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AN APPROACH TO LAND USE/

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An Analysis of the Characteristics of

Land Use/Land Cover Data in Minnesota

Minnesota State Planning Agency
Physical Planning Division
August 1981

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I. EXECUTIVE SUMMARY

A. INTRODUCTION

Effective land use planning and growth management is dependent upon accurate and up-to-date land use and land cover data. Information regarding changes in land use patterns provides a basis for evaluating the effectiveness of existing controls, and points to factors which influence change. In 1979, the Legislative Commission on Minnesota Resources requested the State Planning Agency, Division of Physical Planning, to develop rapid and inexpensive procedures for monitoring uses and covers on the land.

The overall purpose of the Land Use Change Project is:
To develop and evaluate rapid and inexpensive techniques for monitoring changes in the use and cover of land on an ongoing basis.

"Land cover" refers to the "form" of those features covering the earth's surface, including vegetation, bare land, water, and man-made constructions such as structured or paved surfaces. "Land use" refers to the "function" attributed to land or water. An area is said to have a use if a private or public party has developed a plan or policy for its management, or if use can be clearly inferred from visible activity on land (e.g. agriculture, recreation, residential). This definition of land use includes so-called passive uses such as preservation or conservancy status. An example of land cover on a parcel of land may be trees or, more specifically, deciduous trees, while the land use on the same parcel may be commercial forestry, recreational, or residential. A Classification Manual For Land Cover and Land Use in Minnesota, State Planning Agency, 1978, defines and describes these terms in more detail.

During the course of the Land Use Change Project, the State Planning Agency evaluated a number of procedures and techniques for monitoring land use and land cover conditions. These include the use of remote sensing - aerial photography and LANDSAT data (data on the earth's surface which is transmitted from satellites); state agency records and inventories; plat books; and other public data sources. The evaluation of these land use and land cover monitoring techniques was undertaken to provide answers to the following basic questions:

- Can the State of Minnesota produce an updated, state-wide land use/land cover map using LANDSAT data alone? When? At what cost? What categories of information could it contain?

- Should Minnesota invest in high altitude aerial photography coverage of the state again? If so, what would be the cost? Is the information obtained from the high altitude photos useful enough to justify the cost?

- What priority should be placed on state and local records and inventories pertaining to the land? How long would it take to get state and local land use data together in a unified format on a state-wide basis? How much would it cost? Who would pay for it? What type of research needs to be undertaken prior to making extensive use of these data sources?

The primary purpose of this report is to summarize the major findings of the numerous technical studies undertaken by the State Planning Agency in response to the above questions. Chapter II discusses the characteristics of each procedure for mapping and collecting basic land use and land cover data. Specifically, it suggests criteria by which each procedure can be evaluated for a particular application, including availability, cost, frequency of data collection, and uniformity of data.

Case studies are presented in Chapter III of this report:

- To illustrate possible planning applications and issues that require land use/cover information;
- To illustrate possible sources of data; and
- To match up applications with sources and describe a variety of land use/land cover products.

Selection of the case studies was based on the following considerations:

- Diversity of land use and land cover types;
- Diversity of data sources;
- Diversity of geographic location within Minnesota;
- Diversity of scale and level of detail.

B. METHODOLOGY

In order to evaluate the usefulness of aerial photography, LANDSAT, and state agency records and inventories, the State Planning Agency undertook a number of projects. A brief description of the products and publications resulting from these efforts follows:

1. The Catalog of Data Sources: Land Use in Minnesota, a computerized inventory of natural resource data collected and maintained by major state agencies and the Metropolitan Council.

   This catalog is the result of the State Planning Agency's efforts to obtain, organize and disseminate information on land use and land cover data which are collected in Minnesota. It is intended to serve as a working document for planners and decision-makers who are interested in gaining an overview of available data sources.

   Information contained in the catalog was obtained from questionnaires administered by the Land Use Change Project staff. This information was edited and entered into computer files of the Minnesota Environmental Resources Information and Data Exchange (INDEX).

2. Plat maps of Isanti county from 1969 to 1979 (1969, 1972, 1975, 1979, respectively). The original plat maps produced by the Rockford Map Company display parcel boundaries and ownership data. They are often used locally as tax maps for assessment, for planning aids, and as a base for zoning. State Planning Agency staff enchanced these plat maps of Isanti County by indicating in different colors those parcels of 2½ acres or less, 3-10 acres, and 11-35 acres for each year. Displayed consecutively, the color-coded plat maps can be used to indicate areas of subdivision as well as consolidation of land ownership parcels over time.

Portions of this data are summarized in the State Planning Agency publication, Growth Management Notebook, 1981. One set of full-size color plat maps showing historical changes in Isanti County are available for review at the State Planning Agency.

3. Pilot studies conducted by the Land Management Information Center of the State Planning Agency evaluating LANDSAT data with regard to:

   - Land cover classification alternatives in one urbanizing area;
   - Monitoring the conversion of land from forest to agriculture;
   - The integration of LANDSAT analysis capabilities with the Minnesota Land Management Information System (MLMIS).

4. A pilot study evaluating the usefulness of high altitude aerial photography for measuring the degree of change in urban growth and development. This information has been used to:

   - Provide a baseline for measuring future change conditions in fast-growing counties and areas adjacent to selected Minnesota municipalities;
   - Describe and graphically display the impacts of urban changes;
   - Provide documentation to support recommended techniques and policies for managing future growth in a manner which provides for optimum social, economic and environmental benefits;
   - In conjunction with other research efforts, determine correlations between urban growth patterns and land use controls; and
   - Update urban land use data of the Minnesota Land Management Information System (MLMIS) for key growth areas of the state.

   This study resulted in a number of products, including:

   - A technical paper describing the methodology used in interpreting urban structures data from 1968 and 1977 high altitude aerial photographs of the state, the reliability and accuracy of the data, and the usefulness of techniques using high altitude aerial photography in assessing urban land use and in monitoring urban change. This paper is entitled, The Use of High Altitude Aerial Photography to Monitor Changes in Urban Structures in Minnesota; Computerized maps, and narrative describing urban change between 1968 and 1977 around Owatonna, Fergus Falls, Faribault and Cambridge/Isanti County. These can be found in the State Planning Agency publication, Growth Management Notebook, 1981;
   - Computerized maps indicating the location of urban structures in 1968 and 1977 and urban change between 1968 and 1977 in Wright, Sherburne, Blue Earth, Goodhue and Chisago counties and for areas surrounding Willmar, Mankato, St. Cloud, Morris, and Bemidji;
   - Computerized maps and narrative describing the location of urban structures in 1968 and 1977 and urban change between 1968 and 1977 in the 10 mile zones surrounding the state's nuclear generating plants in Monticello and Prairie Island. These maps are included in the Minnesota Department of Public Safety's report, A Study Relating to Nuclear Power Plants and Emergency Response, February, 1981.

With the exception of the Nuclear Study mentioned in Section 4, all of the papers and documents mentioned in the preceding discussion are available from the Minnesota State Planning Agency.

C. SUMMARY FINDINGS

The findings contained in Chapter II are briefly summarized below:

The rapidly developing technology of REMOTE SENSING offers an efficient and timely approach to the mapping and collection of basic land cover data, and to a lesser extent, land use data. Capabilities at the present time include:

- Multispectral scanner data available from LANDSAT over extensive areas on a repetitive basis that may be as frequent as every 9 or 18 days, weather permitting;
- High-resolution color infrared and panchromatic black and white photography being acquired from varying altitudes. Frequencies of collection range from 1 to 10 years or longer. Some of this photography is being obtained by using relatively low altitude flights, often covering a county or less on any one flight or contract. Photography has been acquired from flights funded by the U.S. Geological Survey, other federal agencies, and by state and local agencies.

Further information on aerial photography and LANDSAT is contained in Chapter II of this report.

1. AERIAL PHOTOGRAPHY

a. LAND USE/LAND COVER APPLICATIONS

Land use/land cover applications of aerial photography at various scales are summarized in the table found on page 5. As a general rule, air photos are more accurate in determining land covers than land uses, since land covers are more closely related to visible physical features.

b. LIMITATIONS OF TECHNIQUE

Air photo imagery is limited in that it can display only the top layer of ground features. This means that features which lie under tree cover, or any other 'overhead' obstructions, do not appear on the imagery. This makes it particularly difficult to detect urban uses in wooded areas. Even when structures do appear clearly on air photos, it is often difficult to determine the uses which are made of the structures (i.e., residential, commercial, industrial, or agricultural uses).

Given the availability of comparable high altitude aerial photos of Minnesota for 1968-69 and 1977, the use of 1:90,000 and 1:80,000 scale aerial photography was evaluated as one possible procedure for measuring and describing change in urban structures. Data on the location of structures was interpreted from both 1968-69 and 1977 photos for several fast growing counties surrounding the Twin Cities metropolitan area as well as around several out-state

A COMPARISON OF VARIOUS SCALES OF AERIAL PHOTOGRAPHY

Category	Common Scales	Distance Equivalent	Approximate Land Area Covered by a 9 x 9 Inch Photo
LARGE-SCALE (approximate range is from 1:1 to 1:12,000)	1: 4,800	1 inch = 400 feet	.46 sq. mi.
	1:12,000	1 inch = 1,000 feet	2.9 sq. mi.
	Uses: Engineering and measurement surveys; site specific studies; thermal (e.g. heat loss) studies; crop, soil and vegetation identification.		
	Users: MN Dept. of Transportation, MN Pollution Control Agency, MN Dept. of Natural Resources, local units of government, developers, educational institutions.		
	Frequency of Data Collection: As needed for small parts of the state.		
MEDIUM-SCALE (approximate range is from 1:12,000 to 1:55,000)	1:15,840	1 inch = .25 miles	5.1 sq. mi.
	1:24,000	1 inch = .38 miles	11.6 sq. mi.
	1:31,680	1 inch = .5 miles	20.25 sq. mi.
	1:40,000	1 inch = .63 miles	32.3 sq. mi.
	Uses: Topical studies on land use, land cover (e.g., vegetation), forest types, soil surveys, geology and hydrology.		
	Users: U.S. Geological Survey, U.S. Forest Service, U.S. Dept. of Agriculture, Soil Conservation Service, MN Dept. of Transportation, MN Dept. of Natural Resources, MN State Planning Agency, MN Geological Survey, MN Dept. of Agriculture, Regional Development Commissions, county agencies, education institutions, sportsmen.		
	Frequency of Data Collection: Average of every 3 to 5 years.		
SMALL-SCALE (approximate range is from 1:55,000 to 1:120,000)	1:62,500	1 inch = .99 miles	78.8 sq. mi.
	1:80,000	1 inch = 1.26 miles	129.1 sq. mi.
	1:90,000	1 inch = 1.42 miles	163.4 sq. mi.
	Uses: Generalized land use, land cover (e.g., vegetation) soils, geology and hydrology; ground truth for land satellite images.		
	Users: U.S. Geological Survey, U.S. Forest Service, U.S. Dept. of Agriculture, Soil Conservation Service, U.S. Dept. of Defense, MN Dept. of Transportation, MN Dept. of Natural Resources, MN State Planning Agency, MN Geological Survey, Regional Development Commissions, MN Dept. of Agriculture, county agencies, educational institutions.		
	Frequency of Data Collection: Average of every 8 to 10 years. (Complete coverage of the state for 1968-69 and 1977 is available at 1:90,000 and 1:80,000 respectively.)		

municipalities. Interpretation, coding and mapping of urban land use information obtained from the air photos was completed for Isanti, Goodhue, Chisago, Wright, Sherburne and Blue Earth counties and for areas surrounding Willmar, Mankato, St. Cloud, Morris, Bemidji, Fergus Falls, Owatonna and Faribault. Change data is found by comparing numbers and location of structures on 1968-69 high altitude aerial photographs with those of 1977 high altitude aerial photographs. Urban structures were interpreted by 10-acre parcels. Ten-acre urban structures data were aggregated to 40-acre parcels for analysis. 1968-69 photos are at a scale of 1:90,000 and the 1977 photos are at a scale of 1:80,000.

Major findings and conclusions on the limitations of using this technique are the following:

- On the whole, the procedure of using high altitude aerial photography to measure location and change in urban structures is reliable in low density, open areas associated with rural, agricultural areas of the state;
- In medium and high density residential areas, accurate counting of individual structures from air photos is difficult. Errors are usually marginal, however, and are due to technical problems associated with the placement of grids on the photos;
- Structure counts were not accurate in areas of mixed urban uses where small accessory buildings (not included in the study's definition of structures) or non-residential buildings were scattered among residential structures;
- Because of tree cover along lakeshore, many structures were not visible from the high altitude aerial photos. Reliability and accuracy of the data in these areas of the state is not high.

See The Use of High Altitude Aerial Photography to Monitor Changes in Urban Structures in Minnesota, Minnesota State Planning Agency, 1981, for further discussion.

Additional limitations of air photos include atmospheric obstruction (especially for panchromatic imagery), time-of-year and lack of coordination among photo suppliers and users.

Many of the limitations of air photo imagery are associated with the large network of photo suppliers (both public and private) and users. The only scales of photography which are feasible for the state to finance on a state-wide basis are small-scale (high altitude). This means that users needing larger-scale imagery must either locate existing photo imagery or finance a flight to provide new imagery. Most Minnesota counties and many cities do occasionally finance such flights. However, there appears to be a lack of coordination among many political units which could benefit from compatible imagery.

c. COSTS

In 1977, a complete set of 1:80,000 high altitude air photos for Minnesota cost approximately $450,000. The costs involved in such an effort have increased with inflation and the current high cost of silver (used in films and papers). It would take a major financial commitment (about $1,000,000 at 1981 prices for state-wide coverage) on the parts of the State of Minnesota and federal programs. Costs of interpreting small-scale air photos for the urban use classification alone and for entering the data into the computer are estimated to be $900 for a study area which covers nine Minnesota townships. See the Minnesota State Planning Agency's report, The Use of High Altitude Aerial Photography to Monitor Changes in Urban Structures in Minnesota, Appendix B, for a detailed listing of interpretation and computer-related costs.

d. FUTURE PLANS OF ACTION

Due to the multiplicity of programs which provide and/or make use of aerial photography, there exists a need for a central place responsible for maintaining current information on aerial photography in Minnesota. This need was recognized in 1975 and The Mapping and Remote Sensing Information Center (MARSIC) of the Minnesota State Planning Agency was established. The Center published a catalog of air photo and map holdings in 1978 (Inventory of Aerial Photography and other Remotely Sensed Imagery of Minnesota), and periodically reports on new products and services.

Numerous federal and state agencies currently have programs which produce aerial photo images of portions of Minnesota. These are discussed in detail in Chapter II. These include the U.S. Geological Survey, the U.S. Department of Agriculture and the Minnesota Department of Natural Resources. The need for coordinating these ongoing activities is essential if maximum benefit is to be derived from existing programs. An important component of this coordination in Minnesota is MARSIC.

There are no existing or proposed plans for repetition of the approximately one-point-in-time coverage of the entire state which has been carried out twice to date - in 1968-69 and again in 1977.

e. SUMMARY

Given the extensive use which has been made of the photo enlargements of 1968-69 and 1977 state-wide high altitude aerial photography, repetition of state-wide aerial photo efforts would be welcomed by many air photo users. However, given:

- The high costs of obtaining high altitude photo coverage of the state (estimated in 1981 to be approximately $1 million);
- The fact that accurate data on forests, crop type, irrigation and water can be obtained quickly and relatively inexpensively from LANDSAT (see following section on LANDSAT);
- The fact that, viewed from a state-wide perspective, the broad outlines and boundaries of many of the state's major land covers as displayed on the 1969 Minnesota Land Use map - notably water and forested areas - have not changed much in the past decade;

- The difficulty in detecting urban uses in wooded areas, especially along forested lakeshore, and the uses made of urban structures (i.e., residential, or industrial/commercial) from small-scale photos;
- The numerous federal and state agencies which have programs which currently produce or intend to produce photo images of portions of Minnesota; then

it does not seem justifiable to repeat state-wide coverage using high altitude aerial photography in the near future. Focus should be on making the best use of available remote sensing resources which provide partial coverage of the state and in training potential users in their application.

2. LANDSAT

LANDSAT is a satellite orbiting the earth at an altitude of about 560 miles. Monitors transmit a steady flow of information about the earth's surface characteristics to ground receiving stations. This information can be used by land planners, managers and researchers to whom monitoring of certain land cover characteristics is important.

a. LAND USE/LAND COVER APPLICATIONS

In Minnesota, LANDSAT can be used to monitor surface water, mining areas, forests, patterns of irrigation, and areas of diseased or stressed vegetation. A project recently completed by the State Planning Agency investigated the utility of LANDSAT data in monitoring large-scale land clearance and drainage activities in a forest/wetland environment of Aitkin County in northern Minnesota. Initial analysis of the results indicates that LANDSAT does represent a satisfactory method of monitoring large-scale changes in forest/wetland areas which are being converted to agriculture. LANDSAT is useful to geologists in searching for distinctive surface geologic features and to detect hazard zones such as fault lines. The repetitive nature of the coverage makes LANDSAT useful for maintaining crop inventories. It can be used to estimate acreage planted in major crops such as wheat, oats, barley and corn and to monitor areas struck by disease or drought stress during the growing season.

b. FREQUENCY OF DATA COLLECTION

Each LANDSAT satellite passes the same spot on the each every 18 days. Depending on weather conditions and the number of operational satellites, data may be available as frequently as every 9 or 18 days.

c. EXTENT OF COVERAGE

Each LANDSAT scene covers an area of 13,000 square miles. This broad view makes LANDSAT a good choice in viewing large areas to identify places where more detailed information is needed.

d. LIMITATIONS OF TECHNIQUE

LANDSAT shares with aerial photography the problem of "seeing" the top layer of land cover only, with few applications for detecting land use. For example, if there are houses beneath relatively dense tree cover, these will go undetected. Other limitations include relatively limited resolution or detail, and frequent cloud cover. The limited resolution makes the use of LANDSAT very difficult for monitoring low density urban development. The Minnesota State Planning Agency undertook a pilot study of the northeast suburban portion of the Twin Cities (White Bear Lake). The variety of land uses and covers in this area (lakes, wetlands, forested areas, suburban and exurban areas) offered the chance to assess the practicality and/or difficulty of using LANDSAT data to classify various land use and cover types. Project results indicate that the low density urban category is the most problematic when using LANDSAT data; it is often classified as other cover types (e.g., pasture, open land, agricultural land).

In addition, because of different vegetation types and the surrounding environment, accurate identification of wetlands from LANDSAT is extremely difficult in Minnesota. Lastly, the lag time between the satellite pass-over and the time that data (computer tapes or images) are available to the state - a minimum of two to three months - is a limitation.

e. COST

The cost of acquiring LANDSAT computer tapes covering the entire state would be nearly $4,000 at current (1981) prices. The costs will rise an undetermined amount (estimated at five to ten times) if and when the program is shifted from NASA and USGS to the National Oceanic and Atmospheric Administration (NOAA). There are costs associated with acquiring computer equipment and programs for LANDSAT classification. However, in the case of Minnesota, this investment was made when the Land Management Information Center of the State Planning Agency acquired its own stand-alone computer system in January, 1980. Additional costs of using LANDSAT data include those for computer processing and personnel.

f. FUTURE PLANS OF ACTION

Further testing of LANDSAT on specific cover types will be necessary before going forward on extensive LANDSAT projects in Minnesota. Specifically, inventories of forest cover by the Department of Natural Resources and 'clear lakes' (water clarity) by the Pollution Control Agency using LANDSAT are currently underway. Both LANDSAT projects are funded by the Legislative Commission on Minnesota Resources.

g. SUMMARY

The hope that LANDSAT can provide continuous state-wide data on all land covers and uses in Minnesota is not borne out by current research efforts. In particular, LANDSAT has problems associated with monitoring low density urban development and wetland identification. The production of a state-wide land use/land cover map solely using this technique or procedure does not seem feasible in the very near future.

Some land cover/land use types are more appropriate than others for classification using LANDSAT analysis techniques. LANDSAT is good for the classification of forest, water and agricultural lands. The accuracy of LANDSAT classification for these land covers is as good as that using many other means, and is at a much lower cost. In large, homogeneous areas, various forest types can be delineated. The same is also true for crop types. Unfortunately, tree species in Minnesota forests are often very heterogeneous, making application of LANDSAT to forest cover typing in a large area very difficult.

