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ABSTRACT

A METHOD FOR ANALYZING THE ENVIRONMENT OF AN URBANIZING AREA --UTILIZING HIGH ALTITUDE COLOR INFRARED PHOTOGRAPHY

by

M. Susan Beckman Thomason

The technology of remote sensing has recently become available to planners and others interested in the land resource. Without technical expertise, the utility of remotely sensed imagery often appears obscure. The objective of this research effort is to explore, in a non-technical manner, the usability of high-altitude, small-scale color infrared imagery in analyzing the environment of an area in Michigan experiencing increased development pressure. Small-scale (1:113, 500) color infrared photography was used as the principal data source for this study. The imagery was taken by an RB-57 jet aircraft on May 7, 1974 for the National Aeronautic and Space Administration and was obtained by the Michigan State University Remote Sensing Project.

The study begins by providing a basic introduction to pertinent remote sensing concepts and briefly discusses film, photo interpretation, and availability of imagery in Michigan. It then reviews the state-of-the-art in environmental analysis methodology focusing on the purposes for which methods have been developed and the types of environmental factors which are used in making environmental evaluations.

The study then describes the test site or study area in Michigan

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for which an inventory-classification system and analysis method are later developed. The study area is 144 square miles in size and lies entirely in Allegan County between the cities of Grand Rapids and Kalamazoo. Growth characteristics and the environmental setting of the study area are discussed, prior to development of an inventory classification system.

The classification system developed for use with the small-scale color infrared imagery in the study area inventories parcels of land that are 160 acres in size. Such a parcel is .25 by .25 inches on the imagery employed. The major categories of data inventoried include: relief, land cover, land use, transportation routes, drainage, amenities/disvalues, residential settlement patterns and special concerns. The existing study area is primarily agricultural in nature and the inventory-classification system is designed for those with limited experience in photo interpretation.

An evaluation of the physical environment of the study area is made and the implications for accommodating future development are noted. The general interactions between development and the environment are discussed and followed by a five-step method for analyzing the inventoried data. The method focuses on existing community development as it appears on the photographs, and identifies environmentally sensitive features and potential development constraints. Use of the method is illustrated in the assessments made for all existing communities in the area as well as other non-community-related locations. Observations and recommendations are advanced for all development areas.

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color infrared imagery provides substantial detail for a general environmental analysis. The inventory and analysis method generates useful information about existing development patterns and enables identification of potential problems regarding accommodation of future development. Such information may be used to direct new policies concerning urban growth and expansion or to highlight locations which should receive additional environmental study prior to making decisions regarding development or non-development. The entire research effort is most applicable to regional studies covering areas which are at least several townships in size.

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A METHOD FOR ANALYZING THE ENVIRONMENT OF AN URBANIZING AREA
--UTILIZING HIGH ALTITUDE COLOR INFRARED PHOTOGRAPHY

By

M. Susan Beckman Thomason

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER IN URBAN PLANNING

School of Urban Planning and
Landscape Architecture

1977

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ACKNOWLEDGMENTS

The writer wishes to thank Myles Boylan, Professor of Urban Planning at Michigan State University who served as advisor in this academic effort. Sincere appreciation is also extended to Professor Sanford Farness and all other faculty members of the School of Urban Planning and Landscape Architecture for their guidance during my graduate studies.

I wish to express my appreciation to Bill Enslin and other members of the Michigan State University Remote Sensing Project. From 1973 to 1975, the writer served as a Graduate Research Assistant in the Remote Sensing Project which is funded by a National Aeronautic and Space Administration grant to Michigan State University (NASA NGL 23-004-083).

To my husband Arlen, I wish to extend special thanks for his encouragement throughout preparation of this thesis.

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INTRODUCTION

In recent years there has been an increasing interest in the natural environment. According to the First Annual Report of the Council on Environmental Quality:

> Historians may one day call 1970 the year of the environment. They may not be able to say that 1970 actually marked a significant change for the better in the quality of life; in the polluting and fouling of the land, the water, and the air; or in health, working conditions, and recreational opportunity. Indeed, they are almost certain to see evidence of worsened environmental conditions in many parts of the country.
>
> Yet 1970 marks the beginning of a new emphasis on the environment--a turning point, a year when the quality of life has become more than a phrase; environment and pollution have become everyday words; and ecology has become almost a religion to some of the young.[1]

This new awareness and interest is largely a response to problems that have been compounded over many years. These problems include: the unrestricted growth of cities, scatteration of development, consumption of prime agricultural land and open space and, in general, a wasting of our resources.

The increased emphasis on the environment is having profound effects on the planning profession. The influence is especially strong in the area of land use allocation because of the close relationship that exists between "natural qualities of the land and the activities making use of the land."[2] According to an Environmental Protection Agency report issued in February 1974, land use planning is now evolving on three fronts with:

1) an increasing concern for the natural environment and a concomitant questioning of the economic assumption that growth is always beneficial;
2) a search for information on how to allocate urban activities while preserving the integrity of environmental systems; and
3) a shift in approach from the long range master plan to implementation and action.[3]

These new considerations in land use planning reflect the need to improve the decision-making processes which affect the allocation and use of land and natural resources. Historically, land use decisions have been made on the basis of short-term economic considerations and political exigency. Numerous public officials and concerned citizens fear that many decisions of public concern are being based on factors "unrelated or contrary to the real concerns of sound land use policy."[4] Policy conflicts that arise are generally settled by negotiation and political bargaining rather than through the use of empirical information on environmental implications of proposed decisions.

In order to improve the decision-making process, reliable data on the physical environment is essential. This data should include information on components such as: soils, land use, vegetation, topography, water characteristics, settlement patterns, unique physical features, and location of transportation routes. The data must then be synthesized so that an evaluation of the area can be made. Various methods have been developed for analyzing the physical environment. A state-of-the-art review of these methods reveals

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that no one approach has been found to be the best for every type of situation. A common limitation of all the methods is the availability of information on the physical environment including its timeliness, cost, scale and quality. Many applications of the various methods indicate that the users were forced by time or other constraints to "make do" with the best data available. "This is perhaps a function of the urgency of information demands characteristic of the new environmental emphasis in planning."[5]

Remote sensing is a recently developed technology which can serve as an extremely valuable means of obtaining information on the physical environment since large areas can be rapidly covered. Remote sensors include multi-spectral scanners, radar, passive microwave systems, high altitude aerial cameras and others. The objective of this study is to investigate the utility of small scale color infrared imagery taken from high altitude aircraft as a major data source for environmental analysis. It is intended for use by planners and others with little technical expertise in remote sensing whose need for the ability to make environmentally informed decisions regarding development at a large scale would benefit from the use of remote sensing technology. The material of this thesis is presented in the following components:

(1) a brief introduction to remote sensing providing a basic understanding of pertinent remote sensing concepts;

(2) a state-of-the-art review of environmental analysis methods to determine the types of assessments which have been made, why they have been developed, and what environmental factors they have considered;

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(3) selection and description of a site in Michigan covered by small-scale high-altitude color-infrared imagery to be used as a study area in which to test a new inventory and analysis method;

(4) development and application of the inventory and analysis method in the study area;

(5) evaluation of data generated from the inventory/analysis method and its implications for accommodating future development or non-development within the study area; and

(6) expansion of the findings from the above components to generate workable indicators of environmental conditions and implications for development inside and outside the study area.

Throughout Michigan, remotely sensed imagery is increasingly being used by various planning organizations. Present users of remote sensing include state natural resource and highway officials, both state and regional land use planning personnel, as well as private citizens with a diversity of interests. The increasing use of such imagery by so many indicates that planners not yet knowledgeable of the technology will likely be exposed to it in the foreseeable future. Despite historically overenthusiastic claims for magic results from remote sensing technology, it must be emphasized that it is only a tool, but a tool that can reduce the time and cost involved in assembling and analyzing contemporary and useful data on the physical environment. Remote sensing is envisaged as a tool that can be used by professional planners, planning commissions, city councils, county boards, state legislatures, park and recreation officials, land use commissions, students, as well as business and industrial organizations.

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FOOTNOTES

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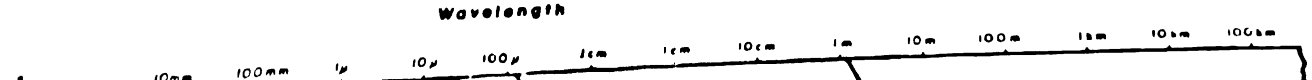
CHAPTER I

INTRODUCTION TO REMOTE SENSING

In very general terms, remote sensing is defined as "detecting the nature of an object without actually touching it."[6] Under such a definition, the camera can be considered as the original remote sensing device. With the elaborate technology currently associated with the term, remote sensing can more functionally be defined as "the detection, recognition or evaluation of objects by means of distant sensing or recording devices."[7] Such devices include thermal scanners in orbiting satellites and aerial cameras mounted in high-altitude aircraft.

Light, x-rays, radiant heat, radio waves and other forms of energy are composed of electromagnetic waves. The various energy types are differentiated by their wavelengths and frequencies. The continuum in which each energy type is assigned a range is known as the electromagnetic or EM spectrum. In remote sensing, energy types are conventionally distinguished by wavelength (see Figure 1). Currently, remote sensing concentrates on wavelengths in the range of .3 microns to about 3 centimeters, although the EM spectrum ranges from the minute gamma rays to the very long radio waves. One micron equals 1μ equals .0000001 meter.

Remote sensors record both reflected and emitted energy in different bands of the EM spectrum. Ground objects reflect and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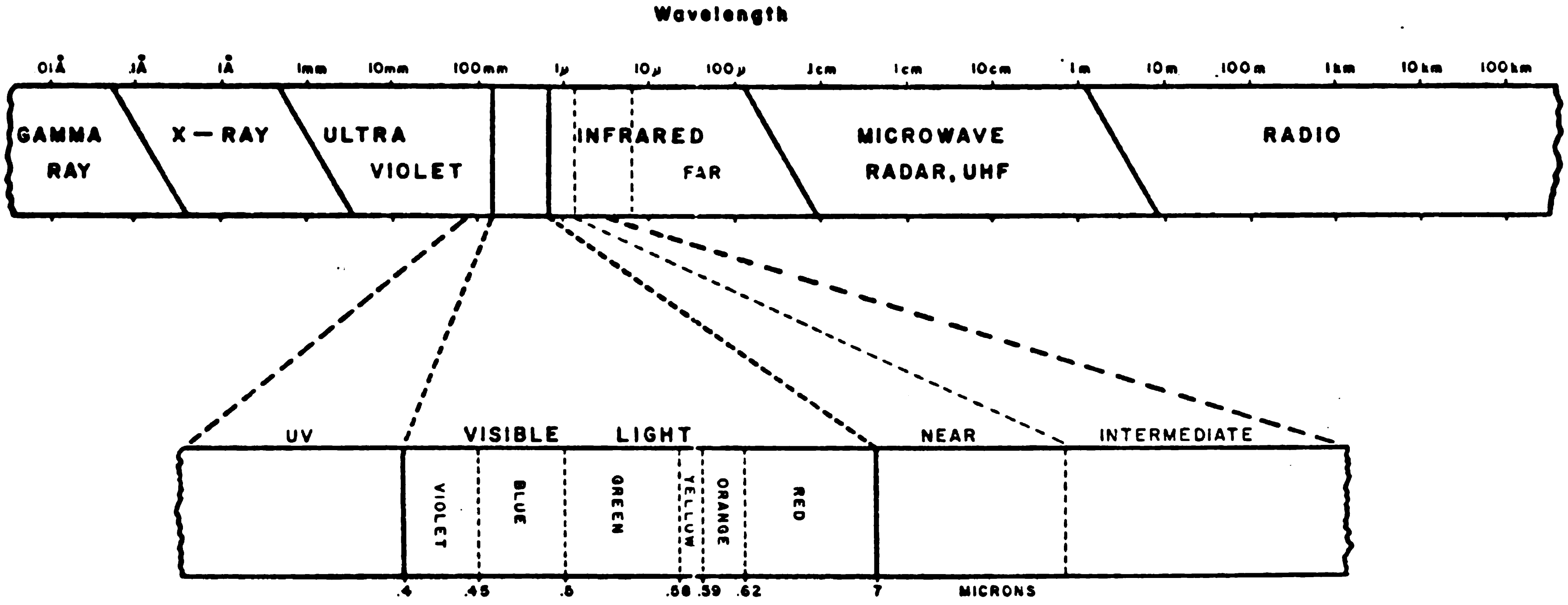

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emit energy in different amounts as a function of time and material composition. Because of these differences, it is possible for a sensor to record a scene so that objects can be identified and differentiated. The appearance of objects is generally rendered in tonal and/or color contrast between the object and its background. The greater the contrast, the more easily the object can be distinguished. The characteristic appearance of an object in a particular wavelength band is known as its tonal signature. The displays produced by remote sensors are known collectively as imagery. A photograph is one type of imagery which records visible light on film.

In the EM range in which remote sensing concentrates (.3μ to 3 cm.), sensors include cameras, scanners, radiometers and others. Whereas conventional cameras directly record an image onto a photographic emulsion or film, scanners and radiometers record reflected or emitted energy signals as electronic impulses which can then be mechanically translated into a photograph-like image.

The human eye is sensitive to only a small region of the EM spectrum, i.e. from .4 to .7 microns. Photographic film expands that range because it is made sensitive to wavelengths from .3 to 1.2 microns. Wavelengths of greater or lesser magnitude must be detected by non-photographic sensors.

One type of non-photographic sensor is the multi-spectral scanner (MSS). The MSS is a line scanning device which uses an oscillating mirror to simultaneously scan the terrain passing beneath the spacecraft in several wavelength bands. The scanner produces four synchronous images, each at a different wavelength band of the EM spectrum. Figure 2 is an example of the imagery produced by the

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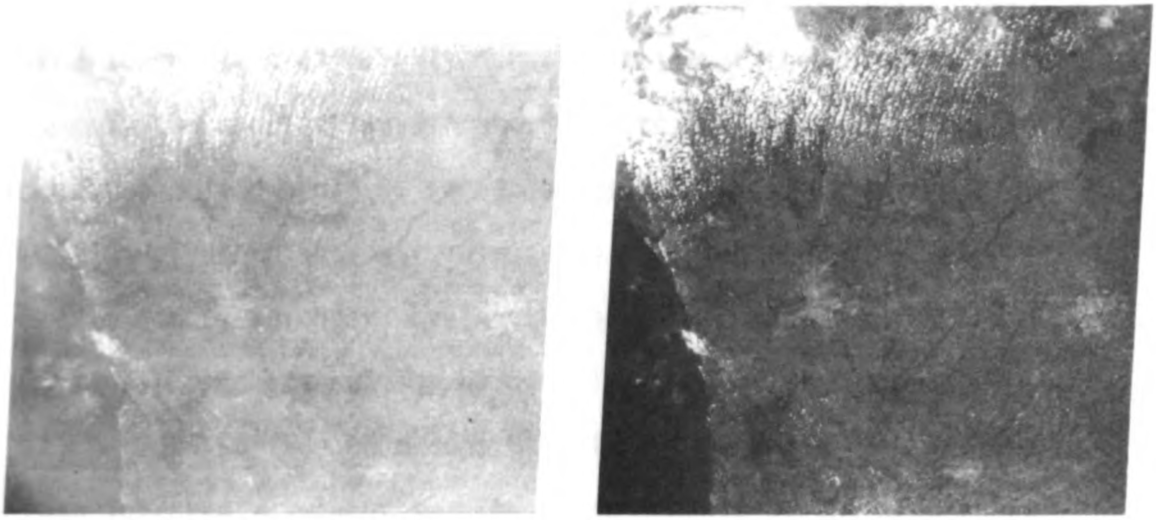

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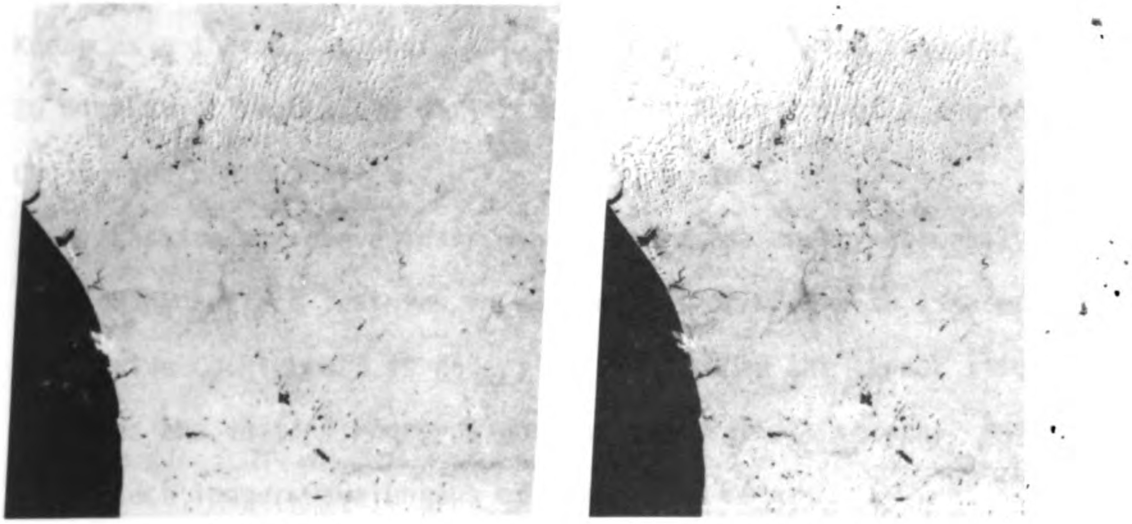

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MSS aboard the first Earth Resources Technology Satellite (ERTS/LANDSAT - 1). Band 4 or Channel 4 is sensitive to wavelengths of .50 to .60μ (yellow-green light). Band 5 records red light at .60 to .70μ. Band 6 is sensitive to near infrared radiation of .70 - .80μ and Band 7 to intermediate infrared of .80 to 1.10μ. Each band accentuates different characteristics of the earth's surface. Band 4, the shortest wavelength, permits the greatest underwater penetration and hence is sometimes useful in qualitative discrimination of depth and/or turbidity in standing bodies of water. Band 5 senses a longer wavelength and as a result reduces the amount of atmospheric attenuation or blue light permitting a sharper view of the land surface than does Band 4. Bands 6 and 7 record the long infrared wavelengths. The large amounts of infrared energy reflected by land features and absorbed by water bodies enables rapid discrimination of the land/water interface with Bands 6 and 7.

Another type of scanner senses radiant heat rather than light. Known as a thermal scanner, this device senses in the range of 3 to 20 microns. Temperature differentials in fractions of a degree Centigrade can be detected with this instrument.

Passive microwave instruments record the energy naturally emitted by surface features in wavelengths of .75 mm to 1 meter. The active counterpart is radar; active because the sensor itself supplies the initial energy signal and records its return. Radar can detect longer wavelengths of 1 mm. to 3 meters.

Despite the existence of and increasing research on highly sophisticated sensors, the camera is still the most extensively used form of remote sensing. The modern aerial camera is generally

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equipped with very high quality lenses and rapid shutter speeds. Multiple lens cameras are available and permit the simultaneous use of different film/filter combinations. With the aerial camera, the most widely acquired and usable type of imagery is that of the visible and reflectance infrared (not thermal) portions of the EM spectrum as recorded on film.

Film

Black and white film sensitive to all the visible colors and known as panchromatic is the most familiar type of aerial coverage. Black and white infrared film is also available and is sensitive to near infrared wavelengths.

Conventional color film, film which renders an object in colors similar to those seen by the human eye, is also used in aerial photography. Because the colors are familiar, it is relatively easy to identify ground objects.

The film type that is of increasing importance in remote sensing is color infrared film (CIR) also known as false-color film. This type of film was originally used by the military for detecting camouflage because natural vegetation and camouflage have significantly different infrared reflective properties. Because CIR records infrared wavelengths, it is able to penetrate haze and smog, although it cannot penetrate clouds. This is a substantial advantage over conventional color, especially when coverage is taken at high altitudes. NASA-sponsored RB-57 jet aircraft typically fly at 60,000 feet. 60,000 feet of smog and haze over an urban area severely attenuates conventional color film which is sensitive to the relatively short wavelength

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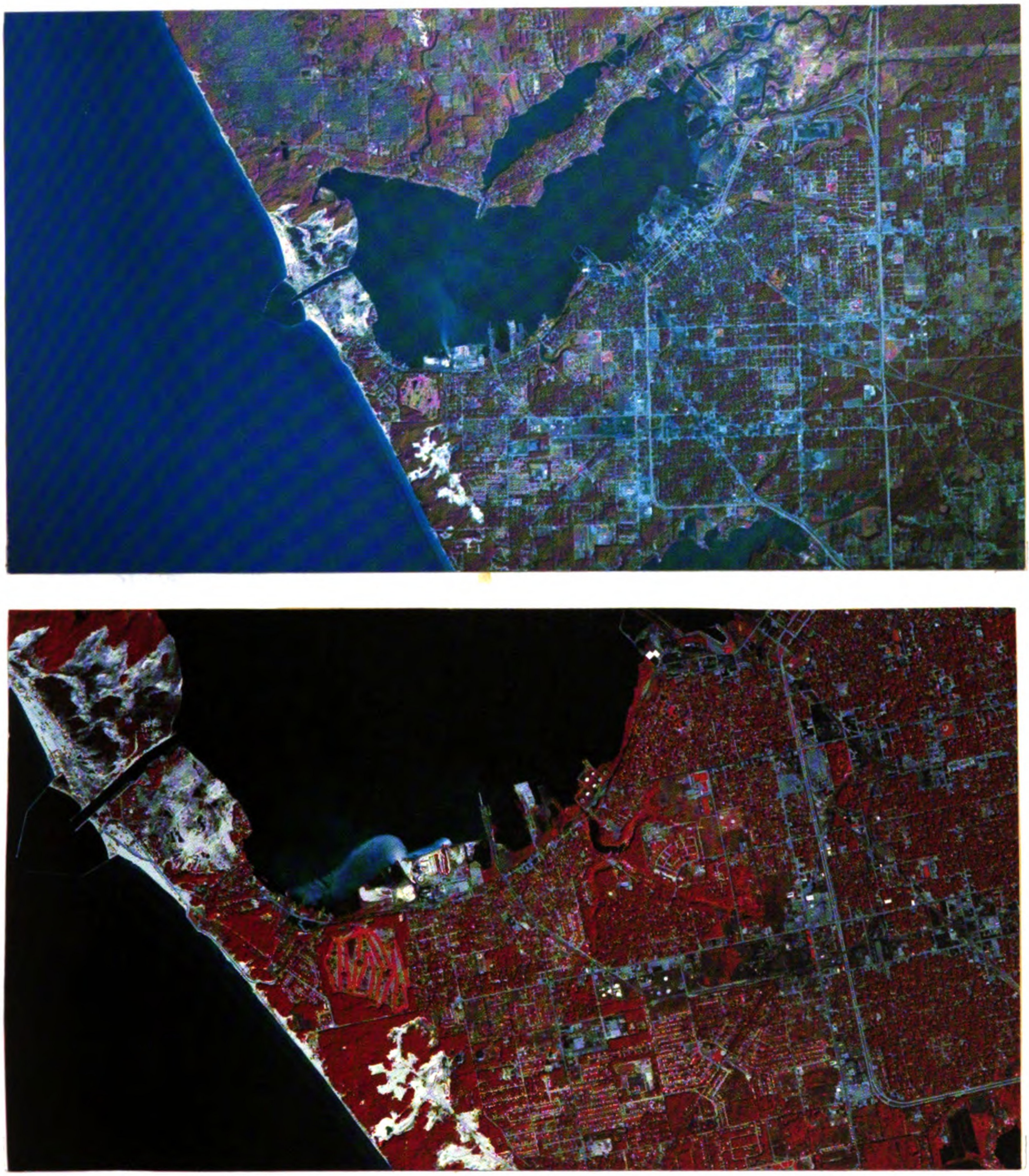
The chemical composition of CIR film has been designed to print reflected infrared energy as red, red light as green and green light as blue. Vegetation appears in varying shades of red because, on the average, vegetation reflects twice as much infrared as green wavelengths. Blue and violet light is reduced or eliminated from the imagery through the use of yellow ("minus blue") filters. Figure 3 shows the tonal difference resulting from use of different filters. The top image at a scale of 1:120,000 was taken with infrared film and a light yellow filter. A blue-green cast is evident in this image. The lower image was shot simultaneously with a darker yellow filter. Most of the blue has been removed and color contrasts are much more pronounced. This example of tonal contrast demonstrates the important differentiations possible with CIR film. Land/water interfaces are dramatic and vegetation types can be distinguished by the varying shades of red. Differentiating between urban and non-urban areas is also made easier. For this reason, color infrared film is becoming one of the most widely used remote sensing tools in urban and land use analysis (Dueker and Horton, 1971).

