REMOTE SENSING
IN URBAN AND
REGIONAL PLANNING

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"REMOTE SENSING IN URBAN AND REGIONAL PLANNING"

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To

my wife

MARY ANN WOODROFFE

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CHAPTER 1

INTRODUCTION

In the past few years, urban, regional and environmental planners have been confronted by many new problems. These problems require an assortment of information pertaining to man and his environment. Accordingly, the purpose of this thesis is to demonstrate how remote sensing can be implemented as a planning tool to help in analyzing and solving planning problems.

Remote sensing is a fairly new term, symbolizing the techniques of data collection using sensing equipment to detect wavelengths in the electromagnetic spectrum.[1] The actual field of remote sensing covers many other fields, such as; photo interpretation, photogrammetry and multispectral sensing.

In the field of urban planning, remote sensing techniques have in the past, and still do, offer an excellent means to analyse the changing physical forms of a city. By delineation of growth or blight areas over a period of time a planner can see the fluctuation of the problem areas much more readily than conventional methods. Thus remote sensing

[1]The visible spectrum is a small segment of the electromagnetic spectrum, (see Figure 2).

techniques establish a means of continuous monitoring of urban areas providing a basis for continuous development planning, which has only recently been introduced to planning agencies.

Regional planning, on the other hand, finds remote sensing's greatest assets in land-use identification and classification. Using remote sensing imagery, physical features, man made or natural, can easily be depicted by a trained interpreter or planner, resulting in a uniform identification and classification process for small or large areas.

For environmental planning, remote sensing techniques offer a data collection and storage system that can be used for urban and natural environments. This system helps provide planners with a better understanding of urban and regional phenomena related to the natural environment.

It is not surprising to find that all planners who have a good understanding of remote sensing techniques can assess, evaluate and monitor urban and regional phenomena much more quickly and accurately than by any other method. Remote sensing offers an economical, time saving, practical method to acquire information about the different environments, giving a visual perspective that becomes a permanent record.

CHAPTER 2

TECHNIQUES OF REMOTE SENSING

1. History of Remote Sensing

Remote sensing as seen today has only developed in the last 200 years, although it was the early Greeks who found that objects could be measured by bending or deflecting rays of light. Later, Leonardo da Vinci, Albrecht Dürer, and others described the principles of perspective geometry. It was not until Daguerre in 1839 used a fixing agent to retain a photographic image that these theories became practical. The first major application related to remote sensing was in the production of maps for towns and villages. By applying terrestrial photographs and simple geometry, map production time was considerably reduced.

In 1858 the photographer Gaspard Felix Tournachon ascended in a balloon to photograph an area near Paris for topographic map making. In the United States the first successful photographs to be taken from a balloon was over Boston by Samuel A. King and J. W. Black, in 1860.[2] From then on photography was used solely by the military and aided both sides in the American Revolution. During the first World War aerial

[2]Manual of Photographic Interpretation, pg. 3.

photography became a major tool of war. As aircraft were developed and modified so were aerial cameras and photographic techniques.

Between World War I and World War II many companies were created in Canada and the United States, as aerial photography suppliers and map makers.

During the Second World War the military once again made more improvements on aerial cameras, films and processing. They also trained many civilians in the art of air photo interpretation.

During the late 1930's and early 1940's Canada and the United States witnessed the emergence of planning agencies at various administrative levels: state or provincial, county, regional, metropolitan and city. The Chicago Planning Commission was one of the first to use aerial photography and photo interpretation in the making of their Master Plan of Residential Land Use.

Today most planning agencies use aerial photography, or have done so, in one way or another (see Figure 1).

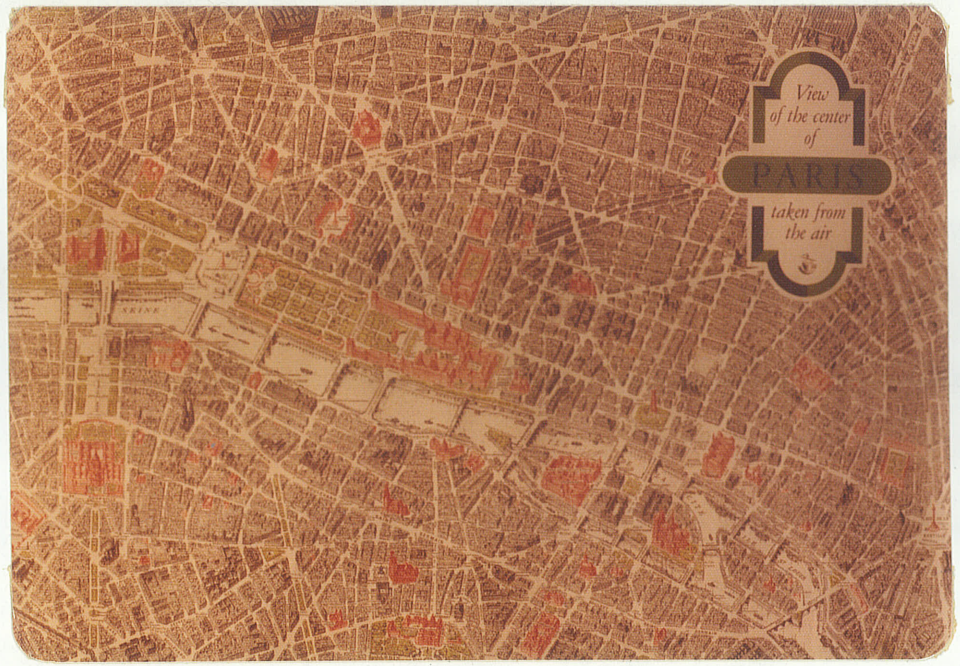


Figure 1. A map of the center of Paris taken from the air. Published by the Ministere des Travaux Publics, des Transports et du Tourisms, 1958.

(Although drawn by artists for promotional purposes, oblique and vertical aerial photographs were used in the preparation of this map.)

2. Photo Interpretation

Recognizing features on aerial photographs is a highly skilled art, requiring years of familiarization with objects, based upon their pictorial elements, that is, shape, shadows, colour, dimension, tone, texture, pattern, location, and association with other objects.

The information is portrayed in a photograph taken on the earth's surface, in the air, or from space. Considerable information can be detected from a single photograph based upon two-dimensional study. However, much more information may be obtained from a three-dimensional stereoscopic image.

Generally, photo interpreters study photographs by first looking at the most familiar features and relating these to the least familiar. Some of the most familiar features are:

- transportation systems
- drainage patterns
- topography
- natural vegetation
- agricultural land use
- rural non-agricultural land uses
- urban land uses
- heavy industrial areas

These can easily be recognized on photographs or imagery by their pictorial elements. Some of the less familiar features are: houses, barns, traffic lights, etc.

When recognizing features on photographs one must keep in mind at all times the quality of photography or imagery to allow for distortions. This quality is controlled to a large extent by specifications and environmental conditions when the photography is obtained, thus resulting in obscuring some normally available information while emphasizing others.

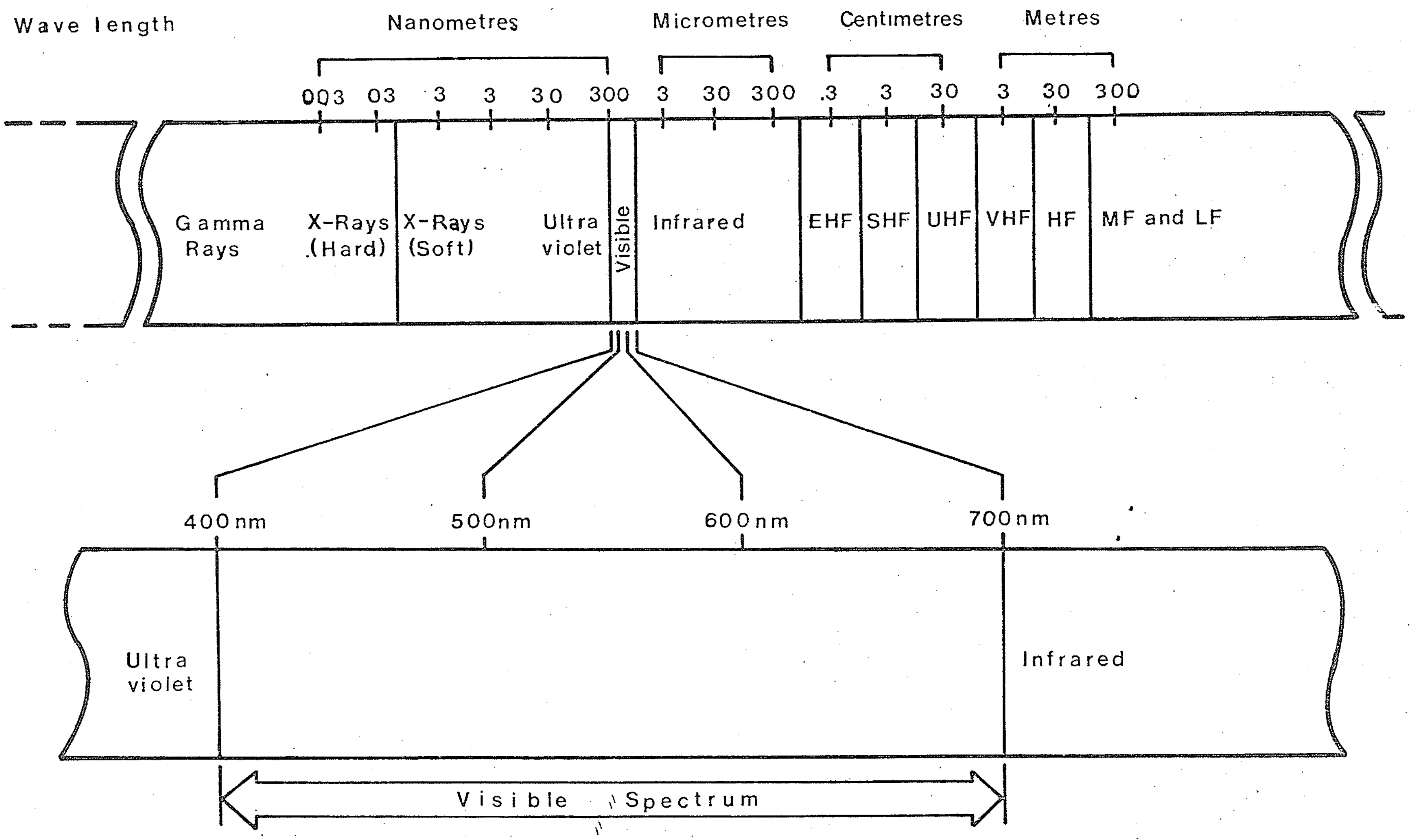
Becoming one of the most important pictorial elements in photo interpretation is colour. The human eye is found to be sensitive to radiation ranging in length from 0.40 (the violet threshold) to 0.70 microns (the red threshold).[3] It is substantially more sensitive to the middle range of this visible spectrum, the highest sensitivity being in the green range at about 0.54 microns (see Figure 2).

Thus the eye can distinguish the many colour combinations in the environment.

[3] A micron, one millionth of a meter, or about one twenty five thousandth of an inch, is the unit by which infrared wavelengths are measured.

FIGURE 2

Electromagnetic Spectrum



3. Photogrammetry

Photogrammetry is the technique of making reliable measurements from photographs. Vertical and horizontal measurements are made on many different kinds of photographs, including aerial and terrestrial. A wide variety of investigators, engineers, planners, foresters, agriculturists, biologists, and medical doctors, have done many types of studies, ranging from power dam site selection to analyzing human bone structure, using photogrammetric techniques.

By far the largest application of photogrammetry has concentrated on aerial photography, although the principles apply to terrestrial and satellite photography as well (see Table 1).