A land use in which there is much interest is the urban classification, especially low density urban development found in areas of urban expansion. The use of LANDSAT data to classify these areas is not recommended if any degree of reliability is desired. Only large homogeneous areas of urban development, especially urban areas of high density, can be identified from LANDSAT images.

3. LAND RECORDS AND INVENTORIES

Remote sensing technology alone is not adequate for efficient generation of land use and cover data and maps. Additional sources of information such as land records and compiled inventories are available and should be used when land use and cover data are being compiled for mapping, planning or research purposes. A state-wide procedure should take full advantage of data routinely collected by state and local agencies and organizations (e.g., permits, licenses, leases).

Land records (by-products of record keeping) and inventories (intended surveys of land use and land cover) are spatially-related documents that record governmental and private interest in the physical, environmental, legal and fiscal aspects of the land - whether on, above, or under the surface of the earth. Land records and inventories include governmental data required, collected and maintained for real estate and taxation, land transfer, environmental protection, and land use and resource planning and management. Examples of records which are collected by Minnesota agencies include Water Use Permits and Peatland Leasing Records (both collected by the Department of Natural Resources). Examples of inventories maintained by state agencies include the Minnesota Land Management Information System (State Planning Agency), the Natural Heritage Information System (Department of Natural Resources) and the Airport Inventory (Department of Transportation).

In recent years, concern has been expressed by private citizens and public officials in agencies at all levels of government about the inadequacy and cost of land records, including procedures for obtaining, maintaining and integrating useful data for planning, managing and regulating land and its related resources.

Expectations for an effective land records system include the following:

- That information about the location and physical characteristics of land is accessible from public records;
- That government has established common standards by which land data and records can be shared and aggregated from one level of government to another;
- That socio-economic data, such as demographic and fiscal data about a particular place, can be integrated with physical data about the land;

- That various units of government do not duplicate each other's land information gathering activities;
- That government is using appropriations for land records and inventories in a cost-effective manner.

These expectations are often not met with the current land records situation in Minnesota. The following scenario illustrates the complexity of these problems. Several groups or agencies need information about the same resource. The lack of coordination among these groups, and their single-mission or single-resource focus often leads to duplicative, unintegrated and expensive data products. For example, a tax assessor may see little similarity between his land record needs and those of an engineer siting an electrical transmission line while, in fact, there is similarity. The end result is multiple, uncoordinated record gathering and unmet information needs.

Concerns about the inadequacy of land records prompted the State Planning Agency to identify advantages and limitations of existing land records and inventories, such as lack of coordination, and to provide recommendations for improving the current situation.

a. ADVANTAGES OF LAND RECORDS AND INVENTORIES

The advantages of using land records and inventories as means of monitoring land use and land cover are briefly summarized below. For a more detailed discussion, see Chapter II of this report.

(1) Flexibility. Many land records and inventories provide a great amount of information on land uses and land covers for individual sites in Minnesota. This allows data users a high degree of flexibility in selecting items of data which are most important for a particular application. The same inventory or set of records can thus be used by different users with varying data needs.

(2) Ongoing Nature of Records. Many permits, leases and licenses are routinely maintained by public agencies for administrative purposes regardless of whether or not data pertaining to land use or land cover is extracted from them. The ongoing collection of these permits, licenses and leases makes them good indicators of land uses and activities as well as changes in land use/cover over time.

(3) User-Oriented Format of Inventories. Inventories are often formatted in ways which allow easy use by land use and resource planners and managers. Common formats include maps, tables, indices, lists and computer files. The computerized format of some land inventories (for example, MLMIS) makes it feasible to map and combine data on any land cover or use with data on other natural resource and social factors.

(4) Cost. The routine collection of many public records on an ongoing basis means that costs associated with data collection are accounted for either by funding provided by the collecting agency or by fees paid by applicants for the permits, licenses or leases. Costs of using this data are those incurred through extracting the data from the records and inventories and putting it into usable format. The time and cost of obtaining the data can be reduced if this extraction and organization of items of information can be incorporated into existing data collection and filing routines rather than developed independently.

b. LIMITATIONS OF RECORDS AND INVENTORIES

(1) Inaccessibility. In Minnesota, all records collected by government agencies are public (i.e., accessible to the public) unless classified otherwise by federal law, state statute or temporary classification. Some government records and inventories containing land use and land cover data are classified nonpublic to insure confidentiality of some information. An example is The National Pollution Discharge Elimination System Permits (PCA).

(2) Incomplete Geographic Coverage. Many data collection programs collect data for limited areas of the state. This data may be useful to others, but the usefulness may be limited by the small area of coverage. Often, data collected locally may not conform to political or natural resource boundaries. Yet, while lack of complete geographic coverage of land records can be a problem, other problems can emerge even when complete coverage for a large area does exist. This limitation applies most specifically to records collected at the local level. For example, various governmental units which require building permits may collect different items of information on the permits. The categorization and display of this information may also vary from county to county.

(3) Lack of Compatible Geographic Referencing Systems. In order for land records and inventories to be useful to the largest number of potential users, it is important that commonly used and understood geographic referencing systems be used when identifying locations of features. Examples of such geo-referencing systems include Public Land Survey (PLS) description, legal description, latitude-longitude location and Universal Trans-Mercator (UTM) location. Some land records and inventories do not include important geographic indicators. Other records do include such indicators, but are filed in ways which make them difficult to work with.

(4) Lack of Knowledge of the Existence of Data in Records and Inventories. Data users are often not aware of the existence of accessible records and inventories which contain data they need. As well, there is no centralized location where data users can access or find out about all the data which may of use to them. Inefficient use of data found in records and inventories can often be attributed to lack of knowledge of what data currently exists and where it can be located. Recognizing this, the State Planning Agency undertook an effort to catalog land use and land cover data routinely collected by major state and regional agencies. The result of this effort, the Catalog of Data Sources: Land Use in Minnesota, contains information about the majority of land records and inventories collected and maintained by the State Departments of Agriculture, Natural Resources, Transportation, Energy, Planning, Pollution Control, the Minnesota Geological Survey and the Metropolitan Council. (See the Appendix of this report for a listing of the table of contents of the Catalog.) Future efforts of the State Planning Agency will add data sources to the current inventory and develop a procedure to periodically update the information.

(5) Institutional Barriers. Government agencies have made only limited attempts to set standards for coordinated data collection. The information contained in records is often not shared among agencies, nor is the information widely distributed for possible use by others. Very little is done to ensure that data collected by each agency is compatible with and complementary to the data collection efforts of other agencies.

c. FUTURE PLANS OF ACTION

During fiscal years 82 and 83, further efforts will be undertaken by the State Planning Agency to:

- Describe and analyze the state's land data system as it presently exists with respect to: gaps, overlaps, frequency of data collection, and use of geo-codes;
- Develop standards for data collection by state agencies;
- Conduct short-term research to evaluate how long it would take to bring about the necessary changes in record keeping, associated costs, applicability, and usefulness of the data in analyzing natural resource issues and related trends; and
- Implement a pilot program designed to integrate data on urban structures derived from building permit data routinely collected by the census, as well as data on commercial/industrial development from the State Department of Economic Development, with natural resource data in MLMIS. This type of effort is intended to evaluate the usefulness and applicability of permit data as a means of monitoring general urban land use trends.

d. SUMMARY

A state-wide procedure for monitoring land use and land cover should take full advantage of information and data routinely collected by state and local agencies and organizations (e.g., permits, licenses, leases and inventories). To the extent that a comprehensive monitoring procedure draws on the realm of public records and inventories, it links or coordinates users of land use and cover data with the network of agencies and institutions that collect and store that data. One feature of such a procedure, then, should be the identification of those agencies and institutions and levels of government responsible for various aspects of the data collection effort. Recommendations to this end are presented in the concluding sections of this chapter.

D. MAJOR CONCLUSIONS

The following conclusions have been drawn from the findings of the numerous projects and studies summarized above.

1. There is no one simple technique or method which will yield relatively accurate data on all land covers and land uses. Minnesota will continue to be dependent upon utilizing a number of data sources and procedures.

2. Without a program to coordinate these procedures, set standards, establish plans of action for each procedure, and account for gaps and overlaps, lack of coordination and incompatibility of sources is likely to continue.

3. Generally, the information sources used for measuring land covers is different from those used for measuring land uses. Remote sensing (satellite imagery and aerial photography) products are primary sources of data for land cover classification. Images are available from federal, state and private sources; a listing of those is contained in the Minnesota State Planning Agency's Inventory of Aerial Photography and Other Remotely Sensed Imagery of Minnesota.

4. LANDSAT is best suited for the classification of water, forest and agricultural lands. The use of LANDSAT to classify areas of low density urban development or wetlands in Minnesota is not recommended.

5. Information sources on detailed land uses are varied, as air photo and LANDSAT interpretation of complex and intensive land uses is difficult at any scale. When detailed information is required tax records, building permits, official maps, plat book maps, licensing records, field work, and agency records and inventories are most appropriate.

6. At the present time, a large number of federal, state and local agencies and organizations produce a vast amount of information on the use of Minnesota's land. The data gathered by the agencies and organizations, utilizing a wide variety of procedures, do not conform to one set of standards regarding frequency of collection, geographic referencing, etc. This reduces compatibility among data sets, minimizing their usefulness in planning and decision-making.

E. RECOMMENDATIONS

The State of Minnesota needs to collect and store data in a more systematic manner, make better use of the data it collects, and to identify, establish and implement plans of action to meet unmet data needs.

Drawing on the major findings developed in the separate pilot projects and case studies and based on the guidelines set forth below, the State Planning Agency proposes that a state program be initiated to meet the following objectives:

1. Set standards for state-financed mapping and land data collection efforts. Standards should be developed regarding priority of focus, frequency of data collection, scheduling of updates, use of geo-codes, level of scale and detail, etc. Local levels of government should be encouraged to follow these established standards.

   Standardization of land use and land cover data collection is an important step in an effort to share land use information. Unless terms are commonly understood and applied, there will be misunderstanding and lack of coordination.

   Under a system of standardized land use/land cover classification terms and geographic referencing, completed studies and inventories become a cumulative record of land use and cover characteristics and change. State agencies that have responsibilities for land management will benefit because standardization of data among agencies will facilitate data sharing and its collection and storage. Local land planners and public officials will benefit because standardized information acquired from any source will be easier to use and interpret. Local levels of government might acquire summary and overview data at county and regional scales from state agencies. Also land cover data from satellite imagery in standard format may be useful to officials of local levels of government as these materials become more widely available. Typically, the flow of land use information has been from the local to the state level. Standardization of land use and cover data may help to increase information flow in both directions.

2. Review state requests to conduct land data collection or mapping, in order to assure that established standards are met.

3. Serve as a focal point for land and natural resource information and refer users of land information to appropriate sources.

4. Assess the need for and provide technical assistance to local officials with designated functions for land information. For example, the state might assist in designing workshops for local planners in air photo interpretation techniques and the application of air photo imagery in land use planning.

F. GUIDELINES

The following are suggested guidelines for determining priorities and for developing standards and a schedule for monitoring land use and land cover in Minnesota.

- Information on Minnesota's land and natural resources should be accessible to and usable by all levels of government, by agencies at each level, and by citizens.

- Data collection on land use and land cover should be done by the lowest possible government level that has the technical ability to collect it accurately and efficiently and that has the finances and capabilities otherwise to do so.

- Standards for land data collection should be developed collaboratively by representatives from all levels of government and implementation of those standards coordinated by the higher levels of government, in order to assure effective compilation and integration among all levels of government. Although land use and land cover data may be maintained in separate individual data bases (that is, maintained in local, regional and state offices), users should be able to access much of this data through the facilities and assistance of a centralized bureau - such as the Land Management Information Center of the Minnesota State Planning Agency.

The state can choose to follow one of several alternative courses of action regarding: types of desired products; priority of focus; schedule for the collection, organization, and dissemination of land use and land cover data; and frequency of updating data on the various land covers and uses.

1. TYPES OF PRODUCTS

Information on various uses and covers of land should be kept in a format which is readily accessible to a wide variety of users, and flexible enough to produce numerous land use maps and cover maps for a variety of specific applications ranging from:

a. One single map displaying dominant cover and uses of land at one point in time and which attempts to fulfill diverse user requirements (i.e., an updated Minnesota land use map), to

b. A series of maps and inventories which address different specific uses or cover types (e.g., an irrigation map, a map of change in urban/built-up areas, a detailed forest cover map and a map of commercial forest uses).

A state-wide land use/land cover monitoring procedure should recognize that data users have a variety of needs regarding type and format of information and level of detail. The procedure should be flexible enough to serve a broad range of users' needs.

- The minimum unit (e.g., 10-acre or 40-acre) selected for the collection and mapping of land use and land cover data and the level of detail used to categorize land use and land cover should be kept at a scale appropriate for as many varying planning and research needs as possible. This would minimize the expenditure of time and money by data users at state, regional and local levels. Whereas generalized data cannot be made more detailed and is therefore limited in its usefulness, detailed data can be aggregated to provide a generalized overview of a region or the state.

2. FOCUS AND FREQUENCY OF DATA COLLECTION AND UPDATES

Regarding priority of focus and scheduling of data collection and updates, the state can choose to:

a. Collect, update, and map all land use and land cover data simultaneously. Proponents of this alternative usually envision using one procedure - such as small scale aerial photography - for obtaining

current land use/land cover data. The main advantage of this approach is its timeliness. As mentioned earlier in this report, this can also be expensive. Moreover, no one single data source can presently yield accurate and detailed data on all major land covers and uses. Or

b. Undertake a partial, scheduled collection of land use and land cover data. Land data would be collected and mapped for certain portions of the state and/or for certain land uses and covers. This activity would be undertaken according to a schedule based on established priorities. This scheduling would necessitate making choices and setting priorites on the relative importance of land uses and land covers for which data is to be collected, updated and mapped.

In the short run, this alternative would be less costly than the first alternative. However, this approach would not yield data on all land covers and uses quickly. Yet, when the overall data collection and updating is completed, procedures for obtaining data on all priority land uses and land covers should be in place. Pursuing this alternative would require the coordination, cooperation and commitment of various levels of government and agencies within each level to follow these priorities and schedules for data collection and updating.

The following statements are offered as guidelines when setting priorites and determining data collection and updating schedules. Careful selection of the kind of land use and cover changes being monitored is important and should be based on the rapidity and permanancy of these changes. Review of the relative importance and type of changes expected should precede detailed land use and cover data collection and mapping efforts.

- Change: Those areas of the state undergoing change from one land use/cover to another should receive priority in data collection, mapping and updating; mapping of changes is less costly on a state-wide basis than complete remapping.

- Rates of Change: Changes in land use and land cover occur at highly variable rates from place to place. For example, the development of a new residential subdivision in a given location generally takes place within a few months. On the other hand, the natural reversion of crop land and pasture to forest land occurs over a much longer period of time. Variations in rates of change should be evaluated in order to provide an appropriate frame of reference for the systematic collection and updating of land use and land cover data. Specifically, annual updates may be necessary for rapidly changing uses or areas of the state; less frequent updates for others.

- Irreversibility: Some changes in land use and land cover are more difficult to reverse than others, or cannot be reversed at all, and need to be evaluated differently from those changes that can be easily reversed. For example, once a residence is built up on prime agricultural land, it is quite unlikely that such an area will ever be returned to agricultural uses. This permanence of residential/urban uses of land has generated a major interest at the state and local levels in mapping areas of urban growth and development and in assessing their impact on agricultural land and lakeshore. However, changes in other natural resources such as forestry, wetlands and agricultural uses should not be neglected.

- Case Studies: For applications which require data about the nature and degree of change but not the exact location of specific changes, samplings of representative study areas should be considered as alternatives to complete detailed studies.

Given the above criteria, it is recommended that Minnesota place priority on monitoring and updating the following:

LOSS OF PRIME AGRICULTURAL LAND;
ATTRITION OF WETLANDS;
URBAN GROWTH AND DEVELOPMENT;
LAKESHORE QUALITY;
CHANGES IN FORESTRY RESOURCES;
TRANSPORTION.

During fiscal years 82 and 83 the State Planning Agency, Division of Physical Planning, will continue to identify and evaluate the most appropriate data sources for monitoring each of these priority issues.

II. DESCRIPTIONS OF DATA SOURCES

This chapter discusses remote sensing (aerial photography and LANDSAT) and land records and inventories as sources of information about land use and land cover conditions. Each source is evaluated in terms of its availability, cost, frequency of collection and uniformity. Charts summarizing the results of this evaluation for aerial photography and LANDSAT appear on pages 30 and 36. respectively.

A. REMOTE SENSING

The term "remote sensing" refers to the detection of the nature of an object without touching it. With regard to land covers and land uses, remote sensing usually refers to the collection of data on ground surface features from aircraft or spacecraft. For many purposes, remote sensing can provide the most practical and cost-effective means of obtaining land use and land cover information. A brief introduction to remote sensing terminology and the principles involved in the operation of various remote sensors will provide perspective for a discussion of the use of remote sensing in obtaining land cover and land use information.

All remote sensors work by detecting and recording energy. Remote sensors can be categorized as either active - sending out energy and measuring its return or penetration (e.g. radar and x-ray machines) or passive - collecting energy which is reflected or emitted at the ground surface (e.g. cameras, thermal sensors, multispectral scanners and human eyes). Remote sensing is based on the principle that different objects reflect or emit different amounts of energy in different portions of what is known as the electromagnetic spectrum. The electromagnetic spectrum consists of the entire range of energy emitted by the sun. Remote sensors measure energy in limited portions of the spectrum. The human eye, for example, only detects energy in a very small portion of the spectrum, commonly called the visible portion of the spectrum. Whereas some objects are most easily distinguished in the visible portion of the spectrum, it is easier to distinguish among other objects from data recorded in portions of the spectrum which are invisible to the human eye. Therefore the objects of interest determine, in part, the most appropriate remote sensor for the job.

For purposes of distinguishing among various land covers and land uses, the portions of the spectrum which are of greatest interest are those in the visible and near infrared ranges. Images produced from the most common aerial photography and LANDSAT multispectral scanning (discussed below) represent those portions of the spectrum.

1. AERIAL PHOTOGRAPHY

Aerial photography is probably the best known and most commonly used method of remote sensing of ground features. A great deal of variation exists within the realm of aerial photography, resulting in a wide variety of images. The same area can be represented on two different air photos in ways which appear very different and provide different kinds of information about the area. As a

result, the usefulness of any given air photo imagery will depend on the user's specific data needs.

The aerial photography section of this chapter will discuss some of the ways in which air photo imagery varies. This variation occurs along a number of dimensions which will be referred to as "characteristics" of air photos. As well, the advantages and disadvantages to the use of aerial photography, and the extent and kinds of use of aerial photography in Minnesota will be discussed. The reader is referred to sources of further information on aerial photography in Minnesota. Finally, a discussion of existing and projected aerial photography programs in Minnesota is presented.

a. CHARACTERISTICS OF AERIAL PHOTOGRAPHS

A discussion of aerial photography necessitates an understanding of certain terms and concepts. The following paragraphs provide descriptions of some characteristics of aerial photographs, as well as some of the implications for the usefulness of imagery as it varies on these characteristics. The characteristics which are discussed include scale, film type, time of year, imagery format and angle between the camera lens and the earth's surface.

(1) Scale. The scale of an air photo is the ratio of distance on the photo to actual distance on the ground. This is usually written in a form such as 1:40,000, which is read "one to 40,000." In this case, one inch on the photo is equal to 40,000 inches on the ground. As the second number in this ratio (e.g., 40,000) increases, the size of a photographic image of a given area decreases. An air photo at a scale of 1:40,000 is said to be at a larger scale than an air photo which is at a scale of 1:80,000. For purposes of this report, three general categories (large, medium and small) of scale will be used to make comparisons among air photos which are at different scales. These categories of scale appear in the table on page 29.

(2) Film Type. Different film types detect and record energy representing different portions of the electromagnetic spectrum. Aerial photography utilizes two of the most common types of film for normal everyday use: panchromatic black and white and natural color. Both of these record images representing the visible portion of the electromagnetic spectrum and are similar to films found in personal cameras. Today, aerial photography is making increased use of infrared portions of the spectrum. Infrared films are useful for penetrating atmospheric obstructions (e.g. haze or smog) and determining healthiness of vegetation. Infrared films are available in either color or black and white.