Photo Interpretation

Many of the more sophisticated remote sensors record electromagnetic energy as electronic impulses which must be mechanically converted to a tonal image. For example, the ERTS I (LANDSAT 1) images in Figure 2 were produced by an electron beam recorder which translated the electronic impulses that had measured intensities of



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Top Photo - 1:120,000 Bottom Photo - 1:60,000

Figure 3. RB-57 Color Infrared Imagery

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reflected light from satellite, to a photograph-like image here on earth. The most prevalent type of image interpretation, however, is that done manually. Interpretation involves the identification and delineation of features from the photographs or images and includes field checks and use of available collateral information. The amount of information that can be extracted from a particular image is largely dependent on the scale and quality of the aerial image, the ability of the interpreter, and the collateral data available, e.g. topographic maps. Interpretation is based on an analysis of the apparent properties of surface features including size, shape, tone, texture, pattern, shadow and association. It is primarily a deductive process in which the interpreter proceeds from the general to the specific. But the imagery "_gives_ us nothing; we must extract information from the imagery as a function of our knowledge and core of experience."[8]

Studies have repeatedly shown that the person most familiar with a particular area is often the best interpreter, eventhough previously untrained in image interpretation. According to a report by Shelton _et_ _al_.,

> Ideally, the user should do the interpretation; he would, during that process gain an understanding of the study area far deeper than is usually possible by other methods. He also would have an advantage over most interpreters by virtue of his existing knowledge in the study area. An interpreter is doing more than just recognizing certain land uses or physical features; in the case of land use particularly, he is interpreting events and conditions as they affect land use and as they have observable characteristics which serve to identify them.[9]

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Availability of Imagery

There are four principal types of remotely sensed imagery currently available in Michigan. At the smallest scale is MSS imagery from ERTS, now known as LANDSAT (refer to Figure 2). This black and white imagery at an approximate scale of 1:1,000,000 (one inch equals 16 miles) generally comes in 10" x 10" frames--each frame depicting an area of approximately 115 miles square. This type of imagery is suitable for macro-regional analysis. Enlargement of LANDSAT frames is possible, but "detail on interpretability does not substantially increase."[10] Selected MSS images can be reproduced as color composites. Three black and white spectral bands are sequentially exposed through different color filters onto color film at a scale of 1:1,000,000, but color composites do not exist for all LANDSAT scenes.

A second type of imagery was produced by the NASA Skylab Program which consisted of one unmanned and three manned missions from May 22, 1973 through February 8, 1974. The spacecraft travelled in an equatorial orbit 270 miles above the earth and crossed Michigan in a northeast-southwest direction. Most of the southern half of the lower peninsula was covered at scales of 1:1,000,000 and/or 1:3,000,000. Skylab imagery consists of black and white, color and color infrared photography.

The third type of imagery, and the type with which this thesis is primarily concerned, is high altitude, color infrared photography. This coverage is obtained principally by RB-57 jet aircraft at an altitude of approximately 60,000 feet (refer to Figure 3). Two camera systems typically provide imagery at scales of 1:60,000 and

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1:120,000. At 1:60,000, one inch is approximately equal to one mile. The individual frames of this CIR imagery are generally 9" x 9". Four frames at the scale of 1:120,000 cover an area almost equal to the size of Eaton County, Michigan.[11]

The fourth type of generally available imagery is medium-altitude photography provided by the Agricultural Stabilization and Conservation Service (ASCS) and other government agencies. Each frame is typically black and white panchromatic at scales of 1:15,840, 1:20,000 or 1:40,000. This type of imagery has been the most widely used in various types of planning activities.

Additional aerial imagery is available from various government agencies at the state and federal levels. Examples include the U.S. Forest Service, U.S. Geological Survey, the Michigan Department of State Highways and Transportation, and the Michigan Department of Natural Resources. The types and scales of their imagery as well as the areas covered, are variable.

Summary

The technology of remote sensing is highly sophisticated and complex. But as the "canned program" permits the non-computer expert to utilize the computer, so too can some introductory training permit the layman to effectively use much of the output available from remote sensors. The primary importance of remote sensing lies in applications rather than hardware; integrating remotely-sensed data with other conventional sources of resource information to plan, to make policy, and to act.

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supply all the physical information necessary for a complete analysis of the environment. Its capabilities are extensive, however, and many organizations concerned with natural resources and land use could substantially benefit from its use. Increasingly, remotely sensed imagery is being used for land use/cover and natural resources inventories; to record what is on the ground at a particular point in time. The advantages to using remote sensing for such inventories include its timeliness, large area coverage and economy. It is the intent of this thesis to go beyond the inventory state, however, where most work has been done to investigate the utility of remote sensing in processes which analyze and evaluate the landscape; processes which are referred to as "environmental analysis."

The widespread attention on the natural and cultural environment which developed in the late 1960's and early 1970's spurred rediscovery and new development of numerous methods for environmental analysis. The next chapter presents a state-of-the-art review of these methods to provide an understanding of the environmental analysis process and serve as a basis for development of the environmental analysis method in Chapters IV and V.

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[7] T. Eugene Av
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[7] T. Eugene Avery, Interpretation of Aerial Photographs (Minneapolis, Minnesota: Burgess Publishing Company, 1968), p. 135.

[8] C.P. Weatherspoon et al., Proceedings of the Second Conference on Environmental Quality Sensors (Washington, D.C.: Environmental Protection Agency, 1973), p. v-60.

[9] R.L. Shelton et al., Land Use, Environmental Features and Natural Resources Inventory of the Hudson River Valley (Ithaca, New York: Center for Aerial Photographic Studies, 1969), p. CL-2.

[10] Mark C. Sullivan, Image Interpretation for a Multi-Level Land Use Classification System (East Lansing, Michigan: Michigan State University, 1973), p. 5.

[11] Ibid., p. 5.

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CHAPTER II

STATE OF THE ART REVIEW OF ENVIRONMENTAL ANALYSIS METHODS

Land use and natural resources planning based on increased environmental awareness has been rapidly developing across the United States. Environmentally protective legislation has been established in many locations for various categories or types of land. Among the more prominent are protection of wetlands in Massachusetts, river basins in New England, bay areas in San Francisco, shorelines in Wisconsin and agricultural land in Hawaii (Bosselman and Callies, 1971). Various organizations and individuals are demanding respect for the ecosystem, protection of open space, and the integration of development plans with provisions protective of the environment.

The increased emphasis on protection of the natural and human environment has stimulated the development and rediscovery of methods for analyzing and evaluating man's biotic and abiotic surroundings. This chapter describes eighteen environmental analysis methods which can be considered representative of the state-of-the-art. The vast majority of them were developed in the late 1960's and early 1970's.

The process of environmental analysis consists of essentially three steps. The first involves the identification of a problem or formulation of a purpose to which an analysis method is designed to respond. The second step is an inventory of pertinent environmental data. The third step consists of an analysis and evaluation of the inventory data as it relates to the identified purpose.

The eighteen methods described in this chapter were developed for oftentimes substantially different purposes. But despite such differences and although specific definitions and level of detail vary, at least some aspects of the following factors were generally inventoried: topography, soils, land cover/use, geology, water resources and climate.

The greatest weakness in the methods reviewed in this chapter involves the third step of the environmental analysis process; i.e., the evaluation of inventoried data. Most methods fail to clearly define the specific steps used in evaluating inventory data; a fact which prevents results from being readily duplicated. It appears that this lack of step-by-step evaluative instruction may be partially intended, underscoring the fact that the evaluation process often requires subjective judgments when specific scientific parameters are unavailable. In addition, there may be a general reluctance to transpose detailed evaluations of natural environments and man's interactions with them from one geographical region to another because of known and unknown variations which may be present. There is no singularly best environmental analysis method for all situations. The impressions given above may explain why the eventual development of any universally applicable method is considered unlikely. Such an observation does not diminish the importance of environmental analysis methods. The continuing need for a better understanding of the environment requires refinements and new developments in the methodology of environmental analysis.

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The environmental analysis methods which follow have been broadly categorized and are summarized in a common format to permit comparison of methods. In order to place each method in an appropriate perspective, the purpose for which each method was developed is identified. Then each method is briefly described and the factors used to evaluate the environment are outlined. Comprehensive methods, those which evaluate extensive or sizable areas and/or many components of the ecosystem are discussed first. Next, special purpose methods are considered. They represent techniques developed for rather specific reasons such as appraising the potential of an area for recreational activities. Special purpose methods involve a much narrower analysis than do comprehensive methods. Finally, because the methodology of environmental analysis is not limited to specific methods, a list of various sources with a conceptual approach to the subject has also been provided. This list represents writings which discuss environmental analysis in general terms including topics such as the rationale for conducting such analyses, the basic man-environment interactions which must be addressed and general suggestions on development of evaluative systems. When additional detail is required, the original documents should be consulted.

Comprehensive Methods

1. Dee, Norbert, Janet Baker, Neil Drobny and Ken Duke. "An Environmental Evaluation System for Water Resource Planning." Water Resources Research, Vol. 9, No. 3, (June 1973)

   PURPOSE: To evaluate the environmental impacts of proposed water resource projects.

METHOD: This is a highly detailed method which assigns numerical values to various environmental components in an attempt to quantitatively measure the impact of a particular action. The four major categories evaluated include: ecology, environmental pollution, esthetics, and human interest. The critical stage in this method is assignment of numerical values and weights.

2. Gentili, Joseph and Mitchell J. Lavine, eds. <u>Owego Environmental Study</u>. Ithaca, New York: Cornell University, 1974.

   PURPOSE: To provide a basis for decisions relating to proposed alterations of the Owego, New York landscape.

   METHOD: Initially, several maps of various natural resource features were prepared. The integration of this data was made in a "compatibility matrix" which represents a series of decisions concerning relationships between the inventoried natural features and prospective land uses. The impact of natural systems on land uses is considered. The reciprocal relationship, the impact of the land uses on natural systems, is not considered. Ratings resulting from the matrix analysis are: Not Compatible, Low Compatibility, Moderate Compatibility, and Full Compatibility.

3. Hills, G. Angus. <u>The Ecological Basis for Land Use Planning</u>. Ontario, Canada: Ontario Department of Lands and Forests, 1961.

   PURPOSE: To establish a scientifically derived frame-work for various resource management problems.

   METHOD: The Angus Hills Method (as outlined in <u>Landscape Architecture</u> (January 1968), p. 147 and here cited verbatim)

I. CLASSIFICATION
   1. Given a total study area.
   2. The total site area is divided into regions which are then further subdivided several times into land areas of decreasing size.

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    (a) Site Regions, by defining areas of broad climatic similarities;
    (b) Landtypes, by separating areas of differing geologic composition;
    (c) Physiographic site classes, by separating areas of differing micro-climate;
    (d) Physiographic site types, by separating areas of differing micro-landform variation.
3. A possible range of general land-uses is determined, and physical requirements for each use is identified.
4. Each physiographic site type is subdivided into <u>site phases</u> for general kinds of uses according to the physical requirements for the use.

II. EVALUATION

4. Site types (see 2) are grouped into common landscape units to provide a basis for evaluation.
5. Landscape units are subdivided into landscape subunits to evaluate a particular use with respect for:
    (a) Its use capability:
        i) At the local level ratings are established on the basis of the sub-unit's inherent features;
        ii) At the broad level on the basis of the subunit's geographic context;
    (b) Its use suitability, on the basis of the sub-unit's present condition.
    (c) Its use feasibility, on the basis of present forecast socio-economic climate.
6. A land-use is recommended for each landscape sub-unit.
7. Multiple land-uses are recommended for each landscape unit.

4. Lewis, Philip Jr. "Quality Corridors for Wisconsin." <u>Landscape Architecture</u>, Vol. 54 (January 1964): 100-108.

PURPOSE: To identify and evaluate resource patterns to help guide future growth.

METHOD: The Philip Lewis method (as outlined in <u>Landscape Architecture</u> (January 1968), p. 147, and here cited verbatim)

1. Given a total study area.
2. Kinds of uses (or activities) to be planned for are identified and the use requirements (or use criteria) are established.
3. A case study area is selected within which:
    (a) Resources which meet the above use criteria are identified.
    (b) Major resources are inventoried and located within case study area (as patterns) or separate transparent overlays.
    (c) Patterns of major resources are combined into one pattern.
    (d) Additional resources are inventoried and located (as patterns) on separate transparent overlays.

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(e) A variety of patterns may be identified for special purposes from a few additional resources.
(f) Patterns of additional resources are combined into one pattern.
(g) Patterns of major and additional resources are compared and a correlation between the two is established.

4. Inventory of major resources takes place over total study area.
5. Inventory of additional resources takes place over total study area.
6. Points are assigned to major and additional resources.
7. Points are totaled to identify relative priority areas.
8. Demand for planned uses is established and final priorities and areas are defined.
9. Limitations of each priority area to specific kinds of uses are identified and specific kinds of uses are assigned to each area.

Linear patterns or corridors are generally identified. In most cases, these corridors consist of areas containing wetlands, water, floodplains, sandy soils near water, and steep topography.

5. McClellan, G. ed. "Environmental Planning in Waterloo County," <u>The Waterloo County Area Selected Geographical Essays</u>. Waterloo, Canada: University of Waterloo, 1971.

PURPOSE: To develop an optimal land use plan for 1990 in an urbanizing area.

METHOD: This was primarily an inventory in which overlays were used. It was possible, however, to vary the weights assigned to the various factors analyzed. Areas were identified which had a potentially high value for the development of one or more of the following: a) recreation, b) water quality, c) unique natural features, d) wildlife, e) groundwater recharge, f) forested areas, g) agriculture, and h) unique cultural features.

6. McClellan, G. ed. "Ecological Concepts of Subdivision Design," The Waterloo County Area Selected Geographical Essays. Waterloo, Canada: University of Waterloo, 1971.

PURPOSE: "To identify and articulate those environmental conditions which may influence, either positively or negatively, the

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various forms of urban land use." (p. 256)

METHOD: This method used an environmental team approach including specialists and a team coordinator. The procedure was to subject areas not yet developed, to an intensive quantitative and qualitative environmental analysis.

The initial inventory included the following factors: flora, fauna, climatic elements, water quantity and quality, geomorphology, soils, slope patterns and land history. In the words of the report, the "survey defined the natural diversity of the undeveloped areas and in doing so, gave detailed understanding of the environmental interactions of the site. With the understanding derived from this comprehensive survey, we were able to identify several situations where phyto-sociological and earth science inputs would have been most useful in improving the overall handling of development and in creating a more viable natural environment in an urban context. Based on this research, we reached the conclusion that soils, geomorphology, phytosociology and surface water are the constant prime elements in the ecological survey." (p. 257)

7. McHarg, Ian. Plan for the Valleys. Philadelphia, Pennsylvania: Wallace-McHarg Associates, 1963.

PURPOSE: To conduct a resource inventory and to analyze the existing conditions and pressures to demonstrate what can happen to the environment if development proceeds without considering the "intrinsic suitability" of a given area.

METHOD: The Ian McHarg method (as outlined in Landscape Architecture, January 1968, p. 147, and here cited verbatim)

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Diagrammatic Outline of the Analysis Procedure

1. Given a total study area.
2. Features of natural or cultural processes are defined and structured into broad resource categories.
3. Features of natural or cultural processes are inventoried for total study area.
4. Inventory of features is supplemented with descriptions of related processes.
5. Limiting factors of each process described are identified and related to their features.
6. Relative value is attributed to processes.
7. Having attributed value to the processes, principles are formulated relative to limiting factors.
8. Potential land-uses are considered and possible effect on the limiting factors is identified.
9. Possible effects of each land-use requirement is weighed against each limiting factor.
10. Land areas suitable to each land-use are compared.
11. Conflicts between overlapping suitable uses are resolved by comparing economic return.
12. Demand for these possible uses is established for their area requirements, and compared with other areas identified as suitable.

8. Maltby, Richard A. A Method for Determining the Use Potential of Land. Thesis for M.U.P., Michigan State University, 1965.

PURPOSE: To consider the suitability of natural resources and man-made features for supporting agricultural, recreational, residential and industrial development.

METHOD: An outline of the land user's requirements for the following factors was to be a guide for assigning such uses: 1) agricultural soil capability, 2) soil permeability, 3) water--both ground and surface, 4) land drainage, timber resources or woodland, 6) type of terrain and degree of slope, 7) wetlands, 8) highway, roads and accessibility, 9) railroad facilities, and 10) central water supply and sewage disposal.

The following maps were manually compiled for the analysis: Soil Permeability, Groundwater Supply Potential, Lake Size, River and Stream Size, Woodlands, Wetlands, Slope, Roads and Railroads.

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9. Murray, Timothy, Peter Rogers, David Sinton, Carl Steinitz, Richard Toth, Douglas Way. Honey Hill: A Systems Analysis for Planning the Multiple Use of Controlled Water Areas. Cambridge, Massachusetts: Harvard University, 1971.

PURPOSE: As stated on page 393 of the report itself, the method developed was in response to the following question,

> How can one propose a solution to a planning problem, in this case the multiple use for a reservoir site, when the activity demands on the site are unclear and when the costs and benefits to be derived from any proposal must be evaluated in terms of multiple objectives including dollar benefits and costs, environmental resource quality and the social benefits of consumer satisfaction?

METHOD: Two approaches were developed, "that of professional judgment proposals evaluated and improved by a simulation model, and that of a linear program generated proposal evaluated and improved through the use of a simulation model." (page 397) The procedures developed included the traditional components of problem identification, data inventory and analysis. It was in the preparation, evaluation and improvement of plans that the Honey Hill Method diverged from the traditional, chiefly by employing simulation models.

The data inventory was computer-compatible and made much use of computer graphic displays. Aerial photos at approximately 1:20,000 were one data source. A selection of activities which could be part of a development proposal for their study area was made and consisted essentially of recreation, residences and transportation infra-structure. Space Standards, site, service and accessibility requirements were established for the various activities. Resource systems at various sites were assessed in terms of vulnerability and demands were assessed for the possible activities. Costs to provide the facilities and incomes to be derived from participation in the types of activities were also considered.

10. Ohio Department of Natural Resources. Land Capability Analysis: The Wolf Creek Project. Columbus, Ohio: Ohio Department of Natural Resources, February, 1974.

PURPOSE: To evaluate the ability of land to accommodate various types of development and of incorporating this evaluation into the planning process.

METHOD: The land capability analysis relies almost exclusively on characteristics of soils in determining capabilities. This analysis is based on an inventory of the physical variables in an area and an assessment of how their properties can affect or be affected by the following types of land uses: residential, commercial, industrial, agricultural, transportation, recreation, conservation and underground utilities. This is a computer-based data system.

11. Sharpe, Carl and Donald L. Williams. "The Making of an Environmental Fit." Landscape Architecture, Vol. 62 (April 1972), pp. 210-215.

PURPOSE: To select an area with potential for accommodating a new town.

METHOD: This analysis combined McHarg's approach in the assembly of natural resource data and Lewis's concept of natural amenities and existing land use. The overall integration of data was done on the computer with a cluster analysis program.

12. Toth, Richard E. Criteria for Evaluating the Valuable Natural Resources of the TIRAC Region. Stroudsburg, Pennsylvania: Tocks Island Regional Advisory Council, 1968.

PURPOSE: To develop guidelines for controlling growth and expansion.

METHOD: Eight factors of the natural resource base are inventoried and mapped. They include geology, climate, water, soils, vegetation, wildlife, slope and visual aspect. The possible effect of these factors on various "man-activity" components such as settlement, transportation or recreation, are identified in a matrix. Natural features are thus viewed as constraints on various types of development.

13. Vermont State Planning Office. The Vermont Interim Land Capability Plan. Montpelier, Vermont: Vermont State Planning Office, June 1971.

PURPOSE: "To identify land and water resource opportunities and limitations relevant to the continuing evolution of Vermont settlement."

METHOD: A series of maps were created for each Vermont county depicting: generalized land use, surface waters and drainage divides, limitations for development, capability for agriculture and forestry (high potential agricultural soils), and unique fragile areas.

Any development was to be planned so as to relate logically to established settlements, to avoid areas where environmental, historical or educational damage would occur, to conform with known environmental limitations, and to avoid the displacement of important non-urban uses relying upon basic characteristics of the land.

Special Purpose Methods[*]

1. John A. Dearinger (Kentucky), 1968

PURPOSE: To evaluate and rank the potential of small watersheds near urban areas for various recreational activities.

FACTORS EVALUATED: topography, geology, soils, hydrology, vegetation, climate. Cultural information includes land use, land use capability, transportation, water pollution, and historical sites.

METHOD: This inventory results in eleven major elements: climate, scenery, natural environments, historical value, soils, water quality, water quantity, fish populations, human population characteristics, local and tourist access, and "disvalues" such as junkyards.

The process of evaluating the elements is quite subjective and the importance of each element is determined by multipliers supposedly based on observations made in Kentucky.

2. R. Burton Litton, Jr. (California), 1968

PURPOSE: A description and analysis of the visual forest landscape.

FACTORS EVALUATED: Form, spatial definition and light, distance, observer position and sequence.

METHOD: The identification of the variables above is followed by an identification of landscape composition characteristics including: panoramic, feature, enclosed, and focal landscapes.

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[*] The source for the special purpose methods is: A Comparative Study of Resource Analysis Methods by Carl Steinitz, Timothy Murray, David Sinton, and Douglas Way. Cambridge, Massachusetts: Harvard University, 1969.

This method is an attempt to integrate design with natural resources data and has been used on highway corridors, etc.

3. Soil Conservation Service, 1966

   PURPOSE: To provide a method for county and state agencies to appraise the potentials for various outdoor recreational developments.

   FACTORS EVALUATED: Climate, scenery and scenic areas, wildlife, people, proximity and access, rural ownership and land use patterns.

   METHOD: The procedure is to inventory variables that are considered important in making an outdoor recreation plan (emphasis is on soils and water). Local groups are to determine priorities and therefore the ordering of variables is not explicitly directed.

4. Edward A. Williams (California), 1969

   PURPOSE: The planning and acquisition of major open land areas near metropolitan areas; holdings of 90 or more acres.

   FACTORS EVALUATED: Open land is divided into groupings of: 1) land unsuited for urbanization because of natural hazards or constraints; 2) class 1 and 2 soils, specialty agriculture, special geological characteristics, major wildlife habitats and ecologies, high scenic quality; 3) proximity to urban centers.

