ENGINEERING APPLICATIONS OF REMOTE SENSING

JANUARY 31, 1980 — FEBRUARY 1, 1980

PROCEEDINGS OF
A WORKSHOP SPONSORED BY:

CANADA CENTRE FOR REMOTE SENSING

OTTAWA, ONTARIO

PROCEEDINGS OF THE FIRST NATIONAL WORKSHOP
ON
ENGINEERING APPLICATIONS OF REMOTE SENSING

JANUARY 31 - FEBRUARY 1, 1980
OTTAWA, ONTARIO

CONDUCTED BY: THE WORKING GROUP ON ENGINEERING APPLICATIONS OF REMOTE SENSING

SPONSORED BY: THE CANADA CENTRE FOR REMOTE SENSING

PREPARED BY: L. T. TAM

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FOREWORD

These proceedings document the Technical Papers presented at the First National Workshop organized by the Working Group on the Engineering Applications of Remote Sensing. This publication also includes the recommendations formulated during the Concurrent and Plenary Sessions in the following areas:

1. Transportation Engineering
2. Land Development
3. Energy Conservation - Thermography.

The Working Group on the Engineering Applications of Remote Sensing would like to thank all the participants for their interest and support which made the Workshop a successful event.

I would also like to acknowledge the contribution of all the authors of the presented papers and the following individuals who assisted in the assembly and publication of these proceedings.

1. Dr. L. Morley
2. Mr. P. Hession
3. Mr. L. Tam

B. Sen Mathur
Chairman
Working Group on Engineering
Applications on Remote Sensing

PART 1 INTRODUCTION

The Working Group on Engineering Applications of Remote Sensing was formed in August 1977 under the aegis of the Canadian Advisory Committee on Remote Sensing (CACRS). Two of its mandates, among others, are to identify requirements for remote sensing data and to initiate and organize workshops, seminars, etc., all related to engineering applications.

The Working Group considers as important that its activities should represent a consensus of the users and that the users should be fully aware of the capabilities, benefits and limitations of available remote sensing systems and procedures. Accordingly, the first national workshop on engineering applications was held on January 31 and February 1, 1980 to enable the participants to acquire or update their knowledge on remote sensing and also make their requirements known. The areas of engineering applications considered were limited to Transportation Engineering, Land Development and Energy Conservation - Thermography. The Working Group, through this workshop, planned to obtain definitive views on the requirements of the engineering community in the selected areas to be able to establish recommendations for the CACRS.

The Workshop was divided into 2 parts: technical sessions on the first day for presentations on sensors and applications (refer Part 2) and discussion sessions on the second to develop and formulate recommendations (refer Part 3).

PART 2 TECHNICAL SESSIONS, JANUARY 31, 1980

Mr. Mathur welcomed the participants to the Workshop and explained that although the invitations were mailed in early December 1979, the postal service was such that many did not receive them until mid January 1980. Mr. Mathur then introduced Dr. L.W. Morley, Director-General, Canada Centre for Remote Sensing.

Dr. Morley briefly described the formation of the Working Group on Engineering Applications, explained the rationale for its formation and went on to wish the participants a rewarding experience with the workshop.

The subjects reviewed by the speakers and their contents are reproduced here in order of their presentation.

PRESENTED PAPERS

Presented Papers

	*Orbital and Airborne Sensors	F.J. Ahern	
1025521	A General Look at Remote Sensing as Applicable to Selected Engineering Applications	F.R. Brumbaugh	p. 5
	*Synthetic Aperture Radar	R. van Koughnett	
	*Applications Development at C.C.R.S.	M. Strome and J. Cihlar	
1025522	Remote Sensing Engineering Applications for Land Development Projects	S.J.G. Bird	p. 13
1025523 y 1022292 copy	Remote Sensing Applications in Transportation Engineering in Ontario	L.T. Tam	p. 36
1022293 copy	Thermography and Energy Conservation: Some Current activities in Canada	J.N. Barry	
	Remote Sensing for Environmental Impact Assessment and Construction Monitoring	G.F. Tomlins and J. Cihlar	

* Paper not received in time for publication

A GENERAL LOOK AT REMOTE SENSING AS APPLICABLE TO SELECTED ENGINEERING APPLICATIONS

Presented at

The Workshop on "Engineering Applications of Remote Sensing"

January 31 and February 1, 1980

by

Fred R. Brumbaugh

Intertech Remote Sensing Ltd.
2841 Riverside Drive, Suite 202
Ottawa, Ontario K1V 8N4

INTERTECH

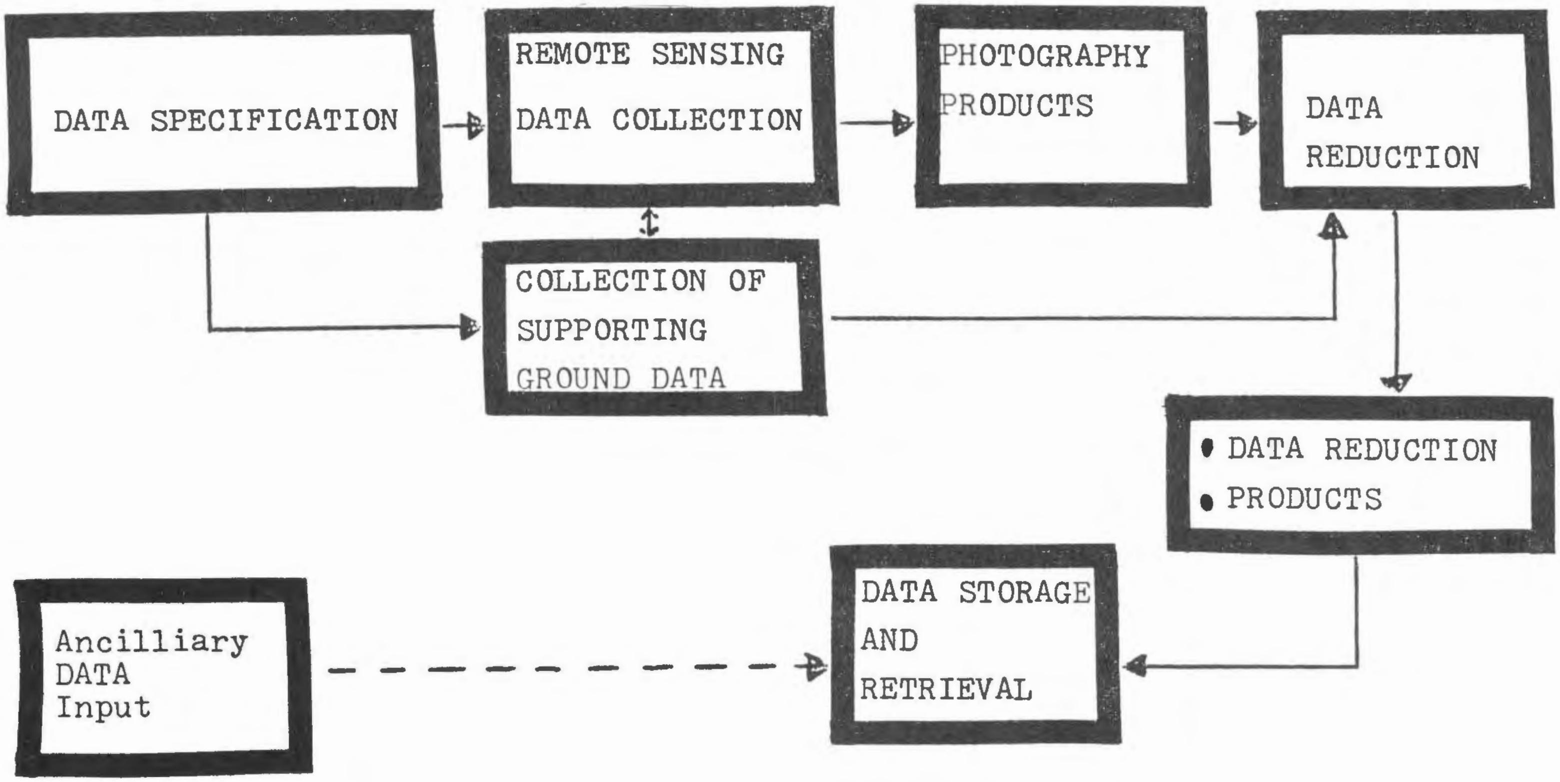
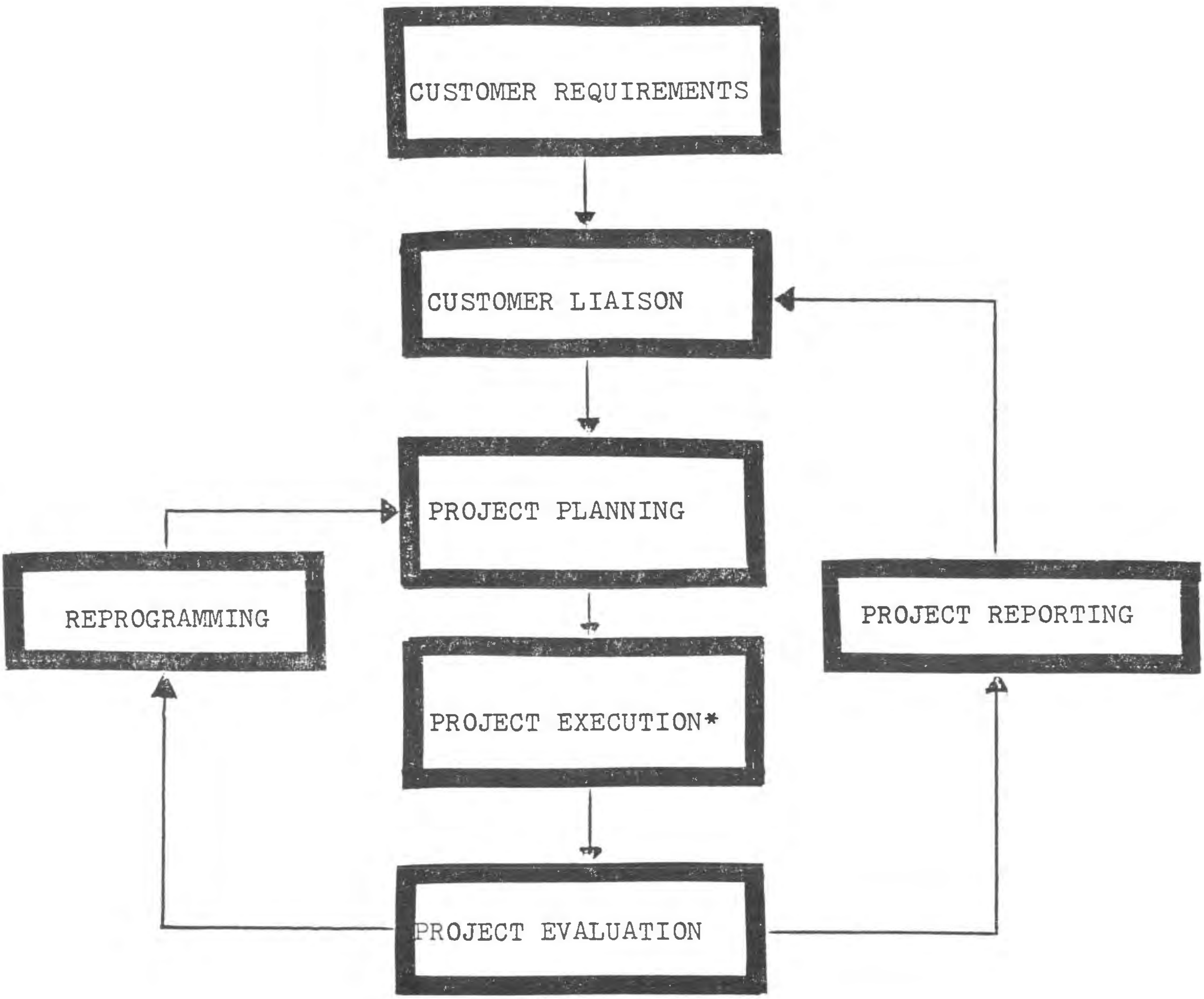


Diagram of a Remote Sensing Project Execution Subsystem



Typical Project Management Model

Summary of Remote Sensing Data Used in This Study

Site(s) Alcoa Site - Sandow Mine

Description Lignite Mining - Power Generation

Characteristics	NASA-Skylab S190B Camera	NASA-Landsat 1 & 2	NASA RB57	ASCS	Low Altitude (Handheld)
Film Type	Natural Color (S0242)	*	Color Infrared	Black & White	Color Infrared
Frame Identification	SL 94-124	**	Msn 197(34-0118)	Various	None
Image Acquisition Format	4.5" x 4.5"	9-1/2" 9-1/2"	9-1/2" x 9-1/2"	9" x 9"	35mm
Acquisition Scale	1:950,000	1:1,000,000	1:120,000	1:20,000; 1:26,000; and 1:40,000	Various
Altitude	235 n.mi.	490 n.mi.	60,000'	10,000'	6500'
Nominal Ground Resolution	15-25m	80-100m	3-5m	1m	Various
Date of Image Acquisition	January 1974	9 May '73 and 2 May '76	April 1972	1941,1951,1958, 1964,1972	June 1977
Repetitive Coverage	No	Yes - 18 day cycles	No	Not on regular basis	No
Area Coverage (per frame)	3,600 sq. mi.	10,000 sq. mi.	256 sq. mi.	Various	Various
Spectral Information	.4-.7 microns	Discrete Bands Band 4 .5-.6 microns Band 5 .6-.7 microns Band 6 .7-.8 microns Band 7 .8-1.1 microns	.5-.8 microns	.4-.7microns	.5-1.2 microns (approx.)

* Multispectral Scanner data was used for this investigation. False color composites (resemble color infrared photographs) were generated as follows: For 9 May 1973 image - used bands 4, 5, & 6
For 2 May 1976 image - used bands 4, 5, & 7

**9 May 1973 Frame ID #-1290-16312 - 2 May 1976 Frame ID E-2466-16140

Summary of Qualitative Assessment for Five Different Platforms and Sensor Configurations Used to Illustrate the Level of Detectability, Identification, and Measurement Accuracies for Selected Mining and Reclamation Features and Activities

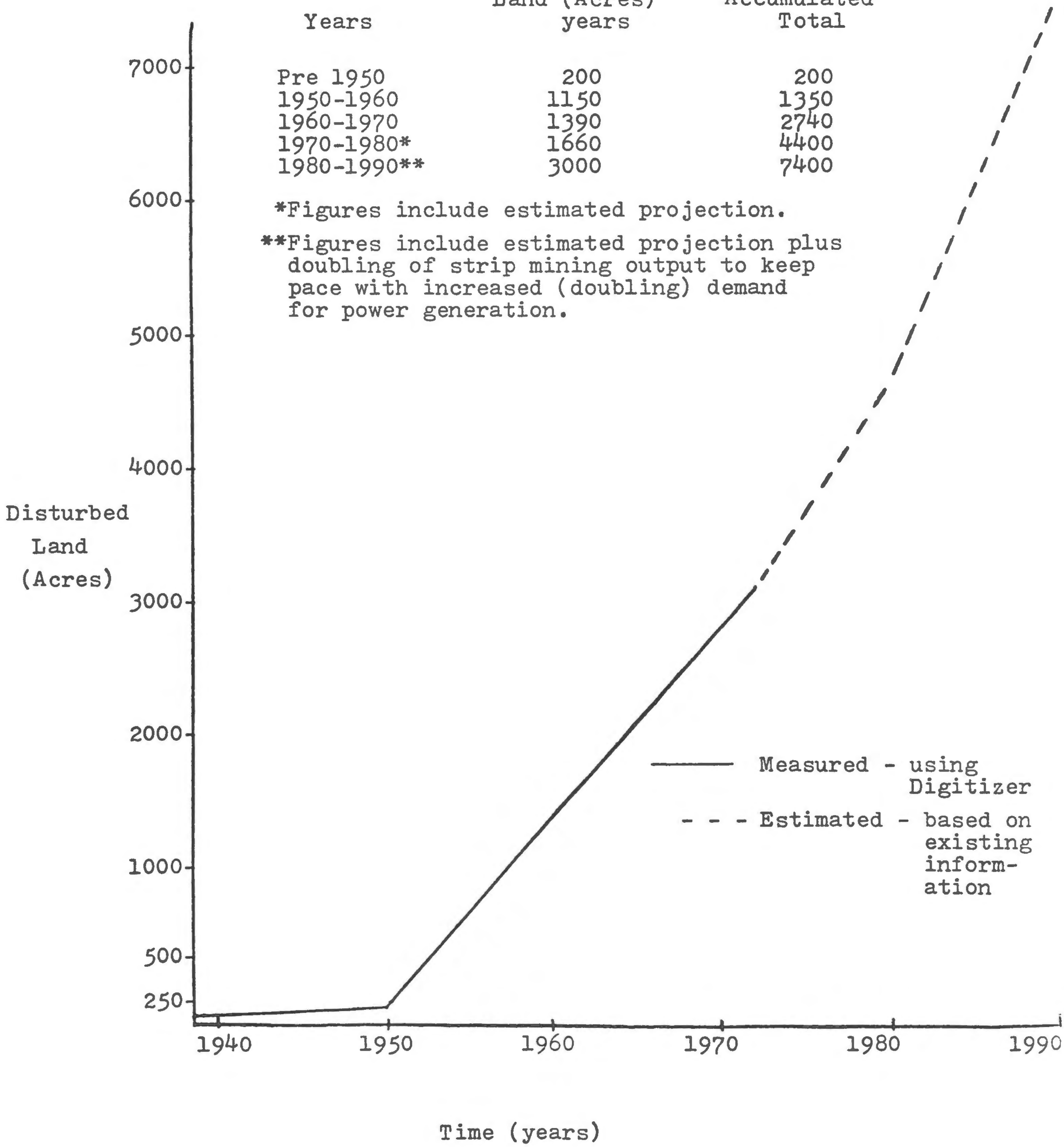
Feature/Activity	LANDSAT MSS (color composites)			Skylab/Camera (color)			RB57/Camera (Color Infrared)			USDA/ASCS Camera (Black & White)			Handheld Camera (Color Infrared)		
	D*	I	MA	D	I	MA	D	I	MA	D	I	MA	D	I	MA
o Active Surface Mine Operation	H	H	F	H	H	F	H	H	G	H	H	G	H	H	P
- Spoil Banks	L	L	P	H	H	F	H	H	G	H	H	G	H	H	P
- Access Roads	L	L	NA	H	H	NA	H	H	NA	H	H	NA	H	H	NA
- High Walls	L	L	NA	L	L	NA	H	H	NA	H	H	NA	H	H	NA
o Reclamation															
- Preparation for seeding in progress or completed	L	L	P	L	L	P	H	H	G	H	L	G	H	H	P
- Some revegetation observed	L	L	P	H	L	F	H	H	G	H	L	G	H	H	P
- Revegetation successfully established	H	L	F	H	L	F	H	H	G	H	L	G	H	H	P
o Impoundments	H	H	F	H	H	F	H	H	G	H	H	G	H	H	P
o Orphaned Areas	H	L	F	H	H	F	H	H	G	H	H	G	H	H	P