Aerial photography is usually taken vertically from an aircraft giving a bird's eye view of the terrain below. The size and scale of the photography are determined by the flying height of the aircraft and the camera system used (see Figures 3 and 4).

With proper overlap of photographs - that is, say, 60% of both photos revealing the same terrain area from two vertical positions - one can with stereoscopic viewing equipment distinguish and measure the relief of features. With these two photographs and some basic measurements one can determine the height, size and distance of features such as trees, houses, telephone poles and lakes.

TABLE I

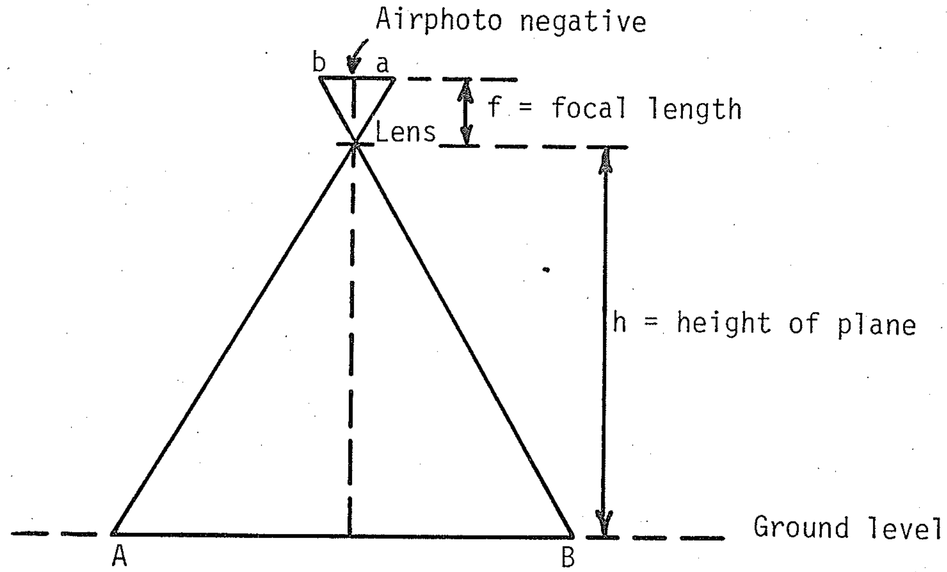
GUIDELINES FOR AERIAL SURVEYS

Description of Task	Film Type*	Season	Scale
Forest mapping; conifers	Pan	Fall, winter	1:12,000-1:20,000
Forest mapping; mixed stands	IR	Late spring, fall	1:10,000-1:12,000
Timber volume estimates	Pan or IR	Spring, fall	1:5,000 -1:20,000
Locating property boundaries	Pan	Late fall, winter	1:10,000-1:25,000
Measuring areas	Pan	Late fall, winter	All scales
Topographic mapping; highway surveys	Pan	Late fall, winter	1:5,000-1:10,000
Urban planning	Pan	Late fall, winter	1:4,800-1:9,600
Automobile traffic studies	Pan	All seasons	1:2,400-1:6,000
Surveys of wetlands or tidal regions	IR	All seasons-low tide	1:5,000-1:30,000
Archeological explorations	IR	Fall, winter	1:2,400-1:20,000
Identifying tree species	Colour	Spring, summer	1:600 -1:4,800
Assessing insect damages	Colour IR	Spring, summer	1:600 -1:5,000
Assessing plant diseases	Colour IR	Spring, summer	1:1,200-1:7,200
Water resources and pollution	Multispectral	All seasons	1:4,800-1:8,000
Agricultural soil surveys	Colour	Spring or fall, after plowing	1:4,800-1:8,000
Mapping range vegetation	Colour	Summer	1:600 -1:2,400
Real estate assessment	Colour negative	Late fall, winter	1:4,800-1:12,000
Industrial stockpile inventories	Colour negative	All seasons	1:1,200-1:4,800
Recreational surveys	Colour negative	Late fall, winter	1:5,000-1:12,000

*NOTE:
Color aerial photography can also be used-often to greater advantage than black and white photography.

Source: "Photointerpretation for Land Managers" Kodak Publication M-76, pg. 19.

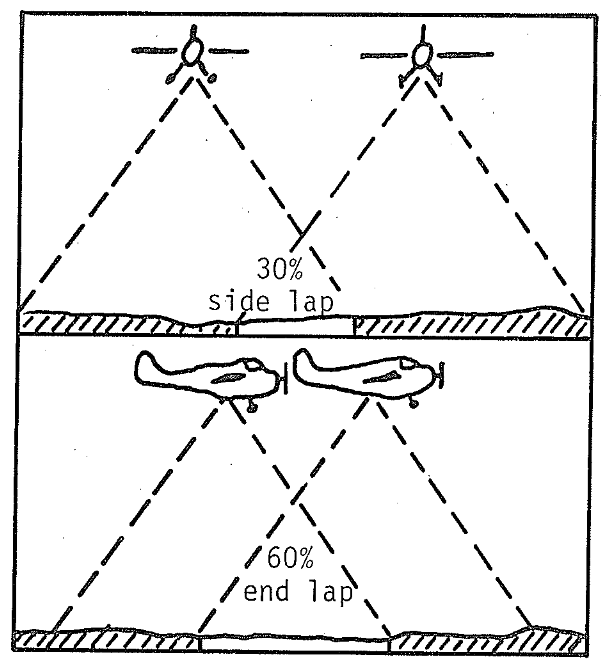
FIGURE 3



$$RF = \frac{ab}{AB} = \frac{f}{h}$$

Scale of airphotos.

FIGURE 4



Overlap of airphotos.

The ease with which these measurements are made is greatly influenced by the quality of the photographs. Affecting this quality is the amount of cloud in the photo, shadow caused by relief, glare from the sun, identification of ground control, and horizontality of the aircraft to the earth's surface.

Another type of air photo is the oblique aerial view. Oblique views are photographs taken toward the horizon, sometimes including the horizon, called a high-oblique. These photographs are taken in aerial photography missions for orientation of vertical photographs, or for different perspectives of the terrain. This is the view most commonly seen and understood by the public in advertisements, or personal slide shows.

A composite picture, assembled by taking non-overlapping vertical aerial photographs, placing them together like a jigsaw puzzle and gluing or photographing them to make a map or large picture is called a mosaic (see Figure 5).

If the mosaic is constructed at a certain scale, using ground survey points, it is referred to as a "controlled mosaic". Otherwise it is referred to as an "uncontrolled mosaic". When assembled, both types of mosaics are excellent for planning purposes. With the use of transparent overlays one can show features such as property boundaries, trails, soil types, vegetation classes, land uses, parks, concentration of wildlife, different building types, and many more features.

Figure 5. A controlled aerial mosaic of Metropolitan Winnipeg, by Western Photogrammetry Limited, June 1970.

Vertical photography is also used to make photomaps and orthophotomaps.[4] Both can be made from a single photo, a composite, or a mosaic and show clearly most of the information on the ground.

Types of film have a great effect on the quality of photographs and the distinguishing characteristics of the features. In the past, black and white film was used mostly for aerial surveys because of its low cost and high resolution. Today more aerial photography users prefer colour photography as it provides more information. There are approximately 80 shades of black to white, while colour has unlimited combinations and variations.

Colour quality is affected by haze, smog, and increased flying height. Hence when taking colour photography the most natural colour balance is achieved on a clear morning without a haze filter and a flying height approximately 2,000 feet or less. At higher altitudes haze filters are usually required; in fact, without the correct exposure and proper filter, colour aerial photographs are likely to be of poor quality.

To-date colour photography has not been used extensively in making regional terrain studies. It has not been demonstrated conclusively that interpretation of colour prints is easier, and more efficient, than interpretation of terrain from conventional black and white photographs with the exception being special limited studies, particularly where vegetation is concerned.

[4]Orthophotomaps are photomaps in which the image is distortion-free.

The cost of colour photography has been reduced in recent years, but is still substantially higher than that of conventional black and white aerial photography. The higher costs result not only from higher prices for materials, but more expensive processing and precision flying.

Conventional black and white film and normal colour film are sensitive only to wavelengths in the visible portion of the spectrum. Colour infrared film is sensitive to the visible and near infrared portions of the electromagnetic spectrum. Thus colour infrared film is not sensitive to thermal emissions (heat) which have wavelengths in the middle and far ranges of the infrared portion of the spectrum. But because it is like the visible portion, it contains wavelengths which are predominately the result of reflected rather than emitted radiation from the sun.

Colour infrared film uses the same dyes found in normal colour film, but each dye is made sensitive to a different portion of the spectrum. A "colour shift" thus results on colour infrared film whereby greens appear blue, reds appear yellow, and near infrared wavelengths appear red on the photographs [5] (see Figures 6 and 7). The red on the photographs is of considerable importance in that it is the healthy vegetation which has a strong reflectance in the near infrared portion of the spectrum. Different types of vegetation appear as different shades of red. As a result, infrared film has been an invaluable aid in the detection of

[5] "Aerial Photography As A Planning Tool", Proceedings of the Kodak Seminar: Kodak Publication M-128, pg. 17.

Figure 6. Infrared photo taken over Riding Mountain National Park, Manitoba, 6/8/74. Flying height 5200 ASL.

Figure 7. Infrared photo taken over Winnipeg, Manitoba, 7/9/72. Flying height 31,000 feet.

certain kinds of diseased plants and trees, or types and stages of growth, in agricultural and forestry research and management.

In the urban environment it has been found that the type and amount of vegetation and the degree of landscaping is an indicator of socio-economic status of residential neighbourhoods. Thus variation of the intensity of reds on an infrared photograph provides a dramatic and readily apparent initial indicator of the quality of the environment of most areas of a city.

The quality of infrared films to penetrate haze and smog makes it excellent for urban remote sensing, supplying a much sharper image than normal colour or black and white film.

4. Multispectral Sensing Systems

Over the last few years several new scientific developments in the field of aerial imagery have taken place, basically due to aerospace research. By using two or more sensors to receive electrical signals that modulate a light source, imagery of the earth's surface in different parts of the electromagnetic spectrum is produced. The operating system is usually referred to as multiband, spectral-zone, or multispectral sensing.

The multispectral sensing systems are usually installed in aircraft, but other platforms have been used such as balloons, helicopters, spacecraft and satellites.

As mentioned earlier visible light covers that part of the spectrum having a wavelength between 0.40 microns in the violet band and 0.70 microns in the red band. This is a very small portion of the known spectrum of electromagnetic waves emitted by the sun (see Figure 2).

The infrared portion of the spectrum is so broad that different sensors are required to record different portions. Investigators usually subdivide the infrared band into photographic infrared, near infrared, middle infrared, and far infrared. The boundaries between these divisions are not clearly defined and usually overlap.

Infrared photography depends on reflected or absorbed energy from the sun. Infrared imagery, operating between 0.90 microns and the far infrared section of the spectrum, depend on thermal energy; i.e., heat emitted from buildings, or heat re-emitted from terrain at night after having been absorbed in the day time. This thermal energy recorded in the middle infrared band can be monitored only during the night where black and white, colour, and near infrared photography cannot. Far infrared imagery on the other hand can be recorded either during the day or night without serious interference from the sun.

5. Radar Imagery

The band of the electromagnetic spectrum lying between 1 millimeter and 1 meter is referred to as the microwave region. This is the range in which radar operates - radar being an abbreviation of radio detection and ranging, where two antennae transmit a short pulse of energy of known characteristics to either side of an aircraft or ship. The energy then returns as reflected energy. The returning echos are converted into electron beams that flash across a cathode-ray tube, a line at a time. A camera records each line on a moving film to build up a photographic-like image of the terrain.

Side-looking airborne radar, commonly abbreviated SLAR, has radar imagery covering strips from 50 to 100 miles in width on both sides of the aircraft's flight line. The ground surface directly below the aircraft is not covered.