   METHOD: This method is concerned exclusively with various types of open space. Potential areas were evaluated by the factors listed above and those areas were then overlain on an existing open space map. Means for protecting open space, primarily legal, were examined and implementation strategies were developed. The study which formed the basis of this technique is "Open Spaces--

the Choices Before California."

5. Ervin Zube (Massachusetts), 1968

PURPOSE: To map and define visually homogeneous areas within the study area.

FACTORS EVALUATED: Contrast, spatial variety, enclosure, and major water features.

METHOD: This method involves a broad classification scheme for large areas. A linear program model was also adapted to Zube's work. Suitability for a particular use is to be "a function of the county's land resource and landscape unit characteristics." Constraints result in recommendations to either maintain existing visual conditions, add open space; add forest; add water; add water and open space, etc.

Sources with Conceptual Input to the Study of Environmental Analysis

1. Burchell, Robert W. and David Listokin. The Environmental Impact Handbook. New Brunswick, New Jersey: Rutgers University, 1975.
2. Davis, Charles M. A Study of the Land Type. Durham, North Carolina: Army Research Office, March 1969.
3. Dickinson, Robert E. Regional Ecology--The Study of Man's Environment. New York: John Wiley and Sons, Inc., 1970.
4. Fabos, Julius Gy. "An Analysis of Environmental Quality Ranking Systems," Recreation Symposium Proceedings, U.S. Department of Agriculture, 1971.
5. Graham, Edward H. Natural Principles of Land Use. New York: Oxford University, 1944.
6. Hackett, Brian. Landscape Planning. Newcastle-Upon-Tyne, England: Oriel Press Limited, 1971.
7. Isachenko, A.G. Principles of Landscape Science and Physical-Geographic Regionalization. Translated by N.J. Rosengren. Carlton, Victoria, Australia: Melbourne University Press, 1973.

8. Land Use Analysis Laboratory. *A Land Classification Method for Land Use Planning*. Ames, Iowa: Iowa State University, 1973.

9. Linville, Jack, Jr. and Ron Davis. *The Political Environment - An Ecosystems Approach to Urban Management*. Washington, D.C.: American Institute of Planners, 1976.

10. Lyle, John and Mark von Wodtke. "An Information System for Environmental Planning," *Journal of the American Institute of Planners*, Vol. 40. No. 6, (November 1974): 394-413.

11. Odum, Eugene. "The Strategy of Ecosystem Development," *Human Identity in the Urban Environment*. eds. Gwen Bell and Jacqueline Tyrwhitt. Baltimore, Maryland: Penguin Books, Inc. 1972.

12. Sorenson, Jens C. "Some Procedures and Programs for Environmental Impact Assessment," *Environmental Impact Analysis: Philosophy and Methods*. eds. Robert Ditton and Thomas Goodale. Madison, Wisconsin: University of Wisconsin, 1972.

13. Steinitz, Carl. "Landscape Resource Analysis--the State of the Art," *Landscape Architecture*, Vol. 60, No. 2 (January 1970): 101-105.

14. Warner, Maurice L. and Edward H. Preston. *A Review of Environmental Impact Assessment Methodologies*. Washington, D.C.: Office of Research and Development of the Environmental Protection Agency, April 1974.

15. Weatherspoon, C.P., J.N. Rinker, R.E. Frost and T.E. Eastler. "Remote Sensor Imagery Analysis for Environmental Impact Assessment." *Proceedings of the 2nd Conference on Environmental Quality Sensors*. Washington, D.C.: Environmental Protection Agency, 1972.

Summary

The increased emphasis on protection of the natural and human environment has stimulated the development and rediscovery of methods for analyzing and evaluating man's biotic and abiotic surroundings. Numerous methods exist but no one method can claim to be appropriate for all needs. Variations in available environmental data and in the interpretation of such data due to geographic differences, require that any method must be adapted to fit the needs of a particular study.

This chapter contains summaries of eighteen environmental analysis methods identifying the purpose for which each method was developed and briefly describing the factors used to evaluate the environment. No attempt was made to include all methods, but the review can be considered comprehensive and representative of the state-of-the-art.

As was evident in reviewing the eighteen methods in this chapter, much diversity is found in the purposes for which individual methods have been developed and in the factors which were employed to make environmental evaluations. Certain limitations regarding environmental data are shared by all methods, however, because any environmental evaluation can only be as accurate as the data on which it is based. Continuously expanding programs and legislation protective of the environment imply a need for improved methods of evaluation and better data about the environment to serve as input to those methods.

Some of the problems of data base availability include cost of acquisition, timeliness, accuracy, scale and comprehensibility. This thesis explores the role of a new data source, high altitude, color infrared photography, in the field of environmental analysis; a source which can improve the overall quality of the data base for environmental analysis.

In the established sequence of this thesis, the step which follows the review of environmental analysis methods involves selecting a site in Michigan in which to test the utility of high altitude color infrared photography. Chapter III identifies the selected site and describes its environmental and growth characteristics.

CHAPTER III

SELECTION AND DESCRIPTION OF THE STUDY AREA

The area between the cities of Grand Rapids and Kalamazoo, Michigan contains extensive agricultural and recreational acreage. Grand Rapids and Kalamazoo, major urban areas of southwestern Michigan with 1970 populations of 197,649 and 85,555 respectively are expanding and little analysis of the impending growth problems of the area lying between these cities has been done.

The major objective of this research effort is to investigate the utility of small scale color infrared imagery as a data source for environmental analysis in areas under pressure for development and urbanization. Development, as defined by the American Law Institute in A Model Land Development Code, means "the carrying out of building, engineering, mining or other operations in, on or under land, or the making of any material change in the use of any buildings or other land."[12]

The term development is widely used in legal as well as planning disciplines and conceptually the term "can be divided into tangible and intangible activities. The tangible activities include the construction and alteration of buildings and the other activities typically associated with changes in the use of the land. The intangible activities include a limited number of types of transactions in land which are very directly related to the type of development that may occur on the land. These transactions include the dividing of land into parcels and the creation or extinguishment of rights of access or riparian rights."[13]

The area lying between Grand Rapids and Kalamazoo is experiencing increased pressure for development. In other words, the demand for urban and built-up land is increasing. On March 1, 1974, the NASA-sponsored Project for the Use of Remote Sensing in Land Use Policy Formulation at Michigan State University requested high-altitude RB-57 color infrared coverage of the urbanizing corridor between the cities of Kalamazoo and Grand Rapids, Michigan. This request was part of the Remote Sensing Project's continuing research effort to experiment with applications of remote sensing to resource analysis and land use planning in Michigan. Color infrared photography was requested because it is highly useful in land use analysis, as was explained in Chapter I. The mission, Mission 273, was flown on May 7, 1974 at an approximate altitude of 56,750 feet. Color infrared imagery at scales of 1:56,570 and 1:113,500 was later provided to the MSU Project. Figure A-1 in Appendix A indicates the flight lines and resultant coverage at both scales. Specifications for Mission 273 and approximate conversion factors are also given in Appendix A.

For use as a test site in the environmental analysis which follows in Chapters IV and V, a study area was arbitrarily delineated within the total area covered by the imagery. The study area is a north-south corridor extending from the northern to the southern boundary of Allegan County. US-131, a major arterial from the Michigan/Indiana border north to Petoskey, and a limited access freeway between Grand Rapids and Kalamazoo roughly approximates the center line of the corridor which extends laterally about three miles east and three miles west of the arterial. (See Figure 4.) Portions of eight townships, all within Allegan County, are included in the study area, namely: Dorr, Leighton, Hopkins, Wayland, Watson, Martin, Otsego and Gun Plain. The study area or test site is 24 miles long from north to south and 6 miles wide from west to east. This 144 square mile area comprises approximately 17 percent of the total land area of Allegan County. Four overlapping frames of color infrared imagery at a scale of 1:113,500 were used for data extraction and interpretations. Black and white prints of the original color infrared imagery are provided as Figures 7 through 10 in Chapter IV.

The first portion of this chapter describes the growth characteristics of the study area supporting the contention that this area is being exposed to increasing development pressure. The second portion of the chapter describes the general physical and biotic characteristics of the study area; a prerequisite to any environmental evaluation of the land.

Growth Characteristics of the Study Area

The entire State of Michigan lies within the drainage basin of the Great Lakes. Studies compiled by the Great Lakes Basin Commission in 1975[14] indicate that urban demands for land in the Basin will increase substantially and that much of this expansion (86 percent) will occur within the Standard Metropolitan Statistical Areas (SMSA's) by 1980. Grand Rapids and Kalamazoo are both classified as SMSA's.

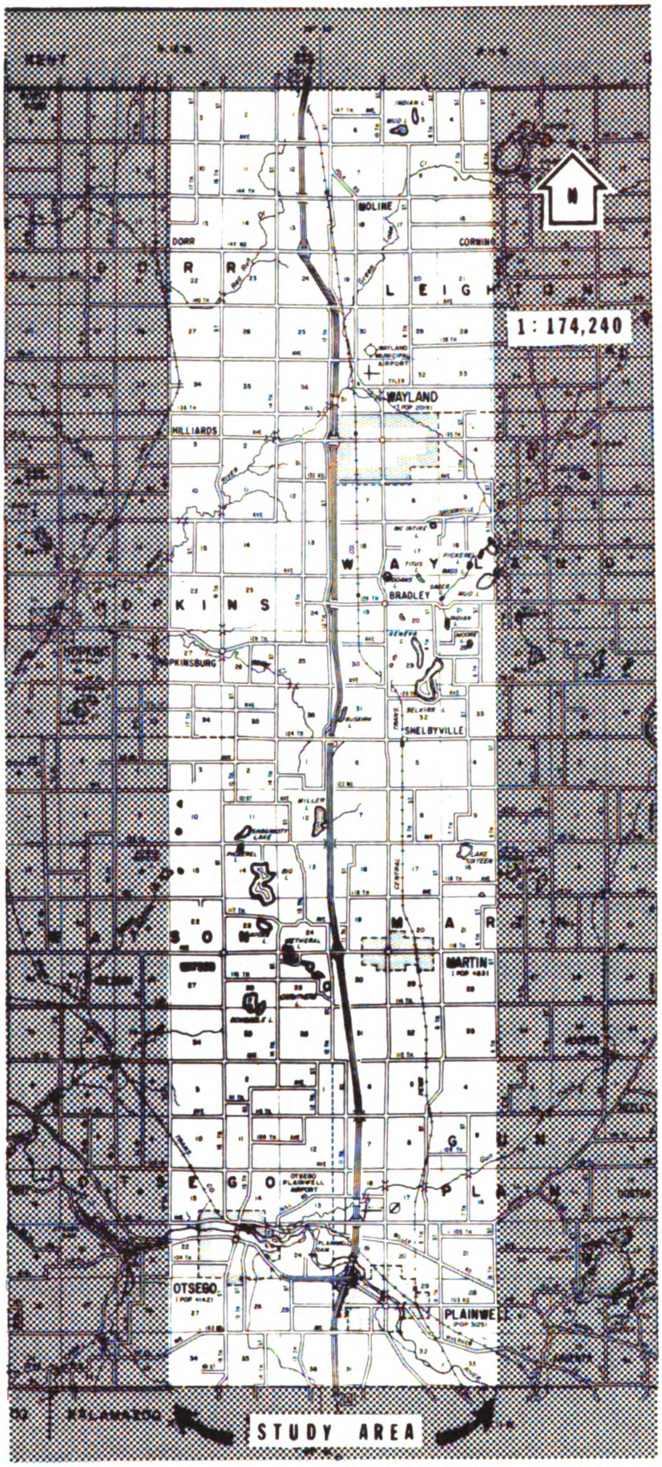

Figure 4. Study Area in Allegan County

Within the Grand Rapids SMSA approximately 25,000 acres are now considered urban and built-up while in the Kalamazoo SMSA the figure is about one-half that amount. Between 1980 and 2000, urban and built-up land in both SMSA's is expected to grow by approximately 10,000 acres. In the year 2020, nearly 50,000 acres in Grand Rapids and 25,000 acres in Kalamazoo is projected to be urban and built-up. This expansion will affect surrounding areas outside the SMSA's.

> The rate and direction of urban expansion is influenced by many factors. Population, population growth, economic activity, and transportation networks are some of the more important factors. These affect growth around existing urban areas and also between centers of economic activity.[15]

The area lying between Grand Rapids (Kent County) and Kalamazoo (Kalamazoo County) is not part of either SMSA. However, urban and built-up land in this region which includes the study area, is projected to increase by 5,000 acres between the present time and 1980, and to increase by another 10,000 acres between 1980 and 2000.

To demonstrate the current growth relationship between the study area and the cities of Grand Rapids and Kalamazoo, population growth was analyzed. Table 1 lists the population growth of the townships and major cities included in the study area between 1960 and 1970. Those townships closest to the cities of Grand Rapids (Dorr and Leighton Townships) and Kalamazoo (Otsego and Gun Plain Townships) exhibited some of the highest rates of growth in the study area.

Information gathered from the 1970 Census of Population concerning the place of work of a sample group of Allegan County residents and shown in Table 2, serves to illustrate the interdependence of Allegan County with the urban areas of Grand Rapids and Kalamazoo.

Table 1. Study Area Population Growth

Population	1970	1960	% Change
Dorr Township	3,055	2,313	32.1
Gun Plain Township	3,231	2,796	15.6
Hopkins Township	2,084	1,766	18.0
Hopkins Village	566	556	1.8
Leighton Township	2,354	1,951	20.7
Martin Township	2,125	1,963	8.3
Martin Village	502	483	3.9
Otsego City	3,957	4,142	-4.5
Otsego Township	3,721	2,564	45.1
Plainwell City	3,195	3,125	2.2
Watson Township	1,331	1,065	25.0
Wayland City	2,054	2,019	1.7
Wayland Township	1,661	3,450	-51.9

Total 1960 Population --- 28,193

Total 1970 Population --- 29,836

1970 Test Site Density*---103.6 persons per square mile (*288 square miles for the eight townships noted above)

Average density for all of Allegan County---80.6 persons per square mile

Table 2. Employment by Place of Work Data Summarized

Dorr Township (directly south of Grand Rapids)

Of 680 persons employed:
50% worked in Grand Rapids (city)
15% in other areas of Kent County
31% in Allegan County

Leighton Township (east of Dorr Township)

Of 746 persons reporting:
31% worked in Grand Rapids (city)
13% in other areas of Kent County
34% in Allegan County

Gun Plain Township (north of Kalamazoo)

Of 1192 persons employed:
24% worked in Kalamazoo (city)
13% in other areas of Kalamazoo County
62% in Allegan County

In Plainwell, the major city in Gun Plain Township, of 1039 persons reporting:

24% worked in Kalamazoo (city)
10% in other parts of Kalamazoo County
63% in Allegan County

Otsego Township (west of Gun Plain Township)

Of 1264 persons employed:
20% worked in Kalamazoo (city)
10% in other areas of Kalamazoo County
67% in Allegan County

In Otsego, the major city in Otsego Township, of 1239 persons employed:

17% worked in Kalamazoo (city)
3% in other areas of Kalamazoo County
78% in Allegan County

For all eight townships, of 9042 persons reporting, 1495 or 16.5 percent worked in Grand Rapids and areas of Kent County; 1738 or 19.2 percent in Kalamazoo City and County; and 5436 or 60.1 percent in Allegan County. Table 3 lists complete employment by place of work findings from the U.S. 1970 Census which pertain to the study area.

In summary, growth in the study area, as it is related to population and employment is currently influenced by nearness to the cities of Grand Rapids and Kalamazoo. In addition, the increased demand for urban and built-up land in the Grand Rapids and Kalamazoo SMSAs is projected to spillover to the area which lies between them; an area which includes the test site.

Environmental Characteristics of the Study Area

As discussed in Chapter II, any evaluation of a land area requires consideration of major features of the natural environment such as: climate, soils, water resources, topography, geology and land cover/use. This portion of Chapter III describes in general terms, the environmental setting of the study area and thus lays the foundation for development of the environmental inventory and analysis method in Chapters IV and V. The references used for the descriptions which follow oftentimes addressed areas of land much larger in size than the study area. At the time this study was initiated, there had been no detailed environmental inventories published for either the townships in the study area or for Allegan County. The Allegan County Soil Survey, as an illustration, was made in 1901 by the Soil Conservation Service and is out-of-print. As a result of the lack of specific information, it was necessary to generalize facts from sources of a broader scope, and apply them to the study area.

Table 3. Employment by Place of Work Data

Township or City of Residence	Total Number of Employed Surveyed*	Place of Work Area Number[1]	No. of Persons at Work in Selected Areas[1] Surveyed During Census Week	Percentage of Total Surveyed in Selected Areas
Dorr Township	680	2	341	50
		3	104	15
		10	214	31.5
Hopkins Township	820	2	98	12
		3	45	5
		8	25	3
		10	489	60
Leighton Township	746	2	230	31
		3	206	28
		8	19	--
		9	9	--
		10	256	34
Martin Township	544	2	29	5
		3	15	3
		8	99	18
		9	20	4
		10	366	67
Gun Plain Township	1192	8	291	24
		9	152	13
		10	742	62
		15	4	--
Otsego City	1239	3	6	--
		8	209	17
		9	42	3
		10	969	78
Otsego Township	1264	8	251	20
		9	121	10
		10	851	67
		15	12	1
Plainwell City	1039	3	6	--
		8	251	24
		9	108	10
		10	658	63
Watson Township	279	2	6	2
		8	56	20
		9	35	12
		10	167	60
Wayland City	756	2	177	23
		3	84	11
		9	15	2
		10	465	62
Wayland Township	483	2	112	23
		3	36	7
		8	28	6
		9	7	1
		10	259	54

---

* A sample population of employed persons over 14 years of age who worked during the Census week

[1]

Area Number	Place of Work
2	Grand Rapids (City)
3	Remainder of Kent County
8	Kalamazoo (City)
9	Remainder of Kalamazoo County
10	Allegan County
15	Battle Creek (City)

Climate

The climate of the study area can be characterized as humid-continental. Humidity is moderate and temperatures range from an average of 24°F in February to 73° F in June. Precipitation averages 33 inches per year, snowfall averages 50 inches per year, and severe storms are uncommon.

Prevailing winds are from the southwest, a factor to be considered when planning the location of facilities which generate air pollutants or odors. This information can also be utilized when locating residences in order to take advantage of the cooling effect of the winds.

Although the area's climate is somewhat moderated by Lake Michigan, as is the case for the entire lower peninsula of the state, the study area lies east of the famed fruit production belt of Michigan which parallels the Lake Michigan shoreline.

Geology/Hydrology

The study area lies within the Kalamazoo River basin which encompasses 2060 square miles. The Kalamazoo River flows west by northwest and terminates at its confluence with Lake Michigan. The main branch of the Kalamazoo crosses the study area as do two of its major tributaries, the Rabbit River and Gun River. (See Figure 5.)

The bedrock underlying the study area consists of formations dating back approximately 325 million years, i.e. Mississippian. Most of the Kalamazoo River Basin of which the study area is part, is underlain by Coldwater shale. In addition, a narrow band of the Marshall sandstone formation crosses the area in a northwest-southwest alignment between Muskegon and Battle Creek. But as is the

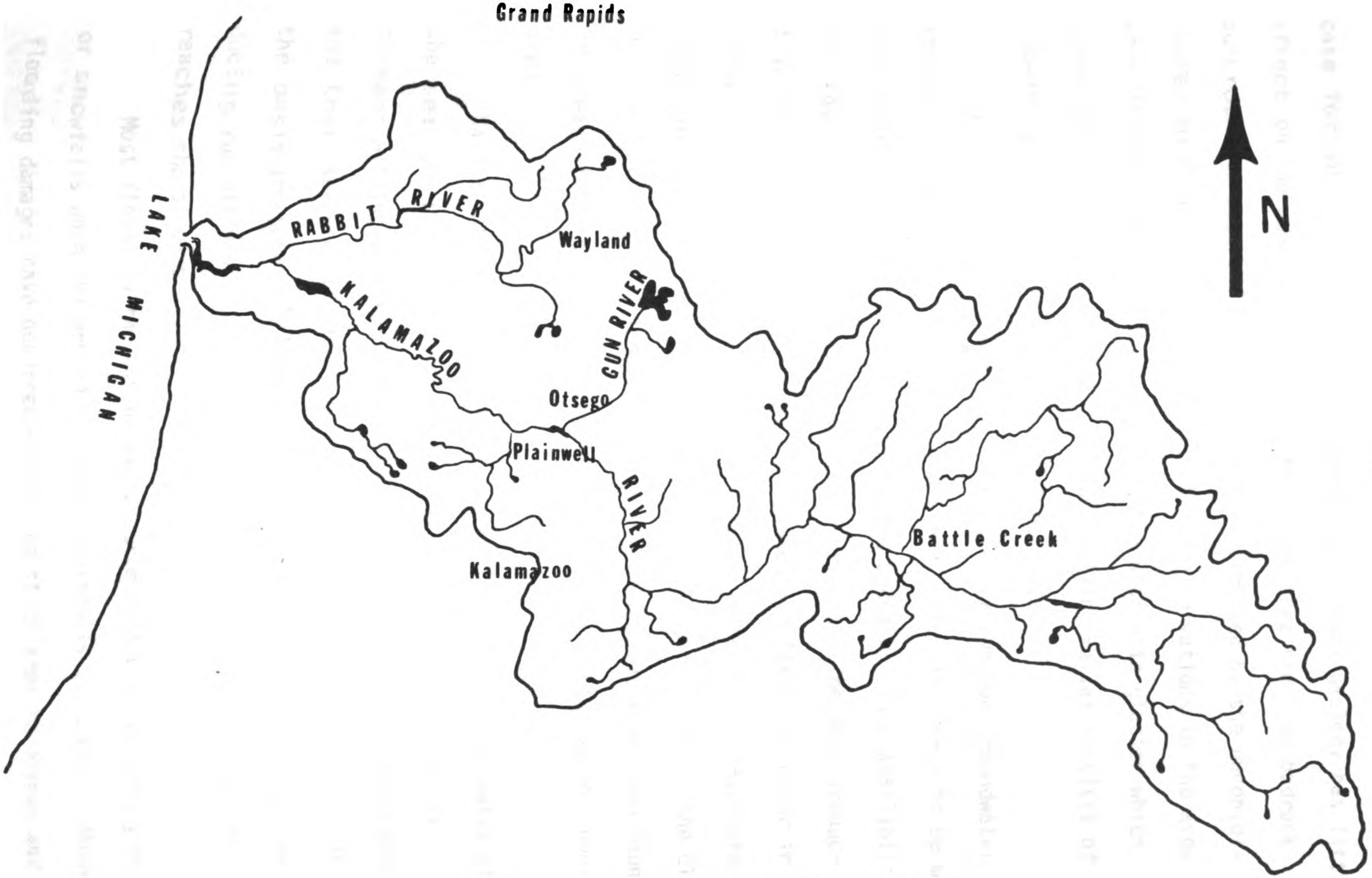

Figure 5. Kalamazoo River Drainage Basin

case for most lower peninsula communities, bedrock geology has little effect on the economy or development of the area since no bedrock outcroppings occur. The entire surface is masked by the unconsolidated materials of glacial drift. Surface formations in the area were formed by the final recession of the Wisconsin glacier which began about 20,000 years ago. The low, rolling relief consists of outwash plains, moraines and lake bed deposits.

Allegan County is not covered by a comprehensive groundwater report of any detail. In general, however, water is likely to be more available from glacial deposits than from bedrock. This availability in glacial drift and alluvium is quite variable. The more productive aquifers (over 500 gallons per minute) are likely to occur in thick sand and gravel deposits near streams. The poorest aquifers would probably be found in thin glacial drift deposits or in the clay or silt till and lake deposits. High yield aquifers have been found in areas of the Kalamazoo River Basin including the Otsego/Plainwell area.

