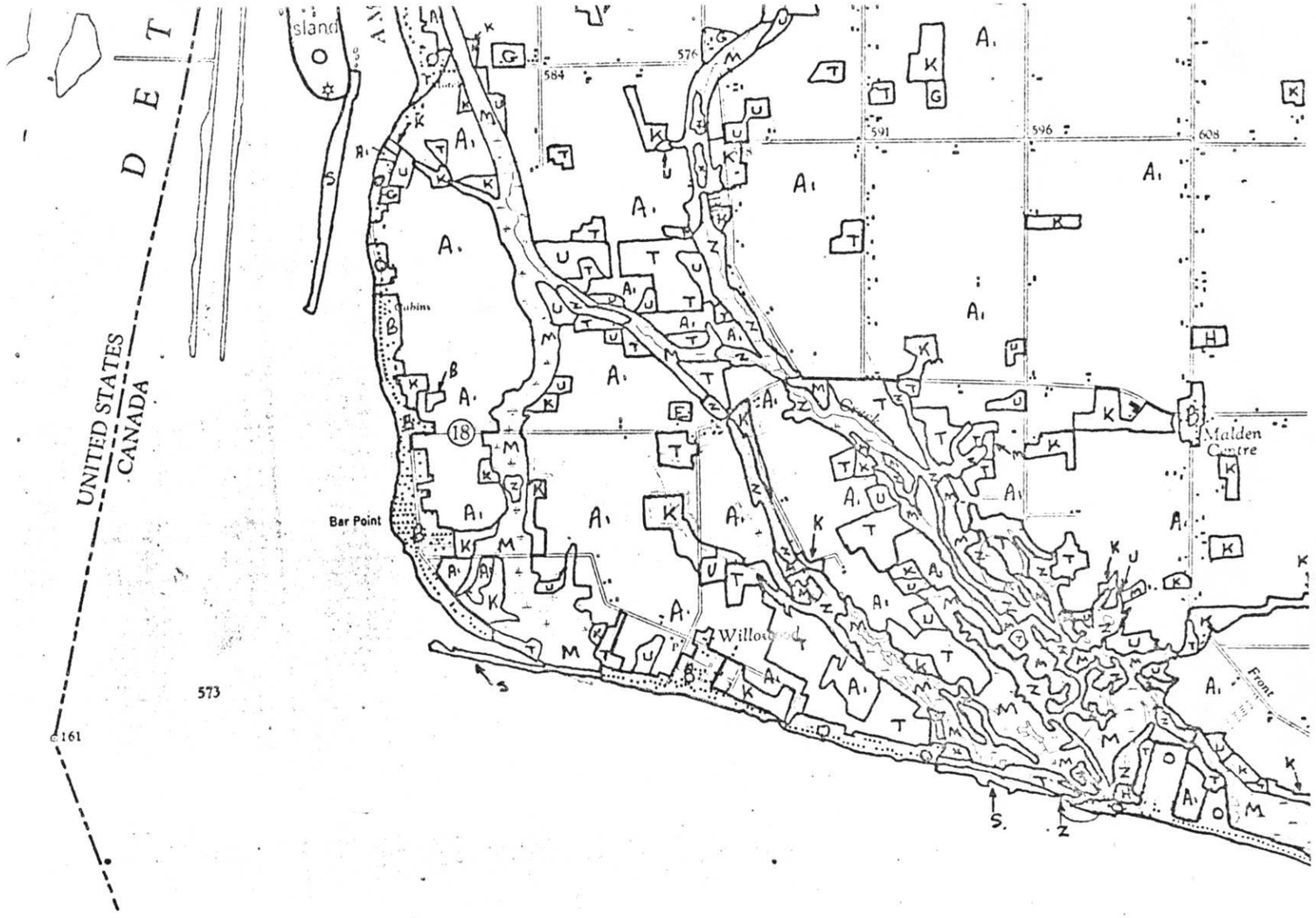
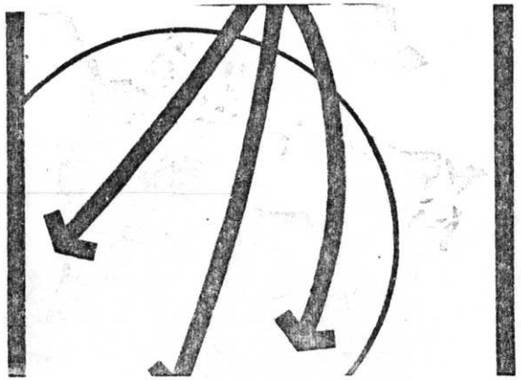
REMOTE SENSING IN CANADA





MAPPING LAND USE IN THE GREAT LAKES BASIN

AN EVALUATION OF CONVENTIONAL AND REMOTE SENSING TECHNIQUES

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FOR TASK FORCE B, LAND DRAINAGE REFERENCE GROUP
INTERNATIONAL JOINT COMMISSION

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INTRODUCTION *

The Governments of Canada and the United States of America, pursuant to Article IX of the Boundary Waters Treaty of 1909, requested the International Joint Commission to conduct a study of pollution of the boundary waters of the Great Lakes System from agricultural, forestry and other land use activities, in the light of the provision of Article IV of the Treaty which provides that the boundary waters and waters flowing across the boundary shall not be polluted on either side to the injury of health and property on the other side, and in the light also of the Great Lakes Water Quality Agreement signed on April 15, 1972.

Studies requested by the International Joint Commission on water quality in the lower Great Lakes, completed and submitted in 1969, demonstrated that diffuse land drainage sources of pollutants were not only significant but also difficult to measure. The acceleration of tertiary treatment at point sources will magnify the relative importance of land drainage sources of many pollutants, and it calls for a much better definition of the impact of land use activities, practices and programs on water quality in the Great Lakes. This is the charge from IJC to the Land Drainage Reference Group and it is the general objective of the Study Plan. Also, it is clear to the Reference Group that, of the many and varied activities developing from the Canada-United States Agreement on Water Quality in the Great Lakes, the study on Great Lakes pollution from land use activities is but one component of an overall strategy. Therefore, a Study Plan was developed recognizing the other activities and following a general review of ongoing programs relevant to the charge of the Reference Group.

