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CR-157004

SEMI-ANNUAL STATUS REPORT
of the
NASA sponsored
Cornell University Remote Sensing Program
December 1, 1977 - May 31, 1978

NASA Grant NGL 33-010-171

Original photography may be purchased from
EROS Data Center

Sioux Falls, SD 57198

Principal Investigator: Ta Liang
Co-Investigators: Arthur J. McNair
Warren R. Philipson

**ORIGINAL CONTAINS
COLOR ILLUSTRATIONS**

Remote Sensing Program
Cornell University
Hollister Hall
Ithaca, New York 14853

June 1978

NOGL-33-010-171

(E78-10130) CORNELL UNIVERSITY REMOTE
SENSING PROGRAM Semiannual Status Report, 1
Dec. 1977 - 31 May 1978 (Cornell Univ.,
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N78-25496

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Cornell University

REMOTE SENSING PROGRAM
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HOLLISTER HALL
ITHACA, NEW YORK 14853
(607) 256-4330, 256-5074

June 7, 1978

NASA Scientific and Technical
Information Facility
P.O. Box 8757
Baltimore-Washington International Airport
Maryland 21240

Subject: NASA Grant NGL 33-010-171

Gentlemen:

In accordance with the provisions of the subject grant, we are transmitting herewith two (2) copies of our 12th Semi-Annual Status Report, covering the period December 1, 1977 to May 31, 1978. In addition, three (3) copies of this report are being sent directly to the University Research and Applications Branch, Office of University Affairs, NASA Headquarters, Washington, D.C. 20546 (Attention: Mr. J.A. Vitale).

Sincerely yours,

Ta Liang
Ta Liang
Principal Investigator

TL/pw

cc: Mr. J.A. Vitale, NASA Headquarters
Mr. T.K. Sandridge, NASA Headquarters
Deans E.T. Cranch and P.R. McIsaac
Mr. T.R. Rogers and Mr. F.J. Feocco
Director W.R. Lynn

INTRODUCTION

The primary objective of the NASA-sponsored, Cornell University Remote Sensing Program is to promote the application of aircraft and satellite remote sensing, particularly, in New York State. In accordance with the guidelines of the NASA Office of University Affairs, this is accomplished through conferences, seminars, instruction, newsletters, news releases, and most directly, through demonstration projects. Each demonstration project must be, in some way, unique; essentially noncompetitive with commercial firms; and, potentially benefit- or action-producing. Relatively little emphasis is placed on technology transfer, per se.

The activities of the Remote Sensing Program staff, from December 1, 1977 to May 31, 1978, are reviewed in this Semi-Annual Status Report, the twelfth to be submitted to NASA since the Program's inception in June 1972.

COMMUNICATION AND INSTRUCTION

Contacts and Cooperators

The single, most time-consuming function of the Cornell Remote Sensing Program is conferring with past, present and potential users, cooperators, visitors, and other callers, who seek data, assistance, equipment or information. During the past six months, the Program staff spent many hours discussing remote sensing with representatives of various federal, state, regional, county and local agencies, public and private organizations, the academic community, and foreign countries.

During the spring semester, Program staff hosted seminar speakers from four federal agencies and six private companies in the United States and Canada (Appendix G). Program staff also held special orientation sessions for participants of Cornell's Soil Science Institute--30 professional soil scientists with the U.S. Soil Conservation Service, U.S. Forest Service and Bureau of Land Management (Appendix G)--and presented a Program review paper at the Annual Meeting of the American Society of Photogrammetry (Appendix F).

In addition to receiving project cooperators from the New York State Department of Health, the St. Lawrence Seaway Development Corporation, the General Electric Company, Cargill, Inc., (salt mine), and the U.S. Department of Labor, Mining Safety and Health Administration, Program staff traveled to discuss projects with officials of several divisions of the New York State Department of Environmental Conservation. Many new and continuing dialogs were also held via the mail and telephone, particularly in the course of developing remote sensing demonstration projects (Appendix E).

With non-NASA travel funds, the principal investigator of the Program visited the U.S. Geological Survey in Flagstaff, Arizona, the Environmental Research Institute of Michigan, in Ann Arbor, and the U.S. Army Engineer Topographic Laboratories, in Ft. Belvoir, Virginia; and he provided remote sensing consultation to government agencies in Afghanistan and Taiwan, and attended the 12th International Symposium on Remote Sensing of Environment in the Philippines.

Newsletters and News Releases

The Program's "Cornell Remote Sensing Newsletter" continued to provide a valuable link to and beyond the Cornell community. The Newsletter, which highlights remote sensing activities at Cornell while reporting other items of general interest, is now received monthly by more than 400 individuals and groups in some 30 states and 15 countries outside the United States (Appendices H and I).

Program investigations continued to receive publicity through newspaper items (e.g., Appendix A) and through nationally distributed news releases prepared for the Eastman Kodak Company. Work on assessing aquatic vegetation, reported in several sources, appeared again in "Aerial Applicators," and an earlier study of vineyard drainage was reported in "Wines and Vines" (Appendix F).

Seminars

For six years, the Program's weekly Seminar in Remote Sensing has continued to bring experts from government, industry and other institutions to Cornell to discuss remote sensing topics with students and staff (Appendix G). The high quality of the seminars is reflected in the interest shown by audiences during the past semester. Attendance ranged from about 45 to 65, with registration in the Seminar comprising 18 graduate and 28 undergraduate students from 19 Cornell divisions.

Courses, Special Studies and Workshops

As described in previous Semi-Annual Status Reports, the Seminar in Remote Sensing is but one course in a complete curriculum of instruction in aerial photographic studies, photogrammetry and remote sensing. Under this curriculum, students may perform independent research in remote sensing through special topics courses, professional masters design projects, or through M.S. or Ph.D. theses. Also noted in earlier reports are the relatively large number of foreign students receiving a university education in remote sensing, and the many formal and informal orientation sessions conducted regularly by the Remote Sensing Program staff. During the past six months, for example, Program staff offered special workshops on remote sensing for soil survey to some 30 practicing soil scientists from across the United States (Appendix G).

DATA AND FACILITIES

As described in earlier reports, staff research and instruction have been enhanced through continued acquisition of a wide range of remotely sensed, aircraft and satellite data, and through extension of capabilities for their analysis and interpretation. These data, along with Program facilities and equipment, are made available at no cost to cooperators, students and other interested users.

With assistance from the NASA Office of University Affairs, the Program has received Landsat, Skylab, high-altitude and low altitude coverage of sites in the Northeast, and a new high-altitude aircraft mission was recently flown over New York's Finger Lakes Region. The U.S. Environmental Protection Agency has also overflowed Program-selected sites at no cost to the Program; and imageries have been obtained from the U.S.A.F. Rome Air Development Center, the U.S. Geological Survey, the U.S. Department of Agriculture, the St. Lawrence Seaway Development Corporation, the National Air Photo Library of Canada, the Tri-State Regional Planning Commission, the National Archives, Eastman Kodak Company and several commercial mapping firms.

The Program maintains or has access to a spectroradiometer and selected image analysis equipment (i.e., zoom and non-zoom stereoscopes, density slicer, color-additive viewer, Zoom Transfer Scope, densitometer, stereoplotters, and other photogrammetric and photographic instruments). The Program also maintains a series of computer routines for analyzing multispectral digital data. These routines are receiving increased usage in Program-sponsored and spinoff investigations with Landsat and aircraft scanner data.

PROJECTS COMPLETED

During the six-month period, December 1, 1977 to May 31, 1978, the Cornell Remote Sensing Program staff completed two demonstration projects and one assistance project. Also completed was a graduate thesis on a study which was supported in part by the NASA grant.

1. Photo-Historic Evaluation of Revolutionary War Sites

The Program staff worked with the Deputy Historian of Fulton County, N.Y., to better define the setting of the Battle of Stone Arabia, fought during the Revolutionary War in 1780 (Appendix A). Based on an analysis of available aerial photographic coverage of the area, the staff compiled 1:24,000 scale map overlays depicting hedge rows, semi-permanent field boundaries, and farm roads or trails that were not shown on the topographic map. Suspected sites of forts and mass burial were also examined but unconfirmed. The submitted material was displayed in a symposium concerning the Battle and will be input to an historic diorama and publication.

2. Wetland Analysis for Source of Encephalitis

Working closely with the N.Y.S. Department of Health, Program staff used available aerial photographs to characterize mosquito breeding sites in Oswego County, N.Y. (Appendix B). This central New York study area contains numerous wetlands and is the only inland area in North America to have experienced confirmed outbreaks of Eastern Equine Encephalitis. It is hoped that photo-characterization of field-identified breeding sites of the primary mosquito (Culiseta melanura) will lead to the development of an effective spraying program. State Health personnel are currently assessing relationships between photo- and field-gathered information.

3. Assistance Project--Study of Salt Mine Problems

The Program staff assisted the mining engineer of Cargill, Inc., in his ongoing study of linears and their effects on salt mining operations in Lansing, N.Y. (Appendix C). Program staff compiled a map of geologic linears identified with medium and high-altitude aircraft photographs and satellite imagery. In addition, staff members provided consultations, imageries and facilities for their analysis to the Cargill mining engineer and to Mine Safety and Health Administration inspectors from Denver, Colo., and Geneva, N.Y.

4. Thesis--Monitoring Aquatic Vegetation with Aerial Photography

Brian L. Markham of the Program staff completed a study in which large scale color and color-infrared aerial photographs were used to assess changes in aquatic vegetation that accompanied phosphorus reduction in a eutrophic lake in New York State (Appendix D). This investigation, supported in part by NASA and by the U.S. Department of the Interior, Office of Water Research and Technology, has generated nation-wide interest (Appendix F).

PROJECTS IN PROGRESS

Program-Sponsored

As of June 1, 1978, the Program staff was conducting four projects under the NASA grant: (1) Landsat analysis for pheasant range management, (2) assessment of vineyard-related problems, (3) examination of county agricultural districts, and (4) thermal analysis of building insulation. The objectives, cooperators, users, expected benefits and actions, and status of these projects are described, as follows:

1. Landsat Analysis for Pheasant Range Management

- cooperator/user: N.Y.S. Dept. Environmental Conservation
- benefit/action: Landsat and other remotely sensed data will be used by state in developing a statewide pheasant range management plan
- expected completion date: Methodology - Sept. 1978

The Program staff is working closely with the New York State Department of Environmental Conservation to develop the most appropriate methods for inventorying land covers that are thought to influence pheasant populations. Because of the size of the area that will ultimately be surveyed--a major portion of New York State--Landsat data were judged to be the best potential source of land cover information. Program staff efforts are concentrating on extracting requisite information from the Landsat computer-compatible tapes. If these efforts are successful, less costly means for extracting the information from the Landsat data will also be evaluated.

2. *Assessment of Vineyard-Related Problems*

- cooperators: Taylor Wine Company and other vineyards; N.Y.S. Agricultural Experiment Station, Geneva, N.Y.; Cornell Depts. of Plant Pathology and Pomology; Eastman Kodak Co.
- users: Taylor Wine Co. and other vineyards; N.Y.S. Cooperative Extension.
- benefits/action: Appropriate action by vineyards on range of problems assessed with remotely sensed data; development of remote sensing as a vineyard management tool; ultimately, improved production.
- expected completion date: January 1979

The Program staff is examining the extent to which remotely sensed data might provide useful information for assessing vineyard-related problems. The first phase of the investigation, an evaluation of vineyard drainage, was completed and described in the Program's 7th Semi-Annual Status Report (Dec. 1975). For the second phase of the investigation, Program staff used large-scale color infrared aerial photographs to assess plant vigor. This project was discussed in the Program's 9th Semi-Annual Status Report (Dec. 1976). Follow-up studies of vineyard siting, crop vigor, yield-related factors and practical monitoring techniques are being conducted using low-altitude, multispectral aircraft data acquired for the Program by NASA during the summer 1977. (Some delay has been experienced in obtaining the computer-compatible tapes of the multispectral scanner data.)

3. *Examination of County Agricultural Districts*

- cooperator/user: Planning Board, Columbia County, N.Y.
- benefit/action: Assessment of land and land-use may cause agricultural and town zoning districts to be re-defined.
- expected completion date: January 1979

Agricultural districts in New York State are zones created to encourage the continuance of a strong agricultural industry. This is accomplished through legislation which offers farmers an opportunity

to protect themselves from the effects of urbanization and which discourages other forms of development in good farm areas. Each agricultural district must be reviewed every eight years.

According to representatives of the Planning Board of Columbia County, N.Y., land presently included within some agricultural districts in the county may not be actively farmed (or considered prime land), while other land outside of the districts may be desirable for inclusion in a district. At the request of the Planning Board, the Program staff is conducting a countywide inventory, categorizing land use as "active agriculture," "inactive agriculture," or "other." The initial phase of the inventory is based on 1973 NASA high altitude aerial photographs. As planned, updating of the 1973 inventory will be achieved with Landsat imagery if cloud-free data are available for late spring or summer 1978 (such data were not available for 1976 or 1977). An evaluation of land as prime agricultural land will also be undertaken in the near future.

4. Thermal Analysis of Building Insulation

- cooperator/users: Cornell Physical Plant Operations
Cornell Univ.; Public Utilities
- benefits/actions: Improved building insulation where required, with decreased energy losses and heating/cooling costs; possible survey implementation by utilities
- expected completion date: June 1979

With Program staff assistance, Cornell's Physical Plant Operations (PPO) contracted for an airborne thermal survey of campus steamlines (6th Semi-Annual Status Report, June 1975). After studying the thermal data for steamline leaks, personnel of the PPO requested that the Program utilize the data to evaluate roofing insulation of campus buildings. With these data as a focal point, the Program staff began a study to develop an airborne survey/analysis methodology which would characterize roofing materials as well as insulation needs. Toward this end, the Program requested NASA to overfly the campus area during the winter and spring of 1976. Only the spring mission was flown, and the data were not supplied to the Program until five months after the mission. These delays were accompanied by changes in personnel and initiation of projects with more immediate "payoffs." Further, during this period, many similar studies were conducted by other research groups in the United States and Canada. It is expected that the thermal investigation will be re-defined and re-initiated in the near future.

Spinoff Project

During the past six months, members of the Program staff have been involved in a non-NASA funded project which arose directly from a Program-sponsored investigation. As a consequence of earlier work on remote sensing strategies for inventorying dams, the U.S. Depart-

ment of the Interior, Office of Water Research and Technology is funding a one-year study, "Remote Sensing Assessment of Dam Flooding Hazards: Methodology Development for the New York State Dam Safety Program." This study will be ongoing through September 1978.

FUTURE PROJECTS

The Program staff is continually soliciting and screening new remote sensing demonstration projects. As noted, criteria for project acceptance are that the project must be, in some way, unique; that project acceptance would not be competing unduly with private companies or consultants; and that, if completed successfully, the project would produce tangible benefits or actions by definable users.

Among topics under current consideration are:

1. With the *New York State Department of Health*--as a guide for field surveys, conduct a comprehensive inventory of potential mosquito breeding sites in an urban area.
2. With the *Planning Board of Columbia County, N.Y.*--analyze the suitability of potential Hudson River shoreline recreation sites, which would be developed with spoil materials from river dredging by the U.S. Corps of Engineers.
3. With the *Board of Hudson River-Black River Regulating District*--use Landsat data to relate flood stages of Black River to actual area inundated and consequent agricultural losses.

Depending on user interest, personnel and available funds, any of these as well as other projects may be undertaken.

PROGRAM STAFF

The Program staff includes Prof. Ta Liang, principal investigator, Prof. Arthur J. McNair and Dr. Warren R. Philipson, co-investigators, Messrs. Thomas L. Erb and Brian L. Markham, research specialists, Ms. Josephine Ng, data analyst, Ms. Deborah Halpern, photographic laboratory technician, and Ms. Pat Webster, secretary. Prof. Donald J. Belcher and Dr. Ernest E. Hardy are general consultants to the Program and, for specific projects, assistance has been provided by many Cornell and non-Cornell personnel. Among those at Cornell, special mention is due Mr. Carl Diegert, of the School of Operations Research and Industrial Engineering. Students and others who have contributed to the Program staff effort over the past six months include David W. Adams, Jan P. Berger and Edward Schmidt III.

LIST OF APPENDICES

- A. Photo-Historic Evaluation of Revolutionary War Sites
- B. Wetland Analysis for Source of Encephalitis
- C. Assistance Project--Study of Salt Mine Problems
- D. M.S. Thesis--Monitoring Aquatic Vegetation with Aerial Photography
- E. Project-Related Correspondence
- F. Selected News Items/Program Paper
- G. Recent Seminars/Orientation Sessions
- H. Newsletter Recipients
- I. Recent Newsletters

APPENDIX A

**PHOTO-HISTORIC EVALUATION OF
REVOLUTIONARY WAR SITES**

Aerial Photos May Provide Answers to Questions

Stone Arabia Battle Area Study Received

An aerial photographic study of the Battle of Stone Arabia area which may have answered questions concerning the battle has been received by the Fulton County deputy historian.

The study was done through the Cornell University Remote Sensing Program funded by a NASA grant, according to Deputy Historian Lewis G. Decker.

Decker, who serves as chairman for the Battle of Stone Arabia symposium, said that a map with two overlays showing hedge rows, field boundaries and farm roads had been included in the report. These features were identified through soil drainage and crop anomaly analysis of aerial photographs, he said.

Through analysis, researchers had also found interesting tonal patterns in the area believed to be the site of Fort Paris, an American headquarters and stronghold during the battle, the exact location of which had never been determined.

The map also showed the site of Fort Keyser, a fortified stone house, and the probable area where American soldiers were buried. Shown on the map is the site of the monument to Col. John Brown, the commander of the American forces who was killed at the battle, and the location of the actual battle which is marked with a large glacial boulder inscribed in 1830 by Rufus Grider, a Mohawk Valley historian.

Decker said that the research program noted that because the Stone Arabia area consists primarily of glacial deposits which exhibit irregular soil drainage patterns, the evidence

for the location of Fort Paris and the burial site is not conclusive.

The university research team was approached with the idea of creating a map of the area during the summer, Decker said.

The Fulton County Yorkers Post had been asked by the Stone Arabia Battle Chapter, Sons of the American Revolution to build a miniature diorama of the battle earlier last year. The chapter and the Gloversville Historical Society then agreed to sponsor, along

with the Yorkers Post, a symposium on the battle.

Although much information was researched by the post using clippings from old Mohawk Valley newspapers and other written material concerning the period, many questions about the battle, such as the location of roads at that time and the site of the fort and burial area, remain-

ed unanswered.

Decker had known about the university's sensing program and contacted the university, hoping that some information could be obtained.

He said that a special presentation of the material obtained from the program as well as a publication compiled by the chapter, post and historical society concerning the battle will be displayed at the last symposium to be held at 7:30 Thursday night, March 30, at Roanay Memorial Library, St. Johnsville.

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MAP SHOWS (1) Stone Arabia Battle site marked with large glacial boulder and inscription; (2) site of Ft. Keyser (fortified stonehouse); (3) site of monument to Col. John Brown, commander of

the American forces, who was killed in the battle; (4) approximate site of Ft. Paris, American headquarters and stronghold during the battle.



Cornell University

REMOTE SENSING PROGRAM
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HOLLISTER HALL
ITHACA, NEW YORK 14853
(607) 256-4330, 256-5074

12 January 1978

Mr. Lewis G. Decker
Deputy Fulton County Historian
187 Bleecker Street
Gloversville, New York 12078

Dear Mr. Decker:

We are submitting the results of our aerial photographic study of the site of the Revolutionary War, Battle of Stone Arabia. The analysis was conducted under our NASA Grant, NGL 33-010-171, by Mr. Brian L. Markham, who was assisted by Mr. Jan P. Berger, Ms. Laurie B. Schuller and Mr. David W. Adams.

We have enclosed a portion of the Canajoharie, New York, U.S. Geological Survey topographic map (1:24,000 scale), along with two acetate overlays to the map. On one map overlay, we have compiled hedge rows and other semi-permanent field boundaries; and on the other overlay, we have compiled farm roads or trails which were not shown on the topographic map. These features were identified through stereoscopic analysis of contact prints of panchromatic (black-and-white) aerial photographs. The dates, scales, identification numbers and sources of the photographs are listed below, for your reference.

In general, hedge rows were identified from the summer (1960) photographs and checked with the spring (1968) photographs. Other field boundaries, that were observed in both the 1960 and 1968 photographs, were also delineated. Hence, the field boundaries included on the overlays are more-or-less permanent, at least through 1968. Although farm ownership can be interpreted from aerial photographs, it can normally be gotten more accurately from town or county tax maps.

Concerning the possible sites of mass burial and forts, we did not find any strong evidence for or against the suggested locations. Geologically, the Stone Arabia area consists primarily of glacial deposits which exhibit irregular soil drainage patterns. Since soil drainage and crop anomalies are principal photographic indicators of past structures or burial sites, the area is not easily analyzed. On the other hand, some interesting tonal patterns were observed in the area of the believed site of Fort Paris, as well as in one other location. Although the causes for these tonal anomalies are unknown, the locations are shown on the farm roads overlay.

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The capacity to identify historic features, such as burial or fort sites, is very much dependent upon the scale of photography and the conditions at the time of the photography, particularly the moisture conditions. It is possible that other photography (new or old) would provide additional information. There may be older (1940s) photographic coverage of the Stone Arabia area, and we will explore this possibility. Further, if you wish to contract to have the area flown with new photography, we would assist you in planning the mission.

We would appreciate being advised of how and to what extent the enclosed information is utilized.

Very truly yours,

Warren R. Philipson
Warren R. Philipson
Sr. Research Associate

WRP/pw

cc: Prof. Ta Liang

Encs.

Aerial Photographs Used in Analysis of Stone Arabia

DATE	SCALE	ID NUMBERS ^{1/}	SOURCE
2 Sept 60	1:20,000	EHG-1AA-186 to 190 (4 photos)	U.S. Dept. Agriculture ^{2/}
		EHG-1AA-211 to 214 (4 photos)	
19 Apr 68	1:24,000	NY-8-1549-1149 to 1151 (3 photos)	Lockwood Mapping ^{3/}

^{1/} For non-stereoscopic coverage: photos EHG-1AA-187, 189, 212 and 214; or photo NY-8-1549-1150

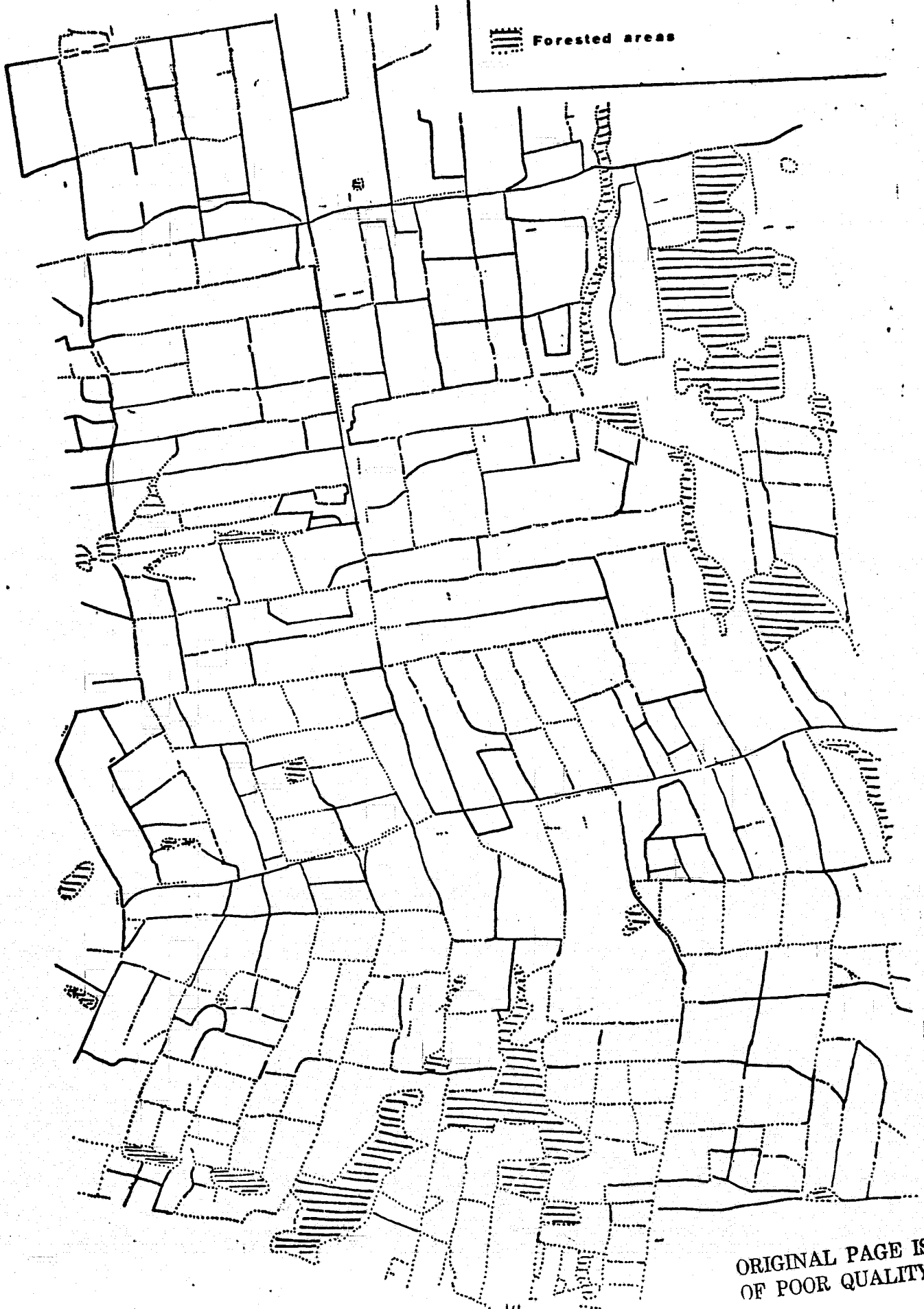
^{2/} Aerial Photography Field Office, Administrative Services Div., ASCS-USDA, 2505 Parley's Way, Salt Lake City, Utah 84109 (cost: \$2/photo)

^{3/} Lockwood Mapping, Inc., 580 Jefferson Rd., Rochester, New York 14623 (cost: probably about \$10/photo)

..... Hedge rows

— Other field boundaries

▨ Forested areas

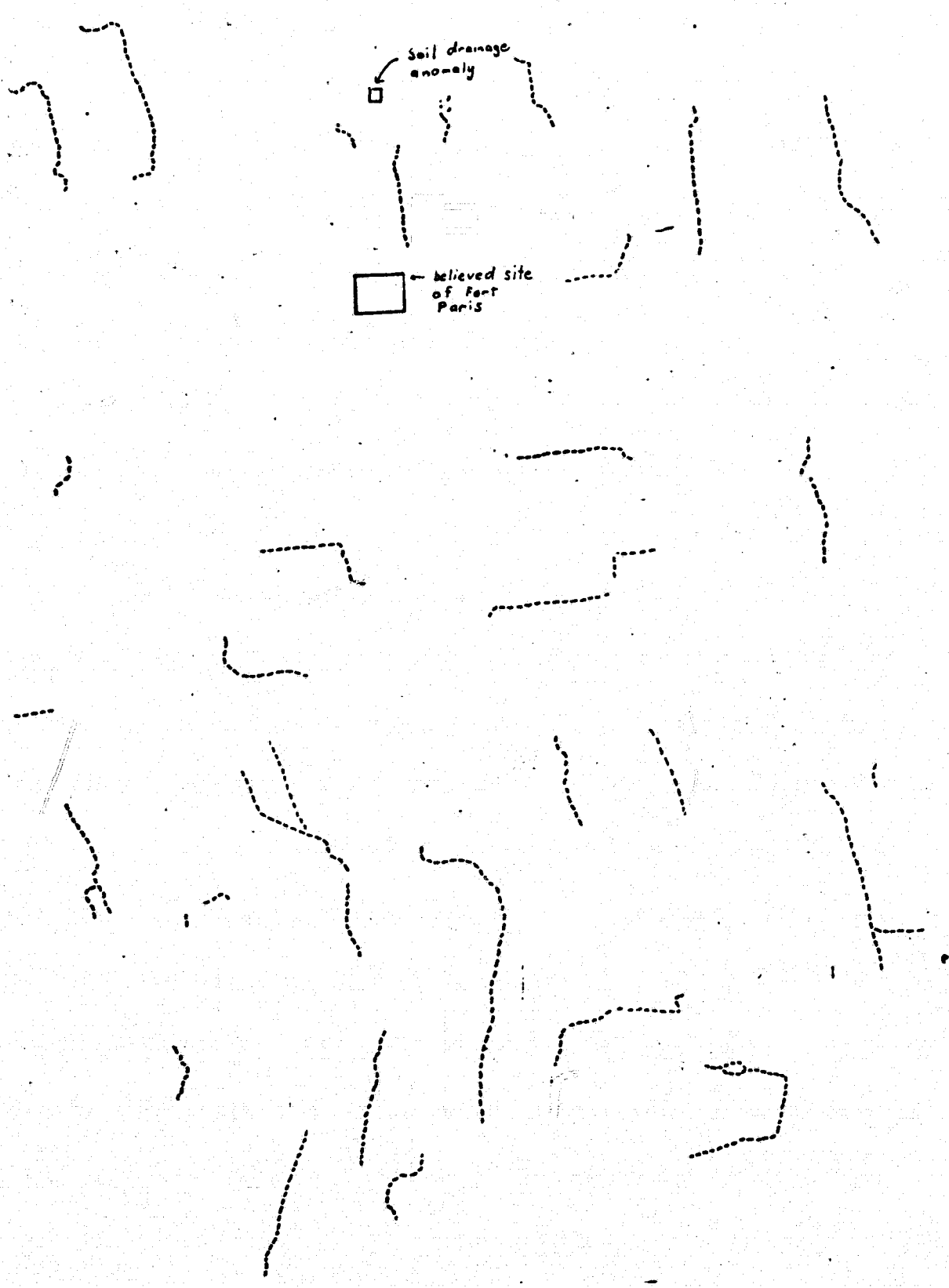


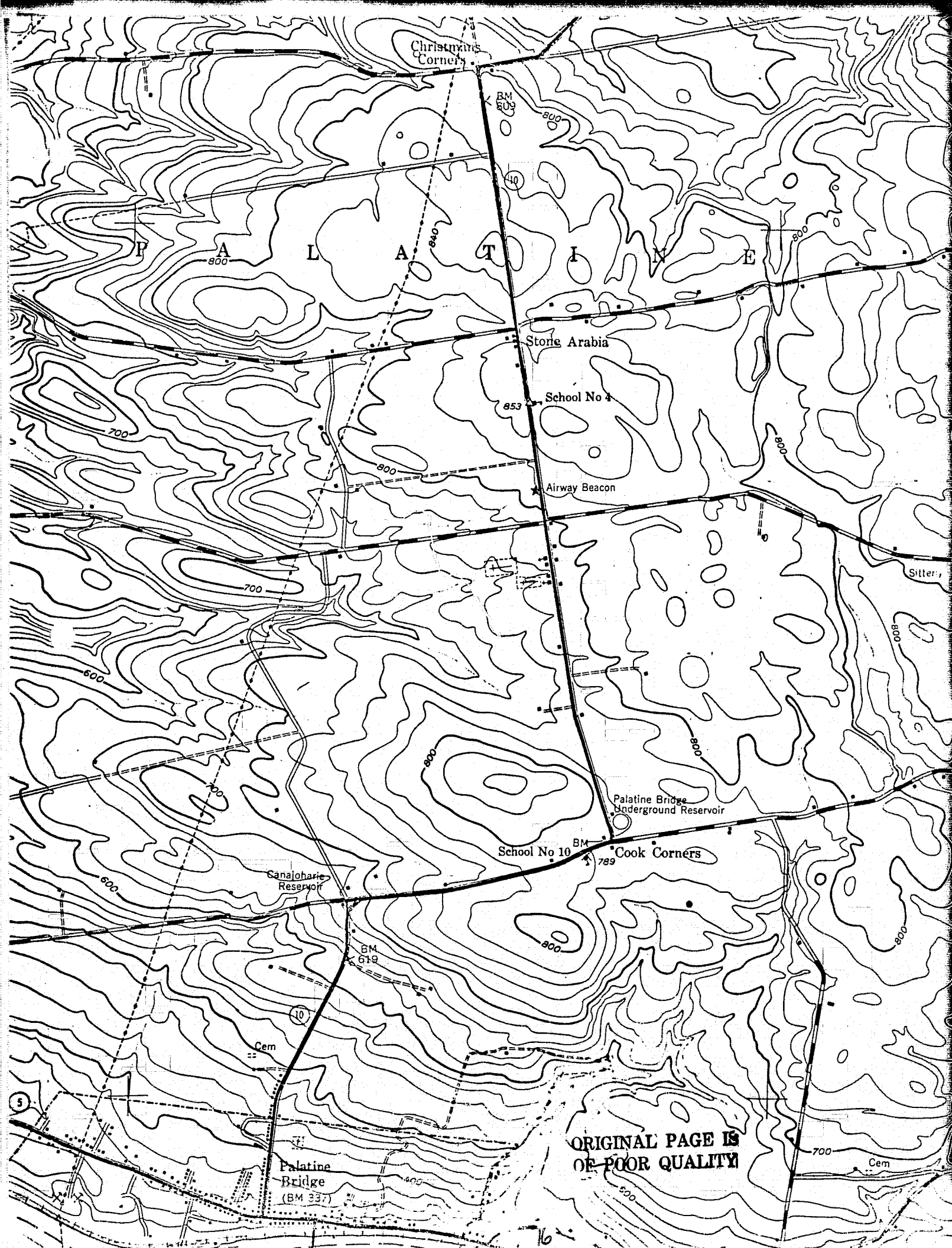
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14

--- Farm roads/trails





Christmas Corners

BM 803

P

800

L

A

T

I

N

E

Stone Arabia

School No 4

853

Airway Beacon

700

800

700

600

700

800

800

800

Sitter

Palatine Bridge Underground Reservoir

School No 10

BM 789

Cook Corners

Canajoharie Reservoir

BM 619

Cem

800

800

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Palatine Bridge (BM 337)

700

Cem

500

16

APPENDIX B
WETLAND ANALYSIS FOR SOURCE OF
ENCEPHALITIS



Cornell University

REMOTE SENSING PROGRAM
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HOLLISTER HALL
ITHACA, NEW YORK 14853
(607) 256-4330, 256-5074

May 31, 1978

Dr. Charlie Morris
N.Y.S. Dept. of Health
Room 133, Illick Hall
College of Environmental Science and Forestry
Syracuse, New York 13210

Dear Charlie:

Enclosed are the results of my aerial photographic study of the Toad Harbor Swamp in Oswego County, N.Y. This study, like the previous analysis of the adjacent Big Bay Swamp, was conducted under our NASA Grant NGL 33-010-171. Together, the two studies should demonstrate the kinds of photo-derivable information that might be useful for identifying Culiseta melanura mosquito breeding sites.

Included are five overlays to the 1:24,000 scale, U.S. Geological Survey topographic maps (Mallory and Cicero) that depict the swamp. There is one overlay for each of the following: (1) cover types derived from May 1967 aerial photographs (photos described below); (2) areas of uniform cover type derived from August 1972 aerial photographs; (3) areas of conifers (evergreen), mixed conifers and deciduous trees, and deciduous trees derived from March 1973 aerial photographs; (4) relative canopy closure; and (5) relative canopy height, both derived from May 1967 and September 1955 aerial photographs. A legend describing the overlay separations and symbols is enclosed as a single sheet.

In general, the separations were based on stereoscopic analysis, using a 2/4 power stereoscope with the 1955 and 1967 photographic contact prints, and a variable power stereoscope and light table with the 1972 and 1973 photographic films. The May 1967 photographs were thought to be most useful for delineating cover types. The trees were partially foliated, and it was still possible to see through the canopy to determine the underlying conditions. Also, evergreen coniferous trees were still distinguishable from deciduous trees. The photographs comparable to the July 1965 coverage of Big Bay Swamp were flown in late October 1964 (see below) after partial leaf fall, and were thus no more valuable than the May 1967 photographs for determining canopy closure and height. Thus, the May 1967 photographs were used to determine these factors, using the September 1955 photographs as a back-up.

The Toad Harbor Swamp was generally similar to the Big Bay Swamp, both being dominated by relatively small crowned trees of various heights and spacings (cover types 1 & 4 with their variations), with somewhat

Dr. Charlie Morris

May 31, 1978

larger crowned trees towards the edges and near stream channels (2, 3, 5, 6). The Toad Harbor Swamp did have a larger number of evergreen coniferous trees (cover type 7) than the Big Bay Swamp. In addition, the October 1964 photographs presented evidence that some deciduous conifers (Tamarack?) were present in some areas (indicated on May 1967 cover types, overlay). The Toad Harbor Swamp also included some areas of emerged vegetation, and previously drained and cleared areas, now reverting to wooded wetland.

The same problems in analyzing the photographs (resulting in potentially excessive detail and erroneous heights) and in the limitations of the data sources (timeliness of photography) were present as for the Big Bay Swamp analysis (described in letter of March 7, 1978).

Thirty-five millimeter slides were made of the enclosed overlays, and these are currently being processed. If you need a copy of these slides, please contact us. Also, please keep us informed of the results of your field surveys, and your findings as regards the value of the airphoto-derived data. If you encounter any problems, please feel free to contact us (preferably before June 23, as after that date it will be more difficult to contact me).

Yours truly,

Brian L. Markham

Brian L. Markham
Research Specialist

BLM/pw

cc. Prof. Ta Liang
Dr. Warren R. Philipson

Encs.

Aerial Photographs Used in Analysis of Toad Harbor Swamp

DATE	SCALE	FILM TYPE	ID NUMBERS	SOURCE
6 Sept 55	1:20,000	black and white	ARY-2P-114 to 117, 189 to 191	U.S. Dept. Agriculture <u>1/</u>
26 Oct 64	1:20,000	black and white	ARY-1EE-5 to 8	U.S. Dept. Agriculture <u>1/</u>
13 May 67	1:24,000	black and white	NY-1-1380-907 to 909, 1012 to 1013	Lockwood Mapping <u>2/</u>
20 August 72	1:130,000	color infrared	Flight 72-145 Frames 3356-3357	NASA <u>3/</u>
23 March 73	1:130,000	color infrared	Flight 73-041 Frames 800-801	NASA <u>3/</u>

- 1/ Aerial Photography Field Office, Administrative Services Div., ASCS-USDA, 2505 Parley's Way, Salt Lake City, Utah 84109.
- 2/ Lockwood Mapping, Inc., 580 Jefferson Rd., Rochester, New York 14623.
- 3/ EROS Data Center, Sioux Falls, South Dakota 57198.

Toad Harbor and Big Bay Swamp Cover Types
(May 1967 aerial photographs)

Type #*	Description**
1	Relatively tall, small crowned trees (most approximately same height) with nearly 100% canopy closure. Very smooth uniform texture on airphotos. (1' is same but somewhat lighter).
1a	Same but somewhat lower height.
1b	Same but somewhat more open canopy and lower height. (1b' is same but somewhat darker).
1c	Similar trees but very low and open. (1c' is same but somewhat darker).
2	Tall, widely spaced irregular crowned trees, crown size generally large, but variable.
3	Moderately tall, closely spaced relatively large crowned trees--nearly 100% canopy closure. Very uniform appearances (all one species?).
4	Moderately low small crowned trees with semi-open canopy. Generally light toned trees. Tree heights somewhat more irregular than 1b. (4' has a few conifers intermixed).
4a	Same, but somewhat taller.
4b	Same, but somewhat lower.
5	Somewhat irregular height, though generally tall, moderate-size crowned trees with relatively closed canopy; mixed brown types, perhaps with predominance of the type found in 3'.
5a	Same, but somewhat more open.
6	Tall, larger crowned trees generally occurring along stream channels. Generally lighter tones (possibly influenced by somewhat drier soils along channels?).
7	Very dark toned (coniferous?) moderately tall trees.
7a	Similar to 7 but lower trees.
8	Small crowned trees, very open canopy.
9	Relatively large crowned trees--low and sparse.
10	Marginally wetland wooded areas--apparently drier.
11	Non-wooded wetland areas. Probably a mixture of emerged vegetation and low shrubs. Generally light tones.
12	Dark-toned areas of wetland with mixtures of shrubs and other vegetation. Areas apparently cleared and ditched for 'muckland' farming, but abandoned--now returning to wooded wetlands.
U	Upland islands.

* Mixed cover types indicated by a hyphen, e.g., 2-5.

** All cover types deciduous unless otherwise indicated.

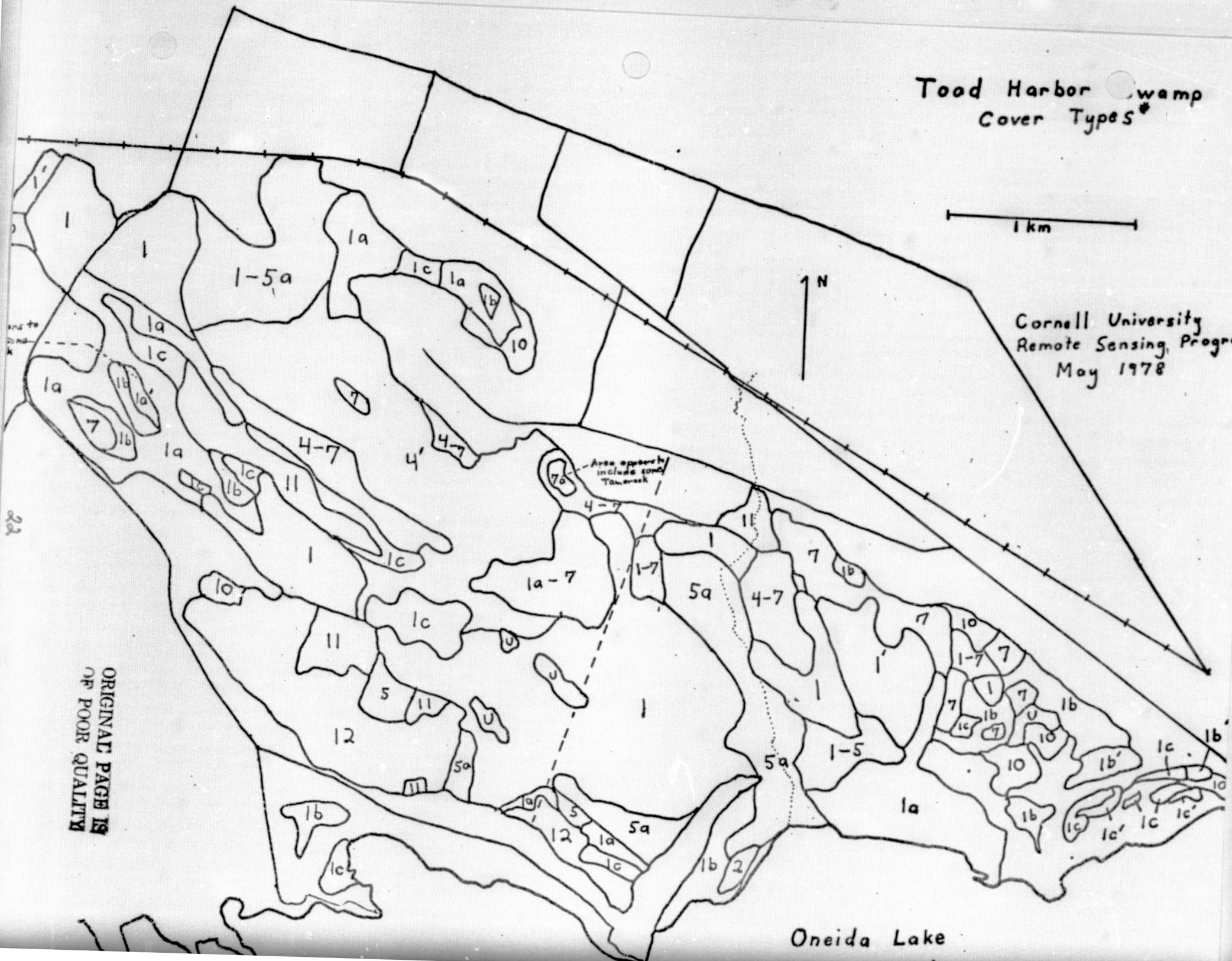
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Toad Harbor Swamp
Cover Types

1 km

N

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May 1978



Oneida Lake

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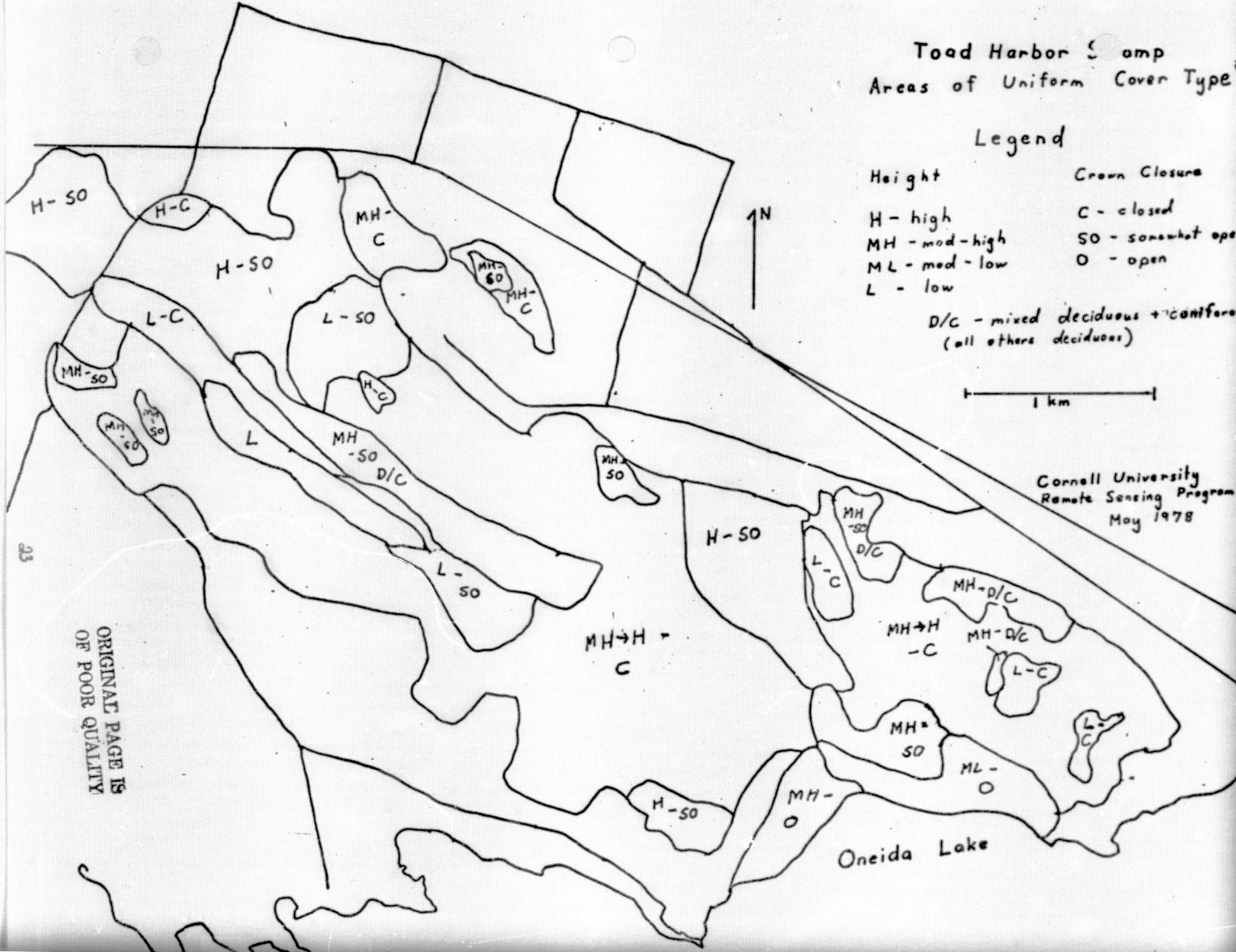
Toad Harbor Swamp Areas of Uniform Cover Type

Legend

Height	Crown Closure
H - high	C - closed
MH - mod-high	SO - somewhat open
ML - mod-low	O - open
L - low	
D/C - mixed deciduous + coniferous (all others deciduous)	

1 km

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May 1978



23

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Toad Harbor Sump

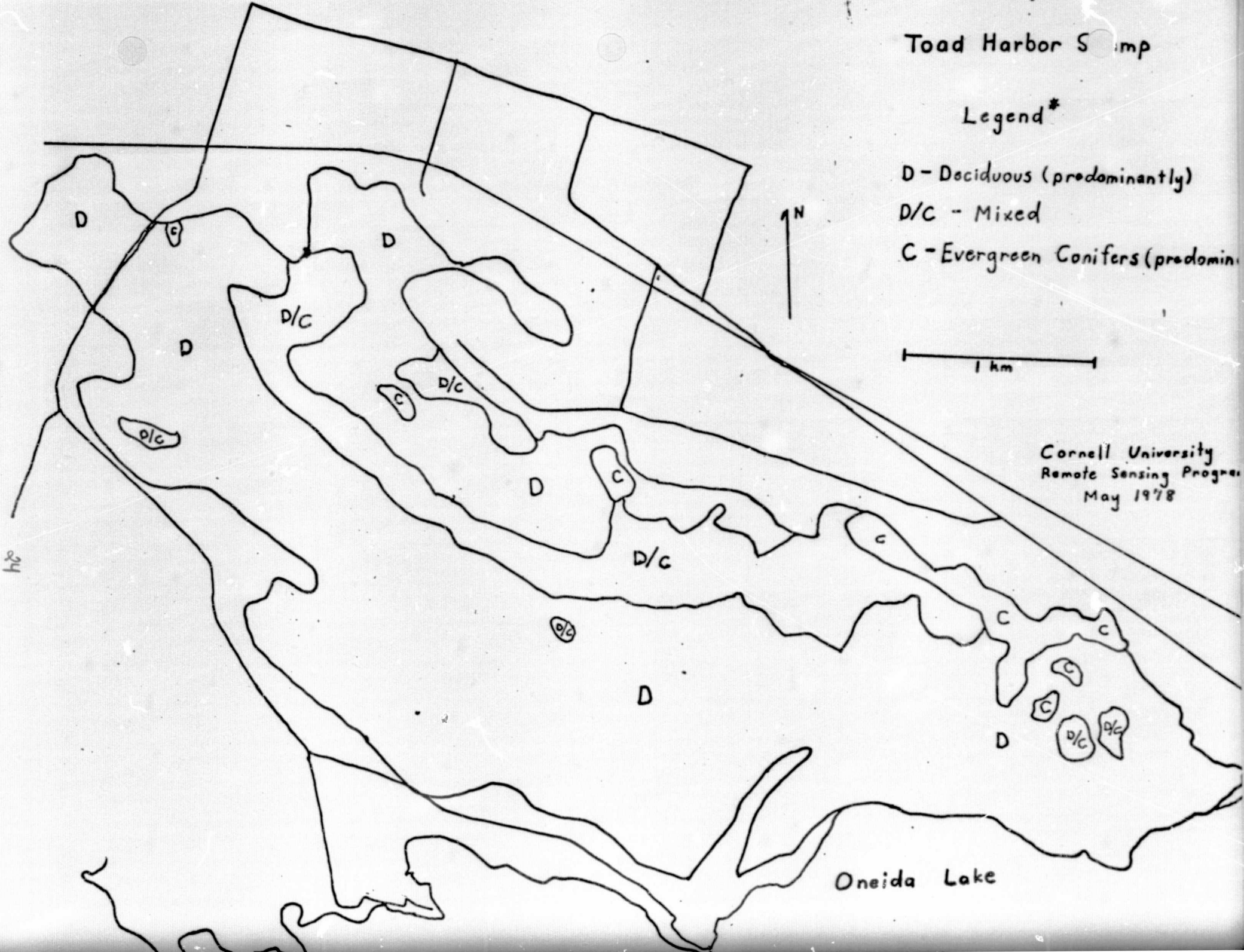
Legend*

- D - Deciduous (predominantly)
- D/C - Mixed
- C - Evergreen Conifers (predominant)

N

1 km

Cornell University
Remote Sensing Program
May 1978



h2

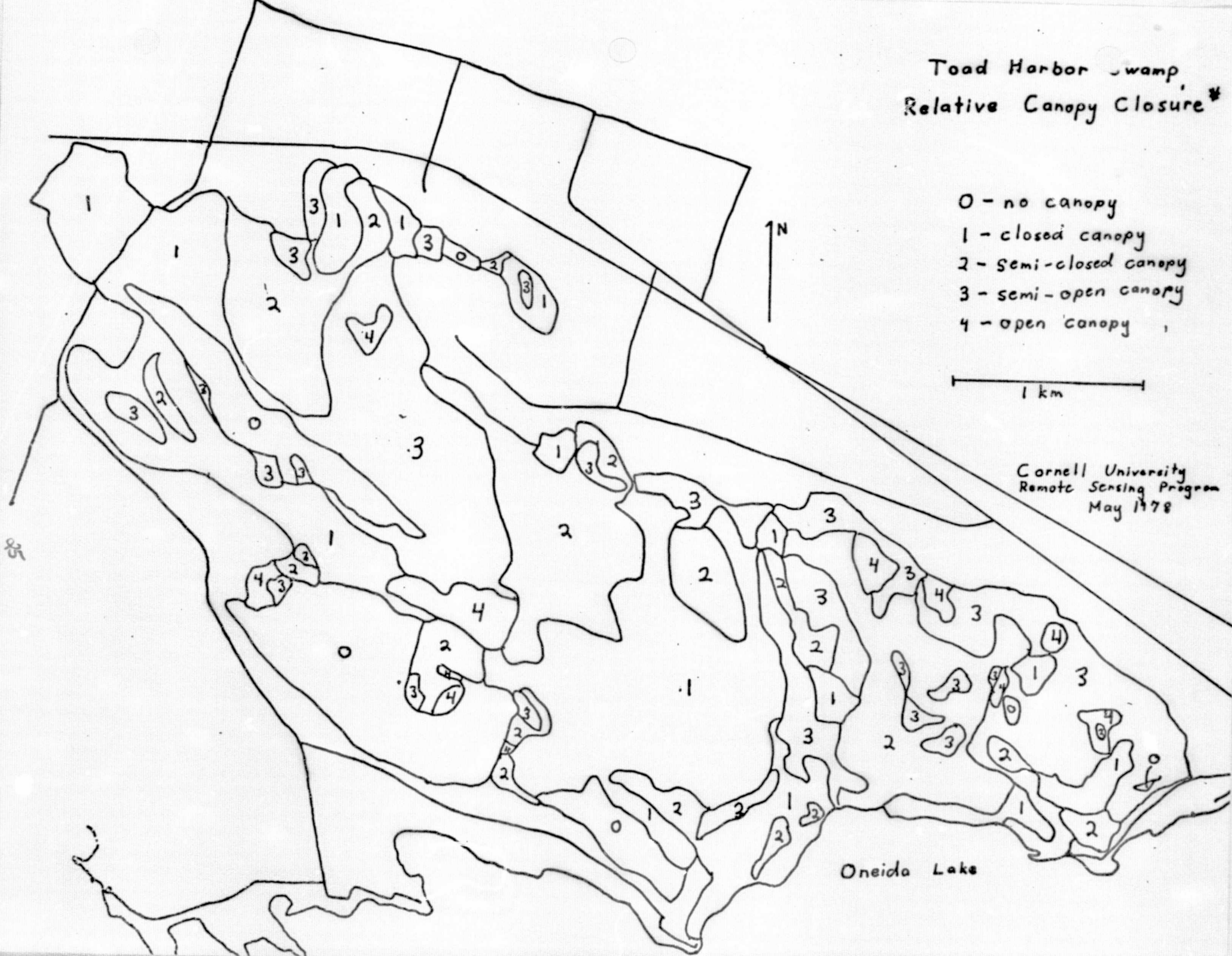
Oneida Lake

Toad Harbor Swamp,
Relative Canopy Closure*

- 0 - no canopy
- 1 - closed canopy
- 2 - semi-closed canopy
- 3 - semi-open canopy
- 4 - open canopy

1 km

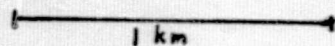
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May 1978



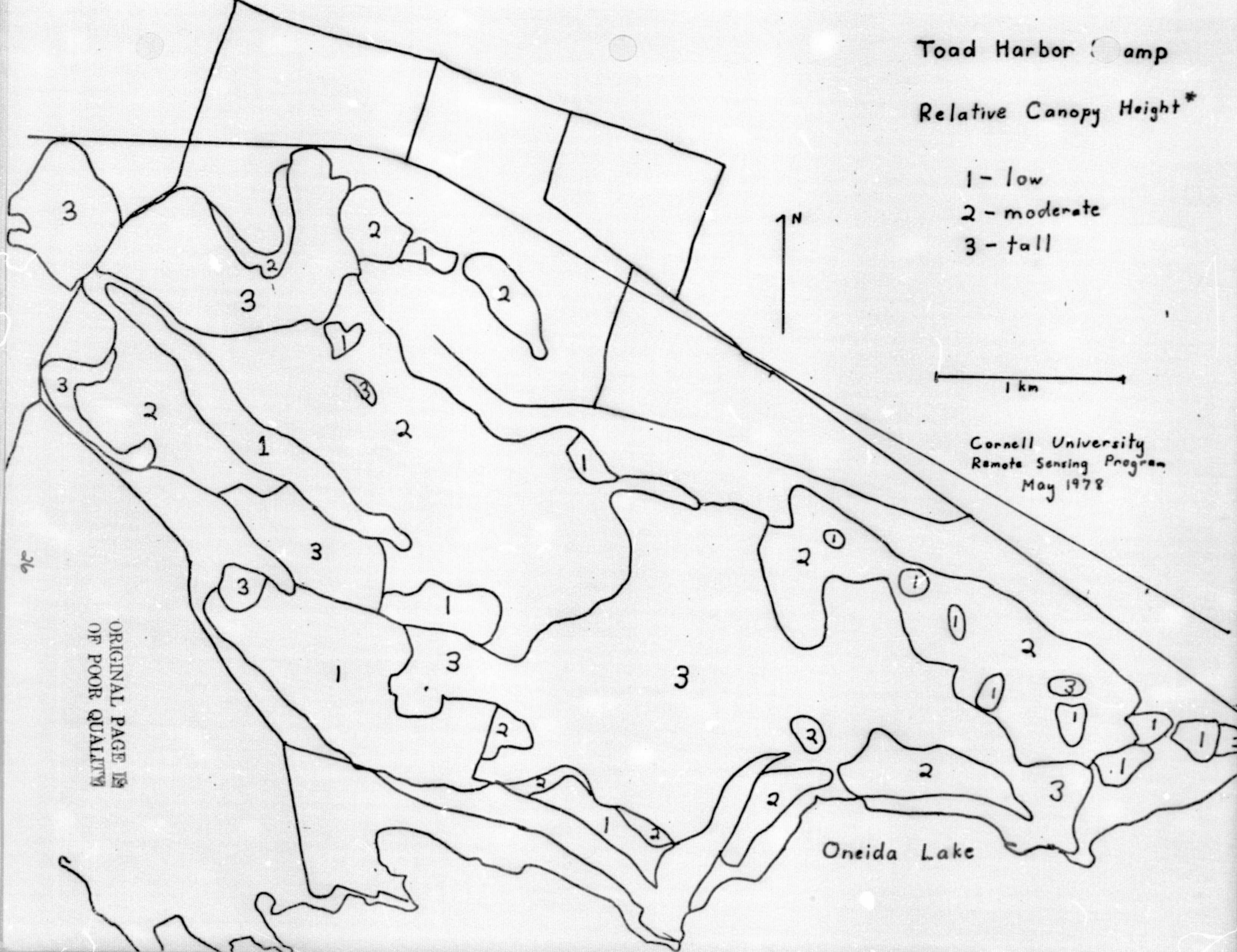
Toad Harbor Camp

Relative Canopy Height*

- 1 - low
- 2 - moderate
- 3 - tall



Cornell University
Remote Sensing Program
May 1978





Cornell University

REMOTE SENSING PROGRAM
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING
HOLLISTER HALL
ITHACA, NEW YORK 14853
(607) 256-4330, 256-5074

March 7, 1978

Dr. Charlie Morris
N.Y.S. Dept. of Health
Room 133, Illick Hall
College of Environment Science and Forestry
Syracuse, N.Y. 13210

Dear Charlie:

Enclosed are the results of our aerial photographic study of the Big Bay Swamp in Oswego County, N.Y. As you know, I conducted this analysis under our NASA Grant, NGL 33-010-171, in an effort to demonstrate the information derivable from aerial photographs that might be useful for identifying Culiseta melanura mosquito breeding sites.