*Legend: D = Detectability (H = High, L = Low); I = Identification (H = High, L = Low); MA = Measurement Accuracy (G = Good, F = Fair, P = Poor); NA = Not Applicable

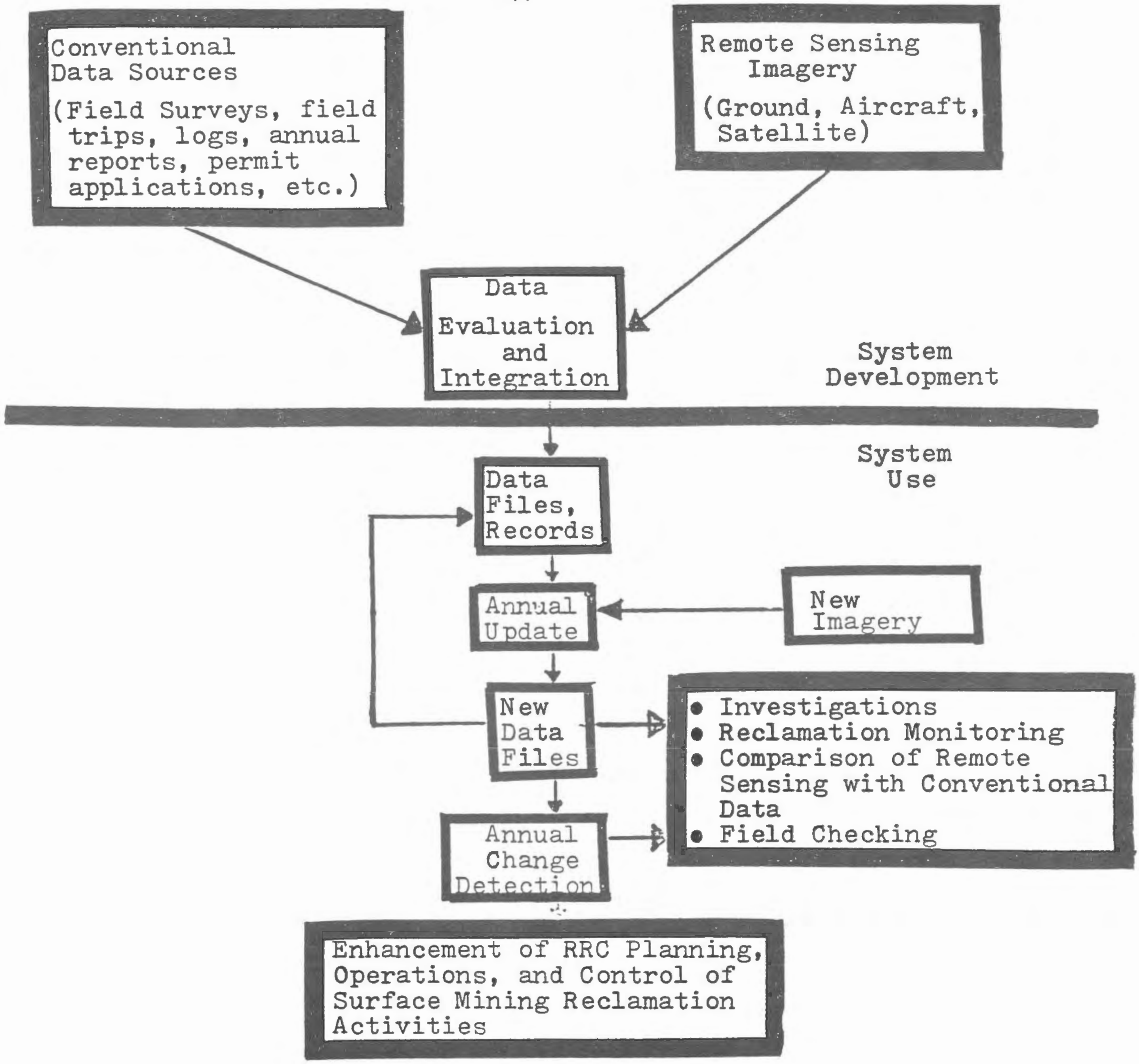
Years	Disturbed Land (Acres) years	Disturbed Land (Acres) Accumulated Total
Pre 1950	200	200
1950-1960	1150	1350
1960-1970	1390	2740
1970-1980*	1660	4400
1980-1990**	3000	7400

*Figures include estimated projection.

**Figures include estimated projection plus doubling of strip mining output to keep pace with increased (doubling) demand for power generation.

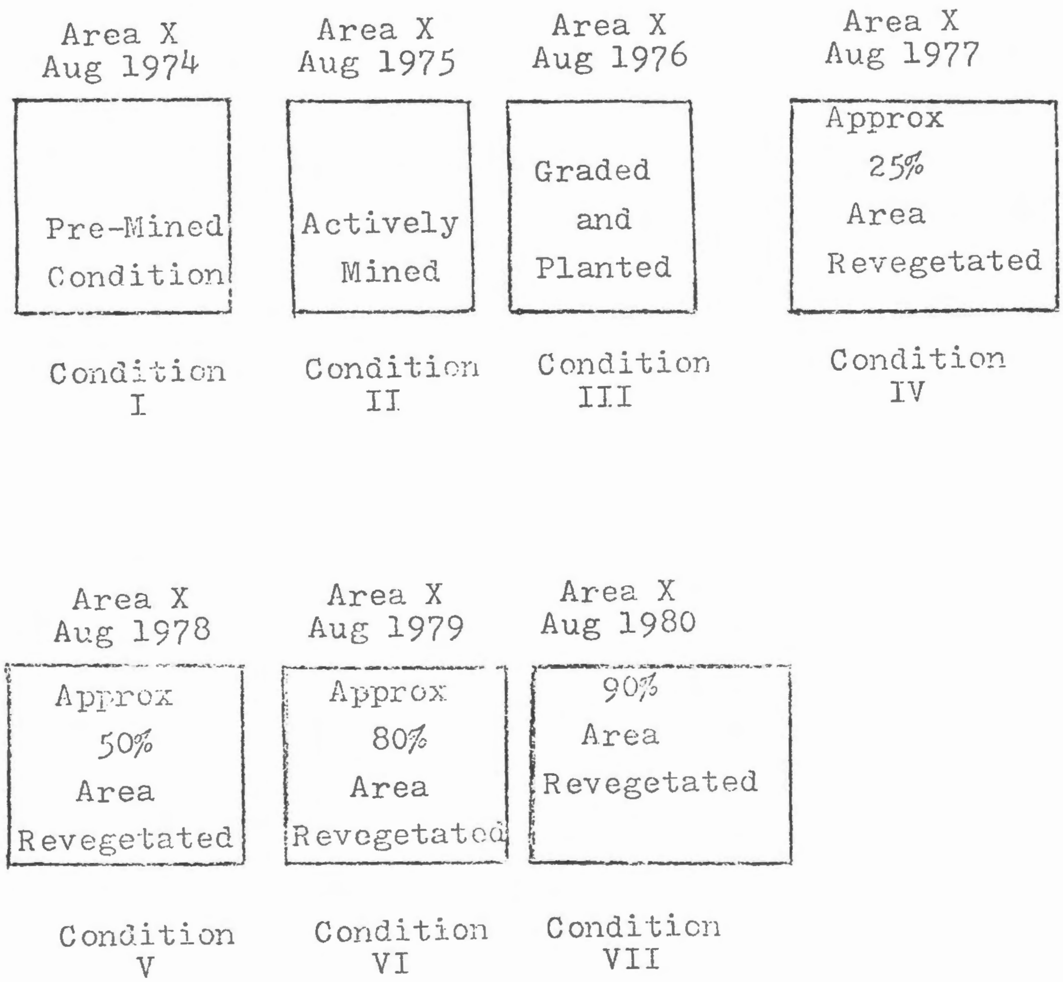


General trend plot showing the amount of disturbed land (calculated and projected) as a function of time for the Alcoa-Sandow mining site.



Formulation of flow within the Reclamation Monitoring Change Detection System.

THIS Figure shows a very simple technique that could be effectively used to measure the annual progress of a reclamation program.



Idealized Technique for Measurement Assessment of Revegetation (Reclamation) Standards Criteria*

*Blocks can represent either actual photographs or appropriately annotated overlays keyed to photographic bases showing extent and location of revegetation pattern in a chronological sequence.

REMOTE SENSING ENGINEERING APPLICATIONS

FOR

LAND DEVELOPMENT PROJECTS

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Presented at The
Workshop on Engineering Applications of Remote Sensing
Working Group On Engineering Application of Remote Sensing
Canada Centre for Remote Sensing
Ottawa, Ontario

January 31, 1980

ABSTRACT

The scope of this paper includes the terrain requirements for all proposed land developments and related support activities, with the exclusion of transportation corridors.

The individual physical and biological terrain requirements for evaluating the development capabilities are discussed separately in relation to Remote Sensing. The present capabilities and limitations of remote sensing evaluations are set out in each case. The Primary Sensors under the state-of-the-art are identified as well as Secondary Sensors where applicable.

Recommendations for further refinement of either Primary or Secondary Sensors are also given. These suggested programs are governed by the engineering applicabilities and long term cost benefits in improving the economical analysis of terrain for proposed land development projects.

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1. INTRODUCTION

1.1 Background

A knowledge of the suitability of the terrain for various land uses is required by planners, land developers, civil engineers, landscape architects, soil scientists and geologists. Because the terrain conditions strongly influence the capability of the land to support various species of vegetation, this information is also important for botanists, foresters, wildlife ecologists and others concerned with vegetation mapping and evaluation.

The successful application of remote sensing to land development considerations is based on the integration of multiple interrelated data sources and analytical procedures.

Remote sensing and airphoto interpretation techniques are useful only if the economics of the project are significantly improved in relation to direct investigation techniques. An additional advantage of these techniques relates to the identification and evaluation of existing and potential specific problems that are not easily seen on the ground. Examples of these conditions are underground water erosion; landslides or rockfalls; flooding; bank erosion and deposition along streams and rivers; vegetation stress.

All designs of successful remote sensing projects involve the following:

(1) Clear definition of the terrain characteristics to be examined, including the accuracy requirements and

the eventual use of the study conclusions.

(2) Evaluation of satisfying the project requirements using remote sensing techniques.

(3) Identification of the remote sensing data acquisition procedures required to satisfy the objectives.

(4) Determination of the data interpretation procedures to be employed, including reference data requirements.

(5) Degree and intensity of ground truthing (field investigation) required and identification of the disciplines necessary to satisfy the project requirements.

The capabilities to interpret remote sensing data are essential. This obvious statement is supported by the occurrence of situations where people have acquired masses of remote sensing data and have not had the capabilities to interpret them. Experience is also required to determine the application of remote sensing techniques to a particular land development situation.

In summary, airphoto interpretation and other forms of remote sensing are useful and economical tools. Some techniques are well established; others have not yet reached that stage. Remote sensing data provides valuable input for most land development projects, yet should never be an end in itself. In any case, the efficiencies and resulting economics of selective field verification of interpreted data cannot be underestimated. The overview of the study area provided by remote sensing also reveals particular benefits and/or problems which are difficult and sometimes impossible to detect through field investigations. Time lapse photography or imagery over intervals of weeks, months or more particularly years provides an accurate and true method of measuring physical and biological changes over these time periods. In addition, as hearings in various forums relating to development approval are rapidly on the increase, remote sensing photography/imagery and data analyses carried out therefrom by experienced personnel are accepted as evidence on their entirety.

1.2 Objectives

The objectives of this paper are threefold.

1. To describe the remote sensing applications to the physical and biological terrain characteristics required for land development projects, indicate the optimum photography or imagery for evaluating each factor, and state the limitations of each as presently envisaged.

2. To recommend those terrain characteristics and related photography or imagery where further research and development should take place, and to indicate the present priorities for land development studies for both government and industry.

3. To provide a discussion document for the Engineering Applications Committee Workshop, January 1980 and to achieve agreement, wherever possible on future remote sensing activities.

1.3 Scope

Land development, in the context of this paper, involves the potential for residential, commercial, industrial (light, heavy and extractive), recreational (cottages, campgrounds, parks and marinas), forestry (merchantable timber) and agriculture. Support facilities for these potential land uses include industrial and commercial water supply sources (both surface and groundwater); sewage treatment facilities (treatment plants, lagoons and septic tile systems); solid waste disposal sites; and storm water management.

It should be noted that transportation corridors for the provision of highway, rail and hydro access are not discussed on this paper. The assumption is therefore made that these services either exist in close proximity to the proposed development lands,or that they can be provided over existing or selected rights-of-way. Mr. Lawton Tam, P.Eng., Ontario Ministry of Transportation and Communications discusses the remote sensing applications for transportation and service corridors in his paper prepared for the same workshop.

The conclusions set out herein are based on the following:

(a) Seven years of carrying out and directing remote sensing university research projects.

(b) Sixteen years of direct involvement in over 300 land development related projects, located primarily in Ontario, but also in all other provinces and both territories.

(c) Preparation of state-of-the-art reports and specifications of photography and imagery for future remote sensing evaluation and monitoring requirements, prepared by Bird and Hale Ltd. for the Ontario Ministry of Transportation and Communications in 1976 and for Parks Canada in 1979.

The arealextent of the proposed development is not a factor in these discussions. Remote sensing techniques have been economically applied to the development capabilities of land tracts varying in size from 10 acres (4 hectares) to 2,000 square miles (approx. 5,000 sq.km.).

Scale of the mapping of terrain characteristics has varied throughout these projects from 1:1,000 to 1:70,000. Therefore, the scope of this paper is not limited by the scale factor, although the most appropriate for each terrain characteristic is discussed where applicable.

The emphasis in the following discussion is placed on existing photography and imagery because of its availability over all areas of Canada. Conclusions and recommendations are limited to operational systems, primarily government financed and operated, as these systems can be directed toward specific geological areas to acquire the necessary imagery at reasonable costs for future investigations. Of course, the latter is true only if the proper rationale for these further investigations be clearly set out.

2.0 TERRAIN DATA REQUIREMENTS AND SENSOR STATUS 6.

The most significant terrain (both land and water) requirements for land development purposes are discussed in this section. In each case, the most effective sensor in presently evaluating the data is stated and referred to as the "primary sensor"*. "Secondary sensors" which may improve the present day capabilities are discussed in relation to their operational characteristics, weather requirements, limitations, interpretability by experienced personnel, and relative costs. In the author's opinion, the latter is by far the most significant. It must be recognized that any sensor system must be more economical than the other more direct means of terrain data acquisition, such as field investigation.

2.1 Soil and Rock Types

The surficial soils and rocks are related to the landforms. Assuming that the interpreter has a thorough understanding of all glacial processes, the pattern elements for the identification of landforms and the probable soil types are well established and proven for panchromatic photography.

Colour photography has been used for the identification of soil and rock types. However, a time study comparison for equal sized townships by the same qualified interpreter indicated that the interpretation of colour photos versus panchromatic took 2.5 times as long. Therefore, panchromatic is the primary sensor and colour is the secondary sensor.