The techniques used in interpreting radar imagery are much the same as those used for conventional aerial photographs. And, like air photos, radar images should be oriented so that the shadows fall toward the observer to give the proper appreciation of depressions and high points.

6. LANDSAT Imagery

Remote sensing of various types carried in space vehicles provide us with extremely small-scale images of the earth's surface if the vehicle is operated at orbital altitudes. Pictures of our planet showing remarkable clarity and great coverage have been obtained in this manner. Mosaics and maps are being made from some of these pictures taken with very high resolution lens and given a scale of 1 inch equal to 80 miles on the earth's surface.

In particular, the repetitive data acquired on an 18 day cycle by NASA's Earth Resources Technology Satellite (ERTS-1) are available in four spectral bands. Such data, at scales of 1:250,000 and smaller, can assist all planners, particularly regional and resource planners (see

Figures 8 and 9).

The Canadian Program of Remote Sensing handles ERTS imagery, now LANDSAT, from a tracking and recording station at Prince Albert, Saskatchewan. In Ottawa a data handling facility and reproduction and distribution center, has been established in conjunction with the National Air Photo Library.

LANDSAT images can provide information for geological mapping at small scales, mineral exploration, analysis of contemporary terrain conditions, progress of freeze-up and break-up, construction sites, and transportation routes. In the absence of suitable topographic maps, LANDSAT imagery can serve as small scale base maps (less than 1:250,000).

LANDSAT data are currently acquired by a multispectral scanner (MSS) in 4 wavebands.[6]

MSS Band 4 visible green (yellow-green)	500-600 nanometers
MSS Band 5 visible red (orange-red)	600-700 nanometers
MSS Band 6 photographic infrared	700-800 nanometers
MSS Band 7 photographic infrared	800-1100 nanometers

Black and white images for each band and two types of colour composite are commonly available. C1, a colour composite which simulates colour aerial infrared photography, is a combination of the two visible bands MSS Bands 4 and 5 (see Figure 8), and one infrared band usually

[6] Alan F. Gregory: "Applications of Remote Sensing with Special Reference to the Geosciences", Seminar paper, Department of Geology, University of New Brunswick, March 7, 1975.

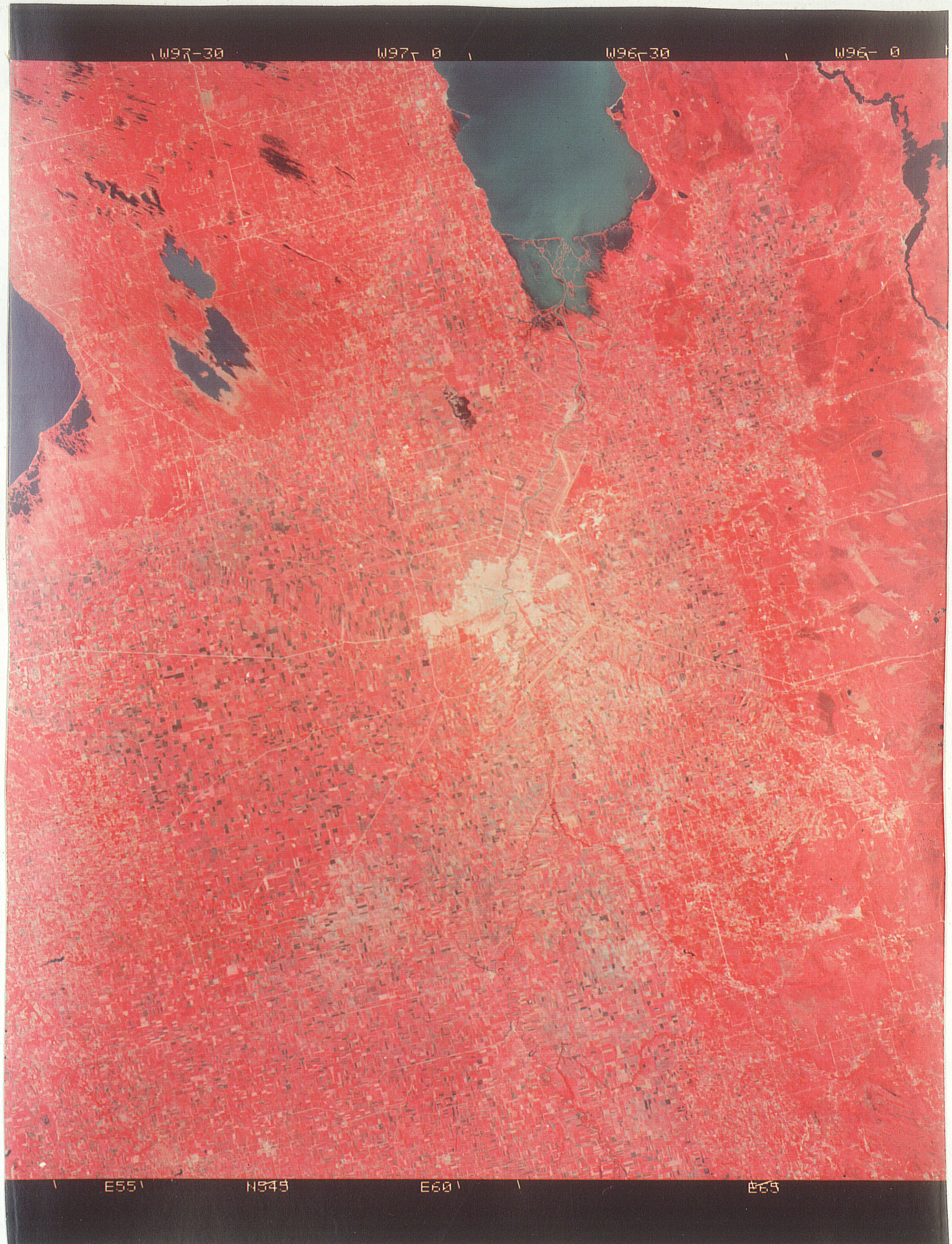


Figure 8. ERTS Imagery taken on July 15, 1975. Elevation 480 nautical miles over Winnipeg. Using Bands 4, 5 and 7.

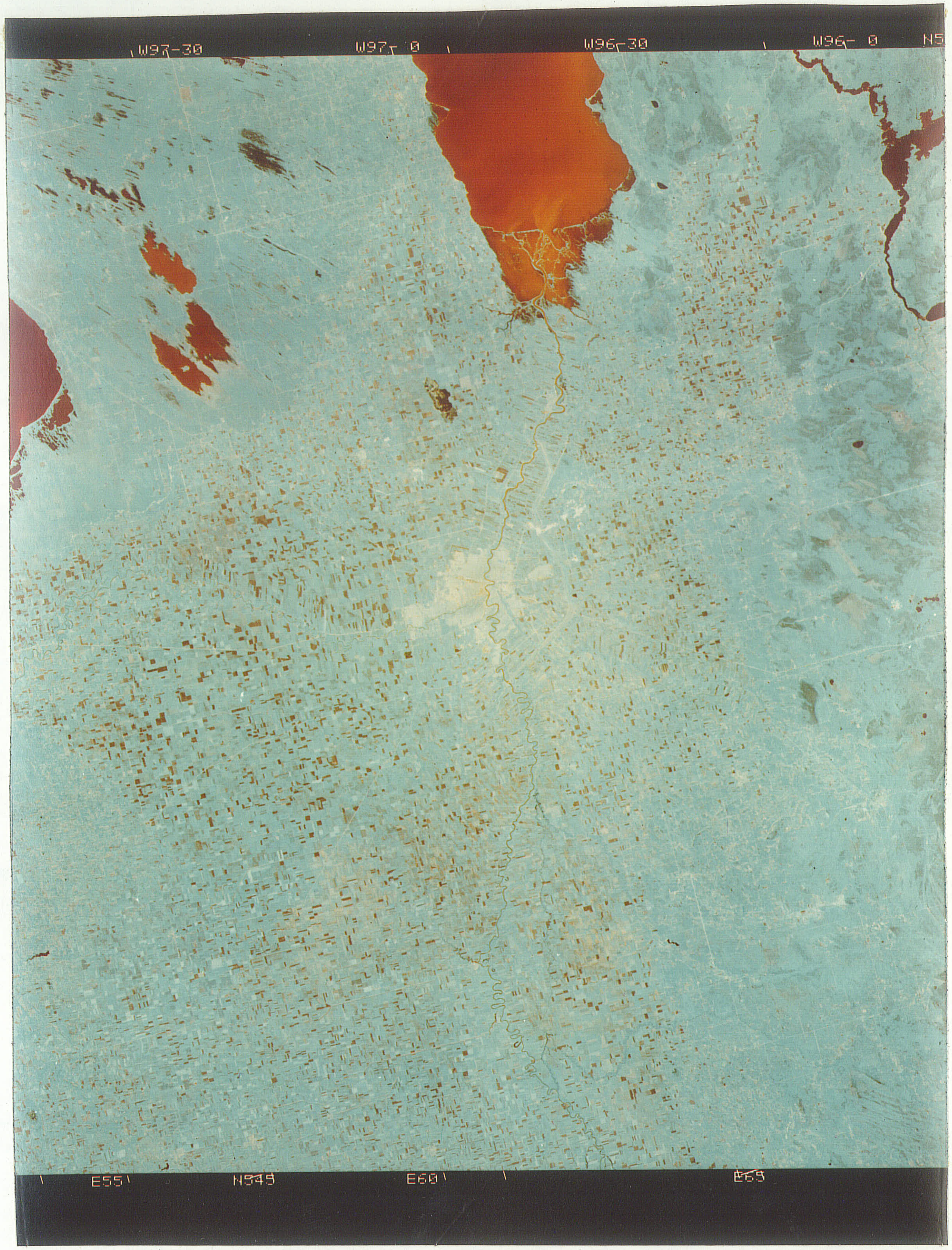


Figure 9. ERTS Imagery taken on July 15, 1975. Elevation 480 nautical miles over Winnipeg. Using Bands 5, 6 and 7.

MSS Band 6. C2 is a combination of the visible red MSS Band 5 and the two infrared bands MSS Bands 6 and 7 (see Figure 9). Each type of image emphasizes different aspects of the scene and hence is more useful for some observations and measurements than others. A generalized listing of uses for each waveband is presented in Table 2.

7. Summary

Remote sensing, which includes photo interpretation, photogrammetry, and multispectral sensing, is a relatively new field in which space age technology and the computer have recently opened up new vistas.

Photo interpretation is a highly skilled art involving training and familiarization over time.

Photogrammetry is the science of making measurements on photographs and has concentrated on aerial photography, providing much valuable information for professional people and the public.

The actual method of using aerial photographs involves becoming trained in the orientation and use of stereoscopes and measuring equipment in order to recognize and identify the features. The interpreter studies the characteristics of these features separately, then in relation to each other and in relation to the whole pattern.

Black and white photographs are used extensively in planning large areas because of their low cost and high accuracy in measuring. The main use of colour photography is in low level flying of relatively small areas of terrain, displaying information not obtainable by conventional

TABLE 2

Generalized List of Uses for Each LANDSAT Waveband
(for well-illuminated, snow-free scenes)

	Feature	Band 4	Band 5	Band 6	Band 7	C1	C2
1.	well exposed soil and bedrock, beaches, salt flat, desert drainage	F*	E	F	P	G	F
2.	geological structure, surficial textures, lineaments	F	G	E	G	G	G
3.	landforms	F	E	G	F	E	G
4.	soil moisture	P	F	G	G	F	G
5.	rivers and streams	P	F	G	E	G	G
6.	boundaries of water bodies and wetlands, flooding	P	F	G	E	G	E
7.	water turbidity, submarine topography	G	E	F	P	G	F
8.	water penetration	E	F	P	P	F	P
9.	vegetation coverage and stress (including logging, forest fire scars, etc.)	F	G	G	G	E	G
10.	anthropogenic elements (urban development, transportation infrastructure)	G	E	P	P	E	G
11.	rural land use, agriculture	G	E	E	E	G	G
12.	atmospheric transmission (through smoke, haze and dust)	P	F	G	E	F	G

*Arbitrary ratings of Excellent, Good, Fair, Poor from experience.