Natural streamflow in the Kalamazoo River Basin fluctuates with the seasons; high in the spring and low in the winter. But the streams within the project area are not characterized by rapid erosion and their sediment content is generally low. Because the soils in the basin are generally porous, infiltration is increased thus reducing run-off peaks and equalizing the groundwater supply which reaches the streams.

Most floods in the basin have occurred after heavy spring rains or snowfalls when the ground is already partially saturated. Minor flooding damages have occurred within the study area in Otsego and

Plainwell, chiefly because of encroachment on the floodplain.

Wetlands

There are few large lakes within the study area and no extensive wetland complexes remain. The area is crossed by a network of artificial drainage channels or straightened natural channels which were developed primarily for improving drainage of agricultural fields. The area does, however, have a large number of small ponds and pitted areas that are at least seasonally filled with water.

Soils and Topography

There is no up-to-date soil survey for Allegan County but according to a 1968 publication of the Michigan State University Cooperative Extension Service, Soils of Michigan, two major land divisions are found in the study area. Land Division "T" is composed primarily of the Miami and Conover soil associations, while division "V" is comprised of Fox and Oshtemo soil associations. (See Figure 6.)

The soils in Land Division "T" were derived chiefly from limy loam glacial till. Drainage varies from good to poor in depressions and natural drainageways. Topography is nearly level to rolling and is favorable for tillage operations. Topography in Division "V" also ranges from nearly level to rolling and many of the level outwash areas are strongly pitted. Soils can be tilled easily and are moderately productive. A lack of moisture holding capacity and low natural fertility, however, are limiting factors in crop production.

Two other land divisions are found in the study area; Land Division "O" is composed primarily of the Rubicon, Grayling and Roselawn soil series and was formed from materials low in lime.

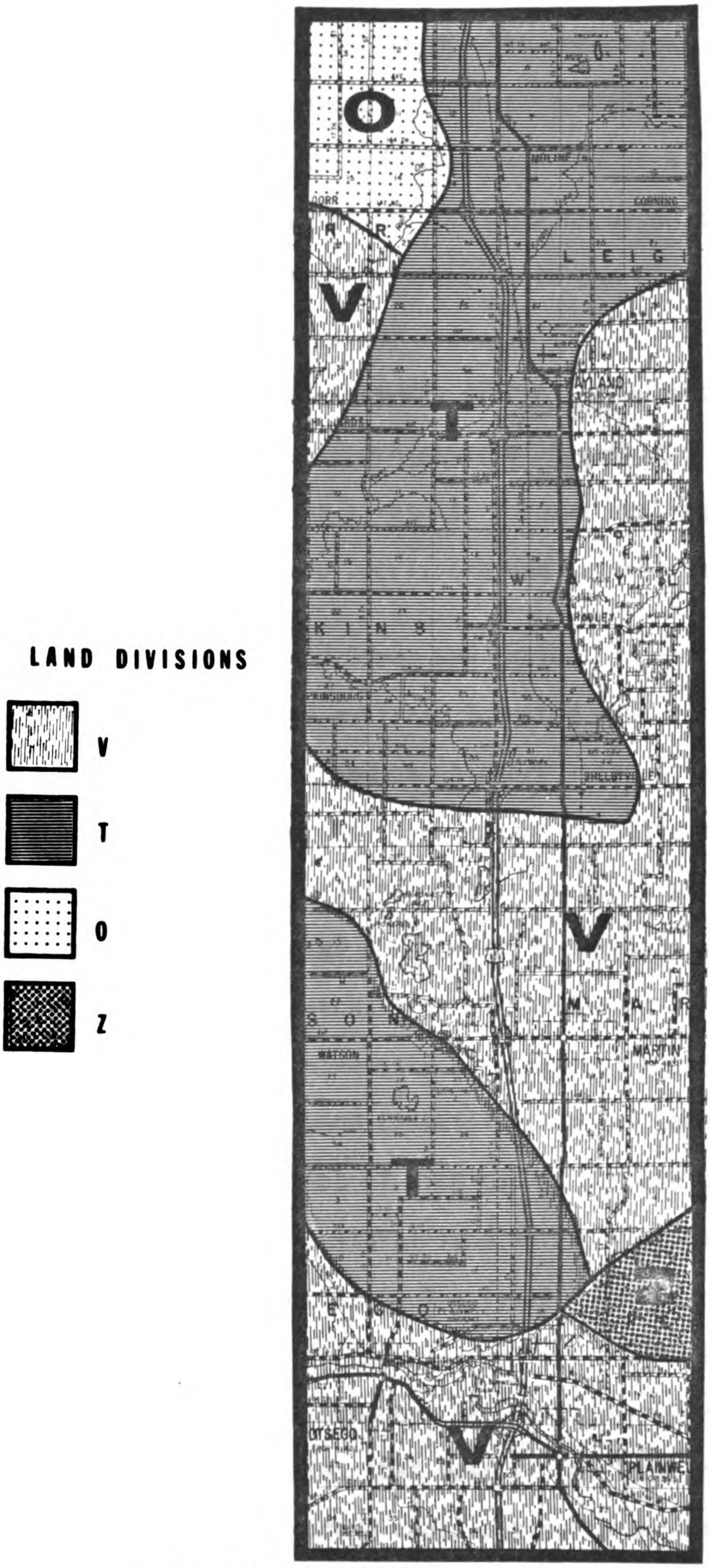

Figure 6. Land Division Map of Study Area

They are mainly well drained sands with topography ranging from level plains to hilly uplands. Natural fertility is low, as is moisture holding capacity. Wind erosion may be a problem when the soil is tilled. Land Division "Z" contains organic soils (muck and peat). Fertility, control of water table and wind erosion are major problems for successful use of these soils.

It should be noted that the glacial materials responsible for soils in most of the lower peninsula of Michigan differed significantly in texture and as a result, natural drainage conditions can vary from well-drained to poorly drained in very short distances.

Land Cover and Agriculture

The study area was entirely forested when first settled with mixed southern hardwoods and oak-hickory associations. The area now dramatically illustrates the farming pursuits which have occurred. The majority of the land is now or has previously been in cultivation. Wooded areas are scattered and generally small in size.

Professor J.O. Veatch in Special Bulletin 231 (October 1941), of the Michigan State University Agricultural Experiment Station entitled "Agricultural Land Classification and Land Types of Michigan," presented a dot map of Michigan at a scale of 1:750,000 showing proportions of agricultural land in Michigan with high (first class), medium (second class), low (third class), and very low (fourth class) values for general farming. According to a 1972 report by Whiteside and Schaner, Veatch's generalized map is still valid. This map indicates that most of the land in the study area consists of first and second class agricultural land.

A glance at an aerial photograph or a drive through the area confirms that much of the land can be and is being farmed. However, a significant amount of land during a field survey in August 1975, appeared idle. This seemed particularly true in areas closest to urban centers. Statistics from the U.S. Department of Commerce Census of Agriculture between 1964 and 1969 showed a decrease of 196 farms in Allegan County in those five years. The number of farms of less than 100 acres decreased from 1,565 to 1,481 (-5.4%) and the number of farms between 100 and 219 acres dropped from 859 to 740 (-13.9%). Checking the pattern of land ownership on the Allegan County Plat maps, it is clear that very few large parcels are held in single ownerships. It thus seems likely that the small farms are most prevalent but declining.

Summary

Color infrared imagery covering an area under increasing pressure for development which roughly approximates a corridor from Grand Rapids to Kalamazoo, was obtained by the MSU Remote Sensing Project. A portion of the area covered was designated as a test site to be used in evaluating the environmental analysis method in Chapters IV and V of this thesis. The 144 square mile test site or study area lies entirely in Allegan County.

Growth in the study area as it is related to population and employment is currently influenced by nearness to the cities of Grand Rapids and Kalamazoo. In addition, the increased demand for urban and built up land in the Grand Rapids and Kalamazoo SMSAs is projected to spillover to the area which lies between them; an area including the test site.

The natural features of the study area described in this chapter lend themselves to agriculture and most of the land is now or has previously been in cultivation. The potential impacts of urban expansion in what is now a predominantly rural, agricultural area include: 1) suburban land value appreciation far above farm land prices and the resultant loss of agricultural land; 2) increased costs of public services to be born by local governments which often lack a large commercial and/or industrial tax base; costs which are particularly high when development occurs in the rural fringe; and 3) increased pressure for development of open space and other natural features.

Development pressures in the study area indicate that early planning for growth and identification of areas most suited for development should be undertaken now. The following chapter presents the inventory and analysis method to be used in evaluating the study area environment and the implications for development therein.

FOOTNOTES

[12] American Law Institute, A Model Land Development Code (Philadelphia: American Law Institute, April 15, 1974), p. 21.

[13] Ibid., p. 23.

[14] Great Lakes Basin Commission, Appendix 13 - Land Use Management (Ann Arbor: Great Lakes Basin Commission, 1975), pp. 73-79.

[15] Ibid., p. 74.

CHAPTER IV

INVENTORY AND ANALYSIS METHOD

The purpose of environmental inventory is to provide data about selected components of the natural environment; information which can then be used as a basis for evaluating the environment. Depending on the type of evaluation to be made, different components of the environment will assume varying degrees of importance. Illustrations of different types of evaluation that have been made are provided in Chapter II which summarizes the purposes for which various environmental analysis methods were developed.

In order to analyze and evaluate the environment in the study area in Allegan County as it relates to accommodating increased amounts of development, it is necessary to first inventory those natural and man-made features which will be important for land use decisions and resource protection. In addition, since the objective of this research effort is to employ small scale color infrared imagery in a non-technical manner as the primary data source, it is necessary to integrate the data requirements for environmental evaluation with a realistic level of detail to be interpreted from the imagery.

Development of the Inventory

There is an abundance of information concerning the development of inventory systems. In Michigan, for example, the Office of Land

Use of the Department of Natural Resources, developed a land cover/use classification system for the entire state.[16] The system was developed with four levels of detail for characterizing mapped areas with scales ranging from 1:250,000 to 1:1,000,000 (Level I), 1:125,000 to 1:250,000 (Level II), 1:50,000 to 1:125,000 (Level III), and 1:24,000 to 1:50,000 (Level IV). The system was designed for compatibility with aerial photography and other remotely sensed imagery as well as with computers and illustrates a general trend in that "plans for inventories almost always now imply or specify an associated computer-based information system, particularly as the tasks are defined in terms of larger areas of land than can be assessed by direct observation."[17] Recently developed environmental analysis methods such as numbers 9-11 in Chapter II which are computer compatible, further substantiate this trend.

Because of the increasing emphasis on computer utilization, and for the convenience found by numerically coding data for large areas, the inventory method developed for this research effort was designed to be computer compatible. Although no computer storage or manipulation was employed, all data were recorded on computer data sheets according to a numerical coding system.

In the interest of standardization and the advantages that a statewide system would offer, the potential for extensive use of the Michigan Land Use Classification System was investigated. According to that System, a combination of Levels II and III could have been best employed (see Table 4) since the scale of the color infrared photography was 1:113,500. The Michigan System heavily emphasizes land cover and land use inventory data. Because of the investigative

Table 4. Michigan Land Use Classification System - Levels I and II*

Level I	Level II
1--Urban and Built-up	11--Residential 12--Commercial, Services and Institutional 13--Industrial 14--Transportation, Communication and Utilities 16--Mixed 17--Extractive 19--Open and Other
2--Agriculture	21--Cropland, Rotation and Permanent Pasture 22--Orchards, Bushfruits, Vineyards and Ornamental Horticulture areas 23--Confined feeding operations 29--Other Agricultural land
3--Rangeland	31--Herbaceous rangeland 32--Shrub rangeland
4--Forest Land	41--Broadleaved 42--Coniferous 43--Mixed
5--Water	51--Streams and Waterways 52--Lakes 53--Reservoirs 54--Great Lakes
6--Wetlands	61--Forested 62--Non-Forested
7--Barren	72--Beaches and Riverbanks 73--Sand other than beaches 74--Bare, exposed rock 75--Transitional areas 79--Other

*Only those categories applicable to the imagery and study area were here reproduced.

nature of this study and its attempt to obtain more analytical information, it was determined that development of a new classification system was required. Consequently, use of the Michigan Land Use Classification System was minimal.

The inventory classification system developed in this research effort was designed for use with small scale, high altitude color infrared imagery as the principal data source, which unavoidably required some photo interpretation. The system was also designed for use by individuals with little technical expertise in remote sensing such as planners who would benefit by the ability to utilize available imagery in assessing and directing development decisions in a more environmentally informed manner. Many operations which utilize remotely sensed imagery oftentimes request that specialists prepare the initial inventory. This is often the case when a planning agency, for example, wishes to obtain such an inventory but feels it lacks either the time, hardware or manpower with sufficient expertise to perform the initial interpretation. The objective of the classification system and methods presented herein, was to devise a technique for use with color infrared imagery that would be understandable, easily reproducible by other planners and relatively inexpensive to employ assuming the imagery was available. The degrees of complexity and sophistication of the tools used in this system were designed to reflect those resources typically available to the intended users including the resources of manpower, time and hardware.

The classification system initially developed in this research effort employed the major categories A through H as listed in Table 5, as well as many of the specific numbered items. The system was developed as a result of the following actions: (1) a review of those factors inventoried by various other environmental analysis

Table 5. Coding System

A. Relief (Colums 9-12)
1 - level
2 - undulating
3 - hilly

B. Land Cover (Columns 14-28)
1 - open land
2 - urban and built up
3 - forested
4 - other
5 - wetland
6 - major lake (plus 100 acres)
7 - minor lake (less 100 acres)
8 - major stream
9 - minor stream

B. Accessory Information (Predominant condition)
1 - frontage developed
2 - frontage moderately developed (at least cleared)
3 - frontage undeveloped (thick vegetation)
4 - under construction
0 - none

C. Land Use (Columns 30-44)
1 - cultivated cropland
2 - tree farm
3 - orchard/vineyard
4 - urban non-residential
5 - park/playground
6 - residential
7 - undetermined/other
8 - extractive
9 - no apparent use/idle

C. Accessory Information
1 - airport
2 - rail station
3 - mobile home park
0 - none

D. Drainage (Columns 46-50)
1 - very poor (wetland)
2 - poor
3 - moderate
4 - well

E. Transportation Routes (Columns 52-56)
1 - US 131 interchange
2 - US 131
3 - paved road
4 - bituminous road
5 - gravel, soil surfaced or similar
6 - divided highway
7 - railroad
9 - road bridge
0 - no roads

F. Amenities/Disvalues (Columns 58-62)
1 - golf course
2 - athletic field
3 - track
4 - junkyard/dump
5 - cemetery

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Table 5. (Continued)

F. (Continued)
6 - other
7 - drive-in theatre
0 - none

G. Residential Settlement (Columns 64-65)
1 - low density
2 - medium density
3 - high density
5 - undetermined
0 - no evidence of residential settlement

G. Accessory Information
1 - no pattern
2 - scattered
3 - linear
4 - clustered or neighborhood
5 - subdivision

H. Special Concerns (Columns 67-71)
1 - artificial drainage (straight channel)
2 - residential construction
3 - other construction or indeterminate construction
4 - water impoundment structure (dam)
5 - other
6 - ponds
7 - eroded areas evident
8 - oil wells
9 - none

methods in Chapter II; (2) a review of the Michigan Department of Natural Resources classification system which can employ remote sensing imagery; and (3) a review of those natural and man-made factors which could be reasonably extracted from the imagery by a non-expert and which could influence the quality of development and the quality of the surrounding environment. As work progressed and familiarity with the imagery was achieved, alterations, additions and deletions were made to an original format. The system shown in Table 5 is the final classification utilized. Complete definitions of the various categories follow the discussion of interpretation methods.

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Interpretation Methods

Four color infrared (CIR) transparencies at a scale of 1:113,500 depicting the 144 square mile study area, were used. Black and white prints of the color infrared transparencies illustrating the actual size and scale of the originals are provided in Figures 7 through 10. A 10X (power) Seerite Tripod Magnifier was the only magnification equipment used. A fluorescent light table for illuminating the transparencies was also required.

Step 1. Michigan's original land survey system and resultant road network form, in essence, a grid pattern or network on the ground. For this study, each transparency was placed in a plastic (acetate) jacket for protection. All square mile sections on the ground were then outlined directly on the jacket in black drawing ink using a Rapidograph 3060 No. 00 pen point. (Illustrated in Figures 7 through 10). Instead of making an acetate overlay with standard section dimensions drawn in, the sections were outlined directly on the jacket to more closely follow the actual configuration of the ground sections. These ground sections are slightly distorted from the one mile square dimension because of the sperical shape of the earth; i.e. all lines on the ground are not truly perpendicular. Each photograph was gridded at least 1 and one-eighths inch from the sides and 1 and seven-eighths inch from the top and bottom to minimize the distortion which increases with distance from the photographic center or principal point.

Step 2. The second step was to draft a detachable quarter-section grid to overlay on the full sections already drawn. (See Figure 7.) This quarter section grid, because of its standard dimension of

Figure 7. *RB*
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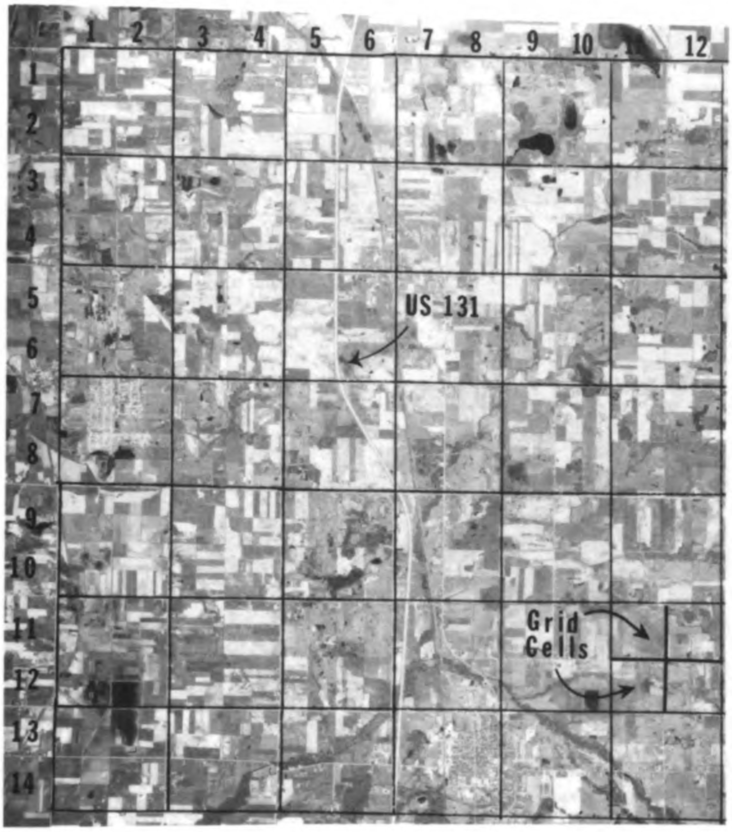

Figure 7. RB-57 Color Infrared Image: Black and White Reproduction
Actual Size Mission 273 - Frame Number 10-0046

Figure 8.

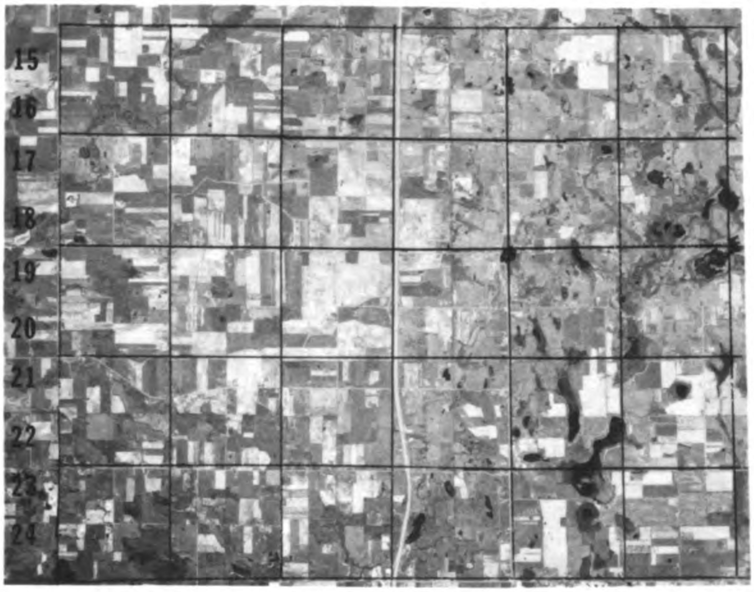

Figure 8. RB-57 Color Infrared Image: Black and White Reproduction Actual Size Mission 273 - Frame Number 10-0045

Figure 9. RB-57 Color Infrared Image: Black and White Reproduction Actual Size Mission 273 - Frame Number 10-0044

Figure 10.

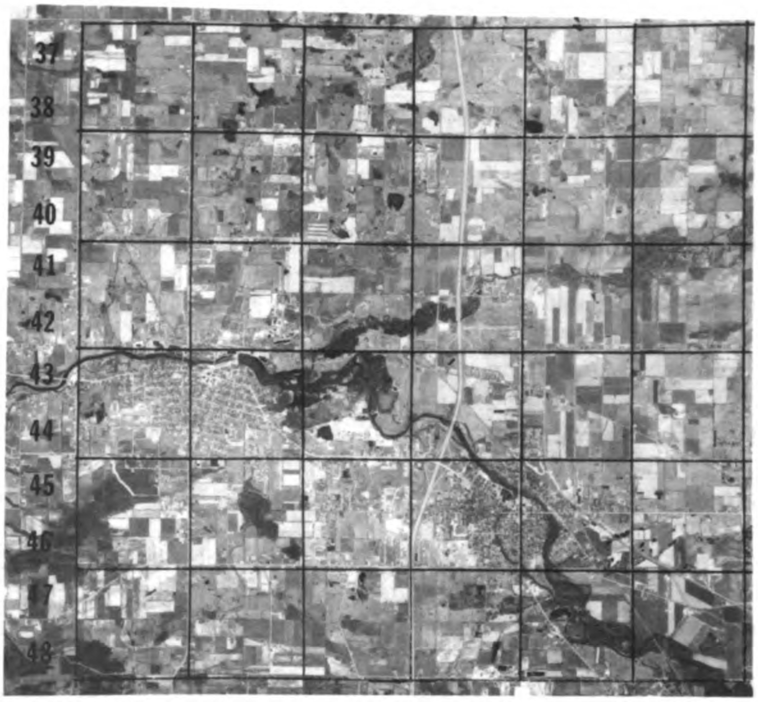

Figure 10. RB-57 Color Infrared Image: Black and White Reproduction Actual Size Mission 273 - Frame Number 10-0043

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approximately .25 inch by .25 inch did not precisely align with each drawn full section. It was determined, however, that the removable characteristic of the quarter section grid permitted viewing beneath the lines and this was a more important capability than complete conformity with the full section grid lines. Each quarter section (160 acres) is henceforth referred to as a grid cell, and represents the smallest data gathering unit for this study. This 160 acre unit was chosen because it could be easily outlined and rapidly identified to retrieve inventory data.