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* *"sensor", for the purposes of this paper, refers to the complete remote sensing system and includes platforms, photographic or imaging equipment, film and filters, and photographic prints or imagery renditions.*

As the costs of colour photography and printing are significantly higher than panchromatic, further refinement of this secondary sensor would not be warranted.

2.2 Depth of Overburden

The depth of soil over bedrock or large boulders is inferred from not only landform type, but also numerous indicators, one of which is the tonal and textural patterns "reflected" by the fractures and micro drainage of the underlying consolidated strata. As these patterns are commonly indicated by changes in soil moisture and/or vegetative species, a sensor which more accurately indicates these factors is of assistance. Most experienced interpreters have become skilled at estimating depth of overburden using panchromatic photography and it must be considered the primary sensor. However, as infrared colour photography is particularly sensitive to soil moisture and vegetative stress, consideration should be given to further research in its usage for this purpose.

2.3 Soil and Site Drainage

It is recognized that soil drainage and site drainage are independent of each other under certain circumstances. A well drained soil can, for example, be contained within a basin of unfractured bedrock, resulting in poor site drainage. On the other hand, poorly drained soils sloping towards a drainage outlet represent the reverse of the above.

The drainage conditions relating to soil and site conditions are vitally important to land development. Landform identification combined with regional site topographic slopes will normally lead the experienced interpreter to the proper conclusions. However, a water table elevation within approximately 1.5 m. of the surface is difficult to interpret. The identification of deep rooted tree species is of assistance in marginal cases, wherever the surface tonal pattern elements indicate a well drained site, although the reverse is in fact true. Therefore, while the primary sensor is panchromatic photography, secondary sensors such as infrared colour and colour photography are worthy of further investigation. Infrared colour would indicate the moisture stress on the species while colour photography would assist in species identification.

2.4 Water Supply Sources and Pollutants

Surface water supply can be evaluated using panchromatic photography, which must be considered as the primary sensor. Factors directly affecting water quality and potential treatment requirements, particularly significant aquatic growth and turbidity,can be qualitatively assessed but not differentiated into sub groups on panchromatic photography. Offshore bar formations and directions of longshore littoral drift movement can be seen in water depths up to 5 m, depending upon water clarity. This information is useful in locating water intakes and marina sites related to recreational development. Pollutants, such as municipal treatment plant outfalls, leakage of effluent from malfunctioning septic tile beds, and minor oil spills cannot be differentiated from sediment movement or turbidity.

Because colour differences in pollutants and aquatic vegetation types permit classification of these water based conditions, colour photography is of considerable assistance. The importance of colour, combined with the increased water penetration capabilities of this film type is doubtless the reason that the U.S. Coast and Geodetic Survey use colour photography along the coastlines. In addition, the shorelines of several inland lakes in Ontario have been photographed and analyzed in colour by the Ontario Centre for Remote Sensing.

While panchromatic is the primary sensor for the evaluation of water supply sources, this is mainly due to its availability. If colour photography, now considered as the secondary sensor, were available for coastlines and inland lakes undergoing development pressure, colour would become the primary sensor.

The concern over the adverse effects on the aquatic environment of warm water discharge could be more accurately evaluated by obtaining thermal line scan imagery of the affected area. However, the cost of this imagery combined with the clear sky and "still-air" weather requirements renders its use very marginal. This is particularly true when actual water temperatures at varying depths can be economically determined from a boat using established position-fixing techniques.

Groundwater supplies can only be evaluated by inference from the landforms (including consolidated and unconsolidated materials) and the apparent areas of recharge as seen on firstly panchromatic and secondly, colour airphotos. If the geology is such that the identification of seepage zones would assist in the evaluation, colour infrared airphotos or LANDSAT imagery at spring breakup would apparently increase the accuracy and completeness of seepage zone mapping. However, it is the author's experience that the applicable geological conditions are present only on about ten percent of the terrain examined for development purposes.

2.5 Vegetation

The analysis of vegetative communities for species identification, wildlife habitat and trafficability of vegetation is initially carried out using panchromatic photography. The detail required for specific recommendations relating to land development necessitates selective field checking by a biologist experienced in airphoto interpretation. Colour or panchromatic airphotos would be of considerable assistance, but only if available at contact scales of 1:5,000 or greater, taken after partial leaf growth to permit examination of the understory. The cost of acquisition, particularly during the optimum growing period of the year, is not competitive with the selective field investigation costs. Therefore, the primary sensor is and will likely remain panchromatic photos, mainly for economic reasons.

LANDSAT imagery is of far too small a scale to be applicable to vegetation analysis for land development.

2.6 Forestry

Interpretation of panchromatic airphotos at scales between 1:15,840 and 1:20,000 is used for "timber cruising". Therefore, the primary sensor is panchromatic, which is used to determine tree or stand height, tree crown diameter and density of stocking. At scales smaller than 1:20,000, individual trees generally cannot be recognized when growing in stands, and stand tone and texture become the important identifying criteria.

As forest inventories are carried out over large tracts of land to evaluate the short and long term economics of access road construction, available low-cost photography is required to achieve the economics of airphoto interpretation. In addition, the interpreters must be highly skilled and field verification is normally required.

Because the interpretation is as much an art as a science in the opinion of most practitioners, and for the economic reasons mentioned above, the acquisition of other than panchromatic photography does not appear to be feasible. LANDSAT is only applicable to general regional analyses because of its scale and resulting lack of detail.

2.7 Agriculture

Site capabilities for agriculture require analysis using panchromatic photography and this is therefore the primary sensor. Scales of 1:10,000 to 1:20,000 have provided sufficient detail. Field verification of surface soil types within each terrain unit is normally required. Agriculture capabilities have been mapped using colour photography, but no accuracy improvements were noted and the analysis took over twice as long, a situation similar to that discussed in Section 2.1.

2.8 Erosion and Soil Stability

The pattern elements are well established for the identification and evaluation of wind, water and gravity erosion using panchromatic photography at scales of between 1:10,000 and 1:20,000. While panchromatic is the primary sensor for these reasons, colour infrared photography is a useful supplement and therefore is a proven secondary sensor. This is particularly true for refining the interpretive analysis of soils subject to potential gradual gravity erosion or sudden landslides. As excessive moisture accumulations in susceptible soils represent potential areas of gravity failures, the films capability to detect moisture stress in deciduous trees and its sensitivity to small differences in soil moisture conditions is significant. For example, infrared colour has been used for analyses of areas along rivers or large streams where the proposed land use involves heavy loadings such as high rise apartments.

The unique properties of infrared colour film and the information provided is recognized, but has not,to the author's knowledge,been clearly documented regarding its reliability under varying geological conditions and the optimum scales and times of year to obtain the most relevant data.

Time lapse photography in terms of years, as presently available, provides the only accurate means of determining rates of water erosion along stream and river banks. However, it is difficult to accurately assess the causes of such erosion without consulting weather records over long periods of time, and making assumptions based only on experience which in fact may be unreliable.

2.9 Sanitary Landfills

Land development may relate to sanitary landfills in one or more of the following ways.

1. The development, particularly a large area of dense residential usage , will create the need for a solid waste disposal site or extension of existing facilities.

2. The proposed development is located adjacent to an old landfill site which has been operational within the past five years or less.

3. The proposed development is located on an old landfill site where the solid waste buried therein is not recorded as to category of wastes or quantity.

In the case of (1) above, the applications of remote sensing techniques, involving the interpretation of panchromatic photography and test soil borings to meet the provincial regulations, will lead to selection or rejection of potential sanitary landfill sites.

Situations (2) and (3) above, involve an assessment of the degree and areal extent of migration of methane gas and/or leachate, resulting from decomposition of concentrations of organic or chemical wastes. The only practical means of determining these effects involves the examination of vegetation in the vicinity of the landfill sites. Infrared colour photography records relative vegetative vigour. The effects of uptake, by the root system, of the leachates and/or methane gases and their related compounds show on this photography. The problem involves the identification of vegetal damage caused by the landfill related compounds versus that caused by other stresses or diseases. Under the present state-of-the-art, this can only be achieved through detailed and selective vegetation examination in the field by an experienced botanist. However, the infrared colour photography is the primary sensor. Consideration has been and is being given to the application of thermal scanning imagery to record the heat differences resulting from the decomposition of organic wastes. As discussed previously on this paper, the ideal weather conditions required combined with the cost of the imagery acquisition, render this inoperable and uneconomical in the author's opinion. This statement is made on the basis of thorough research with infrared scanning imagery and examination of infrared colour photography to determine the extent of methane gas migrations surrounding extensive landfill sites.

3.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions and recommendations are set out in the same order as the sub-sections of Section 2.

3.1 Soil and Rock Types

No further investigations are required, as the present techniques are well established using panchromatic photography.

3.2 Depth of Overburden

Infrared colour photography, because of its sensitivity to soil moisture and vegetative stress, deserves further investigation. This should be carried out over areas of variable overburden (1.5 m to 3.0 m), where panchromatic photographs have already been analyzed and field check points have been selectively located and ground truths obtained. Analysis by an experienced interpreter(s) who is not familiar with the ground truth data, using both the panchromatic and infrared colour of selected test areas in different physiographic regions, would provide an initial substantiation of this recommendation.

3.3 Soil and Site Drainage

While panchromatic photography satisfies the basic requirements of determining soil and site drainage, simultaneous colour and infrared colour photographs of an area previously ground truthed, as discussed in Section 3.2, would be worthy of further investigation under the conditions discussed in Section 2.3.

This recommendation should be considered as a secondary consideration relative to that discussed in Section 3.2.

The only additional cost implication involves the simultaneous acquisition of colour photography in addition to the infrared photography. If a 70 mm. multi-camera pack is used, cost considerations for investigative purposes would be minimal.

3.4 Water Supply Sources and Pollutants

The advantages of colour airphotos particularly for aquatic vegetative analyses and pollutant identification are well established. Therefore, the acquisition of this photography as part of an ongoing government sponsored program along ocean and great lake coastlines and inland lakes is recommended at a contact scale between 1:10,000 and 1:20,000. This program should initially concentrate on the areas under the greatest land development pressure, both present and anticipated.

LANDSAT imagery is useful for regional studies and monitoring of water quality indicators, such as large changes in the areal extent of aquatic growth. However, the scale of this imagery is not suitable for land development projects.

3.5 Vegetation

Panchromatic is the primary sensor and will continue to be for the foreseeable future due to scale requirements of 1:5,000 or better for supplementary photography. This scale requirement combined with the time limitations related to growing season and hence optimal photo acquisition time, further reinforces this conclusion.

3.6 Forestry

LANDSAT is useful for general evaluations but not for specifics due to scale limitations. Panchromatic is the primary sensor due to the large areas to be interpreted and the resulting cost of additional photography.

The interpretation of tree species characteristics is a practised art by specialists and also requires verification through selective field checking. Therefore, the conclusions for forestry interpretation are similar to those for vegetation (Section 3.5).

3.7 Agriculture

No further investigations are required, as the use of panchromatic photography is well established as the primary sensor.

3.8 Erosion and Soil Stability

Identification of areas subject to wind and water erosion is well established using panchromatic photography. While this is the primary sensor, the problem of accurately establishing the rates of erosion, particularly along the shorelines of streams, rivers and lakes, remains. Therefore, because of the long periods (several years) between available photographs for comparative purposes, the finite causes of the erosion are not yet defined. Once the causes are clearly understood, the remedial measures necessary to negate or minimize the erosion can be more efficiently and economically designed.

Is is recommended that a number of known areas of shoreline erosion, consisting of variable soils and offshore current and wave action conditions, be selected for testing.

Acquisition of temporal panchromatic photography at scales of 1:5,000 to 1:10,000 for time periods not exceeding one month apart, should be taken throughout the year or selected portions thereof. This data would provide a much greater understanding of the causes of bank erosion, particularly when compared with weather records and ground truthing during flights.

Further investigation of the applicability of infrared colour photography to accurately predict potential areas of soil failure is recommended. There is a natural economic tendency for heavily loaded structures to be located adjacent to rivers for the purposes of aesthetics, water supply for industries, etc. Therefore, a program of simultaneous infrared and panchromatic photography at scales of 1:5,000 to 1:10,000 should be carried out in areas having sensitive soils. This would likely have to be a long range investigation whereby the same test areas are photographed at regular intervals of six months to one year. The end result would be a quantitative explanation of the benefits of infrared colour photography. The simultaneous panchromatic photographs would permit clearer definition of the pattern elements for gravity erosion and their relative significance.

3.9 Sanitary Landfills

The adverse effects of leachates and methane on vegetation surrounding existing landfill sites has been established. Infrared colour photography reflects the changes in vegetative vigour resulting from these stresses as well as those caused by moisture variations and/or diseases from other causes. The vegetative stress patterns shown on the infrared colour, which is the primary sensor, have not yet been differentiated as to causes of vegetative stress. Therefore, under the present state-of-the-art, an experienced botanist must differentiate these causes by time consuming field investigations.

It is recommended that a research program be considered to define the causes and resultant airphoto patterns of vegetative vigour related to landfill sites on infrared colour photography. The resolution of these patterns would significantly reduce the field investigation requirements and would have the secondary benefits of identifying the airphoto patterns of vegetative stresses from other causes.

Infrared scanning imagery should not be considered for further investigation due to high costs, limited availability of operational sensors and strict weather condition requirements.

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REMOTE SENSING APPLICATIONS IN TRANSPORTATION ENGINEERING IN ONTARIO

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ABSTRACT

The utilization of remote sensing in transportation engineering is described based on the activities at the Ministry of Transportation and Communications which has a mandate for transportation in Ontario. The advantages are presented briefly. The limitations and implementation problems are then discussed followed by some suggested work.

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ACKNOWLEDGEMENT

The author would like to express his gratitude to Mr. B. Sen Mathur, Head, Remote Sensing Section, who provided the opportunity to present this paper and without whose encouragement and support the writing of this paper would have been impossible.

The Ministry of Transportation and Communications has kindly given permission to present the paper and to quote from its RECAP report.

1. INTRODUCTION

This paper describes and discusses the application of remote sensing products and techniques, at present, in the various phases of transportation engineering* in Ontario, based on the programs and activities of the Ontario Ministry of Transportation and Communications. It does not attempt to be a compendium of applications, even for this one organization. Rather, the object is to show, by focussing on the Ministry, the variety and extent of the use of remote sensing in its engineering operations.

Because of user requirements and limitations yet to be overcome, orbital sensors have not been used in proven and operational applications in this case. The primary sensor has been the aerial camera. However, applications development has been continuing on photography and imagery acquired with other airborne sensors such as the multispectral camera and thermal scanner.

This paper is organized into 3 main parts to deal with

- applications developed and in use,
- applications investigations and development completed and in progress,
- advantages of applications and implementation problems.

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* the subject of pipeline is excluded in this paper since it falls under a separate subcommittee in the Working Group.

2. PRESENT REMOTE SENSING APPLICATIONS

2.1 General Description

The Ontario Ministry of Transportation and Communications is responsible for the planning and development of an integrated, balanced transportation system in Ontario involving such modes as highway, mass transit, ferry and aviation service. The engineering operations to fulfil this mandate and where remote sensing is applicable involve the planning, design, construction and maintenance of all physical assets which fall within its jurisdiction.

At present, aerial photography obtained by aerial cameras remains to be the basis for remote sensing at the Ministry. Depending on requirements, the scale has varied from 1:500 to 1:135,000; the film can be black and white panchromatic, colour, colour infrared and black and white infrared. The frequency of use follows in this order with over 80% of the photography used in the black and white panchromatic category.

The standard products derived from the aerial photography are

(a) contact prints: used almost exclusively for interpretation. Very few transparencies are produced.

(b) enlargements: used as data base or for presentation.

(c) mosaics: both semi-controlled and uncontrolled mosaics are produced. Most are the uncontrolled type. Mosaics are also used as data base or for presentation.

Few enlargements are produced in colour due to cost and, to some extent, limitations in existing reprographic equipment. Cost alone precludes the production of colour mosaics.

Mosaics, enlargements and sometimes contact prints are used frequently by various organizational units such as the Property Office, Insurance and Claims Section, Engineering Materials Office as data base and for presentation, primarily because they facilitate communication. Whenever it is required to extract, analyze or interpret data using remote sensing techniques, the work is performed by the Remote Sensing staff. A remote sensing study typically consists of these main stages:

(a) defining the problem and establishing the terms of reference,
(b) assembling airphotos or airborne imagery, (and collecting background materials if necessary),
(c) performing image analysis and interpretation,
(d) conducting selective and limited field verification,
(e) presenting and documenting findings on data base and in text.

The following subsections (2.2 - 2.6) briefly describe the major areas of remote sensing applications which are proven and operational.

2.2 Planning

Remote sensing studies for planning purposes involve relatively large areas but usually only a general level of detail is required. It is important that the entire area be investigated completely and the data provided at a consistent time frame and detail level. If required, the study can then progress from the general to the particular, concentrating on specific areas or sites for more detail analysis.

Remote Sensing is applied in

(a) route location for highways* and railways:
  - to establish corridors and alignments and provide alternatives,
  - to evaluate and compare characteristics of selected routes,
  - to estimate and compare costs.

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* the term is used to include all classes of roads, from freeways to access roads

(b) site selection and evaluation for facilities ranging from airstrips to patrol and maintenance yards:
   - to locate feasible sites,
   - to evaluate and compare the engineering characteristics of selected sites.