Because of the complexity of the problem and the necessity to understand behaviour of pollutants from upstream fields to boundary waters, much of the effort will have to be applied to selected study watersheds. Because of this need to extrapolate, as well as for basic needs, a land use inventory is required. Trends in land use patterns and practices also will be essential.

The Study Plan emphasizes four main tasks:

Task A. *To assess problems, management programs and research and to attempt to set priorities in relation to the best information now available on the effects of land use activities on water quality in boundary waters of the Great Lakes,* to be completed in 1973.

Task B. *Inventory of land use and land use practices, with emphasis on certain trends and projections to 1980 and, if possible, to 2020.* Present land use report to be completed in early 1974, report on trends to be completed early in 1975.

Task C. *Intensive studies of a small number of representative watersheds, selected and conducted to permit some extrapolation of data to the entire Great Lakes basin and to relate contamination of water quality, which may be found at river mouths on the Great Lakes, to specific land uses and practices.* Preparation activities in 1973, intensive surveys in 1974 and 1975.

Task D. *Diagnosis of degree of impairment of water quality in the Great Lakes, including assessment of concentrations of contaminants. of concern in sediments, fish and other aquatic resources.* This will be largely available from ongoing monitoring programs, supplemented by some special surveys.

The Study will require three years of intensive surveys, with much of the fourth year devoted largely to preparation of the final report, to be presented in 1976.

The estimated cost of the Study is $8,872,000. In addition, available estimates of the cost of ongoing studies relevant to the task of the Reference Group through the study period (1973 to the end of 1976) total $6,866,000.

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* Parts of the Introduction taken from reports prepared by the Land Drainage Reference Group.

The Reference Group met on a number of occasions since December last year. For purposes of reviewing pertinent ongoing studies, to attempt to integrate activities and examine needs and sources of funds for additional studies, the Canadian Section met additional times.

The Canada Centre for Remote Sensing was requested by the Canadian Chairman of the Land Drainage Reference Group, Dr. M. Johnson, and the Chairman of the Task B group, Mr. Lloyd Eckel, to participate in the US-Canada meeting in Rochester, N.Y., July 12, 13, 1973. This was mainly to assit in evaluating the results of the LARS pilot project based on automated computer interpretation of satellite imagery and to assist in the discussion of alternate methods. Mr. Lloyd Eckel in his letter of July 16, 1973 asked the participation of CCRS Applications Division staff members in this TASK B TECHNICAL COMMITTEE. The objective: To evaluate possible methods of land use mapping suggested by different sources and to make recommendations for the selection of the most appropriate one for Canada. Reporting by Mid-August, 1973.

OBJECTIVES

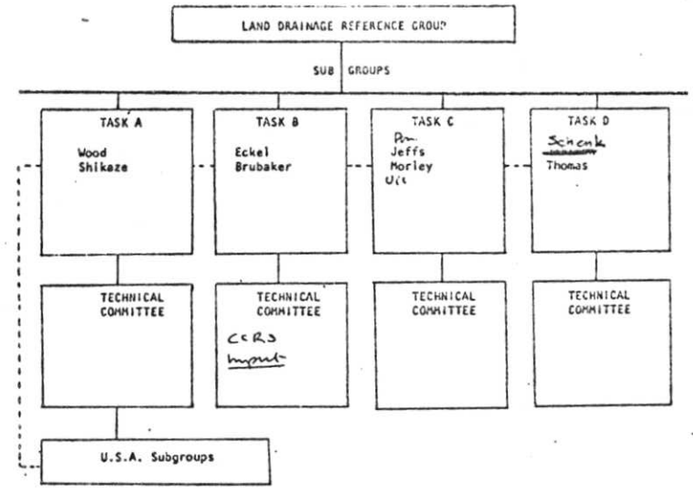
TASK B: Inventory of land use and land use practices, with emphasis on certain trends and projections to 1980 and, if possible, to 2020. Present land use report to be completed in early 1974, report on trends to be completed early in 1975.

The objectives of this report are:

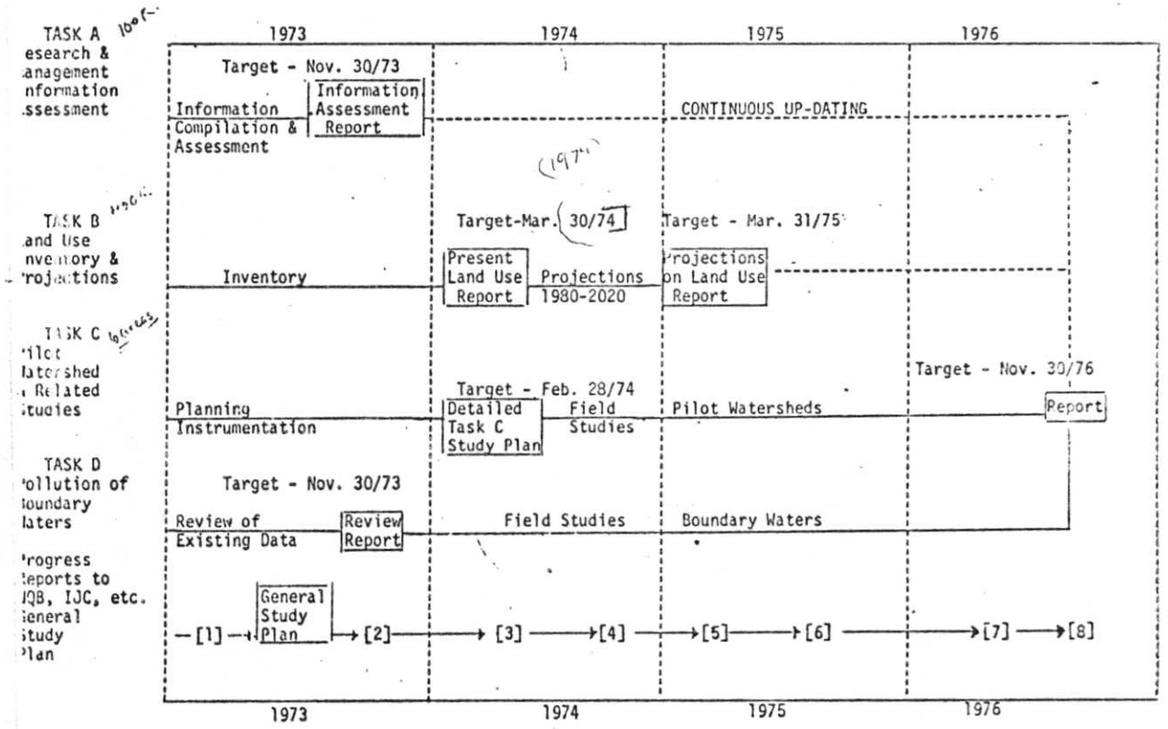
(1) To discuss and evaluate presently existing land use information sources and their suitability for accomplishing TASK B goals.