Included are both slides and Mylar copies of five overlays to the 1:24,000 scale, U.S. Geological Survey topographic maps (Mallory, Cicero, Central Square) that depict the swamp. There is one overlay for each of the following: (1) cover types derived from May 1967 aerial photographs (photos described below); (2) cover types derived from July 1965 aerial photographs; (3) areas of uniform cover type derived from August 1972 aerial photographs; and (4) relative canopy closure and (5) relative canopy height, both derived from July 1965 aerial photographs. A legend describing the overlay separations and symbols is enclosed as a single sheet. In general, the separations were based on stereoscopic analysis, using a 2/4 power stereoscope with the 1965 and 1967 photographic contact prints, and a variable power stereoscope and light table with the 1972 photographic film. In general, the May 1967 photographs were thought to be most useful for delineating cover types. The trees were partially foliated and it was still possible to see through the canopy to determine the underlying conditions. The July 1965 photographs were thought to be more useful for determining canopy closure and height as the trees were completely foliated.

There was a tendency to place areas that appeared only slightly different from surrounding areas into another cover type. Lacking ground information, I had few guidelines to indicate to what degree observed differences were significant. As such, these separations may be too detailed for your purposes. The overlays depicting canopy closure and relative height might be useful for distinguishing the more important differences. Estimating vegetative height in certain areas was difficult as there were few reference points available, i.e., the ground or water beneath the trees was not visible.

As most of the information was derived from 11 to 13 year old photographs, it may not be completely representative of present conditions. There is more recent aerial photographic coverage of this area, although we do not have it; however, it appears that most of this photography was flown at the wrong time of the year (no foliage) for interpreting the factors of interest. Recently it has come to my attention that there should be 1:24,000 scale April or May 1977 color aerial photographic coverage of the area which may be suitable for this study. I will explore the possibility further.

As mentioned, we suggest that you try projecting our data onto your field map. The overlays can be projected with an overhead projector, or you could use the 35 mm slides which are also enclosed. It is generally best to project onto a rear projection screen, however, a white wall or piece of white cardboard should work. I wish you luck in matching the map scales.

If you find that our information looks potentially valuable for defining Culiseta melanura breeding sites, we can prepare similar overlays for the adjacent Toad Harbor Swamp.

Please keep us informed and please feel free to contact us about any problems you may encounter.

Yours truly,

Brian L. Markham

Brian L. Markham
Research Specialist

BLM/pw

cc: ✓ Dr. Warren R. Philipson
Prof. Ta Liang

Encs.

Aerial Photographs Used in Analysis of Big Bay Swamp

DATE	SCALE	FILM TYPE	ID NUMBERS	SOURCE
2 July 65	1:20,000	black and white	ARY-4EE-4 to 7	U.S. Dept. Agriculture <u>1/</u>
13 May 67	1:24,000	black and white	NY-1-1380-861 to 863	Lockwood Mapping <u>2/</u>
20 August 72	1:130,000	color infrared	Flight 72-145 Frames 3356-3357	NASA <u>3/</u>

1/ Aerial Photography Field Office, Administrative Services Div., ASCS-USDA, 2505 Parley's Way, Salt Lake City, Utah 84109.

2/ Lockwood Mapping, Inc., 580 Jefferson Rd., Rochester, New York 14623.

3/ EROS Data Center, Sioux Falls, South Dakota 57198.

Big Bay Swamp Cover Types
(July 1965 and May 1967 aerial photographs)

Cover 7/65	Type #* 5/67	Description **
1	1	Relatively tall, small crowned trees (most approximately same height) with nearly 100% canopy closure. Very smooth uniform texture on airphotos.
	1a	Same but somewhat lower height.
	1b	Same but somewhat more open canopy and lower height. (1b' is same but somewhat darker).
	1c	Similar trees but very low and open.
2	2	Tall, widely spaced irregular crowned trees, crown size generally large, but variable.
3	3	Moderately tall, closely spaced relatively large crowned trees--nearly 100% canopy closure. Very uniform appearances (all one species?).
4	4	Moderately low small crowned trees with semi-open canopy. Generally light toned trees.
4a	4a	Same, but somewhat taller.
4b	4b	Same, but somewhat lower.
5	5	Somewhat irregular height, though generally tall, moderate-size crowned trees with relatively closed canopy; mixed crown types, perhaps with predominance of the type found in '3'.
5a		Same, but somewhat more open.
5b		Similar, but lower height and more open.
6	6	Tall, larger crowned trees generally occurring along stream channels. Generally lighter tones (possibly influenced by somewhat drier soils along channels?).
-	7	Very dark toned (coniferous?) trees.
-	8	Small crowned trees, very open canopy.
-	9	Relatively large crowned trees--low and sparse.
-	10	Marginally wetland wooded areas--apparently drier.
7	-	Relatively open mixture of tall trees (lighter tones).
8	-	Similar to 1b, except lighter tones (may be due to lower moisture, 1965 was dry).
8a		Similar to 1c, except lighter tones.
9	-	Very light toned trees.
U	U	Upland islands.

* Mixed cover types indicated by a hyphen, e.g., 2-5.

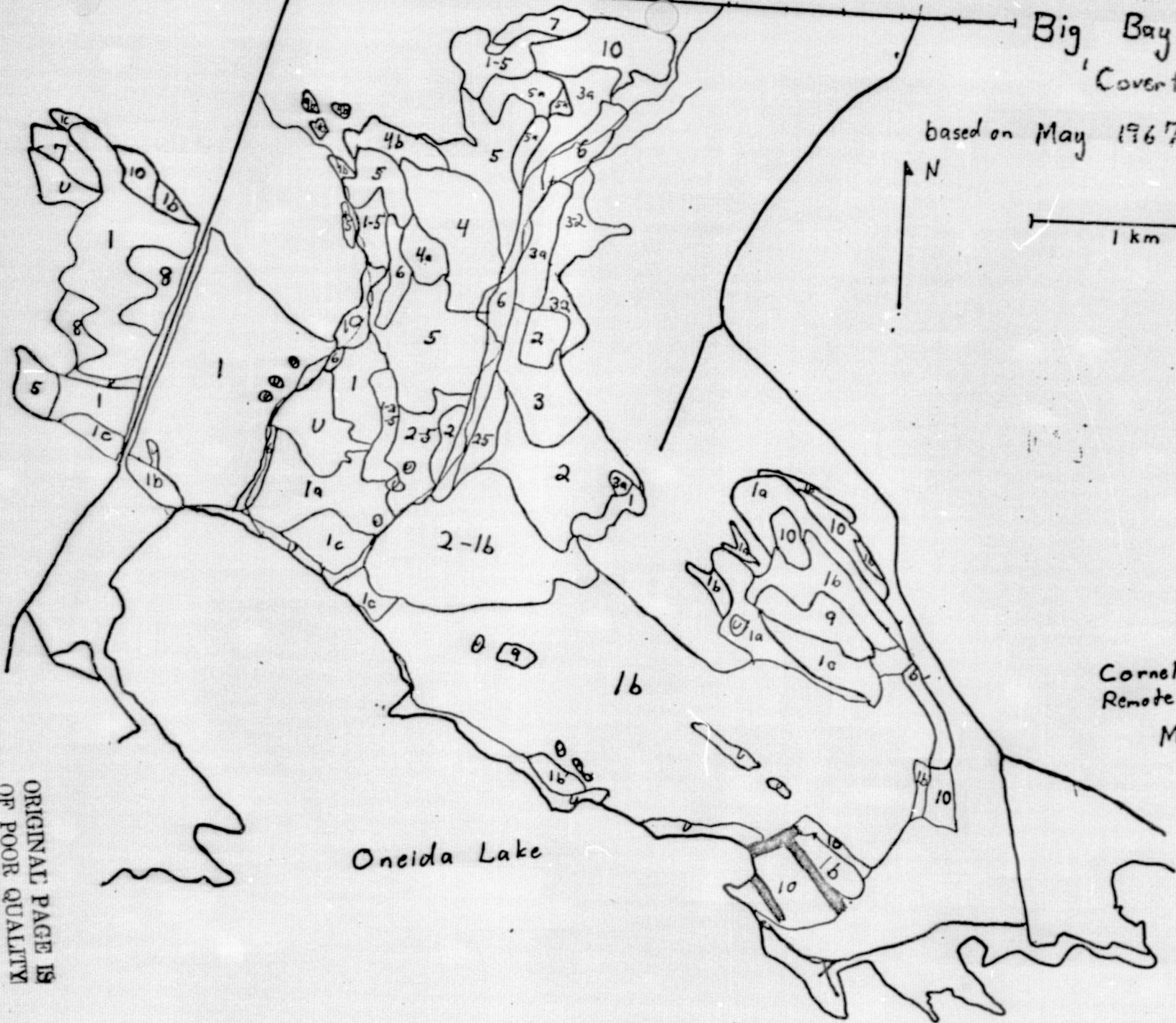
** All cover types deciduous unless otherwise indicated.

Big Bay Sump
'Cover types'

based on May 1967 Aerial Photos

N

1 km



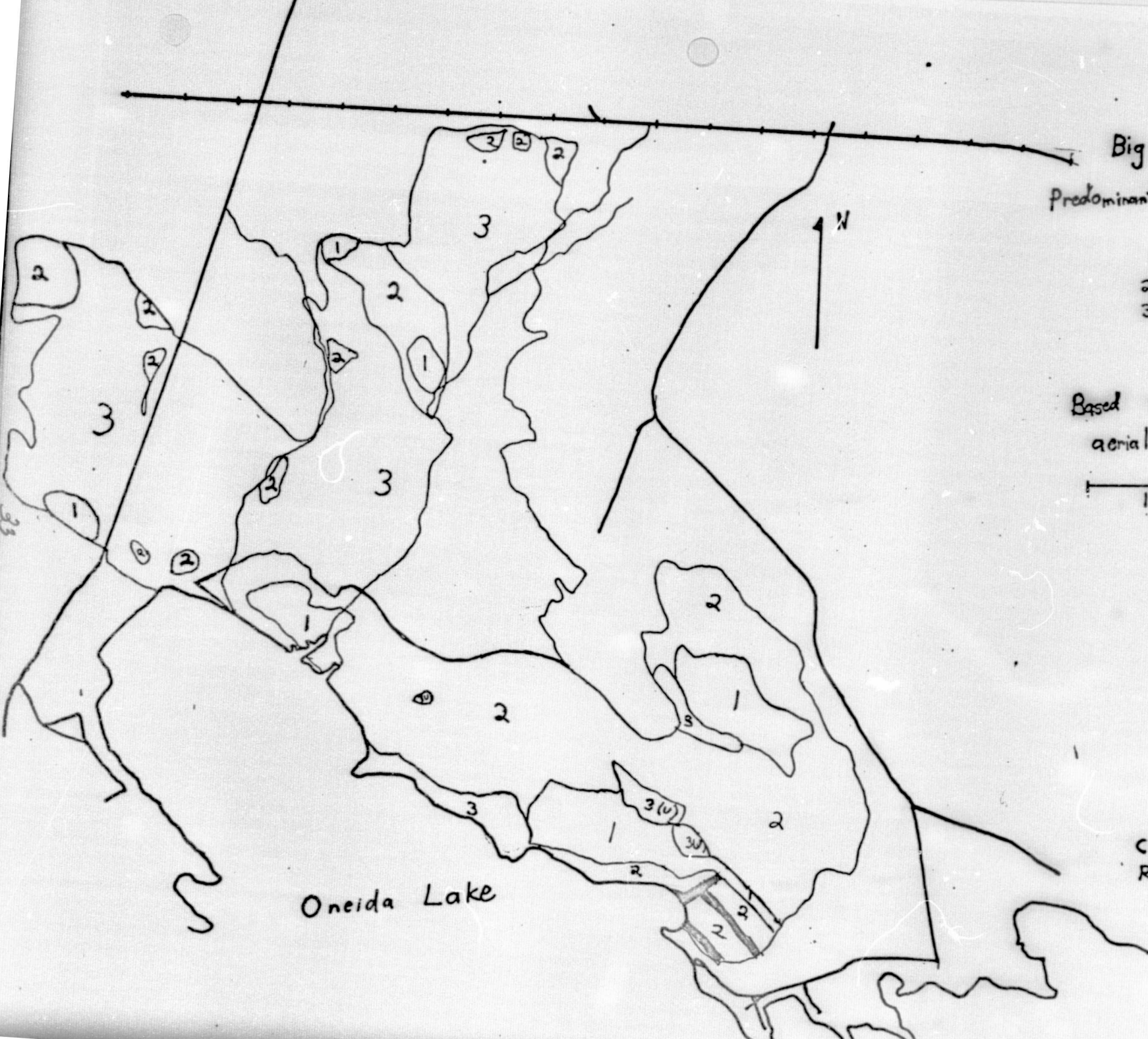
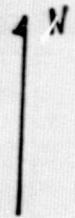
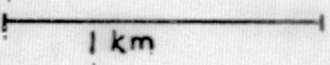
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March 1978

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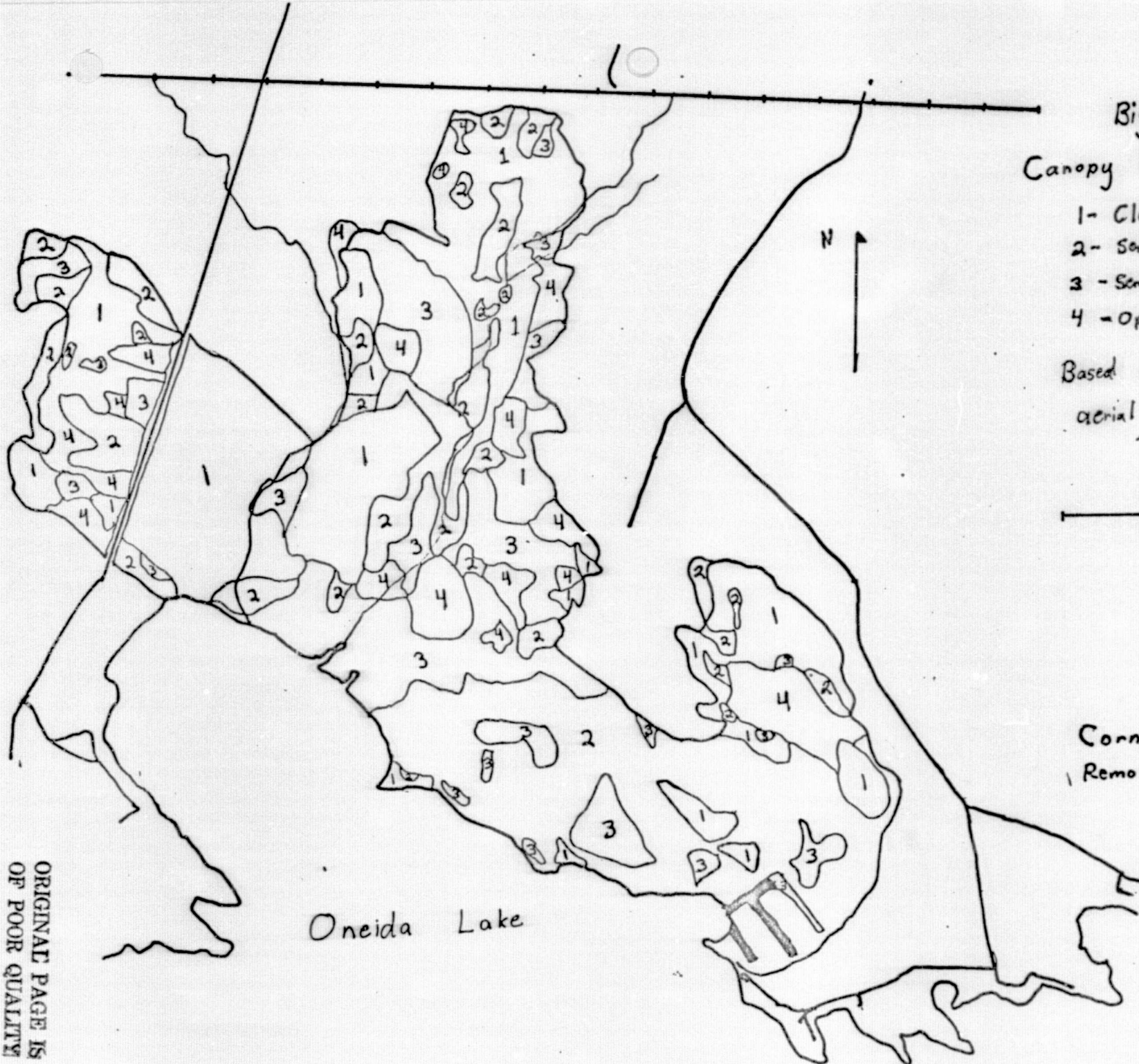
Big Bay Swamp
Predominant Canopy Height
(relative)

- 1 - low
- 2 - medium
- 3 - high

Based on July 1965
aerial photographs



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Remote Sensing Prog
March 1978



Big Bay Swamp
Canopy Closure (relative)

- 1 - Closed
- 2 - Semi-closed
- 3 - Semi-open
- 4 - Open

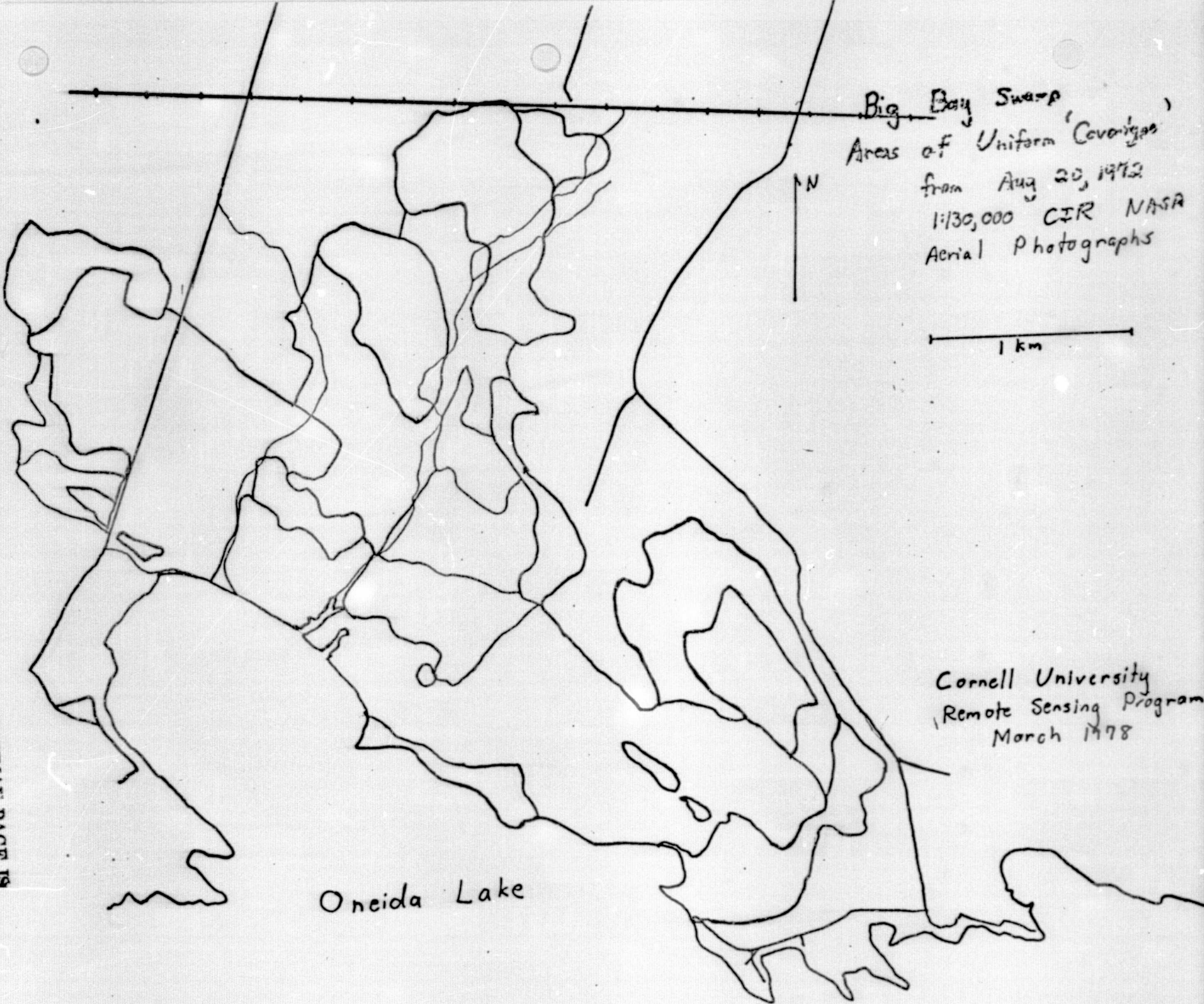
Based on July, 1965
aerial photographs

1 km

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March 1978

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Big Bay Swamp
Areas of Uniform Coverage
from Aug 20, 1972
1:130,000 CIR NASA
Aerial Photographs

1 km

Cornell University
Remote Sensing Program
March 1978

Oneida Lake

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APPENDIX C
ASSISTANCE PROJECT--STUDY OF SALT
MINE PROBLEMS

*Salt Sales Office:
191 Portland Pt. Road
Lansing, N.Y. 14882
Salt Mine Office:
Lansing, New York
607/533-4221*

March 9, 1978

Mr. Warren Philipson
Remote Sensing Program
Hollister Hall,
Cornell University
Ithaca, New York 14850

Dear Mr. Warren:

Thank you for allowing me to spend a day using your photos and equipment. I was impressed by the equipment, and by the expertise and knowledge your people have.

Also, thank you for devoting so much time and effort to our problem. A special note of thanks goes to Tom Erb, of course.

I have sent some information and two maps for Tom to work with. If there are any questions or if I can be of any further help to you, please let me know.

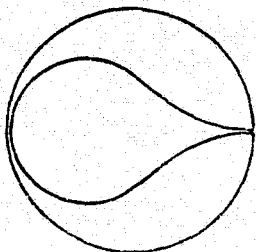
Again, thank you.

Sincerely,

David B. Plumeau

David B. Plumeau
Mine Engineer
Cargill, Inc.

DBP:dlm



— EXCERPTS —

DATE: May 9, 1978
TO: Gary B. Petersen
FROM: David B. Plumeau

Dear Gary:

The following report summarizes the geology study I've done during the past year. I feel that it explains the geological setting of the mine property as thoroughly as our time permits. It is a good paper for new employees to read to familiarize themselves with the geology. Of course, a much more detailed study could have been done, but that would have been a research exercise, with little additional benefit for Cargill. The study is by no means over, but the future work will be limited to a much smaller scale than the past year has seen.

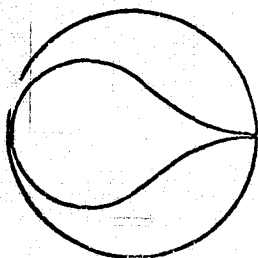
Regards,

David B. Plumeau

Dave Plumeau
Mining Engineer

DP/taa

cc: Joe Pinkham
Nick Nicola
Jack Parker



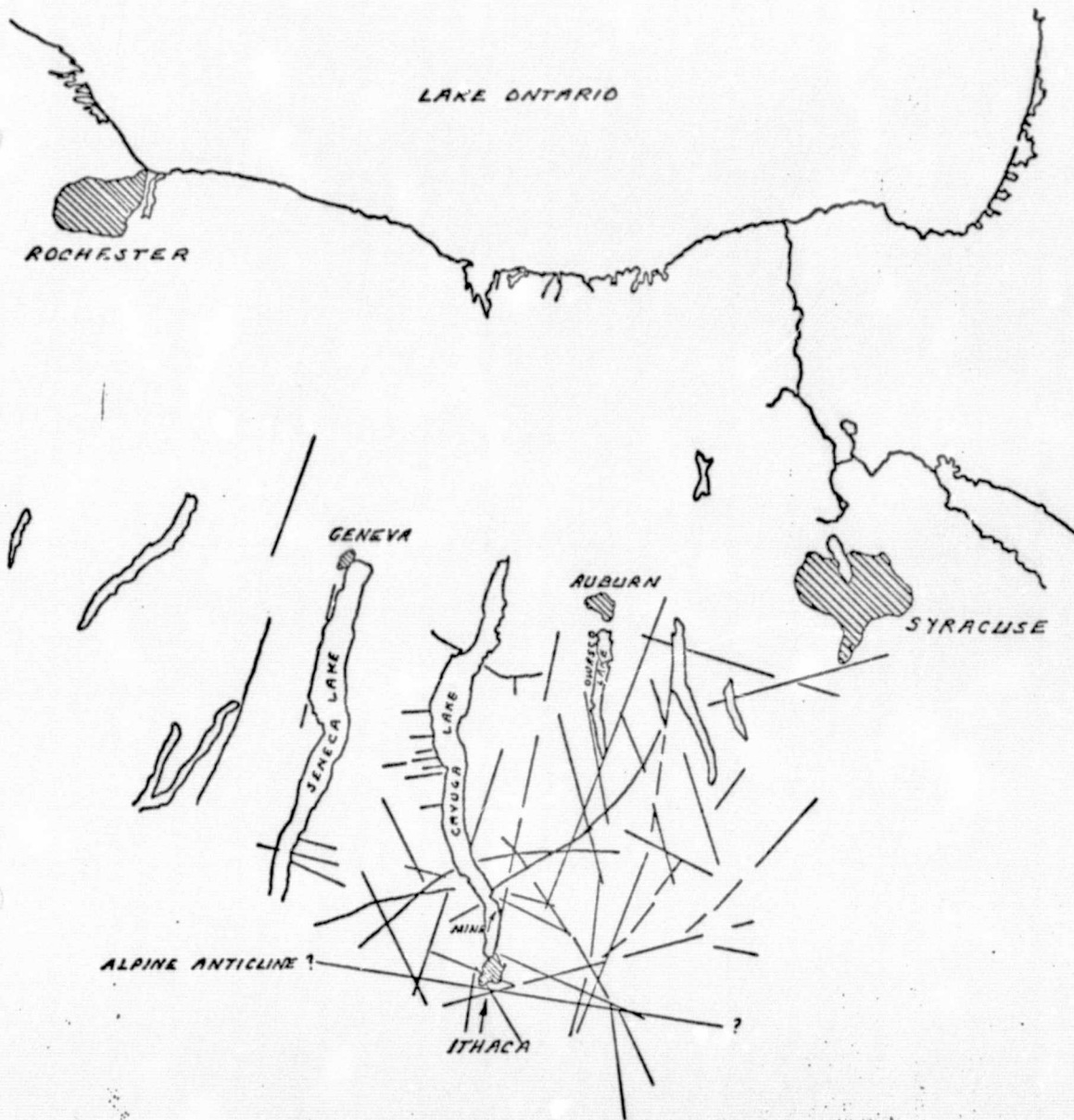


FIGURE 6
 LINEAMENTS IN CAYUGA LAKE REGION
 TRACED FROM LANDSAT SATELLITE IMAGE

Figure 6 is a map of the Cayuga Lake Basin traced from an image made by the Landsat Satellite. It is easy to see that many linear features crisscross the landscape. Most of them are surface indications of geologic features. The mine property is bounded by one on the north (running roughly east-west) and is cut by one running north-south near the main shaft. How the features affect mining is not yet known.

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Using high and low level aircraft photos, quite a number of linear features have been identified in the mine area. These features are probably surface indications of joint planes in the bedrock. When these features are drawn on a mine map, it is seen that they do correlate to some of the areas of bad roof. (see Figure 7) The red circles are intersections of the linears which will be watched during mining of the E-2, P-5 and P-6 panels to see if there is definite correlation between surface features and underground conditions. The No. 17 core hole was drilled on one of these linear features. Apparently, the permeability created by the joint planes (which show up as a surface linear) promoted the gas blow out experienced during cementing of the core hole. Needless to say, future core holes will not be located on linear features. Work will continue with the airphoto lineament analysis over the next year to try to accurately predict mining conditions from surface indications.



Figure 7. Roof conditions and surface lineaments in "No.6" salt seam.

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APPENDIX D

M.S. THESIS--MONITORING AQUATIC
VEGETATION WITH AERIAL PHOTOGRAPHY

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MONITORING AQUATIC VEGETATION

WITH

AERIAL PHOTOGRAPHY

A Thesis

**Presented to the Faculty of the Graduate School
of Cornell University**

**in Partial Fulfillment for the Degree of
Master of Science**

by

Brian Lee Markham

May 1978

ABSTRACT

Large scale color and color infrared aerial photographs were used to study the changes in aquatic vegetation that occurred in a eutrophic lake in New York State, between 1968 and 1976. Photo-interpretive techniques, supplemented by ground data, were used to define a classification system and map the aquatic vegetation present for each year with available photographic coverage. The vegetative areas for each year were determined from the vegetation maps (by type when possible), and the changes in these areas were analyzed.

The study found that the total area of emersed and floating vegetation changed relatively little between 1968 and 1976; however, changes in the composition and location of the emersed and floating beds were more substantial. Burreed, cattail, lilies and bulrush all appear to have declined during the eight-year period, and pickerelweed appears to have increased. Submersed vegetation increased dramatically (approximately 400%) between 1968 and 1976, with the pattern of change suggesting a continual increase.

Based on the experience gained in conducting this study, the value of aerial photographs to studies of changes in aquatic vegetation was assessed, and a preliminary methodology for determining these changes with aerial photographs, set forth.

BIOGRAPHICAL SKETCH

Brian Lee Markham was born on April 5, 1954 in Baltimore, Maryland. As an undergraduate in Cornell University's College of Agriculture and Life Sciences, he majored in natural resources with a specialization in wildlife science. For all undergraduate semesters he maintained Deans' List status and received his Bachelor of Science with distinction in May 1976. He was employed for four summers during his undergraduate years as a biological aid with the Fish and Wildlife Service at several national wildlife refuges along the east coast of the United States.

Beginning in June 1976 he enrolled in a graduate program in Cornell University's School of Civil and Environmental Engineering, majoring in Aerial Photographic Studies and Remote Sensing and minoring in Soil Science. As a graduate student he was employed as a research assistant during the summers and as a teaching assistant during the school year. Both assistantships were in his major field, the former involved airphoto interpretation and field work on aquatic vegetation and the later involved teaching laboratories for the introductory course on airphoto interpretation of soils and geology. While completing his thesis he was employed by the Cornell University Remote Sensing Program as a research specialist. He is a member of the American Society of Photogrammetry.

ACKNOWLEDGEMENTS

A large number of people and organizations have contributed support either directly or indirectly to various phases of this study, and I wish to thank them all.

I want to especially thank my special committee, Professor Ta Liang, Professor John H. Peverly and Dr. Warren R. Philipson for their assistance in conducting and reporting this study. Additionally I thank Prof. Liang for increasing my understanding of airphoto interpretation, John Peverly for building my knowledge of aquatic plants, and most of all Warren for providing the day after day technical and moral support without which the completion of this thesis would not have been possible (or at least would have been extremely difficult).

Special acknowledgement is due A. E. Russell, who assisted in the field activities, identified the plant species and provided a botanist's view of the study. Her help was invaluable.

Also, I want to thank the staff of the Remote Sensing Program, especially T. L. Erb, whose support and tolerance of my weird schedule while writing this thesis enabled its completion.

Additionally, appreciation is extended to S. P. Allen of the N.Y.S. Department of Health, for supplying limnological data and background information; to J. R. Gregrow and M. E. Musgrave, for assisting in the data

compilation and analysis; to D. L. Wickersham, D. M. Green and S. B. Smith for assisting in the field; to J. E. Walker and T. W. Gallagher of Calspan Corporation, for assisting in the analysis of selected photographic films; and to L. O. Rycroft for typing this thesis.

Support for this investigation was provided in part by the United States Department of the Interior, Office of Water Research and Technology, as authorized under the Water Resources Act of 1964 through Annual Allotment Agreement Nos. 14-34-0001-7067 and 7068. Additional support was provided by Grant NGL 33-010-171 from the National Aeronautics and Space Administration (NASA).

Aerial photographs used in this study were provided by the Eastman Kodak Company (1968 and 1969), the U.S. Environmental Protection Agency (1973), NASA (1974) and the State University of New York, College of Environmental Science and Forestry (1976). Published and unpublished data were provided by the New York State Department of Health.

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I. INTRODUCTION

Perhaps one of the most difficult to study, and hence least studied components of the aquatic environment are the aquatic macrophytes. This is especially true of the submerged types of vegetation. Being not only difficult to quantify accurately, they may also be difficult to locate, and once located, difficult to relocate to check for changes.

Aerial photographs have frequently been used to inventory and detect changes in terrestrial vegetation and land use. One of the main advantages is their ability to concentrate a large amount of information into a map-like projection that enables easy comparison of the vegetation and land use of different years. Recently, aerial photographs have come to be used more and more in studying the aquatic environment, including aquatic macrophytes.

This aerial photographic study was undertaken to determine the changes in aquatic vegetation that had occurred in a eutrophic lake in New York State, between 1968 and 1976. The lake was of particular concern because a new tertiary sewage treatment plant with phosphorus removal had been constructed for the lake's only major population center in 1973. This plant has been removing approximately 76% of the phosphorus from the sewage since 1973 (Tofflemire et al., 1976), and was expected to reduce the total phosphorus loading to the lake by 40% (Hetling

and Sykes, 1971). It had been theorized that with a reduction phosphorus inputs, algal populations would decline, increasing water transparency and allowing submersed vegetation to increase (Hetling et al., 1975).

By conducting this study of vegetative changes, it was also hoped that 1) the utility and limitations of aerial photography for monitoring aquatic vegetation could be determined, and 2) a preliminary methodology for monitoring vegetative changes with aerial photographs could be developed.

II. LITERATURE REVIEW

A. Studies of Emerged and Floating Vegetation

As early as 1937 (Dalke, 1937), aerial photographs were recognized as having value in mapping wetland vegetation. Broad ecological zones could be delineated with black-and-white panchromatic photographs. These delineations were later ground-checked to determine their species composition. As time progressed, greater emphasis was placed on the photo-identification of plant species or associations with fewer field checks. These types of studies became more prevalent when color aerial photographic products became readily available, especially after the introduction of color infrared films (CIR) in the 1960's.

1. Species Identifications

To date, remote sensing studies of emerged and floating vegetation have been predominantly photo-interpretive, with minimal emphasis on spectral pattern recognition (Anderson, 1971; Benton, 1976; Olson, 1964; Seher and Tuellar, 1973). Using standard photo-interpretive classes of texture (spatial frequency patterns), height, shape, boundary, location and tone (or color if multi-layered films) on proper photography, the analyst can separate many species or groups of species.

The actual species separable depend to a great extent

on the species present in the study area, but certain groups of species appear to be generally separable with proper photography: 1) leafy-topped rushes and grasses (Scirpus fluviatilis, Phragmites communis, Zizania aquatica); 2) rushes without leafy tops (Scirpus acutus, S. americanus), though in sparse stands they may not be discernible or may be confused with submersed aquatics; 3) plants with sword-shaped leaves (Acorus calamus, Typha sp., Sparganium eurycarpum) and 4) plants with large flat leaves (Nuphar sp., Nymphaea sp., Pontederia cordata) (Anderson, 1971; Cowardin and Myers, 1974; Olson, 1964).

Given proper conditions, species within a group are often also separable: Scirpus fluviatilis and Zizania aquatica on black-and-white and color photographs (Olson, 1964); Phragmites communis and Zizania aquatica on CIR (R. R. Anderson, 1969a); Scirpus acutus and Scirpus americanus on color and CIR (Seher and Tuellar, 1973); Nuphar advena and Pontederia cordata on color and black-and-white (Olson, 1964), CIR (Brown, 1977); and Sagittaria sp. and Nuphar sp. or Pontederia cordata (Brown, 1977). The identification of species in mixed stands is more difficult (and less accurate) than in pure stands (Olson, 1964; Brown, 1977).

2. Film Types (and other sensors)

An early study comparing the accuracy of identifica-

tions of species on color versus black-and-white films showed little advantage of the color films over black-and-white, although color films were generally preferred by the interpreters (Olson, 1964). As color films improved and became more widely used, however, they generally replaced black-and-white panchromatic films for aquatic plant studies. Schneider (1968) claimed that color films were better for water resources studies, including the discrimination of marsh vegetation communities.

Recent studies have concentrated on using color and CIR films for species identifications. Seher and Tuellar (1973) reported no statistically significant difference in the accuracy of interpretations on CIR versus color, but the overwhelming majority of investigators have cited the superiority of CIR film over color for species identifications in fresh, brackish and saline waters (R. R. Anderson, 1969b, 1970 and 1971; Anderson and Wobber, 1973; Benton, 1976; Benton and Newman, 1976; Brown, 1977; Pestrong, 1969). The higher reliability of interpretations using CIR film arises from the greater reflectance differences between marsh plant types in the near-IR portion of the spectrum than in the visible portion (Anderson, 1971). To improve the ability to differentiate species, Anderson (1971) suggested that multispectral photography with narrow-band filters in the near-IR portion of the spectrum be used, the filters used being dependent on the species separations desired.

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Black-and-white IR film (89B filter) when overexposed by approximately two f-stops was found useful for identifying very sparse stands of bulrush (Scirpus sp.), which were not visible on regular or CIR films (Cowardin and Meyers, 1974). The overexposure also enhanced the separation of bulrush from submersed vegetation, both of which were dark on color or CIR photographs.

Anderson (1971) and Reimold et al. (1973) did observe that certain tidal marsh species were separable on thermal images, but the thermal images were not as useful as the photographic data.

3. Photographic Scale

In general, with an increase in photographic scale, there is an increase in the accuracy of aquatic plant identifications. Olson (1964) noted a 10% increase in accuracy going from 1:20,000 to 1:12,000, and a 5% increase from 1:12,000 to 1:5,000 photography. Seher and Tuellar (1973) reported an increase in accuracy from 77% at 1:10,000 to 89% at 1:1,000. Anderson et al. (1975) reported that large pure stands of Nymphaea odorata, Typha sp. and Phragmites communis could still be identified with Skylab data (1:3 million contact scale), but not with Landsat imagery (1:3 million "contact" scale, but poorer resolution due to non-photographic nature).

Scales of 1:6,000 to 1:12,000 have been most frequently used. Scales up to 1:40,000 have been shown to

be useful for monitoring aquatic vegetation with respect to plant control (Benton, 1976).

4. Photographic Exposure

The majority of investigators have noted no special exposure requirements for photography flown for studies of emersed and floating vegetation. In only the one case noted above for black-and-white IR film was additional exposure deemed to produce additional information (Cowardin and Meyers, 1974).

5. Timing of Aerial Photographic Coverage

The best time of year to fly aerial photography for aquatic vegetation studies will vary with climate and the local species. In general, a time towards the later part of the growing season, when most species have achieved maximum biomass, will produce the best results--late August to early September in the Northeastern United States (Brown, 1977). But certain species of plants will have died back by this time, so multi-date photography may be necessary to get complete information. Brown (1977) suggested mid-late June and late August as the two best times in New York and New Jersey. Seher and Tuellar (1973), however, noted no advantage of early summer over late summer photography (Nevada).

Both Anderson (1970) and Benton (1976) noted changes in the spectral reflectances of certain plant species

through the growing season, yet neither commented on the effect of these changes on the separability of the different types.

B. Studies of Submersed Vegetation

The grouping of plant species into emerged, floating and submersed categories is somewhat arbitrary. Many species have both floating and submersed leaves, and their categorization will vary with the investigator. Here, in general, as long as the plant has a predominance of submersed leaves, it will be considered submersed.

1. Detection

To utilize an aerial photographic system for detection of submersed vegetation, the interactions of light with the water and with the air-water interface must be understood.

When light strikes the surface of the water, part of it is reflected off at an angle equal to the angle of incidence, and part of it enters the water. The smaller the angle of incidence, the greater the reflected portion, and the lesser the portion available to illuminate underwater features. A high sun angle should thus be best for detecting submersed vegetation. At high sun angles, however, sunlight will reflect off the water surface into the aerial camera. This produces sunglint on the film and effectively obscures all submersed features.

For optimum detection of submersed vegetation, photo-

graphy should be flown at a sun angle which is a compromise between maximum light penetration and lowest potential for sunglint. Rudder and Berrey (1972) recommended solar angles between 15 degrees and 32 degrees; Lukens (1968) between 25 and 35 degrees. Because sunglint may also be a problem at low sun angles if the water is rough, Lukens (1968) recommended that wind speeds be less than 8 knots.

Water is a much poorer transmitter of light than is the atmosphere. Hence, a smaller amount of light reaches submersed targets than terrestrial ones. To compensate for the decreased irradiance underwater, longer exposures are usually required to photograph submersed objects. This usually causes slower speed films to be unsuitable for water penetration studies. An increase of two f-stops (four times the exposure) over values used for terrestrial objects have been recommended by R. L. Anderson (1969) and Vary (1969). Yost and Wenderoth (1968) indicated that four f-stops overexposure would produce the best results. R. R. Anderson (1969a) noted that one f-stop overexposure on CIR film significantly increased water penetration.

One problem with overexposing film for increased water penetration is that shallow water regions often become too overexposed, with a corresponding loss of information on submersed vegetation. This is primarily a problem on the single-layer films (black-and-white). Shallow water areas may be overexposed on one layer of a multi-layer film. On one of the other layers, however,

they will likely be more properly exposed. This feature of color films gives them a clear preference for studying underwater detail (Lockwood et al., 1974). Underwater, the contrast is also considerably reduced, requiring films with high gammas for optimum discrimination of features (Lockwood et al., 1974; Ross, 1969; Vary, 1969; Helgeson, 1970; Ross, 1976).

The attenuation of light by water is not spectrally uniform and varies with the nature and quantity of the materials dissolved or suspended in the water. Relatively pure water has peak transmittance in the blue-green region of the spectrum (Fig. 1). Highly productive waters, which contain larger concentrations of plankton and yellow substances, have the peak transparency shifted towards the green and overall transparency reduced (Fig. 1). In dystrophic (bog) lakes, transparency is very low and shifted towards the orange-red (Fig. 1).

The spectral transparency of water is only one of several factors that determine the spectral region to be used for maximum detectability of submersed vegetation. Other major variables are the spectral composition of the light illuminating the vegetation and the spectral reflectance properties of the vegetation and its background (Specht et al., 1973). The spectral transparency of water is one of the key factors determining the spectral composition of the light reaching the vegetation (others being the spectral irradiance from the sun and sky, sun angle, water

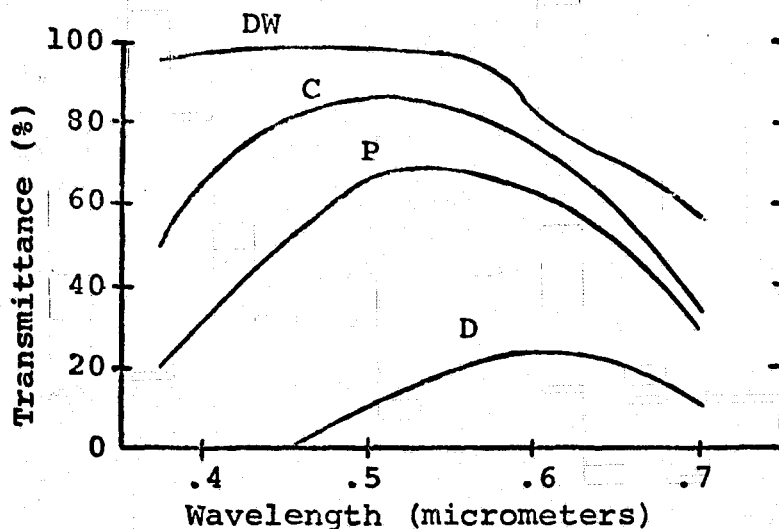


FIGURE 1. Spectral transmittance of 1 meter columns of water from various sources:
 DW - Distilled water
 C - Clear water lake
 P - Productive lake
 D - Dystrophic (bog) lake
 (after Ruttner, 1963)

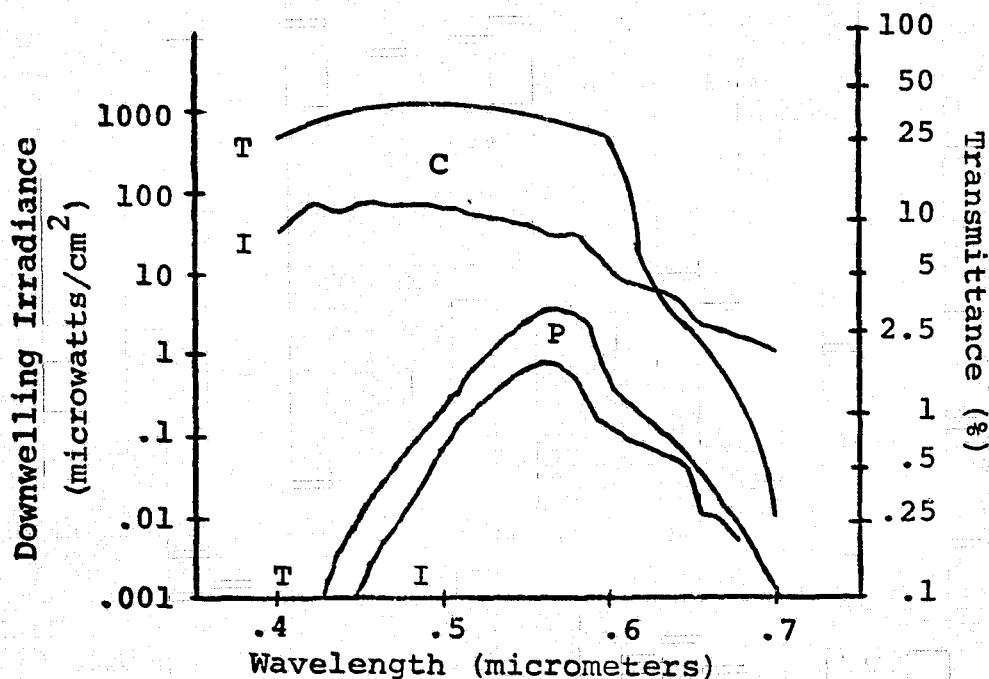


FIGURE 2. Spectral transmittance (T) for 10 meter water columns from clear (C) (Clarke and James, 1939) and productive (P) (Hulbert, 1945) water bodies; and spectral irradiance (I) at 5 and 10 meter depths in clear and productive water bodies, respectively (Tyler and Smith, 1970). Note log scales.

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surface state and depth). Hence the curves for the two are often quite similar in shape, at least at relatively shallow depths (Fig. 2). The spectral reflectance characteristics of submersed vegetation and the background bottom materials have not been well documented.

Of the two common multi-layer films (color and CIR), color is superior for depth penetration in clear waters due to its sensitivity to the blue-green spectral region (Wenderoth, 1969). But CIR can produce good results (Vary, 1969), as transparency is also high in the green region of the spectrum, though possibly not as high as in the blue-green. Neither of these films has the proper peak sensitivity for maximum depth penetration, approximately $0.46 - 0.51 \mu\text{m}$ (Ross, 1969; Helgeson, 1970). This prompted the development of a special two-layer water penetration film, with one layer peaked in this region and another in the green (for use in water color studies and depth penetration in more eutrophic waters) (Specht et al., 1973). This film provided water penetration superior to regular color film in clear water regions.