(c) production of thematic maps which depict an area under themes such as topography, soils, surface drainage, land use, property values etc. according to established classifications.

2.3 Design

Remote Sensing is used to provide data for design by analyzing and classifying the pertinent terrain elements and characteristics to greater details than in the case of planning studies.

In the drainage design area, drainage studies are performed to provide data for the design of bridges, culverts, ditches and storm sewers. In each instance, catchment boundaries are determined and watershed characteristics provided according to specifications.

In the geotechnical area, soils and rocks are classified and described, their distribution and boundaries provided to facilitate field work and as preliminary information for foundation investigations.

2.4 Construction

Remote Sensing is used to inventory sources of aggregate materials, mainly sand and gravel. Existing pits and quarries are located. Potential ones are delineated and evaluated by identifying the materials and estimating the extent and quantities.

2.5 Maintenance

Compared with the previous applications, studies for maintenance purposes are site-specific: remote sensing is used to establish emergency detour sites in case of bridge failures and to determine skid resistance values of wet pavements. For the latter, instead of using airborne remote sensing, the pavements are photographed at close range. The resultant stereoscopic pairs of photographs are then analyzed in terms of the characteristics of the aggregates and pavement matrix. These photographs are viewed in the same way as airphotos and the analysis techniques used are also similar.

2.6 Other Applications

Changes caused by construction activities sometimes result in litigation and claims. Remote sensing studies are conducted to assist in legal disputes and claims settlement. Multitemporal photographs are interpreted to establish "before and after" conditions and then compared to show the nature and extent of changes. Since airphotos are permanent, unbiased records of terrain conditions, the findings are factual (Figure 1).

The above remote sensing applications are established product lines at the Ministry which are available, upon request, for its day-to-day operations. Their frequency and extent of use vary, depending upon the geographical location and perceived local needs. In the design area, the use of remote sensing to provide data for culvert design is almost a standard procedure. These applications are grouped here according to the phases of a transportation program most often used in. They are, however, also used elsewhere. For example, drainage study for design can be applied in litigations, although the level of analysis then is much higher. Similarly, granular materials search, commonly done for construction purposes, can be performed as part of a regional inventory in a planning study.

Figure 1 Tree Count

This is a simple use of airphotos - to count the number of trees that were inadvertently removed during construction. Because the claim appeared to be excessive and expert opinion varied on how many trees *could* have been there, airphotos were used and provided the only indisputable count of the exact number of trees that were removed.

3. APPLICATIONS DEVELOPMENT

Concurrent with the applications of proven and operational techniques, there are provisions for applications development, availability of policies and standards and internal technology transfer. Once a potential area for remote sensing application is identified, the procedure followed has been to justify the need and establish the terms of reference and requirements with potential users before work actually begins. Activities in applications development are described under 2 categories: completed studies and work in progress.

3.1 Major Studies Completed

(a) Drainage Study: A guide prepared for use by designers. It provides a description of and discussions on conducting remote sensing studies for the design of bridges, culverts, ditches and storm sewers.

(b) Small Watersheds: The standards and procedures of using remote sensing techniques to study small watersheds to provide data for developing design charts.

(c) Pavement Skid Resistance: An investigation into the methodology of determining skid resistance numbers of wet pavements by the photo interpretation method. The major systems of viewing the stereoscopic pairs of pavement photographs and related instruments were evaluated.

(d) Pavement Distress Features: An investigation into the feasibility and procedure of using airphotos to detect, identify and measure the various pavement distress features.

(e) Watershed Analysis: An investigation into determining certain watershed parameters from LANDSAT imagery using an image analyzer.

(f) Miscellaneous: Pertinent instruments such as the Zoom Transfer Scope and the rolling disc planimeter with electronic readout were evaluated.

3.2 Major Work in Progress

(a) Surveillance of the Environmental Effects of a Highway Facility: A pilot study was commissioned following the completion of a state-of-the-art report[1] which identified and established the applicability of remote sensing to monitoring the environmental effects of new highway construction. Aerial photography, multispectral photography and thermal imagery are used to study 2 test areas in terms of 12 major environmental parameters considered to be locally significant. The imageries are acquired seasonally each year and in the case of airphotos, several scale-film combinations are used. The objective is to determine the actual capability and cost effectiveness of remote sensing when used for environmental surveillance of highways. The study is long term and will follow several construction contracts through to completion and beyond (Figures 2 and 3).

(b) Photographic Coverage of Major Constructions: This study is to determine the cost effectiveness of having suitable and timely aerial photography on major construction sites. It was initiated based on a preliminary study which indicated that theoretically a very high cost-benefit ratio could be achieved.

(c) Multispectral Photography: The use of multispectral photography has been studied in conjunction with the Environmental Surveillance project. Effort has been concentrated on familiarization with this type of photography. Some work was done on investigating the viewing systems available and their

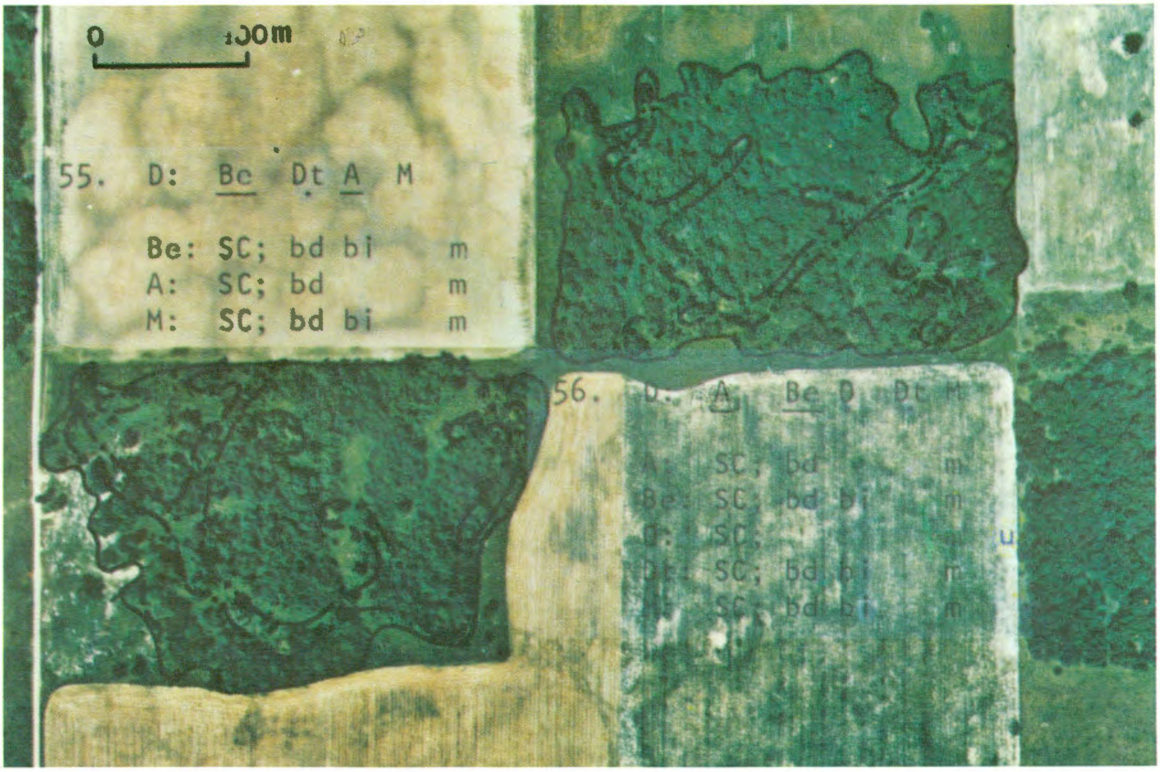
Figure 2 Surface Drainage Parameter, showing the level of drainage details required for the Environmental Surveillance Project.

Source: Mathur, B.S., "Towards Determining the Role of Remote Sensing in Environmental Surveillance of New Highways", Transportation Research Board Annual Meeting, January 1979.

feasibility for everyday use.

(d) Thermal Imagery: Investigation into thermal imagery is also conducted in conjunction with the Environmental Surveillance project. The work to date has been to gain experience with this kind of imagery.

(e) Deicing Bubble System: A combination of airphotos and thermal imagery is used to study the capabilities and effectiveness of mapping surface temperatures and areas of open water in a shipping channel kept open in winter by a deicing bubble system (Figure 4).



LEGEND

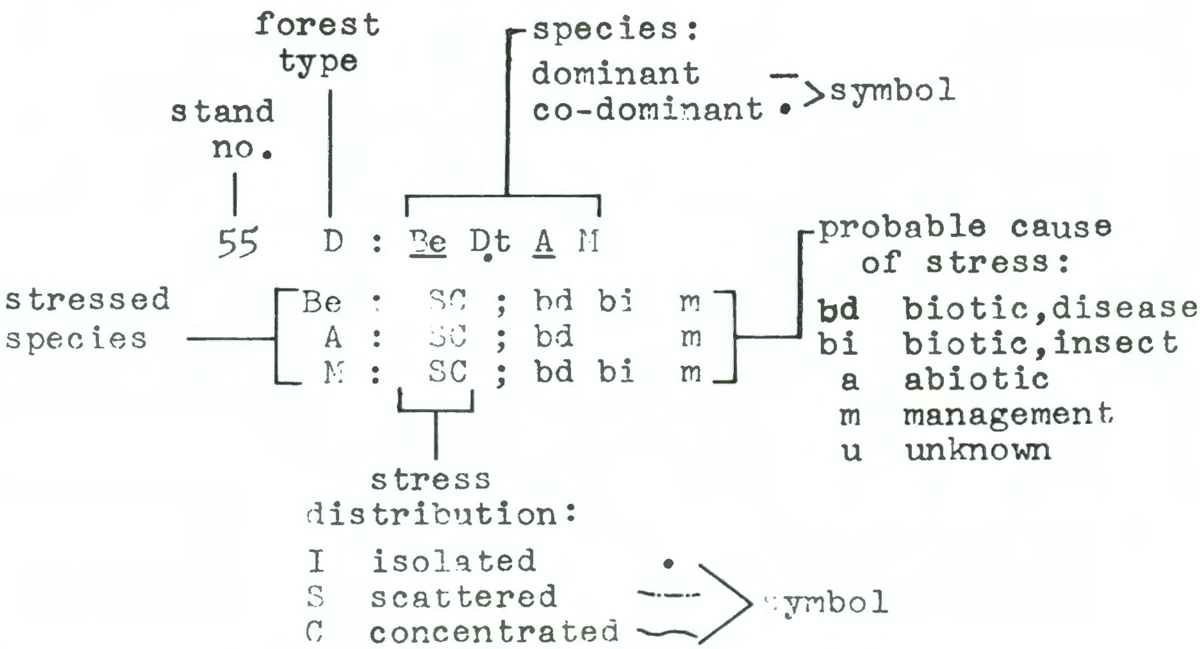


Figure 3 "Natural Vegetation: Stress Conditions" Parameter, showing the amount of information that is obtained by remote sensing techniques.

Source: Mathur, B.S., "Towards Determining the Role of Remote Sensing in Environmental Surveillance of New Highways", Transportation Research Board Annual Meeting, January 1979.

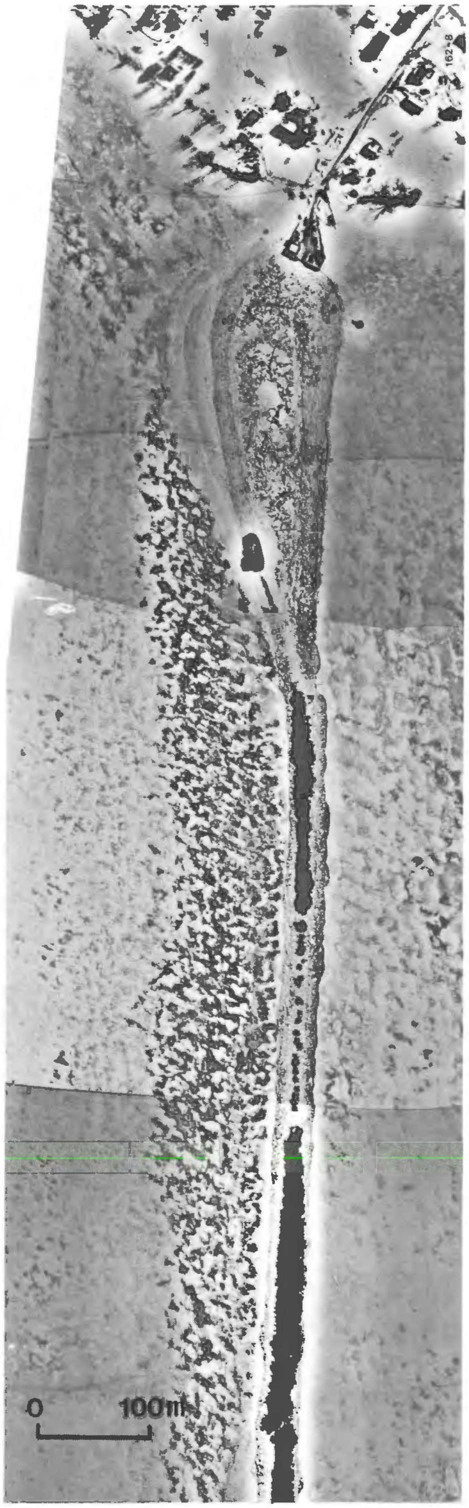


Figure 4 Deicing Bubble System (black and white reproduction)
Colour infrared photography is used to delineate that portion of the channel kept open by the bubble system. Analysis of thermal imagery would provide the surface temperature distribution of the open water.

4. ADVANTAGES OF APPLYING REMOTE SENSING

The advantages derived from applying remote sensing lie in the unique characteristics of the imageries: that they are simultaneously synoptic, permanent and unbiased record of the terrain and contain infinite details. In addition, satellite imageries provide frequent repetitive coverage. With airphotos, a three-dimensional model of the ground is produced when they are viewed stereoscopically. These advantages and others are all well-documented and need not be discussed here further.

That the Ministry recognizes the advantages of remote sensing is borne by the fact that both the products and services have been used extensively in many areas of operation and that appropriate organizational units have been established to provide these services. The reasons can best be summed up as follow:

> "Through the application of remote sensing techniques and analysis, considerable engineering field data can be obtained with an office environment with limited field verification. The gathering of this field data in such a manner results in substantial monetary savings by eliminating the need to undertake ground surveys."[2]

To this end, an internal exercise is being conducted to review and promote the use of remote sensing as a substitute method of obtaining engineering field data.

5. LIMITATIONS AND IMPLEMENTATION PROBLEMS

A more complete perspective on the application of remote sensing will be obtained by considering the limitations and implementation problems, some of which are identified below in terms of

- existing applications,
- new technology,
- people.

5.1 Existing Applications

Remote Sensing imageries used for applications already developed must meet the requirements of the interpreter which are in turn dictated by the user's needs: to detect, identify and evaluate objects or phenomena at an acceptable time frame, level of detail and accuracy. The information has to be provided on time also. It is primarily for the reason of details and accuracy that airphotos are used almost exclusively in applications dealing with highways, airports and waterways at the provincial level. However, in using airphotos, basic problems in terms of scale, season, film emulsion and availability will always be present. The high cost of airborne remote sensing in many cases precludes ideal coverage to be obtained. So far, although compromise and improvisation have proven to be an effective solution, there will always be occasions where remote sensing cannot be used because coverage to meet the minimum requirements is not available.

5.2 New Technology

For an application to become operational, the following conditions must be met:

(a) there must be a need for it,
(b) the appropriate technique can be developed by remote sensing and future service will be provided,
(c) the user is willing to accept the application as a substitute for the existing method.

In developing new applications, existing or new remote sensing technology can be used. Existing technology, considered here to be up to the level of conventional aerial photography, is well developed, readily available and economical. For new technology, the imagery and special instruments for analysis, if required, have to be available. To compete successfully against photography and field methods, it must provide information which otherwise is costly, difficult or impossible to obtain. Since airphotos have been in use longer, it is relatively better known, better researched and documented and new technology must be able to provide unique information to be viable.

Most applications development using new technology involves basic research which can only be provided by national organizations such as the Canada Centre for Remote Sensing. At the level where remote sensing is applied operationally, there is little resource to acquire special imageries and analysis equipment and to conduct research. The most that can be done is to adapt developed technology to the existing operation.

5.3 People

By itself, remote sensing applications and technology does nothing at all; it just sits there. People must apply it and therefore the user and the practitioner must be considered.

A potential user may not be aware of the capabilities and availability of remote sensing techniques. If he does, his attitude will affect ultimately how they are going to be used. There are more and more demands to determine the cost effectiveness of remote sensing techniques, particularly when compared to existing procedures. Often, it is difficult, even in engineering applications, to quantify benefits in absolute terms and this lack can result in a negative attitude. Sometimes it can happen that a technique may be rejected totally if it is not proven to be technically perfect; or that a novel or even well-demonstrated technique may be rejected for no more reason than a lack of familiarity or plain selfish protectionism.