(3) Time of Year. The season during which air photos are taken greatly affects the number of kinds of uses to which the photos may be put. Leaf-on photography is taken during the summer months or growing season in Minnesota. Leaf-on photography allows determination of vegetative types and conditions (e.g., crops and forest types). Leaf-off photography is taken during the spring or fall months, but seldom during the winter months when there is snow cover. Leaf-off photography allows easier identification of soil types, geologic formations, and other ground surface features (e.g., buildings) which may be hidden by leaves at other times.

(4) Imagery Format. Most air photos that are available to the public are printed from 9" x 9" negatives. These negatives are usually contact printed to produce 9" x 9" images. The amount of area displayed on 9" x 9" image depends on the scale of the photography - the larger the scale, the smaller the area displayed. (The approximate land area covered by a 9" x 9" image is provided for various scales of photography in the table on page 29. Some images represent enlargements from original negatives. In the case of the 1968-69 and 1977 statewide high altitude aerial photography of Minnesota, images were enlarged from 1:90,000 and 1:80,000 negatives to a scale of 1:24,000, the same scale as the 7½ minute quadrangle sheets published by the U.S. Geological Survey (commonly referred to as topo maps). These images are available as inexpensive blueline (ozalid) prints measuring over 18" x 30".

(5) Angle. The angle of aerial photography refers to the angle of the camera lens relative to the surface of the earth. For the purposes of discussion in this paper, the only air photos considered are vertical photographs. Vertical photographs result from a camera lens facing the earth's surface at a 90 degree angle (i.e., the lens is directly over an object). Air photos taken from any angle other than vertical are called oblique photographs. Oblique photographs are uncommon in remote sensing due to their bias toward the side of objects facing the camera, and their tendency to hide or obscure objects located behind other objects.

b. THE EXTENT AND KINDS OF USE OF AERIAL PHOTOGRAPHY IN MINNESOTA

The features appearing on air photo imagery are interpreted by users to yield the information they need. In some instances, air photo interpreters will pay attention to a limited number of features. For example, foresters may have little interest in portions of images displaying urban areas or open pasture. In other instances, interpreters may pay attention to a large number of features. If air photos are interpreted in efforts to create a general land use/land cover map, it may be important for the interpreter to consider many features to determine the predominant use or cover in an area. In any case, the interpreter must be knowledgable in the way ground features and conditions of interest appear on air photo imagery.

Since different types of imagery show ground features differently, the particular features of interest to the user determine his or her preference for type of imagery. This preference is reflected in the amount of use made of various types of imagery.

The State Planning Agency conducted a survey of aerial photography/remote sensing users during the summer of 1975 to determine the amount and kinds of use being made of Minnesota air photos. Over 100 written inquiries were mailed to persons representing commissions, agencies, departments, libraries and individuals. In addition to the mailed inquiries, telephone inquiries and personal interviews were also conducted to complete the survey. Survey results yielded valuable information on both current (as of summer, 1975) and anticipated needs for aerial photography. Significant findings are presented below and are organized according to scale, film type, time of year and user preferences for frequency of air photo coverage.

(1) Scale. Respondents indicated their preferences for various scales of aerial photography in the following manner.

SCALE PREFERRED	PERCENTAGES OF RESPONDENTS
Large-scales (approximate range from 1:1 to 1:12,000)	
larger than 1:12,000	33.7
Medium-scales (approximate range from 1:12,000 to 1:55,000)	
1:15,840	11.6
1:24,000	29.1
1:31,680	2.4
1:52,500	8.1
Small-scales (aproximate range from 1:55,000 to 1:120,000)	
smaller than 1:80,000	15.1
	100.0%

A high proportion (1 in 3) of respondents preferred large-scales of 1:12,000 or larger. This group of users was largely made up of people who do engineering work of some kind. This group includes: highway construction and maintenance; pipeline, power line and telephone cable rights-of-way; sanitary landfills, etc. The uses of large-scale photography are often project-oriented and cover small areas of land, usually in narrow strips or spots. While multiple use of these images does not have the same potential as smaller-scale photography of larger areas, it should be possible to extend usage of the large-scale photographs to people beyond the original purchasing agency. For example, beyond their use in specific project work, large-scale photography images also have considerable value for technical or educational purposes in schools, colleges and universities throughout the state. Further, they may be useful to local units of government interested in land use data for a small area under their jurisdiction.

Each of the medium-scales of aerial photography listed in the scale preference table has had a fairly well-defined user group. The 1:15,840 scale of photography traditionally has been used by foresters. Until quite recently it was almost the only scale used in forest inventories since it has excellent resolution for purposes of tree identification. However, recent technical developments in aerial photography have meant that smaller-scales can be used for some types of forestry and other vegetative studies. Until recently, the use of air photographs at scales of 1:20,000 was normal for purposes of agricultural crop recognition. Scales down to 1:40,000 can now be used successfully for some of these inventories. In the medium-scale range, one scale in particular stands out in user requirements - that of 1:24,000. This is not surprising, since this is the scale of the U.S. Geological Survey 7½ minute quadrangle topographic maps. This

scale is rapidly becoming the "standard" medium-scale for many kinds of mapping and planning. Within Minnesota, state agency users can obtain 1:24,000 quad-centered blueline prints of enlarged photos for any place in the state. This convenience resulted from a high altitude aerial photography program funded by various state and federal sources in 1968-69 and again in 1977. As of April, 1981 115,000 of these enlargements had been used by public agencies. This number of photos is enough to cover the complete state more than 65 times. (1,700 images are required for complete coverage.)

Increased use is being made of small-scale photography in Minnesota and other places. As mentioned, the state purchased state-wide coverage in 1968-69 and again in 1977. One of the first uses of this photography was to prepare a 1969 State of Minnesota Land Use Map. Land use data from this source enhanced a computerized information data bank called the Minnesota Land Management Information System (MLMIS). Both the state-wide air photo flights and the creation of a computerized data bank have been emulated in other states. Recognition of Minnesota's early steps in land use mapping and planning is widespread in the nation.

Of equal importance to having the small-scale photos is the ability to make enlargements, as discussed above for the 1968-69 and 1977 imagery of Minnesota.

(2) Film Type. There was an almost equal division in the respondents' preference for film type. Approximately half of the respondents to the 1975 survey preferred panchromatic film and half preferred infrared film. Had this survey been carried out a decade or more ago, a much smaller number of respondents probably would have indicated a preference for infrared material. These user preferences for film type indicate a rapidly increasing awareness of the potentials for infrared photography for interpretation. This includes both color infrared and black and white infrared photography. The advantages of infrared photography result in part from better penetration of haze and smog in the infrared part of the spectrum. This gives sharper images, shows bodies of water through sparse vegetation, and provides a better indication of healthiness of vegetation.

There is still a strong demand for conventional panchromatic black and white photography. Air photos produced from this film are usually less costly to obtain because of lower initial costs and lower costs to produce special products such as enlargements. In addition, panchromatic film produces photos which show many cultural features (e.g., roads, railroads, houses, etc.) better than infrared photos, and does a better job of recording in shadow areas.

(3) Time of Year. A large majority (77.3%) of the users surveyed indicated a need for spring or fall photography - that is, leaf-off times. This is simply because most cultural feature interpretation (e.g., summer home identification) is better without leaves on the trees, as is identification of shorelines, soil types, geologic features, or other features that may be obscured by vegetation under leaf-on conditions. Conversely, of course, interpreters concerned with various kinds of vegetation identification comprise the respondents (22.7%) requiring summer (leaf-on) photography. These two different time of year requirements are not compatible and necessitate multiple photographic

coverage. But these two groups of users also have different requirements for scale and frequency of coverage. Consequently, it is likely that both types of photos must continue to be acquired by the state.

(4) Frequency of Coverage. Respondents also indicated their preference for frequency of aerial photography coverage. A large block of respondents (over one-quarter) wanted photography on an "as needed" basis. This group included those who needed coverage for a specific project (highway engineering, powerline routing, etc.) and users looking for immediate coverage of special events, like disaster areas (floods, tornados, etc.). Another large group of users felt that they needed photographic coverage every five years or so. This group included many agricultural and forestry land managers, plus land use planners interested in monitoring land use change at a local level. Typical uses in this latter group included studies of urban expansion, changes in farmland acreages, changes in water levels in lakes and streams, and the impact of various vegetative management programs. Not one of the respondents to the 1975 survey thought that a frequency of coverage over 10 years could serve their needs. In most cases, photography has a useful life of 4 to 6 years (excluding its use as a historical record).

(5) Relationships Between Frequency, Film Type and Scale. During the course of the survey, it became apparent that there were some correlations between frequency of coverage, film type and scale of photography desired. There is a large group of users requiring large-scale panchromatic photography on an "as needed" basis for small parts of the state.

A second large group of users need medium-scale photography (some using panchromatic, some infrared) for sizable portions of the state on a 4 to 8 year rotation. This group includes most forest and agricultural inventory groups, plus local land use planning and managing users.

A third group of users requires a small-scale photography program, covering the entire state every 5 to 10 years. Such statewide programs should include the small-scale photography, plus 1:24,000 reproducible enlargements. This group of users includes people with state-wide perspectives of changing land use patterns, plus a vast variety of people involved in state land management programs. Included in this latter group are sections of the Department of Transportation, the Department of Natural Resources, the State Planning Agency, the Regional Development Commissions, the Department of Agriculture, the Pollution Control Agency and others.

c. ADVANTAGES TO THE USE OF AERIAL PHOTOGRAPHY

The widespread use of aerial photography in Minnesota can be attributed to a number of factors. Using existing methods of interpretation, aerial photography is able to provide detailed, accurate land use data for many purposes in an inexpensive manner. The number of man-hours required to obtain many kinds of land use data from photographic imagery is substantially less than for existing field survey or other methods. When compared with other methods of obtaining data, techniques which make use of aerial photography seem to offer advantages when such factors as timeliness, flexibility, and reliability of information are considered in relation to the cost of acquiring the data.

The comprehensiveness of recorded information is another advantage of aerial photography. Each air photo image provides a wealth of data which can be returned to as many times as needed to satisfy diverse user requirements. Every image provides an undisputable historical record of what an area looked like at a given point in time.

Aerial photography can allow a synoptic view of a geographic area which is unlike that allowed by any other data source. A person who is familiar with air photo imagery can get a sense of the patterns of land use and cover at a glance. Then, closer investigation can yield greater detail in areas where clarification is needed. For example, a 9" x 9" image at a scale of 1:80,000 displays an area which is more than 11 miles on a side. An area this size can easily encompass a metropolitan area of moderate size, as well as much of the land which is in close enough proximity to be impacted by the city. This image could be used either by itself or in conjunction with larger-scale imagery to provide information on the metropolitan area's land features.

It is relatively easy and inexpensive to photographically enlarge or reduce air photo imagery to match the scale of photography to maps or other data. This type of process is not unique to the realm of aerial photography, but it offers many advantages nonetheless. One advantage which is unique to aerial photography is worthy of mention. If two images of the same area are photographed from different points in the air, they can provide a three-dimensional view of the area if viewed at the same time through a stereoscope. The use of "stereo pairs" of photos expands the number of kinds of uses which can be made of air photos.

d. LIMITATIONS TO THE USE OF AERIAL PHOTOGRAPHY

Air photo imagery is limited in that it can display only the top layer of ground features. This means that any features which lie under tree cover, or any other "overhead" obstruction do not appear on the imagery. This makes it particularly difficult to detect urban uses in wooded areas. Even when buildings appear clearly on air photos, it is often difficult to determine the uses which are made of the structures. As a general rule, air photos are more accurate in determining land covers than land uses, since land covers are more closely related to visible physical features than are land uses.

Many air photo limitations are associated with the large, complicated network of air photo suppliers and users. The only scales of photography which are feasible for the state to finance on a state-wide basis are small-scale (high altitude). This means that users needing larger-scale imagery must either locate existing imagery or finance a flight to produce new imagery. Most counties and many cities do occasionally finance such flights. However, there appears to be a lack of coordination among many political units which could benefit from compatible imagery. For instance, some cities which lie on county borders (e.g., St. Cloud, Mankato, Lake City) could benefit from photo coordination between the counties they touch. Even for areas where adequate imagery does exist, it is possible for potential users to be unaware of its existence, resulting in the use of inferior data sources or unnecessary replication of flights.

Another limitation of air photo imagery is inherent in the limited applications which can be made of specific kinds of imagery. Some users need leaf-on imagery while others need leaf-off. Some need panchromatic black and white while others need color infrared. These sorts of limitations cannot be avoided, but can be partially alleviated by better coordination among air photo users.

Problems can sometimes be encountered in acquiring existing imagery, or in getting new imagery in a timely manner. Imagery of interest to air photo users may be held by either public or private vendors. There is usually no problem obtaining this imagery, though sometimes at substantial cost. However, obstacles such as loss of negatives or classification of photography as non-public (especially in the case of military aerial photography) can prove problematic. Since there are a limited number of outfits which conduct air photo flights and a limited number of good flying days in a year (or in a leaf-on or leaf-off season), a certain amount of planning and time allowance must be integral parts of efforts to obtain new imagery.

A final limitation to the use of aerial photography applies most specifically to panchromatic imagery. As atmospheric conditions become continually more polluted, panchromatic images are becoming increasingly obscured. Since infrared photography does a better job of penetrating such atmospheric barriers, it is not greatly affected by changes in the atmosphere.

e. INVENTORIES AND INFORMATION ON AERIAL PHOTOGRAPHY IN MINNESOTA

Due to the multiplicity of programs which provide and/or make use of aerial photography, there exists a strong need for a central place responsible for maintaining current information on aerial photography in Minnesota. This need was recognized and such a central place was established in 1975. The Mapping and Remote Sensing Information Center (MARSIC) of the Minnesota State Planning Agency provides numerous functions concerning aerial photography as well as other remotely sensed imagery and maps of Minnesota.

Among other activities, the Center has periodically published comprehensive catalogs of air photo and map holdings and reports of new products and services. The Inventory of Aerial Photography and Other Remotely Sensed Imagery of Minnesota (revised June, 1978) contains the most complete catalog of Minnesota's aerial photography to date. This inventory is available at Documents Section, 140 Centennial Building, 658 Cedar Street, St. Paul, Minnesota 55155. To be placed on the mailing list for updated reports, or for any other information regarding aerial photography in Minnesota, contact the Mapping and Remote Sensing Information Center (MARSIC) at the Minnesota State Planning Agency, Land Management Information Center, LL45 Metro Square Building, 7th and Robert Streets, St. Paul, Minnesota 55101, or call 612/296-1211.

f. CURRENT AND PROJECTED MAJOR AERIAL PHOTOGRAPHY PROGRAMS IN MINNESOTA

Numerous federal and state agencies currently have active remote sensing programs which produce aerial photography images of portions of Minnesota. Primary among these are the U.S. Geological Survey, the U.S. Department of Agriculture and the Minnesota Department of Natural Resources. There are, however, no existing or proposed plans for repetition of the approximately one-point-in-time coverage of the entire state which has been carried out twice to

date - in 1968-69 and again in 1977. In fact, the Land Use Change Project was funded to evaluate alternatives to the use of small-scale aerial photography as a source of data on land uses and land covers.

Due to the diversity of the aerial photography which is produced and the lack of a plan for one-point-in-time uniform state-wide coverage, the need for coordination of ongoing remote sensing activities is essential if maximum benefit is to be derived from existing programs. This coordination is multi-faceted and includes, among other things, communication among persons responsible for determining what areas are to be flown when, at what scales and with what film; and collection and dissemination of information on what photography is available to users. Considering the amount of money which is invested in producing air photos, a commitment to planning, coordination and communication of air photo activities seems to be a worthwhile investment. An important component of this coordination and communication process in Minnesota is the Mapping and Remote Sensing Information Center of the State Planning Agency.

Given the responses to the 1975 user survey and the extensive use which has been made of photo enlargements of 1968-69 and 1977 statewide high altitude aerial photography, a repetition of the statewide air photo efforts would be welcomed by many air photo users. The costs involved in such an effort have increased dramatically with inflation and the current high cost of silver (used in photographic films and papers). It would take a major financial commitment (approximately $1,000,000 at 1981 prices for a repetition of statewide coverage) on the parts of the State of Minnesota and federal programs.* In light of continually higher costs of photo processing and current conditions imposing limitations on government spending, it may not be justifiable to repeat statewide coverage in the near future. This makes it all the more important to make the best use of available remote sensing resources and land use records and inventories which could provide data if properly organized and standardized.

The U.S. Department of Agriculture's Agricultural Stabilization and Conservation Service (ASCS) has recently reactivated an extensive air photo program. This program provides 1:40,000 summer (leaf-on) black and white panchromatic photography for a large number of counties in primarily agricultural parts (southwestern two-thirds) of the state. Other recent air photo efforts of the U.S. Department of Agriculture include coverage of the state's national forests by the Forest Service (1:15,840, leaf-on black and white panchromatic and black and white infrared) and scattered coverage of counties by the Soil Conservation Service (1:48,000 negatives, leaf-off black and white panchromatic and black and white infrared).

The Forestry Division of the Minnesota Department of Natural Resources has provided 1:15,840 summer (leaf-on) black and white infrared coverage of most of the predominantly forested regions (northeastern two-fifths and southereastern corner) of the state within the past 15 years. Most recently, portions of central and southeastern Minnesota have been photographed.

* Additional costs are incurred when using aerial photographs as data sources. These include the costs of photo processing, interpreting, coding, computerizing, etc. For a more detailed listing of costs associated with the use of aerial photographs as sources of urban structures data, see The Use of High Altitude Aerial Photography to Monitor Changes in Urban Structures in Minnesota, Appendix B, published by the Minnesota State Planning Agency.

The U.S. Geological Survey of the U.S. Department of Interior has recently had an active program of aerial photography to provide images for use in its topographic mapping program. This photography is at varying scales (1:15,000 to 1:30,000), leaf-off and black and white panchromatic.

Possibly the most significant aerial photography effort taking place in Minnesota is one that is occurring on a national level. A number of federal agencies including the U.S. Departments of Interior and Agriculture have proposed and begun implementation of a National High Altitude Photography Data Base. (Unfortunately, the status of this program is questionable at this time due to proposed cutbacks in federal spending.) Two cameras are used on the same aircraft to provide two sets of aerial photographs from this national effort. One of the cameras provides 1:80,000 black and white panchromatic photos, while the other camera provides 1:58,000 color infrared photographs.

First priority areas were flown beginning in federal fiscal year 1980. The original intention of the program was to secure coverage of the conterminous United States with both kinds of images within a three to four year period of the program's onset. Priority of areas for coverage was determined by a steering committee and based on federal priorities. For a number of reasons, coverage of the majority of Minnesota was given low priority status and only small areas were scheduled to be flown in fiscal years 1980 and 1981. As well, the program has failed to keep up with the original schedule of flights. Due to the tenuous status of the program, it is questionable whether coverage will be secured for all of Minnesota. Even if this coverage is secured, it will encompass a long enough time span that the imagery will be of limited usefulness for uses which require statewide one-point-in-time coverage.

If the national high altitude photography data base does manage to provide air photo coverage of the state, images from the 1:80,000 black and white film will be available through the EROS Data Center in Sioux Falls, South Dakota and images from the 1:50,000 color film will be available through the Agricultural Stabilization and Conservation Service in Salt Lake City, Utah. If this photography is not completed, coordination of other aerial photography programs will become all the more important in order to maintain the most effective aerial photography coverage of Minnesota.