Step 3. Using a base map from the Michigan Department of State Highways and Transportation, the study area in Allegan County was divided into a grid. (See Figure 11.) Running from west to east and from north to south, each grid cell on the map corresponded to a quarter mile section on the ground. The northwest corner of the grid was labelled (01,01) as X and Y coordinates, and is the same area as the northwest one-quarter of Section 3 in Dorr Township. The northeast corner of the grid was labelled (12,01) and corresponds to the northeast one-quarter of Section 4 in Leighton Township. The southwest corner of the grid was labelled (01,48) and corresponds to the southwest one-quarter of Section 34 in Otsego Township. The southeast corner of the grid was labelled (12,48) and corresponds with the southeast one-quarter of Section 33 in Gun Plain Township. This numbering system was also applied to the grid made on the color infrared photographs and is shown in Figures 7 through 10.

It was recognized early in this effort, that the capability to identify the grid cell, the ground location and the extracted interpretation data was of critical importance. The township, range

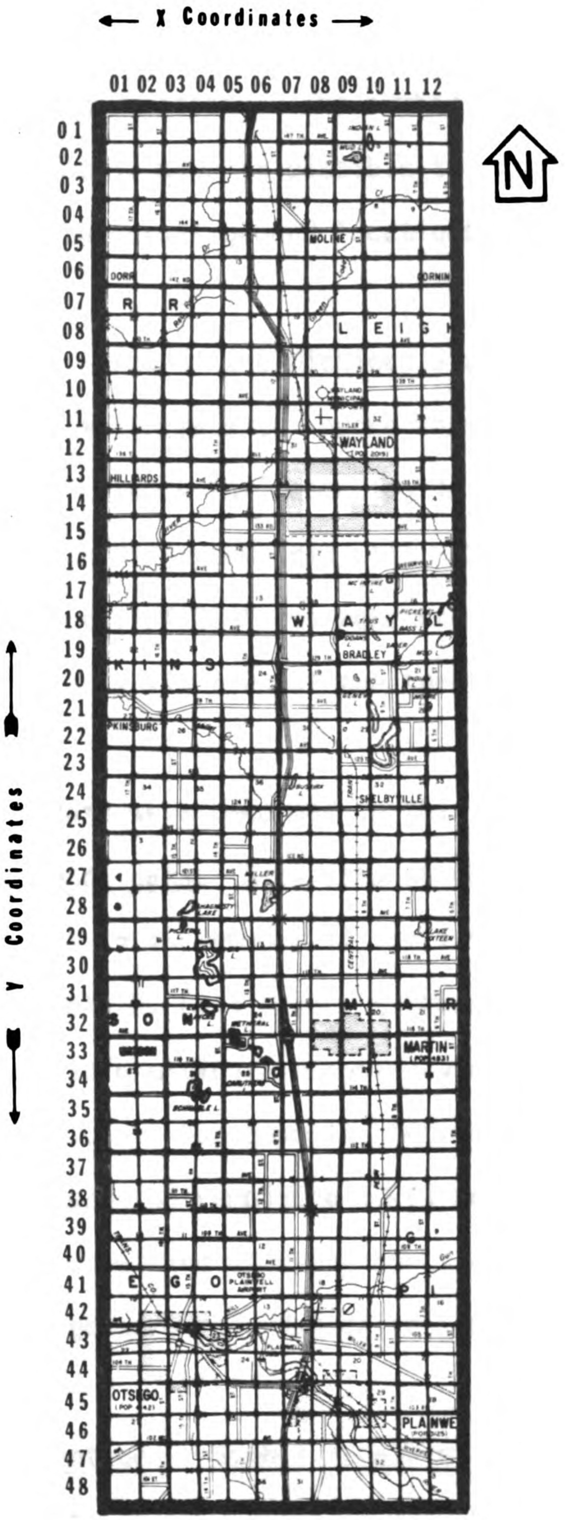

Figure 11. Gridded Study Area

and section layout of Michigan made it relatively easy to delineate standard size, squared areas on the grid overlays and have them correspond with ground locations. The numbering system as devised with X and Y coordinates, made it possible to rapidly correlate coded information with actual ground locations and cells on the imagery.

Step 4. Data Coding Forms of the Michigan State University Computer Laboratory were used as formats to record the data. Each form provided 30 rows and 80 columns for recording information. As utilized, each row represented a different grid cell. (See "Key Coding Sheet" in Appendix B.) A total of 20 forms were used to record data for the 576 grid cells; only six rows of the twentieth sheet were required.

Two types of data were recorded in this classification system; area data and occurence data. Area data which was recorded in deciles (percentage groupings in increments of ten), is found in the following categories: A. Relief, B. Land Cover, C. Land Use, and D. Drainage. These categories of information are applicable to entire cells but in differing proportions. For example, between 10-20 percent of a cell could be hilly and the remaining 80-90 percent might be level. The entire cell has some kind of topographic characteristic, however.

Decile groupings were recorded on the coding sheets in the following manner:

Range of Percentage	Symbol Appearing in Coding Sheet
0-10 percent	0
10-20 percent	1
20-30 percent	2
30-40 percent	3
40-50 percent	4

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Range of Percentage	Symbol Appearing in Coding Sheet
50-60 percent	5
60-70 percent	6
70-80 percent	7
80-90 percent	8
90-100 percent	9

For any single cell, the aggregation of percentages for any area data category was equal to 9, and represented the entire cell. In the example of topographic relief just mentioned, hilly topography would have been coded "1" and the level topography "8." The numbers sum to "9." An advantage of using decile ranges is that it clearly illustrates that figures derived in the interpretation are estimates. Furthermore, since each grid cell on the imagery measured only .25 inch by .25 inch, the decile system made ocular estimation of size much faster. Speed of interpretation would have been severely impeded if an exact percentage were required. As an additional note of clarification, it should be remembered that the "0" decile coding in area data categories does not represent "none." Use of the zero enabled the coding of percentages to be maintained with only one digit and provided a means to indicate area data which accounted for less than ten percent of a grid cell area.

The second type of data recorded was occurrence data. This type includes the following categories: E. Transportation Routes, F. Amenities/Disvalues, and H. Special Concerns. Information such as a paved road or a golf course is either present or absent and could not always be recorded in percentages.

"Category D. Settlement Patterns" does not fall neatly into either area or occurrence data categories. It could technically be considered an "area" concept, but because of the small scale of the

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imagery, this assessment was generalized or averaged for entire cells and thus percentages were not given.

Classification System

The information to be obtained with the coding system was broken down into eight categories: Relief, Land Cover, Land Use, Drainage, Transportation Routes, Residential Settlement Patterns, Amenities/Disvalues, and Special Concerns. Each category is here defined and its associated problems discussed.

Category A. Relief (Coding Sheet Columns 9-12)

Relief was approximated for each cell from USGS topographic maps covering the test site. The bulk of the site (72.9%) was covered on the 15-minute quadrangle titled Wayland, Michigan (1959). The remainder of the test site was covered on four USGS 7 1/2 minute quadrangle maps: Otsego (1973 photo revised), Kalamazoo NE (1973 photo revised), Cutlerville (1972 photo revised) and Caledonia (1972 photo revised).

Because the scales of the available topographic maps differed (15 minute quadrangles give 20-foot contour intervals and 7 1/2 minute quadrangles give 10-foot contours) and because of the subjective nature of assessing topography for a large area at a small scale, the following classes of slope were approximated:

Level: 0-6%
Undulating: 6-25%
Hilly: over 25%

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Category B. Land Cover (Columns 14-28)

Land cover comprises the earth's surface cover and is distinct from land use (Category C). For this analysis, land cover included:

(1) Open land; land which is undeveloped or vegetated but not forested or wetland.

(2) Urban and built-up; an item used in instances where the degree of urbanization was extensive enough to obscure the original natural surface.

(3) Forested. In many classification schemes, forests are broken down into hardwoods and conifers and then further subdivided into upland and lowland species. Because of the agricultural and open character of the study area, forest cover was generally confined to areas along water-courses and in scattered woodlots; not in large tracts. Detailed forest-type analysis and inventory was therefore not considered necessary in this study. In those areas categorized as "forested," tree crown coverage was generally estimated at least fifty percent. Because the imagery was taken in May and the deciduous trees had no leaves, this percent coverage was approximated from bare, deciduous branches.

(4) Other. This category was used only twice when other categories were inapplicable. Those instances occurred in Cells (10,12) with huge water storage ponds and (12,46) which housed a large power substation.

(5) Wetlands. Because the imagery was flown in May, 1974, following a particularly wet spring season, the wet areas appeared quite prominently on the imagery. No attempt was made to separate forested and non-forested wetlands, chiefly because the deciduous

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trees had no leaves. Seasonally wet areas were also identified but could not be distinguished from all-season wetlands. Ponds and small wetlands were sometimes difficult to differentiate because of the high-water levels. Consequently, ponds were classified as wetlands only when emergent vegetation was apparent; generally in the littoral zone, or edge.

(6) Major Lake; over 100 acres in size (taken from the DNR Classification System).

(7) Minor Lake; less than 100 acres (taken from the DNR Classification System).

(8) Major Stream; the main branch of the Kalamazoo River.

(9) Minor Stream; other water courses with a natural appearance.

Category B. Land Cover - Accessory Information
(Columns 16, 19, 22, 25, 28)

This category applied to lake or river frontage properties only and was intended to express their predominant condition relative to development.

1 - developed
2 - moderately developed; at least cleared of forest cover as in farm areas
3 - undeveloped; natural forest cover along banks remained intact
4 - frontage under construction
0 - information not applicable

Category C. Land Use (Columns 30-44)

Land use represents the principal activities occurring in the study area at the time the imagery was flown. The following land uses were inventoried:

(1) Cultivated cropland; farm land in production with soil tillage or crops evident.

(2) Tree Farm; evident plantings of conifers.

(3) Orchard/vineyard. The pattern for this category is easy to identify when large areas were so used, but small ones were less likely to be correctly identified. It was also not always possible to determine if the orchards were active or inactive.

(4) Urban non-residential: This was used when it was evident that commercial/institutional/industrial or similar non-residential development was present.

(5) Park/playground; determined by presence of athletic fields, baseball diamonds, etc.

(6) Residential; areas in which housing is the principal use. Density of housing was not considered in this category, but residential was indicated only when sizable enough to warrant a decile range in a cell.

(7) Other or undetermined. Often by checking contiguous areas it was possible to get some idea of the activity in question. For example, Cell (04,42) has 60-70 percent classified as other or undetermined. It is a massive construction site and was noted as such in the margin of the coding sheet.

(8) Extractive; presence of sand or gravel surface excavations. This category was checked on USGS topographic sheets, which were used to supplement information obtained on extractive operations. Sixteen sites were recorded from the topographic maps that had not been identified on the imagery. These sixteen sites were subsequently re-checked on CIR photos flown June 4, 1974 at a scale of 1:31,680. The results of the check were as follows:
  - one of the sites in which a gravel pit was supposedly located is now within a massive construction site and is no longer intact; i.e. Cell (04,42)
  - one other site in Cell (01,08) is now a lake surrounded by a subdivision;
  - eleven of the supposed sand and gravel pits are no longer visible. In most cases vegetation covers all all or nearly all of the sites;
  - three sites remained questionable as gravel pits in an active state. These three sites were, however, recorded as extractive.

(9) No Apparent Use/Idle. "Idle" described open areas where vegetation oftentimes was starting to obscure the formerly even edges of farm fields and where various non-cultivated

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plants and trees appeared randomly through the fields. This category also accounted for those areas covered by wetlands, forests and other natural features which appeared to accommodate none of man's activities.

Category C. Land Use - Accessory Information
(Columns 32, 35, 38, 41, 44)

This category provided for the identification of features of land use which could be seen on the imagery, but which were more detailed than the classification components in the principal land use category.

1 - airport
2 - rail station
3 - mobile home park
0 - none

Category D. Drainage (Columns 46-49)

The absence of much vegetative cover and the ability of infrared film to detect moisture differences in the bare soil provided the basis for this comparative category.

(1) Very poor drainage. This designation applies to pond/lake/wetland/watercourse and wherever surface water appeared to be present. Soil if not water-covered, appeared very black indicating a high moisture content. It cannot be assumed that such soils were alluvial, however; only that they were quite wet.

(2) Poor drainage. Tones appeared dark grey but it was evident that drainage was better than in the very poor category.

(3) Moderate drainage. Tone was lighter than in the poor category indicating somewhat drier conditions. Some mottling of soils was also usually evident.

(4) Well drained. Tone of ground was very light indicating dry conditions. Relative to the other assessments of drainage, this is the lightest in tone.

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Category E. Transportation Routes (Columns 52-56)

These were derived from a county map prepared by the Michigan Department of State Highways and Transportation. Accessibility is an essential element in the development potential of any area and the following types of transportation were identified:

(1) US 131 Freeway interchange
(2) US 131 Freeway
(3) paved road
(4) bituminous road
(5) gravel, soil surfaced or similar
(6) divided highway (not a freeway)
(7) railroad
(9) road bridge
(0) no roads

Only the highest quality road in a cell was recorded. The quality ranking of roads as used in the General Highway County Maps by the Michigan Department of State Highways and Transportation (MDSHT) is as follows: freeway, divided highway, paved road, bituminous road and gravel or soil-surfaced. For clarification, the paved road and bituminous road definitions are here given as used to determine General Highway County Map classifications.

> <u>Bituminous Road</u> - An earth road, a soil-surfaced road, or a gravel road to which has been added, by any process, a bituminous surface course with or without a seal coat. The base course of which is a nonrigid type and the combined thickness of surface and base is <u>less than 7 inches</u>.
>
> <u>Paved Road</u> - A bituminous road as described or higher surface type, the base course of which is a rigid type of any thickness or a nonrigid type of such thickness that the total depth of surface and base is <u>7 inches or more</u> in compacted thickness.

The divided highway component, (6) in the inventory was added after much inventory work was completed. As a result, the road quality sequence of the MDSHT was not preserved for this inventory.

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was located on the border of a grid cell it was recorded for that cell. This implies that duplication occurred when two or more cells shared a road at their boundary. As a result, it is not possible to correctly determine the number of roads in the study area by aggregating the roads by grid cell. In addition, if the US-131 limited access freeway was located in a cell, the highest quality road providing local service was also recorded.

Category F. Amenities/Disvalues (Columns 58-62)

This category of occurrence data was incorporated to identify those types of uses which could add or detract from the development potential of a land parcel, depending on the ultimate use of that parcel.

(1) golf course

(2) athletic field

(3) track (race track, go kart, etc.)

(4) junkyard or dump

(5) cemetery; the topographic maps supplied most of this information since grave stones and driveway patterns in small cemeteries could not be accurately identified at this scale.

(6) other; this category was clarified in the margin of coding sheets.

(7) drive-in theatre

(0) none identified

Category G. Residential Settlement Patterns (Columns 64-65)

This category was designed as an aid in recognizing the types of development existing in the area. All density determinations were subjectively derived relative to residential settlement in the study area

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study area only. Each designation of low, medium, or high density is generalized or averaged for the entire cell, eventhough the settlement may be present only in part of the cell. The number of structures in each call were visually approximated and then averaged for each cell. Because an actual count of residences could not accurately be derived, a traditional density figure in number of homes per acre was not given.

(1) Low Density; less than two dwellings per acre. This was the major type of settlement in the test site accounting for 526 of the 576 cells.

(2) Medium Density; between two and five dwellings per acre. A total of 31 cells were included in this category. They were generally located in or near towns like Dorr, Moline, Wayland, Shelbyville, Martin and near Plainwell and Otsego; on good roads near the towns, and peripheral to high density areas.

(3) High Density; six or more structures per acre. Only 8 cells were so identified and recorded. They were either in Plainwell, Otsego or Wayland--the major communities in the test site.

(0) No evidence of residential settlement. This grouping was used when the natural cover of an area appeared intact or was completely farmed and where no structures were discerned. Only 11 of the 576 cells fell into this category.

Category G. Residential Settlement - Accessory Information - Pattern of Settlement

This category of accessory information was developed as an aid in assessing the probable efficiency of residential settlement and the resulting service requirements. The following patterns were identified.

(1) No pattern; used when no settlement was apparent

(2) Scattered

(3) Linear or Strip

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(4) Clustered or Neighborhood

(5) Subdivision. Newer than the neighborhoods, many of the homes which fell into this group were apparently constructed as a unit development.

Category H. Special Concerns

This group represents features identified on the imagery that provide additional insight to the characteristics and potential problems of a particular parcel.

(1) Artificial drainage or channel straightening present

(2) Residential construction in progress

(3) Indeterminate construction in progress

(4) Water impoundment (dam)

(5) Other

(6) Ponds

(7) Eroded areas evident; exposed ground without protective vegetation

(8) Oil well (determined from topographic maps)

Miscellaneous Points Regarding Coding

Copies of the actual coding sheets are shown in Appendix B. The following miscellaneous points should be noted.

1) The information in Columns 58-62 concerning transportation facilities was gathered from the Allegan County Highway map produced by the Michigan Department of State Highways and Transportation in September 1969.

2) On the original coding sheets the information gathered from the USGS topographic maps was recorded in blue to distinguish it from information derived from the remotely sensed imagery.

Reproduction of the color differences was not possible for this text. Color coding may be of advantage to other users of this system, however, and should be considered.

3) Space for general comments was available on the left side of the coding sheets preceding the columns with coding data. This area was often used to document information recorded as "other." For example in Cell (02,43) a sewage treatment plant was identified and recorded under the Amenities/Disvalues category as "6-Other," but was documented in the area to the left of Column 1.

4) Gravel and sand pits were often suspected from the imagery and were re-checked on the topographic maps. Oil wells and some sand and gravel operations were recorded from the topographic map that had not been seen on the imagery. Subsequent checks of the data recorded from the topographic maps concerning such features generally indicated that information on these maps was largely outdated in relation to sand and gravel excavations.

5) In Columns 52-56, if more than one railroad was identified in a cell, the code for railroad (7) was recorded more than once.

6) In certain instances it was difficult to determine whether or not seemingly idle or unused fields were cultivated and lying fallow, or used as pastureland, or permanently idle. In most situations of this nature, the assumption was made in favor of an agricultural use and assignment of deciles reflected this assumption. It was considered preferable to say farmland was producing than to assume it permanently idle.

Field Checks

A total of three field trips were made to the test site during this study. The first was made in June of 1975 before any photo interpretation was done. The purpose of this first trip was to become acquainted with the study area on a very general basis and to obtain an idea of the character of the environment. This field trip consisted of a "windshield survey" only.

The second and third field trips were made in August and October of 1975, respectively. Each trip was made with specific sites identified for checking. The sites checked on the October 12 field trip are given in Table 6.

Table 6. Examples of Field Checked Sites.

Cell Number	Apparent Use From Imagery	Correct Use	Accurate Initially
07-02	junk cars	Auto junkyard	yes
06-03	junkyard	Auto junkyard	yes
07-09	cemetery	Go-Kart track	no
08-15	junk cars	Packing Co. with Truck bodies scattered	no
07-21	wetland	NOT ACCESSIBLE	--
12-21	landfill	dump with exposed sand	no
08-31	lake or wetland	lake	yes
06-34	junkyard	dump	yes
10-36	landfill	abandoned excavation	no
08-38	multi-family	farm buildings	no
04-42	Construction site	Construction site	yes
07-42	dotted area	Skeet and trap shooting range	no
12-18	marl deposits	INACCESSIBLE	--

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Summary

An inventory or classification system was developed for use in the study area with small scale color infrared imagery. Eight major inventory categories were established, namely: relief, land cover, land use, drainage, transportation routes, amenities/disvalues, residential settlement patterns, and special concerns. Inventory data was gathered in a four step process which involved dividing the study area into one-quarter mile-square grid cells, correlating the photo grid with actual ground locations, numbering the individual grid cells with X and Y coordinates, and recording all interpreted data for each grid cell in a computer coding sheet format. With the exception of topographic and transportation route information all data was obtained from small-scale color infrared imagery. Data generated from this inventory provides the basis for the environmental analysis in Chapter V which follows.

FOOTNOTES

[16] Michigan Department of Natural Resources, Michigan Land Use Classification System - Part 3 (Lansing, Michigan: Michigan Department of Natural Resources, February, 1974).

[17] R. Shelton and E. Hardy, Design Concepts for Land Use and Natural Resources Inventories and Information Systems (Ann Arbor: University of Michigan, 1974), p. 3.

CHAPTER V

EVALUATION OF THE PHYSICAL ENVIRONMENT OF THE STUDY AREA AND IMPLICATIONS FOR DEVELOPMENT

This chapter presents an evaluation of the physical environment in the study area based on data gathered from the inventory and analysis method in Chapter IV and describes the method used to make the evaluation. Although the state-of-the-art review of environmental analysis methods in Chapter II revealed that an abundance of methods have been developed, procedures for actually evaluating data obtained from various inventories are obscure. In the case of evaluating data derived from remotely sensed imagery there is very little written on procedures which have previously been tested that can be applied to planning in large areas undergoing urban expansion. This chapter describes such a procedure.

The most important land use trend in the study area for the next several years will be increasing urbanization. The location of urban development will have a significant impact on agriculture, recreation, and the entire natural resource base. It is therefore important to understand the existing natural and urban conditions, and their probable interactions which might affect the location and soundness of development. It is readily acknowledged that interpretations and evaluations made herein will serve only in an advisory and educational role in the eventual location of development. Future development in the study area will result from a complex interaction of political, economic, cultural, institutional and environmental factors. In consideration of this fact, no attempt has been made to identify a particular quantity of land that will be or should be developed. As Anthony Downs stated,

> Urban development and growth involves dozens of important variables each of which could reasonably take on several different future values. Some of these variables are:
>
> 1. Location of new growth in relation to existing metropolitan areas.
> 2. Contiguity of new growth to smaller existing communities located beyond the continuously build-up portions of metropolitan areas (including outside such areas).
> 3. Type of planning control.
> 4. Level of quality standards required in new constructions.
> 5. Degree of public control over new urban development.
> 6. Degree of public subsidy for new urban development.
> 7. Distribution of housing subsidies among various income groups.
> 8. Degree of social class integration.
> 9. Degree and nature of racial integration.
> 10. Mixture of transportation modes.
>
> Just considering these ten variables, and several arbitrarily chosen values for each one, yields at least 93,322 logically possible combinations--each representing a potential form of future urban growth.[18]

Environmental constraints may also be considered a variable in development decisions and it is with such environmental constraints that this chapter is largely concerned. The analysis which follows is presented in two parts. Part A provides background information on the interactions between development and the natural environment.

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It is presented on a category by category basis as followed in the inventory of Chapter IV, and applies conventional interpretations of development constraints where appropriate. Part B provides a five-step method for evaluating the inventory data and assesses the environment of developing locations in the study area to illustrate use of the method.

Interactions Between Development and the Environment

Category A. Relief

In analyzing topographic variation in the study area, broad ranges of slope were recorded: 0-6 percent (level), 6-25 percent (undulating), and over 25 percent (hilly). Slope classes commonly used in soils mapping in Michigan are much more detailed as follows: A = 0-2 percent, B = 2-6 percent, C = 6-12 percent, D = 12-18 percent, E = 18-25 percent, F = 25-35 percent, and G = over 35 percent (Whiteside, Schneider and Cook, 1968).

The very broad ranges used in this study were selected because of variations in scale of United States Geological Survey topographic maps covering the area. Most of the area was covered on the small scale (1:62,500), fifteen minute quadrangle. In addition, it was necessary to generalize relief over the basic data unit, the grid cell, which was one quarter mile square. Such generalization could be rapidly made with the broad ranges of slope.

In general, the topography in the study area has relatively little variation. There is less than a 200 foot difference in elevation between the lowest and highest points in the 144 square mile study area. The lowest point is an elevation of 695 feet in Section

23 of Otsego Township on the banks of the Kalamazoo River. The highest elevation is 885 feet and is located in Section 29 of Wayland Township.