In the case of the practitioner, work priority, personal knowledge, experience and interest in a subject and profit motives may favour certain applications. Thus the full attention may not be available for others.

To summarize, even if the technology is available, the "role of tradition, a parochial outlook, and the feeling that innovations constitute a threat, might form a barrier against the use of remote sensing to its full potential".[3]

6. FUTURE WORK

Based on experience at the Ministry, some suggested work are as follow:

(a) More research should be done on aspects basic to interpreting imagery from some sensors e.g. multispectral photography and thermal imagery. The available knowledge in these areas is scattered and the documentation is inadequate. In some cases, sufficient information is lacking.

(b) Guidelines should be prepared for establishing remote sensing applications to standardize the procedures used.

(c) The capabilities and limitations of remote sensing in each established application should be well documented and the cost effectiveness provided.

7. CONCLUSIONS

Remote sensing, primarily in the form of aerial photography, has widespread use in transportation engineering. In some cases, the use is only rudimentary. In others, it is systematic and intensive and results from remote sensing studies have constituted the basis for decision making. At the Ministry of Transportation and Communications, some of the applications in use were developed in house to meet its particular needs while the others were already well known. Regardless, the objective has been to maximize the efficiency and effectiveness of its operations.

There is always the need to develop new applications but existing technology should be used to the fullest extent. Therefore, effort should concentrate on

- broadening the use of existing techniques and
- developing applications based on new technology.

For the latter, any new application so developed will have to compete against existing methodology, be it remote sensing or otherwise. Moreover, the ignorance, reservation and prejudice of the user may prevent its full acceptance and utilization.

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ABSTRACT

THERMOGRAPHY AND ENERGY CONSERVATION: SOME CURRENT ACTIVITIES IN CANADA

Information on the use of thermography in energy conservation programs has been collected from a selected number of agencies actively working in the field in Canada. The results of this information gathering exercise have been summarized and are presented in a manner that reflects without going into detail, the level of interest and activity in the subject across the country.

Some problems associated with starting or conducting a successful thermography program are reviewed.

THERMOGRAPHY AND ENERGY CONSERVATION:

SOME CURRENT ACTIVITIES IN CANADA

JOHN N. BARRY

PHILIP A. LAPP LIMITED

My presentation this afternoon will be general in nature. What I have attempted to do during the month of January was to put together a picture across Canada of the use of thermography in energy conservation programs.

In putting together this picture, I had in mind tomorrow's discussion session so in my discussions with people working in the field, I not only asked what their current activity and emphasis was, I made a point of noting problems they perceive as either jeopardizing their programs or at least hindering their progress. If I have succeeded in capturing the highlights of the activity across the country and the associated problems, where they exist, I will have achieved my objectives for this talk and we should have a good basis for an exchange of views and some useful discussion in tomorrow's session.

The information for this presentation was acquired through a series of visits and phone calls over the last several weeks. In all, 12 individuals in 12 different agencies were interviewed. Most of these interviews were brief -- in most cases I stated my intention as being able to capture what might be called the 'flavour' of what was being done right now or what is being planned for the immediate future. In many cases individuals I spoke with also volunteered comments on what they considered to be current problems in conducting thermography programs.

Some of those present are probably fairly well acquainted with what is going on across this country because they have been, at one time or another a focal point because of particular expertise or facilities. I ask them to bear with those of us who are so tied up with our own work that we don't have time to take a wider look.

Following the method of the early explorers, I shall cover the country from East to West, beginning with Nova Scotia and ending with British Columbia.

In Nova Scotia, use is being made of both aerial thermography acquired with an airborne line-scanner and thermography from raster-scan mobile equipment. The aerial thermography program operates from the Nova Scotia Research Council in Dartmouth and is based on a data set acquired in 1977. This program proceeds on an as-requested basis with requests for thermograms and analysis occuring at a rate of two to three buildings per month. Most of the requests are for flat-roofed buildings. No general presentation to the public at large has been attempted yet in Nova Scotia and there is no perceived public demand for one.

The services of ground-based mobile thermography equipment are available in Nova Scotia through consulting services but the extent of this activity has not been reported.

A very active thermography program has been underway in Prince Edward Island since 1977. This program is supported by the Enersave Program in the Department of Industry and Commerce in

P.E.I. Mr. Don Gilles of the University of Prince Edward Island is the principal technical expert. He prepares thermograms, does the preliminary analysis and makes the final analysis at the site in the case of a commercial or public institution.

A major presentation to the public at Summerside P.E.I. was made in the winter of 1977-78. This event followed the usual pattern of publicity in advance with invitations to the public to come and view a thermogram of their home. The presentation was very well received and served to heighten interest in thermography in the commercial and institutional sectors.

Since that time, the Enersave Program has supported a systematic survey of most major buildings for which airborne scanner data exists. Mr. Gilles estimates that in the past two years flat-roofed buildings at over 100 sites have been analysed and thermograms of buildings at a number of other sites have been looked at and rejected as not being good enough to warrant further analysis.

The P.E.I. Government purchased a hand-held thermography unit in 1978 to complement the airborne scanner input to their heat-loss analysis program. This instrument is now used on a regular basis to survey private homes and public and private buildings. Through advertising in the local media, citizens are invited to request an on-site thermography analysis if they feel, for example, that a recent up-grading of the insulation in their homes is showing disappointing results. When a request is accepted, thermography is taken at the site and the builder or insulation contractor is invited to view the replay of the video recording at the local Enersave office. This program is just getting underway but already it has proven very popular with the public.

The new scanner is also being used to identify poorly insulated homes. Since it is generally true that a house with a poorly insulated attic is poorly insulated in the walls too, houses or groups of houses exhibiting a warm pattern in the airborne scanner data will be selected for on-site examination. This program is also in an early stage and no significant results are available for this report.

My own company, Philip A. Lapp Limited played a lead role in the first experiments with aerial thermography in Prince Edward Island and Nova Scotia. In the Spring of 1977 we were awarded a contract from CCRS to coordinate the collection of raw data, prepare and analyse thermograms for a number of flat-roofed buildings, assess the reaction of building owners to a thermography analysis of a roof, make recommendations on a format for presenting an analysis to a building owner, and develop expertise in thermogram analysis in Prince Edward Island and Nova Scotia. We were assisted in this research by the Ontario Centre for Remote Sensing, the Nova Scotia Research Foundation, the Department of Industry and Commerce in P.E.I. and Mr. Gilles.

In 1978 we were awarded a second research contract to examine ways and means for interpreting thermograms of roofs with standing water. This project yielded two results. We were able to establish that a frozen ice surface at thermal equilibrium with the rest of a roof blends into a thermogram so as to be virtually indistinguishable from the surrounding dry surface. We learned also that the freezing rates for standing water areas on a roof were highly variable from one location to another because of the differences in volume and depth. With such a variation in these transient cooling rates we concluded that it was impossible to make an unambiguous interpretation of a warm thermal pattern at a standing water spot unless the interpreter could satisfy him or herself that the cooling and freezing process had definitely gone to completion. This problem with thermal transients in water and ice is aggravated by the fact that clear weather is best for collecting aerial data but clear weather causes maximum melting of ice on a flat roof during the day preceding the night-time flight.

The Research and Productivity Council (RPC) of New Brunswick purchased a hand-held scanner in the mid-1970's and has been active in promoting its use as a diagnostic tool ever since. The instrument has been tried in "every conceivable application" including steam trap surveys, insulation surveys, surveys of boiler tubes, and fire detection from a helicopter. A current project has as its goal the inclusion of the scanner in the energy bus program in New Brunswick. The intent is to reach building owners interested in energy conservation and demonstrate the value of thermography in energy conservation. There are no reports as yet on the success of this project.

In the Province of Quebec an ambitious aerial thermography program was begun in 1978. This program was funded by the Provincial Government and called for aerial thermography to be collected and analysed for 10 cities. In the first set of flights data was collected for three cities and a public presentation emphasizing residential housing was carried out in Joliette, Quebec. This presentation was well received. The Provincial Treasury Board has requested a cost-effectiveness study of aerial thermography, and further activity is being held up until this study gets underway. At the present time no time-scale has been set for completion of this study.

The Quebec government has purchased a hand-held thermography unit. This equipment is used on a regular basis from November to April by the Department of Public Works to detect and analyse thermally weak or damaged walls and roofs. According to Mr. Herve Audet, the cost-effectiveness of this system has been proven many times over. In one instance alone, $100,000 worth of roof damage was uncovered and corrected. The success of the program with the ground equipment assures its continued support. In addition there is similar equipment available through commercial service companies in the Montreal area.

The Ontario Centre for Remote Sensing (OCRS) has been active in thermography as a means of detecting heat-loss through roofs for several years now and has a continuing R&D program. OCRS has published reports on experiments to assess the validity of heat-loss interpretation versus attic insulation in individual homes and the validity of interpreting thermograms of flat-roofed buildings for anomalous heat loss due to damaged insulation.

With the Ontario government, OCRS is coordinating a 5-year program to acquire aerial thermography for sixty-eight to eighty Ontario cities and present the results to the public in the conventional type of centralized display of thermograms of residential areas. The city of Lindsay was chosen for the first of these presentations in 1977. The Lindsay experiment was very successful and in the intervening period, four more cities have had public residential programs. The present plan is to acquire data for eight to twelve more cities in the 1980-81 survey season.

The thrust of the Ontario residential program is public awareness of heat-loss through poorly insulated attics. No attempt is being made to quantify results for any individual home, and staff at OCRS would be reluctant to attempt to take interpretation any further than at present, given the current state-of-the-art.

OCRS is completing the acquisition of a complete new Daedalus airborne scanner system including the ground processor. This equipment will be installed in an OCRS aircraft and will be used principally for research and development. OCRS is particularly interested in acquiring aerial data for one or two test sites under a variety of environmental conditions and exploring the possibility of widening the acceptable environmental window that presently restricts data acquisition so severely.

The Canada Centre for Remote Sensing (CCRS) in Ottawa has been a focal point in aerial thermography in Canada for the past several years. CCRS's was the only airborne scanner system available for either experimental or operational programs and as a consequence there was a very heavy peak demand on CCRS facilities for Spring and Fall flying.

In 1978 CCRS undertook a series of workshops in thermal infrared technology as applied to heat-loss analysis. These workshops were aimed at filling gaps in Canada between locations where some expertise was known to exist. Workshops were held in Quebec City, Winnipeg, Edmonton (2 workshops on two different days), and Vancouver (2 workshops on two consecutive days).

As thermography has become more widely used and accepted, CCRS has phased out most of the in-house R and D programs. In addition all flying and processing with the original CCRS Daedalus scanning system is now conducted on a commercial basis by Intertech Remote Sensing Ltd.

The scientific work at CCRS has emphasized aerial thermography and optimum use of the Daedalus scanner system. The people I spoke to at CCRS believe that the current state-of-the art in aerial thermography yields two worthwhile results: reliable, rapid, screening of problem areas in flat roofs over a wide survey area, and identification of problems in the attic systems of individual homes with unheated attics. I use the term attic system because I wish to include in the system the insulation over the top-floor ceiling, the ventilation system and the geometrical shape and aspect of roof with respect to the external environment. The task of assessing the thermogram of an attic that is well ventilated, or to turn it around, the task of interpreting a thermogram of a roof without knowing whether the attic is well ventilated or not, is a risky one and no hard and fast answers are available except for certain limiting environmental conditions such as high wind or no wind. In the limiting cases some assumptions on the part of the interpreter appear to be reasonable.

The Base Maintenance Directorate in the Department of National Defence is completing a thermography survey of roofs and buried steam lines at approximately 32 bases across Canada. Daedalus line-scanner data for these sites has been acquired in a series of daytime and night-time flights conducted over the past several years. Experience has shown that a flat roof can deteriorate quickly due to water penetration of the membrane. Thus a monitoring program on a three to five year cycle is required for effective quality control. Consequently, beginning in 1980 and continuing for approximately 5 years, DND plans to conduct a repeat fly-over of the same bases.

In keeping with this view of possible rapid deterioration of a roof after the membrane has been penetrated, DND has a policy of using acquired data within a year to avoid errors in matching an out-of-date thermogram to the current condition of a roof.

The DND procedure for handling thermography has two steps. When the airborne line-scanner data is acquired it is processed and thermograms are analysed for suspected heat-loss anomalies on roofs and steam-lines. Following this initial analysis, an on-site survey is carried out using a hand-held thermography instrument of which DND currently has six in inventory. This second infrared scan serves as a check on the original interpretation. If water damage in the insulation on a roof is suspected, a cut may be made to confirm the suspected source of the warm pattern on the two thermograms. This two-step thermography approach is judged to be essential for a reliable infrared interpretation.

The wide-area airborne scanner survey serves three functions in the DND program: first, it is a time-saver because the Daedalus scanner output is a speedy pointer to problem areas; second, it provides a quick estimate of the extent of damage on a roof and thus allows a quick determination of how much of a roof can be 'saved', and third, it allows a simple comparison of the thermal performance of the sloped roofs on the individual homes on the base. Although systematic investigation of the single homes in the living quarters on a base is not a high priority item in the survey, the line-scanner data is usually studied briefly to obtain an overall impression of the thermal performance of these houses.

The thrust of the DND program is tied to cost-effective maintenance of roofs on a large scale. Energy conservation comes into the program through the upgrading of thermal performance at the time repairs are made. In the view of DND staff most closely associated with the roof maintenance program, the cost effectiveness of using thermography is best gauged in qualitative terms. Thermography adds a large measure of confidence in the maintenance program because it has no equal as a screening tool; with limited resources the value of a quick reliable screening tool is self-evident.

The Federal Department of Public Works in Ottawa has been an active user of thermography for several years. The projects carried out by DPW have emphasized the use of hand-held scanners operated inside or just outside a building or flown at close range in a helicopter. High-altitude airborne scanner data is taken when there is a wide area to be covered. The high-altitude data is then used for rapid screening. A newly-approved heat-loss surveillance program called Blitz has been given extensive publicity in the local press recently. The objective of the Blitz program is to survey federal public buildings such as post offices, railway stations and airports across the country for anomalous heat loss and recommend corrective action. It is expected that the publicity arising out of such a program will give the technology of thermography increased credibility with the Canadian construction industry. According to DPW staff, interpretive skills have now reached a level that permits a quantitative evaluation of the thermal performance of the interior of a building. This in turn is expected to lead to a much wider acceptance of thermography in evaluating new construction and in monitoring thermal performance of flat roofs.

In Manitoba, the Manitoba Remote Sensing Centre in Winnipeg has embarked on a trial public residential presentation for the city of Brandon. The airborne scanner data has been acquired and the other necessary planning is underway with a view to holding the presentation sometime in the next few months. It is interesting to note that a local utility in Winnipeg turned down a request to support the cost of the flights and of the follow-up presentation to the public in the Greater Winnipeg area because it was felt there would not be enough interest.

The Manitoba Remote Sensing Centre has purchased a hand-held scanner and plans to display it during the 1980-81 heating season in heat-loss analysis of homes.

The principal activity in Alberta thus far has been to collect and present aerial thermography for two large population areas in the province - Vulcan, Alta. and High River, Alta. This project was supported by a public utility - Canadian Western Natural Gas, and involved presentations to the public for several days at a central location. The project was well received and it is expected that more of a similar kind will be carried out. Aerial data has also been collected over two university campuses - Calgary and Edmonton, but no reports are available.

The two thermal infrared workshops that were presented by CCRS in Edmonton in February 1978 were well attended by a cross-section of staff from government and business, indicating a high level of interest in the subject. One might suppose that this interest will manifest itself in solid support for future heat-loss detection projects.

Last on this list, but by no means least, is the thermography program in British Columbia. B.C. Hydro is now well underway in a widely-publicized and well-received program to examine heat loss anomalies in residential, commercial and institution roofs. Mr. William Barchard is in charge of the B.C. Hydro program and supplied some statistics which highlight its principal features.

First of all, in the view of outsiders not directly connected with the B.C. project but in a position to assess it in a wide context, the project is the most successful overall in North America. From the point of view of acceptance, it has consistently received an enthusiastic response from all major sectors to which it is directed - school boards and other public institutions such as hospitals and public buildings, commercial and industrial enterprises, and finally, private citizens interested in the thermal performance of their homes. This enthusiasm shows no signs of abating.

Secondly, the B.C. program is, financially speaking, one of the largest commitments by a public utility to energy conservation. The approved objective of the program is to acquire and present thermography analysis for all major population centres in B.C. There are about 37 such centres. Technically speaking this reduces to acquiring airborne scanner data over approximatley 1800 line miles. To date, about 400 line miles or 22% have been flown successfully.

Third, thermography analysis of anomalous heat loss through residential roofs has been presented to an estimated 165,000 home owners in British Columbia. These contacts have been accomplished through public presentations in shopping malls. The residential program relies principally on night-time thermography with only occasional reference to day-time photography.

Fourth, on the commercial, industrial and institutional side of the program the roofs on over 2000 buildings and building complexes have been analysed and the data presented on an individual basis to the owners. Not unexpectedly, these analysis are much more thorough than the analysis carried out in the residential part of the program. Standard practice is to examine the thermogram, architectural drawings, and daytime air photos taken within 24 hours of the night-time data, and in conjunction with a responsible person from the site, establish a correlation between the thermal pattern of the roof and the relevant architechural features and interior patterns of use. After this basic correlation has been established, the anonalous parts of the thermogram are interpreted and conclusions reached. Mr. Barchard estimates the cost return on flat-roofed buildings alone in terms of $50 million in identified and corrected or correctable roof damage.