A COMPARISON OF VARIOUS SCALES OF AERIAL PHOTOGRAPHY

Category	Common Scales	Distance Equivalent	Approximate Land Area Covered by a 9 x 9 Inch Photo
LARGE-SCALE (approximate range is from 1:1 to 1:12,000)	1: 4,800	1 inch = 400 feet	.46 sq. mi.
	1:12,000	1 inch = 1,000 feet	2.9 sq. mi.
	Uses: Engineering and measurement surveys; site specific studies; thermal (e.g. heat loss) studies; crop, soil and vegetation identification.		
	Users: MN Dept. of Transportation, MN Pollution Control Agency, MN Dept. of Natural Resources, local units of government, developers, educational institutions.		
	Frequency of Data Collection: As needed for small parts of the state.		
MEDIUM-SCALE (approximate range is from 1:12,000 to 1:55,000)	1:15,840	1 inch = .25 miles	5.1 sq. mi.
	1:24,000	1 inch = .38 miles	11.6 sq. mi.
	1:31,680	1 inch = .5 miles	20.25 sq. mi.
	1:40,000	1 inch = .63 miles	32.3 sq. mi.
	Uses: Topical studies on land use, land cover (e.g., vegetation), forest types, soil surveys, geology and hydrology.		
	Users: U.S. Geological Survey, U.S. Forest Service, U.S. Dept. of Agriculture, Soil Conservation Service, MN Dept. of Transportation, MN Dept. of Natural Resources, MN State Planning Agency, MN Geological Survey, MN Dept. of Agriculture, Regional Development Commissions, county agencies, education institutions, sportsmen.		
	Frequency of Data Collection: Average of every 3 to 5 years.		
SMALL-SCALE (approximate range is from 1:55,000 to 1:120,000)	1:62,500	1 inch = .99 miles	78.8 sq. mi.
	1:80,000	1 inch = 1.26 miles	129.1 sq. mi.
	1:90,000	1 inch = 1.42 miles	163.4 sq. mi.
	Uses: Generalized land use, land cover (e.g., vegetation) soils, geology and hydrology; ground truth for land satellite images.		
	Users: U.S. Geological Survey, U.S. Forest Service, U.S. Dept. of Agriculture, Soil Conservation Service, U.S. Dept. of Defense, MN Dept. of Transportation, MN Dept. of Natural Resources, MN State Planning Agency, MN Geological Survey, Regional Development Commissions, MN Dept. of Agriculture, county agencies, educational institutions.		
	Frequency of Data Collection: Average of every 8 to 10 years. (Complete coverage of the state for 1968-69 and 1977 is available at 1:90,000 and 1:80,000 respectively.)		

APPLICATIONS OF AERIAL PHOTOGRAPHY FOR VARIOUS LAND USES AND LAND COVERS

LAND USE OR LAND COVER	APPLICATIONS (from Photo Interpretation)	PHOTOGRAPHY PREFERENCES FOR THESE APPLICATIONS: SCALE (Large, Medium or Small)	TIME OF YEAR (Leaf-On or Leaf-Off)	FILM TYPE (Infrared or Panchromatic)
Forestry	Forest type Acreage Damage assessment (e.g., insect infestation, fire, storm, disease, etc.)	Medium	Leaf-on	Both
Agriculture	a. Crop type b. Acreage c. Crop healthiness	a. Large b. and c. Medium	Leaf-on	Infrared
Water	Location and acreage of water bodies	All	Both	Panchromatic
Marsh	Location and acreage Vegetative type	All	Leaf-on	Both
Urban	a. Location of structures b. To a limited degree, use of structures (e.g., residential, commercial/industrial, agricultural)	a. All b. Large	Leaf-off	Panchromatic
Extractive	a. Location of mining activities b. Identification of areas with mining potential	a. All b. Small	Leaf-off	a. Both b. Infrared
Pasture and Open Land	a. Location and acreage b. Vegetative types	Medium	Both	a. Both b. Infrared
Transportation	a. Location of transportation routes b. Planning of transportation routes	a. All b. Large	Leaf-off	Panchromatic
Soil	Identification of soil type (soil surveys)	Large and Medium	Leaf-off	Both
Multiple Uses/ Covers	a. Generalized land use b. Ground truth for LANDSAT	a. Small b. Large and Medium	a. Leaf-off b. Both	Both

General note: Data for most land covers and some land uses can be interpreted from aerial photographs. Limitations are imposed if imagery is not at an appropriate scale, time of year, film type, etc. for the particular covers or uses of interest. The limitations of aerial photography do not appear on this chart, but can be found in the text of Chapter II.

2. LANDSAT

a. HISTORY OF THE PROGRAM

LANDSAT, formerly known as ERTS (Earth Resources Technology Satellite) is a satellite orbiting the earth at an altitude of about 560 miles. Monitors transmit a steady flow of information about the earth's surface characteristics to ground receiving stations. This information can be used by land planners, managers and researchers to whom monitoring of certain land cover characteristics is important.

The first satellite was launched by NASA in 1972. Its purpose was to demonstrate the value of continuous, worldwide data gathering from an orbital platform. It was followed by LANDSAT-2 in 1975 whose orbit was synchronized with LANDSAT-1 so that together, cloud cover permitting, they could provide almost complete global coverage every 9 days. Although LANDSAT-1 failed in January 1978, LANDSAT-3 was launched in March 1978, again allowing 9-day coverage. To maintain continuity of data, all three of these satellites have carried essentially the same data recording equipment (multispectral scanner) and have orbited at the same altitude.

Within recent months, LANDSAT-2 was retired due to problems and LANDSAT-3 has experienced difficulties. However, LANDSAT-2 has unexpectedly corrected itself and again provides the basic 18-day coverage; use of the malfunctioning LANDSAT-3 sensor is limited to special requests for 9-day coverage.

b. HOW THE SATELLITE WORKS

Although the product from the system that the public most often sees resembles a photograph, the system is not a photographic one. Rather, the main piece of data equipment is a multispectral scanner (MSS) which records numerical values representing the intensity of sun reflectance from the earth's surface features. The multispectral scanner records information in both the visible and near infrared (invisible) parts of the electromagnetic spectrum. The MSS takes four readings for each 1.1 acre area on the ground (referred to as a picture element or "pixel") - one for the intensity of green light reflected, one for the intensity of red light reflected, and one each for the intensity of infrared light reflected in two different portions of the near infrared part of the spectrum. These intensity levels are recorded in computer-readable digital form and are transmitted back to ground receiving stations on earth. Data for any part of the United States are transmitted to one of the three U.S. receiving stations.

From the receiving stations the data is relayed to the Master Data Processing facility at Goddard Space Flight Center in Greenbelt, Maryland, where it is stored on computer-compatible tapes (CCTs). The data can be converted from the tape format into photograph-like images in black and white or color. Photographic negatives of these images and computer tapes are sent to the Earth Resources Observation System (EROS) Data Center in Sioux Falls, South Dakota, for storage and distribution. Satellite images and tapes can be ordered directly from EROS. The images are generally available as prints or transparencies, in sizes of 9" x 9", 20" x 20", or 40" x 40" and at prices

ranging from 10 to 50 dollars. The tapes are available in several formats to accomodate different types of computers. Each image or tape covers an area of about 13,000 square miles, about 115 miles on a side. It takes 19 images or tapes to completely cover Minnesota. The current cost per tape is approximately $200.00. However, all prices are likely to increase substantially in the near future.

c. HOW LANDSAT DATA IS ANALYZED

There are two methods of deriving land cover data from LANDSAT. One is to use the photographic images and interpret them as if they were conventional air photos. Because of the much smaller scale, only areas of approximately 10 acres or larger can be reliably identified. This technique is useful for gaining an overview of broad areas, however, and can usually be accomplished at a quite modest cost with little specialized equipment. The USGS has used visual interpretation of both air photos and LANDSAT images in its land use mapping program (LUDA).

The second method, computer processing of the computer-compatible tapes, is somewhat more complicated but can be faster and yields more detailed results than does manual interpretation of images. The computer can identify objects or patterns as small as 1.1 acres, maintaining the original scale of the data. This method is more exact because it can utilize all four bands of data, which is more than can be displayed on a photographic image. This process of assigning pixels on LANDSAT images to categories of land cover or use is known as classification of the data.

To make the data most useful, several refinements of the data should occur prior to actual classification. One is geometric correction of the data, for use in either the photographic products or in the computer. On an uncorrected image, a road which in reality runs north-south will appear to run diagonally due to the north to south path of the spacecraft flight which records data during the eastward rotation of the earth. Such distortion makes locating actual ground points more difficult and makes it hard to match the image to a standard map. Up until this time, EROS Data Center has not routinely preformed geometric corrections on the computer tapes that it sells; it is, therefore, the user's responsibility to make the corrections. Mathematical calculations are made utilizing identifiable ground control points (such as road intersections) which resample the data to "correct" the image. Another type of correction can also be performed to remove the effects of atmospheric haze. These steps are taken prior to classification.

There are two basic procedures used to classify LANDSAT data: "unsupervised" and "supervised." In an unsupervised classification, the computer looks at all the digital information and groups all the pixels into like classes based on their spectral reflectance values. Generally, this system will result in the production of a large number of classes (40-50) which the computer reads as being statistically significant. The operator must then decide which actual cover types these classes represent and how to group them into a final scheme, such as 4 types of forest cover or 8 land cover categories, for the end product. To do this, the operator uses "ground truth" which may be low altitude air photos, maps of any type, windshield surveys, etc. The importance of adequate and accurate ground truth cannot be overestimated in the process of producing a successful classification. The acquisition of good ground truth can be the most expensive and time-consuming element in the classification process.

In the supervised classification, the operator starts with the ground truth, identifying on a map or air photo several examples of each cover type of interest. These areas are then identified on the computer terminal screen as "training sets," and entered into the computer's memory. On the basis of the numerical values of each training set, the computer then assigns each pixel in the entire scene to one of the identified groups or marks it as "unclassified." Many iterations of this process are likely to be needed to produce a successful classification (if one is possible, given the nature of the individual cover type). Again, good ground truth is crucial.

Both classification procedures rely heavily on the "art" as well as the "science" of the process. The user must be willing to accept a variable probability of correct classification. This probability can, however, be assessed and improved with persistent efforts on the part of the data user.

d. ADVANTAGES OF LANDSAT IN LAND COVER MAPPING

Despite the complicated and sometimes unpredictable nature of the classification process, LANDSAT does offer some advantages over more conventional methods of land cover mapping.

(1) Cost. The cost of acquiring the base data is considerably less than with high altitude air photos. (Low altitude coverage for all of Minnesota would be prohibitive.) Complete coverage of the state with LANDSAT computer tapes would cost nearly $4,000 at current prices. The costs will rise an undetermined amount (estimated at five to ten times) when the program is shifted from NASA/USGS to the National Oceanic and Atmospheric Administration (NOAA). By contrast, in 1977 a complete set of 1:80,000 high altitude air photos and 1:24,000 enlargements for Minnesota cost approximately $450,000. Additional savings result from relatively inexpensive computer classification of LANDSAT data, as opposed to manual photo interpretation which can be very costly and time-consuming. There is a cost associated with acquiring computer equipment and programs for LANDSAT classification. However, in the case of Minnesota, this investment was made when the Land Management Information Center of the State Planning Agency acquired its own stand-alone computer system in January 1980.

(2) Flexibility. Because each LANDSAT satellite passes the same spot on the earth every 18 days, satellite imagery can be acquired during different seasons for different purposes. Crop type differentiation or forest classification can be done during the vegetative season, for example. Or images from different times of year can be combined to improve accuracy in a single classification. Statewide air photos are usually taken before trees have leafed out to facilitate identification of structures, limiting possibilities for vegetation mapping. The combination of 18 day coverage (assuming no cloud cover) and low unit costs encourage the use of LANDSAT for special-purpose land cover monitoring.

(3) A Synoptic View. The large area covered by a LANDSAT scene (13,000 square miles) offers the advantage of a broad perspective impossible with another data source. This makes LANDSAT very useful for identifying geologic features such as faults or lineaments, and glacial

geologic features. It would take 4,000 air photos at a scale of 1:20,000 (medium-scale) to cover the same area.

This broad view makes LANDSAT a good choice in viewing large areas to identify places where more detailed information is needed. It has been successfully used to identify areas of diseased trees which may then be investigated more closely by very low altitude photos or by ground survey.

(4) Computer-Compatibility and Speed. LANDSAT's computer-compatibility is also an important advantage. Since the data is already in numerical form it can be used directly in computerized geographic information systems to produce tabular summaries or in computerized plotting systems to produce maps and map overlays showing different aspects of the earth's surface such as land cover, vegetation and the location of water bodies. This information can be combined with soils, slope, rainfall and data from other sources to produce natural resource atlas maps which, with the speed and efficiency of the computer, can be updated much more frequently than ever before.

(5) Examples of Useful Applications of LANDSAT. LANDSAT works most sucessfully where the cover type being monitored or classified is distinct in reflectance value from neighboring pixels. In Minnesota, LANDSAT could effectively be used to monitor surface water, mining areas and selected other land use and land cover patterns. Mapping water areas is relatively easy and foolproof utilizing LANDSAT, for example, because its pattern of reflectance values is so distinct. The western states make regular water supply estimates based on amount and extent of mountain snow cover using LANDSAT data. Patterns of irrigation can stand out distinctly, especially in time of drought. Mapping of areas of strip mining or of diseased or stressed vegetation are other examples of successful applications of LANDSAT. Also, smaller differences in reflectance values can be detected if the areas are relatively large (20-30 pixels at minimum) and relatively homogeneous.

The synoptic view offered by LANDSAT also contributes to its usefulness in other areas. Oil companies have been enthusiastic users of LANDSAT data from the beginning to search for distinctive geologic features. Geologists also use LANDSAT to detect hazard zones.

The repetitive nature of the coverage makes LANDSAT useful for worldwide monitoring of crop inventories. The U.S. Department of Agriculture's LACIE Program (Large Area Crop Inventory Estimates) makes world estimates of acreage planted in major crops such as wheat, oats, barley and corn and monitors areas struck by disease or drought stress during the growing season.

e. LIMITATIONS TO THE USE OF LANDSAT

LANDSAT shares with aerial photography the problem of "seeing" the top layer of cover only. Even more than with air photos, LANDSAT images and classifications are limited to detecting land cover, with few applications for detecting land use. If there are houses beneath relatively dense tree cover, these will go undetected. Or if a forested area is actually used as pasture, this use will go undetected. Other limitations of LANDSAT include relatively limited resolution or detail, frequent cloud cover, and a lengthy time lag between the spacecraft pass-over and the time that the computer tapes or images become available.

The limited resolution makes the use of LANDSAT very difficult for monitoring low density urban development. Usually the buildings are too small to occupy an entire pixel (1.1 acres in size) and the reflectance value of the rooftop (which will be different from structure to structure, depending on the color and type of material of the roof) will be averaged in with the value of surrounding roads, grass, trees, parking lots, etc. Even in areas of dense development, LANDSAT can determine only that it is structured or paved, not the use. With good ground truth, urban classifications can be improved. However, the usefulness of LANDSAT for monitoring low density residential development or lake-shore development is quite limited. Small amounts of change in any cover type are difficult to detect.

LANDSAT classifications run into problems where the same reflectance values represent different, sometimes very differnt, cover types. Salt flats, sandy areas and some rocks have about the same reflectance value, for example, as built-up areas. Again, excellent ground truth is essential to an adequate classification.

Appropriate use of LANDSAT will also vary from one part of the country to another. In some coastal areas, wetland mapping apparently has had some success. In Minnesota, because of different vegetation types and the surrounding environment, accurate identification of wetlands is extremely difficult. Identification of irrigated areas in a dry climate is much easier and probably more accurate than in humid areas such as Minnesota.

Determining just how accurate LANDSAT classifications are has been a long-standing problem. The problem has several facets including: lack of interest among many early investigators; computer software which makes statistical or mapped comparison difficult; lack of adequate ground truth to make accurate comparisons between classifications and actual ground features. Since accuracy of classifications of various cover types varies from one part of the country to another, and from image to image, further testing of classification techniques on specific cover types will be a necessary component of Minnesota's LANDSAT program.

APPLICATIONS OF LANDSAT DATA FOR VARIOUS LAND USES AND LAND COVERS

LAND USE OR LAND COVER	APPLICATIONS (from Computer-Assisted Classification)	MAJOR LIMITATIONS (if any)
Forestry	a. Location and acreage of forested land b. Forest type c. Damage assessment (e.g., areas of diseased trees)	b. Many forested areas of Minnesota contain numerous tree species growing in association and in varying proportions, making LANDSAT classification difficult.
Agriculture	Crop type and acreage	
Water	Location and acreage of water bodies	
Marsh	Location and acreage	Minnesota has widely varying vegetation types within wetlands, making general classification of wetlands difficult.
Urban	Location of large urban areas	LANDSAT cannot be used to locate all low density development. Also, LANDSAT classifications have difficulty discriminating roof tops in high density urban areas from other surfaces such as sand, rocky areas and paved surfaces.
Extractive	Location of mining activities. Identification of areas with mining potential	
Pasture and Open Land	Location and acreage	
Transportation	Identification of large transportation facilities (e.g., airports)	Narrow, linear features (e.g., roads, railroads) are not conducive to LANDSAT classification

B. LAND RECORDS AND INVENTORIES

Land records are the individual components of record-keeping systems designed to assess, regulate or monitor activities which take place on land. ("Land" is used here to refer generally to the area on, above or below the earth's surface.) Examples of records include permits, licenses and leases. By contrast, land inventories are compilations of data concerning land and activities which occur on it. Land inventories can take the form of maps, computer files, tables, indices or lists, and can be obtained from records, other inventories, field investigations or remotely sensed imagery.

Land records and inventories reflect governmental and private activities and interest in physical, environmental, legal and fiscal aspects of the land. Records and inventories include data required, collected and maintained for real estate and taxation purposes, land transfer, environmental protection, and land use and resource planning and management.

This section explores the usefulness of records and inventories as sources of land use and land cover data. An abundance of data on land uses and land covers is contained in records and inventories collected and maintained by numerous public and private agencies and organizations. However, the data may be either inaccessible or unsuitable for some uses due to any one of a number of limitations. These limitations and some guidelines for overcoming them are also presented.

Although consideration is given to records and inventories at various levels of government (e.g., federal, state and local) and to both the public and private sectors, the focus of this discussion will be on those records and inventories which provide data which is useful on a state-wide basis.

1. LAND RECORDS

Land records are often collected in accordance with legal requirements set forth in federal laws, state statutes or local ordinances. These records usually take the form of permits, licences or leases. An example of a record collected at the federal level is Offshore Drilling Leases. Examples of records which are collected by state agencies in Minnesota include Water Use Permits, Utility Licenses to Cross Public Land and Water, and Peatland Leasing Records. (These three records are collected by divisions of the Department of Natural Resources). An example of a record collected at the local level is building permits (collected in most, but not all locales).

a. ADVANTAGES TO THE USE OF LAND RECORDS

(1) Flexibility. Many land records provide a great amount of information on land uses and land covers for individual sites or small areas. This allows data users a high degree of flexibility in selecting the items of data which are most important for a particular application. The same set of records can be used by different users with varying data needs.

(2) Cost. A major advantage to the use of records as data sources lies in the fact that many records are routinely collected on an ongoing basis. This means that the costs associated with this collection are accounted for, either by funding provided by the collecting agency or by fees paid by the individuals or organizations applying for permits, licenses or leases. The costs of using data collected in this way are usually limited to those incurred through extracting the desired information from records and organizing it in a usable format.

Further time and cost savings can result if this extraction and organization of items of information from records can be incorporated into the data collection and filing routines. Substantial savings can sometimes result from filing the records according to geographic locations, whether the records are maintained manually or on computer files. For example, the Department of Natural Resources collects many records which can be filed by geographic locaters such as county names, watersheds, Public Land Survey description, etc. (In fact, many records are filed in this way.) Such filing can be advantageous for internal use of the data as well as for use by others outside the agency.

(3) Land Records as Sources of Data on LAND USE. Whereas remote sensing products often prove to be the best sources of land cover data, land records often serve as better sources of data concerning activities taking place on the land (i.e., land use). This is because different land uses can occur in areas which have the same land cover and appear the same on remote sensing imagery. In these instances, alternatives such as field investigation or familiarity with an area are the only methods ensuring accurate land use data unless land records or inventories are available.

b. LIMITATIONS TO THE USE OF RECORDS

Even though land use records contain a vast amount of data on land uses and land covers, this data is not always accessible or in a form which makes it usable by those who could benefit from it. Some of the limitations on the use of data contained in records are discussed below.

(1) Inaccessibility. In Minnesota, all records collected by government agencies are public (i.e. accessible to the public) unless classified otherwise by federal law, state statute or temporary classification. Some government records containing land use and land cover data are classified nonpublic to insure confidentiality of some information. For example, National Pollution Discharge Elimination System Permits and State Disposal System Permits collected by the Minnesota Pollution Control Agency contain information which is nonpublic under a Minnesota State Statute. This restricts use of data contained in these records though it is still possible in some instances to obtain and use summary data derived from these records.

Accessibility of records collected by private individuals and organizations (e.g. utility companies, forest products companies, agri-business, etc.) is generally more limited than for government records. Use of such records is heavily dependent on voluntary cooperation of the record holders.

(2) Incomplete Geographic Coverage. Many data collection programs, including some which operate under state agencies, collect data for limited areas of the state. For example, the Department of Transportation often collects extensive amounts of data when planning transportation routes. This data may be contained in records or inventories, and often provides a high level of detail and resolution on land uses and land covers for a relatively small area. The data may be useful to others, but the usefulness is limited due to the relatively small area of coverage and the lack of conformity of the area of coverage to political or natural resource boundaries.

