	1,101	830	478
7	65			65		
8	32				16	
9		172				
10	713	680				
11						
12						
13						
14	32	16		16	16	
15	3,514	124	146	3,903	3,320	1,749
16	481	16	32	1,036	162	162
17	65			340	16	263
Total	7,498	1,101	308	9,247	9,538	4,356

	EATON COUNTY						BARRY COUNTY	
	Kalamo	Bellevue	Carmel	Walton	Eaton	Brookfield	Maple Grove	Assyria
1	173	1,976	1,733	3,530	1,004	2,769	154	1,279
2		251	202	471	259	784		648
3	30	192	121	403	161	175	4	141
4			16					
5								
6	141	2,170	372	680	325	466	16	810
7		16		32	16	16		65
8			16	16				
9			16					
10		100	470	130	178			32
11								
12								
13								
14		16	16	178				65
15	713	3,741	1,781	3,093	1,636	2,672	94	2,316
16		429	113	664	97	32		264
17				65		81		16
Total	1,053	8,891	4,858	9,263	3,676	7,012	268	5,636

Table XI cont.
(Sheet 4 of 4)

Distribution of Land Cover Within the Upper Kalamazoo Watershed
by Sub-Basins, County, and Township in Hectares

	Kalamazoo River-Kalamazoo Area Sub-Basin					
	CALHOUN COUNTY			BARRY COUNTY		
	Battle Creek	Bedford	Pennfield	Johnstown	Assyria	Maple Grove
1	113	679	186	470	372	696
2	288	1,069	81	534	777	251
3	104	228	32	91	74	49
4						
5						
6	13	1,117	138	551	470	235
7		130	16	113	16	
8		113	16		32	
9	113	16				
10	1,231	1,279	32			
11	113	113				
12						
13	49	16	16			
14						16
15	810	3,336	713	1,506	874	599
16	583	826	826	16	282	113
17	65	146	49	81	81	
Total	3,433	9,101	1,296	3,643	2,980	1,960