Experience in the B.C. program has revealed that among broad classes of flat-roofed buildings examined, schools exhibit the highest incidence of thermally weak or thermally damaged roofs.

The flat-roof portion of the B.C. program is not advertised. Analysis of buildings is carried out in response to specific requests.

Thermogram interpretation in the B.C. program is conducted by in-house staff, trained in-house. To initiate this training program, staff from CCRS conducted two one-day workshops in Vancouver in April 1978. These were attended principally by B.C. Hydro staff.

Mr. Fred Brumbaugh, the General Manager for Intertech in Ottawa, gave me some overall impressions of the current use of aerial thermography to detect heat-loss. First of all, the Daedalus scanner is in heavy demand across the country for the usual work during the heating season. Second, acceptance of aerial thermography is still growing if one is to judge from the number of projects being planned, especially in Ontario and British Columbia. Third, architectural and engineering firms are increasing their use of airborne thermal scanning to investigate energy loss in thermal plumes being discharged into open water. Another unusual request for airborne data has come from the United States. In Montana, a client has requested a preliminary search for geothermal sources. Fourthly, there has been a lot of interest in thermography at the municipal level but thus far no municipality has approved a budget for a major acquisition and presentation project.

That completes my scenario of what is going on at present in Canada. By way of conclusion, I believe there are very successful programs underway in Canada at the present time; they could well serve as models for similar programs in other areas. I wish to spend the remaining time in a brief review of the problems that people I interviewed are experiencing.

Equipment: Availability of the airborne system when environmental conditions are right, and quality control in the processed film output were noted as a serious operational problem in trying to meet project objectives for a particular survey season. The fact that only one scanner and ground processor exists in Canada and there is no back-up frustrates attempts to maintain schedules and forecast cash flow. Three agencies remarked on this problem.

Public Awareness and Acceptance: Publicity and positive response to the use of thermography in energy conservation has reached a very satisfactory level in many cities and provinces but in several other areas of the country the people I spoke with are definitely finding a wait-and-see attitude on the part of those who could either support a project financially of benefit by it, or both. In the view of one person, the experts know all the strong and weak points of thermography but the public at large is, in the main, unaware that it exists as anything but an interesting scientific novelty. An aspect of public acceptance that OCRS has noted is that the smaller the town the more uniform and the more positive is the response. Extrapolated to large cities, this probably means that the program will have to be sold through the media more carefully and with more money.

Public Expectations: There are instances on record where the capability of thermography has been oversold and a very strong backlash has come from an agency that was very disenchanted with the results it bought and paid for. While these events are, fortunately, not numerous, they seem to have a more widespread effect than one would like and the education process must be begun over again. There are also instances where a data set of poor quality was used, with predictable results. One wonders it it might be advantageous for Intertech to restrict the use of poor data until the user is made fully aware of its limitations and its relative quality.

That completes my presentation Mr. Chairman. You, as well as many of those present here will know that I have skipped over many interesting details in in such a quick trip through the current work in the thermography field. I hope that some of the more important details will be brought out in the discussions tomorrow, meanwhile, I will leave the subject for now in the expectation that some of the facts I have brought to light will be a stimulus for a lively session tomorrow.

Thank you.

DRAFT

REMOTE SENSING FOR ENVIRONMENTAL IMPACT ASSESSMENT AND CONSTRUCTION MONITORING

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Abstract

Following a brief introduction to the Federal and Provincial Environmental Impact Assessment procedures, the potential role of satellite and other remotely sensed data for construction monitoring and environmental impact assessment is discussed. The environmental monitoring applications development program at the Canada Centre for Remote Sensing (CCRS) is outlined, and the possible use and benefits offered by remotely sensed data are illustrated by three selected examples of recent major development projects in Canada.

Remote Sensing for Environmental Impact Assessment and Construction Monitoring

1. Introduction

Technological growth and development of the human society increasingly more often implies large-scale modifications of the environment. Such modifications may be intentional and desirable but in many cases are detrimental, particularly when the relationships among environmental components constituting the natural ecosystem are changed in an adverse manner. Since people are an integral component of the ecosystems in which they live, these changes are of keen interest to society.

In Canada, large-scale environmental changes frequently occur as a result of resource development or exploitation. Construction of dams, surface mining, oil sands development, and the building of infrastructures such as highways and pipelines all substantially modify the environment. The realization that a certain level of environmental quality must be maintained to prevent adverse impact upon the society has lead to regulatory mechanisms being implemented by various governmental agencies in Canada. For these mechanisms to be effective, data and information about environmental changes must be provided which have the accuracy, timeliness, and form necessary for making accurate assessments of these changes. Such data and information can be collected in different ways, with individual methods being well suited for acquiring specific variables but not suited for others.

Since remote sensing technology permits acquiring data and information from a distance, it can be applied in cases where the environmental changes of interest modify the electromagnetic spectrum, i.e. the interaction of electromagnetic radiation with the environment is modified when these changes are present. Where this condition is satisfied, remote sensing offers the unique advantage of large area coverage in short time periods and frequent revisits over the same area. Since remote sensing technology encompasses a broad range of the electromagnetic spectrum and platforms from low altitude aircraft to satellites, the possibilities it offers to monitoring environmental changes are numerous. This has been sucessfully demonstrated by individuals concerned with environmental changes who employed remote sensing techniques in various projects.

As both environmental changes and remote sensing technology represent a range of possibilities, individual environmental variables are more effectively characterized by some techniques than by others. Thus, given the problem of environmental change monitoring, a variety of remote sensing and other methods integrated in an optimum manner will constitute the most effective procedure. The objective of Canada Centre for Remote Sensing (CCRS) efforts in environmental monitoring is to develop the remote sensing component of such procedures and, in particular, to develop, document, and assist in transferring to user agencies methodologies for analyzing and applying satellite data. The approach adopted in this development is briefly described in subsequent sections.

2. Information Needs in Construction Monitoring and Environmental Impact Assessment

The Federal Environmental Assessment and Review Process (FEARP), established by Cabinet decision on December 20, 1973, provides the mechanism for determining the potential environmental impact of all federal* projects, programs and activities before they begin. The procedure is schematically outlined in Figure 1. Each project is subjected to a screening process by the initiating department as early as possible in the planning stage. Results of the screening lead to one of three decisions. If the project is judged to have no significant adverse environmental effects it may proceed with mitigating measures as required. If the environmental effects appear significant, the project is referred to the Federal Government's Minister of the Environment for a formal review. In cases where the environmental effects cannot be determined, the project is examined in further detail through a procedure called the Initial Environment Evaluation (IEE).

The IEE may be considered as the second stage of the self-assessment (screening) process. Once the IEE has been carried out and reviewed by the department concerned, the project may proceed if an absence of significant environmental effects is indicated, but all environmental design measures specified in the IEE must be implemented. Should the IEE indicate that adverse environmental effects may be expected, the project is again referred for formal review.

The Federal Environmental Assessment and Review Office (FEARO) is responsible for carrying out the formal review for all projects which have been referred to the Minister of the Environment. The review consists of the formation of an Environmental Assessment Panel, formulation of guidelines for and the preparation of an Environmental Impact Statement (EIS), technical and scientific reviews of the EIS by federal and/or provincial agencies, and extensive public information programs and reviews.

The Environmental Assessment Panel reports its conclusions to the federal Minister of the Environment who, together with the Minister of the initiating department and their Cabinet colleagues, is responsible for the final decision concerning the project. More detailed information on the assessment process is given by FEARP (1976, 1978, 1979).

During the last decade each province has, separately from the federal process, established a framework in which environmental impact assessments may be undertaken. This framework is based on legislation in most cases, but in Nova Scotia, Quebec and Alberta environmental assessments are undertaken as a matter of ministerial policy. In general, the provincial approaches suffer from a lack of definition (Mitchell and Turkheim, 1977). Major questions (such as when should the assessment be undertaken, what projects should be assessed, and what should be the contents of the assessment) are not adequately resolved in the provincial mechanisms. A consequence of this lack of cohesive base is that detailed comparisons between similar projects within a province, or within the entire country, are difficult to make.

*Federal projects are considered to be those initiated by federal departments and agencies, those for which federal funds are solicited, and those involving federal property.

As a result of the federal and provincial regulatory procedures, the majority of new engineering projects in Canada now require some form of environmental impact assessment and the initiator, whether a public agency or a private developer, is responsible for acquiring the data and preparing the impact statement. Since environmental impact assessments are time-consuming and costly processes, any means of reducing the time spent in their preparation-without appreciable loss of information quality - can be expected to both reduce the manpower required and shorten lead-times to project execution of rejection. Traditionally, data-acquisition for the establishment of baseline conditions relied on an often outdated and imcomplete literature search and on partial or full coverage of the project area by field survey teams. In recent years, utilization of existing aerial imagery and occasionally new aerial image acquisition have become more widespread. Remote sensing technology now offers a potential for optimising data collection through a procedure called Multi-Stage Sampling. Using this procedure, a general study of the project area is made using inexpensive satellite imagery, and the requirement for second-level data acquisition (e.g., airborne sensing at various altitudes) can be more profitably specified. The final level of sampling, ground data acquisition, may then be optimised by selecting suitable sites using the previously acquired remotely sensed data. Colwell (1971) and Arno (1979) have shown that this approach is far more cost-efficient than more traditional methods of data acquisition because fewer ground sampling sites are required. Joyce (1978) reported that for classification of ten major land cover types on one LANDSAT scene, less than one-thousandth of the terrain under investigation would require ground verification sampling if the sites were previously designated using LANDSAT and aerial imagery.

The monitoring of engineering projects is of interest to the developer as well as to federal or provincial agencies concerned with land use and environmental quality. The developer requires information on construction progress and on the environmental effects of his operation, in order to meet standards laid-down for air and water pollutants and solid waste disposal. On the other hand, public agencies need to monitor the impact of construction and operation on river and air quality, fisheries, wildlife, forestry or agriculture. Remote sensing techniques have a considerable economic advantage over more traditional methods of data acquisition for the monitoring of construction and construction impact. The periodic coverage of the project area by satellite sensors allows inexpensive and regular surveillance at a regional scale, while more detailed data can be acquired from specifically designed airborne missions.

Acquisition of aerial photography for land classification, evaluation of terrain, site and route location, and construction and impact monitoring is now routinely performed by many public agencies and private industries (Youngerman et al, 1978; Dai, 1978; Marmelstein, 1978; Berger et al, 1978; Stafford et al, 1976, etc.), and does not therefore justify extensive developmental effort. However, satellite imagery is a relatively recent tool, the potential applications of which are often not adequately appreciated. The following section therefore documents the advantages and constraints of LANDSAT data as applied to engineering-related problems, and briefly reviews some applications of these data to environmental impact assessment and construction monitoring.

3. Engineering Applications for LANDSAT Data

3.1 Advantages and Constraints

The spatial resolution of LANDSAT Multispectral Scanner (MSS) data (approximately 80 meters) is the major constraint for using these data as it restricts the level of surface detail imaged. However, for large areas, LANDSAT offers a unique opportunity to provide inexpensive and comprehensive data during the reconnaissance and project planning stages. This type of information is usually more useful than a mosaic of airphoto scenes because a single LANDSAT scene is essentially orthographic, is imaged under constant atmospheric conditions, and does not suffer from variations in photographic processing. The Return Beam Vidicon (RBV) data of LANDSAT 3 have improved resolution of 40 meters, but the infrequent RBV coverage has severely reduced its usefulness. A further constraint of LANDSAT data is their inability to present 3-dimensional information.

The spectral resolution of LANDSAT MSS data (four bands between 0.5 and 1.1μm) extends further into the infrared region than panchromatic or colour infrared aerial film (0.4 - 0.9μm). The major advantage however, is that the four discrete LANDSAT wavelength bands can supply multi-dimensional spectral signatures of land-cover types to aid in image interpretation. Alternatively, false colour composites can be prepared for any scene using three appropriate bands.

The temporal resolution of LANDSAT is possibly the major advantage over airborne sensing. LANDSAT's 1 and 2 are no longer operational, but LANDSAT 3 continues to scan the same 185km.square parcel of earth's surface at the same local time every 18 days. More frequent coverage in northern latitudes is available due to image side-lap. Atmospheric conditions - particularly cloud cover - inhibit the amount of information available, but even in areas of very high cloud frequency annual monitoring at a synoptic scale is now practical. Seasonal and historical changes in land-use/land-cover can also be identified.

The geometry of raw LANDSAT data suffers from skew because of the motion of the spacecraft during the scan of the sensor. However, geometric correction procedures are now generally available (Butlin et al, 1978), and LANDSAT scenes can be registered to 1:50,000 NTS maps with an accuracy of 50 meters or better.

The cost of LANDSAT data is substantially less than that of new airborne sensed data. Dey et al (1978) estimated the cost of new airborne sensing to be between 5x and 50x the cost of LANDSAT digital data acquisition and interpretation. LANDSAT data acquisition and interpretation costs for an area of 34,000km^2 have been estimated at \$0.6/km^2 (Joyce, 1978), and between \$0.2 and \$1/km^2 (Dey et al, 1978).

3.2 Selected Examples of LANDSAT Applications to Engineering Projects

At the reconnaissance and planning stages of various engineering projects, managers and designers are beginning to recognize the benefits of inexpensive and recent synoptic images of the project area in the context of regional influences (cultural, topographic, climatic and hydrologic). The U.S.

Army Corps of Engineers investigated the roles of orbital sensors and high and low altitude airborne sensors for identifying and evaluating regional and local geologic features for the design of dams, nuclear power plants, underground installation, highways and railroads (Gelnett, 1978). It was concluded that remote sensing itself should not be considered as the final and definitive answer to geological exploration and related problems, but that the use of appropriate sensors and proper interpretation can reveal important geologic features that may not be identified in any other way. They also concluded that proper utilisation of remote sensing methods provided a significant economic advantage, particularly for concentrating ground data acquisition work. Barr and James (1975) reported that orbital sensors such as LANDSAT are useful for providing a good synoptic base from which potential transportation corridors can be evaluated. Beaumont and Beavers (1978) found that LANDSAT photographic products were well suited to studies involving decisions on highway route location in remote and poorly documented areas. Haefner et al (1978) interpreted the hydrographic network, watersheds, and various areas of homogenous landform units in the Yemen Arab Republic from LANDSAT colour composite images, and reported that the maps generated provided good basic information for forthcoming agricultural inventories and planning programs. Land classification maps from LANDSAT photographic products for the siting of Port Labrador were derived by Lapoukhine and Hiroven (1978). At the Land Region, and Land District levels, the maps were comparable with maps derived from aerial photographs and fieldwork. The U.S. Federal Power Commission compared LANDSAT, Skylab and U2 imagery in the assessment of land-use for a proposed power corridor (Anderson and Gumbmann, 1975), and found LANDSAT to be the best data source for classifying land-use and vegetation mapping at Level 1 (Land Region) classification, and computer enhancement of the data also gave some Level II (Land District) information. LANDSAT has been recommended for use in the siting of facilities sensitive to geologic stress such as dams, nuclear power plants, refineries and other industrial facilities. Macro-tectonic lineaments and regional fault patterns are often identifiable on LANDSAT, and when combined with data from airborne and ground surveys, engineering geological maps can be more efficiently produced (Moon et al, 1977, McKim et al, 1978, and Rengers, 1979). As an extreme example of the potential savings realisable from studying LANDSAT imagery at the planning phase of engineering projects, an $8,000,000 intake for drinking water was poorly located in turbid waters of Lake Superior. Even superficial examination of LANDSAT imagery prior to construction would have illustrated the high turbidity of the area of water chosen for the intake (Scherz and Van Domelen, 1973). The remotely sensed imagery was however found useful in the subsequent lawsuit.

Following the engineering selection of a suitable site or route location, an environmental evaluation of the effects of construction and operation is often required. In order to measure or predict change, baseline information describing the natural conditions of the environment is necessary. In most areas of Canada, the type of baseline information required does not exist (Thie and Wachmann, 1974), and acquisition of these data by traditional methods (aerial photography and field survey work) is both time consuming and expensive. LANDSAT has been found useful in many land classification studies, and significant savings in both time and money have resulted with little reported loss of accuracy. Hathout et al (1978) compiled a land use/land cover map of the province of Manitoba from 56 LANDSAT colour composite images and concluded that the advantages of economy and recent imagery made LANDSAT the best data-source available for mapping at 1:1,000,000 scale. Prout (1978), using machine processed LANDSAT digital data, was able to classify seven land cover classes of a coastal zone each with an accuracy of at least 80%. Rubec (1978) used an unsupervised computer classification technique to classify land cover/land use in Manitoba, and found good correlation between the LANDSAT and airphoto maps for wooded cover (95-106%), agriculture and crop-land (83-84%) and water (90-100%). This approach was not found sufficiently accurate for the identification of urban areas, bare ground and rangeland. Schubert (1978) applied visual interpretation, interactive classification, and automatic classification procedures to Canada Land Inventory land-use mapping, and concluded that visual interpretation of simulated colour infrared images generated by computer provided the best information on land-use from LANDSAT data.