Object resolution averages about 200-300 feet with higher resolution for objects of high contrast.

black and white photography. Colour aerial films are best suited to provide information on cultural features, gullies, erosional landforms, and in soil variations. Colour infrared film generally is better suited for mapping, drainage and vegetation.

The newest and most exciting advances in remote sensing techniques are in multiband sensing with the use of spacecraft. These operate in portions of the electromagnetic spectrum from the microwave to the ultraviolet region. Infrared, microwaves, and radar sensors operate under both day and night conditions, and radar sensors are not seriously hindered by clouds and bad weather. Thus, regardless of weather or light conditions, information about the terrain can be gathered.

Since the United States NASA program ERTS (now LANDSAT) started, Canada has been receiving photographs by satellite from 480 nautical miles up. The satellite covers Canada every 18 days, at a scale of 1:1,000,000. The images are received in Prince Albert, Saskatchewan and then sent to Ottawa for development into photographs. The Department of Energy, Mines and Resources in Ottawa interprets the results and rates the quality of the imagery as good, fair and poor then releases the photographs to interested persons.

From this overview it is apparent that new sensor systems are providing additional information on both natural and man-made features beyond the capability of films in cameras and beyond the limits of human vision.

CHAPTER 3

URBAN PLANNING APPLICATION

1. Introduction

At no time in history has man assembled in such large numbers, as evidenced today in our major cities. In less than 200 years places like New York have grown from relatively small towns, to cities with populations in the millions.

In recent years changes in the urban pattern have been very rapid, thus causing extensive spreading into the surrounding countryside. In cities like Winnipeg, the population has doubled in 35 years. Other cities in Canada such as Montreal, Toronto, and Vancouver have grown at much faster rates.

Commerce and industry has shifted from the centre to the outskirts of the city, mostly because of the increased use of the car which has changed the habits and movements of most of the population. As a result, the capacity of existing facilities such as roads, sewage disposal, water supply, and availability of land for all new essential services and utilities has frequently been overextended. A speedier and less costly means of evaluating these trends of urban development, is required so that one can keep pace with the pressure of extending or constructing new facilities. This applies not only to development of new urban areas, but also in the prevention of decay of existing centres of population. Important too is the reassessment, at frequent intervals, of existing programs in order to meet future requirements.

To solve problems associated with massive urban growth and transition, planners, engineers, developers and administrators all depend on large quantities of data involving evaluating, collecting, recording and displaying large volumes of information. Urban growth patterns must be examined and future forecasts predicted for comprehensive planning of transportation, industry, commerce, residential areas, building and zoning regulations, tax assessment, and utility and maintenance service.

Most of the data required can easily be obtained by remote sensing techniques, offer savings in time, flexibility, reliability, and cost for gathering, storing, and retrieving of urban information.

2. Mapping the City

a. Conventional Methods

Through conventional means, the study of the evolution of an urban centre is the end product of the process of accumulation and analysis of masses of statistical data drawn from wherever possible; i.e., census tract material, tax and utility records, ground surveys, and extrapolation of field samplings. These are very slow processes, requiring sometimes many years. By the time the data are ready for use, the information has become obsolete and its value questionable.

The use of tax and utility records usually requires someone familiar with data storage and retrieval systems. The first step, and sometimes the hardest, is receiving permission to analyse the data, followed by a comprehensive analysis of the quality and accuracy of the information.

Ground surveys are still an unpopular task but used extensively for gathering material. These surveys could involve a windshield survey of residential housing, a door to door canvassing, or a questionnaire handled by phone, mail or personal interview. These are very tedious and time-consuming methods, but have become a regular part of the planning process.

Once a ground survey or tax and utility receipt type survey has been done, the planner is then faced with analyzing the material. Usually only a sample survey has been done for certain years, areas, income groups, etc., leaving the planner to extrapolate the missing data. This requires long hours, an in-depth knowledge of the survey, and sometimes a lot of second-guessing.

Maps of course are a favourite tool of most planners, for displaying or urban information. The map, if properly prepared, should depict with great precision all physical features and their position on the earth's surface. But, to most planners, the map is only a good base from which to start work, saving them valuable time, money, and manpower.

b. Remote Sensing Methods

One of the basic tools of planning is a complete and up-to-date inventory of existing facts and conditions, clearly presented in graphical form. Most cities have more than enough maps, but these are often improperly coordinated and, in most cases, do not provide all the necessary information. A good set of maps graphically representing all social, economic, physical, and topographic features should present most of a city's problems and help make coordination of all the city's activities easily. In the past, the cost of acquiring such maps has been prohibitive. But today it is possible, through remote sensing, to secure much of the needed data at a price any community or city can justify.

Map information required for the efficient operation of all departments is provided by the following: (1) area maps, (2) topographic maps, (3) photographic mosaics, (4) tax or block maps, (5) photo enlargements, and (6) different types of photo maps. All these may be, and usually are, made from aerial photography.

Today the incorporation of remote sensing has added a new dimension to compiling land use maps. Different types of photography is supplying different kinds of information. For example colour infrared film is being increasingly utilized in studies of urban land use and urban residential area quality (see Table 3). The extraction of general land use information, such as estimation of square footage of building space, or determination of the extent of urban blight, is also possible.

c. Comparison

The number of man hours required to extract land use data from aerial photography is substantially less than for existing field survey

TABLE 3

LAND USE IDENTIFICATION

FROM DIFFERENT TYPES OF PHOTOGRAPHY*

Photography	Scale	Type	Urban/Rural Contrast	Residential	Commercial	Industrial	Transportation	Open improved	Open unimproved
Colour infrared	1:60,000	Transp.	1	1	1	1	1	1	1
Colour infrared	1:137,000	Transp.	2	1	2	1	1	1	2
Colour infrared	1:240,000	Transp.	3	3	3	3	2	3	3
Colour infrared	1:66,000 (enlarged from 1:240,000)	Transp.	4	4	4	4	3	4	4
Panchromatic (red band)	1:160,000	Paper print	3	2	3	3	2	3	3
Panchromatic (red band)	1:38,000 (enlarged from 1:160,000)	Transp.	2	1	2	2	1	2	3

1-Excellent; 2-Very Good; 3-Good; 4-Fair; 5-Poor

*Notes handed out at 'Remote Sensing Workshop', University of Manitoba, December 3-12, 1975.

methods. When compared with tax and utility receipts, ground surveys and extrapolation of field samples, remote sensing techniques offer significant advantages in time, flexibility, and reliability of information. A further advantage provided by remote sensing techniques is the comprehensiveness of the recorded information covering all visible features.

3. Urban Growth

Managed urban growth means a careful allocation of resources to provide for well established community needs within the parameters of accepted environmental standards and fiscal capacity. Many people are convinced that the implementation of managed growth policies will result in the development of better communities, the preservation of presently desirable environments and a general all-around improvement in the quality of life.

As part of the overall appraisal of an area, it is necessary for the planner to determine viable neighbourhoods by taking into consideration the physical character of the areas and the proximity to places of employment, commerce, parks, and schools.

Competition for use of land, urban development and redevelopment, and the need for better management of urban growth is a matter of great interest to all those concerned with land.

Orderly growth and management of cities is hampered at present by the lack of adequate, timely information describing urban conditions.

More detailed information on land use, urban blight, urban growth, and decay patterns is extremely valuable to many agencies and government departments as well as private industry. Use of remote sensing, an attractive alternative to current urban data gathering techniques, is available (see Appendix C).

4. Analysis of Urban Phenomena

a. Movement of People and Goods

The movement of people and goods is a fundamental aspect of urban living. Its effects can influence the location of industry, commerce, recreation and community services. The traffic generated by one of these specific activities or functions will, over a period of time, further affect the activity or function of the surrounding land.

For example, the development of a trading area for a commercial center requires as a basic feature the establishment of a traffic drainage pattern with the proposed center as the focus of travel. Commercial centers may be grouped into regional, community, or neighbourhood shopping centers, depending on the services provided and the number of people served. The trade area served by a center is commonly judged in terms of automotive traffic accessibility.

Remote sensing techniques can be used to depict vehicle and pedestrian movement and/or interchange; thus enabling comprehensive planning for different modes of transportation and their interconnection.

b. Traffic and Parking Studies

Traffic studies may utilize remote sensing to determine the speed and location of vehicles, and their spacing in a traffic stream. Aerial strip photography may be used to study congestion and pedestrian movement. Ground photographs are useful in determining the number of passengers per vehicle, type of vehicle, driving habits, etc. Included may be both movies and stills taken from high vantage points such as overpasses and adjacent buildings.

For data collection on parking facilities, much of the desired information can be secured from aerial photography taken from an airplane or balloon (see Appendix B). A series of photographs taken at different times of day and on different days of the week can provide a fairly complete inventory of most parking facilities within a city - both on and off the street. Through larger scale photography, additional detailed information, such as adequate parking space size, congestion created by parking spaces located too close to exits or entrances, or space being wasted to protect manoeuvering areas, could be determined.

c. Water Distribution Plants and Sewage Systems

From aerial photos it is possible to determine most data needed for the design of reservoirs, water purification plants, water distribution systems, sewage treatment plants, sewage collection systems, and refuse disposal landfill sites. These include number of homes to be served, distance between them, vacant land, general type of usage, (residential, commercial, industrial or agricultural), and overall service areas. Aerial reconnaissance will supply missing data without recourse to costly detailed field surveys. Use of ground surveys usually prohibits investigation of all the possible solutions, and, therefore, frequently the best may not be found. With remote sensing techniques all avenues are available for study. Therefore, the most economical and practical method of layout of pipelines, pumping stations, forcemains and associated works may be determined.

d. Blight Areas

The development and spread of urban blight conditions can be recognized by remote sensing in the identification of the spatial distribution of various grades of housing quality, thus making it possible to delineate those substandard housing areas where deprivation and its socio-economic problems exist. Present methods of housing data collection by planning agencies are too expensive, time-consuming, and infrequent.

Important features recognizable by remote sensing are city block patterns, street width, housing density, size and shape of buildings and lots, size of driveways, number of cars visible, quality of vegetation and landscaping, and condition of yards.

e. Special Studies

In addition to the previously mentioned specific applications, remote sensing assists in urban area studies, for the following:

(1) Land-use evaluation regarding amendments to official plans and zoning by-laws.

(2) Building-permit applications to determine the effect of setbacks from street lines and impact on existing development.

(3) Tax-base adjustments in determining incorrectly assessed property and hidden parcels of land.

(4) Tours of an area to determine points of interest and tour routes.

(5) Car accidents in evaluating the scene of the accident and unusual or contributory hazardous conditions.

(6) Public exhibits to demonstrate to the public the progress made regarding various projects.

(7) Traffic engineering to evaluate development proposals and their effects on traffic flows, with regard to the existing and proposed transportation network, lanes of pavement, function and design of road intersections, traffic signals, origin and destination surveys, parking spaces, preliminary road design and their effect on existing and future developments.

(8) To study the effects of hurricanes, floods, hail storms and other disasters.

5. Planning Application

Urban planning decisions depend on research data gathered from examination of the city as a whole and as individual segments. After the information has been gathered, analyzed, and a decision made, the result is incorporated in a plan.