Some regional and local records also contain useful land use and land cover data. One example of records collected at the local (i.e. municipal, township or county) level is building permits. Building permits provide data which can be quite valuable to data users. However, building permits are not required in all areas of the state. This means that anyone interested in working with building permit data on a regional or state-wide level would find gaps in geographic coverage.

While lack of complete geographic coverage of land records can be a problem, other problems emerge even when complete coverage for a large area does exit. This applies most specifically to records collected at the local level. Using the example of building permits again, governmental units which require building permits may collect different items of information on these permits. This means that a study relying on building permit data may encounter problems with obtaining the same data from neighboring municipalities. A similar problem results when different persons (e.g. applicants) complete permit forms, sometimes providing incomplete or inaccurate information.

(3) Lack of Compatible Geographic Referencing Systems. In order for land records to be useful to the largest number of potential users, it is important that commonly used and understood geographic referencing systems be used when identifying locations of features on the records. Examples of such geo-referencing systems include Public Land Survey (PLS) description, legal description, latitude-longitude location and Universal Trans-Mercator (UTM) location. Data which is referenced by any one of these geographic indicators can be spatially located by anyone who is familiar with their use.

Some land records do not include important geographic indicators. Other records do include such indicators, but are filed in ways which make them difficult to work with. For example, records which are alphabetized or filed in chronological order by permit number may contain commonly understood geographic indicators but can prove difficult to work with for someone interested in obtaining data for a specific geographic area.

While various records may pertain to the same area of land, they are often geographically referenced in ways which prohibit integration of the data contained in the records. This makes analysis of the cumulative effect of land activities difficult or impossible.

The following are examples of geographic referencing systems associated with some state-required permits, licenses and leases: the Department of Natural Resources geo-references Public Waters Permits (Waters Division) by county name, lake name, city, Public Land Survey (PLS) and watershed district; Water Use Permits (Waters Division) by

permit number, river basin, DNR lake number, PLS, legal description, watershed and surveyor's metes and bounds; Utility Licenses to Cross Public Land and Water (Land Bureau) by county name, PLS and legal description; Peatland Leasing Records (Division of Minerals) by PLS, legal description and lease number; the Pollution Control Agency geo-references Solid Waste Disposal Permits by county name and legal description; the Metropolitan Council geo-references Monthly Building Permit Data by county name and minor civil division (MCD).

Some records have a recognizable need for specialized geographic referencing techniques or systems. These records can be more useful if they contain more commonly understood geographic indicators as well. This allows integration with other data.

(4) Lack of Knowledge of the Existence of Data in Records. Data users are often not aware of the existence of accessible records which contain data they need. This is possible due to a combination of the enormous amount of data being collected by way of land records and a lack of systematic cataloguing and dissemination of information contained in records. This situation can result in data users substituting inferior data or unknowingly collecting data which already exists.

(5) Institutional Barriers. Government agencies have made only limited attempts to set standards for coordinated data collection. The information contained in records is often not shared among agencies, nor is the information widely distributed for possible use by others. Very little is done to ensure that data collected by each agency is compatible with and complementary to the data collection efforts of other agencies. As well, there is no centralized location where data users can access or find out about all the data which may be of use to them.

2. LAND INVENTORIES

Like records, land inventories are often maintained in compliance with legal mandates set forth in federal laws, state statutes and local ordinances. In many instances, inventories are compilations of data contained in records. Other sources of inventory data include field investigations, remotely sensed imagery and other inventories.

Examples of inventories maintained by state agencies include the Minnesota Land Management Information System (State Planning Agency), Minnesota Agriculture Statistics (Department of Agriculture), the Natural Heritage Information System (Department of Natural Resources, Office of Planning), the Airport Inventory (Department of Transportation) and Electric and Gas Data by County (Energy Agency). Examples of inventories maintained by regional agencies include the Metropolitan Land Use Inventory (Metropolitan Council) and the Upper Minnesota Valley Natural Resources Information System (Upper Minnesota Valley Regional Development Commission). An example of a privately produced inventory for counties is plat books.

a. ADVANTAGES TO THE USE OF LAND INVENTORIES

All of the advantages mentioned above for land records also apply to land inventories. Refer to the land records section for discussion of these three advantages:

(1) Flexibility.

(2) Cost.

(3) Inventories as Sources of Data on LAND USE.

In addition, land inventories offer one major advantage which land records often do not. This is discussed below.

(4) User-Oriented Format of Inventories. Inventories are often formatted in ways which allow easy use by land use and resource planners, managers and researchers. Common formats include maps, computer files, tables, indices and lists. Whereas land records are often simply useful by-products of transactions and are not designed with a variety of data users in mind, land inventories are more often intentionally designed in ways which make them most useful to a variety of potential users.

One example of a user-oriented inventory is the Minnesota Land Management Information System (MLMIS) of the State Planning Agency. A computerized data base of natural and cultural resource features is maintained on MLMIS for use by agencies and individuals representing the public and private sectors. MLMIS was designed to facilitate easy and inexpensive data entry, analysis and output of many types of spatially-oriented data. Output can be in map, table or other formats.

A geographic information system employing a wide range of sophisticated computer technology, such as the Minnesota Land Management Information System, is invaluable for some users of land use and cover information. For the user who wants a map and statistics on a one-time basis for a limited area, computer technology may be of limited value. But, for the user who faces the task of developing a set of baseline maps and statistics pertaining to land use and cover, updating such data and maps periodically, and combining several sets of data about land and its use (soils, ownership, demographic trends, taxation rates, etc.), a computer system with capability for storing and manipulating data geographically is indespensible.

MLMIS is actually an inventory of inventories, since each data file on this computer system represents an inventory of one or more land use or land cover types for a defined geographic area. The area presented on a computer file can vary from smaller than a city or township to larger than the entire state in size. As well, the level of resolution of the data can vary from less than an acre to greater than a county in areal units.

Many inventories appear in the form of maps. Often, great care is taken to make sure these map inventories are as clear and readable as possible. When this is done, the data presented on the maps is useful to the maximum number of potential users.

b. LIMITATIONS TO THE USE OF INVENTORIES

The limitations discussed above for land records also apply to land inventories. Please refer to the land records section for discussion of these five disadvantages:

(1) Inaccessibility.

(2) Incomplete Geographic Coverage.

(3) Lack of Compatible Geographic Referencing Systems.

(4) Lack of Widespread Knowledge of the Existence of Data in Inventories.

(5) Institutional Barriers.

c. THE COUNTY PLAT BOOK AS AN EXAMPLE OF A PRIVATELY PRODUCED INVENTORY

Private firms such as the Rockford Map Company in Rockford, Illinois produce maps showing land ownership information. These maps usually display parcel boundaries, acreages, owners' names, roads, railroads and bodies of water in all but incorporated areas and other areas which are subdivided into small (usually 2 1/2 acres or less) parcels. Usually, one map is produced per township, and all of the maps for a county are bound into one plat book. Map symbols, scale and accuracy of information can vary widely from county to county.

Plat maps are used for tax assessment purposes as well as for planning and zoning and other uses. Historians, geologists, surveyors and tax officials are aware of the research value of county plat maps. In those cases where a number of atlases have been published over time for the same county, these may be used in comparative studies of townships on a county-wide basis. For example, the State Planning Agency recently used plat maps of Isanti County from 1969 to 1979 (1969, 1972, 1975, 1979) to study historical changes both in the subdivision and consolidation of parcels of land over this time period. A discussion of the subdivision of land in Isanti County can be found in the State Planning Agency's Growth Management Report, 1981.

County plat books are found in many places across the state, including libraries and county historical societies. Where they are available, they are usually accessible to the general public. A recent publication of the Center for Urban and Regional Affairs (CURA), University of Minnesota, Windows to the Past, a Bibliography of Minnesota County Atlases, by Mai Treude, lists plat books for all Minnesota counties and indicates such things as publisher, map scale and locations where plat books can be found.

Plat maps are not without limitations. They may contain parcel boundary and ownership data that are out of date or otherwise incorrect. The maps are used by government, but government does not impose any regulations to assure quality control over the data on the maps. Lack of consistency from county to county in the dates and scales of plat maps imposes limitations on the usefulness of these maps in study areas encompassing more than one county. It is usually a matter of coincidence if adjacent counties have compatible plat maps.

Some plat book maps are printed at such a small scale that space constraints limit the amount of information which can be conveyed on them. In Isanti County, for example, owners' names are eliminated on small parcels of land. Also, neither owners' names nor parcel boundaries are indicated for subdivided land on Isanti County plat maps.

3. EFFORTS TO CATALOG AND COORDINATE LAND RECORDS AND INVENTORIES IN MINNESOTA

A tremendous amount of data concerning land and natural resources is contained in land records and inventories. However, inadequecies are revealed upon comparison of the costs involved in collecting and maintaining much of this data with the limited amount of use being made of it. As mentioned above under "limitations of land records and inventories," the inefficient use of data found in records and inventories can be attributed in part to the lack of widespread knowledge of exactly what data can be found and where. Then, if the desired data can be located, often limitations can result from incomplete geographic coverage, lack of adequate geographic referencing or inefficient filing systems. In short, lack of coordination among various data collection and maintenance programs results in an unorganized network of data with which it can be extremely difficult for data users to work.

An effective network of land use and land cover data should meet the following standards:

- Whenever possible, land use and land cover data contained in records and inventories should be organized and formatted in a way which makes it useful and easily accessible to anyone interested in using it;
- Whenever possible, records and inventories containing land use or land cover data should make use of commonly understood geographic referencing systems when referring to land areas which are described;
- Data collection efforts should be coordinated in a way which prevents duplication of data collection;
- Exposure of available data should be provided to the maximum number of potential data users.

Recognizing the lack of existing mechanisms to meet this latter standard, the State Planning Agency undertook an effort to catalog land use and land cover data routinely collected by major state and regional agencies. The result of this effort, the Catalog of Data Sources: Land Use in Minnesota, contains information about the majority of land records and inventories collected and maintained by the State Departments of Agriculture, Natural Resources, Transportation, Energy, Planning, Pollution Control, the Minnesota Geological Survey and the Metropolitan Council. (See the Appendix of this report for a listing of the table of contents of the Catalog.)

The catalog is intended to serve as a working document for planners and decision makers who are interested in gaining an overview of available data sources. For each entry, the catalog details a number of features including availability, cost, frequency of update, extent of coverage, geographic referencing system(s) used, method of collection and application of the data.

This information was obtained via questionnaires, edited and entered into computer files of the Minnesota Environmental Resources Information and Data Exchange (INDEX).

Knowledge of information contained in the catalog will allow users to make use of existing data rather than unknowingly collect the same or similar data. The catalog should also prove useful in discovering gaps and overlaps among existing data collection efforts.

In addition, the Water Planning Board has compiled a System for Water Information (SWIM) catalog which enumerates state water quality and quantity data sources. The goal of the Minnesota Water Planning Board in this effort is to have individual agencies coordinate data collection and filing programs to eliminate duplication and make water information readily accessible for use by local and state government.

III. CASE STUDIES

INTRODUCTION

The case studies presented in this chapter illustrate the application of the data sources described in the preceding chapter to a variety of land use/land cover policy and planning issues. Cases were selected to represent a diversity of: (1) land use and land cover types; (2) data sources; (3) geographic locations within Minnesota; and (4) scale and level of detail. The selected cases deal with:

(1) LOCATION OF URBAN STRUCTURES IN THE 10-MILE ZONES SURROUNDING MINNESOTA'S NUCLEAR POWER PLANTS: MONTICELLO AND PRAIRIE ISLAND

(2) LOSS OF AGRICULTURAL LAND: OLMSTED COUNTY

(3) CONVERSION FROM FOREST/WETLAND TO AGRICULTURE: AITKIN COUNTY

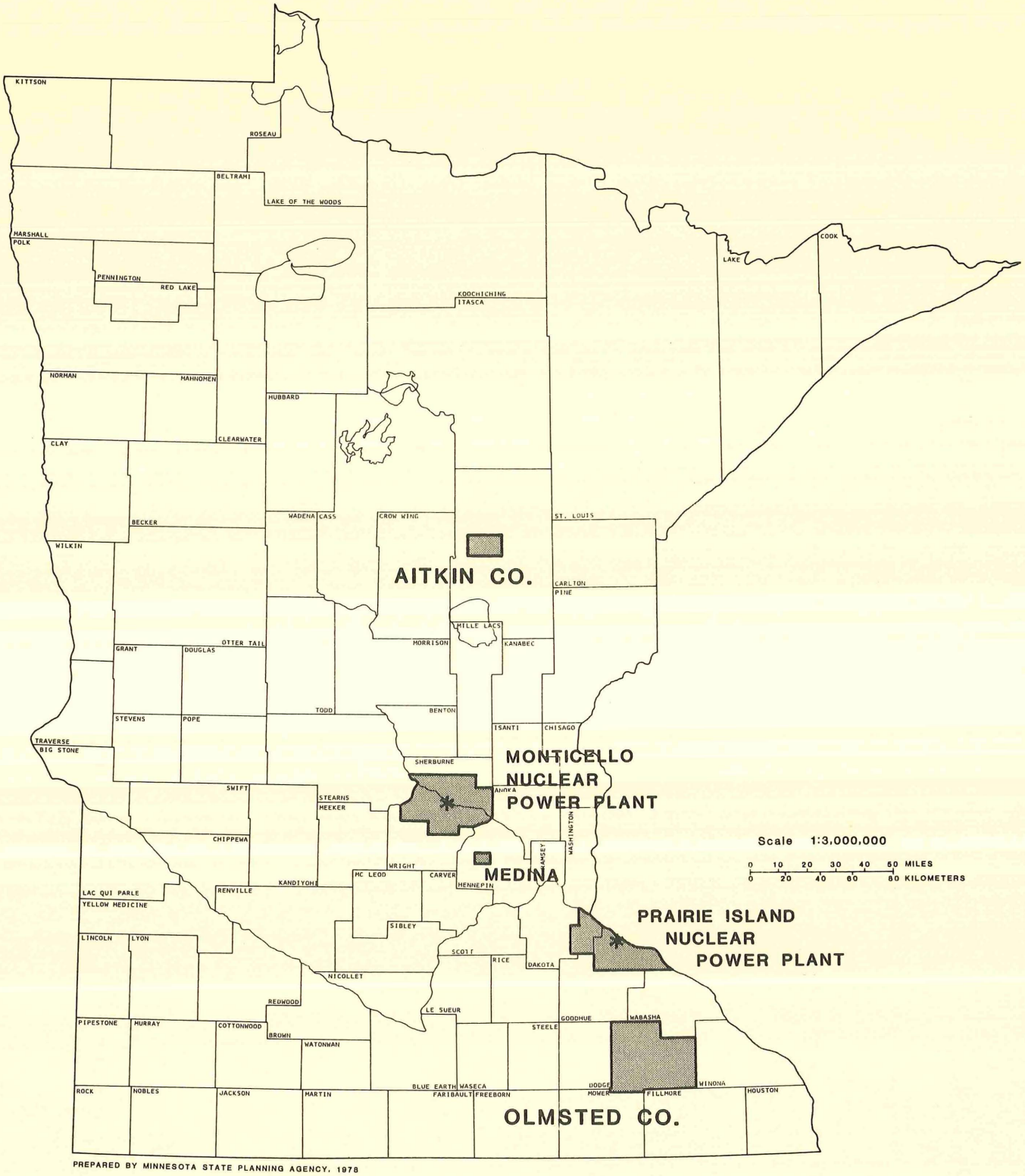
(4) COMMUNITY LAND USE SUITABILITY STUDY: CITY OF MEDINA, MINNESOTA

Figure 1 illustrates the extent and location of each case study site.

Each case study includes: (1) a brief description of the policy or planning issue(s) addressed; (2) the information required to address or resolve these issues; (3) the data sources which provided this information; (4) the procedures used to analyze the data; and (5) a brief description of case study findings and conclusions.

FIGURE 1

CASE STUDY SITE LOCATIONS



PREPARED BY MINNESOTA STATE PLANNING AGENCY, 1978

SPA BASE MAP #1

1. LOCATION OF URBAN STRUCTURES IN THE 10-MILE ZONES SURROUNDING MINNESOTA'S NUCLEAR POWER PLANTS: MONTICELLO AND PRAIRE ISLAND

A. ISSUES

Minnesota has two nuclear power plant facilities. The plants, operated by Northern States Power Company, Inc. (NSP) are located at Monticello and Prairie Island. (See Figure 1, page 46) Additionally, a third plant is located at Genoa, Wisconsin, on the Minnesota border.

The State, in conjunction with the political subdivisions surrounding the nuclear power plants, has the responsibility of developing contingency plans to minimize the effects of an accident. The Department of Public Safety, Division of Emergency Services, is responsible for coordinating development of these plans in accordance with federal rules and regulations. The Minnesota Legislature, under Minnesota Session Laws 1980, Chapter 611, required a report to be prepared on, among other things, the adequacy of existing land use regulations near nuclear plant sites. Accordingly, the State Planning Agency was asked to evaluate local land use controls for areas within 10 miles of the State's nuclear power plants. In the absence of an established density standard against which to compare local land use controls, this evaluation compared the effectiveness of controls and their implementation to the stated purposes of existing local ordinances.

In addition, this planning and review process necessitated that procedures be established to provide information on the location of structures within 10 miles of the state's nuclear power plants. This information would serve as a base line to analyze the extent and future impact of new construction within these zones. Specifically, the planning and review process requires alternative procedures for:

(1) Identifying the location of certain community facilities which, because of their use, are deemed to be of "critical" importance in an emergency situation. These include hospitals, health care facilities, nursing homes, schools, media broadcasting stations and relay towers, telephone operations, power generating facilities, and transportation facilities. Base line information is also needed on the location of dairy farms and related structures near the plants because of possible contamination of dairy products during an emergency situation.

(2) Monitoring general patterns of growth and development around each nuclear power plant on an annual basis. Data is needed on the location of new structures, especially new residential developments and/or new critical facilities in close proximity to the plants. It is suggested in the State's study relating to nuclear power plants and emergency response that information on the location of critical facilities and on general patterns of growth and development be tabulated and displayed in map form.

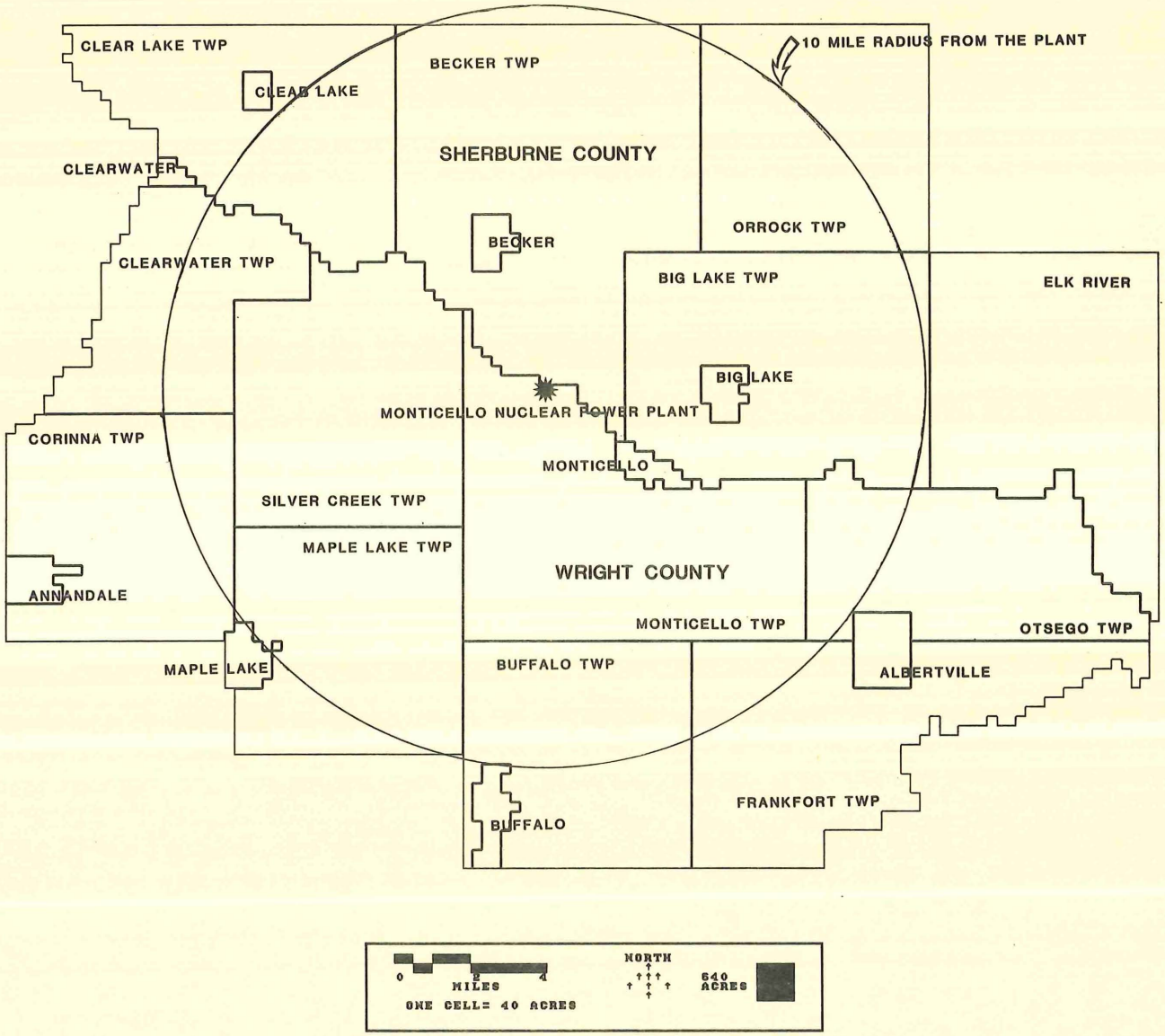
B. DATA SOURCES AND PROCEDURES

State Planning Agency staff met with officials of local government in the affected areas to solicit their advice on how best to accomplish these tasks.