At the development stage of an engineering project, more detailed data are almost always required. Airborne remote sensing is often used at scales of 1:100,000 to 1:20,000 for terrain analysis, to locate and evaluate construction materials, and for feasibility studies. However, there is also a need for more general information, some of which can be supplied by LANDSAT. The high coverage frequency of LANDSAT is useful for identifying historical and seasonal changes in drainage patterns (Welch, 1976; Beaumont and Beavers, 1978), snow cover and snow-melt (Miller and Belon, 1974; Wiesnet, 1979) and in distribution of icings (Sloane et al, 1976). In permafrost areas, forest fires remove vegetation and increase the active layer. When the ice-rich surface permafrost melts, flow-slide development and other erosion is triggered (McQuillan, 1975). Many studies have shown LANDSAT to be well-suited to identifying and mapping burned areas and areas susceptible to forest fires (Zsilinsky, 1974; Laframboise, 1975, 1976; and Harrington, 1979 amongst others). When combined with soils and slope information, LANDSAT - derived land cover data can be used to evaluate the erosion potential of an area (Joyce, 1979; and Cihlar, 1979). LANDSAT derived data have been used to aid the siting of sewage outfalls. By mapping the distribution of Fraser River sediment over a wide area of the Georgia Strait using LANDSAT and airborne imagery at various tide conditions, Gower (1973) was able to illustrate surface currents and thus infer effluent dispersion patterns.

During the construction, operation and abandonment stages of a major engineering project, the main information requirements are for change phenomena. During construction, periodic coverage is useful for determining and evaluating construction progress, and may act as the basis for detecting unforeseen stressed conditions. Upon completion, imagery of the project area acts as a record of "as-built" conditions, and further monitoring (say on an annual basis) will aid in the detection and evaluation of environmental sensitivities. Such imagery will act as a valuable record should litigation occur (Kurtz and Jarman, 1977).

The repetitive cycle of LANDSAT makes it well suited to the detection of changes, though the low spatial resolution limits the extent of change that is identifiable. At small scales (1:250,000 or less), LANDSAT is capable of monitoring forest clearcutting and reservoir areas (e.g., Figures 5 and 6). Magnification of LANDSAT digital data, in which each pixel is repeated two, four or more times, can enable small changes in areas less than 400 hectares to be identified and evaluated (e.g., Figure 4). Rubec and Thie (1978) evaluated LANDSAT digital data for monitoring land-use change in a 500km^2 test area in rural Manitoba and concluded that automated interpretation of LANDSAT spectral data currently provides sufficiently reliable classification for certain land-use classes to permit operational and accurate land-use monitoring at a detailed scale of 1:50,000. During the construction and operation of large hydro-electric developments, LANDSAT digital data have been used to monitor water volume (NASA, 1977; Laframboise, 1979), and water quality - as sediment and organic material in suspension, and peat-bogs and other floating debris (Laframboise, 1979). Berger et al (1979) used LANDSAT digital data to update dam inventories in New York State, and to assess the hazard class as a function of downstream land use. LANDSAT data has also found wide use for inventorying and monitoring strip mine operations. Solomon et al (1979) developed a classification system based on ratioed LANDSAT bands which was capable of discriminating seven major land cover classes and three sub-classes related to mining activity (rough spoil, smoothed spoil, partially revegetated areas). Examination of aerial imagery indicated that all recent mining activity had been identified, but the classifier was unable to discriminate the cover condition of older, or narrow contour mines. The cost of the classification was estimated at 0.0927¢/acre, compared to a cost of 17¢/acre for aerial data. Moore et al (1977) reported on an inventory of mining wastes in Canada undertaken from visual interpretation of LANDSAT colour composite photographic products. The minimum detectable area of mine waste was stated to be 1 hectare. Four classes of waste were identified (overburden, tailings, waste rock and slag) together with two classes of water, two classes of vegetation cover, and two classes of mining facilities. They concluded that given satisfactory baseline conditions, subsequent inventories and monitoring of mine wastes can be satisfactorily undertaken using visually interpretated LANDSAT imagery alone.

4. The CCRS Construction Monitoring Program

The foregoing review of LANDSAT applications to engineering related problems illustrates some of the possibilities and problems of using LANDSAT data for land cover classification and monitoring. In particular, the low spatial resolution creates problems of identification of small features.

How large must a feature be before it is identifiable from LANDSAT? How different must the feature be from its background? Such questions are not easily resolved as they depend upon the type of feature, its location, and upon the interpreter's supplementary knowledge. Also, only limited experience exists in using LANDSAT data for this type of work. In order to more fully explore the role of LANDSAT in engineering studies, the Applications Division of the Canada Centre for Remote Sensing began in 1979 an examination of the roles of current and future satellites for the assessment of environmental impact, and for the monitoring of major construction projects. This program has as its main objectives:

(i) to review and document information needs for environmental impact and post-construction monitoring;

(ii) to develop, verify and document methods for using remote sensing data to provide information on items selected from objective (i), with special emphasis on the roles of current and future satellites for monitoring dams, port construction and highways.

This work is to be based upon analysis of three recent major construction projects in Canada. Two of these demonstration projects - the Wreck Cove

Hydro Electric project and the Dempster Highway have recently been completed, while the third - the Roberts Bank Port Expansion Proposal - has recently been the subject of a FEARO review. Each of these projects has been chosen to illustrate one or more of the potential roles of remotely-sensed data for the assessment of environmental impact and the monitoring of construction projects with emphasis on satellite-sensed data.

4.1 Roberts Bank Port Expansion Proposal

A proposal to substantially enlarge the Roberts Bank Port, situated close to the southern arm of the Fraser River Estuary near Vancouver, British Columbia, was submitted to FEARO in May 1975. In March 1979 the Environmental Assessment Panel recommended to the Minister of the Environment that full-scale expansion of the Port should not be permitted on the basis of unacceptable impacts on the estuarine ecology, and the potential for adverse social impacts (FEARO 1979). The Panel's recommendations were endorsed by the Minister. The proponent, the Port of Vancouver, is currently undertaking further work with respect to an acceptable environmental design for a reduced development.

Estuaries are very important ecologically (Odum, 1971). As habitat classes, estuaries rank along with tropical rain forests and coral reefs as having the highest gross primary productivity of any of the major ecosystems of the biosphere, and characteristically they tend to be more productive than either the sea on one side, or the freshwater drainage on the other. However, estuarine environments are very vulnerable to damage by pollution, dredging, diking, filling and other man-made alterations. The rich biota of these environments depend upon a highly integrated food-chain, the disruption of one link of which can have severe cummulative effects on other organisms higher up the food chain.

The resources of the Fraser River estuary are substantial (Fox and Nowlan, 1978). The fishery resource is of tremendous value, the salmon harvested there constituting the backbone of the commercial fishing industry in Southern British Columbia. Large quantities of herring are also harvested each year. A variety of industries (forest products, chemical, mineral and fish processing) are established along the estuary, and the water is used extensively for transportation, as a source of industrial water supply, and as a receptacle for effluent. Most of the sewage effluent from the Greater Vancouver Region is discharged to the estuary.

While the conflicting interests of economic development and natural resource maintenance can be resolved by proper management, constraints must be placed upon the type and extent of development allowed. In order to sensibly set such constraints, a great deal of information is required, both baseline data to which future changes may be compared and dynamic information concerning the impacts of man-induced change.

During the environmental assessment of the Roberts Bank Port expansion proposal, the Panel became concerned about the possible impact the proposed development would have on a major eelgrass meadow situated in the intertidal area between the existing Port and the Tsawwassen Ferry Terminal. This eelgrass meadow has major ecological significance as it is used as a spawning ground by herring and a rearing ground by juvenile salmonids (Beak, 1977). Construction of the Port in the late 1960's had resulted in a loss of a portion of the eelgrass, but some doubt was expressed regarding the long-term impact of the Port on the eelgrass meadow. Two opposing viewpoints offered during the environmental impact assessment were that:

- the overall area of eelgrass had diminished since port construction due to erosion from dredging, increased currents in dredged areas, and ship movements;

- the overall area had increased due to the protection offered by the port causeway from tidal erosion.

No historical data from which the annual distribution of the eelgrass meadow could be determined was available at the time of the environmental assessment, and the Panel therefore judged that the risk of damage to the eelgrass meadow was too great to allow full expansion of the Port.

LANDSAT imagery of this area was not used at any stage of the environmental assessment procedure.

This project has been chosen as a demonstration project to illustrate the potential of existing and future satellites for:

(i) classifying estuarial environments;

(ii) mapping areal distribution of ecologically sensitive vegetation, such as the eelgrass meadow; and for

(iii) monitoring the impact of port construction on estuarial environments.

Although the work has only recently begun, promising results have been obtained. LANDSAT imagery of various summer scenes since 1972 (when LANDSAT 1 was first launched) are being analysed both digitally and by analogue methods. Although many constraints affect the suitability of individual scenes (summer season is required for peak biomass, low cloud cover and low-tide-conditions are necessary for eelgrass recognition), one or more summer images have been found for each year since 1973 in which the eelgrass meadow is visible. Each scene is photographically or digitally enlarged to display the distribution of the meadow. Figure 2 shows a typical band 6 image of the full scene, while Figures 3 and 4 illustrate analogue and digital enlargements of the same scene from which the eelgrass distribution is being mapped. Note that Figure 4 is geometrically distorted because the effective LANDSAT pixel size (57m horizontal x 79m vertical) created by overlap of the instantaneous-field-of-view recorded by the sensor is not compensated for on the Image Analysis System TV monitor. The overlap is necessary to reduce the signal to noise ratio and to avoid any gaps in the data.

Digital enhancement of the raw data is undertaken in an attempt to map the biomass density across the eelgrass meadow. The Department of Fisheries (Pacific Region) considers eelgrass density to be of major importance to fish spawning and rearing (Levings, 1979). Rouse et al (1973) developed a Vegetation Index for estimating biomass density in which the difference of LANDSAT bands 7 and 5 divided by the sum of the same bands was found to correlate with rangeland vegetation biomass. Bartlett and Klemas (1979) found that a ratio of LANDSAT bands 7 and 5 correlated with green biomass of S. alterniflora (salt marsh cord grass) with a coefficient of 0.90.

These and other band combinations are being assessed for their potential for estimating eelgrass biomass.

The potential of future high resolution satellites (such as LANDSAT-D to be launched late-1981 and SPOT, scheduled for launch in 1984) for the classification and monitoring of estuarial resources will also be evaluated. Airborne MSS imagery of the Roberts Bank area will be flown at two altitudes in the summer of 1980, and the data will be processed to simulate the ground resolutions and spectral bands of the sensors designed to be on board these two satellites. A field survey of the project area will be undertaken simultaneously with the aerial overflight to provide ground verification information for the remotely-sensed data.

4.2 Wreck Cove Hydro Electric Project

Wreck Cove is a hydro electric project located in the highlands plateau of Cape Breton Island on land adjacent to Cape Breton Highlands National Park. Four major impoundments have been created by the construction of 19 dykes and dams, and the diversion of a portion of head water flows from seven rivers (see Figures 5 and 6).

A proposal for this project was submitted to FEARO for Panel Review in March 1975 because of potential adverse effects on the national park. In 1977, the Panel submitted their report to the Minister of the Environment in which the major recommendation was that the Cheticamp spillway and dam be so constructed that no innundation of Park Lands occurs (FEARO, 1977). The Minister endorsed the Panel's recommendations.

This recent and major hydro electric project offers an opportunity to assess land use and land cover changes using LANDSAT derived information throughout the course of the project and subsequently to monitor the impact of the project on surrounding flora and fauna, and to monitor the rehabilitation of (temporarily) disturbed land.

LANDSAT imagery of the project area will be analysed to identify and locate such features as water bodies, vegetation stands, wetlands, and disturbed land, and to monitor the changes of reservoir surface area, vegetation and rehabilitation. In addition, the potential role of future high resolution satellites will be evaluated by simulating the design ground resolution and spectral bandwidths of the satellite sensors using airborne Multi-Spectral Scanner (MSS) data.

A major aspect of the analysis procedure is the evaluation of both analogue and digital products. Digital methods of analysis normally provide considerably more detail than analogue analysis, but access to necessary hardware is limited. Costs for digital analysis can also become significant. Analogue LANDSAT products, which are inexpensive and readily available, will therefore be evaluated for their information content with respect to large area construction monitoring.

An example of the potential of LANDSAT data for monitoring reservoir construction is given in Figure 4. Clear-cut areas designated for the new impoundments are clearly visible on this summer 1977 image. Also clearly distinguishable are access roads to the Wreck Cove project area and to areas of clear-cutting. Figure 5 shows the same area one year later, after the impoundments have been filled. Even at this small scale, major dams are identifiable (see arrows) as are borrow areas and differences in water turbidity. An acetate overlay on which the boundary of the national park has been drawn may be placed over this geographically corrected (DICS) product to show that no innundation of park-lands has taken place.

4.3 The Dempster Highway Corridor

The Dempster Highway, completed in 1979, was begun in 1958 and as such did not become subject to the FEARO procedure. After several years of inactivity (1962-1969) the project recommended, and between 1969 and 1979 construction of the 721km two-land highway between Dawson in the Yukon Territory and Inuvik (NWT) proceeded at a fairly constant rate (Wright, 1979).

CCRS is cooperating with the Department of Natural Resources, Government of Yukon, to provide LANDSAT-derived maps of areas encompassing the highway route. Topographical maps of much of this area are available only at small scale (1:250,000) and with a limited surficial detail. Existing aerial photography of the highway route is available in several formats and scales, but only for a very narrow strip (less than 4 miles) on either side of the highway. For several years, ground survey teams have been collecting data on soils and vegetation associations in the area of the corridor; however, only a relatively small portion of the corridor has to-date been so mapped.

LANDSAT digitally processed data are being evaluated for their potential to provide inexpensive baseline vegetation data. Panchromatic single-band products at a scale of 1:50,000 are being produced from geographically corrected DICS tapes (Butlin et al, 1978) on a Versatec plotter. Other products being evaluated include Return Beam Vidicon (RBV) data, single band photographic enlargements, and colour composite photographic products produced from enhanced MSS data of 3 bands. Enhancements currently being evaluated include intensity-stretching to improve contrast and interpretation accuracy. The interpretation potential of band rationing and band combinations to retain multi-band information on the single channel Versatac plots will be investigated at a later stage.

Interpretation accuracy will be assessed by comparison over areas for which recent aerial photography is available and/or in which recent field investigations have been undertaken. These data will also be used as training samples in the classification process.

Pre-construction imagery of sample areas along the highway corridor will be analysed in order to evaluate the potential of existing LANDSAT imagery for assessing the impact of highway construction.

5. Summary and Conclusions

During the last decade, federal and provincial regulatory procedures have been established to determine, in advance, the potential environmental impact of all major engineering developments in Canada. The requirement for environmental impact assessments has resulted in a need for copious environmental data, the provision of which imposes a heavy financial burden on the initiator of the project. Proper use of remotely sensed data can significantly reduce the costs of generating the environmental data without appreciable loss of information quality. A multi-stage data acquisition program is recommended, in which satellite and aerial imagery are used to optimize the location and number of ground sampling sites. Satellite-sensed data is furthermore useful for environmental and construction monitoring due to the frequent coverage of the same area of the earth's surface.

At this point in time, few conclusions can be made regarding the three "construction-monitoring" demonstration projects being undertaken at the Canada Centre for Remote Sensing. Much of the work has so far centred on the Roberts Bank Port Expansion proposal, and it has been determined that the eelgrass meadow situated between the Port causeway and the Tsawwassen ferry terminal can be identified, located and measured from either analogue or digital analysis of LANDSAT data. Historical LANDSAT data will also enable the annual distribution of the eelgrass to be monitored between the years 1973 and 1979. The relative accuracies of the two analysis techniques have not yet been evaluated; nor has the ability of LANDSAT to distinguish between eelgrass and other vegetation in the intercauseway area.

At the Wreck Cove hydro electric development, preliminary visual analysis of LANDSAT imagery has shown that the construction progress of major developments in which extensive changes of land cover occur may be monitored with LANDSAT data. New access roads, borrow areas and dams are identifiable on analogue products and the monitoring of reservoir innundation presents no difficulties. Variations in water turbidity are observable on colour composite images at scales as small as 1:250,000.

Preliminary work undertaken on the Dempster highway corridor study shows that NTS-compatible maps can be conveniently produced from LANDSAT digital data. Once interpreted, using colour composite LANDSAT imagery together with aerial and ground data, these maps will provide inexpensive baseline vegetation data for the corridor route.

6. Future Work

Investigations of the potential of LANDSAT data for supplying environmental and engineering related information will continue for each of the three demonstration projects until mid-1981. The roles of future high-resolution satellites will be assessed from analysis of airborne MSS data to be collected during the summer of 1980. The advantages and limitations of analogue and digital interpretation techniques will be evaluated and documented.