This plan, usually a development plan, deals with different facets of community development, and is the only document that takes into account the interrelationships of the developers, land-owners, and the governments. It should be pointed out that planning and preparation of a development plan reflects the spirit and thinking of society. Our way of living is based on principles of free enterprise, individual freedom and private ownership. Meanwhile we want to provide the basic necessities of comfortable living for each individual. This double incentive forms the spirit of every planning measure and is the most important aspect of the development plan.

The fundamental purposes of the development plan are:

a. To improve the physical environment of the community as a setting for human activities.

b. To promote public interest; the interest of the community at large, rather than the interests of individuals or special groups within the community.

c. To facilitate the democratic determination and implementation of community policies on physical development.

d. To effect political and technical co-ordination in community development.

e. To inject long range consideration into the determination of short range actions.

f. To bring professional and technical knowledge to bear on the making of political decisions concerning the physical development of the community.[7]

What is becoming more evident is that urban change has caused development plans to be continuously modified; i.e., they are becoming outdated before they can be implemented. Melville Branch[8] contends that

[7]Kent, T.J. Jr., The Urban General Plan.

[8]Melville C. Branch, City Planning and Aerial Information, Harvard University Press, 1971.

"continuous master planning" is the answer, in which certain elements of the city are projected far into the future; others for the middle range; some short range, and a few not at all. Continuous master planning or continuous development planning would encompass the spectrum from the past, to the present, to the distant future. Obligations and commitments from the past, immediate needs, long range objectives, tactics, strategy, certainties and uncertainties would be included.

Whether we use the old static development planning or the new continuous development planning techniques, the need for zoning, urban renewal, environmental impact and other urban projects still remain.

Periodic photography reveals dynamic changes constantly occurring in and around an urban area where building permits, engineering studies, or direct observations only identify certain individual developments. Few cities have information systems which correlate the different records of changes in the physical-spatial city. The easiest and least expensive way of accomplishing this for city planning is by aerial photography taken at least once a year - and in faster changing areas every six months.

By viewing aerial photos at a scale of 1:4,800, city planners are in a position to judge the effect of their recommendations on such things as urban sprawl and to develop policies and a system of priorities to ensure that consolidation of development will take place in an orderly, social and economical manner.

Industrial, commercial, or residential sites can be selected from aerial photos based on their proximity to public transportation, schools, open space, and on their compatibility with existing urban development for low rental housing, metropolitan zoos, recreational areas, shopping centers and subdivision layouts.

In small area studies the planner who wishes to associate features of interest with the space they occupy do not have to rely on aerial photography companies or government departments to obtain aerial coverage. By proper training they can gather their own aerial photography by mounting a small camera, such as a 35 mm camera in a single-engine aircraft. This could in many cases be much more efficient, economical and quicker if done properly (see Appendix B).

6. Summary

Aerial photography deserves a larger place in city planning, as it is through photography that the various types of maps and map information may be kept up-to-date. In some cities, which are undergoing great growth, new photography is needed every two years, and rapid growth areas every six months. However, in towns or villages developing at a slow rate, new photography is not required for at least every five years. The new photography and mosaics can be used for a wide variety of purposes beside bringing the basic maps up-to-date; i.e., depicting housing quality, establishing estimates on incomes, social habits and preferences, studies of movement of people and goods, traffic, parking, utility works and servicing, urban blight and renewal areas, land use, building permit evaluation, storm damage, and special studies.

It is of paramount importance that city and municipal governments have the necessary up-to-date maps, so that planning studies can have a base to work from.

Current and long range urban and urban fringe problems can be accurately and systematically monitored and analyzed by remote sensing techniques. Thus, through the use of remote sensing and current statistical data, the various levels of government and private industry can better serve the public.

CHAPTER 4

REGIONAL PLANNING APPLICATION

1. Introduction

The need for regional or large area planning has become very obvious in land development, due in part, to the effects of increasing urbanization, new transportation systems, resource exploration, conservation, and the various ecological upsets. Traffic congestion, higher land values, pollution of the air, water and land, increased water and sewage services, are but a few problems that jump political boundaries and disrupt the environments. Thus in recent years regional planning has become more concerned with area-wide problems, leaving local problems to the local planning agencies.

Regional planning must combine the physical, social and economic factors associated with development so that a compatible mixture can be obtained to protect the environments.

The principal areas of concern in regional planning are the ever expanding urban fringe area, resource development, new town development, agricultural, forest, and wildlife habitats.

In areas around urban centers we find the problem of rich agricultural land being subdivided for industrial, commercial, or residential use. This is a phenomenon brought about by the massive increase in urban population as a result of the movement or rural people to urban centers and the out-migration of the city dwellers to the surrounding country, but still within easy access of the city.

Other problems encountered are similar to those covered in Chapter 3, 'Urban Planning Application', but on a much larger scale.

The establishment of new towns and resource areas linked with the problems of non-renewable resources has caused much concern for proper regional planning, particularly in the location of mining, agriculture, forestry and recreational areas.

The need for transportation facilities to and from these areas, by either aircraft, railroad, or highway can have adverse affects on the environment; along with power lines, gas pipeline corridors, and canals which disrupt the natural habitat of most animals for miles. Thus we find man, wherever he treads, influences the natural environment and his fellow man.

Interferences can only be judged by past experience, or knowing the past situations. Therefore future planning can reduce many mistakes and improve the interactions, but only after some kind of past data source is available.

2. Mapping the Region

a. Conventional Method

Regional mapping was traditionally done by land surveyors with whatever technology was available at the time. For instance, much of Western Canada was mapped as land surveyors subdivided the prairies into townships. The methods used were fairly accurate but produced spotty results and the preparation of maps was very time consuming. The railway surveyors later complemented the positional accuracy of the regional maps, but their methods were linear in approach and therefore the regions did not receive blanket coverage.

With the introduction of aerial photography and the slotted templet technique[9] large regional areas were mapped with considerable speed.

Accuracy was somewhat sacrificed, but coverage was complete, thus making it possible to map all of Canada's 10 million square kilometers of land surface by 1968, at a scale of 1:250,000. However, by this time, engineers, planners, geologists, foresters, and developers were requiring more information at larger scales.

It took approximately seven years to produce a colour line map from aerial photography if all conditions were fulfilled; i.e., the quality, amount and type of ground control, aerial photography, and experience of the manpower employed throughout all stages of the map compilation.

The Federal government was the sole producer of regional maps and because of the large areas, long map compilation time, and heavy demand

[9]Slotted templet. A templet on which important photographic distances are represented as slots cut in a sheet of cardboard, metal, or other material. Used to transfer principal points from a photograph to a map sheet.

they found they could not handle all requests. Therefore they encouraged Provincial governments to set up their own mapping departments, thus making it possible to cover many large areas at different map scales and satisfy many map users.

b. Remote Sensing Methods

In the early 1960's the introduction of the computer and improved photogrammetric techniques later reduced the map making time of colour line maps to three years. This was a major breakthrough in the map making field.

Today map users need more information on their maps so that they can relate phenomena easily and quickly. In the late 1960's the photomaps followed by orthophoto maps were developed. These maps are made out of aerial photos and can be enhanced if required, expanding the usable information yielded by the photographs. The basic problem encountered is educating the public to use these new maps. Planners and engineers trained in photo interpretation have no problem using them and sometimes prefer them over ordinary line maps.

Presently with the introduction of satellite imagery, infrared film, radar imagery, etc., a whole new outlook on regional mapping has come about.

Satellite imagery,described earlier, gives a new perspective of regions never obtained before. The coverage of metropolitan regions on one photograph is possible.

With infrared films we are now able to detect man's interference with the natural environment much more easily. Such things as the detection of disease in plants, insect infestation, pollution, plant growth rate and differentiation of crop species, have been made much easier.

Radar imagery is used in assessing the depth to permafrost, and for showing the surface configuration of major landforms, thus aiding in visualizing physical features and in making regional planning studies. Many radar images of mountainous regions provide more useful information than conventional aerial mosaics, because they tend to generalize the surface configuration of large areas as well as enhance features of low relief and gentle slopes.

Radar has enabled the mapping of regions never before photographed, by its ability to be unaffected by cloud, fog, and smog. A prime example is some of our northern islands in the Arctic Circle photographed in the early 1970's for the first time by radar, and finally mapped.

Radar, along with satellite imagery, are also used for weather detection to help in forecasting. Truly it can be said that space age mapping is here.

c. Comparison

Remote sensing has made it possible to map metropolitan and regional areas in a fraction of the time it used to take. New techniques in photo maps and orthophoto maps have made it possible to see large areas of terrain on a single map, thus giving the trained photo interpretor the means to detect interactions, problems and possible solutions. There is really no comparison with the past methods since it took decades to map a fraction of what can be mapped now in a few years, if not months. Remote regions and inaccessible areas can be mapped by satellite or radar in aircraft any time of the year.

3. Regional Development

Today, the expected fuel shortage in 20 years is forcing both Canada and the United States to exploit their last great reserves in the Arctic. This development of the North for oil and the increased demand for other resources has brought about the need for a more rational approach to planning.

The planner must now possess an awareness of the sometimes irreversible damages which unplanned approaches to resources and other development have caused. He must now provide reliable information with respect to the environmental and ecological consequences of human activities which can be expected to have an impact on natural landscapes, biotic systems and their components.

Another concern of regional planners is the coordination of rural development programs. In Canada much of this function is vested in the provincial and federal planning agencies, and their prime concern is the development of rural areas to provide the facilities, conditions, and opportunities to establish an alternative to living and working in urbanized areas while maintaining and proliferating the primary purposes of agriculture, forestry, mining, and fishing production. The task is of considerable magnitude, and couldn't be performed without a constant flow of information regarding the various changes and interactions within a regional structure.

Much of this large scale data can be obtained through remote sensing. For instance information on the present extent location and productivity of land used for different purposes is needed for analysis by the planner. Planners can look at existing urban and rural areas, and study the patterns of growth, surrounding land uses and existing problems in a very convenient method. That is, using aerial photographs (see Chapter 3, 'Urban Planning Application'). One can see the similar problems encountered on the urban fringe; the problems of transportation, sewage and water treatment, and distribution systems. Since the land is the prime resource this is where most surveys or investigations must start.

4. Analysis of Regional Phenomena

a. Land Use Identification and Classification

Planning of any kind requires the identification and classification of all land in the study areas whether it be urban, semi-urban, or regional. There is no one system of land-use classification so that any one of a number available are adequate. What is important is that the system is well documented and identification is consistent (see Appendix C).

Anderson (1972)[10] has suggested various criteria that should be taken into account when devising a land-use classification system from remote sensing.

- minimum accuracy of 90%
- equal accuracy for different categories

[10] Andersons "Land Use Classification System for Use with Remote Sensor Data", see Appendix A.

- repeatable results
- usable over an extensive area
- land cover as surrogate for activity
- suitable for different seasons
- effective use of sub-categories
- collapse of categories
- comparison with previous data
- multiple use to be recognized

In practice, interpretation of imagery should be related to actual ground conditions. Consequently ground truthing is a meaningful adjunct, both in order to establish a basis for the land use classification system and to train personnel in photo interpretation techniques.

b. Transportation

Black and white or colour aerial photography has been used for route location and design of highways and railroads since the Second World War. The areas of concern would be flown and photography taken; then three or four highway alternatives chosen, followed by an evaluation of each alternative with respect to cost, materials required, land suitability, land capability, scenic beauty, and estimated time of completion. All this would be done in the office.

Today with infrared film, highway planners can predict with a fair degree of accuracy the environmental impact of a proposed structure on its surroundings.