A second approach, using narrow-band spectral filters with black-and-white film, to encompass the wavelengths of maximum water transparency, also achieved high water penetration (Wenderoth, 1969). A third, unusual approach, involved the use of a color film lacking the blue layer (Vary, 1969). This was based on the premise that since the blue wavelengths of light are most subject to scattering by

the atmosphere and the water, a film lacking the blue layer should produce the best results, even though the maximum water penetration is in the blue-green. Most other investigators have agreed that the lower half of the blue spectrum (0.40 - 0.45 μm) is generally too affected by haze (both air and water) to be of much use in water penetration, but they maintain that the upper half (0.46 - 0.50 μm) contains essential water penetration information that is not negated by the presence of haze (Ross, 1969; Helgeson, 1970; Specht et al., 1973).

In more eutrophic waters, color film loses its advantage over CIR for water penetration, as a blue-sensitive layer provides poorer penetration than a green sensitive one (which is common to both films). Yost and Wenderoth (1969), in using selectively filtered black-and-white films, noted that the green band (0.48 - 0.59 μm) had twice the water penetration of the red (0.59 - 0.71 μm) and three times the penetration of the blue (0.38 - 0.52 μm) in turbid near-coastal waters of the Northeast.

Anderson (1971) and Welch (1969) both reported comparable water penetration of color and CIR film in eutrophic waters when the films were properly exposed. A number of other investigators (Lukens, 1968; Wile, 1973; Wolff and Lindner, 1974) claim superiority of color film over CIR film for water penetration in eutrophic waters. Apparently, the reason for this discrepancy is exposure. Due to the wider exposure latitude of the green layer of

most color films than the green layer of CIR film (Kodak, 1972), when the films are exposed properly for terrestrial features (underexposed for underwater features), color film will penetrate water better than CIR film. One of the problems with CIR film is that it is a somewhat slower film than certain color products, and due to the longer exposures needed for underwater photography, the exposures required may be too long to avoid image blur on higher speed aircraft (Rudder and Berry, 1972).

Nine film-filter combinations (CIR not included) were tested in a study of the coastal waters off California. A high speed color film (SO-397-Kodak), Kodak's experimental water penetration film, and a black-and-white film filtered to receive only green radiation provided the maximum water penetration. However, only the three-layer color film did not exhibit excessive exposure of shallow water areas (Lockwood et al., 1974).

2. Species Discrimination

Essentially all investigators have met with very little success in attempting to differentiate species of submersed vegetation that are more than several centimeters below the water surface (Wile, 1973; Wolff and Lindner, 1974; Benton and Newman, 1976; Orth and Gordon, 1975; Benton, 1976). Several factors have contributed to this failure, including: (1) the tendency of submersed vegetation species to grow in mixed stands, (2) the apparently

small differences in reflectance between submersed species of vegetation (except in the near-IR portion of the spectrum, which is absorbed in the surface few centimeters of water), and (3) the effects of different amounts of water between the surface and the vegetation.

The only cases where submersed plant species discrimination was possible were when there was some difference in their growth patterns. Chara sp. were separable from other submersed vegetation as they did not grow any distance up from the bottom (Lukens, 1968).

Once the submersed vegetation reaches (or nearly reaches) the water surface, differences in reflectances (especially in the near-IR region) between species may become apparent, allowing discrimination. Gustafson and Adams (1973) were able to differentiate Myriophyllum sp. from Ceratophyllum sp.; Benton (1976) was able to separate Myriophyllum sp., Ceratophyllum sp. and Hydrilla sp.; Seher and Tueller (1973), Myriophyllum sp. and Potamogeton pectinatus. Gustafson and Adams (1973) and Benton (1976) found CIR superior for discrimination; Seher and Tueller (1973) found no difference between color and CIR films.

3. Timing of Aerial Photographic Coverage

Late summer has been recognized as the best time to obtain photography for submersed vegetation studies. At this time of the year the submersed vegetation is at maximum development (Lukens, 1968; Seher and Tueller, 1973).

Toward the later part of the period, the emersed plants have browned, whereas the submersed plants are still green, providing a good contrast. Also the water may tend to be clearer and there is generally less haze compared to earlier in the summer (Lukens, 1968).

4. Photographic Scale

The same conditions apply as for emersed and floating vegetation (Sec II-A-3).

5. Studies of Changes in Submersed Vegetation

Only two published studies (excluding an earlier report on portions of this study, Markham et al., 1977) have attempted to detect changes in submersed vegetation over a period of several years using aerial photographs. Gustafson and Adams (1973) measured areal changes in Myriophyllum spicatum over several growing seasons and attempted to relate the density of the photographic emulsion to ground-derived biomass data. Although they achieved a high correlation, their film density measurements relied primarily on the dyes in the film, causing their results to be somewhat questionable. Orth and Gordon (1975) looked at changes in Zostera marina between 1971 and 1974 in the Chesapeake Bay. They used subjective ratings of 25%, 50%, 75% and 100% vegetative coverage to categorize submersed beds.

C. Summary

Relatively large scale CIR aerial photographs flown towards the later part of the growing season have generally been most useful for studies of emersed and floating vegetation. Separations of many species or groups of species have been possible. Studies of submersed vegetation have been more complicated due to interference from the intervening water. Generally only the detection of submersed vegetation has been possible. A moderately-low sun angle and extra exposure are usually best for submersed vegetation studies. Of the two common multi-layer films, color is the more useful in very clear waters. In more turbid waters, color and CIR have performed about equally when properly exposed. For the best water penetration, a selectively filtered, high contrast, high-speed film should be used.

III. METHODS AND MATERIALS

A. Study Lake

Located in east-central New York State, Canadarago Lake (Fig. 3) has a surface area of 770 hectares with a maximum length of 6.4 km and a maximum width of 1.9 km (Fig. 4). The lake is characterized by a well-developed littoral shelf which slopes gently lakeward to a depth of two to three meters, depending on the location (Fig. 4). Beyond this shelf the depth increases rapidly to up to 13 meters (Fig. 4). Canadarago Lake is similar to many of the lakes in central New York State, including the Finger Lakes. For detailed information on the physical, chemical and biological characteristics of Canadarago Lake, refer to Hetling et al. (1975).

B. Existing Photography and Ground Data

At the commencement of this study, large scale color or color and color-infrared (CIR) transparencies of Canadarago Lake were available for 1968, 1969, 1973, and 1974 (Table 1). The known available historic black-and-white panchromatic photographs (May-November only) of the lake were obtained (Table 2).

Existing ground data consisted of concurrent or same-day measurements of lake water level (USGS, 1969 - 1976) and Secchi disc transparency (Hetling et al., 1975;

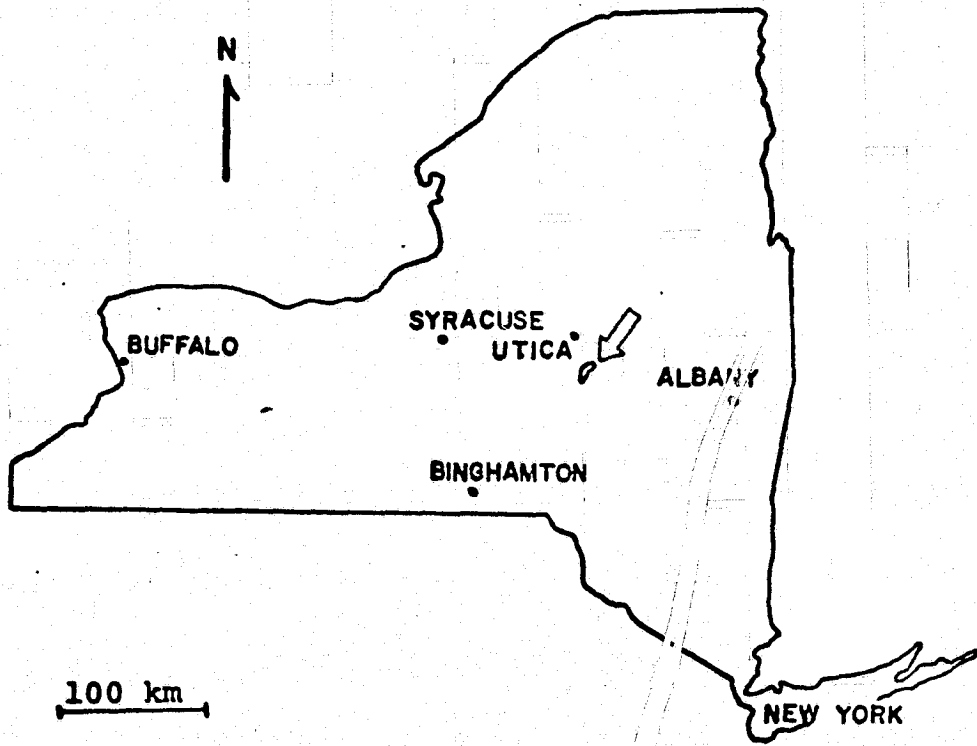


FIGURE 3. Canadarago Lake, New York State

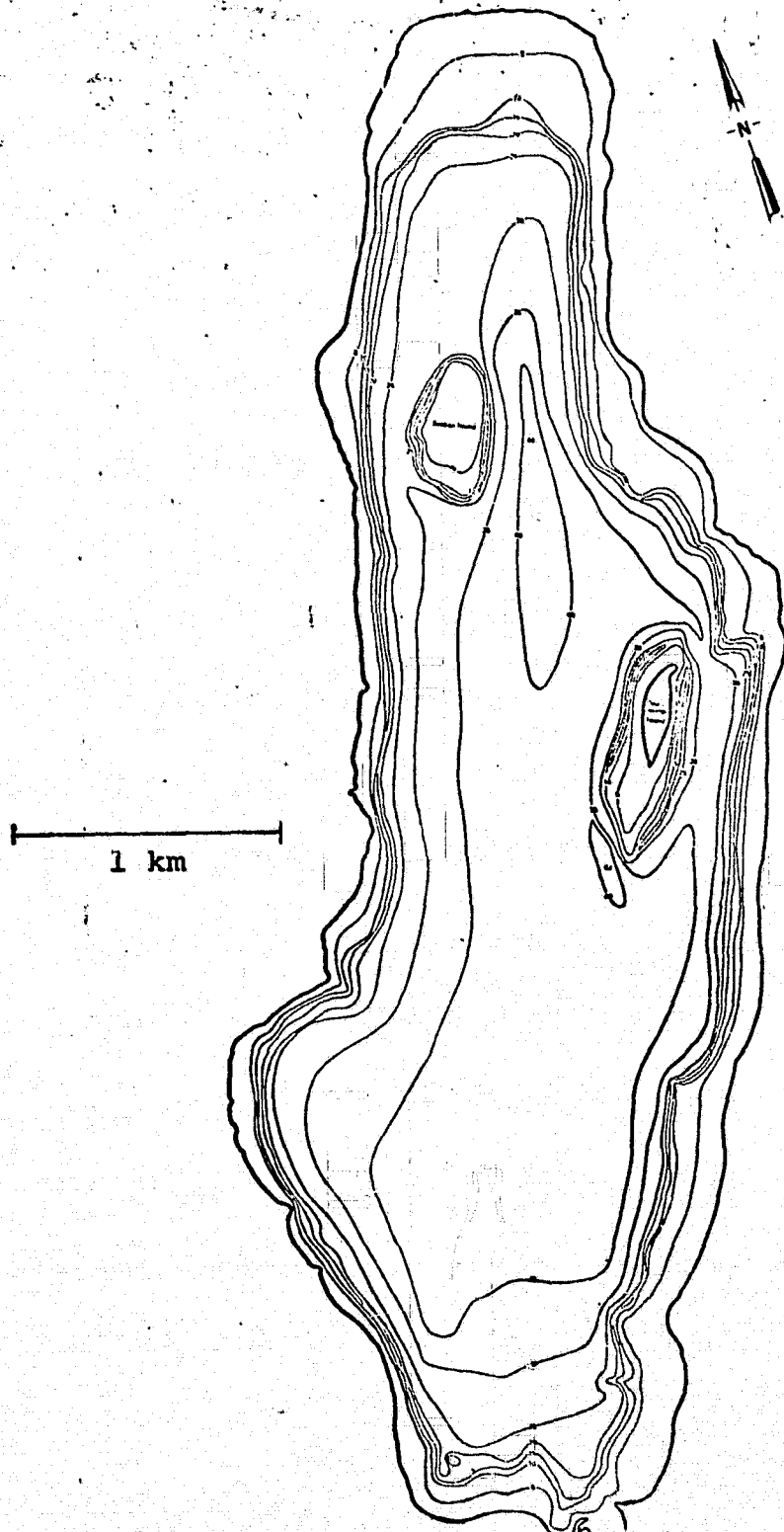


FIGURE 4. Bathymetric map of Canadarago Lake (contour interval 5 feet) (Weir and Harman, 1974)

TABLE 1. Aerial photographic coverage used for study of Canadarago
Lake vegetation and conditions during flights

FLIGHT DATE	SECCHI DISC (m)	GAGE HEIGHT (m)	FILM TYPE/ FORMAT*	SPECTRAL FILTER	APPROX. SCALE**	COMMENTS
1968 Aug. 15	est. >2 ***	***	C,2448/9.5 CIR,8443/9.5	none Wild 500nm	6 & 12 6 & 12	original transparencies, C-slightly underexposed(1:6,000), sunglint, green shift CIR-underexposed(1:6,000), green shift
1969 July 31	1.3	0.7	C,2448/9.5 CIR,8443/9.5	none Wild 500nm	5 5	original transparencies, shoal area missed CIR-a few cloud shadows
1973 July 25	5.6	0.67	C,S0242/70	none	16+ (panoramic)	duplicate transparencies.
1973 Sept. 27	3.0	0.59	C,2448/9.5	Wratten 2B	5	duplicate transparencies, partial coverage, 50%
1974 May 11			C,S0397/9.5 CIR,2443/9.5	Wratten 2A Wratten 12	6 & 14 6 & 14	duplicate transparencies
1974 Aug. 22	4.5	0.62	C,S0397/9.5 CIR 2443/9.5	Wratten 2A Wratten 12	6 & 14 6 & 14	duplicate transparencies, sunglint @ north end of lake, small areas missed(1:6,000), CIR-underexposed
1976 July 20	2.0	0.68	C,2448/70 CIR,2443/70	haze Wratten 15	6 6	original transparencies, sunglint along northeast shore, C-haze,partial coverage,90% CIR-partial coverage,60%
1976 Aug. 31	2.6	0.74	C,2448/70 CIR,2443/70	haze Wratten 15	6 6	original transparencies, a few cloud shadows, CIR-partial coverage, 60%

*Notation: C-color or CIR-color infrared film, numeric or alphanumeric code is Eastman Kodak Co. film designation/9.5 inch or 70 millimeter film width.

**Scale notation: "6" refers to 1:6000; "12" to 1:12000; etc.

***No secchi disc readings were taken at the time of the 1968 photography--the estimate is based on comparisons with the other photographs. No water level data either.

TABLE 2. Historic photography of Canadarago Lake
(black-and-white panchromatic)

Date	Scale	Format	Source
1936-primarily October 28, but some Sept. 26, and October 4	1:15,840	7" x 9" (nitrate film)	National Archives
1942-summer, exact date unknown	1:36,000	7" x 7"	Defense Intelligence Agency
1960-May 27	1:20,000	9" x 9"	Department of Agriculture
1973-October 24	1:40,000	9" x 9"	Department of Agriculture

Smith, 1976; Allen, 1977) for all summer flights since 1969 (Table 1). Field derived data on floating and emersed vegetation in Canadarago Lake, collected by the New York State Department of Health in 1968 and 1969 (Fuhs et al., 1972), and similarly derived data on submersed, floating and emersed vegetation in 1973 (Allen, 1973) were also available.

C. Aerial Photographic Analyses, New Aerial Photography
and Field Program

The field program and aerial photography conducted during the summer of 1976 were integrated into a plan designed to determine the value of aerial photographs for 1) detecting aquatic vegetation and 2) distinguishing between various species and associations of plants. Consequently they were closely linked with aerial photographic analyses in the laboratory. Overall this plan proceeded in relatively discrete steps:

- 1) Aerial photographic analyses (existing photography 1968 - 1974)
- 2) Initial field work
- 3) First aerial photographic flight - concurrent field work
- 4) Aerial photographic analyses (new and existing photography)
- 5) Continued field work

- 6) Aerial photographic analyses
- 7) Field work - second aerial photographic flight
- 8) Aerial photographic analyses (new and existing photography)

1. Aerial Photographic Analyses

All aerial photographic film transparencies were examined on a light table using a zoom stereoscope. Areas of known species composition (from field work) were characterized in terms of their airphoto characteristics of location, shape, distinctness of boundary, texture, vegetative height and tone (color). Using these training areas, a preliminary classification system for mapping vegetation using color and CIR aerial photography was devised. This legend was then used to identify (map) areas not previously characterized in the field. After field checking these areas, the classification system was modified, as necessary, to conform with field observations. Subsequently, the classification system was modified to be compatible with all of the 1968 - 1976 photographs.

To check the ability of the photographs to detect vegetation, additional areas were selected where vegetation appeared to be present or where no vegetation was apparent on the 1976 photos. These areas were subsequently checked in the field for the presence or absence of vegeta-

tion. Special emphasis was given to sites where vegetation was apparent in all years 1968 - 1976. If these checked with ground information, it would increase confidence in the information derivable from the earlier photographs.

The black and white panchromatic prints were examined with a 2-4 power, pocket stereoscope.

2. New Aerial Photographic Coverage

Two aerial photographic missions were flown during the summer of 1976, through arrangements with the State University of New York, College of Environmental Science and Forestry at Syracuse: one on July 20, the other on August 31 (Table 1). Logs from these two flights are in Appendix A.

3. Field Program

The field program consisted of a number of surveys of the lake vegetation conducted from a boat, beginning in mid-June 1976 and continuing through the end of August. The initial surveys were to determine the principal species present, their locations, and to uncover any potential problems in ground checking the aerial photographic interpretations. The later surveys consisted of checking specific points for the presence and/or type of vegetation. Samples of vegetation were collected,

field identified if possible, and taken to the laboratory for verification or identification. Color and CIR 35 mm photographs of representative vegetative stands were taken.

To aid in locating specific points on the lake (one of the first problems encountered), color prints of portions of the August 1974 color aerial photographs were used. Specific docks, floats, nearshore cottages (with various colored roofs) and some relatively permanent vegetative patches served as reference points for positioning on the lake.

In several areas, the positional accuracy provided by the prints was insufficient, so styrofoam panels (2-by-4 foot - painted flat white) were anchored adjacent to certain vegetative patches prior to the July 20 and August 31 aerial photographic flights. A total of 14 targets were used for the July flight; only three for the August flight. Two of the floats for the August flight were placed to aid location of the submerged shoal by the aircraft pilot. Concurrent with both overflights Secchi disc transparency readings were taken at several predetermined points (lake sampling stations established by the N.Y.S. Department of Health).

D. Spectral Analyses

The August 1976 aerial photographs were used for preliminary analysis of the spectral characteristics of

the various vegetative types. The photometric console of Calspan Corporation (Buffalo, N.Y.) was used to perform the analysis, using Calspan's Scene Color Standard Technique (Piech and Walker, 1974). This technique, which attempts to remove atmospheric effects and calibrate the film so that object reflectance values can be obtained for each film layer, is described in Appendix B.

E. Vegetative Mapping

Once the system for classifying aquatic vegetation was defined, the vegetative units were delineated on acetate overlays to each year's (1968 - 1976) photographic transparencies. Certain vegetative units were subcategorized according to percentage cover (e.g., submersed vegetation - continuous, broken, scattered). A series of photographic standards were prepared to keep the interpretations of the percentage cover classes relatively uniform.

After the delineations were completed, the percentage of the area within each applicable mapping unit that was actually vegetation was measured with a crown density scale (a device designed to estimate percentage of tree cover on aerial photographs). From these measurements, average percentage vegetative cover values for each applicable vegetative unit were obtained for each year.

A series of 1:5,000 scale base maps were compiled

to record the multi-year vegetative delineations. Basic control, consisting of road intersection points around the perimeter of the lake, was obtained from the 1:24,000 scale U.S. Geological Survey topographic maps covering Canadarago Lake (Richfield Springs and Schuyler Lake 7 1/2' quads.).

The coordinates of these points were recorded, then the points were replotted on acetate at a scale of 1:10,000. A Baush and Lomb Zoom Transfer Scope was used to transfer the shoreline and other detail from a single 1973, 1:40,000 scale aerial photograph (Table 2) to the 1:10,000 scale map. Additional detail was added using the May 1974 photographs (Table 1).

This 1:10,000 scale base map was a necessary intermediary to producing the 1:5,000 scale base maps due to the limitations of the available equipment. The lake shoreline was divided into 12 sectors, and each sector was enlarged to 1:5,000 using the Zoom Transfer Scope. Thus, 1:5,000 scale maps, capable of serving as common bases for compiling and analyzing vegetative information, though of potentially low cartographic accuracy, were produced.

Vegetative delineations on the acetate overlays to the photographic transparencies were transferred to the appropriate 1:5,000 scale sector map using the Zoom Transfer Scope. Vegetative information for each year was

transferred to a different set of acetate overlays to the sector maps.

Vegetative areas were measured on the 1:5,000 scale maps using a 1 cm-by-1 cm grid with 1 mm-by-1 mm divisions. The squares covering each vegetative unit were manually counted while being viewed under magnification on a light table, and were recorded on a sector basis. Ground areas of total vegetation, emersed and floating vegetation, and submersed vegetation were obtained for each sector by multiplying the measured grid areas by the appropriate percentage cover factor (if applicable) and a 1:5,000 scale factor. Total lake vegetation figures were obtained by summing the areas for all the sectors.

F. Analysis of Vegetative Change

The areas of total vegetation, combined emersed and floating vegetation, and submersed vegetation were compared over the whole lake (excluding the shoal) with 1968, 1969, 1974 and 1976 data, and over part of the lake with 1973 data included (the lake was only partially covered by the 1973 photographs). The vegetation maps for the different years were overlain to determine more precisely the location and nature of the vegetative change.

Changes in emersed and floating plants were evaluated on a whole lake basis by mapping unit and by species (or species group) for 1969 and 1976. For the

species analysis, it was necessary to estimate the percentage cover of each species in the map units of mixed vegetative types. This was done in a manner similar to that adopted for determining percentage within the floating and submersed vegetative types. Average percentage cover figures for each species (type) in each mixture delineation were obtained with a crown density scale, multiplied by the areas of the mixture, and totaled for the particular vegetative type (species).

IV. RESULTS

A. Vegetation Field Identified

The species observed during the summer of 1976 field surveys of Canadarago Lake and their relative abundances are listed in Table 3. Two additional types, Potamogeton pectinatus and Najas sp., were noted during a partial survey conducted in the summer of 1977. They are perhaps best characterized as being occasional. Vegetative growth was restricted to areas less than about 3.5 meters deep, in part because of sharp bottom drop-offs.

B. Photo Characteristics of Vegetation

1. Non-Spectral

The non-spectral aerial photographic characteristics of the most common vegetative types in Canadarago Lake are listed in Table 4; some of these are illustrated in Figure 5. These characteristics, with the exception of height, were fairly uniform with all photographic coverages. Relative heights remained about the same, but on the July photographs, the absolute heights of the emersed species were lower than on the August photographs. Of the submersed species, Heteranthera dubia especially tended to be somewhat farther below the water surface in July than in August.

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TABLE 3. Plant species of Canadarago Lake in 1976
(identified by A.E. Russell)*

	SUBMERSED	FLOATING	EMERSED
COMMON	<u>Myriophyllum spicatum</u> L. <u>Heteranthera dubia</u> (Jacq.) MacM. <u>Potamogeton crispus</u> L. <u>Anacharis canadensis</u> (Michx.) Planchon <u>Chara</u> sp.	<u>Nuphar advena</u> (Sol.) R. Br.	<u>Pontederia cordata</u> L. <u>Scirpus acutus</u> Muhl.
FREQUENT			<u>Sparganium eurycarpum</u> Engelm. <u>Typha latifolia</u> L. <u>Phalaris arundinacea</u> L.
OCCASIONAL	<u>Ceratophyllum demersum</u> L. <u>Potamogeton filiformis</u> Pers. <u>Ranunculus aquatilis</u> L.	<u>Lemna minor</u> L. <u>Nymphaea odorata</u> Ait. <u>Polygonum amphibium</u> L. <u>Spirodela polyrhiza</u> (L.) Schleid	<u>Sagittaria latifolia</u> Willd. <u>Scirpus validus</u> Vahl. <u>Equisetum fluviatile</u> L.
RARE	<u>Potamogeton foliosus</u> Raf. <u>Potamogeton gramineus</u> L. <u>Potamogeton perfoliatus</u> L.** <u>Vallisneria americana</u> Michx.***		<u>Acorus calamus</u> L. <u>Carex lasiocarpa</u> Ehrh. <u>Eleocharis palustris</u> (L.) R. & S. <u>Ludwigia palustris</u> (L.) Ell. <u>Sparganium americanum</u> Nutt.

*Nomenclature from Clausen (1949)

**Identified by M.E. Musgrave

***Identified by D.M. Green

TABLE 4. Non-spectral airphoto characteristics of aquatic vegetation in Canadarago Lake, based on all photography

VEGETATION	LOCATION/DEPTH	SHAPE/BOUNDARY OF PATCH	TEXTURE OF PATCH (1:6,000 scale)	HEIGHT
<u>Floating</u>				
Lilies (<i>Nuphar advena</i> ; <i>Nymphaea odorata</i>)	Shoreline to 2m depths; in sheltered areas; often with pickerelweed, bulrush & submersed types	Usually lobate patches with distinct boundary	Uniform granular in dense mats; becoming broken & clumpy with decreasing density	Negligible; at water surface
<u>Emersed</u>				
Pickerelweed (<i>Pontederia cordata</i>)	Near shore to 1m depth, but not at shoreline; in sheltered areas; often with lilies, bulrush and burreed	Usually distinct patches with curving boundary; often small round patches; shape becomes more irregular & boundary less distinct in sparser areas	Uniform granular in dense patches; becomes less uniform in sparser patches	Low (0.5m±) if visible
Bulrush (<i>Scirpus acutus</i> ; <i>Scirpus validus</i>)	Shoreline to 1.5m depth; usually decreasing in density with increasing depth; often with lilies, pickerelweed & submersed types	Patches often elongate along shoreline with irregular boundary; boundary ranges from distinct for dense patches to nondescript for sparse areas	Clumpy in dense patches; relatively uniform fuzzy texture for intermediate density; degrades to scattered fuzz for sparse areas	Tall (2m±), irregular in height, but usually only visible in dense stands
Burreed (<i>Sparganium eurycarpum</i>)	Shoreline to 0.5m depth; generally extends farther from shore than cattail; usually with pickerelweed	Irregular shape with distinct boundary	Uniform granular texture becoming broken towards edges	Tall (2m±)

TABLE 4. (Continued)

VEGETATION	LOCATION/DEPTH	SHAPE/BOUNDARY OF PATCH	TEXTURE OF PATCH	HEIGHT
Cattail (<i>Typha latifolia</i>)	Shoreline to 0.5m depth	Irregular shape with distinct boundary	Uniform granular texture with scattered pits; becomes clumpy towards edges	Tall (2m±)
<u>Submersed</u>				
Water milfoil (<i>Myriophyllum spicatum</i>)	In depths to 3m; often forms dense patches along shoal edges; often with other plants in depths less than 2m	Usually distinct roundish clumps; may coalesce to form continuous patches	Variable; usually somewhat uneven due to varying heights of plants below surface	At water surface to slightly below
Mud Plantain (<i>Heteranthera dubia</i>)	Near shore to 2m depth; often with milfoil, elodea and muskgrasses	Often continuous patches with irregular boundaries; edges of patches usually indistinct as they grade into scattered clumps	Idem	Idem
Elodea (<i>Anacharis canadensis</i>)	In depths to 1.3m; usually with mud plantain and muskgrasses	Insufficient areas of pure stands to characterize	Smooth	On bottom to some distance above
Curly-leaved pondweed (<i>Potamogeton crispus</i>)	In depths to at least 2m; distribution not well known	No photos during maximum development, June-early July; dies back leaving rings of vegetation	Variable	Usually at surface in June or July
Muskgrasses (<i>Chara</i> sp.) genus of benthic algae; not macrophyte	In depths to 1.2m; may be with mud plantain, elodea and lilies	Irregular areas with indistinct boundaries	Smooth	On bottom

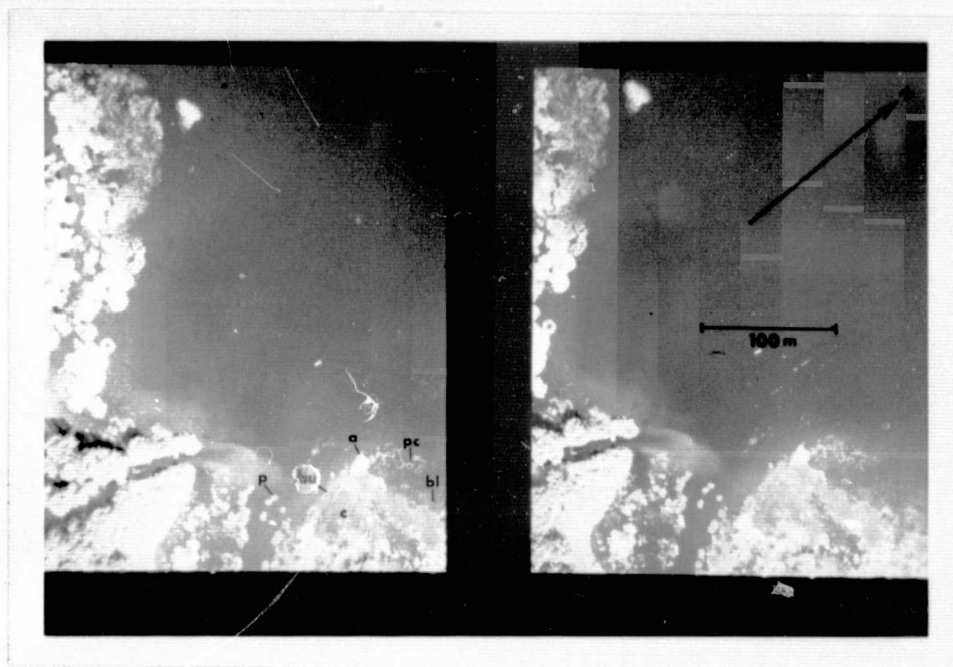


FIGURE 5. Color infrared aerial photographs (July 20, 1976) of southeast portion of Canadarago Lake (stereogram*).

- | | |
|--|---------------------------------|
| l - lilies | c - cattail |
| p - pickerelweed | bu - burreed |
| bl - bulrush | pc - <u>Potamogeton crispus</u> |
| a - the area shown in Figure 10 (bulrush and lilies) | |

* the stereo effect is reversed in certain areas of these copies

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2. Spectral

The spectral airphoto characteristics of the emersed and floating vegetative types for the August 31, 1976 aerial photographs are shown in Table 5. The data given are for pure dense stands of vegetation; exposure and reflectance values were obtained by densitometric analysis of ground areas of approximately 0.07 meters² (Appendix B).

The visual tones of the submersed vegetation beds on the August 1976 photographs varied considerably, but the variation was related primarily to the distance of the vegetative tops below the water surface, rather than to interspeciate differences. On the CIR film, submersed vegetation with leafy tops at the surface was imaged in shades of red to greenish red; vegetation with leaves near the surface, in green or reddish green tones; and vegetation farther below the surface, as a bluish green. On color film, the tonal differences were less pronounced. Plants at or near the surface appeared dark brownish gray and with increasing depth showed a lightening in tone (Fig. 6).

The tones of the various plant species on a given film type at a similar time of the year varied between the different aerial photographic coverages (Fig. 7). Tonal "keys" (similar to the non-spectral "keys" in Table 4) applicable to all the aerial photographs were therefore not derivable. However, the relationships of the tones

TABLE 5. Spectral characteristics of emersed and floating (lilies) aquatic vegetation in Canadarago Lake, based on 31 August 1976, 1:6,000 scale, aerial photography

A. Relative exposures of blue (B), green (G), red (R) and infrared (I) film layers, derived from film sensitometric curves, and visual tones

TYPE OF VEGETATION	COLOR FILM				COLOR INFRARED FILM			
	B	G	R	TONES	G	R	I	TONES
Lilies								
C-2, CIR-3*	2.9	4.4	3.2	light green	5.1	4.8	10.1	white to light pink
Pickerelweed C-3, CIR-2	1.8	2.1	1.5	medium green to med. gray	1.6	2.2	7.8	medium pink to orange
Bulrush C-2, CIR-2	1.8	1.8	1.6	medium gray	1.2	1.6	2.8	dark red
Burreed C-1, CIR-3	1.2	1.4	1.0	dark green	1.0	1.1	4.9	bright red
Cattail C-2, CIR-0	2.5	3.0	2.8	light brown- ish green				(in cloud shadow)

*Number of different sample locations read on "C"-color (Kodak 2448) and "CIR"-color infrared (Kodak 2443) films

B. Blue (B), green (G) and red (R) reflectances and their ratios calculated from the color film (Kodak 2448), using the Scene Color Standard technique (Piech and Walker, 1971 and 1974) (Appendix B)

VEGETATION	B(%)	G(%)	R(%)	R/G	G/B	R/B
Lilies	5.3	13.0	9.5	0.73	2.45	1.79
Pickerelweed	2.8	5.6	3.6	0.65	1.98	1.28
Bulrush	2.6	4.2	3.7	0.87	1.67	1.45
Burreed	1.0	3.3	1.7	0.51	3.24	1.65
Cattail	4.3	9.1	8.8	0.96	2.13	2.05

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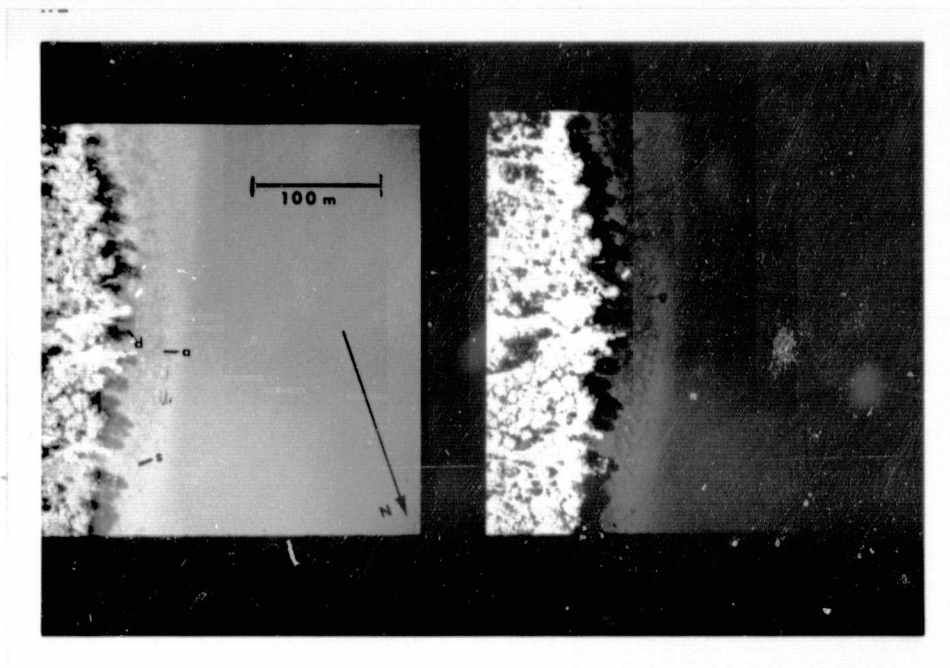


FIGURE 6. Submersed vegetation along the northeastern shore of Canadarago Lake. On these August 31, 1976 color (left) and color infrared (right) aerial photographs, note (1) the variation in color of the submersed vegetation on the CIR film (reddish at surface [r], greenish somewhat below the surface [g]), (2) the relatively uniform tones of the submersed vegetation on the color film, and (3) the variation in percent cover of the submersed beds, being dense at d, sparser at s. The bright green patch (blue on CIR) at a is algae.

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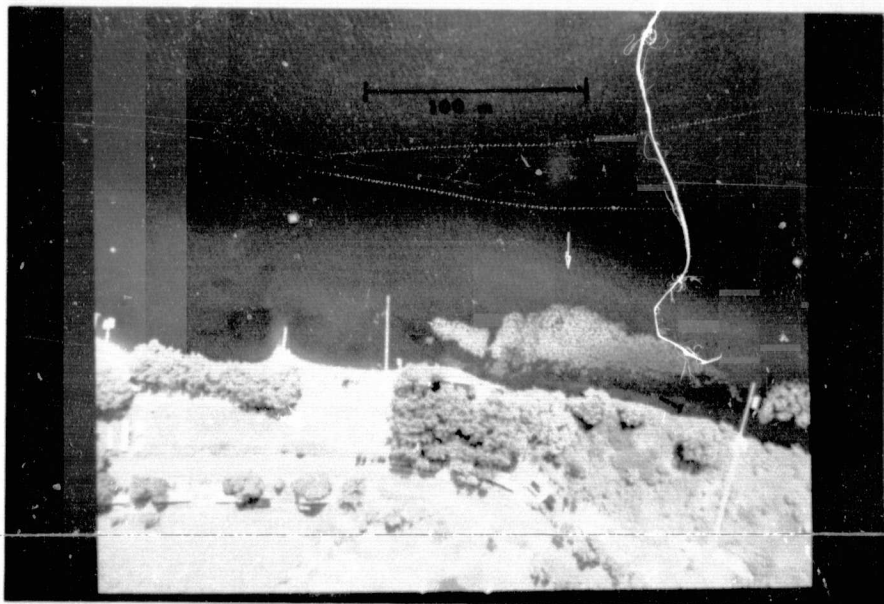
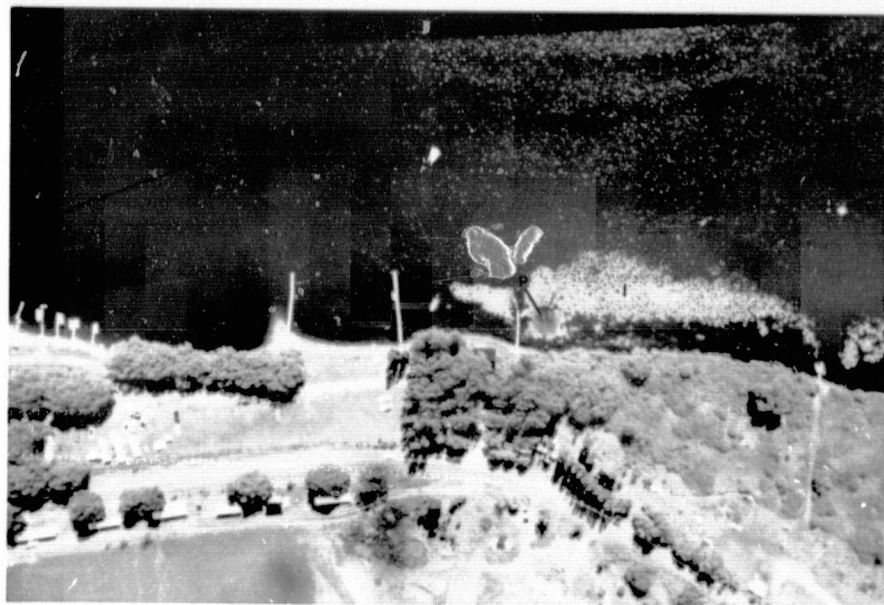


FIGURE 7. Color infrared aerial photographs of western shore of Canadarago Lake. Note the differences in colors of vegetative types between the July 31, 1969 (upper) and July 20, 1976 (lower) aerial photographs. Note also the large decrease in area of bulrush (bl) between 1969 and 1976, with dead roots (r) still present in 1976, and the relatively minor changes in pickerelweed (p) and lilies (l).

of the species within one film were similar to those within another (e.g., lilies would always be the lightest toned vegetation; bulrush the darkest). By using these relationships, it was possible to produce a "within-film" spectral key (i.e., applicable only to that particular aerial photographic film).

Seasonal changes in vegetative reflectance also produced between-film tonal differences. Since the 1976 films were not both calibrated (only August), quantitative evaluation of the changes was not possible. Even with uncalibrated data, certain changes were obvious. For both pickerelweed and cattail, the red reflectance increased relative to the green reflectance between late July and late August, both appearing browner on the August than on the July photographs (Fig. 8).

C. Detectability and Identifiability of Vegetative Types

The detectability (ability to identify as vegetation as opposed to water or other features) of the different vegetative types varied (Table 6). Although the data in Table 6 are primarily derived from the 1976 photographs, they are generally applicable to all the photographs. Differences in exposure, processing, transparency, and atmospheric effects produced differences, however.

In general, for emersed and floating vegetation, CIR film provided somewhat better detectability (especially

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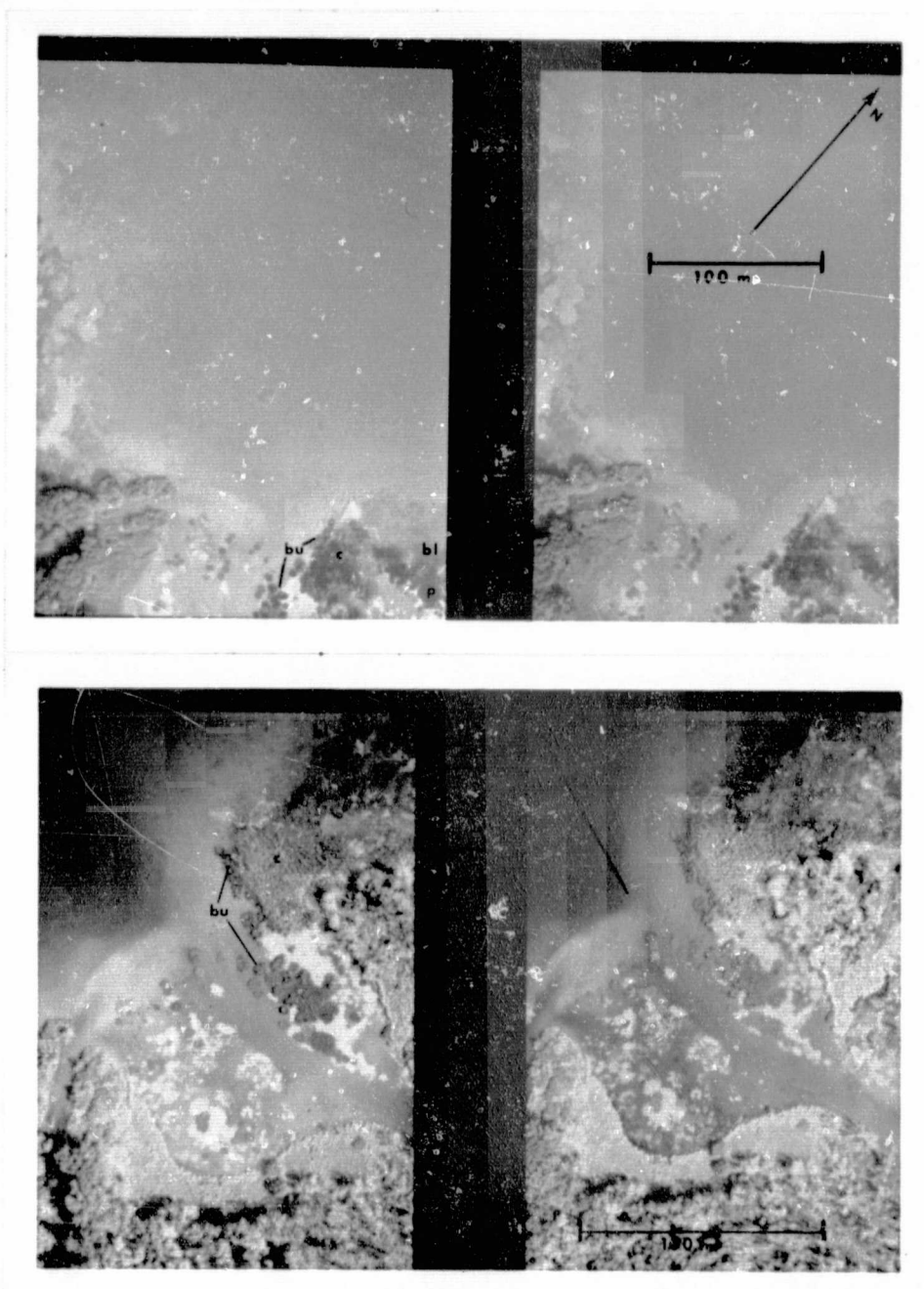


FIGURE 8. Seasonal changes in vegetative reflectance. Note especially the change in reflectance of cattail (c) relative to burreed (bu). On the July 20, 1976 aerial photographs (upper stereogram), the reflectance properties of the two are very similar; whereas on the August 31, 1976 photographs (lower stereogram), the cattail is browner than the burreed. Though not readily apparent on these copies, pickerelweed (p) is greener on the July photographs also, being more distinct from bulrush (bl) at this time.

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TABLE 6. Detectability and identifiability of vegetative types as a function of film type and plant density (based primarily on August 31, 1976 photographs)

Vegetation Type	Density	Detectability in Pure Stands		Identifiability in Pure Stands/ Confusing Types		Identifiability (I) and Detectability (D) in Mixed Stands (if different from pure stands)			
		Color	CIR	Color	CIR	I/D	Mixed With	Film	Reason
Lilies (lil)	d	++	++	++/none	++/none				
	m	++	++	++/none	++/none				
	s	+	++	++/none	++/none	-	D	pkw-d	C/CIR obscured by leaves
Pickerel-weed (pkw)	d	++	++	++/none	++/none				
	m	+ ¹	++	-/bul, suba ¹	+/bul				
	s	(-) ¹	(+)	(=/bul, suba) ¹	(+/bul)	=	D	bur-d	C/CIR obscured by leaves
						-	I	bul-m,d	CIR blends into background
Bulrush (bul)	d	++	++	++/none	++/none				
	m	+	++	-/pkw ¹ , suba	+/pkw ¹	=	I	pkw-m	C blends into background
	s	-	+	=/pkw ¹ , suba,b	+/pkw ¹	-	I	pkw-m	CIR " " "
						=	I	lil, pkw, sub	CIR " " "
Burreed (bur)	d	++	++	++/none ²	++/none ²				
	m	+	++	+/cat ²	+/cat ²				
	s	NA	NA	NA	NA	=	I	pkw-m,d	C/CIR blends into background
Cattail (cat)	d	++	++	++/none ²	++/none ²				
	m	++	++	+/bur ²	+/bur ²				
	s	NA	NA	NA	NA				

Legend and footnotes on next page.

for sparse vegetative stands) than did color film. The greater difference between the reflectances of vegetation and water in the near-IR region of the spectrum as compared to the visible region, accounts for the superiority of the CIR film.

The detectability of the submersed vegetation did not vary significantly between the two film types. The detectability of submersed vegetation growing near to the surface was good. All field-checked areas that were noted as having submersed vegetation in all years (1968 - 1976) showed vegetation in 1976; likewise, areas that did not show vegetation during any of these years were found to have no vegetation in 1976.

The detectability of low-growing bottom vegetation (largely Chara sp.) was poor if based on only one date of aerial photography, as these vegetative stands (particularly sparse ones) could be confused with (1) submersed rocks or rocky areas, especially when they were covered with organic debris, (2) areas of accumulated organic debris and (3) roots of past vegetative stands, especially emersed types (Fig. 7). On multi-date aerial photographic coverage, the areas of vegetation tended to exhibit greater changes in shape and location than did those of rocks, accumulated organic matter or dead roots, facilitating separation (Fig. 9). When low-growing vegetation occurred mixed with rocks, debris or dead roots, differen-

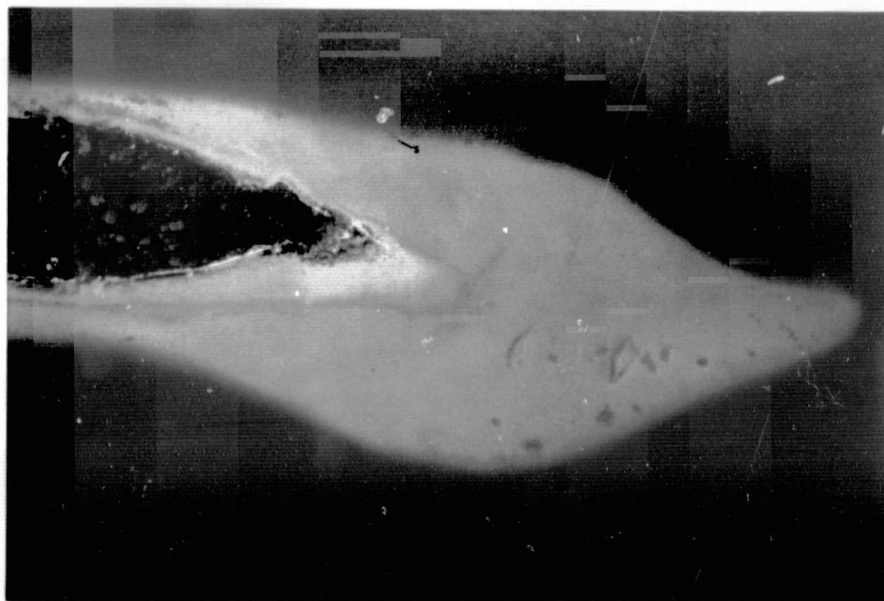
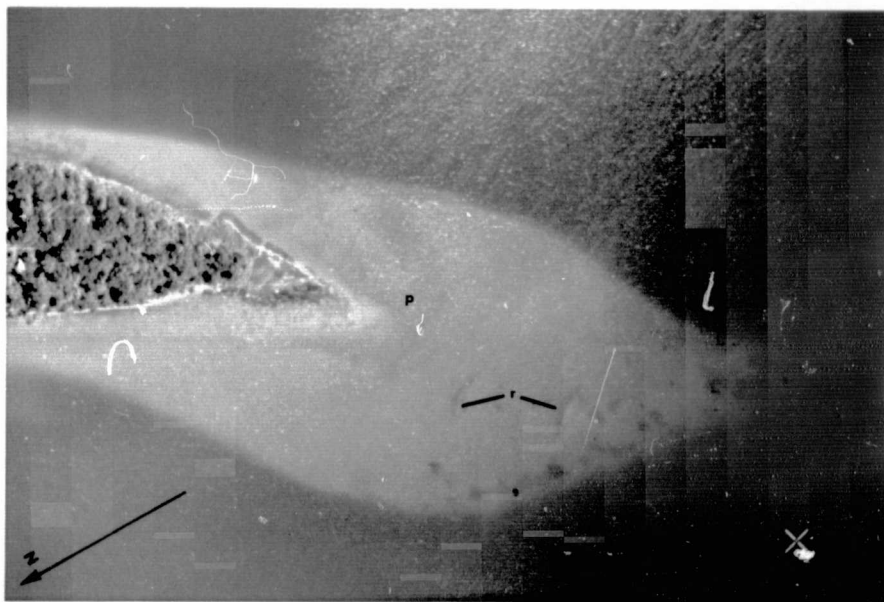


FIGURE 9. Color aerial photographs of the area to the south of Deowongo Island (1968, upper and 1974, lower). Temporal photographic data are useful for distinguishing aquatic vegetation from other submersed features. Rocks (r) and color patterns on the bottom (p) generally maintain shape and location through time, whereas submersed vegetation (s) may maintain location, but change shape, or may appear or disappear.

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tiation was generally not possible. Areas where vegetative pieces and debris had accumulated along the shoreline presented tones similar to submersed vegetation, though their location and shape usually were sufficient for separation. Certain species of algae that bloomed along the shore of the lake in August, 1976, had locations and shapes similar to submersed vegetation types, but their tones were different (greener on color, bluer on color IR) (Fig. 6).

For vegetation occurring in relatively pure stands, the identifiability (ability to distinguish from other plant forms) of the different plant types varied (Table 6). In general, the emersed and floating types were more easily identified on CIR film than color film, there being greater interspeciate tonal differences on the CIR film. The CIR film was especially useful for discriminating among the lesser reflecting vegetative types: bulrush, submersed vegetation and pickerelweed.

The identifiability of the different species of submersed vegetation in general was poor; the different species are therefore not listed in Table 6. Little differentiation was possible, except between surfaced, near surface and well below surface vegetation; a separation which is not entirely species related. (At certain times of the year this ability to differentiate height above bottom may be useful, e.g., in late August, Chara sp.

and Najas sp. are the only principal species well below the surface.) By location, certain vegetative beds could be identified as Myriophyllum sp., as this was the only species observed in depths greater than about two meters, and it had a tendency to grow along the edge of the littoral shelf. Potamogeton crispus did display a unique growth pattern (Table 4) which often allowed its identification, but it was a relatively minor species at the times of most of the photographic overflights. Many of the species tended to grow in mixed stands, further hampering attempts at identification.

In mixed vegetative stands, the identifiability or in some cases even the detectability of certain vegetative types decreased. For obvious reasons, vegetation beneath another layer of vegetation (e.g., submersed vegetation growing under a cover of lilies) was not detectable with aerial photographs. Due to the change in background, bulrush, in particular, was less easily identified in mixtures, especially when sparse (Figs. 5 and 10).