(2) To bring together the results obtained earlier by specialists advising the Chairman of TASK B (from Bangay, Jenns, Zsilinszky, Thie, Hardy, LARS).

(3) To discuss methods to acquire data needed for TASK B, ie: classification system, levels of detail, data presentation, accuracy, cost, speed, operational aspects, timing.



PROPOSED SCHEDULE OF ACTIVITIES - LAND DRAINAGE REFERENCE STUDY
(Calender Years)



(4) To provide detailed estimates for the suggested 3-area classification system suggested by Thie at the Rochester conference.

(5) To indicate the possible role of CCRS in the operational aspects of the selected alternative.

In the "Study plan to assess Great Lakes Pollution from land use activities" by the Land Drainage Reference Group (March 30, 1973), the activities of Task B are described in some detail. In brief the essence of this report is:

Activity 1: Land Use Inventory: Much information is available in Canada and US; all land use data will be presented on a watershed basis; a budget of $115,000 is required in Canada for synthesis of statistics for the purposes of this study.

Activity 2: Trends in Land Use: Trends for 1980-2020 that are detectable at this time must be carefully considered; supplementary funds needed to carry out this work are $135,000 in Canada.

Land Drainage Reference Group members identified that three levels of detail should be considered in the land use mapping. In discussions, level 1, 2 and 3 were mentioned; 1 being very general, 3 being very detailed. However, no clear definitions could be found.

PRESENT STATUS

The Land Drainage Reference Group met on the following dates: December 19, 1972 in Toronto; January 16-17, 1973 at Detroit; Toronto on March 6-7, 1973 and in Rochester on July 12-13, 1973. In addition, the Canadian section met on a number of occasions.

Members of the TASK B group had discussions at the LARS Institute (Laboratory for the Application of Remote Sensing) Purdue, Indiana. As a result of this meeting, Dr. Baumgardner of LARS directed a pilot project to make a land-use classification from ERTS satellite imagery. Results of a six county survey in South West Michigan were presented by him at the Rochester meeting. Canadian members of TASK B investigated the existing land-use data base; Mr. L. Eckel, Chairman, TASK B received submissions and comments from:

(1) Mr. G.E. Bangay, Social Sciences Section, CCIW. Memo related to the availability of Canada Land Inventory Data, and cost of updating this information.

(2) Mr. W.E. Jenns, Supervisor, Inventory and Mapping, Surveys and Mapping Branch, Ontario Ministry of Natural Resources.

(3) Mr. J.E. Brubaker, School of Engineering, University of Guelph.

(4) Mr. V. Zsilinszky, Provincial Co-ordinator, Remote Sensing, Ministry of Natural Resources.

(5) Prof. E.E. Hardy, Cornell University, Department of Natural Resources.

On March 30, 1973 a study plan to assess Great Lakes pollut... from land-use activities was submitted to the International Joint Commission and the Great Lakes Water Quality Board. This plan identified, as target date for the present land-use report, March 30, 1974. As target date for the projections and trends report was indicated March 31, 1975. The estimated cost was $115,000 to be borne by the Ontario Ministry of Agriculture and Food ($35,000); Ontario Ministry of Natural Resources ($15,000); Ontario Ministry of Environment ($15,000), and the Canada Department of the Environment ($50,000). However, the Ontario portion of the budget is not yet approved.

EXISTING DATA BASE FOR LAND USE PATTERNS AND PRACTICES

CANADA LAND INVENTORY:

Canada is in a relatively favourable position as recently the Canada Land Inventory Project was completed. This project is multi-disciplinary in nature and the capability of land for wildlife, recreation, forestry, agriculture and the present land-use were mapped. This sytem covers a large part (the developed part) of the basin. (FIG. 2). Land use maps are available at the 1:50,000 scale and will become available at the 1:250,000 scale in the future. The smallest unit identified is 6.4 acres. The mapping program started in 1962 and maps vary in age.

To judge the usefulness of C.L.I. data for the study objective, we must assess level of detail provided, classification system and its relevance to pollution of the Great Lakes and the timeliness or accuracy of the information. Staff of the CCRS Applications Division completed a quick evaluation and the results are as follows:

Timeliness - Four areas were selected to measure the changes in land-use that may have taken place since the year of mapping; one in an urban fringe near Windsor; one near a small town in a well developed agricultural area - Essex; one in a northern area where natural cover is dominating - Engelhardt, Ontario, and one area in North Western Ontario near Kakabeka Falls. The existing C.L.I. maps were compared by Mr. R. Ryerson (CCRS) with recent aerial photographs (1971).

Conclusions: The changes that occurred in the study areas are surprisingly insignificant. In areas dominated by natural woodlands or agriculture, the amount of changes are smaller than the accuracy margin of the C.L.I. data. In the Urban fringe area near Windsor few changes occurred. No updating appears to be required in predominantly agricultural and natural cover areas.