FIGURE 2

LOCATION OF THE MONTICELLO NUCLEAR POWER PLANT

MINOR CIVIL DIVISIONS DISPLAYED HERE ARE LOCATED WITHIN APPROXIMATELY TEN MILES OF THE MONTICELLO NUCLEAR POWER PLANT



On the basis of these meetings, as well as formal evaluation of alternative techniques by State Planning Agency project staff, the following sources were recommended for establishing baseline information and for keeping construction data annually updated.

(1) Alternative Sources of Information Needed to Develop Baseline Data

a. County and city land use maps, zoning and other official maps: Each of the counties and municipalities keeps zoning and land use maps which can be useful in locating critical facilities and patterns of development. The frequency of updating these maps varies among units of government.

b. Aerial photography data: The seven-county metropolitan area is photographed every two years. However, only a small part of the area being studied is in the Twin Cities metropolitan area. When used in conjunction with local maps, low altitude aerial photos (e.g. 1:9600) are an extremely useful tool for locating critical facilities and in mapping general patterns of urban structure change. Data on the location of urban structures obtained from aerial photos varies considerably in scale and resolution. One method which has been used to collect data on urban structures involves counting the number of structures located within parcels of a predetermined size. Depending on the desired level of resolution, such data may be collected in parcels ranging from one to 40 acres in size.

Figure 2 is a map showing the location of the Monticello nuclear power plant within the study area. Also shown are names and boundaries of minor civil divisions falling within a circle 10 miles distant from the plant. The Monticello study area includes portions of Wright and Sherburne Counties, which are located to the northwest of the Twin Cities metropolitan area. The Mississippi River, on which the nuclear plant is located, forms the border between these two counties. The Prairie Island study area includes portions of Dakota and Goodhue Counties. The Genoa, Wisconsin study area includes part of Houston County.

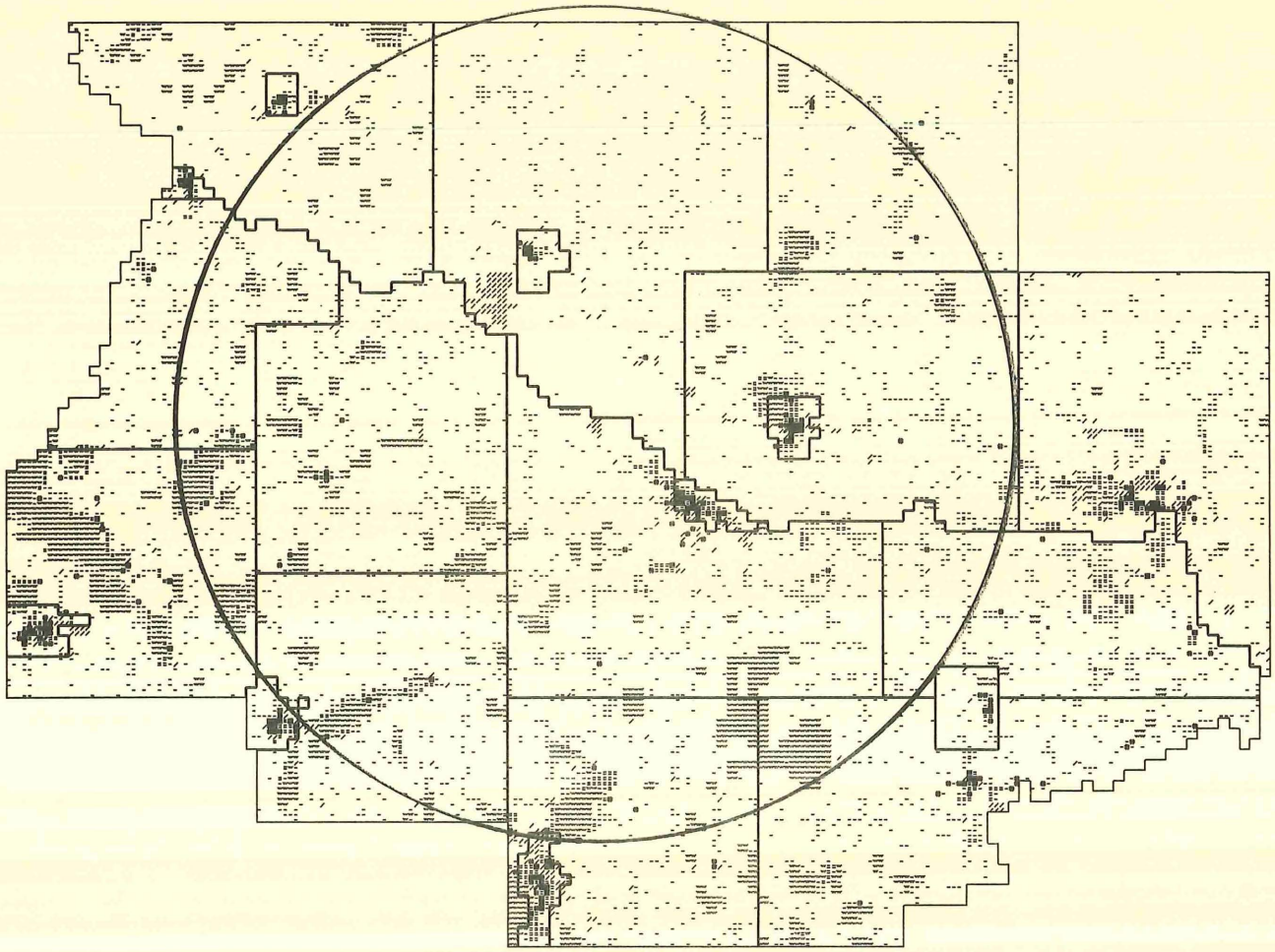
A set of three maps for the Monticello study area allows the identification of structures and construction which took place between 1968 and 1977 (Figures 3, 4 and 5). These maps display data which were interpreted from high altitude aerial photos (1:90,000 and 1:80,000) and entered into MLMIS for Sherburne and Wright Counties. This work was done by the State Planning Agency, Division of Physical Planning, as part of the Land Use Change Project. The maps are an example of one technique available for establishing a baseline of information and for monitoring new construction.

Structure counts were obtained for 10-acre parcels by interpreting 1968 and 1977 aerial photos. The 1977 structure count data are displayed for the area around the Monticello plant by 10-acre parcel (Figure 3) and aggregated into 40-acre parcels (Figure 4). The 40-acre map is most useful for obtaining an overview of the location and density of 1977 structures. Each 40-acre parcel corresponds to four 10-acre parcels appearing on the 10-acre structure map.

FIGURE 3

THE NUMBER AND TYPE OF STRUCTURES PER 10-ACRE PARCEL, 1977

MINOR CIVIL DIVISIONS DISPLAYED HERE ARE LOCATED WITHIN APPROXIMATELY TEN MILES OF THE MONTICELLO NUCLEAR POWER PLANT

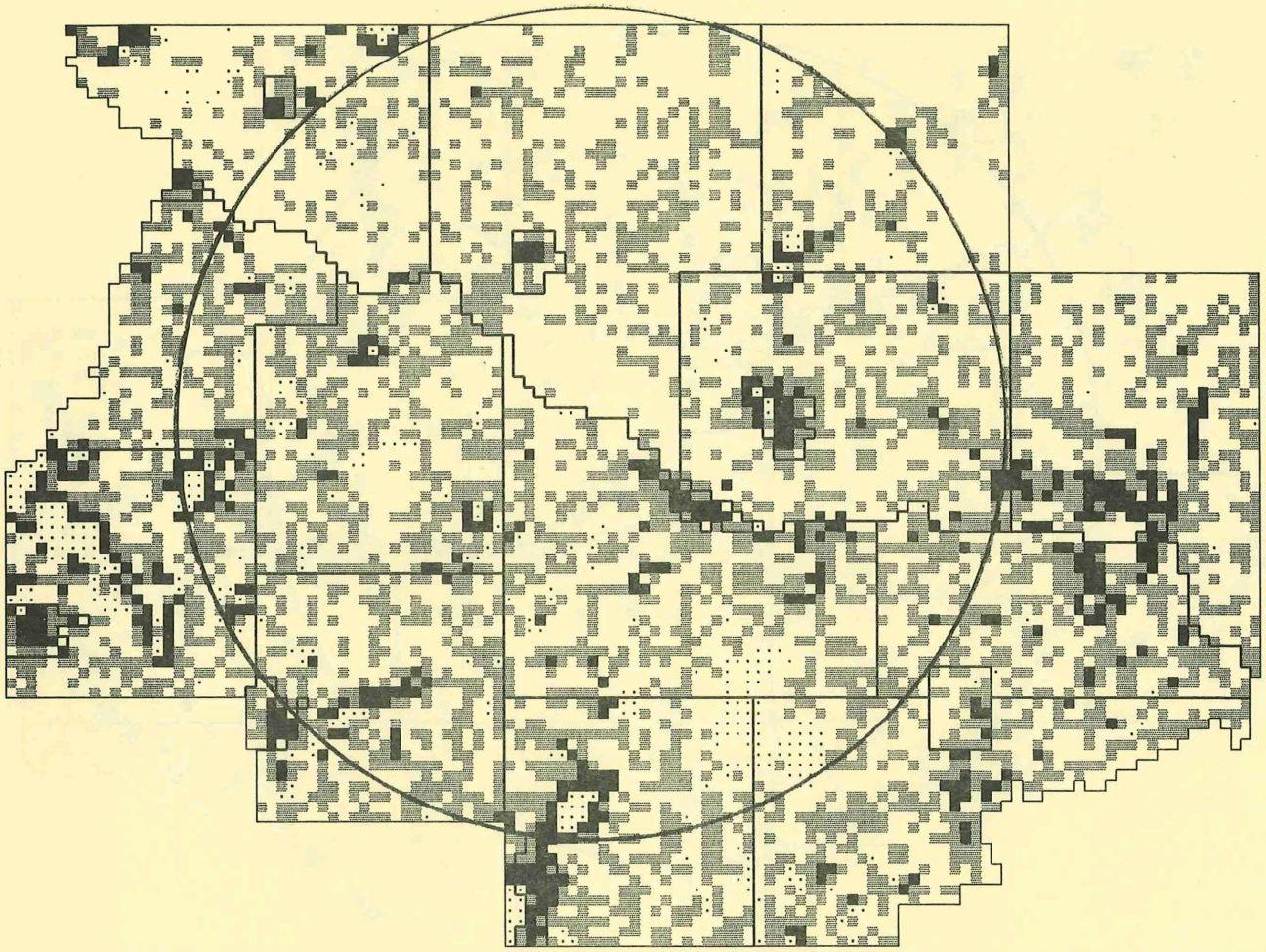


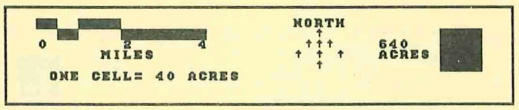
SYMBOL	PERCENT	LEGEND
	79.4	NO STRUCTURES
---	11.5	1 TO 4 RESIDENTIAL STRUCTURES
▪▪▪	1.5	5 OR MORE RESIDENTIAL STRUCTURES
///	1.1	1 TO 4 NON-RESIDENTIAL STRUCTURES
///	0.0	5 OR MORE NON-RESIDENTIAL STRUCTURES
▪▪	0.4	1 TO 4 RESIDENTIAL AND 1 TO 4 NON-RESIDENTIAL STRUCTURES
▬	0.3	5 OR MORE STRUCTURES - MIXED RESIDENTIAL AND NON-RESIDENTIAL
~~	5.7	WATER

FIGURE 4

THE NUMBER OF STRUCTURES PER 40-ACRE PARCEL, 1977

MINOR CIVIL DIVISIONS DISPLAYED HERE ARE LOCATED WITHIN
APPROXIMATELY TEN MILES OF THE MONTICELLO NUCLEAR POWER PLANT



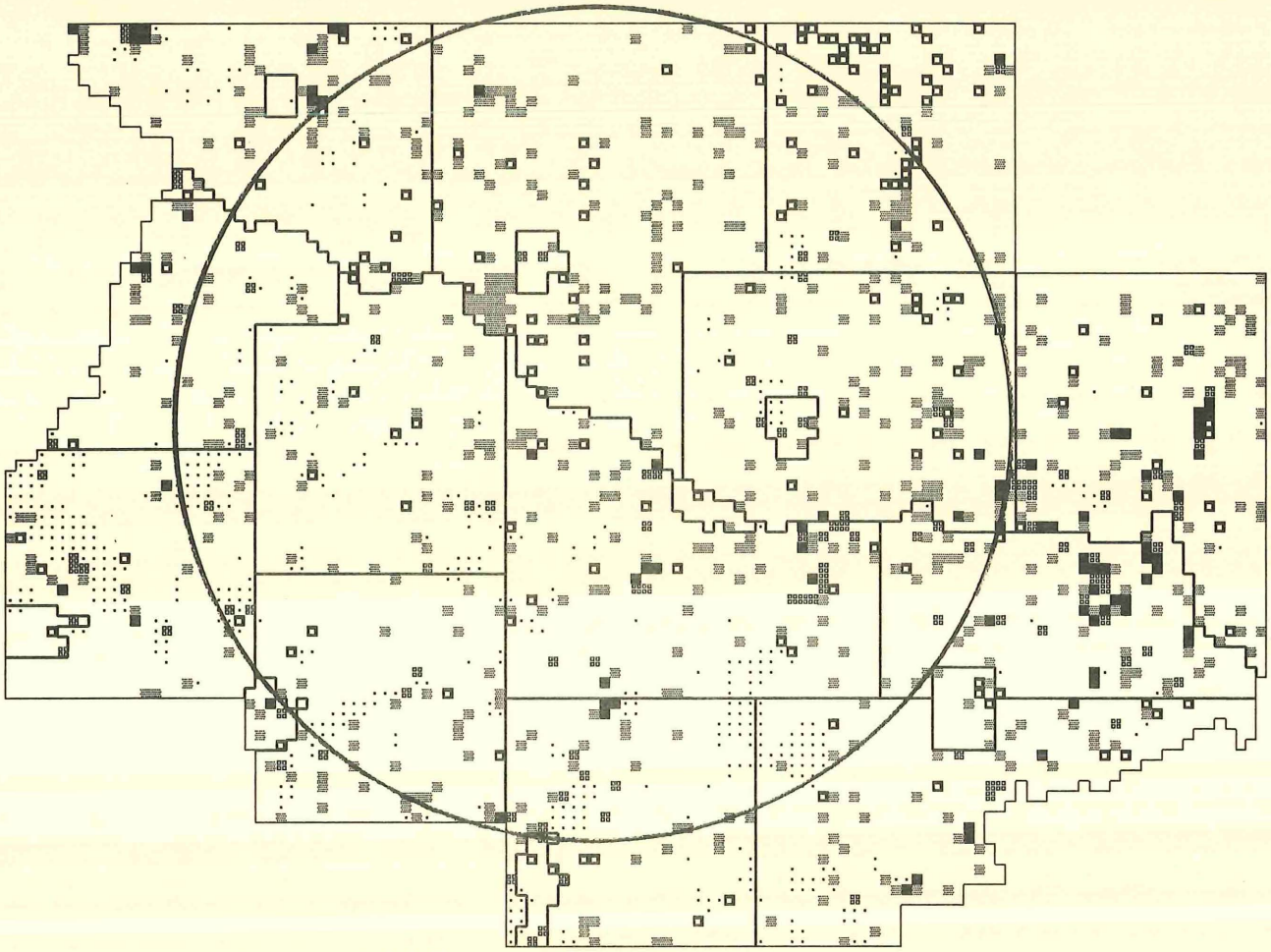


SYMBOL	PERCENT	LEGEND
	56.2	NO STRUCTURES
	33.4	1 TO 4 STRUCTURES
	6.1	5 OR MORE STRUCTURES
...	4.3	WATER

FIGURE 5

CHANGE IN THE NUMBER OF STRUCTURES PER 40-ACRE PARCEL, 1968-1977

MINOR CIVIL DIVISIONS DISPLAYED HERE ARE LOCATED WITHIN APPROXIMATELY TEN MILES OF THE MONTICELLO NUCLEAR POWER PLANT



SYMBOL	PERCENT	LEGEND
	82.8	NO CHANGE
	1.9	LOSS OF STRUCTURES
	6.6	GAIN FROM 0 STRUCTURES TO 1-4 STRUCTURES
	1.4	GAIN FROM 1-4 STRUCTURES TO 5+ STRUCTURES
	1.0	GAIN FROM 0 STRUCTURES TO 5+ STRUCTURES
...	6.3	WATER

The 10-acre map provides greater detail concerning location and uses of structures. The 10-acre map can be used in conjunction with the 40-acre structure map in areas where detailed information is desired. As an example, locate the northeastern-most parcel on Figure 4, the 40-acre 1977 structures map. This map indicates that five or more structures were located in that 40-acre parcel, whereas the corresponding four parcels on the 10-acre map (Figure 3) indicate that the southeastern and northwestern 10-acre parcels contained all of those structures. Furthermore, it is possible to discern that both of these parcels contained one to four residential structures.

Changes in the number of structures per 40-acre parcel (Figure 5) were determined by comparing 1977 and 1968 structure counts. (1968 structure counts are not displayed.) For each 40-acre parcel, this comparison determined whether or not the category of number of structures (e.g. 0, 1 to 4, or 5+) differed between 1968 and 1977 for that parcel. All of the parcels displaying change in Figure 5 are ones for which such a difference was noted.

Using the structure change map (Figure 5), it is possible to determine the distribution and density of new construction which occurred over the period between 1968 and 1977. It is also possible to locate 40-acre parcels which lost structures. Many of these losses occurred in agricultural areas and on land acquired for the Sherburne National Wildlife Refuge in the northern portion of the Monticello study area.

c. Fire department location numbers: Townships in Goodhue, Wright, Sherburne and Houston Counties map structures by fire department numbers. This information is updated annually by each city or county fire department. Individual structures are identified by township, section and fire number. At the meeting held with local officials in the area around the Prairie Island plant, it was noted that in Goodhue County, civil defense authorities currently map all structures by fire number. Such maps could provide base line data on the location of structures in the area.

(2) Methods to Annually Update Data on New Construction

Townships, municipalities and counties routinely keep a variety of records and permits which can be used as a means of keeping data on new construction current. These records and inventories include:

a. Building permits: Building permits can be effectively used as a means of keeping construction information current. Permits provide data on the intended size and use of structures (e.g. residential, commercial, agricultural or industrial). Permits may identify structures by tax parcel number and legal description, name of subdivision, block number, lot number, street number and address. All of these data may not be found on every permit, however. All of the counties in the study areas use computers for some of their record-keeping. These computer systems may prove useful in summarizing and standardizing building permit data.