In addition remote sensing offers planning capabilities far superior to any other existing method in remote regions; not only for highway determination, but also for winter roads, power transmission lines, oil and gas pipelines, and water transportation systems.

c. Water Resources

Monitoring water levels and checking on periodic fluctuations in major rivers, tributaries, lakes and reservoirs can be easily done by remote sensing at scheduled intervals. Black and white photos or infrared colour photos are usually used for shoreline, tidal marsh, and wetland studies. Conventional colour films are often utilized for water penetration analysis and for checking on siltation levels.

d. Pollution Probing

Thermal infrared photography gives images based on the presence or absence of heat, thus, industrial pollution can be spotted in terms of mapping surface water and soil temperatures.[11]

e. Land Inventory

Although some types of field surveys cannot be supplemented entirely, remote sensing provides an economical tool that can greatly reduce the field time and cost for land inventory tasks. Professional geologists regularly use remote sensing for mapping land capability classes and for delineating important soil or mineral boundaries. Forestry managers and planners rely on air surveys for classifying timber areas, determining timber amounts, harvesting costs, and environmental impact. Planners can use air photography for land-use determination and growth potential.

[11]Remote sensing and pollution is looked at in greater depth in Chapter 5, "Environmental Planning Application".

f. Special Studies

In addition to the previously mentioned specific applications, remote sensing is used in the following:

(1) Regional inventories for construction material, crop yield, preparation of regional soils maps, terrain evaluation, and slope-stability evaluations.

(2) Special land-use studies for parks, game reserves, wilderness areas, tourist attractions, such as, nature trails, ski areas, lakes, etc.

(3) Urbanization; (a) monitoring urban sprawl and the effects on existing land uses, (b) designing and monitoring new towns and their effects on the surrounding environment (see Appendix D).

5. Planning Application

Remote sensing is a most appropriate planning tool for gathering, analyzing, and evaluating of regional problems on a continuous basis.

It can be easily seen that going from an urban scale to a regional scale the factors of prime concern are less on a personal level and deal generally with land-use relationships. Here too, the role of the planner diversifies as the problems change and the needs of society shift. Remote sensing can monitor these regional changes giving up-to-date information with complete coverage of the regions and close-up views of specific features.

This is done in a fraction of the time compared to ground surveys, particularly in remote areas, and at a reasonable price (see Appendix C).

During the planning process, remote sensing can be used as a medium in which immediate feedback can be received by those knowledgeable in photo interpretation. This is accomplished by using remote sensing imagery as a data file and as part of a working report.

The final outcome of the planning process, is usually a documented report. Included in this report can be graphics or displays using remote sensing imagery as an aid in portraying information. These graphics would be in the form of base maps, or detailed enhanced photos.

Thus remote sensing imagery becomes a communication medium throughout the planning process and a complimentary part of the final report.

6. Summary

Land classification systems and remote sensing techniques can become key assets for regional and metropolitan planning agencies. They allow complete coverage of an area and an analytical method of analyzing the available information.

Regional mapping has come a long way from mapping several square miles which took years to complete, to areas of thousands of square miles in a few months. The latest introduction of photo maps and orthophoto maps are excellent for planners, engineers, and anyone experienced in photo interpretation, but due to the lack of experience by many, they are not used to any great extent.

In planning work which involves land-use inventories, the historical continuity in the collection, compilation, and interpretation of data on the use of land in Canada has proven invaluable. The study of present land-use and resource problems has been facilitated by using photographs which cover large areas and can include boundaries of various zones.

In the planning process remote sensing imagery becomes a means of communication with professionals, semi-professionals and the public, with final reports using the imagery for display of valuable information.

CHAPTER 5

ENVIRONMENTAL PLANNING APPLICATION

1. Introduction

It is only within the past 20 years that an awareness of the highly complex interrelationships of the natural and man-made elements of our environment has emerged. These interrelationships have brought about the need for effective management and planning decisions with regard to the environment.

Until recently, environmental problem solving has been hindered by a lack of understanding of the environment and time consuming data gathering techniques. It has been through remote sensing, that a fast, efficient environmental data gathering system has been developed. Thus the effects of transportation systems, exploration for mineral resources, and expansion of urban areas can be monitored for their impact on the natural and human environments.

The need for sound appraisal of environmental factors for the development of policy decisions, and implementation of pollution abatement procedures has been seen by industrial and governmental planners. This appraisal or assessment of environmental problems requires a multi-disciplinary approach of a team of experienced scientists, planners and engineers equipped with "space age" technology.

2. Environmental Data Gathering

a. Conventional Methods

As a recognized concern, environmental planning has only emerged in the last twenty years. Up to this time data have been gathered by regional and urban map making techniques, taking specific study sample areas and dealing with local environmental problems. The use of aerial photography increased the production of maps and became a valuable tool in gathering data.

b. Remote Sensing Methods

Aerial photography, supported by other types of remote sensors, is just beginning to provide unique capabilities for assessing and monitoring the purity of air, land, and water. Perhaps in no other way can large areas of air, land, and water be examined so thoroughly.

Both natural and infrared colour films offer different advantages in environmental studies. The superiority of natural colour films stems from the fact that, conditions imaged, appear just about the way an experienced ground investigator would expect them to appear in nature. Colour infrared film, on the other hand, often permits detection of significant conditions which might be missed in natural colour photography. This is particularly true where vegetation is concerned. The application of remote sensors permits inventories of fish and wildlife - a very important component of our environment.

Less widely appreciated are the advantages provided by satellite sensors which can survey regional environmental phenomena affecting large numbers of people, or wildlife, regardless of artificial (political) boundaries, and give continual monitoring of the areas over long periods of time.

c. Comparison

Remote sensing has made it easier to locate critical areas which require field work, thus helping to reduce the workload and offering savings in time and money, leaving more of both for confirming laboratory analysis and taking corrective action.

3. Environmental Crisis

Technology has increased production of goods and services, but the demand for products has also escalated, thus leaving us with what is now commonly referred to as the consumption-oriented, or growth-oriented society. We are now just beginning to see that there are limits to growth and consumption as well as financial constraints. This has been brought about by what many authors believe is an environmental crisis.

The term environmental crisis actually refers to a host of problems which fall under one or another of three basic headings: (1) depletion of resources, (2) pollution, and (3) threats to the delicate balance of the ecosystems. Though opinions may differ regarding the urgency of any particular dimension of the environmental crisis, most people agree that there are very serious problems.

An article in the Monthly Letter of the Royal Bank of Canada, February 1969, clearly shows man's thinking:

> "Man, part of nature, has become enticed into a nearly fatal illusion: that his skills in science and technology make him independent of the laws of nature.
>
> He spreads insecticides without examining into whether they would be fatal to birds and beneficial to insects and might kill people. He poured millions of pounds of detergents into rivers before learning that they polluted the water. He allowed lakes to die of oxygen starvation. He contributed to the deadliness of smog by floating noxious substances into the air."

Man has polluted the atmosphere, land, and water but it is only now that the extensive scale of this pollution is becoming evident and critical. A prime example of this is the lakes of southern Norway and Sweden where the pH level[12] is so low that fish no longer live in the water because of the industrial effluents discharged into the atmosphere and water in Germany and Great Britain.[13]

Pollution, whether air or water, is a matter of degree, and what we are dealing with is an overload crisis. Pollutants, from fossil fuels and industrial processes, over-population, and increased densification threaten to overwhelm our air and water supplies.

Anti-pollution campaigns; clean-up programs and legislation by our Federal and Provincial governments; the Environmental Protection Agency in the United States; and the Law of the Sea internationally, all attest to the universal concern about our physical environment. Even the

[12]pH level is a means of evaluating the acidity or alkalinity of water.

[13]H. Ayles, Environmental Impact Assessment, Biological Perspective.

media devote increasing amounts of time and space to this vital subject.

Environmental controls if used require public and professional feedback and an iterative procedure. Through monitoring techniques made possible by adaptation of remote sensing technology, environmental planners have a tool for displaying all the physical information and a technique for getting feedback.

4. Analysis of Environmental Planning

Our ability to survive on this planet depends on the availability of clean water, fresh air and adequate food supply. It also depends on our ability to protect the global ecosystems. Hence, there is a necessity for a constant monitoring of our environment. To this effect a number of specific remote sensing techniques may be applied in the following cases:

a. Air

Air pollution, as we define it today, is man-made and is detrimental to human and animal life, vegetation and property. Natural air pollutants, such as wind-blown dust, pollen and volcanic gases have been with us since the beginning of time; thus pure air is a rare phenomenon. But since the Industrial Revolution, artificial air pollutants have become an increasing threat to civilization. In 1960, Sawicki, Elbert and other scientists experimenting with cancer-producing hydro-carbons found that hydro-carbons in urban air are comparable in composition from city to city.[14]

[14]Manual of Remote Sensing, pg. 126.

It is known that the major man-made pollutants fall into two categories: a) gases, b) solid and liquid particulates. The gaseous pollutants include sulphur oxides, carbon monoxide, nitrogen oxides and hydro-carbons. The solid and liquid particulates are non-flammable particles emitted from coal, oil and lead additives of gasoline.

These pollutants can be monitored or identified by remote sensing techniques. Thus automobile congestion, aircraft concentration, industrial pollutants and incendiary areas, can be located, analyzed, and redistributed to minimize their effects on the natural and man-made environments.

b. Water

Looking at a world may we are not surprised to think of our planet consisting of more than enough water, covering 72% of the earth's surface. However, upon close examination we find that only 0.35% is drinkable.[15] We deceive ourselves in thinking that we have plenty, but with pollutants such as sewage, insecticides, fertilizers, industrial chemicals, detergents, acid drainage from mines, and now, nuclear reactor coolants, we begin to suspect that maybe there will be a crisis; particularly when there are more polluted rivers, beaches, and lakes throughout our country.

The dimensions, patterns, geographic locations and distribution, as well as man-made features are some of the information needed to determine

[15]McGraw-Hill Encyclopedia of Science and Technology.

major polluters. Remotely sensed data often can be used to detect and map such features far better and more quickly than through ground-based methods.

Aerial photography surveys of industrial localities along waterways can cover areas and facilities where pollution sources may originate, such as industrial plants, storage areas, waste-treatment facilities, and transportation structures. Most pollutants can be detected in water by colour photography due to a discoloration.

At present, remote sensing techniques can detect temperature differences in water, thus aiding in detection of seasonal change and ice break-up, such as in the Northwest Passage for shipping.

c. Wildlife

Aerial photographs permit a wildlife specialist or ecologist to understand the composition, density and distribution of wildlife cover; the depth and water quality of a lake or stream; the extent of erosion and siltation; the type and amount of pollution, and other characteristics of the environment in relation to fish and wildlife.

The geology and climate of an area, reflected in the nature of the soil and plant cover, largely influence or determine the density, species composition, and distribution of wildlife. Anything that changes the area such as forest cutting, fire, flood, pollution, agriculture, insects or disease, land development etc., will affect the wildlife.

Many of the remote sensing techniques used in urban and regional planning can be used for wildlife analysis. Natural colour and infrared colour can detect plant growth, type, species, and amount while thermal infrared can give accurate animal counts by detecting animal body temperature differences.

The use of remote sensing is of particular value in remote areas and large marshlands where ground studies are difficult and sometimes impossible to do.

Satellite imagery is used for detection of spring mortality and reproduction rates of migrating fowl in the Canadian North. Climate has a dramatic effect on their survival since a late spring could prevent nesting and consequently kill many eggs and young.

d. Weather

Remote sensing of the atmosphere from satellites and high altitude aircraft has been practical for many years and has met with much success. There is much interest, both from the public and scientific community on local and regional weather phenomena. Tornadoes, funnel clouds, hail, and hurricanes have been reported and monitored by satellite photography, thus giving adequate warning to the public.

e. Land

Accidents occur everyday causing some form of pollution; oil spills, pipeline breaks, train derailments, highway mishaps, industrial explosions, floods, forest fires, and land erosion are but a few. The biggest polluters of all are people by the strewing of garbage onto the streets, highways, waterways, lakes, parks, in the cities and the countryside, all the time - actually millions of tons per year in Canada.