Classification system - The system may not be ideal for the study of the relation of land-use and pollution and for the necessary extrapolation of TASK C. A further separation of the Urban area B is much needed, and a further separation of A (Arable) would be desirable.

However, the level of detail and the number of separate land use categories classified are considerably higher than can be obtained from any of the proposals based on resource satellite information.

Conclusion: The C.L.I. system appears acceptable for all areas other than Urban.

In addition to maps, the Lands Directorate, DOE, can provide land use information in a tabular form on a watershed, sub-watershed and probably county basis. This information would be essentially free of charge and is expected to be accessible around the end of 1973.

Updating the C.L.I., if required, would, according to Mr. Bangay's memo, cost $50,000. Staff from the Land Classification Section of the Lands Directorate indicated that this was a very conservative estimate (at a later stage, an amount of $95,000 was quoted by C.L.I. staff.)

The C.L.I. data for wildlife, forestry, recreation and agriculture may provide considerable help in prediction of trends in land use changes. It can assist in providing the physiographical ecological part of the predictive model together with the important economic and social data from the basis for the assessment and prediction of trends. For example, land presently in agriculture, rated low for agriculture (sub-marginal, or marginal) may in time revert to a different use such as forestry, recreation, etc. Relationships of change established in TASK C could be extrapolated using the physical base as a guide.

Since 1941, census data have been available for all of Ontario. The information is very detailed and can be provided on a county and township basis. The information, as far as agriculture is concerned, would be at the most detailed level; level 3. As the information is provided for every 10th year since 1941, past changes can be studied, while also the 1981 and following census can be used to modify the models for prediction of trends in land use.

Statistics Canada has a working system that could extract data on a subdrainage basin (based on telephone conversation with H. Scott, Statistics Canada, late July, 1973).

Data provided:

CROP DATA - all field crops by county in acres
- all field crops by township (not included are vegetable, fruit or greenhouse crops. These are often submerged for reasons of confidentiality, but are available on a county basis.)

USE OF LAND - harvested cropland, improved pasture, summer fallow, woodland, unimproved pasture. In addition, fertilizer use and irrigation is available for each crop and the land or crop acreage sprayed or dusted.

LIVESTOCK DATA - cattle, pigs, sheep and poultry.

Advantages of using census data:

(1) Data from the same date as major total airborne coverage of Southern Ontario and Northern Ontario urban areas (1971 high altitude imagery, scale 1:137,000).

(2) Total resources of Census available for development of predictive procedures.

(3) Breakdown of crops finer than could be obtained through use of only Remote Sensing from aircraft or satellite.

LAND USE CATEGORY	MAP SYMBOL
Urban	
a) Built-up areas	B
b) Mines, quarries, sand and gravel pits	E
c) Outdoor recreation	O
Horticulture	H
Orchards and vineyards	G
Cropland	A
Improved Pasture and Forage Crops	P
Rough Grazing and Rangeland	K
Woodland	
a) Productive	T
b) Unproductive	U
Swamp, Marsh or Bog	M
Unproductive Land	
a) Sandflats, dunes, and beaches	S
b) Rock and other unvegetated surfaces.	L
Water	Z

Fig. 2. Present land use classification summary.

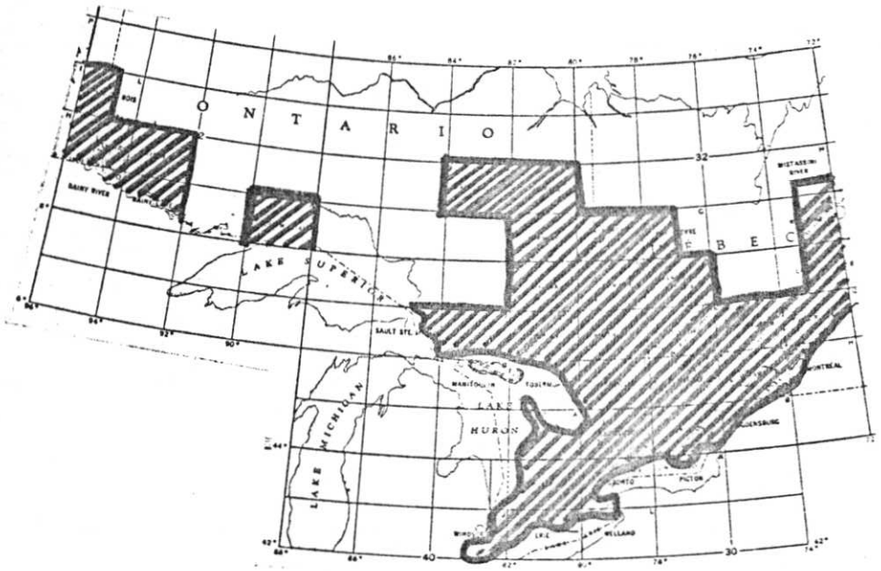


FIG. 2 Canada Land Inventory classification system and Co
Land Inventory coverage in Ontario

...nada

(4) Data updated for each class and area every 10 years.

Disadvantages:

(1) Data not of the same time period as ERTS or C.L.I. derived data.

(2) High level of detail not directly compatible with more general satellite interpretation systems.

(3) Does not contain small urban areas, forest areas, etc.

(4) Does not include (in all cases) every detail because of confidentiality restrictions.

In conclusion, the Census of Canada 1971, provides a large amount of very detailed information which is easily accessible and retrievable on county, townships and possible watershed basis. No significant costs are involved in acquiring and presenting the data.

ONTARIO MINISTRY OF AGRICULTURE AND FOOD *

The Ontario Ministry of Agriculture (Economics Branch) has available on a yearly basis agricultural statistics by number of acres per county for: winter wheat, oats, barley, mixed grains, dried beans, soybeans, shelled corn, rye, spring wheat, flaxseed, buckwheat, dried peas, field roots, potatoes, fodder corn, hay, hay and seeded pasture, tobacco, apples , cantelopes, cherries, grapes, peaches, pears, plums, raspberries, strawberries, asparagus, beans, beets, cabbage, carrots, cauliflower, celery, corn, cucumbers, lettuce, onion, parsnips, peas, peppers, rutabaga, spinach, tomatoes.