Information gathered on relief in this study is not sufficiently detailed to permit site planning but it does enable one to visualize the topographic character of the site. This capability becomes important when determining developable areas since different uses require differing terrains. Scenic sites with rolling to hilly surroundings are a particularly valuable resource in the study area since most places are level.

Slope is a significant factor in urban development since building costs generally increase with steep slopes. In addition, accelerated erosion becomes an important concern in areas of steep slope cleared of stabilizing vegetation. Farming likewise is poorly suited to such areas. No arbitrary determinations of which slope can or cannot be developed are here advanced. As Carl Steinitz noted,

> Topographic slope is a prime example of an objectively measurable variable used in a variety of interpretations, notably for its impact on urbanization. The cut-off point between "good" and "bad" slope for urbanization ranges anywhere from 9 to 45 degrees. Thus it appears not to be the data inventory which distinguishes a method, but interpretation of the data.[19]

Category B. Land Cover

The surface of the study area as seen from the air and recorded in the inventory of Chapter IV, consists chiefly of open land, woodlots, wetlands, urban/built-up areas, lakes and streams. This relatively simple categorization of the study area's major land cover features can be very useful in a variety of ways.

The inventory data in this category can assist in understanding the hydrologic regime of the area. For example, areas with vegetative cover are able to hold precipitation and facilitate its percolation into the soil. Conversely, areas where vegetation has been removed or where the surface has been sealed, cause increased rates of runoff and consequently decreased groundwater recharge.

The various types of land cover represent habitats for different species of plants and animals. The amounts of such land areas are important in determining wildlife support capabilities. Transitional or interface zones between cover types such as open fields and woodlots are generally supportive of a highly diverse plant and animal community. This is known as the "edge effect" and indications of the areas likely to support wildlife can be obtained from the inventory.

Forested areas or woodlands play an important aesthetic role in the countryside and near developments. They moderate the effects of wind, and temperature, absorb certain air pollutants and may serve to buffer noise. Woodlands stabilize soil and slow runoff from precipitation.

Wetlands are perhaps the most critical natural feature in the environment. In those few cases where wetlands are found adjacent to a lake, particular care should be taken for their protection. Dr. Christa Schwintzer of the University of Wisconsin described the relationship of wetlands to lake water quality in the following manner.

> Wetlands are important in determining the quality of lake waters and the seasonal flow rates into the lakes. In addition, they affect the quality and quantity of stream flow and ground water. They improve water quality by filtering out wastes and breaking them down into simple inorganic compounds

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> which can be taken up by the vegetation. Wetlands also regulate the seasonal flow of water by storing water temporarily during periods of high input due to snow-melt and rainfall, discharging it during periods of low input. The effectiveness of individual wetlands in performing these functions depends on many characteristics including size, location, soil, vegetation, and relationship to the regional water table.

Aside from the value of wetlands for water quality and their obvious use for waterfowl habitat, wetlands are important to urban areas. If located upstream of an urban area, wetlands store surface runoff and help alleviate the threat of floods. The soils or substratum in a wetland are generally organic and require extensive and costly modification in order to support foundations. Also, the location of the water table in wetlands can serve as a relatively rapid indicator of groundwater levels and the feasibility of successful septic tank operations.

Streams and creeks are highly valuable as well. Aesthetically, a high quality stream environment draws recreational enthusiasts. Functionally, though, streams are a seasonal source of groudwater recharge. They represent corridors for the migrations of birds, waterfowl, and various land animals. Development of a watershed often leads to increased runoff and sedimentation which can result in irregular water flows in the streams as well as irregular groundwater recharge.

Lakes are even more susceptible to the negative impacts of such development and are prime attractors for this development, which often takes the form of second homes on the lakefront. The study area is bounded by urban centers of employment, and pressure for lakefront development in the currently rural settings is sure to increase. The evidence of lakefront and other shoreline development was recorded in the inventory.

Category C. Land Use

Existing use of land in the study area has been inventoried as principal activities that can be rapidly identified on small scale color infrared imagery. Because activities conducted on any single parcel of land can influence activities conducted on nearby parcels, an important consideration in locating development is compatibility with surrounding land. The land use category provides for a rapid identification of various types of activities and can be used to assess probable compatibility of proposed developments with existing uses.

The principal land use in the study area is agriculture. Much has been written about the increasing encroachment of urban development into some of the best agricultural land in the nation. The trend is similar in Michigan. As Whiteside and Schaner stated,

> Cities were initially developed on or near the best agricultural land because during this formative period of city growth, Michigan had an agrarian economy. Food (particularly bulky and/or perishable produce) could be marketed near where it was produced without spoilage in transit.[20]

As the labor demands of agriculture decreased and rural to urban area migration accelerated, the swelled populations of cities forced expansion and "as a consequence, the urban area growth has covered much of our better farmland."[21]

Substantial acreages of farmland in Allegan County have been lost to agriculture. In 1959, 324,000 acres were farmed. By 1964 the figure had dropped to 288,000 acres; by 1969 to 275,743 acres; and by 1974 to 265,134 acres. The value of agriculture and agricultural land seems likely to increase. Protection of existing farmland in the study area thus becomes an important objective.

Category D. Drainage*

Because of the geologically young age of the study area surface dating back 20,000 years and its flat to undulating topographic character, there is no well developed surface drainage pattern. Many depressions and wetland areas are found as are a few meandering streams. Artificial surface drainage ditches and tiled fields are clues to the often poor internal drainage of the soil. On the color infrared imagery in some areas a pronounced mottling is apparent. It is especially evident in well developed farm fields where vegetative cover has not yet emerged. Such mottling is characteristic of young glacial till or ground moraines. The mottled soil tones are caused by differences in reflection of sunlight due to the varying moisture content of the soil. As a general rule in this type of landform, "a slow gradation of light to dark tones between mottles indicates fine materials; sharp changes indicate coarser materials."[22] Similarly, soils on rises as small as two to three feet are generally drier and hence lighter in tone. Surrounding areas at a lower elevation are wetter and appear darker.[23]

The study area was photographed when crop cover was minimal (early in May) and water tables were high. The layout of fields, the existing vegetative cover and land uses of the area are all characteristics of "thick Midwestern till deposits of the Wisconsin

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*The interpretive information for this category is drawn largely from Terrain Analysis by Douglas Way, 1973.

age (that) are typically under agricultural use."[24] The fine-grained soils, particularly those in the darker toned depressions, have a high moisture content and generally low strength. It cannot be assumed that the darker depressions contain alluvial soils, only that the soils are wet. In such areas, barring availability of detailed soil analyses, careful planning and design will be required to avoid unstable foundations.

Areas documented as having large expanses of poorly drained soils, should be immediately suspected as sites in which septic tank leaching fields would be difficult to establish. Sanitary landfill sites will similarly be ill-suited to such wet areas. Ponds are generally easy to create owing to the often impervious nature of the soils, high water table and many natural depressions. The abundance of existing ponds primarily on farmsteads, gives testimony to this capability. Ponds in the study area were inventoried under Category H.

Much of the study area is comprised of outwash. Surfaces are generally quite flat and may be pitted. Several pitted areas have been indicated on the coding sheets in the left margin. Such pits were created when ice blocks from the glacier were buried and eventually melted. The pits are often steep sided and contain water or organic material. Soils in such areas are usually quite permeable and well drained internally. Areas around the pits are generally intensively cultivated. What often appears on the CIR as a silhouette-type pattern of drainage channels, may well be the ancient channel scars of glacial drainage. These areas generally contain more fines and organic material. Soils in the outwash are anticipated to be coarse as compared to the finer texture of soils in till plain areas. Concerns in regard to sewage disposal in such areas are related chiefly to the depths to groundwater table and how rapidly effluent might percolate to the groundwater supplies. For that reason, the mixture of granular materials, landfill sites are likely ill-suited since leachate may contaminate groundwater.

Sand, gravel and aggregate are usually available in outwash areas. Foundations for residences can be provided in such areas because of the moderate load bearing capacity of soils.

Some glacial lake bed deposits are found in the extreme southern portion of the study area in the vicinity of the Kalamazoo River. This area is quite flat and much is cultivated reflecting the moist and highly productive quality of the soils. Water table is likely high and artificial drainage is often necessary. Conditions are generally unsuitable for septic tank leaching fields. Intensively developed areas generally require sewage treatment facilities to protect surface water quality. Sanitary landfill operations are possible due to the fine texture of lakebed deposits but only if the depth to water table is sufficient to insure protection against contamination. Sand, gravel, aggregate and borrow are usually unavailable in such areas. Siltation is a critical problem because of the easily erodible fine silts and clays.

In an area like western Allegan County which lacks a comprehensive, up-to-date soil survey, CIR imagery flown early in the spring when water levels are high, and vegetative cover minimal, provides drainage data which would otherwise be unavailable.

Category E. Transportation Routes

Among the factors which interact to determine the development pattern of an area, accessibility is a primary consideration. As Marion Clawson noted,

> No piece of land stands alone; perhaps none ever did and certainly none does in a complex society and economy such as we have in the United States. The externalities of a piece of land usually affect the activity on it more than do its internalities. We typically live, work, shop and play on different tracts of land, many of which we share with others, who in turn use still other tracts. The many and complex interrelations between different tracts of land are made possible only by methods of transportation of goods and persons and by methods of exchanging ideas. The access that a piece of land has to other tracts may affect the activity on it, and its value, more than any characteristic of the piece of land itself.[25]

The study area in Allegan County is one of the most accessible areas of the entire state. Nearly all grid cells inventoried are served by some type of road. Railroads and airports are also present. The major transportation facility in the study area is the US-131 freeway. This arterial extends from the Michigan/Indiana border northward to Petoskey where it joins US-31 en route to the Straits of Mackinac and the Upper Peninsula of Michigan. Within the study area, US-131 is a limited access freeway with interchanges spaced at varying intervals. The limited access character of the road precludes service to local traffic and subsequently in grid cells containing segments of the freeway, the highest quality, non-freeway road was also inventoried.

The impact of transportation networks on the natural environment is both direct and indirect. Direct effects of construction and placement are of no concern in this study because the transportation facilities are already in place. The significance of transportation facilities is therefore most related to their indirect effect on natural features; i.e. allowing people ready access to those features.

Category F. Amenities/Disvalues

Certain cultural features which have been introduced to the landscape can act to benefit development in a positive or negative manner. Such features which could be identified on the color infrared imagery included: golf courses, athletic fields, tracks, junkyards, cemeteries, and drive-in theatres. The value of such features near a site depends on the intended use of that site. Junkyards would be considered a disvalue when located near residential development, but might be of benefit near a recycling operation.

Cagegory G. Residential Settlement Patterns

The importance of residential settlement patterns to developers, local governments and others required to service such settlements has been extensively explored in recent publications such as The Costs of Sprawl by the Real Estate Research Corporation. Identification of the approximate densities of residential settlements and the spatial pattern they exhibit can provide information on the efficient or inefficient use of space, permit cost estimates of servicing such settlements if they expand, and can provide insight into the historical development of the area. In conjunction with information contained in Category H concerning construction activities, development trends can be assessed.

Category H. Special Concerns

This category represents potential problems or advantages to development that would generally require additional investigation. For example, the presence of artificial drainage canals or straightened drainage courses should indicate that an area has had drainage problems and that additional information should be secured prior to considering development. Construction activities indicate potential erosion and sedimentation problems and loss of land such as farms to development. The location of ponds gives a clue to impermeable soils and can provide information relative to studies of insect breeding (e.g. mosquitoes). In addition, in rural areas which depend upon volunteer fire departments, location of ponds as water sources for fire fighting is an obvious benefit. Essentially, these "special concern" items should be viewed as "flagged" items requiring further study.

Analysis Method and Application to Study Area

This portion of Chapter V presents the analysis of inventory data generated in Chapter IV for the study area. It illustrates a five-step method for assessing development activities and general environmental conditions in the study area. It permits rapid identification of potential problems based on a general understanding of the interactions between development and the natural environment as explained in the first part of this chapter.

All data recorded on the inventory coding sheets was reviewed during this phase of the research. The review consisted of a series of steps developed to identify primary activities or natural features and indications of development-related problems. Because the study area is primarily agricultural, STEP ONE was devised to screen out those cells with obvious urban development activity or natural sensitivity.

STEP ONE. The data coding sheets were scanned to identify cells with the following characteristics which were established after reviewing the inventory data for the study area:

(a) "Urban and Built-Up" covering 20 percent of a grid cell or more indicating developed areas;

(b) "Urban and Built-Up" covering less than 20 percent indicating areas in the process of developing;

(c) "Major Lakes," those over 100 acres in size, and all lakes with developed frontage illustrating areas of existing or probable recreational development pressure;

(d) "Wetlands" of 20 percent and larger representing a naturally sensitive feature; and

(e) "Forested" areas of 40 percent and above; a valuable resource in this study area which generally lacks sizeable wooded areas.

Cells with these characteristics were identified on a map (Figure 12) of the study area in different symbols to be later analyzed in greater detail relative to activities occurring in those individual cells and in surrounding cells.

STEP TWO consisted of a review of the remaining 77 percent of the cells not screened out in step one, in order to assess the general conditions in what were most often agricultural lands, and to identify any indications of development. The following examples illustrate the types of assessment made for cells involved in this second step.

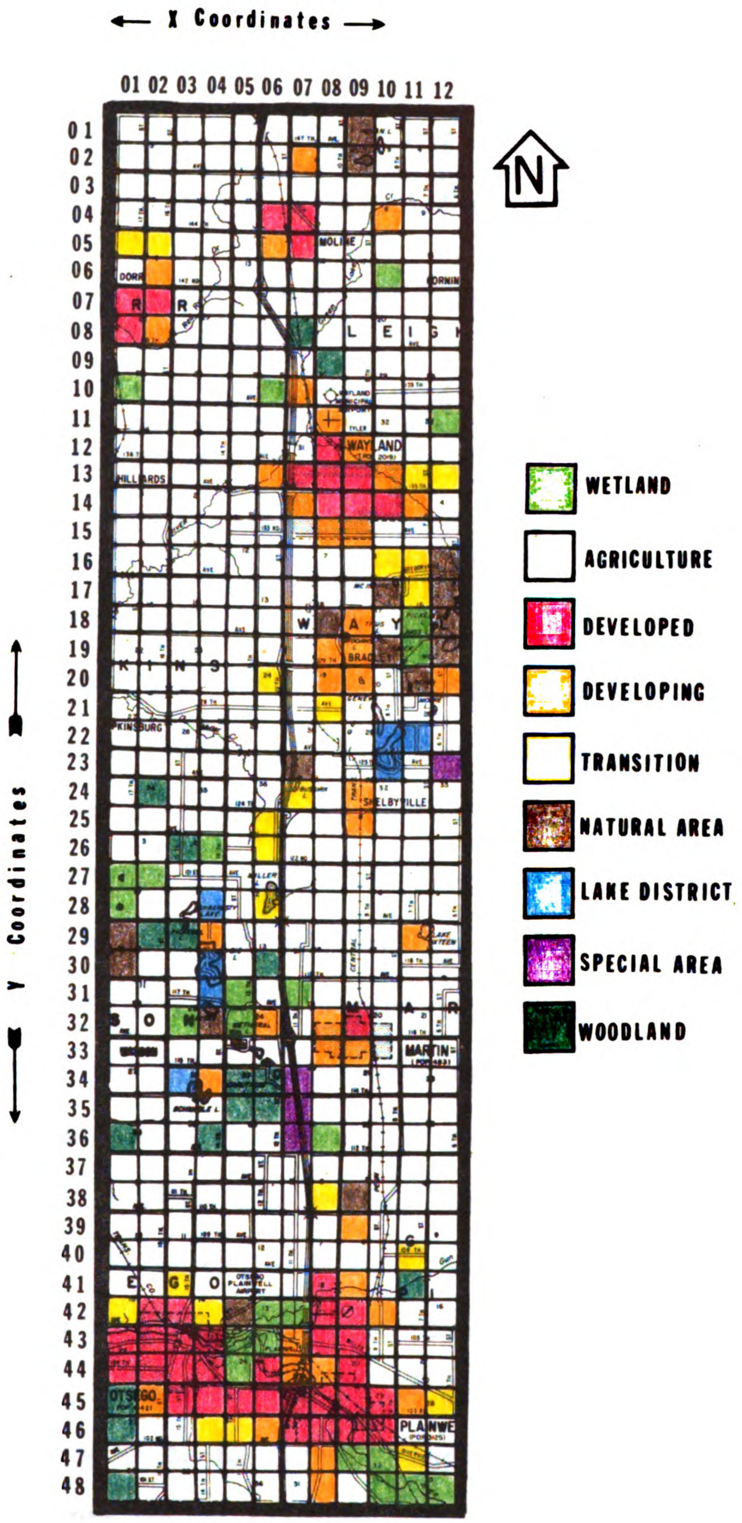

Figure 12. Evaluation Map of the Study Area.

Cell Number	Assessment Based on Interpreted Data
(01,01)	All open land, all in cultivation, all well-drained, though artificially assisted.
(01,02)	80-90 percent agricultural; small wetland and wooded areas about 10-20 percent of total; slight drainage problems and some areas of relatively high water table; area is artificially drained and contains a cemetery.
(01,03)	Mostly agriculture but shows evidence of residential use in a linear pattern.
(01,04)	Cell is chiefly open land with small areas of wetland and woods. Only a small percentage is being cultivated. Most of the area is well-drained.
(01,05)	This cell appears well suited to agriculture but only 20-30 percent is in cultivation. Residential development is evident in a linear pattern and residential construction is taking place.

The illustration of assessments, points out that not all categories of information on the coding sheets were included in assessing each grid cell. The rationale behind this omission was that not all categories of information were important in all cases. For example, limited areas of wetlands or woodlots in the midst of agricultural fields were not considered detrimental. In view of the fact that large acreages are often cultivated in just such admixtures of open, wooded and wetland features, their viability as farms was assumed to be only minimally affected. In addition, the mixture of habitats provided for wildlife in such situations could be assumed beneficial. As a result, unless extensive acreages of wetlands (over 20 percent) or woodlands (over 40 percent) were observed they were not considered to be barriers to agriculture, nor was agriculture considered detrimental to them.

When no natural barriers to the dominant agricultural activity were observed, and in the absence of urban encroachment which generally took the form of linear residential development and residential construction activity, the cell was coded as agricultural on the map noted in Step 1 (Figure 12). The cells so coded were generally at least 40 percent cultivated.

STEP THREE provided for treatment of cells remaining after steps one and two. These cells for various reasons could not be neatly categorized either as agricultural or as having characteristics outlined in Step One. These remaining cells fell chiefly into two groups. The first were cells with a strong mixture of water, woodland, wetlands and sometimes a small amount of residences and agriculture, which appeared likely to provide diverse habitats for wildlife and serve as "natural areas" amidst the vast agricultural acreage in the study area.

The second group consisted of cells which appeared to be in a transition stage from rural to urban use. These cells did not yet show evidence of "Urban and Built-Up" features as categorized and defined under the Land Cover Category, but had linear patterns of residential settlement and/or residential construction and high percentages of idle land when agricultural suitability seemed high. These cells were generally located adjacent to or nearby cells with development or in areas with great amounts of natural amenities such as lakes and other natural features. Cells which fell into these groups, Natural Areas and Transition Areas, were coded on the map.

STEP FOUR. Having screened the inventory data for all the cells and having attained a map with a representative symbolization for each cell, it was possible to visualize individual cells as parts of the overall study area. Subsequent to this, it was also possible to identify probable sources of conflict with neighboring cells. This is an essential element of the analysis and was determined to be most easily evident when a map was employed. The map serves to draw the individual data cells together and permits a view of the total area.

STEP FIVE. Having assembled a map of selected conditions in the study area, a detailed analysis of those regions with urban development and those regions with natural amenities or sensitivities was begun. Areas of extensive, contiguous agriculture were not further analyzed except where they were proximate to different uses or natural features. Based on the preponderance of land in cultivation, the suitability of the region for agriculture as discussed in Chapter III, and the increasing importance of agriculture to Michigan, the assumption was made that agriculture when not in conflict with other uses or natural features, is the highest and best use of land in the study area. The detailed analyses and implications of community-related and non-community-related development follows.

Analysis of Community-Related Development

The status of existing development and the types of expansion in progress were analyzed for the communities of Dorr, Moline, Wayland, Bradley, Shelbyville, Martin and Otsego-Plainwell. These communities were analyzed geographically as they appeared on the color infrared photography without regard to political boundaries such as village limits.

Grid cells in the study area which housed development were identified in Figure 12 as either "developed," "developing," or "transition" areas. The analyses of the communities in the study area concentrate on these cells and consequently their definitions are here repeated.

Developed Cells: Those grid cells with at least 20 percent of their Land Cover category inventoried as Urban and Built-Up.

Developing Cells: Those grid cells with less than 20 percent of their Land Cover category inventoried as Urban and Built-Up.

Transition Cells: Those grid cells which did not yet show Urban and Built-Up features but which had linear patterns of residential settlemtnt and/or residential construction and high percentages of idle land when agricultural suitability appeared high. These cells were generally located near other development cells or in areas with substantial amounts of natural amenities such as lakes or other natural features.

Dorr

Development in the community of Dorr consists largely of residential subdivision type development. Developed areas include cells (01,07), (02,07), and (01,08). These cells are located in Section 22 of Dorr Township. There are virtually no wetlands in these cells and less than 10 percent of the area might experience high water tables during spring. Drainage improvements have been made in the area. The community contains a minimal amount of woodland and one small lake with developed frontage. Approximately 30 percent of the area is still farmed and about 20 percent remains open.

Developing areas of Dorr, those with less than 20 percent classified as urban and built-up, occur in cells (02,06) and (02,08). The major development in Cell (02,06) consists of a mobile home park. Much of the remainder of the cell is either farmed (50-60 percent), wooded (20-30 percent), or open and apparently inactive. Cell (02,08) with the exception of the 10-20 percent in linear residential development, is being farmed. Again, only minimal areas appear to have seasonally high water tables.

Development trends in Dorr appear to be occurring to the north of the cells just mentioned. Cells (01,05) and (02,05) have been identified as transition areas. While both cells appear quite suited to agriculture, only 20-30 percent is being cultivated in cell (01,05) and no cultivation was apparent in (02,05). Linear residential settlement patterns are in evidence as is residential construction. Cell (01,06) which is effectively surrounded by developed and developing areas has apparently maintained its agricultural integrity to date. 70-80 percent remains cultivated but residential settlement has assumed a linear configuration.

Summary Analysis

The community of Dorr has etched out an area of approximately two square miles in the study area as its "zone of influence." Development is not occurring in a spatially efficient manner. Dorr appears fortunate with its relatively level terrain and minimal drainage problems. It lacks, however, many natural amenities and should take precautions for protection of the limited wooded acreages it has. Development trending to the north appears wise in view of the wetland area located to the south in Cell (01,10).

Moline

Developed portions of the community of Moline are centered in cells (06,04), (07,04) and (07,05) which includes parts of Section 12 in Dorr Township and Sections 7 and 18 in Leighton Township. With the exception of 10-20 percent of cell (06,04), urban and built-up development is residential. This development is chiefly of a neighborhood or cluster type in (06,04) and less dense with a linear pattern in (07,04) and (07,05). The area is almost entirely open land and the urban uses are intermixed with large acreages of agricultural land. There appear to be no drainage problems.

Developing areas, those with less than 20 percent classified as urban and built-up are located in cells (07,02) and (06,05). Cell (07,02) contains a small lake and a small amount of wetland. Drainage implications of development should be carefully studied near these areas. Residential development has assumed a linear pattern in this cell but agricultural acreage is still substantial (70-80 percent). An additional indicator of development is the junkyard or dump located in the area.