D. Classification System

In Table 7 is shown the legend used for compilation of multi-date maps of the aquatic vegetation of Canadarago Lake from 1:6,000 scale aerial photographs. Six pure types of vegetation were generally separated (only five were separated on the late July photographs due to the



FIGURE 10. Mixture of bulrush (emersed) and lilies (floating) along the southeastern shore of Canadarago Lake (Figure 5). On the 1:6,000 scale aerial photographs, the bulrush is not apparent. This stand was thus mapped as lb (broken lilies). (photo by A.E. Russell)

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TABLE 7. Classification system for mapping vegetation in Canadarago Lake with 1:6,000 scale, aerial photographs

MAPPING UNIT*	COMMENTS
Pure Stands	
1. Lilies	
1a. continuous (85-100%)	Some bulrush or submersed vegetation may be included as these types are not discernible in mixtures with lilies unless they are dense or moderately dense
1b. broken (45-85%)	
1c. scattered (10-45%)	
2. Pickerelweed	Some bulrush, burreed, lilies or submersed vegetation may be included (as per lilies)
3. Bulrush	Some submersed vegetation may be included (as per lilies)
3a. continuous	
3b. scattered	
4. Cattail	
5. Burreed	Some pickerelweed may be included (as per lilies)
4/5. Cattail or Burreed	For use where cattail and burreed cannot be separated
6. Submersed Types	Some bulrush may be included; separation of surface and bottom types is possible with some photography; bottom types designated with 1 (e.g. 6a1)
6a. continuous (85-100%)	
6b. broken (45-85%)	
6c. scattered (5-45%)	
Mixtures	
21. Pickerelweed and Lilies	
25. Pickerelweed and Burreed	
31. Bulrush and Lilies	
32. Bulrush and Pickerelweed	
321. Bulrush, Pickerelweed and Lilies	
61. Submersed Types and Lilies	
6b-1b.	
6b-1c.	
6c-1b.	
6c-1c.	
63. Submersed Types and Bulrush	
6b-3b	
6c-3b	

*All units may have minor inclusions of any vegetative type due, in part, to the inability to delineate units less than approximately one millimeter in diameter on the photographs (i.e., six meters on the ground).

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inseparability of cattail and burreed at this time of the year). Seven major categories of mixtures were separated.

Subclasses denoting percentage cover (i.e., continuous, broken, scattered) were used only for the lilies and submersed types. Two subclasses of bulrush were established in order to separate bulrush at a sufficient density that it would appear on all photographs.

The range of each percentage cover class is indicated in Table 7. The average cover factor applied in converting the map delineations to vegetative areas varied somewhat from year to year (Table 8a), on the average being 0.96 for map unit 1a, 0.73 for 1b, 0.33 for 1c; 0.95 for 6a, 0.69 for 6b and 0.25 for 6c.

E. Seasonal Changes in Vegetative Area

Although aerial photographic coverage of Canadarago Lake was acquired on two dates during both the 1973 and 1976 growing seasons (Table 1), quantitative evaluation of seasonal changes was limited to portions of the 1976 photographs. The July 1973 photographs were relatively small scale and panoramic, hindering measurement. During 1976, parts of the lake were missed or obscured by sunlint on the July photographs, and cloud shadows obscured some areas on the August photographs.

TABLE 8. Percentage cover factors for assessing vegetative area in Canadarago Lake (derived from aerial photographs using a crown density scale)

a. Factors for converting delineated areas of pure stands of vegetation to actual areas of vegetation (percent vegetation/100)

unit	1968	1969	1973	1974	1976
1a	0.94	0.97	--	0.97	0.95
1b	0.73	0.73	--	0.78	0.68
1c	0.33	0.30	--	0.40	0.30
6a	0.95	0.94	0.94	0.97	0.96
6b	0.68	0.67	0.66	0.75	0.72
6c	0.24	0.20	0.28	0.28	0.27

b. Factors for converting delineated areas of mixed stands of vegetation to areas of vegetation by type (percent vegetation/100)*

unit	1969	1976
21	0.43/0.57**	0.58/0.42
25	--	0.5/0.5
31	0.56/0.34	0.29/0.71
32	0.64/0.36	0.53/0.47
321	0.39/0.34/0.27	0.43/0.23/0.34

*In some cases, vegetation mixture delineations included a small percentage of non-vegetative (water) areas - the percentages are adjusted to an assumed 100% total vegetative cover

**First vegetative type/second vegetative type/etc.

1. Emersed and Floating Vegetation

The principal change between the July 1973 and September 1973 dates of photography was the disappearance of the floating leaves of numerous lily patches, producing a decrease in the emersed and floating vegetative area. In 1976, between July 20 and August 31, vegetative area changes were small. For the one area evaluated for seasonal changes, the vegetative area increased from 0.48 to 0.53 hectare (approximately 9%). A few small patches of Nymphaea odorata (lilies) did develop between these two dates; this vegetation was also present in August 1974. This vegetative change could thus be considered a true seasonal change as opposed to expansion of the area of vegetative colonization.

2. Submersed Vegetation

Some increase was apparent in submersed area between the two dates of aerial photographic coverage in 1973. The increase was primarily associated with areas identified as predominantly narrow-leaved pondweed (probably Heteranthera dubia) in the 1973 Department of Health surveys; the area of Myriophyllum sp. changed relatively little. In 1976, for the areas evaluated, a change from 2.30 to 2.33 hectare was observed between July 20 and August 31 (approximately 2%). There was some decrease in the area of Potamogeton crispus, little change in the areas of Myriophyllum spicatum and

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Chara sp., and some increase in the apparent area of Heteranthera dubia.

F. Vegetation Maps and Areas

Figures 11 and 12 are examples of vegetation maps for portions of Canadarago Lake in 1976, along with photographs of the same areas. Whole lake vegetative areas are tabulated (Table 9), and the principal ones plotted (Fig. 13). Sparse bulrush (3b) was not included in the plotted vegetative area totals as it did not dependably appear on all of the aerial photographs. The effect of its inclusion would be to produce lower total emersed and floating vegetative area figures for the years lacking good CIR photographic coverage (Table 9).

G. Vegetative Changes

1. Total Vegetation

Between 1968 and 1976, the total area of emersed, floating and submersed vegetation in Canadarago Lake increased 64%, from 13.2 to 21.6 hectares. These and interim year increases are presented in Figure 13, where the values do not include vegetation on the shoal (Fig. 4) or sparse bulrush. Interim increases in non-shoal vegetation are as follows: 1.2 hectares, 1968 - 1969; 3.8 hectares, 1969 - 1974; and 3.4 hectares 1974 - 1976.

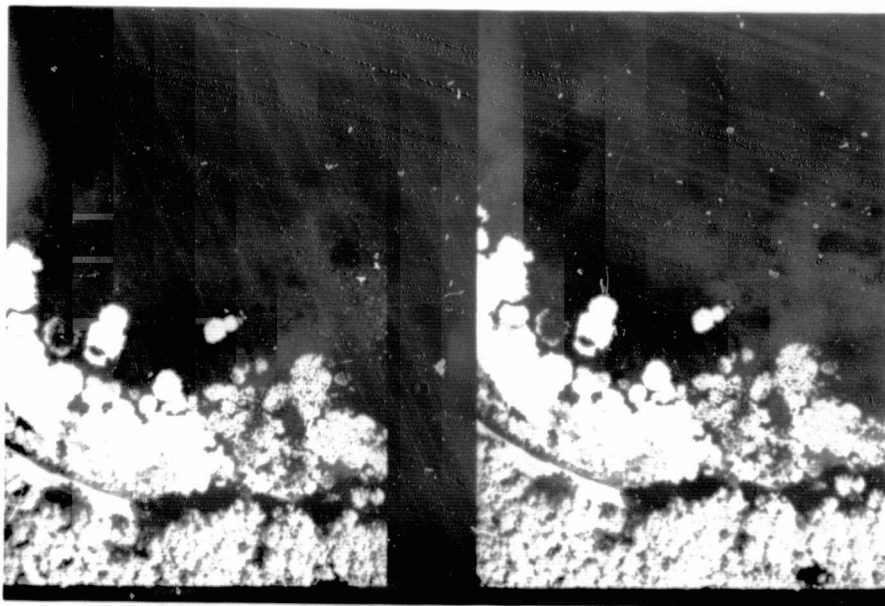
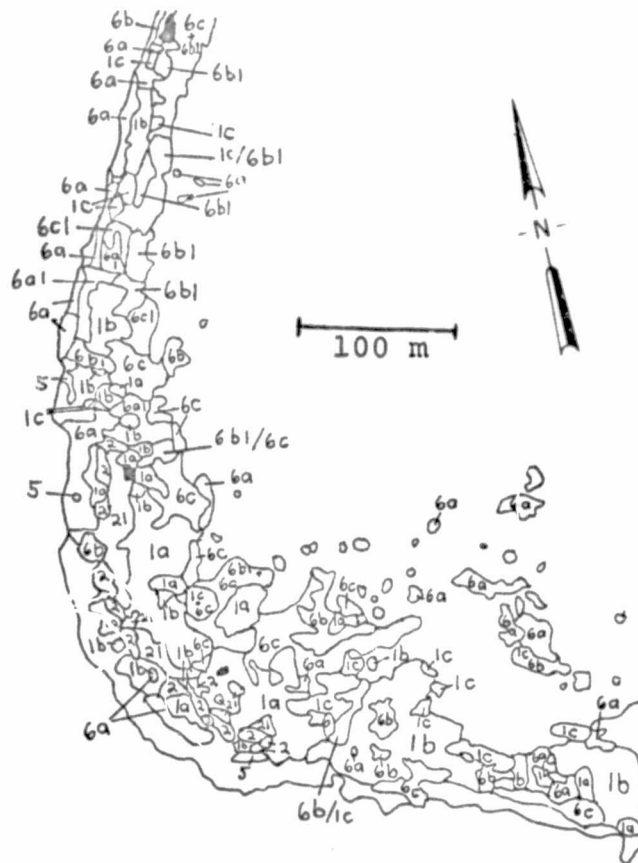


FIGURE 11. Portion of 1976 vegetation map (legend in Table 7) and stereogram of August 31 color infrared aerial photographs used to prepare map

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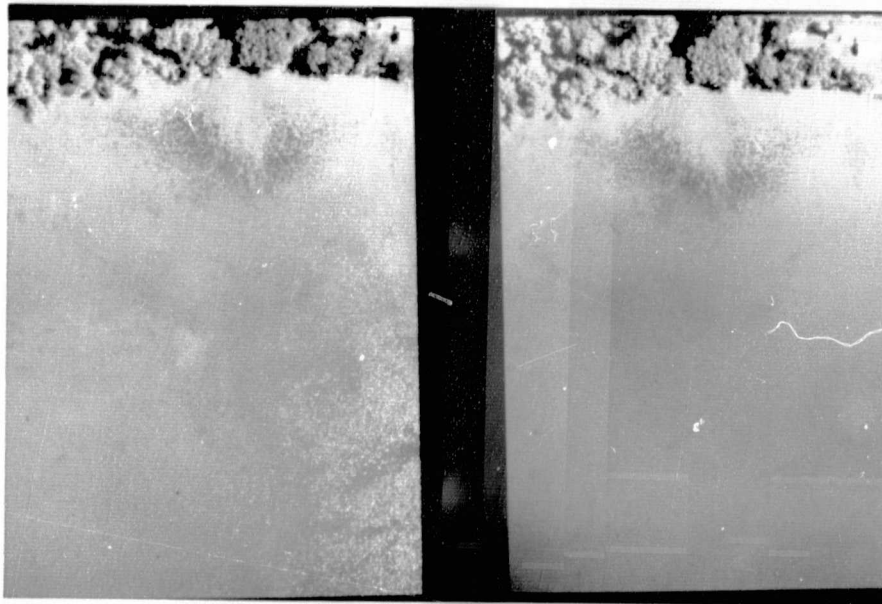
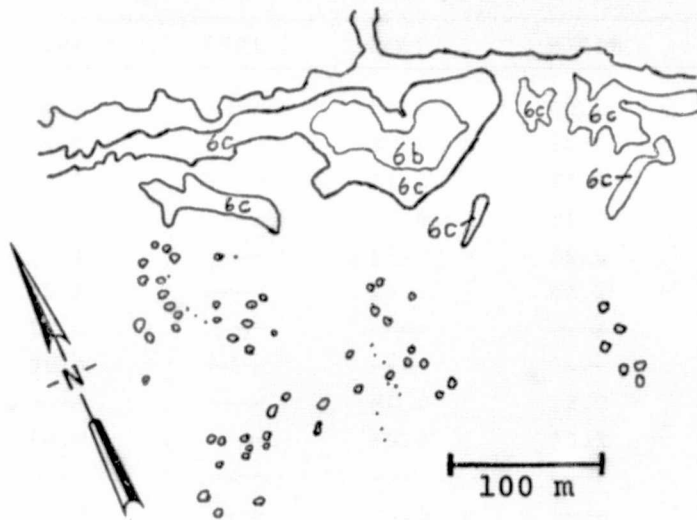


FIGURE 12. Portion of 1976 vegetation map (legend in Table 7) and stereogram of August 31 color photographs used to prepare map.

TABLE 9. Airphoto-derived areas of aquatic vegetation in Canadarago Lake, N.Y., between 1968 and 1976 (hectares)

unit	1968	1969	1973	1974	1976
1a	1.39	2.48	----	1.85	2.04
1b	2.37	2.58	----	2.27	3.17
1c	2.59	2.43	----	3.06	2.24
2	0.46	0.54	----	1.28	2.21
3a	2.21	2.34	----	1.71	1.77
3b	1.55	2.43	----	0.80	1.77
4	----	----	----	0.22	0.20
5	----	----	----	0.06	0.12
4/5	0.84	0.78	----	----	----
21	2.04	0.84	----	0.60	0.43
25	----	----	----	----	0.09
31	----	0.29	----	0.20	0.22
32	1.12	0.39	----	0.16	0.36
321	0.47	0.81	----	0.61	0.13
Total unmixed floating	3.88	5.01	----	4.78	4.74
Total floating and emersed	12.56	13.42	----	10.40	12.02
Total floating and emersed (-3b)	<u>11.01</u>	<u>10.97</u>	----	<u>9.60</u>	<u>10.26</u>
Total floating and emersed (-3b and w/o % cover factors)	13.47	13.45	----	12.01	12.97
6a	1.00(.07) ¹	1.89(m)	[2.47(.15)] ²	4.12(.18)	5.23(.40)
6b	1.18(.09)	1.53(m)	[1.47(---)]	3.94(.01)	3.11(.24)
6c	1.84(---)	3.34(m)	[3.11(.04)]	6.22(.03)	8.34(.24)
6a1					0.17
6b1		Not separated these years			1.88
6c1					1.51
Total submersed	<u>2.18(.13)</u>	<u>3.46(m)</u>	<u>[4.16(.16)]</u>	<u>8.65(.18)</u>	<u>11.39(.62)</u>
Total submersed(w/o % cover factors)	4.01(.17)	6.75(m)	[7.05(.19)]	14.28(.21)	20.23(.88)
Total vegetation (-3b)	<u>13.19(.13)</u>	<u>14.43(m)</u>	<u>[----(.16)]</u>	<u>18.25(.18)</u>	<u>21.64(.62)</u>
Total vegetation (-3b and w/o % cover factors)	17.48(.17)	20.20(m)	[----(.19)]	26.29(.21)	33.19(.88)
Submersed for 1973 area	<u>1.51(.13)</u>	<u>2.17(m)</u>	<u>4.16(.16)</u>	<u>5.29(.18)</u>	<u>6.29(.62)</u>

¹figures in parentheses are for shoal area, 'm' denotes missed

²brackets indicate that figures are for the 1973 area

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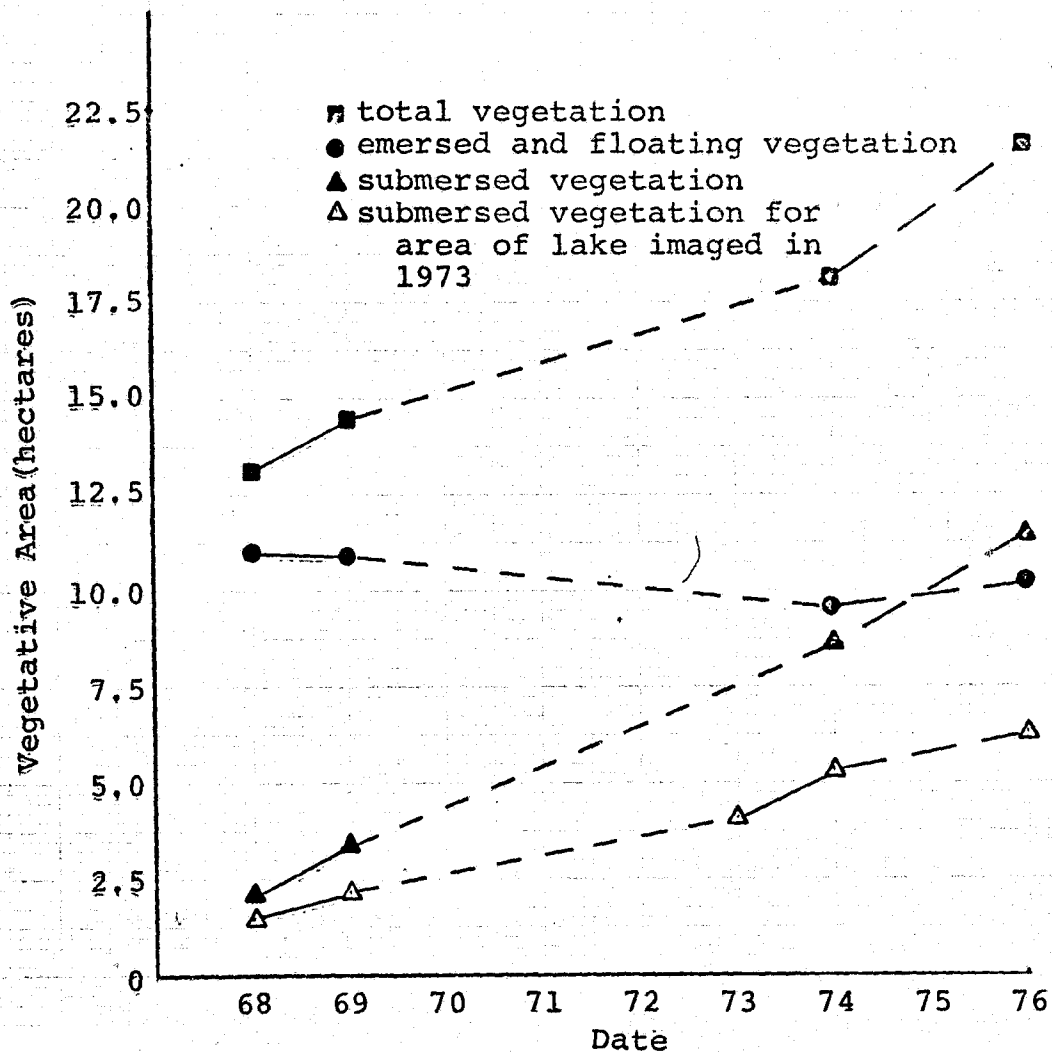


FIGURE 13. Changes in areas of different vegetative types in Canadarago Lake from 1968 through 1976 (sparse bulrush [3b] and vegetation on shoal not included)

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2. Emersed and Floating Vegetation

The total area of emersed and floating vegetation changed little between 1968 and 1969; decreased slightly (1.4 hectares), between 1969 and 1974; and increased slightly (0.7 hectare) between 1974 and 1976 (Figs. 14 - 18). The net change 1968 to 1976 was a 0.7 hectare decrease. The largest of these changes was 13%.

Although the overall areal changes in emersed and floating vegetation were relatively small, changes in species composition and location were more marked. Species changes were evaluated only with the 1969 and 1976 photographs; the factors used to convert mapping unit areas to species areas are in Table 8b. Vegetative areas by mapping unit and by species are shown in Figures 19a and 19b, respectively.

A small decrease in the total measured area of floating vegetation (lilies) occurred (Fig. 19), consisting primarily of (1) a general decrease in percentage cover, especially in some deeper water beds (Fig. 20); (2) a loss of some sparser beds (1c), again especially in deeper waters (Fig. 20) and often with replacement by submersed types; and (3) some replacement of mixed lilies/emersed stands by pickerelweed. In some areas lilies increased.

As regards the emersed species, there was a considerable increase in the area of pickerelweed, while bulrush, burreed, and cattail decreased. The increase

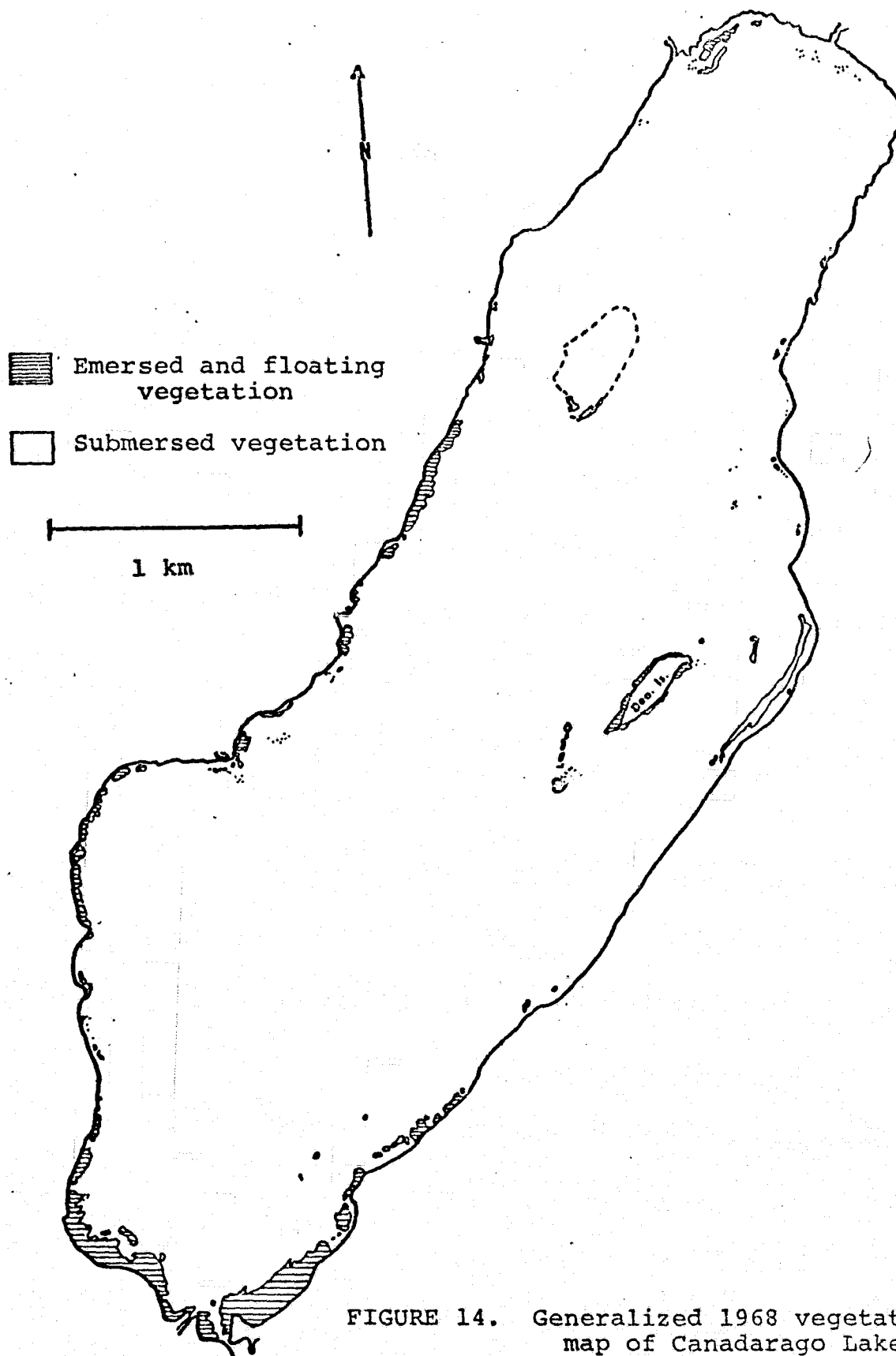


FIGURE 14. Generalized 1968 vegetation map of Canadarago Lake (sparse bulrush not mapped)

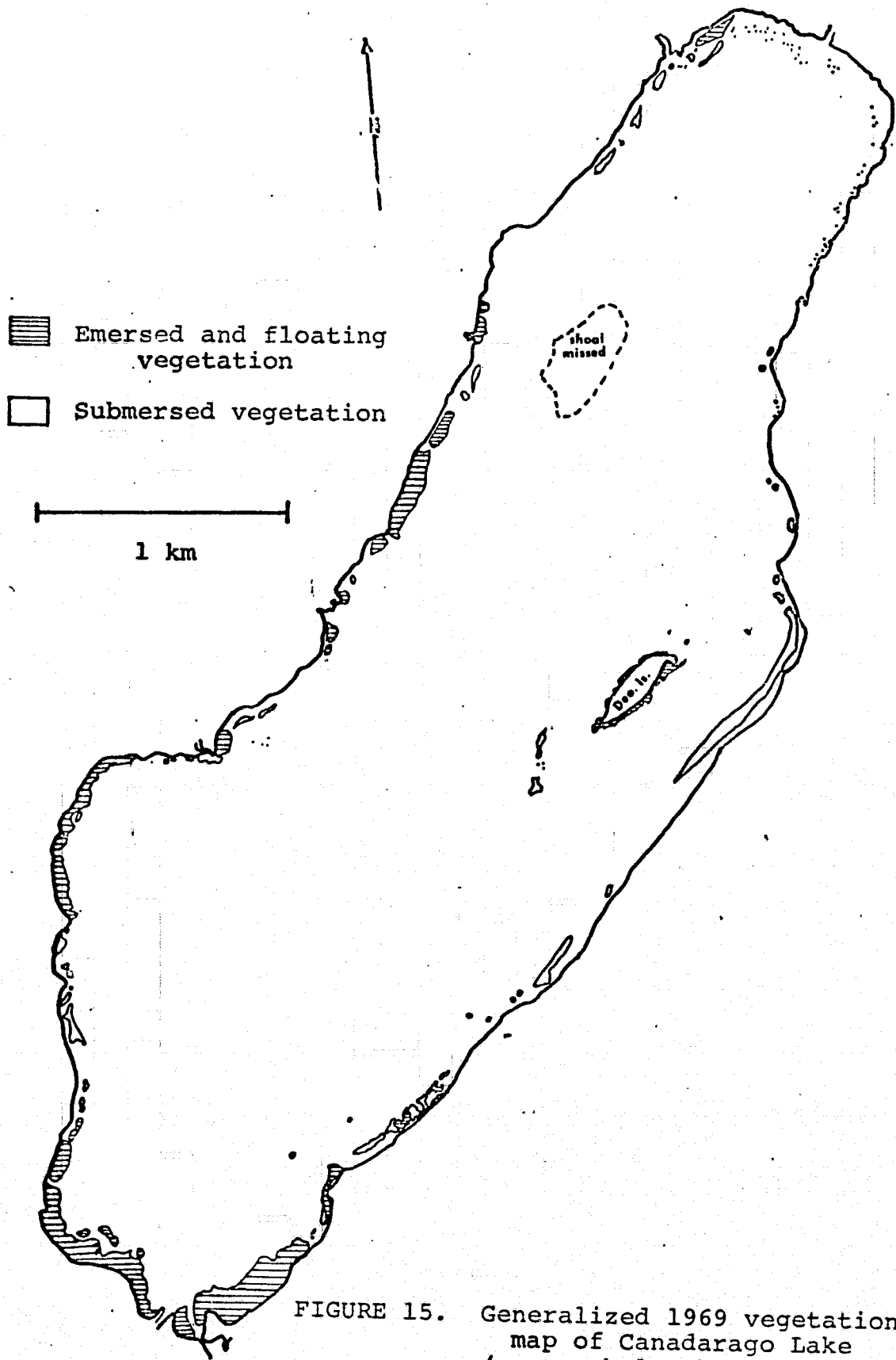


FIGURE 15. Generalized 1969 vegetation map of Canadarago Lake (sparse bulrush not mapped)

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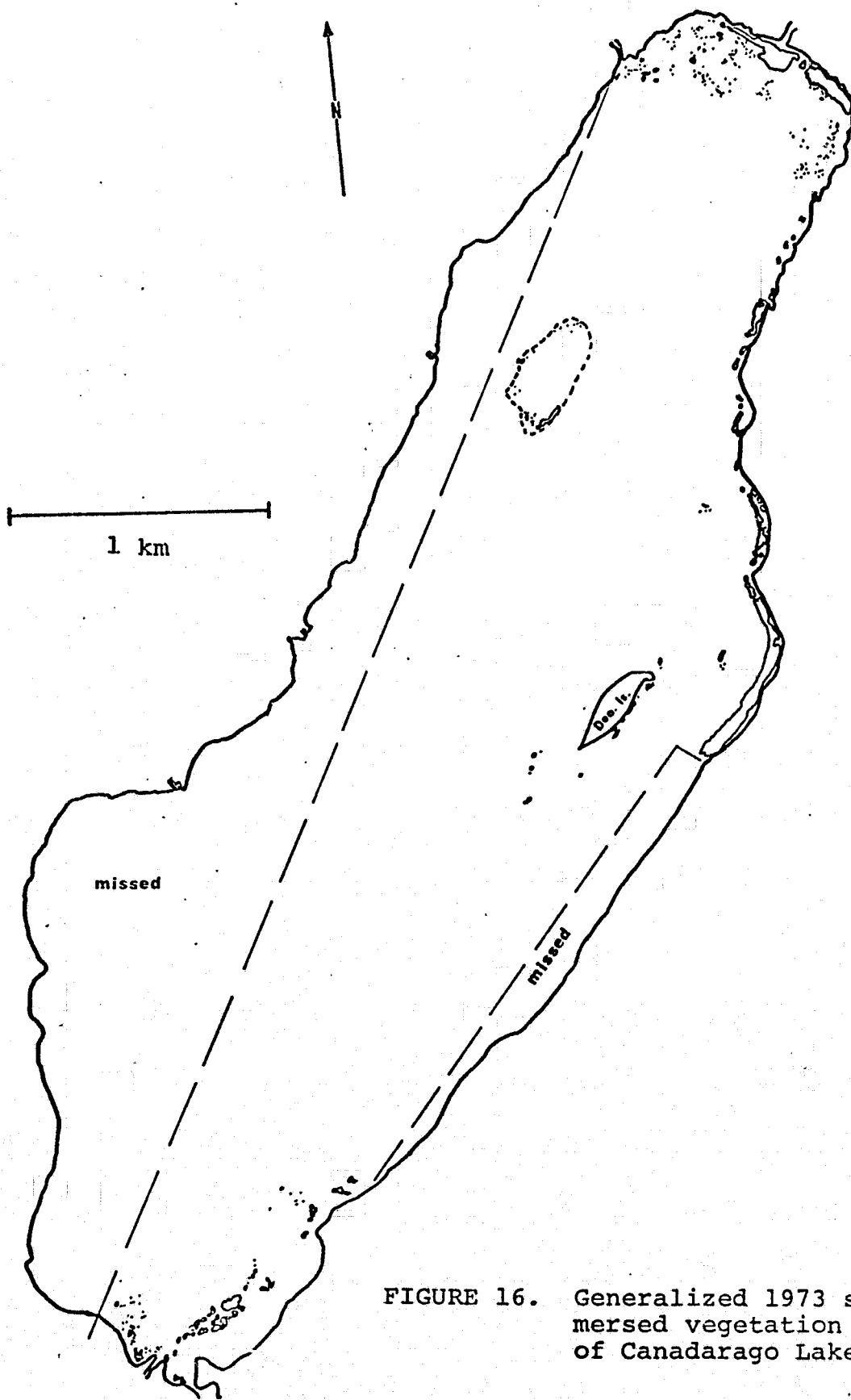


FIGURE 16. Generalized 1973 submersed vegetation map of Canadarago Lake

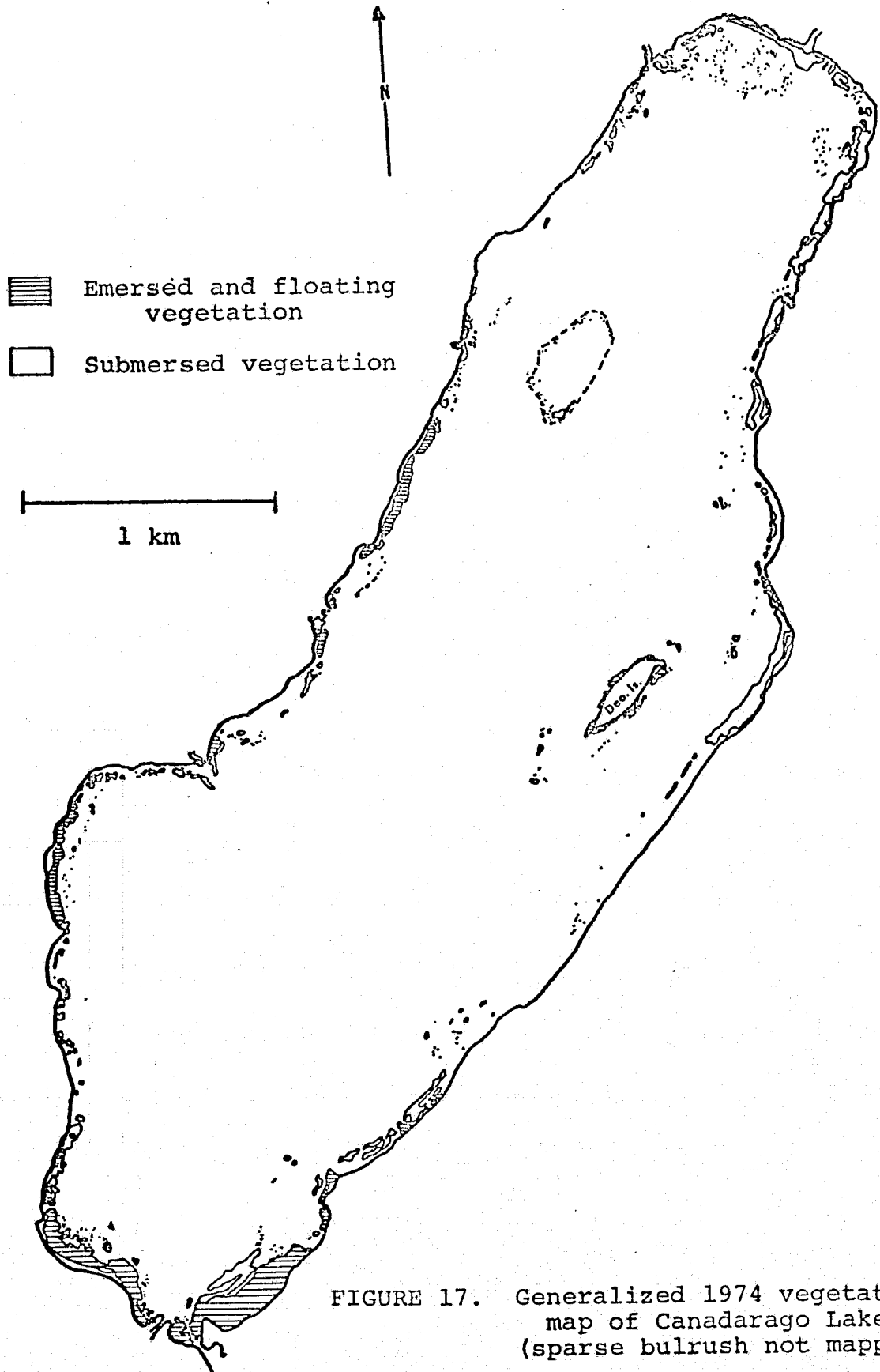


FIGURE 17. Generalized 1974 vegetation map of Canadarago Lake (sparse bulrush not mapped)

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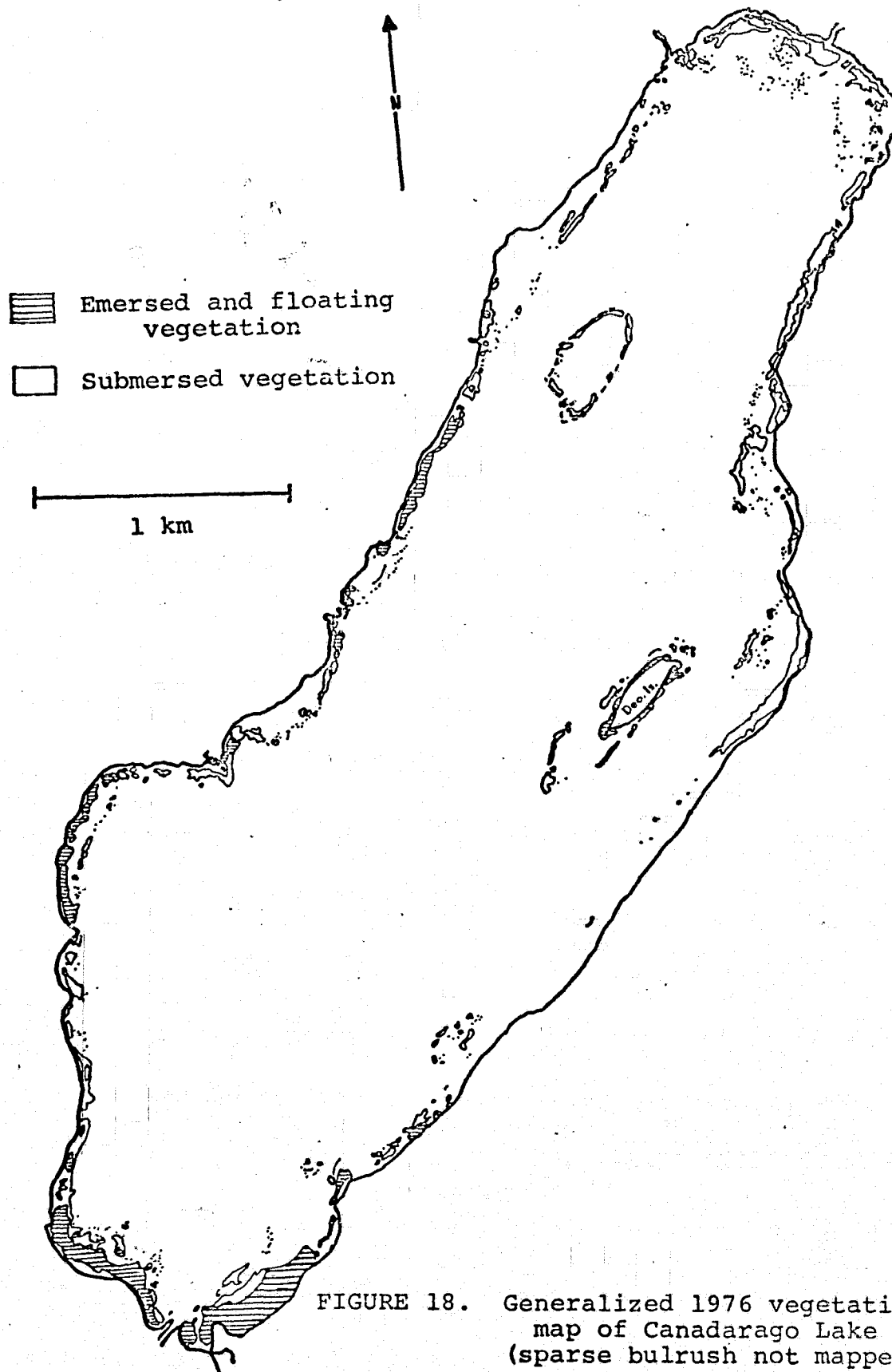
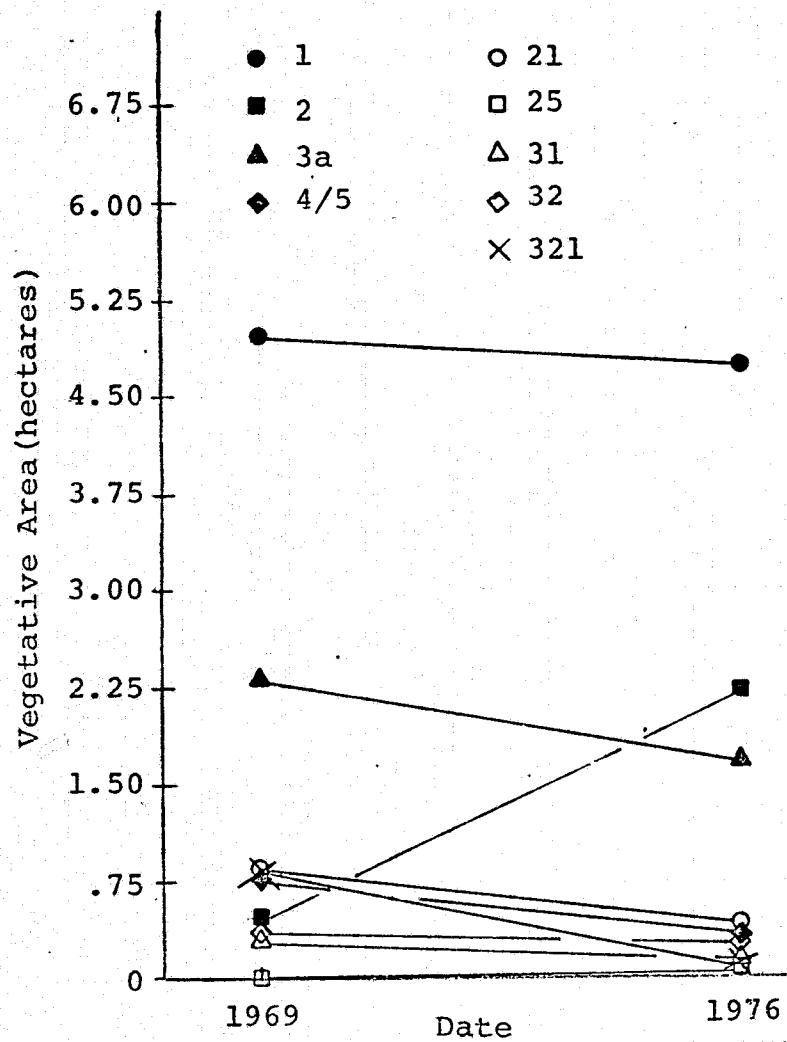
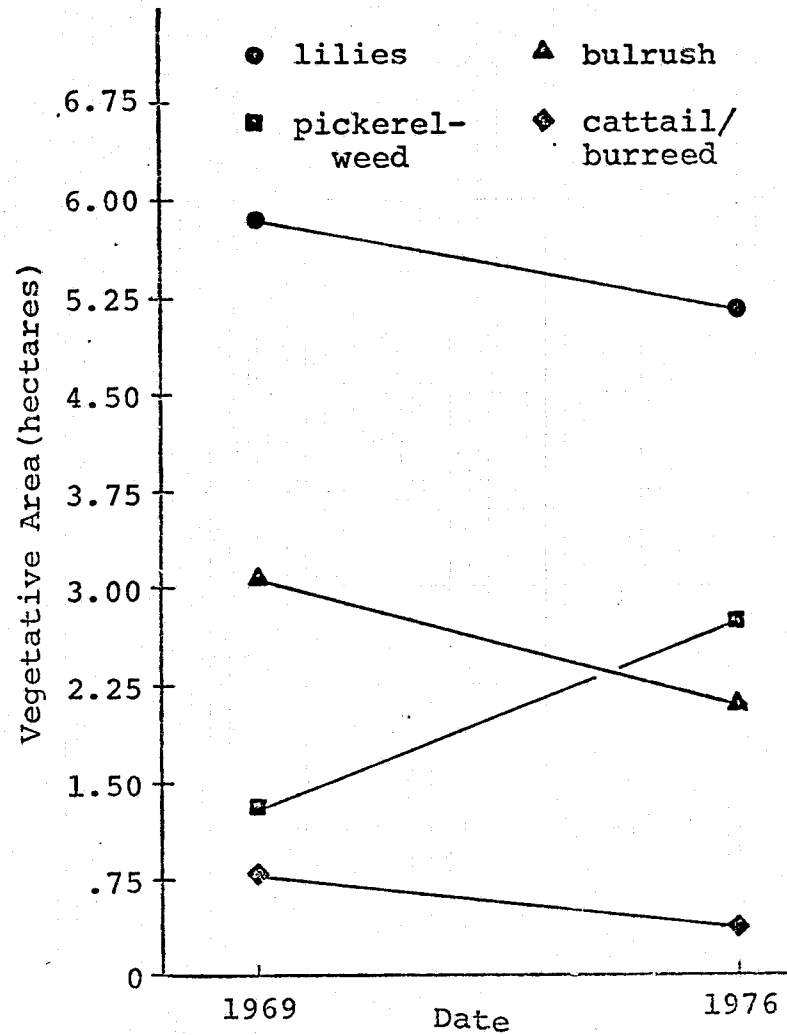


FIGURE 18. Generalized 1976 vegetation map of Canadarago Lake (sparse bulrush not mapped)



a. by mapping unit



b. by species or type

FIGURE 19. Changes in the areas of emerged and floating vegetative types in Canadarago Lake, N.Y., between 1969 and 1976 (areas derived aerial photographs).

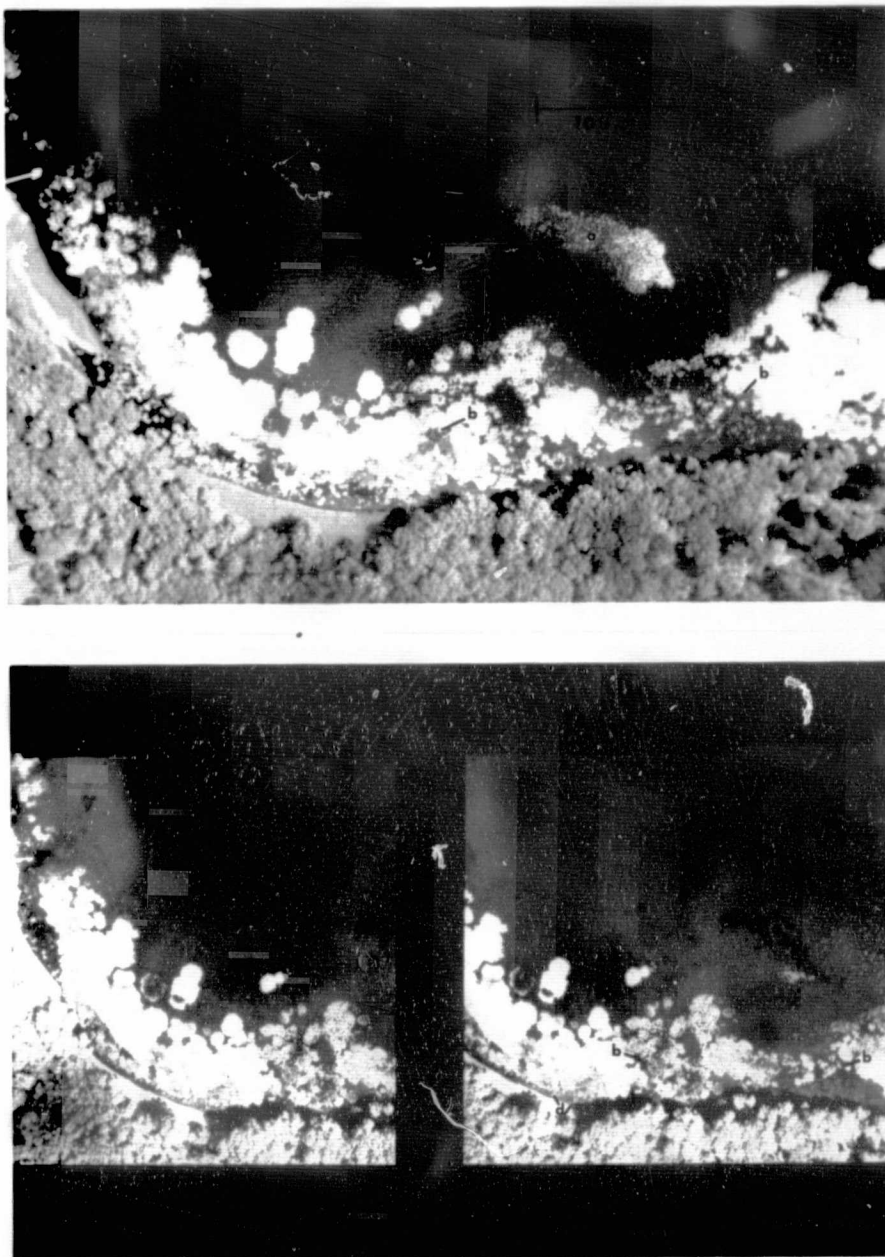


FIGURE 20. Vegetative changes along the south shore of Canadarago Lake. Between July 31, 1969 (upper) and August 31, 1976 (lower) the following changes occurred: (1) a decrease in lilies, especially the sparser patches in deeper waters, with frequent replacement by submersed types (a); (2) a decrease in pickerelweed, primarily in deeper water areas (b); (3) a general increase in submersed vegetation (c); and (4) the appearance of some small burreed areas (d).

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in pickerelweed was confined almost exclusively to one part of the lake. Here, pure or nearly pure stands of pickerelweed replaced mixtures of pickerelweed and other species (primarily bulrush) (Fig. 21). Other changes in pickerelweed, although generally minor, included some decreases in deeper waters and some increases in shallower waters (Fig. 20). In general, several moderate sized areas of bulrush disappeared (Fig. 7), with other decreases along the east shore of the island and within the area where pickerelweed increased (Fig. 21). Although a few small areas of burreed appeared by 1976, the decrease in the area of burreed and cattail constituted approximately one half of the 1969 area. This decrease occurred near the outlet to the lake where the principal stands of burreed and cattail occur (Fig. 22).

3. Submersed Vegetation

Between 1968 and 1976 the total area of submersed vegetation in Canadarago Lake (including the shoal area) increased by more than 400%, from 2.3 to 12 hectares (Figure 13 excludes shoal vegetation).

Excluding the shoal area, which was not imaged in 1969, the submersed vegetation increased by about 1.3 hectares or 59% between 1968 and 1969. The increase was relatively well distributed around the lake, with the largest changes occurring along the northern and southern-

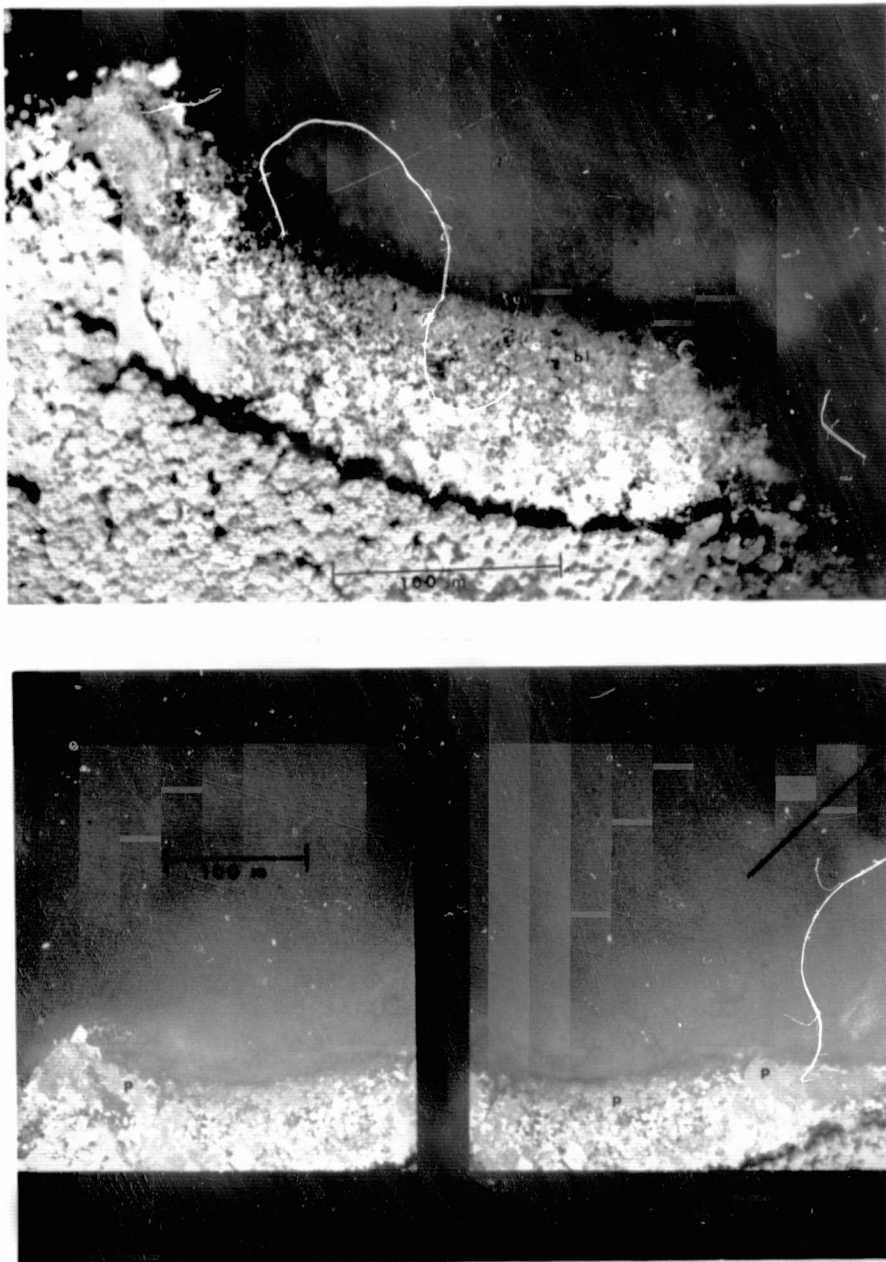


FIGURE 21. Vegetative changes in the southeast portion of Canadarago Lake. Note the following changes between July 31, 1969 (upper photo) and July 20, 1976 (lower photo): (1) increased predominance of pickerelweed (p) and (2) decreased abundance of bulrush (bl).