Five year averages for most of the above crops are available from 1941 to 1970. These data may be of use in the prediction of near future trends. Within a year new equipment may allow interpolation for mapping at a more detailed level.

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* Source: Letter of J.E. Brubaker, Ontario Ministry of Agriculture and Food to Mr. Lloyd Eckel.

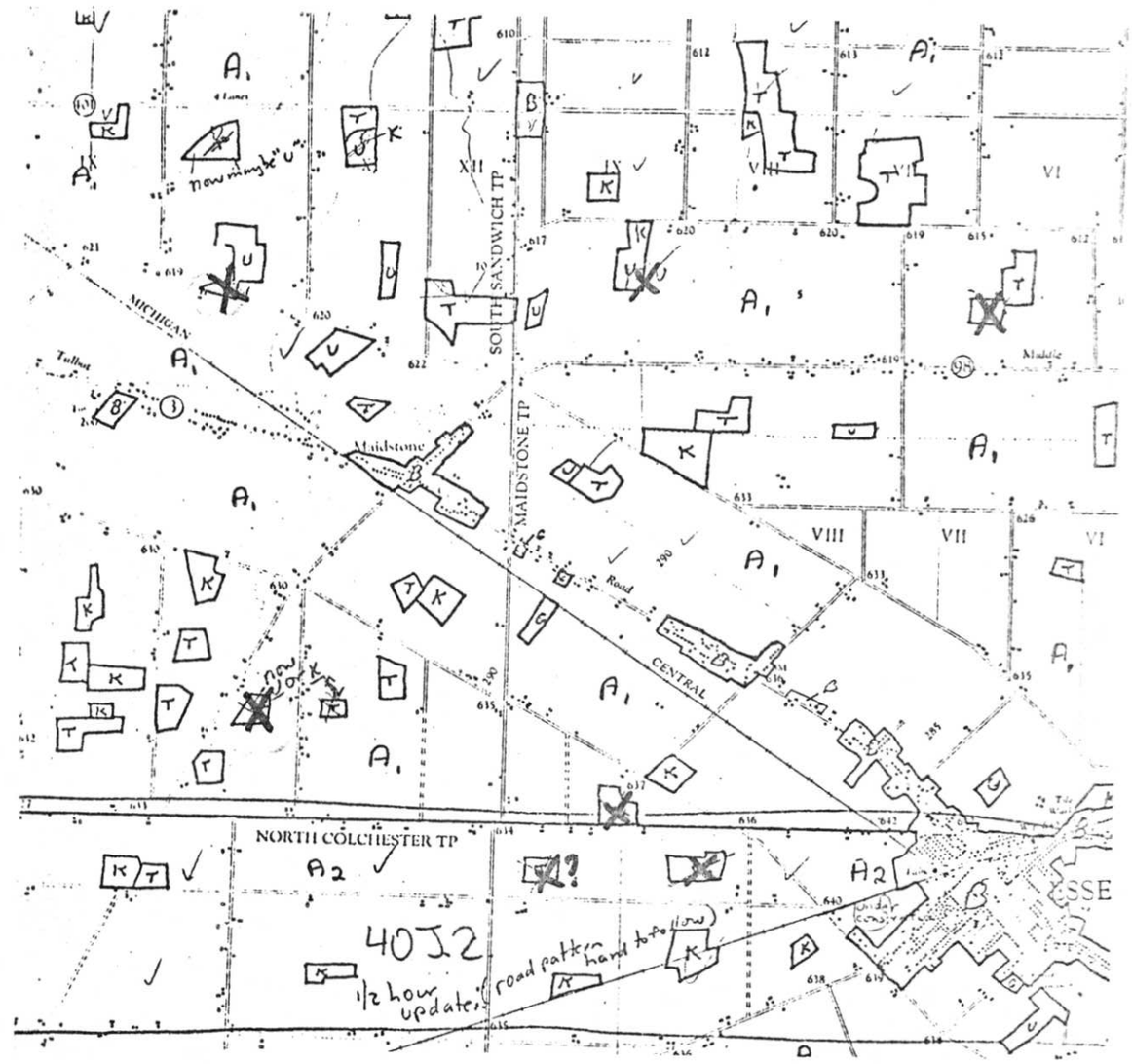

FIG. 3 Example of changes in land use that have taken place since 1962 in the area around ESSEX, Ont.

ALTERNATIVE PROPOSALS FOR MAPPING LAND USE

During the past couple of months different organizations and individuals have worked on proposals for Land Use mapping in the Great Lakes Basin.

(1) LARS (Laboratory for Application of Remote Sensing) - Purdue University, Indiana.

(2) Prof. Hardy, Lands Resource Information Laboratory, Cornell University.

(3) Mr. Zsilinszky, Ontario Ministry of Natural Resources, Remote Sensing Centre.

(4) Canada Centre for Remote Sensing .

Each of these are discussed in detail on the following pages.

LARS LAND-CLASSIFICATION FROM ERTS SATELLITE

A study team from LARS, headed by Dr. Marion Baumgardner, is presently completing a pilot project in which they are testing the use of the LARS computer programs with satellite data to map land use in 6 counties in the U.S.

Dr. Baumgardner presented the preliminary results at the Rochester meeting of the Land Drainage Reference Group.

Two levels of information were classified from ERTS satellite imagery:

(1) A land use map of each county delineating the following major land use categories:

a. urban
b. agriculture
c. forest
d. water

2. A list in tabular form of the following land use categories for each county:

a. urban (low density)
b. urban (medium density)
c. urban (high density)
d. transportation
e. extractive
f. row crops
g. close grown crops
h. pasture and meadows
i. orchards and vineyards
j. forest and woodlands
k. water
l. wetlands
m. barren lands

A small amount of existing training areas were used. No ground truthing was done and no data as to accuracy of classification were available.