Cell (06,05) has a limited amount of woodland (10-20 percent) and large agricultural acreage. A linear pattern of development is apparent here also. No significant drainage problems are anticipated.

Cell (07,03) appears sandwiched between two developing cells. It is almost totally cultivated and appears to have escaped encroaching development thus far.

Summary Analysis

Development in Moline appears less extensive than in Dorr but indications of non-contiguous development of the area may create efficiency problems in terms of energy and services. Moline lies in a very level area and appears to have few drainage problems. Likewise, as in the case of Dorr, it has few natural amenities and should explore methods for protecting the water bodies and woods it has.

Wayland

Wayland is one of the largest communities in the study area and a large number of grid cells reflect its influence. Developed areas include the following cells: (08,12), (07,13), (08,13), (09,13), (08,14), (09,14) and (10,14). Developing areas include cells (07,10), (08,11), (09,12), (06,13), (10,13), (07,14), (11,14), (08,15) and (09,15). These cells essentially circle the developed cells. Transition areas are located in cells (11,13) and (12,13). The total area influenced by Wayland in terms of development is approximately four and a half square miles.

Urban and built-up areas in developed cells account for over fifty percent of the land surface. Land uses consist chiefly of residential development (35 percent) in densities and patterns ranging from low density scattered, to high density clustered. Another 20 percent of the cells are devoted to urban non-residential uses, 10 percent to agriculture and 35 percent are inactive. Very few wetlands are found in the area and drainage assessments indicate few drainage problems should be encountered relative to high water tables in spring. Nearly 9 percent of the developed cells are wooded and provide a valuable resource for the community. Virtually all cells in this category show evidence of construction activities in progress.

Developing cells show different characteristics than do the developed cells just discussed. There is a greater amount of wetland (4 percent) and wooded area (15 percent). Open areas constitute 77 percent of the total surface and 10 percent is urban and built-up. Land uses are also different with several cells containing identifiable percentages of urban non-residential and lacking significant residential development. These cells also show greater percentages of active agriculture (43 percent). Residential settlement in most of these cells is of a low density, linear or strip pattern. Construction activities appeared to be occurring in over half of the developing cells. Drainage conditions will require more careful analysis relative to accommodating additional development in these cells than appeared needed in the developed cells. Provision of buffer zones for the Wayland airport in Cell (08,11) should also be explored.

The fact that only two cells have been placed in the Transition Cell category while many were placed in the developing cell category, indicates the more rapid pace at which development has been generated from Wayland's main area of urbanization than was the case in the communities of Dorr and Moline. The transition areas of Wayland lie west of existing development. Cell (11,13) closest to existing development exhibited residential construction activity and a linear pattern of settlement. Agriculture has maintained a strong position thus far, accounting for 70 to 80 percent of the land use. Cell (12,13) does not yet display the linear settlement pattern characteristic of the transition areas analyzed previously. It does however, show evidence of residential construction activity and has a high percentage of inactive land which appears for the most part, to be otherwise suited for agriculture.

Summary Analysis

The urban development associated with the community of Wayland is the most expansive yet analyzed. Partially because of its size it has greater natural amenities like streams, woodlots, and wetlands, than do the other communities reviewed. This engenders a responsibility for protection of these resources but also provides the opportunity for development of a very attractive community.

Existing development in the area also appears more balanced between urban residential and urban non-residential. The similarity of natural features in the developing and transition areas and the abundance of undeveloped land remaining available in the developing and developed cells, indicates that the expansiveness of development that is occurring, is an unnecessary consumption of land from a physical environmental perspective.

Bradley

Urbanization in the community of Bradley consists almost entirely of residential development. All of the cells where development is occurring (08,19), (08,20), (09,18) and (09,19) were categorized as having "urban and built-up" areas of less than 20 percent of their total size.

Cells (08,19) and (09,19) contain a small lake with moderately developed frontage. The rest of the lake frontage in cells (09,19) and (09,20) is undeveloped. Patches of wetlands occur in the cells and drainage studies would be required to safely accommodate development. Residential patterns in the area are primarily linear in character. Cell (08,20) remains mostly agricultural but the other cells are 50-60 percent inactive.

Development trends in Bradley appear to be moving south of existing development. Cell (08,21) has a relatively high proportion of inactive land (50-60 percent) and exhibits a linear pattern of residential settlement.

Cell (09,20) which was identified early in the screening process since it contained at least 20 percent wetland, also appears to lie in the path of development. Cell (09,20) contains an undeveloped lake, 20-30 percent wetland, and 30-40 percent woodland. Thirty percent of the area is in agriculture but construction activities (residential) and a linear pattern of existing residential settlement are evident.

Summary Analysis

Bradley can be characterized as an area of sprawling residential development located in a region with rolling topography and a diversity of natural features. The apparently random development taking place, however, may threaten the integrity of the natural features. The need for further studies is clearly indicated to determine methods for protecting the natural environment while accommodating sound development. The nearness of the developing cells in Bradley to the lakes and wetlands further west, provides a clue and a warning of the probable hydrologic interconnectedness of the entire area.

Shelbyville

Development in Shelbyville is found in two cells, (09,24) and (09,25) and is chiefly residential in nature. The existing development is of moderate density and is in neighborhoods and along roads. A railroad runs through both cells. Ten percent of the Shelbyville area is wetland and 70-90 percent is open. Agriculture dominates outside the residential areas accounting for 70 to 90 percent of land use. Drainage problems occur in the wetland areas but seem restricted to those areas. Development pressures outside these cells appears limited since no transition areas were identified.

Summary Analysis

Based on information provided in this inventory, Shelbyville appears to be a spatially efficient community. The lack of evidence of expansion may indicate stability or stagnation. Additional information about this community is required in order to ascertain the actual status of growth. Particularly informative data might concern Shelbyville's fiscal status and environmental stability. Although beyond the scope of this research effort, Shelbyville might provide a case study in efficient use of space and environmental compatibility in a rural setting.

Martin

Development in the community of Martin is most concentrated in Cell (09,32) and is less extensive in Cells (08,32), (08,33) and

(09,33). Cell (09,32) is chiefly residential (20-30 percent) and agricultural (70-80 percent). Settlement is moderately dense and located in small neighborhoods. Development in Cell (09,33) is somewhat lesser in size but contains more urban non-residential development. Residences have developed linearly and most of the remaining area of the cell is used for agriculture. This type of situation is expressed in Cell (08,32) and (08,33) but Cell (08,32) also contains a mobile home park. A minimal amount of Martin is wetland, not more than five percent and drainage problems appear restricted to those wetland areas. There is a minimal amount of wooded area as well, only about one percent. Some construction activity was evident in Cell (09,33).

Summary Analysis

Development in Martin seems to have maintained compatibility with agricultural pursuits in the area. Approximately 80 percent of the area is under cultivation while most of the remainder is developed. Densities of linear residential settlement in Martin are generally higher than those in other "developing" cells previously analyzed, which points to somewhat increased spatial efficiency. No significant environmental constraints were evident in the level terrain of Martin. The area lacks much natural feature diversity and could be easily characterized as an agricultural town.

Otsego/Plainwell

Because of the contiguousness of developed land between Otsego and Plainwell, this area is being here considered as a single development area. Twenty-nine grid cells or seven and one-quarter square miles were classified as developed. These cells include: (01,43), (01,44), (02,42), (02,43), (02,44), (03,42), (03,43), (03,44), (03,45), (04,43), (04,44), (04,45), (05,45), (06,44), (06,45), (07,45), (07,46), (08,41), (08,42), (08,43), (08,45), (08,46), (09,42), (09,43), (09,44), (09,45), (09,46), (10,45), and (10,46). As a group, these developed cells comprise an area that is 56 percent urban and built-up, 40 percent open, 3 percent wooded and 1 percent wetland.

High water tables and drainage problems are encountered in various sections of Otsego/Plainwell but are most prominent along the Kalamazoo River. Several athletic fields, tracks and cemeteries are located here where over twice as much area is devoted to residential use than urban non-residential uses. Farming still plays an important role in these developed areas where it accounts for approximately 15 percent of land use. Residential settlement patterns are chiefly neighborhoods, linear or strips, and subdivisions. Several cells show construction activities in progress.

The following cells were categorized as developing in the Otsego/Plainwell area: (02,45), (06,46), (07,43), (07,44), (08,44), (08,47), (08,48), (09,41), (10,42) and (11,45). All these cells have level terrain, more woodlands and more wetlands than the developed cells. Agriculture is much more prominent, accounting for 50 percent of land use. What is apparently idle land accounts for another 34 percent of the land use; 17 percent is urban and built up. Half of the cells show evidence of construction in progress and the residential settlement patterns are low to moderate density linear development with scattered and neighborhoods accounting for the remainder. Several cells have had drainage improvements and several have ponds.

High water tables and potential drainage problems must receive additional consideration in these areas for the sake of water quality and urban safety.

Seven cells were classified as transition cells with all but one showing linear patterns of residential settlement. These cells include (01,42), (03,41), (04,42), (04,46), (05,46), (11,47) and (12,45). These cells are located on the periphery of existing development. Topography is more variable than in the developing cells and open areas account for 86 percent of the total area with 11 percent wooded and 3 percent wetland. Land use is primarily agricultural (53 percent) with another 30 percent apparently idle. High water tables and wetlands are scattered and must be further studied before locating additional development. Construction activities are evident in over half of the cells.

Ten cells contiguous to cells with development in the Otsego/Plainwell area contain 20 percent or more wetland. These cells lie along the Kalamazoo River and her Gun River tributary. Because of the importance wetlands play in storing precipitation, their protection can serve to protect the urban developments downstream. Past flooding in Otsego/Plainwell would seem to further emphasize the need for wetland protection. These special cells include: (05,43), (05,44), (06,42), (06,43), (07,42), (09,47), (10,47), (10,48) and (12,48). Most of these cells are not developed and remain occupied by the streams, woods and wetlands (55 percent). A minimal amount of urban uses and some agriculture is found. Drainage constraints are substantial and existing development has located linearly along existing roads. Some construction activity is apparent. Overall, these are the most critical areas in the Otsego/Plainwell complex and additional development should not encroach further on the wetlands.

Summary Analysis

Development through Otsego/Plainwell has been quite expansive and has consumed large amounts of land. Wetlands are the area's most sensitive feature, and additional analysis and special protection should be afforded them. Based on the large amounts of available land in cells already developed or showing such a trend, no additional expansion appears likely to be efficient. Agricultural areas are being presently threatened with urban encroachment; particularly those farm tracts directly abutting development.

Analysis of Non-Community-Related Development

Additional developing and transition cells have been identified in the study area which are not contiguous to existing communities. They are located primarily along the US-131 freeway and/or in areas near recreational resources (usually lakes) or natural settings. Such are Cells (10,16), (11,16) and (11,17) located near the Pickerel Lake complex. They display large ratios of idle to agricultural use when their apparent suitability is for agriculture. For example, such a cell might be 50 percent idle and 40 percent agriculture without apparent constraints to farming such as poor drainage (Cell (10,16)), or a cell may have greater amounts of natural features such as wetlands and woods than are found in most other cells in the study area (Cells (11,16) and (11,17)). These cells also show signs of construction activity which is often lakefront development.

Lakes and Lakefronts

Cells with lakes over 100 acres in size and with lakes whose frontage was developed, were shown separately in Figure 12. These cells should be studied in relation to surrounding cells to identify any additional development nearby but outside the study area. With the method used in this thesis, development of lakefronts that was small in size, smaller than typical residential development, was indicated as developed lakefront rather than as urban and built-up or residential. For an illustration, compare coded inventory data for Cell (11,29) with Cell (04,28). These lakefront areas were singled out because of the increasing pressure for lakefront and second-home developments and the problems of water quality that such developments often bring.

Woodlands

Because of the vast acreages devoted to agriculture and the large expanses of open land, wooded areas are a particularly valuable resource in the study area. Those cells designated as "Woodlands" in Figure 12 contain at least 40 percent forest cover. These areas should be further analyzed as to quality and condition of the wooded tracts, and activities occurring in the cells should be studied for compatibility with woodland communities. Agricultural use of adjacent non-wooded areas is a generally compatible activity. Woodlands in a woodland/agriculture balance as shown in Cell (10,36) would probably not require any special protection.

Natural Areas

This category includes the several cells in the study area with a balance or combination of natural features such as steep topography, woods, wetlands, and water bodies. They may support some agriculture and a minimal amount of residences but provide areas of important diversity and several ecotones in the chiefly agricultural study area.

Special Cells

Four cells would fit none of the previous categories. Cells (07,35) and (07,36) house the U.S. 131 Dragway in which stock car races are held. Cell (07,37) is entirely inactive in use, although it appears capable of supporting agriculture. It was assumed this parcel provides a buffer between agricultural uses south of the race way. Cell (12,23) contains a large golf course and supports a small amount of agriculture. No indications of encroaching development were identified, however, and it was therefore not categorized as developing or transitional.

Summary

Based on information generated by the inventory developed in Chapter IV, an analysis and evaluation of the study area was made. Beginning with a discussion of the interactions between development and the environment as the latter was represented in eight major inventory categories, a five-step method was developed to evaluate inventory data in the study area. The method pays particular attention to existing community developments, analyzing them for natural constraints to expansion, presence of special features, and apparent development related problems.

A total of 105 grid cells or 18.2 percent of the 576 grid cell study area were classified as various types of development areas. The most intensively developed grid cells, defined as those with 20 percent or more categorized as urban and built-up, were 43 in number or 7.4 percent of the total area. On the average, approximately one quarter of this land area is still farmed and just over 50 percent is actually urban and built-up. These aggregated figures illustrate the observation made in most of the individual communities; that substantial quantities of land remain in areas with existing development. In other words, past development in most places has been a large consumer of the land resource.

As individual communities and some non-community related areas were analyzed, potential development-related problems were identified, as were natural features requiring protection. Observations and general planning recommendations were also made.

The following chapter presents conclusions and recommendations drawn from this research effort relative to the study area and potentially applicable to similar areas experiencing increased development pressure.

FOOTNOTES

[18] Anthony Downs, "Alternative Forms of Future Urban Growth in the United States," Journal of the American Institute of Planners (January, 1970): 3.

[19] Carl Steinitz, "Landscape Resource Analysis - The State of the Art," Landscape Architecture (January, 1970): 103.

[20] E. Whiteside and D. Schaner, Michigan Agriculture: Agricultural Land Use Trends and Future Needs for Agricultural Land (East Lansing, Michigan: Michigan State University, 1968), p. 6.

[21] Ibid.

[22] Douglas Way, Terrain Analysis (Stroudsburg, Pennsylvania: Dowden, Hutchinson and Ross, Inc., 1973), p. 210.

[23] Paul Wolf, Elements of Photogrammetry (New York: McGraw-Hill, Inc., 1974), pp. 463-464.

[24] Way, p. 210.

[25] Marion Clawson, Land Use Information--A Critical Survey of U.S. Statistics Including Possibilities for Greater Uniformity (Baltimore: John Hopkins Press, 1965), p. 4.

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The desire to guide land use growth patterns in a more efficient and environmentally aware manner, is a goal which is increasingly being adopted by planners and policy makers; a goal which requires accurate and up-to-date information about environmental conditions. The major objective of this research effort has been to explore the usability of small-scale color infrared imagery as a data source in analyzing the environment of an urbanizing area. Conclusions and recommendations drawn from this research effort are presented in three components which represent the major topics analyzed in the previous five chapters. The first component concerns the usability of small scale color infrared imagery as determined by this study. The second component involves the findings of the inventory and analysis method as they relate to development in the test site and in similar areas. The third component summarizes recommendations made for future growth in the study area.

Usability of Color Infrared Imagery

The study area chosen between Grand Rapids and Kalamazoo is experiencing development pressures which are likely to grow rather than diminish. This can be expected as populations in Grand Rapids and Kalamazoo expand and as new developments (such as the proposed

Cedar Point amusement park to be located about 25 miles from the study area) become established.

Environmental data for the study area in Allegan County is scarce. No comprehensive planning studies are available and the only soil survey was conducted in 1901 and is out-of-print. Available information is of a type that generalized over large regions such as the Lower Lake Michigan Drainage Basin. With these two factors, increasing pressure for development and a lack of environmental information, the potential for beneficial use of recent remotely sensed imagery was readily apparent.

The use of small scale imagery such as 1:113,500, has received little attention when compared to larger scale imagery (such as 1:24,000). Most inventories which use color infrared photography prefer larger scales which inherently can provide more detail. The advantage of small scale imagery lies in the lesser number of photographs required, and the ability to see large areas in a small image. Recognizing that oftentimes the nature of planning for large urbanizing areas is essentially a process of identifying potential problem areas and assessing development in a generalized rather than detailed manner, the use of small scale imagery was viewed as potentially adequate and the detail of larger scale imagery as superfluous. It is the conclusion of this research effort, that the small scale imagery of the urbanizing Grand Rapids to Kalamazoo corridor provides an abundance of detail useful in analyzing and eventually useful in guiding existing and future development.

Inventory/Analysis Method and Implications for Development

This research effort has provided a method for analyzing the environment in an area under increasing pressure for development. The method uses small-scale color infrared imagery as its primary data inventory source and assesses environmentally sensitive features, development patterns and potential development constraints. The method is intended for non-technical users, most particularly regional planners dealing with multiple county or multiple township areas.

The method for inventorying data as presented in Chapter IV requires a minimal amount of previous experience with aerial photo interpretation. A textbook such as T. Eugene Avery's Interpretation of Aerial Photographs provides valuable, basic information and instruction. Some exposure to color infrared or false color film is also necessary to become acquainted with the color shifts (from natural color) which appear with infrared. With this minimum of prerequisites, use of color infrared for conducting an analysis as presented in Chapters IV and V is well within the capability of most planners and other resource oriented individuals.

In retrospect, the inventory presented in Chapter IV actually provided more data than was used in the analysis. Categories such as "Amenities/Disvalues" had been established to provide information auxiliary in nature, and were to be used when considering the future locations of particular types of development. Because no specific future development was hypothesized, this auxiliary information received little attention in the analysis. It is considered to be quite usable in more specific, local planning studies, however.

The analysis conducted in Chapter V identified several elements which served to indicate development pressure and potential environmental problems. It is presumed that the inventory/analysis method developed for the study area can be used in similar geographical areas. Certain changes in the inventory classification system would likely be required. Features progressively screened in the five-step method of Chapter V would need to be redefined or altered. Such changes should not substantially affect utility of the method, however.

Various inventoried factors from Chapter IV were especially useful in conducting the analysis and evaluation in Chapter V. Even before this study was begun, the importance of identifying sensitive features such as wetlands (particularly when located upstream from existing development) was recognized. Some of the most informative data not previously anticipated as such, was found in the grid cells which were eventually classified as "transitional development cells." The single most important clue to identificaton of these areas was a linear pattern of residential settlement. This factor in combination with signs of residential construction and/or excessive proportions of apparently idle land which otherwise appear suitable for agriculture, defines those areas at the leading edge of urban expansion. It is generally the case in these peripheral areas of strip development that planning is lacking and problems with water quality and provision of public services are greatest. By identifying these areas, steps can be taken to prevent or mollify the impact of further encroachment on agricultural or natural areas.

The spatially inefficient expansion of urban areas was illustrated by the large amounts of apparently unused land in developed areas, excluding those portions unusable because of natural features. This inefficiency is further illustrated in cases where transition areas and areas of development circumscribe agricultural areas as evidenced in the community of Dorr.

Another factor of interest is that the peripheral, developing and transitional areas generally house the junkyards and dumps, which it is assumed, are also used by residents of the smaller communities. This is illustrated in Cell (06,03) an agricultural area outside of Moline.

Analysis of all development areas with the inventory system devised in Chapter IV, permits identification of several factors thay may warrant additional study at the local level. One such factor is the ratio of urban residential to non-residential development which may provide an indicator of the economic balance that exists in a community. Another factor is the identification of areas of construction activity that can provide an indication of growth as well as aid in locating areas of accelerated erosion. Analysis of soil loss potentials and possible sedimentation in streams can then be undertaken. Areas where land uses are incompatible or could be incompatible can be isolated as can areas with strong mixtures of natural features. These latter areas provide important habitat for wildlife and esthetic diversity for man. By recording the inventory data on a generalized map via the screening method, the available buffer zones around sensitive features such as wetlands can be identified. Agricultural areas if protected from development pressures, can act as excellent buffers between natural areas and developed areas. They functionally contain development and restrict over-use while aesthetically providing a visual gradation from development to non-development. Large eroding areas can be identified from the inventory; large since the finest resolution on the 1:113,500 imagery was 9 feet. No correlation could be drawn between steep slopes and eroded areas, but general erosion information could be useful at the local level.

Study Area Recommendations

Recommendations were made for individual communities in the study area in Chapter V. To summarize, based on the various factors identified in the inventory and analysis of this urbanizing corridor, and recognizing the spatial extensiveness of development in nearly every community, the recommendation is made that further development be accommodated in areas which are currently developed or developing as shown in Figure 12. No estimates of acreages necessary to accommodate future development have been made, but there is clearly an abundance of "environmentally available" land in areas of existing development. This recommendation is based on several assumptions concerning beneficial urban growth; assumptions which are largely shared by Governor Milliken's Special Commission on Land Use (1972). The first is that agriculture is important to the economy of Michigan and most of the best agricultural land is located in southern Michigan. The decline in agricultural land

> ...is primarily due to the transition of agricultural land to urban uses, and is accelerated by developmental patterns that create artificial economic pressure on the remaining land in agricultural use.[26]

Agricultural land in the study area should be preserved.

The second assumption is that growth confined to existing areas of development is more efficient in such terms as energy conservation and provision of public services.

> The urbanization process is characterized by disorderly growth resulting in developmental patterns that render inefficient the provision of public utilities, transportation and government services.[27]

The third major assumption is that the natural areas shown in Figure 12 should be protected from development since they are limited in number and inherently valuable for several reasons such as providing wildlife habitat, recreational opportunity and aesthetic surroundings.

The development process is a complex interaction of many factors, only one of which is the physical environment. The recommendations and conclusions of this research effort recognize that complexity but maintain that benefits to the public would result from more spatially efficient development. This research effort has provided a non-technical method for analyzing environments in areas under pressure for development and has made recommendations for protection of natural features, identified through the use of small scale, color infrared imagery. The method could easily be used to conduct generalized environmental analyses and identify major sensitive features in other areas.

FOOTNOTES

[26] Governor's Special Commission on Land Use, Land Use Report - Appendix B (Lansing, Michigan: Office of the Governor, 1972), p. 18.

[27] Ibid.