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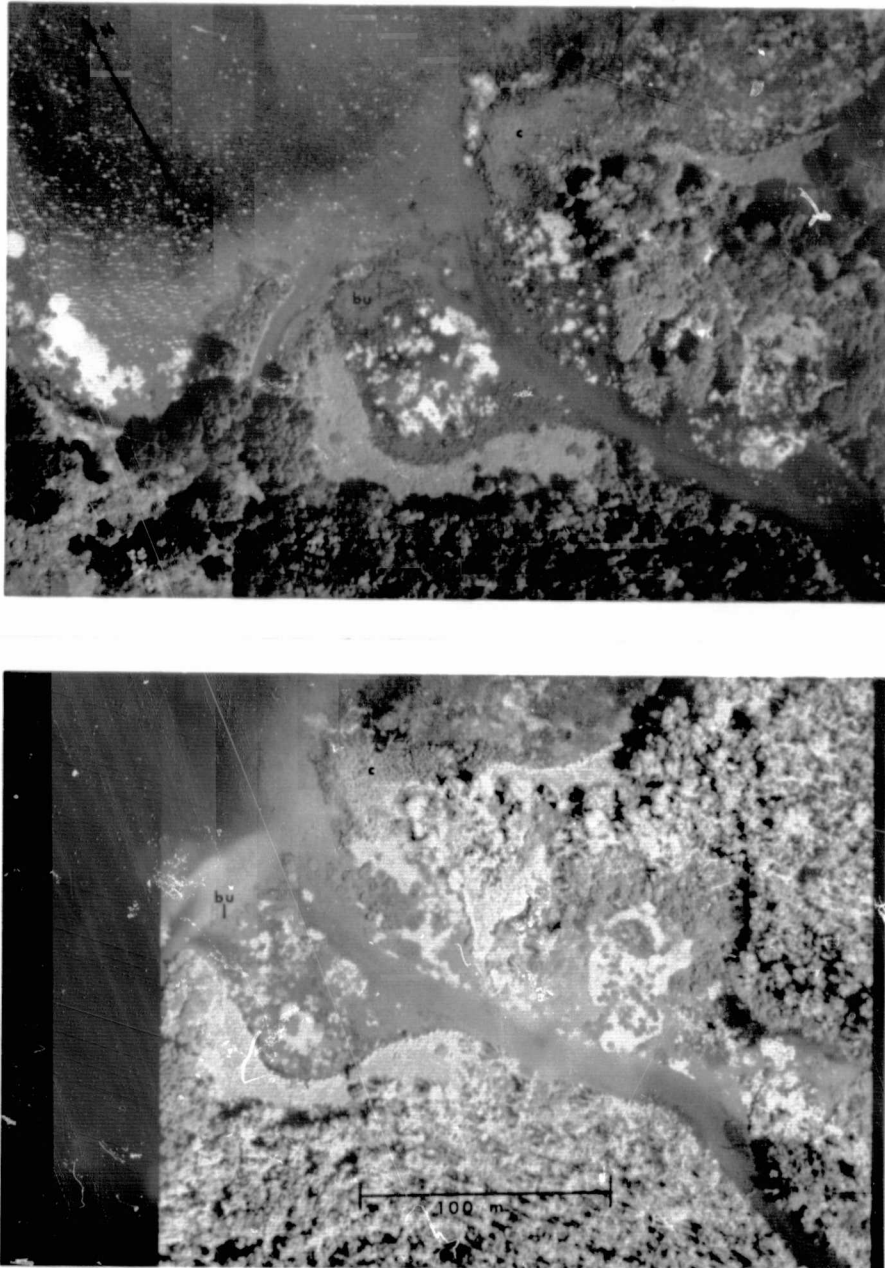


FIGURE 22. Vegetative changes near the outlet to Canadarago Lake. A large decrease in both cattail (c) and burreed (bu) occurred between August 15, 1968 (upper photo) and August 31, 1976 (lower photo).

most quarters of the western shore and the central portion of the eastern shore (Figs. 14 and 15 - due to the generalizations necessary in producing these small scale maps, not all of the vegetative changes noted may be obvious). The changes were essentially restricted to the shallower water areas (less than 1.5 m) and consisted of both expansion of existing beds and initiation of new beds.

Between 1969 and 1974, non-shoal submersed vegetation increased by some 5.2 hectares, or approximately 150%. The increase was generally well distributed on all but the south-central portion of the eastern shore, where some decrease occurred (Figs. 15, 17). Although some increase occurred in deeper waters (greater than 1.5 m), the predominant increase was in shallower waters. On the shoal areas to the south of the island (in relatively deep water), the submersed vegetation decreased somewhat in area, though that remaining appeared more vigorous. Much of the change involved the formation of new beds, with some older ones disappearing, but the expansion of existing beds was also significant.

Although incomplete, the 1973 photographic coverage indicates little variation in the patterns of change between 1969 and 1973 and between 1969 and 1974. From 1973 to 1974, most of the change involved expansion, or increase in percentage cover of existing beds (Figs. 15 and 16).

Between 1974 and 1976, non-shoal submersed vegetation increased by about 2.7 hectares or 32%, and the total area of submersed vegetation increased by about 3.2 hectares or 36%. Much of the increase occurred in deeper waters on the shoal, around the island, and along the edge of the littoral shelf around much of the lake (Figs. 17 and 18).

In Appendix C is a discussion of possible reasons for the changes in vegetation observed between 1968 and 1976.

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V. DISCUSSION

A. Canadarago Lake Vegetation

1. Spectral Characterization of Aquatic Vegetation

As opposed to emersed and floating vegetation (Table 5), spectral characterization of submersed vegetation was not attempted, for it would have required removal of the effects of (1) reflections from the water surface and (2) reflection and absorption from varying amounts of water intervening between the camera and the plants. To remove these effects would be complicated, if possible, and was beyond the scope of this preliminary investigation into the spectral characteristics of aquatic vegetation.

For photographs flown at similar times of the year, the between-film differences in color of the various vegetative types (Fig. 7) were related to variations in the photography (emulsion, exposure, processing) and the atmosphere. Although these differences precluded the use of uniform 'tonal' keys, spectral keys applicable to all same-season photographs could theoretically have been produced through further film calibrations (as attempted by Calspan's Scene Color Standard technique). No attempt was made to produce these spectral keys as (1) the within-film tonal keys were adequate for differentiation of the vegetative types, (2) a microdensitometer, required to calibrate the films, was not readily available, and

(3) spectral keys would not have been applicable to the films lacking sensitometric data (duplicates - Table 1).

2. Factors Affecting the Detectability and Identifiability of Aquatic Vegetation

The data in Table 6 were derived from photographs taken under a particular set of conditions. For the other photography flown, these conditions were different (Table 1), which, in some cases, affected the ability to detect or identify aquatic plant types. The principal variables affecting the detectability and identifiability of the plant types were: (1) sunglint, (2) water level and transparency, (3) film exposure, (4) photographic scale and (5) date of photography.

a. Sunglint

Specular reflection from the water surface is primarily a problem when photography is flown at high sun angles or when waves are present. Sunglint principally affects the detectability of submersed vegetation, but to some extent, hinders the visibility of all aquatic vegetation. If severe, it completely masks all submersed vegetation; if slight, it interferes primarily with the detection of small or sparse vegetative beds. The August 1968 photographs (Table 1) were the most severely affected by sunglint; most areas were imaged by one frame where

sunlint effects were minor, but sunlint-free stereoscopic coverage was limited. Rough water along the lake's northern shore concurrent with the August 1974 and July 1976 photographic overflights created some sunlint problems.

b. Water Level and Transparency

The detectability of non-surfaced submersed vegetation will be affected by the water transparency to an extent determined by the amount of water between the vegetation and the surface. Water transparencies (Secchi disc) and water levels at the times of the photographic overflights are shown in Table 1. Water level differences between the dates were small, 0.15 meter at maximum.

Water transparency showed greater variation: a maximum of 5.6 meters on July 25, 1973 and a minimum of 1.3 meters on July 31, 1969. The effects of bottom reflectance on the aerial photographic tones could be observed in water areas with depths to at least the prevailing Secchi disc transparency. However, on the July 1976 photographs, vegetation with leaves 1 meter (or half the Secchi transparency) below the water surface had very low contrast with vegetation-free bottom areas. Although no vegetative beds with leafy tops greater than 1 meter below the surface were located during the field surveys, if present, they would likely be undetectable on the July

aerial photographs. On the August 1976 photographs, vegetation 1 to 1.2 meters below the surface showed a much improved contrast with surrounding non-vegetated areas, although the transparency was only 0.6 meters greater than in July. Again vegetation greater than this depth below the surface was not observed, and its detectability is unknown. Higher haze and sunlint effects on the July photographs may have accounted for the poorer water penetration relative to the transparency.

The fraction of the Secchi disc transparency to which submersed vegetation will be detectable is dependent on a number of factors, including the exposure and contrast (gamma) of the film and the contrast between the vegetation and the background bottom material. Given proper exposure and atmospheric conditions and "normal" contrast between the bottom materials and the vegetation, submersed plant detectability with regular color or CIR films in Canadarago Lake can be expected to somewhat greater than one half (but less than the full) the Secchi disc transparency. Specially filtered or water penetration films could potentially do better.

c. Film Exposure

As noted in Table 6, no difference in the detectability of submersed vegetation was apparent between color and CIR film. This was true only when both films were

given slight overexposure (0.5 f-stop) relative to that recommended by the Kodak aerial exposure calculator (Kodak, 1970). With less exposure, color film showed a decided advantage over CIR.

The detectability of certain emerged species (particularly bulrush and burreed) was affected by the exposure. Sparse stands in particular went undetected without slight overexposure.

The CIR photographs acquired in 1968 (1:6,000) and 1974 were the only photographs affected by severe exposure problems (Table 1). The color photographs acquired in 1968 were slightly underexposed for identifying submersed vegetation, and a shift in their color balance also affected their contrast.

d. Photographic Scale

The principal scale of photography used for this analysis was 1:6,000. Smaller scale photographs were occasionally used if areas were either missed or obscured by sunlint on the larger scale films. With the smaller scale photography came some decrease in detectability of the vegetative beds, especially small or sparse ones.

e. Date of Photography

Seasonal changes in the height and spectral reflectance of the aquatic plants affected their detecta-

bility and separability. Bulrush and pickerelweed were more spectrally distinct on the July 1976 than on the August 1976 photographs, therefore their separability was better on the earlier date. Cattail and burreed, spectrally very similar on the July photographs, were separable on the August photographs (Fig. 8). The increase in height and possibly also leaf size of pickerelweed over the summer tended to progressively decrease the detectability of plants (primarily lilies) growing mixed with it.

The increase in length of some of the submersed plants (primarily Heteranthera dubia) between July 20 and August 31, placed the plants closer to the water surface, enhancing their detectability on the later date.

Myriophyllum spicatum showed a slight tendency to decrease in nearness to the surface between these dates. In most cases, it had stems at the surface on July 20, and between July 20 and August 31, a number of stems broke off slightly below the surface. Most areas still had some stems at the surface on August 31.

During the month of August 1976, the overwhelming majority of the observed beds of submersed plants had their tops within 1 meter of the water surface. High water transparencies (in excess of 4 meters) in late July-mid August 1976 allowed visibility of plants to several meters depth from a boat. On the 1968 and 1969 photographs, a number of vegetative beds that in 1974 and 1976

had reached the surface of the water on similar dates, were still some distance below the surface.

If the summer of 1976 can be considered a typical growing season for the aquatic vegetation in Canadarago Lake (if one exists), then it appears that an adequate level of submersed vegetation detectability can be achieved between late July-early August to late August-early September with a minimum of 2 meters Secchi transparency.

3. Limitations to Methodology

a. Limitations Inherent to Classification System

The classification system used takes only partial account of variations in percentage cover within the vegetative beds. Only for the submersed and floating (lilies) vegetative types were the beds categorized as to percentage cover. This was a result of two factors. First, most of the emersed species (pickerelweed, cattail, burreed) usually formed a nearly complete cover when in pure stands, and when in mixed stands, the aggregate usually formed a nearly continuous cover. Therefore, cover factors were not as necessary for these types. Second, the tendency of the submersed and floating types to become clumpy when not continuous made cover estimates for these plants relatively easy and reliable to determine using a crown density scale. The other species maintained little

or no clumpiness as they became sparser, showing simply a wider spacing of stems. It was generally not possible to determine the percentage cover of non-clumping species (especially those with narrow leaves) on 1:6,000 scale aerial photographs, as the individual plants or the gaps between the plants were too small to be resolved and/or measured. One of the submersed types (Chara sp.) showed little tendency to clump; cover estimates for Chara sp. beds were thus poorer than for the other submersed types. Sparse bulrush was separated from denser stands because it did not dependably appear on all photographs. Its subsequent exclusion from the vegetative area totals, though causing some underestimation of the total vegetative area, did thereby take partial account of the variations in percent cover of bulrush stands.

Each mixture category in the classification system includes only those vegetative beds where each mixture component makes up a sufficient proportion of the mixture to be detected. As the detectability of the different species in mixtures varied (Table 6), the demarcation between a pure stand and a mixed stand was not constant between species (e.g., a vegetative stand 10% lilies and 90% bulrush might be classed as 31, bulrush and lilies, whereas one 90% lilies and 10% bulrush would be classed as 1, lilies).

b. Classification and Delineation Errors

Classification errors could be present for any of the classification categories, but would be expected to be minimal for the relatively pure dense vegetative stands. The most likely errors would have occurred in classifying: (1) submersed and floating vegetation into the percentage cover classes, (2) some vegetative mixtures (primarily those where the species did not maintain any spatial integrity within the mixture - i.e., no clumps definable within the mixture), (3) very sparse vegetative stands, and (4) areas of interspersed submersed plants with rocks or other dark bottom features. Delineation errors likewise could be present anywhere, but would be most pronounced on the very small vegetative beds.

c. Percentage Cover Measurements Errors

Considerable human judgement is involved in the use of a crown density scale, likely making the estimates of percent vegetative cover one of the larger sources of error. There were more problems in estimating percent cover of each species in mixed stands, than total percent cover. The species percent cover factors (Table 8b) are therefore less accurate than the total percent cover factors (Table 8a). In Table 9, the vegetative areas computed without the use of cover factors are presented for comparison.

d. Transfer, Base Map and Area Measurement Errors

Certain portions of the shoreline had few control points with which to align the photographic overlays to the base map. For the most part this would produce systematic errors in the position of a map unit rather than in its area. Also, the control points on certain portions of the shoreline were almost entirely along a single line, making it impossible to compensate for tilt in the original photography. Errors are also present in the base map and area measurements.

e. Detectability and Separability

Differences Between Films

Due to differences in sunlint, water transparency, film type, exposure, and time of year among the different photographic coverages, the capacity to detect and/or identify certain vegetative types varied (Sec. D). These differences may have produced errors in the vegetative areas derived from the aerial photographs. Sub-optimal conditions would especially tend to make the measured area of submersed vegetation below the actual value, but would also tend to lower the measured area of emersed and floating vegetation. For each photographic overflight used for mapping vegetation the severity of the overall conditions varied, producing the following effects.

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August 15, 1968

The underexposure and color shifts in both the color and CIR films (primarily CIR) made species identifications difficult, especially in mixed stands. There was a tendency to lump large areas of emerged and floating vegetation into certain mixed categories (e.g., 21, 32) as the species were hard to distinguish. Thus, emerged and floating categorizations for this year are not highly reliable. The overall area of emerged and floating vegetation (once sparse bulrush is excluded) would be less affected, although it might be slightly low.

The problems with sunglint, in addition to the exposure and color shift problems would likely make the submersed vegetation figure somewhat low, due principally to the lower likelihood of detection of sparse, small or low-growing vegetative beds. Somewhat better exposed, smaller scale photography did provide some back-up.

July 31, 1969

This photography was excellent in terms of exposure (for both the color and CIR films) and sunglint. However, water transparency was quite restricted (Table 1), and submersed vegetation that had not grown to within 0.6 to 1 meter of the surface would tend to be obscured. The extent of the vegetation below this depth at this time is unknown, but is thought to be a relatively small percentage

of the total area. Burreed and cattail were not separable on these aerial photographs.

September 27, 1973

As the only large scale photographs were color, emersed and floating species identifiability was hampered to begin with; but, in addition, all of these species had "browned" considerably, further eroding the ability to identify them. Thus, none of the emersed and floating beds were categorized as to type. This "browning" did improve the ability to distinguish bulrush from submersed vegetation on color film (normally easily confused - Table 6) as the submersed vegetation had not browned. In addition, large scale coverage of the lake was only partial, restricting the comparisons that could be made with the other years.

The detectability of submersed vegetation was adequate due to high water transparency, proper exposure and lack of sunlint.

August 22, 1974

The color infrared photographs were underexposed, hampering the detection and identification of some species. The emersed and floating categorizations are therefore somewhat suspect, and the overall area of emersed and floating vegetation may be slightly low.

The water was exceptionally clear and submersed

vegetation was in general easily detected, except in a few locations where rough water caused sunglint to interfere.

August 31, 1976

Except for some cloud shadows over some important beds of emersed and floating vegetation, conditions were very good and the area figures for all vegetative types should be the most accurate overall. Also, the July 1976 photographs were available to discriminate species in the vegetative beds cloud covered on the August 31 date.

f. Seasonal Areal Changes in Vegetation

Emersed and Floating Vegetation

If the development of the emersed and floating vegetation in Canadarago Lake during 1976 can be considered typical, then areal changes in these vegetative types between late July and late August are generally small. For most years, vegetative area figures obtained from photography flown anytime during this period should be representative of the vegetative area for that year and therefore comparable with other years. The September 1973 photography was flown too late in the season to obtain a reliable measure of emersed and floating vegetative areas.

Submersed Vegetation

For 1976, the changes in submersed vegetation for the July 20 - August 31 period were small, but for 1973, between July 25 and September 27, they were somewhat larger. Though these changes were not measured, they were still thought to be relatively small percentagewise. Submersed vegetative growth, being susceptible to changes in water transparency, is more likely than emersed or floating vegetation to show differences in growth patterns between years. Thus, though submersed area figures derived from photography flown between late July-early August and late August-early September in any year are thought to be comparable (assuming adequate water transparency), the comparability is likely less than that for the emersed and floating types. Photography flown through late-September may be usable if a greater degree of water transparency is present (as was present September 27, 1973). As certain species (e.g., Myriophyllum spicatum) begin to die back towards late summer, the stems start breaking off the plant above the substrate. The vegetative area does not change considerably, but its distance below the surface does; thus the need for greater water transparency.

All of the photographic missions were flown after the die-back of Potamogeton crispus, an important submersed plant which predominates in June and dies back considerably by mid-July. Hence, for none of the years is information

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available on this species. Some P. crispus persists throughout the summer, but indications are that the amount that persists is not directly related to the amount present early in the season. Differences in the amount of P. crispus persisting through the summer may tend to obscure changes in the area of the later summer species. Fortunately, persisting P. crispus usually forms in distinct rings (Fig. 5) which can be separated from other submersed types if not mixed together.

The total areal contribution of detected P. crispus persisting was negligible for all years studies. There is the possibility, however, that during any year when ground information was not obtained, P. crispus persisting in mixed stands with other submersed species could have made a significant contribution to the areal extent of the late-summer vegetation and not have been detected.

g. Overall Limitations

There is no measure available of the overall accuracy of the methodology. The measured areas and changes in areas of total emerged and floating vegetation should be most accurate, followed closely by those of total submersed vegetation and emerged and floating plant associations (when good CIR coverage was available). The vegetative areas by plant type would be expected to be less accurate. The measured areas of lilies and combined burreed and cattail would still be expected to be relatively reliable; those of pickerelweed

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and especially bulrush, less so.

The changes in total emerged and floating vegetative area (13% maximum) may all have been within the error of the measurements. Of the changes in emerged and floating plant types, even the least reliable (bulrush) is still thought to be indicative of the general pattern of change. The changes in the combined area of burreed and cattail were reliably measurable as these species grew in limited areas in normally monospecific stands. The measured changes in submersed vegetation were large enough that, although some error was present, they should still provide an accurate picture of the actual changes.

The pattern of submersed vegetative increase (approximately equal increments per year between photographic coverages) suggests that the vegetative increase was continuous and uniform over the 8-year period. But, as no data are available for four of the years and especially with a three year running gap, this is not the only possibility. The disappearance by 1973 or 1974 of several important vegetative beds, which had increased between 1968 and 1969 (Figs. 14 - 18), may indicate that the vegetative development between 1969 and 1973 was not a time continual increase.

B. Utility of Aerial Photographs for Monitoring Aquatic Vegetation

Ideally, a biologist interested in studying changes

in aquatic vegetation would want monthly measures of plant biomass by species during the growing season of each year. The immensity and difficulty of this task is attested to by the singular lack of data of this sort in the literature for anything but small lakes or small portions of larger lakes. Data collection for a single survey of a moderate-sized lake may take a period of several weeks and during this period the plants are actively growing and/or dying. When the survey is completed, a true measure of total lake biomass at any given time may not be available. Any methodology which would improve the efficiency or accuracy of these vegetative biomass surveys, would greatly enhance the ability to detect year to year vegetative changes.

Aerial photography and other forms of remote sensing have not been proven capable of providing direct measurements of aquatic plant biomass. Species or minimally 'type' identification is required prior to biomass determination and species determinations of submersed vegetative types from aerial photographs are generally not possible. For emersed and floating plants, and to some extent, submersed vegetative types with leaves at the water surface, some correlation between the aerial photographic characteristics (especially texture, height and tone) and biomass may exist. Reimold et al. (1973) were successful in relating aerial photographic characteristics to broad categories of plant biomass in a salt marsh area, and the percent cover classes used in this study for lilies would

probably show some correlation to plant biomass on an areal basis. Spectral reflectance (as determined from a photograph, e.g., by the method of Piech and Walker, 1974) could also be used to obtain some information on plant biomass, by a technique similar to that of Pearson et al. (1976). The principal problem with either of these approaches is that they only work well in relatively pure vegetative stands, and freshwater aquatics often tend to grow in mixed stands.

What the aerial photographic data can provide for an aquatic plant biomass survey is definition of the area to be sampled. Typically, without aerial photographs, this is done by delineating on a map of the lake the area from the shoreline to the known or assumed maximum depth of aquatic plant growth. Then a number of sampling points within this zone are randomly selected. By this process, a number of sampling points are normally chosen at which no vegetation is present. With aerial photographs, the extent of vegetative cover in the lake can be determined, and the sampling points restricted to areas where vegetation will be found. Some field work will thereby be eliminated and the accuracy of the final biomass figures increased. New aerial photographs and a redefinition of the sampling area would be required immediately prior to each year's survey as the vegetations' locations could change.

The effectiveness of this method will be lake dependent. In lakes where vegetation covers essentially

all the shallow water areas, little may be gained; in lakes where substantial barren areas occur in shallow waters, substantial benefits could be expected. Also, the value of aerial photographic data will vary with other characteristics of the lake and its vegetation, especially the lake morphometry and bottom materials, and the vegetative types and their distribution.

For example, in lakes with extensive shallow water areas, relatively limited intermediate water depth areas with low growing forms, and relatively reflective bottom materials, aerial photographs will be highly effective for defining the vegetative area. (Canadarago Lake is of this type.)

In contrast, in lakes with extensive areas of moderately deep water, with relatively dark bottom sediments colonized by low-growing submersed vegetation, the utility of aerial photographs will be low. The vegetation will likely not be separable from the bottom materials, unless the transparency at the time of photography is unusually high. But, in the shallow waters, the aerial photographs will still be useful for excluding some areas from the sampling. In lakes of this type, the sampling scheme should perhaps be stratified into (1) shallower waters where vegetative area is identifiable on aerial photographs and (2) deeper waters where it is not dependably identifiable.

In any case, the use of appropriate aerial photographs

will provide some increase in the efficiency and accuracy of vegetative biomass surveys in most lakes. Whole-lake, field biomass surveys will still frequently be impractical, and other techniques must be employed to detect vegetative changes.

Aerial photographs are perhaps of greatest value for detecting vegetative changes. Aerial photographs can be used to obtain accurate measures of the areas of: (1) combined emersed and floating vegetation and (2) near-surface submersed vegetation. Given sufficient water transparency and contrast between the bottom and vegetation, total submersed vegetative area can also be measured. With multi-year aerial photographic coverage, changes in these vegetative areas can be determined.

Although vegetative area does not provide a true indication of vegetative biomass within a lake (e.g., sparse vegetative stands areas have a lower biomass than more dense vegetative stands of the same area), it still provides a useful indication of vegetative growth. Vegetative area also seems to be somewhat more constant through the growing season than biomass. Gustafson and Adams (1973) noted a maximum variation of eight percent in vegetative area for Myriophyllum sp. between late-June and early-September, whereas a 25 percent variation in estimated biomass was observed. Therefore, the exact timing of a photographic overflight for measuring vegetative area may not be as critical as the timing of a ground biomass survey.

In addition to providing information on total vegetative area, aerial photographs are also useful for providing more detailed information on emerged and floating plants. Dominant types or species of emerged and floating vegetation are generally separable on the aerial photographs, and with limited field checks, identifiable. For submersed vegetation, although surface-reaching types may be separable from low-growing types, little is usually available from the photographs in terms of speciation.

As emerged and floating freshwater aquatics often grow in mixed stands, and as it is usually not possible to estimate accurately the proportions of each type from aerial photographs, it is difficult to obtain reliable measures of vegetative area on a species basis. Vegetative areas on a plant association basis can, however, be obtained from aerial photographs. With multi-date coverage, changes in these areas can be detected.

Overall, in many lakes, multi-date aerial photography will provide an effective means for assessing changes in areas of total, emerged and floating, and, given adequate transparency, submersed vegetation. In addition, given selected field checks, changes in the areas of the dominant emerged and floating vegetative associations will be detectable. Little information on submersed plant species will usually be provided by the aerial photographs.

C. The Use of Aerial Photographs for Assessing Changes
In Aquatic Vegetation: A Preliminary Methodology

1. Assess the Suitability of Aerial Photography
for the Water Body Being Studied

Aerial photographs will provide some information on aquatic vegetation in almost all water bodies, but in certain cases, the amount of information gained may not be worth the expense involved. A number of factors affect the cost effectiveness of aerial photographs; perhaps the two most important factors are the size of the water body and the spectral contrast between the submersed vegetation and the bottom material (assuming information on submersed vegetation is desired).

In many cases, the greatest portion of the cost of an aerial photographic mission is in getting the aircraft aloft and to the lake. As such, the smaller water bodies will be more expensive on a per area basis, unless they are done in conjunction with other nearby lakes and ponds. Small water bodies may be able to be monitored less expensively by other methods. As there is considerable cost flexibility in aerial photographic systems, there is no definable lower size limit for the practical use of aerial photographic data. However, Canadarago Lake (770 hectares--though only approximately 15% of this is littoral zone) was an appropriately sized lake for an aerial photographic study, as should be lakes several times smaller.

In order for submersed vegetation to be detectable, it usually must have a spectral reflectance (as seen by the sensor) that is different from its background (the bottom material). Textural and height differences may also be important, but generally only for relatively near-surface vegetation.

Healthy vegetation has a high reflectance in the near-IR and, as such, is usually easily separable from its background of non-living material. But unless the submersed vegetation is near the water surface, where it will be easily detected, the IR radiation is absorbed by the water before it reaches the plant surface. The submersed vegetation must therefore be spectrally different from the bottom material somewhere within the visible spectrum, usually in the green or blue-green where the water is usually most transparent, or aerial photographic data will likely be of little value.

The ideal way to determine whether there is a measurable spectral difference between the submersed vegetation and the bottom material(s) is to use a spectroradiometer. Spectroradiometric readings of upwelling radiance from representative areas of the vegetation and bottom material at various depths should be obtained. These values will indicate whether any surface-manifest difference exists between the spectral reflectances of the bottom and the plants.

In many cases, spectroradiometric readings will not be necessary or, due to the equipment expense involved,

possible. In the many lakes with coarse (silt or sand) littoral bottom materials, the contrast between vegetation and the bottom will be obvious from a boat or on any existing aerial photographs. Lakes with high calcium carbonate concentrations in the sediments will also tend to show a good contrast between vegetation and the bottom. The greatest problems can be expected to occur in lakes with finer bottom sediments, especially if they are organic. The detection of low-growing submersed vegetation in lakes with dark organic bottoms is unlikely.

The "average" water transparency might be considered to be another important factor governing the suitability of aerial photographs for detecting submersed vegetation in a given lake. But since water transparency is also one of the most important factors affecting the depth to which submersed vegetation may grow, aerial photographs may be just as useful in a low transparency lake as in a high transparency one. The seasonal patterns of transparency are more important. Aerial photographs would be expected to be more useful in a lake where the normal periods of maximum transparency correspond to the times of maximum submersed vegetative development than in a lake where minimum transparency and maximum vegetative development coincide.

2. Obtain Existing Aerial Photographic Coverage

It is generally a good idea to obtain all existing readily available photographs of the water body, as they

are inexpensive and are often useful throughout the analysis (even if they were not flown during the growing season). Normally, all that will be available are medium scale (1:15,000 - 1:40,000) black-and-white panchromatic photographs. Although these photographs were not flown to image underwater details, they may provide some indication of the depth penetration possible in the lake.

3. Determine Spectral Region of Maximum Detectability of Submersed Vegetation

In order to choose the proper film-filter combination for maximum depth detectability of submersed plants, it is necessary to determine the spectral region where this maximum detectability will occur. However, if the lake is extremely shallow (less than approximately 2 meters) or if the vegetation is known to be restricted only to very shallow waters, detailed consideration of this matter may not be necessary (depending on the overall water transparency).

In principal, the ideal approach would be to use a spectroradiometer to measure the spectral radiance upwelling from various depths and types of submersed vegetation and nonvegetated bottom areas. The measurements would have to be taken under atmospheric, sun angle and surface state conditions similar to those expected at the time of the photographic overflights. The spectral region(s) of greatest difference(s) between the upwelling radiance from

the bare bottom areas and the submersed vegetation would be expected to be where maximum depth detectability of submersed vegetation would be encountered.

Similar results may be obtainable by using a small format camera and a series of narrow-band filters with a black-and-white panchromatic film. This system could be flown over representative sites in the study lake. The spectral transparency of the filter which allowed the best detectability of submersed vegetation should correspond to the spectral region of this maximum detectability.

An alternative approach is to consider the factors that affect the spectral detectability of submersed vegetation. The principal factors are: (1) the spectral transparency of the water, (2) the spectral distribution of the light illuminating the vegetation, and (3) the differences between the spectral reflectances of the vegetation and the bottom materials. Each of these properties can be measured or inferred from measurements and the literature.

a. Water Transparency

The spectral transparency of lake water is primarily determined by the quantity of dissolved organic compounds, especially humic acids. Suspended particulate matter, although reducing the overall transparency, has a relatively non-selective effect on transparency, especially at low concentrations (Wetzel, 1975). At high concentrations of

colored particles, especially those containing chlorophyll, the particulate matter's absorption bands can have a significant effect on the spectral water transparency.

The purest of lake waters approach the characteristics of distilled water, with peak transparency in the blue-green spectral region (0.49 μm) and with high transparency throughout the blue and green spectral regions (Fig. 1). With increasing organic color the transparency is progressively shifted towards the longer wavelengths: to the green region in slightly colored lakes and to the red in highly organic lakes (Figs. 1 and 23).

The spectral transparency of the water can be: (1) determined directly with a spectroradiometer or a submersible photometer and a series of filters, (2) inferred from color-evaluations (e.g., platinum units) of water samples settled of particulate matter (Fig. 23), or possibly (3) inferred from a Secchi disc measurement (Fig. 24). The Secchi disc measurement would need to be taken at a time when the suspended particle concentration was relatively low (i.e., not during an algal "bloom" or after a heavy rain), in order to give a good indication of dissolved organic color.

b. Spectral Distribution of Light Reaching
the Vegetation and Bottom

Although a lake's water may be highly transparent to certain wavelengths of light, if there is little or no

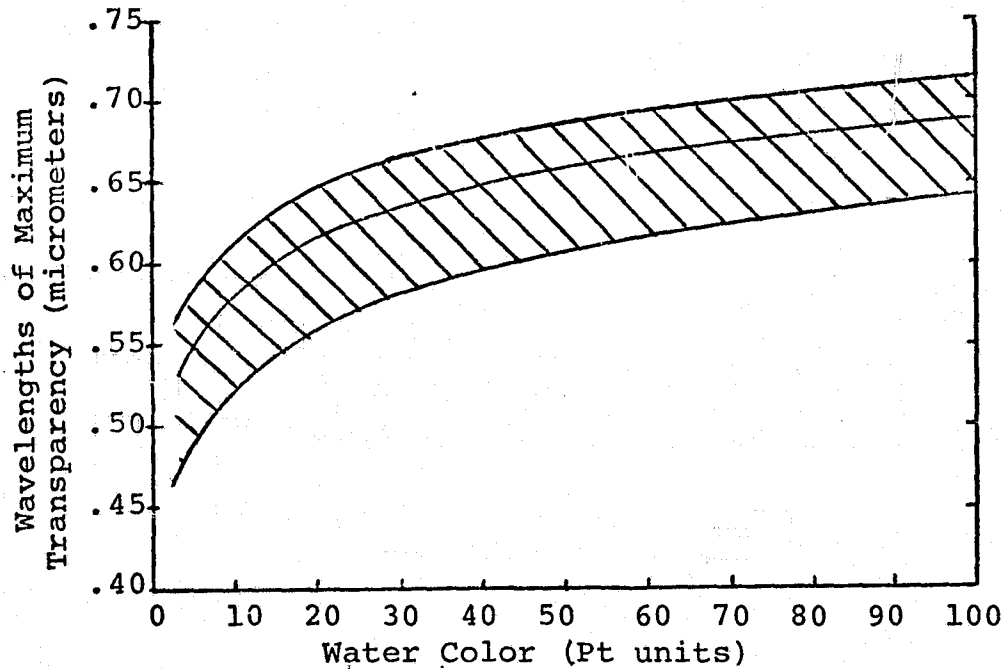


FIGURE 23. General relationship between lake water color and the spectral region of maximum water transparency (derived from data of James and Birge, 1938).

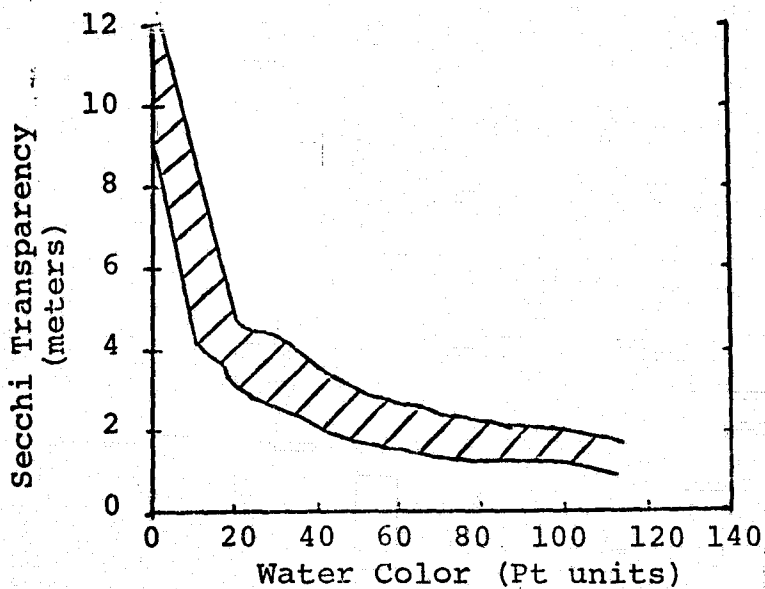


FIGURE 24. General relationship between Secchi transparency and lake water color (after Aberg and Rodhe, 1942).

light illuminating the bottom at these wavelengths, the bottom vegetation will not be detectable by systems sensing at these wavelengths. The peak irradiance underwater, however, is generally spectrally close to the region of maximum transparency, as the spectral attenuation is one of the important factors determining the spectral character of the light reaching the bottom. But other factors, including the spectral nature of the solar illumination, solar altitude, water surface conditions, depth and scattering characteristics of the water also affect the irradiance underwater, tending to make its spectral characteristics somewhat different than the transparency's.

For very clear waters, the greatest amount of light is present in the blue (0.4 - 0.5 μm) portion of the spectrum, but with the curve being relatively flat in blue and green regions in waters to at least 5 meters depth (Fig. 2). In more productive waters, the peak irradiance is shifted towards the green portion of the spectrum and is also considerably reduced (Fig. 2).

In summary, the spectral distribution of light reaching the vegetation and bottom can be measured using a spectroradiometer or a photometer with filters, or its peak can be assumed to coincide approximately with the spectral region of maximum transparency, a reasonable assumption to depths of about 10 meters. This is approximately the depth limit for vascular macrophytes, though macrophytic algae and mosses may grow deeper (Wetzel, 1975).

c. Vegetative versus Bottom Reflectance

Although some data on the spectral reflectance properties of submersed plants and bottom materials are available, they are likely insufficient for determining where the greatest spectral differences occur in a given lake (Fig. 25).

In general, bottom materials would be expected to have a more or less flat response, with the overall reflectance being related to the particle size distribution and the amount of organic matter present. The coarser the material and the less organic matter, the higher the reflectance. Vegetation generally has low red and blue reflectances and higher green reflectance. So, with the coarser bottom types, the greatest reflectance differences should be in the blue and red regions, although differences in the green region may be substantial (Fig. 25). With the finer bottom sediments the situation is not clear, and it may be reversed, with vegetation being the higher reflector. The spectral differences here may not be sufficient to separate the vegetation from the bottom.

Spectral reflectance can be measured in situ using two spectroradiometers: one measuring irradiance at the lake bottom and one measuring radiance upwelling from the target, just above the lake bottom. Alternatively, samples can be taken and measured in the lab with a spectrophotometer. However, disturbing and transporting the materials

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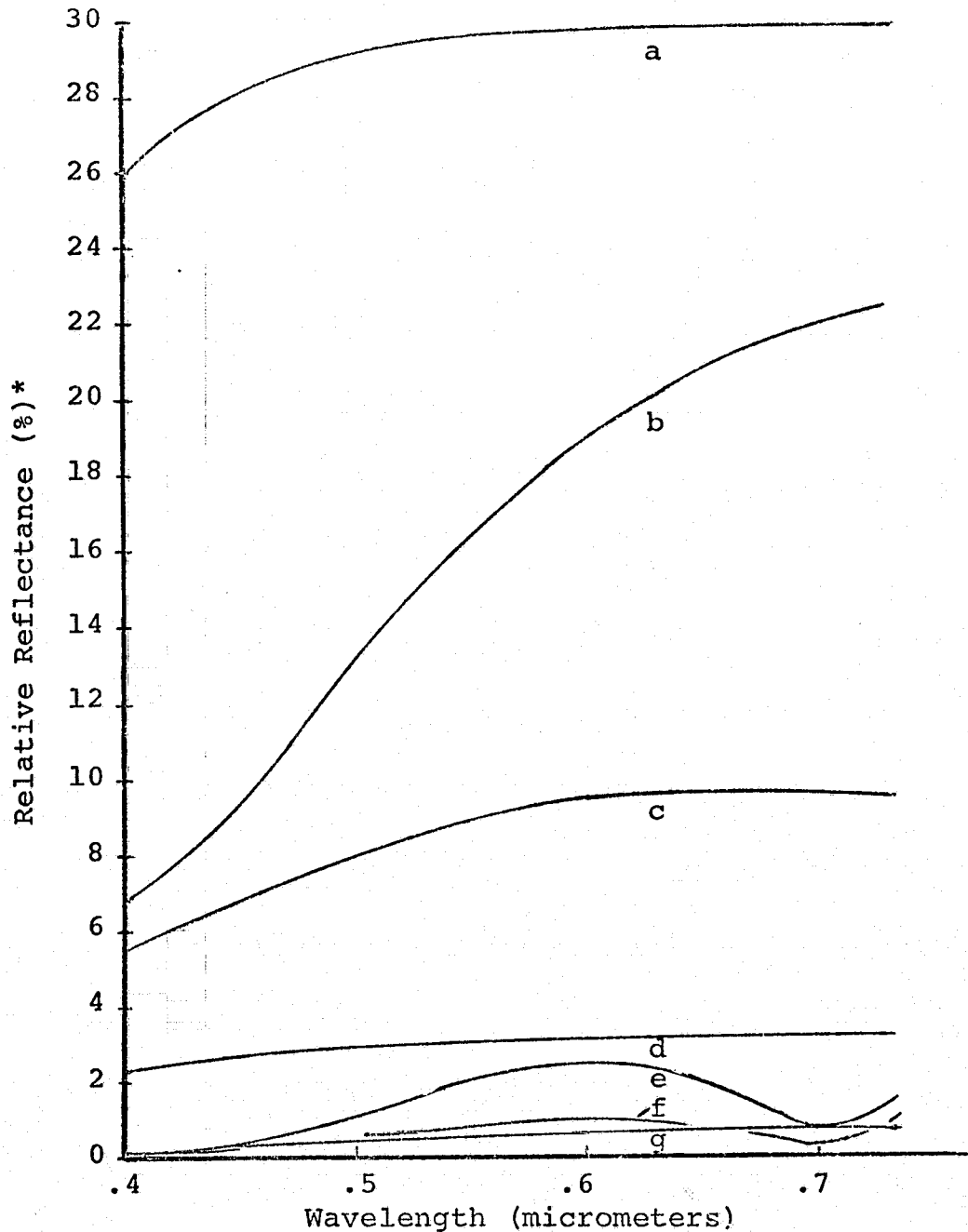


FIGURE 25. Spectral reflectances of various bottom materials and aquatic plants (data from Spooner, 1969)

a-white pebbles	d-black rocks
b-calcareous sand and shell fragments	e-water sprite
c-gray rocks	f-waterweed
	g-green mud

*Variations in the procedures used for measuring the aquatic plant reflectances versus the bottom material reflectances may make the data not strictly comparable

may change their reflectance properties.

d. Summary

Once all of the obtainable data on the lake transparency, spectral irradiance and vegetative and bottom reflectance characteristics are available, they must be synthesized. Ideally, complete information will be available. However, if the equipment necessary to obtain detailed information on each of the factors is available, it would generally make more sense to go with the first alternative: measuring (at the surface) the spectral radiance upwelling from various depths and types of submersed vegetation and non-vegetated bottom areas. In this way, the potentially complicated and approximate calculations necessary to determine these values from the measured parameters of water transparency, light intensity and reflectance, would be avoided. These calculations would generally involve: (1) multiplying the spectral irradiance (at lake bottom) by the spectral reflectances of the plants and bottom materials, and (2) multiplying the resultant figures by the spectral transmittances of the water.

Realistically, the best that will be available in many cases will be measurements of the spectral water transparency or perhaps only several Secchi disc readings. Still, by using the measured or assumed (from Secchi disc - Fig. 24) spectral region of maximum transparency as the proper region for maximum detectability of submersed vegetation,

good results should be expected. The extent to which detailed analyses of spectral reflectances and radiances will improve the selection of the proper spectral region is unknown. It is interesting to note that, frequently, the greatest differences in reflectance between vegetation and bottom materials may not be in the region of maximum water transparency.

4. Obtain New Aerial Photographic Coverage
and Ground Data

a. Films/Filters/Exposures

Suggested film-filter-exposure combinations are listed in Table 10. A CIR film (e.g., Kodak 2443) with a minus-blue filter (Wratten 12 or equivalent) overexposed by one-half f-stop relative to the exposure recommended by the Kodak aerial exposure computer (Kodak, 1970) is generally the most useful combination in most lakes. It provides: (1) good discrimination between submersed and emersed vegetation; (2) good discrimination between the various types of emersed and floating vegetation; and (3) good detectability of emersed vegetation (including sparse vegetation) and submersed vegetation (at least in lakes where maximum detectability is in the green region and in shallow water regions of clearer lakes). Exposure for water penetration is very critical for this film as the green-sensitive layer has high contrast and therefore

TABLE 10. Recommended aerial film-filter-exposure combinations*
for monitoring aquatic vegetation

SPECTRAL REGION OF MAXIMUM DETECT- ABILITY	NUMBER OF CAMERAS AVAIL- ABLE	INFORMATION DESIRED			
		TOTAL VEGETATION (no distinctions required)	EMERSED AND FLOATING VEGETATION ONLY (including vegetative species)	SUBMERSED VEGETATION ONLY	BOTH EMERSED AND FLOATING AND SUBMERSED VEGETATION (including emersed and floating species)
Blue-	1	B	A	B(may increase to +1 f-stop) or D fly after 'browning' of emersed vegetation	A(if emersed vegeta- tion more important) or B(if submersed)
Green	2	A(may increase to +1 f-stop) and C	A(may decrease to normal exposure) and E(to detect very sparse stands)	A and C (if no emersed vege- tation present can use B instead of A)	A and C
Green to	1	A(may increase to +1 f-stop)	A	A(may increase to +1 f-stop) (if no emer- sed veg. present can use B instead of A)	A
Red	2	A(may increase to +1 f-stop) and C	A(may decrease to normal exposure) and E(to detect very sparse stands)	A and C (if no emersed vege- tation present can use B instead of A)	A and C

- * A - CIR film @ +1/2 f-stop(relative to Kodak aerial exposure computer) with Wratten 12 filter
 B - Color film @ +1/2 f-stop with/without haze filter
 C - B&W high contrast film(e.g., RO-2569 for blue-green detectability) filtered to proper spectral region
 D - Water penetration film(Kodak SO-224), if available, with Wratten 3 filter
 E - B&WIR film @ +2 f-stops with Wratten 89B filter

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relatively narrow exposure latitude. Exposing the film properly for terrestrial features results in relatively poor water penetration. But when the film is properly exposed for submersed vegetation, the high contrast aids underwater feature discrimination.

A color film (e.g., Kodak 2448, SO-397) at one-half stop overexposure, with or without a haze filter, is a useful combination in clearer water (blue-green detectability) lakes. However, the film does not provide as good discrimination between certain emersed and submersed types and among emersed and floating types, nor as good detectability of sparse emersed stands as CIR film. The color film is, however, less susceptible to damage due to improper storage. Although better than CIR, color film is not ideal for detection of submersed vegetation in lakes with maximum detectability in the blue-green region. Its blue-layer sensitivity peaks in the shorter wavelength portion of the spectrum, rather than in the blue-green portion. A film like the special water penetration film (SO-224) developed by Kodak would be more appropriate, as its sensitivity is maximum in the blue-green. This film, however, is likely to be unavailable, and might show a greater tendency than color film to overexpose shallow water areas when exposed for deeper water.

If a two-camera system is available, it becomes possible to more nearly optimize the film-filter-exposure combinations. A high-speed, high-contrast, black-and-white

film sensing radiation only at or near the region of maximum detectability of submersed vegetation is generally the most useful second system. This system should produce near optimal detection of submersed vegetation. A considerably higher-than-normal contrast film is required as the brightness range of underwater targets is extremely limited. Most aerial films have gammas (Δ density/ Δ log exposure) of less than 2.5 and are less than ideal for the purpose. Black-and-white films used for copying line diagrams (e.g., Kodak RO-2569) are normally processed to produce gammas greater than ten, although this can be reduced to about six, which is more appropriate for water penetration work (Ross, 1976). To obtain the proper spectral filtration for this type of film, either a narrow-band interference filter centered on the proper wavelength or a more broad-banded Wratten-type filter should be used. The former should be employed when the spectral region of maximum detectability of submersed vegetation is well known; otherwise, the latter should be used. A high-speed film is required to avert the need for a wider-band filter than optimum. The amount of light received through a narrow-band filter may be insufficient to expose the film without image-motion problems. As exposure indices for use with this type of film-filter combination are not available, it will be necessary to do some experimentation to obtain proper results.

When a high-contrast black-and-white film is used with a second camera system, it then becomes advisable to use CIR

as the primary film for even clear water lakes as the superior water penetration ability of color film is no longer needed (Table 10). Other changes in the primary film-filter-exposure combination may also be worthwhile when using two cameras instead of one camera (Table 10).

b. Film Format and Coverage

To be useful for detecting vegetative changes, the aerial photographs must image some ground reference points in each frame. This usually means that the lake shoreline must be imaged in all or most frames. In order to do this, the aircraft must fly approximately parallel to the shoreline positioned such that the shoreline(s) is(are) imaged on the extreme left or(and) extreme right edge(s) of the frame, with the rest of the frame imaging the water. At a given scale, the distance from the shore that can be imaged is a function of the film format; the larger format imaging the greater distance lakeward. Therefore, in general, larger formats are preferable. Cost, camera and film availability, however, may dictate the use of smaller formats.

Nine-by-nine inch format cameras are expensive and complicated pieces of equipment that normally require special mounting in a port in the belly of the aircraft. As such, only a large organization would have sufficient funds to obtain and maintain the camera and aircraft. Seventy millimeter cameras, at the other extreme in format

size, are usually lower in price and can be mounted externally to the aircraft and easily removed. Thus the aircraft would only need to be rented. Also, non-aerial photographic films (e.g., RO-2569) would likely be unavailable in nine-inch rolls.

The photography should be obtained with normal stereoscopic overlap (60%). To provide the simplest image geometry, the photography should be flown in as near as possible to vertical attitude.

c. Photographic Scale

A number of factors will dictate the scale of the photography to be flown, including: (1) the level of detail required, (2) the available funds, and (3) the film format in relation to the maximum distance of vegetation from the shoreline.

In general, the level of detail required will determine the proper scale. Scales in the high altitude and satellite range (1:100,000 plus) are often adequate to detect gross vegetative changes. For detailed vegetative studies, however, especially where detailed separations of emersed and floating vegetative types are required, scales should be larger than 1:10,000. This large scale is especially needed to distinguish vegetative height. Costs may increase substantially with larger scale, as four photographs at a scale of 1:5,000 are needed to cover the same area as one at a scale of 1:10,000.

Once the film format has been determined, it will dictate the maximum scale that can be used (e.g., if the vegetation extends up to 400 meters offshore, the maximum scale usable for 70mm film, 56mm format, is about 1:7,000, whereas for a 9-inch format film it is about 1:2,000). If the lake is flown at several different scales, however, the larger scale photographs may not be required to image the shoreline. Aquatic features (e.g., vegetative beds) that were imaged on the smaller scale photos can be used for control.

d. Time of Day

Photography at moderately low sun angles (25 - 35 degrees, Lukens, 1968) is generally best for surveys of aquatic vegetation. This is a compromise between reducing sunlint and maximizing water penetration. At higher sun angles, more light is reaching submersed vegetation and therefore it should be more easily detected; but specular reflection from the water's surface (sunlint) obscures the vegetation. At lower sun angles, less light reaches the plants and shoreline tree shadows may become a problem, but sunlint is reduced. What is desired is the maximum sun angle possible without getting objectionable sunlint.

e. Time of Year

To obtain the most information on aquatic vegetation, photography should generally be flown mid-late summer

(between mid-August and early-September for most lakes in New York State). At this time, many of the species are near the stage of maximum development. However, certain early species (e.g., Potamogeton crispus) will be well past their peak development. There is no single time of the year when all species can be satisfactorily photographed.

If submersed vegetation is of principal concern, this period can be extended to late summer-early fall (late September for New York). Most submersed vegetative beds remain intact to this time, whereas many of the emerged and floating beds may not. Also, emerged species have browned by this time making them less easily confused with submersed vegetation, especially on color film (also noted by Lukens, 1968). If emerged and floating vegetation is of primary interest, the early portion of this period (mid-August for New York) is preferable.

f. Meteorological Conditions
at Times of Flights

The optimum conditions for aerial photography of aquatic vegetation are no clouds, haze or surface wind. Low velocity winds are acceptable as long as the water remains relatively calm. In certain areas of the country (including central New York State) these conditions may occur for only one or two days during the several week late-summer flying period. It is therefore necessary to be prepared for flying when they occur.

g. Water Conditions

Low concentrations of algae and suspended materials are desirable at the time of overflight, to maximize water penetration. It may be useless to fly during an algal bloom or after a heavy rainstorm as penetration will be severely restricted.

h. Concurrent Ground Data

The minimal ground information needed at the time of overflight is water transparency measurements (Secchi disc) at several locations on the lake. This information is needed when comparing photographs from different years, as large differences in transparency may produce apparent changes in submersed vegetative area.

If separations of emersed and floating species or types are to be performed, then sites to serve as training areas for the photointerpreters must be ground checked. Problems may be encountered in locating the field-checked areas on the aerial photographs. If there are no nearby "landmarks," targets (e.g., styrofoam panels) may be placed at each ground-checked site or at the beginning and end of each transect, prior to the overflight. The ground checking need not be conducted concurrently with the overflights, though it should be done within a few days of it.

i. Other Ground Data

After film processing and the initial analyses, it will usually be desirable to perform additional field checks. For example, emersed and floating species identifications from the aerial photographs may merit ground-checking. The additional ground checks will serve to refine the identification keys. Areas of low-growing, submersed vegetation are often difficult to interpret (although multi-date coverage usually improves their discrimination) and hence they may merit some selective field checks. Also, there are usually anomalously appearing areas on the photographs for which ground checks would be desirable. Having the photointerpreters perform or at least be present during the field checks should improve the accuracy of the interpretations.

If information is desired on submersed species, this must be acquired by field surveys, preferably with prints of the photographs in hand for annotation. These field checks should be performed within approximately two weeks after flying. This requires rapid processing of the film and makes a within-house processing capability extremely desirable.

j. Summary

In obtaining photographs for assessing vegetative changes, one of the most important considerations is consistency in the photographs and in the conditions at the times of the photographic overflights. Unless consistency

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is maintained, the vegetative changes apparent on the photographs may be different than the actual changes. Perhaps the most critical factors for consistency are the film-filter-exposure combination and the water transparency conditions. Unfortunately, the second of these factors is under little control by the investigator.

5. Analyze Films

Films can be analyzed directly on a light table with a stereoscope. Alternatively, prints (contact or enlarged, depending on the initial film format) can be made and analyzed with a pocket stereoscope.

First, a legend based on the airphoto characteristics of the vegetative types present and the ground data collected must be defined for "mapping" the vegetation. Then, the first year's vegetation can be mapped, i.e., delineations made on overlays to the photographs and transferred to a base map. Existing aerial photographs may be useful at this point in identifying areas of submersed rocks and dark sediments. These features have a relatively static nature as opposed to the more dynamic nature of aquatic plants.