Other than ground truthing, the main problem was geometric correction of the data. LARS is currently working on a program for this.

At an earlier meeting of Task B members at LARS, Dr. Baumgardner had estimated that $100,000 would be needed to classify the Canadian and U.S. portion of the Basin. He provided some more precise estimates based on experience with the six counties. In the project 30 man days and 20 cpu hrs.(@ $250/hr.) were used.

Cost of mapping the Great Lakes Basin using the LARS approach were identified as follows:

A	Level 1 mapping by county; Level 2 in tabular form using 100% of the data point would cost for the total basin.....$400,000
B	As A, but using 25% of the data points.....$150,000-$200,000
C	As A, but U.S. portion only.....$175,000-$200,000
D	As B,but U.S. portion only.....$100,000
Added to these should be ground truthing costs.....$50,000-$80,000	

Some points that came up during the discussion of Dr. Baumgardner's presentation in Rochester:

- Data (level 2) can only be presented in a tabular form for geometric areas (counties) but not for irregular watershed basins.

- Ground truthing is necessary over the total basin - costs are not included in estimates.

- Similar accuracy figures for all aspects of the entire project would be supplied. This in part would be accomplished by overflights in urban areas. Such complex areas are separated from their surroundings and handled individually with special training sets to obtain maximum separation.

- Probably because of poor ground truthing, a number of classification problems were noted. These included the following incorrect identification tendencies: bare soil for transportation; close crown orchard for forestry; parks and golf courses for agriculture in rural areas; and orchard was in some cases confused with pasture. In addition to these problems a large area was identified as urban in a rural area.

- If overlays using different passes were used, displacement would be ($\pm\frac{1}{2}$) digital element.

Ionia County, Michigan
20 miles East of Grand Rapids

Symbol	Class	Symbol	Class
Y	trees	0	orchard
W	water	I	agriculture
blank, .	interstate/urban (I-96)	2	truck farm
/	pasture, grass		

FIG. 4 LARS computer print out for Ionia County

Some other considerations:

- At this time no hard fact has been made available re accuracy, either actual or expected.

- The classes tested by LARS may not be suitable for the extrapolation of TASK C.

- Boundaries may not be useful units of aggregation for level two data in Canada. No geographical reference system is available for level two data at a finer scale than (approx.) a grid cell of twenty-five miles per side.

- The use of the digital computer maps will likely be restricted to the study itself. The information will not be easily accessible to common users like municipalities and county administrations.

In conclusion: *While the LARS method appears theoretically feasible, there are a number of operational problems that would endanger the satisfactory completion of this method within the time frame. The level of detail provided is significantly less than what can be obtained in most areas from existing data in Canada.*

ALTERNATIVE PROPOSED BY DR. HARDY

The method Dr. Hardy suggests as feasible to collect land use data is characterized primarily by its reliance on human interpretation. Secondly, diazo composites of blow-ups of ERTS imagery provide the material with which the interpreters work.

The ERTS imagery is first modified to ensure similar contrast frame to frame band by band. It is then blown up from 70 mm to a scale of 1:250,000. Using various colours for various bands (most often cyan, magenta, and yellow) diazo composites are produced. These are then interpreted using overlays on light tables. The pilot study using no ground truth, maps or current information tested out at over 80% accuracy against LUNAR (Land Use & Natural Resource Inventory of New York), which was three years old at the time.

At this time, the Hardy system would be capable of extracting eight to ten Level I land-use categories as named by Anderson, Hardy and Roach. The classes will be modified by Hardy and Roach, both of whom are currently in the Resource Information Laboratory at Cornell. Hardy suggests one-half of the Level II data could also be collected with the use of ground truth, base maps, and other corollary sources. The cost for such existing data was included in the figure reported to V. Zsilinszky, July 25, 1973. The minimum mapping unit would be twenty-five hectares, while the minimum recording unit would be ten hectares.

Accuracy levels given, i.e., minimum eighty-five percent, are believed realistic. Expected accuracy may be over ninety percent. Only slight variations would be expected class to class. Certain precautions can be taken to lower even further the probability of having important errors in the system.

The products from Hardy's method would be:

(1) Complete storage, retrieval, and summary system accessible by UTM grid or similar system.

  (a) Density level maps
  (b) Digital summary

(2) Complete coverage of the area with ink drafted overlay maps at 1:250,000 scale, reproducible for I.J.C. and other users.

(3) A baseline inventory prepared, suitable as a basis of comparison and with output suitable for manual use and readily reproduced.

Delivery would be within one year from outset. The system would cost at most $150,000;$65,000 for the Canadian sector. Ten to twelve man years would be required.

Disadvantages of the Hardy system would include the following:

- The technique, with reference to Level II, is not yet operational.
- We are not sure if the land use classes suitable for interpretation are the classes of importance to TASK B.
- Ground truth costs for more remote areas may slightly increase costs.
- The CCRS technique would have more information, the same or higher accuracy, and at 30-50% less cost.
- Considerable manpower is required, with up to two weeks training and ground work for each.
- There is still some question as to the availability of suitable imagery.

Advantages of the Hardy system include:

- The technique is less expensive than computer techniques suggested.
- Canadian resources would be input into Canadian personnel to perform the task in Canada while Hardy could provide the necessary training for the Canadian personnel.
- Hardy is not only an expert in remote sensing, but also a recognized authority in costing remote sensing, land use classification and land use change.
- The inventory would not only be provided for the I.J.C., but would also be available for use by others.
- Hardy's aggregation units can be made to coincide with existing data.
- The materials used are inexpensive. Computer costs are a relatively small part of the total as compared to LARS.
- Hardy and his group have the expertise (with LUNR) to service an inventory upon its completion, or ot advise on such service.
- At least broad limits and floor values have been placed on the accuracy one may expect.
- The technique using diazo is easily learned thus providing a basic pool of talent in Canada in a new useful technique at virtually no cost to Canada, or the I.J.C.