All of the counties involved except Dakota report information on a monthly basis to the U.S. Bureau of Census on the number of building permits issued and on local public construction (e.g. hospitals, commercial buildings, public works and utilities buildings, schools, etc.) for unincorporated areas. Municipalities

report these data directly to the Census in these counties. These data - in aggregated form for each township and municipality - can be useful in getting an overview of the amount of residential and non-residential construction activity in incorporated areas for a given time. Data on the location of new structures obtained from building permits can be overlayed on base maps for each study area.

b. Utility records: Records on meter hookups and plats maintained by utilities (electric and telephone) are another potential source of information on the location of new construction around each plant.

C. FINDINGS AND CONCLUSIONS

The Minnesota Department of Public Safety's report, A Study Relating to Nuclear Power Plants and Emergency Response, February 1981, recommends that base line information and annual updates be prepared by the counties to coincide with the Division of Emergency Services' annual review of emergency response plans for each facility. Data should be gathered and tabulated by the State Planning Agency and forwarded to the Division of Emergency Services prior to the scheduled review of the emergency response plan for each plant.

In the report it is suggested that information on general patterns of growth and development and the location of critical facilities be tabulated and displayed in map form. These maps should display the data for sectors within one mile concentric circles - for a distance of 10 miles around each plant, each zone divided by sectors along compass points.

Townships and municipalities currently keep data on urban structures using a variety of procedures. The various sources of information presented above will continue to be evaluated by State Planning Agency staff. The combination of techniques and data sources ultimately selected will depend upon the uses of data on the location of critical facilities and urban structures by the Department of Public Safety, Division of Emergency Services, and the level of detail required by them for the purpose of planning and evaluating the State's emergency response plan.

2. LOSS OF AGRICULTURAL LAND: OLMSTED COUNTY

This case study summarizes a project undertaken by the Center for Urban and Regional Affairs (CURA) at the University of Minnesota to measure loss of prime farmland to urban development in the decade from 1970 to 1980 in Olmsted County. Olmsted County is in the southeastern sector of Minnesota and includes the rapidly expanding area of Rochester. (See Figure 1, page 46)

A. ISSUES

This study was undertaken to provide answers to the following planning and policy questions:

(1) How much rural land is being lost in Olmsted County to residential development?

(2) How much of the developed land is prime farmland?

(3) To what extent are land use controls effective in restricting these losses?

Information needed to address or resolve these issues were identified to include:

(1) The location of each new residential structure in unincorporated areas of the county;

(2) The pre-development land use of each site and of the entire county in 1971;

(3) A measure of soil productivity for each site and for the entire county;

(4) The nature and extent of land involved in municipal annexations;

(5) The nature and history of local growth management tools and policies.

B. DATA SOURCES AND PROCEDURES

The data sources used to determine the various land use or land cover characteristics itemized above are presented below.

1. Regarding the location of residential structures in unincorporated areas of Olmsted County, several types of local records were used as data sources. In addition, 1971 medium-scale (1:20,000) air photos, located through The Inventory of Aerial Photography and Other Remotely Sensed Imagery of Minnesota, published by the Mapping and Remote Sensing Information Center of the Minnesota State Planning Agency, were used to establish a base line of residential locations in 1971.

Several alternative records were explored to locate residential structures in 1976. Initially, it was hoped that county building permit data could be used to monitor urban growth. However, these data were found to be lacking. First, many permits were on file where no construction had taken place. Secondly, information on the geographic location of the structures was often incomplete or inaccurate. Thirdly, no permit could be located for many homes; specifically, no permit is required for mobile homes.

Investigators turned to other sources of data to allow the identification of homes sited between 1971 and 1976. The county had conducted a "windshield survey" of the county in the fall of 1976. This data was compared to data interpreted from the 1971 photos. Homes appearing on the resulting local land use maps but not on the 1971 air photos were designated as "new". Post-1976 development was identified using county assessor records. These records have been computerized in Olmsted County. Comparison of the 1980 roll with the 1976 roll allowed identification of new lots and new residences in this time period.

2. 1971 medium scale (1:20,000) air photos, available from the Agricultural Stabilization and Conservation Service, were interpreted to determine the land use of each site developed through 1976. The land use of sites developed after 1976 was determined from 1975 air photos (1:31,600 - 1:44,000) available from the Soil Conservation Service (SCS). Information on land use totals across the county was obtained from the 1969 State of Minnesota Land Use Map prepared by MLMIS.

3. Soil productivity ratings for each site were determined by locating sites as of 1976 on SCS maps and noting soil type. In cases where structures were on a boundary between soil productivity groups, both soils were noted. Productivity ratings were obtained from interviews with the local SCS soils scientist. For post-1976 development, productivity ratings of the dominant soil were interpreted directly from a productivity map.

   Productivity ratings on a county-wide basis were obtained using Minnesota Cropland Resources, an inventory of soil productivity groups produced by the Minnesota State Planning Agency. (See Figure 6)

4. Lands that have been annexed around Rochester can be gathered from two sources: The Minnesota Municipal Commission and the local Consolidated Planning Office. Once noted, these areas were plotted on a soils map. Areas of each soil type were measured with a planimeter and tallied by amount of productivity.

5. Regarding data on local zoning and subdivision ordinances, written and oral testimony were gathered from the Consolidated Planning Office; data on sanitary controls were gathered from interviews with the County Health Department. Several iterations were required.

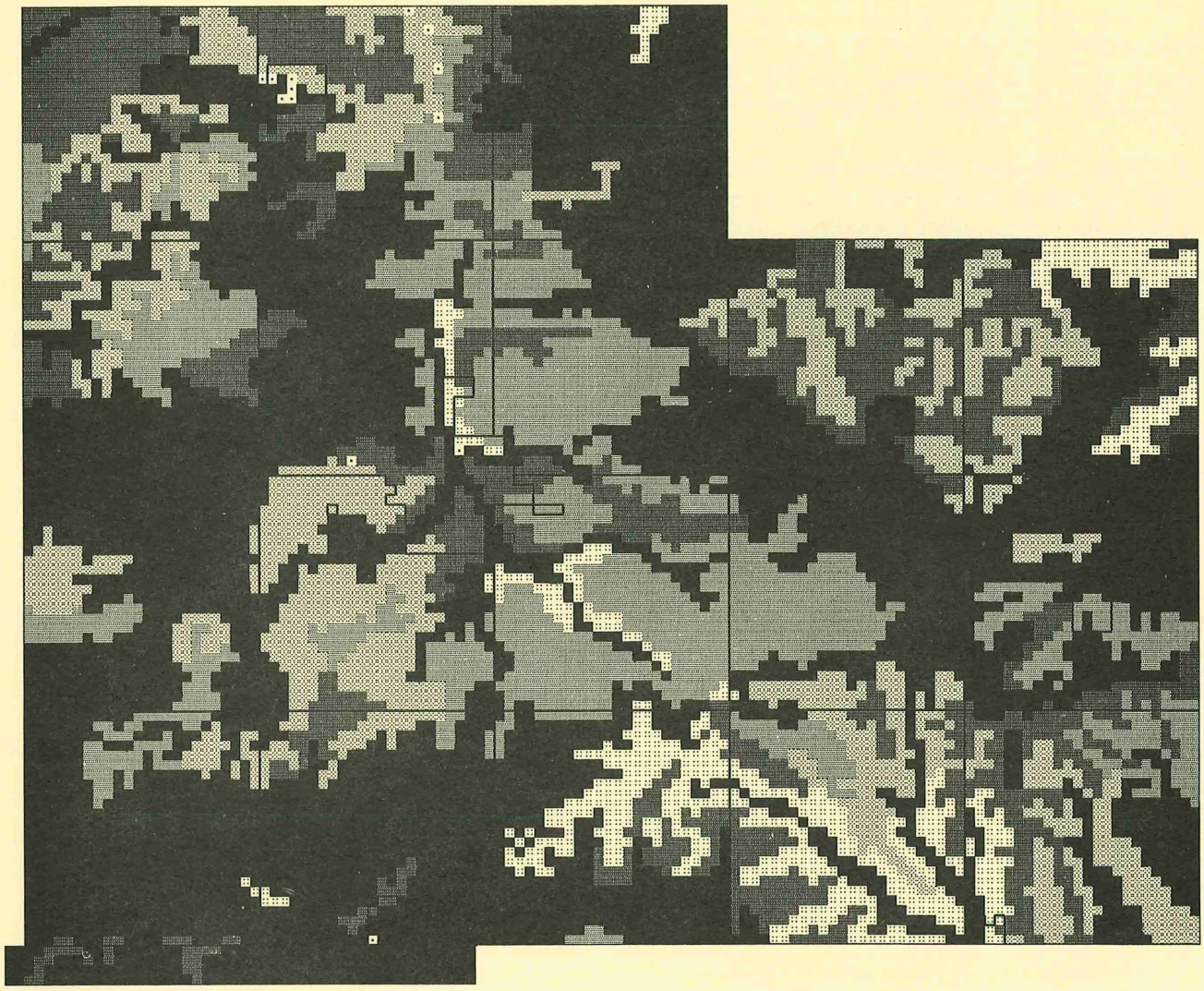
C. FINDINGS AND CONCLUSIONS

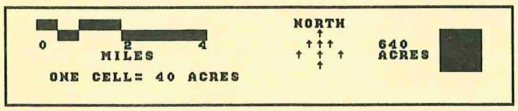
Even with ineffectively implemented land use controls, prime farmland was not lost to any great extent from 1971 to 1976 in Olmsted County. Although data sources indicate that 668 homes were built during this time in rural areas, only 80 (12 percent) were on productive soils which had been in agricultural use in 1971. For purposes of comparison, it is important to note that nearly half

FIGURE 6

CROPLAND PRODUCTIVITY

OLMSTED COUNTY, MINNESOTA





SYMBOL	PERCENT	LEGEND
	49.8	GROUP 1 SOILS (MOST PRODUCTIVE) - RATINGS OF 76 TO 94
	16.0	GROUP 2 SOILS - RATINGS OF 57 TO 75
	14.9	GROUP 3 SOILS - RATINGS OF 38 TO 57
	13.6	GROUP 4 SOILS - RATINGS OF 19 TO 37
	5.5	GROUP 5 SOILS (LEAST PRODUCTIVE) - RATINGS OF 0 TO 18
	0.1	WATER

(46 percent) of Olmsted County is prime farmland. Development seems to be avoiding this land. Annexations consumed prime land at about the same rate. It appears that the marketplace is doing an effective job of preserving prime farmland. Mail surveys sent to land sellers and new buyers have been administered by CURA staff in an attempt to verify and estimate these market forces.

The period from 1976 to 1980 is characterized by more strict land use controls but continued rural development. Curiously, a higher percentage of this later development took place on prime farmland. The reasons remain unclear. Further investigations by CURA staff are planned.

The Olmsted County case study clearly illustrates the need for a variety of data sources when measuring complex phenomena such as the loss of agricultural lands to urban development. Data sources used in this study include air photo imagery at various scales; state and local records, maps and inventories; and face-to-face interviews and field work. For more detailed information on this project, contact CURA, University of Minnesota.

3. CONVERSION FROM FOREST/WETLAND TO AGRICULTURE: AITKIN COUNTY

As indicated in the previous case study, there is concern that Minnesota is losing significant amounts of agricultural land. In the area described in the present case study, the reverse is occurring - new agricultural land is being created by clearing forest land and by draining wetlands. These land use changes are cause for concern in both state and federal agencies.

A. ISSUES

The site under examination is in Aitkin County in the northeastern part of Minnesota. (See Figure 1, page 46) The land cover is predominantly forest, both upland and lowland, and wetlands/bogs interspersed with lakes. The area is sparsely populated. The climate, with its short growing season, is a constraint on many kinds of commercial agriculture. The area does, however, support some agricultural enterprises in forage crops and small grains, with some recent developments in man-made wild rice paddies. Parts of the county are laced with unused drainage ditches built during the early part of the century in a largely unseccessful attempt to bring agricultural activity to this part of the state.

Several years ago a developer acquired 50,000 acres, or about 10 percent of the County's privately owned land. The developer intended to clear and drain about 25,000 acres and sell the land for various agricultural purposes. The remainder would be left in its natural condition and sold for recreational use. By late 1980, it was estimated that he had already cleared and drained between 7,000 and 10,000 acres, reopened some abandoned drainage ditches and dug many new ones.

The Aitkin County Commissioners have enthusiastically supported this drainage project which is, however, in violation of several state and federal laws. In Minnesota, it is illegal to drain a wetland over 10 acres in size without obtaining a permit from the Minnesota Department of Natural Resources (DNR) and agreeing to put an equal number of acres back into public wetlands. To date, the developer has ignored requests from the DNR to go through the permitting process.

The U.S. Army Corps of Engineers says that the developer is in violation of Section 301 of the Clean Water Act for discharging dredged material into several area lakes and rivers. Upon completion of an environmental assessment the Corps issued several cease and desist orders which the developer has ignored. In addition, complaints have been made by several of the area's wild rice farmers that the new drainage has lowered the water table sufficiently so that the paddies no longer hold sufficient water.

In late 1980, the Minnesota Environmental Quality Board and the Environmental Review Section of the Minnesota Department of Natural Resources contacted the Land Management Information Center at the State Planning Agency to explore possible ways of monitoring these changes. Shortly thereafter, the Soil Conservation Service agent in Aitkin County also contacted LMIC, citing his concerns of the extensive changes in this area. LMIC offered to demonstrate the capability of LANDSAT to monitor this type of change in Aitkin County.

Information needed to address or resolve this issue includes: land cover and land use characteristics in the area, both prior to and after development, including location of wild rice paddies, lakes, open land/pasture and forest.

B. DATA SOURCES AND PROCEDURES

Computer tapes of LANDSAT data were acquired for three dates: May 1973, May 1978 and July 1980. The size of the pilot area was determined by the concentration of drainage activity and by areas of cloud cover in the 1980 LANDSAT scene. The pilot area was approximately 9x15 miles with the Mississippi River running from northeast to southwest diagonally through the site.

For each scene, data were aggregated into seven cover types: (1) lakes and open water (2) rice paddies with standing water (3) other rice paddies and bogs (4) open land, pasture, forage crops and grassy sloughs (5) low trees and scrub vegetation (6) forest (7) bare ground.

Ground truth was determined from USGS topographic quadrangle maps (1973) and 1:24,000 blueline prints made from 1:80,000 black and white air photos (1977). Persons knowledgeable about the area were queried, but a shortage of time did not permit actual field checking of cover types.

LANDSAT data was also integrated with the MLMIS Geographic Information System. The site was overlaid with township lines, section lines and 40-acre parcel boundaries. Land use/cover data from 1969 air photos, originally coded by 40-acre parcels, was resampled to a 50 meter UTM cell so that it could be more easily compared with the LANDSAT data.

C. FINDINGS AND CONCLUSIONS

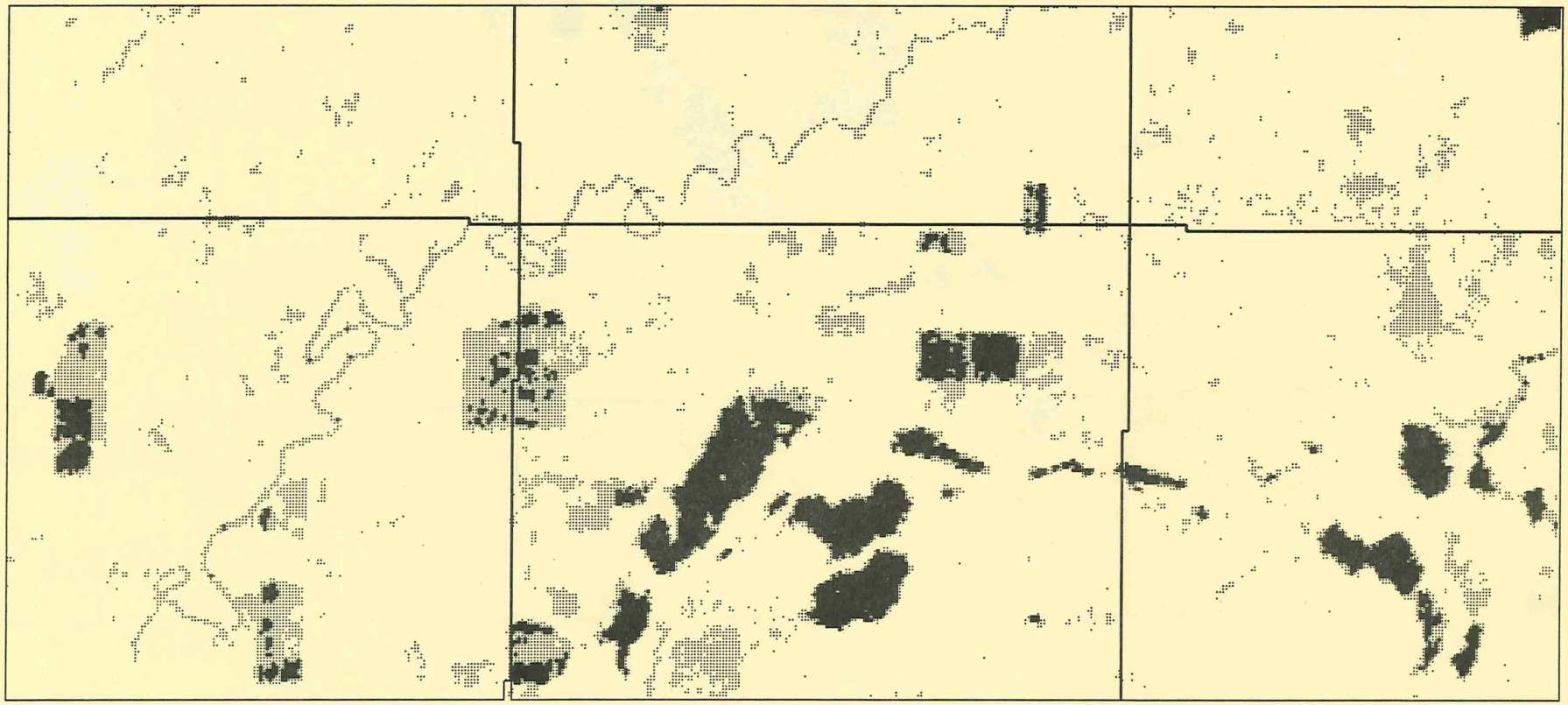
It was not practical to reproduce the full color classifications in this paper. Figures 7, 8 and 9 show a black-and-white summary of the unsupervised classifications. Water, wild rice paddies and the major areas of land clearance and drainage are shown in gray tones. The remainder of the classes have been suppressed to present the significant cover types more clearly.

In 1973, the locations of a few wild rice paddies are clearly shown (Figure 7). By 1978, some of these paddies have been expanded but no major clearance or drainage projects are evident (Figure 8). Data for 1980, however, shows a significant amount of land conversion (Figure 9). The large dark gray block in the northeastern corner represents an area of about 5,000 acres which has been converted into potential agricultural land. This conversion is most likely due to a combination of drainage of wetlands and clear-cutting of forests. Moreover, several of the rice paddies which had been closest to this drained area, particularly to the west and southwest, no longer appear in the 1980 scene. This disappearance lends support to the contention that the lowering of the water table had adversely affected some wild rice growers.