There are several approaches to detecting changes between the vegetation in the initial year and that of subsequent years. One approach is to map the vegetation for each subsequent year in the same manner as for the first year and then compare changes in the maps. Alternatively,

the next year's photographs can be optically superimposed with the first year's and only the changes delineated. Then, these changes can be transferred to the base map. Although the second alternative may be more accurate, as the entire mapping process is not repeated each year, it may also be more difficult to implement. Optical superimposition of the two photographs can be difficult, even with a Zoom Transfer Scope, and it is generally not possible to do while viewing both sets of photographs stereoscopically. A third alternative is to optically superimpose each subsequent year's photographs with the first year's vegetation maps. Using a stereo Zoom Transfer Scope will allow stereoscopic viewing of the photographs superimposed on the base map.

VI. CONCLUSIONS

A. Vegetative Changes

Based on a multi-date aerial photographic analysis, the overall area of emersed and floating vegetation in Canadarago Lake changed little between 1968 and 1976. Floating vegetation (lilies) decreased somewhat, primarily in deeper waters; pickerelweed increased considerably in one area, changed little in others, and died out completely in some locations, primarily in deeper waters; and bulrush, burreed and cattail all appear to have declined.

The total area of submersed vegetation increased by more than 400% during the 1968 to 1976 period, expanding from 2.3 to 12.0 hectares. The pattern of increase suggests a continuous, uniform increase, although this is not the only possibility, as photography was available for only five of the nine years. The vegetative increase between 1968 and 1973 was more concentrated in the shallow water areas (less than 1.5 meters) whereas from 1973 to 1976, the deeper water areas (2 - 3.5 meters) were more important.

B. Vegetative Mapping

In many lakes, sequential aerial photography will provide an effective means for assessing changes in total, emersed and floating (combined), and submersed vegetative areas. The depth to which submersed vegetation can be monitored will depend on many conditions, including the

water transparency at the times of the overflights, the bottom materials of the lake and the types of submersed vegetation. In general, greater difficulties can be expected in lakes with darker bottom materials or with a predominance of low-growing vegetative types.

With appropriate photography, various emersed and floating vegetative types can be separated and, with limited field checks, identified. Submersed types, however, are usually not separable. Although the various emersed and floating types can be separated, it will generally not be possible to obtain area figures on a type by type basis. The different types grow intermixed, and it is difficult, if possible, to estimate accurately the proportions in the mixtures from any but very large scale aerial photographs. Areas of plant associations will be more accurately determinable.

Vegetative area, or even vegetative area by association, is not the ideal measure of the amount of vegetation present. Biomass or standing crop is generally preferable. At present, aerial photographs can provide little direct data on biomass, especially in cases where species grow intermixed, as is common in aquatic environments. However, area measurements of vegetation are important input to biomass calculations. In addition, by knowing the distribution of aquatic plants prior to a ground survey, the ground survey can be expedited and its accuracy improved.

In many cases, especially in large lakes, biomass surveys will be too expensive. Here, determinations of the area of aquatic vegetation as taken from aerial photographs will provide a useful measure of the amount of vegetation present and allow detection of changes.

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APPENDIX A: AERIAL PHOTOGRAPHIC FLIGHT LOGS

PHOTOGRAPHIC FLIGHT LOG SENSOR DATA		MISSION NO. <u>76-JO2</u> PAGE <u>1 / 1</u>			
PROJECT LOCATION <u>Canadarago Lake</u>		Date: <u>20 July 76</u>			
NATURE OF PROJECT <u>Weedbed Mapping</u>					
SITE DESCRIPTION <u>Canadarago Lake Shore, Deowongo Island, Shoal Area</u> <u>NW end of lake</u>					
SENSOR DATA		POSITION			
		1	2	3	4
CAMERA TYPE	<u>Hasselblad</u>	<u>500EL/M</u>	<u>500EL/M</u>	<u>500EL/M</u>	
CAMERA NO.					
LENS FOCAL LENGTH		<u>80 mm</u>	<u>80 mm</u>	<u>80 mm</u>	
FILM TYPE		<u>2448</u>	<u>2443</u>	<u>2448</u>	
EFF. AERIAL FILM SPEED		<u>32</u>	<u>40</u>	<u>32</u>	
F/STOP (NORM)	<u>+1/2 .f stop</u>	<u>5.6</u>	<u>5.6</u>	<u>5.6</u>	
(HAZE)					
FILTRATION		<u>Hz</u>	<u>Wr 15</u>	<u>Hz</u>	
SPECTRAL BAND		<u>.4 - .7</u>	<u>.5 - .9</u>	<u>.4 - .7</u>	
MAGAZINE NO.	<u>1</u>	<u>4</u>	<u>5</u>	<u>3</u>	
	<u>2</u>				
	<u>3</u>				
	<u>4</u>				
	<u>5</u>				
AIRPORT DEPARTURE <u>0943</u> RETURN <u>1204</u>					
AIRPORT NAME AND LOCATION <u>Camillus, Camillus, N.Y.</u>					
AIRCRAFT TYPE <u>Cessna 172</u> AIRCRAFT NUMBER <u>7213Q</u>					
PILOT <u>George Potter</u> PHOTOGRAPHER <u>William Johnson</u>					
OBSERVERS <u>None</u>					
REMARKS <u>Films overexposed by 1/2 stop from the setting recommended</u> <u>in the Kodak Aerial Exposure Computer</u>					
<u>Note1: All shutters @ 1/250 sec.</u>					
<u>Note2: Large Scale Altitude 2860' msl</u>					
<u>Small Scale Altitude 4430' msl</u>					

PHOTOGRAPHIC FLIGHT LOG SENSOR DATA		MISSION NO <u>76-J03</u> PAGE <u>1/1</u>			
PROJECT LOCATION <u>Canadarago Lake</u>		Date: <u>31 Aug. 76</u>			
NATURE OF PROJECT <u>Weedbed Mapping</u>					
SITE DESCRIPTION <u>Canadarago Lake Shore, Deowongo Island, Shoal Area</u> <u>NW end of lake</u>					
SENSOR DATA	POSITION				
	1	2	3	4	
CAMERA TYPE <u>Hasselblad</u>	<u>500EL/M</u>	<u>500EL/M</u>	<u>500EL/M</u>		
CAMERA NO.					
LENS FOCAL LENGTH	<u>80 mm</u>	<u>80 mm</u>	<u>80 mm</u>		
FILM TYPE	<u>2448</u>	<u>2443</u>	<u>2448</u>		
EFF. AERIAL FILM SPEED	<u>32</u>	<u>40</u>	<u>32</u>		
F/STOP (NORM) <u>+1/2 f stop</u>	<u>4.7</u>	<u>5.6</u>	<u>4.7</u>		
(HAZE)					
FILTRATION	<u>Hz</u>	<u>Wr 15</u>	<u>Hz</u>		
SPECTRAL BAND	<u>.4 - .7</u>	<u>.5 - .9</u>	<u>.4 - .7</u>		
MAGAZINE NO.	<u>1</u>	<u>4</u>	<u>3</u>	<u>2</u>	
	<u>2</u>				
	<u>3</u>				
	<u>4</u>				
	<u>5</u>				
AIRPORT DEPARTURE <u>0940</u>		RETURN <u>1212</u>			
AIRPORT NAME AND LOCATION <u>Camillus, Camillus, N.Y.</u>					
AIRCRAFT TYPE <u>Cessna 172</u>		AIRCRAFT NUMBER <u>72130</u>			
PILOT <u>George Potter</u>		PHOTOGRAPHER <u>William Johnson</u>			
OBSERVERS <u>None</u>					
REMARKS <u>Films overexposed by 1/2 stop from the setting recommended</u> <u>in the Kodak Aerial Exposure Computer</u>					
Note1: <u>All shutters @ 1/250 sec.</u>					
Note2: <u>Altitude 2860' msl.</u>					

APPENDIX B: CALSPAN'S SCENE COLOR STANDARD TECHNIQUE

Calspan's Scene Color Standard technique (Piech and Walker, 1974) attempts to calibrate multi-layer films in order to obtain object ground reflectance values by compensating for atmospheric, exposure, emulsion and processing differences.

The first step in the process is to generate density-log exposure curves for each layer of the film. With the step wedge that is imaged on a portion of the film prior to processing, the densities of each film layer resultant from a known exposure (or known difference in exposure) are measured with a densitometer (using the appropriate filter). The curves are then plotted (Fig. A1).

Next, densitometric measurements are made of a series of terrain elements in both the sun and shade. Rooftops are one of the most frequently used objects, as portions of the same roof material usually occur in both sun and shade. These densities are converted to exposures using the D-log E curve. The following equations describe the exposures obtained in sunlight (E) and shade (E'):

$$E = \alpha R + \beta$$

$$E' = \alpha' R + \beta$$

where R equals the reflectance of the terrain object, β is a parameter proportional to the amount of airlight, α is a parameter proportional to atmospheric transmittance and total (sunlight and skylight) irradiance, and α' is a parameter proportional to atmospheric transmittance and skylight

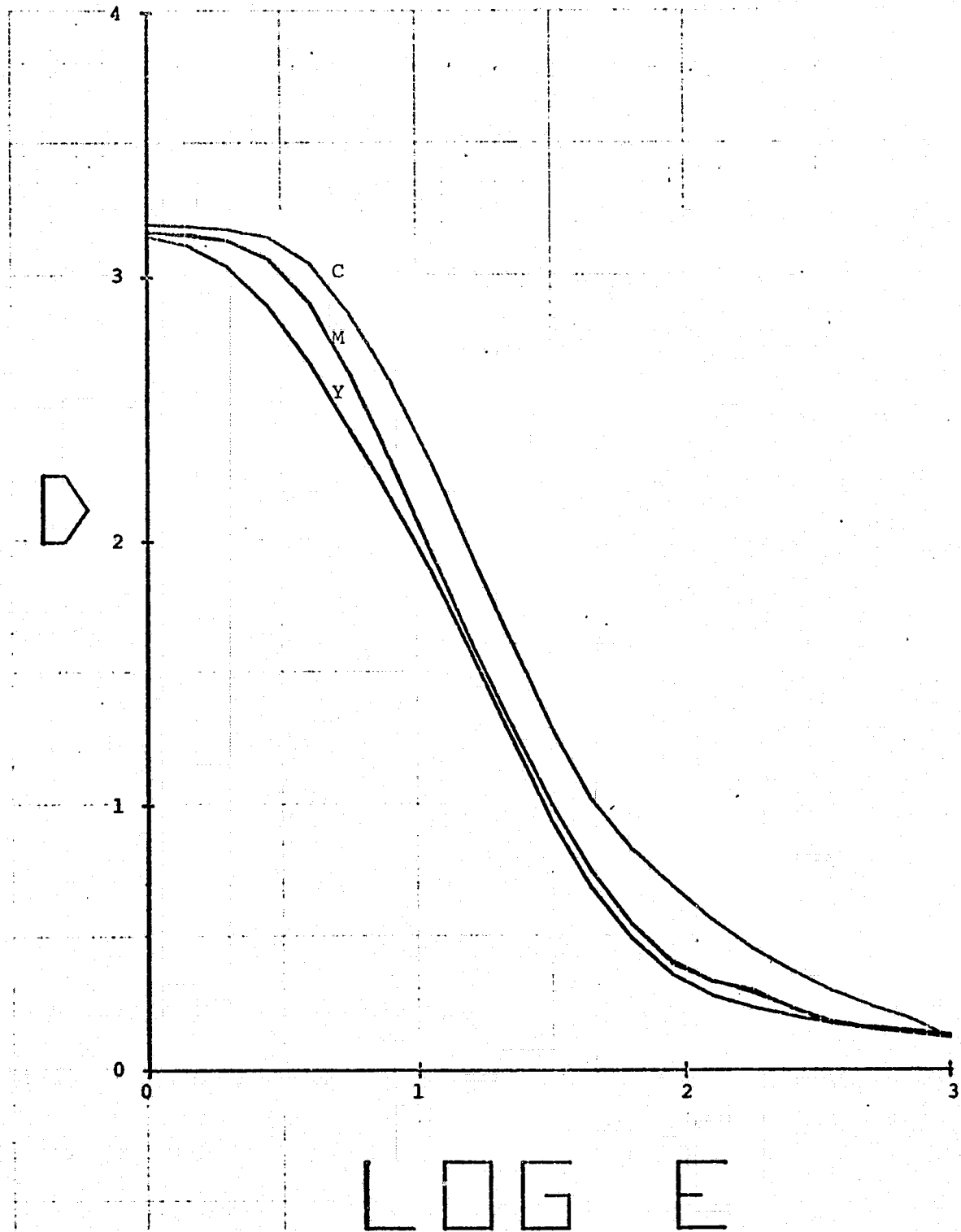


FIGURE A1. Density versus log-exposure for the three film layers, C-cyan (red-sensitive), M-magenta (green-sensitive), Y-yellow (blue-sensitive), of August 31, 1976 color (2448) film.

irradiance. By substitution:

$$E = (1 + \frac{\delta}{\alpha'})E' - \beta(\frac{\delta}{\alpha'})$$

where δ is a term proportional to sunlight irradiance only and $\alpha = \delta + \alpha'$.

This is an equation of the form $y = mx + b$, where m (slope) = $1 + \delta/\alpha'$ and b (y-intercept) = $-\beta(\delta/\alpha')$. Therefore, by plotting a series of E versus E' , β and δ/α' can be determined (Fig. A2).

Once β has been determined, only α needs to be determined to relate film density to a reflectance, using the equation $E = \alpha R + \beta$ and the D-log E curves. To calculate α , the density of one object of known reflectance needs to be determined. Then, by substituting E , R , and β into the equation, α is determined. Usually a series of known (or assumed known) reflectance objects are used and a least squares fit curve used to calculate α (Fig. A3).

Now the film calibration is complete: given film densities for any object, its reflectances can be calculated. A factor is also used to compensate for fall-off towards the edge of the camera lens.

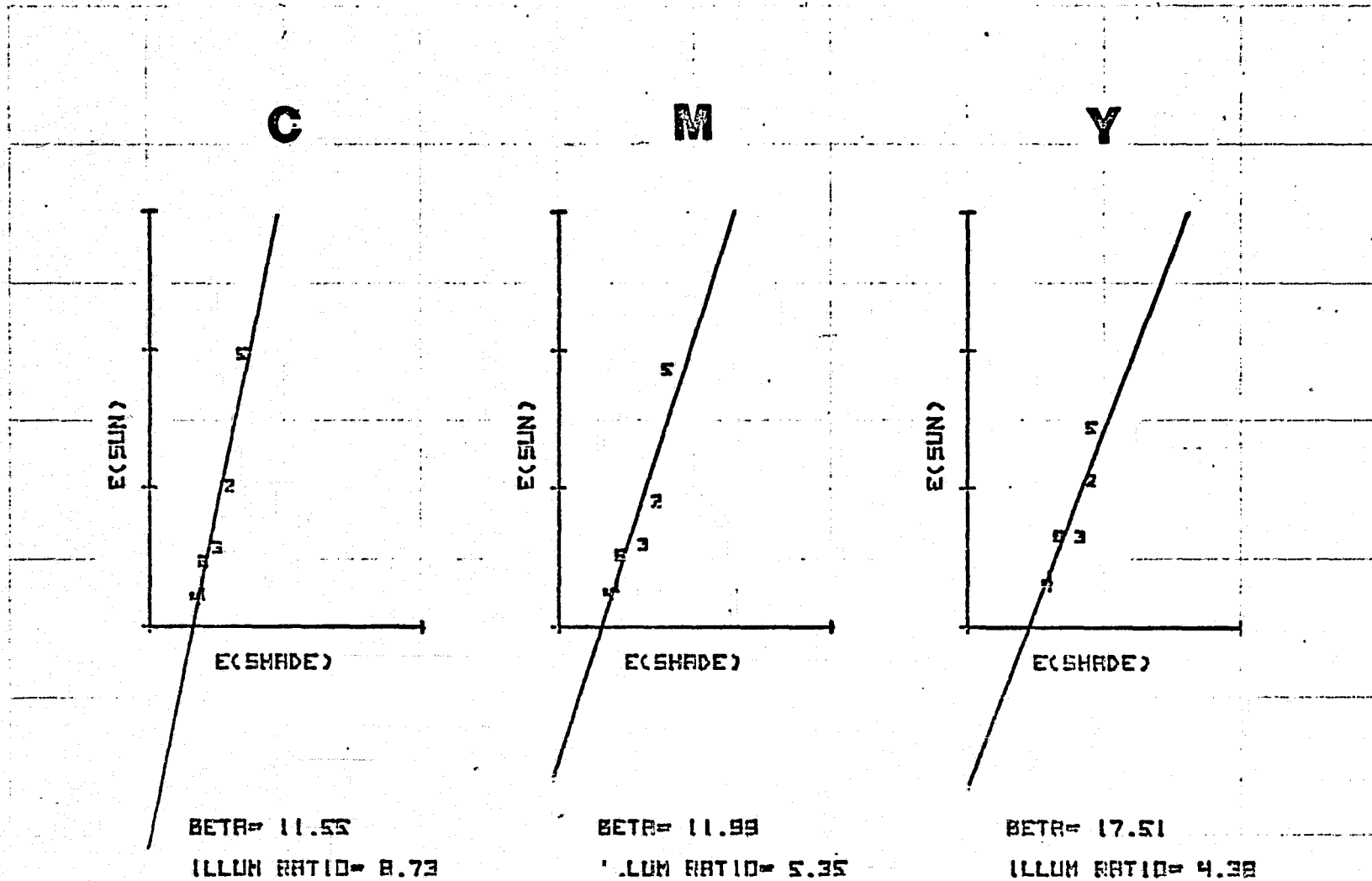
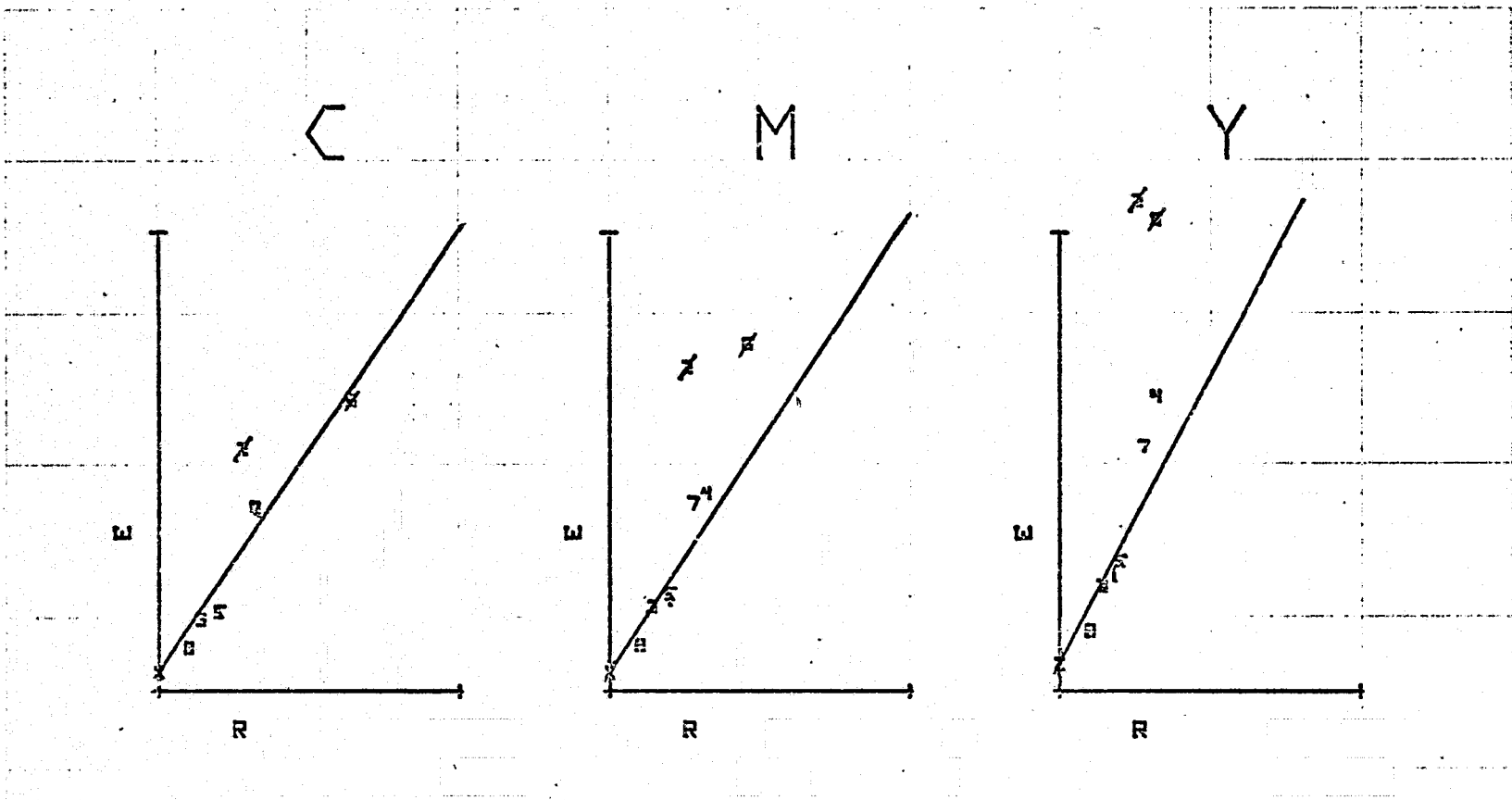


FIGURE A2. Exposure (sun) versus exposure (shade) of selected terrain objects on each layer of August 31, 1976 color (2448) film.

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BETA= 11.55
ALPHA= 555.78

BETA= 11.98
ALPHA= 580.82

BETA= 17.51
ALPHA= 754.88

FIGURE A3. Exposure versus reflectance of selected terrain objects for each layer of August 31, 1976 color (2448) film.

APPENDIX C: VEGETATIVE VERSUS OTHER CHANGES

(modified from Markham et al., 1977)

A. Emersed and Floating Vegetation

Although the overall changes in Canadarago's emersed and floating vegetation were relatively minor, the changes in species were more important. A number of factors can produce changes in the growth of emersed and floating plants, but the most likely causes in Canadarago Lake were changes in water depth and competition with other aquatic plants.

The average water levels in Canadarago during various periods of the year, beginning in 1969 (a water-level recording device was first installed Oct. 1968), are shown in Figure A4. Year-to-year differences never exceeded 20 cm for any of these periods. For the whole growing season (nominally May 1 - Nov. 1), the water level has generally increased on the order of 10 cm. Although relatively small, this increase could have placed some vegetation in a depth zone marginal for its existence, also making it less competitive with other species, especially submersed. That submersed plants have replaced floating plants in certain areas of the lake reinforces this explanation. But other conditions (e.g., light) could also have changed, giving submersed plants a competitive advantage over floating and emersed plants.

Not indicated in the water level data is that a

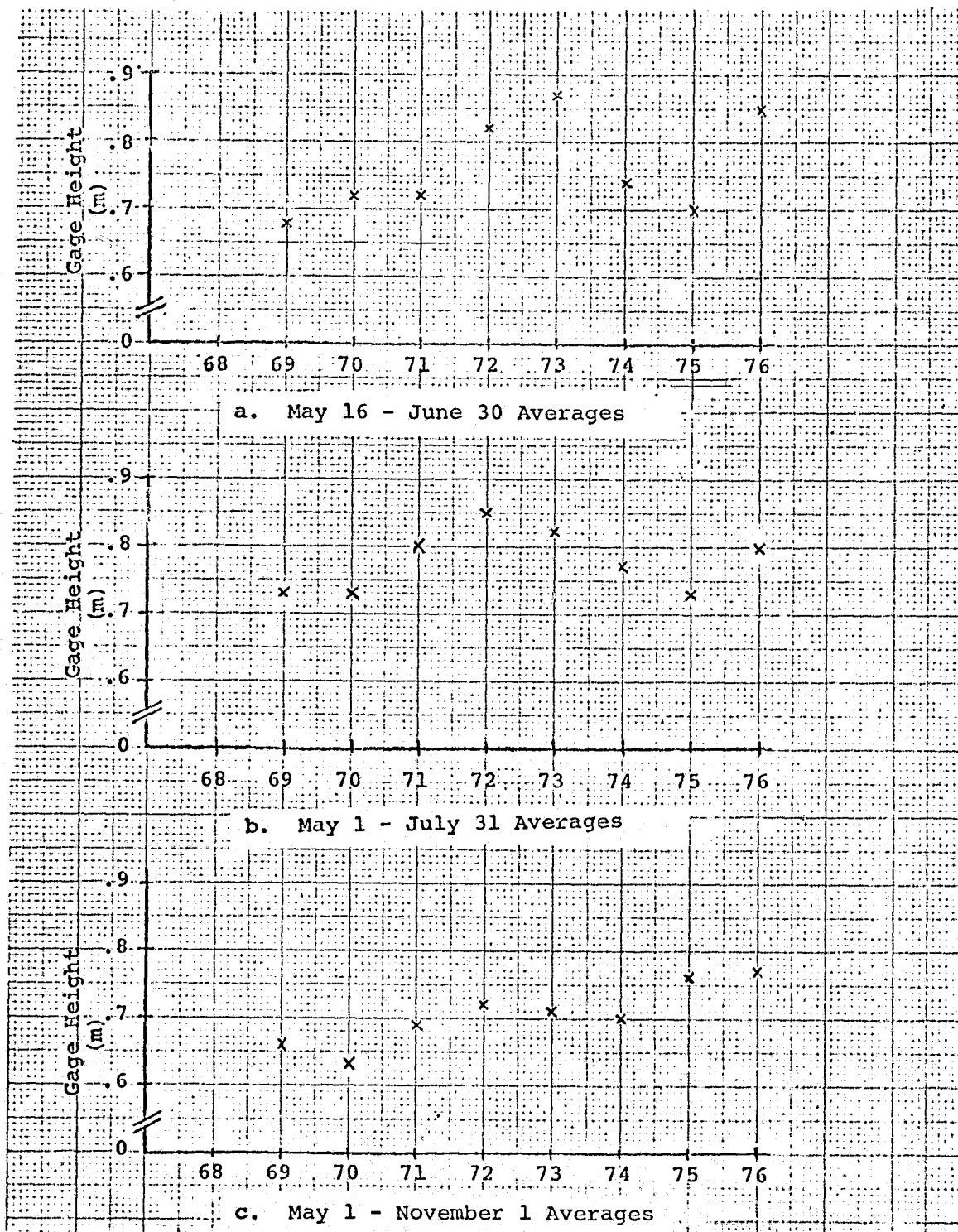


FIGURE A4. Seasonal average water levels for Canadarago Lake (data from USGS, 1968-1976 and 1977).

water control structure, Panther Mountain Dam, was constructed at the outlet of Canadarago Lake, in June 1964. This dam was designed to prevent the extremely low, summer water levels which exposed muddy areas along Canadarago's shoreline. Because the dam maintained the water at higher levels than in previous summers, it is possible that some changes in emerged and floating vegetation were a consequence of the vegetation equilibrating with the level first experienced in June 1964 (i.e., dying back in deeper water areas and increasing in shallow water areas).

The amount by which the dam changed the water level is unknown; yet, older, summer (1942) and fall (1936) photographs show areas of exposed lake bottom that are underwater in more recent photographs. These photographs also show floating vegetation extending farther lakeward than at present in many areas.

Although an increased water level in or since 1964 could possibly account for the decrease in lilies, burreed and cattail, and the disappearance of some areas of pickerelweed, it does not seem to account for the large increase in pickerelweed in one part of the lake; nor does it account for the disappearance of several patches of bulrush. It is possible that no available data can fully explain these changes.

B. Submersed Vegetation

1. Water Levels

In 1936, Muenscher reported extensive beds of emersed, floating and submersed vegetation in Canadarago Lake; and, overall, the vegetation does appear to be more extensive on the 1942 aerial photographs than on more recent photographs. The increased summer water levels, beginning with the construction of Panther Mountain Dam in 1964, could have been at least partly responsible for the decline in submersed vegetation as compared with earlier times. But this would not explain the increase since 1968, unless the submersed vegetation were equilibrating with the new water level. If this were the case, the increases would be expected in shallow water areas--areas that were previously too shallow or dry to support submersed vegetation. A major portion of the change in submersed vegetation has occurred in shallow waters, offering support to this explanation.

Water level differences between 1969 and 1976 (Fig. A4) could also have caused the observed changes in submersed vegetation by altering the amount of available light. Given the relatively small water level differences over this period, however, this would seem unlikely.

2. Light

Light is perhaps the most important factor affecting the growth of submersed aquatic plants, however, little

information is available on the amount of light required by these plants during different seasons. For example, how important are light levels in the late summer, after a plant's maximum biomass has been reached? Do they affect the vegetation's growth the next summer? Given that certain submersed species have reportedly grown under ice cover (Boylen and Sheldon, 1976), how significant are winter light levels?

That light during the early growth season is critical for the development of certain submersed plants should be expected (Peltier and Welch, 1970); this is the time when the plants are farthest below the water surface and growing most actively. But early growth seasons vary between species, and they may be ill-defined or non-existent for certain perennial populations.

For species that have an obvious dieback in winter (M. spicatum, H. dubia), the critical growth period is probably during the late spring or early summer (approximately May 15 to June 30 for M. spicatum; perhaps June 1 to July 31 for H. dubia). For the more perennial species (A. canadensis, Chara sp.) there may be no defined period. For P. crispus, the earliest species, the critical growth may include late summer, early fall and the period immediately after ice breakup in the spring (late April to mid-May).

The only measure of water transparency for which

there are fairly consistent data on Canadarago Lake is the Secchi disc reading. Although only one station has been monitored with weekly or, more commonly, bi-weekly readings in most years since 1969, the data provide a basis for comparison.

The average Secchi disc transparency for three periods are shown in Figure A5. The first period, May 1 to June 30 (Fig. A5a), includes the presumed critical growth period for M. spicatum; the second period, May 1 to July 31 (Fig. A5b), covers the growing season until the time of the earliest photography, including the presumed critical growth period for H. dubia; and the third period, mid-April to mid-November (Fig. A5c), covers the entire nominal growing season.

The Secchi transparency during the presumed critical growth period for M. spicatum was low (less than 1 meter) during 1973 and 1974 (Fig. A5a). Since a good portion of the increase in vegetation between 1969 and 1973 or 1974 was M. spicatum, it is unlikely that the observed increase could have been due to water transparency these two years; especially since the change was primarily in shallow water where transparency would be less of a factor. Also, conditions between 1970 and 1972 would have affected the amount of vegetation present in 1973 and 1974. In 1975, the transparency during this period was greater than in other years. This could have contributed to the increase

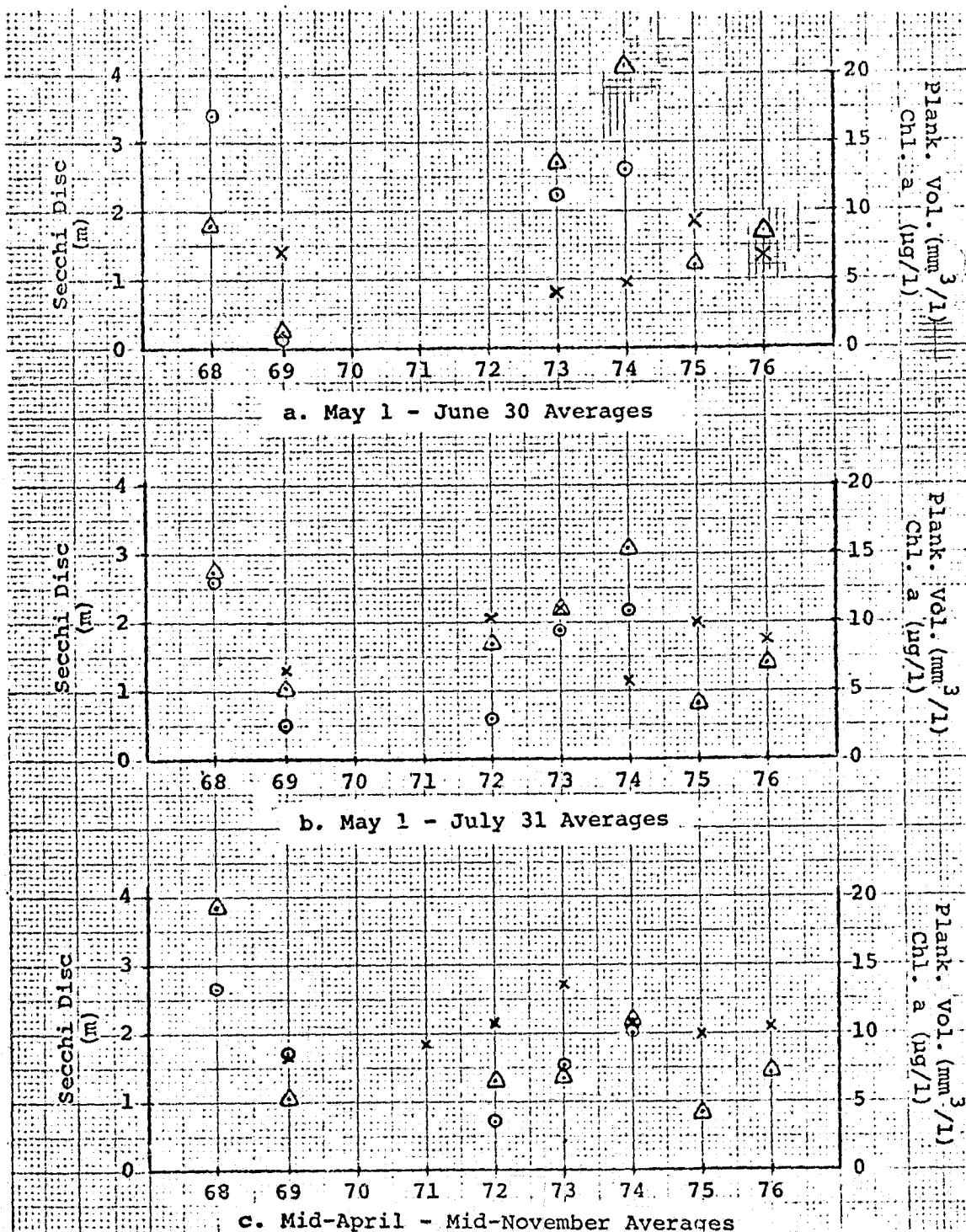


FIGURE A5. Seasonal average Secchi disc transparencies (x)*, phytoplankton volumes (Δ)*, and chlorophyll a concentrations (O) in Canada-rago Lake (data from Fuhs et al., 1972; Smith, 1976; Allen, 1977)

*sampling point 8

in M. spicatum in deeper water between 1974 and 1976.

For the period between May 1 and July 31, the transparency was lowest in 1969 and 1974 and highest in 1973 (Fig. A5b). The increase in H. dubia between 1969 and 1973 could be related to the higher transparencies in 1972 (only 3 readings) and 1973. (Although the average transparency was high in 1973, it varied from low during May and June to very high during July.) The somewhat higher transparencies in 1975 and 1976 may be partly responsible for the increases in H. dubia between 1974 and 1976, but the low 1974 transparency seems unlikely to account for the apparent increase in H. dubia between 1973 and 1974.

For the full growing season, mid-April to mid-November, the 1969 data showed the lowest overall transparency while the 1973 data showed the highest (Fig. A5c). The somewhat higher overall transparency since 1969 could be at least partly responsible for the increase in submersed vegetation since that date, primarily in the late-developing or persistent species (Anacharis canadensis, Chara sp.).

Because data on algae were available or more complete than data on transparency for several years, and because algae concentration is an important factor affecting transparency, an analysis of algae changes is also required. Moreover, algae may also be involved in other

an O. prolifica bloom (Hetling et al., 1975).

3. Nutrients

Rooted macrophytes are generally capable of absorbing nutrients from the sediments through their roots and from the water via their stems. The extent of this dual capability varies between species and is not well known (Hutchinson, 1975), yet few natural populations of submersed plants in eutrophic lakes are thought to be nutrient-limited (Gerloff, 1969; Freedman and Canale, 1977; Oglesby, 1974). Changes in water nutrient concentrations should have little direct affect on rooted submersed growth, although they may affect growth by changing algal concentrations. (Forsberg, 1964, has shown that species of Chara sp. are inhibited by high phosphorus concentrations.)

Average concentrations of total and soluble phosphorus over the growing season are presented in Figure A6. Little change in total phosphorus is noticeable, even after the treatment plant began operation in 1973, and the pattern of soluble phosphorus is anomalous. Overall, the data do not exhibit any clear relationship with changes in submersed vegetation. The increased submersed vegetation could possibly have compensated for the reduced phosphorus inputs to the lake by increasing the release of phosphorus from the sediments (DeMarte and Hartman,

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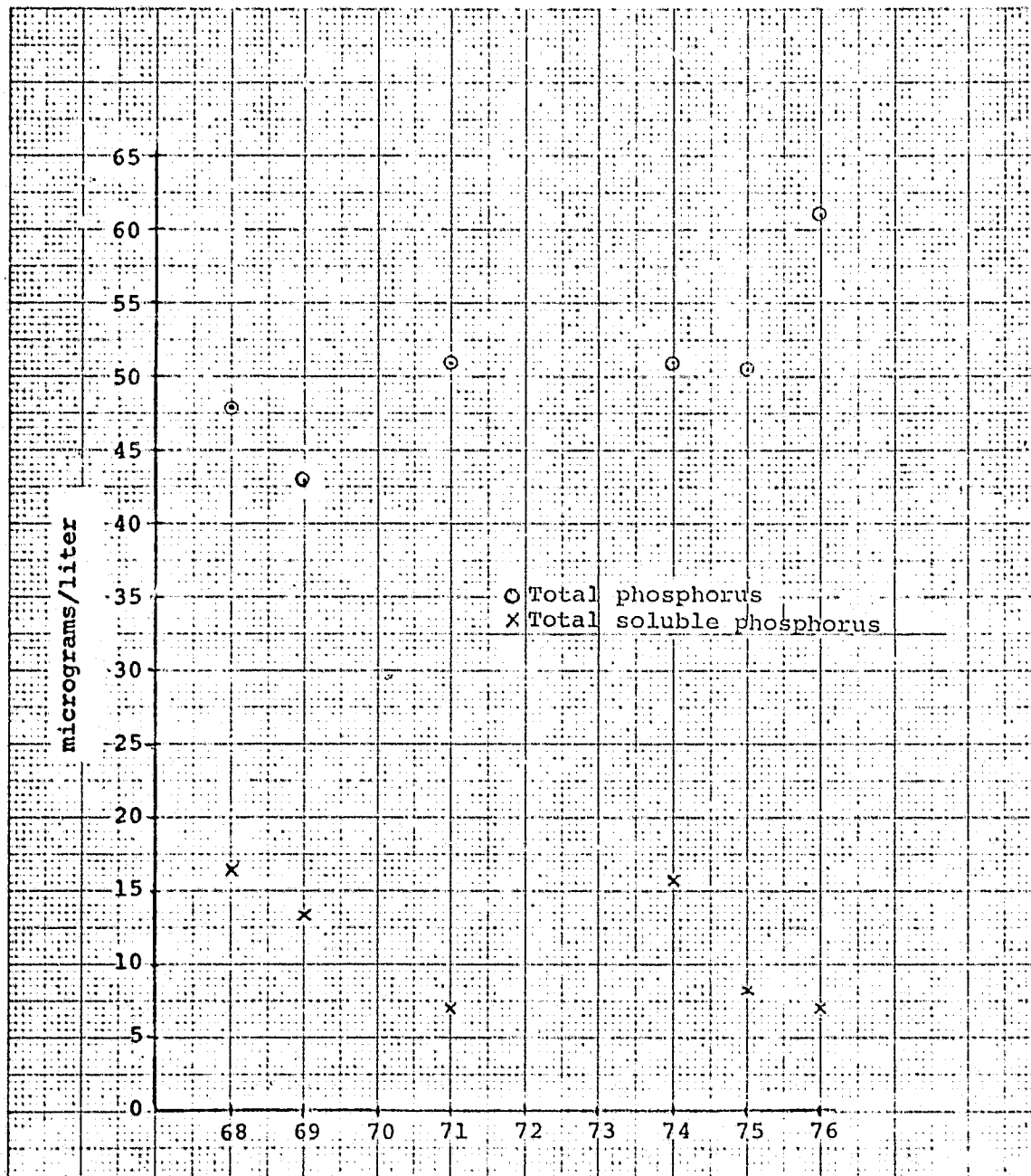


FIGURE A6. Average (mid-April - mid-November) concentrations of phosphorus in the surface 4.5 meters of Canadarago Lake (data from Hetling et al., 1974; Allen, 1977).

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1974); increased runoff may also have been partly responsible (Fig. A8). But no cause for the lower percentage of soluble phosphorus is provided by available data.

The summer average concentrations for the various forms of nitrogen are shown in Figure A7. No clear trends are evident for either nitrate and nitrite, or ammonia, however, there are only four years with good data. Organic nitrogen is lower in 1974 through 1976 than in either 1968 or 1969.

4. Sediment Oxygen Content/Smothering

It is likely that the sludge that entered the lake from the pre-1973 (non-operating) sewage treatment plant caused anaerobic conditions at the mouth of Ocquionis Creek, at the north end of the lake (Fig. 2). The improved treatment of sewage following the construction of the tertiary treatment plant would have led to improved oxygen concentrations and decreased sediment inputs in this area. The 1968 and 1969 aerial photographs show a concentration of dark sediments near the outlet of Ocquionis Creek, and these sediments are absent on the post-treatment plant photographs.

The improved oxygen concentrations should have made the substrate in this area more favorable for plant growth. Also, the decreased loading of suspended matter from the former sewage treatment plant should have reduced

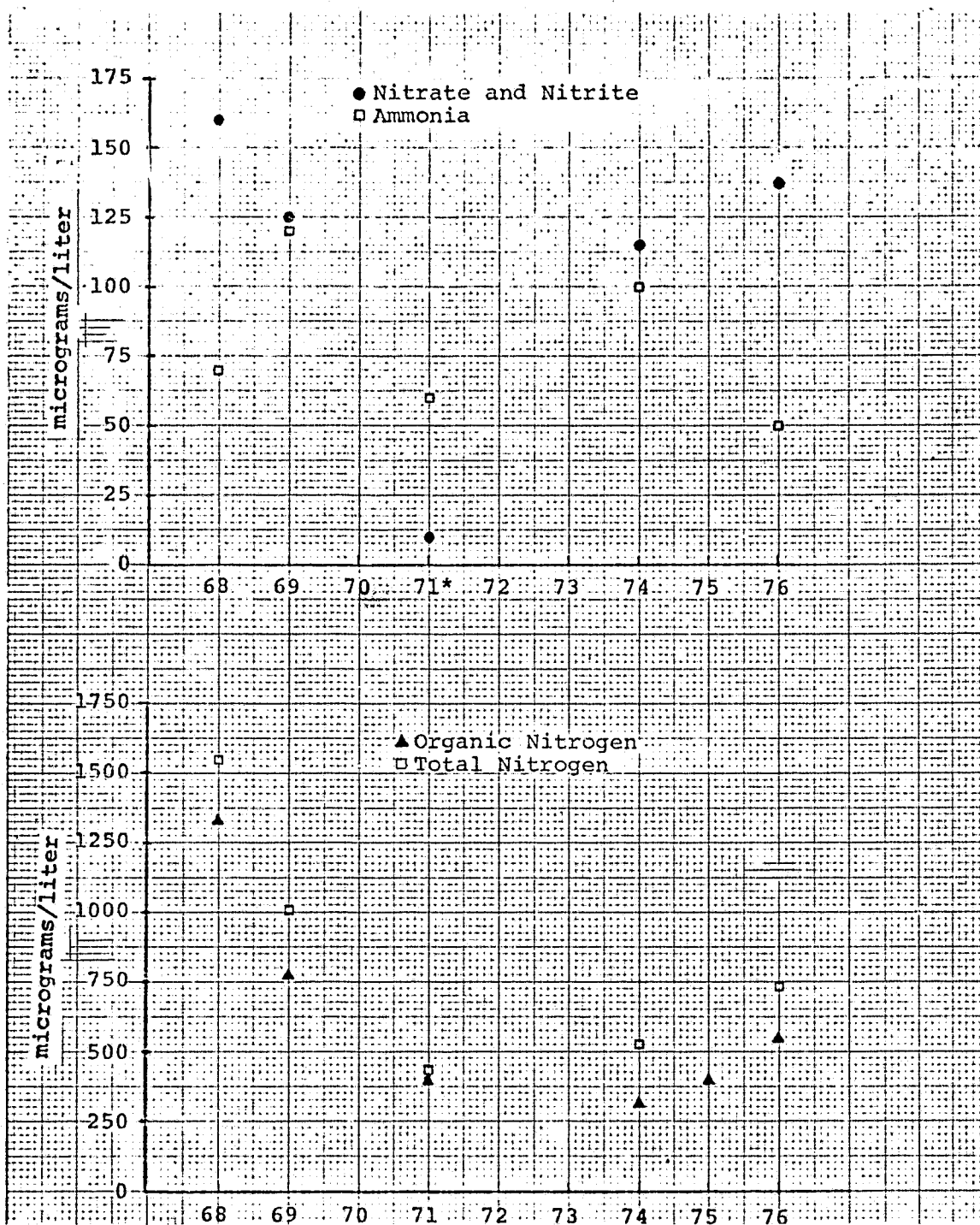


FIGURE A7. Average (mid-April - mid-November) concentrations of nitrogen in the surface 4.5 meters of Canadarago Lake (data from Hetling et al., 1974; Allen, 1977).

*1971 data available only 8/12 - 11/12, a time of normally low NO_3 and NO_2 .

the effects of covering any vegetative growth near the sewage input. Vegetation in this area increased substantially between 1969 and 1973, although it is not known when the increase actually occurred.

5. Drought

Central New York State was unusually dry from 1963 through 1966. As illustrated in Figure A8, the discharge of Oaks Creek, Canadarago's outlet, was considerably below that of other years. This low outflow would have resulted in a longer than normal water retention time (Fig. A8). Given that the lake was already highly eutrophic, that there was a lower dilution rate of sewage phosphorus inputs to the lake due to lower runoff levels, and that there was a lower flushing rate of plankton and nutrients, it is probable that the lake was even more highly eutrophic at this time. Dense algal blooms could have severely limited the light available to submersed plants, reducing their growth and area of colonization. (Although the drought would have produced lower water levels and thus increased available light, the water levels were altered by the dam construction in 1964.)

With the greater runoff after 1966, algal populations might have decreased, increasing the light available to submersed plants. And since 1971, the above-normal runoff has led to the potential for further decreases in

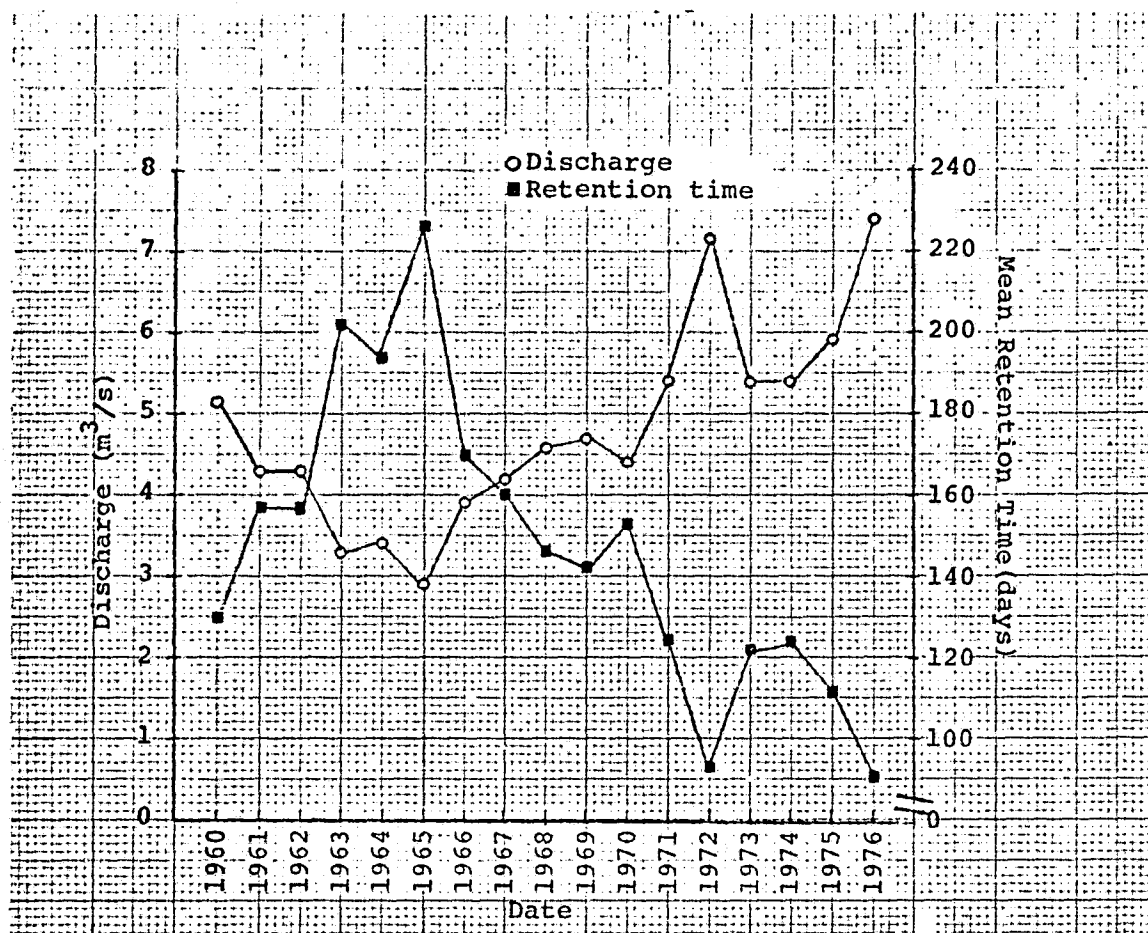


FIGURE A8. Yearly average discharges of Oaks Creek at Index, NY (approximately 8 km downstream from point of outflow from Canadarago Lake) and yearly mean retention times* for Canadarago Lake (data from USGS, 1960-1976 and 1977).

*not corrected from contribution of non-Canadarago Lake flow (actual retention times are longer) and assuming constant lake volume.

algal blooms accompanied by increases in available light. But since 1973, when the principal source of phosphorus inputs from sewage was removed, the increased runoff could no longer act as a diluent for this phosphorus input. On the contrary, increased runoff may have led to increased phosphorus inputs from other sources, primarily sediments, with the phosphorus likely to be in forms unavailable to algae (Porter, 1975). The flushing rate would still be high.

C. Summary

Some of the changes in emersed and floating plants may be related to summer water levels, which increased after the construction of a lake outlet dam in 1964. As regards submersed vegetation, the data are not sufficient to determine the cause(s) of the change, and gaps in the vegetative record also hinder a complete analysis. Nevertheless, the data do not support the hypothesis that increases in submersed vegetation are an indirect consequence of decreased phosphorus inputs to the lake; that is, that the decreased phosphorus would reduce phytoplankton which, because of the increased water transparency, would allow submersed vegetation to increase.

It is notable that, since the tertiary treatment plant began operation in 1973, Canadarago Lake data have shown:

- no decrease in total phosphorus, averaged over the summer months;
- no defined decrease in average phytoplankton concentration, although large year-to-year fluctuations have occurred since 1968;
- no defined increase in average Secchi transparency during certain critical times of the year, although overall transparency may be higher; and
- a substantial increase in submersed vegetation that could have begun as early as 1968, five years prior to the treatment plant construction.

The increase in submersed vegetation might be attributed, at least in part, to any of the following:

- recovery from the drought of the mid-1960's (1963 - 1966), a period of potentially high phytoplankton and low light penetration;
- adaptation to increased summer water levels caused by the construction of an outlet dam in June 1964;
- higher than average rainfall, with more rapid lake flushing, since 1971;
- since 1968, lower average phytoplankton concentrations than in 1968;
- since 1969, higher average water transparencies

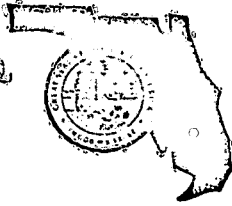
than in 1969;

- very high water transparencies during July 1973;
- higher than average water transparencies during the early growth period, May 1 - June 30, 1975; and,
- because of improved sewage treatment, increased sediment oxygen content, with decreased suspended sediment (or increased light) at the point of sewage input to the lake--a localized effect.

APPENDIX E
PROJECT-RELATED CORRESPONDENCE

DEC 12 1977

Florida



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TOM WEBB, JR.

SECRETARY

December 2, 1977

Dr. T. Liang
Cornell Center for
Environmental Research
Cornell University
Ithaca, New York, 14853

Dear Dr. Liang:

During our visit to the annual ASP meeting held in Washington in 1975, we were introduced to you by one of your former students, Mr. Frank Perchalski. At that time we discussed various topics in the field of remote sensing. Since that time we have been informed of your activities through the "Cornell Remote Sensing Newsletter".

In reading the December 1977 issue, your article on the "LANDSAT Assessment of Aquatic Vegetation" is a timely topic. We are presently considering entering into a demonstration project with NASA in determining the feasibility of using LANDSAT data in our areas of interest. Our priorities for study are:

1. LANDSAT application to enhance present land use data base (LUDA 1:125,000 approximately)
2. LANDSAT application to the inventory and analysis of surface water bodies and related vegetation

There are also other topics being considered. We would like to obtain a copy of your report in order to determine if it would be feasible to do such inventorying on a practical level here in Florida. We are having our inter-agency meeting on the 13th of this month. One of the major points we have been faced with concerning the LANDSAT data is the limited resolution of the system.

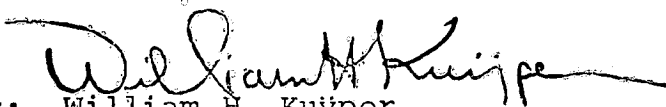
Letter to Dr. Liang
December 2, 1977
Page two

It appears in your studies, when you use the digital data, you seem to have a higher degree of definition in identifying the various vegetation environments and conditions. We are hoping you can offer us, through your report, some insights as to whether we should undertake such a study. If your report shows us strong positive indicators or the opposite, it would be beneficial to know this prior to that time.