Hardy's method should be able to provide the same basic information as LARS with similar mapping units and classes. The approach, philosophy, costs, and certain other features are, however, very different. It is the opinion of CCRS personnel that, for the entire Canadian basin, neither technique is suitable in terms of costs, accuracy, and information content.

The Hardy method could be used; however, in the Ontario Wildlands without any substantial additional cost to the CCRS proposal's outlined cost. For the agriculture and urban areas, Hardy's cost exceeds CCRS cost by a factor of two.

If the Hardy-CCRS systems were linked for Canada and Hardy mapped the U.S. portion, the utility of data to the I.J.C. would be increased through increased clarity and consistency.

ALTERNATIVE PROPOSED BY C.C.R.S.

On request of Lloyd Eckel, Chairman of TASK B, the CCRS Applications Development staff evaluated in detail the suggestions made by the CCRS delegation at the Rochester meeting. The method suggested and now proposed distinguishes itself from others in that it uses a combination of suitable existing information sources and airborne and satellite Remote Sensing techniques where appropriate and needed.

In brief the concept can be defined as follows:

(A) Use present land use C.L.I. data (as is) for agricultural dominated areas (level 1 and level 2 in map form and tabular). Use Census Canada data for level 2 and 3 information.

(B) Use high altitude aircraft data (1:137,000 scale) for remapping of URBAN and URBAN influenced areas.

(C) Use satellite data (human interpretation) for unmapped areas in Canada: Wildlands and Forest areas. (Level 1 and 2)

(D) Use of C.L.I. and Ontario Land Inventory data to describe the physiographical-ecological relationships of land use and land capabilities for wildlife, recreation, forestry and agricultural uses.

The feasibility of A, B, C and D were evaluated and the conclusions as to data format, data quality, data presentation and cost are discussed below:

A: Agriculturally dominated areas - The Canada Land Inventory Present Land Use information was found (in preliminary tests) to be timely and accurate enough for level 1 and 2 mapping. Maps are presently available at 1:50,000 scale and will be shortly available at the 1:250,000 scale.

In addition C.L.I. Land use data can be made available in a tabular form on a watershed, sub-watershed and county basis.

Level 3 type information can be provided from Census of Canada and Ontario Agriculture sources in a tabular form on a county, township or possibly watershed basis.

B: URBAN dominated areas - C.L.I. data proved to be insufficient for URBAN mapping. In the first place, the legend is likely inadequate for the objective of TASK B; in the second place, these areas were subject to great change. Therefore, the use of high altitude airborne imagery was tested (about 1:135,000 scale). Existing 1971 imagery (1:137,000) scale was considered as well as the r ing of the area by the Airborne Operations Section of the Cana Centre for Remote Sensing using colour infrared film at high altitude.

A test site was interpreted by CCRS staff. The Windsor area was selected for this purpose on the 1971 colour imagery (1:137,000). At this scale, a city the size of Windsor occupies approximately 15% of one frame. The scale restraint dictated the land use classes that were used. Two levels of mapping detail were tried: minimum unit 6.4 acres and minimum unit 20 acres. The C.L.I. codes were used as much as possible and expanded when feasible. Below is the list of the codes and the categories of features they represent:

C.L.I. URBAN Land Use Expansion

B = Built-up areas
- B1 = Industry
- B2 = Commercial, institutional (church, school, gas station, plants, cemeteries, etc.)
- B3 = Residential
- B4 = Airports
- B5 = Rail facilities
- B6 = Highway facilities

O = Outdoor Recreation
- O1 = Golf courses
- O2 = Land based outdoor recreation (other than golf)
- O3 = Water based recreation (parks adjacent to water)

It is suggested that the following areas should be mapped from high altitude airborne imagery: The Golden Triangle; Brantford to Niagara; Kingston; Belleville; Windsor; Sault St. Marie; London; Hamilton-Toronto; Toronto; Bowmanville-Boulton; Thunder Bay; Welland Canal; North Bay; Peterborough; Sarnia and Sudbury. Maps produced would be at the 1:50,000 scale.

C: Wildland areas - Satellite imagery would be used in areas for which no C.L.I. data are available, mainly in the forested "wildlands". Much suitable imagery is already available, while more will be coming in during this summer and next winter. Preliminary work with instrumentation at the CCRS have shown that the following legend for classification could be used:

(1) Forested areas - optional split into: Coniferous
Hardwoods
Mixed forests

(2) Potential Forested areas - recent cut over areas
- recent forest fires

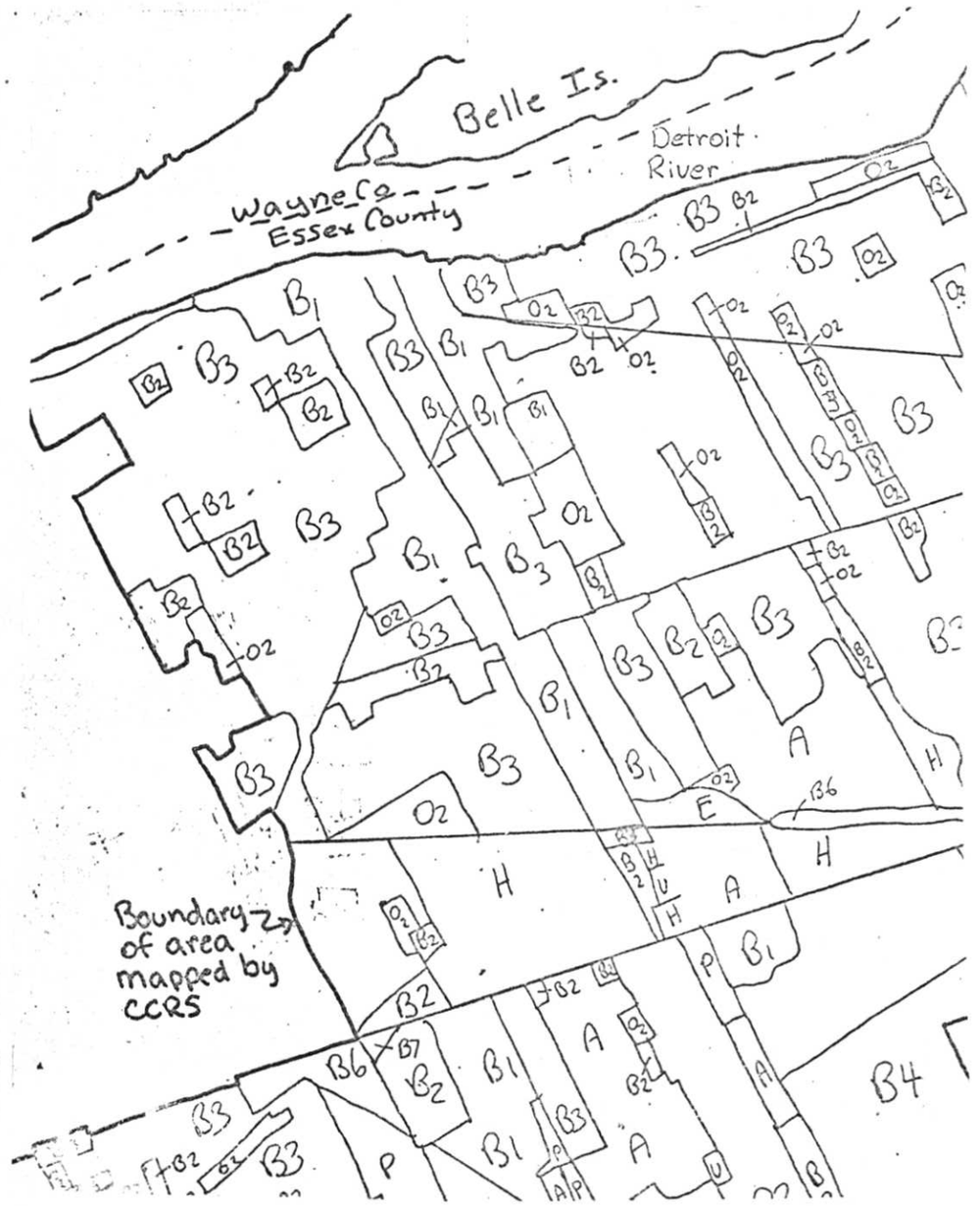

FIG. URBAN classification of the Windsor area

C: Con't

(3) Wetlands - Fens
- Bogs
- Swamp and marshes

(4) Human activities would be classified according to the C.L.I. system.

Level 1 classification and level 2 would be provided in a map and tabular form according to county and watersheds. Smallest unit of classification would be 40-60 acres, but usually considerably larger. Mapping at the 1:250,000 scale.

D: Physiographic-ecological relationships of land use - the Canada Land Inventory has capability maps available at the 1:250,000 scale level for wildlife, recreation, forestry, agriculture. These maps describe land base, limiting factors to different uses. This information can also be tabulated on a watershed basis. Suggested is that by means of overlay techniques, present land use is related to capability and physiography. This information would be presented in a report form. Results may be of value in prediction of trends.

COST ESTIMATES - CCRS ALTERNATIVE

					Options
(1) Use of C.L.I. for agricultural areas					
	no basic charge for information			0	
	coordination + data treatment			1500	
	correlation of land use and C.L.I. capability data			....	4000
(2) URBAN					
	Interpretation and mapping of 30 small scale photos	180 man days	240	15000	
	Report writing, ground truthing	60 man days			
	Ground truthing - fixed wing 35 hrs. @ $60.00			2100	
	Obtaining high altitude R.E. imagery (optional) 400 line miles @ $5.50				2200
	Processing of original film				400
	Photographic prints or transparencies (colour)			700	
	Materials			1000	
				18800	
(3) WILDLANDS					
	Interpretation of satellite imagery, 15 areas; 4 channels, spring, summer and winter imagery	50 man days			
	mapping, computation	30 man days	110	9000	
	Report writing, ground truthing	30 man days			
	Instrumentation and materials			2000	
	Ground truthing - fixed wing 20 hrs. @ $60.00			1200	
(4) SMALL SCALE MAP OF BASIN					
	1:1,000,000 or 1:2,000,000 scale				5000
(5) Supervision - coordination				4000	
	Office overhead (including space, typing, materials)			4000	
	Contingency			4500	
				45000	

CONCLUSIONS AND RECOMMENDATIONS

1. Delay of the TASK B completion until the final phase of TASK C will not likely jeopardize the overall objectives of the Land Drainage Group. Such delay may in fact provide a superior end product.

2. The legend for land classification and level of detail required are still not agreed upon by the Land Drainage Reference Group.

3. For Canada the use of the existing data base (C.L.I., Census Canada) is advised as much as possible, since both the quality, kind, uniformity and detail appear to be quite acceptable for achieving the objectives of TASK B.

4. Even the earliest present land use maps of the C.L.I. are still acceptable as presentation of today's conditions in agriculturally dominated areas. No significant changes in land uses occurred in tests conducted.

5. In Urban areas the C.L.I. does not provide sufficient information and is out of date.

6. The LARS computer automated system appears feasible, but the cost is very high for the kind and quality of information provided ($200-$400K)

7. The HARDY approach appears quite attractive for the U.S. The level of detail is at least equivalent or better than LARS while the cost is significantly lower. Information is easier accessible for resource managers. ($150K).

8. For Canada a low cost mapping may be quite adequate using the existing data base (C.L.I.-Census) and Remote Sensing ($50K).

    (1) URBAN AREAS - Airborne Remote Sensing
    (2) AGRICULTURE - C.L.I. and Census
    (3) WILDLANDS - Satellite Remote Sensing

9. Staff and facilities of the Canada Centre for Remote Sensing (Applications Division; airborne operation) can be made available to complete the Canadian land use mapping project.