Through remote sensing, environmental protection agencies can monitor pollution-susceptible areas to give immediate warning and attention for any accidents that might occur or signs of possible incidents, thus making for quicker clean-up and possible charges against polluters.

5. Environmental Planning Applications

Farsighted plans must be made if conflicts are to be resolved as population increases and the conflicting demand for land becomes greater. Today the protection and preservation of the natural environment is receiving increasing attention by many sectors of our modern society. This heightened awareness, along with the obvious need to consider the environmental implications of our technological actions, has given rise to environmental assessment studies (see Appendix D).

These environmental assessment studies should be an integral part of all planning and development programs and used in all stages of the project.

There are many different types of assessment studies usually taking the form of a classification or evaluation of land and involve present use, use capability, use suitability, or use feasibility studies. The feasibility studies can be financial, technological, or economic in nature.

All environmental assessment studies deal primarily with terrain, marine, atmospheric, and urban environments and are essential for inventories of the present composition and characteristics of the ecosystems within these environments. Thus an in depth study of the interrelationships can be performed and a data base established.

Reconnaissance mapping for environmental surveys are commonly obtained at small scales of 1:40,000 to 1:60,000, followed by large scale coverage of selected areas where concentrations of facilities usually associated with pollution sources are observed.

The scale range most suitable for interpretation of pipelines, sewage treatment plants, raw materials and waste holding features, industrial facilities, shipping docks and structures, and mining operations, usually is 1:4,000 to 1:8,000 (see Table 1, pg. 10).

6. Summary

Effective management and planning decisions with regard to the environment are becoming more essential today than ever before, basically due to the effects of human activities on the natural environment.

There is a public awareness of the sensitivity of the ecology on the environment as evidenced by many polluted streams, lakes, and rivers.

For a proper analysis of the environments a wealth of information is required. This information had been difficult to assemble until remote sensing techniques were discovered. Remote sensing has brought about the assessment and monitoring of the purity of air, land and water over large areas. Although research is just beginning in environmental assessment, remote sensing is the most practical way of collecting and storing most of the information, until further analytical techniques become available.

Natural colour photography portrays features on the ground similar to the way an experienced ground investigator would expect to observe them in nature. Colour infrared photography often permits detection of significant conditions, particularly with vegetation, that might otherwise have been missed on colour photographs.

Other remote sensors permit detection of wildlife by a difference in body heat to the surroundings, allowing a more accurate inventory on animals, fish and birds.

In order to have sensible planning for future development, the composition of the total environment must be known and understood. Just knowing the components is a major step in the right direction, but it is really not enough since the interactions of all factors must be determined in order to predict accurately the results of man's interference with the natural environment, thus eliminating or cutting down on pollution of air, land, and water.

Remote sensing can help solve environmental problems and supply valuable information on past and present changing situations. For best results reconnaissance surveys of environmental areas should be done at 1:40,000 to 1:50,000 scale followed by an in depth survey at 1:4,000 to 1:8,000 scale.

It must be emphasized that data gathered by remote sensing will seldom provide sufficient information by itself to solve problems of the environment. Ground truthing by field surveys, planners' experiences and familiarity with the problem are other key ingredients. One of the chief advantages of remote sensing is the unified coverage of a study area. The data obtained from photo interpretation are available in the same unified form, thus making for comprehensive planning and greater reliability.

CHAPTER 6

FUTURE

Advances, innovations, new discoveries and technical breakthroughs in remote sensing are happening every week. In Canada and the United States millions of dollars are being spent each year on remote sensing and its applications. Many results have not been publicized but those reported so far show clearly a new form of physical, social and economic planning, for the future. Such advances as, a 90% reduction in field surveys, continuous development planning, and daily monitoring of change in the urban and natural environments are but a few.

1. Planning by Satellite

Modern satellites are passing repeatedly and without bias over every part of the earth on a daily basis. Their instruments are insensitive to political or topographic boundaries and they have to date been programmed in a manner designed to evaluate their applicability for many users. In the future, these satellites will be designed to monitor and gather information for selected users, thus optimizing their efficiency and producing more meaningful information for planners.

Computers in the near future will be able to take raw remote sensing data directly from aircrafts and/or satellites and store the information in a common data storage system, immediately, eliminating much of the time consuming interpretation process required at present. This will save hundreds of man-hours and make available a fast, continuous, up-to-date information system.

The use of a stationary satellite platform or a skylab will allow planners to monitor a particular area of Canada or the whole country simultaneously. Using different remote sensing techniques, day and/or night time observation will be possible for studies of any selected area.

2. Remote Sensing Techniques

The use of thermal films to detect heat loss in housing, other buildings, gas lines, etc. will help find problem areas and reduce wasted energy. Infrared films will be used to determine major polluters and diseased vegetation, so that control and protection of our environment can be established. Other breakthroughs in remote sensing will compel existing techniques to be used by planners to analyze selected areas of a city without creating public unrest. That is, they will be able to monitor any area of a city, or plan a new facility, design a new expressway, study cause and effects of changes, or whatever, without going into the area and agitating private individuals or inducing private speculation.

Major breakthroughs in filter, film combinations and processing techniques will allow specially trained remote sensing personnel to gather specific environmental information, with increased accuracy and reduced costs.

Planning groups in governments and private industry will become more aware of the interrelationships between land-use, quality of environment and future living standards. Utility companies, water resource agencies, air pollution control groups, and many other public and private agencies will make more and better use of maps created by remote sensing techniques so that these interrelationships can be researched.

In the near future all of the basic information required will be kept on file in a computer data storage system, sometimes referred to as an urban or resource information system. Each user will have their own minature computer handling facility and access to the common data storage system. With their own facility, they will be able to analyze, reorganize, and add or delete pertinent data. With the common data storage system they will be able to extract required information or update their own, so that all users will have the latest information possible.

With the introduction of a common data storage system already started in some American cities, planners will have an instrument for measuring the results of their previous decisions and public officials, private developers and interested citizens will be able to monitor the on-going growth process in urbanized areas. Planners will also be able to measure the consequences of growth, that strain the physical capabilities of the country.

For a data storage system to function properly, much urban environmental data is required. As shown throughout this thesis most of this information is available through remote sensing.

3. Planning Boards

While most planning boards are still reluctant to provide funds for purchase of remote sensing imagery, they will realize in the not too distant future that an investment of this kind is measurable in time saved, dollars spent, and in terms of having a permanent up-to-date bird's eye view of the landscape, also aiding in the evaluation of land use and decision making. This view is readily accessible, yet is virtually unobtainable through any other technique.

CHAPTER 7

CONCLUSION

The analysis of remote sensing imagery and interpretation of the derived information play a steadily increasing role in the planning stages of most urban and regional planning projects.

Remote sensing can be one of the most useful tools in the continued economic growth and development of a country. However, if remote sensing is to be fully utilized as a planning tool in the progressive development of urban and regional areas, the many various applications must be demonstrated which can be of a beneficial use to planners. In this manner, the greatest benefit can be derived, and the maximum possible service rendered.

Regardless of whether the area under consideration is of an urban or regional scale, remote sensing is one of the most effective methods of gathering detailed, accurate and complete data in a very short period of time.

Depending upon the detail required, aerial photography taken from varying altitudes and with various films, speeds, and spans, is the most widely used form of remote sensing. Factors which have a direct bearing on the quality of photographic imagery from aerial cameras include: (1) physical factors, such as ground luminance and reflectance, atmospheric scattering of light, angle of sun and spectral quality of sunlight; (2) film, emulsion and filter properties; (3) camera and equipment factors, such as lens characteristics, image motion-compensation devices, shutter mechanisms and multispectral techniques. The right combinations of these will produce high quality results that will give photographs of fine detail with good tonal or colour differentiation.

The newest and most exciting advances in remote sensing techniques are in multiband sensing from air or spacecraft. These operate in portions of the electromagnetic spectrum from the microwave to the ultraviolet region. Infrared, passive microwaves, and radar sensors operate under both day and night conditions, and radar sensors are not seriously hindered by clouds and bad weather. This means that regardless of weather or light conditions the earth's surface can be photographed.

Satellite remote sensing technology offers considerable potential for obtaining significantly improved rural and urban land use data. The synoptic coverage allowed by orbital imagery will materially reduce data-handling problems, and most area coverage will be continuous. Presently, a single image will provide an effective mosaic that traditionally required many man-hours to assemble from conventional contact prints. Other advantages of an orbiting spacecraft are repeated coverage, reduced data, acquisition time, reduced cost, and in many cases, higher quality data.

Remote sensing is a new technology which reduces time and expense, but it cannot acquire all types of information needed. It has the potential of providing accurate and timely information on which planners can base important decisions.

Remote sensing provides a number of techniques to evaluate, in a qualitative and quantitative sense, the condition of our environment. It will enable the planner to estimate and map the distribution of the various factors concerned and will enable a better understanding of different ecosystems. The information from satellites and aircraft will find its way to many users besides planners, resource managers, law enforcing agencies, engineers, geologists, foresters etc. The planner must be well acquainted with this information and able to utilize it for the greatest benefit to the environment and its inhabitants.

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APPENDIX A

LAND-USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA

Classification Level	Source of Information
I	Satellite imagery, with very little supplemental information.
II	High-altitude and satellite imagery combined with topographic maps.
III.................	Medium-altitude remote sensing (1:20,000) combined with detailed topographic maps and substantial amounts of supplemental information.
IV	Low-altitude imagery with most of the information derived from supplemental sources.

Level I	Level II
01. Urban and Built-up Land	01. Residential 02. Commercial and services 03. Industrial 04. Extractive 05. Transportation, Communications, and Utilities 06. Institutional 07. Strip and Clustered Settlement 08. Mixed 09. Open and Other
02. Agricultural Land	01. Cropland and Pasture 02. Orchards, Groves, Bush Fruits, Vineyards, and Horticultural Areas 03. Feeding Operations 04. Other
03. Rangeland	01. Grass 02. Savannas (Palmetto Prairies) 03. Chaparral 04. Desert Shrub
04. Forest Land	01. Deciduous 02. Evergreen (Coniferous and Other) 03. Mixed
05. Water	01. Streams and Waterways 02. Lakes 03. Reservoirs 04. Bays and Estuaries 05. Other

LAND-USE CLASSIFICATION SYSTEM FOR USE WITH REMOTE SENSOR DATA (cont'd)

Level I	Level II
06. Nonforested Wetland	
	01. Vegetated
	02. Bare
07. Barren Land	
	01. Salt Flats
	02. Beaches
	03. Sand Other Than Beaches
	04. Bare Exposed Rock
	05. Other
08. Tundra	
	01. Tundra
09. Permanent Snow and Icefields	
	01. Permanent Snow and Icefields.

APPENDIX B

TERMINAL PARKING STUDY, DUNDAS, ONTARIO*

This example is typical of how remote sensing can be used in small area studies by planners for monitoring, design and planning.

INTRODUCTION

A study was undertaken to demonstrate that oblique aerial photography provides a useful and cost-effective method of investigating parking characteristics in a shopping plaza. Photography was taken with two hand-held 35 mm cameras containing colour slide film and panchromatic film. From a flying height of approximately 1500 feet, photographs showing the whole plaza, including access roads, were taken every 15 minutes over a period of one and one-half hours. The time chosen was 11:15 a.m. to 12:45 p.m. Contact scale of the photographs was approximately 1:9,000 and enlargements of the panchromatic photographs were produced at 1:1,800.

ANALYSIS

1. Parking Turnover

The parking stalls were coded by row and number on a data sheet. For each colour photograph, the colour and type of the vehicle occupying the stall was recorded. Analysis of the data permitted determination of the following characteristics:

*Philip J. Howarth, David A. Kinnaird, Case presented at the Remote Sensing Workshop, University of Manitoba, December 3-12, 1975.

a. total supply of parking

b. demand for parking

c. rate of turnover

d. incidence of illegal parking.