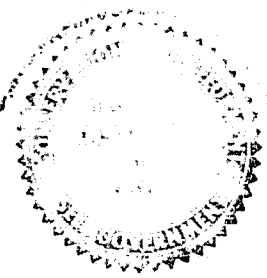
Your newsletter has had many interesting articles in the past. Our compliments to your worthy publication.

Very truly yours,

Jon S. Beazley, P.E.
State Topographic Engineer


By: William H. Kuyper
Remote Sensing Engineer

JSB/WK/mc



Seneca County, New York
Soil and Water Conservation District

321 E. Williams at Mill Street, Waterloo, New York 13165

William J. Cool, District Manager Telephone: (315) 539-3411

December 13, 1977

Mr. Warren R. Philipson
SR. Research Associate
Cornell University
Remote Sensing Program
Hollister Hall
Ithaca, New York 14853

Dear Mr. Philipson:

This communication will acknowledge receipt on October 5, 1977 of maps, overlays and other materials to be used for selecting priorities for drainage improvements in Seneca County. We are using this information as a tool in our selection process at this time.

We have also found that this material provides a quick reference to difficulties one may encounter when purchasing property. The information seems to be accurate even on a individual farm basis.

The only place for improvement that we might suggest would be another overlay showing township boundaries and some roads to help in quickly locating a particular farm or property.

The Soil and Water Conservation District board of directors and staff wish to express their appreciation for this fine land use tool. We thank you and your staff for the assistance and cooperation shown during this project.

Sincerely yours,

William J. Cool
District Manager

WJC/kh

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May 15, 1978

Mr. Warren R. Philipson
Sr. Research Associate
Cornell University
Remote Sensing Program
Hollister Hall
Ithaca, New York 14853

Dear Mr. Philipson:

In response to your letter of May 11, 1978, we have the following subjects which may lend itself to satellite scanning with this organization as a user and cooperator.

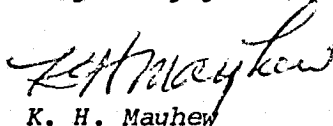
1. Snow pack seasonal coverage, moisture content and intensity. Some work has been done in this field or is in process; but not over the Western and Southern Adirondachs which is the drainage area of the Hudson and Black Rivers. We ground monitor snow cover at some 40 stations in the Hudson and the Black River Drainage Areas but have no true estimate of snow pack coverage in the late spring months. The area of such coverage would yield much greater accuracy in run-off water management planning.
2. Surveillance of annual flood coverage in the Black River Valley at different monitored stream flow stages would be most useful. Flood plain areas are currently rule-of-thumb estimates and inadequate for agricultural loss estimates.
3. No true inventory of the number and capacity of dams within the drainage areas has ever been assessed. These retardant storage areas would be helpful and of immediate use in assessing run-off factors.

May 15, 1978

4. Ground water elevations and retention capability is the weakest point in our water surveillance program. We have two active recording stations in a 2000 sq. mile area, hardly an accurate indicator of ground water conditions, one of the important facets of the complete water management field.

Would you kindly review the above to ascertain what potential your Program may be of mutual assistance? Your prompt reply would be appreciated.

Very truly yours,



K. H. Mayhew
Assistant Chief Engineer

KHM:fmg

APPENDIX F

SELECTED NEWS ITEMS/PROGRAM PAPER

AERIAL Applicator

FARM, FOREST & FIRE

"TM Reg Pending"

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from the cockpit

As 1977 draws to an end, this magazine wants to salute the U.S. Department of Agriculture and particularly the various State University Cooperative Extension Services for the way in which they handled a rather complex agricultural calendar year. With drought in the West, floods in various areas of the East, unpatterned pest and insect infestations in many places, the USDA put out a mountain of good information for most sections, and for aerial applicators in general.

While the USDA has a variety of regulatory functions, they don't seem to throw the weight around as do most other Federal regulatory agencies, bureaus or commissions. For the most part, USDA personnel seem anxious to help rather than hinder, and in this day of semi-socialism that is a refreshing note.

J.B. Kendrick Jr., who is, among other titles, Director of the Agricultural Experiment Station and Cooperative Extension Service at the University of California at Berkeley, had some interesting things to say in this regard in a recent Editorial printed in California Agriculture magazine. He is constructive, particularly when it comes to Pest Management.

He says that "one way to increase the food and fiber supply significantly would be to reduce the losses caused by pests and diseases." He reports that in California 10 to 20 per cent of total food and fiber production is lost before harvest each year, while in some developing countries, estimated crop losses run as high as 75%. He is of the opinion that we are far from our goal of acceptable control, and that opinion, in this magazine's conjecture, leaves plenty of room for the aerial application industry to expand.

Mr. Kendrick opines that the increasing dependence on pesticides has the inherent drawback of relying on a single line of defense because it has "introduced problems of pest resistance, destruction of natural controls, outbreaks of secondary pests, reduction of pollinators and other beneficial species" and furthermore costs too much (an estimated 10 to 20 per cent of crop production.)

He advises that one promising approach is a system of crop production known as "Integrated Pest Management." This system is a "flexible multidimensional approach to control, using a range of biological, cultural and chemical techniques, as required, to hold pests below damaging economic levels . . ." As Mr. Kendrick puts it, ". . . no single arbitrary control method will suffice because of the remarkable adaptive powers of insects, weeds, plant pathogens and because of the many variables related to season, location, and cropping patterns and pests."

For Integrated Pest Management, "we must know the biology of the pest, its natural enemies, the host plant, and their interrelationships in the environment. We must be able to predict the pest's occurrence, its population levels, and the potential economic damage. We must know more about the influence on pests of various weather conditions and of cultural practices such as irrigation, cover-crop management and harvesting procedures."

Mr. Kendrick advises that the Integrated approach is currently being used on a limited scale against specific pests, but does not elucidate in his editorial. He does state the research programs in these areas must be expanded so that all techniques can be effectively mobilized.

All in all, his thoughts are certainly not regulatory for man, albeit they are for pests. This is the type of constructive thinking and helpful attitude we mentioned in the first two paragraphs of this article. We like Cooperative Extension Services and the USDA.

ON THE COVER: Prototype installation of the 600 h.p. Pratt & Whitney R-1340 on the new Grumman Ag-Cat B, long wing version of the famous G164A. Previously powered with the popular PEW R-985 450 h.p. and 525 Continental, this field approved conversion by Mid-Continent Aircraft Corporation, Hayti, Missouri for Wayne Smith of Lonoke, Arkansas has been named the S-MC "600" Special. Faster on less fuel, with unlimited performance, it carries a full load effortlessly. Interest is extremely high for conversions at engine change time.

AERIAL PHOTOGRAPHS PROVIDE EVALUATIONS

Since 1968, scientists have been collecting data at Canadago Lake in central New York State for what may prove to be a classic study of the revitalization of a eutrophic body of water. The lake is relatively small (6 km by 1.5 km, with depths to 13.4 m), and isolated from pollutants except for effluent from a sewage treatment plant at nearby Richfield Springs (pop. 1,600).

In January, 1973, a new tertiary sewage treatment plant for the village went into operation as a Federal and New York State demonstration project. It replaced a plant built in the late 1800s. The old plant, virtually inoperable in its final years, had been discharging almost raw sewage into the lake. This caused a high phosphorus enrichment in the lake with consequent growth of algae.

The new treatment plant has reduced the lake's phosphorous input by about 40 percent. With a definite discharge cutoff date, the lake provided an ideal site to study the before-and-after effects of the cleanup on both plant and fish life. It was theorized that a change in sewage treatment would cause a change in the lake's ecology, and this seems to be the case.

Although many components of the lake's ecosystem have been monitored since 1968, little emphasis had been placed on recording changes in aquatic vegetation accompanying the decrease in nutrient loading. The lake had been highly productive of algae, which reduced light penetration through water and apparently inhibited the growth of rooted plants.

The question was whether the lower nutrient level would reduce the algae population, thus encouraging the growth of higher forms of vegetation. Given that aerial photographs of the lake had been taken both before and after the treatment plant start-up, a project to develop evaluative techniques was undertaken in the Remote Sensing Program of the School of Civil and Environmental Engineering, Cornell University.

"Aerial photos have been used in the past to map weed beds," says Brian L. Markham who, with botanist Ann E. Russell, conducted the analysis under the direction of Dr. Warren R. Philipson and Prof. Ta Liang. "Our objective was to demonstrate that aquatic vegetation could be identified reliably from aerial photographs with little or no concurrent ground data. This was also part of a larger project, now under way, to assess what changes have taken place in the lake."

Markham's study was begun under the school's grant from the National Aeronautics and Space Administration, and continued under a grant from the United States Department of the Interior, Office of Water Research and Technology. Photographs were provided by Eastman Kodak Company, the U.S. Environmental Protection Agency, NASA, and the State University of New York College of Environmental Science and Forestry.

Aerial Photographs of the lake had been taken in 1968, 1969, 1973, and 1974. Fortunately, most of the photography had been done both with Kodak Aerochrome MS film 2448 (Estar base) and with Kodak Aerochrome infrared film 2443 (Estar base) to provide a comparison between normal color and infrared color images.

By studying the aerial images at a scale of 1:6,000 with a zoom stereoscope, Markham was able to compare weed beds and note changes over a six-year period. From these data, he developed three predictive classifications to be used in field studies during the summer of 1976. It was predicted that areas having vegetation throughout the six-year period and those in which vegetation had developed between 1968 and 1974 would have vegetation at the time of the field survey. Areas revealing no vegetation over the period were expected to still be barren. "We found excellent agreement between the predictions and the ground-truth study," Markham states.

The other part of the study was aimed at identifying major types of vegetation from the photographs. Viewing the photographs, Markham found that he could identify five types of floating or emergent vegetation through location, shape, color, and texture of the patch, and its height above the water surface. Working with the stereoscope, Markham examined plant heights as low as 0.5 meters.

Using prints of the 1974 photography for reference,

Markham and Russell identified and mapped the various stands of weeds during the summer's field study. Concurrently, new photography was flown in July and August, and later correlated with field identifications.

Overexposure of the film by about one-half stop aided water penetration. Markham reports that he also saw some stereo effect underwater. He could thus differentiate between low-lying bottom plants and those growing up from the bottom to near the surface.

The August, 1976, photographs also were analyzed densitometrically to determine whether spectral characterization would aid in identification of emergent and floating species. "We found that, for our purposes, densitometric analysis did not add to the information we could extract visually with a stereoscope," Markham comments. "We did not attempt to characterize the submergent species in this manner because of the complicating effects of the water. In general, the tones of the submersed vegetation seemed to vary more with the water depth than with the vegetative type."

Several conclusions were drawn from the project:

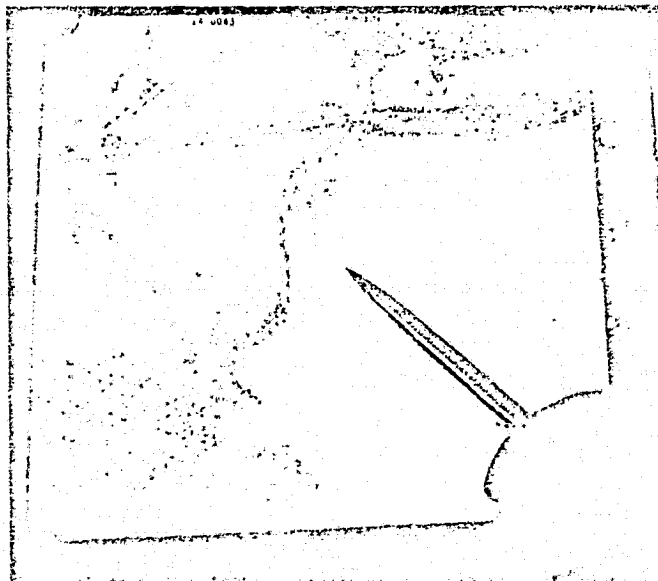
- It is possible to identify and differentiate species of floating and emergent vegetation from aerial photographs with little or no ground data. Given sufficient water transparency, submersed vegetation can be recognized and differentiated from other bottom features, such as rocks. However, the different submersed types were generally not separable in the aerial photography.

- Larger scale photography is preferable for detailed vegetation surveys. Generally, scales larger than 1:10,000 are recommended.

- Smaller format photography is adequate for species identification, but the coverage afforded by larger format photography is preferable for mapping. Film used for earlier photography was 9½ inches wide, while the 1976 photography was done with 70 mm film.

"We saw changes in the lake over the period of the study," Markham says, "and the major changes involved the submersed vegetation. The changes may have occurred because of the change in water transparency, but we don't know for certain. So, we have the effect but not the cause."

"What we have done is to develop a relatively simple, inexpensive way to assess changes of this sort through aerial photography," he concludes. "Historically, this is important. If past photography of a body of water exists, we can reach back in time and gauge years of change in the short time it takes to analyze the photos."



By studying and comparing aerial photographs such as this one, investigators can quickly identify changes in lake vegetation that have taken place over several years. With large-scale photos (1:6,000), it is possible to discriminate types of floating and emergent vegetation, and also to separate submersed weeds from such bottom features as rocks.

WINES & VINES

and Wine Merchant



MEMBER AUDIT BUREAU OF CIRCULATIONS

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COVER: Typical of late autumn is this illustration furnished courtesy of IDEALS magazine, published in Milwaukee and one of the most beautiful publications in the world. The photograph was used for their Thanksgiving issue in 1976.

CLOUT

It always is dangerous to ask a reader if he noticed what you did in last month's issue. Clearly he may suffer even more grievously than I from the problem of having a good memory but a short one.

Did you note the October cover? I hope so. It was the winning poster for the Third Annual Wine Festival staged by the Enological Society of the Northwest in Seattle. I bring this up because it illustrates the point I want to make: the country's growing interest in wine.

The Seattle group is for consumers, but it has winegrowers among its members, too. In Washington, Oregon, Idaho, Rhode Island, Kentucky, the Carolinas, Texas and many other states the involvement with wine is waxing. *Wines & Vines* is heartily in favor. Again calling upon your memory, you may recall that, in the 1977 Directory, wineries are listed in more than 60% of the U.S. Michigan, no stranger to wine these many years, had its first commercial wine judging at its State Fair in 1977. There were similar events in Missouri and Oregon. Evidence, I say, that the interest in wine is both catholic and widespread.

Getting back to the Northwest group, it not only has a highly professional wine judging (of Northwest wines); it has a year-long array of seminars and tastings, wine talks, wine tours and more—all this with no paid staff. The work is done by volunteers.

Last month, too, we had the first installment of Julius Jacobs' piece about the many consumer organizations with wine as the *raison d'être*. No other licensed beverage commands this kind of support. None ever will. If you are politically myopic you might say that such outside influences are of no value, that they only take away markets by encouraging wine growers in other states. That is precisely the reason they should be encouraged and assisted.

It is one thing to have California and New York plead their case before this tribunal or that, or this legislative body or that. How much stronger is the case if it is argued on more than 30 different fronts? By persons who are growing grapes, making wine, entering the market place, consuming wine. And demanding fair treatment. Where is the clout?

Does it lie in a few special pleaders? With bigness as their principal impact? Or in the combined influence of some dozen voices, large and small, raised for a fair deal on local, state and federal levels? Americans, for good reason or no, question bigness and embrace smallness. Our tariff and tax systems are tailored along those lines. The concept of the "biggs" helping the "smallss", however, has historic appeal in our democracy.

We are closer than ever before to universal U.S. support for wine.

We have only ourselves to blame if we blow it.

ORIGINAL PAGE IS
OF POOR QUALITY

Aerial photography: new planning tool

near Ovid, and vineyards were planted in both locations by Taylor in 1975 and 1976. The two sites were working farms prior to being selected as test sites, according to Harland Tyler, vineyard manager.

The Ovid site needed additional drainage prior to vineyard planting and the company wasn't certain of the effectiveness of drainage tile already in place. Tyler wanted to be certain of drainage before planting "because once the trellis and vines were in we would have to tear the vineyard apart to put in more tile."

At this juncture, the company was contacted by the Remote Sensing program at Cornell. Funded by NASA (National Aeronautics and Space Administration) this program explores uses of remote sensing techniques for solving environmental problems. Researchers under Dr. Ta Liang, professor of civil and environmental engineering at Cornell, offered assistance with drainage planning. Vineyard Manager Tyler's system in planning drainage has been to walk the fields after a rain to locate wet spots. The Remote Sensing Program manager, Dr. W. R. Philipson, said "we felt that aerial photography would provide better perspective and allow us to study the entire field simultaneously." It was the farmland at the Ovid test site which was to be analyzed.

Work began by tracing a base map of the Ovid site using a 1:24,000 scale U.S. Geolog-

ical Survey topographic map to show the two fields under investigation. This was enlarged by using a zoom transfer scope. All other work was prepared as transparent overlays to the base map. Using a 1972 soil survey of Seneca county, an overlay was prepared delineating the four soil types which underlie the site. This was used as a starting point although it wasn't specific enough to pinpoint needed areas for tile drainage.

To obtain greater accuracy the engineers in the Remote Sensing Program employed an aerial photo of the specific location, made during a 1968 New York land use and natural resources inventory. The photos were made on Kodak Double-X Aerographic film 2405 (Estar base) by contractors who covered 49,000 square miles of the state at that time.

It became apparent at once that existing drainage tile could be identified in the fields because they appeared as straight (relatively), light colored lines. It also became apparent that "wet spots" could be identified where moisture collected and did not drain. These appeared as dark-colored objects in the fields.

Two overlays were prepared—one a map of existing drainage tiles. The reasoning was that the vineyard foreman would wish to connect into these as new drainage was installed. The other overlay was a map of the wet spots—and this was particularly helpful in the actual tile drainage installation. Any of the old clay tile that was found was connected into the main plastic lines, Woody Clark, one of the officials, explained, because if left alone, there was always a possibility it could become plugged and create its own wet spot in the future.

When rains began in the summer of 1975, the people in charge began roaming the fields and locating the actual wet spots. But tiling operations had started a month earlier because the aerial maps gave them something to start from. After the job was finished, a recheck showed that all shaded areas on the map had been covered with extensive tiling.

More than 38,000 feet of tile were installed in the two potential vineyard acreages, in contemplation of spring planting. The project director, Dr. Liang, feels that the Remote Sensing project for the Taylor company can well be applied to similar problems of other farmers. In the former instance the photography was already in existence—and the project in entirety took about a half day to complete. Dr. Liang says "this proves it is worthwhile to buy a couple of photographs, study them and use the data, because so little time is involved, it's a very efficient process."

NASA and the Cornell Remote Sensing project will make the Taylor Wine Company report available to anyone. The techniques can be applied by many commercial firms that offer photo-interpretation services. Courses are offered in this subject by many universities.

Thomas L. Erb, with the impressive title of image analyst/research engineer, says that it isn't possible to imagine all the uses for the aerial photos that already exist.

Julius Jacobs

AERIAL photography to monitor land drainage is being employed in New York State vineyards. Because of projections for increased wine usage and the need for more vineyards to keep up with demand, the Taylor Wine Company has sought "flatter sites where it will be easier to use heavy equipment."

Sometimes this is difficult to find because acreage is becoming more limited in the best New York State vineyard areas. Cornell University experts conducted temperature studies in conjunction with the state's Agricultural Extension Service. They came up with two land parcels on the east and west sides of Seneca Lake. One is near Dresden, the other

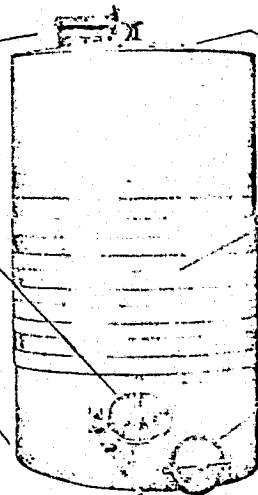
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CORNELL'S REMOTE SENSING PROGRAM:
REMOTE SENSING FOR THE USER

W.R. Philipson, T. Liang, T.L. Erb and B.L. Markham

Remote Sensing Program
Cornell University
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Ithaca, New York 14853

Paper to be presented at the 44th Annual Meeting
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BIOGRAPHICAL SKETCHES

Warren R. Philipson received his B.C.E., M.S. in Civil Engineering, and Ph.D. in Soil Science (Agronomy) from Cornell. Over the past 12 years, he has taught, conducted research and participated in remote sensing projects in various parts of the world. A senior research associate in Civil and Environmental Engineering, he co-directs the Remote Sensing Program.

Ta Liang received his B.E. from Tsing Hua University, China, and his M.C.E. and Ph.D. from Cornell. He has conducted research and taught courses in airphotos and physical environment evaluation at Cornell since 1957. In consulting and research, his international experience spans 40 years. A professor of Civil and Environmental Engineering, he is principal investigator of the Remote Sensing Program.

Thomas L. Erb received his B.S. in Civil and Environmental Engineering from Cornell, where he did graduate work in Aerial Photographic Studies and Remote Sensing. He has been associated with the Remote Sensing Program since its inception, in 1972. A research specialist in Civil and Environmental Engineering, he conducts remote sensing projects and lectures in airphoto interpretation.

Brian L. Markham received his B.S. in Natural Resources from Cornell, where he is completing an M.S. in Aerial Photographic Studies and Remote Sensing. He has been employed as a biological aide by the U.S. Fish and Wildlife Service, and as a graduate teaching assistant in airphoto interpretation at Cornell. He is currently a research specialist in Civil and Environmental Engineering.

ABSTRACT

Begun in 1972, Cornell's NASA-sponsored Remote Sensing Program has strengthened instruction and research in remote sensing, building upon Cornell's years of experience in aerial photographic studies; established communication links; and conducted demonstration projects for numerous town, county, state and private organizations in New York State. In compliance with NASA's guidelines, each project has been, in some way, unique; essentially noncompetitive with commercial firms; and aimed at producing tangible benefits or actions. These projects are outlined and characterized according to elements that have generally governed their impact: (1) whether the project seeks surface or subsurface information, and (2) whether the goal of the project is to inventory or to detect/monitor. The Cornell Program has shown that remote

sensing can provide useful information, even in a state where agencies have used remotely sensed data for years and where substantial quantities of detailed information are already available.

INTRODUCTION

On June 1, 1972, Cornell University's School of Civil and Environmental Engineering initiated a Program in Remote Sensing. Sponsored by a grant from the Office of University Affairs of the National Aeronautics and Space Administration (NASA Grant NGL 33-010-171), this Program was a consequence of some thirty years of pioneering work in aerial photographic studies and photogrammetric engineering. For Cornell, the grant has provided the means and opportunity to increase its overall competence in remote sensing. For NASA, the Cornell Program has provided a vehicle for demonstrating and promoting the application of aircraft and satellite remote sensing, particularly, in New York State. This discussion is a review and analysis of the Program's experiences through December 1977*.

GENERAL REVIEW

Briefly, the first year was devoted to strengthening instruction and developing the foundation for user-oriented research in remote sensing. A weekly seminar and monthly newsletter were instituted, university and non-university contacts were made, aircraft and satellite imageries were collected, and cooperative investigations, directed at New York and the northeastern United States, were begun. Program activities were expanded during the second and third years and, while several demonstration projects were completed, new projects of a more clearly defined, benefit-producing nature were undertaken. These and many other projects, and the Program as a whole, have come to fruition during the ensuing years.

COMMUNICATION AND INSTRUCTION

Contacts

Since 1972, staff and students supported by the Program have worked with representatives of many groups. These are summarized in Table 1, where the various groups have been categorized according to whether their representatives (1) cooperated in one or more projects, (2) were users of the results of a project in which they may or may not have participated, or (3) were involved in either preliminary discussions or discussions which have not as yet led to a specific project ("other").

In addition to hosting project-related visitors and invited seminar speakers, the Program staff has received numerous guests from within the United States and from many other countries. Occasionally, this was in conjunction with spe-

*Program activities have been described, in detail, in eleven Semi-Annual Status Reports, submitted to NASA and available from NTIS, 5285 Port Royal Rd., Springfield, Va. 22161.

ial remote sensing orientation sessions or workshops. Over the past few years, for example, special lectures were held for groups ranging from New York State highway superintendents to participants in AID-sponsored Institutes on Policies for Science and Technology in Developing Nations.

The Program's "Cornell Remote Sensing Newsletter" also provides a communication link to and beyond the Cornell community. The monthly Newsletter, which highlights remote sensing activities at Cornell while reporting items of general interest, is now received by more than 400 individuals and groups in some 30 states and 14 foreign countries.

Courses

With NASA support, the Program staff has continued to upgrade Cornell's longstanding curriculum in Aerial Photographic Studies. The Program's weekly Seminar in Remote Sensing has brought experts from government, industry and other institutions to Cornell to discuss remote sensing research, developments and applications with students, staff and faculty (Table 2). A three credit-hour course, "Remote Sensing," was also developed as part of the regular curriculum of the School of Civil and Environmental Engineering. And, overall, greater emphasis is being placed on non-photographic sensors and sensing techniques, as well as on the handling, analysis and interpretation of various sensor data outputs.

Data and Facilities

Remote sensing research and instruction have been enhanced through acquisition of a wide range of aircraft- and satellite-derived data, and through expanded capabilities for their analysis. The Program's data, facilities and equipment are made available at no cost to cooperators, students and other interested users.

With assistance from the NASA Office of University Affairs, the Program has received Landsat, Skylab, high-altitude and low-altitude coverage of sites in the Northeast. The U.S. Environmental Protection Agency has also overflowed Program-selected sites, and imageries have been obtained from various other government and private sources. These data complement the Program's file of more than 600,000 older, worldwide aerial photographs.

With NASA funding, the Program has acquired selected photographic and darkroom equipment, a versatile zoom stereoscope, an additive-color viewer, and a series of routines for analyzing multispectral digital data on Cornell's IBM 370/168 computer. These supplement image analysis equipment obtained in previous years with other funding (i.e., zoom and non-zoom stereoscopes, Zoom Transfer Scope, stereoplotters and other photogrammetric instrumentation).

PROJECTS

As stated, numerous remote sensing demonstration projects have been conducted by, or in conjunction with, Program staff (Ta-

ble 3). In compliance with NASA's guidelines, the initiation of each followed screening to ensure that the project was, in some way, unique; that undertaking the project would not be competing unduly with private companies or consultants; and that, if completed successfully, the project would produce tangible benefits or actions by definable users. Relatively little emphasis was placed on technology transfer, per se.

Finding projects that conformed with these criteria has been difficult; especially, since the focus of the Cornell Program is New York State. The earliest project solicitations were aimed at state agencies. Although Program staff encountered little or no resistance against new techniques, it did encounter major problems in developing action- or benefit-producing projects. Most state agencies are not "action" agencies. Further, most state agencies normally require much time and data before taking any action, including a "planning action." Although totally justified, this makes it difficult, if possible, to trace remote sensing or other input to a final action or benefit. With regard to New York State planning activities, moreover, much of the state-wide planning data that could be derived effectively through remote sensing had already been derived or were being derived by other groups.

Just prior to the Program's inception, for example, Cornell University had completed the state-wide Land Use and Natural Resources Inventory (LUNR), in which more than one hundred types of area or point land use were identified from aerial photographs, transferred to 1:24,000 scale map overlays, and entered into a computer file/weighted retrieval system. In addition, another Cornell investigator, Dr. Ernest E. Hardy, was comparing satellite with LUNR data in NASA-sponsored, Landsat and Skylab experiments; and William Harting, of the Tri-State Regional Planning Commission, was conducting a NASA-sponsored experiment to assess the value of Landsat data for planning in the New York City area.

As a second example, where university programs in other states might have attempted to demonstrate geologic applications of satellite and aircraft remote sensing to their state geological survey, the soils and geology of New York State have been mapped and studied in some detail, and Dr. Yngvar W. Isachsen, of the State Geological Survey, was already conducting Landsat and high-altitude aircraft investigations with direct support from NASA.

As a third example, where wetlands have been the subject of remote sensing studies across the country, in New York, a state agency was conducting the "official," state-wide wetlands inventory, using 1:24,000 scale aerial photographs. This agency, like others in the state, has years of experience in applying aerial photography.

Many examples could be cited; examples which show why, during the second and third years of operation, the primary focus of project solicitations shifted from state agencies to county, town and private users. Although much of value can be accomplished with remote sensing at the county and town levels, the applicability of aircraft data is increased and that of

satellite data is decreased--at least when the satellite data are of a resolution comparable to that of Landsat. This can be surmised from the list of projects which have generated the most substantive benefits or actions by county, town or private users (Table 3A). All have relied on aircraft data as the sole or primary source of information.

Even those demonstration projects that were conducted for state agencies tended to attack localized problems which were generally not amenable to solution or analysis with satellite data. These projects are listed in Table 3B.

The Program's reliance on aircraft data should not be interpreted as implying that satellite data were not consulted on many occasions, for many projects. Satellite data did, in fact, supply a basic source of information for several studies, particularly, when recent, periodic or synoptic coverage was desired. Studies of this nature are outlined in Table 3C.

PROJECT ANALYSIS

In general, the Program staff has found that a project's impact can often be forecast by whether the project seeks surface (directly observable) or subsurface (indirectly observable) information, and whether the goal of the project is to perform a complete, area-wide inventory or to detect and/or monitor some specific items (Table 4).

Although exceptions can be cited, a project which inventories surface or directly observable features may lead to the user adopting the inventory technique, but it will seldom generate any other action or benefit (Table 4). Surface information can normally be gotten without remote sensing (less efficiently) and, by itself, governs few decisions or actions (wetlands being a notable exception).

In contrast, a remote sensing project which calls for an inventory of subsurface or indirectly observable features will often lead to an action or benefit (Table 4). Information such as depth of soil over bedrock is difficult or costly to obtain in other ways. When required, it often governs the final decision or action. Because techniques for inventorying subsurface features rely heavily on interpretation, they are more difficult to transfer.

The distinction between inventorying and detecting or monitoring is sometimes vague, yet a project which involves the detection or monitor of surface (directly observable) features often produces the greatest possible impact. A successful demonstration of remote detection or monitoring, as was performed with lake outfalls or landfill leachate (Table 4), commonly leads to an action or benefit. Moreover, the remote sensing techniques are relatively easy to transfer.

Projects aimed at detecting or monitoring subsurface features may lead to an action and/or benefit; but, similar to subsurface inventories, the required techniques are normally difficult to transfer without extensive training (Table 4).

As recorded in Table 4, most of the Program's action- or benefit-producing projects have involved either detection/monitoring of surface features or inventories of subsurface features. Reiterating, techniques for accomplishing the former are rather easily transferred, while techniques for accomplishing the latter are not. It is interesting to note that the development and transference of techniques for inventorying and detecting subsurface features has been Cornell's primary thrust in airphoto/remote sensing research and instruction for thirty years. This could also be characterized as developing and transferring marketable techniques which are not easily replaced. One other point of interest is that, in most cases, the inherent value of multispectral data (image or digital form) has been found to be greater when applied in gathering surface information, while the inherent value of stereoscopic data has been found to be greater for gathering subsurface information (Table 4).

CONCLUSION

The NASA-sponsored Cornell Remote Sensing Program has become the recipient of numerous requests for consultation and cooperative action--from members of the university community as well as from representatives of various state, regional, county, town and private groups. As members of the Program staff extended their expertise beyond more traditional aerial photography, increasing use has been made of high-altitude, satellite and non-photographic data, in instruction, research and demonstration projects. Several of these demonstration projects, conducted under the NASA grant, have led, in turn, to grants for applied remote sensing research from other sources. The NASA-sponsored Program has thus been of benefit to New York State, Cornell University, the Program staff and students, the latter through improved instruction, research and employment opportunities.

AERIAL Applicator FARM, FOREST & FIRE

"TM Reg Pending"

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from the cockpit

As 1977 draws to an end, this magazine wants to salute the U.S. Department of Agriculture and particularly the various State University Cooperative Extension Services for the way in which they handled a rather complex agricultural calendar year. With drought in the West, floods in various areas of the East, unpatterned pest and insect infestations in many places, the USDA put out a mountain of good information for most sections, and for aerial applicators in general.

While the USDA has a variety of regulatory functions, they don't seem to throw the weight around as do most other Federal regulatory agencies, bureaus or commissions. For the most part, USDA personnel seem anxious to help rather than hinder, and in this day of semi-socialism that is a refreshing note.

J.B. Kendrick Jr., who is, among other titles, Director of the Agricultural Experiment Station and Cooperative Extension Service at the University of California at Berkeley, had some interesting things to say in this regard in a recent Editorial printed in California Agriculture magazine. He is constructive, particularly when it comes to Pest Management.

He says that "one way to increase the food and fiber supply significantly would be to reduce the losses caused by pests and diseases." He reports that in California 10 to 20 per cent of total food and fiber production is lost before harvest each year, while in some developing countries, estimated crop losses run as high as 75%. He is of the opinion that we are far from our goal of acceptable control, and that opinion, in this magazine's conjecture, leaves plenty of room for the aerial application industry to expand.

Mr. Kendrick opines that the increasing dependence on pesticides has the inherent drawback of relying on a single line of defense because it has "introduced problems of pest resistance, destruction of natural controls, outbreaks of secondary pests, reduction of pollinators and other beneficial species" and furthermore costs too much (an estimated 10 to 20 per cent of crop production.)

He advises that one promising approach is a system of crop production known as "Integrated Pest Management." This system is a "flexible multidimensional approach to control, using a range of biological, cultural and chemical techniques, as required, to hold pests below damaging economic levels . . ." As Mr. Kendrick puts it, ". . . no single arbitrary control method will suffice because of the remarkable adaptive powers of insects, weeds, plant pathogens and because of the many variables related to season, location, and cropping patterns and pests."

For Integrated Pest Management, "we must know the biology of the pest, its natural enemies, the host plant, and their interrelationships in the environment. We must be able to predict the pest's occurrence, its population levels, and the potential economic damage. We must know more about the influence on pests of various weather conditions and of cultural practices such as irrigation, cover-crop management and harvesting procedures."

Mr. Kendrick advises that the Integrated approach is currently being used on a limited scale against specific pests, but does not elucidate in his editorial. He does state the research programs in these areas must be expanded so that all techniques can be effectively mobilized.

All in all, his thoughts are certainly not regulatory for man, albeit they are for pests. This is the type of constructive thinking and helpful attitude we mentioned in the first two paragraphs of this article. We like Cooperative Extension Services and the USDA.

ON THE COVER: Prototype installation of the 600 h.p. Pratt & Whitney R-1340 on the new Grumman Ag-Cat B, long wing version of the famous G164A. Previously powered with the popular PEW R-985 450 h.p. and 525 Continental, this field approved conversion by Mid-Continent Aircraft Corporation, Hayti, Missouri for Wayne Smith of Lonoke, Arkansas has been named the S-MC "600" Special. Faster on less fuel, with unlimited performance, it carries a full load effortlessly. Interest is extremely high for conversions at engine change time.

AERIAL PHOTOGRAPHS PROVIDE EVALUATIONS

Since 1968, scientists have been collecting data at Canadago Lake in central New York State for what may prove to be a classic study of the revitalization of a eutrophic body of water. The lake is relatively small (6 km by 1.5 km, with depths to 13.4 m), and isolated from pollutants except for effluent from a sewage treatment plant at nearby Richfield Springs (pop. 1,600).

In January, 1973, a new tertiary sewage treatment plant for the village went into operation as a Federal and New York State demonstration project. It replaced a plant built in the late 1800s. The old plant, virtually inoperable in its final years, had been discharging almost raw sewage into the lake. This caused a high phosphorus enrichment in the lake with consequent growth of algae.

The new treatment plant has reduced the lake's phosphorus input by about 40 percent. With a definite discharge cutoff date, the lake provided an ideal site to study the before-and-after effects of the cleanup on both plant and fish life. It was theorized that a change in sewage treatment would cause a change in the lake's ecology, and this seems to be the case.

Although many components of the lake's ecosystem have been monitored since 1968, little emphasis had been placed on recording changes in aquatic vegetation accompanying the decrease in nutrient loading. The lake had been highly productive of algae, which reduced light penetration through water and apparently inhibited the growth of rooted plants.

The question was whether the lower nutrient level would reduce the algae population, thus encouraging the growth of higher forms of vegetation. Given that aerial photographs of the lake had been taken both before and after the treatment plant start-up, a project to develop evaluative techniques was undertaken in the Remote Sensing Program of the School of Civil and Environmental Engineering, Cornell University.

"Aerial photos have been used in the past to map weed beds," says Brian L. Markham who, with botanist Ann E. Russell, conducted the analysis under the direction of Dr. Warren R. Philipson and Prof. Ta Liang. "Our objective was to demonstrate that aquatic vegetation could be identified reliably from aerial photographs with little or no concurrent ground data. This was also part of a larger project, now under way, to assess what changes have taken place in the lake."

Markham's study was begun under the school's grant from the National Aeronautics and Space Administration, and continued under a grant from the United States Department of the Interior, Office of Water Research and Technology. Photographs were provided by Eastman Kodak Company, the U.S. Environmental Protection Agency, NASA, and the State University of New York College of Environmental Science and Forestry.

Aerial Photographs of the lake had been taken in 1968, 1969, 1973, and 1974. Fortunately, most of the photography had been done both with Kodak Aerochrome MS film 2448 (Estar base) and with Kodak Aerochrome infrared film 2443 (Estar base) to provide a comparison between normal color and infrared color images.

By studying the aerial images at a scale of 1:6,000 with a zoom stereoscope, Markham was able to compare weed beds and note changes over a six-year period. From these data, he developed three predictive classifications to be used in field studies during the summer of 1976. It was predicted that areas having vegetation throughout the six-year period and those in which vegetation had developed between 1968 and 1974 would have vegetation at the time of the field survey. Areas revealing no vegetation over the period were expected to still be barren. "We found excellent agreement between the predictions and the ground-truth study," Markham states.

The other part of the study was aimed at identifying major types of vegetation from the photographs. Viewing the photographs, Markham found that he could identify five types of floating or emergent vegetation through location, shape, color, and texture of the patch, and its height above the water surface. Working with the stereoscope, Markham examined plant heights as low as 0.5 meters.

Using prints of the 1974 photography for reference,

Markham and Russell identified and mapped the various stands of weeds during the summer's field study. Concurrently, new photography was flown in July and August, and later correlated with field identifications.

Overexposure of the film by about one-half stop aided water penetration. Markham reports that he also saw some stereo effect underwater. He could thus differentiate between low-lying bottom plants and those growing up from the bottom to near the surface.

The August, 1976, photographs also were analyzed densitometrically to determine whether spectral characterization would aid in identification of emergent and floating species. "We found that, for our purposes, densitometric analysis did not add to the information we could extract visually with a stereoscope," Markham comments. "We did not attempt to characterize the submersed species in this manner because of the complicating effects of the water. In general, the tones of the submersed vegetation seemed to vary more with the water depth than with the vegetative type."

Several conclusions were drawn from the project:

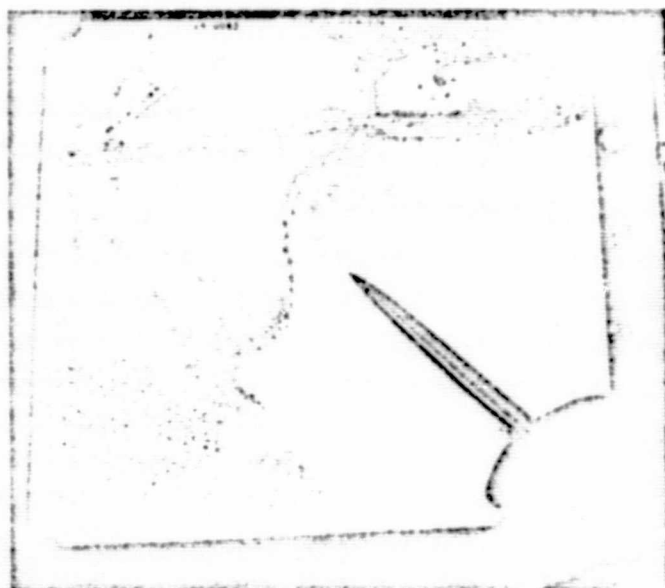
- It is possible to identify and differentiate species of floating and emergent vegetation from aerial photographs with little or no ground data. Given sufficient water transparency, submersed vegetation can be recognized and differentiated from other bottom features, such as rocks. However, the different submersed types were generally not separable in the aerial photography.

- Larger scale photography is preferable for detailed vegetation surveys. Generally, scales larger than 1:10,000 are recommended.

- Smaller format photography is adequate for species identification, but the coverage afforded by larger format photography is preferable for mapping. Film used for earlier photography was 9½ inches wide, while the 1976 photography was done with 70 mm film.

"We saw changes in the lake over the period of the study," Markham says, "and the major changes involved the submersed vegetation. The changes may have occurred because of the change in water transparency, but we don't know for certain. So, we have the effect but not the cause."

"What we have done is to develop a relatively simple, inexpensive way to assess changes of this sort through aerial photography," he concludes. "Historically, this is important. If past photography of a body of water exists, we can reach back in time and gauge years of change in the short time it takes to analyze the photos."



By studying and comparing aerial photographs such as this one, investigators can quickly identify changes in lake vegetation that have taken place over several years. With large-scale photos (1:6,000), it is possible to discriminate types of floating and emergent vegetation, and also to separate submersed weeds from such bottom features as rocks.

WINES & VINES

and Wine Merchant



MEMBER AUDIT BUREAU OF CIRCULATIONS

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COVER: Typical of late autumn is this illustration furnished courtesy of IDEALS magazine, published in Milwaukee and one of the most beautiful publications in the world. The photograph was used for their Thanksgiving issue in 1976.

CLOUT

It always is dangerous to ask a reader if he noticed what you did in last month's issue. Clearly he may suffer even more grievously than I from the problem of having a good memory but a short one.

Did you note the October cover? I hope so. It was the winning poster for the Third Annual Wine Festival staged by the Enological Society of the Northwest in Seattle. I bring this up because it illustrates the point I want to make: the country's growing interest in wine.

The Seattle group is for consumers, but it has winegrowers among its members, too. In Washington, Oregon, Idaho, Rhode Island, Kentucky, the Carolinas, Texas and many other states the involvement with wine is waxing. *Wines & Vines* is heartily in favor. Again calling upon your memory, you may recall that, in the 1977 Directory, wineries are listed in more than 60% of the U.S. Michigan, no stranger to wine these many years, had its first commercial wine judging at its State Fair in 1977. There were similar events in Missouri and Oregon. Evidence, I say, that the interest in wine is both catholic and widespread.

Getting back to the Northwest group, it not only has a highly professional wine judging (of Northwest wines); it has a year-long array of seminars and tastings, wine talks, wine tours and more—all this with no paid staff. The work is done by volunteers.

Last month, too, we had the first installment of Julius Jacobs' piece about the many consumer organizations with wine as the *raison d'être*. No other licensed beverage commands this kind of support. None ever will. If you are politically myopic you might say that such outside influences are of no value, that they only take away markets by encouraging wine growers in other states. That is precisely the reason they should be encouraged and assisted.

It is one thing to have California and New York plead their case before this tribunal or that, or this legislative body or that. How much stronger is the case if it is argued on more than 30 different fronts? By persons who are growing grapes, making wine, entering the market place, consuming wine. And demanding fair treatment. Where is the clout?

Does it lie in a few special pleaders? With bigness as their principal impact? Or in the combined influence of some dozen voices, large and small, raised for a fair deal on local, state and federal levels? Americans, for good reason or no, question bigness and embrace smallness. Our tariff and tax systems are tailored along those lines. The concept of the "bigs" helping the "smalls", however, has historic appeal in our democracy.

We are closer than ever before to universal U.S. support for wine.

We have only ourselves to blame if we blow it.

ORIGINAL PAGE IS
OF POOR QUALITY

Phillip Haring

Aerial photography: new planning tool

near Ovid, and vineyards were planted in both locations by Taylor in 1975 and 1976. The two sites were working farms prior to being selected as test sites, according to Harland Tyler, vineyard manager.

The Ovid site needed additional drainage prior to vineyard planting and the company wasn't certain of the effectiveness of drainage tile already in place. Tyler wanted to be certain of drainage before planting "because once the trellis and vines were in we would have to tear the vineyard apart to put in more tile."

At this juncture, the company was contacted by the Remote Sensing program at Cornell. Funded by NASA (National Aeronautics and Space Administration) this program explores uses of remote sensing techniques for solving environmental problems. Researchers under Dr. Ta Liang, professor of civil and environmental engineering at Cornell, offered assistance with drainage planning. Vineyard Manager Tyler's system in planning drainage has been to walk the fields after a rain to locate wet spots. The Remote Sensing Program manager, Dr. W. R. Philipson, said "we felt that aerial photography would provide better perspective and allow us to study the entire field simultaneously." It was the farmland at the Ovid test site which was to be analyzed.

Work began by tracing a base map of the Ovid site using a 1:24,000 scale U.S. Geolog-

ical Survey topographic map to show the two fields under investigation. This was enlarged by using a zoom transfer scope. All other work was prepared as transparent overlays to the base map. Using a 1972 soil survey of Seneca county, an overlay was prepared delineating the four soil types which underlie the site. This was used as a starting point although it wasn't specific enough to pinpoint needed areas for tile drainage.

To obtain greater accuracy the engineers in the Remote Sensing Program employed an aerial photo of the specific location, made during a 1968 New York land use and natural resources inventory. The photos were made on Kodak's Double-X Aerographic film 2405 (Estar base) by contractors who covered 49,000 square miles of the state at that time.

It became apparent at once that existing drainage tile could be identified in the fields because they appeared as straight (relatively), light colored lines. It also became apparent that "wet spots" could be identified where moisture collected and did not drain. These appeared as dark-colored objects in the fields.

Two overlays were prepared—one a map of existing drainage tiles. The reasoning was that the vineyard foreman would wish to connect into these as new drainage was installed. The other overlay was a map of the wet spots—and this was particularly helpful in the actual tile drainage installation. Any of the old clay tile that was found was connected into the main plastic lines, Woody Clark, one of the officials, explained, because if left alone, there was always a possibility it could become plugged and create its own wet spot in the future.

When rains began in the summer of 1975, the people in charge began roaming the fields and locating the actual wet spots. But tiling operations had started a month earlier because the aerial maps gave them something to start from. After the job was finished, a recheck showed that all shaded areas on the map had been covered with extensive tiling.

More than 38,000 feet of tile were installed in the two potential vineyard acreages, in contemplation of spring planting. The project director, Dr. Liang, feels that the Remote Sensing project for the Taylor company can well be applied to similar problems of other farmers. In the former instance the photography was already in existence—and the project in entirety took about a half day to complete. Dr. Liang says "this proves it is worthwhile to buy a couple of photographs, study them and use the data, because so little time is involved, it's a very efficient process."

NASA and the Cornell Remote Sensing project will make the Taylor Wine Company report available to anyone. The techniques can be applied by many commercial firms that offer photo-interpretation services. Courses are offered in this subject by many universities.

Thomas L. Erb, with the impressive title of image analyst/research engineer, says that it isn't possible to imagine all the uses for the aerial photos that already exist.

Julius Jacobs

AERIAL photography to monitor land drainage is being employed in New York State vineyards. Because of projections for increased wine usage and the need for more vineyards to keep up with demand, the Taylor Wine Company has sought "flatter sites where it will be easier to use heavy equipment."

Sometimes this is difficult to find because acreage is becoming more limited in the best New York State vineyard areas. Cornell University experts conducted temperature studies in conjunction with the state's Agricultural Extension Service. They came up with two land parcels on the east and west sides of Seneca Lake. One is near Dresden, the other

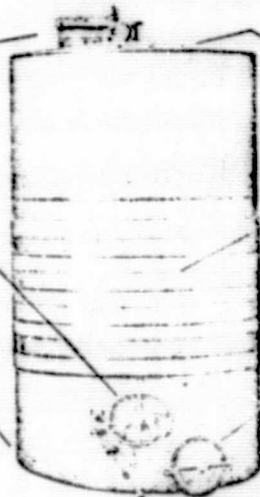
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CORNELL'S REMOTE SENSING PROGRAM:
REMOTE SENSING FOR THE USER

W.R. Philipson, T. Liang, T.L. Erb and B.L. Markham

Remote Sensing Program
Cornell University
Hollister Hall
Ithaca, New York 14853

Paper to be presented at the 44th Annual Meeting
of the American Society of Photogrammetry
26 Feb. - 4 March 1978, Washington, D.C.

**CORNELL'S REMOTE SENSING PROGRAM:
REMOTE SENSING FOR THE USER**

W.R. Philipson, T. Liang, T.L. Erb and B.L. Markham

**Remote Sensing Program
Cornell University
Hollister Hall
Ithaca, New York 14853**

BIOGRAPHICAL SKETCHES

Warren R. Philipson received his B.C.E., M.S. in Civil Engineering, and Ph.D. in Soil Science (Agronomy) from Cornell. Over the past 12 years, he has taught, conducted research and participated in remote sensing projects in various parts of the world. A senior research associate in Civil and Environmental Engineering, he co-directs the Remote Sensing Program.

Ta Liang received his B.E. from Tsing Hua University, China, and his M.C.E. and Ph.D. from Cornell. He has conducted research and taught courses in airphotos and physical environment evaluation at Cornell since 1957. In consulting and research, his international experience spans 40 years. A professor of Civil and Environmental Engineering, he is principal investigator of the Remote Sensing Program.

Thomas L. Erb received his B.S. in Civil and Environmental Engineering from Cornell, where he did graduate work in Aerial Photographic Studies and Remote Sensing. He has been associated with the Remote Sensing Program since its inception, in 1972. A research specialist in Civil and Environmental Engineering, he conducts remote sensing projects and lectures in airphoto interpretation.

Brian L. Markham received his B.S. in Natural Resources from Cornell, where he is completing an M.S. in Aerial Photographic Studies and Remote Sensing. He has been employed as a biological aide by the U.S. Fish and Wildlife Service, and as a graduate teaching assistant in airphoto interpretation at Cornell. He is currently a research specialist in Civil and Environmental Engineering.

ABSTRACT

Begun in 1972, Cornell's NASA-sponsored Remote Sensing Program has strengthened instruction and research in remote sensing, building upon Cornell's years of experience in aerial photographic studies; established communication links; and conducted demonstration projects for numerous town, county, state and private organizations in New York State. In compliance with NASA's guidelines, each project has been, in some way, unique; essentially noncompetitive with commercial firms; and aimed at producing tangible benefits or actions. These projects are outlined and characterized according to elements that have generally governed their impact: (1) whether the project seeks surface or subsurface information, and (2) whether the goal of the project is to inventory or to detect/monitor. The Cornell Program has shown that remote

sensing can provide useful information, even in a state where agencies have used remotely sensed data for years and where substantial quantities of detailed information are already available.

INTRODUCTION

On June 1, 1972, Cornell University's School of Civil and Environmental Engineering initiated a Program in Remote Sensing. Sponsored by a grant from the Office of University Affairs of the National Aeronautics and Space Administration (NASA Grant NGL 33-010-171), this Program was a consequence of some thirty years of pioneering work in aerial photographic studies and photogrammetric engineering. For Cornell, the grant has provided the means and opportunity to increase its overall competence in remote sensing. For NASA, the Cornell Program has provided a vehicle for demonstrating and promoting the application of aircraft and satellite remote sensing, particularly, in New York State. This discussion is a review and analysis of the Program's experiences through December 1977*.

GENERAL REVIEW

Briefly, the first year was devoted to strengthening instruction and developing the foundation for user-oriented research in remote sensing. A weekly seminar and monthly newsletter were instituted, university and non-university contacts were made, aircraft and satellite imageries were collected, and cooperative investigations, directed at New York and the northeastern United States, were begun. Program activities were expanded during the second and third years and, while several demonstration projects were completed, new projects of a more clearly defined, benefit-producing nature were undertaken. These and many other projects, and the Program as a whole, have come to fruition during the ensuing years.

COMMUNICATION AND INSTRUCTION

Contacts

Since 1972, staff and students supported by the Program have worked with representatives of many groups. These are summarized in Table 1, where the various groups have been categorized according to whether their representatives (1) cooperated in one or more projects, (2) were users of the results of a project in which they may or may not have participated, or (3) were involved in either preliminary discussions or discussions which have not as yet led to a specific project ("other").

In addition to hosting project-related visitors and invited seminar speakers, the Program staff has received numerous guests from within the United States and from many other countries. Occasionally, this was in conjunction with spe-

*Program activities have been described, in detail, in eleven Semi-Annual Status Reports, submitted to NASA and available from NTIS, 5285 Port Royal Rd., Springfield, Va. 22161.

ial remote sensing orientation sessions or workshops. Over the past few years, for example, special lectures were held for groups ranging from New York State highway superintendents to participants in AID-sponsored Institutes on Policies for Science and Technology in Developing Nations.

The Program's "Cornell Remote Sensing Newsletter" also provides a communication link to and beyond the Cornell community. The monthly Newsletter, which highlights remote sensing activities at Cornell while reporting items of general interest, is now received by more than 400 individuals and groups in some 30 states and 14 foreign countries.

Courses

With NASA support, the Program staff has continued to upgrade Cornell's longstanding curriculum in Aerial Photographic Studies. The Program's weekly Seminar in Remote Sensing has brought experts from government, industry and other institutions to Cornell to discuss remote sensing research, developments and applications with students, staff and faculty (Table 2). A three credit-hour course, "Remote Sensing," was also developed as part of the regular curriculum of the School of Civil and Environmental Engineering. And, overall, greater emphasis is being placed on non-photographic sensors and sensing techniques, as well as on the handling, analysis and interpretation of various sensor data outputs.

Data and Facilities

Remote sensing research and instruction have been enhanced through acquisition of a wide range of aircraft- and satellite-derived data, and through expanded capabilities for their analysis. The Program's data, facilities and equipment are made available at no cost to cooperators, students and other interested users.