APPENDIX A

Mission 273 Flight Specifications

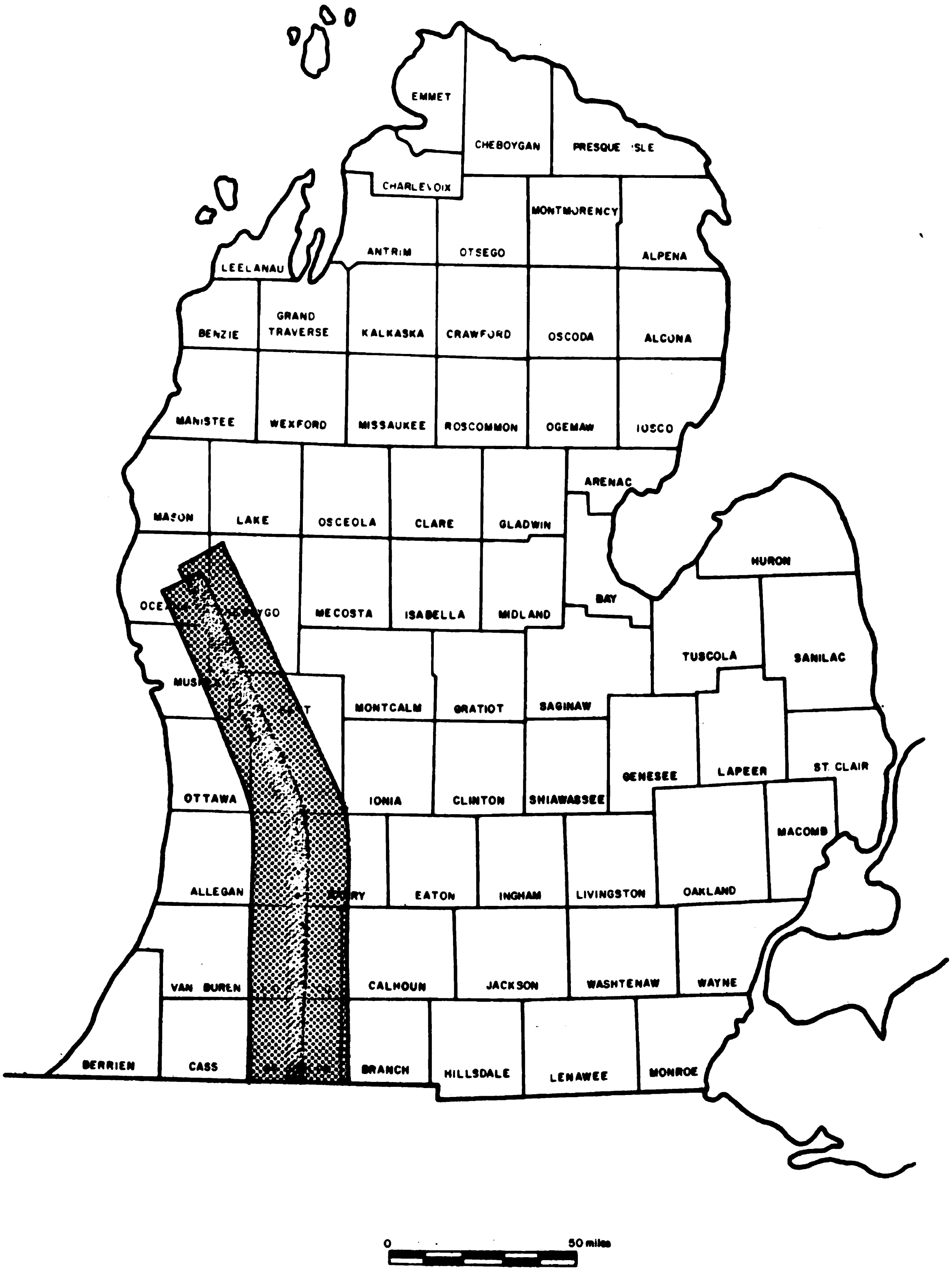

Figure A-1. Mission 273 Flight Line Coverage

Table A-1. Specifications for Mission 273, Roll 10

Image Type: Color Infrared

Film Number: 2443

Image Format: 9 by 9 inches

Band Width: 500-900 nanometers

Resolution Capability: 9 feet

Scale: 1:113,500

Date: 5-7-74

Time: 4:30 p.m. EST

Camera: RC-8

Focal Length: 6 inches

Filter: 12 (yellow)

Altitude: 56,750 feet

Sensor Platform: RB-57

Flying Organization: NASA

Site Number: 279

General Location: Two flight lines from St. Joseph County (Indiana border) north to Grand Rapids then to Freemont Lake in Newaygo County.

Frame Sequence: 5-60 (Frames used herein: 43-46)

General Quality: good

Cloud cover: None

Availability: MSU Remote Sensing Project, East Lansing, Michigan 48824

Table A-2. Approximate Conversion Factors for 1:113,500

Photo	Actual
1 inch	9417 feet
.56 inches	1 mile
1 inch	1.8 miles
1 square inch	3.2 square miles
1 square inch	2,035.7 acres

APPENDIX B

Coding Sheets and Recorded Inventory Data

KEY CODING SHEET

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	Imagery Frame Number
occurrence	Special Concerns
pattern density	Settlement Patterns
occurrence	Amenities/Disvalues
occurrence	Transportation Facilities
well moderate poor very poor	Drainage
accessory decile land use accessory decile land use accessory decile land use accessory decile land use accessory decile land use	Land Uses
accessory decile feature accessory decile feature accessory decile feature accessory decile feature accessory decile feature	Land Cover
hilly undulating level	Relief
	Y-Coordinate
	Y-Coordinate
	X-Coordinate
	X-Coordinate

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of Allegan County between Grand Rapids
and Kalamazoo - RB-57 C.I.R. Imagery

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	03	33	9	51-30-18	17	92			1	8	3	0	12	613	44
	03	34	27	70150-31-18	16	93	60		1	8	4	0	13	3	44
	03	35	9	50-90332-17	17	92			0	9	4	0	12	36	44
	03	36	9	70490330-19	18	91			0	9	4	0	12	6	44
	03	37	9	30-19	19					9	4	0	12	0	43
	03	38	9	50-31-18	18	91			0	9	4	0	12	6	43
	03	39	9	50-31-18	17	92			0	9	4	0	12	7	43
	03	40	81	50-30-19	14	20	95		0	9	4	3	12	61	43
	03	41	72	30-19	62	15	92			9	4	0	13	2	43
	03	42	63	24-15	63	81	14	91		9	4	0	14	0	43
	03	43	63	80129-50	65	43	91	80	1	8	3	0	34	4	43
	03	44	9	29	65	41	52	91		9	3	2	24	0	43
	03	45	9	30-22-17	61	41	13	94		9	4	0	13	0	43
	03	46	9	50-19-30	61	30	18		0	9	4	0	13	1	43
	03	47	9	50-30-19	18	91			0	9	4	0	12	1	43
	03	48	9	30-19	18	91				9	4	0	13	0	43
	04	01	9	50-31-18	17	92			0	9	5	0	12	0	46
	04	02	9	31-18	18	91			0	9	5	0	12	0	46
	04	03	9	50-19	19	90			0	9	5	0	12	1	46
	04	04	9	50-19	19	90			0	9	5	0	12	1	46
	04	05	9	19	19					9	5	0	12	1	46
	04	06	9	30-19	19	90				9	4	5	12	61	46

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04	07	9	90350 31 18	16 93	0		9	4	0	12	7	46
04	08	9	19 30	19		0	9	5	0	12	1	46
04	09	9	19	19			9	5	0	12	0	46
04	10	9	19	19			9	5	0	12	0	46
04	11	9	19	19			9	5	0	12	0	46
04	12	9	30 19	19		0	9	5	0	12	0	46
04	13	9	50 19	19	0		9	49	0	12	1	46
04	14	9	32 90217	17 92	0		9	4	0	12	1	46
04	15	9	50 31 18	18 91	0		9	5	0	12	1	45
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04	19	9	50 30 19	19 90	0		9	4	0	12	0	45
04	20	9	32 17	17 92			9	0	0	12	1	45
04	21	9	30 19	18 91			9	4	0	12	0	45
04	22	9	90231 18	17 92	0		9	5	5	12	1	45
04	23	9	30 19	19 90			9	5	0	12	1	45
04	24	9	50 31 -18	17 92	0	0	9	5	0	12	1	45
04	25	9	50 31 18	18 91	0		9	5	0	12	0	44
04	26	9	53 31 15	14 95	3		6	5	0	12	6	44
04	27	9	32 -50 17	17 92	0		9	5	0	12	1	44
04	28	9	70150 34 -15	80 13 96	0		9	5	0	12	2	44
04	29	9	62131 -21 15 50	80 14 61 94	2		7	5	0	13	0	44
04	30	72	67332 -10 50	99	7	1	1	0	0	12	0	44
04	31	9	60271350 -21 17	16 93	2		7	5	0	12	0	44
04	32	9	70334 15 50	13 95 31	1		8	3	0	12	16	44
04	33	9	51 31 17	16 93	1		8	3	0	12	7	44
04	34	9	71233 20 15 50	13 95 61	1		8	5	0	13	27	44
04	35	9	70390332 -17	16 93	1		8	5	0	12	1	44
04	36	9	50 34 15	14 95	0	1	8	5	0	12	0	44

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	3 4	6 7	9	10 11	14 15	16	17 18	19	20 21	22	23 24	30 31	32	33 34	35	36 37	46 47	49	52 53 54	58	64 65	67 68	73 74
	04	37		9	50	-	19					30		19		90	0	9	5	0	12	6	43
	04	38		9	50		31		18			17		92			0	9	5	0	12	16	43
	04	39		9	50		31		18			30		91		18	0	9	5	0	12	6	43
	04	40		9	50		32		17			16		93			0	9	5	0	12	7	43
	04	41		9	50		19		30			19					0	9	5	0	12	6	43
massive construction site	04	42		54	70	4	50		31	-	18	12		76	-	91	1	8	5	5	0	36	43
	04	43	9		83	1	51		24		11	41		63	-	95	4	5	4	0	24	0	43
	04	44	9		51		80	1	11		27	63		43	-	93	2	7	6	5	24	2	43
	04	45	9		31		80	1	23		15	62		92		15	0	9	6	0	14	1	43
	04	46	9		51		32		16			15		94			1	8	4	0	13	0	43
	04	47	9		30		19		50			19					0	9	4	0	12	1	43
	04	48	9		19							19						9	4	0	12	0	43
	05	01		9	18		31					18		91				9	925	3	12	0	46
	05	02	9		19							19						9	25	0	12	1	46
	05	03	9		31		18					18		91				9	25	0	12	1	46
	05	04		9	19							19						9	24	0	12	1	46
	05	05		9	30		19					19						9	24	0	12	1	46
	05	06	9		19							19						9	14	0	12	0	46
	05	07		9	19							19						9	14	0	13	0	46
	05	08		9	31		18		50			17		92			01	8	5	0	12	67	46
	05	09	9		50		19		30			19					0	9	5	0	12	7	46
	05	10	9		51		30		18			17		92			1	8	5	0	12	6	46
Pitted	05	11	9		50		19					19		90			1	8	5	0	12	0	46
Pitted	05	12	9		50		19					19		90			0	9	5	0	12	1	46
	05	13	9		90	2	19		30			18		91			0	9	59	0	12	0	46
	05	14	9		90	2	30	-	19			19					0	9	4	0	12	1	46
	05	15	9		31	-	18					93		16			0	9	5	0	12	7	45
	05	16	9		19		30					19						9	5	0	12	1	45
	05	17	9		30	-	19		50			18	-	91			0	9	5	0	12	1	45
	05	18	9		19							19						9	4	0	12	1	45

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                  05 19 9    19              19                 9  4     0     12 0     45
                  05 20 9    30 19           19                 9  4     0     12 16    45
                  05 21 9    19              19                 9  4     0     12 1     45
                  05 22 9    90230 19        18 91           0  9  59    0     12 0     45
                  05 23 9    30 90219        18 91           0  9  59    0     12 1     45
                  05 24 9    50 31 18        18 91           0  9  5     0     12 6     45
                  05 25 9    50 90231 18     18 91           1  8  5     0     12 6     44
                  05 26 9    50 32 17        16 93           0  9  5     0     12 1     44
ARTIFICIAL LAKE   05 27 9    70450 30 19     14 95           1  8  5     0     12 13    44
                  05 28  9   50 19           19              0  9  5     0     12 1     44
                  05 29 342  50 19 30        18 91           0  9  5     0     12 0     44
                  05 30 18   50 30 19        18 91           0  9  5     0     12 6     44
                  05 31  9   52 30 17        16 93           2  7  5     0     12 6     44
                  05 32  9   70253 30 16     15 94           3  6  3     5     12 0     44
                  05 33 9    71250 30 18     17 92           2  7  3     0     12 1     44
                  05 34  9   51 35 13        12 97           12 6  5     0     12 7     44
                  05 35 9    51 36 12        10 99           14 4  5     0     12 167   44
Pitted            05 36 9    50 33 16        13 96           11 7  5     0     12 7     44
Pitted            05 37 9    51 31 17        16 93           2  7  5     0     12 0     43
Pitted            05 38 9    51 32 16        16 93           1  8  5     0     12 0     43
                  05 39 9    50 31 18        18 91           0  9  5     0     12 0     43
                  05 40  9   50 30 19        17 91 81        0  9  5     0     12 6     43
                  05 41  9   50 32 17        80 93 16        0  9  5     0     12 0     43
                  05 42 324  90351 32 16     12 97           1  8  5     0     13 6     43
                  05 43 9    83253 70213     99 60           7  2  49    0     13 0     43
                  05 44 9    70453 16        82 62 40-95     4  5  6     0     13 3     43
                  05 45 9    30 27 12        67392              9  6     0     23 0     43
                  05 46 9    31 18           63 15 91           9  4     0     13 0     43
                  05 47 9    50 19           61 18 90        0  9  4     0     13 1     43
                  05 48 9    31 50 18        18 91           0  9  4     0     12 1     43
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	06	01	9		18	50	31 -			18	91		0		9	723	0	12	1	46
	06	02	9		50	19				19			0		9	73	0	13	1	46
	06	03	9		19	60	30			18	70	91	0		9	73	4	12	0	46
LIGHTLY (L.) PITTED	06	04		9	50	23	16			16	41	62	0		9	724	0	24	6	46
L.Pitted	06	05		9	31	21	17			61	91	17	0		9	724	0	13	0	46
L.Pitted	06	06		9	50	19	30			18	91		0		9	14	0	12	0	46
	06	07		9	32	17	50			17	92		0		9	14	0	12	0	46
	06	08		9	19					19					9	25	0	12	0	46
	06	09	9		51	32	16			12	97		1	1	7	5	0	13	17	46
L. Pitted	06	10	9		52	30	17			16	93		2		7	5	0	13	371	46
L.Pitted	06	11	9		50	31	18			18	91		0		9	5	0	12	6	46
	06	12	9		902	19 -	30			18	91		0		9	59	0	12	0	46
	06	13	9		902	21	18			61	17	91	0		9	59	0	14	0	46
	06	14	9		33	16				15	94				9	4	0	12	1	46
	06	15	9		50	31	18			18	91		0		9	5	0	13	0	45
	06	16	9		19					19				1	8	5	0	12	1	45
	06	17	9		19					19					9	5	0	12	1	45
	06	18	9		31	18				18	91				9	4	0	12	0	45
	06	19	9		19	30				19	90				9	14	0	12	1	45
	06	20	9		19	704				18	71		0		9	14	0	12	163	45
	06	21	9		30	19				19					9	4	0	12	0	45
	06	22	9		31	18				18	91				9	4	0	12	1	45
	06	23	9		903	31	18			18	91		0		9	4	0	12	0	45
	06	24		9	902	31	18	50		30	17	92	0		9	24	0	12	61	45
	06	25		9	903	50	714	32	16	16	93	80	1		8	24	0	12	3	44
	06	26		9	714	50	32	16		16	93	80	1	0	8	24	0	12	3	44
	06	27	5	4	712	31	17	20	50	61	14	94	1		8	25	0	14	136	44
	06	28	9		722	903	35	12		11	98		2		7	25	0	13	2	44
	06	29	9		903	31	17	51		16	93		1	1	7	25	0	12	1	44
	06	30		81	34	15				14	95				9	25	0	12	7	44

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DATE

	06	31	9	50 31	18			80-15-94	0	9	25	0	12	0	44
	06	32	9	50 30	18	21		15 61393	0	9	3	0	14	3	44
	06	33	9	72231	16			16 93	2	7	3	0	12	0	44
	06	34	9	71 250	35	13		11 98	2	7	4	4	12	0	44
Pitted	06	35	9	35 50	14			12 97	11	7	5	0	12	0	44
Pitted	06	36	9	51 33	15			13 96	12	6	5	0	12	67	44
Pitted	06	37	9	31 17	51			16 93	1	8	5	0	12	0	43
	06	38	9	50 19				18 91	1	8	5	0	12	0	43
	06	39	9	50 31	18			18 91	0	9	5	0	12	0	43
	06	40	81	51 31	17			17 92	1	8	5	0	12	0	43
	06	41	72	31 18				30 18 91		9	5	0	12	0	43
	06	42	811	52 90	31	16		16 93	2	7	4	0	13	0	43
	06	43	9	81231	54	13		61 13 95	6	3	47	6	13	0	43
	06	44	9	80430	23	16		13 82 61 41-92	1	8	6	3	13	4	43
	06	45	9	24 15				41 633 95		9	6	0	24	5	43
	06	46	9	31 21	17			61 13 95		9	24	0	13	3	43
	06	47	9	51 30	18			18 91	1	8	24	0	12	0	43
	06	48	9	30 19				19		9	24	0	12	1	43
	07	01	9	19 30	50			18 91	0	9	3	0	12	16	43
	07	02	9	70218	21	50		61 70 17 91	1	8	3	4	13	16	46
	07	03	9	19				19	0	9	3	0	12	1	46
	07	04	9	17 22				62 17		9	3	0	13	1	46
	07	05	9	22 17				62 17		9	3	0	13	2	46
	07	06	9	30 19	50			19	0	9	73	0	12	0	46
	07	07	9	30 19	50			19	0	9	73	0	12	163	46
Pitted	07	08	9	34 15	50			14 95	0	9	723	3	12	63	46
	07	09	9	90230	19	50		13 72 94	1	8	723	0	12	13	46
	07	10	9	90250	31	18	20	14-61 94	1	8	723	0	13	137	46
	07	11	9	30 18	51			18 91	1	8	723	0	13	0	46
	07	12	9	90230	19			30-18 91	0	9	125	0	12	0	46

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	3	4	6	7	9	10	14	15	16	17	18	20	21	23	24	30	31	33	34	36	37	39	40	46	49	52	53	54	58	64	65	67	68	69	73	74
	0	7	1	3	9		5	0		3	2	2	2	1	5	6	1	4	1	1	3	9	4	0	9	7	1	4	0	1	3	3			4	6
SANDPIT	0	7	1	4	9		3	3		5	0	2	1	1	5	4	1	1	1	9	7			1	8	7	1	4	0	1	3	1	3		4	6
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	0	7	1	6	9		5	1		3	0	1	8			1	8	9	1					0	9	7	2	5	0	1	2	1			4	5
	0	7	1	7	9		3	2		1	7					1	7	9	2					0	9	7	2	5	0	1	2	0			4	5
	0	7	1	8	9		1	9								1	9								9	7	2	5	0	1	2	6			4	5
	0	7	1	9	9		3	2		1	7					1	7	9	2					0	9	7	1	4	0	1	2	6	1		4	5
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	0	7	2	1	9		1	9		3	0	5	0			1	8	9	1					1	8	2	4		0	1	3	6			4	5
L.PITTED	0	7	2	2	9		3	0		1	9					1	8	9	1					0	9	2	4		0	1	2	0			4	5
	0	7	2	3		9	7	0	3	5	0	3	2	1	7	1	3	9	6					1	8	2	4		0	1	2	0			4	5
	0	7	2	4		9	7	0	3	5	0	3	2	1	7	1	6	9	3					1	8	1	4		0	1	2	3	1	2	4	5
	0	7	2	5		9	5	0		3	2	1	7			1	6	9	3					1	8	1	4		0	1	2	0			4	4
	0	7	2	6		9	5	1		3	1	1	7			1	7	9	2					1	8	2	4		0	1	2	0			4	4
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	0	7	3	2	9		5	0		1	9					1	9							0	9	1	5		0	1	2	6			4	4
	0	7	3	3	9		5	0		3	0	1	9			4	0	1	5	9	4			0	9	1	4		0	1	2	0			4	4
	0	7	3	4	9		5	0		3	3	1	6			1	6	9	3					0	9	2	4		0	1	2	0			4	4
DRAGWAY	0	7	3	5	9		5	0		3	1	1	8			1	3	9	2	7	4			0	9	2	4		3	1	2	1	7	3	4	4
DRAGWAY	0	7	3	6	9		5	0		3	4	1	5			7	3	4	0	9	6	1	0	0	9	2	5		3	0		1	7	3	4	4
	0	7	3	7	9		3	2		1	7	5	0			9	9							0	9	2	5		0	0		1			4	3
	0	7	3	8		9	5	0		3	1	1	8			1	4	9	5					0	9	2	5		0	0		0			4	3
	0	7	3	9		9	5	0		3	0	1	9			1	7	9	2					0	9	2	5		0	1	2	7	3		4	3
	0	7	4	0	5	4	3	0		1	9					1	7	9	2						9	2	5		0	1	2	3			4	3
	0	7	4	1	9		3	0		1	9					1	9								9	2	5		0	1	2	0			4	3
[illegible] RANGE	0	7	4	2	9		9	0	3	3	1	5	4	1	4	1	1	9	8					4	5	1	4		6	1	2	6	3		4	3

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	3–4	6–7	9	10	14–16	17–18	20–21	23–25	30–32	33–34	36–38	39–40	46	47	49	52–54	58	64–65	67–69	73–74
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	07	44	9		802	30	18	21	40	61	98		1		8	169	0	13	0	43
interchange	07	45	9		26	13			73	41	63	92			9	16	0	24	32	43
	07	46	9		30	27	12		653	42	42				9	23	2	24	2	43
	07	47	9		50	30	19		18	91			0		9	24	0	12	0	43
	07	48	9		50	30	19		19				0		9	25	0	12	1	43
	08	01	9		50	19	30		19				0		9	5	0	12	0	46
	08	02	9		50	31	18		18	91			0	0	9	5	0	12	0	46
	08	03	9		30	19			19						9	5	0	12	0	46
	08	04	9		50	19			19				0		9	4	0	12	1	46
	08	05	9		50	19			19				0		9	3	0	13	0	46
	08	06	9		50	19			19				0		9	3	0	12	0	46
	08	07	9		902	19	30		19				0		9	3	0	12	0	46
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	08	10	9		50	32	17		17	92			0		9	3	0	12	1	46
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	08	12	9		902	31	23	15	62	41	11	95	1		8	739	0	24	3	46
	08	13	9		11	28	50		41	67	91		0		9	73	0	34	0	46
	08	14	9		26	13			42	64	93		0		9	73	2	33	318	46
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	08	23		9	702	31	18	50	16	93			1		8	3	0	12	63	45
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0	8	2	8	9			1	9											1	8												9	3			0	1	2	0			4	4
0	8	2	9	9			1	9											1	9												9	9			0	1	2	0			4	4
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SEWAGE TREAT. PLANT

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	09	07		9	90	2	30	19			19					9	4	0	12	6	46
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	09	11	9		30		19				18	91				9	4	0	12	0	46
	09	12	9		90	2	30	20	19		40	17	92			9	39	0	13	0	46
	09	13	9		90	3	30	25	14		41	64	94			9	3	0	24	3	46
	09	14		9	31		26	12			65	41	93		0	9	3	0	24	3	46
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	09	16		9	32		50	17			17	92			0	9	3	5	12	31	45
	09	17		9	30		50	19			91	18			0	9	3	0	13	0	45
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	09	21		9	70	2	51	30	18		15	94			1	8	3	0	12	1	45
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	09	26	9		50		19				19				0	9	73	0	12	16	44
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	09	32	9		50		22	17			62	40	17		0	9	73	0	24	0	44
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ABANDONED EXCAVATION

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	1	1	0	2		9		5	1		3	0		1	8					1	7		9	2					1		8	4	0		1	2	1	2	4	6
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	11	37	9		31		18			17	92				9	5	0	1	2	0	43
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