2. Vehicle Circulation

A qualitative assessment of the effectiveness of the entrances and exits, provision of signing, separation of delivery vehicles and pedestrians was made.

RESULTS

As an example of the results that can be obtained, the following information was recorded from the study:

a. Approximately 27% of the vehicles occupied their stalls for less than or equal to 15 minutes.

b. Approximately 55% of the vehicles occupied their stalls for less than or equal to 30 minutes.

c. Only 20% of the vehicles stayed for periods between 45 and 60 minutes.

d. Vehicles parked for longer than one hour constituted 25% of the total.

e. The maximum amount of illegal parking was of 3%.

CONCLUSIONS

Although a comparatively simple study, it is suggested that more useful information can be obtained from the sequential photography than by undertaking vehicle counts at exits and entrances. Costs of a light aircraft rental and a roll of colour film are obviously inexpensive. Within urban areas, more thought should be given to the possibilities of cheap data collection from light aircraft.

APPENDIX C

LAND-USE CLASSIFICATION STUDY*

Illustrated below is an example of how remote sensing has been used in Regional Planning.

DESCRIPTION OF THE STUDY

1. Area

Located at the western end of Lake Ontario, Burlington is the major centre of a new regional municipality covering approximately 90 square miles. The city serves as a residential area both for Hamilton and Toronto, and many light industries have recently been established. Population is increasing at a rate of more than 5 percent per year making it a good area for the study of land use change.

2. Information Sources

The small scale colour infrared photography used in the study is available through the National Air Photo Library:

a. July 6, 1970 A30300 IR #38 1:60,000

b. September 10, 1973 RSP A30889 IR #10 1:60,000

The Planning Department of the City of Burlington also made available their 1969 land use map at 1:12,000.

*Philip J. Howard, Nancy Koslovii, Bruce William, Case presented at the Remote Sensing Workshop, University of Manitoba, December 3-12, 1975.

3. Land Use Classification

In any mapping study, careful consideration should be given to the classification scheme, bearing in mind the amount and type of information required by the user. It is suggested that the best scheme is one which permits dissaggregation to varying levels of detail. The classification desired for this study is shown as Table I, and gives more detail than usually shown on land use maps.

4. Preparation

To learn the image characteristics of the different land use categories, the 1970 photography was studied in conjunction with the 1969 land use map. Base maps were prepared by tracing the road network from the 1969 map.

5. Mapping

Using firm transparencies, detail was traced from the 1:60,000 1970 photography on to the 1:12,000 base map using a Bausch and Lomb Zoom Transfer Scope (ZTS-4). For the 1973 photography, only areas that had changed were delineated on an overlay. Field checking and determination of unidentified land uses was then carried out.

6. Problems

There were no difficulties in identifying major land use categories, but some problems were encountered at higher levels of detail:

a. differentiation of single family dwellings and duplexes
b. distinction between low rise and high rise apartments

c. shadows and tree canopies obscuring the view

d. central business district (photography not recommended for this area)

e. confusion between office buildings/stores and small manufacturing/warehousing operations.

TIME AND COST

Before innovations are generally adopted, savings in time and/or cost have to be demonstrated. A careful record of the time required to undertake each operation was kept and details are shown in Table II. It is suggested that the times involved are very competitive with the time required to undertake a conventional ground survey.

Estimates of the flying costs (provided by E. McLaren) are shown in Table III. It can be seen that as the area to be covered increases, the total cost of flying per unit area becomes more economical.

DISCUSSION

The advantages of using aerial photography in this study can be demonstrated:

a. Flexibility - only the relevant level of detail need to extracted. Also the same photography may be used for different studies.

b. Accessibility - able to identify areas hidden from the highway.

c. Timeliness - whole area covered at virtually one moment in time.

d. Permanent record - will be possible to obtain historical data if required.

Costs of equipment have to be considered. An instrument such as the Bausch and Lamb Zoom Transfer Scope is comparatively inexpensive and may be used for a variety of enlarging and reducing operations.

As administrative areas become larger, so the costs of flying per unit area become cheaper. It is suggested that high altitude colour infrared photography to cover the total region, with low altitude photography of the more urbanized areas (for engineering purposes), would provide an appropriate and economical photographic coverage for most planning purposes.

CONCLUSIONS

In Canada, the trend is towards larger administrative units consisting of both urban and rural areas. New organizational concepts have to be evolved to provide adequate planning for these large regions. At the same time, new techniques have to be devised to collect and handle information pertaining to the regions. It is suggested that small scale colour infrared photography has a valuable role to play in this task.

Wherever a study is carried out, the procedures to be followed are the same

- decision on the land use classification scheme and the level of detail to be extracted from the photography to meet the needs of the studies being undertaken
- acquisition of photography at a suitable scale
- preparation of base maps
- mapping from the photography
- field verification
- preparation of final maps.

TABLE I Land-use classification scheme for Burlington project

Level 1	Level 2	Level 3	Level 4
1 Urban	11 Residential	11.1 Single family	
		11.2 Multifamily	11.21 Duplex 11.22 Townhouses 11.23 Low-rise apartment 11.24 High-rise apartment
	12 Commercial	12.1 CBD	
		12.2 Suburban shopping centers	
		12.3 Residential stores and services	
		12.4 Highway commercial strip development	
		12.5 Car parking lot	
	13 Institutional	13.1 Administrative and civic	13.11 City hall 13.12 Garbage dump 13.13 Sewage treatment
		13.2 Schools	13.21 Elementary school 13.22 Secondary school
		13.3 Churches	
		13.4 Hospitals	
		13.5 Cemeteries	
	14 Industrial	14.1 Extractive	
		14.2 Primary manufacturing	
		14.3 Secondary manufacturing	
		14.4 Indoor warehousing	
		14.5 Open storage	
	15 Recreational	15.1 Beaches	
		15.2 Parks	
		15.3 Golf course	
		15.4 Arenas	
		15.5 Stadiums	
		15.6 Outdoor theatres	
		15.7 Race tracks	
		15.8 Athletic fields	
		15.9 Greenway	

TABLE I Page 2

Level 1	Level 2	Level 3	Level 4
	16 Transportation & communication	16.1 Major freeway and associated land	16.11 Interchange
		16.2 Railway allowance	16.21 Terminal 16.22 Yard
		16.3 HEP commission	16.31 Station 16.32 Right-of-way
		16.4 Bus terminal	
	17 Open Areas	17.1 Vacant 17.2 Idle (fringe) 17.3 Marsh 17.4 Drainage route 17.5 Under construction	
2 Agriculture	21 Intensive	21.1 Orchard 21.2 Vineyard 21.3 Market garden 21.4 Greenhouse operation 21.5 Small animals	
	22 Extensive	22.1 Grain and fodder 22.2 Rangeland	

TABLE II Times required to map urban land use from high altitude photography

Area	Procedure	Base Map Preparation (hours)	Mapping (hours)	Ground Check (hours)	Total (hours)
Complex urban (7.5 mi^2)	Mapping 1970 land use	1	18	1.5	20.5
	Mapping land use change only	0.6	4	1.5	6.1
Simple suburban (6.5 mi2)	Mapping 1970 land use	1	10	1.5	12.5
	Mapping land use change only	0.6	3	1.5	5.1

TABLE III Costs (1974) of flying high altitude photography of Burlington

Item	Study area only (35 sq. mi.)	All Burlington (c. 90 sq. mi.)
Transit (Ottawa-Burlington-Ottawa)	$600	$600
Line mile charge ($5.50 per line mile; i.e. while camera is operating)	55	187
Colour infrared film	10	66
Film processing	6	21
9 1/2" x 9 1/2" film transparencies	24	72*
9 1/2" x 9 1/2" paper prints	14	53*
Totals	$709	$999

*These costs are based on charges for reproduction in roll form.

APPENDIX D

TOWNSITE SELECTION AND ENVIRONMENTAL ASSESSMENT*

1. Introduction

The purpose of the study was to locate and evaluate townsite alternatives in the Lake St. Joseph area which will serve as a regional resource-based community. The community will serve the mining industry, the forestry industry and tourism. A location should be selected which will allow benefits to be derived by the local native population while having as little impact as possible upon their culture, lifestyle and environs. The study area was 30 miles by 50 miles in Northwestern Ontario.

A study team was selected and brought together consisting of professionals with specialized experience in the field of town and regional planning, environmental analyses, civil engineering, transportation, and public participation to educate and utilize a high percentage of Native peoples and local residents in the area.

In selecting and evaluating potential townsites, a balance between economics to the town construction company, the greatest benefit to the public users; the least impact upon the natural environment, and provision of benefits to the existing population with little disturbance was attempted.

*Lake St. Joseph Northwestern Ontario, Second Interim Report, January, 1976, Underwood McLellan and Associates Limited.

2. Site Selection

To begin the study, large mosaics were obtained to provide an overview of the area. Mining prospects were noted and determined to be the largest potential employer in the area. General regions within the study area were defined which appeared to provide a reasonable relationship to the potential employment areas. Geotechnical constraints were noted; with the major ones to the north being Lake St. Joseph and the Osnaburgh Reserve. Predominance of bedrock and muskeg throughout the area was a major factor to be considered from a physical aspect.

Certain areas were defined on the aerial mosaics which showed some potential. From high level aerial photography and field reconnaissance, potential sites were more specifically defined and several sites eliminated.

3. Study Components

a. Terrain Evaluations

A general description of the topography was related to townsite suitability. Included was a description of the geomorphology and the changes that are taking place over an extended period of time, an engineering evaluation of soils including depth of overburden, errodability and water tables, an evaluation of water resources, direction of flow and other factors which may have a bearing on the townsite selection.

b. Transportation Considerations

A review of all available existing reports on the area was done, looking basically at existing transportation demands, additional needs and deficiencies. An analysis was completed of future travel conditions, needs and alternatives, keeping in mind future development opportunities, the area and constraints, with the need of transporting people and materials as a result of the proposed new activities.

c. Environmental Consideration

An environmental impact assessment was done to identify, predict, interpret and communicate information about the impact of a development on an ecosystem, particularly in northern latitudes where mans' activities are more closely linked to environmental parameters.

Ecosystems of the area and their relationships between components and outside boundaries were defined by input from all members of the study group.

d. Land Use Considerations

An inventory of current land use patterns including trapping, hunting, forestry, mining and wild rice harvesting was established along with commercial fishing, sport fishing and other recreational considerations.

Present mining claims, Indian Reserves, Crown timber cutting rights, and the extent of forestry activity was described in general terms.

e. Geology and Ore Deposit Considerations

Undoubtedly one of the most important constraints considered in the selection of a community site was that the area required for the town must not be underlain by ore deposit. Even deposits which are not considered to be commercially advantageous by today's standards should be avoided since past history indicates that advances in metallurgical and mining technology may create a commercial demand for these materials in a very few years.

f. Forestry Reserves and Potential

A review of a number of previous forestry studies was accomplished so that the changes in the area which are taking place and the commercial viability of various timber stands dictated by demands for forest products could be assessed.

g. Recreation and Tourism Potential

The present recreation and tourist facilities within the district were found to be of a special character heavily dependent upon environmental factors that have significant capacity constraints.

The recreation potentials, cultural heritage, and archaeological sites of the area were all evaluated as an integral part of the site selection.

The result was that ten sites were selected on which terrain evaluations were undertaken with aerial photographs. These areas were subjected to a combination of aerial and ground reconnaissance by a professional team of engineers, planners, environmentalists and others.

On the basis of these individual studies, sites were ranked relative to engineering aspects, environmental constraints and tourist potential. Consequently a schedule of public participation programs, workshops and general discussion were performed for more viable input.

The tools used in assessments of all studies by all experts were air photo interpretation, and aerial and ground reconnaissance. The air photos and mosaics were used as a medium of communication and updating maps.