With assistance from the NASA Office of University Affairs, the Program has received Landsat, Skylab, high-altitude and low-altitude coverage of sites in the Northeast. The U.S. Environmental Protection Agency has also overflowed Program-selected sites, and imageries have been obtained from various other government and private sources. These data complement the Program's file of more than 600,000 older, worldwide aerial photographs.

With NASA funding, the Program has acquired selected photographic and darkroom equipment, a versatile zoom stereoscope, an additive-color viewer, and a series of routines for analyzing multispectral digital data on Cornell's IBM 370/168 computer. These supplement image analysis equipment obtained in previous years with other funding (i.e., zoom and non-zoom stereoscopes, Zoom Transfer Scope, stereoplotters and other photogrammetric instrumentation).

PROJECTS

As stated, numerous remote sensing demonstration projects have been conducted by, or in conjunction with, Program staff (Ta-

ble 3). In compliance with NASA's guidelines, the initiation of each followed screening to ensure that the project was, in some way, unique; that undertaking the project would not be competing unduly with private companies or consultants; and that, if completed successfully, the project would produce tangible benefits or actions by definable users. Relatively little emphasis was placed on technology transfer, per se.

Finding projects that conformed with these criteria has been difficult; especially, since the focus of the Cornell Program is New York State. The earliest project solicitations were aimed at state agencies. Although Program staff encountered little or no resistance against new techniques, it did encounter major problems in developing action- or benefit-producing projects. Most state agencies are not "action" agencies. Further, most state agencies normally require much time and data before taking any action, including a "planning action." Although totally justified, this makes it difficult, if possible, to trace remote sensing or other input to a final action or benefit. With regard to New York State planning activities, moreover, much of the state-wide planning data that could be derived effectively through remote sensing had already been derived or were being derived by other groups.

Just prior to the Program's inception, for example, Cornell University had completed the state-wide Land Use and Natural Resources Inventory (LUNR), in which more than one hundred types of area or point land use were identified from aerial photographs, transferred to 1:24,000 scale map overlays, and entered into a computer file/weighted retrieval system. In addition, another Cornell investigator, Dr. Ernest E. Hardy, was comparing satellite with LUNR data in NASA-sponsored, Landsat and Skylab experiments; and William Harting, of the Tri-State Regional Planning Commission, was conducting a NASA-sponsored experiment to assess the value of Landsat data for planning in the New York City area.

As a second example, where university programs in other states might have attempted to demonstrate geologic applications of satellite and aircraft remote sensing to their state geological survey, the soils and geology of New York State have been mapped and studied in some detail, and Dr. Yngvar W. Isachsen, of the State Geological Survey, was already conducting Landsat and high-altitude aircraft investigations with direct support from NASA.

As a third example, where wetlands have been the subject of remote sensing studies across the country, in New York, a state agency was conducting the "official," state-wide wetlands inventory, using 1:24,000 scale aerial photographs. This agency, like others in the state, has years of experience in applying aerial photography.

Many examples could be cited; examples which show why, during the second and third years of operation, the primary focus of project solicitations shifted from state agencies to county, town and private users. Although much of value can be accomplished with remote sensing at the county and town levels, the applicability of aircraft data is increased and that of

satellite data is decreased--at least when the satellite data are of a resolution comparable to that of Landsat. This can be surmised from the list of projects which have generated the most substantive benefits or actions by county, town or private users (Table 3A). All have relied on aircraft data as the sole or primary source of information.

Even those demonstration projects that were conducted for state agencies tended to attack localized problems which were generally not amenable to solution or analysis with satellite data. These projects are listed in Table 3B.

The Program's reliance on aircraft data should not be interpreted as implying that satellite data were not consulted on many occasions, for many projects. Satellite data did, in fact, supply a basic source of information for several studies, particularly, when recent, periodic or synoptic coverage was desired. Studies of this nature are outlined in Table 3C.

PROJECT ANALYSIS

In general, the Program staff has found that a project's impact can often be forecast by whether the project seeks surface (directly observable) or subsurface (indirectly observable) information, and whether the goal of the project is to perform a complete, area-wide inventory or to detect and/or monitor some specific items (Table 4).

Although exceptions can be cited, a project which inventories surface or directly observable features may lead to the user adopting the inventory technique, but it will seldom generate any other action or benefit (Table 4). Surface information can normally be gotten without remote sensing (less efficiently) and, by itself, governs few decisions or actions (wetlands being a notable exception).

In contrast, a remote sensing project which calls for an inventory of subsurface or indirectly observable features will often lead to an action or benefit (Table 4). Information such as depth of soil over bedrock is difficult or costly to obtain in other ways. When required, it often governs the final decision or action. Because techniques for inventorying subsurface features rely heavily on interpretation, they are more difficult to transfer.

The distinction between inventorying and detecting or monitoring is sometimes vague, yet a project which involves the detection or monitor of surface (directly observable) features often produces the greatest possible impact. A successful demonstration of remote detection or monitoring, as was performed with lake outfalls or landfill leachate (Table 4), commonly leads to an action or benefit. Moreover, the remote sensing techniques are relatively easy to transfer.

Projects aimed at detecting or monitoring subsurface features may lead to an action and/or benefit; but, similar to subsurface inventories, the required techniques are normally difficult to transfer without extensive training (Table 4).

As recorded in Table 4, most of the Program's action- or benefit-producing projects have involved either detection/monitoring of surface features or inventories of subsurface features. Reiterating, techniques for accomplishing the former are rather easily transferred, while techniques for accomplishing the latter are not. It is interesting to note that the development and transference of techniques for inventorying and detecting subsurface features has been Cornell's primary thrust in airphoto/remote sensing research and instruction for thirty years. This could also be characterized as developing and transferring marketable techniques which are not easily replaced. One other point of interest is that, in most cases, the inherent value of multispectral data (image or digital form) has been found to be greater when applied in gathering surface information, while the inherent value of stereoscopic data has been found to be greater for gathering subsurface information (Table 4).

CONCLUSION

The NASA-sponsored Cornell Remote Sensing Program has become the recipient of numerous requests for consultation and cooperative action--from members of the university community as well as from representatives of various state, regional, county, town and private groups. As members of the Program staff extended their expertise beyond more traditional aerial photography, increasing use has been made of high-altitude, satellite and non-photographic data, in instruction, research and demonstration projects. Several of these demonstration projects, conducted under the NASA grant, have led, in turn, to grants for applied remote sensing research from other sources. The NASA-sponsored Program has thus been of benefit to New York State, Cornell University, the Program staff and students, the latter through improved instruction, research and employment opportunities.

Table 1. Project-related contacts of Cornell Remote Sensing Program, June 1972 - Dec. 1977

TYPE OF ORGANIZATION	NUMBER OF ORGANIZATIONS			
	TOTAL	AS COOPERATORS	AS USERS	OTHER
Federal	6	4	2	2
State	16	9	9	4
Regional	5	1	0	5
County	23	11	11	11
Town/Local	5	1	4	1
Private	12	8	7	3

Table 2. Affiliations of Cornell remote sensing seminar speakers, Sept. 1972 - Dec. 1977

TYPE OF ORGANIZATION	NUMBER OF ORGANIZATIONS	
	U.S.	CANADIAN
Federal	22*	5
State & Public	9	0
Private	25	1
Educational	9	1

*Different divisions of same organization (e.g., NOAA/NESS and NOAA/NOS) are counted separately.

Table 3. Benefit- or action-producing demonstration projects conducted by Cornell Remote Sensing Program, June 1972 - December 1977

3A. County and town-level projects

- (1) An inventory of sources of highway construction material was performed for two counties; field testing and site or material acquisition by the counties will continue for many years.
- (2) The best sites for disposing of solid wastes from two municipalities were selected for a county planning department; one recommended site was tested by county and state officials, and negotiations for the site were initiated with the landowner.
- (3) The drainage requirements of a new, 70-hectare vineyard site were evaluated for a major wine company; the submitted information was used in installing over 11,000 meters of artificial (tile) drainage.
- (4) The physical limitations for septic tanks in one town were determined for a county planning department; the data are being used in town zoning and related planning.
- (5) Historical sites along a 6-km gully were identified for a county museum; the data reinforced the need for ongoing efforts to preserve the area as "forever natural."
- (6) The crop status in several vineyards was assessed for a major wine company; fertilizer and other management levels will be adjusted to correct deficiencies, and remote monitoring will be considered for operational status.
- (7) The unique natural resources of a county were identified for inclusion in the county's environmental plan; the county report was published, and the data provide an information base for county and town planning.
- (8) Assistance was provided in evaluating potential park sites in a town; the evaluation led to the rejection of several proposed sites and the retention of several others, subject to correction of the identified limitations.
- (9) The reference base maps of a county and one town in the county were updated using high altitude aerial photographs; the revised maps will be used for planning and town zoning, and county personnel will use the technique to update the other town base maps.

3B. Projects conducted for state agencies

- (10) A comprehensive survey of outfalls to a lake; all outfalls were field checked by a state official and the required actions were taken.
- (11) Selected landfills were monitored for leachate contamination; the sites were checked by state officials, and the monitoring strategy will be published in a U.S. Environmental Protection Agency manual.

Table 3, continued

- (12) An unused, 240-hectare parkland was analyzed for potential development; state planning for park development will be based on the submitted information.
- (13) A physical evaluation of proposed fly ash disposal sites; the site analyses were provided to the power company by the state through formal, public hearings.
- (14) State park analysis for rehabilitation and development; the submitted information is providing the basis for improvements to the largest park in the state park system.

3C. Projects which relied on satellite data

- (15) Mapping of interconnected waterways in a large region; the submitted information was used by the region's planning commission in formulating a recreational program, which was submitted to the state legislature.
- (16) A county-wide analysis of linears for ground water potential; where needed and as is economically feasible, the submitted information will form the basis for follow-up ground study, in addition to being input to long range planning decisions.
- (17) Development of a strategy for state-wide inventory of dams; the strategy, which incorporates aircraft and satellite data, is being evaluated and refined with state officials.
- (18) An assessment of land cover types for pheasant range management; this ongoing project, which covers a major portion of the state, is being developed with a state agency.

Table 4. Characterization of demonstration projects of Cornell Remote Sensing Program

TYPE OF PROJECT	INFORMATION SOUGHT	
	SURFACE (directly observable features)	SUBSURFACE (indirectly observable features)
INVENTORY*	Important information but, by itself, seldom leads to any action or benefit other than the adoption of techniques; Projects 9, 15, (16), (17) and 18**	Important information which, when required, often leads to an action or benefit; Projects 1, 2, 3, 4, 7, 8, 12, 13 and 14
DETECTION/ MONITORING	Often leads to an action and/or benefit; Projects 6, 10, 11, (16) and (17)	May lead to an action and/or benefit; Project 5
COMMENTS	Relatively easy to transfer remote sensing techniques/methods; multispectral data, in image or digital form, often of special value	Relatively difficult to transfer remote sensing techniques/methods without concentrated training; stereoscopic data often of special value

*"Inventory," "Detection" and "Monitoring" include required processes of analysis and interpretation.

**Numbers refer to projects listed in Table 3. Parentheses indicate that project had elements of inventory and detection/monitoring.

APPENDIX G
RECENT SEMINARS/ORIENTATION SESSIONS

SEMINAR IN REMOTE SENSING

LIST OF SEMINARS

Spring Term 1978

<u>Date</u>	<u>Speaker</u>	<u>Topic</u>
Feb 1	Dr. Murray Felsher Chief, Geological and Energy Applications National Aeronautics and Space Administration Washington, D.C.	Present Programs in Applica- tions of Remote Sensing from Space
Feb 8	John R. Schott Research Physicist Calspan Corporation Buffalo, New York	Remote Sensing Applications to Studies of Terrestrial Eco- Systems
Feb 15	William L. Smith Geologist, Remote Sensing Spectral Data Corporation Arlington, Virginia	Multispectral Remote Sensing Applications in Developing Countries
Feb 22	Grover B. Torbert Remote Sensing Manager Bureau of Land Management U.S. Dept. of the Interior Washington, D.C.	Landsat Derived Data and Its Place in BLM's Information Systems Management
Mar 8	Herbert Kaplan National Sales Manager Barnes Engineering Company Stamford, Connecticut	Thermal Scanning for Energy Conservation
Mar 15	E. Larry Heacock Director, Office of Systems Integration National Oceanic and Atmos- pheric Administration Washington, D.C.	Meteorological Sensors and Related Technology for the Eighties
Mar 29	Dr. Raymond T. Lowry Scientist, Intera Environ- mental Consultants, Ltd. Calgary, Alberta, Canada	Applications of Side-Looking Radar Imagery
Apr 5	Dr. Anthony R. Barringer Barringer Research, Inc. Golden, Colorado	Airborne Geochemical Explor- ation

<u>Date</u>	<u>Speaker</u>	<u>Topic</u>
Apr 12	Dr. David G. Goodenough Head, Methodology Section Canada Centre for Remote Sensing Ottawa, Ontario, Canada	Pattern Recognition and Image Analysis at CCRS
Apr 19	(Color/sound films)	"The World of Invisible Color" and "You and M-DAS"
Apr 26	Dr. Alan S. Barrett Applications Specialist Optronics International Chelmsford, Massachusetts	Digital Image Analysis
May 3	Donald J. Belcher Professor Emeritus, School of Civil & Environmental Engineering Cornell University	Pattern Interpretation: Geology, Engineering, and Tropical Soils



Cornell University

REMOTE SENSING PROGRAM
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ORIENTATION SESSIONS ON REMOTE SENSING
FOR PARTICIPANTS OF SOIL SCIENCE INSTITUTE
by staff of Remote Sensing Program

TENTATIVE SCHEDULE (Hollister Hall, Rm. 462)

Friday, 10 February 1978

- | | | |
|-----------|---|------------------|
| 2:00-2:40 | Slide show/lecture, introduction to remote sensing | (W.R. Philipson) |
| 2:40-2:50 | Break | |
| 2:50-3:30 | Slide show/lecture, general (non-soil) applications of remote sensing | (B.L. Markham) |
| 3:30-4:00 | Examine data products and image analysis equipment | (Staff) |

Monday, 13 February 1978

- | | | |
|-----------|--|------------------|
| 2:00-2:55 | Slide show/lecture, landform analysis with stereoscopic aerial photographs | (T.L. Erb) |
| 2:55-3:05 | Break | |
| 3:05-3:30 | Slide show/lecture, remote sensing applied to soil-related studies | (W.R. Philipson) |
| 3:30-4:00 | Examine examples of landforms and various data products | (Staff) |



Cornell University

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13 Feb 1978/wrp
soil science
institute

SELECTED NOTES ON REMOTE SENSING FOR SOIL INFORMATION

-primary value in surveys/analyses of engineering soils (unconsolidated materials); site & route studies; including surveys for construction materials, analysis of landslide susceptibility, assessment of depth of soil over bedrock and depth to ground water.

-valuable source of information for pedological soil survey, especially for medium and low intensity surveys (higher soil mapping orders).

-compare:

<u>soil-forming factors</u> (past conditions)	with black & white <u>panchromatic photos</u> (present conditions)
relief/topography	relief/topography
vegetation/organisms	land cover/use
climate	drainage patterns
time	erosion/gullies
parent material	tone (black to white)

-other types of remotely sensed data:

- . color photos: blue, green and red imaged separately
- . black & white infrared photos: green, red and near-infrared imaged together
- . color infrared photos: green, red and near-infrared imaged separately
- . other reflected spectral data: any spectral band(s) on tape or image
- . thermal infrared: apparent temperatures, emissivities
- . passive microwave: apparent temperatures, emissivities, dielectric properties
- . radar: surfaces, dielectric properties

...additional information regarding soils, particularly for soil survey, is rather limited.

-platforms:

data derived from high-altitude aircraft and satellite normally provide a synoptic view; wider perspective often allows greater insight into geomorphic processes; valuable as base maps; may sacrifice stereoscopic information.

-conclusions:

much soils information can be gotten through analysis of remotely sensed data; most of this information can be gotten through stereoscopic analysis of panchromatic photos; small scale imagery may be useful for soil analysis and mapping.

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APPENDIX I
RECENT NEWSLETTERS

The Newsletter, a monthly report of articles and events in remote sensing, is sent to members of the Cornell community who have an interest in sensors and their applications.

Remote Sensing Seminars--Spring '78

The Seminar in Remote Sensing (CEE A696) is a one credit-hour course of the School of Civil and Environmental Engineering. Seminars are held on Wednesdays, at 4:30 p.m., in 162 Hollister Hall. Each week a different topic on remote sensing research, developments or applications is presented by a guest speaker from industry, government, Cornell or another institution.

Most of the spring semester seminars have been scheduled. The speakers include: William E. Stoney, National Aeronautics and Space Administration (future earth resources satellites); John R. Schott, Calspan Corp. (applications of photographic sensing); Edward F. Yost, Jr., Long Island University and Spectral Data Corp. (multispectral photography); Grover B. Torbert, Bureau of Land Management (BLM's use of satellite data); Herbert Kaplan, Barnes Engineering Co. (applications of thermal sensors); E. Larry Heacock, NOAA/National Environmental Satellite Service (meteorological satellite sensors); Raymond Lowry, Canada Centre for Remote Sensing (applications of side-looking radar); A.R. Barringer, Barringer Research Ltd. (airborne geochemical exploration); John B. McKeon, Bendix Aerospace Systems Div. (applications of satellite data); and David G. Goodenough, Canada Centre for Remote Sensing (digital image analysis). The first, spring semester seminar, an organizational meeting and introduction to remote sensing, will be held on 25 January. Students, faculty and other interested individuals should consult the monthly Newsletter and weekly seminar announcements for detailed information.

LATE CALL FOR PAPERS

Commission IV of the International Society for Photogrammetry will sponsor a Symposium on New Technology for Mapping, to be held in Ottawa, 2-6 Oct. 1978. Those wishing to present a paper should submit their name, address and position, a titled abstract, and the estimated time for presentation, to: J.H. O'Donnell, Topographical Survey, 615 Booth St., Ottawa, Ontario K1A 0E9, Canada. Proposals are due 1 Jan. 1978.

CALL FOR PAPERS

The 5th Canadian Symposium on Remote Sensing will be held in Victoria, British Columbia, 28 to 31 Aug. 1978. Sponsored by the Canadian Remote Sensing Society of the Canadian Aeronautics and Space Institute, the symposium will also include the Aerospace Electronics Symposium. Proposals for papers on all facets of remote sensing and aerospace electronics should be submitted to Dr. Y. Jim Lee, c/o Pacific Forest Research Centre, 506 West Burnside Rd., Victoria, B.C., V8Z 1M5 Canada (phone 604-388-3811; telex 049-7147). The proposals, in English or French, should include a titled summary of less than 200 words and the author's name, affiliation, address, phone and telex. Proposals must be received by 15 Apr. 1978.

NEWFOUNDLAND RECEIVING STATION

The December Newsletter list of non-U.S., Ground Receiving Stations did not include the newly operating station in Newfoundland. This station can receive images over most of the eastern portion of North America, Greenland, Iceland and from as far away as Ireland. For information regarding the availability of Landsat and/or NOAA 4 or 5 data, write: Shoe Cove Satellite Receiving Station, P.O. Box 160, Pouch Cove, Newfoundland A0A 3L0 Canada.

TOKYO SYMPOSIUM

A Symposium on Data Acquisition and Improvement of Image Quality and Image Geometry will be held in Tokyo, 29-31 May 1978. For information regarding the symposium, which is sponsored by Commission I of the International Society for Photogrammetry, contact: Dr. Shunji Murai, c/o Japan Society of Photogrammetry, Rm. 601, Daiichi Honan Bldg., 2-8-17 Minami Ikebukuro, Toshimaku, Tokyo, Japan.

SHORT COURSES

6th Alberta Remote Sensing Course (designed to instruct multidisciplinary users in the practical application, acquisition and analysis of Landsat and aircraft data); 27 Feb-3 March; at Univ. of Alberta, Edmonton, Alberta, Canada; Contact: Cal D. Bricker, Alberta Remote Sensing Center, 11th Floor, Oxbridge Place, 9820 - 106 St., Edmonton, Alberta, Canada T5K 2J6 (phone 403-427-2381).

Advanced Topics in the Analysis of Remote Sensing Data (advanced techniques in numerical analysis of remote sensing data); 10-14 April; \$495 fee; Contact: Continuing Education Business Office, Rm. 110, Stewart Center, Purdue Univ., West Lafayette, Indiana 47907.

SELECTED ARTICLES AND PUBLICATIONS

- Canadian Jour. of Remote Sensing. Dec. 1977. (Contains half of the papers given at Remote Sensing Science & Technology Sympos., in Ottawa, Feb. 1977). Canadian Aeronautics & Space Institute, Saxe Bldg. 60 - 75 Sparks St., Ottawa K1P 5A5 Canada. (\$5.00).
- Gausman, H.W. et al. 1977. Field-measured spectroradiometric reflectances of disked and non-disked soil with and without wheat straw. Soil Sci. Soc. Amer. Jour. 41:4:793-796.
- Haralick, R.M. & P. Currier. 1977. Image Discrimination Enhancement Combination Systems (IDECS). Computer Graphics and Image Processing 6:4:371-381.
- Mapping with Remote Sensing. Proc. of 2nd Annual William T. Pecora Memorial Sympos. 30 papers, 404 pp. Amer. Soc. of Photogrammetry, 105 N. Virginia Ave., Falls Church, VA 22046 (ASP members \$5/others \$10).
- O'Shea, D.C. 1977. Lensless real-image camera. Applied Optics 16:10:2706-2707.
- IEEE Transac. Geoscience Electronics 1977. v. GE-15, n.4 (Oct)
- Ulaby et al. Experiments on the radar backscatter of snow.
 - Flock, W.R. Monitoring open water and sea ice in the Bering Strait by radar.
- Photogrammetric Eng'g & Remote Sensing 1977. v.43, n.9 (Sept)
- Leachtenauer, J.C. Optical power spectrum analysis: Scale and resolution effects.
 - Cox, T.L. Integration of land-use data and soil survey data.
 - van Genderen & Lock. Testing land-use map accuracy.
 - Colvocoresses, A.P. Proposed parameters for an operational Landsat.
 - Ballew & Lyon. The display of Landsat data at large scales by matrix printer.
 - Williamson, A.N. Corrected Landsat images using a small computer.
 - Andrews, H.C. An educational digital image processing facility.
 - Kenefick, J.F. Applications of photogrammetry in shipbuilding.
 - Brumm & Waters. Photodensity control system for orthophoto products.
 - Gausman et al. Relation of Peperomia obtusifolia's anomalous leaf reflectance to its leaf anatomy.

The Newsletter is made possible by a grant from the NASA Office of University Affairs. Comments or correspondence should be directed to Dr. Warren R. Philipson, Remote Sensing Program, Cornell University, 464 Hollister Hall, Ithaca, New York 14853 (tel. 607-256-4330).

The Newsletter, a monthly report of articles and events in remote sensing, is sent to members of the Cornell community who have an interest in sensors and their applications.

THE FUTURE OF REMOTE SENSING - THE PRACTITIONER'S CHOICE

by

John E. Walker

Mr. Walker, Remote Sensing Section Head at Calspan Corporation, Buffalo, N.Y., is a Cornell Civil Engineering graduate with over 20 years experience in remote sensing. The views expressed here are those of Mr. Walker and do not necessarily reflect the views or policy of the Cornell Remote Sensing Program.

Today, many highly significant technical advancements in the state-of-the-art of remote sensing can be cited; however, its future remains in doubt. The many decades of research, development and applications have witnessed a mountainous list of remote sensing limitations compared to operational uses of remote sensing that solve natural resource problems. One parameter of remote sensing has remained essentially unchanged; namely, the basic art of information extraction by direct observation and judgement. It must be realized that classic photo interpretation is and always will be a major factor in extracting information from remotely sensed data. The key to a bright future for remote sensing appears to be in expanding the capabilities of classic photo interpretation by supplementing direct observation and judgement with quantitative data available from the imagery whenever possible.

There are only three major uncontrollable parameters in any passive remote sensing system, i.e., the atmosphere, the illumination and the subjective judgement process. Developing advanced technology to compensate for the effects of these three factors on information extraction should result in a significant step toward reaching the desired objective. (continued, page 2).

SHORT/SPECIAL COURSES

- Remote Sensing and Digital Information Extraction; 6-10 March; \$495 fee; coordinators, R. Bernstein & F. Billingsley; Contact: Continuing Eng'g Education, George Washington Univ., Washington, D.C. 20052.
- Visiting Scientist Program in Remote Sensing (individualized study at Laboratory for Applications of Remote Sensing, Purdue Univ.); duration and costs, variable; Contact: D.B. Morrison, LARS, Purdue Univ., West Lafayette, Indiana 47907 (tel. 317-749-2052).
- Remote Sensing Technology and Applications; 5-day course, offered monthly; \$425 fee; Contact: D.B. Morrison (see above).

SEMINAR IN REMOTE SENSING

The Seminar in Remote Sensing is held on Wednesdays, at 4:30 p.m., in 162 Hollister Hall. Anyone is welcome to attend. Seminars scheduled for February are as follows:

- | | |
|-----------------|---|
| Wed.,
1 Feb | • Present Programs in Applications of Remote Sensing from Space: Dr. Murray Felsher, National Aeronautics and Space Administration, Washington, D.C. |
| Wed.,
8 Feb | • Remote Sensing Applications to Studies of Terrestrial Ecosystems: John R. Schott, Calspan Corp., Buffalo, N.Y. |
| Wed.,
15 Feb | • Multispectral Photographic Remote Sensing Techniques and Applications: Prof. Edward Yost, Long Island University, Greenvale, N.Y., and Spectral Data Corp., Hauppauge, N.Y. |
| Wed.,
22 Feb | • Landsat-Derived Data and Its Place in BLM's Information Systems Management: Grover B. Torbert, Bureau of Land Management, U.S. Department of the Interior, Washington, D.C. |

The Practitioner's Choice (continued)

The atmosphere and illumination affect the photometric property of a remotely sensed image, not its shape, pattern or other spatial properties. Because these factors are uncontrollable, for cost-effective analyses, their effects must be measured--preferably from the images in the data under analysis--and removed from measurements of images of interest. When done properly, the photo interpreter can be provided with new and important clues to extend his capability to extract information, i.e., the true reflectance(s) of the object surface(s). His interpretation of tonal or color differences between images (vegetation stress, turbidity, moisture, etc.) is then quantifiable and unaffected by differences in the atmosphere and illumination from one frame or time to another. With this quantitative basis, the new spatial information displays that can be generated from the original material by a variety of analog and digital means assume greater meaning. Last, but not least, multispectral signatures (algorithms) can be developed that are free of temporal atmospheric and illumination effects so that change-detection methods can be employed successfully.

It should be reemphasized that advanced techniques must supplement, not replace, classic techniques that have become quasi-standards. The foundation for these supplementary, quantitative advanced techniques has been laid over the past two decades and the sub-flooring put in place in the past five years. Information extraction methods have been developed to measure and remove atmospheric and illumination effects from the total energy recorded by sensors. Hopefully, the practitioners of remote sensing and machine data processing will take the time and exert the effort necessary to appreciate fully the truly basic problems of remote sensing to assure its bright future.

SELECTED ARTICLES

- Aviation Week & Space Technology. 1977. Special Report: Satellite technology serving earth. 107:16 (Oct. 17).
- Ben-Asher, J. 1977. Determination of terrestrial albedo from Landsat-1 satellite imagery in photographic form. Soil Science Soc. Amer. Jour. 41:5:835-838.
- Mancuso, T.L. and G.R. Derman. 1977. AVIS takes the Interpretoscope to court. Jena Review 4:205-206.
- Rohde, W.G., J.K. Lo, and R.A. Pohl. 1977. EROS Data Center Landsat digital enhancement techniques and imagery availability, 1977. EROS Data Center, Sioux Falls, So. Dak. 57198.
- ITC Journal. 1977. n.3.
- Gardner & Miller. A comparative study of the amount and types of geologic information received from visually interpreted U-2 and Landsat imagery.
- Makarovic, B. Composite sampling for digital terrain models.
- Donker & Malder. Analysis of MSS digital imagery with the aid of principal component transform.
- Gibson, R. The European Space Agency and remote sensing by satellite.
- Verboom, W. Lines of weakness in the forests, and early human settlements.
- Romijn, M.A. Primer for the production of Landsat colour-composites. Photogrammetria 1977. v.33, n.5 (Oct.)
- Rosenbruch, K. Considerations regarding image geometry and image quality.
- Gliatti, E. Modulation transfer analysis of aerial imagery.

The Newsletter is made possible by a grant from the NASA Office of University Affairs. Comments or correspondence should be directed to Dr. Warren R. Philipson, Remote Sensing Program, Cornell University, 464 Hollister Hall, Ithaca, New York 14853 (tel. 607-256-4330).

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UPDATE ON EARTH RESOURCES SATELLITES

(B.L. Markham)

As of 6 January 1978, Landsat-1 was no longer operational. Orbit degradation had led to overheating and resultant failure of the command and ranging subsystem. Landsat-2, however, is still operational, and Landsat-C is scheduled for launch on 5 March 1978. One week after Landsat-C is launched, its two return beam vidicon cameras (40m ground resolution) and its data collection system (DCS) should become operational, along with four bands of its multispectral scanner (MSS). Two to three weeks after launch, the fifth MSS band (thermal with 240m ground resolution) should also commence routine operation. Landsat-2 will be shut down for four days during and following the launch of Landsat-C, and its DCS will not be reactivated. By design, the respective orbits of Landsat-2 and Landsat-C should provide repetitive coverage of nearly the entire earth every nine days.

The Heat Capacity Mapping Mission Satellite is scheduled for launch in April 1978. This satellite will carry a dual-channel radiometer, operating in the near-infrared (0.8-1.1 μm) and thermal infrared (10.5-12.5 μm) spectral regions, providing day and night coverage with a ground resolution of 0.5 km. The HCMM data will be used primarily for studying thermal inertia and related earth properties. Potential applications include determination of soil moisture, surficial geology and thermal properties of water bodies.

Seasat-A, the first satellite designed specifically for monitoring oceanographic phenomena--waves, surface winds, temperatures, ice, coastal processes--is scheduled for launch in May 1978. The payload includes three active and two passive sensors. (continued, page 2).

MEETINGS AND SYMPOSIA

- Amer. Congress on Surveying & Mapping - Amer. Soc. Photogrammetry Convention; 26 Feb-4 Mar; Washington, D.C.; Contact: Ron Brewer, Publicity Chairman, 9206 Fairhaven Ave., Upper Marlboro, Md. 20870.
 7th Annual Remote Sensing of Earth Resources Conference; 27-29 March; Univ. of Tennessee; Contact: Dr. F. Shahrokhi, Univ. of Tennessee Space Institute, Tullahoma, Tenn. 37388.
 12th Int'l Sympos. on Remote Sensing of Environment; 20-26 April; Manila, Philippines; Contact: Environ. Research Inst. of Michigan, P.O. Box 8618, Ann Arbor, Mich. 48107 (tel. 313-994-1200, ext. 292)

SEMINAR IN REMOTE SENSING

The Seminar in Remote Sensing is held on Wednesdays, at 4:30 p.m., in 110 Hollister Hall. Anyone is welcome to attend. Seminars scheduled for March are, as follows:

- Wed., 1 Mar (No Seminar--Amer. Soc. Photogrammetry Convention)
 Wed., 8 Mar Thermal Scanning for Energy Conservation: Herbert Kaplan, Barnes Engineering Co., Stamford, Conn.
 Wed., 15 Mar Meteorological Sensors and Related Technology for the Eighties: E. Larry Heacock, National Environmental Satellite Service, NOAA, Washington, D.C.
 Wed., 22 Mar. (No Seminar--Spring Vacation)
 Wed., 29 Mar [Topic: Application of Side-Looking Radar Imagery]: Raymond T. Lowry, Canada Centre for Remote Sensing, Ottawa, Canada.

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Satellites (continued)

The active sensors on Seasat-A are an imaging synthetic aperture radar (SAR), which is an L-band radar with a 100km swath width and a 25m resolution; an altimeter, which uses a 13.5 GHz (K-band) compressed pulse radar; and a scatterometer, which is a 14.6 GHz (Ku-band) radar with a 50km resolution. The passive sensors are a scanning multifrequency microwave radiometer (SMMR), which has five channels (6.6, 10.7, 18.0, 21.0 and 37.0 GHz) with ground resolutions of 20 to 100 km; and a visible/infrared scanning radiometer (VIR), which is a slightly modified version of the SR radiometer flown on the ITOS satellites--ground resolutions of 3km and 5km in the visual (0.52-0.73 μ m) and infrared (10.5-12.5 μ m), respectively. Operating continuously, the scatterometer, SMMR and VIR will provide nearly complete global coverage (75°N-75°S) every 36 hours, and the altimeter will provide a continuous trace beneath the satellite. These data will be recorded for subsequent transmission to ground stations. Because of its high data rate, however, the SAR will be operated only in real-time, while in line-of-sight of specially equipped receiving stations (North America only).

Nimbus-G is also scheduled for launch this year, in August. Although the majority of its sensors are designed for study of atmospheric phenomena, two--the coastal zone color scanner (CZCS) and the scanning multichannel microwave radiometer (SMMR)--are designed principally for oceanographic applications. The CZCS is a six-channel, multispectral scanner (0.43-0.45, 0.51-0.53, 0.54-0.56, 0.66-0.68, 0.7-0.8, 10.5-12.5 μ m), with a 0.825km ground resolution. It is intended to provide information on chlorophyll concentrations, sediments, and surface temperatures in coastal waters. A tiltable scanner mirror will be employed to avoid sun glint problems, as the satellite will have a noon equatorial crossing in its sun-synchronous orbit. The SMMR, which is identical to the instrument to be flown on Seasat-A, will be used to study sea surface temperature, surface winds, snow and ice. The CZCS will be operated on command, with the U.S. coastal waters normally being covered; the SMMR will be operated continuously, providing global coverage every 72 hours.

SELECTED ARTICLESPhotogrammetric Eng'g & Remote Sensing 1977. v. 43, n. 10 (Oct.)

- Welch & Lo. Height measurements from satellite images.
- Raju & Parthasarathi. Stereoscopic viewing of Landsat imagery.
- Gut & Hohle. High altitude photography: Aspects and results.
- Thomas & Gerbermann. Yield/reflectance in cabbage.
- Ulliman & French. Detection of oak wilt with color ir aerial photography.
- Estes et al. Measuring soil moisture with an airborne imaging passive microwave radiometer.
- Bryan et al. Computer processing of SAR L-band imagery.
- Maarek, A. Practical numerical photogrammetry.

The Photogrammetric Record. 1977. v.9, n:50 (Oct.)

- Ackermann, F. Some thoughts on the future of photogrammetry.
- Allan, J.A. Map and orthophotograph users and their perceptions.
- Carter et al. An urban management information service using Landsat imagery.
- Hampton, J.N. Aerial reconnaissance for archaeology: Uses of the photographic evidence.

The Newsletter is made possible by a grant from the NASA Office of University Affairs. Comments or correspondence should be directed to Dr. Warren R. Philipson, Remote Sensing Program, Cornell University, 464 Hollister Hall, Ithaca, New York 14853 (tel. 607-256-4330).

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STATE PARK STUDIES

During the past year, Cornell's Remote Sensing Program conducted physical resource surveys for the initial development of a 240-hectare park and for the selective improvement of a 26,000-hectare park. The analyses were completed at the request of, and as a demonstration for, the New York State Office of Parks and Recreation (OPR).

The undeveloped Chimney Bluffs State Park is situated on the shore of Lake Ontario, near Sodus Bay, N.Y. The park's principal attraction is its geologically unique bluffs--a steep, lake-facing wall of pinnacles and fins which are highly susceptible to accelerated erosive damage. Program staff initially assessed the rate of natural erosion of the bluffs from 1938 to 1973 using medium scale aerial photographs and a Zoom Transfer Scope. This temporal analysis found little change over the 35-year period. If the bluffs could be protected from accelerated erosion, park development would seem worthwhile. Using the photographs and available background information, Program staff then prepared large scale site maps depicting land cover, slope categories, and levels of ground water. Depth of soil to bedrock was also evaluated but found to be nowhere limiting. Site design concepts compatible with preserving the bluffs were developed and recorded on a single map overlay. These included trails, picnic sites and areas for vegetative thinning.

The State OPR, its Finger Lakes Regional staff, and county planners are currently reviewing the Program's submissions. All information will be relied upon and incorporated into the final site development, which will begin as soon as possible (continued, page 2).

SHORT COURSES/WORKSHOPS/SYMPOSIA

Image Processing & Pattern Recognition; 17-21 Apr; \$450 fee; Contact: Continuing Education, Stewart Center, Rm. 110, Purdue Univ., West Lafayette, Ind. 47907.

Vegetation Remote Sensing Workshop; 12-16 June and repeated on 19-23 June; \$300 fee; instructors, C.E. Olson & W.G. Rohde; Contact: Dr. C.E. Olson, Jr., School of Natural Resources, Univ. of Michigan, Ann Arbor, Mich. 48109 (tel. 313-764-1413), before 15 April.

31st Annual Conf., Soc. of Photographic Scientists & Engineers; 30 Apr-5 May; in Washington, D.C.; Contact: Robert H. Wood, Executive Director, S.P.S.E., 1411 K St., N.W., Suite 930, Washington, D.C. 20005.

Coastal Mapping Symposium; 14-16 Aug; in Rockville, Md; presented by Potomac Region, Amer. Soc. of Photogrammetry; Contact: Karin Baker, 24628 Lunsford Court, Damascus, Md. 20750.

SEMINAR IN REMOTE SENSING

The Seminar in Remote Sensing is held on Wednesdays, at 4:30 p.m., in 110 Hollister Hall. Anyone is welcome to attend. Seminars scheduled for April are as follows:

- 5 Apr .Airborne Geochemical Exploration: Dr. A.R. Barringer, Barringer Research, Inc., Golden, Colorado.
- 12 Apr .Pattern Recognition and Image Analysis at CCRS: Dr. D.G. Goodenough, Canada Centre for Remote Sensing, Ottawa, Canada.
- 19 Apr .[Digital Image Processing on the Illiac IV: R.M. Hord, Institute for Advanced Computation, Alexandria, Va.]
- 26 Apr .Image Processing Systems: Dr. A.S. Barrett, Optronics International, Inc., Chelmsford, Mass.
- * * * * *
- 3 May .Topic on Multispectral Photography: T.C. Vogel, U.S. Army Engineer Topographic Labs., Fort Belvoir, Va.

Park Studies (continued)

The Program staff also examined the Allegany State Park, the largest in the state parks system. Located in southwestern New York, this park is the focus of state planning for near-future rehabilitation and development. Because field surveys of the entire park would have been too costly, the Program was asked to conduct a reconnaissance evaluation, identifying prime areas for more detailed developmental surveys.

Parkland suitability was judged on the basis of soils and botanical information derived from high and medium altitude aerial photographs and background reports. Areas were categorized according to whether detailed surveys would be desirable or unnecessary; the latter categories including those areas either unsuitable for development or containing no special botanical features. All information was submitted as overlays on a mosaic of enlarged, black-and-white prints of NASA high altitude aerial photographs of the park. Those areas recommended for detailed survey, less than one-third of the total park, are now being evaluated by OPR and Soil Conservation Service personnel.

Two other tasks performed in the Allegany study included (1) an inventory and assessment of soil borrow sites (mined areas) within or adjacent to the park, and (2) the selection of possible corridors for the North Country Trail, a potential addition to the National Trails System. The OPR has requested that remedial action by the State Department of Transportation be taken at several of the borrow sites, and the trail corridor information has been input to the OPR planning process.

The Chimney Bluffs study was conducted by David Fernandez, and the Allegany study by Ronald J. Linkenheil and Ann E. Russell. These students were directed by Warren R. Philipson and Thomas L. Erb. For further information, contact Dr. Philipson, at Cornell, or Mr. Ivan P. Vamos, Deputy Commissioner for Planning and Operations, N.Y.S. Office of Parks & Recreation, Empire State Plaza, Albany, N.Y. 12238.

HCMM RADIOMETER

The dual-channel radiometer to be carried on the Heat Capacity Mapping Mission Satellite will operate in the thermal infrared (10.5-12.5 μm) and visible to near-infrared (0.5-1.1 μm) spectral regions. The latter channel was reported incorrectly in the March Newsletter.

SELECTED ARTICLES

- Jensen, H., L.C. Graham, L.J. Porcello & E.N. Leith. 1977. Side-looking airborne radar. Scientific American. 237:4:84-95.
- Remote Sensing of Environment. 1977. v.6, n.4.
- Lerner & Hollinger. Analysis of 1.4 GHz radiometric measurements from Skylab.
 - Johnson & Norris. A multispectral analysis of the interface between the Brazil and Falkland Currents from Skylab.
 - Rao & Ulaby. Optimal spatial sampling techniques for ground truth data in microwave remote sensing of soil moisture.
 - Engvall et al. Pattern recognition of Landsat data based upon temporal trend analysis.
 - Heilman et al. Evaluating soil moisture and yield of winter wheat in the Great Plains using Landsat data.
 - Schneider & Matson. Satellite observations of snowcover in the Sierra Nevadas during the great California drought.

The Newsletter is made possible by a grant from the NASA Office of University Affairs. Comments or correspondence should be directed to Dr. Warren R. Philipson, Remote Sensing Program, Cornell University, 464 Hollister Hall, Ithaca, New York 14853 (tel. 607-256-4330).

The Newsletter, a monthly report of articles and events in remote sensing, is sent to members of the Cornell community who have an interest in sensors and their applications.

NEW YORK STATE REMOTE SENSING ACTIVITIES

Robert Crowder, N.Y.S. Economic Development Board

Technological forecasters theorize that it is often 20 to 30 years between the development of a new technological form and its general acceptance into the daily lives of the public. It is not surprising, then, that systematic aerial photographic coverage and resource inventorying were proposed for New York State by Governor Franklin D. Roosevelt in 1931, but have not been routinely accepted for everyday use by State agencies until the past decade.

Although slow in getting started, the State government's rate of adopting remote sensing products into routine activities has accelerated rapidly in the past ten years. The landmark project in this process was the Statewide set of 1:24,000 scale black-and-white aerial photographs which were produced for the State by the Lockwood Mapping Company in 1967-70. These photographs have been used extensively for Statewide land use mapping, Statewide planimetric mapping by the Department of Transportation, and for legislatively mandated, statewide freshwater wetlands mapping currently being completed by the Department of Environmental Conservation.

In 1968, aerial photographs formed the basis for the State's Land Use and Natural Resource (LUNR) Inventory, which is presently maintained by the State Economic Development Board and the Resource Information Laboratory of Cornell University. Spurred by the environmental movement and its associated requirements, the LUNR Inventory land use data have seen greater use with each passing year. The Inventory has been updated for the Catskill Mountain area, and an experimental project in Broome and Tioga Counties involved the successful use of 1:76,000 scale color aerial photography from orthophotographic quadrangle mapping for detailed land cover/land use interpretation. Many local land use data bases have been updated from aerial photographs produced for county tax mapping.

In 1975, the State Department of Environmental Conservation contracted with Earth Satellite Corporation for detailed classification and 1:2,400 scale mapping of all coastal wetlands south of the Tappan Zee Bridge. Color infrared aerial photographs at 1:12,000 scale and supplementary data were used as the sources of information. (cont'd p.2).

SEMINAR IN REMOTE SENSING

The final seminar of the spring semester will be held on Wednesday, 3 May, at 4:30 p.m., in B-14 Hollister Hall. Anyone is welcome to attend. The speaker, Donald J. Belcher, is an Emeritus Professor of Civil and Environmental Engineering at Cornell. His topic is "Pattern Interpretation: Geology, Engineering, and Tropical Soils."

ASP CALL FOR PAPERS

The Fall Convention of the American Society of Photogrammetry will be held in Albuquerque, New Mexico, 15-21 October 1978. Various technical sessions are being organized on primary data acquisition, digital processing and photogrammetric applications, and remote sensing applications. For further information, refer to the April 1978 issue of "Photogrammetric Engineering and Remote Sensing," page 518, or contact: Dr. Stan Morain, Technology Application Center, Univ. of New Mexico, Albuquerque, New Mexico 87131 (tel. 505-277-4000). Although abstracts are not due until 15 June, preliminary information should be received by 15 May.

SUMMER VACATION/ADDRESS CHANGES

Volume VI of the Cornell Remote Sensing Newsletter ends with this May issue. The Newsletter is currently received by more than 400 individuals and groups in 30 states and some 15 countries outside the United States. As planned, Volume VII of the Newsletter will begin next September. Notices of address changes should be sent to: Remote Sensing Program, Cornell Univ., Hollister Hall, Ithaca, N.Y. 14853.

State Agency Activities (continued)

With the planning for the 1980 Winter Olympics and the ongoing activities of the Adirondack Park Agency seeking to balance economic and environmental needs, the Adirondack Park has become a focus for remote sensing activity. This spring, the Park Agency will acquire 1:24,000 scale panchromatic aerial photographs of the entire park. Also, under a cooperative mapping agreement, the State and the U.S. Geological Survey are upgrading the map coverage of areas of the Adirondacks with 7.5 minute, 1:25,000 scale metric topographic maps.

The Geological Survey of the State Education Department's Museum and Science Service has been a leader in the use of Landsat, Skylab and high-altitude aircraft imagery for geological studies. It maintains a browse file of Landsat and other imagery up to early 1974, and has recently published a new set of maps with accompanying documentation entitled "Preliminary Brittle Structures Map of New York" (Y.M. Isachsen and W.G. McKendree). The project was highlighted by the discovery of heretofore unknown major geological structures which were not detected before the synoptic coverage from satellites and high-altitude aircraft became available. The project was sponsored by the U.S. Geological Survey and Nuclear Regulatory Commission and has already proven valuable for many uses including site analysis for power generation plants.

New York State wants to continue to build upon the base of successful applications of remote sensing technology which it has established in the past decade, and it looks forward with interest to the streamlining of its remote sensing activities through a currently active interagency map advisory committee. It is hoped that in the next decade the many new remote sensing technologies will be actively used by the State to take advantage of their very real everyday benefits.

CALL FOR PAPERS--WILDLIFE MANAGEMENT

The 4th William T. Pecora Memorial Symposium will be held in Sioux Falls, So. Dakota, 10-12 October 1978. The theme of the symposium is the application of remote sensing data to wildlife management--wildlife habitat inventory and analysis, wildlife population inventory and dynamics, and integrated resources planning. Persons interested in contributing to a poster session should submit ten copies of a 300 to 1000 word summary (typed, double-spaced on one side only) of their proposed presentation to: Dr. Michael E. Berger, National Wildlife Federation, 1412 16th St., NW, Washington, D.C. 20036 (tel. 202-797-6881). Summaries must be received by 31 May.

CALL FOR PAPERS--GEOLOGY

The Annual Meeting of the Geological Society of America, in Toronto, 23-26 October 1978, will convene a Symposium entitled "Geological Applications of Satellite Remote Sensing." The Symposium will include a morning session of invited papers followed by an afternoon poster session. Individuals interested in presenting a poster illustrating recent work in applying satellite remote sensing to geologic activities should submit an abstract (original and two copies, on GSA Abstract forms) no later than 1 June 1978. Send abstracts to: G.S.A. Symposium, Box 20, Germantown, Maryland 20767.

CONFERENCES

Meeting, Central New York Region, American Society of Photogrammetry; 19 May; in Watertown, N.Y.; Contact: Prof. Sumner B. Irish, Dept. of Civil Engineering, Clarkson College of Technology, Potsdam, N.Y. 13675 (tel. 315-268-6517).

International User's Conference on Computer Mapping Software and Data Bases; 23-28 July; at Harvard Univ.; Contact: Allan Schmidt, Harvard Univ., 520 Gund Hall, Cambridge, Mass. 02138.

SPSE International Congress of Photographic Science 1978; 20-26 Aug.; at Rochester Inst. of Technology; Contact: George Bird, School of Chemistry, Rutgers Univ., New Brunswick, N.J. 08903 (tel. 201-932-3029) or Paul Gilman, Research Labs., Eastman Kodak Co., Rochester, N.Y. 14650 (tel. 716-458-1000 x73060).

SELECTED ARTICLES AND PUBLICATIONS

Fitzpatrick-Lins, K. 1978. Accuracy and consistency comparisons of land use and land cover maps made from high-altitude photographs and Landsat multispectral imagery. Jour. Research of U.S. Geol. Survey 6:1:23-40.

Lyzenga, D.R. 1978. Passive remote sensing techniques for mapping water depth and bottom features. Applied Optics 17:3:379-383.

Mamula, Jr., N. 1978. Remote-sensing methods for monitoring surface coal mining in the northern Great Plains. Jour. Research of U.S. Geol. Survey 6:2:149-160.

Proceedings of Int'l Sympos. on Image Processing--Interactions with Photogrammetry and Remote Sensing. Institute for National Surveying and Photogrammetry, Code "Image Processing," Technical University Graz, Rechbauerstrasse 12, A-8010 GRAZ, Austria. (\$10 plus mailing).

Proceedings of 4th Canadian Sympos. on Remote Sensing. Held May 1977, Quebec City, Quebec. Canadian Aeronautics & Space Inst., Saxe Bldg., 70 Sparks St., Ottawa, Ontario K1P 5A5 Canada. (\$40).

Proceedings of Remote Sensing Workshop on Soil Moisture and Groundwater. Held Nov. 1976, Toronto. Canadian Aeronautics & Space Inst. (see above) (\$25).

Proceedings of 11th International Symposium on Remote Sensing of Environment. Held at Univ. of Mich., 25-29 April 1977. (2 vols., 1734 pp.). ERIM, P.O. Box 8168, Ann Arbor, Mich. 48107 (\$60).

Shahrokhi, F. (editor). 1977. Selected papers from 1977 Conference on Remote Sensing of Earth Resources, Vol. 6. Business Office, Univ. of Tennessee Space Inst., Tullahoma, Tenn. 37388. over 600 pp. (\$30).

Weismiller, R.A., I.D. Persinger, and O.L. Montgomery. 1977. Soil inventory from digital analysis of satellite scanner and topographic data. Soil Sci. Soc. Amer. Jour. 41:6:1166-1170.

Photogrammetric Eng'g & Remote Sensing 1977. v. 43, no. 12 (Dec.)

-Johnson & Kase. Mapping an ancient trade route with balloon photography.

-Wang, J. Feature extraction by interactive image processing.

-Veress et al. An analytical approach to x-ray photogrammetry.

-Arthur, D. Limitations of the narrow-angle convergent pair.

-Rabchevsky, G. Temporal and dynamic observations from satellites.

-Rosenfeld & Kimerling. Moving target analysis utilizing side-looking airborne radar.

-Kraus et al. Radar detection of surface oil slicks.

-Weismiller et al. Change detection in coastal zone environments.

-Richardson & Wiegand. Distinguishing vegetation from soil background information.

Photogrammetric Eng'g & Remote Sensing. 1978. v. 44, n.1 (Jan.)

-Marshall & Meyer. Field evaluation of small-scale forest resource aerial photography.

-Collins, W. Remote sensing of crop type and maturity.

Photogrammetric Eng'g & Remote Sensing v.44, n.1 (continued)

- McGuinnis, Jr. & Schneider. Monitoring spring ice break-up from space.
- El-Baz, F. The meaning of desert color in earth orbital photographs.
- Millard et al. Crop water-stress assessment using airborne thermal scanner.
- Munday et al. Outfall siting with dye-buoy remote sensing of coastal circulation.
- Ward, R. More on color compensating filters with infrared film.

Photogrammetric Eng'g & Remote Sensing. 1978. v. 44, n.2 (Feb.)

- Doyle, F. The next decade of satellite remote sensing.
- Henderson & Ondrejka. GEOSAT: Geological industry recommendations on remote sensing from space.
- Maughan, P. A role for private enterprise in remote sensing from space?
- Conitz, M. A development assistance program in remote sensing.
- Stowe, R. Legal implications of remote sensing.

Photogrammetric Eng'g & Remote Sensing v. 44, n.3 (March)

- Benesh, M. Viking Orbiter stereophotogrammetry.
- Tucker, C.J. Are two photographic infrared sensors required?
- Brown, W.W. Wetland mapping in New Jersey and New York.
- Westin & Lemme. Landsat spectral signatures: Studies with soil associations and vegetation.

Photogrammetric Eng'g & Remote Sensing v. 44, n.4 (April)

- Kraus, K. Rectification of multispectral scanner imagery.
- Otepka, G. Practical experience in the rectification of MSS images.
- Austin & Adams. Aerial color and color infrared survey of marine plant resources.
- Gausman et al. Ozone damage detection in cantaloupe plants.
- Gausman et al. Distinguishing succulent plants from crop and woody plants.
- Thomas et al. Snowfield assessment from Landsat.
- Brandli, H.E. The night eye in the sky.
- Chiu & Collins. A spectroradiometer for airborne remote sensing.

Remote Sensing of Environment 1978. vol. 7, n.1

- van Genderen & Vass. Remote sensing: Statistical testing of thematic map accuracy.
 - Bush & Ulaby. An evaluation of radar as a crop classifier.
 - Parashar et al. A theory of wave scatter from an inhomogeneous medium with a slightly rough boundary and its application to sea ice.
 - Kayan & Klemas. Application of Landsat imagery to studies of structural geology and geomorphology of the Mentese region of southwestern Turkey.
 - Strong, A.E. Chemical whittings and chlorophyll distributions in the Great Lakes as viewed by Landsat.
 - Stembridge, J.E. Vegetated coastal dunes: Growth detection from aerial infrared photography.
 - Reginato et al. Estimating forage crop production: A technique adaptable to remote sensing.
 - Kriebel, K.T. Average variability of the radiation reflected by vegetated surfaces due to differing irradiations.
 - Parikh, J. Cloud classification from visible and infrared SMS-1 data.
- Sabins, Jr., F.F. 1978. Remote sensing; Principles and interpretation. W.H. Freeman & Co., San Francisco. 426 pp.
- White, L.P. 1977. Aerial photography and remote sensing for soil survey. Clarendon Press, N.Y. 118 pp. (\$13.95).

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