This case study investigated the utility of LANDSAT data in monitoring large-scale land clearance and drainage activities in a forest/wetland environment in northern Minnesota. LANDSAT data from 1973, 1978 and 1980 were used in the study of the 9x15 mile site. Results showed quite clearly and in a cost-effective manner where the greatest activity had occurred. It was also possible

FIGURE 7

LANDSAT CLASSIFICATION OF LAND COVER TYPES AITKIN COUNTY SITE, 1973

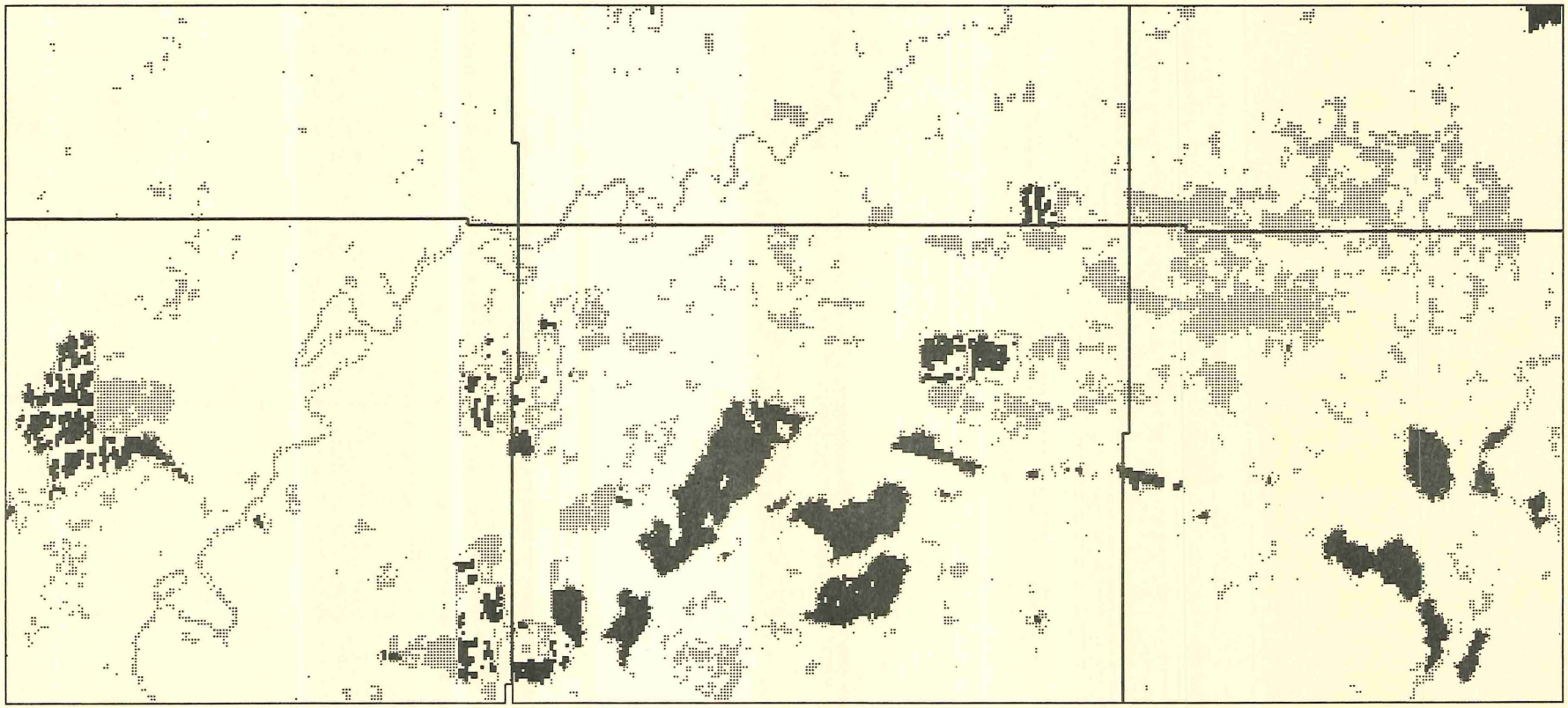


SYMBOL	PERCENT	LEGEND
■	4.1	WATER, STANDING WATER IN WILD RICE PADDIES
⠿	8.5	BOG, WET RICE PADDIES
	87.3	FORESTED AND OTHER

0 miles 2 4

FIGURE 8

LANDSAT CLASSIFICATION OF LAND COVER TYPES AITKIN COUNTY SITE, 1978

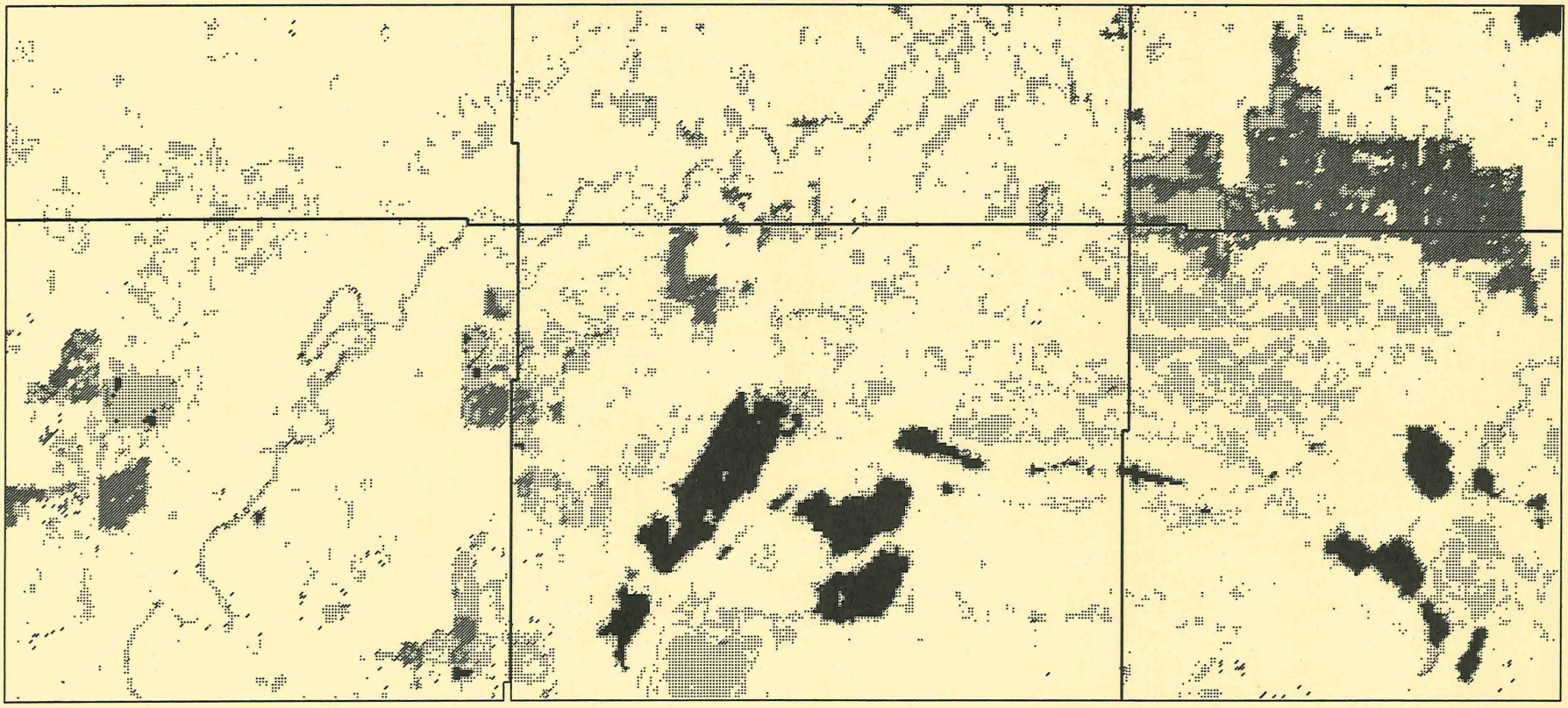


0 miles 2 4

SYMBOL	PERCENT	LEGEND
■	4.1	WATER, STANDING WATER IN WILD RICE PADDIES
⠿	9.5	BOG, WET RICE PADDIES
	86.4	FORESTED AND OTHER

FIGURE 9

LANDSAT CLASSIFICATION OF LAND COVER TYPES AITKIN COUNTY SITE, 1980



SYMBOL	PERCENT	LEGEND
■	2.9	WATER
▒	14.7	BOG, WET RICE PADDIES
▨	5.0	BARE GROUND, CULTIVATED
	77.5	FORESTED AND OTHER

0 miles 2 4

to integrate the LANDSAT data with other data such as soil type, forest cover or watershed boundaries available through the Land Management Information Center's (LMIC) geographic information system.

4. COMMUNITY LAND USE SUITABILITY STUDY: CITY OF MEDINA, MINNESOTA

Minnesota Statutes provide local units of government with the authority to determine the extent and location of various land uses. One way for a community to influence future land use is through comprehensive planning and zoning. This case study illustrates how natural resources data can be utilized to address environmental concerns in local planning and zoning decisions.

A. ISSUES

The proper utilization of a comprehensive plan and zoning ordinance allow a community to protect the natural environment, as well as prevent costly mistakes which result from unwise land use decisions. In order to be effective in achieving these ends, a comprehensive plan must recognize the land use conflicts (e.g. agricultural uses vs. development) which are likely to emerge in a community, and provide alternatives for resolution of these conflicts. A major consideration in this process is the inherent suitability of the environment.

The Metropolitan Land Planning Act of 1974 required that comprehensive plans be prepared by all communities in the Twin Cities Metropolitan area. The comprehensive plans were required to address 10 environmental guidelines. A joint study was undertaken to show how natural resource data could be computerized, analyzed and mapped to address five of these guidelines. Medina, a city of approximately 2600 population which is located twelve miles west of Minneapolis, was one of the areas for which this effort was undertaken. (See Figure 1, page 46) Participants in the study included the Hennepin Soil and Water Conservation District, Metropolitan Council, the University of Minnesota Soils Science Department and the State Planning Agency (Land Management Information Center).

The five Land Planning Act guidelines being addressed are as follows:

(1) Wetlands: The protection and preservation of those wetlands and lowlands permanently or intermittently covered with waters, such as marshes, swamps, bogs, meadows, potholes, and sloughs which are essential to hydrological or ecological systems or for flood control;

(2) Watercourses: The protection and preservation of the natural watercourses, intermittent or permanent, and minimizing the discharge of pollutants into water bodies and watercourses by storm runoff and otherwise;

(3) Agricultural lands: The prevention of premature development for non-agricultural use of prime agricultural lands where such land is essential for agricultural purposes;

(4) Development suitability: The determination of the suitability of soils or bedrock for development, design and construction measures for development which would compensate for existing soil or bedrock problems, and the prevention of the type of development for which such soils or bedrock are unsuitable;

(5) Erosion potential: An assessment of the erosion potential for those slopes which are subject to severe or moderate erosion because of their degree of slope and soil type.

The information needed to address each of these guidelines included:

(1) The location and hydrological function of wetlands;

(2) The location and classification of watercourses; the location of floodplain areas;

(3) Assessment of the potential for agricultural productivity of soils in Medina; the current use of land in areas containing productive soils;

(4) Assessment of the suitability for development of soils in Medina;

(5) The average length of slope and susceptibility to erosion of soils in Medina; rainfall characteristics; the effects of various vegetative and non-vegetative land covers on erosion; delineation of watersheds in Medina.

B. DATA SOURCES AND PROCEDURES

In order to address each of the five environmental guidelines listed above, the best available natural resources data for the Medina study area was identified and coded by square cells, each of which represents an area 2½ acres in size. This information was entered into the Minnesota Land Management Information System (MLMIS). the use of MLMIS allowed quick and inexpensive comparisons (i.e. analysis) of different natural resource variables, as well as display of the information as computer-printed maps.

Products included detailed data maps and opportunity/constraint (i.e. suitability) maps for Medina's resources. The composite suitability map shown in Figure 10 is the result of overlaying simplified versions of three of these suitability maps: (1) wetland uses (water, wetlands, floodplain); (2) agriculture; and (3) development. Neither this map nor any of the other suitability maps represent absolute measures of where various land uses can or cannot occur. Rather, these maps indicate areas where particular land uses would be more or less suited to environmental conditions.

The description of data sources and procedures will focus on the level of detail used in producing the composite suitability map (Figure 10). The criteria used in determining which areas were suitable for each of the three uses (wetland, agriculture, development) are briefly described. The data sources and procedures used to address the guidelines are:

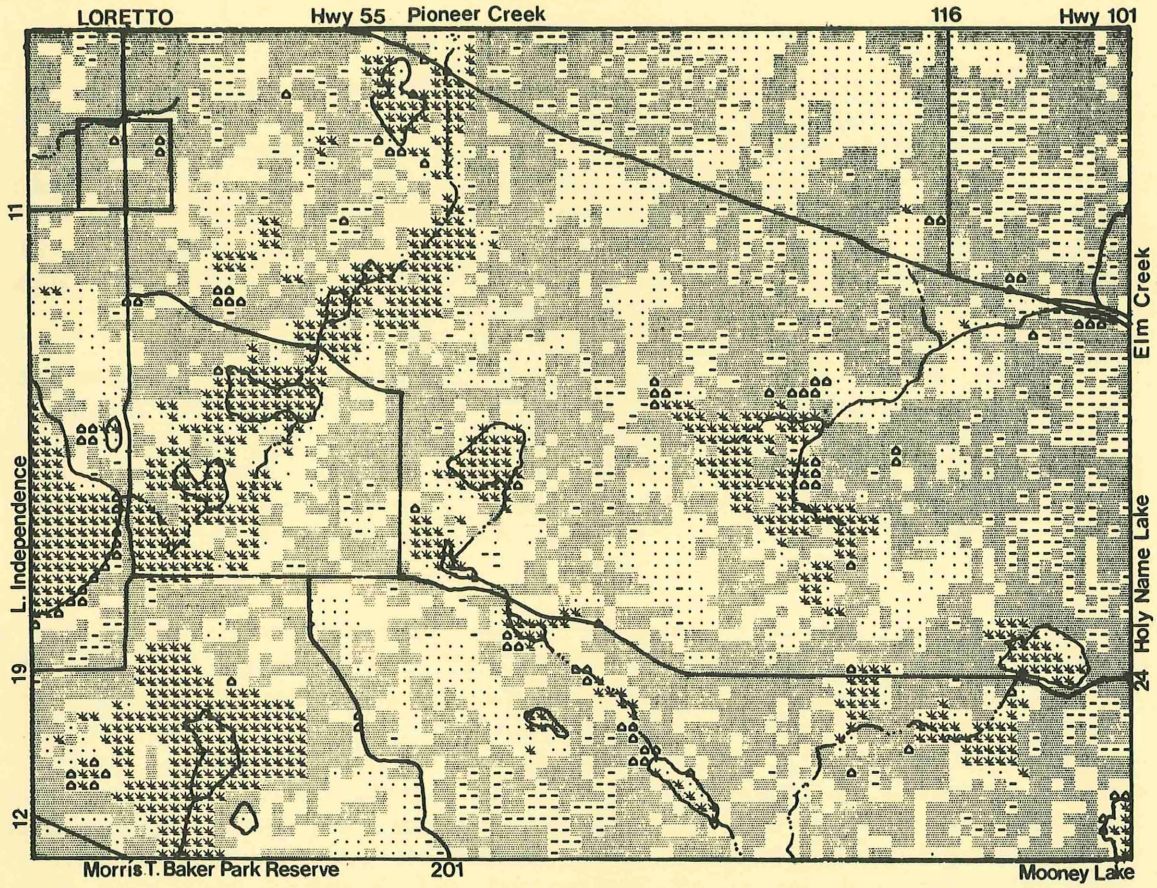
(1) Wetlands: An inventory of wetlands, Wetland Conservation Areas, City of Medina, by the Hennepin Soil and Water Conservation District (1977) was the source of detailed information for wetlands. All open water and wetlands over 10 acres in size were identified in the study as being worthy of consideration for protection and preservation (i.e. "suitable for wetland uses") in Figure 10.

(2) Watercourses: Watercourses and their associated floodplains were taken from several sources. These include the wetlands inventory mentioned above (Wetland Conservation Areas, City of Medina), U.S. Geological

FIGURE 10

COMPOSITE SUITABILITY

MEDINA, MINNESOTA



SYMBOL	PERCENT	LEGEND
ᵛᵛᵛ	12.7	SUITABLE FOR WETLAND USES ONLY (WATER, WETLANDS, FLOODPLAIN)
---	7.9	SUITABLE FOR AGRICULTURE ONLY
ΔΔΔ	1.4	SUITABLE FOR DEVELOPMENT ONLY
▒▒▒	51.6	SUITABLE FOR AGRICULTURE AND DEVELOPMENT
...	12.4	SUITABLE FOR OTHER COMBINATIONS OF WETLAND USES, AGRICULTURE AND DEVELOPMENT
	14.0	NOT SUITABLE FOR WETLAND USES, AGRICULTURE OR DEVELOPMENT

EXPLANATION: Figure 10 shows where particular land uses would be suited to environmental conditions. Land use limitations in areas which are not suitable for a particular use are not necessarily prohibitive, but may require special design or management considerations.

Survey topographic maps and the Flood Hazard Analyses for Elm and Rush Creeks, Hennepin County, Minnesota by the U.S. Department of Agriculture, Soil Conservation Service (1975). Only floodplain areas were significant enough to be considered for preservation (i.e. "suitable for wetland uses") in Figure 10. At the 2½-acre level of resolution used here, small waterways which do not have associated floodplains do not necessarily impose severe limitations on activities which can take place on adjacent land.

(3) Agricultural lands: Detailed soil series data were obtained from the Soil Survey of Hennepin County, by the U.S. Department of Agriculture, Soil Conservation Service (1974). The soil survey contains ratings of agricultural capability for all the soils found in the county. These ratings of I through VIII are based on the expected yield relative to the extent of management practices required. For this study, SCS capability class I and II soils were considered prime and class III soils were considered good farmland, all worthy of consideration for preservation (i.e. "suitable for agriculture") in Figure 10.

Since not all land is available for farming, a further refinement was made to eliminate those areas which are unavailable for farming. Current land use was interpreted from large-scale (1:2400) 1975-76 series aerial photography obtained from the Metropolitan Council. Areas which contained development or were part of a park reserve were considered unavailable for agricultural use and therefore were not considered "suitable for agriculture."

(4) Development suitability: Soil series data were the main data source for determining development suitability in Medina. Since the majority of Medina is unsewered, development suitability was based on assumptions of conventional construction techniques and on-site sewage treatment (i.e., septic systems). Soil Conservation Service staff assisted in rating soils in Medina for their suitability for development. Soil limitations on development which were considered are slope, wetness of soils, depth to water table, soil texture, depth to bedrock and flooding hazard. Wetland areas included in the Medina wetland inventory were also considered in addressing this guideline. Ratings of high, moderate and low suitability were assigned to soils based on these factors. Areas with high and moderate suitability were considered "suitable for development" in Figure 10.

(5) Erosion potential: Erosion potential was assessed using a model which calculates soil loss in tons per acre per year. Some of the data necessary for use of the model had been obtained in the parts of the study which address the other four environmental guidelines. Supplemental data was provided by Soil Conservation Service staff.

One additional element of the study involved determining which watersheds in Medina are most likely discharging high volumes of eroded sediment at their outlet points, and which watersheds are most likely entrapping high volumes of sediment in lakes and wetlands. This was based on a comparison of the amount of severely eroding area to the amount of entrapment area (lakes and wetlands) in each watershed. Watershed boundaries were taken from the wetlands inventory.

C. FINDINGS AND CONCLUSIONS

The land use suitability study for Medina represents the resource assessment phase of the environmental planning process. The study itself was not designed to develop a plan, but rather to describe the opportunities and constraints for future land use patterns. A composite of the analyses for water features, agriculture and development (Figure 10) indicates that 12½ percent of the land in Medina is suitable for wetland uses only, while 8 percent is suitable for agriculture only and slightly over 1 percent is suitable for development only. Over half (51½ percent) of the land is suitable for both agriculture and development and the remainder is suitable for various other combinations of the three uses, or for none of these uses.

This type of information can be useful to a community in developing comprehensive plan alternatives. The composite suitability map represents the capacity of Medina's natural resources for development as well as for preservation. It can also be used to evaluate the appropriateness of current land use patterns. In Medina, as in most communities, large land areas are suited to more than one use. The community has the opportunity to determine which of the suitable uses is most appropriate for a particular area, based on the characteristics and needs of the community.

SUMMARY

The following general conclusions can be drawn from the four case studies presented in this chapter:

1. The choice and application of data sources and procedures is often influenced by the availability and reliability of data. Often the "best" data for a particular application may not be available or may be incomplete and researchers/planners must rely on other data sources. For example, the incompleteness of building permit data in Olmsted County required that the investigators turn to other local records as a means of locating residential structures. As discussed in the Aitkin County case study, the failure of a developer to go through the permitting process required for wetland drainage eliminated permits as a viable data source on the conversion of wetlands/forest to other uses. This meant that investigators were forced to turn to LANDSAT and other remote sensing data sources as alternatives in order to study this land use change.

2. All the case studies clearly illustrate that planners and decision-makers must and, in fact, do draw on a wide variety and combination of data sources - records and inventories as well as remotely sensed data - when addressing complex land use planning issues. This is true whether the land use issue is of state-wide concern or of regional, county or municipal concern.

3. All of the case studies included in this report illustrate the advantages of computerized natural resource inventories. These advantages become especially clear when several factors or variables (e.g. soils productivity data, land use and land cover data, and data on the location of political subdivisions and transportation systems) must be considered simultaneously.

4. The level of detail of the data required to address or resolve a particular land use issue will impact the selection of data sources and procedures.

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