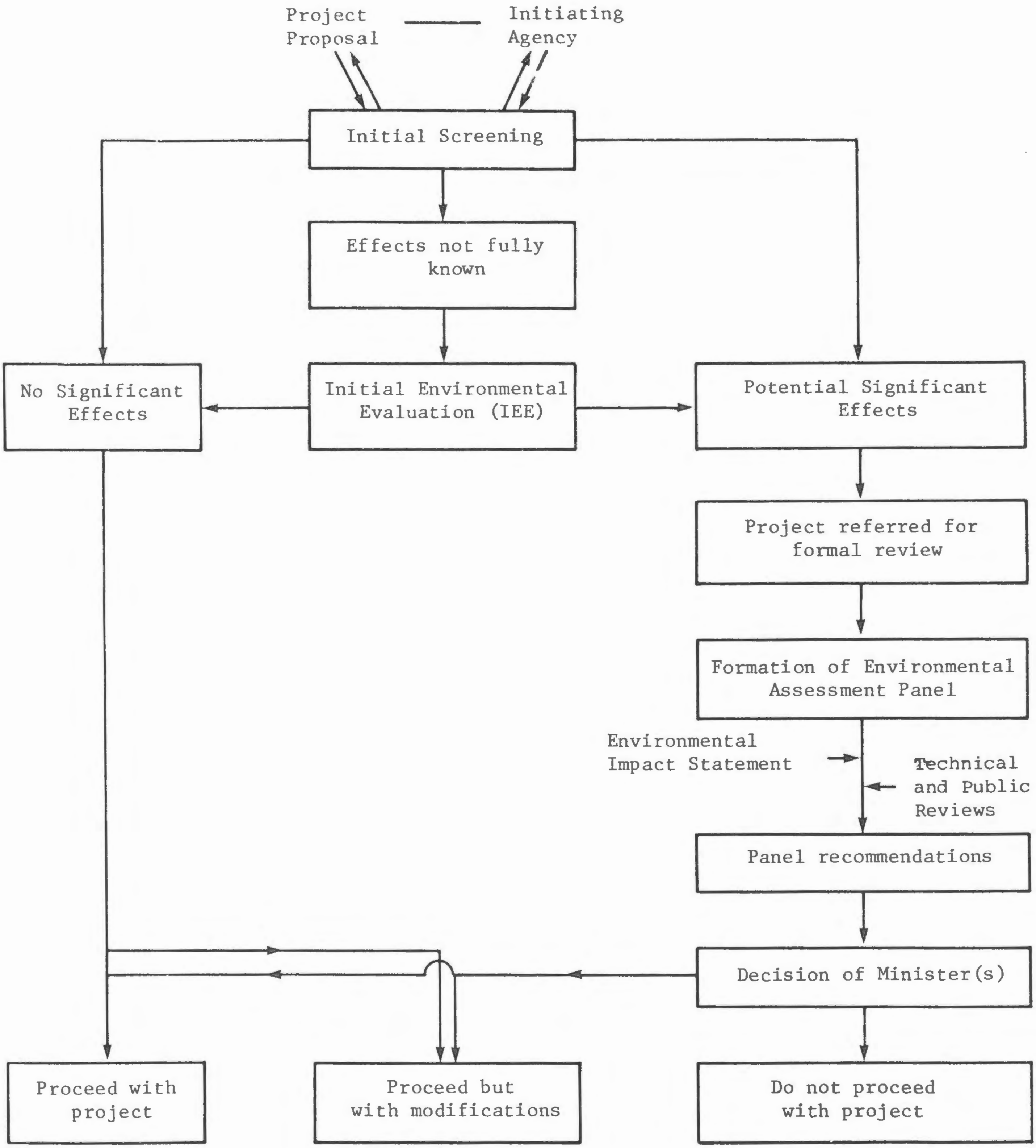

Figure 1 Environmental Assessment and Review Process.

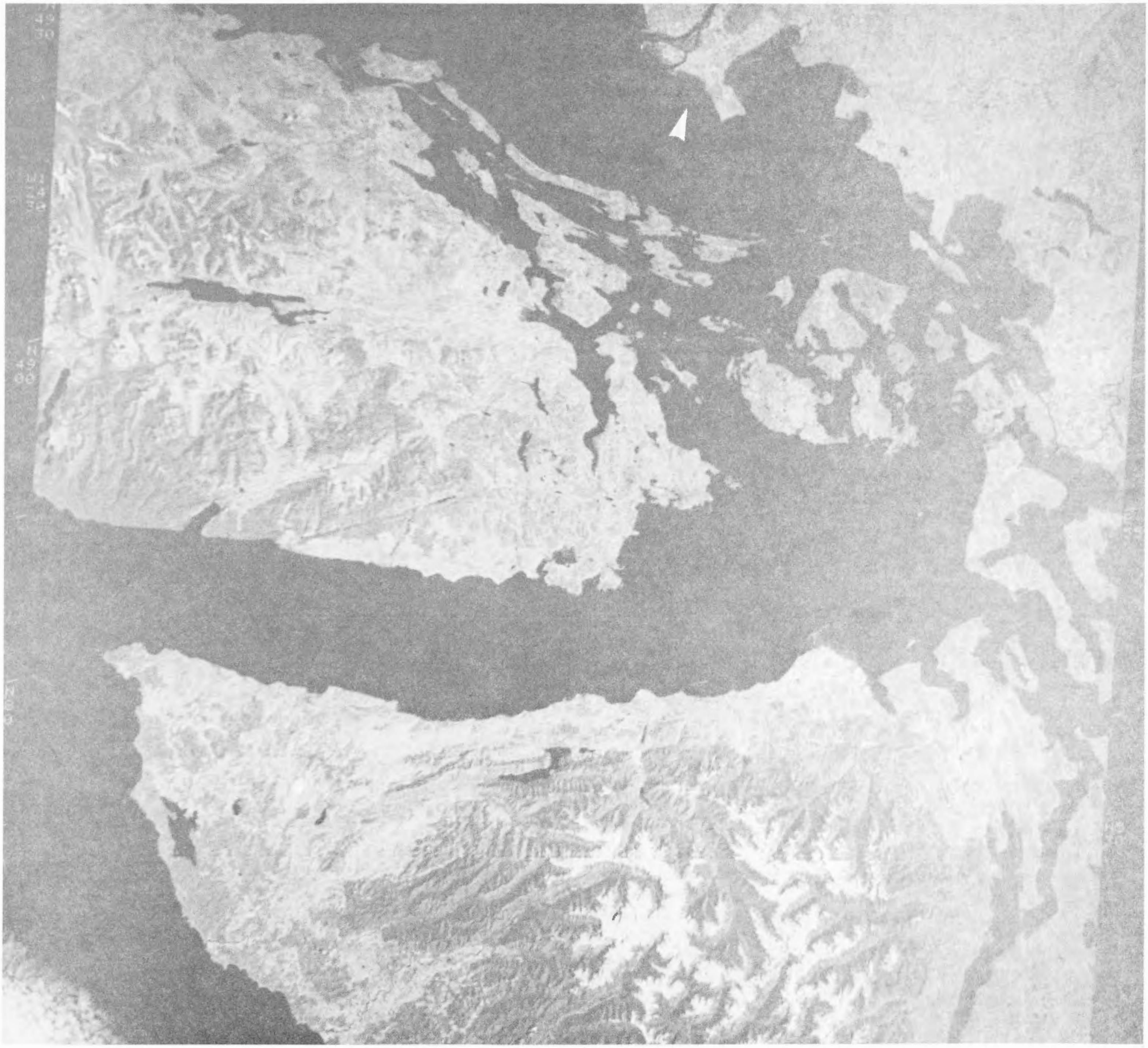

Figure 2 - Victoria and Strait of Georgia, July 20, 1974.
LANDSAT E-1727-182906, PC 51-26, Band 6. Area approximately 185km x 185km.

Figure 3 - Vegetation on Roberts Bank.
Analogue enlargement of area indicated in Figure 2 produced on CCRS Photographic Analysis System, Band 6. Area approximately 8km x 5½km.

Figure 4 - Vegetation on Roberts Bank.
Digital enlargement of area indicated in Figure 2 produced on CCRS Image Analysis System. Image geometry is not corrected in this product (see text). Composite of LANDSAT Bands 4, 5 and 6. Area approximately 8km x 8km.

Figure 5 - Cape Breton Island, Wreck Cove Area, August 10, 1977.
LANDSAT 20931-13502, PC 7-27, composite of LANDSAT Bands 4, 5 and 6.
Area approximately 55km x 40km.

Figure 6 - Cape Breton Island, Wreck Cove Area, July 27, 1978.
LANDSAT 30144-14142, PC 7-27, composite of LANDSAT Bands 4, 5 and 6.
Area approximately 55km x 40km.

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PART 3 DISCUSSIONS: CONCURRENT AND PLENARY SESSIONS, FEBRUARY 1, 1980

Dr. Lapp described briefly the structure of the CACRS and the functions of the working groups and stated that the purpose of the discussion sessions is to establish recommendations to be presented by this Working Group to CACRS, and if approved, to be submitted to the Interagency Committee on Remote Sensing (IACRS).

The participants were divided, according to individual interest, into 3 discussion groups, on Transportation Engineering, Land Development and Energy Conservation - Thermography. Dr. Lapp directed the groups to develop, within their respective area, recommendations on various aspects of the national program, both satellite and airborne.

The recommendations developed during the concurrent sessions in the morning were presented and reviewed in the plenary session, with Dr. Morley providing extensive comments.

The finalized recommendations are presented on p. 98-102.

The workshop concluded at 15:15.

Discussion Group: Transportation Engineering

Members:	P. Chagarlamudi	The Sibbald Group
	J. Cihlar	CCRS
	R.W. Culley	Saskatchewan Department of Highways & Transportation
	A. Gater	Department of Indian and Northern Affairs
	P. Hession (part time)	CCRS
	S. Mathur (part time)	Ontario Ministry of Transportation & Communications
	L. Tam (Group Leader)	Ontario Ministry of Transportation & Communications

Recommendations:

1. The availability, application and feasibility of collecting, transmitting and receiving engineering field data using remote data collection platforms and satellites should be fully investigated and documented, perhaps jointly by the CCRS and Transport Canada.

2. Basic research into the interactive mechanism of engineering materials e.g. soils and rock types should be conducted to facilitate the interpretation of photography and imagery from photographic and non-photographic sensors.

3. The application of remote sensing should be made known to the highest possible level of management in transportation agencies through strong marketing efforts. An initial mechanism would be a brochure, which could be one of a series. The brochure should be simple, brief and have high visual impact.

4. Universities and technical institutions should be encouraged to include specifically engineering applications of remote sensing, using orbital and airborne sensors, in their curriculum, to be up-to-date on the state of the art of remote sensing and to emphasize its importance in engineering applications.

5. In recognizing the fact that most engineering applications require relatively large scales, the routine production of enlarged, digitally enhanced LANDSAT imageries to, for example 1:50 000 or larger, should be investigated.

Discussion Group: Land Development

Members:

T.T. Alfoldi	CCRS
S.J.G. Bird (Group Leader)	Bird and Hale Ltd.
P. Hession (part time)	CCRS
S. Mathur (part time)	Ontario Ministry of Transportation & Communications
D. McQuay	Gartner Lee Associates Ltd.
C. Petzinger	CCRS
I.J. Sneddon	Department of Indian and Northern Affairs
G.F. Tomlins	CCRS
E. Wedler	Ontario Centre for Remote Sensing

Recommendations:

1. A series of intensive, long-term test sites should be established across Canada, to eventually represent each major ecological region. These test sites must

   (a) be of suitable size for both airborne and satellite data analysis.

   (b) contain a wide range of environmental and cultural features.

   (c) have all available remotely sensed data collected, catalogued and archived on an historical,current and continuing basis. For example, if one of the aircraft under the control of CCRS is taking imagery in the vicinity of the test site(s), remote sensing of the test area(s) would be carried out as well.

   (d) have all possible and pertinent ground truthing data collected, catalogued and archived on a continuous basis. Investigators from all disciplines will carry out ground truthing on the test sites because of the obvious advantages of availability of all data. Therefore, a system which enforces the return of all new ground truth data, at no charge to the test site co-ordinator, must be established.

   (e) have all ground truth and remote sensing data available at the cost of reproduction.

   The intensive test site data will be used for a wide variety of purposes, including:

   (a) testing new airborne and satellite sensor data,
   (b) testing new analyses and monitoring techniques,
   (c) technology transfer and education,
   (d) assessment of direct and indirect temporal, enviornmental changes resulting from actual land use changes within the test areas.

2. As engineering applications of satellite imagery generally require greater spatial resolution than that presently available, CCRS should give continuing high priority to arranging for the availability of the highest resolution satellite imagery of Canada to be remote sensored in the future by orbital platforms operated by other countries.

3. Workshops particularly oriented towards engineering applications should be arranged and co-ordinated by CCRS, on a regular basis, in conjunction with the Working Group on Engineering Applications of Remote Sensing.

4. An audio-visual presentation on the engineering applications of remote sensing, accompanied by reproductions of the appropriate imagery should be prepared by CCRS for distribution to the user groups, such as government agencies, private industry, and universities and colleges.

5. Because Canada is so widespread geographically that certain areas such as the Maritimes and the Territories cannot be economically sensored due to transit charges, CCRS should discuss this problem internally with the Surveys and Mapping Branch of EMR as well as the commercial operators. Presumably, the transit charges would be substantially reduced if the sensing requirements in these areas were co-ordinated with the anticipated availability of the aircraft for other projects.

6. Because of the importance of being able to identify the remote sensing imagery taken by users other than the federal government, over particular areas of the country, CCRS should encourage the National Air Photo Library to identify the particulars of the imagery and to provide the names and addresses of those users in possession of the imagery.

Discussion Group: Energy Conservation - Thermography

Members:	H.T. Anderson	Canadian Western Natural Gas Co. Ltd.
	J.N. Barry (Group Leader)	Philip A. Lapp Ltd.
	H.G. Brosz	Ferguson, Brosz & Associates
	R. Gemmel	Manitoba Department of Government Services
	D. Gillis	University of Prince Edward Island
	P. A. Lapp	Philip A. Lapp Ltd.
	L. Marshall	New Brunswick Department of Supply & Services

Recommendations:

The members of the group noted that in view of CCRS being perceived as a prime mover in the application of thermography to heat loss and energy conservation, CCRS should make a conscious effort to monitor and provide support to those who are now becoming active in the field. It is felt that, because of its reputation, CCRS's endorsement could be a major factor in maintaining credibility in thermography technology as it matures into a fully operational engineering tool.

1. CCRS should use its influence with other agencies, federal and provincial - for example HUDAC and CMHC - to promote thermography as an effective audit procedure in CHIP-type home re-insulation programs.

2. CCRS should establish and maintain contact with the newly established Canadian Infra Red Thermography Association - CIRTA. Mr. Peter Mills of the Federal Department of Public Works is suggested as a contact.

3. CCRS should encourage the presentation of technical papers on thermography specifically aimed at educating the building industry and trades on the role of thermography as an effective diaganostic tool. Upcoming conferences that would be a suitable forum for such papers are:

    (a) Canadian Intergovernmental Energy Management Conference - June 1980.

    (b) Annual Solar Energy Conference - August, 1980.

4. CCRS should note the role of fast-framing, hand-held portable equipment in light aircraft as an alternate to the Daedalus line-scanner for specific heat-loss missions.

5. CCRS should make their airborne thermal scanner equipment more generally available during the critical data-collecting seasons. Ideally this availability would be exercised on an "opportunity" basis.

6. CCRS should examine the quality of maintenance on the Daedalus ground processor with a view to improving the consistency of the quality of the final product.

7. The group has no recommendation on the use of satellite data at this time.

PART 4 PROGRAM

WORKSHOP ON "ENGINEERING APPLICATIONS OF REMOTE SENSING"

Thursday, January 31, 1980

Technical Sessions

Chairman: B. Sen Mathur

	Event/Topic	Speaker
08:45	Introduction	B. Sen Mathur
	Opening Address	L.W. Morley
09:00	Orbital Sensors	F.J. Ahern
09:45	Airborne Sensors	F. Brumbaugh
10:30	Coffee	
10:45	Synthetic Aperture Radar	R. van Koughnett
11:15	Applications Development at C.C.R.S.	W.M. Strome J. Cihlar
12:00	Lunch	
	Selected Engineering Applications of Remote Sensing	
13:30	Land Development	S.J.G. Bird
14:00	Transportation Engineering	L. Tam
14:30	Coffee	
14:45	Energy Conservation - Thermography	J.N. Barry
15:15	Environmental Impact Assessment	J. Cihlar J.F. Tomlins
15:45-16:00	Summary	B. Sen Mathur

Friday, February 1, 1980

Discussions

Chairman: P.A. Lapp

	Event/Topic	Discussion Leader/Speaker
09:00	Present and Future Requirements of Remote Sensing for Engineering Applications - Land Development) - Transportation Engineering)Concurrent - Energy Conservation - Thermography)Sessions	P.A. Lapp
12:00	Lunch	
13:30	Plenary Session	P.A. Lapp
14:30	Summary and Conclusions	B. Sen Mathur
15:30	Departing Address	L.W. Morley

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